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Natural Resources Conservation Service

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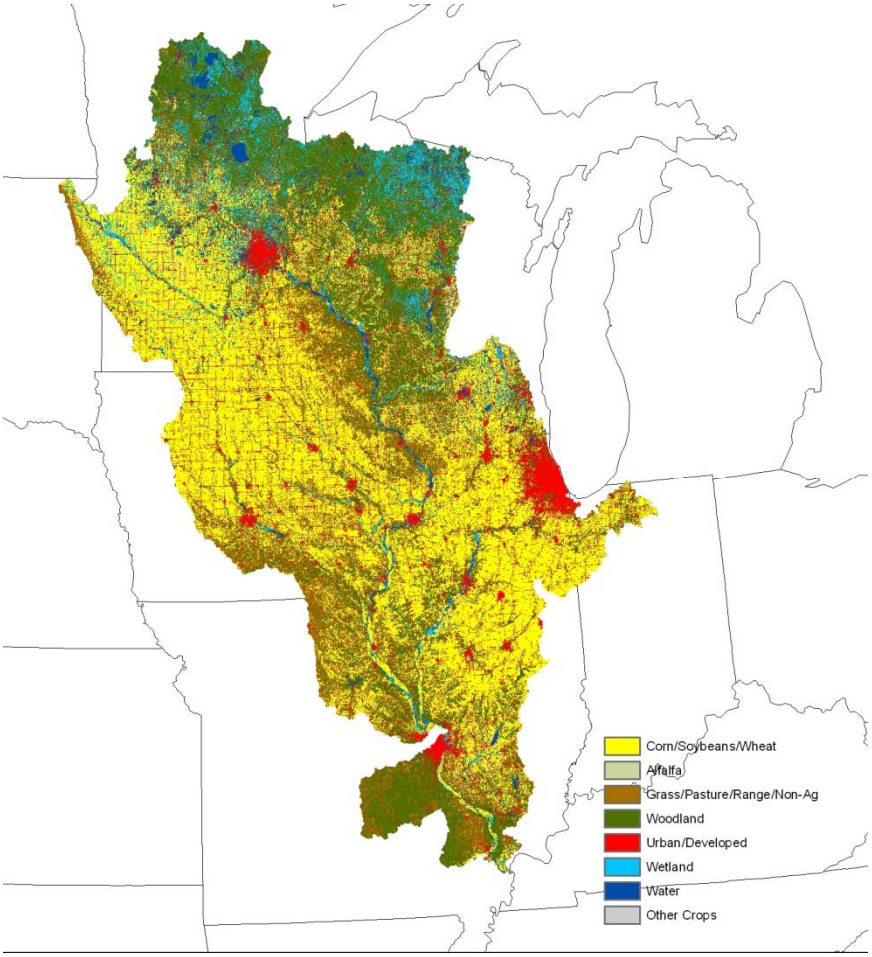
Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Upper Mississippi River Basin



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. Duriancik et al. (2008) summarize the accomplishments of CEAP through 2007. A vision for how CEAP can contribute to better and more effective delivery of conservation programs in the years ahead is addressed in Maresch, Walbridge, and Kugler (2008). Additional information on the scope of the project can be found at http://www.nrcs.usda.gov/technical/nri/ceap/.

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

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Foreword

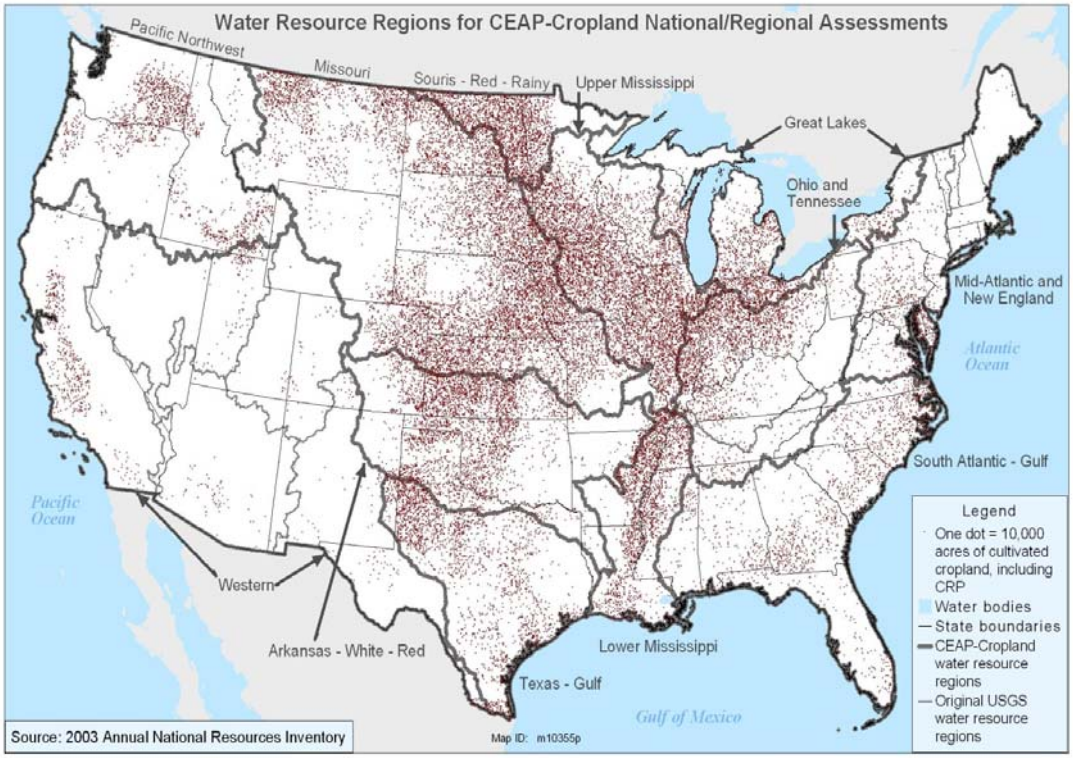
The United States Department of Agriculture has a rich tradition of working with farmers and ranchers to enhance agricultural productivity and environmental protection. Conservation pioneer Hugh Hammond Bennett worked tirelessly to establish a nationwide Soil Conservation Service along with a system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

USDA conservation programs are voluntary. Many provide financial assistance to producers to help encourage adoption of conservation practices. Others provide technical assistance to design and install conservation practices suitable to the goals of the agricultural 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 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 has been 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.

This report on the Upper Mississippi River Basin is the first in a series of regional reports that 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. These 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. Subsequent reports on cultivated cropland will be prepared for regions shown in the following map.



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/umrbdocumentation/. Included are the following reports that provide details on the modeling and databases used in this study:

- The CEAP-HUMUS National Water Quality Modeling System and Databases
- Calibration and Validation of CEAP-HUMUS for the Upper Mississippi River Basin
- Delivery Ratios and Sediment Balance for the Upper Mississippi River Basin
- APEX Model Validation for CEAP
- Documentation of Pesticide Risk Indicators Used in the 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

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

Executive Summary

Good progress has been made on reducing sediment, nutrient, and pesticide losses from farm fields through conservation practice implementation in the Upper Mississippi River Basin, but a significant amount of conservation treatment remains to be done to reduce nonpoint agricultural sources of pollution to acceptable levels.

- Use of soil erosion control practices is widespread, with most acres receiving some form of erosion control treatment. Nevertheless, about 15 percent of the cultivated cropland acres still have excessive sediment loss from fields and require additional erosion control practices.

- Complete and consistent use of nutrient management (proper rate, form, timing, *and* method of application) is generally lacking throughout the region. About 62 percent of the cultivated cropland acres require additional nutrient management to reduce the loss of nitrogen or phosphorus from fields.

- The most critical conservation concern in the region is loss of nitrogen through leaching. About 51 percent of cropped acres require additional nutrient management to address excessive levels of nitrogen loss in subsurface flow pathways, including tile drainage systems. About 36 percent of cropped acres need treatment *only* for nitrogen loss in subsurface flow.

- About 15 percent of the acres are critically under-treated, usually requiring treatment for multiple natural resource problems. These acres are among the most vulnerable acres in the region.

- Nutrient loss from fields is within acceptable limits when soil erosion control practices are paired with management of rate, form, timing, and method of nutrient application that maximizes the availability of nutrients for crop growth while minimizing environmental losses. A *suite* of practices that includes both soil erosion control and consistent nutrient management is required to simultaneously address soil erosion *and* nitrogen leaching loss.

- Treatment of erosion alone can exacerbate the nitrogen leaching problem because reducing surface water 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.

- Conservation practices in the region have also been effective in reducing pesticide residues lost from fields as well as the associated environmental risk.

- Conservation practices have the greatest effect on the more vulnerable acres, such as highly erodible land and soils prone to leaching. Targeted treatment of these vulnerable acres is the most efficient strategy for reducing sediment, nutrients, and pesticide loads to water bodies in the region.

This study was designed to quantify the effects of conservation practices commonly used on cultivated cropland in the Upper Mississippi River Basin (UMRB), evaluate the need for additional conservation treatment in the region, and estimate the potential gains that could be attained with additional conservation treatment.

For purposes of this report, cultivated cropland includes land in row crops or close-grown crops (such as small grains), hay and pasture in rotation with row crops and close-grown crops, and cropland in long-term conserving cover. The UMRB has about 61 million acres of cultivated cropland—58 million cropped acres and about 3 million acres in long-term conserving cover. Acres enrolled in the General Signup of the Conservation Reserve Program (CRP) were used to represent land in long-term conserving cover.

A simulation model was used to estimate the effects of conservation practices that were in use during the period 2003 to 2006. 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. Information on farming activities and conservation practices was obtained from a farmer survey and other sources. Using those data, conservation practice effects were evaluated in terms of—

- reductions in losses of sediment, nutrients, and pesticides from fields;
- enhancement of soil quality through increases in soil organic carbon in the field; and
- reductions in instream loads of sediment, nutrients, and pesticides in the region's rivers and streams.

The physical process models used in this study are mathematical representations of the real world designed to simulate complex and varying environmental events and conditions. To estimate the effects of conservation practices, model simulation results were used to make *relative comparisons* between two model runs—one that includes conservation practices and one that excludes conservation practices. All other aspects of the input data and the model parameters are held constant in the two model runs.

The assessment includes conservation practices in use regardless of how or why they came to be in use. It is not restricted to only those practices associated with Federal conservation programs; the assessment also includes the conservation efforts of States, independent organizations, and individual landowners and farm operators.

The Baseline Conservation Condition

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 CRP 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 UMRB closely reflects this history of Federal conservation programs and technical assistance. An assessment of the extent of conservation practice use in the UMRB for the period 2003–06, representing the "baseline conservation condition," found the following:

- Structural practices for controlling water erosion are in use on 45 percent of UMRB cropped acres, including 72 percent of the highly erodible land.
- About 71 percent of the acres meet tillage intensity criteria for no-till or mulch till and are gaining soil organic carbon. All but 5 percent of the acres have evidence of some kind of reduced tillage on at least one crop in the rotation.
- Producers use residue and tillage management practices, structural practices, or both, on nearly all of the acres in the region.
- Appropriate rates of nitrogen application are in use on about 34 percent of the acres for all crops in the rotation.
- Good nitrogen management practices (rate, timing, and method) are in use on about 14 percent of the acres for all crops during every year of production.

- Good phosphorus management practices are in use on 29 percent of the acres for all crops during every year of production.
- 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 *and* timing *and* method of application, including nearly all of the acres receiving manure.
- 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 67 percent are highly erodible land.

Effects of Conservation Practices for the Baseline Conservation Condition

Model simulation results show that, for cropped acres in the region, *on average* conservation practices have—

- reduced surface water flow from farm fields by 16 percent, re-routing the water to subsurface flow pathways;
- reduced sediment loss from fields by 69 percent;
- reduced total nitrogen loss (volatilization, denitrification, surface runoff, and subsurface flow losses) from fields by 18 percent:
  - reduced nitrogen lost with surface runoff (attached to sediment and in solution) by 46 percent,
  - but only reduced nitrogen loss in subsurface flow by 5 percent;
- reduced total phosphorus loss from fields by 49 percent;
- reduced pesticide loss from fields to surface water, resulting in a 51-percent reduction in edge-of-field pesticide risk for aquatic ecosystems and a 48-percent reduction in edge-of-field pesticide risk for humans (all pesticides combined); and
- decreased the percentage of acres that are losing soil organic carbon from 41 percent to 25 percent.

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 20 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, 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 81 percent, total phosphorus loss has been reduced by 97 percent, and soil organic carbon has been increased by an average of more than 400 pounds per acre.

These 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. Model simulations show that at the outlet of the UMRB (Grafton, IL), use of conservation practices has—

- reduced instream sediment loads by 37 percent;
- reduced instream nitrogen loads by 21 percent;
- reduced instream phosphorus loads by 40 percent; and
- reduced instream atrazine loads by 51 percent.

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

Evaluation of Conservation Treatment Needs

This study also determined that the *combination* of practices in use was often inadequate to address excessive losses of sediment *and* nutrients.

Adequate conservation treatment consists of combinations of conservation practices that treat the specific inherent vulnerability factors associated with each field for *both* sediment and nutrient loss. Not all acres require the same level of conservation treatment because of differences in climate and inherent soil vulnerabilities. The evaluation of conservation treatment needs was conducted by identifying acres that were inadequately treated with respect to the soil runoff or soil leaching potential.

The evaluation of treatment needs for the UMRB determined that—

- 36 million acres (62 percent of cropped acres) are under-treated for one or more of sediment loss, nitrogen or phosphorus lost with surface runoff, and nitrogen or phosphorus loss in subsurface flow:
  - all acres require additional treatment for either nitrogen or phosphorus loss,
  - 58 percent of these acres require additional treatment *only* for nitrogen loss in subsurface flow,
  - 17 percent require additional treatment for sediment loss, nitrogen runoff, *and* phosphorus runoff;
- Of the 36 million under-treated acres, 8.5 million acres (15 percent of cropped acres) are "critical" under-treated acres that consist of the most vulnerable acres in the region, most of which require treatment for multiple resource concerns; and
- 22 million acres (38 percent) are adequately treated relative to their degree of vulnerability.

Conservation treatment needs for further reducing the loss of pesticide residues were not estimated.

Simulation of Additional Conservation Treatment

Additional conservation treatment was simulated for (1) the 8.5 million most vulnerable under-treated acres in the region, and (2) all 36 million under-treated acres. Two levels of treatment were simulated for each set of acres:

- *Treatment with additional erosion control practices*, which consisted of adding in-field practices to control overland flow (terraces, contouring, or stripcropping) for acres without overland flow control practices and having a slope of more than 2 percent, and adding edge-of-field buffering or filtering practices to all acres without edge-of-field practices.
- *Treatment with nutrient management in addition to erosion control practices*, which was modeled by adjusting the commercial fertilizer and manure applications to simulate the appropriate rate of application, the appropriate timing of application, and use of the appropriate application method.

Model simulation demonstrated that sediment and nutrient losses with surface runoff could be effectively controlled in the region by treating the 8.5 million most vulnerable under-treated acres with additional erosion control practices. At this level of treatment, model simulations showed the following for the region as a whole:

- Sediment loss from farm fields would average 0.6 ton per acre per year, compared to the baseline conservation condition average of 1.0 ton per acre per year (a 40-percent reduction).
- Nitrogen lost from the field with surface runoff (attached to sediment and in solution) would average 6.1 pounds per acre per year, compared to the baseline conservation condition average of 8.6 pounds per acre per year (a 29-percent reduction).
- Total phosphorus loss, most of which is lost with surface runoff, would average 2.4 pounds per acre per year, compared to 3.0 pounds per acre per year for the baseline conservation condition (a 22-percent reduction).

However, model simulations also showed that a portion of these nutrient savings was re-routed to subsurface loss pathways, most of which is eventually delivered to lakes, streams, and rivers through seepage, artificial drainage systems, and groundwater return flow in this region.

Treatment with nutrient management practices *in addition to* soil erosion control practices is required to effectively control the loss of soluble nitrogen and phosphorus from farm fields in the UMRB. Treatment at this level of all 36 million under-treated acres, compared to the baseline conservation condition, for the region as a whole would reduce nitrogen loss in subsurface flow from an average of 21.8 pounds per acre to an average of 11.4 pounds per acre (a 48-percent reduction). Total nitrogen loss (all loss pathways) would be reduced 43 percent. Total phosphorus loss

would be reduced to about 1.5 pounds per acre per year, on average, representing a 51-percent reduction from the baseline conservation condition.

Model simulations further showed that the additional reductions in field-level losses would be expected to provide the following improvements in water quality at the outlet of the UMRB (Grafton, IL), compared to the baseline conservation condition.

Percent reductions of instream loads at the outlet of the Upper Mississippi River Basin due to additional erosion control and nutrient management

Environmental outcome	**Treatment of the 8.5 million most vulnerable under-treated acres**	**Treatment of all 36 million under-treated acres**
Sediment reduction	11%	21%
Nitrogen reduction	12%	44%
Phosphorus reduction	12%	27%
Atrazine reduction	6%	18%

The nutrient management treatment level simulated in this study represents feasible and proven conservation practices that can be successfully applied using today's technology. There are, however, emerging conservation technologies that have the potential to further reduce nutrient loss from farm fields and provide even greater conservation benefits once the technologies become more widespread. These include—

- variable rate technology for precise nutrient application rates and placement methods;
- nitrogen use efficiency enhancers (time release and ammonia loss inhibitors);
- water control management which reduces late fall and early spring flushes of nitrate-laden drainage water; and
- constructed wetlands that receive surface water runoff from fields prior to discharge to streams and rivers.

Not all acres get the same benefit from conservation treatment. The more vulnerable acres, such as highly erodible land and soils prone to leaching, inherently lose more sediment and/or nutrients, and therefore greater benefit can be attained with conservation treatment. The gains in efficiency by treating the more vulnerable acres first are demonstrated in the table below using results from the treatment simulations:

Average annual per-acre reductions in loss from treatment of designated acres with additional erosion control and nutrient management

Resource concern	8.5 million critical under-treated acres	27.5 million non-critical under-treated acres	Remaining 22.2 million acres
Sediment loss at edge of field due to water erosion (tons/acre)	2.7	0.7	0.5
Total nitrogen loss for all pathways (pounds/acre)	39	25	9
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	17	6	4
Loss of nitrogen in subsurface flows (pounds/acre)	18	16	3
Total phosphorus loss for all pathways (pounds/acre)	4.6	1.8	1.3

Diminishing returns to additional conservation treatment are pronounced for sediment, phosphorus, and nitrogen lost with surface runoff. For nitrogen loss in subsurface flow, however, diminishing returns are not evident until all the under-treated acres are treated, a reflection of the pervasiveness of the nitrogen leaching problem in this region.

Conclusions

The results of the study lead to the following conclusions for the UMRB:

- Conservation practice adoption has made good progress toward reducing sediment, nutrient, and pesticide losses from farm fields, but significant challenges remain.
  - Erosion control practices are widespread, but some of the more vulnerable acres are not adequately treated for erosion and sediment loss.
  - Nutrient management practices are common, but they do not consistently meet criteria for appropriate application rate *and* method *and* timing for all crops in all years of the crop rotation.
  - Acres receiving manure applications consistently have higher nutrient losses than do acres not receiving manure. Acres where manure is applied require more intensive and comprehensive treatment to attain acceptable levels of nutrient loss than do acres where manure is not applied.
- About 38 percent of the acres are adequately treated for sediment, nitrogen, and phosphorus loss. However, about 62 percent of the acres still require additional conservation treatment to reduce sediment and/or nutrient losses to acceptable levels. The majority require additional treatment only for nitrogen leaching. About 15 percent of the cropped acres are "critical under-treated" acres, most of which require additional conservation treatment for multiple resource concerns.
- Model simulations showed that adequate treatment for *all* resource concerns was rarely achieved with single practice solutions. Full treatment of the most vulnerable acres will require a *suite* of conservation practices designed to—
  - avoid or limit the potential for loss by consistently using nutrient management practices (appropriate rate, form, method, *and* timing) on *all* crops in the rotation;
  - control overland flow and concentrated flow; and
  - trap materials leaving the field using appropriate edge-of-field mitigation.
- Nutrient management is especially important for acres with erosion control treatment because some of the surface water that carries nitrogen and phosphorus in solution is re-routed to subsurface loss pathways, where it is more difficult to treat. A significant portion of these nutrients carried in subsurface flows is eventually delivered to lakes, streams, and rivers through seepage, artificial drainage systems, and groundwater return flow.
- Simulation of additional conservation treatment indicated that, by augmenting conservation practices already in use with needed improvements in nutrient management on under-treated acres in the region, nitrogen savings could be more than doubled with respect to savings already attained.
- Even when fully treated, however, some of the most vulnerable acres will have unacceptable losses, especially during years with extreme weather events. For these acres, a change in the cropping system, land use change, or establishment of long-term conserving cover may be necessary to meet watershed protection goals.

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.

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

Land use

The Upper Mississippi River Basin (UMRB) covers some 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.

About half the area of the UMRB is used for crop production (table 1 and figure 1). About 16 percent of the Nation's cropland is in the UMRB. 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.

The second most common land cover in the UMRB is forest land, which covers about one-fourth of the basin, mostly in the north. The forests consist primarily of deciduous trees with conifers and mixed stands in some areas.

Pastureland and hayland make up about 8 percent of the land cover in the region.

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 about 279,000 farms in the UMRB, about 13 percent of the total number of farms in the United States (table 2) Farms in the UMRB make up about 9 percent of all farmland in the nation.

According to the 2007 Census of Agriculture, the value of UMRB agricultural sales in 2002 was about $44 billion—57 percent from crops and 43 percent from livestock. About 66 percent of UMRB 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).

The majority of farms (59 percent) in 2007 were small operations with less than $50,000 in total farm sales. About 12 percent of the farms had total farm sales greater than $500,000 (table 3).

Thirty-two percent of the farms in the UMRB are smaller than 50 acres, 52 percent are between 50 and 500 acres, and 14 percent are from 500 to 2,000 acres. Only about 2 percent of the farms in the region are operations with more than 2,000 acres (table 3).

Crop production

The UMRB accounts for about 17 percent of all U.S. crop sales, including 30 percent of U.S. sales of grains and oilseeds (table 2). Corn and soybeans are the principal crops grown. Wheat and alfalfa 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 (0.9 billion 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 UMRB. Only about 2 percent of the harvested acres were irrigated in 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 billion in value (table 2). Sales of dairy products ranked second in the region at $5 billion, representing 17 percent of the U.S. total. Beef production is also important in the region. The region accounted for about 11 percent of cattle on feed in the United States in 2007.

Although about half of the farms in the UMRB reported livestock sales in 2007, the majority are small operations. About 55,000 farms had fewer than 30 animal units[1] on the farm; a small number of these had specialty livestock such as rabbits, bison, mink, or deer (table 3). Pastured livestock (cattle, horses, sheep, or goats) predominate on about 35,000 farms; 90 percent of these farms raised fewer than 100 animal units. About 45,000 farms could be defined as animal feeding operations (AFOs). AFOs are typically livestock operations with confined livestock, such as poultry, swine, cattle on feed, or dairies. Sixteen percent of the farms in the UMRB are AFOs, although the bulk of these are relatively small operations. Only about 2,730 of the livestock operations (6 percent of the AFOs) are large, with livestock numbers above the threshold for a Concentrated Animal Feeding Operation (CAFO).

[1] An animal unit is 1,000 pounds of live animal weight.

Watersheds

A hydrologic accounting system consisting of water resource regions, major subbasins, and smaller watersheds has been defined by the U.S. Geological Survey (USGS) (1980). The UMRB is one of the 18 water resource regions in the conterminous United States. Each water resource region is designated with a 2-digit code, which is further divided into 4-digit subbasins and then into 8-digit watersheds, or Hydrologic Unit Catalogs (HUCs). For example, in the UMRB the 8-digit watershed "07110009" belongs to the "07" 2-digit basin and the "0711" 4-digit subbasin.

The 14 subasins within the UMRB are shown in figure 2, and agricultural land use within each subbasin is summarized in table 4. Cultivated cropland is the dominant land use in all but four northern subbasins and the southernmost subbasin. About half of the cultivated cropland in the UMRB is found in four subbasins:

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

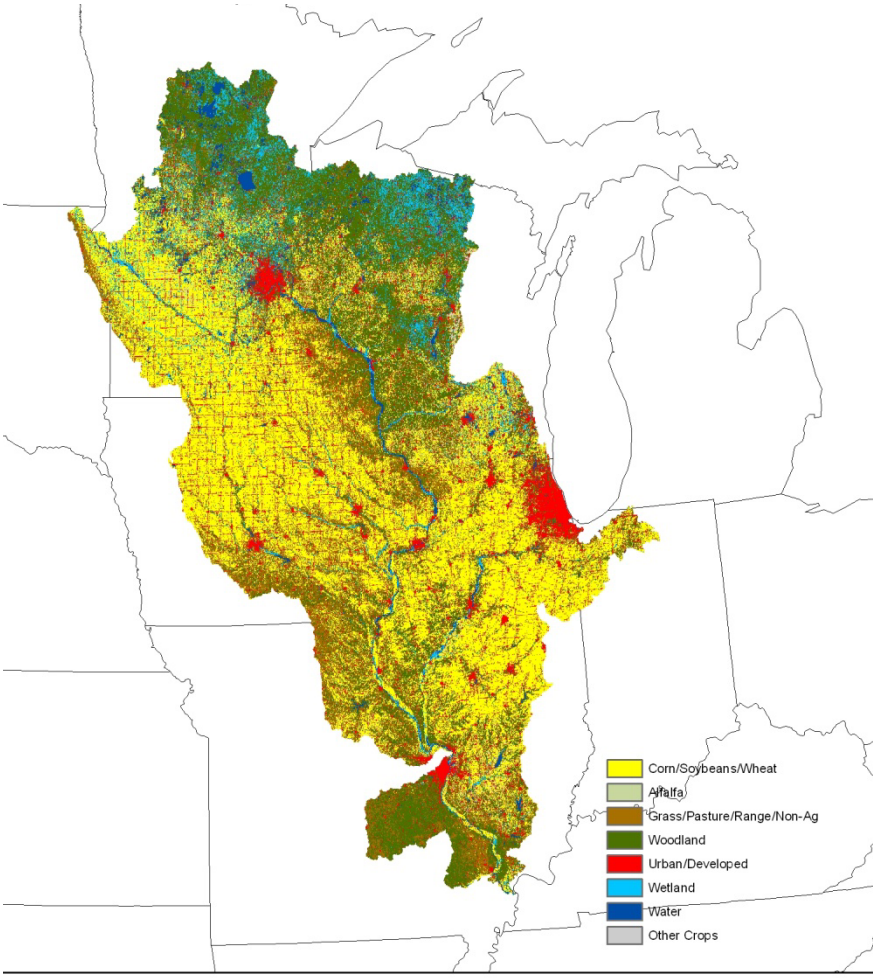
In each of these four subbasins, more than 70 percent of the landscape is cultivated cropland. This region of concentrated cultivated cropland extends through the central portion of the basin, as shown in figures 1 and 2. Pastureland, hayland, and woodland are more prominent land covers in the northern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

Table 1. Distribution of land cover in the Upper Mississippi River Basin

Land use	Acres*	Percent
Cultivated cropland and land enrolled in the CRP General Signup	63,512,000	52
Forest deciduous	22,203,000	18
Hay/Pasture not in rotation with crops	10,118,000	8
Urban	9,965,000	8
Water	3,339,000	3
Wetland forested	3,307,000	3
Range grasses	2,994,000	2
Wetland non-forested	2,643,000	2
Forest evergreen	1,672,000	1
Forest mixed	969,000	1
Range brush	621,000	1
Horticulture and barren	158,000	<1
Total	121,501,000	100

SOURCE: 2001 National Land Cover Data (NLCD) (US EPA, 2007) and the 1997 National Resources Inventory
*Acreage estimates for cultivated cropland differ slightly from those provided elsewhere in this report because of differences in sources.

Figure 1. Land cover in the Upper Mississippi River Basin



SOURCE: 2001 National Land Cover Data (NLCD) (US EPA, 2007)

Table 2. Profile of 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
Total acres	80,748,559	9
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
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
Total crop and livestock sales, million dollars	44,059	15
Animal units on farms		
All livestock types	11,597,113	11
Swine	3,604,576	35
Dairy cows	2,136,316	17
Fattened cattle	1,400,287	11
Other cattle, horses, sheep, goats	2,974,834	6
Turkeys	436,172	19

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 UMRB
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% of farm sales	184,653	66
Livestock sales make up more than 75% 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.

Figure 2. Percent cultivated cropland, including land in long-term conserving cover, for the 14 subbasins in the Upper Mississippi River Basin

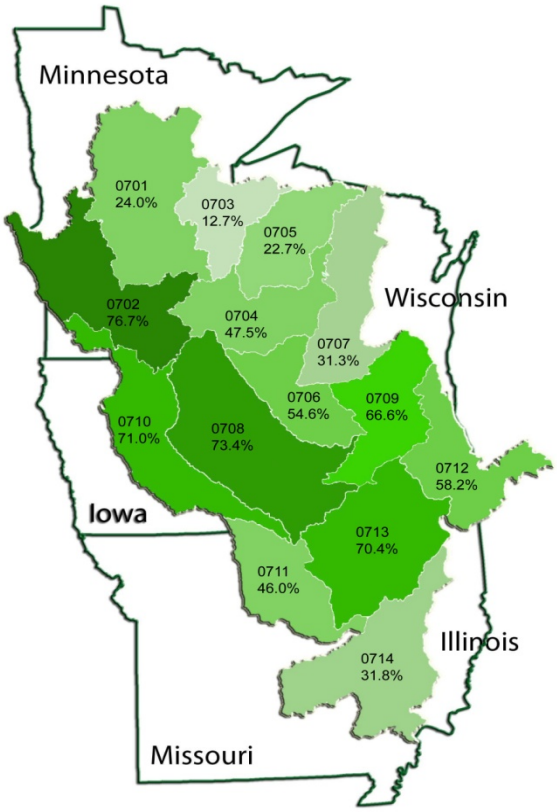


Table 4. Agricultural land use in the 14 subbasins in the Upper Mississippi River Basin (UMRB)

Sub-basin code	Subbasin name	Cultivated cropland (1,000 acres)*	Percent of cultivated cropland acres in long-term conserving cover	Pastureland not in rotation with crops (1,000 acres)	Hayland not in rotation with crops (1,000 acres)	Total agricultural land (1,000 acres)	Percent cultivated cropland in subbasin	Percent of cultivated cropland in UMRB
0701	Mississippi Headwaters	3,102	6.0	659	851	12,904	24.0	5.0
0702	Minnesota River Basin	8,290	4.3	239	166	10,802	76.7	13.2
0703	St. Croix River Basin	629	7.2	230	408	4,950	12.7	1.0
0704	Upper Mississippi-Black-Root	3,271	7.9	485	6	6,880	47.5	5.2
0705	Chippewa River Basin	1,385	3.6	233	0	6,109	22.7	2.2
0706	Upper Mississippi-Maquoketa-Plum	2,999	10.9	396	345	5,489	54.6	4.8
0707	Wisconsin River Basin	2,393	6.2	258	1	7,633	31.3	3.8
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	10,773	5.3	406	462	14,673	73.4	17.2
0709	Rock River Basin	4,663	4.4	406	293	7,005	66.6	7.4
0710	Des Moines River Basin	6,578	5.3	277	624	9,265	71.0	10.5
0711	Upper Mississippi-Salt	2,967	15.4	365	1,062	6,445	46.0	4.7
0712	Upper Illinois River Basin	4,062	0.9	97	105	6,979	58.2	6.5
0713	Lower Illinois River Basin	8,064	1.5	153	471	11,456	70.4	12.9
0714	Upper Mississippi-Kaskaskia-Meramec	3,471	6.6	459	1,355	10,912	31.8	5.5
	Total	62,647	5.4	4,662	6,148	121,501	51.6	100.0

* Acres of cultivated cropland include land in long-term conserving cover.
Note: Estimates in this table were obtained from HUMUS databases on land use, and do not exactly match the acreage estimates obtained from the NRI-CEAP sample.

Chapter 2
Modeling the Effects of Conservation Practices

Scope of Study

This report provides estimates for the Upper Mississippi River Basin (UMRB) of—

- environmental benefits and effects of conservation practices in use in the Upper Mississippi River Basin;
- conservation treatment needs for the region; and
- potential gains that could be attained with additional conservation treatment.

The study was designed to quantify at the regional level 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.

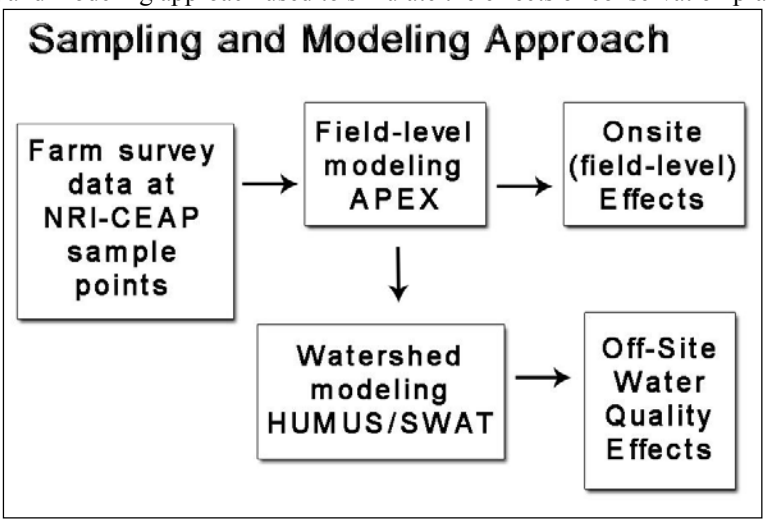
For purposes of this report, cultivated cropland includes land in row crops or close-grown crops, hay and pasture in rotation with row crops and close-grown crops, and land in long-term conserving cover. Cultivated cropland does not include agricultural land that has been in hay, pasture, or horticulture for the most recent 4 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. The UMRB has about 61 million acres of cultivated cropland—58 million cropped acres and about 3 million acres in long-term conserving cover.

Overview of Sampling and Modeling Approach

The assessment uses a statistical sampling and modeling approach to estimate the environmental effects and benefits of conservation practices (figure 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 UMRB. The sample also includes 1,831 additional NRI sample points designated as CRP acres to represent 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 these 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 then used to simulate how reductions of field losses have reduced instream concentrations and loadings of sediment, nutrients, and pesticides within the UMRB. The SWAT model (Soil and Water Assessment Tool) was used to simulate nonpoint source loadings from noncultivated cropland sources 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 current conservation condition scenario.

The effects of conservation practices are obtained by taking the difference in model results between the two scenarios (figure 4).[2] 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.

The NRI and the CEAP subsample

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). NRCS has previously used the NRI for modeling to address issues related to natural resources and agriculture (Goebel and Kellogg 2002).[3]

[2] This modeling strategy is similar 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-NRCS 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 "no-practice" representation of sheet and rill erosion, since C=1 represents smooth-tilled continuous fallow and P=1 represents no supporting practices.

[3] 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).

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

The NRI sampling design implemented in 1982 provided a stratified, two-stage, unequal probability area sample of the entire country (Goebel and Baker 1987; Nusser and Goebel 1997). Nominally square areas/segments were selected within geographical strata on a county-by-county basis; specific point locations were selected within each selected segment. The segments ranged in size from 40 to 640 acres but were typically half-mile square areas, and most segments contained three sample points. At each sample point, information is collected on nearly 200 attributes; some items are also collected for the entire segment. The sampling rates for the segments were variable, typically from 2 to 6 percent in agricultural strata and much lower in remote nonagricultural areas. The 1997 NRI Foundation Sample contained about 300,000 sample segments and about 800,000 sample points.

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.* 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.[4]

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

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.[5] The sample is statistically representative of cultivated cropland and formerly cultivated land currently in long-term conserving cover. Nationally, the NRI-CEAP sample consists of about 18,700 NRI points representing cropped acres,[6] and about 13,000 NRI points representing land enrolled in the General Signup of the CRP.

The UMRB portion of the NRI-CEAP sample consists of 3,703 sample points representing 58.2 million cropped acres and 1,831 sample points representing 2.8 million acres of agricultural land in long-term conserving cover. Table 5 provides a breakdown of sample sizes for the dominant cropping systems that occur in the UMRB.

Table 5. Cultivated cropland in the UMRB

Cropping System	Number of CEAP samples	Estimated acres	Percent of acres
Corn-soybean only	2,694	42,980,688	71
Corn only	316	5,037,033	8
Hay-crop mix	237	3,653,031	6
Corn-soybean with close grown crops	164	2,144,046	4
Soybean only	105	1,507,404	2
Soybean-wheat only	63	783,464	1
Corn and close grown crops	41	752,294	1
Remaining mix of crops	83	1,295,541	2
Sub-total for cropped acres	3,703	58,153,500	95
CRP General Signup, representing cultivated cropland in long-term conserving cover	1,831	2,801,700	5
Total	5,534	60,955,200	100

Note: Cultivated cropland acres in this table differ slightly from estimates provided elsewhere in this report because of differences in sources.

Acres reported using the CEAP sample are "estimated" acres because of the uncertainty associated with the statistical sample. Standard errors for estimated acres used in this report are provided in Appendix A.

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. 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—[7]

- 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;
- practices to improve wildlife habitat and operator's judgment on their effects on local wildlife populations; and
- general characteristics of the operator and the operation.

Farmers were also asked about the presence of structural conservation practices associated with the field. In a separate survey, NRCS field offices provided information on the practices specified in conservation plans.

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 four years.

Farmer responses to the NRI-CEAP Cropland Survey for the UMRB are summarized in Appendix B.

The field-level cropland model—APEX

A complex physical process model called APEX was used to simulate the effects of conservation practices at the field level (Williams et al., 2008; Williams et al., 2006; Gassman et al. 2009 and 2010).[8] 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.[9]

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

[6] 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 because the crops grown were uncommon and model parameters for crop growth were not available.

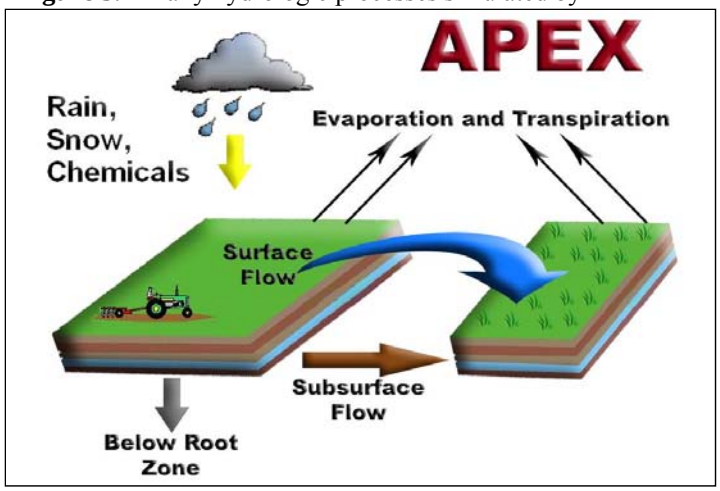
[7] The surveys, the enumerator instructions, and other documentation can be found at www.nrcs.usda.gov/technical/nri/ceap/surveys.html.

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

[9] 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.

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 (figure 5). 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).[10]

Figure 5. 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.

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.[11]

Use of conservation practices in the UMRB 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.[12]

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 (figure 6).

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).[13] 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.

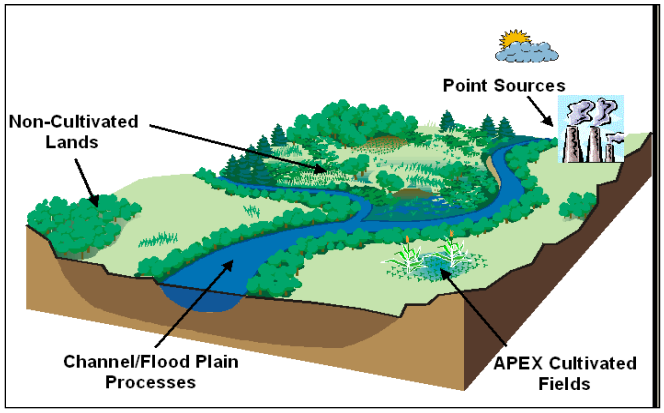
[10] Summaries of APEX model validation studies on how well APEX simulates measured data are presented in Gassman et al. (2009) and in "APEX Model Validation for CEAP" found at http://www.nrcs.usda.gov/technical/nri/ceap/umrbdocumentation/.

[11] 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/umrbdocumentation/.

[12] 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/umrbdocumentation/.

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

Figure 6. Sources of water flows, sediment, and agricultural chemicals simulated with HUMUS/SWAT



Source loads for cultivated cropland are estimated by APEX, and source loads for noncultivated land uses are estimated by SWAT. SWAT simulates the fate and transport of water, sediment, nutrients, and pesticides for the following land use categories, referred to as Hydrologic Response Units (HRUs):

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

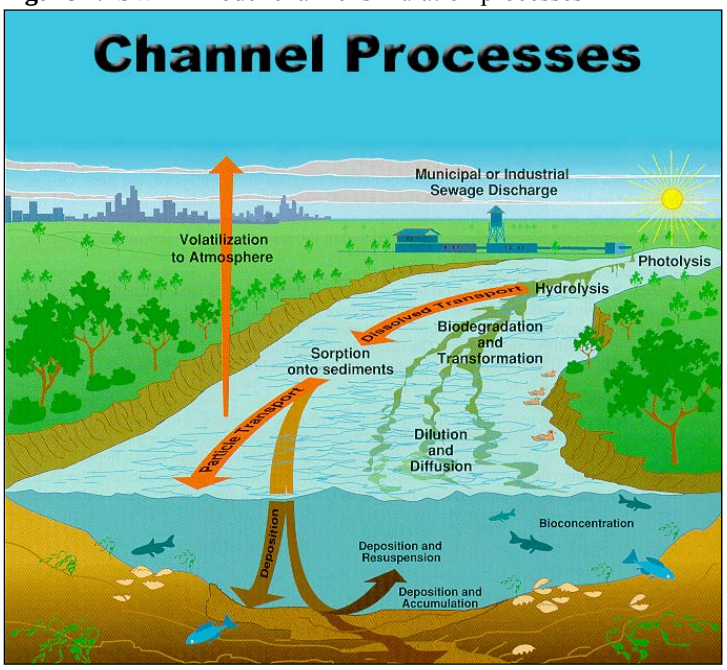
All source loads, including point sources, are introduced into SWAT at the outlet of each watershed (8-digit hydrologic unit code [HUC]). Flows and source loads from upstream watersheds are routed through each downstream watershed, including reservoirs when present. During the routing, channel processes such as sediment deposition and degradation and nutrient and pesticide transformations are simulated (figure 7).[14]

Instream loads of sediment, nitrogen, phosphorus, and the pesticide atrazine are reported for each of the 14 subbasins (4-digit HUC) in the UMRB. Atrazine was the only pesticide modeled in the UMRB because of its dominance in determining environmental risk in the region.

Simulating weather

In the UMRB, weather is the predominant factor determining the loss of soil, nitrogen, phosphorus, and pesticides from farm fields, as well as the effects of conservation practices.

Figure 7. SWAT model channel simulation processes



To capture the effects of weather, each scenario was simulated for 47 years using actual daily weather data for the time period 1960 through 2006.[15] The same 47-year weather data were used in the HUMUS/SWAT simulations that were used in the APEX model simulations.

Annual precipitation over the 47-year simulation averaged about 34 inches in this region. However, annual precipitation varies substantially in the model simulations, both within the region and from year to year, as shown in figure 8. Each curve 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. Generally, the drier parts of the region receive about half as much rainfall (22 inches on average) as the wettest parts of the region (49 inches on average). Year-to-year variability is equally pronounced—the annual median precipitation amount (representing the region as a whole) ranged from 23 inches per year to 46 inches per year.

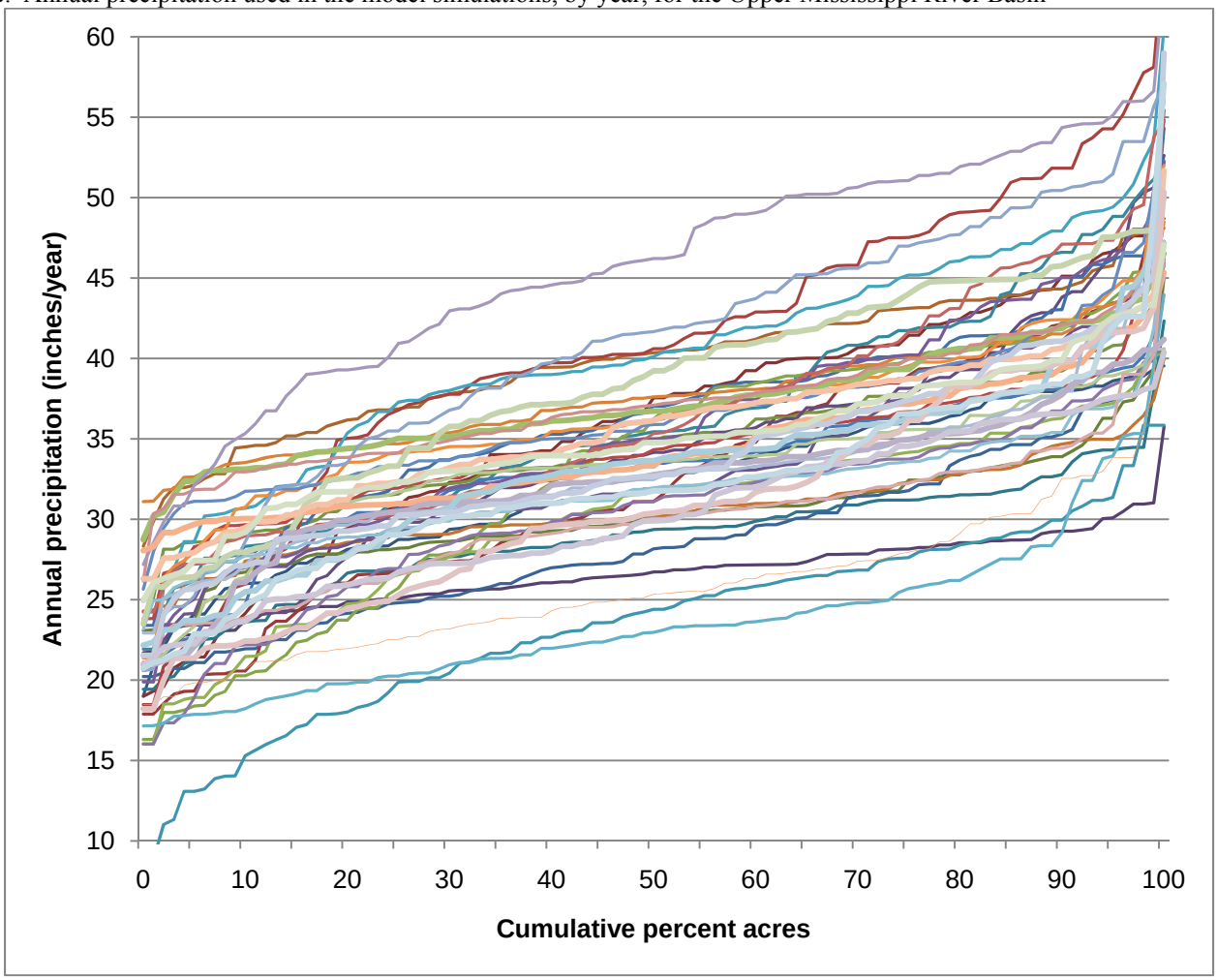
The 5 driest years included in the model simulation (median precipitation less than 28 inches) were 1963, 1966, 1976, 1988, and 1989. The 5 wettest years (median precipitation more than 40 inches) were 1965, 1973, 1990, 1993, and 1998. The effects of conservation practices estimated in this study reflect these extreme conditions.

Because farming activities represent the time period 2003 to 2006, model results do not indicate environmental outcomes for each year of the 47 years.

[14] For a complete documentation of HUMUS/SWAT as it was used in this study, as well as a summary of calibration and validation results for the UMRB, see "The CEAP-HUMUS National Water Quality Modeling System and Databases" at http://www.nrcs.usda.gov/technical/nri/ceap/umrbdocumentation/.

[15] The 47-year record is the extent of 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).

Figure 8. Annual precipitation used in the model simulations, by year, for the Upper Mississippi River Basin



Note: This figure shows how annual precipitation varied within the region and from year to year in the model simulation. Each of the 47 curves shown above represents a single year of data and shows how annual precipitation varied over the region in that year, starting with the driest acres within the region and increasing to the wettest acres for each year. The family of curves shows how annual precipitation varied from year to year. Annual precipitation over the 47-year simulation averaged about 34 inches. 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 40 inches per year for about 75 percent of cropped acres in the UMRB.

Rather, model results represent what would be expected to occur under varying weather conditions for farming activities conducted in the period 2003–06. For most analyses, model results are averaged over the 47 years and reported as average annual values. These average annual estimates thus represent environmental outcomes that would be expected over the long run.

Simulating the no-practice scenario

The purpose of the no-practice scenario is to provide an estimate of the benefits of conservation practices in use within the UMRB. 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 "poor" conservation so that a believable 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 6 summarizes the adjustments to conservation practices used in simulation of the no-practice scenario.

Table 6. Construction of the no-practice scenario

Practice adjusted	Level of criteria	Criteria used to determine if a practice was in use	Adjustment made to create the no-practice scenario
Residue management (tillage)	Crop within a crop year	STIR ≤100	Add two tandem diskings 1 week prior to planting
Nitrogen rate – without manure	Crop within a crop year	Applied N ≤1.4 times harvest removal for non-legume crops	Increase rate to 1.64 times harvest removal (proportionate increase in all reported applications)
Phosphorus rate – without manure	Crop rotation	Applied P ≤1.1 times harvest removal for all crops in rotation	Increase rate to 1.6 times harvest removal (proportionate increase in all reported applications)
Nitrogen rate – with manure	Crop within a crop year	Applied total of fertilizer and manure N ≤1.4 times harvest removal for all crops	Increase manure and N fertilizer application rates to reach 1.64 times harvest removal (all applications increased proportionately)
Phosphorus rate – with manure	Crop rotation	Applied total of fertilizer and manure P ≤ 1.1 times harvest removal, accounting also for manure P associated with increase to meet N criteria	Increase P fertilizer application rates to reach1.6 times harvest removal, accounting for increased manure due to the N criteria
Fertilizer application method	Application event	Incorporated or banded	Change to surface broadcast
Manure application method	Application event	Incorporated, banded, or injected	Change to surface broadcast
Fertilizer application timing	Application event	Within 3 weeks prior to planting, at planting, or within 60 days after planting.	Moved to 3 weeks prior to planting
Cover crop	Crop year	Cover crop planted for off-season protection	Remove cover crop simulation (field operations, fertilizer, grazing, etc.)
Pesticide	Sample	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
Irrigation	Crop year	Pressure systems	Change to Hand Move Sprinkler Systems
Structural practices	Sample	1. Overland flow practices present 2. Concentrated flow—managed structures or waterways present 3. Edge-of-field mitigation practices present 4. Wind erosion control 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. Structures and waterways replaced with earthen ditch, soil condition changed from good to poor. 3. Removed practice and width added back to field slope length. 4. Unsheltered distance increased to 400 meters

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 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. The width of these practices will be returned to the slope lengths as well. (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.

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 are removed so are the grazing operations.

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 one of two primary ways: (1) by altering rates, form, timing, and methods of application, or (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 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.

- **Nitrogen 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 1.40 times the amount of nitrogen removed at harvest. The ratio of 1.64 for the increased nitrogen rate was determined by the average rate-to-yield-removal ratio for crops exceeding 1.4.

Where nitrogen was applied in multiple applications, each application was increased proportionately. For sites receiving manure, the threshold for identifying good management was the total nitrogen application rate, both manure and fertilizer, and both fertilizer and manure were increased proportionately to reach the 1.64 times harvest removal threshold. The assessment for using appropriate nitrogen application rates was made on an average annual basis for each crop in the rotation using average annual model output for nitrogen removed at harvest in the baseline conservation condition scenario.

- **Phosphorus rate:** The no-practice scenario for phosphorus is similar to that for nitrogen, but with a lower threshold. The lower threshold was used 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. The threshold for identifying proper phosphorus application rates was 1.1 times the amount of phosphorus taken up by the crop and removed at harvest. For the no-practice scenario, the amount of phosphorus applied was increased to 1.6 times the harvest removal rate. For crops receiving manure, the increase in P from manure added to meet the N criteria was taken into account. The ratio of 1.6 for the increased phosphorus rate was determined by the average rate-to-yield-removal ratio for crops exceeding 1.1. Fertilizer application events were increased proportionately to meet the 1.6 threshold. No adjustment was made to manure to meet the P threshold. No adjustment was made in the no-practice scenario for manure applications exceeding a phosphorus basis for the manure application rate.

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

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

No-practice representation of irrigation practices. The no-practice irrigation protocols focus on reducing efficiencies both of water delivery from the source to the field and of application methods. 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. All conservation practices, such as irrigation water management, were removed and samples with pressurized systems were changed to "hand move sprinklers." All but three of the 66 cases of irrigated crops used a Center Pivot system in the baseline conservation condition. The other three included two with Big Gun and one Open Discharge Flood system. The Open Discharge Flood system was unchanged.

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 conservation practices that retain pesticide residues within the farm field boundaries.
2. Pesticides and pesticide application practices that minimize the risk that pesticide residue poses to the surrounding environment.
3. Practice of Integrated Pest Management (IPM) at a high level.

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—practicing IPM. An IPM indicator was developed on the basis of survey responses to IPM-related questions in the NRI-CEAP Cropland Survey.

Adoption of IPM systems normally occurs along a continuum from largely reliant on prophylactic control measures and pesticides to multiple-strategy, biologically intensive approaches, and 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 should 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.

[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.

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, should be performed as the basis for suppression activities. Records should be 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 become 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, should be considered as alternatives to conventional pesticides, especially where long-term control of an especially troublesome pest species can be obtained. Where naturally occurring biological controls exist, effort should be made to conserve these valuable tools. *Chemical pesticides* are important in IPM programs, and some use will remain necessary. However, pesticides should be applied as a last resort in suppression systems using a sound management approach.

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.

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. For high IPM cases, the first application event between planting and 30 days before harvest was replicated twice for each crop, one week and two weeks after its original occurrence. For moderate IPM cases, the first application event was replicated one time for each crop, one week after its original occurrence.

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 to create a new simulation.

Chapter 3
The Baseline Conservation Condition

Overview and Summary of Findings

The use of conservation practices in the UMRB closely reflects the history of Federal conservation programs and technical assistance. In the beginning the focus was almost entirely on reducing soil erosion and the 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 strip cropping) 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 to further reduce soil erosion on cropland. 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 late 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, but 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.

This study assessed the use and effectiveness of conservation practices in the UMRB 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 treatments. 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 that are 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.

The effects of conservation crop rotation practices (NRCS practice code 328) were not assessed. This practice consists of growing different crops in a planned rotation to manage nutrient inputs, enhance soil quality, or reduce soil erosion. In the UMRB, crop rotations that meet NRCS criteria occur on over 90 percent of the cropped acres, often for reasons unrelated to conservation benefits, such as the control of pests or in response to changing markets. In contrast, only 25 percent of survey respondents had conservation crop rotation included in a written conservation plan. Estimating the effects of conservation crop rotation practices requires simulation of continuous cropping systems for all crops, for which adequate information on chemical use and other farming practices was not available.

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:

- Structural practices for controlling water erosion are in use on 45 percent of cropped acres (table 7). 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 of those acres.
- Tillage and residue management use is common (table 8).
    - About 71 percent of the acres meet tillage intensity criteria for either no-till or mulch till and are gaining soil organic carbon, including 62 percent of the highly erodible land.

- Overall, 75 percent of the acres are gaining soil organic carbon.
- All but 5 percent of the acres had evidence of some kind of reduced tillage on at least one crop.

- Producers use either residue and tillage management practices or structural practices, or both, on 96 percent of the acres, including 98 percent of the highly erodible land.
- 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 (table 9).
  - Appropriate rates of nitrogen application are in use on about 34 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 14 percent of the acres, including acres without nitrogen applications.
  - About 86 percent of the acres lack consistent use of appropriate nitrogen application rates and/or 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 29 percent of the acres on all crops during every year of production, including acres without phosphorus applications.
  - About 71 percent of the acres lack consistent use of appropriate phosphorus application rates and/or method of phosphorus application, including nearly all of the acres receiving manure.
- 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 67 percent are 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 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 overhead 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 UMRB, including 46 percent of those that are classified as 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. This is the most prevalent group of structural practices in the UMRB; about 32 percent of the cropped acres have one or more of these practices, including 55 percent of the highly erodible land.

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.

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.

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 all 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, crosswind trap strips, herbaceous windbreak, hedgerow planting	3	3	3

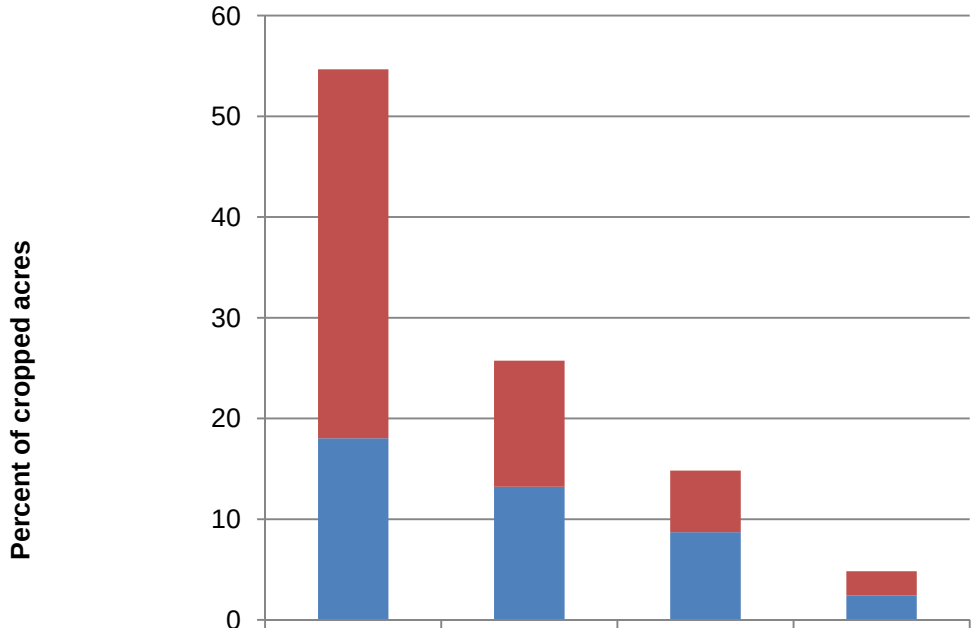
Note: About 18.4 percent of cropped acres in the UMRB are highly erodible land (HEL). Soils are classified as HEL if they have an erodibility index (EI) score of 8 or higher. A numerical expression of the potential of a soil to erode, EI considers the physical and chemical properties of the soil and 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.

Overall, about 45 percent of the cropped acres in the UMRB are treated with one or more water erosion control structural practices (table 7). The treated percentage for highly erodible land acres is much higher—72 percent.

The structural conservation practices for water erosion control in use for each sample were classified as either a high level of treatment, moderately high level of treatment, moderate level of treatment, or low level of treatment. Criteria for each treatment level are presented in figure 9. These treatment levels are combined with soil risk classes to estimate acres that appear to be under-treated for water erosion control in chapter 6.

As shown in figure 9, only 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, some of the fields with slopes less than 2 percent do not need to be treated with structural practices.

Figure 9. Conservation treatment levels for structural practices, baseline conservation condition, UMRB



	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.

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.

The Soil Tillage Intensity Rating (STIR) (USDA-NRCS 2007)[17] was used to determine the soil disturbance intensity for each crop at each sample point. 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.

Overall, 91 percent of cropped acres in the UMRB meet the tillage intensity rating for no-till or mulch till (table 8). About 28 percent meet the criteria for no-till--23 percent with gains in soil organic carbon and 5 percent with soil organic carbon loss. Most cropped acres (63 percent) meet the tillage intensity criteria for mulch till--48 percent with gains in soil organic carbon and 15 percent with soil organic carbon loss. No-till is used more frequently on highly erodible land than on non-highly erodible land. Only 5 percent of the acres are conventionally tilled for all crops in the rotation.

Four levels of treatment for residue and tillage management practices were derived according to criteria presented in figure 10. These treatment levels are combined with soil risk classes to estimate acres that appear to be under-treated for water erosion control in chapter 6. The high and moderately high treatment levels represent the 71 percent of the acres that meet tillage intensity criteria for either no-till or mulch till with gains in soil organic carbon. The high treatment level (63 percent of the acres) includes only those acres where the tillage intensity criteria are met for *each* crop in the rotation. Only 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.

Cover Crops

Cover crops are planted when the principal crops are not growing. The two most important functions of cover crops 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. Cover crops also contribute to soil quality by capturing atmospheric carbon in plant tissue and adding it to the soil carbon.

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). [18]
- 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 UMRB, cover crops are rarely used as a conservation practice. Less than 1 percent of the acres (13 sample points) meet the criteria for a cover crop. Climate is likely to play a large role in its lack of adoption, since the growing season in much of the basin is too short to establish a cover crop following fall-harvested crops. Farmers in the portions of the basin where the climate is warmer and the growing season is longer are more likely to double crop with winter wheat rather than to plant a small grain winter cover crop.

Irrigation Management Practices

Only about 2.5 percent of the cropland—1.5 million acres—receives irrigation water in the UMRB. Irrigation in the region is almost exclusively by pressure systems. Most common are center-pivot or linear-move systems with impact sprinkler heads (56 percent) followed by center-pivot or linear-move with the more efficient low-pressure spray (34 percent). Big gun sprinklers make up 4 percent of the systems, and the most efficient system, center pivot or linear-move with near-ground emitters, are another 3 percent. Because of the small number of irrigation systems reported for the region, the conservation effects of irrigation management practices were not evaluated.

[17] A description of the Soil Tillage Intensity Rating (STIR) can be found at http://stir.nrcs.usda.gov/.

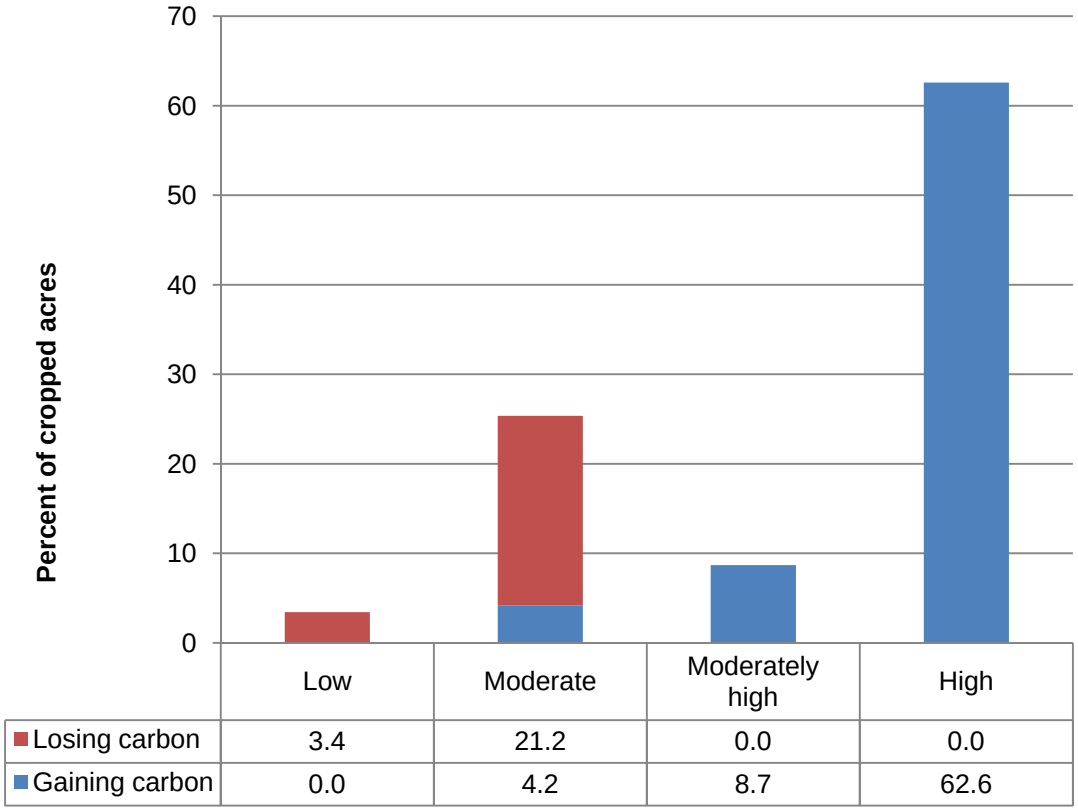
[18] Except for the 2003 survey, the questionnaire allowed the respondent to list the purpose for which a crop was grown, including cover crop. This information was not a reliable indicator of a cover crop for conservation purposes.

Table 8. Residue and tillage management practices for the baseline conservation condition, Upper Mississippi River Basin

Residue and tillage management practice in use	Percent of non-HEL	Percent of HEL	Percent of all acres
Acres with carbon gain	78	63	75
Average annual tillage intensity for crop rotation meets criteria for no-till*	20	36	23
Average annual tillage intensity for crop rotation meets criteria for mulch till**	53	26	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
Acres with carbon loss	22	37	25
Average annual tillage intensity for crop rotation meets criteria for no-till*	2	14	5
Average annual tillage intensity for crop rotation meets criteria for mulch till**	14	20	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

* 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.
HEL = highly erodible land.
Note: Percents may not add to totals because of rounding.

Figure 10. Conservation treatment levels for residue and tillage management, baseline conservation condition, UMRB



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 do not meet criteria for high or moderately high treatment or crop rotation is gaining soil organic carbon; most acres in this treatment level are losing soil organic carbon.
- **Low treatment**: Continuous conventional tillage and crop rotation is losing soil organic carbon.

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 and, when combined with naturally occurring levels of these elements, can create human health risks and other offsite environmental 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. All nutrient management systems have four basic criteria for application of commercial fertilizers and manure.

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 on a crop-by-crop basis:

- 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.
- Where only commercial fertilizer is applied—
  - the rate of commercial nitrogen fertilizer application is less than 1.4 times the amount of nitrogen removed in the crop yield at harvest; or
  - the rate of commercial phosphorus fertilizer application is less than 1.1 times the amount of phosphorus removed in the crop yield at harvest.
- Where manure is applied, the sum of the nitrogen in commercial fertilizer and the nitrogen in the manure is less than 1.4 times the amount of nitrogen removed in the crop yield at harvest. A nitrogen basis for manure applications is considered sufficient to meet requirements for nutrient management.[19]

These nutrient management criteria are intended to represent practice recommendations commonly found in nutrient management conservation plans. Some conservation plans have requirements that are less stringent, while others include more stringent nutrient management practices. The criteria used here to identify the occurrence of nutrient management practices, while generally consistent with NRCS standards, do not necessarily represent the best possible or even the best practical set of nutrient management practices.

As shown in table 9, most acres with nutrients applied meet one or more of the criteria for nutrient management in the UMRB:

- 45 percent of acres meet criteria for timing of nitrogen applications, mostly acres not receiving manure.
- 56 percent of acres meet criteria for method of nitrogen application.
- 34 percent of acres meet criteria for nitrogen application rate.
- 50 percent of acres meet criteria for timing of phosphorus applications, mostly acres not receiving manure.
- 57 percent of acres meet criteria for method of phosphorus application.
- 57 percent of acres meet criteria for phosphorus application rate.

However, few acres meet all criteria. Overall, only 14 percent of the acres meet all criteria for nitrogen applications. Another 2 percent of cropped acres did not apply nitrogen. Proper phosphorus management is more common; 29 percent of the acres meet all criteria for phosphorus applications. About 1 percent of the acres did not apply phosphorus.

Only about 12 percent of the acres meet the criteria for *both* phosphorus and nitrogen management (table 9).

[19] Meeting criteria for the more strict phosphorus basis for manure application was not evaluated. It is a common practice to use a nitrogen basis for manure application, which usually results in over-application of phosphorus. The farmers practicing sound phosphorus management then wait to apply manure again when soil tests show that phosphorus is needed. This prevents phosphorus from building up in the soil to levels that result in significant loss of soluble phosphorus in surface water runoff. It was not possible to determine this behavior from the survey responses.

Table 9. 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 in rotation have application of N (manure and/or fertilizer) within 3 weeks before planting or after planting	51	11	45
Some or all crops in rotation have fall application of N (manure and/or fertilizer) for spring planted crop	41	64	45
Some or all crops in rotation have application of N (manure and/or fertilizer) prior to 3 weeks before 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 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 have N applied at a rate less than 1.4 times the removal in the yield at harvest	33	36	34
Some crops in rotation have N applied at a rate less than 1.4 times the removal in the yield at harvest	59	56	58
No crops in rotation have N applied at a rate less than 1.4 times the removal in the yield at harvest	5	8	6
Timing and method and rate of application			
All crops have N rate less than 1.4 times removal at harvest and application within 3 weeks before planting or after planting with incorporation or banding/foliar/spot treatment	17	2	14
Some crops have N rate less than 1.4 times removal at harvest or application within 3 weeks before planting or after planting or use of incorporation or banding/foliar/spot treatment	70	71	70
No crops have N rate less than 1.4 times removal at harvest or application within 3 weeks before planting or after planting or use of incorporation or banding/foliar/spot treatment	11	27	14
Phosphorus*			
No P applied to any crop in rotation	1	0	1
For samples where P is applied:			
Time of application			
All crops in rotation have application of P (manure and/or fertilizer) within 3 weeks before planting or after planting	57	13	50
Some or all crops in rotation have fall application of P (manure and/or fertilizer) for spring planted crop	36	63	41
Some or all crops in rotation have application of P (manure and/or fertilizer) prior to 3 weeks before 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 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	62	29	57
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	37	71	43
Timing and method and rate of application			
Crop rotation has P rate less than 1.1 times removal at harvest and applications within 3 weeks before planting or after planting with incorporation or banding/foliar/spot treatment	34	2	29
Crop rotation has P rate less than 1.1 times removal at harvest and some crops had application within 3 weeks before planting or after planting and/or some crops used incorporation or banding/foliar/spot treatment	27	24	26
Crop rotation has P rate more than 1.1 times removal at harvest or no crops had applications within 3 weeks before planting or after planting or no crops used incorporation or banding/foliar/spot treatment	39	74	45
Nitrogen and Phosphorus			
Crop rotation P rate less than 1.1 and N rate less than 1.4 times removal at harvest and all applications within 3 weeks before planting or after planting with incorporation or banding/foliar/spot treatment	14	1	12
Crop rotation P rate less than 1.1 and N rate less than 1.2 times removal at harvest and all application within 3 weeks before planting or after planting with incorporation or banding/foliar/spot treatment	9	0	7
All sample points	100	100	100

Note: About 16 percent of cropped acres (9.5 million acres) have manure applied.

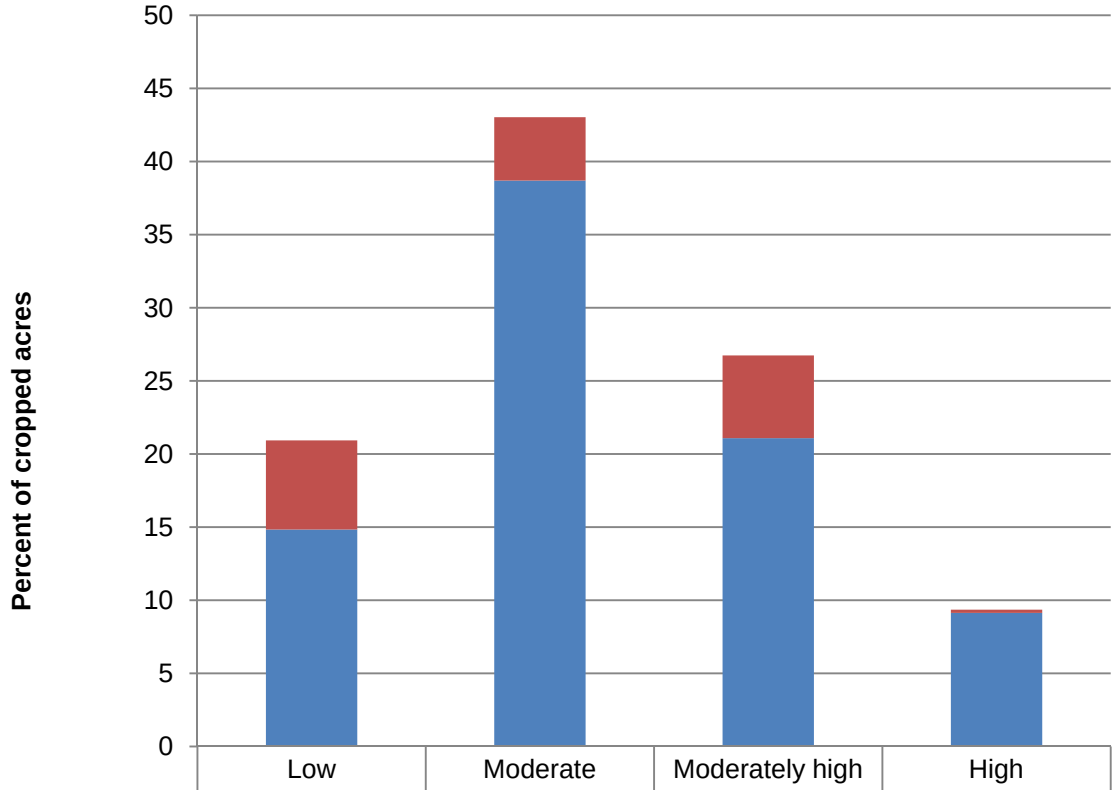
* Adjustments were made to the reported data on nitrogen and phosphorus application rates reported in the survey because of missing data and data-entry errors. In the case of phosphorus, the 3-year data period for which information was reported was too short to pick up phosphorus applications made at 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, 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 22 percent of the acres received a nitrogen adjustment for one or more crops. About 46 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.

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

Four levels of treatment for nitrogen and phosphorus management were derived for use in evaluating the adequacy of nutrient management in the region. These treatment levels are combined with soil risk classes to estimate acres that appear to be under-treated in chapter 6. Criteria for the treatment levels are presented in figures 11 and 12. The high treatment level represents consistent use of appropriate rate, timing, and method for all crops. The high level of treatment for nitrogen additionally requires that application rates be equal to or less than 1.2 times the removal of nitrogen in crop yield at harvest to correspond to the higher standard simulated in the treatment scenarios presented in Chapter 7.

Based on these treatment levels, about 9 percent of the acres in the UMRB have a high level of nitrogen management and about 29 percent have a high level of phosphorus management (figures 11 and 12). Few acres with manure applied meet the criteria for the high treatment levels. About two-thirds of cropped acres have either low or moderate levels of nitrogen management, and 43 percent of the acres have either low or moderate levels of phosphorus management.

Figure 11. Conservation treatment levels for nitrogen management, baseline conservation condition, UMRB

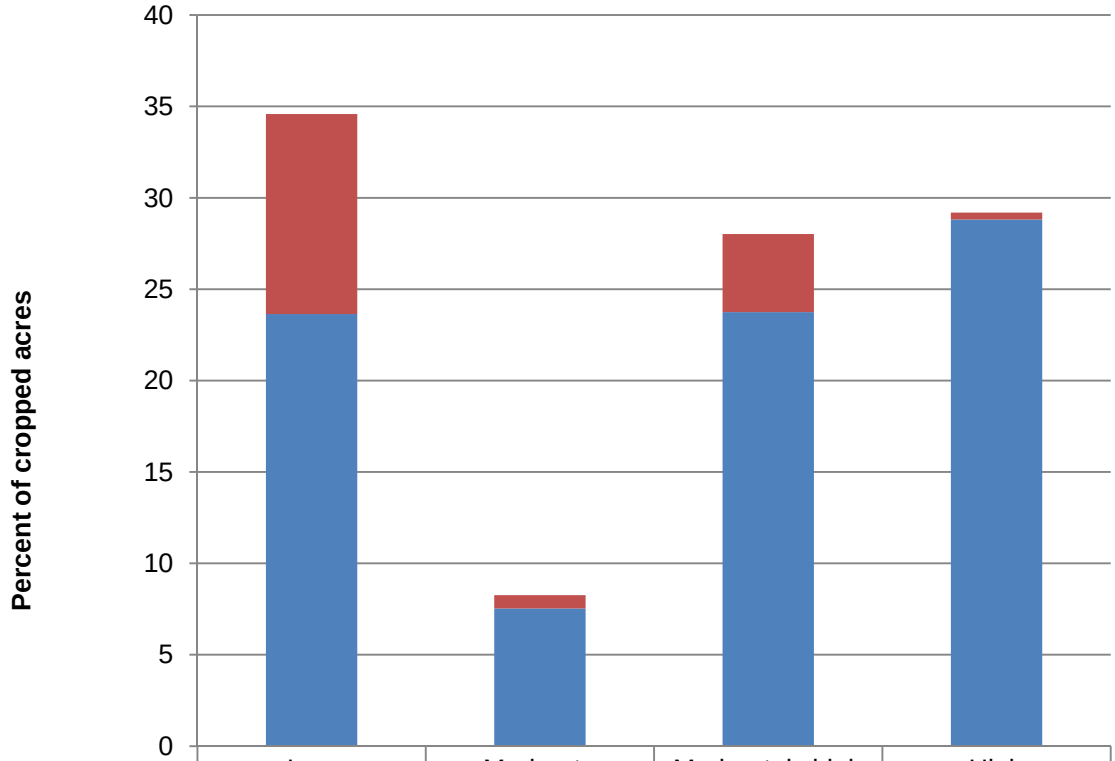


	Low	Moderate	Moderately high	High
Manure applied	6.1	4.3	5.7	0.2
No manure applied	14.8	38.7	21.1	9.1

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, (2) all applications occur within 3 weeks before planting or after planting, and (3) all applications are incorporated or banding/foliar/spot treatment is used. These criteria apply to both manure and commercial fertilizer applications.
- **Moderately high treatment**: Total nitrogen application rates (including manure) are less than 1.4 times the nitrogen in the crop yield for all crops. Timing and method of application criteria 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.

Figure 12. Conservation treatment levels for phosphorus management, baseline conservation condition, UMRB



	Low	Moderate	Moderately high	High
Manure applied	10.9	0.7	4.3	0.4
No manure applied	23.6	7.5	23.7	28.8

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 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 application rate 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 remaining sample points. All sample points have excessive application rates over the crop rotation and inadequate method or timing of application for at least one crop in the rotation.

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, as discussed in chapter 2. Producer responses are summarized in table 10.

Four categories of IPM activities were scored separately: (1) prevention, (2) avoidance, (3) monitoring, and (4) suppression. After normalizing the scores for each category, the categories were combined into a single IPM score using a weight of 1/6 for prevention, 1/6 for avoidance, 1/3 for monitoring, and 1/3 for suppression. An IPM indicator score greater than 50 defined sample points with a high level of IPM activity for cropping systems in the UMRB. Sample points with an IPM indicator score of 25 to 50 were classified as moderately high IPM treatment and sample points with an IPM score less than 25 were classified as low IPM treatment. Pest monitoring activities were the principle determinate of the IPM indicator score; suppression activities had the least influence on the IPM indicator score in the UMRB.

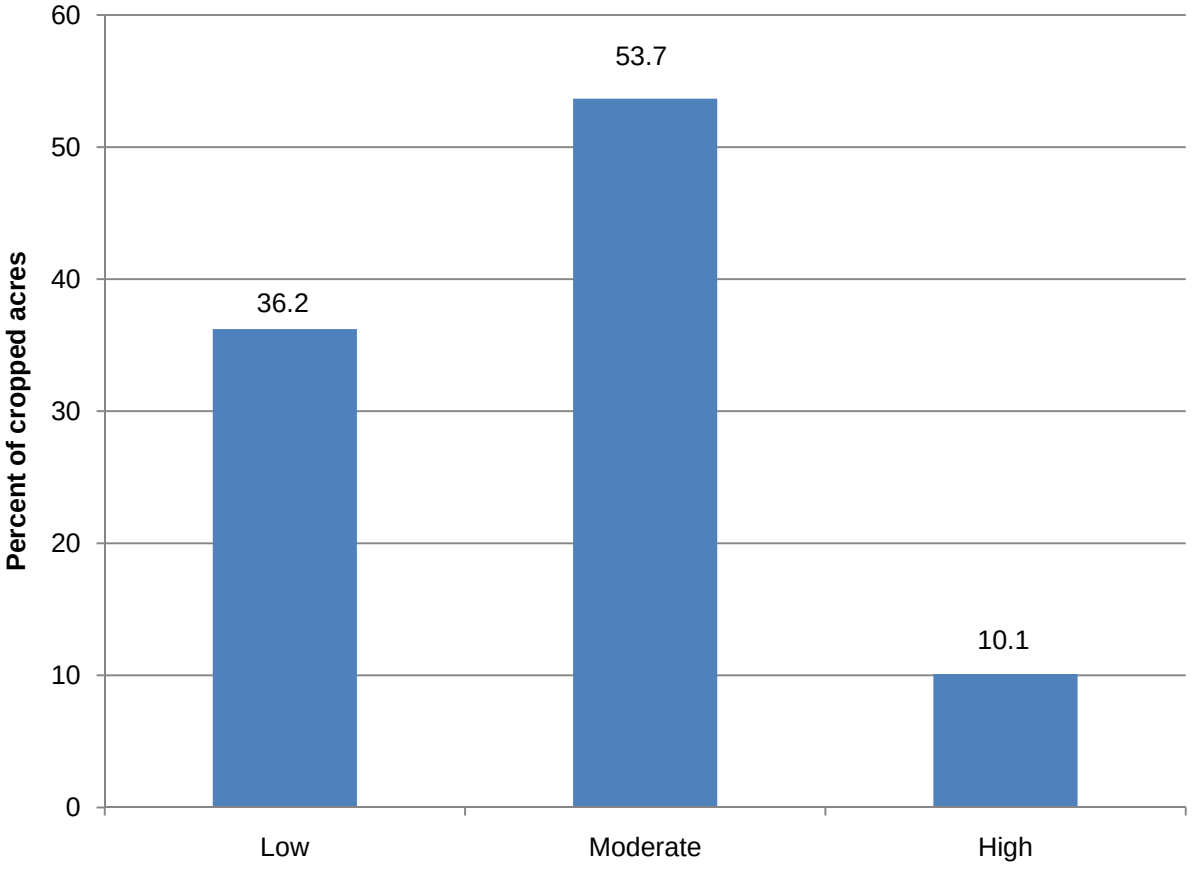
About 10 percent of the acres in the UMRB have a high level of IPM activity (figure 13). About 54 percent have a moderate level of IPM activity, and 36 percent have a low level of IPM activity.

Table 10. Summary of survey responses to pest management questions, Upper Mississippi River Basin

Survey question*	Score	Number samples with "yes" response	Percent of cropped acres
Prevention			
Pesticides with different modes action rotated or tank mixed to prevent resistance	5	1,298	37
Chop, spray, mow, plow, burn field edges, etc.	5	1,502	42
Clean field implements after use	5	1,205	32
Highest possible score for prevention	15		
Avoidance			
Rotate crops to manage pests	8	2,877	77
Use minimum till or no-till to manage pests	6	1,864	50
Choose crop variety that is resistant to pests	6	1,550	44
Planting locations selected to avoid pests	3	333	10
Plant/harvest dates adjusted to manage pests	1	232	7
Highest possible score for avoidance	24		
Monitoring			
Scouting practice: general observations while performing routine tasks	2	1,506	40
Scouting practice: deliberate scouting	10	1,830	50
--Established scouting practice used	4	614	18
--Scouting due to pest development model	2	345	9
--Scouting due to pest advisory warning	2	553	16
Scouting done by: (only highest of the 4 scores is used)			
--Scouting by operator	2	1,306	35
--Scouting by employee	2	27	1
--Scouting by chemical dealer	1	356	10
--Scouting by crop consultant or commercial scout	4	181	5
Scouting records kept to track pests?	4	683	20
Scouting data compared to published thresholds?	4	1,103	32
Diagnostic lab identified pest?	2	157	5
Weather a factor in timing of pest management practice	2	1,411	37
Highest possible score for monitoring	34		
Suppression			
Pesticides used?	0	3,622	98
Weather data used to guide pesticide application	2	2,454	66
Pesticides with different mode of action rotated or tank mixed to prevent resistance	5	1,298	37
Pesticide application decision factor (one choice only):			
--Routine treatments or preventative scheduling	0	2,174	58
--Comparison of scouting data to published thresholds	3	177	5
--Comparison of scouting data to operator's thresholds	2	286	8
--Field mapping or GPS	2	6	<1
--Dealer recommendations	2	660	17
--Crop consultant recommendations	4	115	3
--University extension recommendations	3	4	<1
--Neighbor recommendations	0	1	<1
--"Other"	0	60	2
Maintain ground covers, mulch, or other physical barriers	4	1,273	36
Adjust spacing, plant density, or row directions	4	663	19
Cultivate for weed control during the growing season	2	499	16
Risk level of suite of pesticides used, based on human toxicities			
Risk in lowest 1/3 of acres	10	1,226	34
Risk in middle 1/3 of acres	5	1,224	33
Risk in highest 1/3 of acres	0	1,213	33
Risk level of suite of pesticides used, based on aquatic ecosystem toxicities			
Risk in lowest 1/3 of acres	10	1,222	33
Risk in middle 1/3 of acres	5	1,284	34
Risk in highest 1/3 of acres	0	1,197	33
Highest possible score for suppression	41		

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

Figure 13. Integrated Pesticide Management indicator for the baseline conservation condition, UMRB



Note: The Integrated Pest Management (IPM) indicator was developed using responses to questions in the NRI-CEAP Cropland survey on pest and pesticide management

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 2006, about 32 million acres were enrolled in the CRP General Signup nationally, including about 2.8 million in the UMRB (table 11). Approximately two-thirds of the cropland acres enrolled in the CRP in the UMRB 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.

About 70 percent of CRP-enrolled acres in the UMRB are planted to introduced grasses, about 6 percent to trees, and the remaining 24 percent to either native grasses or plant communities suitable for wildlife habitat (table 11).

Table 11. CRP General Signup acres (1,000s) included in the model simulation for the Upper Mississippi River Basin

Signup #	Signup date	Introduced grass	Native grass	Trees	Softwood trees	Hardwood trees	Wildlife habitat	All	Percent of CRP	Non-HEL	HEL	Percent HEL
5-11	prior to 1992	111.0	17.5	11.2	0	8.5	0	148.2	5	59.2	89.0	60.1
12	06/15–06/26/92	147.3	8.1	11.0	0	3.4	6.9	176.7	6	33.4	143.3	81.1
13	09/11–09/22/95	147.4	3.9	8.3	0	2.3	1.4	163.3	6	43.1	120.2	73.6
15	03/03–03/28/97	708.4	90.1	33.6	0	4.8	23.1	860.0	31	209.4	650.6	75.7
16	10/14–11/14/97	381.5	68.4	28.3	0.6	14.8	122.7	616.3	22	211.8	404.5	65.6
18	10/26–12/11/98	260.5	43.2	11.6	0	9.5	107.7	432.5	15	181.3	251.2	58.1
20	01/18–02/11/00	178.1	107.1	7.7	0	13.3	98.5	404.7	14	190.3	214.4	53.0
	Total	1,934.2	338.3	111.7	0.6	56.6	360.3	2,801.7	100	928.5	1,873.2	66.9
	Percent	69	12	4	<1	2	13	100				

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

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 UMRB 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.

Precipitation and irrigation are the sources of water for a field. Annual precipitation over the 47-year simulation averaged about 33.6 inches in this region (table 12). (Also see figure 8.) Only about 2.5 percent of the cultivated cropland acres are irrigated, at an average annual application of 9.3 inches.

Most of the water that leaves the field is lost through evaporation and transpiration (evapotranspiration). On average, about two-thirds of the water loss from cultivated cropland and land in long-term conserving cover in the UMRB is through evapotranspiration (table 12). Evapotranspiration losses vary, however, according to soil characteristics and land cover. For most acres in the UMRB, evapotranspiration ranges from 60 to 80 percent of the total amount of water that leaves the field (figure 14).

Loss of water through subsurface flow pathways is the second largest source of water loss at an average of about 6.7 inches per year for cropped acres and 9.5 inches per year for land in long-term conserving cover. Subsurface flow pathways include: (1) percolation through the soil profile, (2) subsurface flow into a tile or ditch drainage system, (3) groundwater return flow, (4) lateral subsurface outflow, and (5) quick-return subsurface flow. The percentage of water loss represented by subsurface flow averages about 20 percent for cropped acres and 28 percent for land in long-term conserving cover. However, this percentage is highly variable for cropped acres in the UMRB, as shown in figure 14.

Surface water runoff averages about 12 percent of water loss from fields for cropped acres and 5 percent for land in long-term conserving cover (table 12). The percentage ranges from zero to about 30 percent for cropped acres in the UMRB (figure 14).

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. Model simulations indicate that conservation practices have reduced surface water runoff by about 0.8 inch per year averaged over all acres, representing a 16-percent reduction for the region (table 12).

The re-routing of surface water to subsurface flow is shown graphically in figures 15, 16, and 17 for cropped acres. The amount of surface water runoff varies from acre to acre, ranging from an annual average of zero for some acres to about 10 inches per year. Surface water runoff is highest for acres with higher slopes, soil properties conducive to runoff, and higher precipitation. Similarly, subsurface flows vary from acre to acre (figure 16). The no-practice scenario curves in figures 15 and 16 show what the distribution of surface water runoff and subsurface flows would be if there were no conservation practices—less subsurface flow and more surface water runoff.

Model simulations further show that land in long-term conserving cover (baseline conservation condition) in the region has, on average, about half the surface water runoff and nearly 50 percent more subsurface flow than would occur if the land was cropped (table 12). The distribution of surface water runoff for the baseline conservation condition and the no-practice scenario (simulating a cropped condition) for acres in long-term conserving cover are compared in figure 18.

The variability in the effects of conservation practices in re-routing surface water to subsurface flow is shown in figure 17 for cropped acres and figure 19 for land in long-term conserving cover. This variability reflects different levels of conservation treatment as well as differences in precipitation and inherent differences among acres for water to run off.

Reductions in surface water runoff reduce the loss of nutrients and pesticides exported to the surrounding environment through overland flow. However, the increase in infiltration also re-directs nutrients and pesticides in solution to subsurface loss pathways. Consequently, careful management of nutrients and pesticides is required to offset this re-routing of pollutants when water erosion control practices are used.

Figure 14. Cumulative distributions of the proportion of water lost through three loss pathways

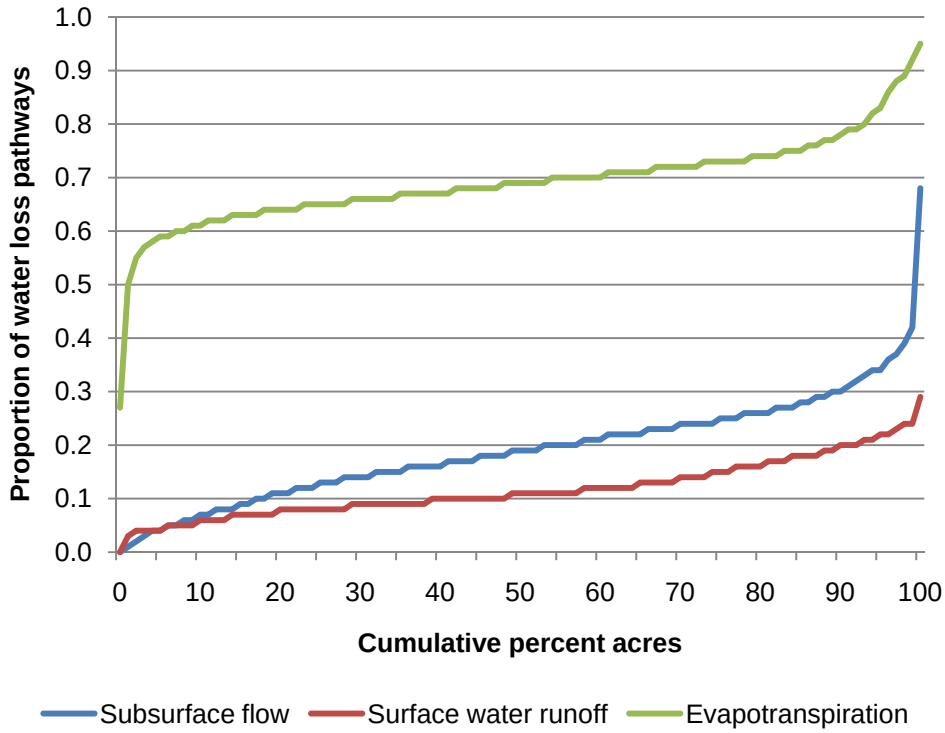


Table 12. Field-level effects of conservation practices on water loss pathways for cultivated cropland in the Upper Mississippi River Basin

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)	33.6	33.6	0.0	0
Irrigated acres*				
Average annual precipitation (inches)	33.1	33.1	0.0	0
Average annual irrigation water applied (inches)	9.3	17.3	7.9	46
Water loss pathways				
Average annual evapotranspiration (inches)	23.4	23.5	0.1	1
Average annual surface water runoff (inches)	4.0	4.8	0.8	16
Average annual subsurface water flow (inches)**	6.7	5.8	-0.9***	-15
Land in long-term conserving cover (2.8 million acres)				
Water sources				
Average annual precipitation (inches)	33.8	33.8	0.0	0
Average annual irrigation water applied (inches)*	0.0	0.2	0.2	100
Water loss pathways				
Average annual evapotranspiration (inches)	22.8	23.2	0.4	2
Average annual surface water runoff (inches)	1.8	4.6	2.8	60
Average annual subsurface water flow (inches)**	9.5	6.1	-3.4	-56

* Only 2.5 percent of the cropped acres in the UMRB 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) percolation through the soil profile, (2) subsurface flow into a drainage system, (3) groundwater return flow, (4) lateral subsurface outflow, and (5) quick-return subsurface flow.
*** Represents an average gain in subsurface flow of 0.9 inch per year (15 percent increase) due to the use of 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 C for the 14 subbasins.

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

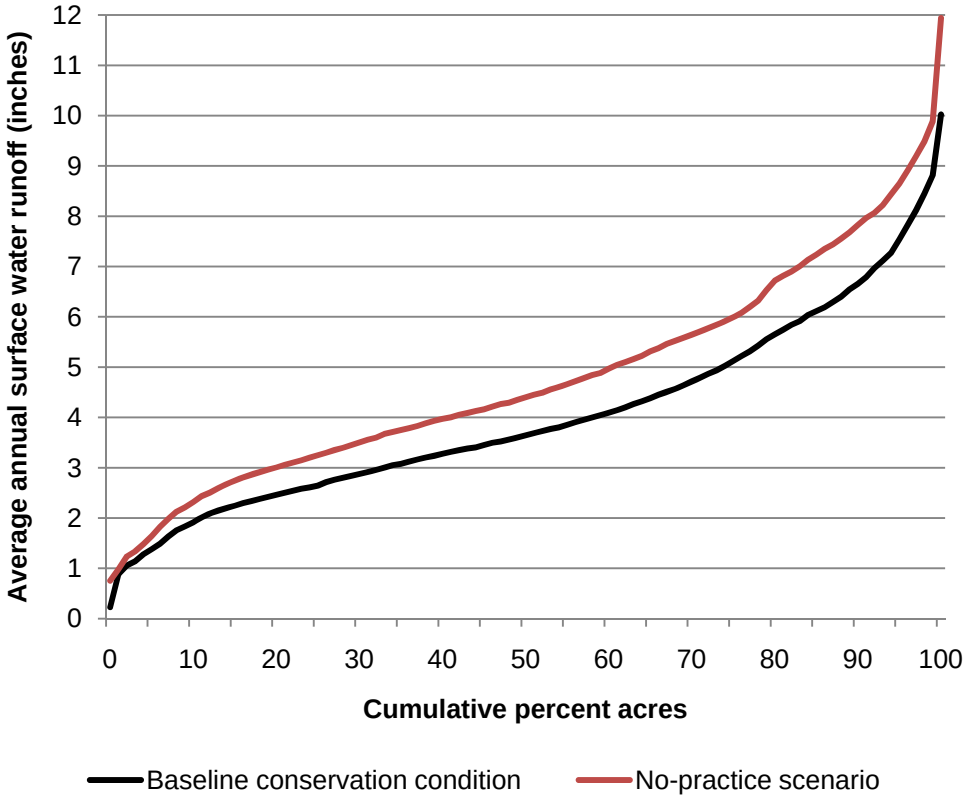


Figure 16. Estimates of average annual subsurface flow for cropped acres in the Upper Mississippi River Basin

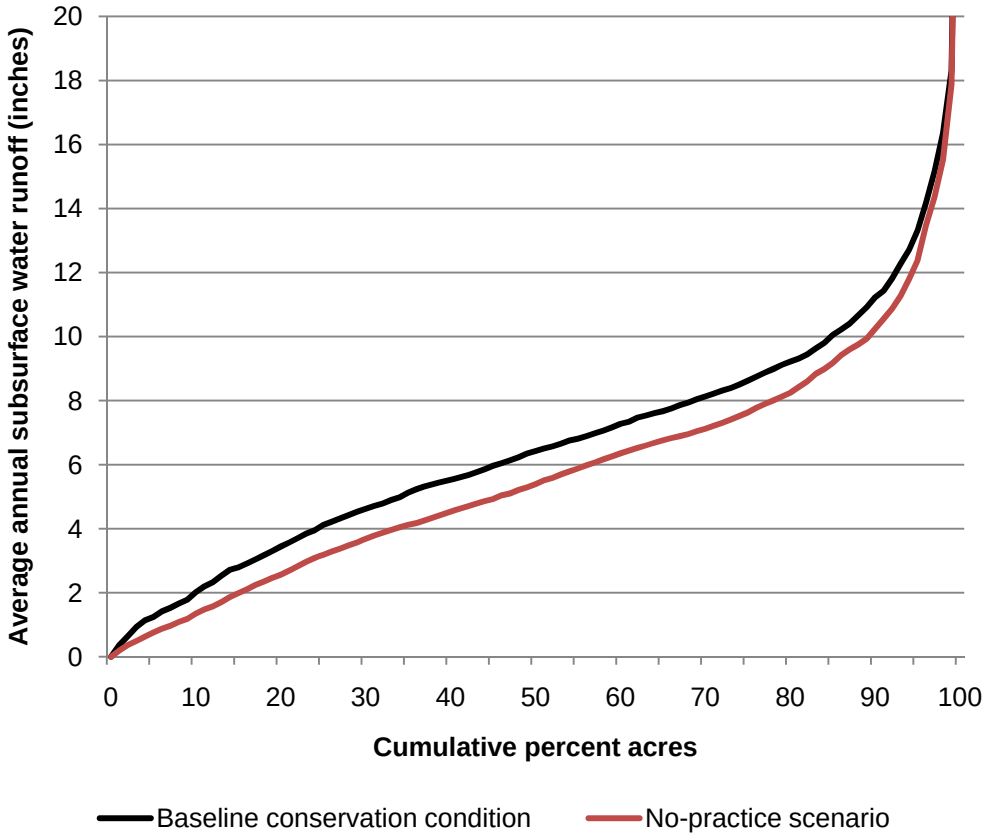
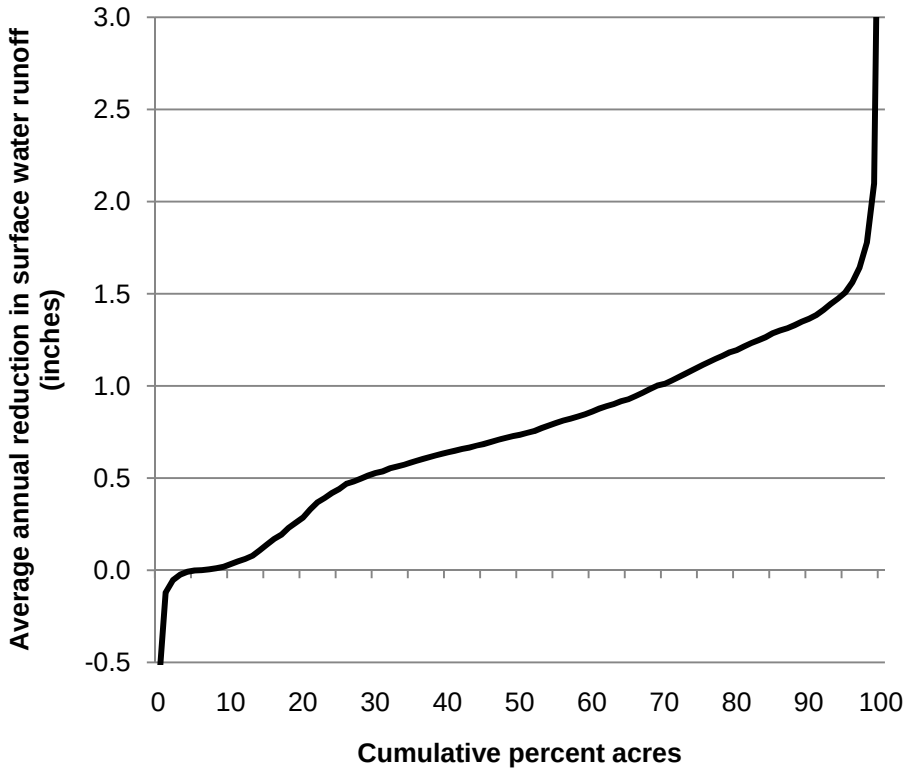


Figure 17. Estimates of average annual reduction in surface water runoff due to the use of conservation practices on cropped acres in the Upper Mississippi River Basin



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

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

The design of this study provides the opportunity to examine not only the overall mean value for a given outcome, but also the entire distribution of outcomes. This is possible because outcomes are estimated for each of the 3,703 sample points used to represent cropped acres in the UMRB and for each of the 1,831 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 1.9 inches per year, indicating that 10 percent of the acres have 1.9 inches or less of surface water runoff, on average. Similarly, the same curve shows that 25 percent of the acres have surface water runoff less than 2.6 inches per year. The 50th percentile—the median—is 3.6 inches per year, which in this case is close to the mean value of 4.0 inches per year. At the high end of the distribution, 90 percent of the acres in this region have surface water runoff less than 6.7 inches per year; and conversely, 10 percent of the acres have surface water runoff greater than 6.7 inches per year. The curves can also be used to define various ranges; for example, half of the cropped acres in the UMRB have average annual surface water runoff of 2.6-5.1 inches per year, where the range is based on the 25th and 75th percentiles.

Thus, the distributions show the full range of outcomes for cultivated cropland acres in the UMRB. 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 17 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 0.8 inch per year, 14 percent of the acres have reductions due to conservation practices greater than 1.3 inches per year, 6 percent of the acres have zero reductions (including all acres not treated for soil erosion control), and 4 percent of the acres actually have increases in surface water runoff (i.e., negative reductions) as a result of soil erosion control conservation practice use. (See footnote to figure 17 for an explanation of the conditions that result in gains in surface water runoff due to conservation practices.)

Figure 18. Estimates of average annual surface water runoff for land in long-term conserving cover in the Upper Mississippi River Basin

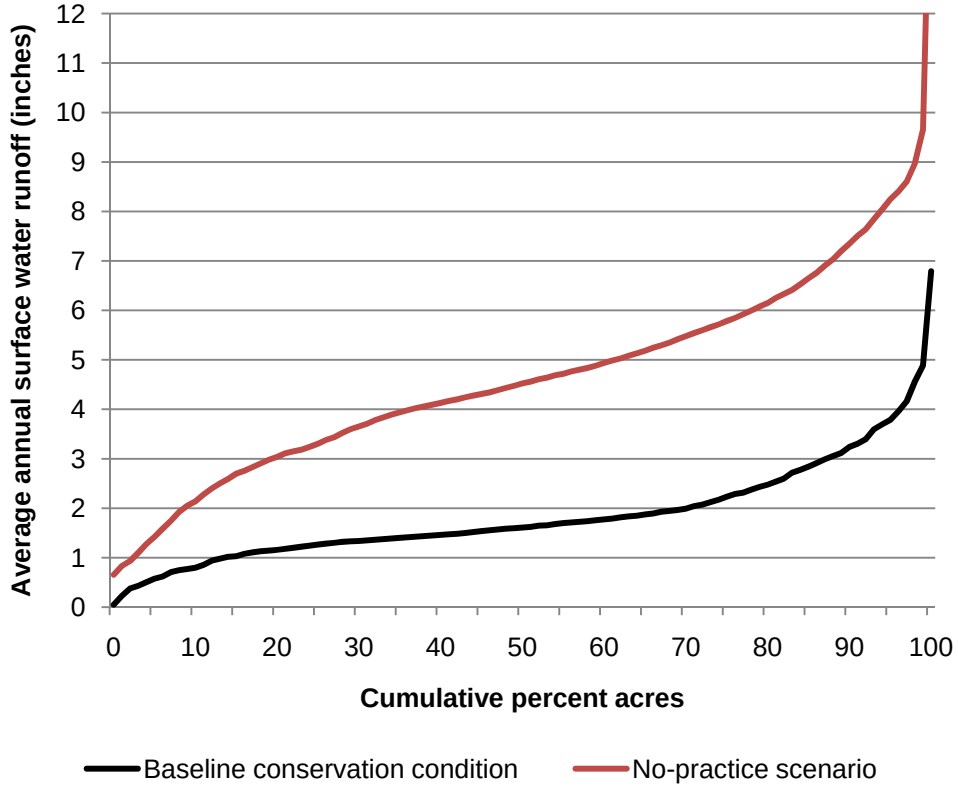
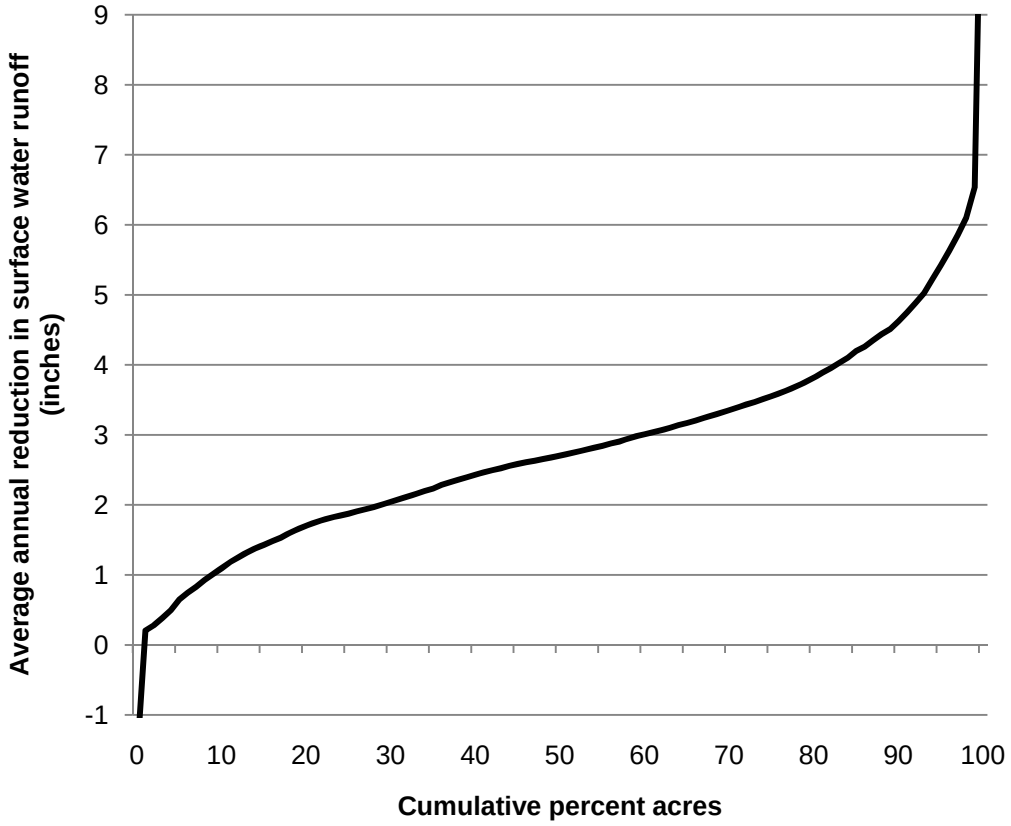


Figure 19. Estimates of average annual reduction in surface water runoff due to conversion to long-term conserving cover in the Upper Mississippi River Basin



While the differences in the reduction of surface water runoff among combinations of structural practices and residue and tillage management are not large, residue and tillage management has more of an effect than structural practices on the re-routing of surface water to subsurface flows (table 13).

Acres that meet criteria for no-till or mulch till and are gaining soil organic carbon reduce surface water flow by an average of 17 percent, both with and without structural practices in use. About two-thirds of the acres in the UMRB are in these two treatment categories (table 13).

Table 13. Estimates of effects of combinations of structural practices and residue and tillage management on average annual surface water runoff for cropped acres in the Upper Mississippi River Basin

		Average annual surface water runoff (inches)			
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	36	4.0	4.8	0.8	17
No-till or mulch till with carbon loss, no structural practices	11	3.7	4.5	0.7	16
Some crops with reduced tillage, no structural practices	3	3.7	4.3	0.6	14
Structural practices and no-till or mulch till with carbon gain	35	4.0	4.8	0.8	17
Structural practices and no-till or mulch till with carbon loss	8	4.4	5.2	0.8	15
Structural practices and some crops with reduced tillage	1	3.9	4.4	0.4	10
Structural practices only	1	4.2	4.4	0.1	3
No water erosion control treatment	4	4.6	4.5	0.0	0
All acres	100	4.0	4.8	0.8	16

Note: Differences in slope, soil texture, hydrologic group, and precipitation for acres in different treatment groups explain some of the differences shown in this table.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Percents may not add to totals because of rounding.

Erosion and Sediment Loss

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 velocity, tillage, vegetative cover, and the texture and structure of the soil are primary determinants of wind erosion.[20]

Wind erosion is a relatively minor resource concern in the UMRB. The greatest concern with wind erosion in the UMRB is crop damage to young seedlings exposed to windblown material. Wind erosion rates as low as 0.5 ton per acre are known to cause physical damage to young seedlings.

For all cropped acres, model simulations show that the average annual rate of wind erosion is only 0.24 ton per acre (table 14). However, a few areas have persistently high rates of wind erosion in some years (figure 20). In the most extreme year included in the model simulations (representing 1967), wind erosion exceeded 1 ton per acre for 27 percent of the cropped acres in the UMRB and exceeded 2 tons per acre for 12 percent of the acres.

Structural practices for wind erosion control are in use on only 3 percent of the cropped acres in the UMRB. 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 54 percent in the region (table 14). Model simulations show that the average annual rate of wind erosion exceeds 1 ton per acre on about 4 percent of the cropped acres (figure 21). Without conservation practices, wind erosion would exceed 1 ton per acre on about 13 percent of the cropped acres. Figure 22 shows that conservation practices have reduced wind erosion by more than 0.5 ton per acre on about 20 percent of the acres.

Even though wind erosion is not a major resource concern in the UMRB, these reductions in wind erosion rates are still significant, especially in areas prone to wind erosion. As shown in later sections, wind erosion can be responsible for significant loss of nitrogen and especially phosphorus from fields.

Since grass or other cover has been established on land in long-term conserving cover, there is no wind erosion currently for these acres. If these acres were cropped without any conservation practices, the wind erosion rate on these 2.8 million acres would average about 0.1 ton per acre per year.

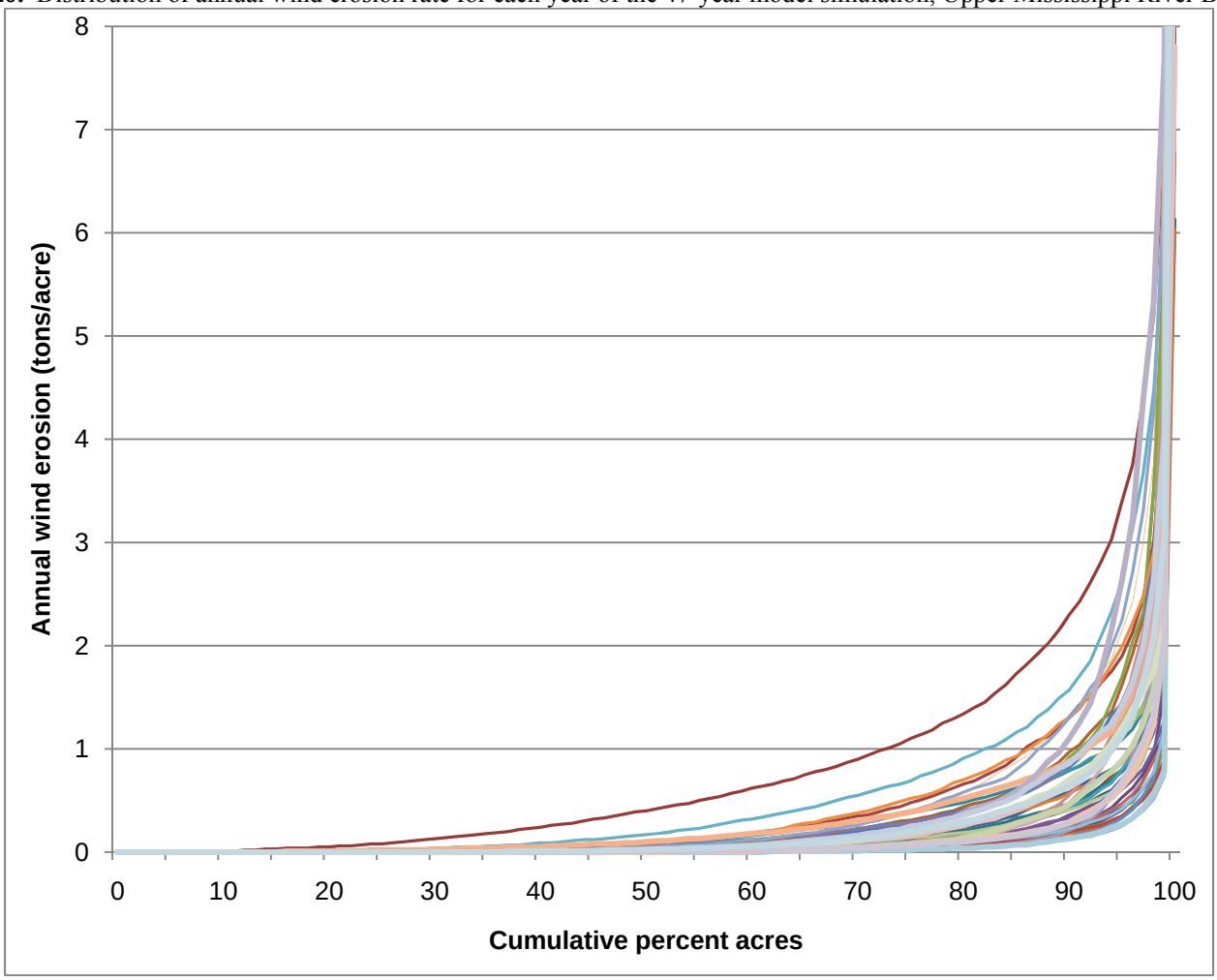
[20] Wind erosion is estimated in APEX using the Wind Erosion Continuous Simulation (WECS) model. The estimated wind erosion rate is the amount of eroded material leaving the downwind edge of the field.

Table 14. 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 wind erosion (tons/acre)	0.24	0.52	0.28	54
Average annual sheet and rill erosion (tons/acre)*	1.04	2.10	1.06	51
Average annual sediment loss at edge of field due to water erosion (tons/acre)	0.98	3.11	2.13	69
Highly erodible land (18 percent of cropped acres)				
Average annual wind erosion (tons/acre)	0.11	0.31	0.20	65
Average annual sheet and rill erosion (tons/acre)*	2.38	5.07	2.69	53
Average annual sediment loss at edge of field due to water erosion (tons/acre)	2.65	8.42	5.77	69
Non-highly erodible land (82 percent of cropped acres)				
Average annual wind erosion (tons/acre)	0.27	0.57	0.30	53
Average annual sheet and rill erosion (tons/acre)*	0.74	1.43	0.69	48
Average annual sediment loss at edge of field due to water erosion (tons/acre)	0.60	1.91	1.31	69
Land in long-term conserving cover (2.8 million acres)				
Average annual wind erosion (tons/acre)	0.00	0.07	0.07	100
Average annual sheet and rill erosion (tons/acre)*	0.13	4.21	4.08	97
Average annual sediment loss at edge of field due to water erosion (tons/acre)	0.06	6.56	6.50	99

* Estimated using the Revised Universal Soil Loss Equation.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix C for the 14 subbasins.

Figure 20. 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) 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 wind erosion varied 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 varied from year to year.

Figure 21. Estimates of average annual wind erosion rate for cropped acres in the Upper Mississippi River Basin

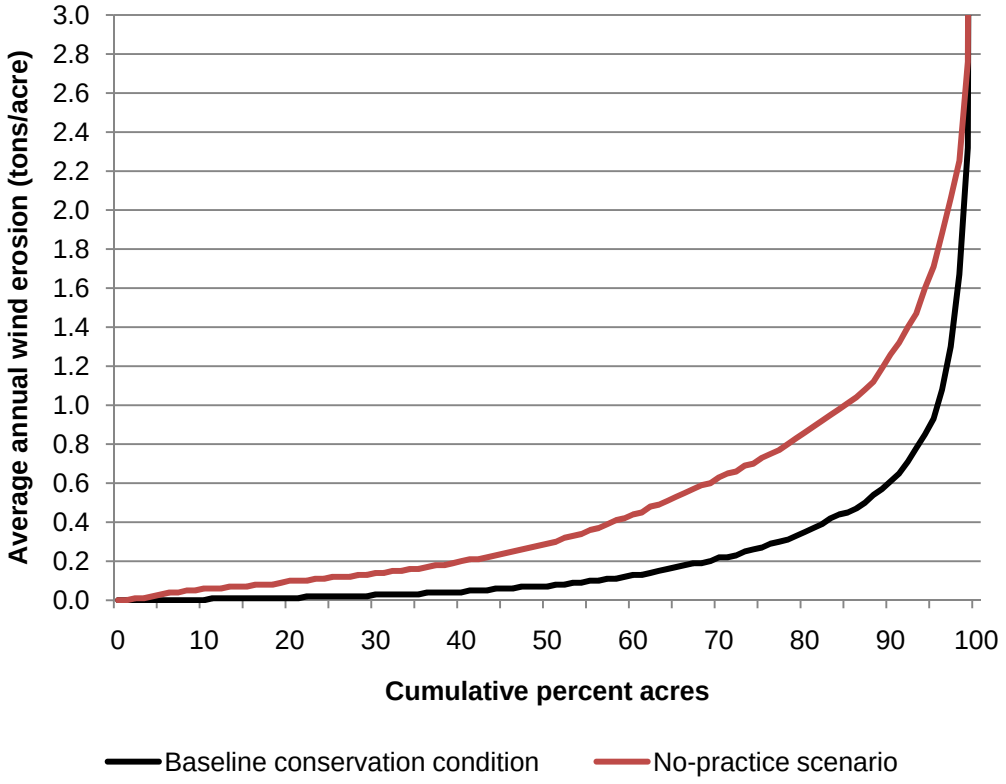
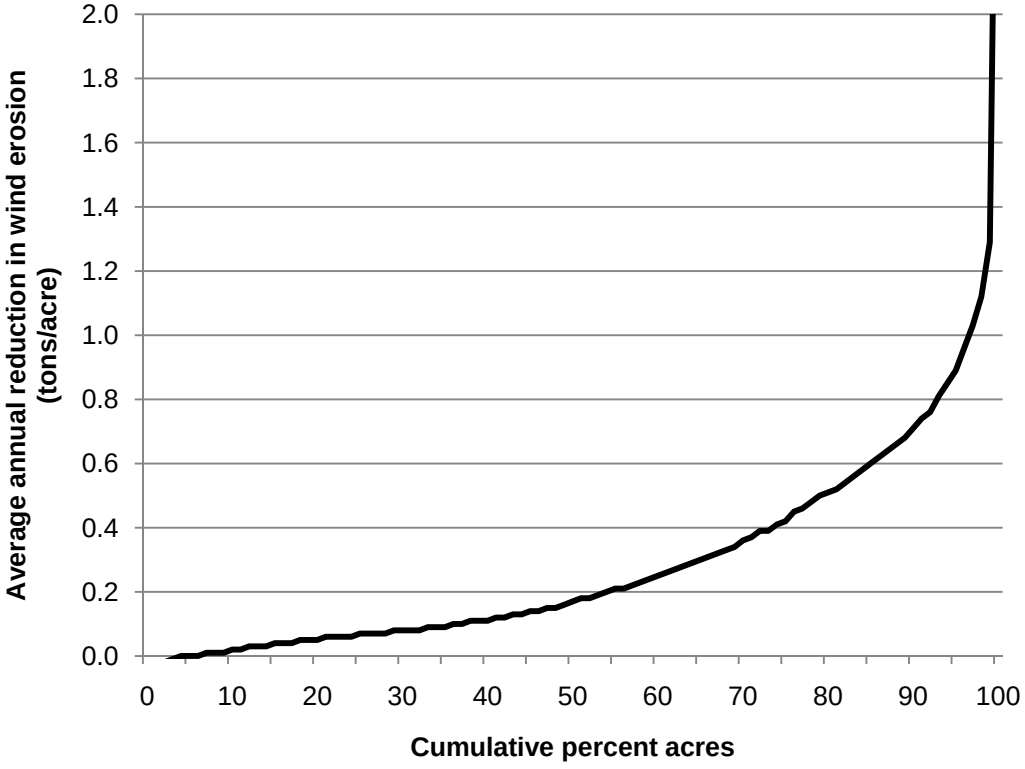


Figure 22. Estimates of average annual reduction in wind erosion rate due to the use of conservation practices on cropped acres in the Upper Mississippi River Basin



Water erosion

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.

Sediment loss, as referred to in this study, is the sediment that is transported beyond the edge of the field by water, where the field includes any edge-of-field filtering and buffering conservation practices. Soil erosion and sedimentation are separate but interrelated resource concerns. Soil erosion is the detachment and transport of soil particles, while 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 settles offsite as well as some sediment that originates from gully erosion processes.[21] Sediment is composed of detached and transported soil minerals, organic matter, plant and animal residues, and associated chemical and biological compounds.

Sheet and rill erosion. Sheet and rill erosion in the UMRB averages about 1 ton per acre per year (table 14). Sheet and rill erosion rates are higher for highly erodible land, averaging 2.4 tons per acre per year compared to the average annual rate for non-highly erodible land of 0.7 tons per acre.

Model simulation results show that conservation practices have reduced sheet and rill erosion on cropped acres in the UMRB by an average of 1.0 ton per acre per year, representing a 51-percent reduction on average (table 14). While the average annual reduction in sheet and rill erosion for highly erodible land is almost four times that for non-highly erodible acres (table 14), the percent reduction due to conservation practices is only slightly higher.

For land in long-term conserving cover, sheet and rill erosion has been reduced from 4.2 tons per acre per year if cropped without conservation practices to about 0.1 ton per acre (table 14).

Sediment loss due to water erosion. The average annual sediment loss for cropped acres in the UMRB is 1 ton per acre per year, according to the model simulation (table 14). As seen for sheet and rill erosion, sediment loss for highly erodible land is much higher than for non-highly erodible land.

On an annual basis, sediment loss can vary considerably. Figure 23 shows that, with the conservation practices currently in use in the UMRB, annual sediment loss is below 0.1 ton per acre for about 20 percent of the acres under all conditions, including years with high precipitation. About 60 percent have annual sediment loss rates less than 1 ton per acre under all conditions. In contrast, sediment loss exceeds 4 tons per acre in one or more years on about 15 percent of the cropped acres.

Model simulations indicate that the use of conservation practices in the UMRB has reduced average annual sediment loss due to water erosion by 69 percent for cropped acres in the region, including both treated and untreated acres (table 14). Without conservation practices, the average annual sediment loss for these acres would have been 3.1 tons per acre per year—three times as much as the 1 ton per acre average for the baseline conservation condition. Figure 24 shows that about 53 percent of the acres would have less than 2 tons per acre per year sediment loss without practices, compared to 87 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 half of the acres, the average annual sediment loss reduction due to practices is less than 1 ton per acre (figure 25). The top 10 percent of the acres had reductions in average annual sediment loss greater than 5.6 tons/acre.

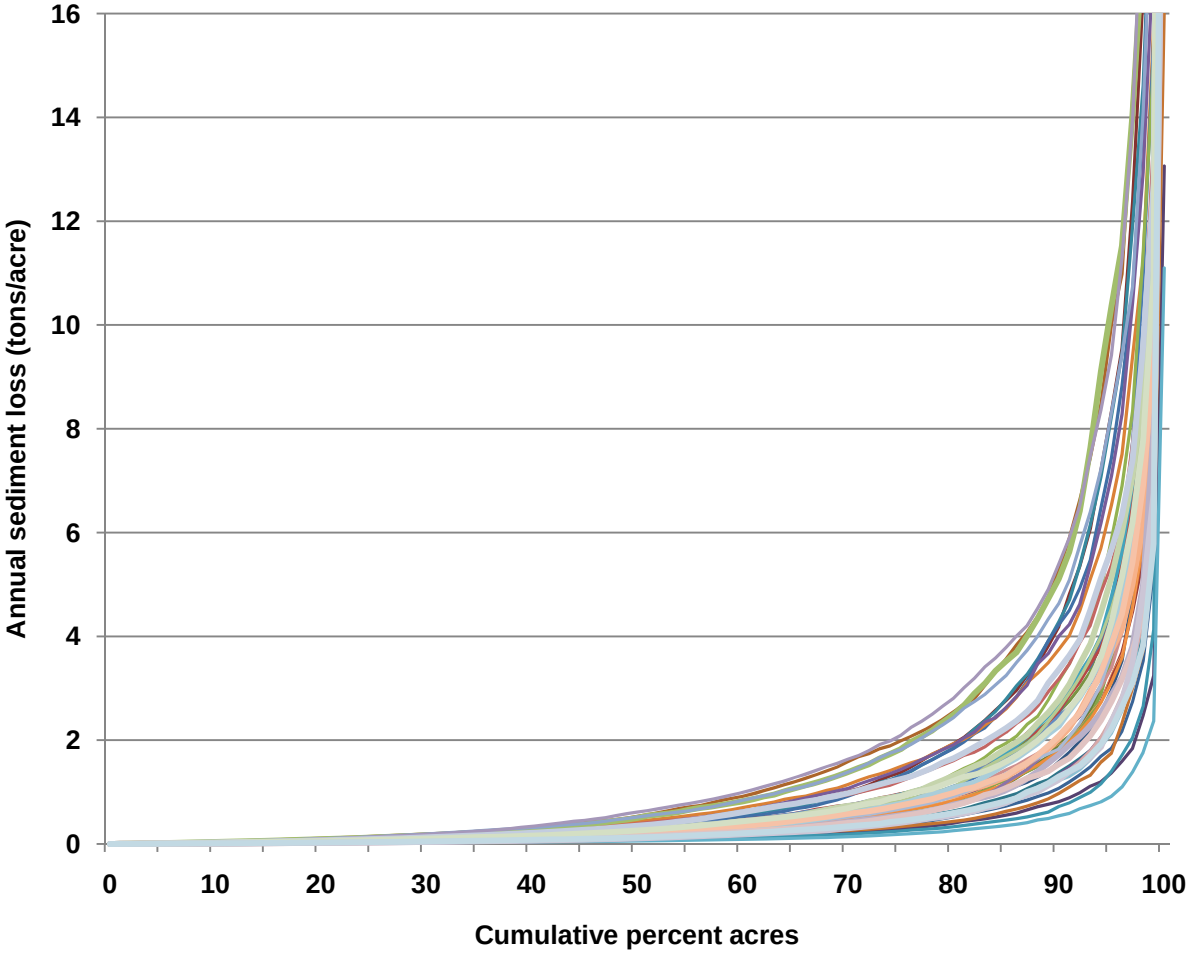
Acres with a combination of structural practices and residue and tillage management have the highest percent reduction in sediment loss (table 15). Acres that are treated with structural practices, meet tillage intensity criteria for no-till or mulch till, and are gaining soil organic carbon (about 35 percent of cropped acres) have reduced sediment loss by 84 percent, on average. For these treated acres, annual sediment loss averages about 0.7 ton per acre.

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 14, figure 26). If these acres were still being cropped without any conservation practices, sediment loss would average about 6.6 tons per acre per year on these 2.8 million acres.

Reductions in sediment loss for land in long-term conserving cover compared to the same acres with crops and no conservation practices vary considerably, as shown in figure 27. The average reduction over all acres in long-term conserving cover is 6.5 tons per acre per year. However, 27 percent of the acres in long-term conserving cover have reductions of less than 2 tons per acre per year average and reductions greater than 10 tons per acre per year occur on about 25 percent of the acres.

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

Figure 23. 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) 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 sediment loss varied 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 varied from year to year.

Figure 24. Estimates of average annual sediment loss for cropped acres in the Upper Mississippi River Basin

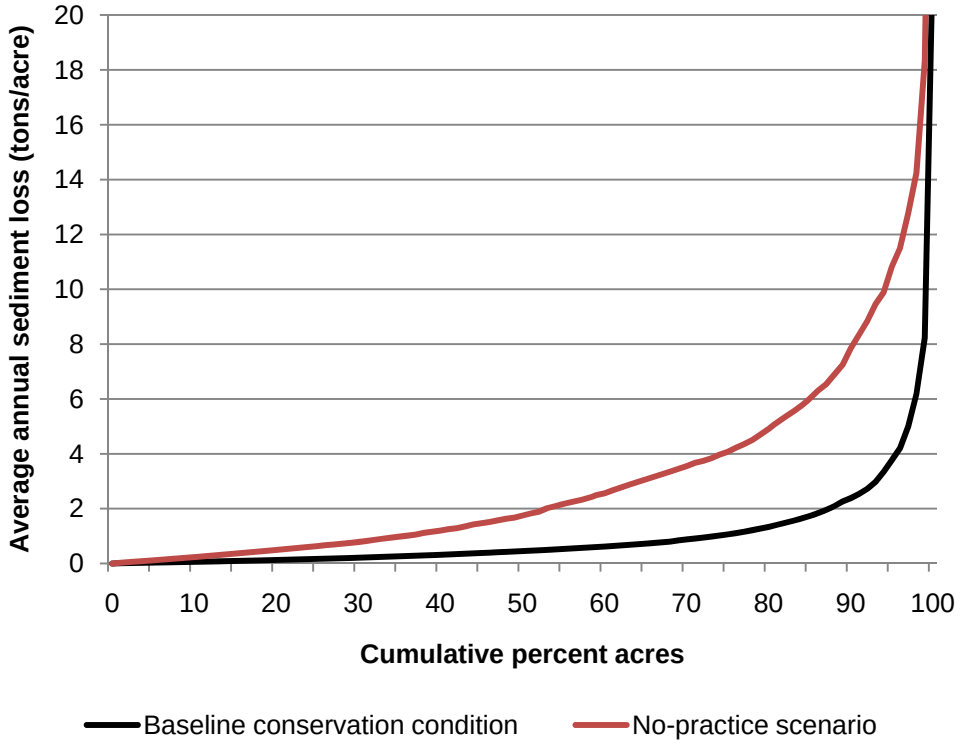


Figure 25. Estimates of average annual reduction in sediment loss due to the use of conservation practices on cropped acres in the Upper Mississippi River Basin

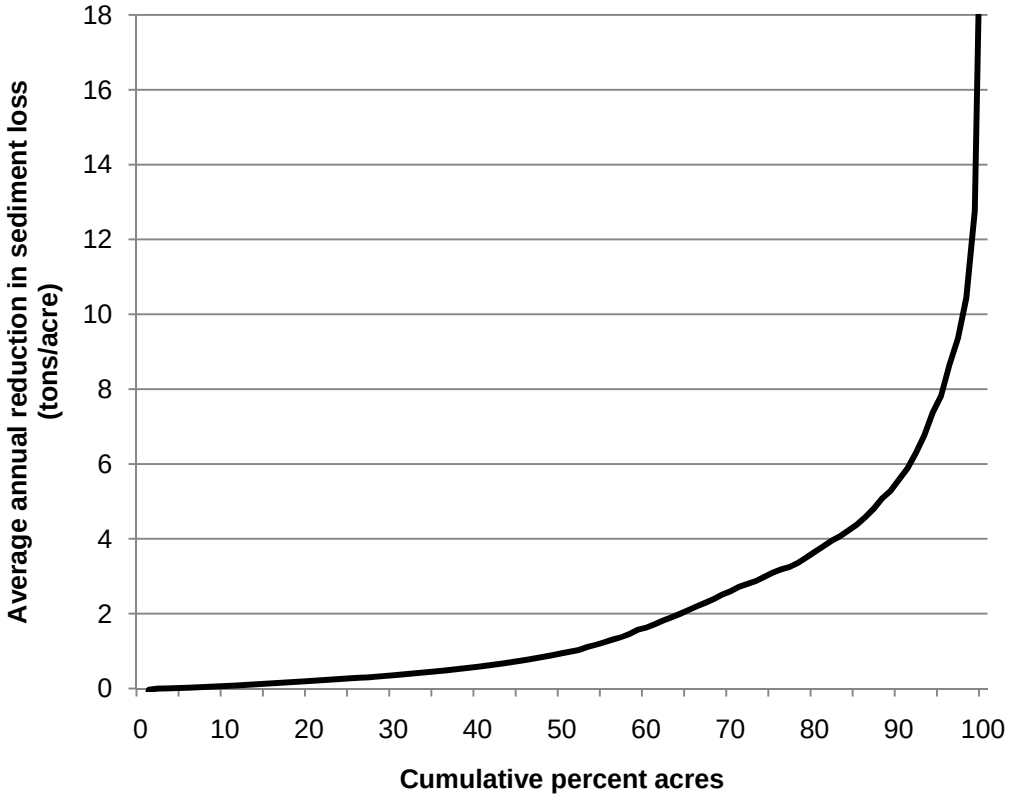


Table 15. Estimates of effects of combinations of structural practices and residue and tillage management on average annual sediment loss for cropped acres in the Upper Mississippi River Basin

		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	36	0.59	1.29	0.69	54
No-till or mulch till with carbon loss, no structural practices	11	1.46	2.49	1.04	42
Some crops with reduced tillage, no structural practices	3	0.83	1.19	0.36	30
Structural practices and No-till or Mulch till with carbon gain	35	0.73	4.45	3.72	84
Structural practices and No-till or Mulch till with carbon loss	8	2.41	7.27	4.85	67
Structural practices and some crops with reduced tillage	1	1.03	3.32	2.29	69
Structural practices only	1	1.68	4.47	2.79	62
No water erosion control treatment	4	2.09	2.15	0.06	3
All acres	100	0.98	3.11	2.13	69

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

Figure 26. Estimates of average annual sediment loss for acres in long-term conserving cover in the Upper Mississippi River Basin

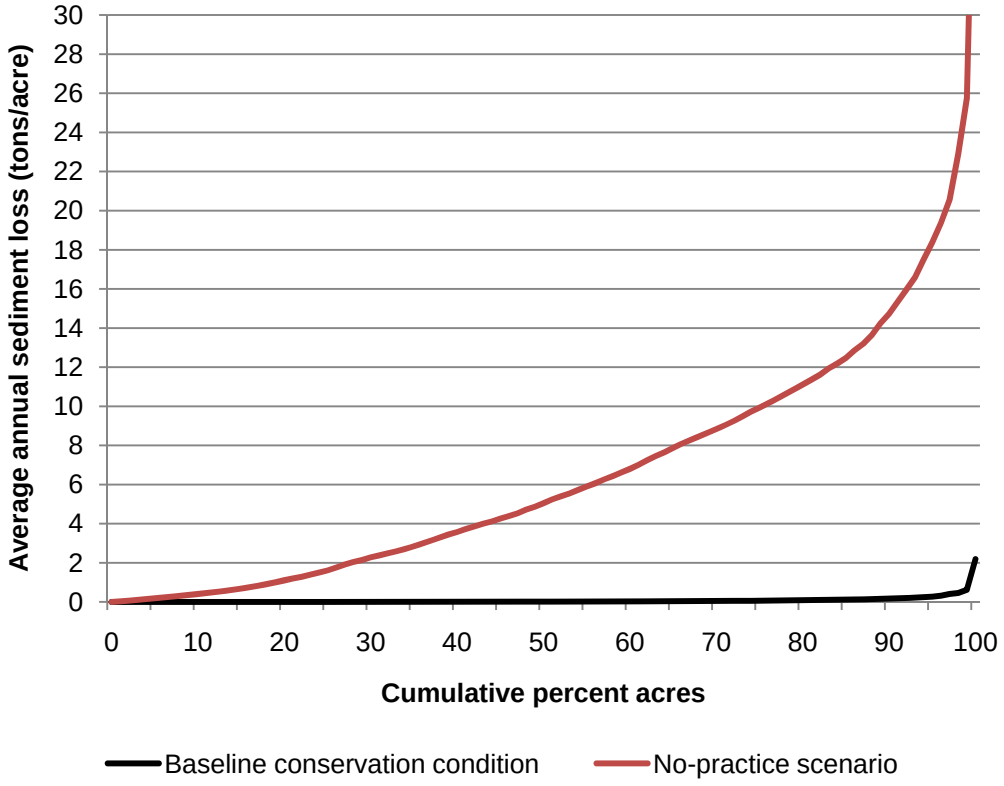
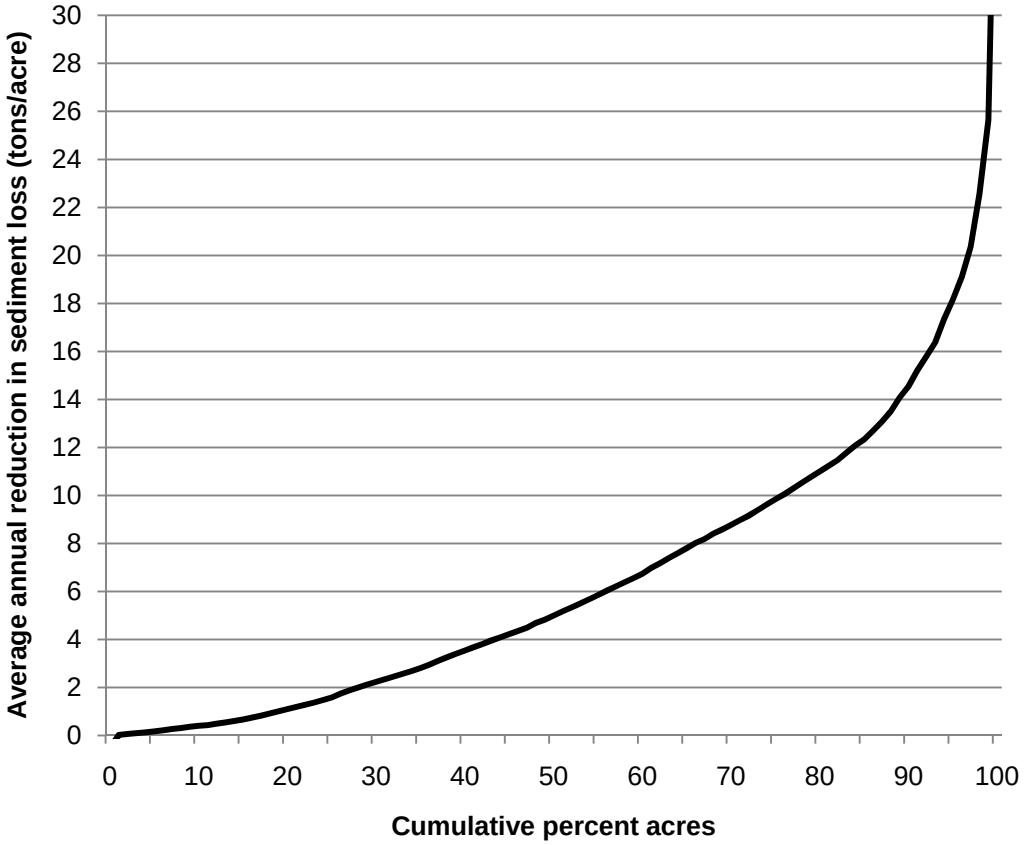


Figure 27. Estimates of average annual reduction in sediment loss due to conversion to long-term conserving cover in the Upper Mississippi River Basin



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.

The 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 tends 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.

Model simulation shows that for the baseline conservation condition the average annual carbon change is a gain of about 70 pounds per acre per year, on average (table 16). Without conservation practices, the annual change in soil organic carbon would average about zero pounds per acre per year, indicating that soil organic carbon is neither losing or gaining, on average for the region.

However, average annual change in soil organic carbon varies considerably among acres in the region, as shown in figure 28. For the baseline conservation condition, about 75 percent of the acres are gaining soil organic carbon (figure 28); for these acres, the annual average gain in soil organic carbon is 138 pounds per acre per year. If conservation practices were not in use, only 59 percent of the acres would be gaining soil organic carbon and the annual rate of gain would be only 100 pounds per acre per year on those acres. Acres that are losing soil organic carbon are diminishing in soil quality year by year.

For land in long-term conserving cover, the gain in soil organic carbon for the baseline conservation condition averages 349 pounds per acre per year. If these acres were still being cropped without any conservation practices, the annual average change in soil organic carbon would be a loss of 70 pounds per acre per year.

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.

These estimates account for losses of carbon with sediment removed from the field by wind and water erosion. 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. Loss of soil organic carbon due to wind and water erosion averages about 189 pounds per acre per year for the baseline conservation condition (table 16). If conservation practices were not in use, loss of soil organic carbon due to wind and water erosion would average an additional 39 pounds per acre per year.

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 reduction in carbon emissions for farm fields averages 70 pounds per acre for the baseline conservation condition, equivalent to a CO2 emission reduction of 7.5 million U.S. tons of carbon dioxide. For acres in long-term conserving cover, the reduction in carbon emissions averages 419 pounds per acre compared to a cropped condition without conservation practices, equivalent to a CO2 emission reduction of 2.2 million U.S. tons of carbon dioxide. However, the rate of emission reduction due to conservation practices varies considerably among acres, as shown in figures 29 and 30.

As observed for sediment loss, acres with a combination of structural practices and residue and tillage management have the highest annual increases in soil organic carbon, and thus the highest decrease in CO2 emissions (table 17). This is due, in part, to reductions in erosion losses for treated acres.

Table 16. 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)	189	228	39	17
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	70	0	70*	--
Land in long-term conserving cover (2.8 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	54	357	303	85
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	349	-70	419*	--

***** 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 C for the 14 subbasins.

Table 17. Estimates of effects of combinations of structural practices and residue and tillage management on average annual soil organic carbon change for cropped acres in the Upper Mississippi River Basin

Conservation treatment	Percent of cropped acres	Average annual change in soil organic carbon (pounds/acre): Baseline conservation condition	Average annual change in soil organic carbon (pounds/acre): No-practice scenario	Gain due to practices
No-till or Mulch till with carbon gain, no structural practices	36	133	73	60
No-till or mulch till with carbon loss, no structural practices	11	-121	-168	48
Some crops with reduced tillage, no structural practices	3	-6	-33	28
Structural practices and No-till or Mulch till with carbon gain	35	148	49	100
Structural practices and No-till or Mulch till with carbon loss	8	-126	-207	81
Structural practices and some crops with reduced tillage	1	34	-6	40
Structural practices only	1	-87	-116	29
No water erosion control treatment	4	-136	-129	-7
All acres	100	70	0	70

Note: Estimates include reductions in loss of carbon from the field through wind and water erosion that are due to the use of conservation practices. Differences in slope, soil texture, hydrologic group, and precipitation for acres in different treatment groups explain some of the differences in sediment loss shown in this table.
Note: Percents may not add to totals because of rounding.

Figure 28. Estimates of average annual change in soil organic carbon for cropped acres in the Upper Mississippi River Basin

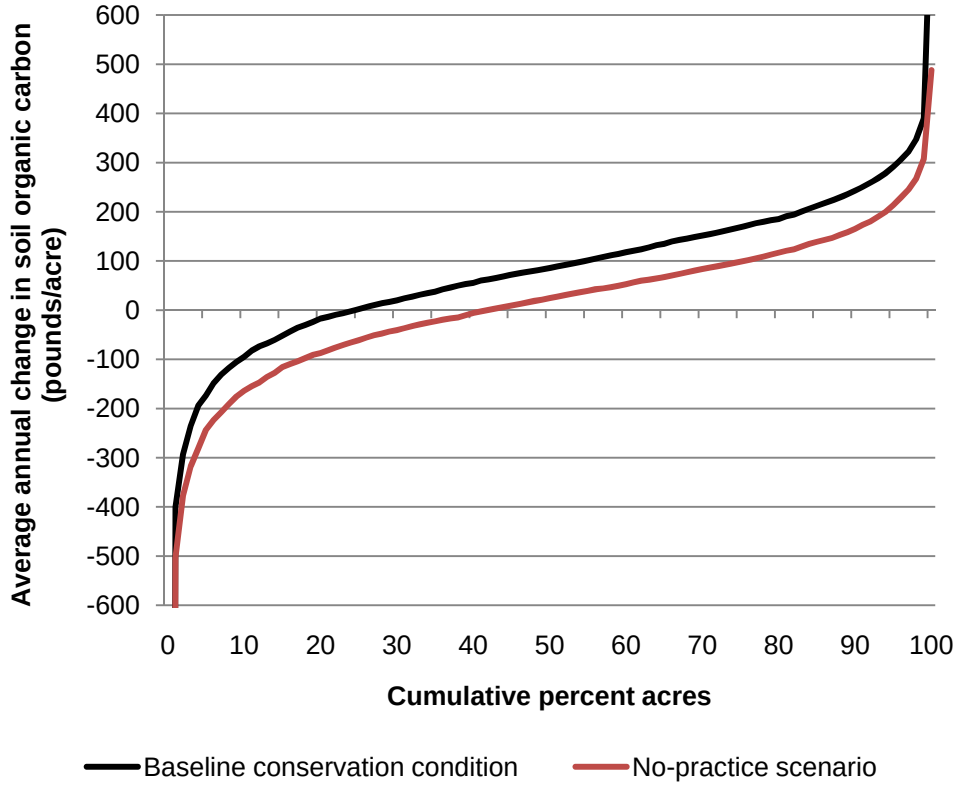
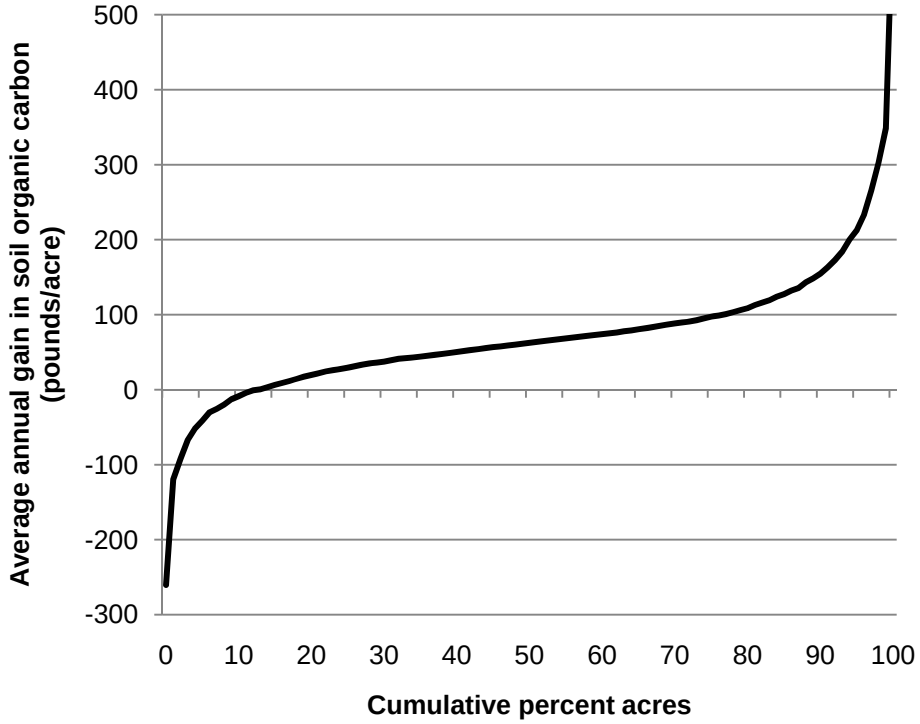
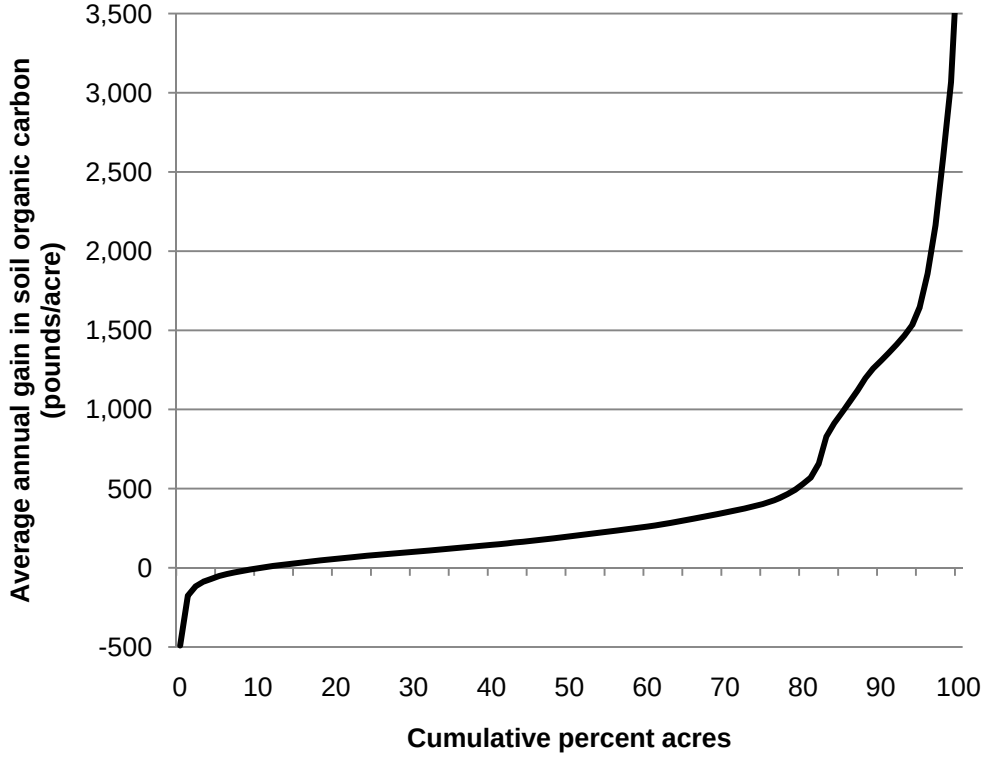


Figure 29. Estimates of average annual gain in soil organic carbon due to the use of conservation practices on cropped acres in the Upper Mississippi River Basin



Note: About 12 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. Reductions in manure application reduce the rate of build-up of soil organic carbon. Reductions in commercial fertilizer application can also reduce the amount of residue produced when other conservation practices are inadequate to control losses.

Figure 30. 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 10 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.

Nitrogen Loss

Plant-available nitrogen sources include application of commercial fertilizer, application of manure, nitrogen produced by legume crops (soybeans, alfalfa, beans, and peas), a small amount of manure deposited by grazing livestock, and atmospheric nitrogen deposition. In total, these sources provide about 152 pounds of nitrogen per acre per year for cropped acres in the UMRB (table 18). Model simulations show that about two-thirds of this (108 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.

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 41 pounds per acre. These nitrogen loss pathways are—

- nitrogen lost due to volatilization associated with fertilizer and manure application (average of 6.7 pounds per acre per year);
- nitrogen returned to the atmosphere through denitrification processes (average of 2.2 pounds per acre per year);
- nitrogen lost with windborne sediment (average of 2.1 pounds per acre per year);
- nitrogen lost with surface runoff, including nitrogen lost with waterborne sediment (average of 8.6 pounds per acre per year); and
- nitrogen loss in subsurface flow pathways (average of 21.8 pounds per acre per year).

In the model simulations for the UMRB, about two-thirds of the nitrogen loss in subsurface flow eventually returns to surface water, on average, while about one-third is carried with water flow that recharges the underlying aquifers.

The percent of nitrogen lost in each loss pathway varies from acre to acre, as shown in figure 31. The dominant nitrogen loss pathway for most cropped acres (71 percent) in the UMRB is nitrogen loss in subsurface flow. On average for all acres in the region, 53 percent of the nitrogen lost from fields is through subsurface flow. Nitrogen volatilization or nitrogen lost as waterborne sediment are the next highest loss pathways, averaging 16 percent and 19 percent of total nitrogen loss, respectively. Nitrogen loss with waterborne sediment is the dominant loss pathway for 18 percent of the acres, while volatilization is the dominant loss pathway for 8 percent of the acres. Nitrogen loss with windborne sediment is the dominant loss pathway for 3 percent of the acres. Nitrogen loss in surface water runoff (soluble) and nitrogen lost through denitrification are rarely the dominant loss pathways, but are significant loss pathways for some acres (figure 31).

In both the baseline conservation condition and the no-practice scenario, average annual nitrogen losses for all loss pathways were higher for acres receiving manure than for acres that did not receive manure (table 18). Losses were also higher for highly erodible land than for non-highly erodible land.

Total nitrogen loss

Model simulations for the baseline conservation condition indicate that some cropped acres in the UMRB are much more susceptible to the effects of weather than other acres and lose much higher amounts of nitrogen and (figure 32). About 40 percent of the acres lose less than 40 pounds per acre per year through the various loss pathways other than removal at harvest under *all* weather conditions. About 20 percent of the acres, on the other hand, lose more than 100 pounds per acre in at least some years. Figure 32 also shows that nitrogen loss for the 20 percent of the cropped acres with the highest losses varies dramatically from year to year when compared to the 40 percent with the lowest total nitrogen loss. Figure 32 further shows that, in the UMRB, total nitrogen loss from cropped acres can exceed 40 pounds per acre in most years on about one-fourth of the acres.

Model simulations show that the conservation practices in use in the region have reduced total nitrogen loss from cropped acres (exclusive of nitrogen removed at harvest with the crop yield) by an average of 9 pounds per acre per year, representing an 18 percent reduction, on average (table 18). Without conservation practices, about 53 percent of the cropped acres would have average annual total nitrogen loss exceeding 40 pounds per acre per year; with conservation practices, only 35 percent of acres exceed this level of loss (figure 33). About 30 percent of the acres have average annual reductions in total nitrogen loss below 2 pounds per acre (figure 34).

A small number of acres (13 percent) have reduced total nitrogen loss by an average of over 20 pounds per acre per year (figure 34). These are acres with higher levels of treatment, including acres with higher levels of nitrogen use and thus more nitrogen available to be reduced by practices. For example, the 16 percent of acres with manure applied had total nitrogen reductions averaging 19 pounds per acre per year, nearly three times the average reduction for acres that did not receive manure (table 18). Similarly, the average reduction in total nitrogen loss on highly erodible land is over twice that for non-highly erodible land (table 18).

Figure 34 also shows that about 20 percent of the acres have an increase in total nitrogen loss due to conservation practice use; some of these gains are small, but 13 percent of the acres have gains of more than 2 pounds per acre. This result primarily occurs on soils with relatively high soil nitrogen content and generally with 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. Cropping systems that include legumes also 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. The baseline conservation condition represents a wide range of conservation adoption. Adoption of soil erosion control practices without also adopting sound nutrient management has a negative impact on nitrogen loss.

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

Model simulated outcome	Average annual values in pounds per acre			
	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (58.2 million acres)				
Nitrogen sources				
Atmospheric deposition	6.0	6.0	0.0	0
Bio-fixation by legumes	57.9	56.1	-1.8	-3
Nitrogen applied as commercial fertilizer and manure	87.8	99.2	11.4	11
All nitrogen sources	151.7	161.4	9.6	6
Nitrogen loss pathways				
Nitrogen in crop yield removed at harvest	107.6	112.9	5.4*	5*
Nitrogen loss by volatilization	6.7	6.5	-0.2**	-4**
Nitrogen loss through denitrification processes	2.2	2.0	-0.2	-10
Nitrogen lost with windborne sediment	2.1	3.3	1.2	37
Nitrogen loss with surface runoff , including waterborne sediment	8.6	15.9	7.3	46
Nitrogen loss in subsurface flow pathways	21.8	22.8	1.0	5
Total nitrogen loss for all pathways except harvest	41.3	50.5	9.1	18
Change in soil nitrogen	1.8	-2.9	-4.7	--
Highly erodible land (18 percent of cropped acres)				
All nitrogen sources	157.4	166.3	8.9	5
Total nitrogen loss for all pathways except harvest	50.1	66.2	16.1	24
Non-highly erodible land (82 percent of cropped acres)				
All nitrogen sources	150.5	160.3	9.8	6
Total nitrogen loss for all pathways except harvest	39.4	46.9	7.5	16
Acres with manure applied (16 percent of cropped acres)				
All nitrogen sources	178.3	199.0	20.7	10
Total nitrogen loss for all pathways except harvest	61.8	81.2	19.4	24
Acres without manure applied (84 percent of cropped acres)				
All nitrogen sources	146.6	154.0	7.5	5
Total nitrogen loss for all pathways except harvest	37.4	44.5	7.1	16
Land in long-term conserving cover (2.8 million acres)				
Nitrogen sources				
Atmospheric deposition	5.9	5.9	0.0	0
Bio-fixation by legumes	11.7	57.2	45.6	80
Nitrogen applied as commercial fertilizer and manure	0.0	97.8	97.8	100
All nitrogen sources	17.6	160.9	143.3	89
Nitrogen loss pathways				
Nitrogen in crop yield removed at harvest	1.1***	108.5	107.4	99
Nitrogen loss by volatilization	7.5	6.6	-0.9	-13
Nitrogen lost with windborne sediment	0.0	0.4	0.4	100
Nitrogen loss through denitrification processes	1.4	2.9	1.4	50
Nitrogen loss with surface runoff , including waterborne sediment	1.1	28.9	27.8	96
Nitrogen loss in subsurface flow pathways	1.7	22.7	21.0	92
Total nitrogen loss for all pathways except harvest	11.7	61.5	49.8	81
Change in soil nitrogen	4.2	-9.9	-14.1	--

* The reduction in yield reflects the increase in nutrients in the representation in the no-practice scenario for nutrient management.

****** On about half of the cropped acres, more nitrogen volatilization occurs with practices than without practices, resulting in a small net gain in nitrogen volatilization 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.

*** 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 C for the 14 subbasins.

Figure 31. Cumulative distributions of the proportion of nitrogen lost through various loss pathways

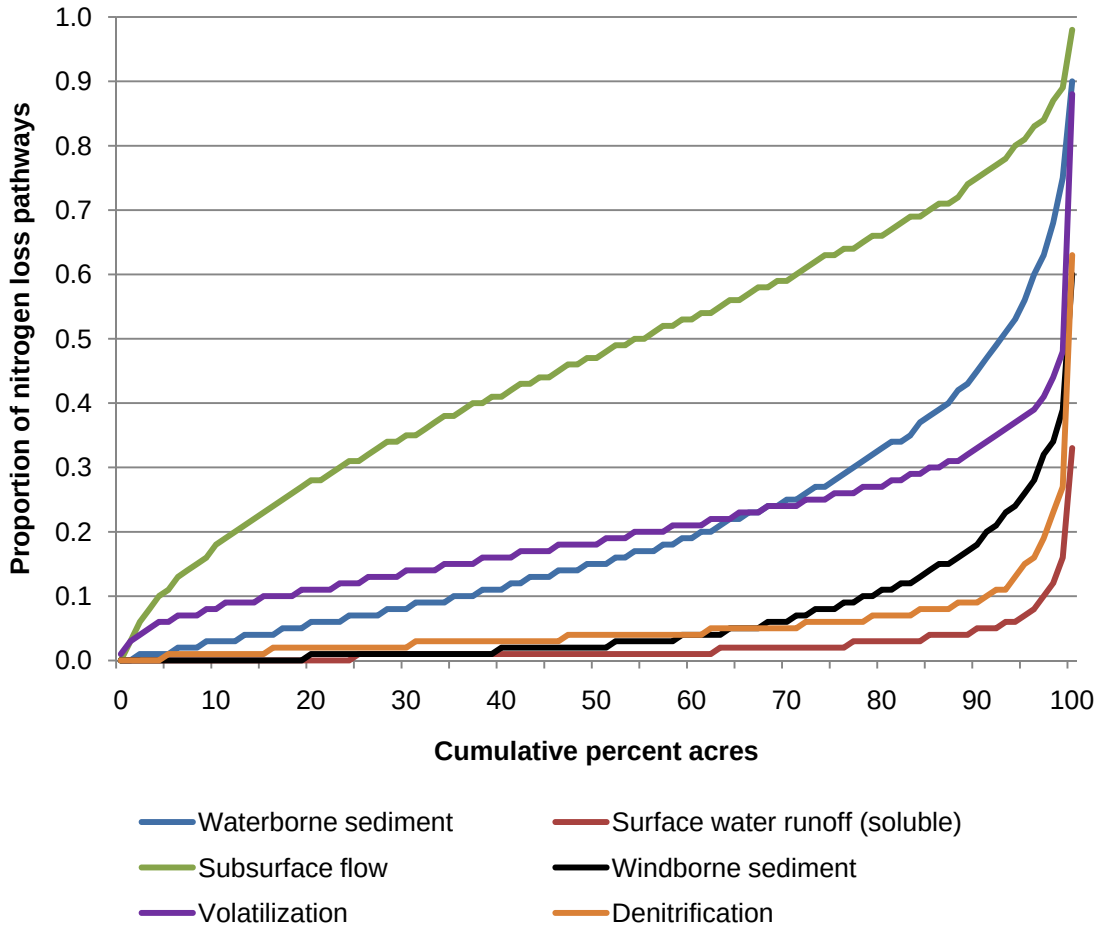
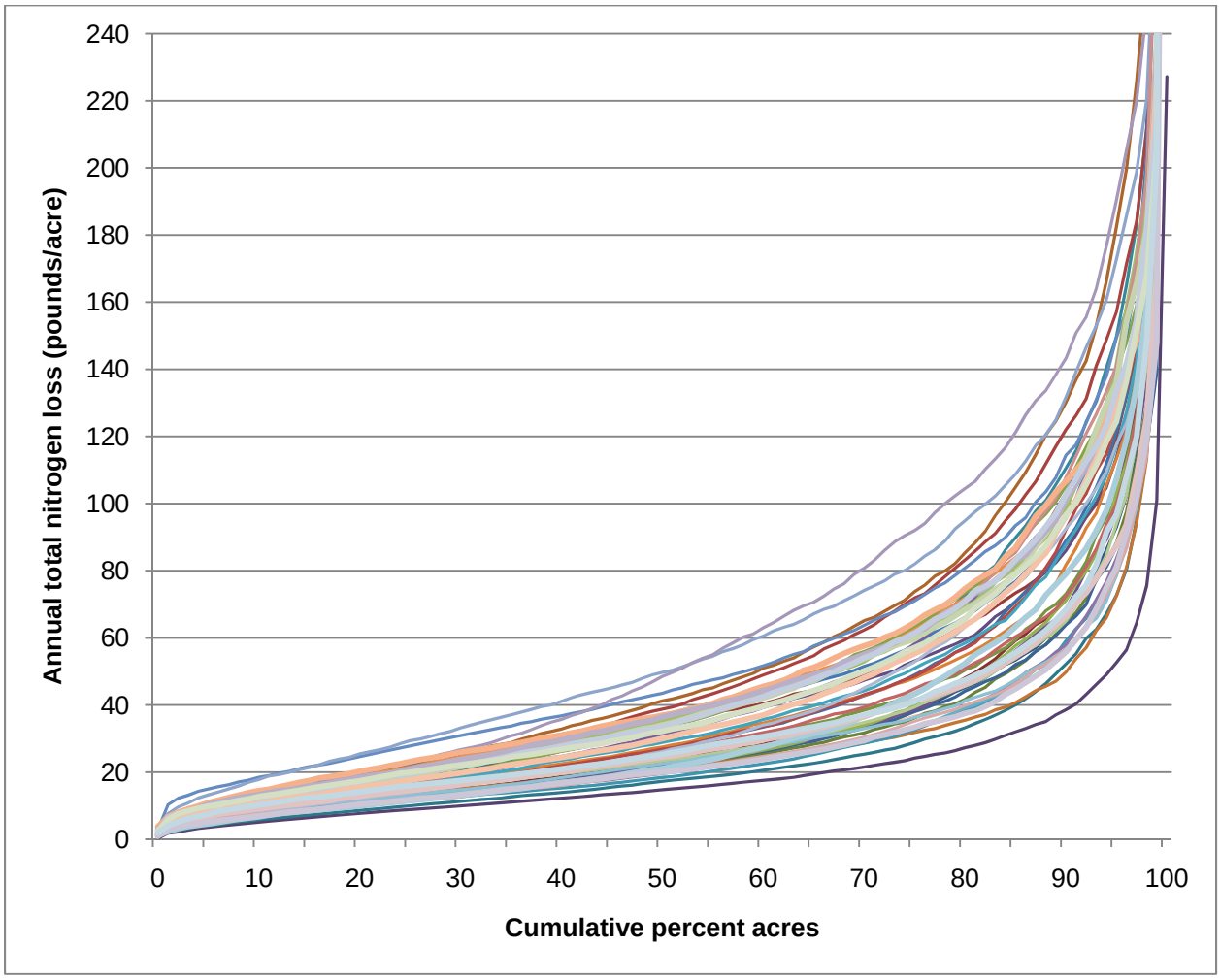


Figure 32. Distribution of annual total nitrogen loss for each year of the 47-year model simulation, Upper Mississippi River Basin



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.

Figure 33. Estimates of average annual total nitrogen loss for cropped acres in the Upper Mississippi River Basin

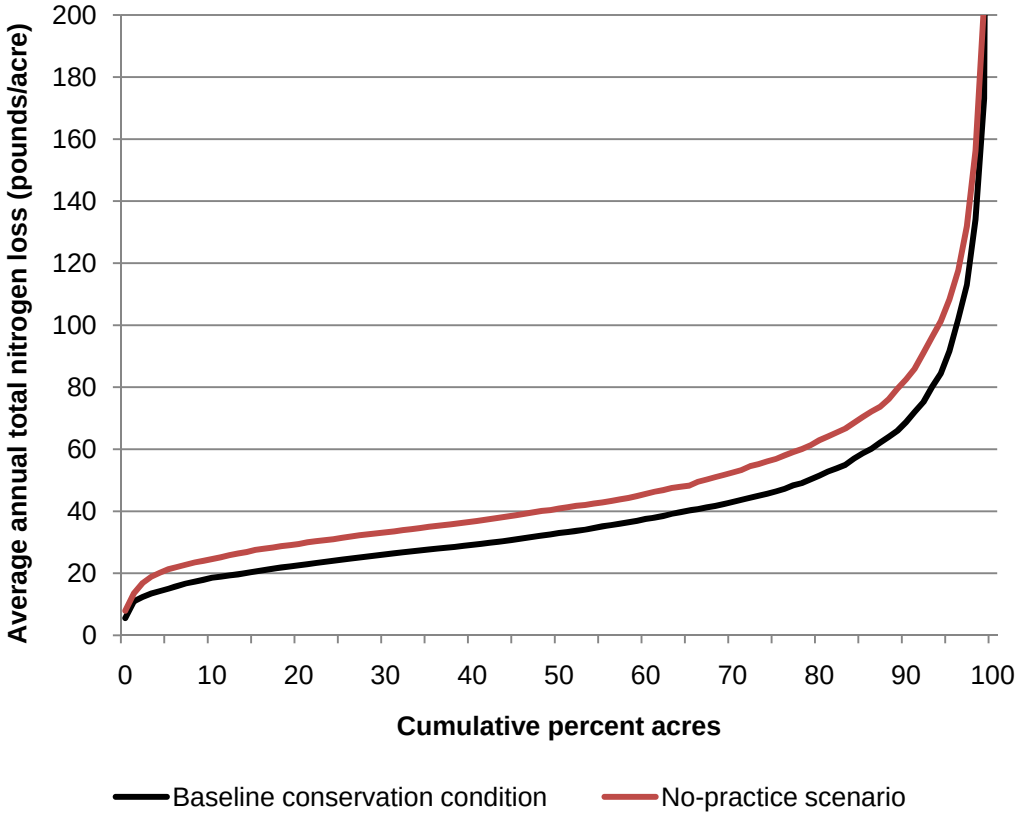
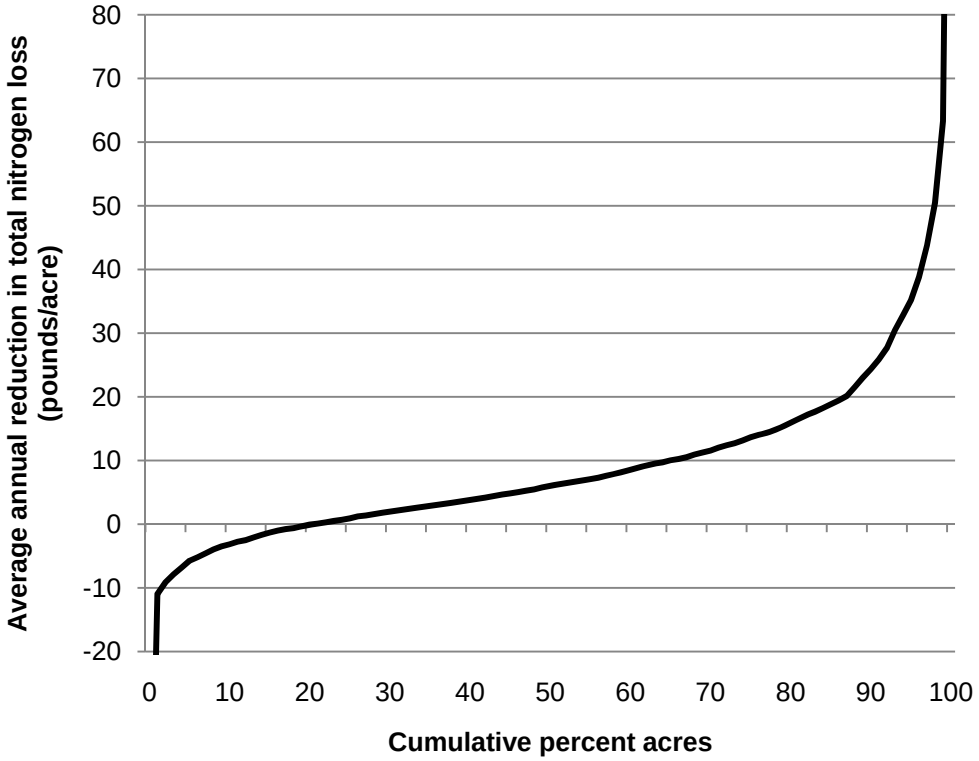


Figure 34. Estimates of average annual reduction in total nitrogen loss due to the use of conservation practices on cropped acres in the Upper Mississippi River Basin



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 20 percent of the acres.

Total nitrogen loss has been reduced by about 81 percent on the 2.8 million acres in long-term conserving cover, compared to the conditions that would be expected had the acres remained in crops. Converting cropped acres to long-term conserving cover is very effective in reducing total nitrogen loss, as demonstrated in figures 35 and 36 and table 18, although the reductions are much higher for some acres than others. Half of the acres in long-term conserving cover have reductions of more than 40 pounds of nitrogen loss per acre per year, compared to a cropped condition.

Nitrogen lost with surface runoff

The bulk of the reduction in total nitrogen loss for cropped acres is due to reductions in nitrogen lost with surface runoff, including both nitrogen attached to sediment and in solution (mineral and organic nitrogen). Model simulations show that, on average, nitrogen lost with surface runoff has been reduced 46 percent due to use of conservation practices in the region (table 18). Without conservation practices, about 36 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 (figure 37).

Figure 38 shows, however, that about half of the acres have reductions of nitrogen lost with surface runoff less than 5 pounds per acre due to conservation practices.

Nitrogen loss in subsurface flow

Conservation practices had little effect on nitrogen loss in subsurface flow in the UMRB, as shown in figure 39. Figure 40 shows that reductions in nitrogen loss in subsurface flow occur for only 47 percent of the acres; on the remaining 53 percent of the acres nitrogen loss in subsurface flow *increased* as a result of conservation practices. (Gains in nitrogen loss in subsurface flow are represented in figure 40 as negative reductions.)

For the region as a whole, model simulations show that conservation practices reduced nitrogen loss in subsurface flow an average of only 1 pound per acre per year, representing a 5 percent reduciton (table 18), on average. This is 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 was re-routed to subsurface loss pathways, resulting in gains or only small reductions in nitrogen loss in subsurface flow. On many acres, the re-routing of surface water runoff to subsurface flow pathways resulted 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 saline seeps at the lower part of the field. The planned practices will solve the erosion problem, but could exacerbate the saline 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 34 shows that about 20 percent of the acres have an increase in total nitrogen loss due to conservation practice use. 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.

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.

Figure 35. Estimates of average annual total nitrogen loss for land in long-term conserving cover in the Upper Mississippi River Basin

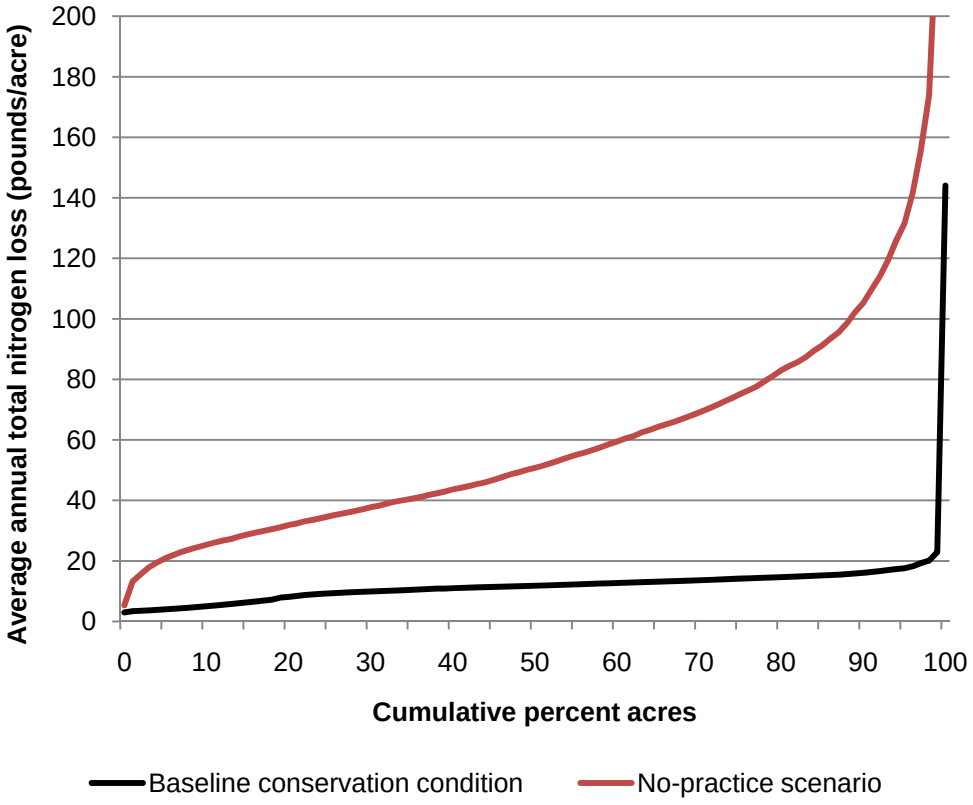


Figure 36. Estimates of average annual reduction in total nitrogen loss due to conversion to long-term conserving cover in the Upper Mississippi River Basin

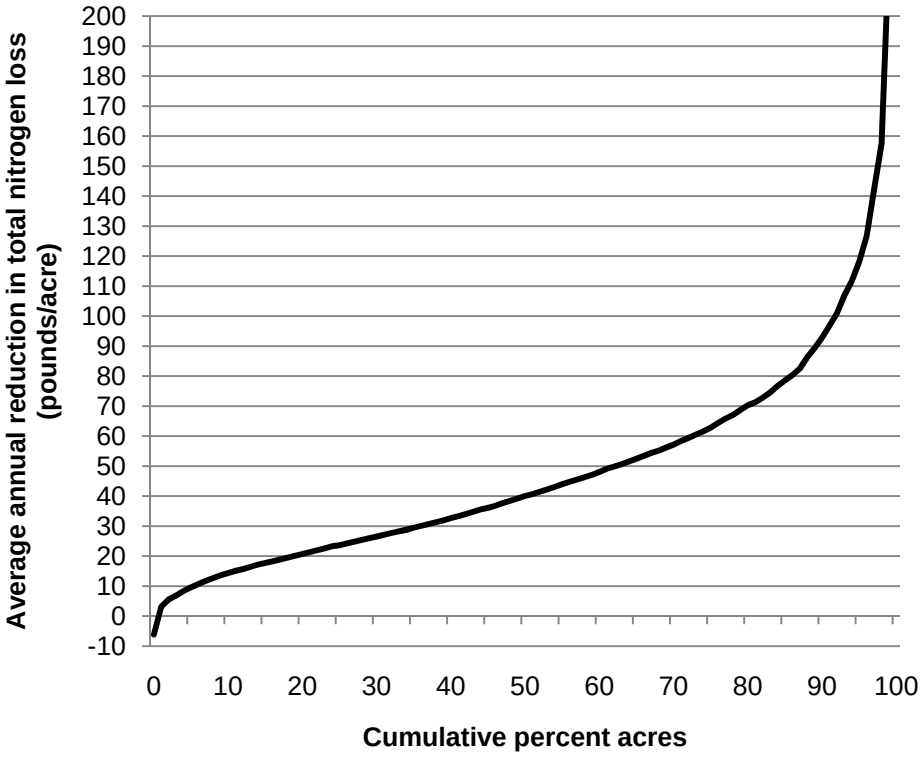


Figure 37. Estimates of average annual nitrogen lost with surface runoff for cropped acres in the Upper Mississippi River Basin

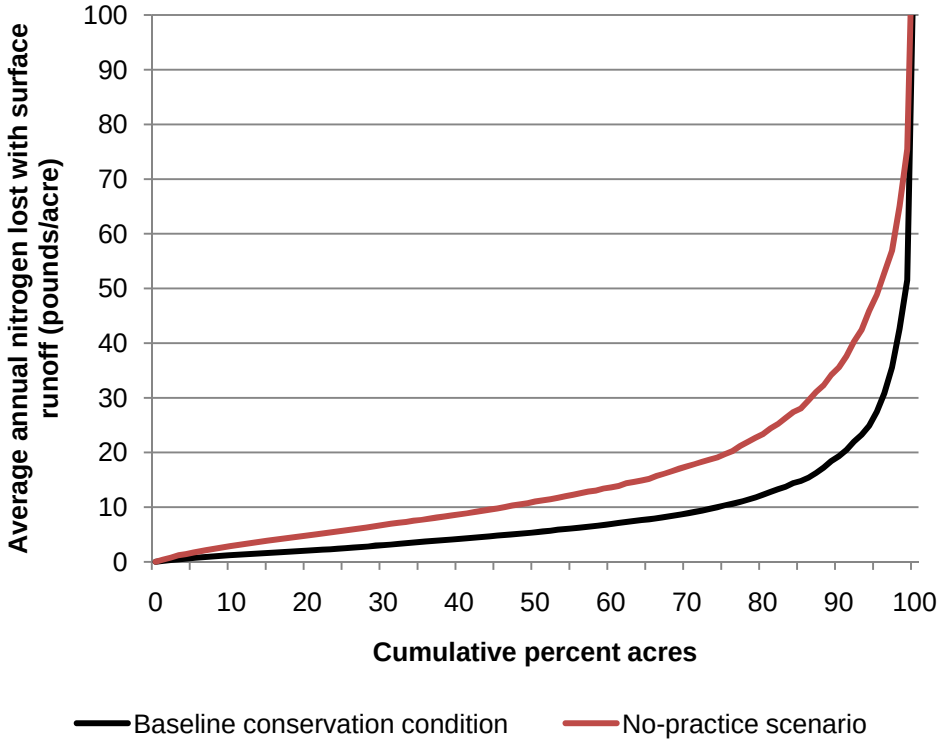
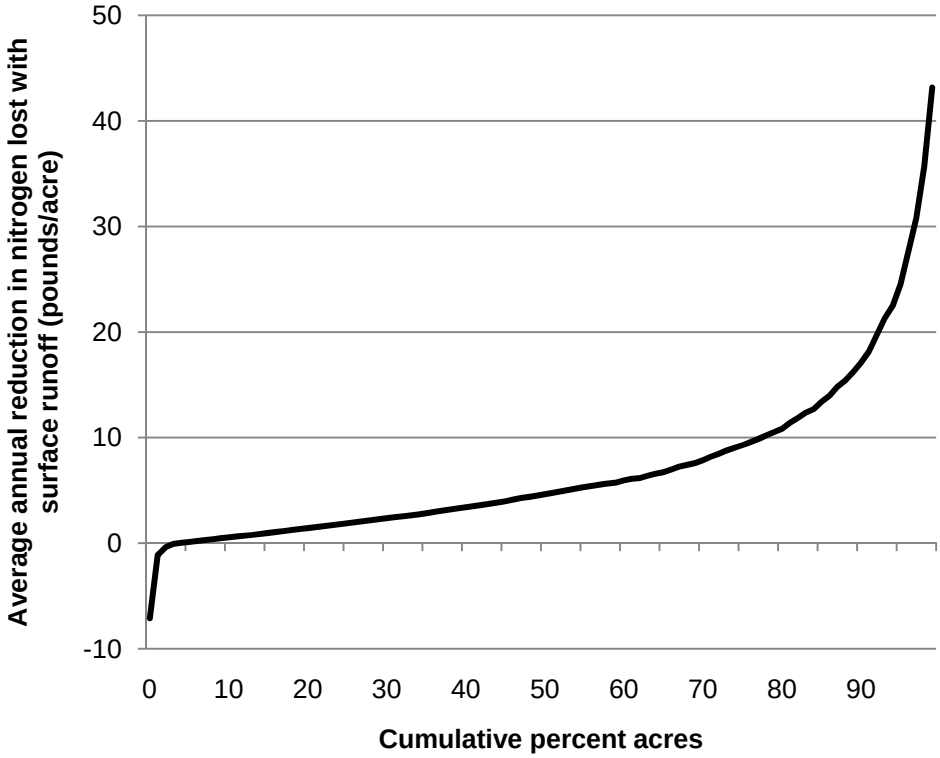


Figure 38. Estimates of average annual reduction in nitrogen lost with surface runoff due to the use of conservation practices on cropped acres in the Upper Mississippi River Basin



Note: About 3 percent of the acres have negative reductions (net gain) in nitrogen lost with surface runoff due to conservation practices, resulting from a small number of acres with negative reductions in surface water runoff (see figure 17).

Figure 39. Estimates of average annual nitrogen loss in subsurface flow for cropped acres in the Upper Mississippi River Basin

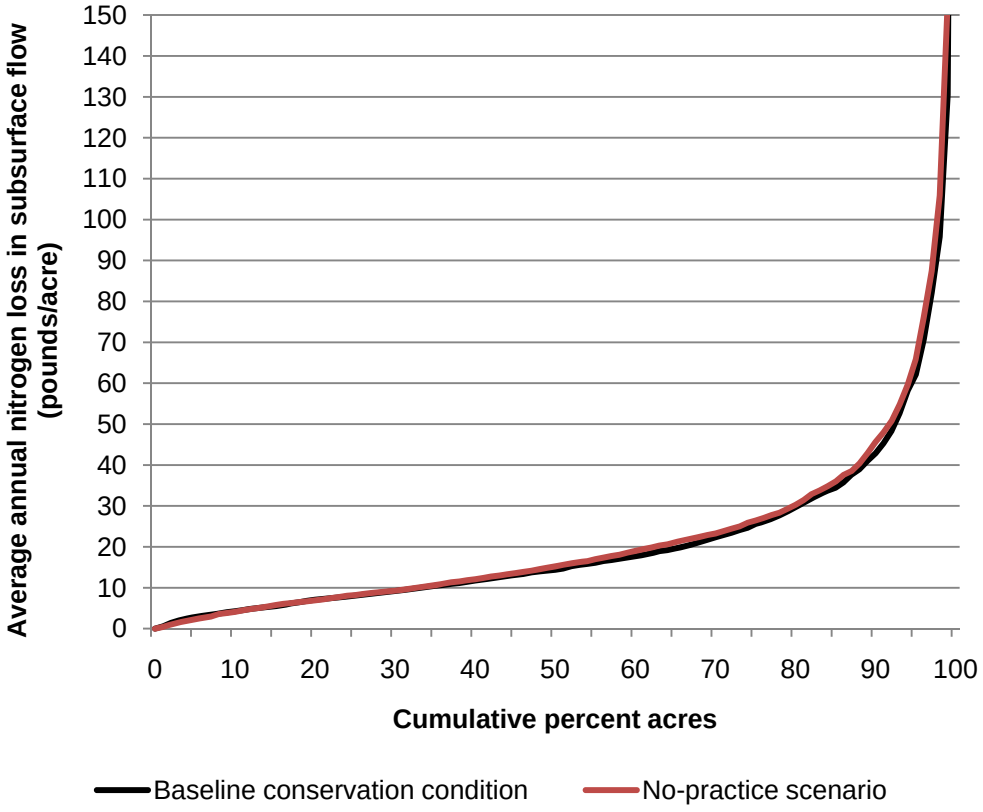
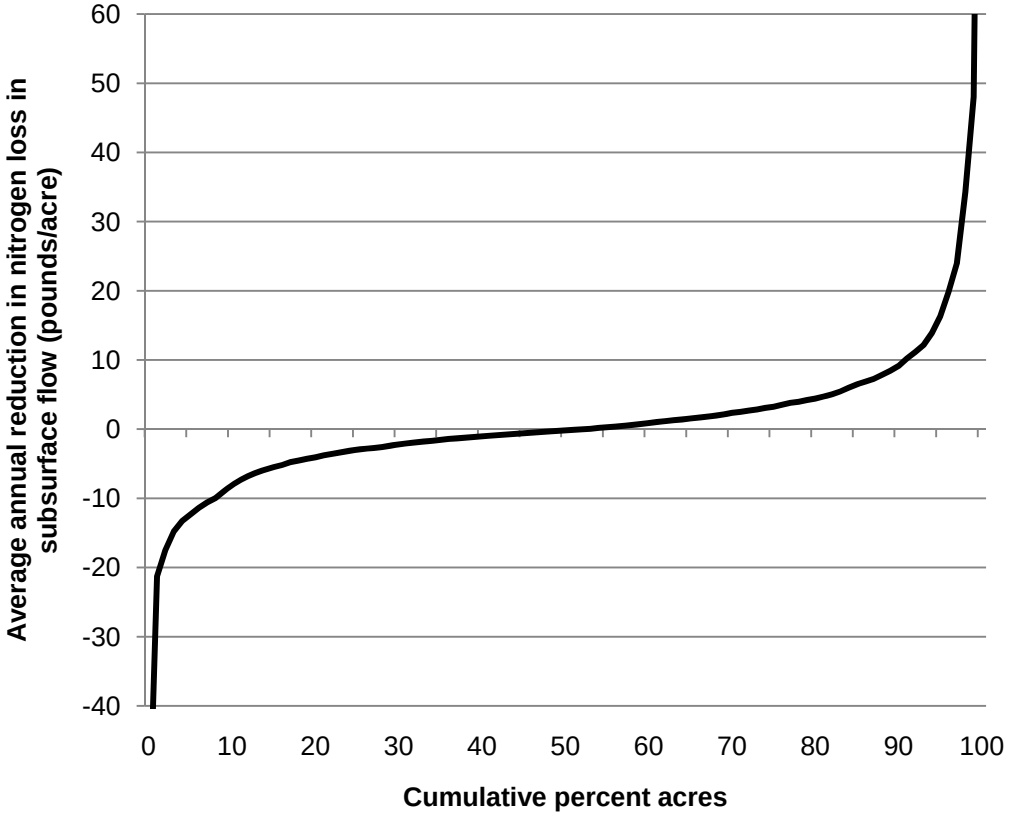


Figure 40. Estimates of average annual reduction in nitrogen loss in subsurface flow due to the use of conservation practices on cropped acres in the Upper Mississippi River Basin



Note: See text for discussion of negative reductions.

Phosphorus Loss

Phosphorus, like nitrogen, is an essential element needed for crop growth. Unlike nitrogen, however, phosphorus rarely occurs in a gaseous form so the agricultural model has no atmospheric component. Only 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.

In the model simulations for the UMRB, about 22 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 19). The majority 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 other than harvest averaged 3.0 pounds per acre per year in the baseline conservation condition (table 19). 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 1.6 pounds per acre per year);
- soluble phosphorus loss in surface runoff, including 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 1.0 pounds per acre per year); and
- soluble phosphorus that percolates through the soil profile into the groundwater (average of 0.02 pound per acre per year).

The percent of phosphorus lost in each loss pathway varies from acre to acre, as shown in figure 41 for cropped acres. The dominant loss pathway for most cropped acres—57 percent of the acres in the UMRB—is phosphorus lost with waterborne sediment. Soluble phosphorus loss in surface water runoff and lateral flow (including discharge to drainage ditches) was the dominant loss pathway for 32 percent of the acres. On average for all acres in the region, 85 percent of the phosphorus lost from fields is lost with surface runoff (sediment attached and soluble). Phosphorus loss with windborne sediment is the dominant loss pathway for 18 percent of the acres, representing 14 percent of total phosphorus loss from fields. Phosphorus loss in percolate is typically small, but is significant for a few acres, as shown in figure 41.

As shown for nitrogen, total phosphorus losses are higher for acres receiving manure than for acres that did not receive manure (table 19). Phosphorus losses are only slightly higher for highly erodible land than for non-highly erodible land.

Model simulations for the baseline conservation condition indicate that some cropped acres in the UMRB lose much higher amounts of phosphorus than other acres (figure 42). About half of the acres lose less than 3 pounds per acre per year through the various loss pathways other than removal at harvest under *all* weather conditions. About one-fourth of the acres, on the other hand, lose more than 6 pounds per acre in at least some years.

Conservation practices have reduced total phosphorus loss for cropped acres by 49 percent, reducing the average loss from 5.9 pounds per acre per year if conservation practices were not in use to 3.0 pounds per acre per year for the baseline conservation condition (table 19).

The effects of conservation practices on phosphorus lost with surface runoff (soluble and sediment attached) are shown in figures 43 and 44 for cropped acres. Conservation practice use has reduced phosphorus lost with surface runoff by 48 percent on average, (table 19). With the conservation practices in use as represented by the baseline conservation condition, about 15 percent of cropped acres exceed 4 pounds per acre per year. Without those practices in use, phosphorus lost with surface runoff would exceed 4 pounds per acre for 44 percent of the acres. Reductions in phosphorus lost with surface runoff due to conservation practice use in the baseline conservation condition vary throughout the UMRB as shown in figure 44.

For land in long-term conserving cover, total phosphorus loss is 97 percent less than it would have been if crops had been grown, reducing total phosphorus loss by 7.4 pounds per acre per year on average (table 19, figures 45 and 46).

Figure 41. Cumulative distributions of the proportion of phosphorus lost through various loss pathways

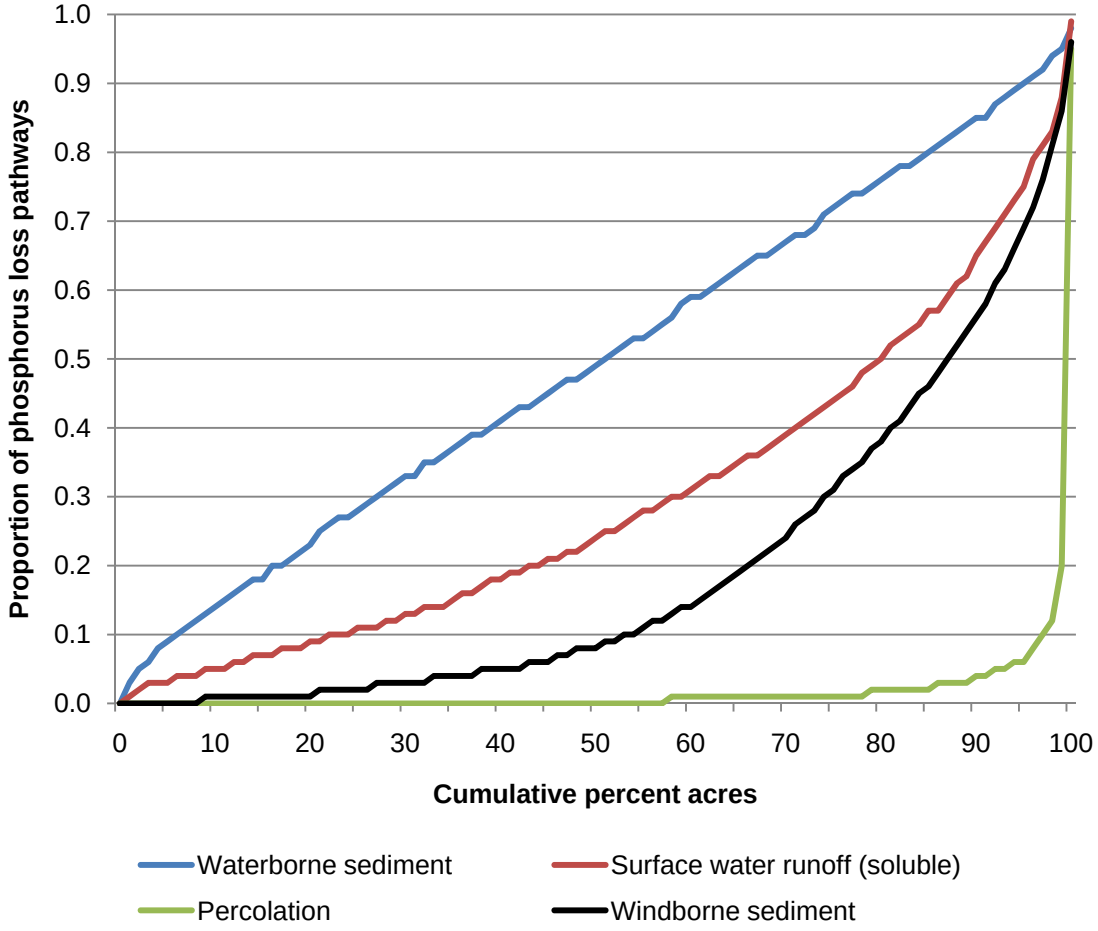


Table 19. Field-level effects of conservation practices on phosphorus sources and phosphorus loss pathways for cropped acres in the Upper Mississippi River Basin

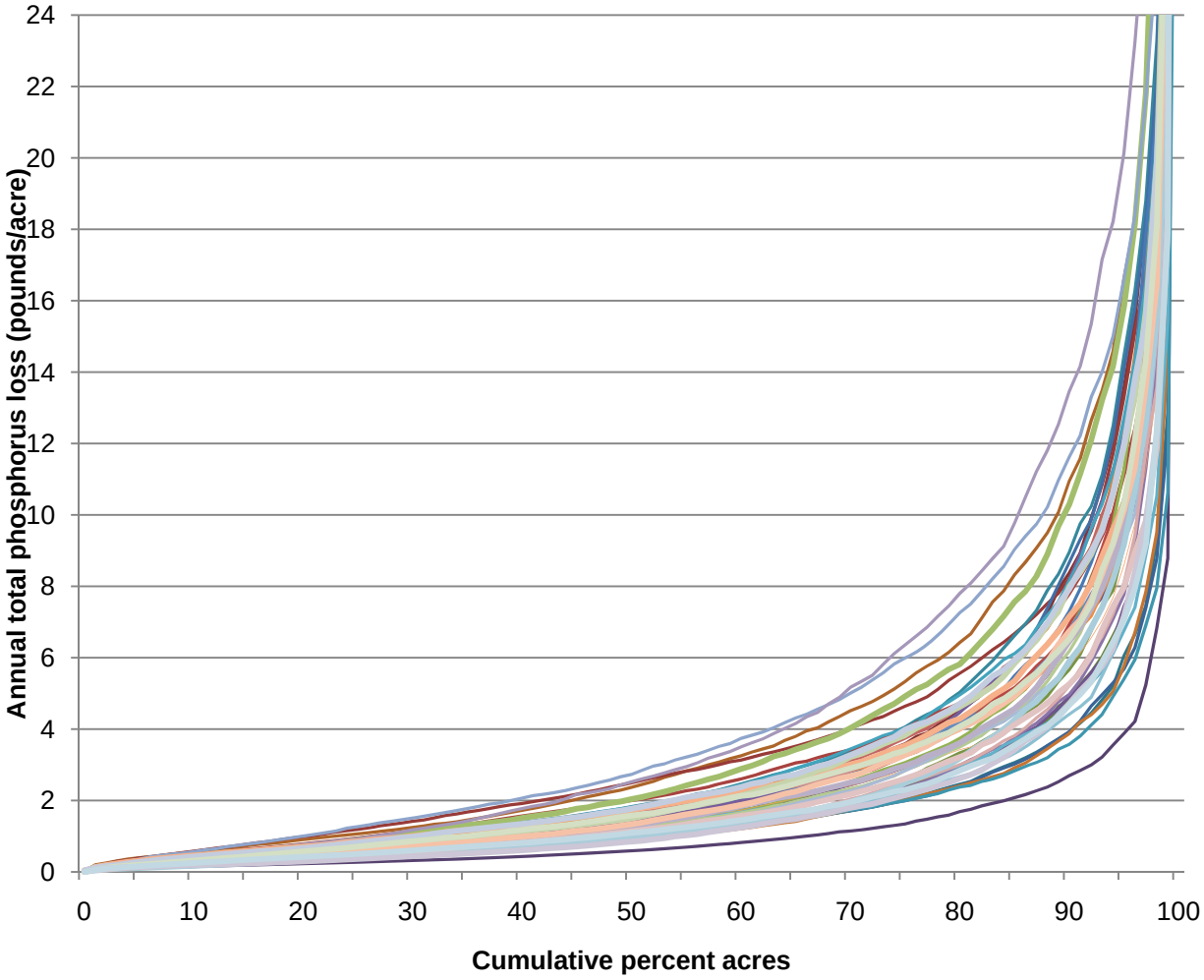
Model simulated outcome	Average annual values in pounds per acre			
	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (58.2 million acres)				
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	22.31	29.53	7.22	24
Phosphorus loss pathways				
Phosphorus in crop yield removed at harvest	16.98	17.82	0.84	5
Phosphorus lost with windborne sediment	0.42	0.91	0.50	55
Phosphorus lost with surface runoff, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage ditches	2.54	4.93	2.39	48
Soluble phosphorus loss to groundwater	0.02	0.02	<0.01	15
Total phosphorus loss for all pathways except harvest	2.98	5.87	2.89	49
Change in soil phosphorus	2.24	5.79	3.56	--
Highly erodible land (18 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	23.12	29.04	5.92	20
Total phosphorus loss for all pathways except harvest	4.64	9.29	4.64	50
Non-highly erodible land (82 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	22.13	29.64	7.51	25
Total phosphorus loss for all pathways except harvest	2.60	5.10	2.50	49
Acres with manure applied (16 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	37.12	44.20	7.08	16
Total phosphorus loss for all pathways except harvest	6.15	9.97	3.82	38
Acres without manure applied (84 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	19.43	26.68	7.25	27
Total phosphorus loss for all pathways except harvest	2.36	5.07	2.71	53
Land in long-term conserving cover (2.8 million acres)				
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	0.00	29.87	29.87	100
Phosphorus loss pathways				
Phosphorus in crop yield removed at harvest	0.48*	16.55	16.07	97
Phosphorus lost with windborne sediment	0.00	0.11	0.11	100
Phosphorus lost with surface runoff, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage ditches	0.19	7.52	7.33	97
Soluble phosphorus loss to groundwater	0.07	0.03	-0.04	-137
Total phosphorus loss for all pathways except harvest	0.26	7.66	7.40	97
Change in soil phosphorus	-0.86	5.47	6.33	--

* 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 C for the 14 subbasins.

Figure 42. 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 43. Estimates of average annual phosphorus lost with surface runoff for cropped acres in the Upper Mississippi River Basin

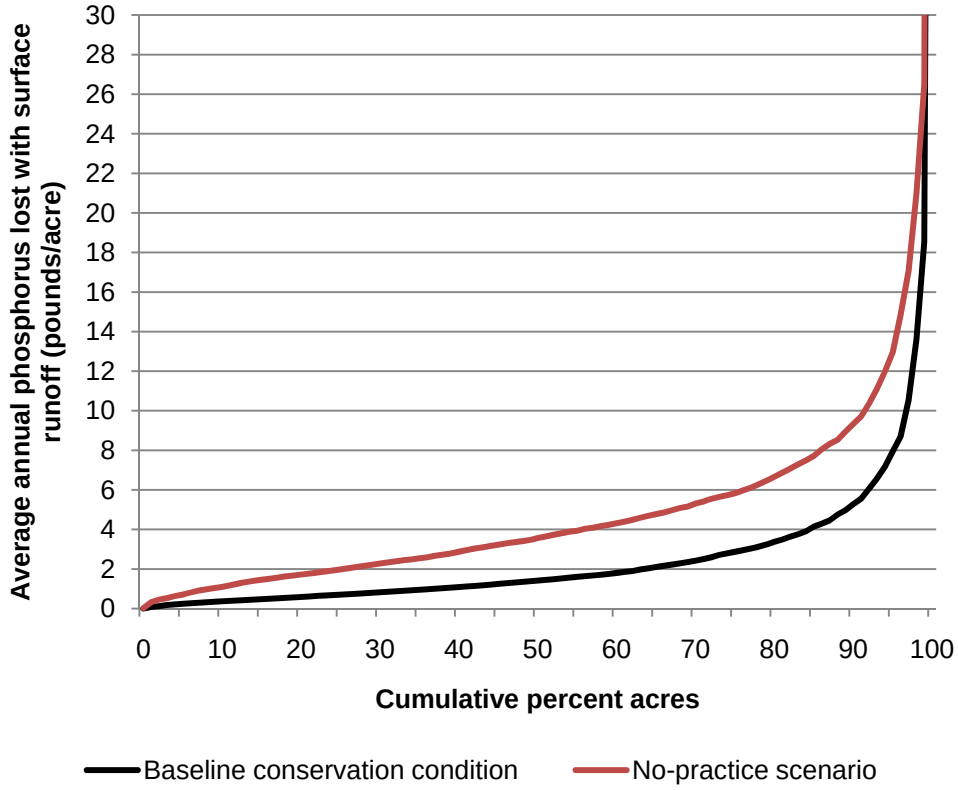
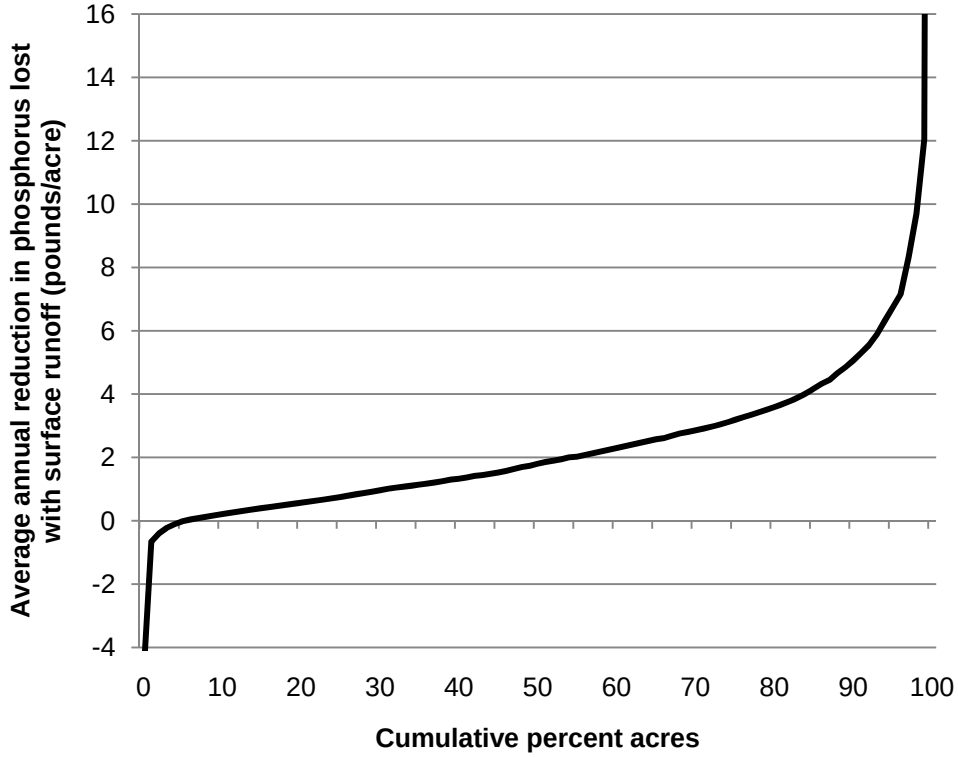


Figure 44. Estimates of average annual reduction in phosphorus lost with surface runoff due to conservation practices on cropped acres in the Upper Mississippi River Basin



Note: A small number of acres with an overall increase in surface water runoff due to conservation practices (see figure 17) causes small negative reductions (gains) in phosphorus lost with surface runoff due to conservation practices for about 2 percent of the cropped acres.

Figure 45. Estimates of average annual total phosphorus loss for land in long-term conserving cover in the Upper Mississippi River Basin

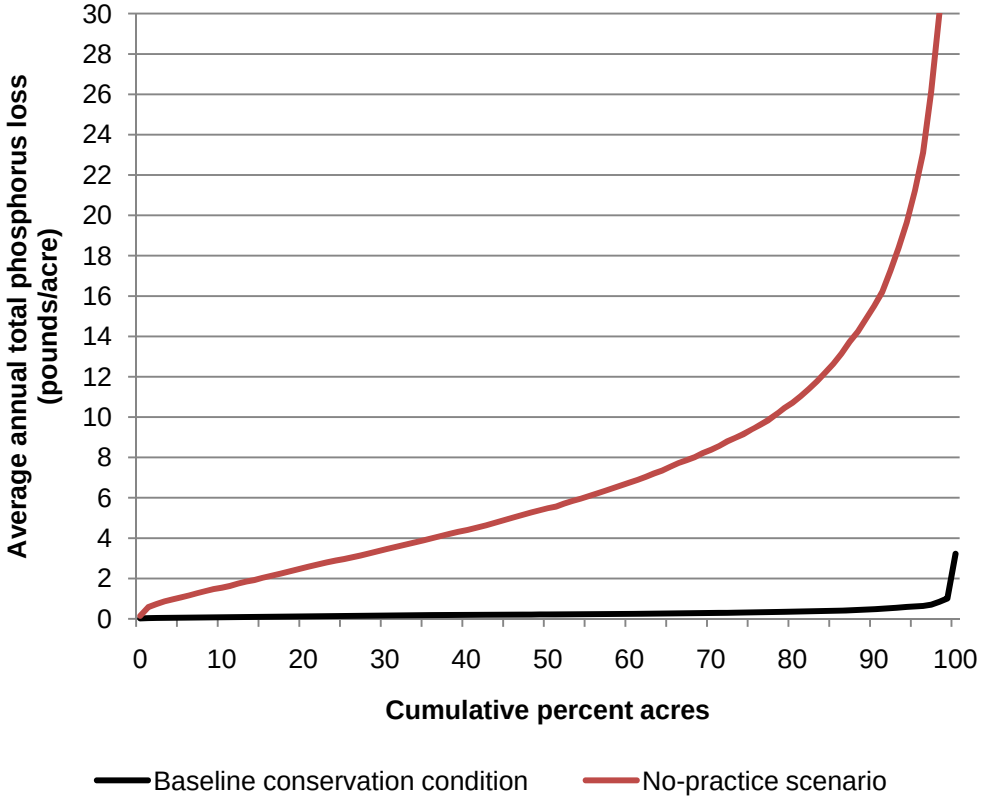
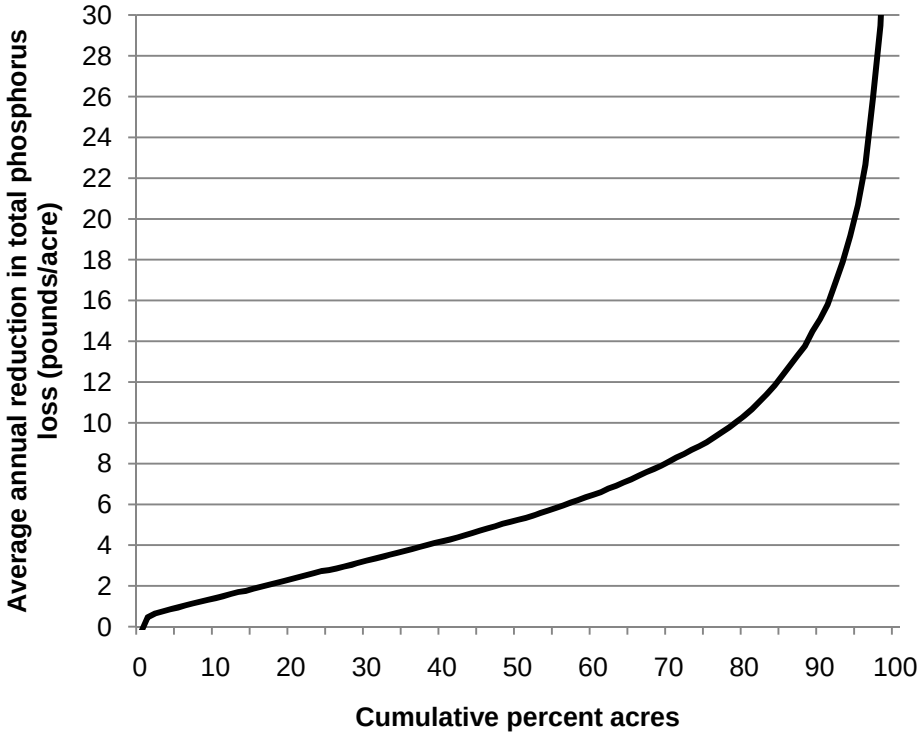


Figure 46. Estimates of average annual reduction in total phosphorus loss due to conversion to long-term conserving cover in the Upper Mississippi River Basin



Pesticide Residues and Environmental Risk

Pesticide loss

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.

The APEX model tracks the mass loss of pesticides dissolved in surface water runoff, adsorbed to sediment loss from water erosion, and dissolved in subsurface flow pathways.[22] For the UMRB, the predominant loss pathway was pesticide loss in surface water runoff—50 percent of the total mass loss for the baseline conservation condition. About 29 percent of the total mass loss was with water-borne sediment. Pesticide loss in subsurface flow pathways averaged 21 percent of the total mass loss.

The average annual amount of pesticide lost from farm fields in the UMRB is about 8.4 grams of active ingredient per hectare per year (table 20). As was observed for sediment and nutrient loss, the majority of pesticide loss occurs on a minority of acres within the UMRB. Two-thirds of the acres have total mass loss less than 8.4 grams of active ingredient per hectare per year, on average. In contrast, about 11 percent of the acres have an annual average pesticide mass loss of more than 20 grams of active ingredient per hectare.

The pesticide applied in the largest amount was glyphosate, consisting of 28 percent of the total amount of pesticides applied in the UMRB (table 21). Atrazine was the second highest (23 percent), followed by acetochlor (18 percent) and s-metolachlor (9 percent). These 4 pesticides accounted for 78 percent of the quantity of pesticides applied in the region.

The most common pesticide residue lost from farm fields is atrazine, which represented about 37 percent of the total mass loss in these model simulations (table 21). Acetechlor represented 16 percent of the total pesticide mass loss and glyphosate represented 11 percent.

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 thus assumed that there was no pesticide residues lost from land in long-term conserving cover.

[22] The APEX model currently does not estimate pesticides lost in spray drift or volatilization.

Environmental risk

Management practices that reduce the impact of pesticides on non-target plant and animal populations consist of a combination of Integrated Pesticide 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 8.4 grams of active ingredient per hectare per year, a 50-percent reduction from the 16.8 grams per hectare for the no-practice scenario (table 20).

Because the environmental impact is specific to the toxicity of each pesticide to non-target species, however, the total quantity of all pesticides lost from the field is not the most useful outcome measure for assessing the environmental benefits of conservation practices. Pesticide risk indicators were developed to represent risk at the edge-of-the field (bottom of root zone for groundwater) to provide a consistent measure that would be comparable from field to field and that best represented the effects of farming activities without being influenced by other landscape factors.

Risk indicators are based on the ratio of pesticide concentration to safe concentrations (toxicity thresholds) for each pesticide. As such, they do not have units. 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. The pesticide risk indicators were developed so that the relative risk for individual pesticides could be aggregated over the more than 150 pesticides in use on cropped acres in the UMRB. [23]

These indicators represent worst-case risk by assuming target species are exposed to concentrations at the edge of the field (bottom of root zone for groundwater). In most environmental

[23] 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 target species are exposed to a mix of pesticides. For more information on the derivation of the pesticide risk indicators, see "Documentation of pesticide risk indicators used in the CEAP cropland modeling," found at http://www.nrcs.usda.gov/technical/nri/ceap/umrbdocumentation/.

settings, however, 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.

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 pesticide toxicities for fish, invertebrates, 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.

Atrazine was the dominant pesticide contributing to all three risk indicators (table 21). Based on the model simulations, the edge-of-field risk indicator for atrazine exceeded 1 for 28 percent of the cropped acres for risk to aquatic ecosystems, 8 percent of the cropped acres for surface water risk to humans, and 3 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).

The pesticide risk indicator for aquatic ecosystems averaged 2.6 over all years and cropped acres (table 20) for the baseline conservation condition. (The 2.6 value indicates that pesticide concentrations in water leaving cropped fields in the UMRB are, on average, 2.6 times the “safe” concentration for non-target plant and animal species.) Figure 47 shows that for most years the overall risk for aquatic ecosystems is low for the majority of acres, 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 of the acres.

The pesticide risk indicators for humans were much lower, averaging 0.4 for surface water and 0.1 for groundwater.

The use of conservation practices in the UMRB has reduced the surface water pesticide risk indicators by 48 to 51 percent (table 20), averaged over all years, all pesticides, and all cropped acres in the UMRB. The groundwater pesticide risk indicator has been reduced by 30 percent, on average.

The distributions of the surface water pesticide risk indicators are shown in figures 48 and 49. For environmental risk to aquatic ecosystems, 40 percent of the acres have an annual average indicator greater than 1 in the baseline conservation condition, compared to 55 percent of the acres without conservation practices. The annual average surface water risk indicator for humans is greater than 1 for 11 percent of the acres in the baseline conservation condition, compared to 21 percent of the acres without conservation practices.

Figure 50 shows the distribution of the reductions in the two pesticide risk indicators due to conservation practices. The benefits of conservation practices were similar for both aquatic risks and human risks on the acres that had those risks, but aquatic risks were more widespread than human risks so conservation practices have greater total benefit for aquatic ecosystems than for human drinking water.

Table 20. 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)	1,650	2,079	429	21
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	8.4	16.8	8.4	50
Edge-of-field pesticide risk indicator				
Average annual surface water pesticide risk indicator for aquatic ecosystem	2.6	5.3	2.7	51
Average annual surface water pesticide risk indicator for humans	0.4	0.8	0.4	48
Average annual groundwater pesticide risk indicator for humans	0.2	0.2	0.1	30

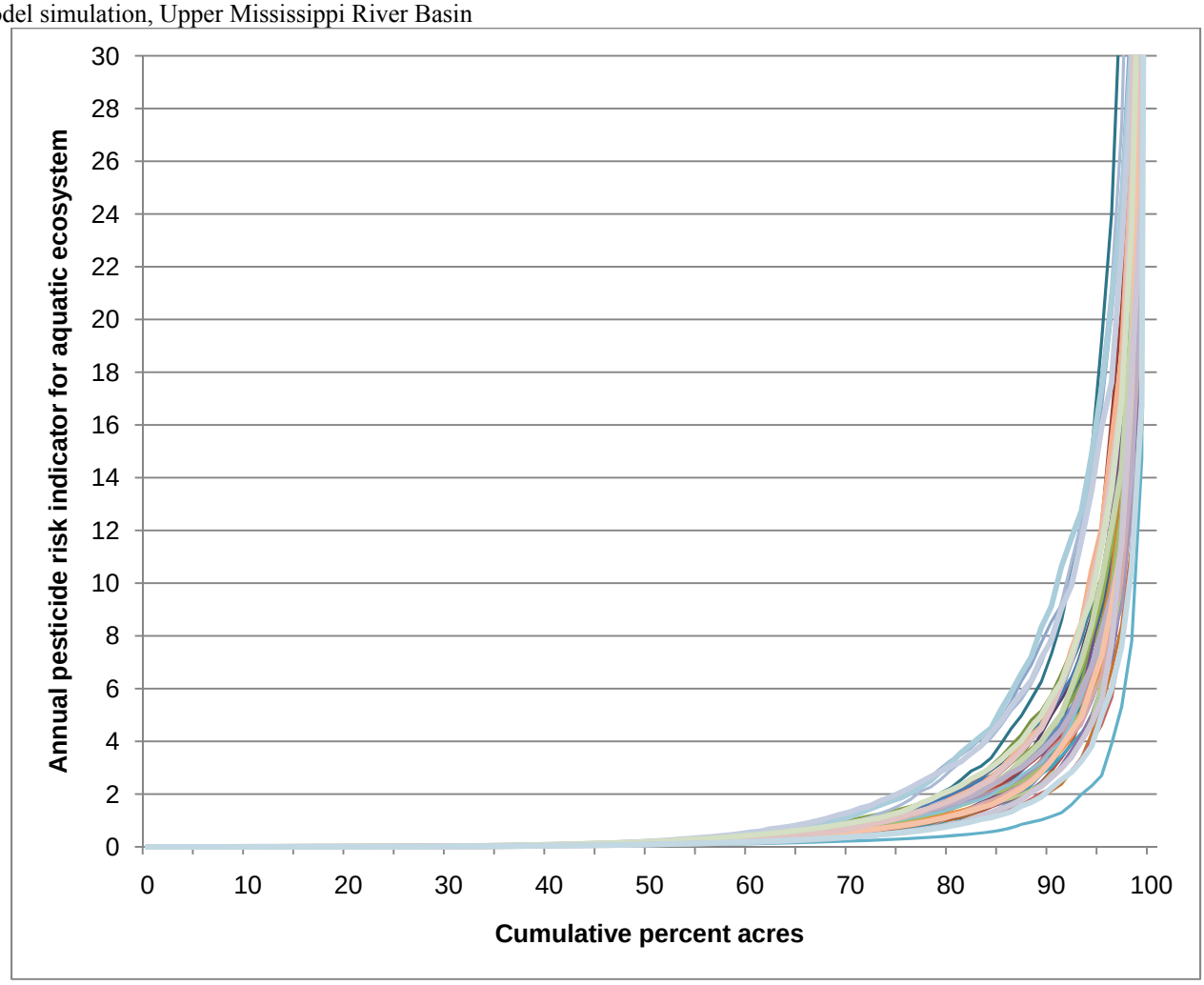
Note: It was assumed that no pesticides were applied to land in long-term conserving cover and there was no data on residual pesticides in the soil for these acres; thus, the assessment of the effects of this practice on pesticide loss was not done.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix C for the 14 subbasins.

Table 21. Dominant pesticides applied, contributing to losses, and in determining edge-of-field environmental risk, Upper Mississippi River Basin

Pesticide (active ingredient name)	Pesticide type	Percent of total applied in the UMRB
Pesticide application*		
Glyphosate, isopropylamine sal	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
Total		87
		Percent of total pesticide loss in the UMRB**
Pesticide loss from farm fields*		
Atrazine	Herbicide	37
Glyphosate, isopropylamine salt	Herbicide	16
Acetochlor	Herbicide	11
S-Metolachlor	Herbicide	8
Sulfentrazone	Herbicide	8
Metolachlor	Herbicide	3
Pendimethalin	Herbicide	2
Flufenacet	Herbicide	1
Dimethenamide-P	Herbicide	1
Clopyralid	Herbicide	1
Simazine	Herbicide	1
Total		88
		Percent of cropped acres with average annual edge-of-field risk indicator greater than 1
Risk indicator for aquatic ecosystem		
Atrazine	Herbicide	28
Acetochlor	Herbicide	6
Phostebupirim	Insecticide	4
Metolachlor	Herbicide	2
Chlorpyrifos	Insecticide	2
Tefluthrin	Insecticide	<1
Carbofuran	Insecticide	<1
S-Metolachlor	Herbicide	<1
Flufenaret	Herbicide	<1
All others combined		<2
Risk indicator for humans, surface water		
Atrazine	Herbicide	8
Alachlor	Herbicide	<1
Acetochlor	Herbicide	<1
Simazine	Herbicide	<1
All others combined		<1
Risk indicator for humans, groundwater		
Atrazine	Herbicide	3
All others combined		<1

* Pesticides not listed each represented less than 1 percent of the total.
** Includes loss of pesticides dissolved in surface water runoff, adsorbed to sediment loss from water erosion, and dissolved in subsurface flow pathways.

Figure 47. Distribution of annual values of the edge-of-field 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 varied from year to year.

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

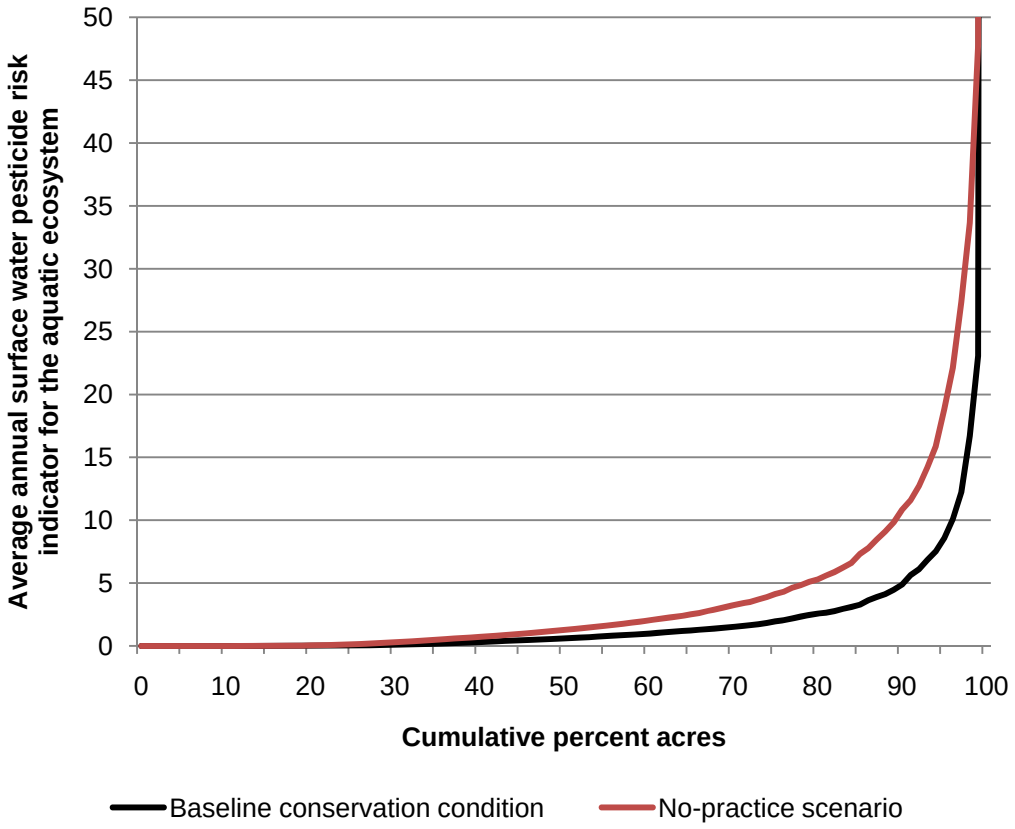


Figure 49. Estimates of average annual edge-of-field surface water pesticide risk indicator for humans in the Upper Mississippi River Basin

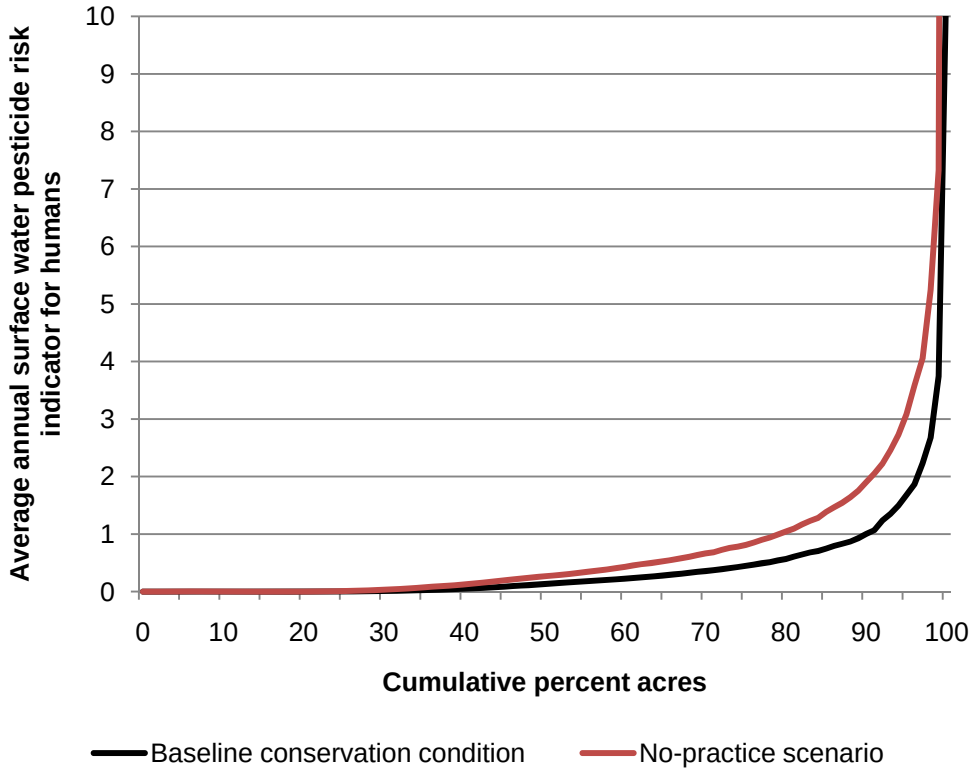
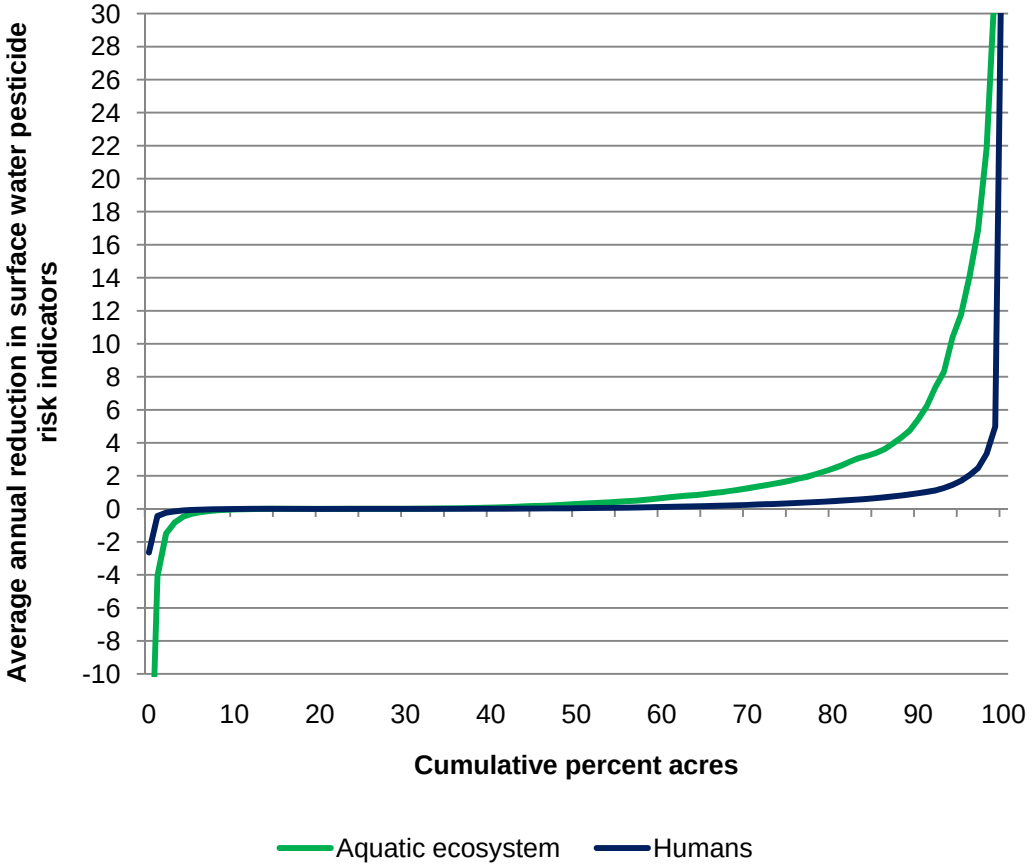


Figure 50. Estimates of average annual reductions in the surface water pesticide risk indicators for aquatic ecosystems in the Upper Mississippi River Basin



Note: Negative reductions in pesticide risk indicators result primarily from an increase in surface water runoff due to conservation practices (see figure 17).

Chapter 5
Offsite Water Quality Effects of Conservation Practices

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 and concentrations of sediment, nitrogen, phosphorus, and atrazine in the UMRB.

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 permanently 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 delivered to streams and rivers.

HUMUS/SWAT model simulations provide comparisons between the baseline conservation condition and the no-practice scenario. For each scenario, only the conditions for cultivated cropland were changed; all other aspects of the simulations—including sediment and nutrient loads from point sources and noncultivated land uses—remained the same.

There are three types of loadings that are relevant to assessing the effects of conservation practices: 1) loadings leaving the field (summarized in the previous chapter), 2) loadings *delivered* to streams and rivers, and 3) loadings in the stream or river at a given point. Loadings delivered to streams and rivers differ from the amount leaving the field because of losses during transport from the field to the stream. Instream loadings are further influenced by loadings exported from upstream subbasins and losses during transport within the stream or river.

Atrazine was the only pesticide for which in-stream loads were assessed in the UMRB 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.

Summary of Results for the Entire Basin

The assessment shows that conservation practices as represented in the baseline conservation condition have reduced the delivery of loads from cultivated cropland into rivers and streams by—

- 71 percent for sediment (table 22) ;
- 23 percent for nitrogen (table 24);
- 49 percent for phosphorus (table 26); and
- 49 percent for atrazine (table 28).

These reductions in cultivated cropland source loads have in turn significantly reduced the amount of these agricultural pollutants found at the farthest downstream gauging station above the confluence with the Missouri River at Grafton, IL, where—

- instream sediment loads have been reduced 37 percent due to conservation practices (table 23and figure 51);
- instream nitrogen loads have been reduced 21 percent due to conservation practices (table 25 and figure 52);
- instream phosphorus loads have been reduced 40 percent due to conservation practices (table 27 and figure 53); and
- instream atrazine loads have been reduced 51 percent due to conservation practices (table 29 and figure 54).

The model simulation also identifies the proportion of instream sediment and nutrient loads that originate from cultivated cropland. (Atrazine sources other than agriculture were not included in the model simulation.) At Grafton, IL, the most downstream point in the UMRB, the percentage of instream loads attributed to cultivated cropland sources for the baseline conservation condition is—

- 28 percent for sediment;
- 74 percent for nitrogen; and
- 65 percent for phosphorus.

Summary of Results for the 14 Subbasins

Delivery of loads from cultivated cropland

The delivery of sediment, nutrients, and pesticides into rivers and streams from cultivated cropland varies among the 14 subbasins within the UMRB (tables 22, 24, 26, and 28):

- The Upper Mississippi-Iowa-Skunk-Wapsipinicon (subbasin code 0708), the Rock River (subbasin code 0709), and the Lower Illinois River (subbasin code 0713) contribute the largest sediment loads from agricultural sources. More than 65 percent of the land cover is cultivated cropland in these three subbasins, among the highest in the UMRB (table 4).
- Two subbasins contribute the largest nitrogen, phosphorus, and atrazine loads from agricultural sources—the Upper Mississippi-Iowa-Skunk-Wapsipinicon (subbasin code 0708) and the Lower Illinois River (subbasin code 0713).
- The Rock River (subbasin code 0709) also contributes among the largest amounts of phosphorus loads in the basin.
- Three subbasins contribute among the smallest sediment, nutrient, and atrazine loads from agricultural sources—the St. Croix River (subbasin code 0703), the Chippewa River (subbasin code 0705), and the Mississippi Headwaters (subbasin code 0701). These three subbasins also have the

lowest percentage of land cover in cultivated cropland (less than 25 percent).

The effects of conservation practices on reducing the loads delivered from cultivated cropland to rivers and streams also vary (tables 22, 24, 26, and 28):

- Subbasins with the largest percent reductions in sediment delivered to rivers and streams due to conservation practices include the Upper Mississippi-Maquoketa-Plum (subbasin code 0706), the Des Moines River Basin (subbasin code 0710), the Upper Mississippi-Iowa-Skunk-Wapsipinicon (subbasin code 0708), and the Upper Mississippi-Salt (subbasin code 0711). Reductions in sediment delivered were 77 percent or higher in these four subbasins.
- Three subbasins have reductions in nitrogen delivered to rivers and streams due to conservation practices of 37 percent or more:
  - the Upper Mississippi-Maquoketa-Plum (subbasin code 0706),
  - the Des Moines River basin (subbasin code 0710), and
  - the Mississippi Headwaters (subbasin code 0701).
- Subbasins with the largest percent reductions in phosphorus delivered to rivers and streams due to conservation practices include the Upper Mississippi-Maquoketa-Plum watershed (subbasin code 0706), the Upper Mississippi-Salt (subbasin code 0711), and the Des Moines River (subbasin code 0701). Reductions in phosphorus delivered were 55 percent or higher in these three subbasins.
- The Minnesota River Basin (subbasin code 0711) has the highest percent reduction (65 percent) in atrazine delivered to streams and rivers.
- The Upper Mississippi-Maquoketa-Plum watershed (subbasin code 0706) and the Upper Mississippi-Salt (subbasin code 0711) have among the highest percent reductions of sediment *and* nutrients delivered into streams and rivers due to conservation practices currently in use. These two subbasins also have the highest proportion of cultivated cropland acres in long-term conserving cover—more than 10 percent of the cultivated cropland in the subbasins.

Instream loads

Four of the 14 subbasins within the UMRB 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. They are:

1. Upper Mississippi-Black-Root (subbasin code 0704)
2. Upper Mississippi-Maquoketa-Plum (subbasin code 0706)
3. Upper Mississippi-Iowa-Skunk-Wapsipinicon (subbasin code 0708)
4. Upper Mississippi-Salt (subbasin code 0711) at Grafton, IL.

Instream loads for these four subbasins consistently increase from the upstream to the downstream subbasins (tables 23, 25, 27, and 29). Instream loads among the nine tributaries and the farthest upstream watershed on the main stem of the Upper Mississippi River—subbasin code 0701—can be directly compared as these are loads that are *delivered into* the Upper Mississippi River.

Percent reductions in instream loads due to conservation practices were highly variable among tributary subbasins, but were much less variable among the five subbasins along the mainstem of the Upper Mississippi River.

Agricultural sources are relatively minor in two subbasins, the St. Croix River (subbasin code 0703) and the Upper Illinois River (subbasin code 0712), which explains the low percent reduction in instream loads due to conservation practices in those subbasins.

The effects of conservation practices on reducing instream loads for the mainstem subbasins are summarized graphically in figures 51 through 54.

Table 22. Average annual ***sediment source loads*** delivered from cultivated cropland for the 14 subbasins in the Upper Mississippi River Basin

		Baseline conservation condition				Reductions in loads due to conservation practices	
Sub-basin code	Subbasin name	Amount (1,000 tons)	Percent of basin total	Tons delivered per cropland acre	No-practice Scenario (1,000 tons)	Reduction (1,000 tons)	Percent
0701	Mississippi Headwaters	775	4	0.25	1,400	623	45
0702	Minnesota River Basin	996	5	0.12	2,640	1,650	62
0703	St. Croix River Basin	301	1	0.48	659	358	54
0704	Upper Mississippi-Black-Root	1,780	9	0.54	5,070	3,290	65
0705	Chippewa River Basin	764	4	0.55	1,560	795	51
0706	Upper Mississippi-Maquoketa-Plum	1,340	7	0.45	6,100	4,770	78
0707	Wisconsin River Basin	1,050	5	0.44	2,710	1,660	61
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	4,130	20	0.38	18,300	14,100	77
0709	Rock River Basin	2,610	13	0.56	7,260	4,640	64
0710	Des Moines River Basin	1,220	6	0.19	6,190	4,980	80
0711	Upper Mississippi-Salt	1,360	7	0.46	5,850	4,490	77
0712	Upper Illinois River Basin	1,050	5	0.26	3,050	2,000	66
0713	Lower Illinois River Basin	2,340	11	0.29	8,170	5,830	71
0714	Upper Mississippi-Kaskaskia-Meramec	798	4	0.23	2,600	1,800	69
	Total	20,500	100	0.33	71,600	51,000	71

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

Table 23. Average annual ***instream sediment loads*** for the 14 subbasin outlets in the Upper Mississippi River Basin

		Baseline conservation condition				Reductions in loads due to conservation practices	
Sub-basin code	Location of subbasin outlet	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 subbasins						
0702	Minnesota River	873	596	32	1,280	407	32
0703	St. Croix River	520	500	4	538	18	3
0705	Chippawa River	962	686	29	1,070	108	10
0707	Wisconsin River	1,120	863	23	1,520	400	26
0708a	Iowa River within 708	1,630	937	43	2,970	1,340	45
0709	Rock River	1,530	682	55	2,850	1,320	46
0710	Des Moines River	792	524	34	1,240	448	36
0713	Illinois River	6,380	4,600	28	9,410	3,030	32
0712	Upper Illinois River within 713	1,960	1,680	14	2,460	500	20
	Outlets along main stem						
0701	Mississippi Headwaters	2,620	1,830	30	3,540	920	26
0704	Upper Mississippi-Black-Root	5,980	4,100	31	7,990	2,010	25
0706	Upper Mississippi-Maquoketa-Plum	9,040	6,270	31	14,200	5,160	36
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	15,600	10,600	32	26,700	11,100	42
0711	Mississippi at Grafton, Illinois	20,900	15,100	28	33,300	12,400	37

* Loadings from non-cultivated cropland were estimated by running an additional scenario that simulated a grass cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres, labeled "Background sources."
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 24. Average annual ***nitrogen source loads*** delivered from cultivated cropland for the 14 subbasins in the Upper Mississippi River Basin

		Baseline conservation condition				Reductions in loads due to conservation practices	
Sub-basin code	Subbasin name	Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cropland acre	No-practice Scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent
0701	Mississippi Headwaters	34,900	3	11.3	58,300	23,500	40
0702	Minnesota River Basin	117,000	11	14.1	151,000	34,700	23
0703	St. Croix River Basin	11,200	1	17.8	16,800	5,620	33
0704	Upper Mississippi-Black-Root	58,500	5	17.9	88,700	30,200	34
0705	Chippewa River Basin	20,100	2	14.5	30,600	10,500	34
0706	Upper Mississippi-Maquoketa-Plum	51,500	5	17.2	82,000	30,600	37
0707	Wisconsin River Basin	44,800	4	18.7	67,000	22,100	33
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	215,000	20	20.0	272,000	56,600	21
0709	Rock River Basin	89,200	8	19.1	116,000	26,600	23
0710	Des Moines River Basin	109,000	10	16.6	136,000	27,800	20
0711	Upper Mississippi-Salt	32,800	3	11.1	53,000	20,200	38
0712	Upper Illinois River Basin	99,000	9	24.4	120,000	21,200	18
0713	Lower Illinois River Basin	170,000	16	21.1	183,000	13,000	7
0714	Upper Mississippi-Kaskaskia-Meramec	46,200	4	13.3	55,800	9,570	17
	Total	1,100,000	100	17.6	1,430,000	332,000	23

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

Table 25. Average annual ***instream nitrogen loads*** for the 14 subbasin outlets in the Upper Mississippi River Basin

		Baseline conservation condition				Reductions in loads due to conservation practices	
Sub-basin code	Location of subbasin outlet	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 subbasins						
0702	Minnesota River	108,000	8,980	92	139,000	31,000	22
0703	St. Croix River	13,600	11,800	13	15,000	1,400	9
0705	Chippawa River	23,500	10,600	55	29,200	5,700	19
0707	Wisconsin River	43,400	16,600	62	59,300	15,900	27
0708a	Iowa River within 708	117,000	21,400	82	148,000	31,000	21
0709	Rock River	94,200	26,900	71	116,000	21,800	19
0710	Des Moines River	117,000	17,600	85	140,000	23,000	17
0713	Illinois River	424,000	198,000	53	454,000	30,000	6
0712	Upper Illinois River within 713	166,000	104,000	37	180,000	14,000	8
	Outlets along main stem						
0701	Mississippi Headwaters	185,000	37,500	80	241,000	56,000	24
0704	Upper Mississippi-Black-Root	304,000	79,000	74	401,000	97,000	24
0706	Upper Mississippi-Maquoketa-Plum	409,000	109,000	73	551,000	142,000	26
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	764,000	181,000	76	995,000	231,000	23
0711	Mississippi at Grafton, Illinois	1,090,000	281,000	74	1,380,000	290,000	21

* Loadings from non-cultivated cropland were estimated by running an additional scenario that simulated a grass cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres, labeled "Background sources".
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 26. Average annual ***phosphorus source loads*** delivered from cultivated cropland for the 14 subbasins in the Upper Mississippi River Basin

Sub-basin code	Subbasin name	Baseline conservation condition: Amount (1,000 pounds)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Pounds delivered per cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
0701	Mississippi Headwaters	2,490	4	0.8	4,970	2,480	50
0702	Minnesota River Basin	3,930	6	0.5	8,460	4,530	54
0703	St. Croix River Basin	757	1	1.2	1,400	640	46
0704	Upper Mississippi-Black-Root	3,810	6	1.2	7,690	3,880	50
0705	Chippewa River Basin	1,910	3	1.4	3,020	1,110	37
0706	Upper Mississippi-Maquoketa-Plum	3,060	5	1.0	7,220	4,160	58
0707	Wisconsin River Basin	5,870	9	2.5	9,040	3,170	35
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	10,800	17	1.0	22,500	11,800	52
0709	Rock River Basin	6,740	11	1.4	12,100	5,370	44
0710	Des Moines River Basin	3,960	6	0.6	9,820	5,860	60
0711	Upper Mississippi-Salt	3,260	5	1.1	7,290	4,030	55
0712	Upper Illinois River Basin	3,500	6	0.9	6,940	3,440	50
0713	Lower Illinois River Basin	8,690	14	1.1	15,500	6,790	44
0714	Upper Mississippi-Kaskaskia-Meramec	3,500	6	1.0	6,250	2,750	44
	Total	62,300	100	1.0	122,000	60,000	49

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

Table 27. Average annual ***instream phosphorus loads*** for the 14 subbasin outlets in the Upper Mississippi River Basin

Sub-basin code	Location of subbasin outlet	Baseline conservation condition: Load from all sources (1,000 pounds)	Baseline conservation condition: Background sources* (1,000 pounds)	Baseline conservation condition: Percent of load attributed to cultivated cropland sources	No-practice scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
	Tributary subbasins						
0702	Minnesota River	3,340	975	71	6,530	3,190	49
0703	St. Croix River	521	428	18	647	126	19
0705	Chippawa River	1,610	530	67	2,230	620	28
0707	Wisconsin River	2,830	799	72	4,440	1,610	36
0708a	Iowa River within 708	6,000	1,470	76	10,700	4,700	44
0709	Rock River	6,060	1,430	76	9,900	3,840	39
0710	Des Moines River	3,540	999	72	7,340	3,800	52
0713	Illinois River	24,100	15,500	36	31,700	7,600	24
0712	Upper Illinois River within 713	10,800	9,170	15	12,700	1,900	15
	Outlets along main stem						
0701	Mississippi Headwaters	7,250	2,930	60	13,100	5,850	44
0704	Upper Mississippi-Black-Root	12,700	4,710	63	21,800	9,100	42
0706	Upper Mississippi-Maquoketa-Plum	19,000	5,830	69	31,800	12,800	40
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	35,200	10,200	71	59,600	24,400	41
0711	Mississippi at Grafton, Illinois	45,200	15,800	65	74,900	29,700	40

* Loadings from non-cultivated cropland were estimated by running an additional scenario that simulated a grass cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres, labeled "Background sources".
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 28. Average annual ***atrazine source loads*** delivered from cultivated cropland for 14 subbasins in the Upper Mississippi River Basin

Sub-basin code	Subbasin name	Baseline conservation condition: Amount (pounds)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Pounds delivered per cropland acre	No-practice Scenario (pounds)	Reductions in loads due to conservation practices: Reduction (pounds)	Reductions in loads due to conservation practices: Percent
0701	Mississippi Headwaters	2,554	2	0.0008	3,397	843	25
0702	Minnesota River Basin	3,741	3	0.0005	10,669	6,929	65
0703	St. Croix River Basin	553	0.4	0.0009	845	292	35
0704	Upper Mississippi-Black-Root	2,691	2	0.0008	5,391	2,700	50
0705	Chippewa River Basin	1,979	2	0.0014	3,088	1,109	36
0706	Upper Mississippi-Maquoketa-Plum	5,240	4	0.0017	10,173	4,933	48
0707	Wisconsin River Basin	2,129	2	0.0009	3,516	1,387	39
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	27,749	22	0.0026	58,753	31,003	53
0709	Rock River Basin	7,876	6	0.0017	16,277	8,401	52
0710	Des Moines River Basin	9,582	7	0.0015	20,436	10,854	53
0711	Upper Mississippi-Salt	12,138	9	0.0041	22,068	9,930	45
0712	Upper Illinois River Basin	11,252	9	0.0028	19,025	7,773	41
0713	Lower Illinois River Basin	29,392	23	0.0036	57,909	28,517	49
0714	Upper Mississippi-Kaskaskia-Meramec	11,713	9	0.0034	17,802	6,089	34
	Total	129,000	100	0.0021	249,000	120,000	49

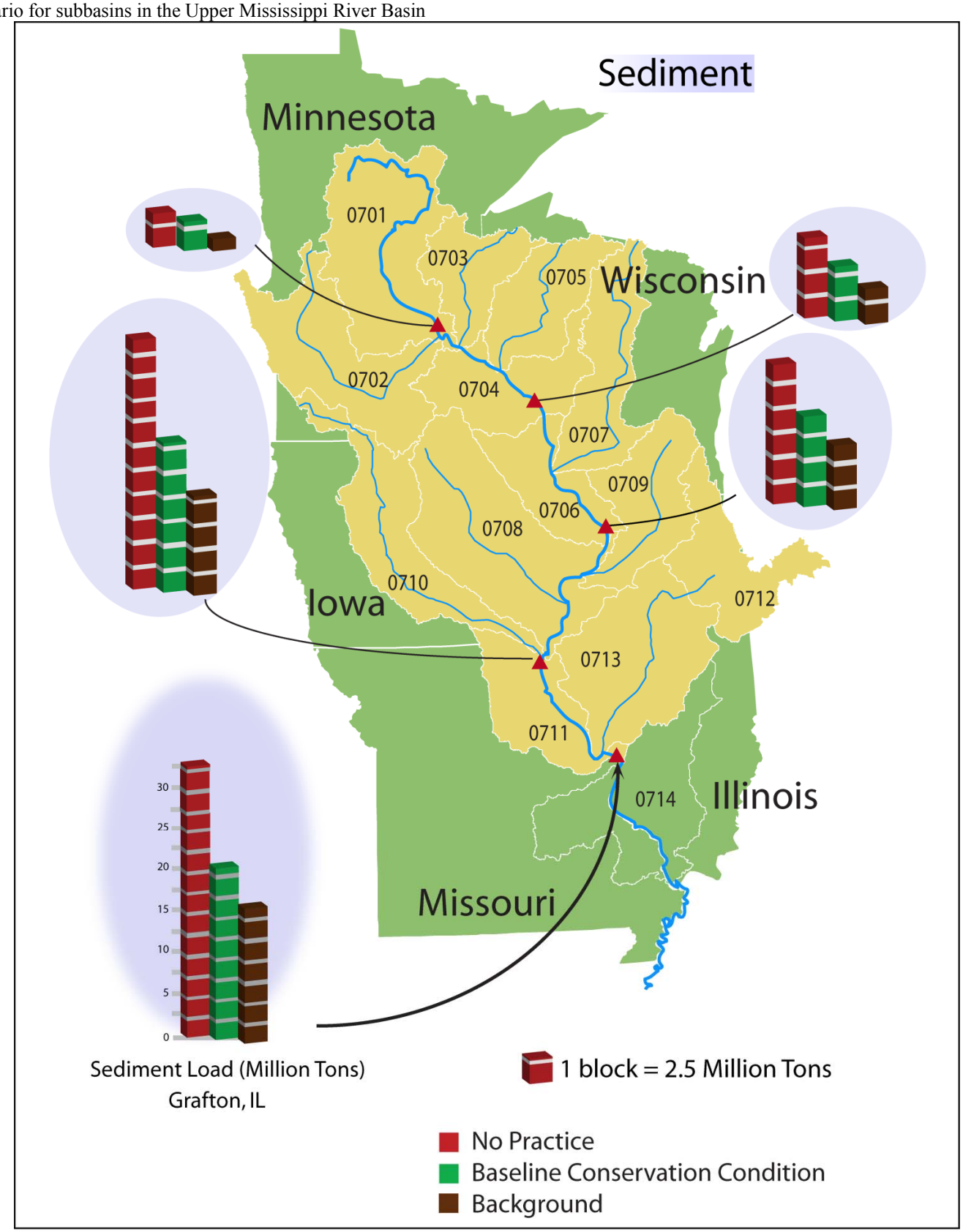
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Percents may not add to totals because of rounding.

Table 29. Average annual ***instream atrazine loads*** for the 14 subbasin outlets in the Upper Mississippi River Basin

Sub-basin code	Location of subbasin outlet	Baseline conservation condition (pounds)	No-practice scenario (pounds)	Reductions in loads due to conservation practices: Reduction (pounds)	Reductions in loads due to conservation practices: Percent
	Tributary subbasins				
0702	Minnesota River	3,052	8,885	5,833	66
0703	St. Croix River	128	201	73	36
0705	Chippawa River	854	1,217	363	30
0707	Wisconsin River	1,146	1,540	393	26
0708a	Iowa River within 708	9,614	19,245	9,631	50
0709	Rock River	4,915	10,219	5,304	52
0710	Des Moines River	3,800	7,428	3,629	49
0713	Illinois River	17,297	33,163	15,866	48
0712	Upper Illinois River within 713	7,144	11,538	4,393	38
	Outlets along main stem				
0701	Mississippi Headwaters	5,470	12,355	6,885	56
0704	Upper Mississippi-Black-Root	7,901	16,477	8,576	52
0706	Upper Mississippi-Maquoketa-Plum	6,315	11,861	5,546	47
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	33,335	69,607	36,272	52
0711	Mississippi at Grafton, Illinois	47,826	98,025	50,199	51

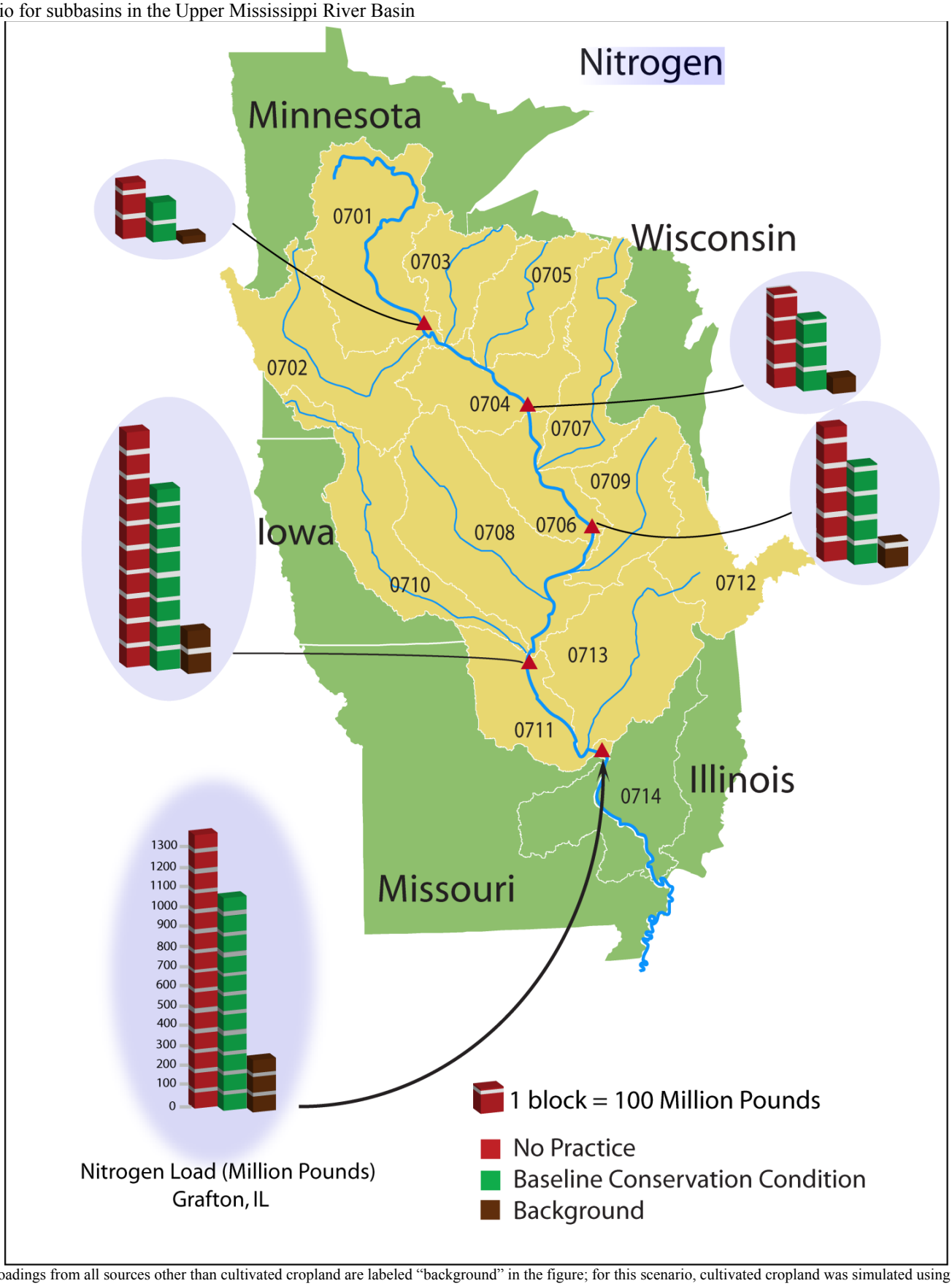
Note: Atrazine sources other than agriculture were not included in the model simulation.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Figure 51. Estimates of average annual instream sediment loads for the baseline conservation condition compared to the no-practice scenario for subbasins in the Upper Mississippi River Basin



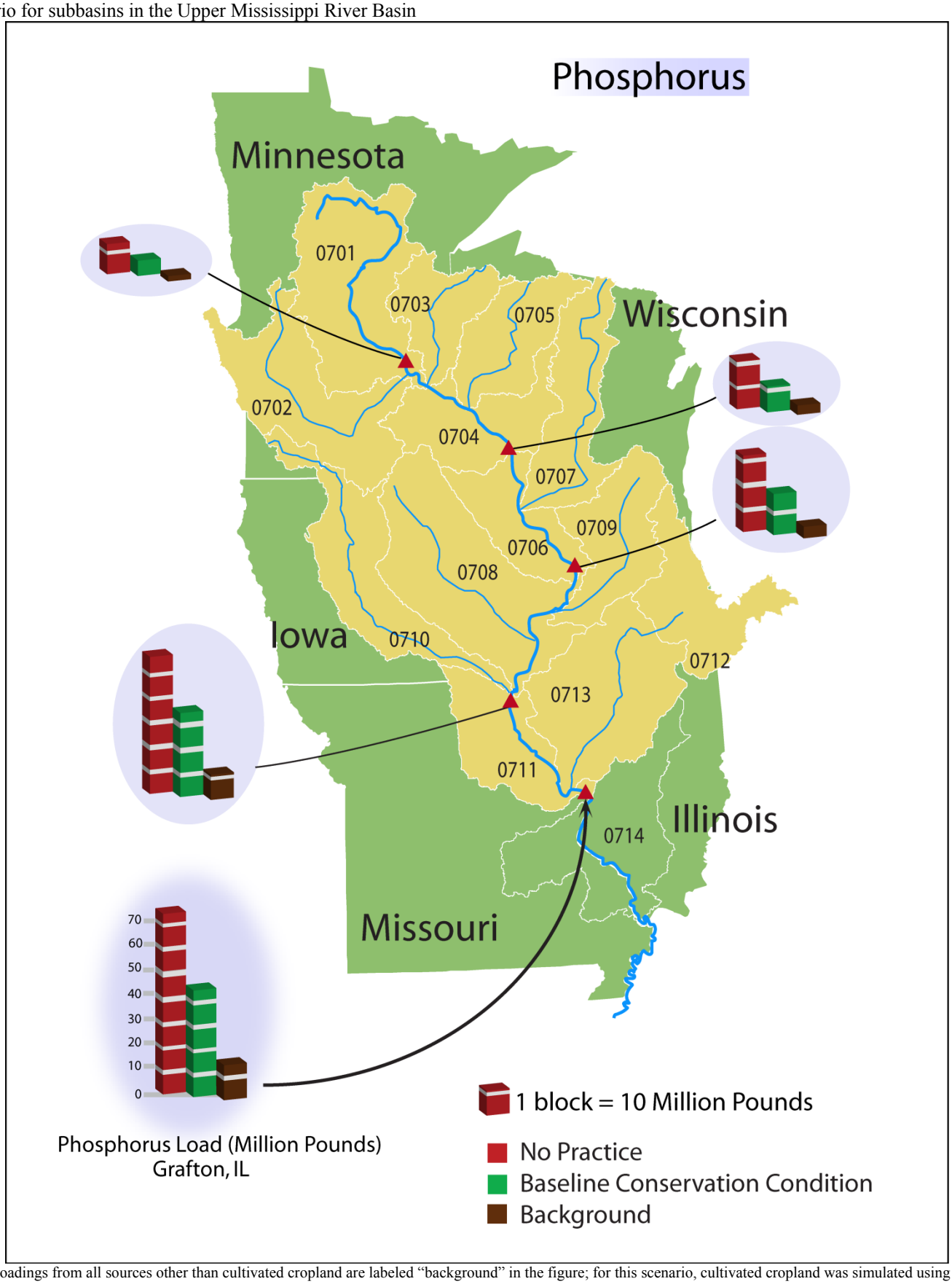
Note: Loadings from all sources other than cultivated cropland are labeled "background" in the figure; for this scenario, cultivated cropland was simulated using a continuous grass cover without any tillage or addition of nutrients or pesticides and no harvest.

Figure 52. Estimates of average annual instream nitrogen loads for the baseline conservation condition compared to the no-practice scenario for subbasins in the Upper Mississippi River Basin



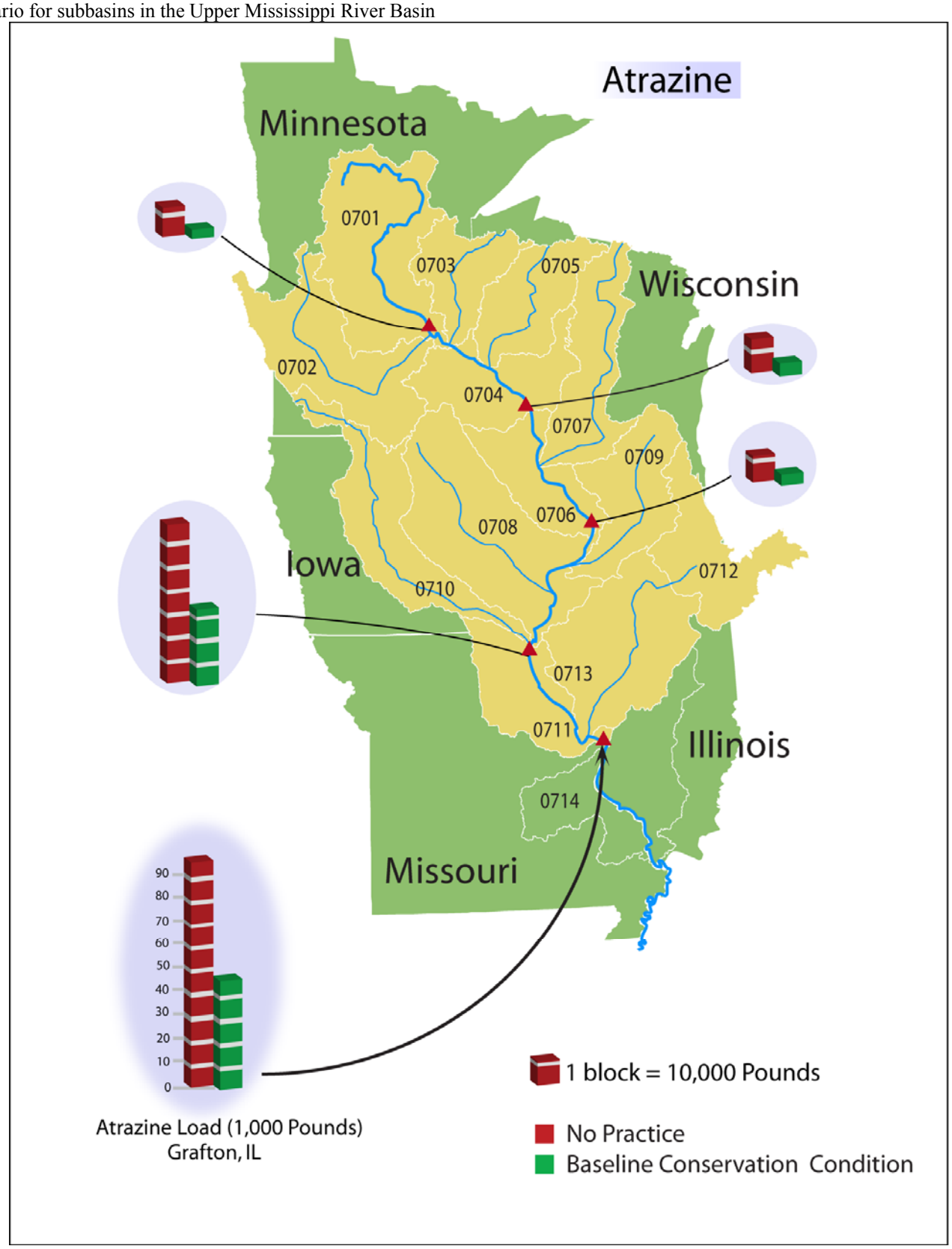
Note: Loadings from all sources other than cultivated cropland are labeled "background" in the figure; for this scenario, cultivated cropland was simulated using a continuous grass cover without any tillage or addition of nutrients or pesticides and no harvest.

Figure 53. Estimates of average annual instream phosphorus loads for the baseline conservation condition compared to the no-practice scenario for subbasins in the Upper Mississippi River Basin



Note: Loadings from all sources other than cultivated cropland are labeled "background" in the figure; for this scenario, cultivated cropland was simulated using a continuous grass cover without any tillage or addition of nutrients or pesticides and no harvest.

Figure 54. Estimates of average annual instream atrazine loads for the baseline conservation condition compared to the no-practice scenario for subbasins in the Upper Mississippi River Basin



Chapter 6
Assessment of Conservation Treatment Needs

The adequacy of the conservation practices in use in the UMRB was evaluated to identify remaining conservation treatment needs for controlling sediment and nutrient loss. Field-level results for the baseline conservation conditions were used to make the assessment. Adequate conservation treatment consists of combinations of conservation practices that treat the specific inherent vulnerability factors associated with each field. Four resource concerns were evaluated:

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

The assessment showed that the suite of practices in use in the UMRB was often inadequate to address all four resource concerns simultaneously.

The conservation treatment needs for controlling pesticide loss were not evaluated because it 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.

Conservation Treatment Levels

Four levels of conservation treatment (high, moderately high, moderate, and low) were defined as combinations of conservation practices for controlling (1) sediment loss due to water erosion, (2) nitrogen lost with surface runoff, and (3) phosphorus lost with surface runoff. Criteria for these management levels are presented in figures 55, 56, and 57, along with results on the extent to which these management levels are represented in the UMRB. The nitrogen management level presented in figure 11 was used to evaluate the adequacy of conservation treatment for nitrogen loss in subsurface flow.

A "high" level of treatment was shown by model simulations to reduce sediment and nutrient losses to acceptable levels for nearly all cropped acres in the UMRB. Key findings are:

- A high level of water erosion control treatment (combination of structural practices and residue and tillage management practices) is in use on about 40 percent of cropped acres (figure 55). However, only about 16 percent of the highly erodible acres have this level of treatment. About 35 percent of the highly erodible acres have a moderately high level of water erosion control treatment.
- A high level of treatment for nitrogen runoff (combination of structural practices, residue and tillage management practices, and nitrogen management practices) is in use on only 3 percent of the acres (figure 56). About 41 percent of the acres have combinations of practices that indicate a moderately high level of treatment.
- A high level of treatment for phosphorus runoff is in use on 10 percent of the acres (figure 57). About 37 percent of the acres have a moderately high level of treatment for controlling phosphorus loss with surface runoff.

Inherent Vulnerability Factors

Not all acres require the same level of conservation treatment because of differences in inherent vulnerabilities. Inherent vulnerability factors for surface runoff include soil properties that promote surface water runoff and erosion. Inherent vulnerability factors for loss of nutrients in subsurface flow include soil properties that promote infiltration.

Soil runoff and leaching potentials were estimated for each sample point on the basis of vulnerability criteria presented in figures 58 and 59. A single set of criteria were developed for all regions and soils in the US to allow for regional comparisons. The spatial distribution of the soil runoff and leaching potentials within the UMRB are presented in figures 60 and 61. The maps show the soil potentials for all soils and land uses in the region. For the assessment of conservation treatment needs, however, only the soil potentials for cropped acres were used.

The majority of cropped acres in the UMRB have a low or moderate soil runoff potential (figure 58). About 13 percent of the acres have a high soil runoff potential, consisting almost entirely of highly erodible land.

About 69 percent of the cropped acres have a moderate soil leaching potential (figure 59). About 5.1 percent have a high soil leaching potential and about 4.4 percent have a moderately high soil leaching potential in this region.

Estimates of sediment and nutrient losses for the no-practice scenario (without conservation practices) demonstrate how vulnerability factors influence losses in the UMRB:

- Sediment loss for the low soil runoff potential averaged 1.4 tons per acre per year, compared to 9.4 tons per acre per year for the high soil runoff potential.
- Nitrogen lost with surface runoff for the low soil runoff potential averaged 8 pounds per acre per year, compared to 40 pounds per acre per year for the high soil runoff potential.

- Nitrogen loss in subsurface flow for the low soil leaching potential averaged 12 pounds per acre per year, compared to 53 pounds per acre per year for the high soil leaching potential.
- Phosphorus lost with surface runoff for the low soil runoff potential averaged 3.0 pounds per acre per year, compared to 9.3 pounds per acre per year for the high soil runoff potential.

Evaluation of Conservation Treatment

Levels of conservation treatment in the baseline conservation condition were evaluated using both the level of conservation treatment and vulnerability factors, as shown in tables 30 through 33. Breaking down the acres into 16 groups (four soil potentials and four treatment levels) reveals 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. As this 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, which includes conservation practices in use in the UMRB, 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 evaluation of conservation treatment needs was conducted by identifying which of the 16 groups of acres were inadequately treated with respect to the soil runoff or soil leaching potential. To complete the evaluation, it was necessary to define thresholds for acceptable levels of sediment and nutrient loss from the field. Scientific literature on field research and edge-of-field monitoring in the Midwest provided guidance for identifying these thresholds. Model simulation of additional conservation practices (described in chapter 7) was also used to derive acceptable levels to ensure that the levels were possible to attain with traditional conservation and were agronomically feasible within the UMRB.

Acceptable levels for field-level losses used in this study to evaluate the adequacy of conservation treatment follow:

- Average of 2 tons per acre per year for sediment loss
- Average of 15 pounds per acre per year for nitrogen lost with surface runoff (soluble and sediment attached)
- Average of 25 pounds per acre per year for nitrogen loss in subsurface flow
- Average of 4 pounds per acre per year for phosphorus lost with surface runoff (soluble and sediment attached)

These acceptable levels represent field losses that are feasible to attain using traditional conservation treatment (nutrient management and soil erosion control). The percentage of acres in the UMRB that can attain these acceptable levels with additional soil erosion control and nutrient management practices as defined in chapter 7 are:

- 99 percent of acres for sediment loss
- 98 percent of acres for nitrogen lost with surface runoff
- 95 percent of acres for nitrogen loss in subsurface flow
- 96 percent of acres for phosphorus lost with surface runoff

Acceptable levels were not used directly to identify specific acres that need additional treatment. Rather, acceptable levels were used to identify groups of acres where the conservation treatment level was most likely inadequate *relative to the inherent vulnerability* of the acres in that group to export soil or nutrients from the field. Thus, the vulnerability and conservation treatment condition associated with acres that need additional treatment is explicitly identified, providing a convenient framework for implementation of targeting strategies.

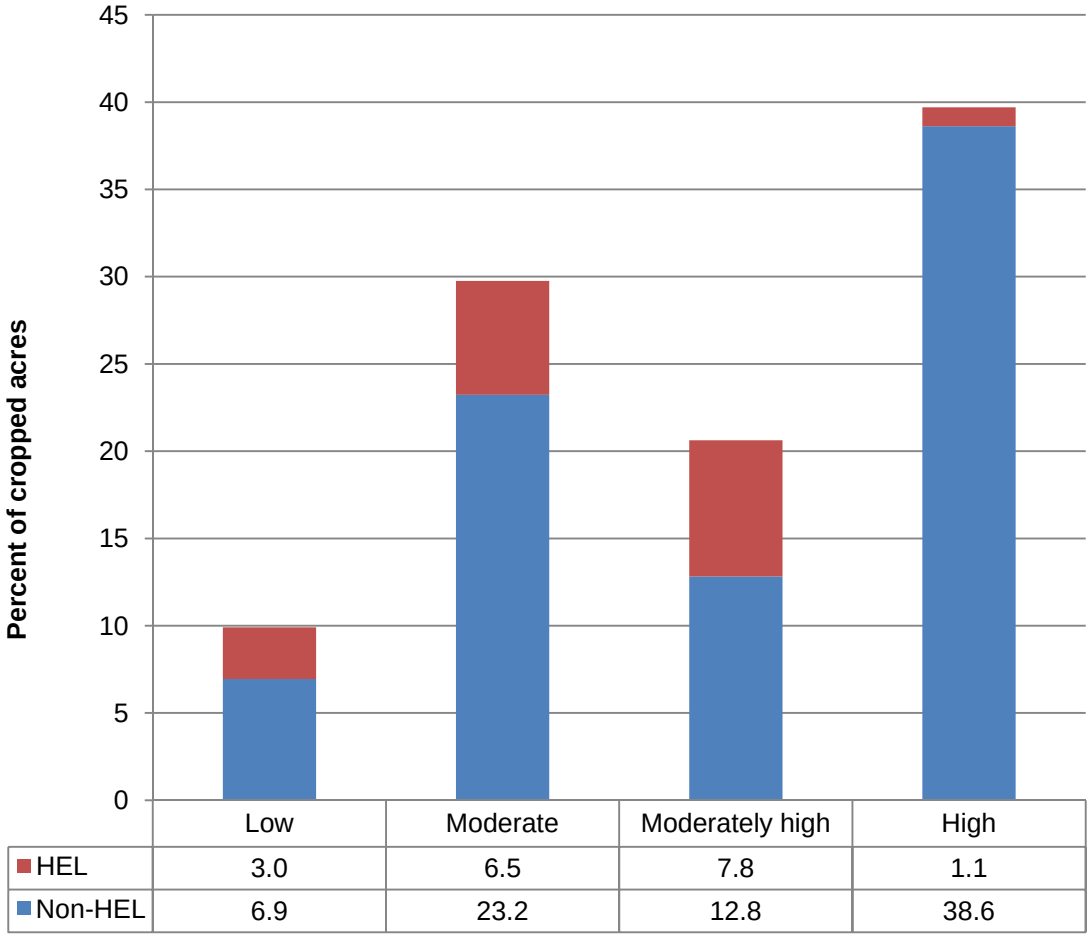
These acceptable levels are used in this study only as an indication of inadequate conservation treatment at the field level. They are not intended to provide adequate protection of water quality, although for some environments they may be suitable for this purpose.

Under-Treated Acres

Two groups of acres needing treatment were identified: 1) under-treated acres, and 2) critical under-treated acres, a subset of under-treated acres.

The percent of acres in each of the 16 groups that exceeded the acceptable levels was calculated, presented in tables 30 through 33, to serve as an indication of adequate treatment for each group of acres. Groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. These are acres where field-level losses are most likely not being controlled adequately with the existing level of treatment and where additional conservation treatment is needed. Critical under-treated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels. Critical under-treated acres represent the most vulnerable acres in the region, usually consisting of acres with a high or moderately high soil runoff or leaching potential.

Figure 55. Conservation treatment levels for water erosion control in the baseline conservation condition, UMRB

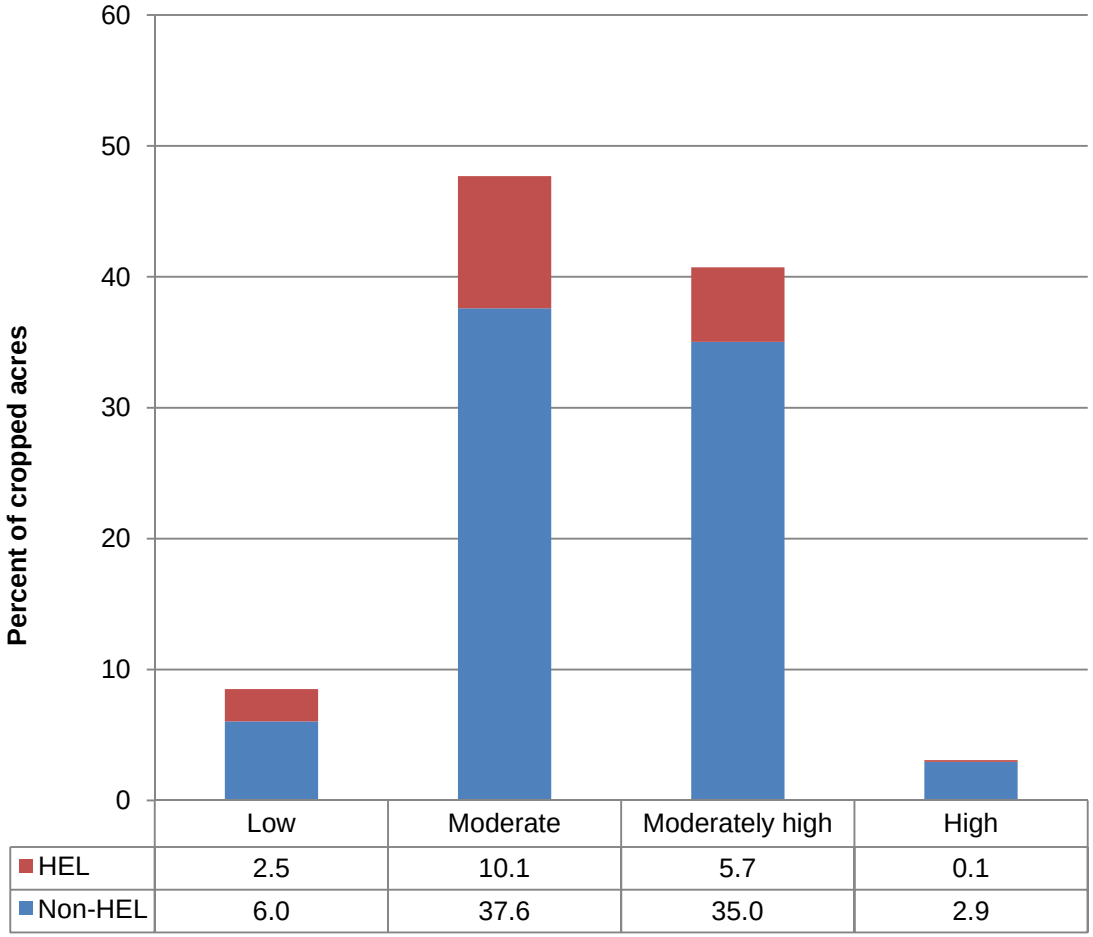


Criteria for water erosion control treatment levels were derived using a combination of structural practice treatment levels and residue and tillage management treatment levels (see figures 9 and 10). Scores were first assigned to these treatment levels as follows: High=4, Moderately high=3, Moderate=2, 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 UMRB is highly erodible land.

Figure 56. Conservation treatment levels for nitrogen runoff control in the baseline conservation condition, UMRB



Criteria were derived using a combination of structural practice treatment levels, residue and tillage management treatment levels, and nitrogen management treatment levels (see figures 9-11). 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:

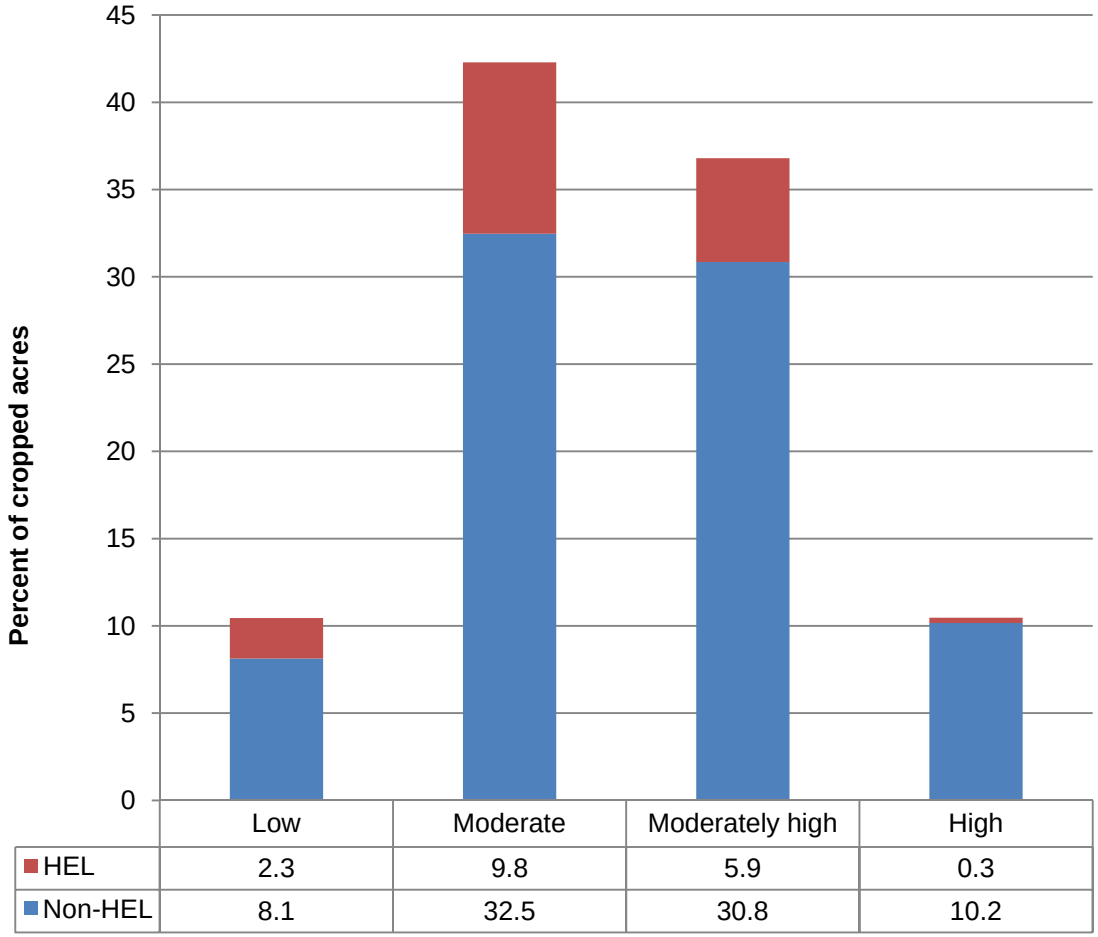
- **High treatment**: Sum of residue and tillage management score and nitrogen management score is equal to 8. (High treatment level for both structural practices and nitrogen management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores 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 UMRB is highly erodible land.

Figure 57. Conservation treatment levels for phosphorus runoff control in the baseline conservation condition, UMRB



Criteria were derived using a combination of structural practice treatment levels, residue and tillage management treatment levels, and phosphorus management treatment levels (see figures 9, 10, and 12) 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:

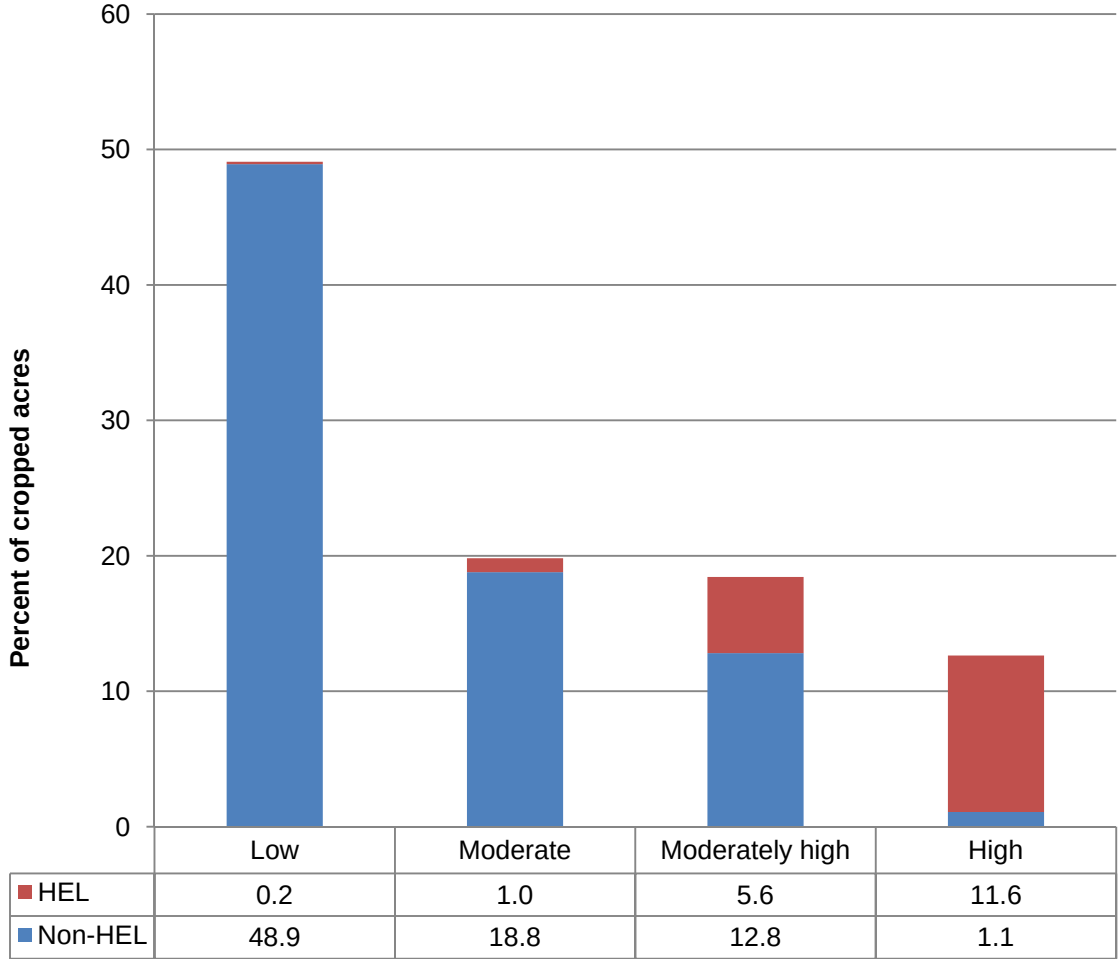
- **High treatment**: Sum of residue and tillage management score and phosphorus management score is equal to 8. (High treatment level for both structural practices and phosphorus management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores 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 UMRB is highly erodible land.

Figure 58. 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, slope, and K-factor, as shown in the table below:

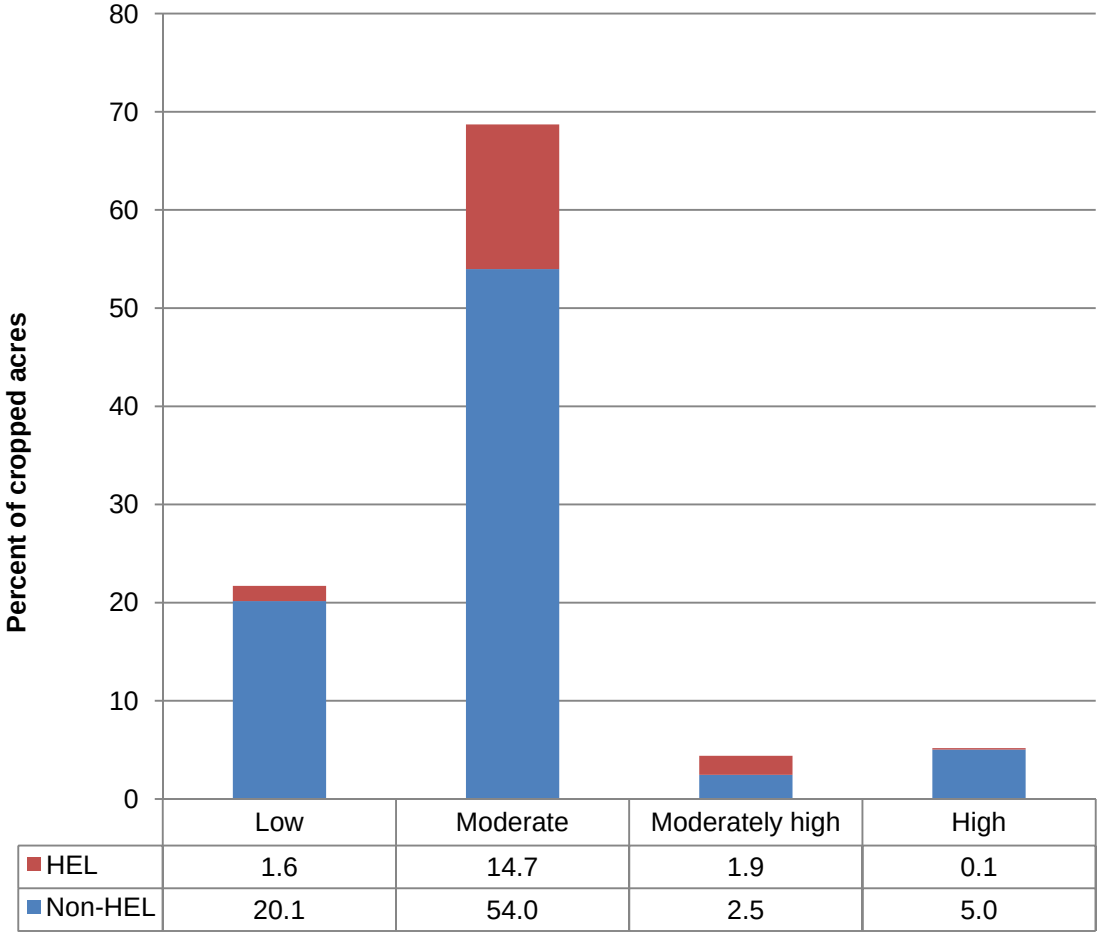
Soil runoff potential	Acres with soil hydrologic group A	Acres with soil hydrologic group B	Acres with soil hydrologic group C	Acres with soil hydrologic group D
Low	All acres	Slope<4	Slope<2	Slope<2 and K-factor<0.28
Moderate	None	Slope >=4 and <=6 and K-factor<0.32	Slope >=2 and <=6 and K-factor<0.28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

Figure 59. 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, 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

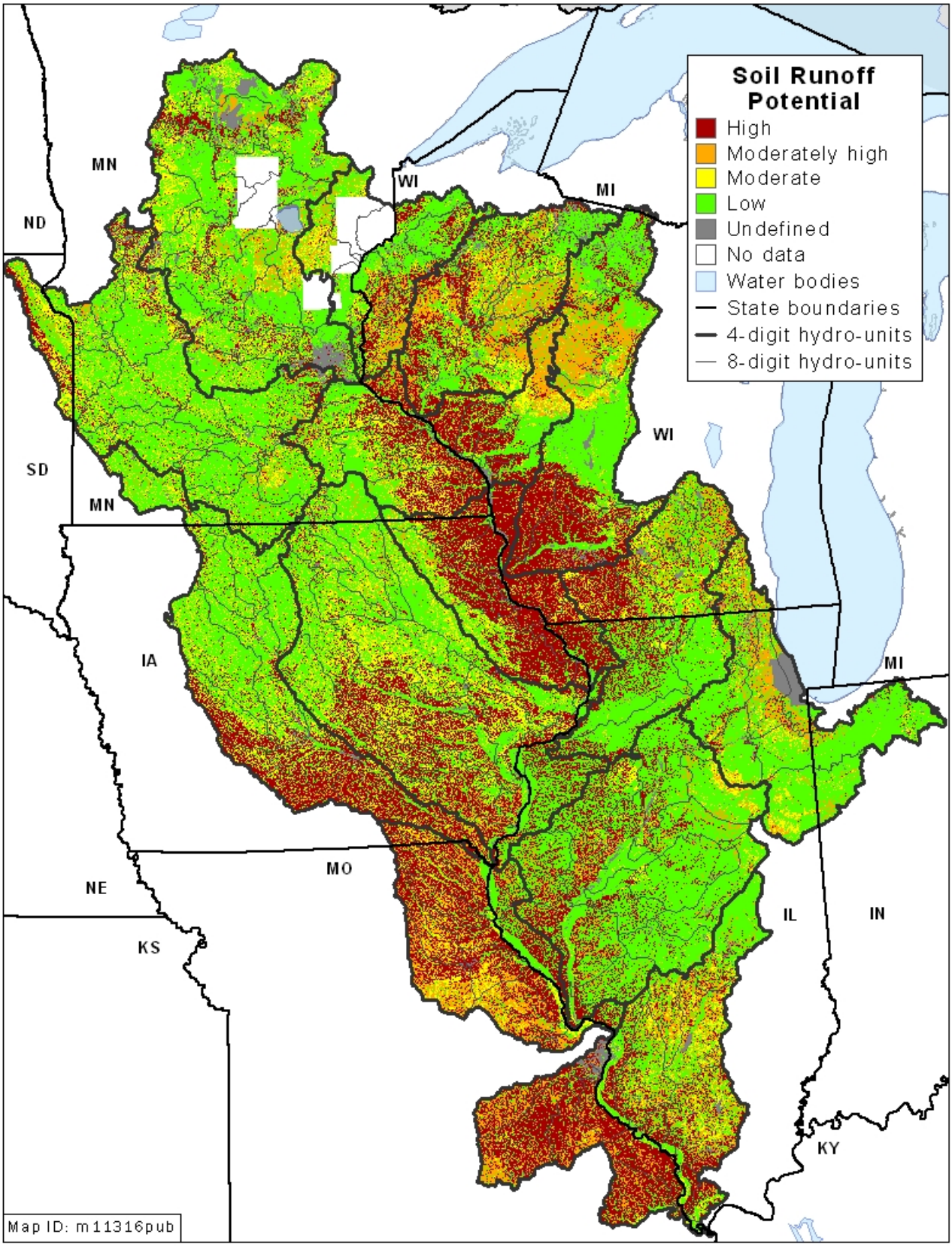
Coarse fragments (stones and rocks) in the soil make it easier for water to infiltrate rather than run off. If the coarse fragment content of the soil was greater than 30 percent, the soil leaching potential was increased two levels (moderate and moderately high to high, and low to moderately high).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

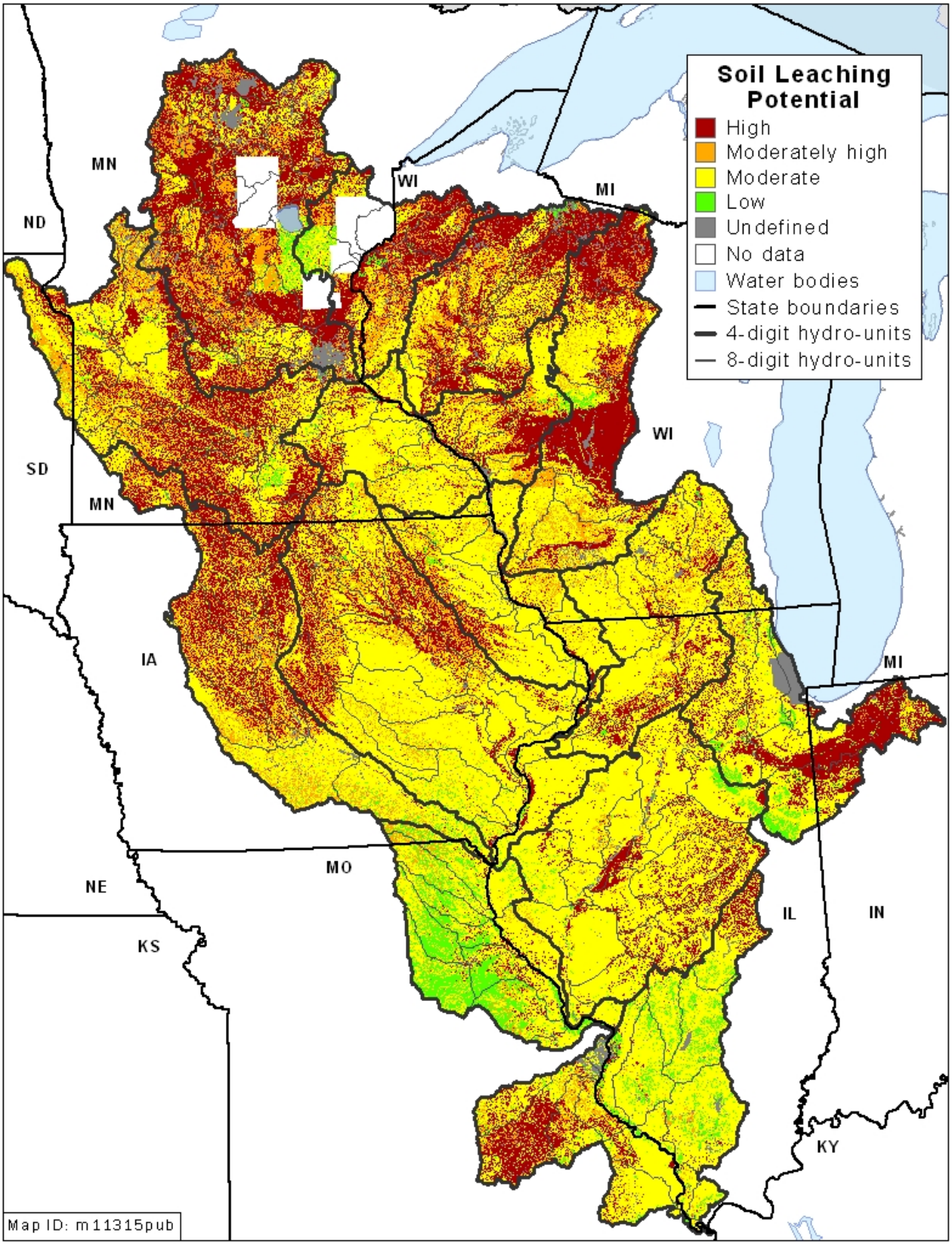
K-factor is a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall. It is determined by the composition of the soil, saturated hydraulic conductivity, and soil structure.

Figure 60. 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 58 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Figure 61. 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 59 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Table 30. Identification of under-treated 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	1,518,547	7,418,626	3,970,228	15,642,150	28,549,550
Moderate	1,429,309	3,376,872	1,967,566	4,750,294	11,524,041
Moderately high	1,541,295	3,599,634	3,278,597	2,307,349	10,726,875
High	1,274,773	2,910,609	2,780,463	387,189	7,353,035
All	5,763,924	17,305,741	11,996,854	23,086,981	58,153,500
Sediment loss estimates without conservation practices (no-practice scenario, average annual tons/acre/year)					
Low	0.8	1.0	2.2	1.4	1.4
Moderate	2.0	2.4	3.9	1.9	2.4
Moderately high	3.8	3.6	5.6	3.4	4.2
High	8.0	9.9	9.3	11.1	9.4
All	3.5	3.3	5.1	1.8	3.1
Sediment loss estimates for the baseline conservation condition (average annual tons/acre/year)					
Low	0.5	0.4	0.5	0.3	0.4
Moderate	1.5	1.0	0.8	0.5	0.8
Moderately high	2.8	1.4	1.0	0.9	1.4
High	5.1	3.7	1.8	0.2	3.0
All	2.4	1.3	1.0	0.4	1.0
Percent reduction in sediment loss due to conservation practices					
Low	33%	58%	80%	80%	74%
Moderate	25%	58%	81%	73%	66%
Moderately high	26%	60%	83%	73%	67%
High	36%	62%	81%	99%	68%
All	31%	60%	81%	79%	69%
Percent of acres in baseline conservation condition with average annual sediment loss more than 2 tons/acre					
Low	5%	2%	1%	0%	1%
Moderate	25%	9%	5%	1%	7%
Moderately high	54%	24%	13%	10%	22%
High	78%	70%	32%	0%	53%
All	39%	19%	12%	2%	12.7%
Estimate of under-treated acres					
Low	0	0	0	0	0
Moderate	0	0	0	0	0
Moderately high	1,541,295	0	0	0	1,541,295
High	1,274,773	2,910,609	2,780,463	0	6,965,845
All	2,816,068	2,910,609	2,780,463	0	8,507,140

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 under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated 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.
Note: Percents may not add to totals because of rounding.

Table 31. Identification of under-treated acres for nitrogen lost 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	1,505,201	12,500,814	13,411,249	1,132,287	28,549,550
Moderate	1,078,669	5,643,944	4,386,837	414,590	11,524,041
Moderately high	1,236,369	5,383,313	3,926,749	180,444	10,726,875
High	1,122,827	4,210,298	1,959,096	60,814	7,353,035
All	4,943,065	27,738,368	23,683,930	1,788,136	58,153,500
Estimates of nitrogen lost with surface runoff without conservation practices (no-practice scenario, average annual pounds/acre/year)					
Low	9	8	8	6	8
Moderate	17	15	14	8	15
Moderately high	26	22	22	18	22
High	48	39	36	42	40
All	24	17	13	9	16
Estimates of nitrogen lost with surface runoff for the baseline conservation condition (average annual pounds/acre/year)					
Low	6	5	3	3	4
Moderate	11	9	6	4	8
Moderately high	20	13	9	7	12
High	37	23	12	6	22
All	18	10	6	3	9
Percent reduction in nitrogen lost with surface runoff due to conservation practices					
Low	39%	44%	55%	56%	49%
Moderate	35%	40%	54%	55%	45%
Moderately high	23%	42%	59%	61%	46%
High	22%	41%	66%	86%	44%
All	27%	42%	58%	61%	46%
Percent of acres in baseline conservation condition with average annual nitrogen lost with surface runoff more than 15 pounds/acre					
Low	5%	2%	0%	0%	1%
Moderate	17%	12%	4%	0%	9%
Moderately high	53%	31%	13%	0%	27%
High	85%	63%	33%	0%	58%
All	38%	19%	6%	0%	14.6%
Estimate of under-treated acres for nitrogen lost with surface runoff					
Low	0	0	0	0	0
Moderate	0	0	0	0	0
Moderately high	1,236,369	5,383,313	0	0	6,619,682
High	1,122,827	4,210,298	1,959,096	0	7,292,220
All	2,359,196	9,593,610	1,959,096	0	13,911,902

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 under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated 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.
Note: Percents may not add to totals because of rounding.

Table 32. Identification of under-treated acres for nitrogen loss in subsurface flow 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	2,397,634	5,032,756	3,838,671	1,354,476	12,623,538
Moderate	8,915,433	17,638,789	10,065,116	3,340,532	39,959,870
Moderately high	593,742	957,979	724,363	278,295	2,554,380
High	257,256	1,380,144	915,952	462,360	3,015,713
All	12,164,066	25,009,669	15,544,103	5,435,663	58,153,500
Estimates of nitrogen loss in subsurface flow without conservation practices (no-practice scenario, average annual pounds/acre/year)					
Low	19	11	10	9	12
Moderate	32	24	17	12	23
Moderately high	61	39	26	12	38
High	83	58	41	47	53
All	32	24	17	14	23
Estimates of nitrogen loss in subsurface flow for the baseline conservation condition (average annual pounds/acre/year)					
Low	22	14	7	7	13
Moderate	33	26	11	8	23
Moderately high	52	34	15	9	30
High	79	56	25	25	44
All	33	26	11	9	22
Percent reduction in nitrogen loss in subsurface flow due to conservation practices					
Low	-19%	-28%	31%	27%	-6%
Moderate	-4%	-8%	33%	33%	2%
Moderately high	14%	14%	41%	28%	20%
High	4%	2%	40%	48%	17%
All	-3%	-7%	34%	36%	5%
Percent of acres in baseline conservation condition with average annual nitrogen loss in subsurface flow more than 25 pounds/acre					
Low	21%	13%	2%	0%	10%
Moderate	42%	39%	4%	1%	28%
Moderately high	57%	52%	11%	0%	36%
High	98%	89%	24%	9%	58%
All	40%	37%	5%	1%	26%
Estimate of under-treated acres for nitrogen loss in subsurface flow					
Low	0	0	0	0	0
Moderate	8,915,433	17,638,789	0	0	26,554,222
Moderately high	593,742	957,979	0	0	1,551,721
High	257,256	1,380,144	0	0	1,637,400
All	9,766,431	19,976,913	0	0	29,743,344

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 under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated 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.
Note: Percents may not add to totals because of rounding.

Table 33. Identification of under-treated acres for phosphorus lost with surface runoff (sediment attached and soluble) 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	2,231,503	10,901,871	10,918,831	4,497,345	28,549,550
Moderate	1,356,846	4,708,559	4,431,296	1,027,340	11,524,041
Moderately high	1,430,747	4,880,731	3,975,252	440,145	10,726,875
High	1,058,478	4,101,378	2,073,750	119,429	7,353,035
All	6,077,574	24,592,538	21,399,130	6,084,259	58,153,500
Phosphorus lost with surface runoff without conservation practices (no-practice scenario, average annual pounds/acre/year)					
Low	5.3	3.1	2.7	2.4	3.0
Moderate	5.9	4.9	4.9	4.2	4.9
Moderately high	12.6	6.5	5.8	6.0	7.1
High	13.8	9.1	7.4	10.6	9.3
All	8.6	5.1	4.2	3.1	4.9
Phosphorus lost with surface runoff for the baseline conservation condition (average annual pounds/acre/year)					
Low	3.8	2.0	1.0	0.6	1.5
Moderate	4.3	3.1	1.7	1.2	2.5
Moderately high	9.6	3.9	1.9	1.6	3.8
High	10.1	4.8	2.0	1.0	4.7
All	6.4	3.0	1.4	0.8	2.5
Percent reduction in phosphorus lost with surface runoff due to conservation practices					
Low	29%	35%	65%	74%	49%
Moderate	28%	37%	65%	72%	49%
Moderately high	23%	41%	68%	72%	46%
High	27%	47%	72%	90%	49%
All	26%	40%	67%	75%	48%
Percent of acres in baseline conservation condition with average annual phosphorus lost with surface runoff more than 4 pounds/acre					
Low	23%	12%	1%	0%	7%
Moderate	42%	21%	3%	2%	15%
Moderately high	79%	24%	6%	5%	24%
High	84%	43%	9%	0%	39%
All	51%	21%	3%	1%	16%
Estimate of under-treated acres for phosphorus lost with surface runoff					
Low	0	0	0	0	0
Moderate	1,356,846	0	0	0	1,356,846
Moderately high	1,430,747	0	0	0	1,430,747
High	1,058,478	4,101,378	0	0	5,159,856
All	3,846,071	4,101,378	0	0	7,947,449

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 under-treated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as under-treated acres. Darker color-shaded cells indicate critical under-treated acres; critical under-treated 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.
Note: Percents may not add to totals because of rounding.

Table 34. Resource concerns needing treatment in the Upper Mississippi River Basin

Reasons for treatment need		Estimated acres needing treatment	Percent of total
All under-treated acres (62 percent of cropped acres)			
Nitrogen leaching only		20,680,259	58
Sediment, nitrogen and phosphorus runoff, and nitrogen leaching		3,802,270	11
Nitrogen runoff and nitrogen leaching		3,102,268	9
Sediment, nitrogen runoff and phosphorus runoff		2,198,556	6
Nitrogen runoff only		1,716,701	5
Other combinations, each including either nitrogen or phosphorus		4,452,936	12
	Total	35,952,991	100
Critical under-treated acres (15 percent of cropped acres)			
Sediment, nitrogen and phosphorus runoff, and nitrogen leaching		3,645,703	43
Sediment, nitrogen runoff, and phosphorus runoff		1,828,798	22
Nitrogen leaching only		1,630,738	19
Nitrogen runoff and nitrogen leaching		563,565	7
Nitrogen runoff, phosphorus runoff, and nitrogen leaching		310,871	4
Other combinations		478,108	6
	Total	8,457,783	100

Note: This table summarizes the under-treated acres identified in tables 30-33 and reports the joint set of acres that need treatment according to each resource concern.
Note: Percents may not add to totals because of rounding.

High levels of treatment were shown by model simulations to provide good protection on the most vulnerable acres. Less vulnerable acres were often adequately treated with a low, moderate, or moderately high level of conservation treatment.

Many of the more vulnerable acres with less conservation treatment, however, require additional conservation practices:

- 8.5 million acres (15 percent of cropped acres) require additional treatment for sediment loss due to water erosion (table 30).
- 13.9 million acres (24 percent of cropped acres) require additional treatment for nitrogen lost with surface runoff (table 31).
- 29.7 million acres (51 percent of cropped acres) require additional treatment for nitrogen loss in subsurface flow (table 32).
- 7.9 million acres (14 percent of cropped acres) require additional treatment for phosphorus lost with surface runoff (table 33).

About 63 percent of the under-treated acres need additional treatment for only one of the four resource concerns, usually nitrogen leaching (table 34). For critical under-treated acres, 79 percent need additional treatment for *multiple* resource concerns.

After accounting for acres that need treatment for multiple resource concerns, the evaluation of treatment needs for the UMRB determined the following (table 34):

- 36 million acres (62 percent of cropped acres) are under-treated for one or more of the four resource concerns that were evaluated:
  - all require additional treatment for either nitrogen or phosphorus,
  - 58 percent require additional treatment only for nitrogen loss in subsurface flow,
  - 9 percent require additional treatment for nitrogen runoff and leaching, and
  - 17 percent require additional treatment for sediment loss, nitrogen runoff, *and* phosphorus runoff.
- 8.5 million of these acres (15 percent of cropped acres) are critical under-treated acres, consisting of the most vulnerable acres in the region:
  - 43 percent require additional treatment for all four resource concerns,
  - 22 percent require additional treatment for sediment loss, nitrogen lost with surface runoff, *and* phosphorus lost with surface runoff, and
  - 19 percent require additional treatment only for nitrogen loss in subsurface flow.

The distribution of under-treated acres among the 14 subbasins within the UMRB is presented in table 35. Percentages of the under-treated acres in the UMRB that are in each subbasin are close to the same percentages of the region's cultivated cropland in each subbasin, indicating that under-treated acres are spread proportionately throughout the region. Critical under-treated acres, however, are often disproportionately distributed, with higher concentrations in some regions than others relative to the percentage of cropped acres.

The breakdown of under-treated acres by cropping system also showed a proportionate distribution of under-treated acres among cropping systems, shown in table 36. For the critical under-treated acres, however, a disproportionately higher percentage occurs for two cropping systems—hay crop mixes and continuous corn—indicating that these two cropping systems tend to occur more frequently on the more vulnerable acres in the region.

Losses for under-treated acres are much higher, on average, than losses for adequately treated acres, as shown in table 37. For example, sediment loss in the baseline conservation condition averages 2.8 tons per acre per year for critical under-treated acres, compared to 0.8 ton per acre per year for non-critical under-treated acres and only 0.5 ton per acre for the remaining acres. Total nitrogen loss averages 65 pounds per acre for the critical under-treated acres and 45 pounds per acre for the non-critical under-treated acres, compared to only 28 pounds per acre for the remaining acres.

Table 35. Under-treated acres for the 14 subbasins in the Upper Mississippi River Basin

Sub-basin code	Subbasin name	Percent of cropped acres in UMRB	Critical under-treated acres: Acres	Critical under-treated acres: Percent of acres in UMRB	Critical under-treated acres: Percent of cultivated cropland acres in subbasin	All under-treated acres: Acres	All under-treated acres: Percent of acres in UMRB	All under-treated acres: Percent of cultivated cropland acres in subbasin
0701	Mississippi Headwaters	5	734,021	9	27	1,606,435	4	60
0702	Minnesota River Basin	13	647,144	8	9	4,299,339	12	59
0703	St. Croix River Basin	1	149,890	2	30	278,811	1	55
0704	Upper Mississippi-Black-Root	5	770,960	9	29	1,996,869	6	74
0705	Chippewa River Basin	2	385,691	5	44	701,957	2	80
0706	Upper Mississippi-Maquoketa-Plum	4	585,939	7	23	2,068,665	6	79
0707	Wisconsin River Basin	2	480,501	6	35	803,021	2	59
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	18	1,448,436	17	14	6,498,400	18	63
0709	Rock River Basin	7	706,938	8	17	2,940,668	8	70
0710	Des Moines River Basin	11	367,660	4	6	3,029,770	8	48
0711	Upper Mississippi-Salt	5	619,743	7	22	1,672,290	5	60
0712	Upper Illinois River Basin	7	696,545	8	17	2,326,329	6	58
0713	Lower Illinois River Basin	14	551,060	7	7	5,493,048	15	66
0714	Upper Mississippi-Kaskaskia-Meramec	7	313,254	4	8	2,237,389	6	55
	Total	100	8,457,782	100	15	35,952,991	100	62

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

Table 36. Under-treated acres by cropping system in the Upper Mississippi River Basin

Subbasin name	Percent of cropped acres in UMRB	Critical under-treated acres: Acres	Critical under-treated acres: Percent of acres in UMRB	Critical under-treated acres: Percent of cultivated cropland acres in cropping system	All under-treated acres: Acres	All under-treated acres: Percent of acres in UMRB	All under-treated acres: Percent of cultivated cropland acres in cropping system
Corn and soybean only	74	4,813,110	57	11	26,019,824	72	61
Corn only	9	1,172,666	14	23	3,584,729	10	71
Hay-crop mix	6	1,244,373	15	34	2,654,540	7	73
Corn and soybean with close grown crops	4	289,622	3	14	1,497,667	4	70
Soybean only	3	158,351	2	11	348,400	1	23
Soybean and wheat only	1	164,093	2	21	408,079	1	52
Corn and close grown crops	1	311,407	4	41	623,610	2	83
Remaining mix of crops	2	304,161	4	23	816,143	2	63
Total	100	8,457,782	100	15	35,952,991	100	62

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

Table 37. Baseline conservation condition model simulation results for subsets of under-treated and adequately treated acres in the Upper Mississippi River Basin

Model simulated outcome	Critical under-treated acres	Non-critical under-treated acres	Adequately treated acres	All acres
Cultivated cropland acres in subset	8,457,782	27,495,208	22,200,509	58,153,500
Percent of acres	15%	47%	38%	100%
Water flow				
Average annual surface runoff (inches)	3.8	3.5	4.7	4.0
Average annual subsurface water flow (inches)	7.7	7.0	5.9	6.7
Erosion and sediment loss				
Average annual wind erosion (tons/acre)	0.3	0.2	0.2	0.2
Average annual sheet and rill erosion (tons/acre)	2.4	1.0	0.6	1.0
Average annual sediment loss at edge of field due to water erosion (tons/acre)	2.8	0.8	0.5	1.0
Soil organic carbon				
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-53	109	68	70
Nitrogen loss				
Nitrogen applied (pounds/acre)	107	98	68	88
Nitrogen in crop yield removed at harvest (pounds/acre)	105	107	109	108
Total nitrogen loss for all pathways except harvest (pounds/acre)	65	45	28	41
Average annual loss of nitrogen through volatilization (pounds/acre)	7	7	6	7
Average annual nitrogen returned to the atmosphere through denitrification processes (pounds/acre)	3	2	2	2
Average annual loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	20	7	6	9
Average annual nitrogen loss in subsurface flow (pounds/acre)	32	27	12	22
Phosphorus loss				
Phosphorus applied (pounds/acre)	26.9	23.2	19.5	22.3
Total phosphorus loss for all pathways except harvest (pounds/acre)	5.9	2.7	2.2	3.0
Loss of phosphorus with surface runoff, including waterborne sediment (pounds/acre)	5.4	2.3	1.8	2.5
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	12.7	7.2	8.2	8.4
Average annual surface water pesticide risk indicator for aquatic ecosystem	2.4	2.6	2.7	2.6
Average annual surface water pesticide risk indicator for humans	0.5	0.3	0.5	0.4

Note: The values reported in this table for the three subsets of acres are influenced by differences in precipitation, slope, and inherent soil vulnerability in addition to the differences in conservation treatment.

Chapter 7
Assessment of Potential Gains from Further Conservation Treatment

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

- Treatment of the 8.5 million critical under-treated acres with water erosion control practices.
- Treatment of all 36 million under-treated acres with water erosion control practices.
- Treatment of the 8.5 million critical under-treated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses.
- Treatment of all 36 million under-treated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses.

The simulated levels of conservation treatment were designed to add the additional practices needed to complete the existing suite of practices so as to reduce sediment and nutrient losses at the edge of the field to acceptable levels. 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.

The simulated additional treatment consists of traditional conservation practices and treatment options that have been implemented over the past 10 years and would be expected to be found in current NRCS conservation plans. The simulated treatment levels are intended to maintain the production capacity within the region to produce crops for food, fiber, forage, and fuel.

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.

The level of conservation treatment is simulated to show potential environmental benefits, but is not designed to achieve specific environmental protection goals. Treatment scenarios were also not designed to represent actual program or policy options for the UMRB. Economic and programmatic aspects--such as producer costs, conservation program costs, and capacity to deliver the required technical assistance--were not considered in the design of the treatment scenarios.

Conservation crop rotations were not included in the treatment scenarios because of the criteria to maintain crop acres and preserve current market value and yield. Nevertheless, crop rotations that are conducted specifically for the purpose of reducing average annual losses of sediment and nutrients from farm fields have a high potential to further improve crop nutrient efficiency and reduce contaminant loadings.

For the same reason, long-term conserving cover was also 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. 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 watershed goals for environmental protection.

Pesticide management was also not addressed in the treatment scenarios. While erosion control practices influence pesticide loss, significant reductions in pesticide 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 very site specific and requires more information about the sample fields than was available from the farmer survey.

Simulation of Additional Water Erosion Control Practices

Erosion and surface water runoff treatment consists of structural and vegetative practices that slow runoff water and capture contaminants that it may carry. Practices were added where needed (summarized in table 38) 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 was added to all other fields 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.

Cover crops were not added since it was unrealistic to expect farmers to adopt cover crops on all fields in the UMRB. Less than 1 percent of the acres meet criteria for use of a cover crop in this region. Similarly, tillage management was not altered in the simulation of conservation treatment because of the widespread use of residue and tillage management in the region.

Simulation of Additional Nutrient Management Practices

The nutrient management treatment scenario consists of additional nutrient management practices where needed *in addition to* the water 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 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 7 percent of the acres (see table 9).

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 UMRB. 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.

About 28 million acres (48%) in the UMRB 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.

Table 38. Summary of additional structural practices simulated for under-treated acres to assess the potential for gains from additional conservation treatment in the Upper Mississippi River Basin

	Critical under-treated acres		Non-critical under-treated acres		All under-treated acres	
Additional practice	Treated acres	Percent of total	Treated acres	Percent of total	Treated acres	Percent of total
Overland flow practice only	0	0	263,860	1	263,860	1
Terrace only	320,703	2	91,738	<1	412,441	1
Filter only	2,254,496	15	8,289,750	40	10,544,246	29
Filter plus overland flow practice	3,362,564	22	5,208,368	25	8,570,931	24
Filter plus Terrace	4,917,831	32	805,735	4	5,723,566	16
Buffer only	1,135,468	7	3,131,436	15	4,266,904	12
Buffer plus overland flow practice	1,232,209	8	1,787,747	9	3,019,956	8
Buffer plus Terrace	1,776,389	12	427,643	2	2,204,032	6
One or more additional practices	14,999,660	99	20,006,276	96	35,005,936	97
No structural practices	173,992	1	827,301	4	1,001,293	3
Total	15,173,653	100	20,833,577	100	36,007,229	100

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

Specific rules for method of application

If the method of application was other than incorporation then fertilizer and manure applications became incorporated. Incorporation reduces the opportunity for nutrients on the soil surface to be carried away in the soluble form or attached to eroding particles. For manure applications on no-till fields, if the manure had been 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. In some cases, incorporation of manure also required a change in the manure form to preserve the beneficial effects of tillage and residue management.

Specific rules for the rate of nutrient applied

All nitrogen application rates for all crops were reduced to 1.2 times the crop removal rate. The 1.2 ratio is in the range of rates recommended by many of the Land Grant Universities. This rate replaces some of the environmental losses that occur during the cropping season, and also accounts for the savings in nutrients due to implementation of water erosion control practices.

For phosphorus, the application rates were adjusted to be equal to 1.1 times the amount of phosphorus removed in the crop at harvest over the crop rotation.

Potential for Field-Level Gains

Treatment of the 8.5 million critical under-treated acres

According to the model simulation, treatment of the 8.5 million most vulnerable under-treated acres with water erosion control practices would nearly eliminate sediment loss for these acres and dramatically reduce nitrogen and phosphorus lost with surface runoff, as shown in table 39.

Sediment loss would be reduced to an annual average of about 0.1 ton per acre per year for these acres, a 95-percent reduction. Nitrogen lost with surface runoff would be reduced to 3 pounds per acre per year on average (84-percent reduction), and phosphorus lost with surface runoff would be reduced to 1.8 pounds per acre per year (67-percent reduction). However, the re-routing of surface water to subsurface flow would reduce nitrogen loss in subsurface flow by only 1 percent, on average, for these acres.

The addition of nutrient management had little additional effect on sediment loss or nitrogen lost with surface runoff, but was effective in reducing nitrogen loss in subsurface flows and phosphorus lost with surface runoff (table 39). Nitrogen loss in subsurface flow for these acres would be reduced 57 percent compared to losses simulated for the baseline conservation condition. Phosphorus lost with surface runoff would be reduced to an average loss of about 1 pound per acre, representing an 82 percent reduction compared to the baseline condition for these acres.

These results support the conclusion drawn from the assessment of the effects of conservation practices that nutrient management practices need to be paired with erosion control practices to obtain net reductions in the loss of soluble nutrients.

Table 40 presents estimates of how treatment of just the 8.5 million most vulnerable 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 8.5 million acres with model results from the baseline conservation condition for the remaining acres. Treating the 8.5 million critical under-treated acres with soil erosion control practices *and* nutrient management practices would, for the region as a whole—

- reduce sediment loss in the region by 40 percent on average, compared to the baseline conservation condition;
- reduce total nitrogen loss by 14 percent:
  - reduce nitrogen lost with surface runoff (sediment adsorbed and soluble) by 29 percent, and
  - reduce nitrogen loss in subsurface flow by 12 percent;
- reduce phosphorus lost with surface runoff (sediment adsorbed and soluble) by 25 percent, and
- reduce environmental risk from loss of pesticide residues by about 4 to 5 percent.

Table 39. Conservation practice effects for additional treatment of 8.5 million critical under-treated acres 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)	3.8	3.1	20%	3.1	20%
Subsurface water flow (inches)	7.7	8.1	-5%	8.2	-6%
Erosion and sediment loss					
Wind erosion (tons/acre)	0.3	0.3	10%	0.3	13%
Sheet and rill erosion (tons/acre)	2.4	0.5	79%	0.5	80%
Sediment loss at edge of field due to water erosion (tons/acre)	2.8	0.1	95%	0.1	95%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-53	71	--	62	--
Nitrogen					
Nitrogen applied (pounds/acre)	106.7	102.0	4%*	69.7	35%
Nitrogen in crop yield removed at harvest (pounds/acre)	105.0	102.6	2%*	98.1	7%
Total nitrogen loss for all pathways except harvest (pounds/acre)	64.6	47.2	27%	25.7	60%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	20.0	3.2	84%	2.7	86%
Nitrogen loss in subsurface flow (pounds/acre)	31.8	31.5	1%	13.6	57%
Phosphorus					
Phosphorus applied (pounds/acre)	26.9	26.1	3%	19.3	28%
Total phosphorus loss for all pathways except harvest (pounds/acre)	5.9	2.3	61%	1.4	77%
Loss of phosphorus with surface runoff, including waterborne sediment (pounds/acre)	5.4	1.8	67%	1.0	82%
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	12.7	5.7	55%	5.7	55%
Surface water pesticide risk indicator for aquatic ecosystem	2.4	1.7	28%	1.7	28%
Surface water pesticide risk indicator for humans	0.5	0.3	29%	0.3	30%

* Total nitrogen applied was 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 8.5 million critical under-treated 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 40. Conservation practice effects for the region as a whole* after additional treatment of 8.5 million critical under-treated acres 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)	4.0	3.9	3%	3.9	3%
Subsurface water flow (inches)	6.7	6.7	-1%	6.7	-1%
Erosion and sediment loss					
Wind erosion (tons/acre)	0.2	0.2	2%	0.2	2%
Sheet and rill erosion (tons/acre)	1.0	0.8	26%	0.8	26%
Sediment loss at edge of field due to water erosion (tons/acre)	1.0	0.6	40%	0.6	40%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	70	88	--	87	--
Nitrogen					
Nitrogen applied (pounds/acre)	87.8	87.2	1%	82.5	6%
Nitrogen in crop yield removed at harvest (pounds/acre)	107.6	107.2	0%	106.6	1%
Total nitrogen loss for all pathways except harvest (pounds/acre)	41.3	38.8	6%	35.7	14%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	8.6	6.1	29%	6.1	29%
Nitrogen loss in subsurface flow (pounds/acre)	21.8	21.8	0%	19.2	12%
Phosphorus					
Phosphorus applied (pounds/acre)	22.3	22.2	1%	21.2	5%
Total phosphorus loss for all pathways except harvest (pounds/acre)	3.0	2.4	18%	2.3	22%
Loss of phosphorus with surface runoff, including waterborne sediment (pounds/acre)	2.5	2.0	21%	1.9	25%
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	8.4	7.4	12%	7.4	12%
Surface water pesticide risk indicator for aquatic ecosystem	2.6	2.5	4%	2.5	4%
Surface water pesticide risk indicator for humans	0.4	0.4	5%	0.4	5%

* Results presented for the region as a whole combine model output for the 8.5 million treated acres with model results from the baseline conservation condition for the remaining acres.
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.

Treatment of all 36 million under-treated acres. Simulation of additional conservation treatment of all 36 million under-treated acres showed that, while per-acre sediment and nutrient loss reductions due to practices would be less on average than per-acre reductions for the 8.5 million most vulnerable under-treated acres, the percent reductions for the region as a whole at this level of treatment would be much higher.

Simulation results for only the 36 million under-treated acres are presented in table 41, and results for the region as a whole are presented in table 42. Treating all 36 million under-treated acres with soil erosion control practices *and* nutrient management practices would, for the region as a whole (table 42)—

- reduce sediment loss in the region by 74 percent on average, compared to the baseline conservation condition;
- reduce total nitrogen loss by 43 percent:
  - reduce nitrogen lost with surface runoff (sediment attached and soluble) by 61 percent, and
  - reduce nitrogen loss in subsurface flow by 48 percent;
- reduce phosphorus lost with surface water runoff by 57 percent;
- reduce environmental risk from loss of pesticide residues by 2 to 15 percent.

Comparison of treatment scenario results

The distributions of sediment and nutrient losses for the two levels of treatment are compared to the baseline conservation condition in the UMRB in figures 62-66. 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 preferentially treating the under-treated acres. For example, 12 percent of the acres in the UMRB exceed an annual average loss of sediment of 2 tons per acre per year in the baseline conservation condition. Model simulations suggest that treating the most vulnerable of the under-treated acres (8.5 million acres) with water erosion control practices would reduce the acres exceeding sediment loss of 2 tons per acre per year to 5 percent. Expanding the treatment to include all under-treated acres (36 million acres) would further reduce the acres exceeding annual sediment loss of 2 tons per acre to less than 1 percent.

Similar effects of additional treatment are shown for nitrogen and phosphorus lost with surface runoff. Treatment of critical under-treated acres with water erosion control *and* nutrient management would reduce the acres exceeding 15 pounds per acre of nitrogen lost with surface runoff to 8 percent (figure 64); treatment of all 36 million under-treated acres would reduce the acres exceeding 15 pounds per acre to 2 percent. Acres exceeding 4 pounds per acre of phosphorus lost with surface runoff would be reduced to 9 percent by treating the critical acres and reduced to 4 percent by treating all under-treated acres.

For nitrogen loss in subsurface flow pathways, however, treatment of all 36 million under-treated acres would be required to reduce the overall regional edge-of-field losses significantly (figure 65). About 26 percent of the acres in the region have nitrogen loss in subsurface flow greater than 25 pounds per acre per year for the baseline conservation condition. This is in part the result of the use of soil erosion control practices with no or only partial use of nutrient management practices. Treating the 8.5 million critical under-treated acres with nutrient management practices would reduce this percentage to only 21 percent. However, treatment of all 36 million under-treated acres would reduce the percentage to 5 percent.

Soil organic carbon was minimally affected by the additional soil erosion control and nutrient management practices, largely because of savings of carbon that would otherwise have been lost from the field through wind and water erosion. Figure 67 shows that the percentage of acres building soil organic carbon would increase from 75 percent for the baseline conservation condition to 82 percent with additional conservation treatment of the 36 million under-treated acres.

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 was reduced about 7 percent for the 36 million acres treated with additional soil erosion control and nutrient management practices (table 41), which represents a 4-percent reduction for the region as a whole (table 42). Figure 68 shows that the distribution of nitrogen removed at harvest is slightly lower for the treatment scenarios but otherwise was similar to the distribution for the baseline conservation condition.

Emerging technologies for reducing nitrogen loss from farm fields

The nutrient management treatment level simulated in this study represents feasible and proven conservation practices that are currently being successfully applied. There are, however, emerging conservation technologies that have the potential to further reduce nutrient loss from farm fields and provide even greater conservation benefits once the technologies become more widespread. These include—

- variable rate technology for precise nutrient application rates and placement methods;
- nitrogen use efficiency enhancers (time release and ammonia loss inhibitors);
- water control management that reduces late fall and early spring flushes of nitrate-laden drainage water; and
- constructed wetlands receiving surface water runoff from farm fields prior to discharge to streams and rivers.

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.

Diminishing returns from additional conservation treatment.

Tables 39 through 42 and figures 62 through 66 suggest diminishing returns from additional conservation treatment when the most vulnerable acres are treated first. These diminishing returns are shown explicitly in table 43, which includes estimates of the effects of additional conservation practices on the 22 million adequately treated acres in the UMRB. Diminishing returns to additional conservation treatment is demonstrated by comparing the average annual per-acre reductions in loss among the three groups of acres.

For example, conservation treatment of the 8.5 million critical under-treated acres would reduce sediment loss an average of 2.7 tons per acre per year on those acres. In comparison, additional treatment of the remaining 27.5 million under-treated acres would reduce sediment loss by 0.7 ton per acre per year on those acres, and treatment of the remaining 22 million acres would reduce sediment loss by only 0.5 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 39 pounds per acre per year on the 8.5 million critical under-treated acres, compared to a reduction of 25 pounds per acre for the remaining 27.5 million under-treated acres and only 9 pounds per acre for the remaining 22 million acres. Total phosphorus loss would be reduced by an average of 4.6 pounds per acre per year on the 8.5 million critical under-treated acres, compared to a reduction of 1.8 pounds per acre for the remaining 27.5 million under-treated acres and only 1.3 pounds per acre for the remaining 22 million acres.

For nitrogen loss in subsurface flow, however, diminishing returns are not evident until all the under-treated acres are treated, indicating that nitrogen leaching losses are pervasive throughout most of the region. Nitrogen lost with surface runoff would be reduced by an average of 18 pounds per acre per year on the 8.5 million critical under-treated acres, compared to a reduction of only 16 pounds per acre for the remaining 27.5 million under-treated acres. However, the reduction for treatment of the remaining 22 million acres averaged only 3 pounds per acre.

Diminishing returns for reduction in environmental risk for pesticides were also not evident, primarily because pesticide risk was not taken into account in the identification of under-treated acres and the assessment of conservation treatment needs.

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

A convenient way to envision the potential gains from further conservation treatment is to contrast the potential sediment and nutrient savings to estimated savings for the conservation practices currently in use. The no-practice scenario represents losses without any conservation practices, and the treatment of *all* acres with nutrient management and water erosion control practices was used to represent a “full-treatment” condition. The difference in sediment and nutrient loss between these two scenarios was used to represent the maximum amount of savings possible for conservation treatment, which totaled 176 million tons of sediment, 876,791 tons of nitrogen, and 142,102 tons of phosphorus for the UMRB.

As shown in figure 69, about 70 percent of the potential sediment savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition. Additional treatment of the 8.5 million critical under-treated acres would account for another 13 percent of the potential sediment savings. Additional treatment of the remaining 27.5 million under-treated acres would account for about 11 percent of the potential savings.

Similar percentages were estimated for total phosphorus savings. About 59 percent of the potential savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition. Additional treatment of the 8.5 million critical under-treated acres would account for another 14 percent of the potential phosphorus savings. Additional treatment of the remaining 27.5 million under-treated acres would account for another 17 percent of the potential savings.

Much less progress is evident for total nitrogen. The baseline conservation condition accounts for only 30 percent of the potential savings from conservation treatment. Treatment of the 8.5 million critical under-treated acres would account for an additional 19 percent of the potential nitrogen savings. Treatment of the remaining 27.5 million under-treated acres would account for another 40 percent of the potential nitrogen savings.

Table 41. Conservation practice effects for additional treatment of 36 million under-treated acres in the Upper Mississippi River Basin

Model simulated outcome	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	3.6	2.9	18%	2.9	19%
Subsurface water flow (inches)	7.2	7.5	-6%	7.7	-7%
Erosion and sediment loss					
Wind erosion (tons/acre)	0.2	0.2	8%	0.2	11%
Sheet and rill erosion (tons/acre)	1.3	0.3	77%	0.3	78%
Sediment loss at edge of field due to water erosion (tons/acre)	1.3	0.1	93%	0.1	93%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	71	131	--	124	--
Nitrogen					
Nitrogen applied (pounds/acre)	100.0	96.1	4%*	65.7	34%
Nitrogen in crop yield removed at harvest (pounds/acre)	106.6	103.6	3%*	99.6	7%
Total nitrogen loss for all pathways except harvest (pounds/acre)	49.9	41.4	17%	21.2	57%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	10.3	2.2	78%	1.8	82%
Nitrogen loss in subsurface flow (pounds/acre)	28.0	27.6	1%	11.1	60%
Phosphorus					
Phosphorus applied (pounds/acre)	24.1	23.5	2%	18.2	24%
Total phosphorus loss for all pathways except harvest (pounds/acre)	3.4	1.7	50%	1.0	71%
Loss of phosphorus with surface runoff, including waterborne sediment (pounds/acre)	3.0	1.3	57%	0.7	78%
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	8.5	4.8	43%	4.8	43%
Surface water pesticide risk indicator for aquatic ecosystem	2.5	2.4	5%	2.4	4%
Surface water pesticide risk indicator for humans	0.3	0.2	27%	0.2	27%

* Total nitrogen applied was 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 36 million under-treated 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 42. Conservation practice effects for the region as a whole* after additional treatment of 36 million under-treated acres 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)	4.0	3.6	10%	3.6	11%
Subsurface water flow (inches)	6.7	6.9	-4%	7.0	-5%
Erosion and sediment loss					
Wind erosion (tons/acre)	0.2	0.2	5%	0.2	7%
Sheet and rill erosion (tons/acre)	1.0	0.4	60%	0.4	61%
Sediment loss at edge of field due to water erosion (tons/acre)	1.0	0.3	74%	0.3	74%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	70	107	--	103	--
Nitrogen					
Nitrogen applied (pounds/acre)	87.8	85.5	3%	66.6	24%
Nitrogen in crop yield removed at harvest (pounds/acre)	107.6	105.7	2%	103.2	4%
Total nitrogen loss for all pathways except harvest (pounds/acre)	41.3	36.1	13%	23.6	43%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	8.6	3.6	58%	3.4	61%
Nitrogen loss in subsurface flow (pounds/acre)	21.8	21.6	1%	11.4	48%
Phosphorus					
Phosphorus applied (pounds/acre)	22.3	22.0	2%	18.7	16%
Total phosphorus loss for all pathways except harvest (pounds/acre)	3.0	1.9	35%	1.5	51%
Loss of phosphorus with surface runoff, including waterborne sediment (pounds/acre)	2.5	1.5	41%	1.1	57%
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	8.4	6.1	27%	6.1	27%
Surface water pesticide risk indicator for aquatic ecosystem	2.6	2.5	3%	2.5	2%
Surface water pesticide risk indicator for humans	0.4	0.3	14%	0.3	15%

* Results presented for the region as a whole combine model output for the 36 million treated acres with model results from the baseline conservation condition for the remaining acres.

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

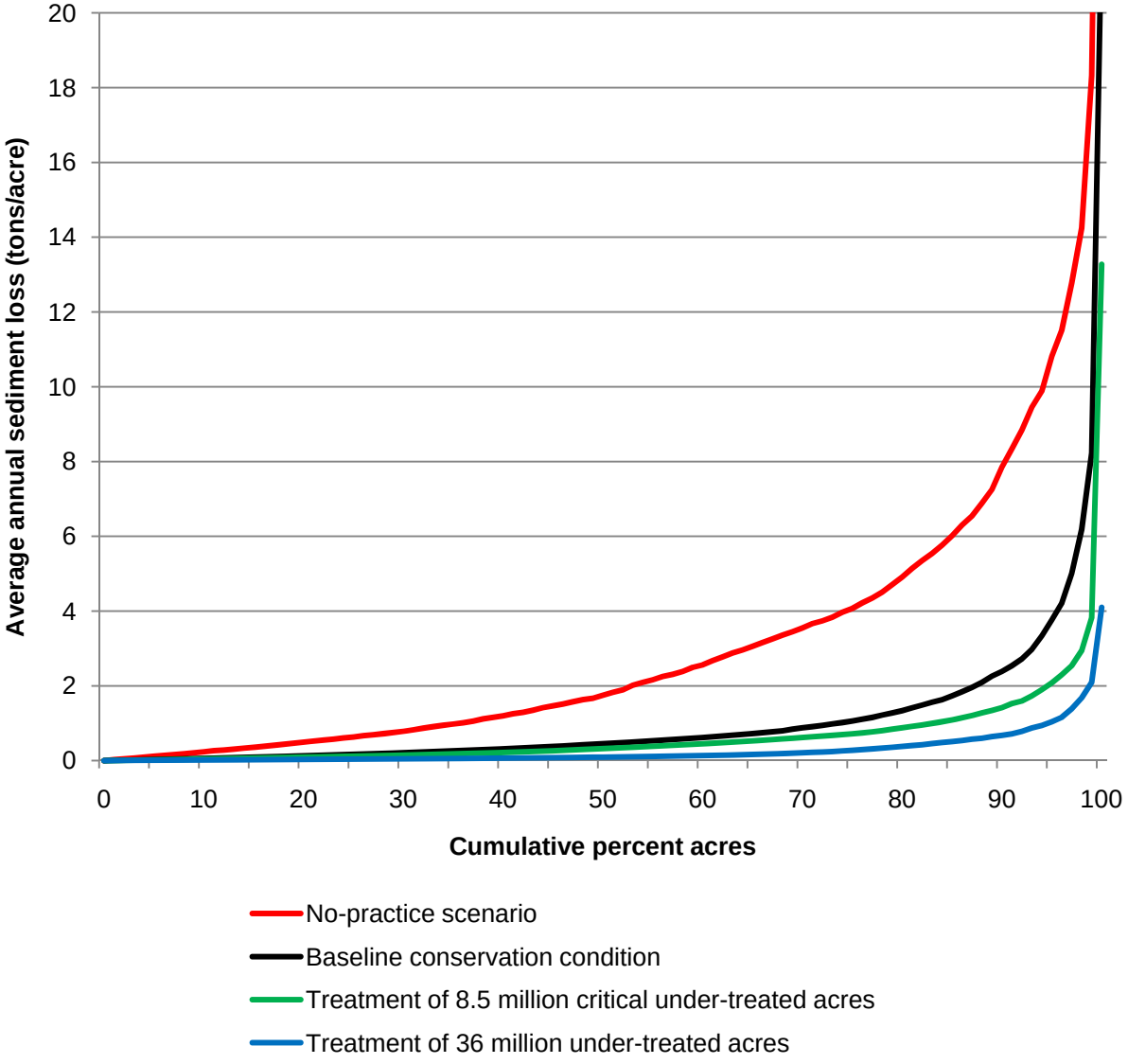


Figure 63. Estimates of average annual total nitrogen loss for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Upper Mississippi River Basin

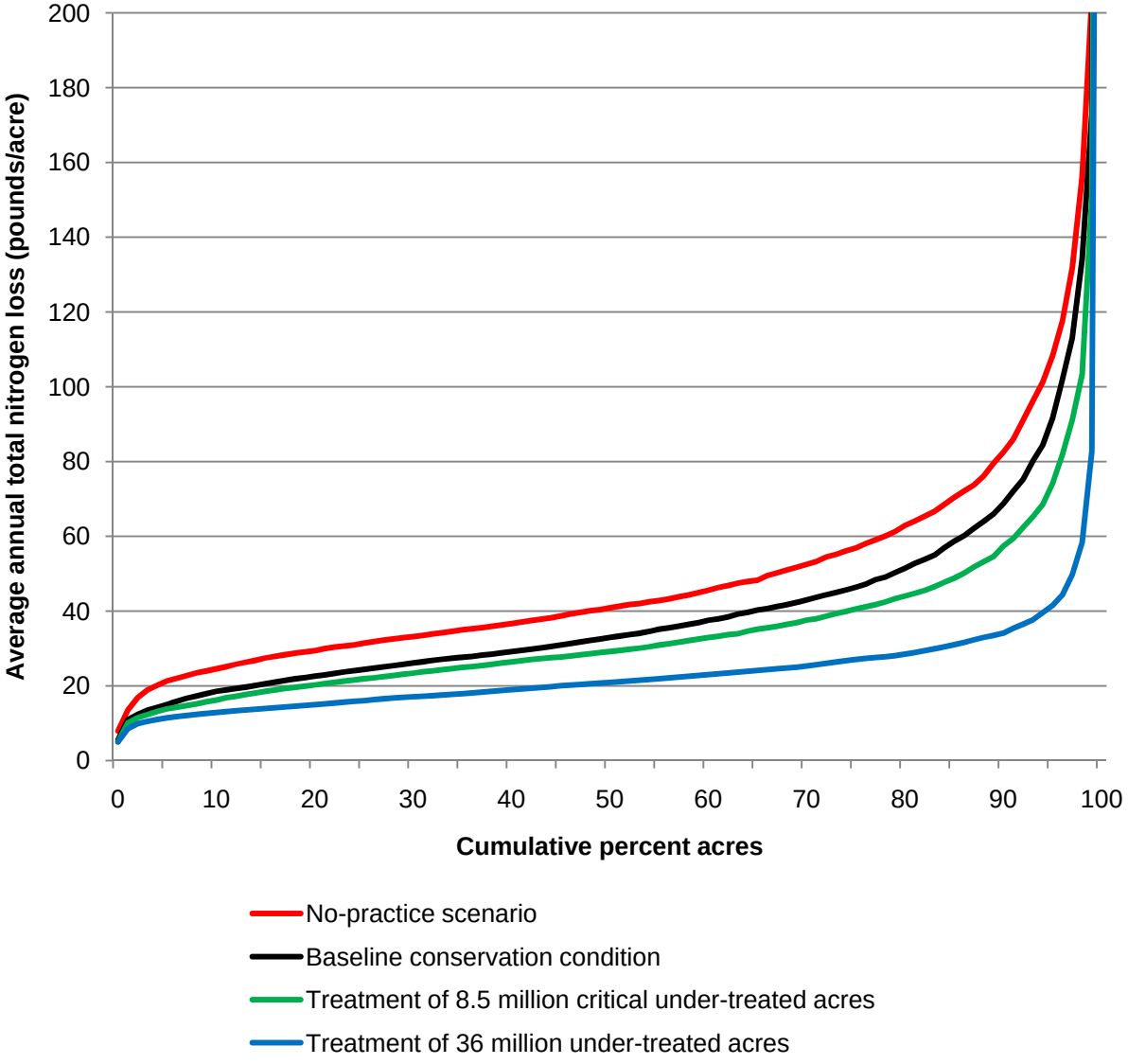


Figure 64. Estimates of average annual loss of nitrogen with surface runoff for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Upper Mississippi River Basin

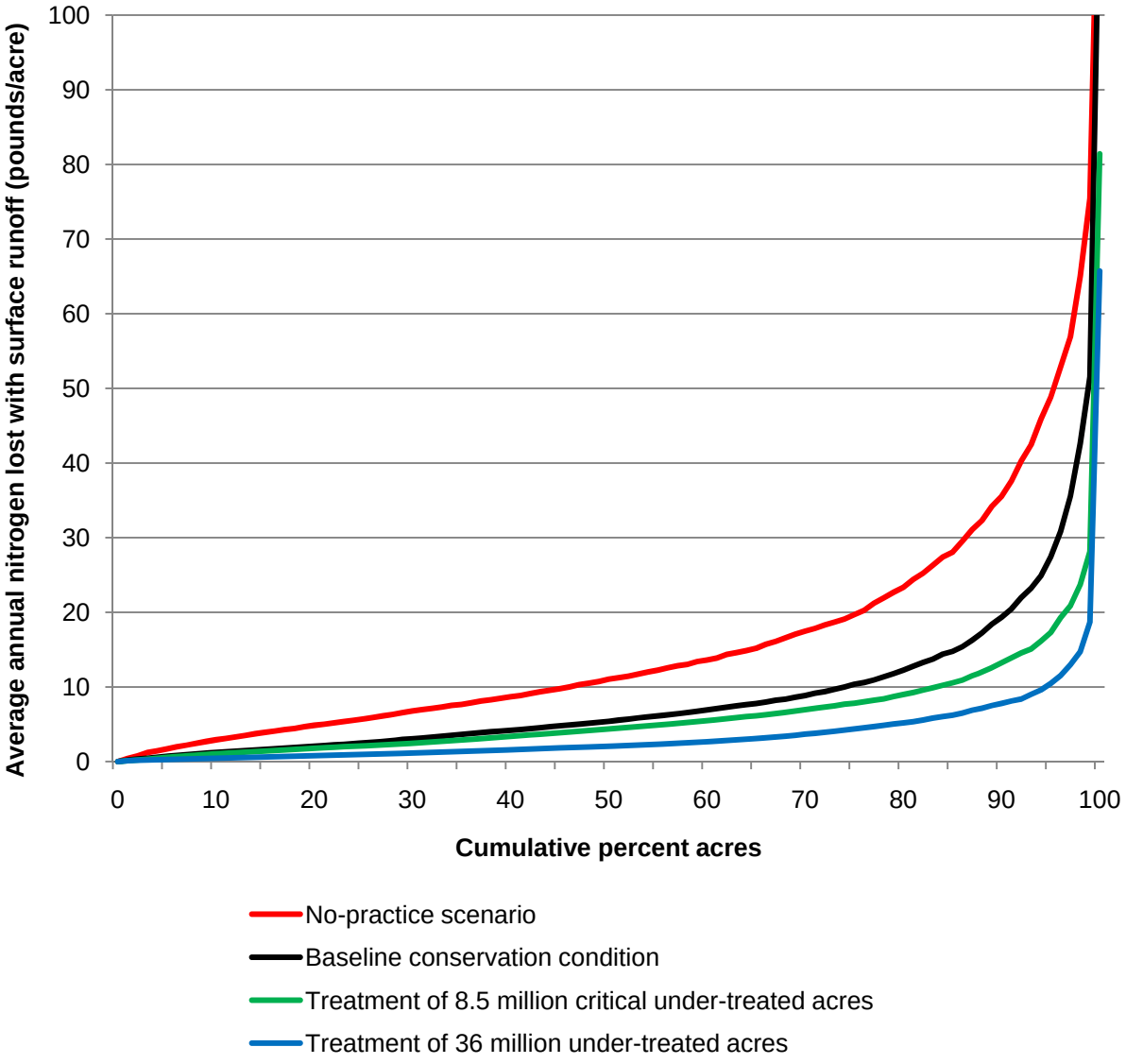


Figure 65. Estimates of average annual loss of nitrogen in subsurface flow for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Upper Mississippi River Basin

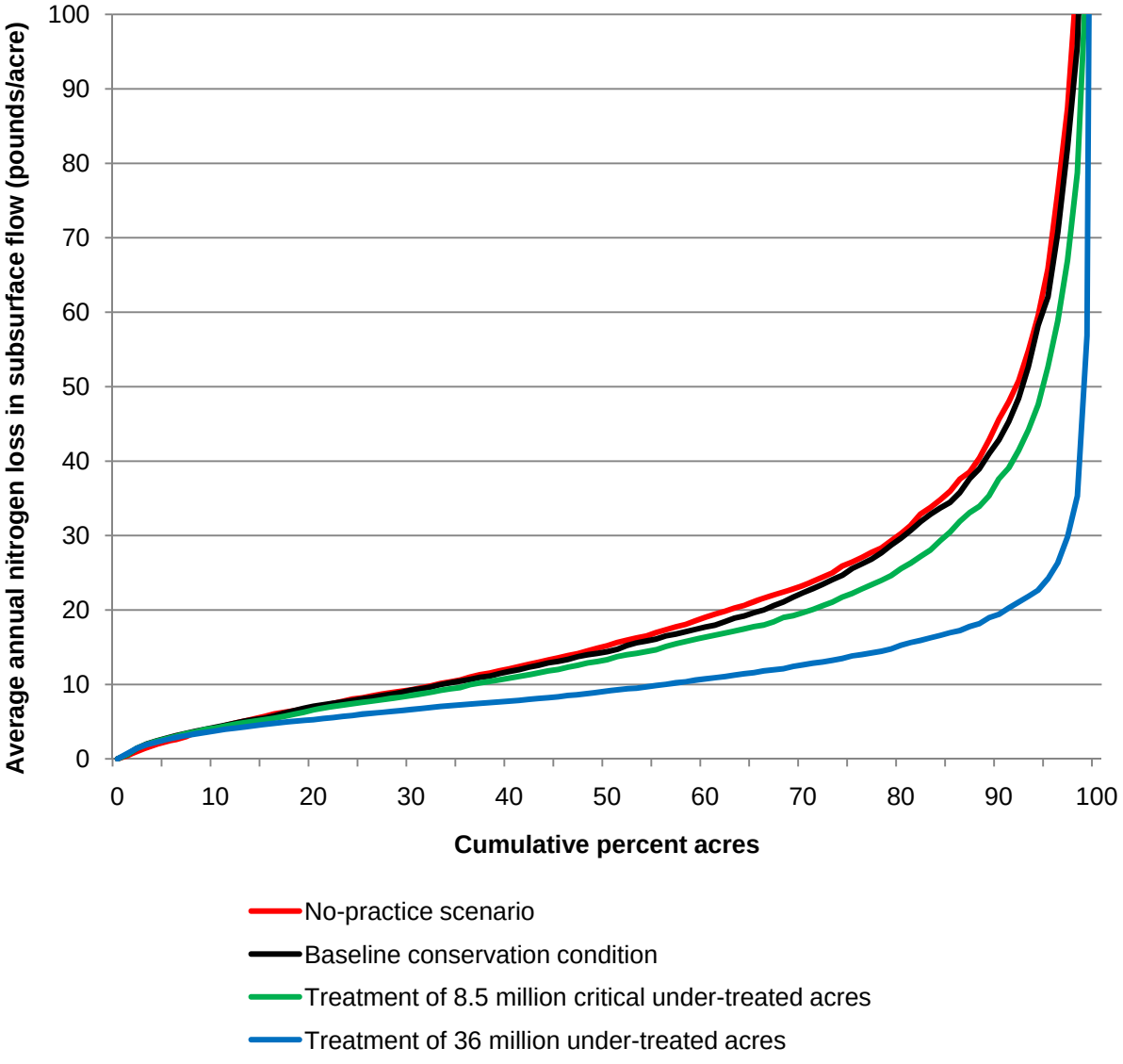


Figure 66. Estimates of average annual phosphorus lost with surface runoff for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Upper Mississippi River Basin

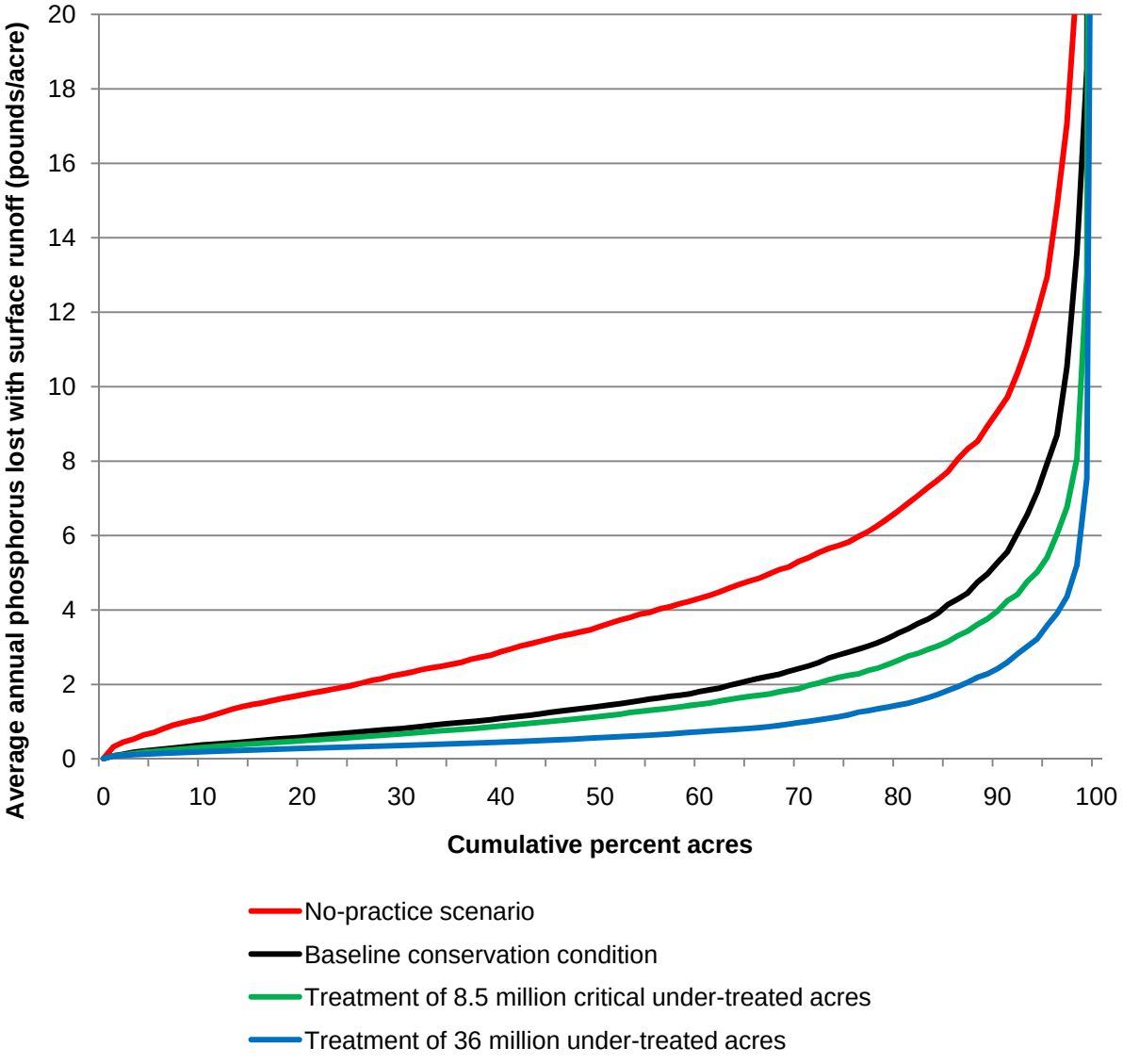


Figure 67. Estimates of average annual change in soil organic carbon for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Upper Mississippi River Basin

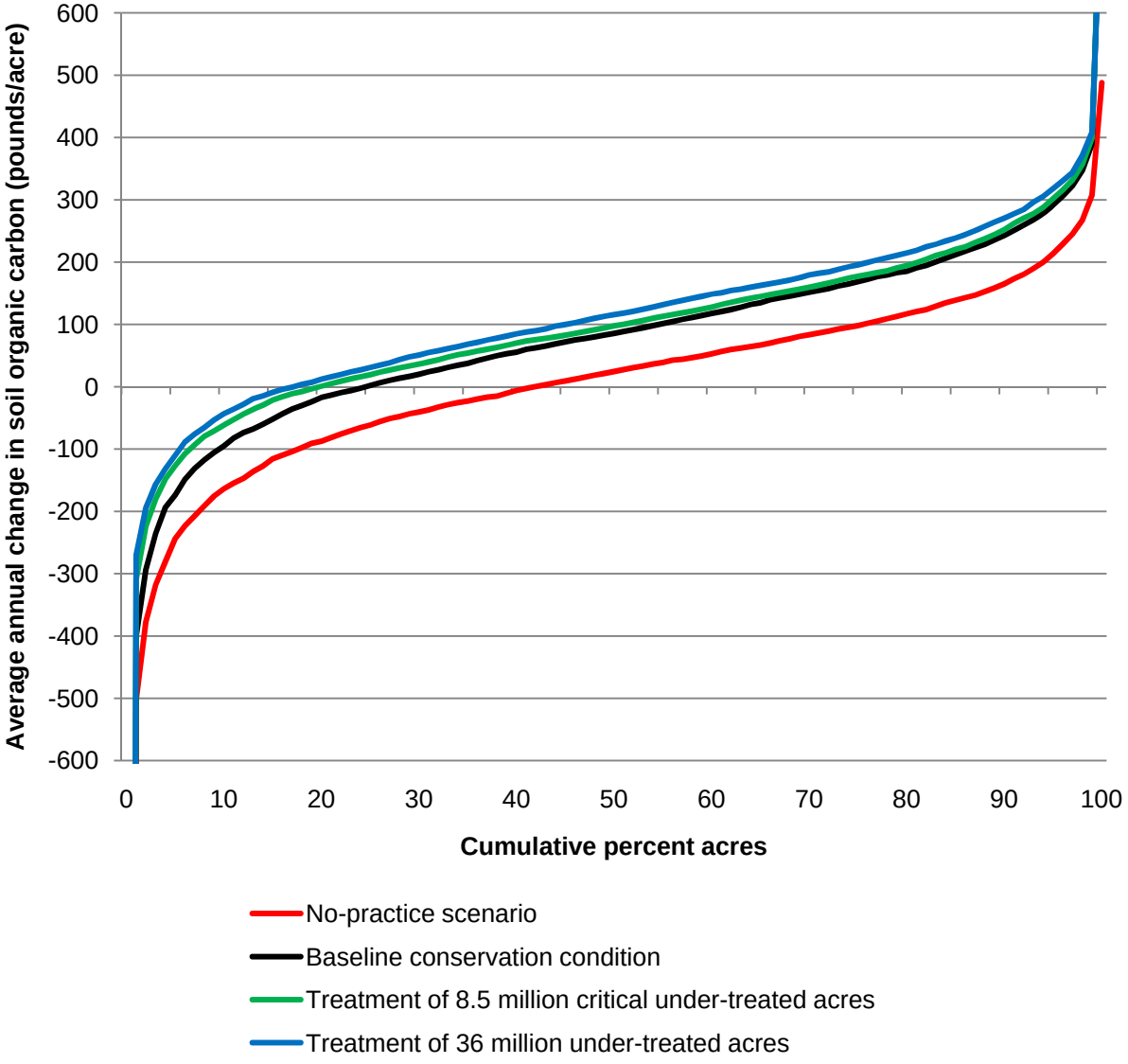


Figure 68. Estimates of average annual removal of nitrogen with crop yield at harvest for under-treated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Upper Mississippi River Basin

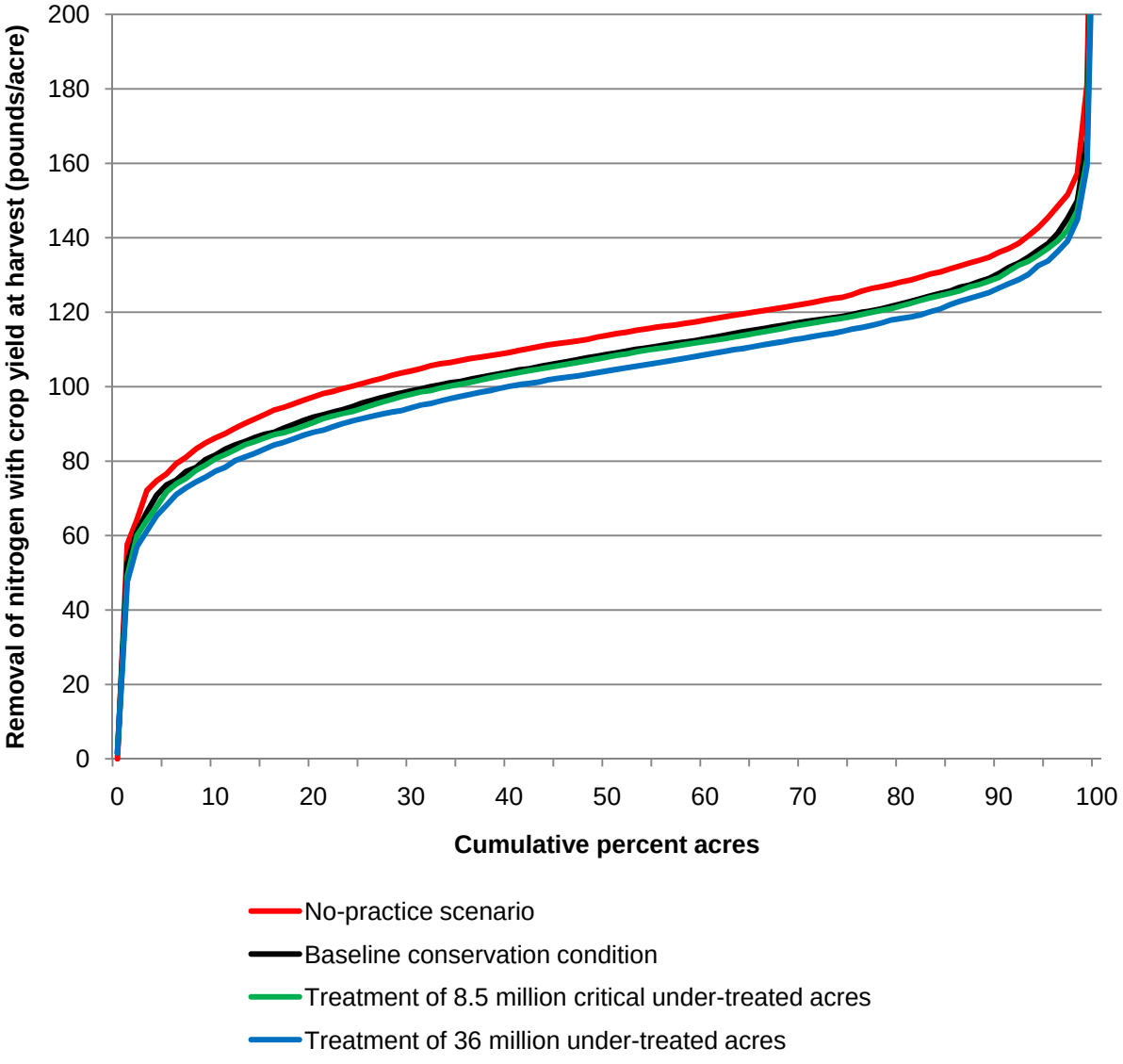
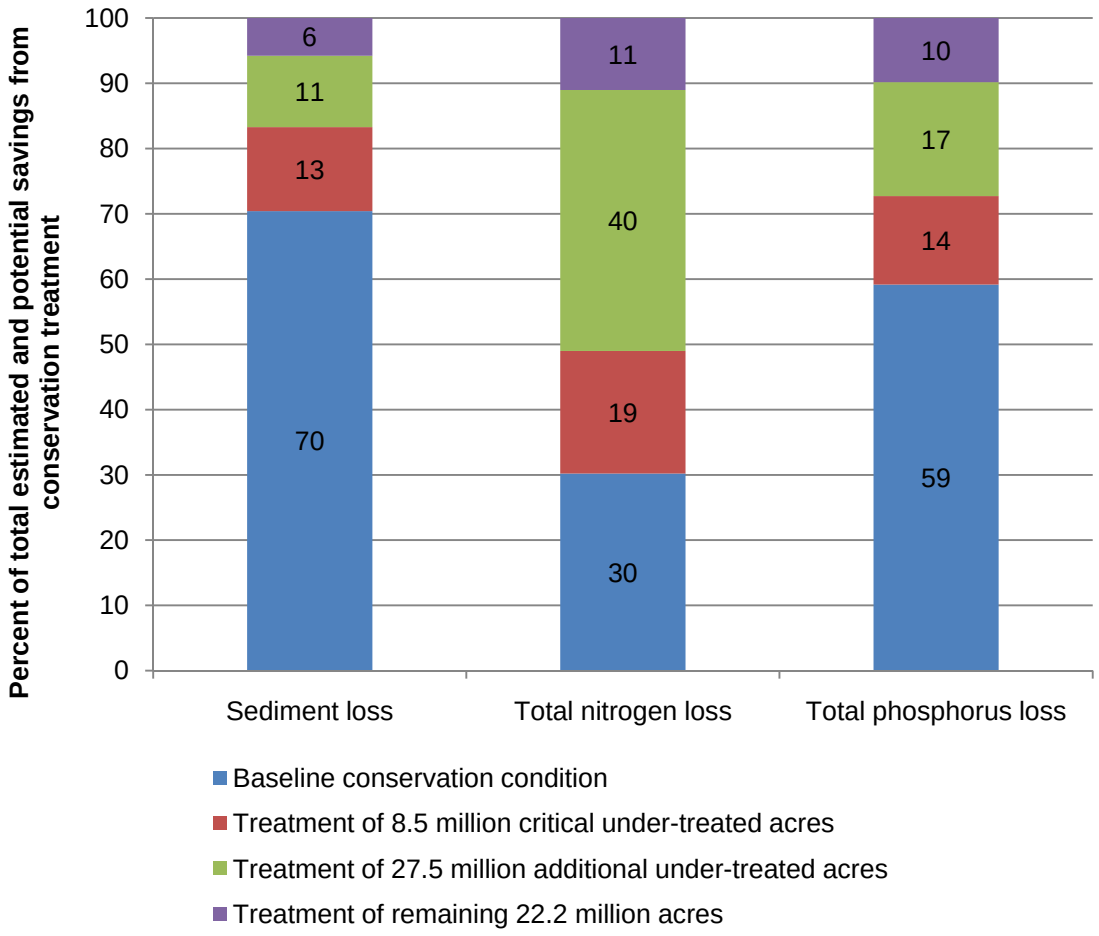


Table 43 Effects of additional conservation treatment with erosion control practices *and* nutrient management practices for three groups of acres comprising the 58 million cropped acres in the Upper Mississippi River Basin

	Additional treatment for 8.5 million critical under-treated acres			Additional treatment for 27.5 million non-critical under-treated acres			Additional treatment for remaining 22.2 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)	3.8	3.1	0.8	3.5	2.9	0.7	4.7	3.8	0.9
Subsurface water flow (inches)	7.7	8.2	-0.5	7.0	7.5	-0.5	5.9	6.5	-0.6
Erosion and sediment loss									
Wind erosion (tons/acre)	0.30	0.26	0.04	0.22	0.20	0.02	0.24	0.22	0.02
Sheet and rill erosion (tons/acre)	2.35	0.47	1.88	0.98	0.23	0.75	0.61	0.18	0.42
Sediment loss at edge of field due to water erosion (tons/acre)	2.82	0.14	2.68	0.77	0.07	0.70	0.53	0.07	0.46
Soil organic carbon									
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-53	62	116*	109	143	35*	68	98	30*
Nitrogen									
Nitrogen applied (pounds/acre)	107	70	37	98	64	33	68	57	11
Nitrogen in crop yield removed at harvest (pounds/acre)	105	98	7	107	100	7	109	104	5
Total nitrogen loss for all pathways except harvest (pounds/acre)	65	26	39	45	20	25	28	19	9
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	20.0	2.7	17.3	7.3	1.5	5.7	5.8	1.7	4.1
Nitrogen loss in subsurface flow (pounds/acre)	31.8	13.6	18.1	26.8	10.4	16.5	11.8	8.8	3.0
Phosphorus									
Phosphorus applied (pounds/acre)	26.9	19.3	7.5	23.2	17.8	5.4	19.5	17.0	2.5
Total phosphorus loss for all pathways except harvest (pounds/acre)	5.9	1.4	4.6	2.7	0.9	1.8	2.2	1.0	1.3
Loss of phosphorus with surface runoff, including waterborne sediment (pounds/acre)	5.4	1.0	4.4	2.3	0.6	1.7	1.8	0.6	1.2
Pesticide loss									
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	12.7	5.7	7.0	7.2	4.6	2.6	8.2	5.0	3.2
Surface water pesticide risk indicator for aquatic ecosystem	2.4	1.7	0.7	2.6	2.7	-0.1	2.7	1.8	0.9
Surface water pesticide risk indicator for humans	0.5	0.3	0.1	0.3	0.2	0.1	0.5	0.3	0.2

* Gain in soil organic carbon.

Figure 69. Comparison of estimated sediment, nitrogen, and phosphorus savings 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 8.5 million critical under-treated acres*	Potential savings from treatment of 27.5 million non-critical under-treated acres*	Potential savings from treatment of remaining 22.2 million acres*	Total estimated and potential savings from conservation treatment
Sediment	124,048,565	22,664,266	19,240,443	10,191,405	176,144,679
Nitrogen	264,923	164,662	350,548	96,658	876,791
Phosphorus	84,074	19,252	24,829	13,947	142,102

*Treatment with erosion control practices and nutrient management practices on all acres.
Note: Calculations exclude land in long-term conserving cover.

Potential for Offsite Water Quality Gains

The field-level model results for the scenarios with additional erosion control practices *and* nutrient management was used with the HUMUS/SWAT model to determine the potential for further reductions in instream sediment and nutrient loads with additional conservation treatment.

Percent reductions relative to the current conservation condition were estimated for each of two scenarios: (1) treatment of the 8.5 million critical under-treated acres, and (2) treatment of all 36 million under-treated acres, including the 8.5 million critical under-treated acres (tables 44 through 47). The distribution of under-treated acres within the UMRB is shown in chapter 6, table 35. The model simulations not only demonstrate the relative gains that can be expected from different levels of conservation effort but also provide insight into which subbasins are the most important in terms of reducing overall loads exported from the UMRB. Figures 70 through 73 compare the baseline condition with the estimates of reductions achievable under the two scenarios.

Summary of results for the entire basin

Model simulations show that at the outlet of the UMRB (Grafton, IL), treatment of the 8.5 million critical under-treated acres with additional erosion control and nutrient management practices would further reduce instream loads, relative to the baseline conservation condition, by—

- 10 percent for sediment;
- 12 percent for nitrogen;
- 14 percent for phosphorus; and
- 7 percent for atrazine.

Treatment of all 36 million under-treated acres would reduce instream loads at the outlet of the UMRB (Grafton, IL), relative to the baseline conservation condition, by—

- 19 percent for sediment;
- 39 percent for nitrogen;
- 37 percent for phosphorus; and
- 20 percent for atrazine.

Summary of results for the 14 subbasins

The subbasins with the highest percent reductions due to additional conservation treatment of the 8.5 million critical under-treated acres would be:

- for sediment, the Rock River (subbasin code 0709) with a 22-percent reduction in load;
- for nitrogen, the Wisconsin River (subbasin code 0707) with a 20 percent reduction in load and the Chippewa River (subbasin code 0705), with a 23 percent reduction;
- for phosphorus, the Wisconsin River (subbasin code 0707) and the Chippewa River (subbasin code 0705), both with 29 percent reductions in loads; and
- for atrazine, the Chippewa River (subbasin code 0705) with a 35-percent reduction.

A similar set of subbasins had the highest percent reductions due to additional treatment of all 36 million under-treated acres. Subbasins with the highest percent load reductions would be:

- for sediment, the Rock River (subbasin code 0709) with a 45-percent reduction in load;
- for nitrogen, the Minnesota River (subbasin code 0702) with a 49-percent reduction in load;
- for phosphorus, the Wisconsin River (subbasin code 0707) with a 51-percent reduction in load; and
- for atrazine, the Chippewa River (subbasin code 0703) with a 39-percent reduction.

Agricultural sources are relatively minor in two subbasins, the St. Croix River (subbasin code 0703) and the Upper Illinois River (subbasin code 0712), which explains the low percent reduction in instream loads due to additional conservation practices in those subbasins.

Table 44. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on ***instream sediment loads***, Upper Mississippi River Basin

Sub-basin code	Subbasin name	Baseline conservation condition: Average annual load (1,000 tons)	Treatment of 8.5 million critical under-treated acres: Average annual load (1,000 tons)	Treatment of 8.5 million critical under-treated acres: Percent reduction	Treatment of all 36 million under-treated acres: Average annual load (1,000 tons)	Treatment of all 36 million under-treated acres: Percent reduction
	Tributary subbasins					
0702	Minnesota River	873	802	8	708	19
0703	St. Croix River	520	509	2	505	3
0705	Chippawa River	962	750	22	697	28
0707	Wisconsin River	1,120	961	14	933	17
0708a	Iowa River within 708	1,630	1,450	11	1,190	27
0709	Rock River	1,530	1,190	22	849	45
0710	Des Moines River	792	743	6	673	15
0713	Illinois River	6,380	6,150	4	5,410	15
0712	Upper Illinois River within 713	1,960	1,930	1	1,830	7
	Outlets along mainstem					
0701	Mississippi Headwaters	2,620	2,420	8	2,160	17
0704	Upper Mississippi-Black-Root	5,980	4,960	17	4,450	26
0706	Upper Mississippi-Maquoketa-Plum	9,040	7,550	16	6,750	25
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	15,600	13,500	14	11,800	25
0711	Mississippi at Grafton, Illinois	20,900	18,700	10	16,800	19

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

Table 45. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on ***instream nitrogen loads***, Upper Mississippi River Basin

Sub-basin code	Subbasin name	Baseline conservation condition: Average annual load (1,000 pounds)	Treatment of 8.5 million critical under-treated acres: Average annual load (1,000 pounds)	Treatment of 8.5 million critical under-treated acres: Percent reduction	Treatment of all 36 million under-treated acres: Average annual load (1,000 pounds)	Treatment of all 36 million under-treated acres: Percent reduction
	Tributary subbasins					
0702	Minnesota River	108,000	97,700	9	54,900	49
0703	St. Croix River	13,600	13,500	1	13,200	3
0705	Chippawa River	23,500	18,200	23	15,200	35
0707	Wisconsin River	43,400	34,800	20	30,000	31
0708a	Iowa River within 708	117,000	107,000	9	72,000	39
0709	Rock River	94,200	80,300	15	56,400	40
0710	Des Moines River	117,000	113,000	3	74,900	36
0713	Illinois River	424,000	404,000	5	304,000	28
0712	Upper Illinois River within 713	166,000	155,000	6	140,000	16
	Outlets along mainstem					
0701	Mississippi Headwaters	185,000	168,000	9	112,000	39
0704	Upper Mississippi-Black-Root	304,000	263,000	13	189,000	38
0706	Upper Mississippi-Maquoketa-Plum	409,000	350,000	15	252,000	38
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	764,000	658,000	14	455,000	40
0711	Mississippi at Grafton, Illinois	1,090,000	959,000	12	666,000	39

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

Table 46. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on ***instream phosphorus loads***, Upper Mississippi River Basin

Sub-basin code	Subbasin name	Baseline conservation condition: Average annual load (1,000 pounds)	Treatment of 8.5 million critical under-treated acres: Average annual load (1,000 pounds)	Treatment of 8.5 million critical under-treated acres: Percent reduction	Treatment of all 36 million under-treated acres: Average annual load (1,000 pounds)	Treatment of all 36 million under-treated acres: Percent reduction
	Tributary subbasins					
0702	Minnesota River	3,340	3,020	10	2,090	38
0703	St. Croix River	521	457	12	454	13
0705	Chippawa River	1,610	1,140	29	845	47
0707	Wisconsin River	2,830	2,020	29	1,400	51
0708a	Iowa River within 708	6,000	5,140	14	3,710	38
0709	Rock River	6,060	4,610	24	3,240	47
0710	Des Moines River	3,540	3,380	5	2,490	30
0713	Illinois River	24,100	23,500	3	20,100	17
0712	Upper Illinois River within 713	10,800	10,700	1	10,300	5
	Outlets along mainstem					
0701	Mississippi Headwaters	7,250	6,220	14	4,980	31
0704	Upper Mississippi-Black-Root	12,700	10,000	21	7,810	38
0706	Upper Mississippi-Maquoketa-Plum	19,000	15,000	21	10,200	46
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	35,200	28,600	19	20,100	43
0711	Mississippi at Grafton, Illinois	45,200	38,700	14	28,500	37

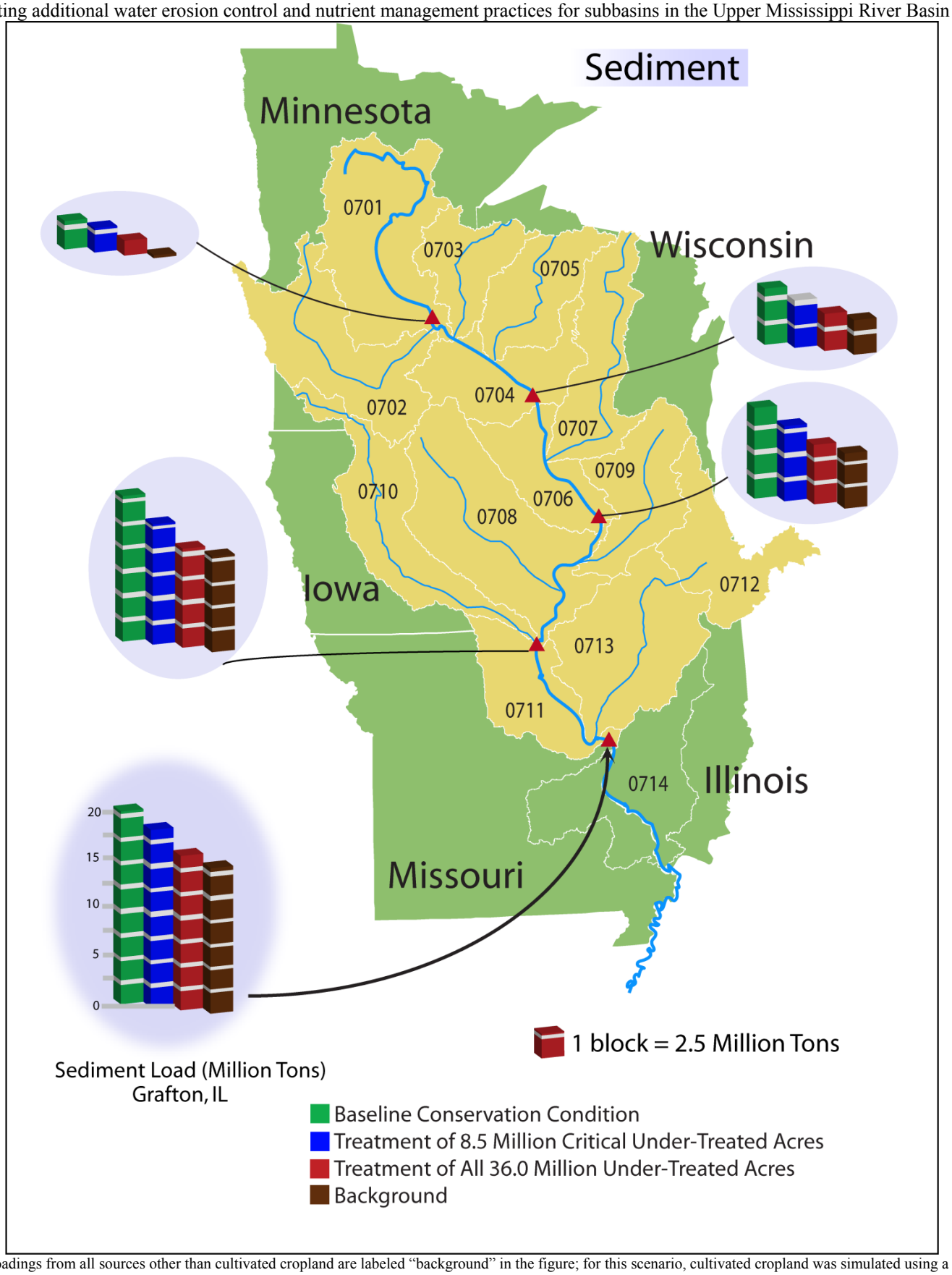
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 47. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on ***instream atrazine loads***, Upper Mississippi River Basin

Sub-basin code	Subbasin name	Baseline conservation condition: Average annual load (pounds)	Treatment of 8.5 million critical under-treated acres: Average annual load (pounds)	Treatment of 8.5 million critical under-treated acres: Percent reduction	Treatment of all 36 million under-treated acres: Average annual load (pounds)	Treatment of all 36 million under-treated acres: Percent reduction
	Tributary subbasins					
0702	Minnesota River	3,052	2,954	3	2,582	15
0703	St. Croix River	128	122	5	108	16
0705	Chippawa River	854	555	35	517	39
0707	Wisconsin River	1,146	1,082	6	930	19
0708a	Iowa River within 708	9,614	9,071	6	7,389	23
0709	Rock River	4,915	4,450	9	3,745	24
0710	Des Moines River	3,800	3,629	4	3,326	12
0713	Illinois River	17,297	17,089	1	15,500	10
0712	Upper Illinois River within 713	7,144	7,161	0	6,787	5
	Outlets along mainstem					
0701	Mississippi Headwaters	5,470	5,103	7	4,520	17
0704	Upper Mississippi-Black-Root	7,901	7,130	10	6,094	23
0706	Upper Mississippi-Maquoketa-Plum	6,315	5,864	7	4,905	22
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon	33,335	30,791	8	26,140	22
0711	Mississippi at Grafton, Illinois	47,826	44,349	7	38,206	20

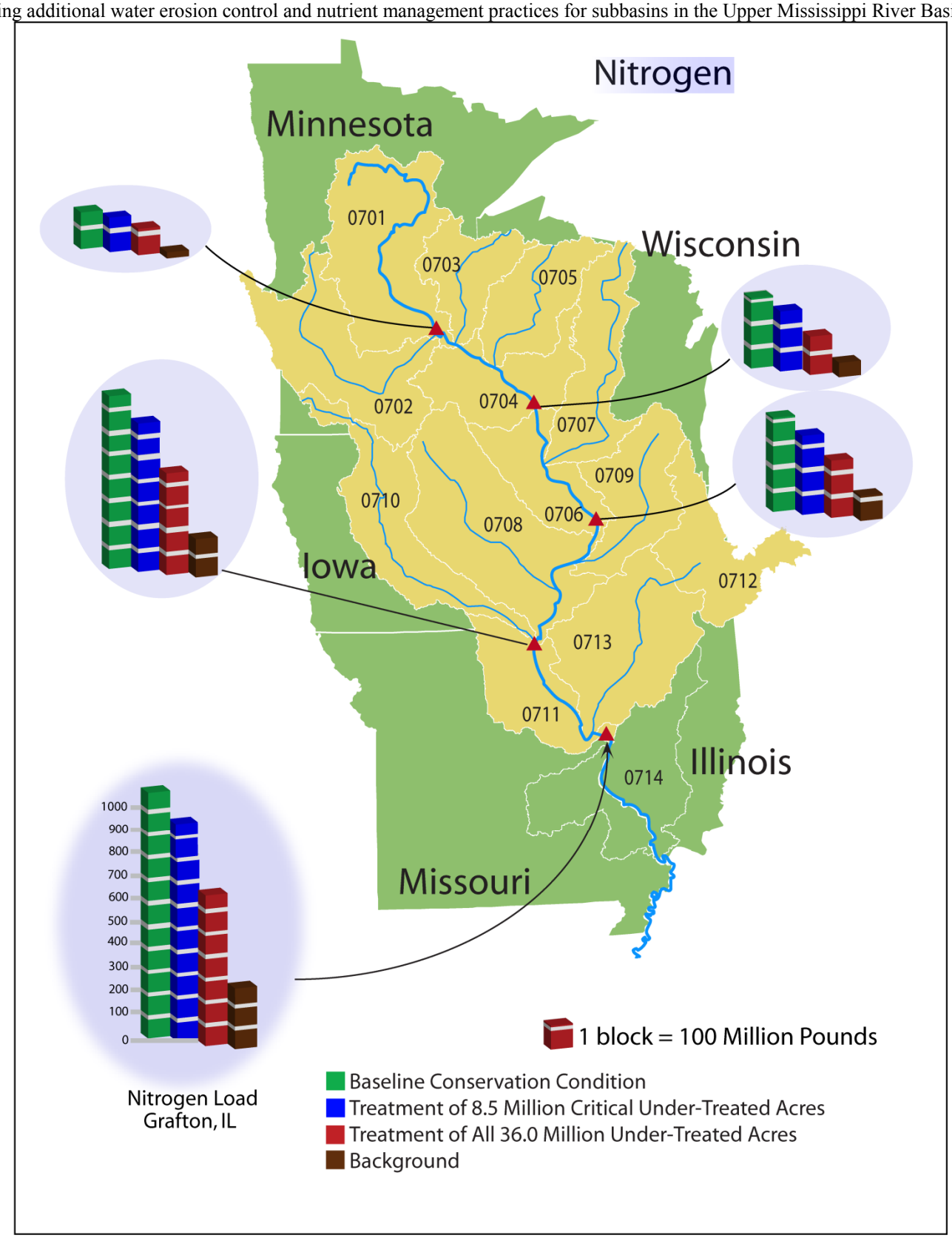
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Figure 70. Estimates of average annual instream sediment loads for the baseline conservation condition compared to two scenarios simulating additional water erosion control and nutrient management practices for subbasins in the Upper Mississippi River Basin



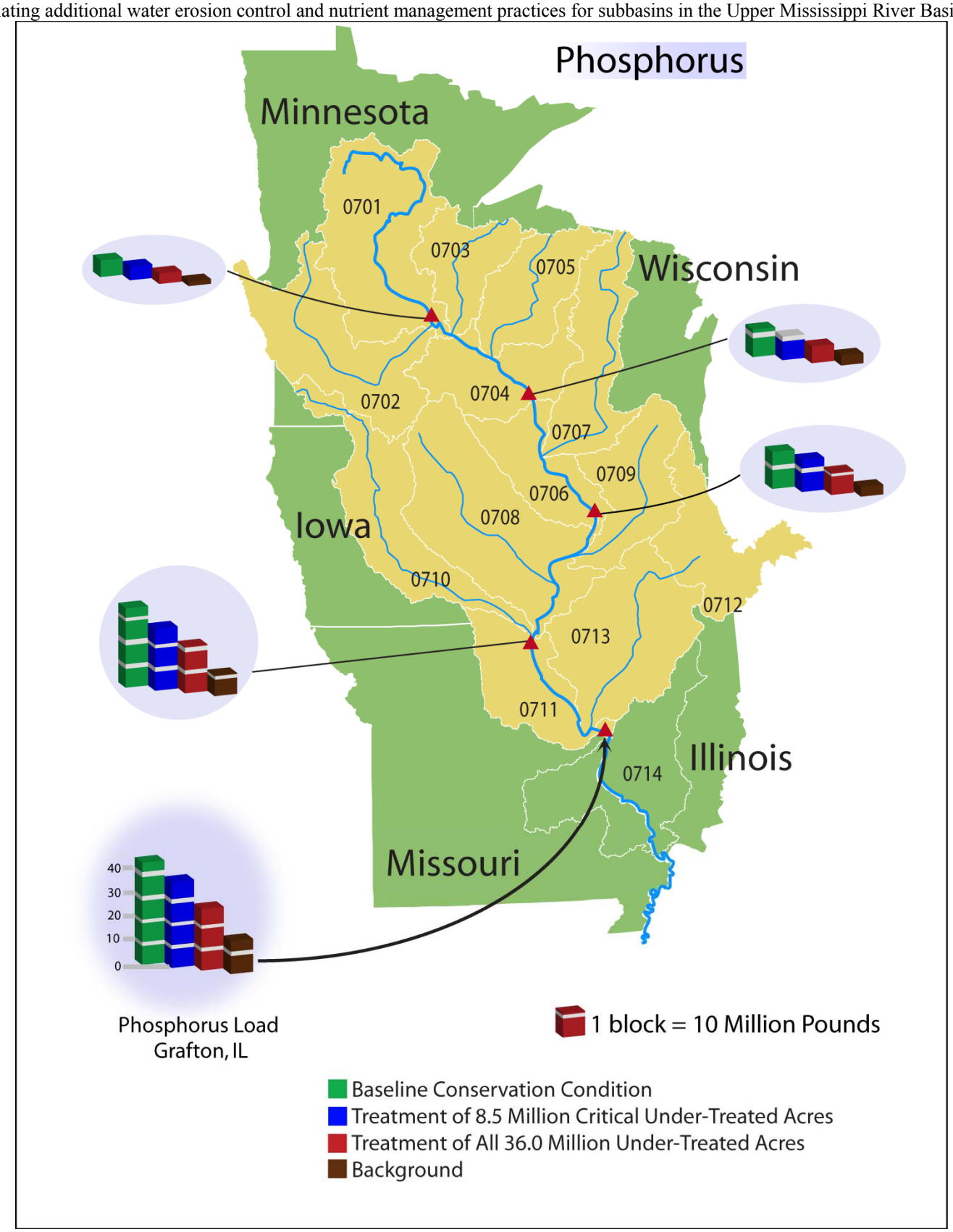
Note: Loadings from all sources other than cultivated cropland are labeled "background" in the figure; for this scenario, cultivated cropland was simulated using a continuous grass cover without any tillage or addition of nutrients or pesticides and no harvest.

Figure 71. Estimates of average annual instream nitrogen loads for the baseline conservation condition compared to two scenarios simulating additional water erosion control and nutrient management practices for subbasins in the Upper Mississippi River Basin



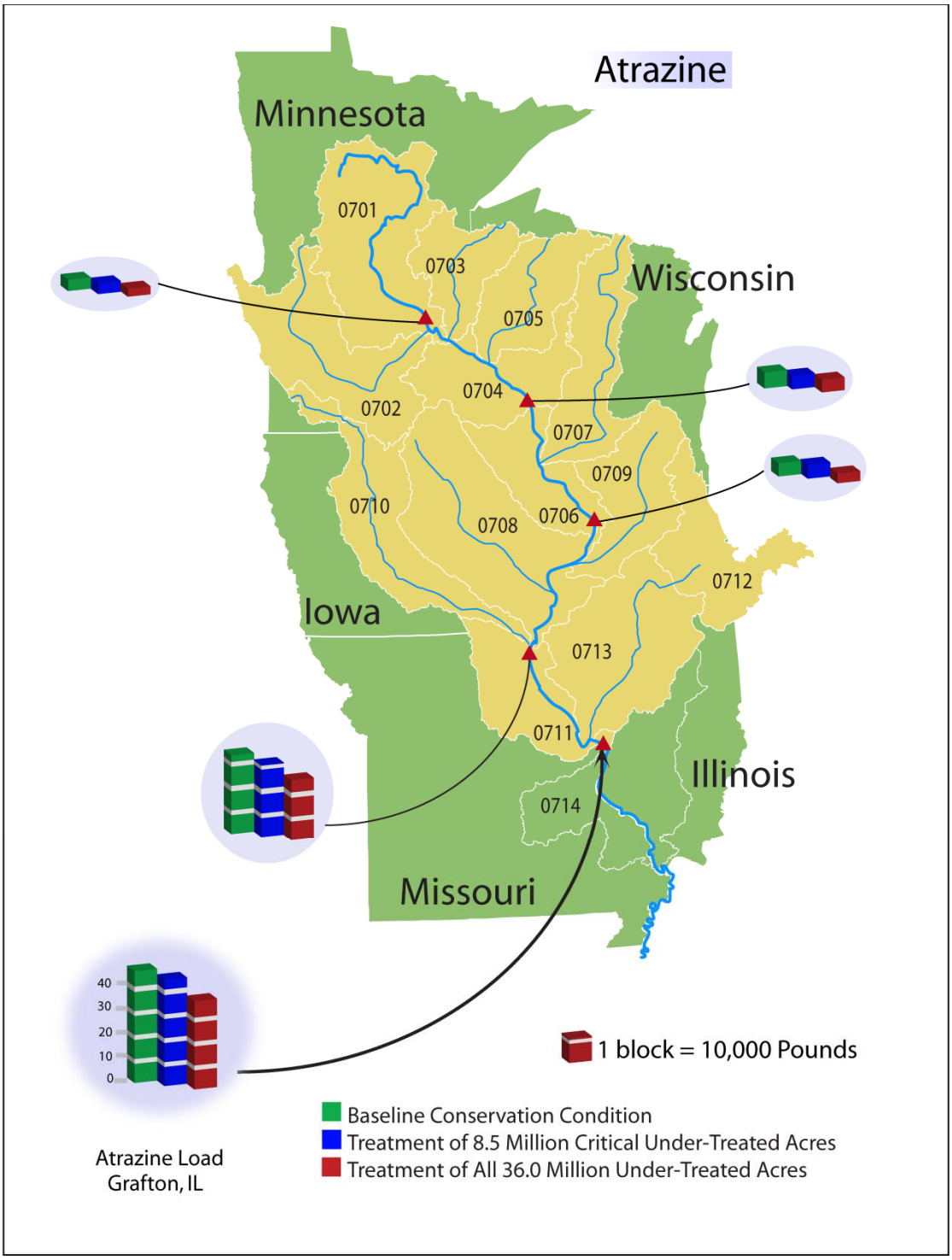
Note: Loadings from all sources other than cultivated cropland are labeled "background" in the figure; for this scenario, cultivated cropland was simulated using a continuous grass cover without any tillage or addition of nutrients or pesticides and no harvest.

Figure 72. Estimates of average annual instream phosphorus loads for the baseline conservation condition compared to two scenarios simulating additional water erosion control and nutrient management practices for subbasins in the Upper Mississippi River Basin



Note: Loadings from all sources other than cultivated cropland are labeled "background" in the figure; for this scenario, cultivated cropland was simulated using a continuous grass cover without any tillage or addition of nutrients or pesticides and no harvest.

Figure 73. Estimates of average annual instream atrazine loads for the baseline conservation condition compared to two scenarios simulating additional water erosion control and nutrient management practices for subbasins in the Upper Mississippi River Basin



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Appendix A: Estimates of acres and standard errors

This appendix will consist of a table reporting estimated acres and the standard error for a collection of key variables included in the report.

Appendix B
Summary Tables of NRI-CEAP Cropland Survey Responses for the Upper Mississippi River Basin

The NRI-CEAP Cropland Survey obtained information from farmers on field-level farming activities and conservation practices for a subset of National Resource Inventory (NRI) cultivated cropland sample points. The survey was specifically designed to obtain information needed as data inputs to the APEX physical process model.

The NRI-CEAP Cropland Survey collected information for all crops and for multiple years, thereby providing a landscape representation of the cropping systems present. A cropping system represents a suite of crops typically grown in a crop rotation along with the field operations and chemical use associated with that suite of crops.

Because of annual financial constraints as well as the logistics of data collection, the data collection process was spread over the 4-year period 2003 through 2006. In each year, a separate set of sample points was selected. The final CEAP sample was constructed by pooling the set of usable, completed surveys from all 4 years. The results therefore represent farming activities from 2003 through 2006.

Survey questionnaire responses are summarized in this appendix for the 3,703 CEAP samples in the Upper Mississippi River Basin (UMRB). These results reflect what was reported in the survey and do not include adjustments that were necessary to conduct the physical process modeling.[24] Because the samples were drawn from an area sample frame, all data summaries are in terms of acres.[25]

Survey Data Collection

The National Agricultural Statistics Service (NASS) administered the survey with assistance from FSA and NRCS. NASS, the agency that has the authority to conduct public surveys for USDA, has the staff, infrastructure, and experience to implement large survey efforts of this nature. The survey was conducted in two phases.

Phase I

The names and addresses of the operators of the fields associated with the sample point locations were obtained in Phase I. The collection of the name and address information provided (1) a contact for providing the operator with survey publicity materials encouraging cooperation, and (2) an initial contact for field enumeration to begin the second phase.

Prior to data collection, NRCS provided NASS field enumerators with aerial photographs and county maps showing the locations of the CEAP sample sites. NRCS combined NRI digital location information with digital county base map products to plot CEAP sample point locations. County maps include roads, towns, hydrographic features, and other information for locating the general vicinity of the sample point. To identify the field associated with the CEAP sample point, an ortho-rectified (scale accurate) aerial photograph was provided showing the location of the sample point.

Phase I data collection occurred in June and July. In 2003 and 2004, NASS enumerators visited Farm Service Agency (FSA) field offices and, using the county maps and aerial photographs provided by NRCS, worked with FSA staff to determine the identity of the farm operator. Once the point had been visibly located on FSA photography, the FSA farm field and tract number information were extracted and recorded. FSA databases were then accessed to provide the name and contact information for the farm operator, as well as information on Conservation Reserve Program (CRP) signups. For sample points that fell on farming operations that did not participate in USDA programs, county plat maps or other types of county records were consulted to determine the farm operator.

In 2005 and 2006, an alternative technology and approach was used to identify farm operators. This approach used the digitized data on field boundaries referred to as the Common Land Unit (CLU), or FSA CLU data layer, which allowed many of the farm operator names and much of the contact information to be obtained through a digital merge process. In this process, NRI digital point location information was merged with CLU data to determine the FSA field and tract number. The field and tract number was then used to extract the name of the farm operator and other pertinent program information from FSA databases.

Prospective respondents received an advance letter and information brochure informing them that they had been selected and that a NASS enumerator would be contacting them to ask about their operation of a selected field. The brochure explained the purpose of the survey and encouraged participation.

Phase II

The CEAP questionnaire was designed to be enumerated as a personal interview with the operator who made the day-to-day operating decisions. Participation in the survey was voluntary, and all data collected are confidential. In addition to the personal interview, NASS enumerators visited the NRCS field offices to obtain additional information about conservation program participation and the content of conservation plans. Data collection was conducted typically from September through December. Following data collection, NASS assembled the survey responses into a database. Edit checks were conducted to identify questionable survey responses and, where necessary, to follow up with the respondent to clear up discrepancies.

Prior to the start of the fall data collection, State survey administrators conducted workshops at the local level to familiarize field enumerators with the questionnaire, techniques for obtaining successful interviews, and educating enumerators

[24] See the documentation report "Transforming Survey Data to APEX Model Input Files" at http://www.nrcs.usda.gov/technical/nri/ceap/umrbdocumentation/.
[25] An area sample frame was used so that the results would represent conditions on the landscape. Representation of results in terms of enterprises or farms, rather than acres, is incompatible with the area sample frame.

on common practices found in their State. The State workshops ranged from 1.5 to 2.5 days. Training methods included section-by-section review of the questionnaire and identification of data relationships between sections.

An established protocol for enumerating, handling, and editing questionnaires was enacted once data collection began. At the start of data collection, field enumerators located and interviewed the respondents. If the initial contact was not the day-to-day decision maker, enumerators identified and located the correct respondent and conducted the interview. If three attempts to locate the respondent during the survey data collection period failed, the enumerator coded the questionnaire as "inaccessible."

Because participation in the CEAP Survey was voluntary, respondents had the option to decline the interview. Some respondents cooperated reluctantly and although they provided responses to some questions, declined to complete sections of the questionnaire that required more detailed information Incomplete surveys were not used for simulation modeling.

When beginning the interview, a screening process was used to determine if the NRI-CEAP point met the required definition of cultivated cropland. If a crop was planted or cropped for production, or if the cropland was idled, in summer fallow, or pasture in rotation with crops, the sample was considered usable for survey purposes and the entire questionnaire was enumerated. If the sample did not meet these criteria, the interview was concluded and the sample points were considered to be out-of-scope.

--29 tables summarizing results from the survey will follow.

Appendix C: Model simulation results on the baseline conservation condition for the 14 subbasins

Model simulation results presented in Chapter 4 for the baseline conservation condition are presented in tables C-1 and C-2 for the 14 subbasins in the UMRB. The column headings refer to the subbasin code. The names of the subbasins are shown below:

Sub-basin code	Subbasin name
0701	Mississippi Headwaters
0702	Minnesota River Basin
0703	St. Croix River Basin
0704	Upper Mississippi-Black-Root
0705	Chippewa River Basin
0706	Upper Mississippi-Maquoketa-Plum
0707	Wisconsin River Basin
0708	Upper Mississippi-Iowa-Skunk-Wapsipinicon
0709	Rock River Basin
0710	Des Moines River Basin
0711	Upper Mississippi-Salt
0712	Upper Illinois River Basin
0713	Lower Illinois River Basin
0714	Upper Mississippi-Kaskaskia-Meramec

Table C-1. Average annual estimates of water flow, erosion, and soil organic carbon for the baseline conservation condition for each of the 14 subbasins in the Upper Mississippi River Basin.

Model simulated outcome	UMRB	0701	0702	0703	0704	0705	0706	0707
Cropped acres (million acres)	58,153,500	2,672,400	7,343,800	505,800	2,704,200	878,900	2,602,200	1,363,100
Percent of acres in UMRB	100	4.6%	12.6%	0.9%	4.7%	1.5%	4.5%	2.3%
Percent of acres irrigated	2.5	14.1%	0.2%	1.6%	1.5%	1.5%	0.0%	7.3%
Water sources (average annual inches)								
Non-irrigated acres								
Precipitation	33.6	28.0	27.4	31.0	32.2	32.1	34.1	32.2
Irrigated acres								
Precipitation	33.1	27.1	25.5	31.3	31.0	31.8	0.0	32.1
Irrigation water applied	9.3	6.7	11.6	4.9	11.1	14.9	0.0	5.8
Water loss pathways (average annual inches)								
Evapotranspiration	23.4	20.1	22.0	20.5	22.5	21.4	22.7	21.6
Surface water runoff	4.0	3.2	2.5	3.4	4.0	3.8	4.0	4.0
Subsurface water flow	6.7	5.7	2.8	7.6	5.8	8.1	7.3	6.9
Erosion and sediment loss (average annual tons/acre)								
Wind erosion	0.24	0.68	0.62	0.42	0.17	0.21	0.13	0.24
Sheet and rill erosion	1.04	0.85	0.59	1.37	1.24	1.33	1.24	1.04
Sediment loss at edge of field due to water erosion	0.98	0.80	0.36	1.60	1.63	1.79	1.44	1.40
Soil organic carbon (average annual pounds/acre)								
Loss of soil organic carbon with wind and water erosion	189	136	150	206	252	188	224	198
Change in soil organic carbon, including loss of carbon with wind and water erosion	70	-95	10	-70	26	-40	128	-58

Table C-1.—continued

Model simulated outcome	0708	0709	0710	0711	0712	0713	0714
Cropped acres (million acres)	10,383,100	4,206,000	6,309,500	2,780,300	3,989,500	8,346,900	4,067,800
Percent of acres in UMRB	17.9%	7.2%	10.8%	4.8%	6.9%	14.4%	7.0%
Percent of acres irrigated	1.6%	2.0%	1.1%	1.4%	5.4%	3.9%	0.0%
Water sources (average annual inches)							
Non-irrigated acres							
Precipitation	34.3	34.1	31.8	37.5	36.2	36.5	40.4
Irrigated acres							
Precipitation	35.1	34.7	30.1	37.9	37.8	36.7	0.0
Irrigation water applied	9.6	10.1	14.0	15.2	10.1	10.5	0.0
Water loss pathways (average annual inches)							
Evapotranspiration	23.5	23.1	23.0	24.8	23.7	25.1	25.9
Surface water runoff	4.4	4.4	3.6	5.8	4.4	4.3	4.3
Subsurface water flow	6.6	6.7	5.2	8.0	9.3	7.6	10.7
Erosion and sediment loss (average annual tons/acre)							
Wind erosion	0.21	0.09	0.37	0.09	0.10	0.05	0.03
Sheet and rill erosion	1.24	1.55	0.81	1.59	0.84	0.96	0.88
Sediment loss at edge of field due to water erosion	1.16	1.70	0.59	1.46	0.77	0.81	0.68
Soil organic carbon (average annual pounds/acre)							
Loss of soil organic carbon with wind and water erosion	230	240	176	241	148	166	142
Change in soil organic carbon, including loss of carbon with wind and water erosion	104	54	104	51	55	155	90

Table C-2. Average annual estimates of nitrogen loss, phosphorus loss, and pesticide loss for the baseline conservation condition for each of the 14 subbasins in the Upper Mississippi River Basin

Model simulated outcome	UMRB	0701	0702	0703	0704	0705	0706	0707
Cropped acres (million acres)	58,153,500	2,672,400	7,343,800	505,800	2,704,200	878,900	2,602,200	1,363,100
Percent of acres in UMRB	100%	4.6%	12.6%	0.9%	4.7%	1.5%	4.5%	2.3%
Percent of acres with manure applied	16.3%	33.4%	16.8%	47.5%	27.7%	62.5%	37.2%	45.9%
Nitrogen (average annual pounds/acre)								
Nitrogen sources								
Atmospheric deposition	6.0	4.8	5.4	4.9	5.8	5.2	6.3	5.8
Bio-fixation by legumes	57.9	37.0	46.4	49.4	50.1	46.6	56.6	43.6
Nitrogen applied as commercial fertilizer and manure	87.8	85.8	77.7	89.3	95.9	95.9	97.7	116.3
All nitrogen sources	151.7	127.5	129.5	143.7	151.9	147.6	160.6	165.8
Nitrogen loss pathways								
Nitrogen in crop yield removed at harvest	107.6	95.7	96.4	89.4	102.8	102.4	108.3	105.5
Nitrogen loss by volatilization	6.7	5.3	7.0	7.2	7.7	8.1	7.6	8.2
Nitrogen loss through denitrification processes	2.2	1.2	1.5	1.1	2.1	1.3	3.3	2.9
Nitrogen lost with windborne sediment	2.1	3.1	5.5	2.9	1.5	1.3	1.1	1.6
Nitrogen loss with surface runoff , including waterborne sediment	8.6	6.7	4.1	11.2	14.2	11.3	11.9	11.6
Nitrogen loss in subsurface flow pathways	21.8	25.8	16.3	39.3	25.1	29.3	21.5	43.4
Total nitrogen loss for all pathways except harvest	41.3	42.1	34.3	61.7	50.6	51.3	45.4	67.6
Change in soil nitrogen	1.8	-11.1	-2.2	-8.4	-2.7	-7.4	5.8	-8.3
Phosphorus (average annual pounds/acre)								
Phosphorus applied as commercial fertilizer and manure	22.3	21.3	20.9	25.5	23.9	26.9	23.7	36.7
Phosphorus loss pathways								
Phosphorus in crop yield removed at harvest	17.0	15.4	15.0	12.3	15.8	14.0	16.6	14.3
Phosphorus lost with windborne sediment	0.4	0.8	1.0	0.8	0.3	0.3	0.2	0.4
Phosphorus lost with surface runoff, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage ditches	2.5	2.5	1.2	3.5	3.3	3.7	2.8	6.4
Soluble phosphorus loss to groundwater	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total phosphorus loss for all pathways except harvest	3.0	3.3	2.2	4.4	3.6	4.1	3.1	6.9
Change in soil phosphorus	2.2	2.7	3.7	8.8	4.2	8.7	3.8	15.6
Pesticides								
Average annual amount of pesticides applied (grams of active ingredient/hectare)	1,650	1,054	1,279	835	1,281	1,024	1,492	1,778
Pesticide loss								
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	8.4	4.4	2.5	7.5	6.8	7.7	8.5	9.7
Edge-of-field pesticide risk indicator								
Average annual surface water pesticide risk indicator for aquatic ecosystem	2.6	12.7	1.1	0.6	1.0	0.8	2.1	1.8
Average annual surface water pesticide risk indicator for humans	0.4	0.4	0.2	0.2	0.2	0.2	0.3	0.2
Average annual groundwater pesticide risk indicator for humans	0.2	0.0	0.0	0.0	0.0	0.2	0.2	0.1

Table C-2. –continued

Model simulated outcome	0708	0709	0710	0711	0712	0713	0714
Cropped acres (million acres)	10,383,100	4,206,000	6,309,500	2,780,300	3,989,500	8,346,900	4,067,800
Percent of acres in UMRB	17.9%	7.2%	10.8%	4.8%	6.9%	14.4%	7.0%
Percent of acres with manure applied	15.1%	16.6%	14.0%	9.3%	6.9%	4.4%	4.4%
Nitrogen (average annual pounds/acre)							
Nitrogen sources							
Atmospheric deposition	6.2	6.2	6.1	6.0	6.6	6.4	5.9
Bio-fixation by legumes	61.8	53.2	64.4	71.7	54.9	64.2	72.1
Nitrogen applied as commercial fertilizer and manure	90.1	93.3	82.7	74.6	87.5	94.4	76.7
All nitrogen sources	158.1	152.7	153.2	152.3	149.0	165.0	154.7
Nitrogen loss pathways							
Nitrogen in crop yield removed at harvest	110.8	102.8	110.7	115.8	104.1	115.1	116.6
Nitrogen loss by volatilization	6.8	7.6	6.6	6.5	6.3	5.9	6.1
Nitrogen loss through denitrification processes	2.7	2.8	1.9	2.2	3.2	2.1	1.7
Nitrogen lost with windborne sediment	2.1	0.9	3.7	0.8	0.8	0.5	0.3
Nitrogen loss with surface runoff , including waterborne sediment	10.2	13.9	5.6	12.1	6.9	7.6	6.4
Nitrogen loss in subsurface flow pathways	20.6	22.6	18.6	14.2	27.3	23.7	19.3
Total nitrogen loss for all pathways except harvest	42.4	47.8	36.4	35.8	44.5	39.7	33.8
Change in soil nitrogen	3.8	0.8	5.1	0.0	-0.6	9.3	3.6
Phosphorus (average annual pounds/acre)							
Phosphorus applied as commercial fertilizer and manure	21.8	22.4	21.4	20.7	20.5	22.7	22.2
Phosphorus loss pathways							
Phosphorus in crop yield removed at harvest	18.0	16.3	17.8	17.7	17.0	18.6	17.8
Phosphorus lost with windborne sediment	0.4	0.2	0.7	0.2	0.2	0.1	0.1
Phosphorus lost with surface runoff, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage ditches	2.7	4.1	1.6	3.2	2.1	2.5	2.4
Soluble phosphorus loss to groundwater	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total phosphorus loss for all pathways except harvest	3.1	4.3	2.3	3.4	2.3	2.6	2.5
Change in soil phosphorus	0.5	1.6	1.2	-0.5	1.2	1.3	1.8
Pesticides							
Average annual amount of pesticides applied (grams of active ingredient/hectare)	1,748	1,743	1,570	1,690	2,014	2,060	1,798
Pesticide loss							
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	10.9	9.2	5.9	13.7	8.8	10.1	11.3
Edge-of-field pesticide risk indicator							
Average annual surface water pesticide risk indicator for aquatic ecosystem	2.1	2.0	2.7	2.6	2.7	3.2	1.4
Average annual surface water pesticide risk indicator for humans	0.5	0.3	0.3	0.7	0.4	0.6	0.4
Average annual groundwater pesticide risk indicator for humans	0.2	0.1	0.1	0.1	0.4	0.3	0.3