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Conservation Effects Assessment Project (CEAP)

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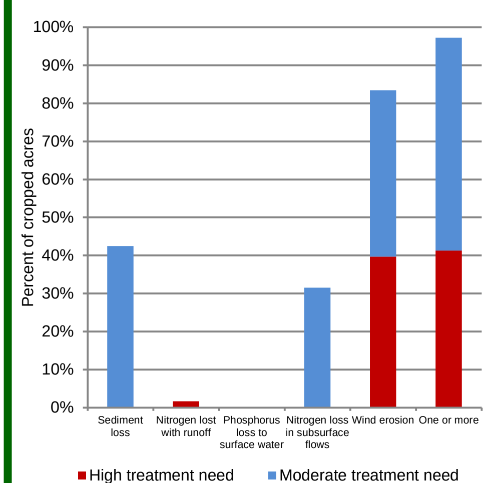
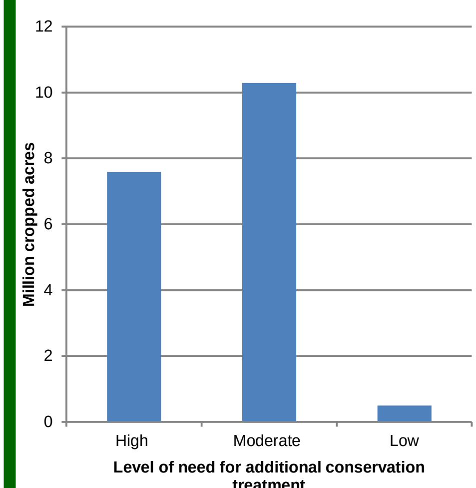
Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Texas Gulf Basin





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Cover photos by (clockwise from top left) **USDA photograph, Gary Kramer, Bob Nichols,** and **Gary Kramer** USDA Natural Resources Conservation Service

CEAP—Strengthening the science base for natural resource conservation

The Conservation Effects Assessment Project (CEAP) was initiated by USDA's Natural Resources Conservation Service (NRCS), Agricultural Research Service (ARS), and Cooperative State Research, Education, and Extension Service (CSREES—now National Institute of Food and Agriculture [NIFA]) in response to a general call for better accountability of how society would benefit from the 2002 Farm Bill's substantial increase in conservation program funding (Mausbach and Dedrick 2004). The original goals of CEAP were to estimate conservation benefits for reporting at the national and regional levels and to establish the scientific understanding of the effects and benefits of conservation practices at the watershed scale. As CEAP evolved, the scope was expanded to provide research and assessment on how to best use conservation practices in managing agricultural landscapes to protect and enhance environmental quality.

CEAP activities are organized into three interconnected efforts:

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

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

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.

Natural Resources Conservation Service, USDA

Daryl Lund, **Project Coordinator**, Beltsville, MD, Soil Scientist
Jay D. Atwood, Temple, TX, Agricultural Economist
Joseph K. Bagdon, Amherst, MA, Agronomist and Pest Management Specialist
Jim Benson, Beltsville, MD, Program Analyst (retired)
Jeff Goebel, Beltsville, MD, Statistician (retired)
Kevin Ingram, Beltsville, MD, Agricultural Economist
Mari-Vaughn V. Johnson, Temple, TX, Agronomist
Robert L. Kellogg, Beltsville, MD, Agricultural Economist (retired, Earth Team Volunteer)
Jerry Lemunyon, Fort Worth, TX, Agronomist and Nutrient Management Specialist (retired, Earth Team Volunteer)
Lee Norfleet, Temple, TX, Soil Scientist
Evelyn Steglich, Temple, TX, Natural Resource Specialist

Agricultural Research Service, USDA, Grassland Soil and Water Research Laboratory, Temple, TX

Jeff Arnold, Agricultural Engineer
Mike White, Agricultural Engineer

Blackland Center for Research and Extension, Texas AgriLife Research, Temple, TX

Tom Gerik, Director
Santhi Chinnasamy, Agricultural Engineer
Mauro Di Luzio, Research Scientist
Arnold King, Resource Conservationist
David C. Moffitt, Environmental Engineer
Kannan Narayanan, Agricultural Engineer
Theresa Pitts, Programmer
Xiuying (Susan) Wang, Agricultural Engineer
Jimmy Williams, Agricultural Engineer

University of Massachusetts Extension, Amherst, MA

Stephen Plotkin, Water Quality Specialist

The study was completed under the direction of **David Smith**, Deputy Chief for Soil Science and Resource Assessment, **Michele Laur**, Director for Resource Assessment Division, and **Mike Golden**, **Douglas Lawrence**, **Wayne Maresch**, **William Puckett,** and **Maury Mausbach**, former Deputy Chiefs for Soil Survey and Resource Assessment, NRCS. Executive support was provided by the current NRCS Chief, **Jason Weller**, and former NRCS Chiefs **Dave White**, **Arlen Lancaster**, and **Bruce Knight**.

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Foreword

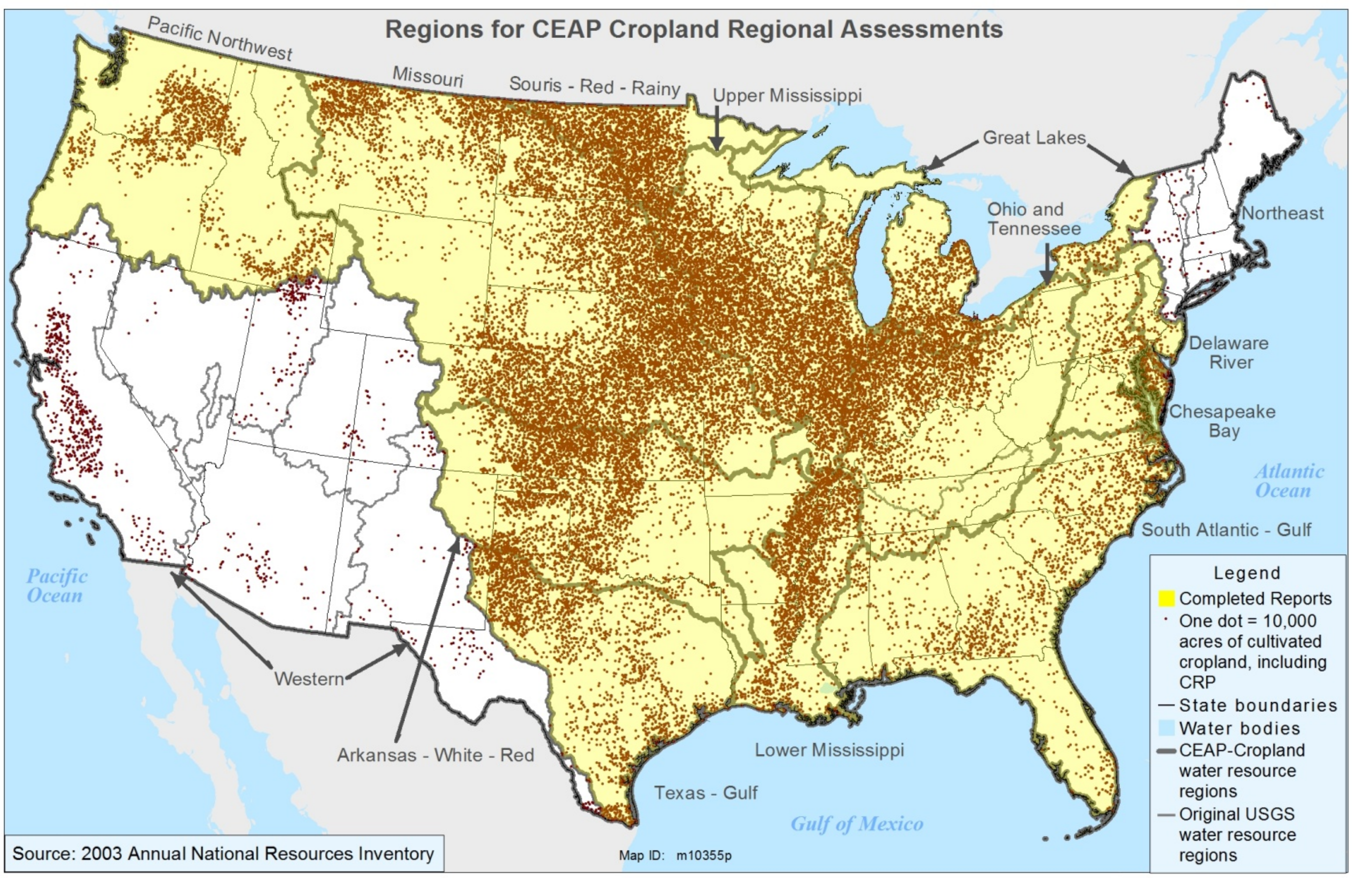
The United States Department of Agriculture has a rich tradition of working with farmers and ranchers to enhance agricultural productivity and environmental protection. Conservation pioneer Hugh Hammond Bennett worked tirelessly to establish a nationwide Soil Conservation Service along with a system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

USDA conservation programs are voluntary. Many provide financial assistance to producers to help encourage adoption of conservation practices. Others provide technical assistance to design and install conservation practices consistent with the goals of the operation and the soil, climatic, and hydrologic setting. By participating in USDA conservation programs, producers are able to—

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

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

The Conservation Effects Assessment Project (CEAP) continues the tradition within USDA of assessing the status, condition, and trends of natural resources to determine how to improve conservation programs to best meet the Nation's needs. CEAP reports use a sampling and modeling approach to quantify the environmental benefits that farmers and conservation programs are currently providing to society, and explore prospects for attaining additional benefits with further conservation treatment. CEAP findings have been released in a series of 12 reports for the 12 regions shown in yellow in the following map.



Model Results Presented in This Report Were Obtained Using an Upgraded APEX Model Version and Enhanced Soil Data

The APEX model used to estimate edge-of-field losses of sediment, nutrients and pesticides in this report is a different version than was used for the previous 11 CEAP reports, as well as earlier drafts of the Texas Gulf Basin report. The upgraded model is called APEXv1307, which replaces the older version, APEXv2110. APEXv1307 incorporates improvements in the routing of surface and subsurface flows and losses of nutrients and sediments from one subarea to the next, thus improving the capability of the model to estimate benefits of conservation practices such as buffers, filters, and drainage water management. The newer APEX model version was used for the final report on the Texas Gulf Basin because reviewers of an earlier draft concluded that we had understated the severity of the conservation treatment need in the region. Results obtained using the newer version of the model portray a more realistic picture of the conservation challenge for this region.

In addition, the source of soils characteristics (soil layer profiles, bulk density, soil texture, etc.) used in the modeling was expanded to include soil data from the national soil characterization database, which is derived from point data and organized by soil horizons. Use of these improved soil horizon data and associated soils characteristics produces more realistic estimations of the flow of water through the various pathways, root growth, changes in soil organic carbon over time, soil pH, and bulk density.

Consequently, results reported herein for the Texas Gulf Basin will not be directly comparable to results reported for other CEAP regions in the 11 previous reports. Results will be more comparable, however, to recent findings for CEAP special study areas.

Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Texas Gulf Basin

Contents

Documentation Reports

There are a series of documentation reports and associated publications by the modeling team posted on the CEAP website at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/pub/. (Go to the "National Assessments: Cropland" section and click on "full list of modeling documentation reports.") Included are the following reports that provide details on the modeling and databases used in this report:

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

Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Texas Gulf Basin

Executive Summary

Agriculture in the Texas Gulf Basin

The Texas Gulf Basin covers about 182,000 square miles and includes western Louisiana, a small portion of eastern New Mexico, and the majority of Texas. The basin lies just south of the Arkansas-White-Red Basin and discharges into the Gulf of Mexico along the entire Texas coast and western Louisiana coast. Agricultural land makes up most of the area—44 percent of the area is rangeland, 15 percent is cultivated cropland, 8 percent is permanent pastureland, and 3 percent is permanent hayland. About 8 percent of the basin area is urban land. Forestland makes up most of the remaining 22 percent.

Agriculture is an important part of the economy in the region. The value of Texas Gulf Basin agricultural sales in 2007 was about $13 billion—about 38 percent from crops and 62 percent from livestock. Farms in the Texas Gulf Basin make up about 9 percent of all land on farms in the Nation. Upland cotton, sorghum, hay, and wheat are the principal crops grown. About 40 percent of the Nation's upland cotton acres and 29 percent of the Nation's sorghum-for-grain acres are in this region. Livestock sales in the region are dominated by cattle sales, which totaled $4.8 billion in 2007 and represented 8 percent of all cattle sales nationally. Though less economically important, around 11 percent of the Nation's sheep, goats, and associated products in 2007 were produced in the region, which totaled $76 million in sales. Poultry and egg sales are also important, totaling $1.8 billion in sales in 2007 and representing 5 percent of the Nation's poultry and egg sales.

The 2007 Census of Agriculture reported 213,033 farms in the Texas Gulf Basin, about 10 percent of the total number of farms in the United States. In terms of gross sales, most of the farms are small; in 2007, 87 percent had less than $50,000 in total farm sales and only 8 percent had $50,000 to $250,000 in total farm sales. Farms with total agricultural sales greater than $250,000 accounted for 5 percent of the farms. About 44 percent of the farms primarily raise crops, about 51 percent are primarily livestock operations, and the rest produce a mix of livestock and crops.

Agriculture in this region is not as inherently productive as in the Upper Mississippi River Basin or the Ohio-Tennessee River Basin because of lower precipitation and generally less fertile, more highly weathered soils. Precipitation on cropped acres in the Texas Gulf Basin averages 27 inches per year, compared to 34 inches per year in the Upper Mississippi River Basin and 42 inches per year in the Ohio-Tennessee River Basin. In 2007, 3.1 million acres (22 percent of harvested acres) were irrigated in the Texas Gulf Basin.

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

The primary focus of the CEAP Texas Gulf Basin study is on the 15 percent of the basin that is cultivated cropland. The study was designed to—

- quantify the effects of conservation practices commonly used on cultivated cropland in the Texas Gulf Basin during 2003–06,
- evaluate the need for additional conservation treatment in the region on the basis of wind erosion and edge-of-field sediment and nutrient losses, including nutrient losses that infiltrate below the root zone, and
- estimate the potential gains that could be attained with additional conservation treatment.

The assessment uses a statistical sampling and modeling approach to estimate the effects of conservation practices. The National Resources Inventory (NRI), 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 for the study. Physical process simulation models were used to estimate the effects of conservation practices that were in use during the period 2003–06. Information on farming activities and conservation practices was obtained primarily from a farmer survey conducted as part of the study. The assessment includes not only practices associated with Federal conservation programs but also the conservation efforts of States, independent organizations, and individual landowners and farm operators. The analysis assumes that structural practices (such as buffers, terraces, and grassed waterways) reported in the farmer survey or obtained from other data sources were appropriately designed, installed, and maintained.

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

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

The effects of conservation practices are obtained by taking the difference in model results between the two scenarios. The need for additional conservation treatment was evaluated using a common set of criteria and protocols applied to all regions in the country to provide a systematic, consistent, and comparable assessment at the national level.

Voluntary, Incentives-Based Conservation Approaches Are Achieving Results

Given the long history of conservation in the Texas Gulf Basin, it is not surprising to find that most cropped acres in the region have some conservation practice use, including both soil erosion control practices and nutrient management practices on most acres.

Conservation Practice Use

The farmer survey found, for the period 2003–06, that producers use either residue and tillage management practices or structural practices, or both, on 66 percent of the acres.

- Structural practices for controlling water erosion are in use on 37 percent of cropped acres. On the 33 percent of the acres designated as highly erodible land, structural practices designed to control water erosion are in use on 35 percent.
- Structural practices for controlling wind erosion are in use on only 3 percent of cropped acres.
- About 30 percent of the cropped acres meet criteria for mulch till.
- No-till is not as common as in other regions; only 5 percent of cropped acres meet criteria for no-till.
- Fifty-two percent of cropped acres are conventionally tilled.

The farmer survey also found that nutrient management practices are frequently used on cropped acres in the Texas Gulf Basin. Cropping systems are less intensely fertilized with lower application rates, drier planting seasons, and more crops harvested during the summer than cropped acres in most other parts of the country.

- About 17 percent of cropped acres have no nitrogen applied. An additional 44 percent of cropped acres meet criteria for timing of nitrogen applications on all crops in the rotation, 63 percent meet criteria for method of application, and 51 percent meet criteria for rate of application.
- About 34 percent of cropped acres have no phosphorus applied. An additional 35 percent of cropped acres meet criteria for timing of phosphorus applications on all crops in the rotation, 52 percent meet criteria for method of application, and 19 percent meet criteria for rate of application.
- About 30 percent of cropped acres meet nutrient management criteria for both nitrogen and phosphorus management, including 17 percent of cropped acres not receiving either nitrogen or phosphorus applications.

About 13 percent of cropped acres are gaining soil organic carbon (that is, the average annual change in soil organic carbon is greater than zero).

Land in long-term conserving cover, as represented by enrollment in the Conservation Reserve Program (CRP) General Signup, consists of about 2.5 million acres—13 percent of the cultivated cropland acres in the region. About 60 percent of the land in long-term conserving cover is highly erodible.

Conservation Accomplishments at the Field Level

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

- reduced wind erosion by 2 percent;
- reduced waterborne sediment loss from fields by 52 percent;
- reduced total nitrogen loss (all loss pathways) by 21 percent;
- reduced nitrogen lost with windborne sediment by less than 1 percent;
- reduced nitrogen lost with surface runoff (attached to sediment and in solution) by 45 percent;
- reduced nitrogen loss in subsurface flows by 29 percent;
- reduced total phosphorus loss (all loss pathways) from fields by 33 percent;
- reduced phosphorus lost with windborne sediment by 19 percent; and
- reduced pesticide loss from fields to surface water, resulting in a 49-percent reduction in edge-of-field pesticide risk (all pesticides combined) for humans and a 62-percent reduction for aquatic ecosystems.

Use of improved irrigation systems in the Texas Gulf Basin represents an annual decreased need for irrigation water of 6.4 inches per year where irrigation is used.

At 2.5 million acres, land in long-term conserving cover is not a significant part of the agricultural landscape in most of the Texas Gulf Basin, but it is important in some subregions. The benefits of this conservation "practice" were estimated by simulating crop production on these acres without use of conservation practices. Model simulation results show that wind erosion and sediment loss due to water erosion have been almost completely eliminated for land in long-term conserving cover. Compared to a cropped condition without conservation practices, total nitrogen loss has been reduced by 25 percent, total phosphorus loss has been reduced by 99 percent, and soil organic carbon has been increased by an average of 376 pounds per acre per year on these acres.

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

Conservation Accomplishments at the Watershed Level

Reductions in field-level losses due to conservation practices are expected to improve 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. Edge-of-field losses of sediment, nitrogen, phosphorus, and the pesticide atrazine were incorporated into a national water quality model to estimate the extent to which conservation practices have reduced amounts of these contaminants delivered to rivers and streams throughout the region. Of the total loads *delivered to rivers and streams* from all sources, cultivated cropland in the Texas Gulf Basin is the source for 66 percent of the sediment, 31 percent of the nitrogen, and 7 percent of the phosphorus.

The model simulations showed that conservation practices in use during the period 2003–06, including land in long-term conserving cover, have reduced average annual loads *delivered to rivers and streams* within the basin, compared to a no-practice scenario, by 60 percent for sediment, 41 percent for nitrogen, 55 percent for phosphorus, and 36 percent for atrazine.

The national water quality model also provided estimates of reductions in *instream loads* due to conservation practice use. *When considered along with loads from all other sources*, conservation practices in use on cultivated cropland in 2003–06 have reduced total instream loads delivered from this region to the Gulf of Mexico by 12 percent for sediment, 10 percent for nitrogen, 6 percent for phosphorus, and 33 percent for atrazine. These percent reductions are relatively low because of the system of reservoirs along the major rivers in the Basin, which trap significant amounts of sediment, nitrogen, and phosphorus delivered from cultivated cropland to rivers and streams.

The evaluation of conservation practices are based on practice use derived from a farmer survey conducted during the years 2003–06. Implementation of the 2008 Farm Bill expanded conservation funding throughout the country. As a result, farmers have increased the use of appropriate nutrient management, cover crops, integrated pest management, and other practices. It is therefore possible that the effects of conservation practice use within this region are greater today than reported here.

Opportunities Exist to Further Reduce Soil Erosion and Nutrient Losses from Cultivated Cropland

While farmers in the Texas Gulf Basin have made progress in reducing losses from farm fields through conservation practice adoption, opportunity for further reduction through improved conservation practices remains. Nearly all cropped acres (97 percent of cropped acres) have a **high** or **moderate** level of need for additional conservation treatment. Acres with a **high** level of need (7.6 million acres) consist of the most vulnerable acres with the least conservation treatment and the highest field-level losses. Acres with a **moderate** level of need (10.3 million acres) consist of undertreated acres that have lower levels of vulnerability or have more conservation practice use than acres with a **high** level of need but still have unacceptable levels of soil erosion or nutrient loss at the field level.

Nearly all acres with a high level of need for conservation treatment *need additional treatment only for wind erosion*. Wind erosion for acres with a high need for additional treatment averaged 14.2 tons per acre per year, compared to 4.75 tons per acre per year for acres with a moderate need and 0.69 ton per acre for acres with a low need. Associated losses of nitrogen and phosphorus were also very high for these acres. About 11.7 pounds per acre of nitrogen and 1.81 pounds per acre of phosphorus are lost with windborne sediment, on average, for the 7.6 million acres with a high need for additional treatment.

Acres with a “moderate” level of need for conservation treatment in this region consist of undertreated acres that generally have excessive wind erosion rates and excessive losses of nitrogen in subsurface flows and sediment lost with water erosion. Many of these acres are located in the eastern portion of the region where precipitation is highest. Sediment loss for these acres averages 1.4 tons per acre per year, and nitrogen loss in subsurface flows averages 19 pounds per acre per year. The acres needing additional treatment for wind erosion also have high wind erosion rates, but overall not as high as for acres with a high need for additional treatment.

Model simulations show that adoption of additional erosion control and nutrient management practices on all undertreated acres (97 percent of cropped acres in the region) would, compared to the 2003–06 baseline, further reduce field losses over all cropped acres in the region by—

- 47 percent for wind erosion,
- 66 percent for phosphorus lost with windborne sediment
- 55 percent for nitrogen lost with windborne sediment,
- 86 percent for waterborne sediment loss,
- 27 percent for total nitrogen loss, and
- 60 for phosphorus lost to surface water.

These field-level reductions would, in turn, further reduce *loads delivered to rivers and streams from cultivated cropland* in the region, relative to the baseline conservation condition, by 84 percent for sediment, 32 percent for nitrogen, 63 percent for phosphorus, and 80 percent for atrazine.

This level of additional conservation treatment would also reduce *total instream loads delivered from the region to the Gulf of Mexico from all sources* by 19 percent for sediment, 8 percent for nitrogen, 4 percent for phosphorus, and 83 percent for atrazine. These reductions in instream nitrogen and phosphorus loads from further conservation treatment are relatively modest because of majority of these loads originate from non-point and point sources within the Basin.

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

- innovations in implement design to enhance precise nutrient application and placement, including variable rate technologies and improved manure application equipment;
- enhanced-efficiency nutrient application products such as slow or controlled release fertilizers, polymer-coated products, nitrogen stabilizers, urease inhibitors, and nitrification inhibitors;
- drainage water management that controls discharge of drainage water and treats contaminants, thereby reducing the levels of nitrogen loss and even some soluble phosphorus loss;
- constructed wetlands receiving surface water runoff and drainage water from farm fields prior to discharge to streams and rivers; and
- improved crop genetics that increase yields without increasing nutrient inputs.

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

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

Not all acres provide the same benefit from conservation treatment. The more vulnerable acres, such as highly erodible land and soils prone to leaching or wind erosion, inherently lose more sediment or nutrients; therefore greater benefit can be attained with additional conservation treatment. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment and nutrient losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to nutrient losses through subsurface flow pathways.

The most pervasive conservation concern in the region is excessive rates of wind erosion during dry periods, including windborne losses of nitrogen and phosphorus. Wind erosion and windborne sediment adversely impact the soil, water, and air quality, and can cause human health issues. Wind erosion accounts for most of the soil and nutrient losses from farm fields in this region. Conservation practices in use during 2003–06 have been relatively ineffective in reducing wind erosion. Model simulations show that the average annual rate of wind erosion is 8.55 tons per acre for cropped acres in the region—12.38 tons per acre per year for highly erodible land and 6.65 tons per acre for non-highly erodible land. Average wind erosion rates vary considerably throughout the region. About 10 percent of cropped acres in the region lose an average of 24 tons or more per acre per year, while 23 percent of cropped acres in the region lose an average of one ton or less per acre per year. About 54 percent of total phosphorus and 21 percent of total nitrogen lost from fields is with windborne sediment.

Targeting program funding and technical assistance for accelerated treatment of acres with the most critical need for additional treatment is the most efficient way to reduce agricultural sources of contaminants from farm fields in this region. The reductions in wind erosion represented by practices in place for the entire basin are only 4 percent of potential reductions. By treating the 7.6 million critical undertreated acres (acres with a high need for treatment) for wind erosion, an additional 55 percent in savings could potentially be gained. To achieve 100 percent of the potential savings would require treating the 10.3 million moderate-need acres.

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

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

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

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

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

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

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

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

Chapter 1
Land Use and Agriculture in the Texas Gulf Basin

Land Use

The Texas Gulf Basin covers about 181,777 square miles and includes western Louisiana, a small portion of eastern New Mexico, and the majority of Texas. The basin lies just south of the Arkansas-White-Red Basin and discharges into the Gulf of Mexico along the entire Texas coast and western portion of the Louisiana coast.

The dominant land cover in the basin is rangeland (44 percent of the area, including water), most of which is brush rangeland located in the western, southern, and central parts of the basin (table 1, fig. 1).

Cultivated cropland accounts for about 15 percent of the area, the bulk of which is located in the northwest portion of the basin. (Cultivated cropland includes land in long-term conserving cover, which is represented by acres enrolled in the General Sign-up of the Conservation Reserve Program [CRP].) Forestland accounts for 19 percent of the area, a quarter of which is also wetlands. Most forested land is in the eastern parts of the region (fig. 1). Permanent pasture and hayland represent 11 percent of the area. Non-forested wetlands, horticulture, and barren land account for less than 1 percent of the area. Water accounts for about 3 percent.

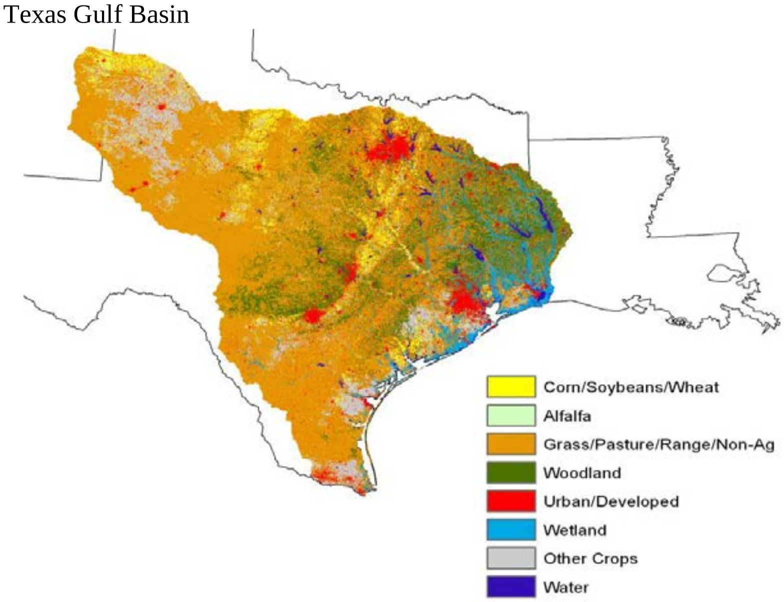
The remaining 8 percent of the area consists of urban land. Major metropolitan areas center include Houston, TX, Dallas-Fort Worth, TX, and San Antonio, TX. Other urban land is concentrated around Austin, TX, the Rio Grande Valley, Corpus Christi, TX, Killeen-Temple, TX, and Beaumont, TX.

Table 1. Distribution of land cover in the Texas Gulf Basin

Land use	Acres*	Percent including water	Percent excluding water
Cultivated cropland and land enrolled in the CRP General Signup**	17,116,566	15	15
Hayland not in rotation with crops	3,055,319	3	3
Pastureland not in rotation with crops	9,659,371	8	9
Rangeland—grass	18,626,821	16	16
Rangeland—brush	33,082,064	28	29
Horticulture	231,058	<1	<1
Forestland			
Deciduous	5,450,212	5	5
Evergreen	8,424,135	7	7
Mixed	1,762,235	2	2
Urban	8,770,734	8	8
Wetlands			
Forested	5,256,596	5	5
Non-Forested	1,401,832	1	1
Barren	557,918	<1	<1
Subtotal	113,394,859	97	100
Water	2,942,123	3	
Total	116,336,983	100	

Source: 2001 National Land Cover Database for the Conterminous United States (Homer et al. 2007).
*Acreage estimates for cultivated cropland differ slightly from those based on the NRI-CEAP sample because of differences in data sources and estimation procedures. Acres enrolled in the CRP General Signup are used to represent land in long-term conserving cover.
**Includes hayland and pastureland in rotation with crops.

Figure 1. Land cover in the Texas Gulf Basin



Source: National Agricultural Statistics Service (NASS 2007).

Agriculture

The 2007 Census of Agriculture reported 213,033 farms in the Texas Gulf Basin, about 10 percent of the total number of farms in the United States (table 2). Land on farms was about 87 million acres, representing about 77 percent of the land base within the region and about 9 percent of all land on farms in the Nation. According to the 2007 Census of Agriculture, the value of Texas Gulf Basin agricultural sales in 2007 was about $13 billion—38 percent from crops and 62 percent from livestock.

About 44 percent of Texas Gulf Basin farms primarily raise crops, about 51 percent are primarily livestock operations, and the remaining 5 percent produce a mix of livestock and crops (table 3).

The average farm in this region is about the same size as in most areas of the country—409 acres compared to an average farm size of 418 acres for the Nation (table 2). Three percent of the farms have more than 2,000 acres and 11 percent have 500 to 2,000 acres (table 3). In terms of gross sales, most of the farms are small; in 2007, 87 percent had less than $50,000 in total farm sales and only 8 percent had $50,000 to $250,000 in total farm sales (table 3). Farms with total agricultural sales greater than $250,000 (table 3) accounted for only 5 percent of the farms in the region.

Crop production

The Texas Gulf Basin accounted for about 3 percent of all U.S. crop sales in 2007, totaling $5 billion (table 2). Upland cotton, sorghum, hay, and wheat are the principal crops grown. About 40 percent of the Nation's upland cotton acres and 29 percent of the Nation's sorghum-for-grain acres are in this region. About 4 million acres of hay, most of which is grass hay, are grown for use as livestock feed. Rice and field corn are also important crops in some parts of the region.

Irrigation is important for crop production in some parts of the region. About 3 million acres of harvested cropland were irrigated in 2007 (table 2), representing 22 percent of cropland harvested in the region and 6 percent of all irrigated harvested land in the nation.

Commercial fertilizers, pesticides, and defoliants are widely used on agricultural land in the region (table 2). In 2007, 11 million acres of cropland were fertilized, 11 million acres of cropland and pasture were treated with chemicals for weed control, and 7 million acres of hay and cropland were treated for insect control. Roughly 3 million acres were treated with chemical defoliants and about 0.6 million acres had manure applied in 2007.

Livestock operations

The Texas Gulf Basin accounted for about 5 percent of all U.S. livestock sales in 2007, totaling $8 billion (table 2). Livestock sales in the region are dominated economically by cattle sales, which totaled $4.8 billion in 2007 and represented 8 percent of all cattle sales nationally. Sheep, goat, and associated product sales in the region make up 11 percent of the nation's total, but generate only $76 million dollars in sales (table 2). Poultry and egg sales were also important, totaling $1.8 billion in sales in 2007 and representing 5 percent of the Nation's poultry and egg sales.

In terms of animal units, livestock populations in the region are dominated by cattle, horses, sheep, and goats. An animal unit (AU) is 1,000 pounds of live animal weight calculated as a yearly average for each farm using information reported in the 2007 Census of Agriculture. Of the 8.7 million livestock animal units in the region, 6.9 million animal units are cattle, horses, sheep, and goats, excluding fattened cattle and dairy cows (table 2). These 6.9 million AUs account for 80 percent of the AUs in the region. Fattened cattle animal units totaled about 0.8 million, representing 9 percent of AUs in the region and 6 percent of fattened cattle animal units in the nation. Poultry animal units totaled 0.4 million AUs. Dairy cows, swine, and other livestock make up 7 percent of the livestock population in this region.

About 6,645 of the farms in the region (3 percent) could be defined as animal feeding operations (AFOs) (table 3). AFOs are livestock operations typically with confined poultry, swine, dairy cattle, or beef cattle. An additional 70,922 farms have significant numbers of pastured livestock (33 percent of farms). About 1,099 of the livestock operations (16.5 percent of the AFOs) are relatively large, with livestock numbers in 2007 above the EPA minimum threshold for a medium concentrated animal feeding operation (CAFO). Of these, about 480 meet livestock population criteria for a large CAFO.

Statistics for the Texas Gulf Basin reported in table 2 are for the year 2007 as reported in the Census of Agriculture. For some characteristics, different acre estimates are reported in subsequent sections of this report based on the NRI-CEAP sample. Estimates based on the NRI-CEAP sample are for the time period 2003–06. See chapter 2 for additional aspects of estimates based on the NRI-CEAP sample.

For example, the Census of agriculture reports that about 22 percent of harvested acres were irrigated in 2007 (table 2). Based on the NRI-CEAP sample for 2003–06, about 30 percent of cropped acres in the region had the facilities and equipment to irrigate the sample field in one or more of the four survey years. The amount of acres that receive irrigation water varies from year to year.

Table 2. Profile of farms and land in farms in the Texas Gulf Basin, 2007

Characteristic	Value	Percent of national total
Number of farms	213,033	10
Acres on farms	87,192,954	9
Average acres per farm	409	
Cropland harvested, acres	14,280,957	5
Cropland used for pasture, acres	5,888,799	16
Cropland on which all crops failed, acres	692,292	9
Cropland in summer fallow, acres	615,004	4
Cropland idle or used for cover crops, acres	3,211,603	8
Woodland pastured, acres	4,722,094	17
Woodland not pastured, acres	1,529,210	3
Permanent pasture and rangeland, acres	54,396,134	13
Other land on farms, acres	1,856,861	6
Principal crops grown		
Cotton, acres	4,122,585	40
Tame and wild hay harvested, acres	3,594,997	11
Sorghum for grain harvested, acres	1,961,345	29
Wheat harvested, all types, acres	1,771,525	3
Field corn for grain harvested, acres	1,280,182	1
Small grain hay harvested, acres	478,268	12
Rice, acres	144,694	5
Irrigated harvested land, acres	3,119,578	6
Irrigated pastureland or rangeland, acres	247,822	5
Cropland fertilized, acres	10,730,220	4
Pastureland fertilized, acres	4,224,759	17
Land treated for insects on hay or other crops, acres	7,353,895	8
Land treated for nematodes in crops, acres	544,566	7
Land treated for diseases in crops and orchards, acres	501,882	2
Land treated for weeds in crops and pasture, acres	11,286,598	5
Crops on which chemicals for defoliation applied, acres	2,986,863	25
Acres on which manure was applied	606,351	3
Total grains and oilseeds sales, million dollars	1,420	2
Total nursery, greenhouse, and floriculture sales, million dollars	784	5
Total cotton and cottonseed sales, million dollars	1,644	34
Total hay and other crop sales, million dollars	1,109	2
Total crop sales, million dollars	4,956	3
Total cattle sales, million dollars	4,832	8
Total poultry and eggs sales, million dollars	1,789	5
Total hog and pigs sales, million dollars	17	<1
Total dairy sales, million dollars	1,247	4
Total horses, ponies, and mules sales, million dollars	97	5
Total sheep, goats, and their products sales, million dollars	76	11
Total other livestock sales, million dollars	100	4
Total livestock sales, million dollars	8,158	5
Animal units on farms		
All livestock types	8,706,094	8
Swine	16,100	<1
Dairy cows	549,426	4
Fattened cattle	815,935	6
Other cattle, horses, sheep, goats	6,932,675	12
Chickens, turkeys, and ducks	353,684	4
Other livestock	38,274	10

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 Texas Gulf Basin, 2007

	Number of farms	Percent of farms in Texas Gulf Basin
Farming primary occupation	84,044	39
Farm size:		
<50 acres	87,143	41
50–500 acres	95,366	45
500–2,000 acres	23,127	11
>2,000 acres	7,397	3
Farm sales:		
<$10,000	141,015	66
$10,000–50,000	45,178	21
$50,000–250,000	17,679	8
$250,000–500,000	3,702	2
>$500,000	5,459	3
Farm type:		
Crop sales make up more than 75 percent of farm sales	93,122	44
Livestock sales make up more than 75 percent of farm sales	109,244	51
Mixed crop and livestock sales	10,667	5
Farms with no livestock sales	53,854	25
Farms with few livestock or specialty livestock types	81,612	38
Farms with pastured livestock and few other livestock types	70,922	33
Farms with animal feeding operations (AFOs)*	6,645	3

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. An animal unit is 1,000 pounds of live animal weight, calculated as a yearly average for each farm using information reported in the 2007 Census of Agriculture.

Watersheds

A hydrologic accounting system consisting of water resource regions, major subregions, and smaller watersheds has been defined by the U.S. Geological Survey (USGS) (1980). Each water resource region is designated with a 2-digit Hydrologic Unit Code (HUC), which is further divided into 4-digit subregions and then into 8-digit cataloging units, or watersheds. The Texas Gulf Texas Gulf drainage is represented by 11 subregions.

The concentration of cultivated cropland within each subregion is an important indicator of the extent to which sediment and nutrient loads in rivers and streams are influenced by farming operations. Nearly half of the cultivated cropland in the region is found in 2 of the 11 subregions, both of which are located in the western portion of the basin (table 4):

- Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205), with 29 percent, and
- Upper Colorado River Basin (code 1208), with 19 percent.

In the Brazos headwaters-Salt Fork-Double Mountain Fork Basin, cropland makes up 53 percent of the land base (table 4 and fig. 2). Thirty-two percent of the land base is in cultivated cropland in the Upper Colorado River Basin (code 1208). Cultivated cropland makes up less than 18 percent of the land base in each of the other subregions (table 4).

Cultivated cropland is a very minor land use in two subregions, where it accounts for only a small percentage of the land base within each subregion:

- Sabine River Basin (code 1201), with 2 percent,
- Neches River Basin (code 1202), with 1 percent,

Cultivated cropland includes land in long-term conserving cover, which represents about 13 percent of the cultivated cropland acres in this region (table 4). The two subregions with the highest proportion of land in long-term conserving cover are also the two subregions with the highest percentage of cultivated cropland:

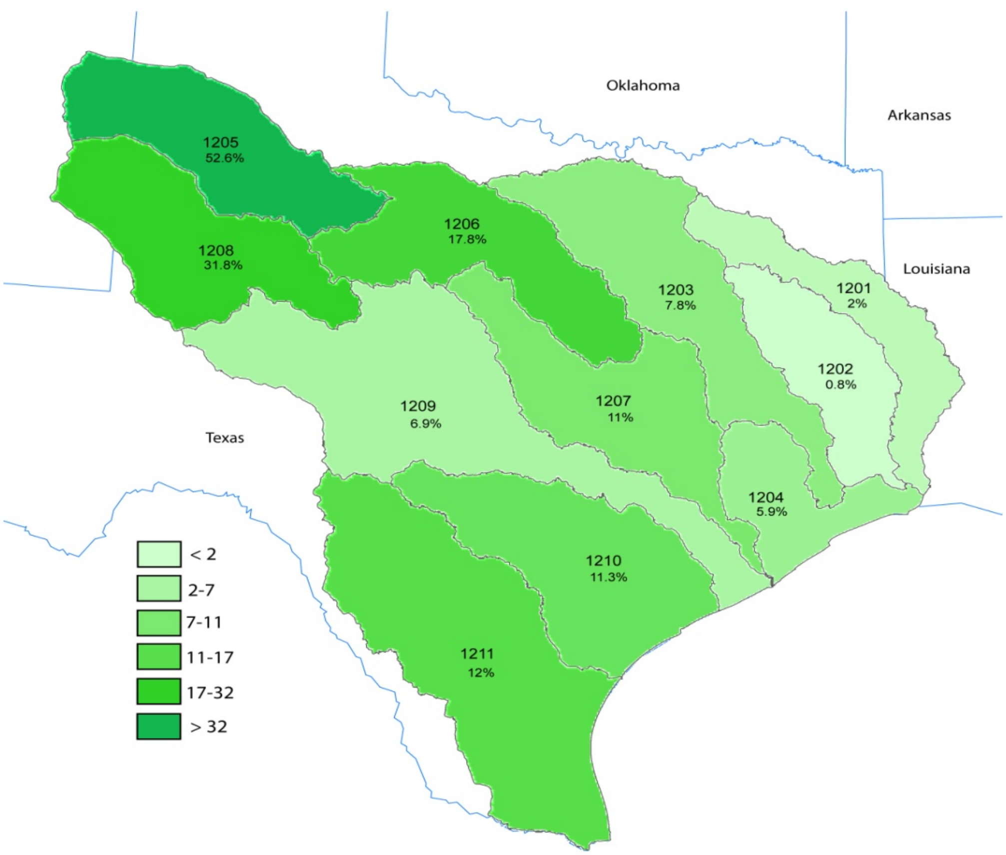
- Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205), with 18 percent, and
- Upper Colorado River Basin (code 1208), with 28 percent.

Table 4. Cultivated cropland use in the 11 subregions in the Texas Gulf Basin*

Subregion	Total area (acres)	Cultivated cropland (acres)*	Percent cultivated cropland in subregion	Percent of cultivated cropland in the Texas Gulf Basin	Percent of cultivated cropland acres in long-term conserving cover
Sabine River Basin (code 1201)	6,303,895	124,191	2.0	0.7	1.1
Neches River Basin (code 1202)	6,370,356	52,513	0.8	0.3	0.4
Upper and Lower Trinity Basin (code 1203)	11,508,081	892,712	7.8	5.2	2.4
San Jacinto River-Galveston Bay-Sabine Lake (code 1204)	5,046,989	295,635	5.9	1.7	0.0
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	9,333,535	4,909,188	52.6	28.7	18.4
Middle Brazos River Basin (code 1206)	9,957,461	1,775,769	17.8	10.4	10.8
Lower Brazos River Basin (code 1207)	9,923,855	1,090,505	11.0	6.4	2.0
Upper Colorado River Basin (code 1208)	10,236,524	3,253,497	31.8	19.0	28.0
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	18,027,193	1,248,198	6.9	7.3	7.7
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	11,461,786	1,297,634	11.3	7.6	0.5
Nueces River-Southwestern Texas Coastal (code 1211)	18,166,412	2,176,723	12.0	12.7	4.6
Total	116,336,087	17,116,566	14.7	100.0	13.2

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

Figure 2. Percent cultivated cropland, including land in long-term conserving cover, for the 11 subregions in the Texas Gulf Basin



Chapter 2
Overview of Sampling and Modeling Approach

Scope of Study

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

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

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

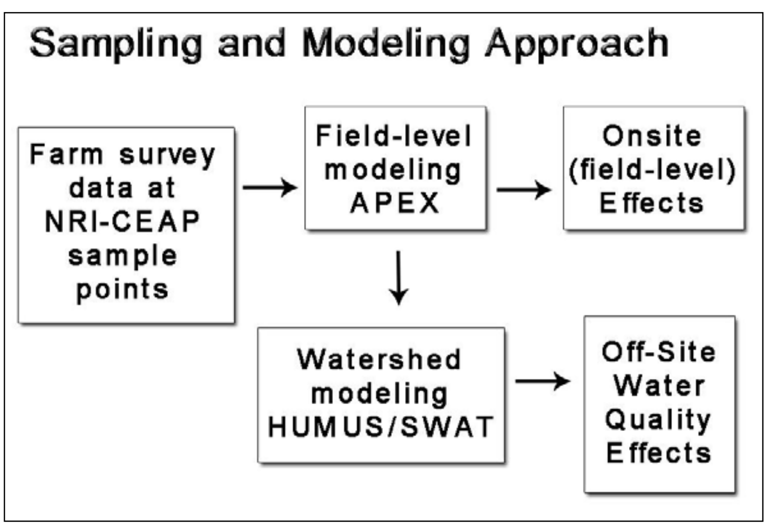
For purposes of this report, cultivated cropland includes land in row crops or close-grown crops (such as wheat and other small grain crops), hay and pasture in rotation with row crops and close-grown crops, and land in long-term conserving cover. Cultivated cropland does not include agricultural land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

Sampling and Modeling Approach

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

- A subset of 693 National Resources Inventory (NRI) sample points provides a statistical sample that represents the diversity of soils and other conditions for cropped acres in the Texas Gulf Basin. The sample also includes 875 additional NRI sample points designated as CRP acres to represent 2.5 million acres of land in long-term conserving cover. NRI sample points are linked to NRCS Soil Survey databases and were linked spatially to climate databases for this study.
- A farmer survey—the NRI-CEAP Cropland Survey—was conducted at each of the 693 cropped sample points during the period 2003–06 to determine what conservation practices were in use and to collect information on farming practices.
- The field-level effects of the conservation practices were assessed using a field-scale physical process model—the Agricultural Policy Environmental Extender (APEX)—which simulates the day-to-day farming activities, wind and water erosion, loss or gain of soil organic carbon, and edge-of-field losses of soil, nutrients, and pesticides.
- A watershed model and system of databases—the Hydrologic Unit Model for the United States (HUMUS)—was used to simulate how reductions of field losses have reduced instream concentrations and loadings of sediment, nutrients, and pesticides within the Texas Gulf Basin. The SWAT model (Soil and Water Assessment Tool) was used to simulate nonpoint source loadings from land uses other than cropland and to route instream loads from one watershed to another.

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



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

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

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

The approach captures the diversity of land use, soils, climate, and topography from the NRI; accounts for site-specific farming activities; estimates the loss of materials at the field scale where the science is most developed; and provides a statistical basis for aggregating results to the national and regional levels. Previous studies have used this NRI micro-simulation modeling approach to estimate soil loss, nutrient loss, and change in soil organic carbon (Potter et al. 2006), to estimate pesticide loss from cropland (Kellogg et al. 1992, 1994, 2002; Goss et al. 1998), and to identify priority watersheds for water quality protection from nonpoint sources related to agriculture (Kellogg 2000, Kellogg et al. 1997, Goebel and Kellogg 2002).

The NRI and the CEAP Sample

The approach is an extension of the NRI, a longitudinal, scientifically based survey designed to gauge natural resource status, conditions, and trends on the Nation's non-Federal land (Goebel 1998; USDA/NRCS 2002). The NRI sampling design implemented in 1982 provided a stratified, two-stage, unequal probability area sample of the entire country (Goebel and Baker 1987; Nusser and Goebel 1997). Nominally square areas/segments were selected within geographical strata on a county-by-county basis; specific point locations were selected within each selected segment. The segments ranged in size from 40 to 640 acres but were typically half-mile square areas, and most segments contained three sample points.

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

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

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

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

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

issue. The core panel and the various supplemental panels are unequal probability subsamples from the 1997 NRI Foundation Sample.

The CEAP cultivated cropland sample is a subset of NRI sample points from the 2003 NRI (USDA/NRCS 2007). The 2001, 2002, and 2003 Annual NRI surveys were used to draw the sample.[3] The sample is statistically representative of cultivated cropland and formerly cultivated land currently in long-term conserving cover.

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

The NRI-CEAP Cropland Survey

A farmer survey—the NRI-CEAP Cropland Survey—was conducted to obtain the additional information needed for modeling the 693 sample points with crops.[4] The USDA National Agricultural Statistics Service (NASS) administered the survey. Farmer participation was voluntary, and the information gathered is confidential. The survey content was specifically designed to provide information on farming activities for use with a physical process model to estimate field-level effects of conservation practices.

The survey obtained information on—

- crops grown for the previous 3 years, including double crops and cover crops;
- field characteristics, such as proximity to a water body or wetland and presence of tile or surface drainage systems;
- conservation practices associated with the field;
- crop rotation plan;
- application of commercial fertilizers (rate, timing, method, and form) for crops grown the previous 3 years;
- application of manure (source and type, consistency, application rate, method, and timing) on the field over the previous 3 years;
- application of pesticides (chemical, rate, timing, and method) for the previous 3 years;
- pest management practices;
- irrigation practices (system type, amount, and frequency);
- timing and equipment used for all field operations (tillage, planting, cultivation, harvesting) over the previous 3 years, and;
- general characteristics of the operator and the operation.

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

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

Estimated Acres

Acres reported using the CEAP sample are "estimated" acres because of the uncertainty associated with the statistical sample. For example, the 95-percent confidence interval for the estimate of 18,368,299 cropped acres in the region has a lower bound of 17,508,846 acres and an upper bound of 19,227,752 acres. (The lower bound is the estimate minus the margin of error and the upper bound is the estimate plus the margin of error.)

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

In the Texas Gulf Basin, sample sizes for two subregions were too small to reliably report cropped acres. Results for the Sabine River Basin (code 1201), with 6 sample points, and the Neches River Basin (code 1202), with 1 sample point, were combined with results for the Upper and Lower Trinity Basins (code 1203) for reporting. All other basins had at least 25 sample points. [5]

NRI-CEAP estimates of cropped acres for the 11 subregions within the Texas Gulf Basin are presented in table 5 along with the 95-percent confidence intervals. These estimates of cropped acres differ from cultivated cropland estimates presented in tables 1 and 4 primarily because those tables also include acres of land in long-term conserving cover but also because of differences in data sources and estimation procedures.

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

[3] Information about the CEAP sample design is in the documentation report "NRI-CEAP Cropland Survey Design and Statistical Documentation;" see page 7.

[4] The surveys, enumerator instructions, and other documentation can be found at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/pub/.

[5] While sample sizes are adequate for reporting acreage in table 5, the sample size in two subregions—codes 1204 and 1207, both with only 25 samples—is too small for reliable reporting of model estimates in Chapter 7 and Appendix B. These two subregions are combined with other subregions for reporting of model estimates.

Cropping Systems in the Texas Gulf Basin

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

The majority of the crop rotations (59 percent of cropped acres) include either wheat or cotton in this region. The dominant cropping system for both cotton and wheat is cotton only or wheat only systems (table 6). Each of the other crops and cropping systems make up less than 10 percent of the cropped acres in the region.

Table 5. Estimated cropped acres based on the NRI-CEAP sample for subregions in the Texas Gulf Basin

Subregion	Number of CEAP samples	Estimated acres (acres)	95-percent confidence interval Lower bound (acres)	95-percent confidence interval Upper bound (acres)
Sabine, Neches, and Upper and Lower Trinity River Basins, (codes 1201, 1202, and 1203)	50	1,327,900	1,091,993	1,563,807
San Jacinto River-Galveston Bay-Sabine Lake (code 1204)	25	522,700	242,149	803,251
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	233	4,047,400	3,538,115	4,556,685
Middle Brazos River Basin (code 1206)	84	2,228,800	1,892,458	2,565,142
Lower Brazos River Basin (code 1207)	25	1,683,800	1,312,703	2,054,897
Upper Colorado River Basin (code 1208)	117	2,567,700	2,212,804	2,922,596
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	59	1,867,700	1,513,913	2,221,487
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	40	1,750,600	1,434,382	2,066,818
Nueces River-Southwestern Texas Coastal (code 1211)	60	2,371,700	1,885,048	2,858,352
Total	693	18,368,299	17,508,846	19,227,752

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

Table 6. Estimated crop acres for cropping systems in the Texas Gulf Basin

Cropping system	Number of CEAP samples	Estimated acres (acres)	Percent of total	95-percent confidence interval Lower bound (acres)	95-percent confidence interval Upper bound (acres)
Cotton only	212	4,036,144	22	3,359,427	4,712,861
Cotton-sorghum only	61	1,693,703	9	1,115,403	2,272,003
Cotton and close-grown crops	52	1,147,649	6	810,209	1,485,089
Cotton and corn only	27	737,398	4	321,096	1,153,700
Wheat only	112	3,141,949	17	2,536,646	3,747,252
Sorghum with and without wheat	44	1,060,441	6	575,920	1,544,962
Sorghum and corn only	14	620,187	3	81,522	1,158,852
Peanuts with and without other crops	23	617,294	3	280,868	953,720
Rice with and without other crops	28	904,041	5	567,861	1,240,221
Hay-crop mix	28	1,080,784	6	592,846	1,568,722
Remaining row crops only	33	1,255,688	7	658,928	1,852,448
Remaining close grown crops only	17	828,174	5	473,446	1,182,902
Remaining mix of row and close grown crops	42	1,244,849	7	709,449	1,780,249
Total	693	18,368,299	100	17,508,846	19,227,752

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

Simulating the Effects of Weather

Weather is the predominant factor determining the loss of soil, nitrogen, phosphorus, and pesticides from farm fields, and has a big influence on the effectiveness of conservation practices. To capture the effects of weather, each scenario was simulated using 47 years of actual daily weather data for the time period 1960 through 2006. The 47-year record is a serially complete daily data set of weather station data from weather station records available from the NCDC (National Climatic Data Center) for the period 1960 to 2006, including precipitation, temperature maximum, and temperature minimum (Eischeid et al. 2000). These data were combined with the respective PRISM (Parameter–Elevation Regressions on Independent Slopes Model; Daly et al. 1994) monthly map estimates to construct daily estimates of precipitation and temperature (Di Luzio et al. 2008). The same 47-year weather data were used in the HUMUS/SWAT simulations and in the APEX model simulations.

Annual precipitation over the 47-year simulation averaged about 27 inches for cropped acres in this region. However, annual precipitation varied substantially in the model simulations, both within the region and from year to year, as shown in figure 5. Each curve in figure 5 shows how annual precipitation varied over the region in one of the 47 years. The family of curves shows the variability from year to year. Annual precipitation ranges from lows of 5 to 25 inches per year to highs ranging from 40 to 80 inches per year.

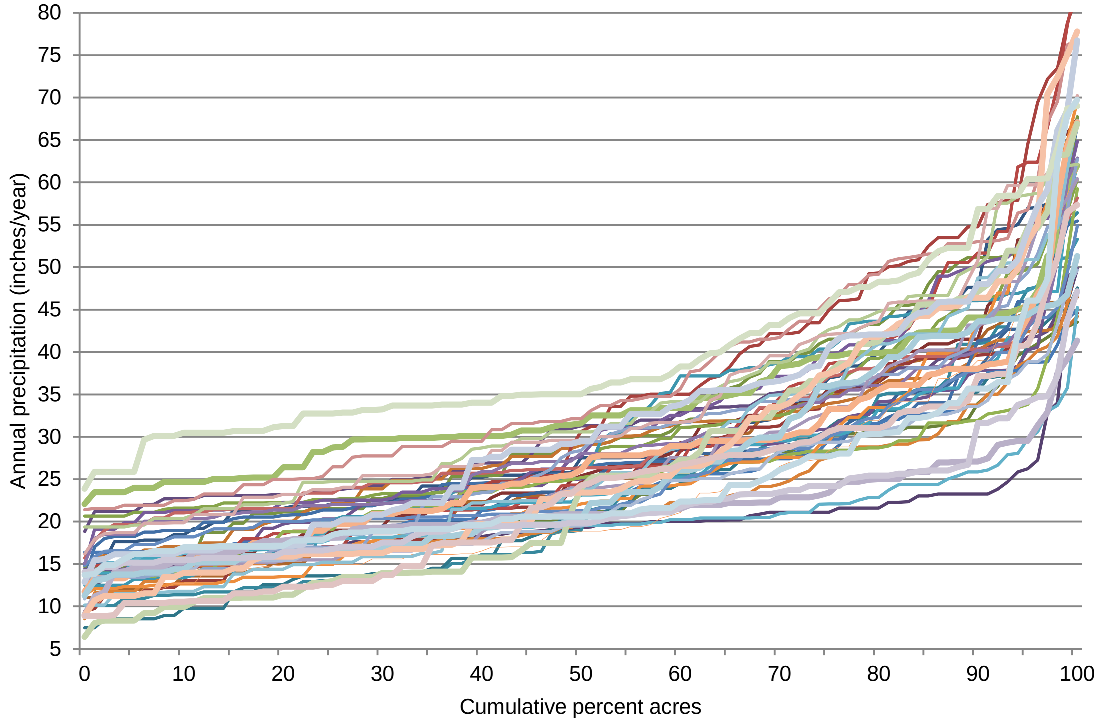
The top curve shown is for the year 2004 the wettest year in this region during the 47 years. The curve for 2004 shows that precipitation exceeded the long-term annual average of 27 inches for 95 percent of the cropped acres in the Texas Gulf Basin. The bottom curves are drought years for most of the region—1963, 1988, 1999, and 2005—when 90 percent or more of cropped acres had less precipitation than the long-term annual average.

Year-to-year variability is especially pronounced—the average annual precipitation amount (representing all cropped acres) ranged from 20 inches in 1963 to 39 inches in 2004 over the 47 years (fig. 6).[6]

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

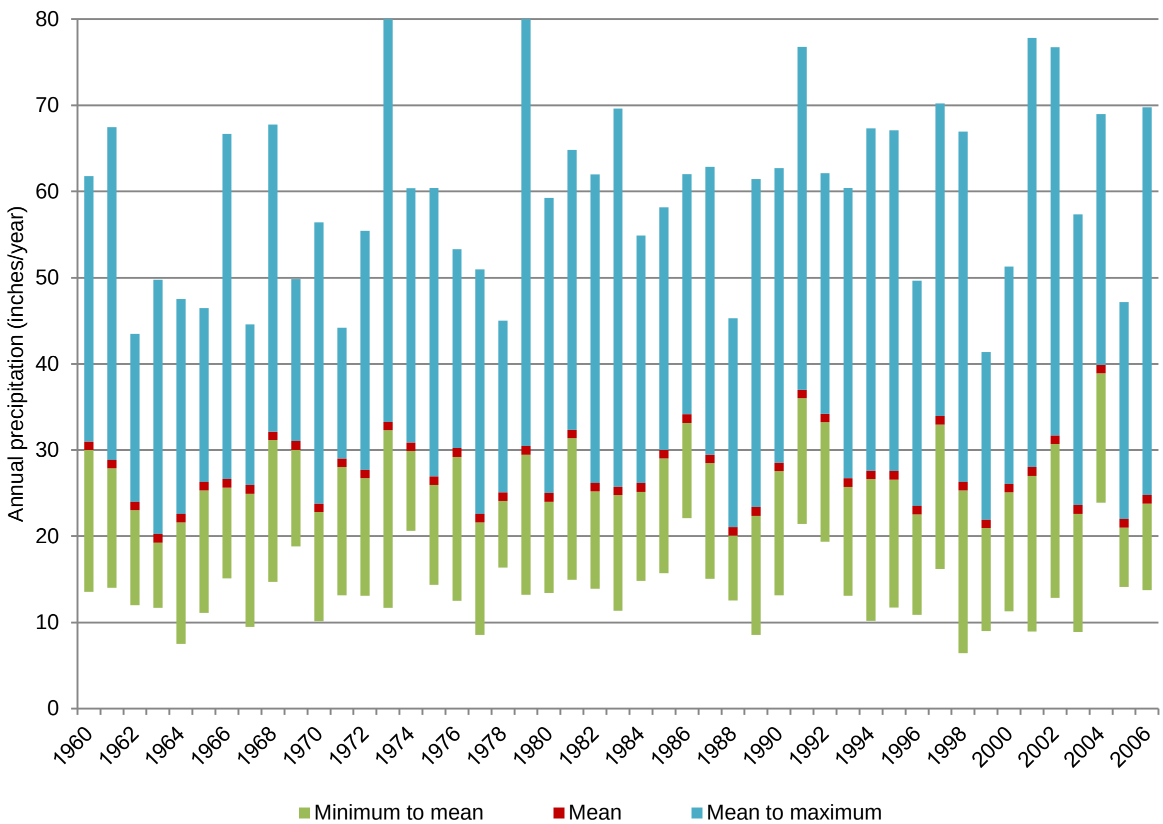
[6] The annual precipitation averages do not convey the impact of tropical weather systems on erosion, sediment, and nutrient losses. Sporadic, intense tropical storm events can occur even in very dry years.

Figure 5. Cumulative distributions of annual precipitation used in the model simulations for cropped acres in the Texas Gulf Basin



Note: Each of the 47 curves shown above represents a single year of data and shows how annual precipitation varies over the region in that year, starting with the acres with the lowest precipitation within the region and increasing to the acres with the highest precipitation. The family of curves shows how annual precipitation varies from year to year. Annual precipitation over the 47-year simulation averaged about 27 inches for cropped acres throughout the region. The top curve shown is for the year 2004, the wettest year on record in this region. The curve for 2004 shows that precipitation exceeded 27 inches for 95 percent of cropped acres.

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



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

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

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

- in-field practices for water erosion control, divided into two groups:
  - practices that control overland flow (terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping), and
  - practices that control concentrated flow (grassed waterways, grade stabilization structures, diversions, and other structures for water control);
- edge-of-field practices for buffering and filtering surface runoff before it leaves the field (riparian forest buffers, riparian herbaceous cover, filter strips, field borders); and
- wind erosion control practices (windbreaks/shelterbelts, cross wind trap strips, herbaceous wind barriers, hedgerow planting).

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

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

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

Historical Context for Conservation Practice Use

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

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

Summary of Practice Use

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

- Structural practices for controlling water erosion are in use on 37 percent of cropped acres. On the 33 percent of the acres designated as highly erodible land, structural practices designed to control water erosion are in use on 35 percent.
- About 3 percent of the cropped acres in the region are treated for wind erosion using structural practices.
- Reduced tillage is used on about half the cropped acres in the region; 48 percent of the cropped acres meet criteria for no-till (5 percent), mulch till (30 percent), or reduced tillage (13 percent).
- Only 13 percent of cropped acres are gaining soil organic carbon in the region.
- Producers use either residue and tillage management practices or structural practices, or both, on 66 percent of cropped acres.
- While most acres have evidence of some nitrogen or phosphorus management, the majority of the acres in the region lack consistent use of appropriate rates, timing, *and* method of application on each crop in every year of production.
  - About 17 percent of cropped acres have no nitrogen applied. An additional 44 percent of cropped acres meet criteria for timing of nitrogen

applications on all crops in the rotation, 63 percent meet criteria for method of application, and 51 percent meet criteria for rate of application.
    - About 34 percent of cropped acres have no phosphorus applied. An additional 35 percent of cropped acres meet criteria for timing of phosphorus applications on all crops in the rotation, 52 percent meet criteria for method of application, and 19 percent meet criteria for rate of application.
    - Appropriate nitrogen application rates, timing of application, and application method for all crops during every year of production, however, are in use on only about 22 percent of cropped acres, in addition to the 17 percent of acres without nitrogen applications.
    - Good phosphorus management practices (appropriate rate, timing, and method) are in use on 10 percent of the acres on all crops during every year of production, in addition to the 34 percent of acres without phosphorus applications.
    - About 30 percent of cropped acres meet nutrient management criteria for both nitrogen and phosphorus management, including the 17 percent of acres not receiving either nitrogen or phosphorus applications.
- During the 2003–06 period of data collection cover crops were used on only 2 percent of the acres in the region.
- The Integrated Pest Management (IPM) indicator showed that only about 5.4 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 2.5 million acres in the region, of which 60 percent is highly erodible.

Structural Conservation Practices

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

1. **The NRI-CEAP Cropland Survey** included questions about the presence of 12 types of structural practices: terraces, grassed waterways, vegetative buffers (in-field), hedgerow plantings, riparian forest buffers, riparian herbaceous buffers, windbreaks or herbaceous wind barriers, contour buffers (in-field), field borders, filter strips, critical area planting, and grade stabilization structures.

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

3. **The USDA-Farm Service Agency** (FSA) provided practice information for fields that were enrolled in the Continuous CRP for these structural practices: contour grass strips, filter strips, grassed waterways, riparian buffers (trees), and field windbreaks (Alex Barbarika, USDA/FSA, personal communication).

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

Overland flow control practices are designed to slow the movement of water across the soil surface to reduce surface water runoff and sheet and rill erosion. NRCS practice standards for overland flow control include terraces, contour farming, stripcropping, in-field vegetative barriers, and field borders. These practices are found on about 33 percent of the cropped acres in the region, including 32 percent of the highly erodible land (table 7).

Concentrated flow control practices are designed to prevent the development of gullies along flow paths within the field. NRCS practice standards for concentrated flow control practices include grassed waterways, grade stabilization structures, diversions, and water and sediment control basins. About 13 percent of the cropped acres have one or more of these practices (table 7).

Edge-of-field buffering and filtering practices, consisting of grasses, shrubs, and/or trees, are designed to capture the surface runoff losses that were not avoided or mitigated by the in-field practices. NRCS practice standards for edge-of-field mitigation practices include edge-of-field filter strips, riparian herbaceous buffers, and riparian forest buffers. CRP's buffer practices are included in this category. Edge-of-field buffering and filtering practices are in use on about 2 percent of all cropped acres in the region (table 7).

Overall, about 37 percent of the cropped acres in the Texas Gulf Basin are treated with one or more water erosion control structural practices (table 7). The treated percentage for highly erodible land acres is about the same as the overall average—35 percent.

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. Although wind erosion is a serious resource concern for many 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).

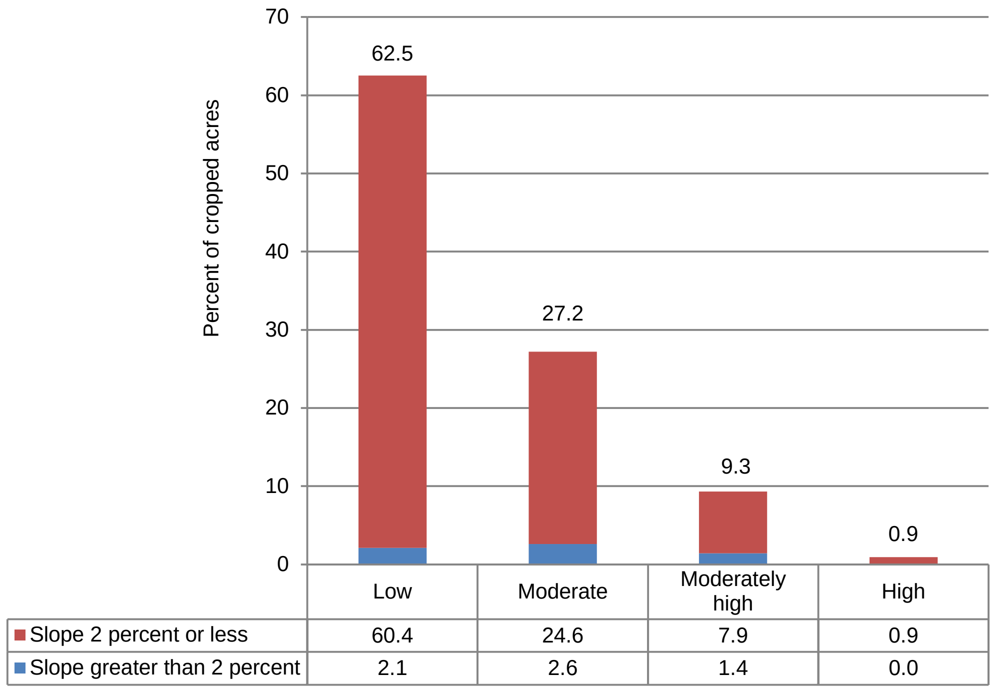
At each sample point, structural conservation practices for water erosion control were determined to be providing either a high, moderately high, moderate, or low level of treatment according to criteria presented in figure 7. About 1 percent of cropped acres in the region have a high level of treatment (combination of edge-of-field buffering or filtering and at least one in-field structural practice). About 63 percent of the acres do not have structural practices for water erosion control; however, nearly all of these acres have slopes less than 2 percent (fig. 7), some of which may not need to be treated with structural practices. These treatment levels are combined with soil risk classes to estimate acres that appear to be undertreated for water erosion control in chapter 5.

Table 7. Structural conservation practices in use for the baseline conservation condition, Texas Gulf Basin

Structural practice category	Conservation practice in use	Percent of non-HEL	Percent of HEL	Percent of cropped acres
Overland flow control practices	Terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping, field border, in-field vegetative barriers	34	32	33
Concentrated flow control practices	Grassed waterways, grade stabilization structures, diversions, other structures for water control	13	13	13
Edge-of-field buffering and filtering practices	Riparian forest buffers, riparian herbaceous buffers, filter strips	2	2	2
One or more water erosion control practices	Overland flow, concentrated flow, or edge-of-field practice	39	35	37
Wind erosion control practices	Windbreaks/shelterbelts, cross wind trap strips, herbaceous windbreak, hedgerow planting	2	4	3

Note: About 33 percent of cropped acres in the Texas Gulf Basin are highly erodible land (HEL). Soils are classified as HEL if they have an erodibility index (EI) score of 8 or higher. A numerical expression of the potential of a soil to erode, EI considers the physical and chemical properties of the soil and climatic conditions where it is located. The higher the index, the greater the investment needed to maintain the sustainability of the soil resource base if intensively cropped.

Figure 7. Percent of cropped acres at four conservation treatment levels for structural practices, baseline conservation condition, Texas Gulf Basin



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

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

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

Residue and Tillage Management Practices

Simulations of the use of residue and tillage management practices were based on the field operations and machinery types reported in the NRI-CEAP Cropland Survey for each sample point. The survey obtained information on the timing, type, and frequency of each tillage implement used during the previous 3 years, including the crop to which the tillage operation applied. Model outcomes affected by tillage practices, such as erosion and runoff, were determined based on APEX processes of the daily tillage activities as reported in the survey.

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

STIR values represent the soil disturbance intensity, which was estimated for each crop at each sample point.[7] 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.[8]

Overall, 35 percent of cropped acres in the Texas Gulf Basin meet the tillage intensity rating for either no-till or mulch till (table 8). About 5 percent meet the tillage intensity criteria for no-till, and about 30 percent meet the tillage intensity criteria for mulch till. About 13 percent of cropped acres did not meet criteria for mulch till or no-till but had reduced tillage on some crops in the rotation (table 8). About half of the cropped acres are conventionally tilled in the Texas Gulf Basin (table 8).

Use of no-till in this region is lower than in the other areas of the country. The percentage of cropped acres that meet the tillage intensity rating for no-till range from 14 in the Arkansas-White-Red Basin to 52 percent in the Ohio-Tennessee River Basin, compared to 5 percent for cropped acres in the Texas Gulf Basin.

Conservation tillage and especially no-till is reduced in this region largely due to the high percentage of acres producing cotton and practices required for mitigation of boll weevils. This is typically accomplished through tillage after harvest to destroy the stalks or pull them from the ground. The region also has a significant amount of cropland with clay textures, and these soil types do not lend themselves readily to no-till.

To evaluate the use of residue and tillage management practices, practice use was classified as high, moderately high, moderate, or low for each sample point according to criteria presented in figure 8. (These residue and tillage management treatment levels were combined with the use of structural practices to estimate conservation treatment levels for water erosion control in chapter 5.)

The high treatment level, representing 7.8 percent of cropped acres, includes only those acres with gains in soil organic carbon and where the tillage intensity criteria are met for *each* crop in the rotation. About 0.8 percent of cropped acres have a moderately high treatment level, where the *average annual* tillage intensity meets criteria for mulch till or no-till and the crop rotation is gaining soil organic carbon.

About 43 percent of cropped acres have a moderate level of treatment because some crops have reduced tillage but do not meet criteria for no-till or mulch till, or they are gaining soil organic carbon but tillage intensity exceeds criteria for mulch till (fig. 8). About 48 percent of the acres have a low treatment level, consisting of continuous conventional tillage for all crops in the rotation *and* loss of soil organic carbon.

Structural practices and residue and tillage management practices influence losses of sediment, nutrients, and pesticides due to water erosion. The majority of the cropped acres (66 percent) in the Texas Gulf Basin have one or both of these types of water erosion control practices (table 9). About 14 percent meet tillage intensity for no-till or mulch till *and* have structural practices. About 21 percent of cropped acres meet tillage criteria without structural practices in use. About 18 percent have structural practices without any kind of residue or tillage management.

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

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

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

Residue and tillage management practice in use	Percent of non-HEL	Percent of HEL	Percent of all cropped acres
Average annual tillage intensity for crop rotation meets criteria for no-till*	5	6	5
Average annual tillage intensity for crop rotation meets criteria for mulch till**	29	32	30
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	13	13	13
Continuous conventional tillage in every year of crop rotation***	53	50	52
Total	100	100	100

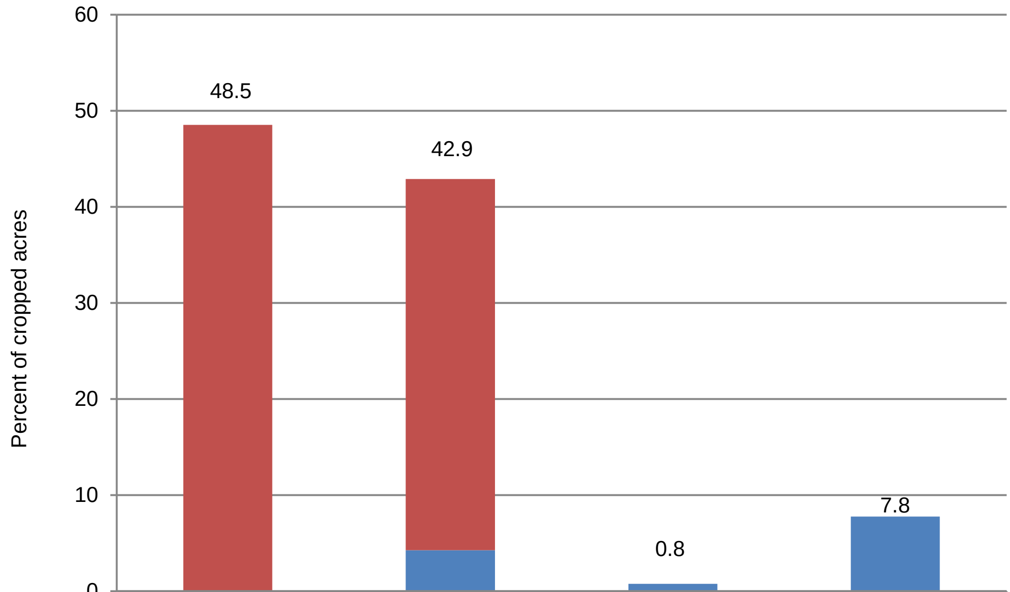
* Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is less than 30.
** Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is between 30 and 100.
*** Soil Tillage Intensity Rating (STIR) for every crop year in the rotation is more than 100.
Note: A description of the Soil Tillage Intensity Rating (STIR) can be found at http://stir.nrcs.usda.gov/.
Note: Percents may not add to totals because of rounding.
Note: Percent residue cover was not used to determine no-till or mulch till.
Note: HEL = highly erodible land. About 33 percent of cropped acres in the Texas Gulf Basin are highly erodible land (HEL).

Table 9. Percent of cropped acres with water erosion control practices for the baseline conservation condition, Texas Gulf Basin

Conservation treatment	Percent of non-HEL	Percent of HEL	Percent of all cropped acres
No-till or mulch till with carbon gain, no structural practices	4	7	5
No-till or mulch till with carbon loss, no structural practices	16	16	16
Some crops with reduced tillage, no structural practices	7	7	7
Structural practices and no-till or mulch till with carbon gain	1	6	3
Structural practices and no-till or mulch till with carbon loss	13	8	11
Structural practices and some crops with reduced tillage	6	6	6
Structural practices only	19	15	18
No water erosion control treatment	34	34	34
All acres	100	100	100

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

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



	Low	Moderate	Moderately high	High
Losing carbon	48.5	38.6	0.0	0.0
Gaining carbon	0.0	4.3	0.8	7.8

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

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

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

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

Since the 2003–06 survey, States in the Texas Gulf Basin have continued to work with farmers to enhance conservation practice adoption in an ongoing effort to reduce nonpoint source pollution contributing to water quality concerns. As a result, some practices may be in wider use within the watershed than the CEAP survey shows for 2003–06. Changes in land use and cropping system in response to market conditions could also result in less use of some conservation practices.

Conservation Crop Rotation

In the Texas Gulf Basin, crop rotations that meet NRCS criteria for conservation crop rotations (NRCS practice code 328) are used on about 51 percent of the cropped acres. This practice consists of growing different crops in a planned rotation to manage nutrient and pesticide inputs, enhance soil quality, or reduce soil erosion. Including a legume, hay, or close-grown crop in the rotation can have a pronounced effect on long-term average field losses of sediment and nutrients, as well as enhancement of soil quality.

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

Cover Crops

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

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

- A cover crop must be a close-grown crop that is not harvested as a principal crop, or if it is harvested, must have been specifically identified in the NRI-CEAP Cropland Survey as a cover crop as an indicator that the harvest was for an acceptable purpose (such as biomass removal or use as mulch or forage material).
- Spring-planted cover crops are inter-seeded into a growing crop or are followed by the seeding of a summer or late fall crop that may be harvested during that same year or early the next year.
- Late-summer-planted cover crops are followed by the harvest of another crop in the same crop year or the next spring.
- Fall-planted cover crops are followed by the spring planting of a crop for harvest the next year.

Some cover crops are planted for soil protection during establishment of spring crops such as protection for small cotton plants.

In the Texas Gulf Basin, cover crops were not commonly used as a conservation practice during the period covered by the farmer survey (2003–06). Only 2 percent of the acres (22 sample points) met the above criteria for a cover crop.

Irrigation Management Practices

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

The Texas Gulf Basin is situated partly in what could be considered the supplemental irrigation area and partly in the traditional western irrigated area, where irrigation is essential for crop production. Irrigation applications are used annually in some places to produce satisfactory yields, especially in the western parts of the Basin, and used in other areas to supplement natural rainfall only in years when needed to overcome soil moisture deficiencies.

Irrigation applications are made with either a pressure or a gravity system. Gravity systems, as the name implies, utilize gravitational energy to move water from higher elevations to lower elevations, such as moving water from a ditch at the head of a field, across the field to the lower end. Pumps are most often used to create the pressure in pressure systems, and the water is applied under pressure through pipes and nozzles. There are also variations such as where water is diverted at higher elevations and the pressure head created by gravity is substituted for the energy of a pump.

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

According to the NRI-CEAP cropland survey, about 30 percent of cropped acres—5.5 million acres—have the capability to provide irrigation water for one or more crops in the Texas Gulf Basin.

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

Approximately 54 percent of the irrigation in the Texas Gulf Basin is by pressure systems and 46 percent is with gravity systems. Most common pressure systems are center-pivot or linear-move systems with low pressure spray (28.4 percent of irrigated acres) followed by center-pivot or linear-move systems with near ground emitters (15.1 percent of irrigated acres). There are lesser numbers of center pivots or linear move systems with impact sprinkler heads, side roll or wheel lines, solid set, and hand move sprinkler systems. Other pressure systems include 133,000 acres of the highly efficient low flow irrigation which includes drip and trickle systems. Common gravity irrigation systems include open discharge (21.7 percent of irrigated acres), polypipe (7.0 percent of irrigated acres), portal systems from unlined ditches (6.2 percent), and numerous other gravity systems. The open discharge category can include little controlled direct discharge from a well, discharge from large irrigation structures, or discharge from alfalfa valves.

Approximately 45 percent of the irrigation systems in the Texas Gulf Basin are capable of irrigation efficiencies that would be considered appropriate for state-of-the-art irrigation.

Nutrient Management Practices

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

Sound nutrient management systems can minimize nutrient losses from the agricultural management zone while providing adequate soil fertility and nutrient availability to ensure realistic yields. (The agricultural management zone is defined as the zone surrounding a field that is bounded by the bottom of the root zone, edge of the field, and top of the crop canopy.) Such systems are tailored to address the specific cropping system, nutrient sources available, and site characteristics of each field. Nutrient management systems have four basic criteria for application of commercial fertilizers and manure.[9]

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 can seldom be completely eliminated, they can be minimized by careful management and kept within an acceptable level.

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

- All commercial fertilizer and manure applications are within 3 weeks prior to plant date, at planting, or within 60 days after planting.
- The method of application for commercial fertilizer or manure is some form of incorporation or banding or spot treatment or foliar applied.
- The rate of nitrogen application, including the sum of both commercial fertilizer and manure nitrogen available for crops in the year of application, is—
    - less than 1.4 times the amount of nitrogen removed in the crop yield at harvest for *each* crop,[10] except for cotton and small grain crops;

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

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

    - less than 1.6 times the amount of nitrogen removed in the crop yield at harvest for small grain crops (wheat, barley, oats, rice, rye, buckwheat, emmer, spelt, and triticale);
    - less than 60 pounds of nitrogen per bale of cotton harvested.
- The rate of phosphorus application summed over all applications and crops in the rotation, including both commercial fertilizer and manure phosphorus, is less than 1.1 times the amount of phosphorus removed in the crop yields at harvest summed over all crops in the rotation.

Phosphorus application rate criteria apply to the *full crop rotation* to account for infrequent applications intended to provide phosphorus for multiple crops or crop years, which is often the case with manure applications. Nitrogen application rate criteria apply to *each* crop in the rotation.

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

As shown in table 10, the majority of acres in the Texas Gulf Basin meet one or more of the criteria for effective nitrogen management. About 17 percent of cropped acres have no nitrogen applied. An additional 44 percent of cropped acres meet criteria for timing of nitrogen applications on all crops in the rotation, 63 percent meet criteria for method of application, and 51 percent meet criteria for rate of application.

Similar results were found for phosphorus management. About 34 percent of cropped acres have no phosphorus applied. An additional 35 percent of cropped acres meet criteria for timing of phosphorus applications on all crops in the rotation, 52 percent meet criteria for method of application, and 19 percent meet criteria for rate of application.

Only a few acres meet all nutrient management criteria (table 10):
- in addition to the 17 percent of cropped acres without nitrogen applications, 22 percent of the acres meet all criteria for nitrogen applications;
- in addition to the 34 percent of cropped acres without phosphorus applications, 10 percent of the acres meet all criteria for phosphorus applications; and
- about 30 percent of cropped acres meet criteria for *both* phosphorus and nitrogen management, including acres with no nutrient applications.

Fall applications still occur on some acres. Nutrients applied in the fall for spring-planted crops are generally more susceptible to environmental losses than spring applications. Based on the survey, about 18 percent of the cropped acres in the Texas Gulf Basin receive fall applications of either commercial nitrogen fertilizer or manure on at least one crop in the rotation, excluding cases where a fall crop was planted. About 12 percent of cropped acres receive fall applications of either commercial phosphorus fertilizer or manure on at least one crop in the rotation, excluding cases where a fall crop was planted.

Lower nitrogen rate criteria are appropriate for acres that meet application timing and method criteria and also are fully treated for soil erosion control because more of the nitrogen applied is retained on the field and is therefore available for crop growth. In the simulation of additional soil erosion control and nutrient management (full treatment) in chapter 6, the rates of nitrogen application, including both commercial fertilizer and manure nitrogen, were proportionately reduced to the following levels—
- 1.2 times the amount of nitrogen removed in the crop yield at harvest for *each* crop, except for cotton and small grain crops;
- 1.5 times the amount of nitrogen removed in the crop yield at harvest for small grain crops; and
- 50 pounds of nitrogen per bale of cotton harvested.

Approximately 27 percent of cropped acres in the region meet *all* nutrient management criteria including these lower nitrogen rate criteria and including acres not receiving nutrient applications (table 10).

Four levels of treatment for nitrogen and phosphorus management were derived to evaluate the adequacy of nutrient management. (These treatment levels are combined with soil risk classes to estimate acres that appear to be undertreated in chapter 5.) Criteria for the treatment levels are presented in figures 9 and 10.

The high treatment level represents consistent use of appropriate rate, timing, and method for all crops, including the lower nitrogen application rate criteria appropriate for full conservation treatment conditions. Based on these treatment levels, about 35 percent of the acres in the Texas Gulf Basin have a high level of nitrogen management and about 45 percent have a high level of phosphorus management (figs. 9 and 10).

About 34 percent of cropped acres have a moderately high treatment level for nitrogen, but only 9 percent have a moderately high treatment level for phosphorus. About 4 percent of cropped acres have a low level of nitrogen management and 30 percent of the acres have a low level of phosphorus management.

According to the NRI-CEAP cropland survey, only about 2.5 percent of cropped acres (0.5 million acres) have manure applied in this region. Most of these acres had a low or moderate level of nitrogen or phosphorus management (figs. 9 and 10).

Table 10. Nutrient management practices for the baseline conservation condition, Texas Gulf Basin

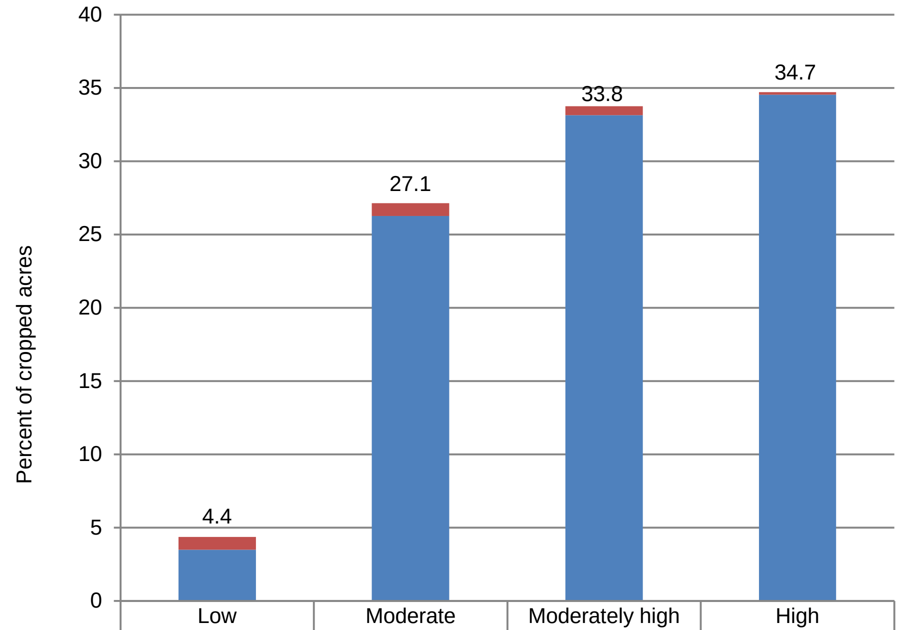
	Percent of all cropped acres
Nitrogen (N)*	
No N applied to any crop in rotation	17
For samples where N is applied:	
Time of application	
All crops have application of N (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	44
Some but not all crops have application of N (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	18
No crops in rotation have application of N (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	21
Method of application	
All crops in rotation have N applied with incorporation or banding/foliar/spot treatment	63
Some but not all crops in rotation have N applied with incorporation or banding/foliar/spot treatment	10
No crops in rotation have N applied with incorporation or banding/foliar/spot treatment	10
Rate of application	
All crops in rotation meet the nitrogen rate criteria described in text	51
Some but not all crops in rotation meet the nitrogen rate criteria described in text	19
No crops in rotation meet the nitrogen rate criteria described in text	12
Timing and method and rate of application	
All crops meet the nitrogen rate criteria, timing criteria, and method criteria described above	22
Some but not all crops meet the nitrogen rate criteria, timing criteria, and method criteria described above	27
No crops meet the nitrogen rate, timing criteria, and method criteria described above	34
Phosphorus (P)*	
No P applied to any crop in rotation	34
For samples where P is applied:	
Time of application	
All crops in rotation have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	35
Some but not all crops have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	12
No crops in rotation have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	19
Method of application	
All crops in rotation have P applied with incorporation or banding/foliar/spot treatment	52
Some but not all crops in rotation have P applied with incorporation or banding/foliar/spot treatment	9
No crops in rotation have P applied with incorporation or banding/foliar/spot treatment	5
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	19
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	46
Timing and method and rate of application	
Crop rotation has P rate less than 1.1 times removal at harvest and meet timing and method criteria described above	10
Crop rotation has P rate less than 1.1 times removal at harvest and some but not all crops meet timing and method criteria described above	5
Crop rotation has P rate more than 1.1 times removal at harvest and may or may not meet timing and method criteria described above	51
Nitrogen and Phosphorus	
Crop rotation P rate less than 1.1 and N rate criteria described in text and all applications within 3 weeks before planting or within 60 days after planting with incorporation or banding/foliar/spot treatment, including acres with no N or P applied	30
Crop rotation P rate less than 1.1 and N rate criteria appropriate for full conservation treatment (see text) and all applications within 3 weeks before planting or within 60 days after planting with incorporation or banding/foliar/spot treatment, including acres with no N or P applied	27
All sample points	100

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

* These estimates include adjustments made to the reported data on nitrogen and phosphorus application rates from the survey because of missing data and data-entry errors. In the case of phosphorus, the 3-year data period for which information was reported was too short to pick up phosphorus applications made at 4- and 5-year intervals between applications, which is a common practice for producers adhering to sound phosphorus management techniques. Since crop growth, and thus canopy development which decreases erosion, is a function of nitrogen and phosphorus, it was necessary to add additional nitrogen 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. Then 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. Nitrogen and phosphorus were added by increasing the existing applications (thus preserving the reported timing and methods), when present, or were applied at plant. (For additional information on adjustment of nutrient application rates, see the documentation report "Adjustment of CEAP Cropland Survey Nutrient Application Rates for APEX Modeling," referenced on page 7).

The need to make adjustments to the reported nitrogen and phosphorus applications is less with use of the updated APEX model, APEXv1307, compared to the need for these adjustments with use of the previous version of the APEX model (see box inset on page 5) because of more realistic estimates of crop yields obtained with reported nutrient applications. For these results, about 8 percent of cropped acres received a nitrogen adjustment for one or more crops and 7 percent of cropped acres received a phosphorus adjustment for one or more crops. Using the previous version of the model, 27 percent of the acres received a nitrogen adjustment for one or more crops and 24 percent of the acres received a phosphorus adjustment for one or more crops. In addition, results using the revised model resulted in 17 percent of acres being modeled without nitrogen applications and 34 percent without phosphorus applications, compared to 9 percent for nitrogen and 23 percent for phosphorus using the previous version of the APEX model.

Figure 9. Percent of cropped acres at four conservation treatment levels for nitrogen management, baseline conservation condition, Texas Gulf Basin



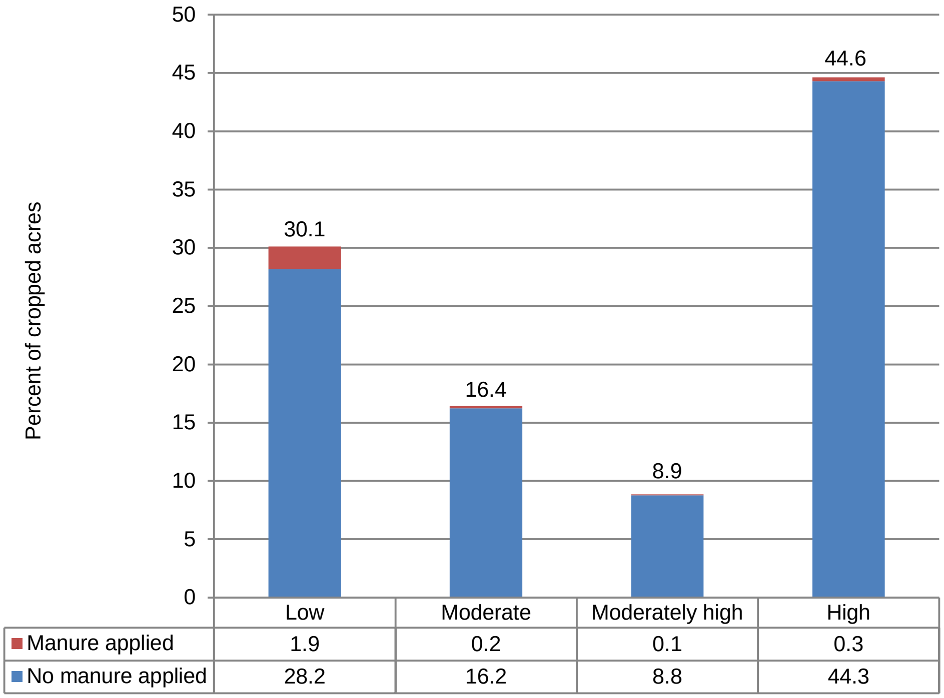
	Low	Moderate	Moderately high	High
Manure applied	0.9	0.9	0.6	0.2
No manure applied	3.5	26.3	33.2	34.5

Criteria for four levels of nitrogen management are:

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

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

Figure 10. Percent of cropped acres at four conservation treatment levels for phosphorus management, baseline conservation condition, Texas Gulf Basin



Criteria for four levels of phosphorus management are:

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

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

Pesticide Management Practices

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

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

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

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

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

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

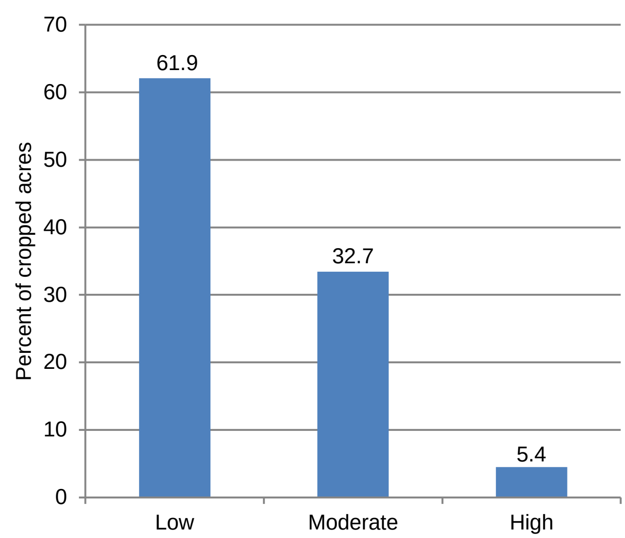
An IPM index was developed to determine the level of IPM activity for each sample point. The index was constructed as follows.

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

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

About 5 percent of the acres in the Texas Gulf Basin have a high level of IPM activity (fig. 11). About 33 percent have a moderate level of IPM activity, and 62 percent have a low level of IPM activity.

Figure 11. Integrated Pesticide Management indicator for the baseline conservation condition, Texas Gulf Basin



[11] For a full documentation of the derivation of the IPM indicator, see "Integrated Pest Management (IPM) Indicator Used in the CEAP Cropland Modeling," referenced on page 7.

Table 11. Summary of survey responses to pest management questions, Texas Gulf Basin

Survey question	Number samples with "yes" response	Percent of cropped acres
Prevention		
Pesticides with different action rotated or tank mixed to prevent resistance	91	16
Plow down crop residues	334	47
Chop, spray, mow, plow, burn field edges, etc.	274	38
Clean field implements after use	351	46
Remove crop residue from field	115	17
Water management used to manage pests (irrigated samples only)	27	4
Avoidance		
Rotate crops to manage pests	196	33
Use minimum till or no-till to manage pests	131	17
Choose crop variety that is resistant to pests	167	24
Planting locations selected to avoid pests	40	7
Plant/harvest dates adjusted to manage pests	52	9
Monitoring		
Scouting practice: general observations while performing routine tasks	310	43
Scouting practice: deliberate scouting	215	31
--Established scouting practice used	132	17
--Scouting due to pest development model	62	8
--Scouting due to pest advisory warning	65	9
Scouting done by: (only highest of the 4 scores is used)		
--Scouting by operator	133	19
--Scouting by employee	5	1
--Scouting by chemical dealer	27	4
--Scouting by crop consultant or commercial scout	89	11
Scouting records kept to track pests?	116	16
Scouting data compared to published thresholds?	133	16
Diagnostic lab identified pest?	24	3
Weather a factor in timing of pest management practice	127	19
Suppression		
Pesticides used?	556	78
Weather data used to guide pesticide application	224	35
Biological pesticides or products applied to manage pests	53	6
Pesticides with different mode of action rotated or tank mixed to prevent resistance	91	16
Pesticide application decision factor (one choice only):		
--Routine treatments or preventative scheduling	283	38
--Comparison of scouting data to published thresholds	36	5
--Comparison of scouting data to operator's thresholds	69	12
--Field mapping or GPS	0	0
--Dealer recommendations	35	4
--Crop consultant recommendations	55	8
--University extension recommendations	6	1
--Neighbor recommendations	1	0
--"Other"	38	7
Maintain ground covers, mulch, or other physical barriers	133	20
Adjust spacing, plant density, or row directions	78	12
Release beneficial organisms	7	1
Cultivate for weed control during the growing season	344	44
Number of respondents	693	100

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

Conservation Cover Establishment

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

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

Landowners receive annual rental payments and cost-share assistance for establishing and maintaining permanent vegetative cover. To be eligible for enrollment in the CRP General Signup, the field (or tract) must meet specified crop history criteria. Other factors governing enrollment in the CRP include natural resource-based eligibility criteria, an Environmental Benefits Index (EBI) used to compare and rank enrollment offers, acreage limits, and upper limits on the proportion of a county's cropland that can be enrolled (USDA Farm Service Agency 2004; Wiebe and Gollehon 2006). Initially, the eligibility criteria included only soil erosion rates and inherent soil erodibility. During the 1990s and to date, the eligibility criteria have continued to evolve, with increasing emphasis placed on issues other than soil erodibility. For contract offer ranking, weight was given to proposals that also benefited wildlife, air and water quality, and other environmental concerns.

As of 2003, about 31.5 million acres were enrolled in the CRP General Signup nationally, including about 2.5 million in the Texas Gulf Basin (USDA/NRCS 2007). Approximately 60 percent of the cropland acres enrolled in the CRP in the Texas Gulf Basin are classified as highly erodible land. The inclusion of non-highly erodible land is due to both the expansion of enrollment eligibility criteria beyond soil erosion issues and the fact that farmers were allowed to enroll entire fields in the CRP if a specified portion of the field (varied by signup and eligibility criterion) met the criteria.

In the Texas Gulf Basin, 68 percent of the CRP land is planted to introduced grasses, 32 percent to native grasses, and about 0.4 percent to trees. The plantings designated in the NRI database for each sample point were simulated in the APEX model. However, in all cases the simulated cover was a mix of species, and all points included at least one grass and one clover species.

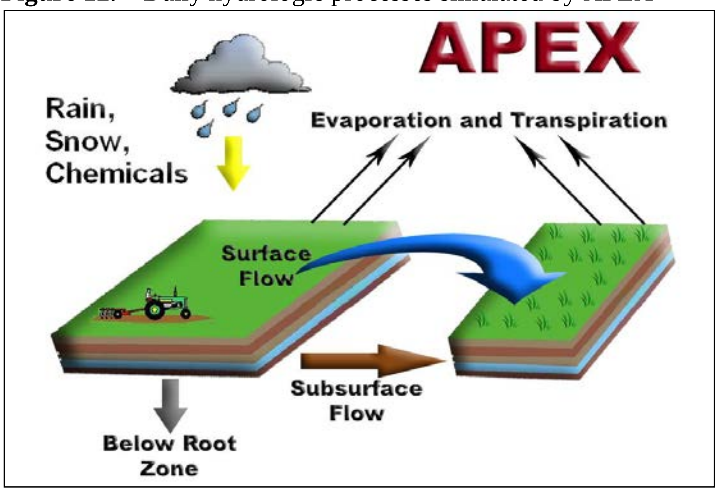
Chapter 4
Onsite (Field-Level) Effects of Conservation Practices

The Field-Level Cropland Model—APEX

A physical process model called APEX was used to simulate the effects of conservation practices at the field level (Williams et al. 2006; Williams et al. 2008; Gassman et al. 2009 and 2010).[12] 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.[13]

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides (fig. 12). The APEX model and its predecessor, EPIC (Environmental Policy Impact Calculator), have a long history of use in simulation of agricultural and environmental processes and of the effect of agricultural technology and government policy (Izaurralde et al. 2006;Williams 1990; Williams et al. 1984; Gassman et al. 2005).[14]

Figure 12. Daily hydrologic processes simulated by APEX



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

APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind erosion, sheet and rill erosion, and the loss of sediment beyond the edge of the field. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field. Exchange of gaseous forms between the soil and the atmosphere is simulated, including losses of gaseous nitrogen compounds.

The NRI-CEAP Cropland Survey was the primary source of information on all farming activities simulated using APEX. Crop data were transformed for the model into a crop rotation for each sample point, which was then repeated over the 47-year simulation. The 3 years of data reported in the survey were represented in the model simulation as 1-, 2-, 3-, 4-, or 5-year crop rotations. For example, a 2-year corn-soybean rotation was used if the operator reported that corn was grown in the first year, soybeans in the second year, and corn again in the third year. In this case, only 2 of the reported 3 years of survey data were used. If management differed significantly for the 2 years that corn was grown (manure was applied, for example, or tillage was different), the rotation was expanded to 4 years, retaining the second year of corn and repeating the year of soybeans. In addition, some rotations with alfalfa or grass seed were simulated as 5-year rotations. Specific rules and procedures were established for using survey data to simulate cover crops, double crops, complex systems such as intercropping and nurse crops, perennial hay in rotations, abandoned crops, re-planting, multiple harvests, manure applications, irrigation, and grazing of cropland before and after harvest.[15]

Use of conservation practices in the Texas Gulf Basin was obtained from four sources: (1) NRI-CEAP Cropland Survey, (2) NRCS field offices, (3) USDA Farm Service Agency (FSA), and (4) the 2003 NRI. For each sample point, data from these four sources were pooled and duplicate practices discarded.[16]

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

[13] 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.

[14] 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 in the collection of CEAP documentation reports referenced on page 7.

[15] For a detailed description of the rules and procedures, see "Transforming Survey Data to APEX Model Input Files," referenced on page 7.

[16] For a detailed description of the rules and procedures for simulation of structural conservation practices, see "Modeling Structural Conservation Practices in APEX," referenced on page 7.

Simulating the No-Practice Scenario

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

- **Consistency:** It is impossible to determine what an individual farmer would be doing if he or she had not adopted certain practices, so it is important to represent all practices on all sample points in a consistent manner that is based on the intended purpose of each practice.

- **Simplicity:** Complex rules for assigning “no-practice” activities lead to complex explanations that are difficult to substantiate and sometimes difficult to explain and accept. Complexity would not only complicate the modeling process but also hamper the interpretation of results.

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

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

- **Maintenance of crop yield or efficacy**. It is impossible to avoid small changes in crop yields, but care was taken to avoid no-practice representations that would significantly change crop yields and regional production capabilities. The same guideline was followed for pest control—the suite of pesticides used was not adjusted in the no-practice scenario because of the likelihood that alternative pesticides would not be as effective and would result in lower yields under actual conditions.

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

Table 12 summarizes the adjustments to conservation practices used in simulation of the no-practice scenario.

No-practice representation of structural practices

The no-practice field condition for structural practices is simply the removal of the structural practices from the modeling process. In addition, the soil condition is changed from “Good” to “Poor” for the determination of the runoff curve number for erosion prediction.

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

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

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

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

Table 12. Construction of the no-practice scenario for the Texas Gulf Basin

Practice adjusted	Criteria used to determine if a practice was in use	Adjustment made to create the no-practice scenario
Structural practices	1. Overland flow practices present	1. USLE P-factor changed to 1 and slope length increased for points with terraces, soil condition changed from good to poor.
	2. Concentrated flow—managed structures or waterways present	2. Structures and waterways replaced with earthen ditch, soil condition changed from good to poor.
	3. Edge-of-field mitigation practices present	3. Removed practice and width added back to field slope length.
	4. Wind erosion control practices present	4. Unsheltered distance increased to 400 meters
Residue and tillage management	STIR ≤100 for any crop within a crop year	Add two tandem diskings 1 week prior to planting
Cover crop	Cover crop planted for off-season protection	Remove cover crop simulation (field operations, fertilizer, grazing, etc.)
Irrigation (See text for details)	Pressure systems	Change to gravity systems except on sandy soils and steep slopes where system changed to hand move sprinkler except where existing system is less efficient
	Gravity systems	Where conveyance is pipeline, change to gated pipe unless existing system is less efficient Where conveyance is ditch, change to unlined ditch with portals
Nitrogen rate	Total of all applications of nitrogen (commercial fertilizer and manure applications) ≤1.4 times harvest removal for non-legume crops, except for cotton and small grain crops	Increase rate to 1.90 times harvest removal (proportionate increase in all reported applications, including manure)
	Total of all applications of nitrogen (commercial fertilizer and manure applications) ≤1.6 times harvest removal for small grain crops	Increase rate to 2.0 times harvest removal (proportionate increase in all reported applications, including manure)
	Total of all applications of nitrogen (commercial fertilizer and manure applications) for cotton ≤60 pounds per bale	Increase rate to 90 pounds per bale (proportionate increase in all reported applications, including manure)
Phosphorus rate	Applied total of fertilizer and manure P over all crops in the crop rotation ≤ 1.1 times total harvest P removal over all crops in rotation.	Increase commercial P fertilizer application rates to reach 2.0 times harvest removal for the crop rotation (proportionate increase in all reported applications over the rotation), accounting also for manure P associated with any increase in manure applications to meet nitrogen application criteria for the no practice scenario. Manure applications were not further increased to meet the higher P rate for the no-practice scenario.
Commercial fertilizer application method	Incorporated or banded	Change to surface broadcast
Manure application method	Incorporated, banded, or injected	Change to surface broadcast
Commercial fertilizer application timing	Within 3 weeks prior to planting, at planting, or within 60 days after planting.	Moved to 3 weeks prior to planting. Manure applications were not adjusted for timing in the no-practice scenario.
Pesticides	1. Practicing high level of IPM	1. All incorporated applications changed to surface application. For each crop, the first application event after planting and 30 days prior to harvest replicated twice, 1 week and 2 weeks later than original.
	2. Practicing moderate level of IPM	2. Same as for high level of IPM, except replication of first application only 1 time, 1 week after original
	3. Spot treatments	3. Application rates for spot treatments were adjusted upward relative to the baseline rate to represent whole-field application (see text)
	4. Partial field treatments	4. Application rates for partial field treatments were adjusted upward relative to the baseline rate to represent whole-field application (see text)

No-practice representation of conservation tillage

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

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

The most common type of tillage operation in the survey was disking, and the most common disk used was a tandem disk for nearly all crops, in all parts of the region, and for both dryland and irrigated agriculture. The tandem disk has a STIR value of 39 for a single use. Two consecutive disking operations will add 78 to the existing tillage intensity, which allows for more than 90 percent of the crops to exceed a STIR of 100 and yet maintain the unique suite and timing of operations for each crop in the rotation. Although a few sample points will have STIR values in the 80s or 90s after adding the two disking operations, the consistency of an across-the-board increase of 78 is simple and provides the effect of a distinctly more intense tillage system.

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

No-practice representation of cover crops

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

No-practice representation of irrigation practices

The no-practice irrigation protocols were designed to remove the benefits of better water management and the increased efficiencies of modern irrigation systems. Irrigation efficiencies are represented in APEX by a combination of three coefficients that recognize water losses from the water source to the field, evaporation losses with sprinkler systems, percolation losses below the root-zone during irrigation, and runoff at the lower end of the field. These coefficients are combined to form an overall system efficiency that varies with soil type and land slope.

The quantity of water applied for all scenarios was simulated in APEX using an “auto-irrigation” procedure that applied irrigation water when the degree of plant stress exceeded a threshold. “Auto-irrigation” amounts were determined within pre-set single event minimums and maximums, and an annual maximum irrigation amount. APEX also used a pre-determined minimum number of days before another irrigation event regardless of plant stress.

The Texas Gulf Basin is situated partly in what could be considered the supplemental irrigation area and partly in the traditional western irrigated area, where irrigation is essential for crop production. However, NRCS irrigation specialists recommended that this basin be treated as part of the western area; therefore we simulate it as such for this report.

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

After making the indicated adjustments to the irrigation technology, the no-practice scenario for irrigation consisted of 5.2 million acres (92 percent of the irrigated acres) of gravity systems and approximately 0.5 million acres (8 percent of irrigated acres) of pressure systems. Primary systems in the no-practice scenario are gated pipe (38 percent of irrigated acres), portals from unlined ditches (32 percent of irrigated acres), and open discharge (22 percent of irrigated acres).

No-practice representation of nutrient management practices

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

The NRCS Nutrient Management standard (590) allows a variety of methods to reduce nutrient losses while supplying a sufficient amount of nutrient to meet realistic yield goals. The standard addresses nutrient loss in two primary ways: (1) by altering rates, form, timing, and methods of application, and (2) by installing buffers, filters, or erosion or runoff control practices to reduce mechanisms of loss. The latter method is covered by the structural practices protocols for the no-practice scenario. The goals of the nutrient management no-practice protocols are to alter three of the four basic aspects of nutrient application—rate, timing, and method. The form of application was not addressed because of the inability to determine if proper form was being applied.

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

- increased to 1.90 times harvest removal for non-legume crops receiving less than or equal to 1.4 times the amount of nitrogen removed at harvest in the baseline scenario, except for cotton and small grain crops;
- increased to 2.0 times harvest removal for small grain crops receiving less than or equal to 1.6 times the amount of nitrogen removed at harvest in the baseline scenario, and
- increased to 90 pounds per bale for cotton crops receiving less than 60 pounds of nitrogen per bale in the baseline scenario.

The ratio of 1.90 for the increased nitrogen rate was determined by the average rate-to-yield-removal ratio for crops exceeding the application-removal ratio of 1.4 in this region. Where nitrogen was applied in multiple applications, each application was increased proportionately.

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

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

For the no-practice scenario, the amount of commercial phosphorus fertilizer applied was increased to 2.0 times the harvest removal rate for the crop rotation. The ratio of 2.0 for the increased phosphorus rate was determined by the average rate-to-yield-removal ratio for crops with phosphorus applications exceeding 1.1 times the amount of phosphorus taken up by all the crops in rotation and removed at harvest in this region. Multiple commercial phosphorus fertilizer applications were increased proportionately to meet the 2.0 threshold.

Manure application rate. For sites receiving manure, the appropriate manure application rate in tons per acre was identified on the basis of the total nitrogen application rate, including both manure and commercial nitrogen fertilizer. Thus, if the total for all applications of nitrogen (commercial fertilizer and manure) was less than or equal to 1.4 times removal at harvest for non-legume crops, the no-practice manure application rate was increased such that the combination of commercial fertilizer and manure applications resulted in a total rate of nitrogen application equal to 1.90 times harvest removal. Both commercial nitrogen fertilizer and the amount of manure were increased proportionately to reach the no-practice scenario rate. For small grains and cotton, the same approach was used using the criteria defined above for commercial nitrogen fertilizer. As done with commercial nitrogen fertilizer, the assessment was made separately for each crop in the rotation.

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

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

Timing of application. Nutrients applied closest to the time when a plant needs them are the most efficiently utilized and least likely to be lost to the surrounding environment. All commercial fertilizer applications occurring within 3 weeks prior to planting, at planting, or within 60 days after planting were moved back to 3 weeks prior to planting for the no-practice scenario. For example, split applications that occur within 60 days after planting are moved to a single application 3 weeks before planting for the no-practice scenario.

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

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

No-practice representation of pesticide management practices

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

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

The first activity is covered by the no-practice representation of structural practices and residue and tillage management. The second activity, for the most part, cannot be simulated in large-scale regional modeling because of the difficulty in assuring that any changes in the types of pesticides applied or in the method or timing of application would provide sufficient protection against pests to maintain crop yields.[17] Farmers, of course, have such options, and environmentally conscientious farmers make tradeoffs to reduce environmental risk. But without better information on the nature of the pest problem both at the field level and in the surrounding area, modelers have to resort to prescriptive and generalized approaches to simulate alternative pesticides and application techniques, which would inevitably be inappropriate for many, if not most, of the acres simulated.

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

One of the choices for methods of pesticide application on the survey was "spot treatment." Typically, spot treatments apply to a small area within a field and are often treated using a hand-held sprayer. Spot treatment is an IPM practice, as it requires scouting to determine what part of the field to treat and avoids treatment of parts of the field that do not have the pest problem. The reported rate of application for spot treatments was the rate per acre treated. For the baseline simulation, it was assumed that all spot treatments covered 5 percent of the field. Since the APEX model run and associated acreage weight for the sample point represented the whole field, the application rate was adjusted downward to 5 percent of the per-acre rate reported for the baseline scenario. For the no-practice scenario, the pesticide application rate as originally reported was used, simulating treatment of the entire field rather than 5 percent of the field. In the Texas Gulf Basin, there were 32 sample points with spot treatments, representing about 4 percent of the cropped acres**.**

Partial field treatments were simulated in a manner similar to spot treatments. Partial field treatments were determined using information reported in the survey on the percentage of the field that was treated. (Spot treatments, which are also partial field treatments, were treated separately as described above.) For the baseline scenario, application rates were reduced proportionately according to how much of the field was treated. For the no-practice scenario, the rate as reported in the survey was used, simulating treatment of the entire field. However, this adjustment for the no-practice scenario was only done for partial field treatments on less than one-third of the field, as larger partial field treatments could have been for reasons unrelated to IPM. About 4 percent of the cropped acres in the Texas Gulf Basin had partial field treatments of pesticides.

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

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

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

[17] 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.

Potential for Using Model Simulation to Assess Alternative Conservation Policy Options

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

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

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

Effects of Practices on Fate and Transport of Water

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

Baseline condition for cropped acres

Precipitation and irrigation are the sources of water for a field. Annual precipitation over the 47-year simulation averaged about 28 inches for non-irrigated cropped acres in this region, and 25 inches for irrigated cropped acres (table 13). (Also see figs. 5 and 6.) In the model simulation, about 30 percent of cropped acres are irrigated at an average application of 19 inches per year.

Most of the water that leaves the field is lost through evaporation and transpiration (evapotranspiration) (fig. 13). Evapotranspiration is the dominant loss pathway for over 99 percent of cropped acres. On average, about 82 percent of the water loss for cropped acres in this region is through evapotranspiration (table 13). Model results indicate that evapotranspiration losses vary, however, according to soil characteristics and land cover; evapotranspiration ranges from about 50 percent to nearly 100 percent of the total amount of water that leaves the field (fig. 14).

Surface water runoff constitutes most of the remaining water loss for cropped acres. Surface water runoff averages about 13 percent of total water loss for cropped acres (table 13), ranging from zero to about 30 percent of total water loss (fig. 14). Average surface water loss for cropped acres is about 4.3 inches per year (table 13). The amount of surface water runoff varies from acre to acre, ranging from an annual average of zero inches per year to about 20 inches per year (fig. 15).

Subsurface flow pathways account for the remaining 4 percent of water loss at an average of about 1.4 inches per year for cropped acres (table 13). However, this percentage ranges up to about 30 percent for some cropped acres in the Texas Gulf Basin, as shown in figure 14. Subsurface flow pathways include—

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

About three-fourths of the land in long-term conserving cover is located in the western portion of the basin (table 4). Annual precipitation for land in long-term conserving cover averages about 19 inches per year, and evapotranspiration represents 97 percent of total water loss, on average (table 13).

Figure 13. Estimates of average annual water lost through three loss pathways for cropped acres in the Texas Gulf Basin

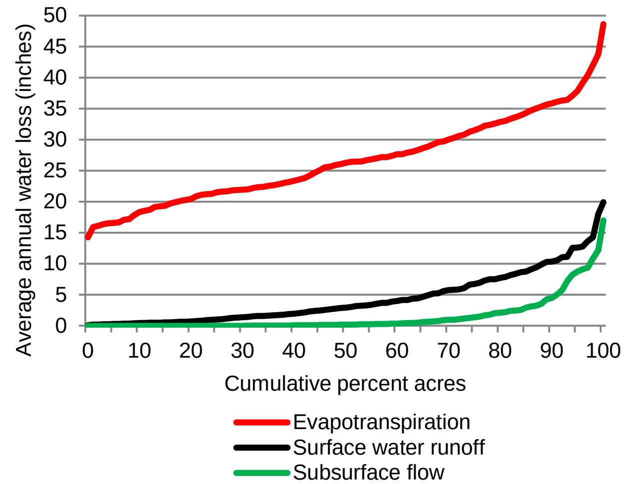
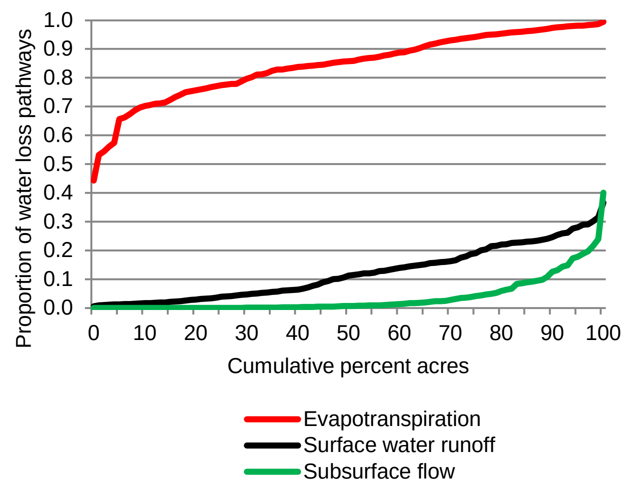


Figure 14. Cumulative distributions of the proportion of water lost through three loss pathways for cropped acres, Texas Gulf Basin



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

Figure 15. Estimates of average annual surface water runoff for cropped acres in the Texas Gulf Basin

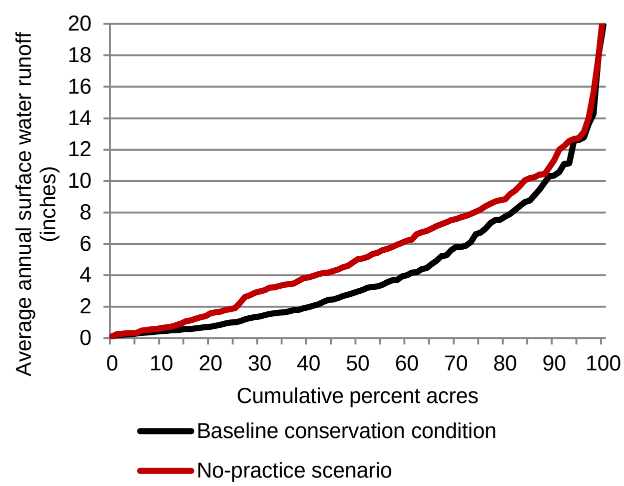


Table 13. Field-level effects of conservation practices on water loss pathways for cultivated cropland in the Texas Gulf Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (18.4 million acres)				
Water sources				
Non-irrigated acres				
Average annual precipitation (inches)	28.2	28.2	0.0	0
Irrigated acres				
Average annual precipitation (inches)	25.2	25.2	0.0	0
Average annual irrigation water applied (inches)*	19.3	25.7	6.4	25
Water loss pathways				
Average annual evapotranspiration (inches)	26.57	26.61	0.04	<1
Average annual surface water runoff (inches)	4.32	5.61	1.29	23
Irrigated acres	4.11	7.88	3.77	48
Non-irrigated acres	4.41	4.61	0.20	4
Average annual subsurface water flows (inches)**	1.42	1.27	-0.15***	-11***
Land in long-term conserving cover (2.5 million acres)				
Water sources*				
Average annual precipitation (inches)	18.8	18.8	0	0
Average annual irrigation water applied (inches)*	0.0	13.2	13.2	100
Water loss pathways				
Average annual evapotranspiration (inches)	18.3	25.9	7.6	29
Average annual surface water runoff (inches)	0.5	3.5	3.0	85
Average annual subsurface water flow (inches)**	0.1	0.8	0.7	89

* In the model simulation, about 30 percent of the cropped acres in the Texas Gulf Basin are irrigated. Land in long-term conserving cover was not irrigated, but some farming practices used to simulate a cropped condition to represent the no-practice scenario included irrigation. Values shown in the table for land in long-term conserving cover are averages over all acres, including non-irrigated acres.
** Subsurface flow pathways include: (1) deep percolation to groundwater, including groundwater return flow; (2) subsurface flow into a drainage system; (3) lateral subsurface outflow; and (4) quick-return subsurface flow.
*** Represents an average gain in subsurface flows of 0.15 inch per year (11 percent increase) for cropped acres 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 B for the 11 subregions.

Tile Drainage

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

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

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

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

In the Texas Gulf Basin, only about 1 percent of the cropped acres (5 sample points) have some portion of the field that is tile drained, according to the farmer survey.

Effects of conservation practices on cropped acres

Cropped acres. Structural water erosion control practices, residue management practices, and reduced tillage slow the flow of surface water runoff and allow more of the water to infiltrate into the soil.[18]

In addition, improved conservation management reduces annual irrigation water use. In this region, about 60 percent of irrigated acres would have more than 25 inches of water applied per year in the no-practice scenario (without conservation practice use), as shown in figure 16. For irrigated acres with conservation practice use (the baseline conservation condition), only 25 percent of irrigated acres have more than 25 inches applied per year. Use of improved irrigation systems in the Texas Gulf Basin increases overall system efficiency from 43 percent in the no-practice scenario to 65 percent in the baseline scenario. This change in efficiency represents an annual decreased need of irrigation water use by about 6.4 inches per year where irrigation is used, a 25-percent reduciton (table 13).

Model simulations also indicate that conservation practices have reduced surface water runoff by about 1.3 inches per year averaged over all acres, representing a 23-percent reduction for the region (table 13). The bulk of these reductions were on irrigated acres, where the reduction in surface water runoff due to use of conservation practices averaged 48 percent.

The variability of the effects of conservation practices on surface water runoff in the region is shown in figures 15 and 17 for all cropped acres and in figure 18 for irrigated acres. Reductions in surface water runoff due to conservation practices range from less than zero to more than 7 inches per year, with the highest gains in water loss reduction achieved on irrigated cropland (figs. 17 and 18). The variability in reductions due to practices reflects different levels of conservation treatment as well as differences in precipitation and inherent differences among acres related to propensity for water to run off.

Figure 17 also shows that about 12 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.

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

Figure 16. Estimates of average annual irrigation water use for irrigated crop acres in the Texas Gulf Basin

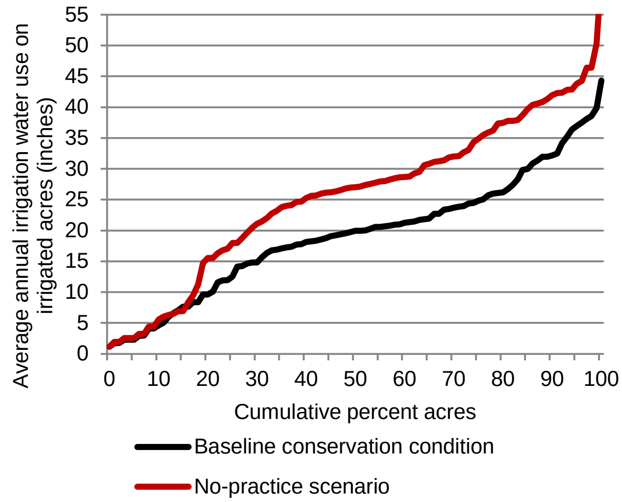


Figure 17. Estimates of average annual reduction in surface water runoff due to the use of conservation practices on cropped acres in the Texas Gulf Basin

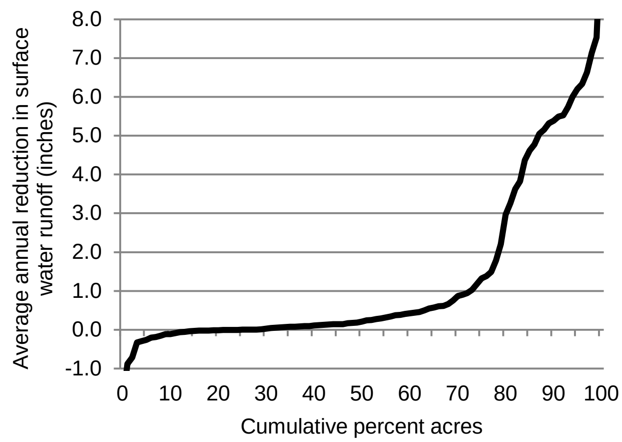
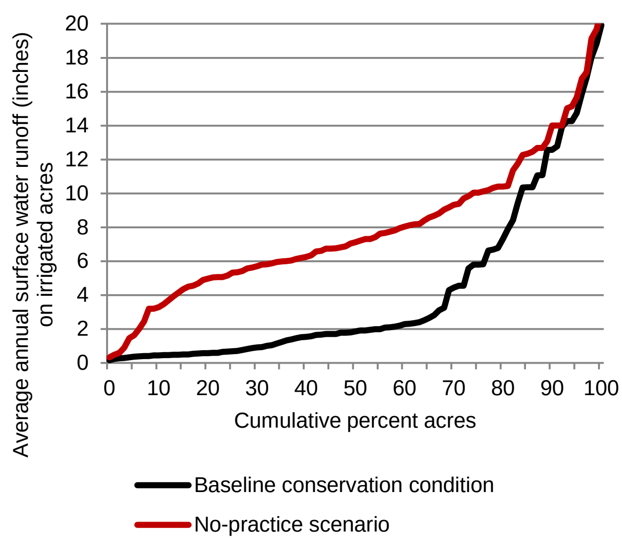


Figure 18. Estimates of average annual surface water runoff for irrigated crop acres in the Texas Gulf Basin



Conservation practices marginally increase water lost to subsurface flows, increasing water loss by an average of 0.15 inch per year (table 13). This is an indirect impact of gains made in reducing surface water losses; some of the surface water moves through the soil and is rerouted to subsurface flow. This rerouted water is also available as soil moisture for crop growth during its movement through the soil column. The variability of the effects of conservation practices on subsurface flows is shown in figures 19 and 20 for all cropped acres. These figures show that conservation practice use has little or no effect on water losses in subsurface flow pathways for most acres in the Texas Gulf Basin.

Figure 19. Estimates of average annual subsurface flows for cropped acres in the Texas Gulf Basin

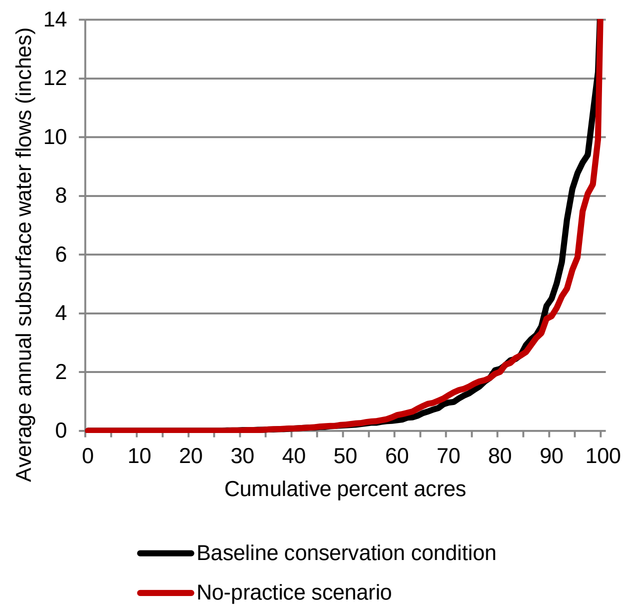
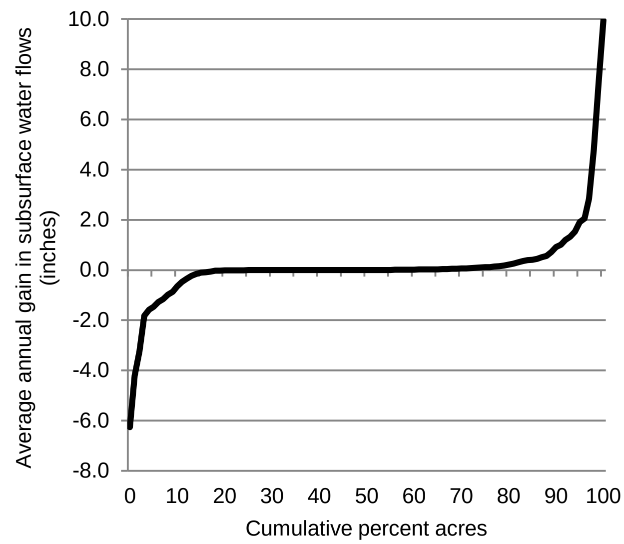


Figure 20. Estimates of average annual gain in subsurface flows due to the use of conservation practices on cropped acres in the Texas Gulf Basin

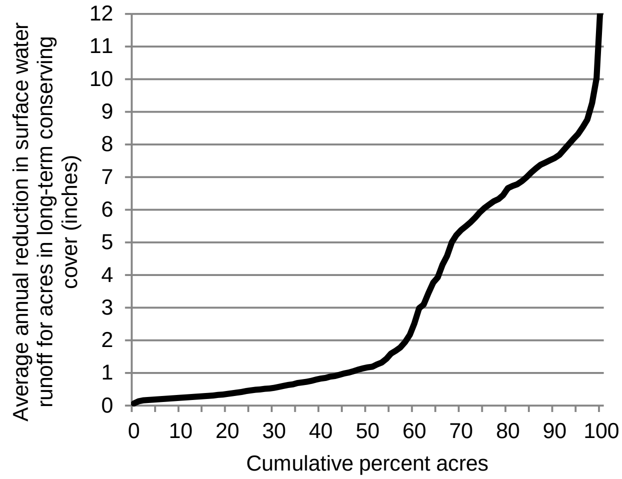


Land in long-term conserving cover. Model simulations further show that land in long-term conserving cover (baseline conservation condition) in the region is dryer, on average, than the rest of the region (19 inches per year average precipitation compared to an average of 25 inches per year for irrigated cropped acres and 28 inches per year for non-irrigated cropped acres). Land in long-term conserving cover thus has less surface water runoff and subsurface flow than would occur if the land was cropped (table 13).

Reductions in surface water runoff due to conversion to long-term conserving cover average 3.0 inches per year in this region (table 13). As shown in figure 21, reductions average less than 1 inch on about half of all acres in conserving cover, while about one-fourth of acres in conserving cover have reductions of more than 6 inches per year.

Reductions in subsurface flows due to conservation practice use were less, averaging 0.7 inch per year (table 13).

Figure 21. Estimates of average annual reduction in surface water runoff due to conversion to long-term conserving cover in the Texas Gulf Basin



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 693 sample points used to represent cropped acres in the Texas Gulf Basin and for each of the 875 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 693 surface water runoff estimates, weighted by the acres associated with each sample point. The 10th percentile for the baseline conservation condition is 0.45 inch per year, indicating that 10 percent of the acres have 0.45 inch 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 1.0 inch per year. The 50th percentile—the median—is 3.0 inches per year, compared to the mean value of 4.3 inches per year. At the high end of the distribution, 90 percent of the acres in this region have surface water runoff less than 10.4 inches per year; and conversely, 10 percent of the acres have surface water runoff greater than 10.4 inches per year.

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

Figure 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 693 cropped sample points. This distribution shows that, while the mean reduction is 1.29 inches per year, only 28 percent of the acres have reductions due to conservation practices greater than 1.0 inch per year. About 12 percent of the acres actually have increases in surface water runoff (i.e., negative reductions) as a result of conservation practice use.

Effects of Practices on Wind Erosion

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

Wind erosion is a significant resource concern for most cropped acres in the Texas Gulf Basin. Wind erosion rates as low as 0.5 ton per acre can cause physical damage to young seedlings. Wind erosion can also deposit sediment rich in nutrients into adjacent ditches and surface drainage systems, where it is then transported to water bodies with runoff. Wind erosion rates greater than 2 tons per acre per year can result in significant losses of soil and associated contaminants over time. Wind erosion rates greater than 4 tons per acre can result in excessive soil loss annually and can also have adverse effects on human health.

Baseline condition for cropped acres

Model simulations show that the average annual rate of wind erosion is 8.55 tons per acre for cropped acres in the region (table 14)—12.38 tons per acre per year for highly erodible land and 6.65 tons per acre for non-highly erodible land.

Annual wind erosion can exceed 1 ton per acre on over half of the cropped acres in all years (fig. 22). In the most extreme year included in the model simulations (representing 2002), the median wind erosion rate was more than 5 tons per acre and the annual rate exceeded 20 tons per acre for more than one-fourth of the cropped acres. Even so, wind erosion is a relatively minor resource concern for some acres in the region. About 20 percent of cropped acres had an average annual wind erosion rate less than 0.5 ton per acre (fig. 22), though not every acre was below this threshold in every year.

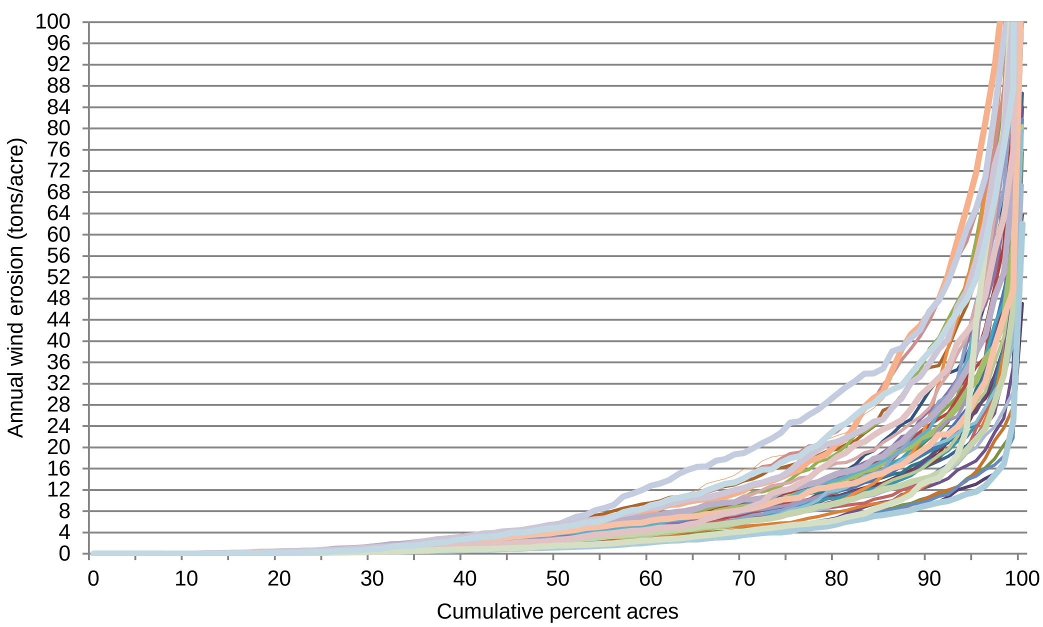
Average wind erosion rates vary considerably throughout the region. About 10 percent of cropped acres in the region lose an average of 24 tons or more per acre per year (fig. 23), while 23 percent of cropped acres in the region lose an average of one ton or less per acre per year.

Table 14. Average annual wind erosion (tons/acre) for cultivated cropland in the Texas Gulf Basin

	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (18.4 million acres)	8.55	8.73	0.18	2
Highly erodible land (33 percent of cropped acres)	12.38	12.68	0.30	2
Non-highly erodible land (67 percent of cropped acres)	6.65	6.77	0.13	2
Land in long-term conserving cover	<0.01	2.02	2.02	100

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Model simulation results for the baseline conservation condition are presented in appendix B for the 11 subregions.

Figure 22. Distribution of annual wind erosion rate for each year of the 47-year model simulation, Texas Gulf Basin



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

Effects of conservation practices

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

Structural practices for wind erosion control are in use on only 3 percent of the cropped acres in the Texas Gulf Basin. While other conservation practices, including residue and tillage management, reduced tillage, and various water erosion control practices, are also effective in reducing wind erosion, they are not currently adopted throughout the region. Model simulations indicate that conservation practices have reduced the average wind erosion rate across all cropped acres in the region by only 2 percent (table 14). Without conservation practices, the average annual wind erosion would have been 8.73 tons per acre per year compared to 8.55 tons per acre average for the baseline conservation condition (table 14). On average, conservation practices have reduced wind erosion by only 0.18 ton per acre per year—0.30 ton per acre for highly erodible land and 0.13 ton per acre for non-highly erodible land.

Reductions in wind erosion due to conservation practices are much higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil (fig. 24). For 25 percent of cropped acres, average annual wind erosion rates were higher in the baseline scenario than in the no-practice scenario by 0.5 ton per acre or more, resulting in the negative reductions shown in figure 24. This condition occurs in areas with relatively low precipitation because the higher fertilization rates used to simulate the no-practice scenario produce significantly more vegetative cover, which in turn provides better protection for the soil from the forces of the wind than in the baseline scenario, where biomass production is less and crop residue losses are higher.

Converting land to long-term conserving cover reduces wind erosion by virtually 100 percent. Since grass or other cover has been established on land in long-term conserving cover, wind erosion is negligible (table 14). If these acres were cropped without any conservation practices, the wind erosion rate on these 2.5 million acres would average about 2.0 tons per acre per year.

Figure 23. Estimates of average annual wind erosion for cropped acres in the Texas Gulf Basin

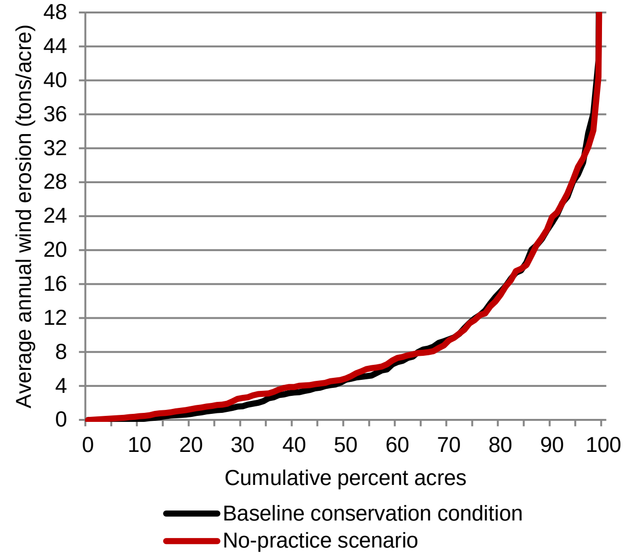
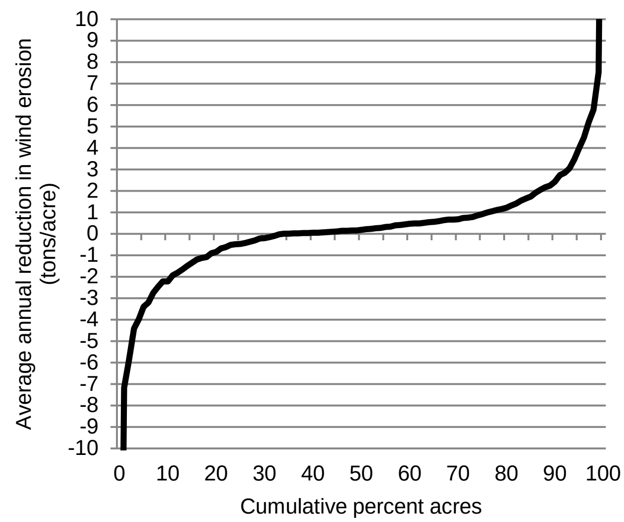


Figure 24. Estimates of average annual reduction in wind erosion due to the use of conservation practices on cropped acres in the Texas Gulf Basin



Costs of Excessive Wind Erosion

Wind erosion represents a major natural resource problem in the western United States. Of the estimated annual 2 billion tons of cropland soil loss by wind, approximately 88 percent occurs in the Western States. During a windstorm, the very fine windblown soil material becomes suspended in the atmosphere and may travel many miles before being deposited back to the surface. Windblown sediment is often deposited in drainage ditches, where it is then easily transported into rivers and streams with surface water runoff. Windblown material originating from cropland is generally rich in nutrients and can contain pesticides and other contaminants.

Programs and mitigating practices are traditionally designed and paid for on the basis of losses in soil productivity, crop quality and yield, and other on-farm economic impacts. But the full costs of wind erosion also include offsite damages. The two most obvious offsite impacts relate to maintenance of roadside ditches and reduced visibility on highways, sometimes resulting in accidents and fatalities. Other impacts include human health issues associated with impaired air quality and costs related to clean up and repair and replacement of equipment and facilities (Huszar 1989). In a study of offsite costs of wind erosion in New Mexico, offsite costs were estimated to average over $400 million per year, dwarfing the $10 million per year onsite damages estimated by other studies (Davis 1989). The annual offsite wind erosion costs for all the western states are estimated at between $3.76 and $12.08 billion (Huszar 1989).

Effects of Practices on Water Erosion and Sediment Loss

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

Sheet and rill erosion

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

Model simulations show that sheet and rill erosion on cropped acres averages about 0.86 ton per acre per year (table 15). Sheet and rill erosion rates are slightly lower for highly erodible land, averaging 0.61 ton per acre per year, compared to the average annual rate for non-highly erodible land of 0.98 ton per acre. This difference is not due to differences in conservation practice usage, as treatment for water erosion is about the same for both groups of acres (tables 7, 8, and 9). The designation of highly erodible land is largely determined by wind erosion in this region, which is much higher for acres designated as highly erodible, as shown in table 14.

Model simulation results also show that conservation practices have reduced sheet and rill erosion on cropped acres by an average of 0.41 ton per acre per year, representing a 32-percent reduction on average (table 15). The percent reduction in sheet and rill erosion for highly erodible land is slightly higher (40-percent reduction) than the percent reduction for non-highly erodible acres (29-percent reduction) (table 15).

For land in long-term conserving cover, sheet and rill erosion has been reduced from 0.95 ton per acre per year if cropped without conservation practices to less than 0.01 ton per acre (table 15), on average.

Sediment loss from water erosion

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

The APEX component for water-induced erosion simulates erosion caused by rainfall, runoff, and irrigation. APEX contains eight equations capable of simulating rainfall and runoff erosion: universal soil loss equation (USLE); Onstad-Foster modification of the USLE; revised universal soil loss equation (RUSLE); RUSLE2; the modified universal soil loss equation (MUSLE); two variations of MUSLE; and a MUSLE function that accepts input coefficients. In any given simulation, only one of the equations interacts with other APEX components. For this study on the Texas Gulf Basin, the APEX model was set up to estimate sediment loss using MUSLE as the specified driver in APEX. This choice allows the APEX model to provide better sediment yield estimates for the more significant rainfall events.[19]

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

Baseline condition for cropped acres. The average annual sediment loss for cropped acres in the Texas Gulf Basin is 1.09 tons per acre per year, according to the model simulation (table 15). As seen for sheet and rill erosion, sediment loss for highly erodible land is lower than for non-highly erodible land.

On an annual basis, sediment loss can vary from year to year, although high losses are restricted to a minority of the acres. Figure 25 shows that, with the conservation practices currently in use in the Texas Gulf Basin, annual sediment loss is below 1 ton per acre for about 60 percent of the acres under all conditions, including years with high precipitation. In contrast, sediment loss exceeds 4 tons per acre in one or more years on about 13 percent of cropped acres.

Figure 25 also illustrates the extent to which high sediment losses are restricted to a minority of acres within the region, even during years with high precipitation. These are the acres that have the highest inherent vulnerability to water erosion and have inadequate soil erosion control.

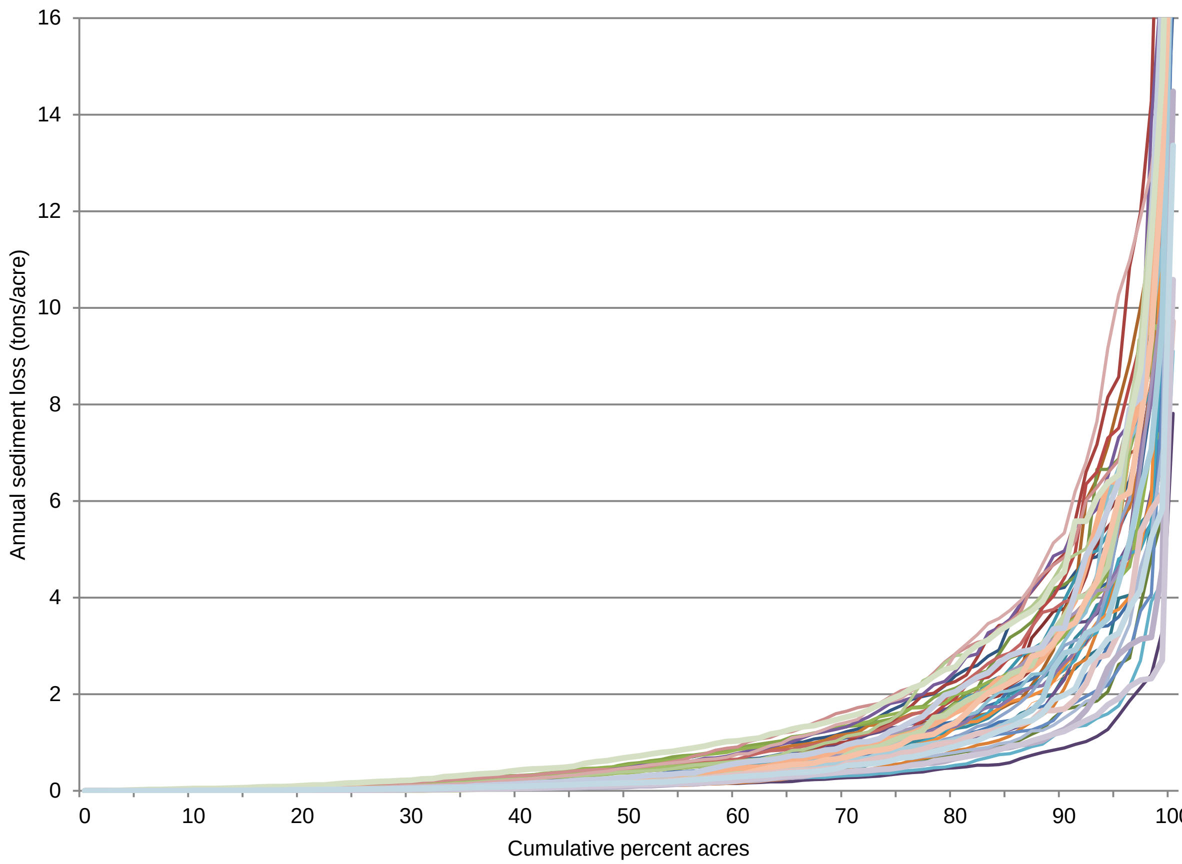
[19] In the previous version of the APEX model, MUST (one of the variations of MUSLE) was used as the driver. The MUST equation tends to be more sensitive to light and moderate rainfall and runoff events, and generates higher sediment yields for these events than MUSLE. In contrast, MUSLE is tailored to better represent the more intense rainfall events. The use of MUSLE rather than MUST generally will increase model estimates of sediment and nutrient loss via surface water runoff and decrease estimates of nutrients lost through subsurface pathways.

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

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (18.4 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.86	1.26	0.41	32
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	1.09	2.25	1.16	52
Highly erodible land (33 percent of cropped acres)				
Average annual sheet and rill erosion (tons/acre)*	0.61	1.02	0.41	40
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	0.73	2.23	1.50	67
Non-highly erodible land (67 percent of cropped acres)				
Average annual sheet and rill erosion (tons/acre)*	0.98	1.38	0.41	29
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	1.26	2.26	1.00	44
Land in long-term conserving cover (2.5 million acres)				
Average annual sheet and rill erosion (tons/acre)*	<0.01	0.95	0.94	100
Average annual sediment loss at edge of field due to water erosion (tons/acre)	<0.01	2.76	2.76	100

* Estimated using the Revised Universal Soil Loss Equation.
**Estimated using MUSLE as the specified driver in APEX. See text.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 11 subregions.

Figure 25. Distribution of annual sediment loss for each year of the 47-year model simulation, Texas Gulf Basin



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

Effects of conservation practices on cropped acres. Model simulations indicate that the use of conservation practices in the Texas Gulf Basin has reduced average annual sediment loss from water erosion by 52 percent for cropped acres in the region (table 15). Without conservation practices, the average annual sediment loss for these acres would have been 2.25 tons per acre per year, compared to 1.09 tons per acre average for the baseline conservation condition. Figure 26 shows that about 35 percent of the acres would have more than 2 tons per acre per year sediment loss without practices, on average, compared to 16 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 cropped acres, the average annual sediment loss reduction due to practices is less than 0.3 ton per acre (fig. 27). In contrast, the top 10 percent of the acres had reductions in average annual sediment loss greater than about 3 tons per acre.

Figure 26. Estimates of average annual sediment loss for cropped acres in the Texas Gulf Basin

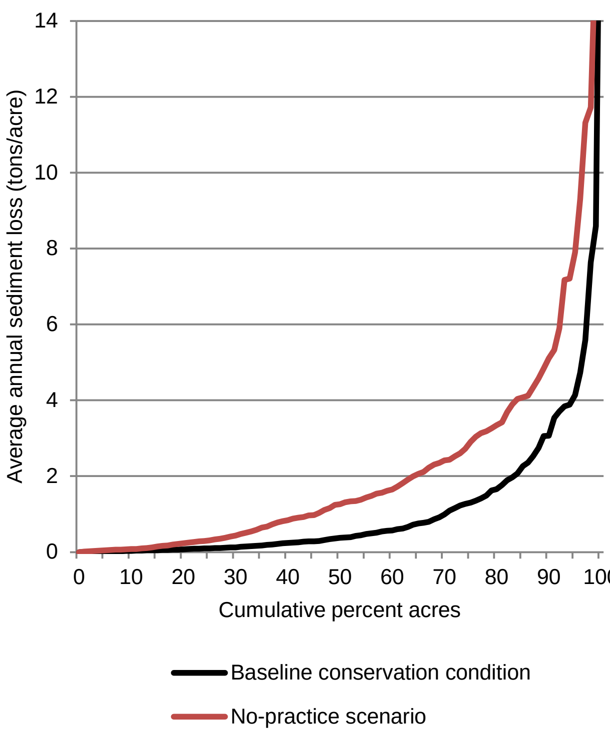
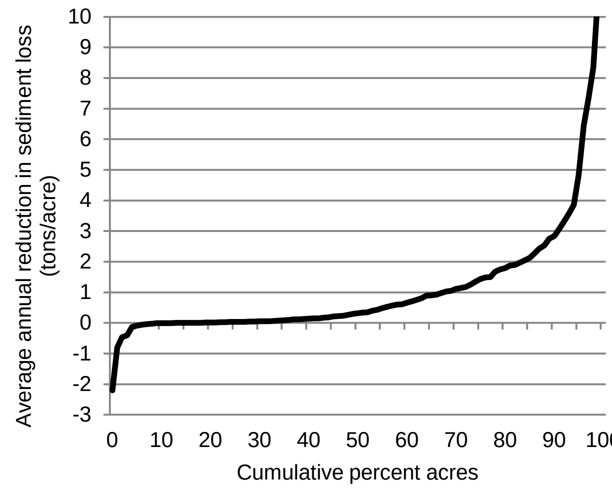


Figure 27. Estimates of average annual reduction in sediment loss due to the use of conservation practices on cropped acres in the Texas Gulf Basin

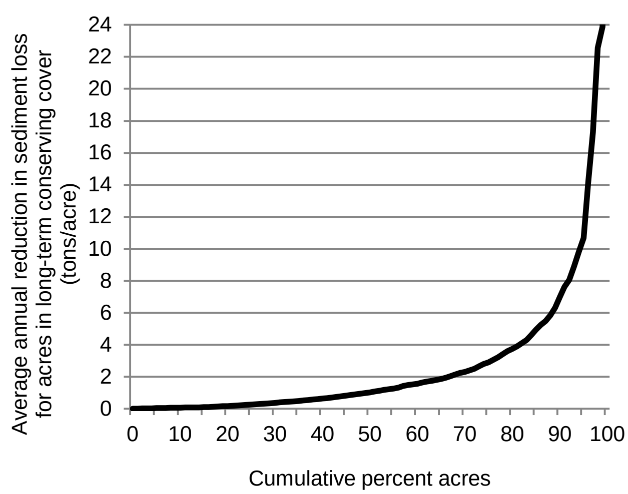


Note: About 5 percent of the acres had less sediment loss in the no-practice scenario than the baseline conservation condition, shown as negative reductions above, resulting from the increase in surface water runoff on some acres due to conservation practices. (See figure 17.)

Land in long-term conserving cover. Acres in long-term conserving cover have very little erosion or sediment loss, and thus show nearly 100-percent reductions when compared to a cropped condition (table 15). If these 2.5 million acres were still being cropped without any conservation practices, sediment loss to water erosion would average about 2.8 tons per acre per year for these acres.

Reductions in sediment loss for land in long-term conserving cover compared to the same acres with crops and no conservation practices vary, as shown in figure 28. About 50 percent of the acres in long-term conserving cover have reductions of less than 1 ton per acre per year. In contrast, reductions greater than 4 tons per acre per year occur on about 18 percent of the acres with long-term conserving cover.

Figure 28. Estimates of average annual reduction in sediment loss due to conversion to long-term conserving cover in the Texas Gulf Basin



Effects of Practices on Soil Organic Carbon

The climate and cropping systems in the Texas Gulf Basin are not conducive to maintaining and enhancing soil organic carbon on cultivated acres.

Soil organic carbon levels in the more humid subtropical eastern portion of the basin are higher than those of the west due not only to the increased rainfall but also because the warmer climate and predominance of low-residue crops such as cotton decrease the ability of these soils to maintain or enhance carbon stores. Additionally, the hotter summer temperatures reduce the production potential of the high-residue crops such as corn, thereby further reducing the carbon sequestration in these soils.

The western portion of the basin is dominated by wheat and other small grain production along with dryland and irrigated cotton. These dry conditions limit the amount of biomass production potential. The drier climate and lower biomass production potential makes it difficult to accumulate carbon under cultivation conditions. Low-residue crop rotations also make it difficult to maintain carbon stores, even with low-intensity tillage.

In this study, estimation of soil organic carbon change is based on beginning soil characteristics that reflect the effects of years of traditional conventional tillage practices and older, lower yielding crop varieties. These effects generally resulted in soils with organic carbon levels at or near their low steady state. Modern high yielding crop varieties with and without the adoption of conservation tillage tend to readily improve the status of carbon in many soils, especially those with beginning stocks far less than the steady state representation of the present management.

Beginning the simulations at a lower steady state for carbon allows for a more equitable comparison of conservation practices, particularly conservation tillage. Because of this, however, model estimates of soil organic carbon change may be somewhat larger than shown in other studies. Nevertheless, model estimates obtained in this study fall within the expected range for the continuum of adoption of new crop genetics and tillage practices.

Baseline condition for cropped acres

Model simulation shows that for the baseline conservation condition the average annual soil organic carbon change is a loss of about 176 pounds per acre per year, on average (table 16), with about 13 percent of the acres gaining annually in soil organic carbon and 87 percent of cropped acres losing soil organic carbon, on average (fig. 29). These estimates account for losses of carbon with sediment removed from the field by wind and water erosion. Loss of soil organic carbon due to wind and water erosion averages about 183 pounds per acre per year for the baseline conservation condition (table 16).

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

Cropping systems can be considered to be maintaining soil organic carbon if average annual losses do not exceed 100 pounds per acre per year; this rate of change is typically too small to detect via typical soil sampling over a 20-year period. Applying this criterion, about 17 percent of the acres in the region would be considered to be maintaining (but not enhancing) soil organic carbon. When combined with acres enhancing soil organic carbon, a total of 30 percent of the acres in the region would be either maintaining or enhancing soil organic carbon.

Table 16. Field-level effects of conservation practices on soil organic carbon for cultivated cropland in the Texas Gulf Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (18.4 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	183	232	49	21
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)*	-176	-184	8**	--
Land in long-term conserving cover (2.5 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	13	238	225	94
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)*	112	-264	376**	--

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

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

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

Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 11 subregions.

Effects of conservation practices on cropped acres

Without conservation practices, the annual change in soil organic carbon would be an average loss of 184 pounds per acre per year, compared to an average loss of 176 pounds per acre for the baseline (table 16). Thus, conservation practices in the region have resulted in an average annual reduction in soil organic carbon loss of only 8 pounds per acre per year on cropped acres.

Average annual change in soil organic carbon varies considerably among acres in the region, as shown in figures 29 and 30. There is negligible difference in the carbon trends between the no-practice and baseline scenarios shown in figure 29. The average annual gain in soil organic carbon due to practices varies among acres, as shown in figure 30, from a loss of about 200 pounds per acre per year to a gain of as much as 300 pounds per acre per year. The amount of gain due to practices depends on the extent of residue and nutrient management use as well as the soil's potential to sequester carbon. Only about 6 percent of cropped acres have a gain in soil organic carbon of 100 pounds per acre or more due to conservation practices.

Some of the increased gain in soil organic carbon due to conservation practices is the result of soil erosion control; keeping soil and associated soil organic carbon on the field promotes soil quality. If conservation practices were not in use, loss of soil organic carbon due to wind and water erosion would average 232 pounds per acre per year, compared to 183 pounds per acre with conservation practices (table 16).

For air quality concerns, the analysis centers on the decrease in carbon dioxide 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 soil organic carbon loss of 8 pounds per acre due to conservation practice use is equivalent to an emission reduction of 0.27 million U.S. tons of carbon dioxide for the Texas Gulf Basin.

Figure 29. Estimates of average annual change in soil organic carbon for cropped acres in the Texas Gulf Basin

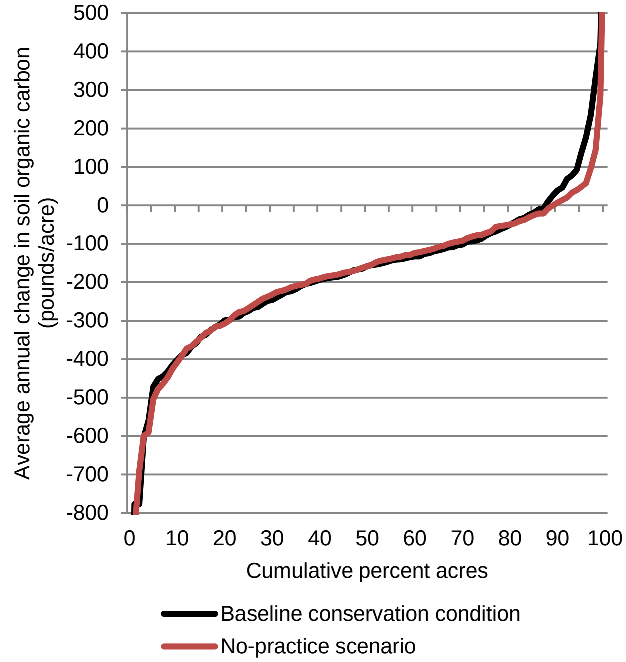
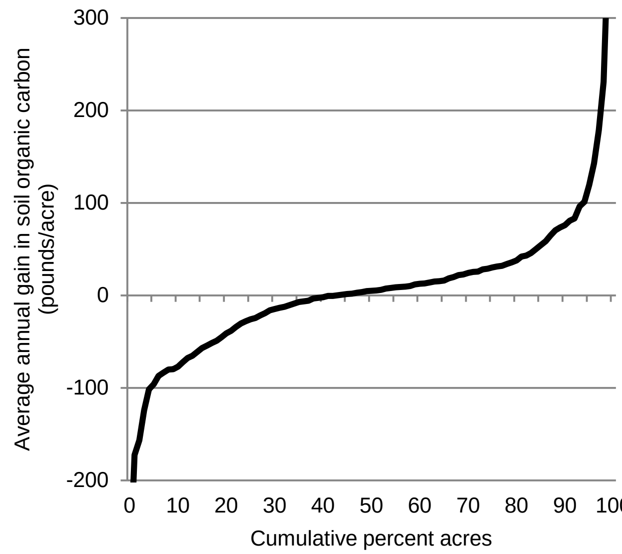


Figure 30. Estimates of average annual gain in soil organic carbon due to the use of conservation practices on cropped acres in the Texas Gulf Basin



Note: About 42 percent of the acres have a higher soil organic carbon increase in the no-practice scenario than the baseline conservation condition because of the higher fertilization rates, including manure application rates, used in the no-practice scenario to simulate the effects of nutrient management practices.

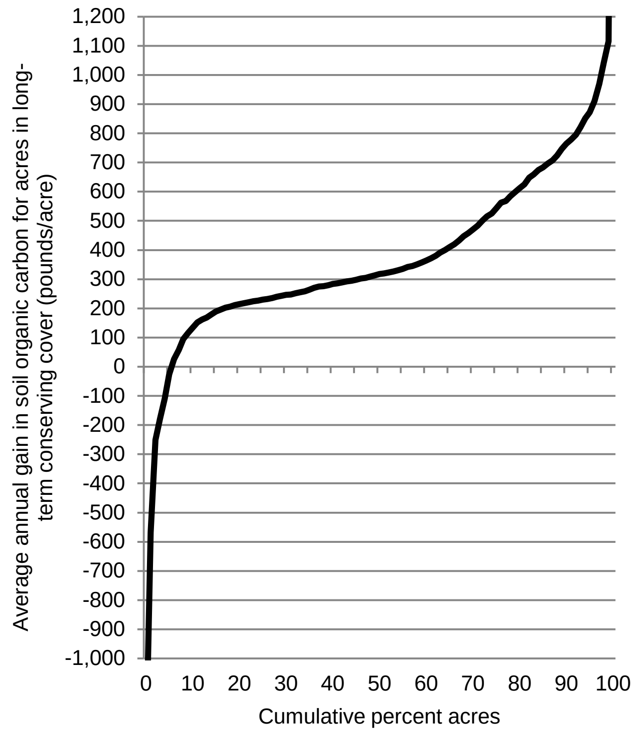
Land in long-term conserving cover

Converting cultivated cropland to long-term conserving cover can dramatically increase levels of soil organic carbon in this region. For land in long-term conserving cover, the annual gain in soil organic carbon for the baseline conservation condition averages 112 pounds per acre per year (table 16). If these acres were still being cropped without any conservation practices, the annual average change in soil organic carbon would be a loss of 264 pounds per acre per year. Thus, for these 2.5 million acres, the gain in soil organic carbon averages 376 pounds per acre compared to a cropped condition without conservation practices. These gains due to conservation practices vary considerably throughout the region, as shown in figure 31.

Part of the gain in soil organic carbon under long-term conserving cover is due to the reduction in loss of carbon with wind and water erosion. Long-term conserving cover reduces this loss from an average of 238 pounds per acre per year without practices to only 13 pounds per acre per year for the baseline, representing a reduction in loss of 94 percent (table 16).

These gains in soil organic carbon due to practice use are equivalent to a carbon dioxide emission reduction of 1.7 million U.S. tons of carbon dioxide for the region. However, the rate of emission reduction due to conservation practices varies considerably among acres in long-term conserving cover, as indicated by the wide range of average annual gains in soil organic carbon shown in figure 31.

Figure 31. Estimates of average annual gain in soil organic carbon due to conversion to long-term conserving cover in the Texas Gulf Basin



Note: About 5 percent of the acres in long-term conserving cover have decreases in annual carbon gain compared to a cropped condition. Biomass production under long-term conserving cover is typically nitrogen limited. The higher biomass production and resulting crop residue from the fertilization of cropped acres can exceed the carbon benefits of long-term conserving cover under some conditions.

Effects of Practices on Nitrogen Loss

Baseline condition for cropped acres

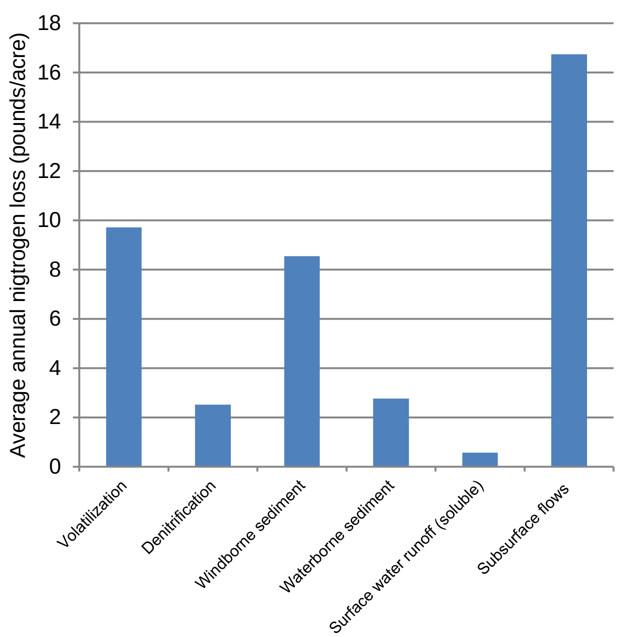
Plant-available nitrogen sources include application of commercial fertilizer, application of manure, nitrogen produced by legume crops (soybeans, alfalfa, dry beans, and peas), a small amount of manure deposited by grazing livestock, and atmospheric nitrogen deposition. On average, these sources provide about 67.4 pounds of nitrogen per acre per year for cropped acres in the Texas Gulf Basin (table 17).

Model simulations show that about 57 percent of this (38.5 pounds per acre) is taken up by the crop and removed at harvest in the crop yield, on average, and the remainder is lost from the field through various pathways.[20]

For the baseline conservation condition, the annual average amount of total nitrogen lost from the field, other than the nitrogen removed from the field at harvest, is about 40.9 pounds per acre. These nitrogen loss pathways are (fig. 32 and table 17)—

- nitrogen lost due to volatilization associated primarily with fertilizer and manure application (average of 9.7 pounds per acre per year);
- nitrogen returned to the atmosphere through denitrification (average of 2.5 pounds per acre per year);
- nitrogen lost with windborne sediment (average of 8.5 pounds per acre per year);
- nitrogen lost with surface runoff (average of 3.3 pounds per acre per year), most of which is nitrogen lost with waterborne sediment; and
- nitrogen loss in subsurface flow pathways (average of 16.7 pounds per acre per year).

Figure 32. Average annual nitrogen loss by loss pathway, Texas Gulf Basin, baseline conservation condition



[20] A small amount may also build up in the soil or be mined from the soil, as shown in table 17 for the variable "change in soil nitrogen."

The two pathways that impact water quality directly—surface water *and* subsurface flows (average of about 20 pounds per acre per year)—account for about half of the total nitrogen loss from farm fields in this region. Most of the nitrogen loss in subsurface flows returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

Model simulation results showed that nitrogen loss to specific loss pathways varies from acre to acre, as shown in figures 33 and 34. Each of three loss pathways is the dominant loss pathway for the bulk of cropped acres in the region:

- Nitrogen lost through subsurface flows is the dominant loss pathway for 31.3 percent of cropped acres.
- Loss of nitrogen in wind erosion is the dominant loss pathway for 31.0 percent of the cropped acres.
- Nitrogen loss through volatilization is the dominant loss pathway for 30.9 percent.

(The dominant loss pathway was determined for each sample point as the pathway with the highest loss.) The dominant loss pathway for the remaining 7 percent of cropped acres was either nitrogen lost with waterborne sediment (4 percent) or nitrogen returned to the atmosphere through denitrification (3 percent).

Total nitrogen losses are lower for highly erodible acres than for non-highly erodible acres because total nitrogen sources are higher for non-highly erodible acres. Total nitrogen loss for highly erodible acres averages 34 pounds per acre per year, compared to 44 pounds per acre per year for non-highly erodible acres (table 17). This difference is partly due to the difference in nitrogen sources between the two groups of acres. Total nitrogen sources for highly erodible acres averages only 58.8 pounds per acre per year, compared to 71.6 pounds per acre per year for non-highly erodible acres (table 17).

Model simulations for the baseline conservation condition indicate that some cropped acres in the Texas Gulf Basin are much more susceptible to the effects of weather than other acres and lose much higher amounts of nitrogen (fig. 35). These are the acres that have the highest inherent vulnerability and/or inadequate nutrient management or runoff controls. About 60 percent of the acres lose less than 40 pounds per acre per year through the various loss pathways in every year. The year with the highest losses, 1992, had losses greater than 100 pounds per acre per year for 23 percent of cropped acres. For weather conditions represented by other years, about 13 percent of the acres lose more than 100 pounds per acre in at least some years. Figure 35 also shows that nitrogen loss for the 30 percent of the cropped acres with the highest losses varies significantly from year to year when compared to the 30 percent with the lowest total nitrogen losses.

The *average annual* total nitrogen loss for the baseline (averaged over all years) is shown in figure 36. About 66 percent of cropped acres lose less than 40 pounds per acre per year, while 6 percent lose 100 pounds or more per acre per year.

Table 17. Field-level effects of conservation practices on nitrogen sources and nitrogen loss pathways for cropped acres (18.4 million acres) in the Texas Gulf Basin

Model simulated outcome	Average annual values in pounds per acre: Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
All cropped acres				
Nitrogen sources				
Atmospheric deposition	4.0	4.0	0.0	0
Bio-fixation by legumes	1.2	1.4	0.1	10
Nitrogen applied as commercial fertilizer and manure	62.1	83.7	21.6	26
All nitrogen sources	67.4	89.1	21.7	24
Nitrogen in crop yield removed at harvest	38.5	45.3	6.8*	15*
Nitrogen loss pathways				
Nitrogen loss by volatilization	9.7	11.0	1.2	11
Nitrogen loss through denitrification	2.5	2.8	0.2	9
Nitrogen lost with windborne sediment	8.5	8.5	<0.1	<1
Nitrogen loss with surface runoff, including waterborne sediment	3.3	6.1	2.7	45
Nitrogen loss with surface water (soluble)	0.6	1.6	1.0	64
Nitrogen loss with waterborne sediment	2.8	4.5	1.7	38
Nitrogen loss in subsurface flow pathways	16.7	23.5	6.7	29
Total nitrogen loss for all loss pathways	40.9	51.6	10.7	21
Change in soil nitrogen	-12.2	-7.9	4.2	--
Highly erodible land (33 percent of cropped acres)				
All nitrogen sources	58.8	80.0	21.1	26
Total nitrogen loss for all loss pathways	34.2	46.2	12.1	26
Non-highly erodible land (67 percent of cropped acres)				
All nitrogen sources	71.6	93.6	22.0	24
Total nitrogen loss for all loss pathways	44.2	54.3	10.1	19

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

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Model simulation results for the baseline conservation condition are presented in appendix B for the 11 subregions.

Figure 33. Cumulative distributions of average annual nitrogen lost through various loss pathways, Texas Gulf Basin, baseline conservation condition

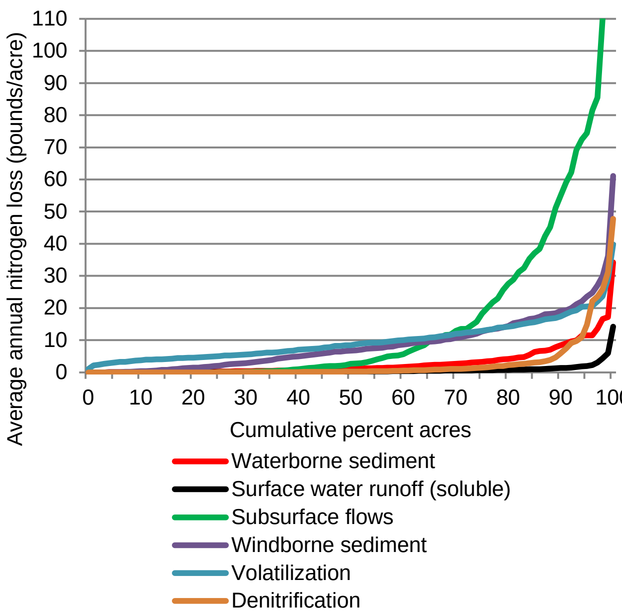
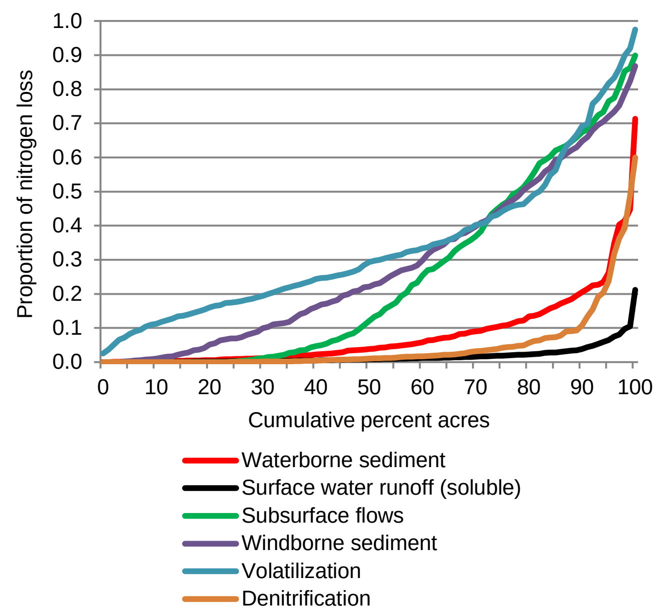
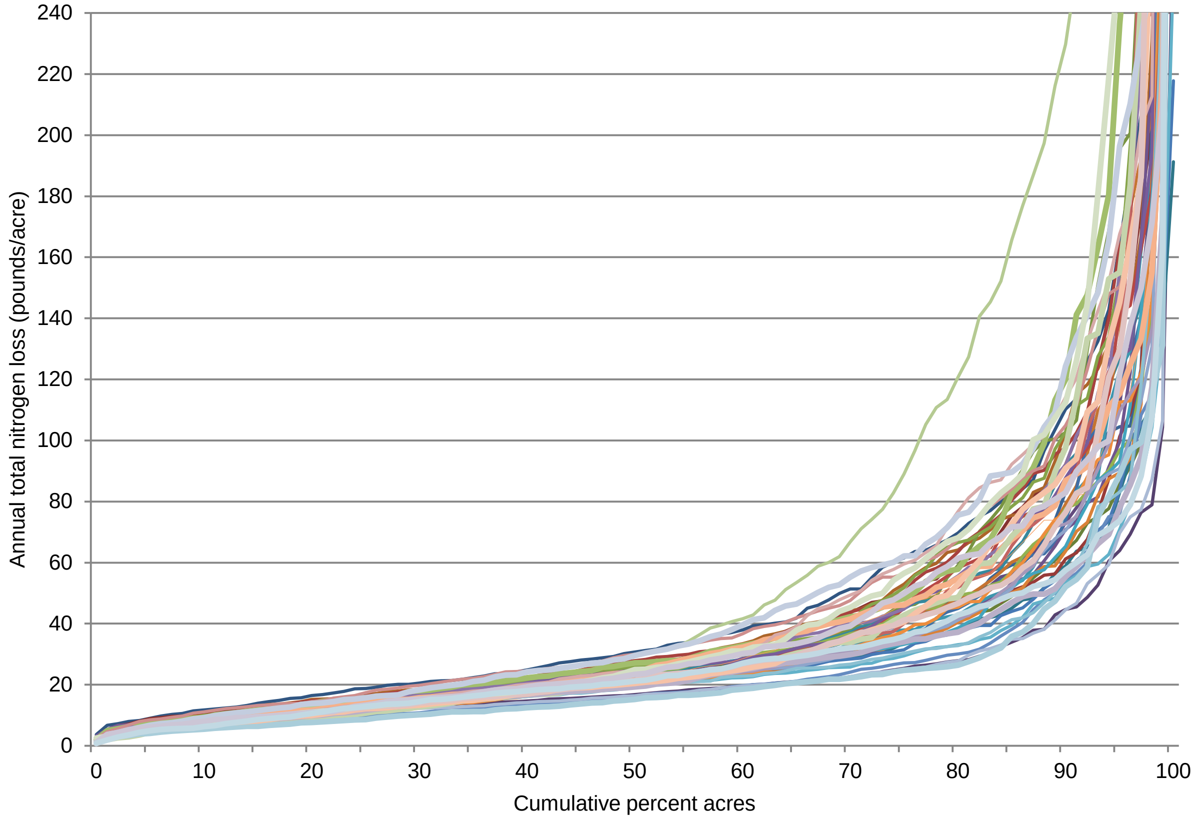


Figure 34. Cumulative distributions of proportions of nitrogen lost through six loss pathways, Texas Gulf Basin



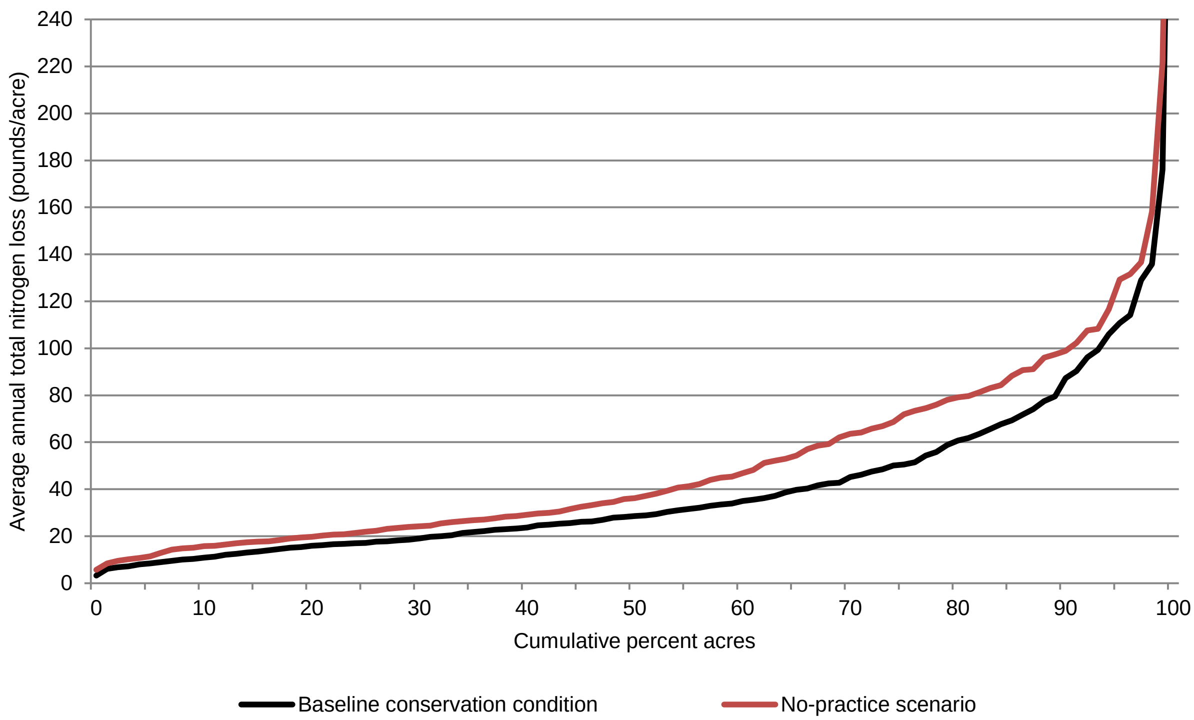
Note: The horizontal axis consists of percentiles for each pathway; a given percentile for one curve will not represent the same acres on another curve.

Figure 35. Distribution of annual total nitrogen loss for each year of the 47-year model simulation, Texas Gulf Basin



Note: This figure shows how annual total nitrogen loss (pounds per acre per year) varied within the region and from year to year in the model simulation for cropped acres. Each of the 47 curves shown above represents a single year of data and shows how annual total nitrogen loss varied over the region in that year, starting with the acres with the lowest total nitrogen loss and increasing to the acres with the highest total nitrogen loss. The family of curves shows how annual total nitrogen loss varied from year to year. The average annual curve for the baseline is shown in figure 36 (below).

Figure 36. Estimates of average annual total nitrogen loss for cropped acres in the Texas Gulf Basin



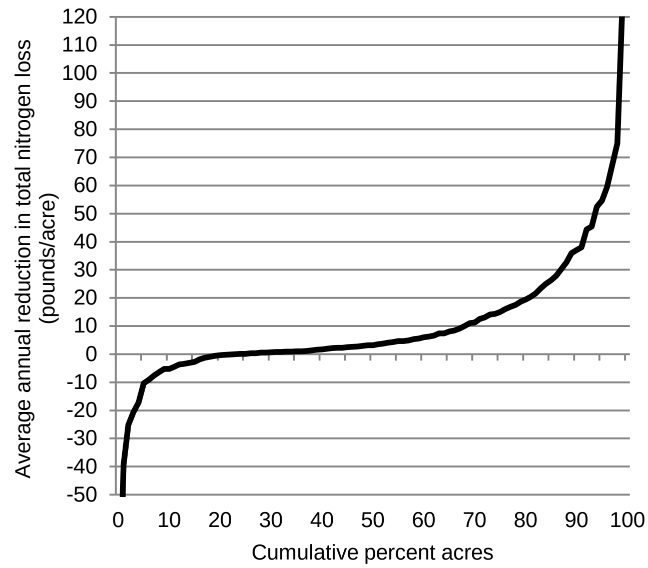
Effects of conservation practices on cropped acres

Total nitrogen loss, all pathways. Model simulations show that the conservation practices in use in the region have reduced total nitrogen loss from cropped acres by an average of 10.7 pounds per acre per year, representing a 21-percent reduction, on average (table 17). Without conservation practices, about 46 percent of the cropped acres would have average annual total nitrogen loss exceeding 40 pounds per acre per year; with conservation practices, 34 percent of acres exceed this level of loss (fig. 36).

The effects of conservation practices vary from acre to acre (fig. 37). About 70 percent of cropped acres have average annual reductions in total nitrogen loss below 10 pounds per acre and 35 percent of cropped acres have reductions less than 1 ton per acre per year. In contrast, about 20 percent of the acres have reduced total nitrogen loss by an average of over 20 pounds per acre per year. These are acres with higher levels of treatment and often higher levels of nitrogen use in the no-practice scenario.

Figure 37 also shows that about 20 percent of the acres have an *increase* in total nitrogen loss due to conservation practice use (shown in figure 37 as negative reductions). Most of these increases are relatively small; only 5 percent of the acres have increases of more than 10 pounds per acre. This result occurs primarily because of increases in nitrogen lost with windborne sediment and nitrogen loss in subsurface flows due to conservation practice use, discussed further in the following subsections.

Figure 37. Estimates of average annual reduction in total nitrogen loss due to the use of conservation practices on cropped acres in the Texas Gulf 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.

Nitrogen lost with windborne sediment. On average for the region as a whole, conservation practices have reduced nitrogen lost with windborne sediment by less than 1 percent (table 17). Conservation practices are effective in reducing nitrogen loss via wind erosion on only a few acres in this region, as shown in figures 38 and 39. Figure 39 shows that conservation practices have reduced nitrogen lost with windborne sediment by more than 1 pound per acre per year on about 22 percent of cropped acres.

Conservation practices lead to *increased* nitrogen lost with windborne sediment on about 45 percent of the cropped acres (fig. 39), although these losses exceed 1 pound per acre on only about 25 percent of cropped acres. Most of these losses are due to increased wind erosion with the adoption of conservation practices, shown in figure 24, which in turn is caused by the higher fertilization rates and biomass production in the no-practice scenario that provides better protection for the soil from the forces of the wind than in the baseline scenario.

Figure 38. Estimates of average annual nitrogen lost with windborne sediment for cropped acres in the Texas Gulf Basin

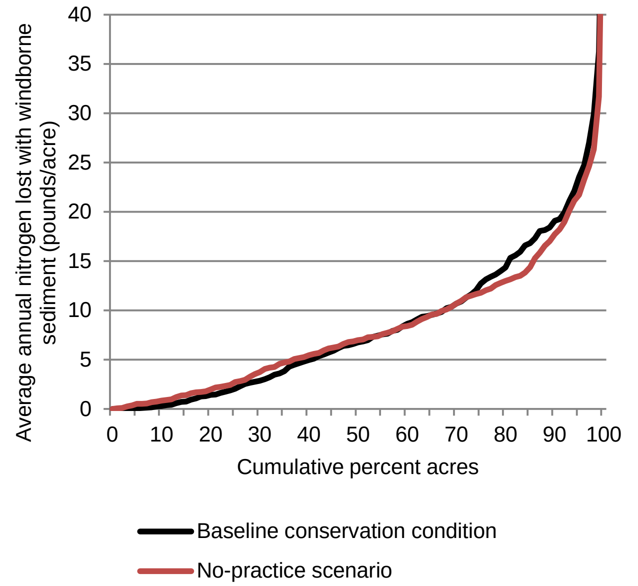
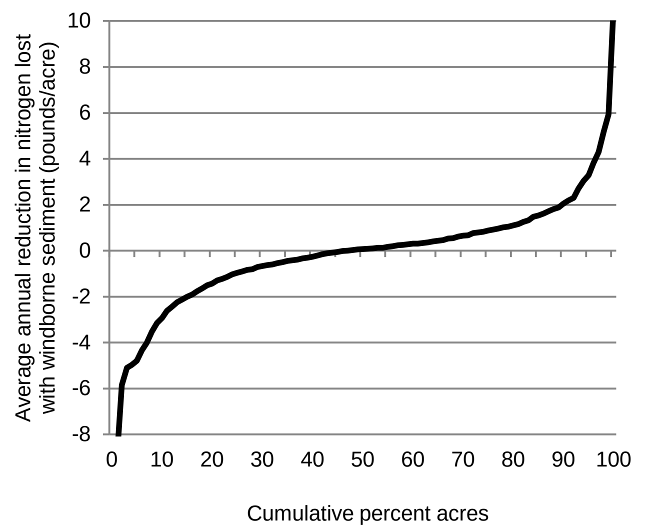


Figure 39. Estimates of average annual reduction in nitrogen lost with windborne sediment due to the use of conservation practices on cropped acres in the Texas Gulf Basin



Note: See text for discussion of conditions that result in increased nitrogen losses in the baseline conservation condition as compared to the no practice condition for 45 percent of the acres.

Nitrogen loss in subsurface flows. Conservation practices are effective in reducing nitrogen loss in subsurface flows on most acres in this region, but make little difference on some acres and even result in increases in nitrogen loss in subsurface flows for about 20 percent of cropped acres (figs. 40 and 41). (Increases in nitrogen loss in subsurface flows are represented in figure 41 as negative reductions.) On average, conservation practices have reduced nitrogen loss in subsurface flows from 23.5 pounds per acre without practices to 16.7 pounds per acre with practices, representing an average reduction of 6.7 pounds per acre per year (29-percent reduction) (table 17). Figure 41 shows that reductions in average annual nitrogen loss in subsurface flows exceed 10 pounds per acre for 20 percent of the cropped acres.

The increases in subsurface flow nitrogen loss due to conservation practice use on 20 percent of cropped acres (fig. 41) are largely due to relatively weak nutrient management practices on acres with structural erosion control treatment. Conservation practices account for a reduction of nitrogen loss in surface runoff (soluble nitrogen and nitrogen lost with waterborne sediment) of 45 percent, on average (table 17). A portion of this reduction in nitrogen lost with surface runoff is re-routed to subsurface loss pathways, resulting in gains or only small reductions in nitrogen loss in subsurface flows. This re-routing of surface water runoff to subsurface flow pathways results in additional nitrogen being leached from the soil. While flushing nitrogen through the soil that would otherwise have been lost to surface runoff makes previously unavailable nitrogen potentially available for plant uptake, this rerouted nitrogen loss pathway diminishes and sometimes offsets 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.

Figure 40. Estimates of average annual nitrogen loss in subsurface flows for cropped acres in the Texas Gulf Basin

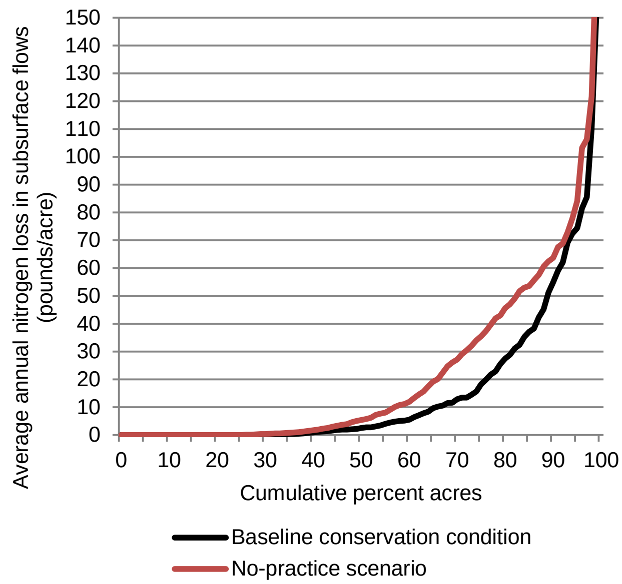
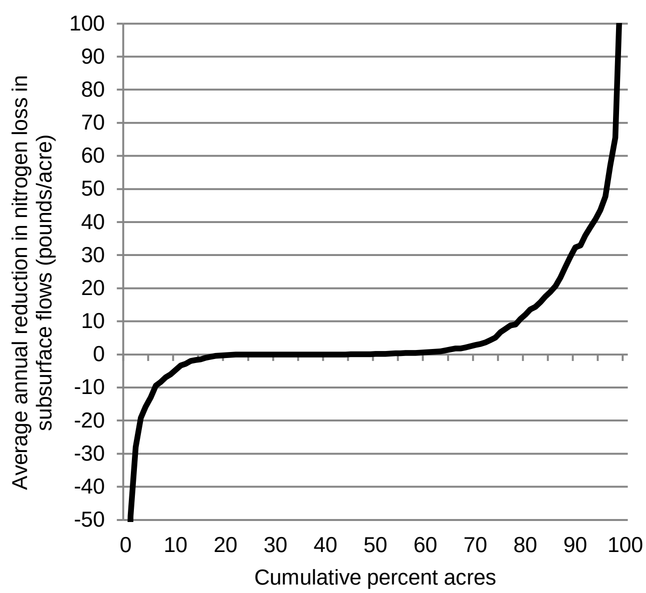


Figure 41. Estimates of average annual reductions in nitrogen loss in subsurface flows due to the use of conservation practices on cropped acres in the Texas Gulf Basin



Note: See text for discussion of conditions that result in increased nitrogen losses in the baseline conservation condition as compared to the no practice condition for 20 percent of the acres.

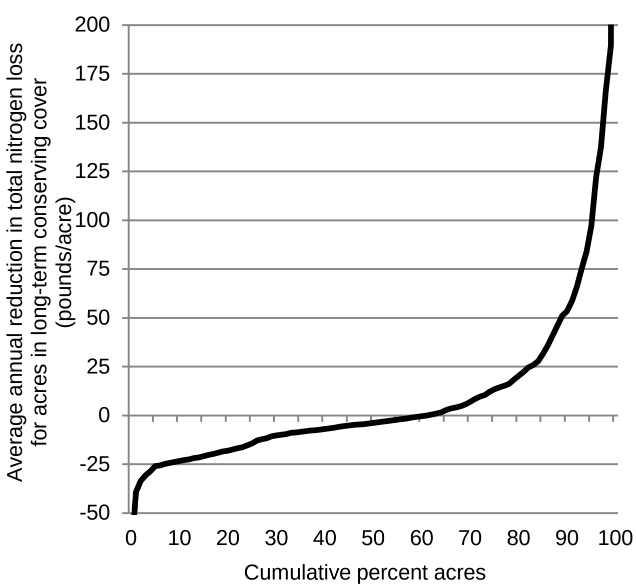
Land in long-term conserving cover

Land in long-term conserving cover in this region have edge-of-field nitrogen losses, on average, of about 26 pounds per acre per year, almost entirely from nitrogen volatilization and denitrification (table 18). Total nitrogen loss has been reduced by about 25 percent on the 2.5 million acres in long-term conserving cover, compared to conditions that would be expected had the acres remained in crops without conservation practices (table 18).

Converting cropped acres to long-term conserving cover is very effective in reducing total nitrogen loss for loss pathways other than volatilization and denitrification, as demonstrated in table 18.

However, conversion of acres to long-term conserving cover also resulted in overall increases in nitrogen volatilization and denitrification losses under the dry conditions in the western portion of the region where the bulk of CRP acres occur. Under cultivation, a significant portion of the crop biomass is removed from the field during harvest. Acres in long-term conserving cover, however, accumulate grass residues on the surface. Under very dry conditions, nitrogen volatilization and denitrification from long-term conserving cover can occur as these residues decompose, especially from nitrogen-rich legumes and other forbs, releasing gaseous nitrogen compounds directly to the atmosphere. These increases in gaseous nitrogen compounds to the atmosphere in this region exceeded reductions in nitrogen loss to other loss pathways on about 60 percent of acres in long-term conserving cover, resulting in the negative reductions in total nitrogen loss shown in figure 42.

Figure 42. Estimates of average annual reductions in total nitrogen loss for land in long-term conserving cover in the Texas Gulf Basin



Tradeoffs in Conservation Treatment

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

- Terraces and conservation tillage are planned to solve a serious water erosion problem. However, in some areas there may be concern about seeps at the lower part of the field. The planned practices will solve the erosion problem, but could exacerbate the seep problem under some conditions. Ignoring that fact does not make for an adequate conservation plan.
- Conservation tillage is planned for erosion control on a cropland field with a high water table. The reduction in runoff may increase leaching of nitrates into the shallow water table. This potential secondary problem requires additional nutrient management practices to address the concern.
- 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 37 shows that about 20 percent of the acres have an increase in total nitrogen loss due to conservation practice use. On a portion of these acres, this result occurs on soils with relatively high soil nitrogen content and generally low slopes where the surface water runoff is re-directed to subsurface flow by soil erosion control practices. The higher volume of water moving through the soil profile extracts more nitrogen from the soil than under conditions without conservation practices. For these fields, the nutrient management component of a farmer's conservation plan would need to be enhanced to reduce or eliminate the negative effects of soil erosion control practices on nitrogen loss.

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

Table 18. Effects of conservation practices on nitrogen sources and nitrogen loss pathways for land in long-term conserving cover (2.5 million acres), Texas Gulf Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
	Average annual values in pounds per acre			
Nitrogen sources				
Atmospheric deposition	2.7	2.7	0.0	0
Bio-fixation by legumes	16.9	1.0	-16.0*	--
Nitrogen applied as commercial fertilizer and manure	0.0	63.2	63.2	100
All nitrogen sources	19.6	66.8	47.2	71
Nitrogen in crop yield removed at harvest	0.01**	37.15	37.14	100
Nitrogen loss pathways				
Nitrogen loss by volatilization	13.96	10.29	-3.67	-36
Nitrogen loss through denitrification	11.60	1.92	-9.68	-503
Nitrogen lost with windborne sediment	<0.01	2.31	2.31	100
Nitrogen loss with surface runoff, including waterborne sediment	0.08	6.71	6.63	99
Nitrogen loss with surface water (soluble)	0.04	0.45	0.41	92
Nitrogen loss with waterborne sediment	0.04	6.26	6.21	99
Nitrogen loss in subsurface flow pathways	0.03	13.11	13.08	100
Total nitrogen loss for all pathways	25.67	34.35	8.68	25
Change in soil nitrogen	-6.11	-5.07	1.04	--

* The average for biofixation increases with enrollment in CRP General Signup as clover was included in the seed mix and legume crops are not frequently grown in the region.
** Harvest was simulated on acres planted to trees where expected tree age is less than the 47 years included in the model simulation. At tree harvest time, the grass also is removed and replanted.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Effects of Practices on Phosphorus Loss

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

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

Baseline condition for cropped acres

In the model simulations for the Texas Gulf Basin, about 11.2 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). About 53 percent of the phosphorus applied is taken up by the crop and removed at harvest—5.9 pounds per acre per year, on average.

Total phosphorus loss for all loss pathways averaged 2.1 pounds per acre per year in the baseline conservation condition (table 19). Most phosphorus loss from farm fields is lost with windborne sediment (fig. 43). Phosphorus lost with windborne sediment averages 1.16 pounds per acre per year, accounting for 54 percent of total phosphorus loss in the region. Other phosphorus loss pathways are—

- phosphorus lost with waterborne sediment (average of 0.59 pound per acre per year, 28 percent of total phosphorus loss);
- soluble phosphorus lost to surface water, including soluble phosphorus in surface water runoff, and soluble phosphorus that infiltrates into the soil profile but quickly returns to surface water either through quick return lateral flow or intercepted by drainage systems (average of 0.26 pound per acre per year, 12 percent of total phosphorus loss); and
- soluble phosphorus that percolates through the soil profile into the groundwater (average of about 0.12 pound per acre per year, 6 percent of total phosphorus loss).

The percentage of phosphorus lost in each of the principal loss pathways varies from acre to acre, as shown in figure 44 for cropped acres. All four phosphorus loss pathways are important for at least some acres in this region (figs 43 and 44). Phosphorus lost with wind erosion is the dominant loss pathway for 51 percent of cropped acres. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.) Phosphorus lost with waterborne sediment is the dominant loss pathway for 27 percent of cropped acres, and soluble phosphorus lost with surface water runoff is the dominant loss pathway for 14 percent of cropped acres. Soluble phosphorus lost with percolation is the dominant loss pathway for the remaining 8 percent of cropped acres.

Phosphorus applied and total phosphorus losses for highly erodible land are about the same as those for non-highly erodible land (table 19).

Phosphorus loss is generally low in this region for most acres, but is high for a minority of acres in most years. About 65 percent of cropped acres lose less than 4 pounds per acre per year through various loss pathways in all years (fig. 45). In contrast, 19 percent of cropped acres lose more than 8 pounds per acre in at least some years. The *average annual* total phosphorus loss for the baseline (averaged over all years) is shown in figure 46. About 60 percent of cropped acres lose less than 2 pounds per acre per year in the baseline scenario, while about 15 percent lose 4 pounds or more per acre per year.

Figure 43. Estimates of average annual phosphorus lost through various loss pathways, Texas Gulf Basin, baseline conservation condition

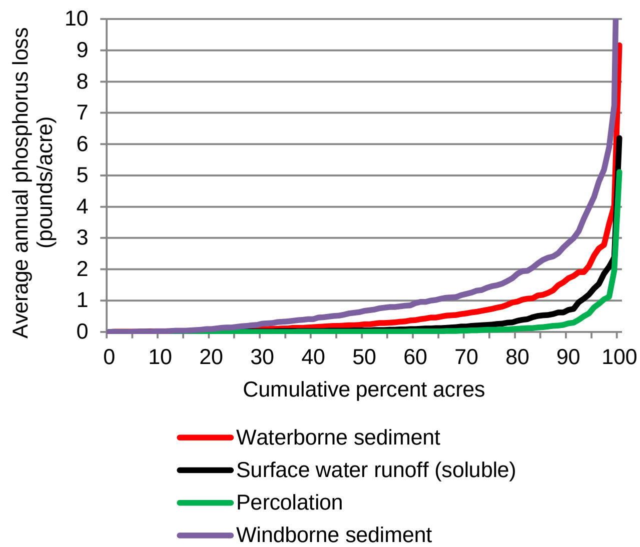
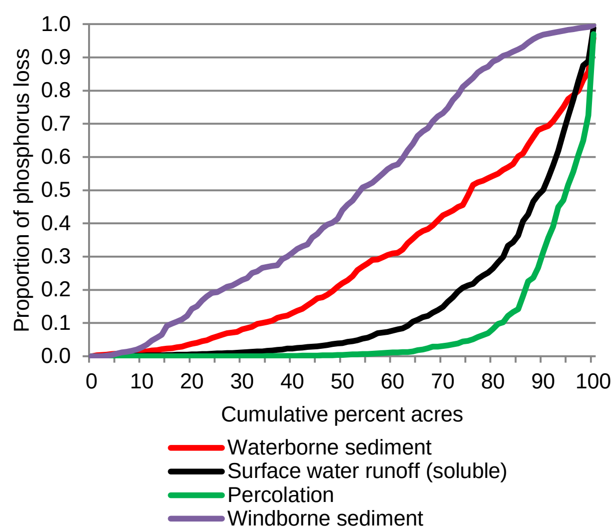


Figure 44. Cumulative distributions of the proportion of phosphorus lost through various loss pathways, Texas Gulf Basin, baseline conservation condition



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

Table 19. Field-level effects of conservation practices on phosphorus sources and phosphorus loss pathways for cultivated cropland in the Texas Gulf Basin

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
	Average annual values in pounds per acre			
Cropped acres (18.4 million acres)				
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	11.25	15.98	4.73	30
Phosphorus in crop yield removed at harvest	5.94	7.04	1.10	16
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	1.16	1.42	0.26	19
Phosphorus lost to surface water (sediment attached and soluble)*	0.85	1.66	0.81	49
Soluble phosphorus lost to surface water*	0.26	0.44	0.18	41
Phosphorus loss with waterborne sediment	0.59	1.22	0.63	51
Soluble phosphorus loss to groundwater	0.12	0.10	-0.02	-19
Total phosphorus loss for all loss pathways	2.13	3.18	1.05	33
Change in soil phosphorus	2.56	4.91	2.34	--
Highly erodible land (33 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	11.7	16.1	4.4	28
Total phosphorus loss for all loss pathways	2.0	3.1	1.1	34
Non-highly erodible land (67 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	11.0	15.9	4.9	31
Total phosphorus loss for all loss pathways	2.2	3.2	1.0	32
Land in long-term conserving cover (2.5 million acres)				
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	0.00	21.98	22.0	100
Phosphorus in crop yield removed at harvest	0.01**	5.51	5.50	100
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	<0.01	0.29	0.29	100
Phosphorus lost to surface water (sediment attached and soluble)*	0.01	1.79	1.78	99
Soluble phosphorus lost to surface water*	<0.01	0.27	0.27	98
Phosphorus loss with waterborne sediment	<0.01	1.51	1.51	100
Soluble phosphorus loss to groundwater	0.01	0.16	0.16	96
Total phosphorus loss for all loss pathways	0.02	2.24	2.23	99
Change in soil phosphorus	-0.02	8.65	8.67	--

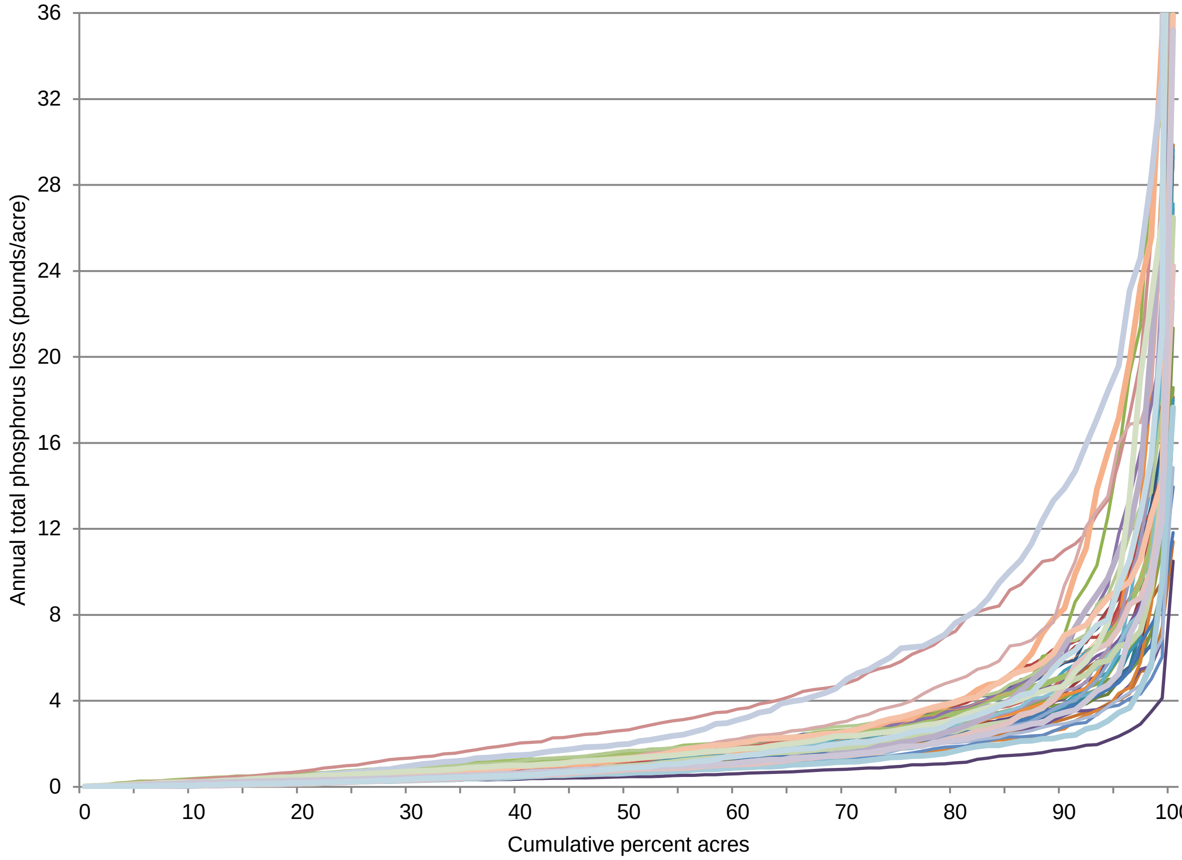
* Soluble phosphorus lost to surface water includes phosphorus in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps.

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

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

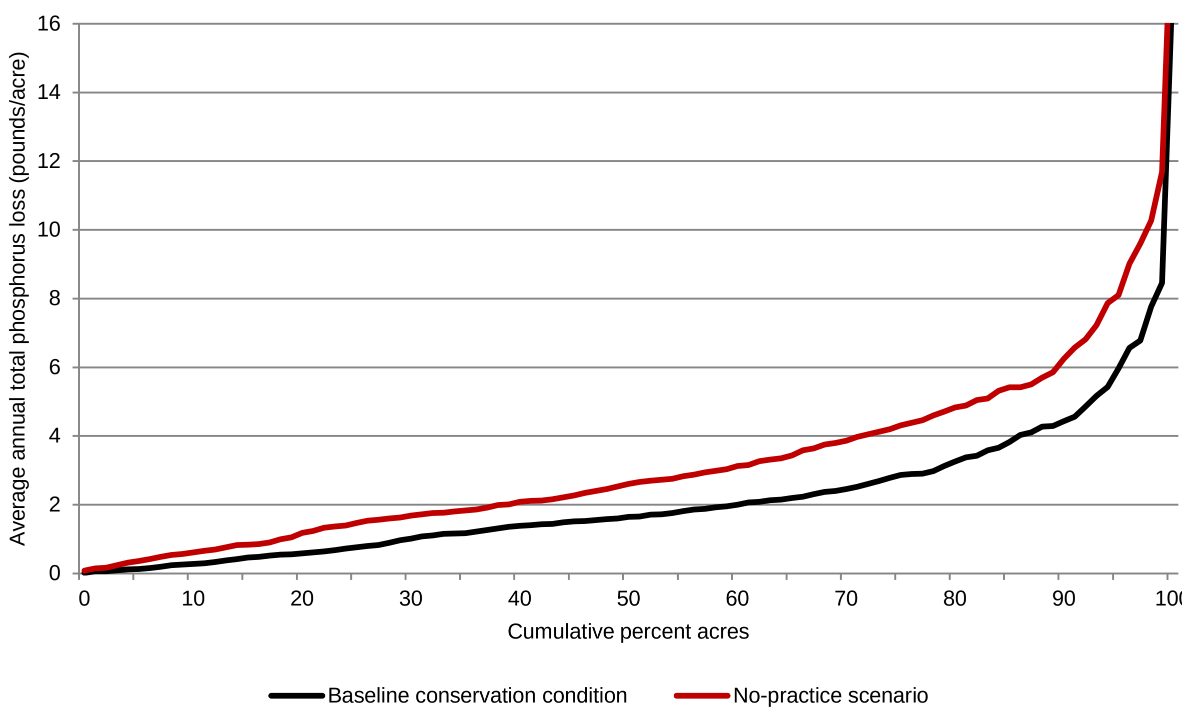
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 11 subregions.

Figure 45. Distribution of annual total phosphorus loss for each year of the 47-year model simulation, Texas Gulf 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 46. Estimates of average annual total phosphorus loss (all loss pathways) for cropped acres in the Texas Gulf Basin



Effects of conservation practices on cropped acres

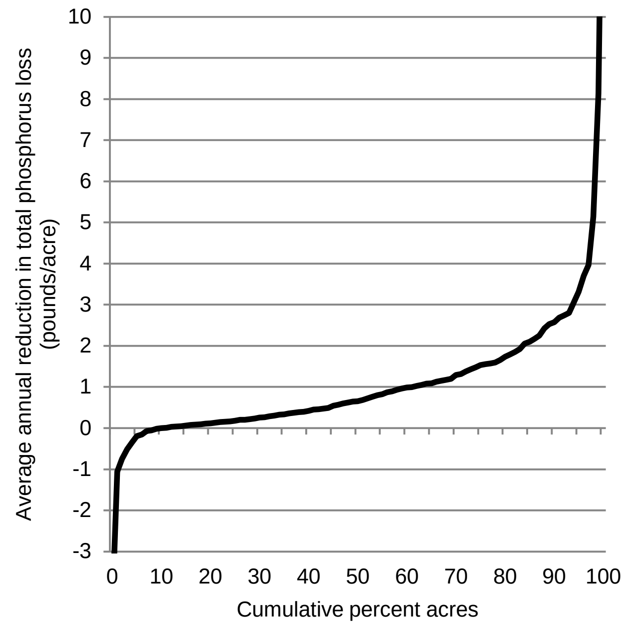
Total phosphorus loss, all pathways. Conservation practices have reduced total phosphorus loss for cropped acres by 33 percent, reducing the average loss from 3.2 pounds per acre per year if conservation practices were not in use to 2.1 pounds per acre per year for the baseline conservation condition (table 19). On average, conservation practices have reduced phosphorus loss to wind erosion by 19 percent, loss to surface water with waterborne sediment by 51 percent, and loss to surface water as soluble phosphorus by 41 percent (table 19). The relatively small amounts of soluble phosphorus lost to groundwater increased by 19 percent due to conservation practice use in this region (table 19). As shown for nitrogen loss in subsurface flows, this occurs because of the re-routing of surface water to subsurface flow paths that occurs with the implementation of runoff control practices.

The effects of conservation practices on total phosphorus loss are shown in figures 46 and 47 for cropped acres. Without conservation practice use, total phosphorus loss would be less than 4 pounds per acre for 72 percent of the acres (fig. 46). With the conservation practices in use as represented by the baseline conservation condition, about 85 percent of cropped acres have less than 4 pounds per acre per year of total phosphorus loss, on average.

The effects of conservation practices on total phosphorus loss vary considerably throughout the Texas Gulf Basin, as shown in figure 47. At the high end, reductions exceed 2 pounds per acre for about 16 percent of the acres. These are acres with higher levels of treatment and often higher levels of phosphorus use in the no-practice scenario.

For about 8 percent of the acres, however, conservation practice use results in *increases* in total phosphorus loss, although the increases exceeded 0.5 pound per acre for only 3 percent of the acres. (Increases in total phosphorus loss are represented in figure 47 as negative reductions.) Increases in phosphorus loss due to conservation practices result from a combination of practices and landscape conditions that cause phosphorus levels to concentrate near or on the soil surface, where it is more vulnerable to surface runoff or wind erosion. Most of these losses are due to increased wind erosion with the adoption of conservation practices, shown in figure 24, which in turn is caused by the higher fertilization rates and biomass production in the no-practice scenario that provides better protection for the soil from the forces of the wind than in the baseline scenario.

Figure 47. Estimates of average annual reduction in total phosphorus loss (all loss pathways) due to conservation practices on cropped acres in the Texas Gulf Basin



Note: About 8 percent of cropped acres in the region have negative reductions in phosphorus loss due to conservation practices. See text.

Phosphorus lost with windborne sediment. Conservation practices in the region have only a slight effect on phosphorus lost with windborne sediment on most cropped acres. Simulation modeling indicates that conservation practice use has reduced windborne sediment losses by 0.3 pound per acre per year on average, a 19-percent reduction from no-practice scenario losses (table 19, fig. 48). Figure 49 shows the extent to which conservation practices are reducing windborne phosphorus loss in the Texas Gulf Basin. About 77 percent of the acres in the basin have loss reductions of less than 0.5 pound per acre or more due to conservation practices. Annual loss reductions exceed 1 pound per acre or more due to conservation practices on only 7 percent of cropped acres.

Conservation practice adoption causes increases in phosphorus lost with windborne sediment on about 13 percent of cropped acres. Most of these increases are small. Only 1 percent of acres experience increases in phosphorus losses of 1 pound per acre or more (fig. 49). These small increases are related to wind erosion losses or associated with the loss of phosphorus in higher amounts of crop residue remaining on the surface from conservation tillage.

Figure 48. Estimates of average annual phosphorus lost with windborne sediment for cropped acres in the Texas Gulf Basin

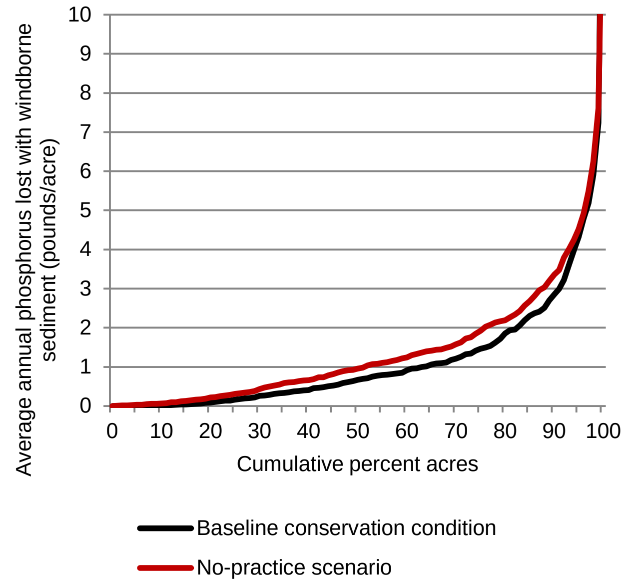
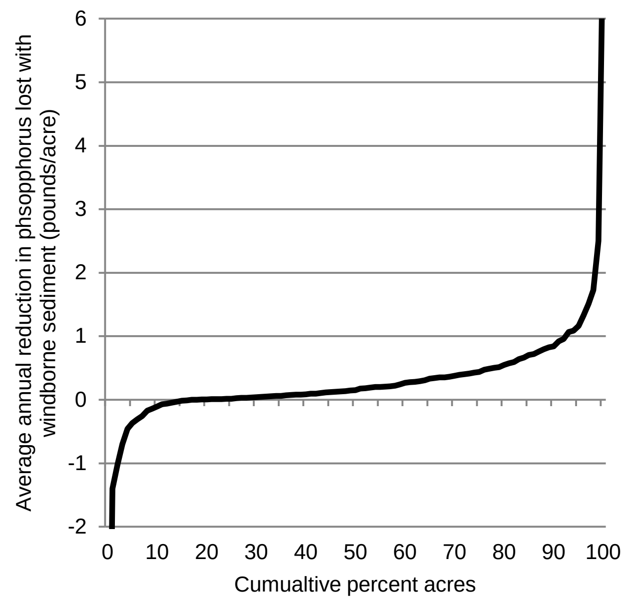


Figure 49. Estimates of average annual reduction in phosphorus lost with windborne sediment due to conservation practices for cropped acres in the Texas Gulf Basin

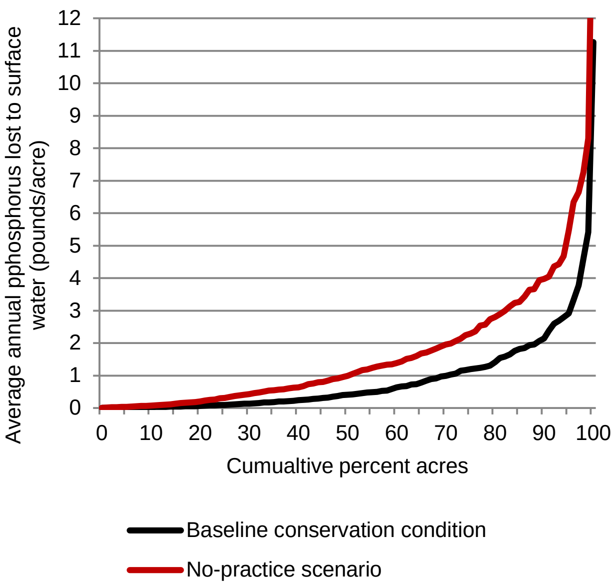


Note: About 13 percent of cropped acres in the region have negative reductions in phosphorus lost with windborne sediment due to conservation practices.

Phosphorus lost to surface water. Conservation practices are more effective in reducing phosphorus lost to surface water than in reducing phosphorus lost with windborne sediment. Phosphorus lost to surface water includes phosphorus lost with waterborne sediment and soluble phosphorus in surface water runoff and in water moving laterally within the soil into drainage systems (tile and surface drainage) and natural seeps, which ultimately contributes to surface water. These losses are reduced by about 49 percent due to the use of conservation practices in the region (table 19).

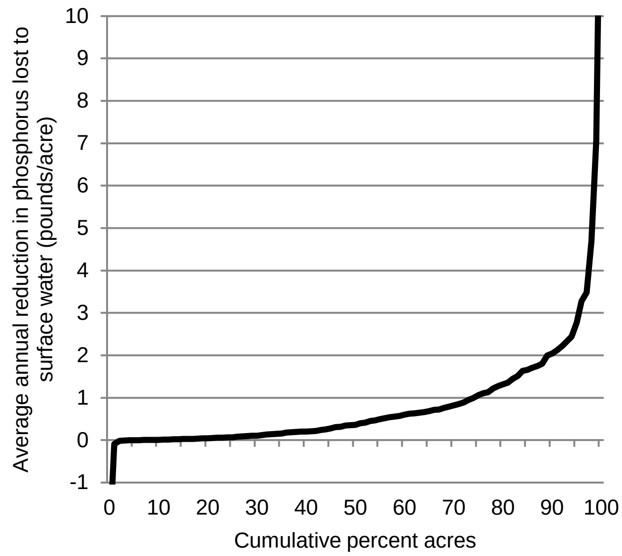
Conservation practice use has reduced phosphorus lost to surface water from cropped acres by an average of 0.8 pound per acre per year. Without conservation practices, about 28 percent of the cropped acres would lose more than 2 pounds per acre per year of phosphorus to surface water, compared to only 11 percent in the baseline (fig. 50). Per-acre reductions exceed 1 pound per acre per year on 25 percent of the Texas Gulf Basin's cropped acres, as shown in figure 51.

Figure 50. Estimates of average annual phosphorus lost to surface water (sediment attached and soluble*) for cropped acres in the Texas Gulf Basin



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

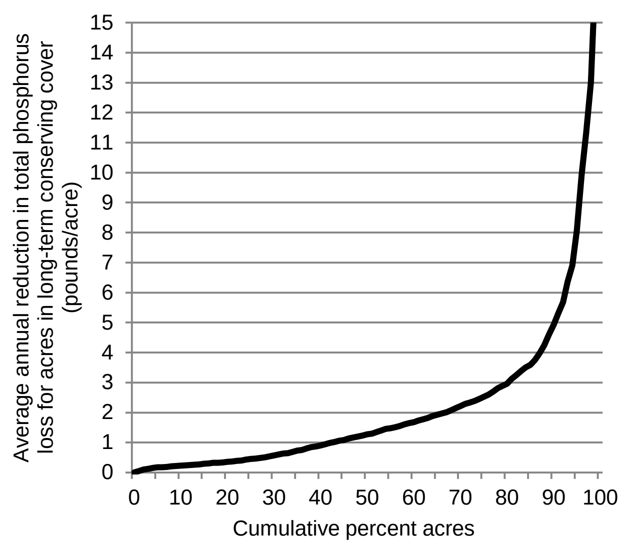
Figure 51. Estimates of average annual reduction in phosphorus lost to surface water (sediment attached and soluble) due to conservation practices for cropped acres in the Texas Gulf Basin



Land in long-term conserving cover

Conversion of cultivated cropland to long-term conserving cover essentially eliminates phosphorus losses from farm fields in this region (table 19). Total phosphorus loss is 99 percent less than it would have been if crops had been grown and no conservation practices used, reducing total phosphorus loss by 2.2 pounds per acre per year, on average (table 19). Per-acre reductions range from zero to more than 10 pounds per acre per year, with reductions of more than 2 pounds per acre per year for about 35 percent of the acres in long-term conserving cover (fig. 52).

Figure 52. Estimates of average annual reduction in total phosphorus loss due to conversion to long-term conserving cover in the Texas Gulf Basin



Effects of Practices on Pesticide Residues and Environmental Risk

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

Model simulations incorporated pesticide use information from the CEAP survey conducted in 2003–06 (active ingredient, application rate, application method, and time of application).

The effects of converting cultivated cropland to long-term conserving cover were not evaluated for pesticides because the survey did not provide information on pesticide use on land enrolled in CRP General Signups. It was thus assumed that no pesticide residues were lost from land in long-term conserving cover.

A total of 126 different pesticides are used in the region, as reported in the survey. The 17 most commonly applied pesticides account for 88 percent of all pesticides applied, by weight, and are presented in table 20. The pesticide applied in the largest amount for the entire region was glyphosate isopropylamine salt at 20 percent of the total weight of all pesticides applied, followed by trifluralin at 15 percent, and malathion at 12 percent. These three herbicides accounted for 47 percent of the pesticides applied in the region, by weight.

Table 20. Pesticides most commonly used in the Texas Gulf Basin

Pesticide (active ingredient name)	Pesticide type	Percent of the total amount of pesticides applied (by weight) in the Texas Gulf Basin
Glyphosate, isopropylamine salt	Herbicide	20
Trifluralin	Herbicide	15
Malathion	Insecticide	12
Atrazine	Herbicide	8
Ethephon	Herbicide	7
Pendimethalin	Herbicide	5
Propanil	Herbicide	4
Propargite	Insecticide	3
Paraquat dichloride	Herbicide	2
Tribuphos	Herbicide	2
Acephate	Insecticide	2
Terbufos	Insecticide	1
Diuron	Herbicide	1
S-Metolachlor	Herbicide	1
Aldicarb	Insecticide	1
2,4-D, dimethylamine salt	Herbicide	1
Fluometuron	Herbicide	1
Total*		88

* Pesticides not listed each represented less than 1 percent of the total applied in the entire region. Percents may not add to total due to rounding.

Baseline condition for pesticide loss

The APEX model tracks the mass loss for three pesticide loss pathways: [21]

- pesticides dissolved in surface water runoff,
- pesticides adsorbed to sediment lost through water erosion, and
- pesticides dissolved in subsurface flow pathways, which include surface and tile drainage systems, lateral subsurface flow, and percolation through the root zone.

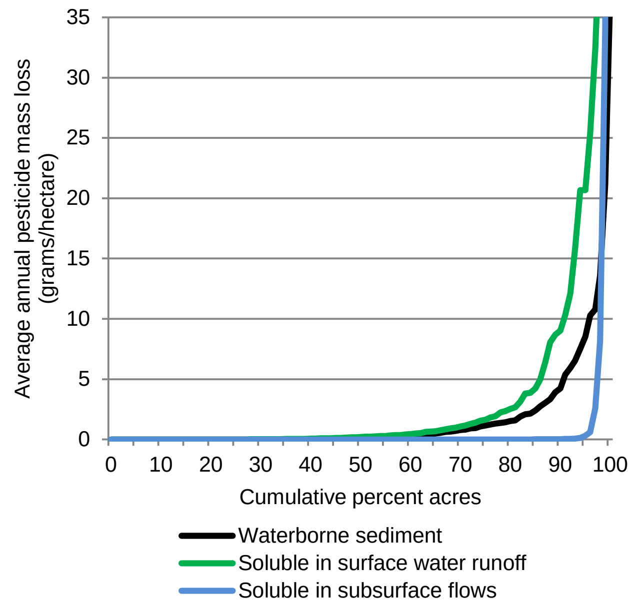
The most important pesticide loss pathway in this region is dissolved in surface water runoff, which accounts for 60 percent of the total loss of pesticides by weight. Pesticides lost with waterborne sediment accounted for about 25 percent, and pesticides in subsurface flows accounted for 15 percent. Over half of the cropped acres have negligible amounts of pesticide loss from farm fields, as shown in figure 53.

Pesticide residue dissolved in surface water runoff was the dominant pesticide loss pathway for 42 percent of cropped acres. Pesticide loss with waterborne sediment was the dominant loss pathway for 30 percent of cropped acres, and soluble pesticide loss in subsurface flow was the dominant loss pathway for 4 percent. About 25 percent of cropped acres had no pesticide losses. (The dominant loss pathway was determined for each sample point as the pathway with the highest pesticide mass loss.)

The most common pesticide residues lost from farm fields in the Texas Gulf Basin are presented in table 21. For the entire region, five herbicides account for 61 percent of all pesticide residues lost from fields in the model simulations—atrazine (26 percent), glyphosate isopropylamine salt (15 percent), quinclorac (12 percent), pendimethalin (4 percent), and paraquat dichloride (4 percent).

The average annual amount of pesticide lost from farm fields in the Texas Gulf Basin is about 6 grams of active ingredient per hectare per year (table 22).[22] As shown in figure 53, however, per-hectare losses are much higher than the average loss for a minority of acres within the Texas Gulf Basin.

Figure 53. Estimates of average annual pesticide loss (mass loss of all pesticides combined) for three loss pathways, Texas Gulf Basin, baseline conservation condition



[21] The APEX model currently does not estimate pesticides lost in spray drift, volatilization, or with windblown sediment.

[22] Grams per hectare is the standard reporting unit for pesticide active ingredients.

Table 21. Most common pesticides contributing to losses from farm fields in the Texas Gulf Basin

Pesticide (active ingredient name)	Pesticide type	Percent of total pesticide mass loss from fields in the Texas Gulf Basin
Atrazine	Herbicide	26
Glyphosate, isopropylamine salt	Herbicide	15
Quinclorac	Herbicide	12
Pendimethalin	Herbicide	4
Paraquat dichloride	Herbicide	4
Metolachlor	Herbicide	3
Dimethenamide-P	Herbicide	3
Fluometuron	Herbicide	3
S-Metolachlor	Herbicide	3
2,4-D, dimethylamine salt	Herbicide	3
Triclopyr	Herbicide	2
Trifluralin	Herbicide	2
Diuron	Herbicide	2
Acetamiprid	Insecticide	2
Dicrotophos	Insecticide	1
2,4-Dichlorophenoxyacetic acid	Herbicide	1
Total*		86

* Pesticides not listed each represented less than 1 percent of the total loss in the entire region. Percents may not add to total due to rounding.

Table 22. Field-level effects of conservation practices on pesticide loss and associated edge-of-field environmental risk for cropped acres in the Texas Gulf 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)	1,376	1,593	217	14
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	6.1	10.9	4.9	44
Edge-of-field pesticide risk indicator				
Average annual surface water pesticide risk indicator for aquatic ecosystems	2.49	6.52	4.03	62
Average annual surface water pesticide risk indicator for humans	0.87	1.69	0.82	49
Average annual groundwater pesticide risk indicator for humans	0.06	0.06	0.00	0

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Model simulation results for the baseline conservation condition are presented in appendix B for the 11 subregions.

Effects of conservation practices on pesticide residues and risk

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

Model simulations show that conservation practices—primarily water erosion control practices—are effective in reducing the loss of pesticide residues from farm fields. Use of conservation practices has reduced the loss of pesticides (summed over all pesticides) in the region by an average of 4.9 grams of active ingredient per hectare per year, representing a 44-percent reduction from the 10.9 grams per hectare for the no-practice scenario (table 22).

However, the total quantity of pesticide residues lost from the field is not the most useful outcome measure for assessing the environmental benefits of conservation practices on reducing pesticide residues. The environmental impact of pesticide residues is specific to the toxicity of each pesticide to the non-target species that may be exposed to the pesticide. For example, some pesticides used in large quantities, such as glyphosate, have relatively low toxicity thresholds for most non-target species.

Pesticide risk indicators were therefore developed to represent risk at the edge of the field (bottom of soil profile for groundwater) and for aggregating pesticide risk over the 126 pesticides included in the model for this region.[23] These edge-of-field risk indicators are based on the ratio of pesticide concentrations in water leaving the field to safe concentrations (toxicity thresholds) for each pesticide. As such, these risk indicators do not have units. Risk indicator values of less than 1 are considered "safe" because the concentration is below the toxicity threshold for exposure at the edge of the field.[24]

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

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

Figure 54 shows that for most years the overall risk for aquatic ecosystems is very low, in part because of the conservation practices in use. Over 75 percent of cropped acres in this region have aquatic ecosystem risk indicator scores below 1 in all years. But in some years the edge-of-field concentrations can be high relative to toxicity thresholds.

The surface water pesticide risk indicator for aquatic ecosystems averaged 2.49 over all years and cropped acres for the baseline conservation condition (table 22). The 2.49 value indicates that pesticide concentrations in water leaving cropped fields in the Texas Gulf Basin are, on average, 2.49 times the "safe" concentration for non-target plant and animal species when exposed to concentrations at the edge of the field.

The two pesticide risk indicators for humans are much lower than for the aquatic ecosystems, averaging only 0.87 for surface water and 0.06 for groundwater (table 22).

Atrazine was the dominant pesticide contributing to all three risk indicators (table 23). Based on the model simulations, the edge-of-field risk indicator for atrazine exceeded 1 for 11 percent of the cropped acres for risk to aquatic ecosystems, 7 percent of the cropped acres for surface water risk to humans, and less than 1 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 stringent human drinking water standard (EPA Maximum Contaminant Level = 3 ppb).

[23] For a complete documentation of the development of the pesticide risk indicators, see "Pesticide risk indicators used in CEAP cropland modeling," referenced on page 7.

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

Pesticide Risk Indicators

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

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

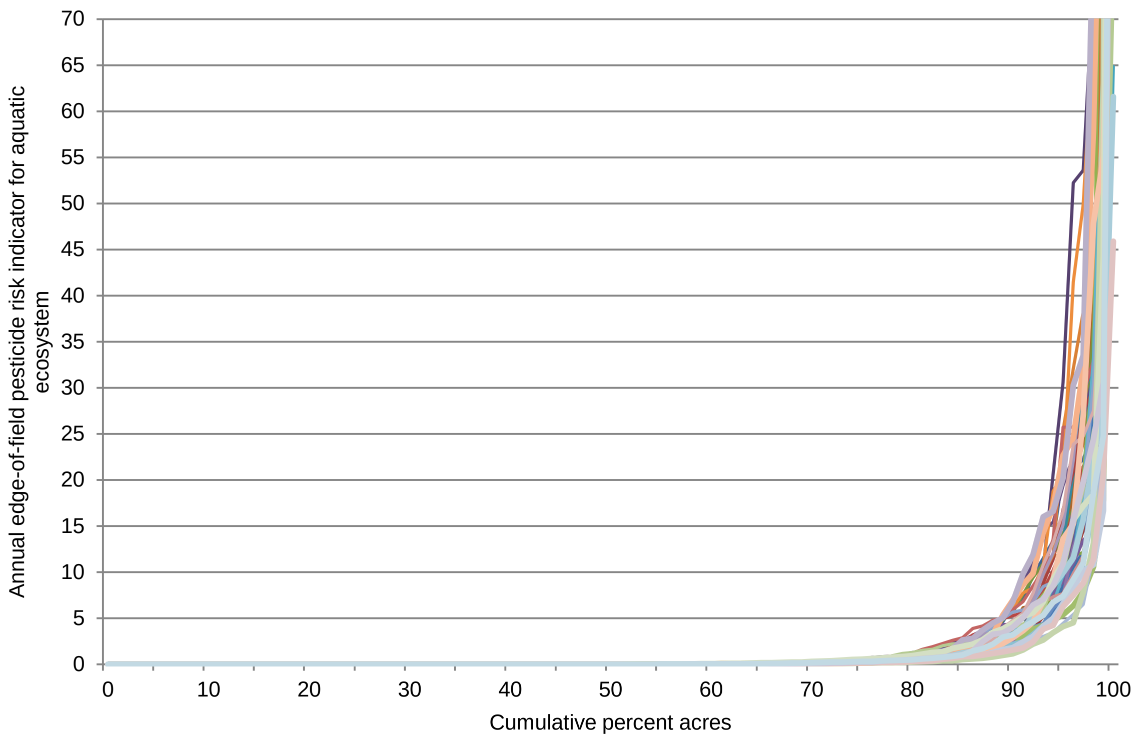
Pesticide risk indicators were calculated for each pesticide as the ratio of the concentration in water leaving the field to the "safe" concentration (toxicity thresholds) for each pesticide, where both are expressed in units of parts per billion. This ratio is called the Aquatic Risk Factor (ARF). ARFs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

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

Two aquatic toxicity thresholds were used in estimating potential risk:

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

Figure 54. Distribution of annual values of the edge-of-field surface water pesticide risk indicator for aquatic ecosystems for each year of the 47-year model simulation, baseline conservation condition, Texas Gulf Basin



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

Table 23. Dominant pesticides determining edge-of-field environmental risk, Texas Gulf Basin

Pesticide (active ingredient name)	Pesticide type	Percent of cropped acres in the region with average annual edge-of-field risk indicator greater than 0.6
Risk indicator for aquatic ecosystem		
Atrazine	Herbicide	11
Malathion	Insecticide	6
Trifluralin	Herbicide	2
Dicrotophos	Insecticide	2
Metolachlor	Herbicide	2
Terbufos	Insecticide	1
Zeta-Cypermethrin	Insecticide	1
Aldicarb	Insecticide	1
Diuron	Herbicide	1
Prometryn	Herbicide	1
Phostebupirim	Insecticide	<1
2,4-D, 2-ethylhexyl ester	Herbicide	<1
Emamectin benzoate	Insecticide	<1
Halosulfuron-methyl	Herbicide	<1
All other pesticides	--	5
Risk indicator for humans, surface water		
Atrazine	Herbicide	7
Dicrotophos	Insecticide	4
Dimethoate	Insecticide	2
All other pesticides	--	1
Risk indicator for humans, groundwater		
Atrazine	Herbicide	<1
All other pesticides	--	<1

The use of conservation practices has reduced the pesticide risk indicator for aquatic ecosystems by 62 percent for the region (table 22, fig. 55). The surface water pesticide risk indicator for humans has been reduced by an average of 49 percent (table 22, fig. 56). The groundwater pesticide risk indicator for humans, which is very low throughout the region, has not been reduced due to conservation practice use (table 22).

Figure 57 shows the distribution of the reductions in the two surface water pesticide risk indicators due to conservation practices. Risk reductions for aquatic ecosystems of greater than 1 occurred on 20 percent of acres, while risk reductions of greater than 1 for humans occurred on only 7 percent of the acres.[25] The benefits of conservation practices were significant 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.

Figure 55. Estimates of average annual edge-of-field surface water pesticide risk indicator for aquatic ecosystems, Texas Gulf Basin

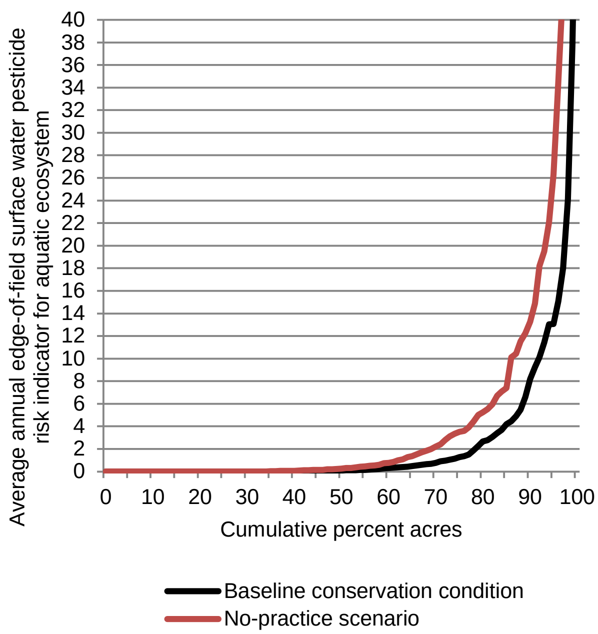


Figure 56. Estimates of average annual edge-of-field surface water pesticide risk indicator for humans, Texas Gulf Basin

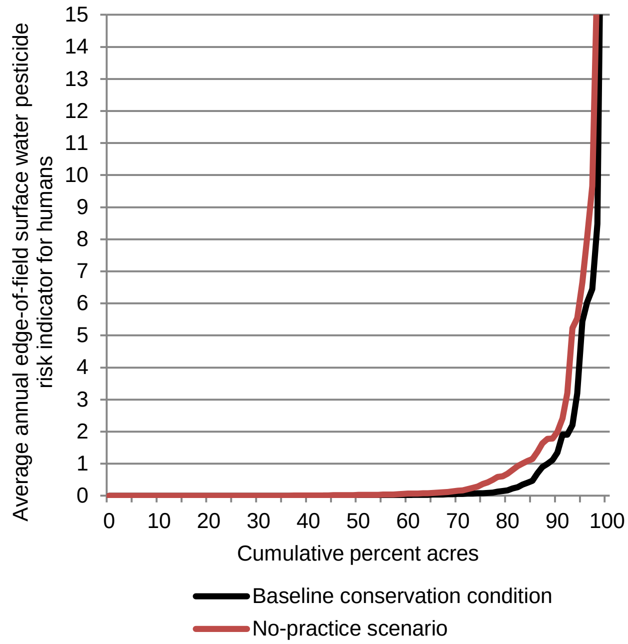
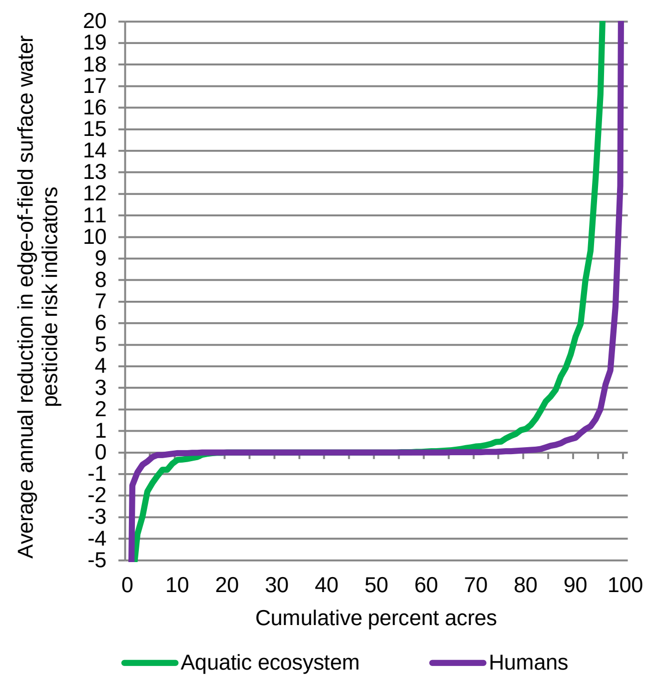


Figure 57. Estimates of average annual reductions in the edge-of-field surface water pesticide risk indicators for aquatic ecosystems in the Texas Gulf Basin



[25] Small negative reductions in surface water runoff, shown in figure 17, also result in small negative reductions in pesticide risk indicators, shown in figure 57. Small negative reductions can also occur on these landscapes as a result of reduced tillage.

Chapter 5
Assessment of Conservation Treatment Needs

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

In summary, findings for the Texas Gulf Basin indicate that—

- *41 percent of cropped acres (7.6 million acres) have a* ***high*** *level of need for additional conservation treatment,*
- *56 percent of cropped acres (10.3 million acres) have a* ***moderate*** *level of need for additional conservation treatment, and*
- *3 percent of cropped acres (498,000 acres) have a* ***low*** *level of need for additional treatment and are considered to be adequately treated.*

The 17.9 million acres with additional conservation treatment needs—undertreated acres—were identified by an imbalance between the level of conservation treatment and the level of inherent vulnerability. Derivation of conservation treatment levels and inherent soil vulnerability classes are described in the next two sections, followed by estimates of undertreated acres.

Field-level model simulation results for the baseline conservation condition were used to make the assessment. Five resource concerns were evaluated for the Texas Gulf Basin:

1. sediment loss due to water erosion;
2. nitrogen loss with surface runoff (nitrogen attached to sediment and in solution—nitrogen runoff);
3. nitrogen loss in subsurface flows (nitrogen leaching);
4. phosphorus lost to surface water (phosphorus attached to sediment and in solution, including soluble phosphorus in subsurface lateral flow pathways); and
5. wind erosion.

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

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

Conservation Treatment Levels

Drawing from the evaluation of practice use presented in chapter 3, four levels of conservation treatment (high, moderately high, moderate, and low) were defined for each of the five resource concerns. A "high" level of treatment was shown by model simulations (see chapter 6) to reduce sediment and nutrient losses to low levels for nearly all cropped acres in the Texas Gulf Basin.

For sediment loss due to water erosion, conservation treatment levels were defined by a combination of structural practices and residue and tillage management practices, as defined in figure 58. A high level of water erosion control treatment is in use on about 7 percent of cropped acres, about half of which are highly erodible acres. Approximately 49 percent of cropped acres in the region have a low level of conservation treatment for water erosion control, and 43 percent have a moderate level of treatment.

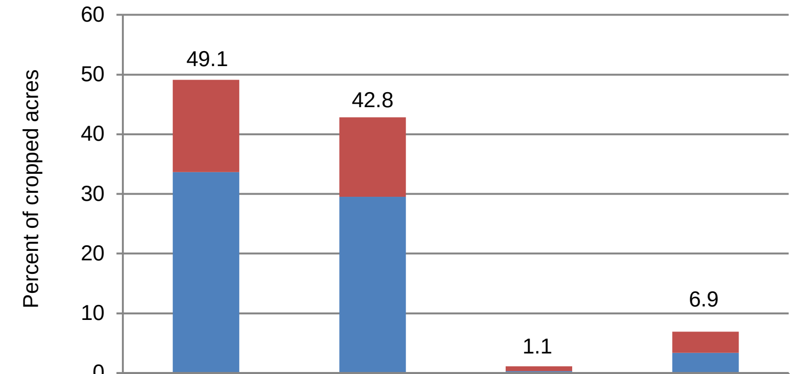
For nitrogen loss with surface runoff, conservation treatment levels were defined by a combination of structural practices, residue and tillage management practices, and nitrogen management practices, as defined in figure 59. A high level of treatment for nitrogen runoff is in use on only 4 percent of cropped acres, slightly more than half of which are highly erodible acres. Eighteen percent have combinations of practices that indicate a moderately high level of treatment. The bulk of cropped acres—60 percent—have a moderate level of treatment, while about 19 percent of cropped acres have a low level of treatment for nitrogen runoff.

For phosphorus lost to surface water, conservation treatment levels were defined by a combination of structural practices, residue and tillage management practices, and phosphorus management practices, as defined in figure 60. A high level of treatment for phosphorus runoff is in use on only 4 percent of cropped acres. About 20 percent of cropped acres have combinations of practices that indicate a moderately high level of treatment. About 42 percent of cropped acres have a moderate level of treatment. Thirty-five percent of cropped acres have a low level of treatment for phosphorus runoff.

The nitrogen management level presented in figure 9 (see chapter 3) was used to evaluate the adequacy of conservation treatment for nitrogen loss in subsurface flows. A high level of treatment for nitrogen loss in subsurface flows is in use on 35 percent of the acres. About 34 percent of cropped acres have combinations of practices that indicate a moderately high level of treatment and about 27 percent have a moderate level of treatment. Only 4 percent of cropped acres have a low level of nitrogen management.

For wind erosion, a combination of structural practices and tillage intensity was used to evaluate the adequacy of conservation treatment, as defined in figure 61. Most cropped acres—about 62 percent—have a low level of treatment for wind erosion in this region. A high level of treatment for wind erosion is in use on less than one percent of cropped acres. Thirty percent of cropped acres have a moderate level of treatment for controlling wind erosion and 8 percent have a moderately high level of treatment.

Figure 58. Percent of cropped acres at four conservation treatment levels for water erosion control in the baseline conservation condition, Texas Gulf Basin



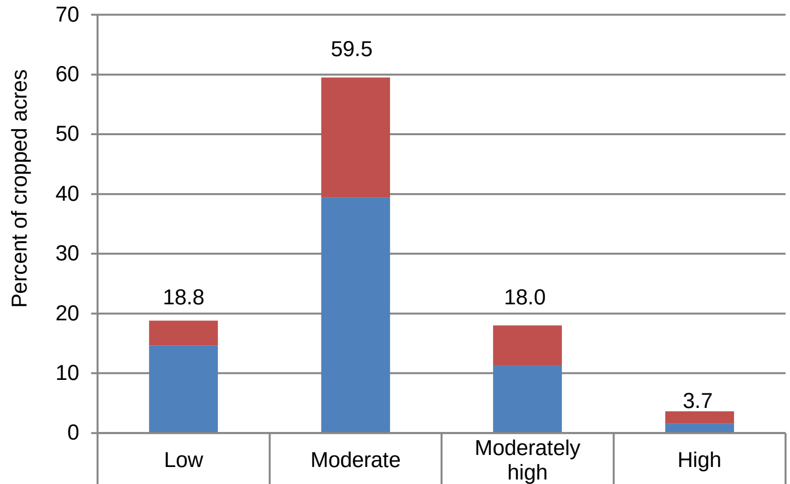
	Low	Moderate	Moderately high	High
HEL	15.4	13.3	0.8	3.6
Non-HEL	33.7	29.5	0.3	3.4

Criteria for water erosion control treatment levels were derived using a combination of structural practice treatment levels and residue and tillage management treatment levels. Scores were first assigned to each of these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1 (see figs. 9 and 10). 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 33 percent of the cropped acres in the basin are highly erodible land (HEL).

Figure 59. Percent of cropped acres at four conservation treatment levels for nitrogen runoff control in the baseline conservation condition, Texas Gulf Basin



	Low	Moderate	Moderately high	High
HEL	4.2	20.1	6.8	2.1
Non-HEL	14.6	39.4	11.3	1.5

Criteria were derived using a combination of structural practice treatment levels, residue and tillage management treatment levels, and nitrogen management treatment levels. Scores were first assigned to each of these treatment levels as follows: High=4, Moderately high=3, Moderate=2, and Low=1 (see figs. 9–11).

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

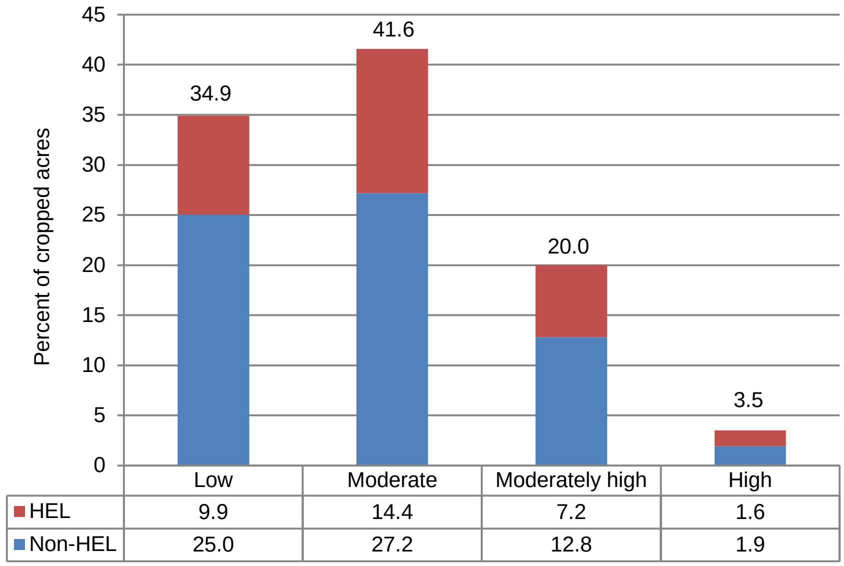
- **High treatment**: Sum of residue and tillage management score and nitrogen management score is equal to 8. (High treatment level for both structural practices and nitrogen management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores 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 33 percent of the cropped acres in the basin are highly erodible land (HEL).

Figure 60. Percent of cropped acres at four conservation treatment levels for phosphorus runoff control in the baseline conservation condition, Texas Gulf Basin



Criteria were derived using a combination of structural practice treatment levels, residue and tillage management treatment levels, and phosphorus management treatment levels (see figs. 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:

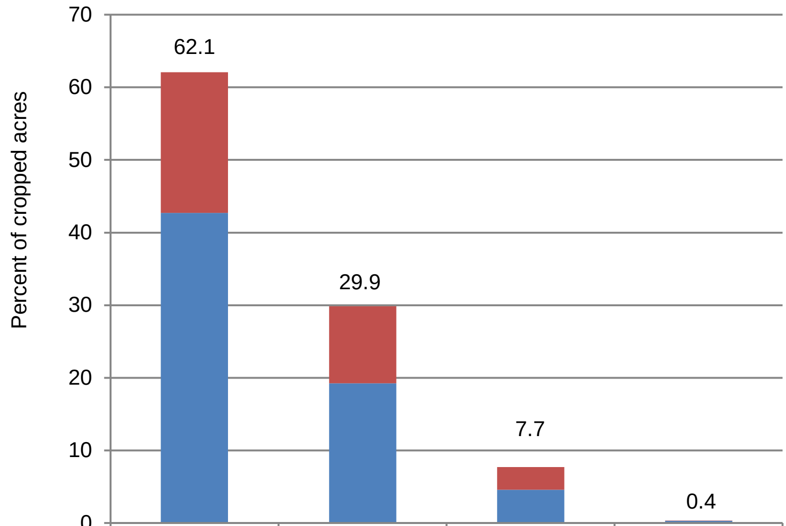
- **High treatment**: Sum of residue and tillage management score and phosphorus management score is equal to 8. (High treatment level for both structural practices and phosphorus management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores 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 33 percent of the cropped acres in the basin are highly erodible land (HEL).

Figure 61. Percent of cropped acres at four conservation treatment levels for wind erosion management, baseline conservation condition, Texas Gulf Basin



	Low	Moderate	Moderately high	High
HEL	19.4	10.6	3.1	0.0
Non-HEL	42.7	19.3	4.6	0.3

Criteria were derived using a combination of structural practices for wind erosion control and residue and tillage management. Criteria for four levels of treatment are:

- **High treatment**: *All crops* meet tillage intensity criteria for either no-till or mulch till and at least one wind erosion control structural practice is in use.
- **Moderately high treatment**: A*ll crops* meet tillage intensity criteria for either no-till or mulch till without any wind erosion control structural practice or a*verage annual* tillage intensity meets criteria for mulch till or no-till and a wind erosion control structural practice is in use.
- **Moderate treatment**: A*verage annual* tillage intensity meets criteria for mulch till or no-till without any wind erosion control structural practice in use.
- **Low treatment**: No wind erosion control structural practices and *average annual* tillage intensity meets criteria for mulch till or no-till.

Note: About 33 percent of the cropped acres in the basin are highly erodible land (HEL).

Inherent Vulnerability Factors

Not all acres require the same level of conservation treatment because of differences in inherent vulnerabilities due to soils and climate. Inherent vulnerability factors for surface runoff include soil properties that promote surface water runoff and erosion—soil hydrologic group, slope, and soil erodibility (the water erosion equation K-factor). Inherent vulnerability factors for loss of nutrients in subsurface flows include soil properties that promote infiltration—soil hydrologic group, slope, water erosion equation K-factor, and coarse fragment content of the soil. Inherent vulnerability factors for wind erosion include annual precipitation, percent slope, and the I-factor from the wind erosion equation. Because the vulnerability indicators are based on soil characteristics, they are referred to as “soil vulnerability potentials.”

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

The criteria for the soil runoff potential are presented in figure 62, followed by the spatial distribution of the soil runoff potential within the Texas Gulf Basin in figure 63. The criteria and spatial distribution for the soil leaching potential are presented in figures 64 and 65. The criteria for the soil wind erosion potential are presented in figures 66 and 67.

The maps in figures 63, 65, and 67 show the vulnerability potentials for all soils and land uses in the region. For the assessment of conservation treatment needs, however, only the vulnerability potentials for cropped acres were used.

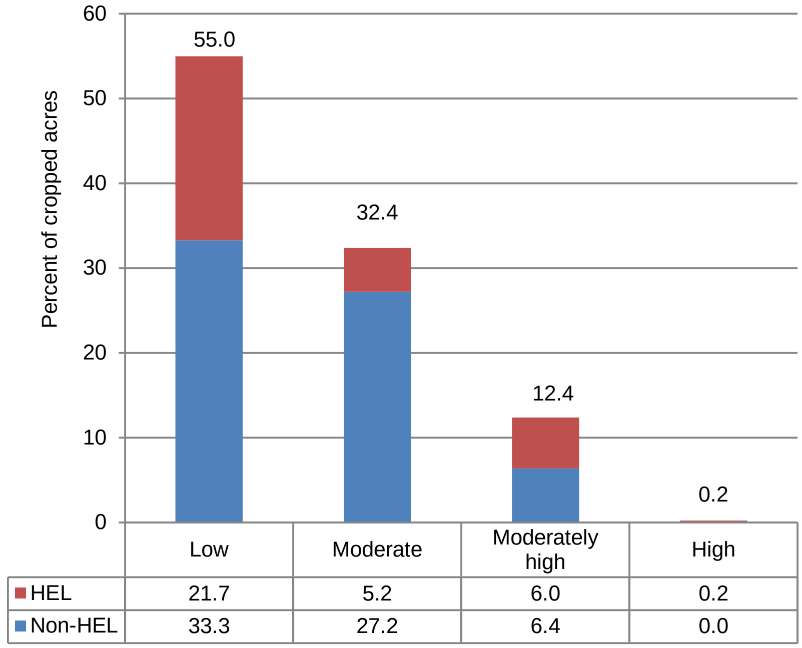
Cropped acres in the Texas Gulf Basin have relatively low soil vulnerability potential for runoff or leaching compared to other regions of the country, but have a higher overall potential vulnerability to wind erosion than other regions.

The majority of cropped acres in this region—55 percent—have a low soil runoff potential vulnerability (fig. 62). Another 32 percent of cropped acres have a moderate level of vulnerability. Only 13 percent of cropped acres have a high or moderately high soil runoff potential vulnerability; most of these acres are in the north and central portions of the region (fig. 63).

Most cropped acres in this region have a moderate soil leaching potential—53 percent (fig. 64). Just over 38 percent of cropped acres have a low soil leaching potential. The remaining 9 percent have a high or moderately high soil leaching potential, mostly located in the northwest and southern portions of the region (fig. 65).

In contrast, about 32 percent of cropped acres in the region have a high or moderately high wind erosion potential (fig. 66). These vulnerable acres are concentrated in the northwestern and southern portions of the region (fig. 67). About 30 percent of cropped acres have a moderate level of soil wind erosion potential. About 39 percent of cropped acres have a low level of soil wind erosion potential, located mostly in the eastern portion of the basin.

Figure 62. Soil runoff potential for cropped acres in the Texas Gulf Basin



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

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

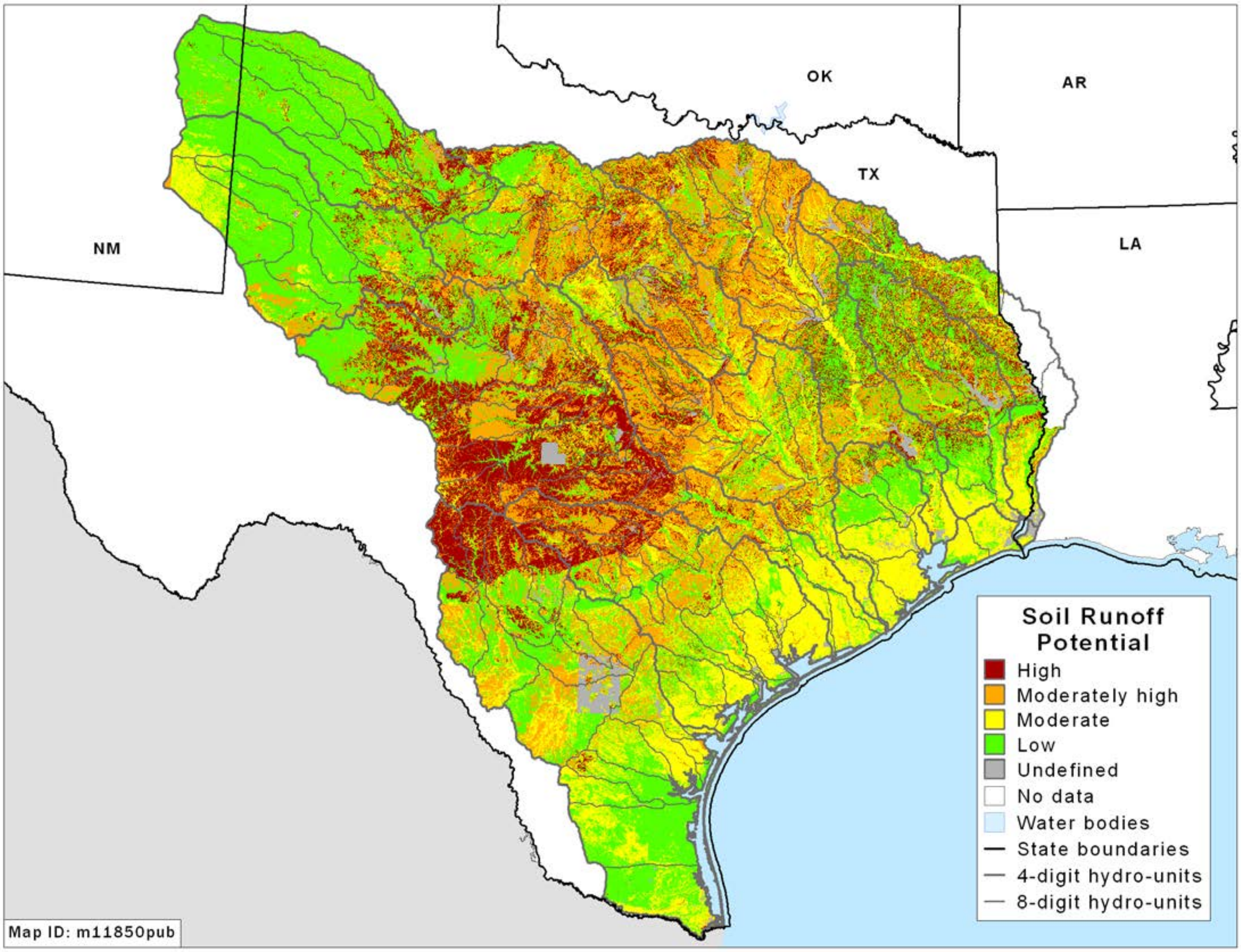
Hydrologic soil groups are classified as:

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

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

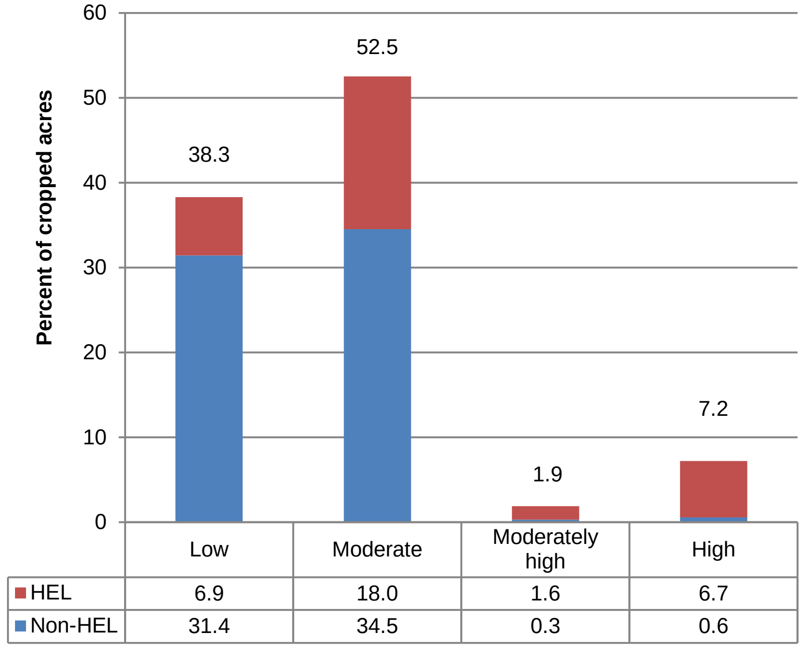
Note: About 33 percent of the cropped acres in the basin are highly erodible land (HEL).
Note: See appendix B, table B4, for a breakdown of soil runoff potential by subregion.

Figure 63. Soil runoff potential for soils in the Texas Gulf Basin



Note: The soil runoff potential shown in this map was derived using the criteria presented in figure 62 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Figure 64. Soil leaching potential for cropped acres in the Texas Gulf Basin



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

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

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

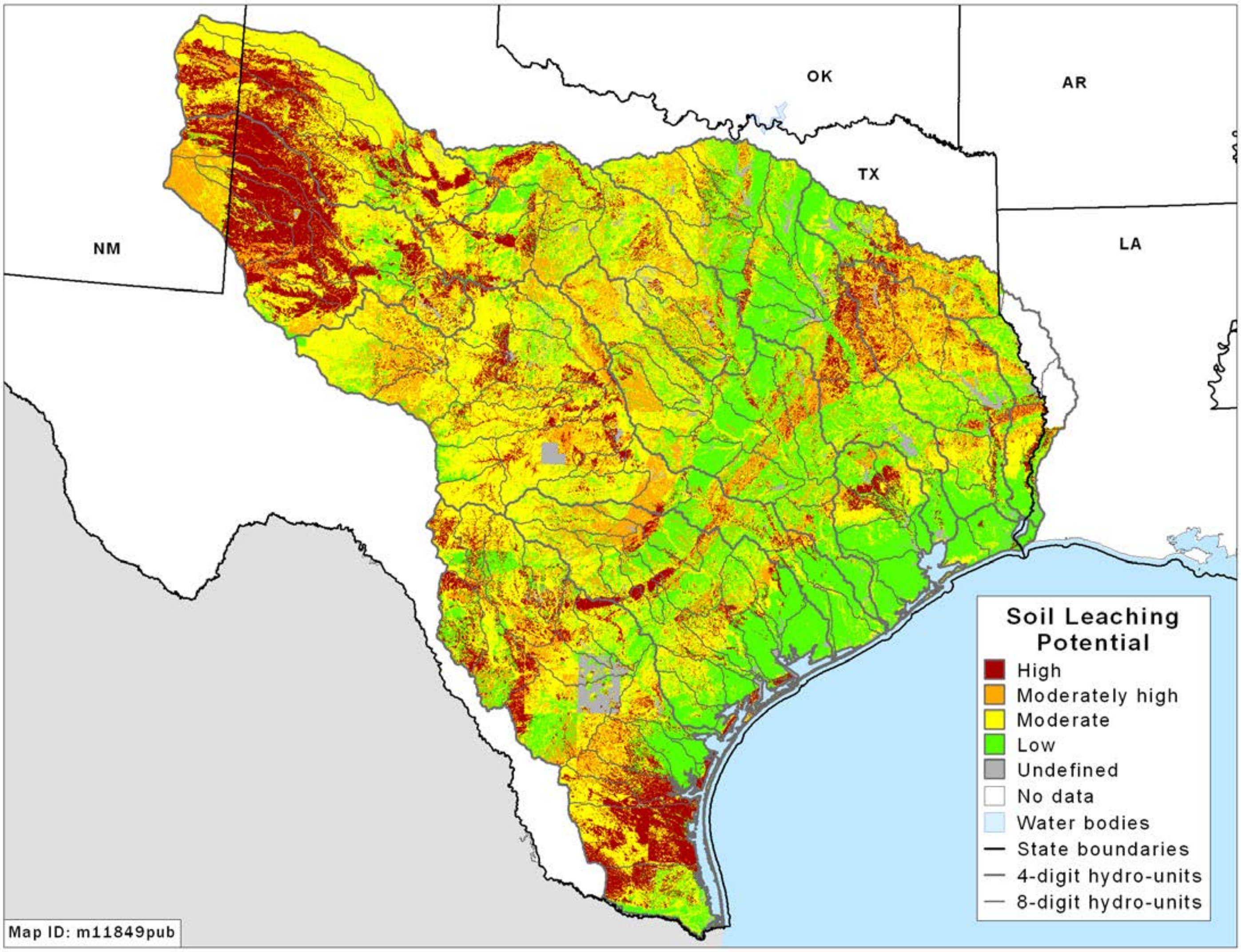
Hydrologic soil groups are classified as:

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

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

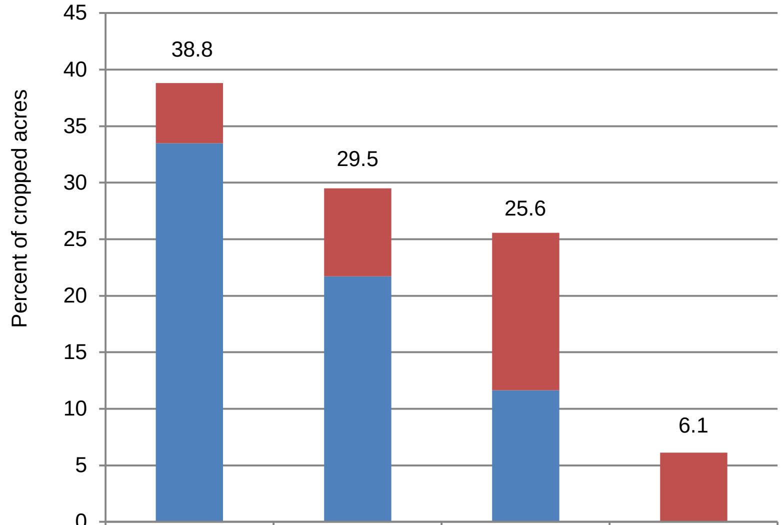
Note: About 33 percent of the cropped acres in the basin are highly erodible land (HEL).
Note: See appendix B, table B4, for a breakdown of soil leaching potential by subregion.

Figure 65. Soil leaching potential for soils in the Texas Gulf Basin



Note: The soil leaching potential shown in this map was derived using the criteria presented in figure 64 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Figure 66. Soil wind erosion potential for cropped acres in the Texas Gulf Basin



	Low	Moderate	Moderately high	High
HEL	5.3	7.8	13.9	6.1
Non-HEL	33.5	21.7	11.7	0.0

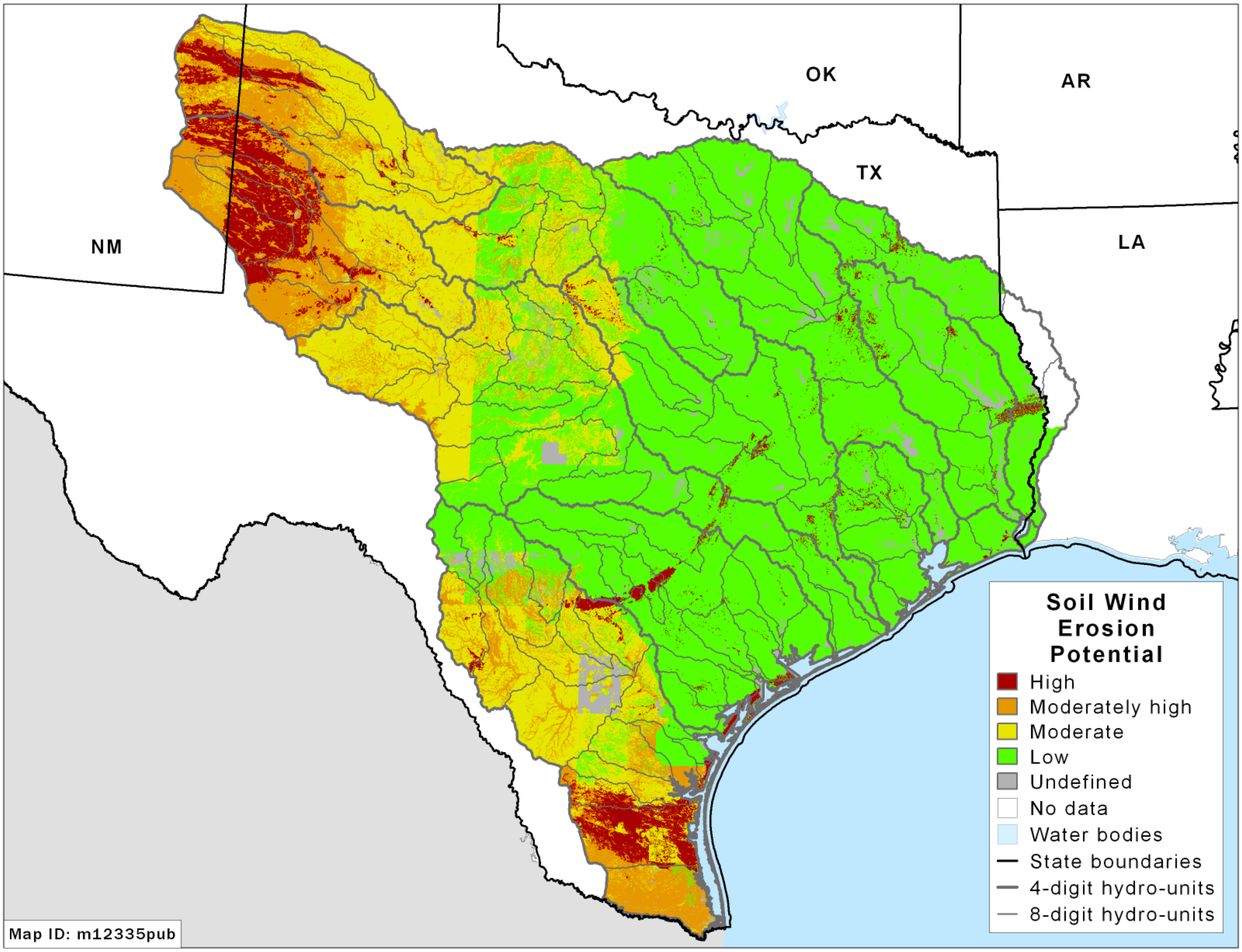
Criteria for four classes of wind erosion potential were derived using a combination of annual precipitation, percent slope, and the I-factor from the wind erosion equation*, as shown in the table below:

Soil wind erosion potential	Acres with I-factor <56	Acres with I-factor <134 and >=56	Acres with I-factor <250 and >=134	Acres with I-factor >=250
Low	Precipitation>=635 mm	Precipitation>=767 mm	Precipitation>=767 mm	None
Moderate	Precipitation<635 mm but >380mm	Precipitation<767 mm but >=508mm and slope>0.5	Precipitation <767 mm but >=635 mm or Precipitation <635 mm but >=508 mm and slope>=3	None
Moderately high	Precipitation<=380 mm	Precipitation<767 mm but >=508 mm and slope<=0.5 or Precipitation <508 mm	Precipitation <635 mm but >=508 mm and slope<3	None
High	None	None	Precipitation<508mm	All acres

* The I-factor from the wind erosion equation is a soil-erodibility index related to cloddiness.

Note: About 33 percent of the cropped acres in the basin are highly erodible land (HEL).
Note: See appendix B, table B3, for a breakdown of soil wind erosion potential by subregion.

Figure 67. Soil wind erosion potential for soils in the Texas Gulf Basin



Note: The soil wind erosion potential shown in this map was derived using the criteria presented in figure 66 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Soil vulnerability has a profound influence on the amount of soil and nutrients lost from farm fields and the extent to which conservation practices are effective in reducing those losses. Estimates of sediment and nutrient losses for the no-practice scenario (without conservation practices), presented in figure 68, demonstrate how vulnerability factors influence losses in the Texas Gulf Basin. Estimates for the baseline are also presented in figure 68 to show how current levels of conservation treatment have reduced losses at each vulnerability level. Three charts (sediment loss, nitrogen loss with surface runoff, and phosphorus lost to surface water) in figure 68 do not show results for the "high" vulnerability potential because of no or few sample points in that category. The chart for nitrogen loss in subsurface flows shows results for moderately high and high combined for the same reason.

Sediment loss for acres with a moderately high soil runoff potential would have averaged nearly 5.75 tons per acre per year without conservation practices, compared to 1.31 tons per acre per year for acres with a low soil runoff potential (fig. 68a). The average annual reduction due to conservation practices is 3.3 tons per acre due to conservation practice use for soils with a moderately high soil runoff potential, compared to a reduction of only 0.9 ton per acre for soils with a low soil runoff potential.

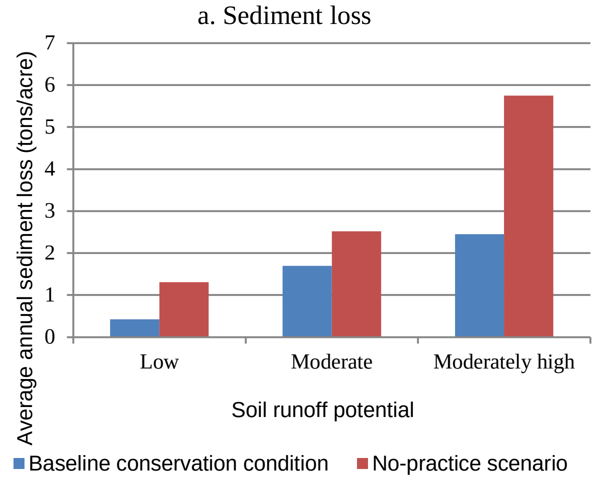
Nitrogen loss with surface runoff for acres with a moderately high soil runoff potential would have averaged 14.0 pounds per acre per year without conservation practices, compared to 2.8 pounds per acre per year for acres with a low soil runoff potential (fig. 68b). The average annual reduction due to conservation practices is 6.4 pounds per acre due to conservation practice use for soils with a moderately high soil runoff potential, compared to a reduction of only 1.6 pounds per acre for soils with a low soil runoff potential.

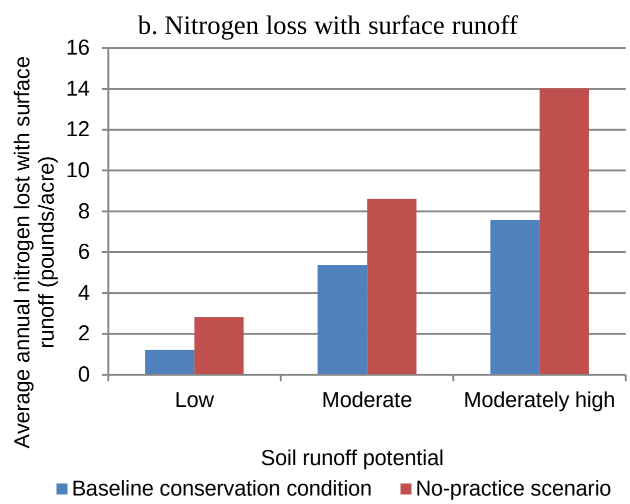
Phosphorus lost to surface water for acres with a moderately high soil runoff potential would have averaged 3.5 pounds per acre per year without conservation practices, compared to 0.9 pound per acre per year for acres with a low soil runoff potential (fig. 68c). The average annual reduction due to conservation practices is 1.9 pounds per acre due to conservation practice use for soils with a moderately high soil runoff potential, compared to a reduction of 0.5 pound per acre for soils with a low soil runoff potential.

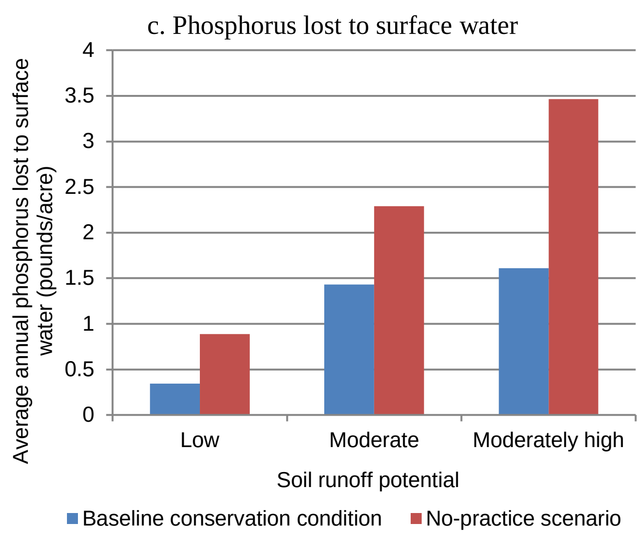
The influence of soil leaching vulnerability on nitrogen loss in subsurface flows is obfuscated by the spatial concentration of low vulnerability soils in the eastern part of the region, where precipitation is highest, as shown in figure 65. Similarly, soils with a high leaching potential are predominantly found in the western and more arid portions of the region. Consequently figure 68d shows an inverse relationship between loss and vulnerability. Losses are lowest, on average, for soils with high or moderately high vulnerability because those soils received much less precipitation than soils with a low vulnerability to leaching losses in this region.

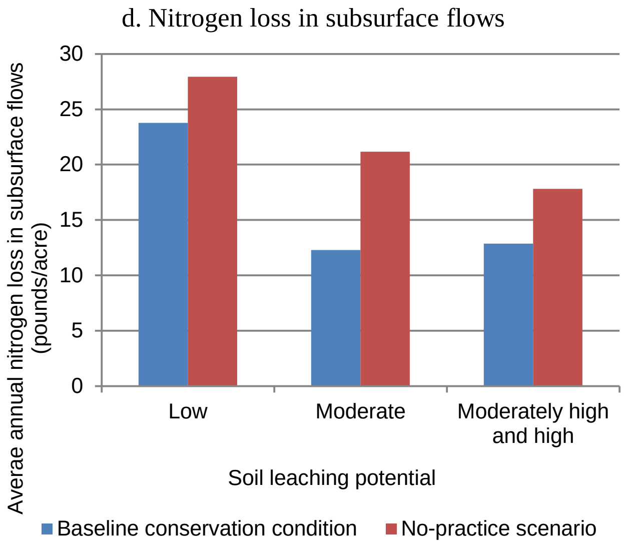
Wind erosion for acres with a high wind erosion potential would have averaged 20.4 tons per acre per year without conservation practices, compared to 3.8 tons per acre per year for acres with a low wind erosion potential (fig. 68e).

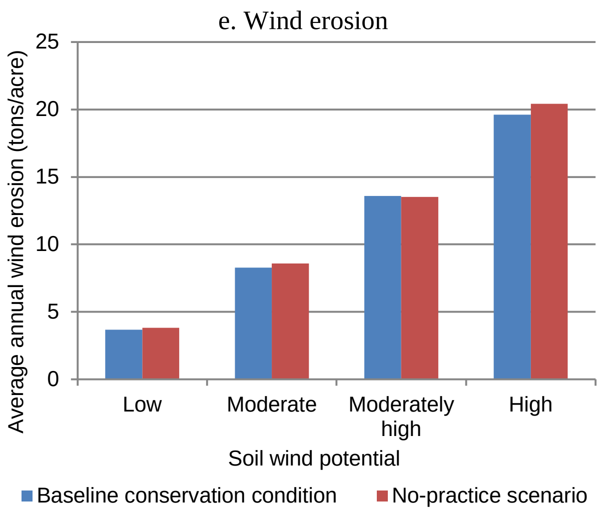
Figure 68. Average annual wind erosion, sediment loss, and nutrient losses for four levels of vulnerability potentials, Texas Gulf Basin











Note: Three charts (sediment loss, nitrogen loss with surface runoff, and phosphorus lost to surface water) in this figure do not show results for the "high" vulnerability potential because of no or few sample points in that category. The chart for nitrogen loss in subsurface flows shows results for moderately high and high combined for the same reason.

Evaluation of Conservation Treatment

The "matrix approach"

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

The matrixes are presented for each of the five resource concerns in tables 24 through 28. Each table includes seven sets of matrixes that, taken together, capture the effects of conservation practices in the region and identify the need for additional conservation treatment.

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

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

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

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

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

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

The criteria and steps in the process are as follows—

1. The percentage of acres that exceeded a given level of loss was estimated for each cell in the matrix as a guide to determining the extent of excessive losses. These are referred to as "acceptable levels." *Losses above these levels were treated as unacceptable levels of loss.* "Acceptable levels"[26] for field-level losses used in this study are—
   - Average of 2 tons per acre per year for sediment loss,
   - Average of 15 pounds per acre per year for nitrogen loss with surface runoff (soluble and sediment attached),
   - Average of 25 pounds per acre per year for nitrogen loss in subsurface flows,
   - Average of 4 pounds per acre per year for phosphorus lost to surface water (soluble and sediment attached), and
   - Average wind erosion of 4 tons per acre per year.
2. Groups of acres with less than 30 percent of the acres exceeding acceptable levels were defined as adequately treated acres and designated as having a **low level of conservation treatment need**.
3. Groups of acres with more than 60 percent of the acres in excess of acceptable levels were designated as having a **high level of conservation treatment need,** indicated by darker shaded cells in the matrixes.
4. The remaining acres were designated as having a **moderate level of conservation treatment need**, indicated by lighter shaded cells in the matrix.

Undertreated acres—those groups of acres with either a high or moderate level of conservation treatment need—are shown in the last matrix in each table. In most cases, undertreated acres consist of acres where the conservation treatment level was one step or more below the soil vulnerability potential.

Acceptable levels were initially derived through a series of forums held at professional meetings of researchers working on fate and transport of sediment and nutrients in agriculture. Those meetings produced a range of estimates for edge-of-field sediment loss, nitrogen loss, and phosphorus loss, representing what could be realistically achieved with today's production and conservation technologies. The range was narrowed by further examination of APEX model output, which also showed that the levels selected were agronomically feasible in all agricultural regions of the country. In the Texas Gulf Basin, for example, percentages of acres that can attain these acceptable levels with additional soil erosion control and nutrient management practices on all undertreated acres are (see the next chapter)—

- 99 percent of cropped acres for sediment loss,
- 100 percent of cropped acres for nitrogen loss with surface runoff,
- 80 percent of cropped acres for nitrogen loss in subsurface flows,
- 98 percent of cropped acres for phosphorus lost to surface water, and
- 69 percent of cropped acres for wind erosion.

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

What is "Adequate Conservation Treatment?"

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

In practice, a *comprehensive planning process* is used to identify the appropriate combination of nutrient management techniques, soil erosion control practices, and other conservation practices needed to address the specific inherent vulnerabilities associated with each field. A field with adequate conservation practice use will have combinations of practices that address all the specific inherent vulnerability factors that determine the potential for sediment, nutrient, and pesticide losses. Full treatment consists of a suite of practices that—

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

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

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

Why Was a Threshold Approach Not Used?

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

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

The conservation goal is full treatment—not treatment to a specific threshold applied broadly across a variety of soils, climates, and landscapes. Protocols for full treatment—avoid, control, and trap—apply equally to all fields in all settings. The hallmark of the matrix approach is that the acres with treatment needs can be readily identified by farmers and conservation planners and treated as needed. Soil vulnerability levels and the existing conservation treatment levels can be readily determined during the conservation planning process.

Table 24. Identification of undertreated acres for sediment loss due to water erosion in the Texas Gulf Basin

Soil runoff potential	Conservation treatment levels for water erosion control: Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	5,257,374	3,822,966	131,974	888,552	10,100,865
Moderate	2,852,768	2,669,282	43,041	385,211	5,950,303
Moderately high	909,265	1,333,179	34,513	0	2,276,957
High	0	40,174	0	0	40,174
All	9,019,407	7,865,601	209,529	1,273,763	18,368,299
Percent of cropped acres					
Low	29	21	1	5	55
Moderate	16	15	<1	2	32
Moderately high	5	7	<1	0	12
High	0	<1	0	0	<1
All	49	43	1	7	100
Sediment loss estimates *without* conservation practices (no-practice scenario), average annual tons/acre					
Low	1.46	1.15	2.57	0.97	1.31
Moderate	2.57	2.70	0.08	1.09	2.52
Moderately high	7.55	4.58	3.49	NA	5.75
High	NA	NA	NA	NA	NA
All	2.42	2.25	2.21	1.01	2.25
Sediment loss estimates for the baseline conservation condition, average annual tons/acre					
Low	0.58	0.31	0.71	0.02	0.43
Moderate	2.19	1.41	0.03	0.18	1.69
Moderately high	3.33	1.90	0.40	NA	2.45
High	NA	NA	NA.	NA	NA
All	1.37	0.95	0.52	0.07	1.09
Percent reduction in sediment loss due to conservation practices, average annual tons/acre					
Low	60	73	73	98	67
Moderate	15	48	58	83	33
Moderately high	56	59	89	NA	57
High	NA	NA	NA	NA	NA
All	44	58	77	93	52
Percent of acres in baseline with average annual sediment loss more than 2 tons/acre					
Low	7	1	0	0	4
Moderate	32	32	0	0	30
Moderately high	49	34	0	NA	39
High	NA	NA	NA	NA	NA
All	19	17	0	0	17
Estimate of undertreated acres for sediment loss					
Low	0	0	0	0	0
Moderate	2,852,768	2,669,282	0	0	5,522,051
Moderately high	909,265	1,333,179	0	0	2,242,444
High	0	40,174*	0	0	40,174
All	3,762,033	4,042,635	0	0	7,804,669

* This group of acres was classified as undertreated acres because a lower level of soil runoff potential met the criteria for undertreated acres. Sample size was very small for this cell.

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

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

Note: NA indicates not applicable because there were no acres in the category or there were too few acres to provide representative results.

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

Soil runoff potential	Conservation treatment levels for nitrogen runoff control: Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	1,499,332	6,034,833	2,018,556	548,145	10,100,865
Moderate	1,647,052	3,244,850	935,136	123,265	5,950,303
Moderately high	310,671	1,649,999	316,288	0	2,276,957
High	0	0	40,174	0	40,174
All	3,457,055	10,929,682	3,310,153	671,409	18,368,299
Percent of cropped acres					
Low	8	33	11	3	55
Moderate	9	18	5	1	32
Moderately high	2	9	2	0	12
High	0	0	<1	0	<1
All	19	60	18	4	100
Estimates of nitrogen loss with surface water runoff *without* conservation practices (no-practice scenario), average annual pounds/acre					
Low	4.9	2.6	2.3	1.3	2.8
Moderate	10.5	8.4	6.7	4.3	8.6
Moderately high	32.6	11.8	7.4	NA	14.0
High	NA	NA.	NA	NA	NA
All	10.0	5.7	4.0	1.9	6.1
Estimates of nitrogen loss with surface water runoff for the baseline conservation condition, average annual pounds/acre					
Low	2.6	1.1	0.8	0.7	1.2
Moderate	7.1	5.0	4.1	1.4	5.4
Moderately high	19.5	5.9	4.6	NA.	7.6
High	NA	NA.	NA	NA	NA
All	6.3	3.0	2.1	0.8	3.4
Percent reduction in nitrogen loss with surface water runoff due to conservation practices, average annual pounds/acre					
Low	46	60	66	48	57
Moderate	32	40	39	67	38
Moderately high	40	50	39	NA	46
High	NA	NA	NA	NA	NA
All	37	48	48	56	45
Percent of acres in baseline with average annual nitrogen loss with surface runoff more than 15 pounds/acre					
Low	0	0	0	0	0
Moderate	11	1	2	0	4
Moderately high	75	7	3	NA	16
High	NA	NA	NA	NA	NA
All	12	1	1	0	3
Estimate of undertreated acres for nitrogen loss with surface runoff					
Low	0	0	0	0	0
Moderate	0	0	0	0	0
Moderately high	310,671	0	0	0	310,671
High	0	0	0	0	0
All	310,671	0	0	0	310,671

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

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

Note: NA indicates not applicable because there were no acres in the category or there were too few acres to provide representative results.

Table 26. Identification of undertreated acres for nitrogen loss in subsurface flows in the Texas Gulf Basin

	Conservation treatment levels for nitrogen leaching				
Soil leaching potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	560,326	2,571,026	2,301,596	1,606,625	7,039,573
Moderate	209,072	1,880,260	3,265,340	4,295,373	9,650,046
Moderately high	0	147,525	91,710	109,910	349,145
High	33,728	386,515	542,617	366,675	1,329,536
All	803,127	4,985,326	6,201,263	6,378,583	18,368,299
Percent of cropped acres					
Low	3	14	13	9	38
Moderate	1	10	18	23	53
Moderately high	0	1	<1	1	2
High	<1	2	3	2	7
All	4	27	34	35	100
Estimates of nitrogen loss in subsurface flows *without* conservation practices (no-practice scenario), average annual pounds/acre					
Low	32.6	46.3	17.9	11.4	27.9
Moderate	94.5	31.8	26.3	9.1	21.2
Moderately high	NA	NA	NA	NA	NA
High	NA	50.5	7.0	5.6	20.5
All	49.7	39.9	21.1	9.6	23.5
Estimates of nitrogen loss in subsurface flows for the baseline conservation condition, average annual pounds/acre					
Low	33.5	47.4	7.5	5.9	23.8
Moderate	22.5	24.8	12.9	5.9	12.3
Moderately high	NA	NA	NA	NA	NA
High	NA	35.0	3.9	1.0	12.9
All	30.6	37.0	9.9	5.8	16.7
Percent reduction in nitrogen loss in subsurface flows due to conservation practices, average annual pounds/acre					
Low	-3	-2	58	48	15
Moderate	76	22	51	35	42
Moderately high	NA	NA	NA	NA	NA
High	NA	31	45	82	37
All	38	7	53	39	29
Percent of acres in baseline with average annual nitrogen loss in subsurface flows more than 25 pounds/acre					
Low	48	55	6	11	28
Moderate	29*	38	17	7	17
Moderately high	NA	NA	NA	NA	NA
High	NA	55	0	0	17
All	43	48	11	8	21
Estimate of undertreated acres for nitrogen loss in subsurface flows					
Low	560,326	2,571,026	0	0	3,131,352
Moderate	209,072*	1,880,260	0	0	2,089,333
Moderately high	0	147,525	0	0	147,525
High	33,728	386,515	0	0	420,243
All	803,127	4,985,326	0	0	5,788,453

* This group of acres was classified as undertreated acres because a higher level of conservation treatment met the criteria for undertreated acres.

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

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

Note: NA indicates not applicable because there were no acres in the category or there were too few acres to provide representative results.

Table 27. Identification of undertreated acres for phosphorus lost to surface water (attached to sediment and in solution) in the Texas Gulf Basin

	Conservation treatment levels for phosphorus runoff control				
Soil runoff potential	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	3,611,554	4,254,268	1,830,942	404,102	10,100,865
Moderate	2,080,961	2,434,095	1,194,124	241,124	5,950,303
Moderately high	718,072	951,437	607,449	0	2,276,957
High	0	0	40,174	0	40,174
All	6,410,586	7,639,799	3,672,689	645,225	18,368,299
Percent of cropped acres					
Low	20	23	10	2	55
Moderate	11	13	7	1	32
Moderately high	4	5	3	0	12
High	0	0	<1	0	<1
All	35	42	20	4	100
Estimates of phosphorus lost to surface water *without* conservation practices (no-practice scenario), average annual pounds/acre					
Low	1.10	0.92	0.54	0.32	0.89
Moderate	2.61	2.45	1.44	2.18	2.29
Moderately high	3.80	4.58	1.33	NA	3.47
High	NA	NA	NA	NA	NA
All	1.89	1.86	0.96	1.01	1.66
Estimates of phosphorus lost to surface water for the baseline conservation condition, average annual pounds/acre					
Low	0.39	0.38	0.19	0.24	0.34
Moderate	2.04	1.30	0.70	1.13	1.43
Moderately high	2.40	1.58	0.72	NA	1.61
High	NA	NA	NA	NA	NA
All	1.15	0.83	0.44	0.57	0.85
Percent reduction in phosphorus lost to surface water due to conservation practices, average annual pounds/acre					
Low	64	58	65	25	61
Moderate	22	47	51	48	37
Moderately high	37	65	46	NA	54
High	NA	NA	NA	NA	NA
All	39	56	54	44	49
Percent of acres in baseline with average annual phosphorus lost to surface water more than 4 pounds/acre					
Low	1	0	0	0	0
Moderate	13	3	0	0	6
Moderately high	6	6	0	NA	5
High	NA	NA	NA	NA	NA
All	6	2	0	0	3
Estimate of undertreated acres for phosphorus lost to surface water					
Low	0	0	0	0	0
Moderate	0	0	0	0	0
Moderately high	0	0	0	0	0
High	0	0	0	0	0
All	0	0	0	0	0

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

Note: NA indicates not applicable because there were no acres in the category or there were too few acres to provide representative results.

Table 28. Identification of undertreated acres for wind erosion in the Texas Gulf Basin

Soil wind potential	Conservation treatment levels for wind erosion control: Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	4,112,066	2,442,664	533,096	39,308	7,127,134
Moderate	3,301,492	1,714,962	399,487	0	5,415,941
Moderately high	3,338,116	1,024,068	318,204	17,802	4,698,190
High	651,624	303,196	164,417	7,797	1,127,034
All	11,403,298	5,484,890	1,415,204	64,907	18,368,299
Percent of cropped acres					
Low	22	13	3	<1	39
Moderate	18	9	2	0	29
Moderately high	18	6	2	<1	26
High	4	2	1	<1	6
All	62	30	8	<1	100
Wind erosion estimates *without* conservation practices (no-practice scenario), average annual tons/acre					
Low	4.5	3.2	1.5	NA	3.8
Moderate	10.8	4.3	8.4	NA	8.6
Moderately high	15.1	7.3	17.9	NA	13.5
High	29.1	10.1	5.9	NA	20.4
All	10.8	4.7	7.6	1.4	8.7
Wind erosion estimates for the baseline conservation condition, average annual tons/acre					
Low	4.6	3.0	0.5	NA	3.7
Moderate	10.8	3.9	6.8	NA	8.3
Moderately high	15.4	6.4	17.9	NA	13.6
High	29.9	8.4	0.7	NA	19.6
All	11.0	4.2	6.2	0.9	8.6
Percent reduction in wind erosion due to conservation practices, average annual tons/acre					
Low	0	8	70	NA	4
Moderate	1	11	18	NA	4
Moderately high	-3	12	0	NA	-1
High	-2	17	88	NA	4
All	-1	11	19	34	2
Percent of acres in baseline with average annual wind erosion more than 4 tons/acre					
Low	43	27	0	NA	34
Moderate	75	35	37	NA	59
Moderately high	83	44	59	NA	73
High	92	50	0*	NA	66
All	67	34	24	0	53
Estimate of undertreated acres for wind erosion					
Low	4,112,066	0	0	0	4,112,066
Moderate	3,301,492	1,714,962	399,487	0	5,415,941
Moderately high	3,338,116	1,024,068	318,204	0	4,680,388
High	651,624	303,196	164,417*	0	1,119,237
All	11,403,298	3,042,226	882,108	0	15,327,632

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

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

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

Note: NA indicates not applicable because there were no acres in the category or there were too few acres to provide representative results.

Conservation treatment needs by resource concern

Wind erosion is the most important conservation resource concern in the Texas Gulf Basin (fig. 69 and tables 29 and 30). About 40 percent of cropped acres have a high level of conservation treatment need for wind erosion and another 44 percent have a moderate level of need. Overall, 84 percent of cropped acres need additional treatment for wind erosion. About 41 percent of cropped acres need treatment *only* for wind erosion, and 43 percent need treatment for one or more resource concern in combination with wind erosion (table 30).

For other resource concerns, the percentage of cropped acres in the Texas Gulf Basin with a high or moderate need for additional conservation treatment was determined to be (fig. 69 and table 29)—

- 42.5 percent for sediment loss (none with a high need for treatment),
- 1.7 percent for nitrogen loss with surface runoff (all with a high need for treatment),
- none for phosphorus lost to surface water, and
- 31.5 percent for nitrogen loss in subsurface flows (none with a high need for treatment)

Undertreated acres in the Texas Gulf Basin are presented by combinations of resource concerns in table 30. Nearly all of the undertreated acres in the Texas Gulf Basin are undertreated for either wind erosion or sediment loss with water erosion or both. Only 1 percent of cropped acres have a need for additional treatment for nitrogen loss in subsurface flows *only*.

Figure 69. Percent of cropped acres that are undertreated in the Texas Gulf Basin, by resource concern

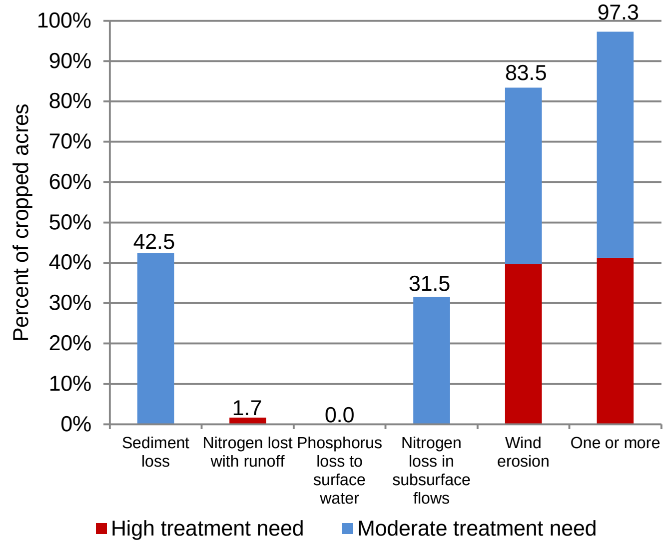


Table 29. Percent of cropped acres in the Texas Gulf Basin with conservation treatment needs for each of the five resource concerns

	Sediment loss	Nitrogen loss with surface runoff	Nitrogen loss in subsurface flows	Phosphorus lost to surface water	Wind erosion	One or more
High level of conservation treatment need	0	1.7	0	0	39.7	41.3
Moderate level of conservation treatment need	42.5	0	31.5	0	43.8	56.0
Low level of conservation treatment need	57.5	98.3	68.5	100	16.6	2.7

Table 30. Undertreated acres with resource concerns needing treatment in the Texas Gulf Basin

Reason for treatment need	Percent of cropped acres in basin	Percent of undertreated acres in basin
Wind erosion only	41.1	42.2
Wind erosion and sediment loss with water erosion	17.0	17.5
Wind erosion and nitrogen leaching	12.8	13.1
Wind erosion, nitrogen leaching, and sediment loss with water erosion	11.3	11.6
Sediment loss with water erosion only	7.5	7.8
Sediment loss with water erosion and nitrogen leaching	4.9	5.1
Nitrogen leaching, nitrogen runoff, sediment loss with water erosion, and wind erosion	1.2	1.2
Nitrogen leaching only	1.0	1.0
Nitrogen leaching, nitrogen runoff, and sediment loss with water erosion	0.4	0.4
Sediment loss with water erosion, nitrogen runoff, and wind erosion	0.1	0.1
All resource concerns in region	97.3	100.0

Note: This table summarizes the undertreated acres identified in tables 24 through 28 and reports the joint set of acres that need treatment according to combinations of resource concerns. Percents may not add to totals because of rounding.

Conservation treatment needs for one or more resource concern

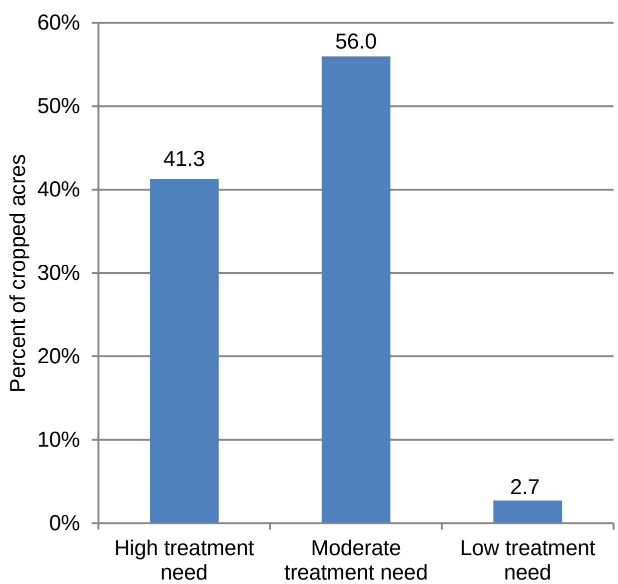
About half of the cropped acres in the region need additional treatment for only one resource concern—

- 41 percent need treatment only for wind erosion,
- 7.5 percent need treatment only for sediment loss with water erosion, and
- 1 percent need additional treatment only for nitrogen loss in subsurface flows.

Other acres require additional treatment for two or more resource concerns (table 30). After accounting for acres that need treatment for multiple resource concerns, the evaluation of treatment needs for the Texas Gulf Basin determined that (fig. 70)—

- 41.3 percent of cropped acres (7.6 million acres) have a **high** level of need for additional conservation treatment,
- 56.0 percent of cropped acres (10.3 million acres) have a **moderate** level of need for additional conservation treatment, and
- 2.7 percent of cropped acres (498,000 acres) have a **low** level of need for additional treatment and are considered to be adequately treated.

Figure 70. Percent of cropped acres with a high, moderate, or low level of need for additional conservation treatment for one or more resource concern in the Texas Gulf Basin



Acres with a high level of need for conservation treatment. In the Texas Gulf Basin, nearly all acres with a high level of need for conservation treatment *need additional treatment only for wind erosion*. As shown in table 31, wind erosion for acres with a high need for additional treatment averaged 14.2 tons per acre per year, compared to 4.75 tons per acre per year for acres with a moderate need and 0.69 ton per acre for acres with a low need. Associated losses of nitrogen and phosphorus were also very high for these acres. About 11.7 pounds per acre of nitrogen and 1.81 pounds per acre of phosphorus are lost with windborne sediment, on average, for the 7.6 million acres with a high need for additional treatment.

Some acres in this category have a high need for additional treatment for nitrogen lost with runoff, but the acres are so few that the average loss shown in table 31 mostly reflects drier acres in the western portion of the region that are prone to severe wind erosion. These acres also had relatively low levels of nitrogen applied (table 31), which explains in part why these acres had less loss of total nitrogen (all pathways) than other cropped acres, on average.

Acres with a moderate level of need for conservation treatment. Acres with a “moderate” level of need for conservation treatment in this region consist of undertreated acres that generally have excessive wind erosion rates and excessive losses of nitrogen in subsurface flows and sediment lost with water erosion. Many of these acres are located in the eastern portion of the region where precipitation is highest. Sediment loss for these acres averages 1.4 tons per acre per year, compared to average losses of less than 1 ton per acre per year for acres with either a low or moderate need for additional treatment (table 31). Nitrogen loss in subsurface flows averages 19 pounds per acre per year, compared to average losses of less than 15 pounds per acre per year for acres in the other two categories. A portion of the acres needing additional treatment for wind erosion in this category also have high wind erosion rates, but overall not as high as for acres with a high need for additional treatment.

Acres with a low level of need for conservation treatment. Acres with a low level of need for conservation treatment consist of acres that are adequately treated with respect to the level of inherent vulnerability for each of the five resource concerns. In the Texas Gulf Basin, only a few acres are in this category—less than 0.5 million acres. Wind erosion averages only 0.7 ton per acre per year for these acres, nitrogen loss in subsurface flows averages only 15 pounds per acre per year, and sediment loss with water erosion averages only 0.4 ton per acre per year (table 31). While gains can be attained by adding conservation practices to some of these acres with a low treatment need, additional conservation treatment would reduce average field losses by only a small amount.

Table 31. Baseline conservation condition model simulation results for subsets of undertreated and adequately treated acres in the Texas Gulf Basin

Model simulated outcome	Acres with a *low* need for treatment	Acres with a *moderate* need for treatment	Acres with a *high* need for treatment	All acres
Cultivated cropland acres in subset	498,490	10,283,869	7,585,940	18,368,299
Percent of acres	2.7%	56.0%	41.3%	100.0%
Precipitation				
Average annual precipitation (inches)	33.0	30.8	22.1	27.3
Water flow				
Average annual surface runoff (inches)	6.4	5.8	2.2	4.3
Average annual subsurface water flow (inches)	2.2	1.7	1.0	1.4
Erosion and sediment loss				
Average annual wind erosion (tons/acre)	0.69	4.75	14.20	8.55
Average annual sediment loss at edge of field due to water erosion (tons/acre)	0.39	1.42	0.68	1.09
Soil organic carbon				
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	88	-174	-194	-176
Nitrogen				
Nitrogen sources (pounds/acre)				
Atmospheric deposition	4.4	4.3	3.7	4.0
Bio-fixation by legumes	0.0	1.5	1.0	1.2
Nitrogen applied as commercial fertilizer and manure	75.4	66.5	55.2	62.1
All nitrogen sources	79.8	72.4	59.8	67.4
Total nitrogen loss for all pathways (pounds/acre)	46.4	43.6	36.9	40.9
Average annual nitrogen lost with windborne sediment (pounds/acre)	0.9	6.6	11.7	8.5
Average annual loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	4.4	4.3	2.0	3.3
Average annual nitrogen loss in subsurface flows (pounds/acre)	14.7	19.1	13.7	16.7
Phosphorus				
Phosphorus applied (pounds/acre)	16.4	11.9	10.1	11.3
Total phosphorus loss for all pathways (pounds/acre)	1.13	1.99	2.39	2.13
Average annual phosphorus lost with windborne sediment (pounds/acre)	0.10	0.72	1.81	1.16
Average annual loss of phosphorus to surface water*	0.81	1.12	0.50	0.85

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

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

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

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

Three sets of additional conservation practices were simulated:

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

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

1. Treatment of the 7.6 million critical undertreated acres (acres with a high need for conservation treatment) with water and wind erosion control practices only.
2. Treatment of all 17.9 million undertreated acres (acres with a high or moderate need for conservation treatment) with water and wind erosion control practices only.
3. Treatment of the 7.6 million critical undertreated acres with nutrient management practices in addition to water and wind erosion control practices to address nutrient losses.
4. Treatment of all 17.9 million undertreated acres with nutrient management practices in addition to water and wind erosion control practices to address nutrient losses.

Except for wind erosion, about half of the potential field-level savings from conservation treatment, relative to losses simulated for the no-practice scenario, has been achieved in this region. The potential savings represented by practices in use in 2003–06 are: 55 percent for sediment, 50 percent for nitrogen, and 51 percent for phosphorus. By treating the 7.6 million critical undertreated acres in the region with additional erosion control and nutrient management practices, an additional 12 percent in savings would be attained for sediment, 22 percent for nitrogen, and 28 percent for phosphorus. To achieve 100 percent of potential savings (i.e., an additional 32 percent for sediment, 28 percent for nitrogen, and 20 percent for phosphorus), additional conservation treatment for the remaining 10.3 million undertreated acres with a moderate need for additional treatment would be required.

The exception to this trend is the potential benefit for further treatment for wind erosion. The reductions in wind erosion represented by practices in place for the entire basin are only 4 percent of potential reductions. By treating the 7.6 million critical undertreated acres (acres with a high need for treatment) for wind erosion an additional 55 percent in savings could potentially be gained. To achieve 100 percent of the potential savings, the remaining10.3 million moderate-need acres would need to be treated.

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

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

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

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

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

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

Simulation of Additional Erosion Control Practices

Treatment to control water erosion and surface water runoff consists of structural and vegetative practices that slow runoff water and capture contaminants that it may carry. Simulations of practices were added where needed (summarized in table 32) according to the following rules.

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

- **Edge-of-field mitigation:**
  - Fields adjacent to water received a riparian buffer, if one was not already present.
  - Fields not adjacent to water received a filter strip, if one was not already present.

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

For additional wind erosion control, the proportion of the field protected from wind was increased. Practices such as windbreaks or shelterbelts, cross wind ridges, stripcropping or trap strips, and hedgerows are typically used for wind control. The effectiveness of these practices is simulated in the model by adjusting the unsheltered dimensions of the standard field that is modeled—a square field 400 meters (1,312 feet) on each side. For sample points where the wind erosion exceeded an average of 4 tons per acre per year in the baseline conservation condition—9.8 million cropped acres—wind erosion practices were added so as to reduce the unsheltered distance to 120 feet. This was typically achieved by adding crosswind trap strips.

Simulation of Additional Nutrient Management Practices

The nutrient management treatment scenario consists of additional nutrient management practices where needed *in addition to* the erosion control practices. The nutrient management practices simulated the application of nutrients at an appropriate rate, in an appropriate form, at appropriate times, and using an appropriate method of application to provide sufficient nutrients for crop growth while minimizing losses to the environment. Simulation of nutrient management required changes to nutrient applications for one or more crops on all but about 27 percent of the acres (see table 10).

Specific rules for application timing

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

- All commercial fertilizer applications were adjusted to 14 days prior to planting, except for acres susceptible to leaching loss.
- For acres susceptible to leaching loss (hydrologic soil group A, soils with sandy textures, or tile drained fields), nitrogen was applied in split applications, with 25 percent of the total application 14 days before planting and 75 percent 30 days after planting.
- Manure applications during winter months (December, January, February, and March) were moved to 14 days pre-plant or April 1, whichever occurs first. This rule allows for mid- March applications of manure in the warmer climates of the Texas Gulf Basin. April 1 is near the period when the soils warm and become biologically active. However, this late date could begin to pressure manure storage capacities and it is recognized that this could create storage problems. The Texas Gulf Basin is unique in its temperature extremes and in some instances in the southern portion of the basin, application could responsibly occur nearly year round.

In the baseline condition, about 18 percent of the cropped acres in the Texas Gulf Basin receive fertilizer applications in the fall for at least one spring-planted row crop in the rotation. The only fall application of nutrients simulated in the nutrient management treatment scenario was for fall seeded crops that received a starter fertilizer at planting time.

Specific rules for 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.

Table 32. Summary of additional structural practices for water erosion control simulated for undertreated acres to assess the potential for gains from additional conservation treatment in the Texas Gulf Basin

Additional practice	Critical undertreated acres (acres with a high level of treatment need) Treated acres	Percent of total	Non-critical undertreated acres (acres with a moderate level of treatment need) Treated acres	Percent of total	All undertreated acres Treated acres	Percent of total
Overland flow practice only	0	0.0	0	0.0	0	0.0
Terrace only	0	0.0	0	0.0	0	0.0
Terrace plus overland flow practice	0	0.0	0	0.0	0	0.0
Filter only	6,644,305	87.6	8,496,467	82.6	15,140,772	84.7
Filter plus overland flow practice	148,981	2.0	196,404	1.9	345,384	1.9
Filter plus terrace	0	0.0	0	0.0	0	0.0
Filter plus overland flow practice plus terrace	0	0.0	74,971	0.7	74,971	0.4
Buffer only	775,034	10.2	1,381,589	13.4	2,156,623	12.1
Buffer plus overland flow practice	0	0.0	0	0.0	0	0.0
Buffer plus terrace	0	0.0	0	0.0	0	0.0
Buffer plus overland flow practice plus terrace	0	0.0	0	0.0	0	0.0
One or more additional practices	7,568,319	99.8	10,149,431	98.7	17,717,750	99.1
No structural practices added	17,621	0.2	134,439	1.3	152,059	0.9
Total	7,585,940	100.0	10,283,869	100.0	17,869,810	100.0

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

Specific rules for the rate of nutrients applied

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

For wheat and other small grain crops (barley, oats, rice, rye, buckwheat, emmer, spelt, and triticale), nitrogen applications above 1.5 times the crop removal rate were reduced to 1.5 times the crop removal rate.

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

Simulation of Irrigation Water Use Efficiency

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

The treatment scenarios had four components:

1. The on-farm conveyance ditches were upgraded to pipelines.
2. Gravity systems and pressure systems were upgraded to center pivot or linear move sprinkler systems utilizing low-pressure sprinkler heads.[27]
3. Irrigation water management practices were simulated, which consisted of timing and rate of application adjustments designed to attain specified irrigation efficiencies.
4. Edge-of-field irrigation induced runoff was essentially eliminated on irrigated acres.

[27] An exception is in rice production areas where gravity systems are required to flood the fields. In these areas, gated pipe replaced ditches in the treatment simulations.

Implementation of the treatment scenario on all irrigated acres would result in an additional 2.1 million acres converted to center pivot or linear move sprinkler systems with low pressure heads.

In the Texas Gulf Basin, the representation of irrigation management in the treatment scenarios increased the average Virtual Irrigation System Efficiency (VISE) from 65 percent in the baseline conservation condition to 80 percent in the treatment scenarios. (As discussed in chapter 3, irrigation efficiencies were represented in APEX simulations as a combination of three different coefficients (losses at the head of the field, percolation losses, and end-of-field runoff) combined into a single efficiency value, VISE).

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

- 1-10 percent on 2.1 million acres (45 percent of irrigated acres),
- 10-20 percent on 0.76 million acres (13 percent),
- 20-30 percent on 1.1 million acres (19 percent), and
- 30-50 percent on 0.95 million acres (17 percent).

Emerging Technologies for Reducing Nutrient Losses from Farm Fields

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

- innovations in implement design to enhance precise nutrient application and placement, including variable rate technologies;
- enhanced-efficiency nutrient application products such as slow or controlled release fertilizers, polymer coated products, nitrogen stabilizers, urease inhibitors, and nitrification inhibitors;
- drainage water management that controls discharge of drainage water and provides treatment of contaminants, thereby reducing the levels of nitrogen and even some soluble phosphorus loss;
- constructed wetlands receiving surface water runoff or drainage water from farm fields prior to discharge to streams and rivers; and
- use of riparian corridors for treating drainage water.

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

Potential for Field-Level Gains

Treatment of the 7.6 million critical undertreated acres

Average annual model output is presented in table 33 for the 7.6 million critical undertreated acres (acres with a high level of treatment need), with nearly all acres treated with filter strips and wind erosion control practices. The baseline results for these acres are contrasted to model output for the two treatment simulations in table 33. According to the model simulation, treatment of these acres with wind and water erosion control practices would reduce wind erosion loss by 45 percent to an average of 7.8 tons per acre per year and reduce waterborne sediment loss from water erosion by 93 percent to an average of 0.1 ton per acre per year. In addition, nitrogen lost with windborne sediment would be reduced 48 percent and phosphorus lost with windborne sediment would be reduced 55 percent.

Although these acres did not have excessive nitrogen and phosphorus losses for other loss pathways, the simulated treatment did reduce some of these losses as well. For example, nitrogen loss with surface runoff would be reduced from 2.0 pounds per acre per year under 2003–06 practice use to 0.2 pounds per acre per year, on average, representing an 87-percent reduction (table 33). Phosphorus lost to surface water would be reduced from 0.5 pound per acre per year under 2003–06 practice use to less than 0.1 pound per acre per year, on average, representing an 82-percent reduction.

Pesticide losses were also reduced by these soil erosion control treatments. The average mass loss of pesticide residues from farm field would be reduced 91 percent (table 33), resulting in reduction in the average annual surface water pesticide risk indicator by 70 percent for aquatic ecosystems and by 69 percent for humans.

Erosion control treatments also re-route surface water to subsurface flows; in this region, the model indicates that nitrogen loss through subsurface flow pathways would increase by 13 percent, or 1.8 pounds per acre per year, with this additional conservation treatment.

Complementing erosion control practices with nutrient management would have little additional effect on wind erosion, sediment loss, nitrogen loss with surface runoff, phosphorus lost to surface water, or loss of pesticide residues, but would be effective in reducing nitrogen loss in subsurface flows (table 33). Nitrogen loss in subsurface flows for these acres would be reduced to an average of 9.8 pounds per acre per year, negating the 13-percent increase observed with erosion control practices alone and representing a 28-percent reduction compared to losses simulated for the baseline conservation condition. These results support the conclusion drawn from the assessment of the effects of conservation practices in chapter 4 that nutrient management practices need to be paired with erosion control practices to attain significant reductions in the loss of soluble nutrients from cropped fields.

Treatment of all 17.9 million undertreated acres

Average annual model output is presented in table 34 for the treatment of <u>all</u> 17.9 million undertreated acres (acres with a high or moderate level of treatment need), excluding only the 498,000 acres with a low level of treatment need. About 10.3 million acres have a moderate need for treatment and are thus less vulnerable or have more conservation practice use than the critical undertreated acres. Thus, table 34 shows that per-acre percent reductions of sediment and nutrient loss due to additional practices would generally be less, on average, than percent reductions for only the 7.6 million undertreated acres with a high need for conservation treatment.

Nonetheless, the per-acre gains from additional treatment of these acres would be substantial. Treatment with both erosion control *and* nutrient management would, compared to the baseline results for these 17.9 million acres—

- reduce average wind erosion from 8.8 tons per acre per year for the baseline to 4.7 tons per acre per year (a 47-percent reduction),
- reduce windborne nitrogen loss from 8.8 pounds per acre per year to 4.0 pounds per acre per year (a 55-percent reduction),
- reduce windborne phosphorus loss from 1.19 pounds per acre per year to 0.4 pounds per acre per year (a 67-percent reduction),
- reduce average annual waterborne sediment loss from 1.1 ton per acre per year 0.1 ton per acre per year (an 86-percent reduction),
- reduce average annual nitrogen loss with surface runoff (including waterborne sediment) from 3.3 pounds per acre per year to 0.7 pound per acre per year (a 79-percent reduction),
- reduce average annual nitrogen loss in subsurface flows from 16.8 pounds per acre per year to 14.1 pounds per acre per year (a 16-percent reduction),
- reduce total nitrogen loss (all loss pathways, including wind erosion) from 40.7 pounds per acre per year to 29.6 pounds per acre per year (a 27-percent reduction),
- reduce total phosphorus loss (all loss pathways, including wind erosion) from 2.16 pounds per acre per year to 1.14 pounds per acre per year (a 47-percent reduction), and
- reduce the average mass loss of pesticide residues from farm fields by 62 percent, resulting in reduction in the average annual surface water pesticide risk indicator by 71 percent for aquatic ecosystems and by 70 percent for humans.

Diminishing returns from additional conservation treatment

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

Table 35 contrasts the per-acre model simulation results for additional erosion control and nutrient management on three subsets of acres in the Texas Gulf Basin—

1. the 7.6 million undertreated acres with a “high” need for additional treatment,
2. the 10.3 million undertreated acres with a “moderate” need for additional treatment, and
3. the 0.5 million acres with a “low” need for additional treatment.

Diminishing returns from additional conservation treatment is demonstrated by comparing the average annual per-acre reductions in losses among the three groups of acres. For example, conservation treatment of the 7.6 million critical undertreated acres would reduce wind erosion by an average of 5.5 tons per acre per year on those acres (table 35). In comparison, additional treatment of the 10.3 million acres with a moderate need for treatment would reduce wind erosion by an average of about 3.0 tons per acre per year on those acres. Treatment of the remaining 0.5 million acres would reduce wind erosion by only about 0.5 ton per acre, on average.

Diminishing returns are also pronounced for nitrogen and phosphorus lost with windborne sediment (table 35). Conservation treatment of the 7.6 million critical undertreated acres would reduce windborne nitrogen loss by an average of 5.1 pounds per acre per year and reduce windborne phosphorus by an average of 1.1 pounds per acre per year on those acres. In comparison, additional treatment of the 10.3 million acres with a moderate need for treatment would reduce windborne nitrogen loss by an average of 4.6 pounds per acre per year and reduce windborne phosphorus by an average of 0.56 pounds per acre per year on those acres. Treatment of the remaining 0.5 million acres would reduce losses by only 0.8 pound per acre per year for nitrogen and less than 0.1 pound per acre per year for phosphorus.

These diminishing returns are not evident or are less pronounced for other losses and loss pathways shown in table 35 because of the predominance of wind erosion concerns in the critical undertreated set of acres and the small number of sample points representing acres with a low level of treatment need.

Table 33. Conservation practice effects for additional treatment of 7.6 million critical undertreated acres (acres with a *high* need for conservation treatment) in the Texas Gulf 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)	2.2	0.5	78%	0.5	78%
Subsurface water flow (inches)	1.0	1.1	-16%	1.2	-16%
Erosion and sediment loss					
Wind erosion (tons/acre)	14.2	7.8	45%	8.7	39%
Sheet and rill erosion (tons/acre)	0.6	0.2	66%	0.2	65%
Sediment loss at edge of field due to water erosion (tons/acre)	0.7	0.1	93%	0.1	92%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-194	-139	--	-144	--
Nitrogen					
All nitrogen sources (pounds/acre)	59.8	58.9	2%	51.6	14%
Atmospheric deposition	3.7	3.7	0%	3.7	0%
Bio-fixation by legumes	1.0	1.2	-30%	1.3	-32%
Nitrogen applied as commercial fertilizer and manure	55.2	54.0	2%	46.7	15%
Nitrogen in crop yield removed at harvest (pounds/acre)	39.2	43.0	-10%	43.0	-10%
Total nitrogen loss for all loss pathways (pounds/acre)	36.9	31.4	15%	25.4	31%
Nitrogen lost with windborne sediment (pounds/acre)	11.7	6.1	48%	6.6	43%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	2.0	0.2	87%	0.2	88%
Nitrogen loss in subsurface flows (pounds/acre)	13.7	15.5	-13%	9.8	28%
Phosphorus					
Phosphorus applied (pounds/acre)	10.08	10.41	-3%*	7.76	23%
Phosphorus in crop yield removed at harvest (pounds/acre)	6.32	7.04	-11%	7.03	-11%
Total phosphorus loss for all loss pathways (pounds/acre)	2.39	1.10	54%	0.98	59%
Phosphorus lost with windborne sediment (pounds/acre)	1.81	0.81	55%	0.71	61%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	0.50	0.09	82%	0.08	84%
Pesticides					
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	2.74	0.25	91%	0.25	91%
Average annual surface water pesticide risk indicator for aquatic ecosystems	2.06	0.62	70%	0.54	74%
Average annual surface water pesticide risk indicator for humans	0.22	0.07	69%	0.06	71%

* Total phosphorus 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 part of the decrease in nitrogen and phosphorus in the crop yield at harvest.
Note: Values reported in this table are for the 7.6 million critical undertreated acres only. Percent reductions are with respect to the baseline conservation condition.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

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Table 34. Conservation practice effects for additional treatment of all 17.9 million undertreated acres (acres with a *high* or *moderate* need for conservation treatment) in the Texas Gulf Basin

	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
Model simulated outcome	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	4.3	1.5	66%	1.5	65%
Subsurface water flow (inches)	1.4	2.5	-80%	2.5	-81%
Erosion and sediment loss					
Wind erosion (tons/acre)	8.8	4.2	52%	4.7	47%
Sheet and rill erosion (tons/acre)	0.9	0.4	51%	0.4	50%
Sediment loss at edge of field due to water erosion (tons/acre)	1.1	0.2	86%	0.1	86%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-183	-123	--	-127	--
Nitrogen					
All nitrogen sources (pounds/acre)	67.0	66.1	1%	57.3	15%
Atmospheric deposition	4.0	4.0	0%	4.0	0%
Bio-fixation by legumes	1.3	1.7	-35%	1.8	-38%
Nitrogen applied as commercial fertilizer and manure	61.7	60.3	2%	51.5	17%
Nitrogen in crop yield removed at harvest (pounds/acre)	39.1	43.1	-10%	42.9	-10%
Total nitrogen loss for all loss pathways (pounds/acre)	40.7	37.1	9%	29.6	27%
Nitrogen lost with windborne sediment (pounds/acre)	8.8	3.7	58%	4.0	55%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	3.3	0.7	78%	0.7	79%
Nitrogen loss in subsurface flows (pounds/acre)	16.8	20.9	-24%	14.1	16%
Phosphorus					
Phosphorus applied (pounds/acre)	11.11	11.40	-3%*	8.50	23%
Phosphorus in crop yield removed at harvest (pounds/acre)	6.03	6.83	-13%*	6.82	-13%
Total phosphorus loss for all loss pathways (pounds/acre)	2.16	1.30	40%	1.14	47%
Phosphorus lost with windborne sediment (pounds/acre)	1.19	0.44	63%	0.40	67%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	0.85	0.40	53%	0.33	62%
Pesticides					
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	6.14	2.30	62%	2.33	62%
Average annual surface water pesticide risk indicator for aquatic ecosystems	2.52	0.78	69%	0.73	71%
Average annual surface water pesticide risk indicator for humans	0.88	0.26	70%	0.26	70%

* Total phosphorus 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 part of the decrease in nitrogen and phosphorus in the crop yield at harvest.
Note: Values reported in this table are for the 17.9 million undertreated acres only. Percent reductions are with respect to the baseline conservation condition.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 35. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices for three groups of acres comprising the 18.4 million cropped acres in the Texas Gulf Basin

	Additional treatment for 7.6 million critical undertreated acres*			Additional treatment for 10.3 million non-critical undertreated acres*			Additional treatment for remaining 0.5 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)	2.2	0.5	1.7	5.8	2.2	3.6	6.4	2.0	4.4
Subsurface water flow (inches)	1.0	1.2	-0.2	1.7	3.5	-1.9	2.2	5.0	-2.9
Erosion and sediment loss									
Wind erosion (tons/acre)	14.2	8.7	5.5	4.8	1.7	3.0	0.7	0.2	0.5
Sheet and rill erosion (tons/acre)	0.6	0.2	0.4	1.1	0.6	0.5	0.4	0.2	0.2
Sediment loss at edge of field due to water erosion (tons/acre)	0.7	0.1	0.6	1.4	0.2	1.2	0.4	0.0	0.3
Soil organic carbon									
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-194	-144	-50	-174	-115	-60	88	217	-129
Nitrogen									
All nitrogen sources (pounds/acre)	59.8	51.6	8.2	72.4	61.5	10.9	79.8	77.8	1.9
Atmospheric deposition	3.7	3.7	0.0	4.3	4.3	0.0	4.4	4.4	0.0
Bio-fixation by legumes	1.0	1.3	-0.3	1.5	2.1	-0.6	0.0	0.0	0.0
Nitrogen applied as commercial fertilizer and manure	55.2	46.7	8.5	66.5	55.1	11.5	75.4	73.5	1.9
Nitrogen in crop yield removed at harvest (pounds/acre)	39.2	43.0	-3.8	39.0	42.9	-3.9	17.4	17.0	0.5
Total nitrogen loss for all loss pathways (pounds/acre)	36.9	25.4	11.5	43.6	32.7	10.9	46.4	51.6	-5.2
Nitrogen lost with windborne sediment (pounds/acre)	11.7	6.6	5.1	6.6	2.0	4.6	0.9	0.2	0.8
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	2.0	0.2	1.8	4.3	1.0	3.3	4.4	0.6	3.8
Nitrogen loss in subsurface flows (pounds/acre)	13.7	9.8	3.9	19.1	17.3	1.8	14.7	23.0	-8.3
Phosphorus									
Phosphorus applied (pounds/acre)	10.08	7.76	2.33	11.86	9.05	2.82	16.43	15.61	0.82
Phosphorus in crop yield removed at harvest (pounds/acre)	6.32	7.03	-0.71	5.82	6.67	-0.85	2.88	2.81	0.06
Total phosphorus loss for all loss pathways (pounds/acre)	2.39	0.98	1.41	1.99	1.25	0.74	1.13	1.74	-0.61
Phosphorus lost with windborne sediment (pounds/acre)	1.81	0.71	1.10	0.72	0.17	0.56	0.10	0.02	0.08
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	0.50	0.08	0.42	1.12	0.51	0.61	0.81	0.14	0.67
Pesticides									
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	2.74	0.25	2.49	8.64	3.87	4.77	3.79	0.60	3.19
Average annual surface water pesticide risk indicator for aquatic ecosystems	2.06	0.54	1.52	2.86	0.87	1.98	1.52	0.53	0.99
Average annual surface water pesticide risk indicator for humans	0.22	0.06	0.15	1.38	0.41	0.96	0.18	0.05	0.12

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

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

Potential sediment and nutrient savings from additional conservation treatment are contrasted to estimated savings for the conservation practices in use in 2003–06 in figure 71. The no-practice scenario represents the maximum losses that would be expected without any conservation practices in use. Treatment of *all acres* with nutrient management and erosion control practices was used to represent a "full-treatment" condition. The difference in sediment and nutrient loss between these two scenarios represents the maximum savings possible for conservation treatment, which totaled 38.6 million tons of waterborne sediment, 198,000 tons of nitrogen, 19,000 tons of phosphorus, and 38,000 tons of windblown sediment for the Texas Gulf Basin (fig. 71).

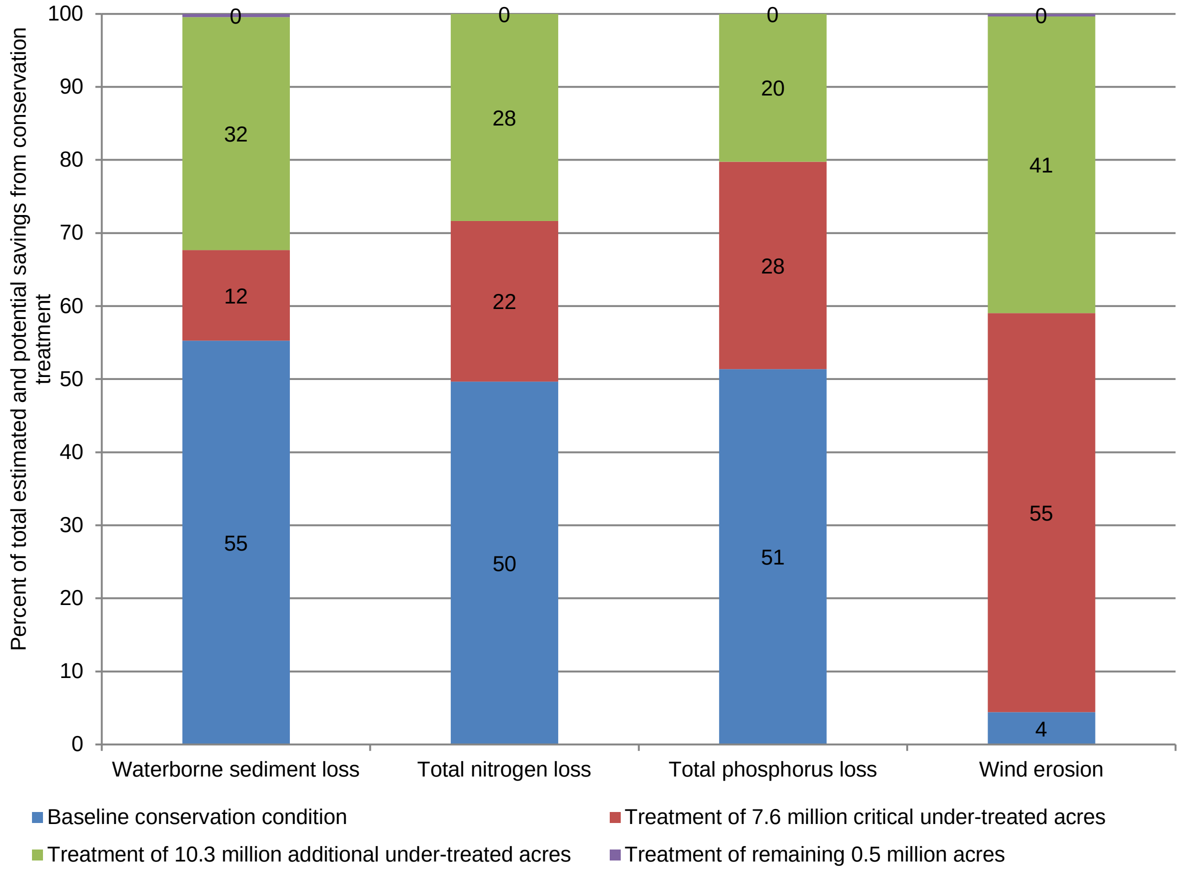
For waterborne sediment loss, about 55 percent of the potential savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition (fig. 71). Additional treatment of the 7.6 million critical undertreated acres would account for another 12 percent of the potential sediment savings. Treatment of the 10.3 million undertreated acres with a moderate need for treatment would account for about 32 percent of the potential savings. Treatment of the 0.5 million adequately treated acres would account for less than 1 percent of potential savings.

About 50 percent of the potential savings for nitrogen are accounted for by the conservation practices already in use (fig. 71). Additional treatment of the 7.6 million critical undertreated acres would account for another 22 percent of the potential sediment savings. Treatment of the 10.3 million undertreated acres with a moderate need for treatment would account for the remaining 28 percent of the potential savings. Treatment of the 0.5 million adequately treated acres would result in negligible potential savings.

For phosphorus loss, current conservation practices achieve 51 percent of potential savings. Additional treatment of the 7.6 million critical undertreated acres would achieve an additional 28 percent of the possible conservation gains, leaving 20 percent that could be achieved by treating the remaining 10.3 million undertreated acres. Treatment of the 0.5 million adequately treated acres would result in negligible potential savings.

For wind erosion control, practices in use in 2003-06 account for only 4 percent of potential reductions. By treating the 7.6 million critical undertreated acres (acres with a high need for treatment) for wind erosion an additional 55 percent in savings could potentially be gained. To achieve 100 percent of the potential savings would require treating the remaining 10.3 million undertreated acres. Treatment of the 0.5 million adequately treated acres would account for less than 1 percent of potential savings.

Figure 71. Comparison of estimated wind erosion, waterborne sediment, nitrogen, and phosphorus savings (field-level) that are due to practices in use in the baseline conservation condition and potential savings with additional erosion control *and* nutrient management treatment of cropped acres in the Texas Gulf Basin



Sediment, nitrogen, phosphorus, and wind erosion saved or potentially saved due to conservation practices

	Estimated savings due to conservation practice use (baseline conservation condition)	Potential savings from treatment of 7.6 million critical undertreated acres*	Potential savings from treatment of 10.3 million additional undertreated acres*	Potential savings from treatment of remaining 0.5 million acres*	Total estimated and potential savings from conservation treatment
Waterborne sediment (tons)	21,341,180	4,787,403	12,314,915	168,380	38,611,879
Nitrogen (tons)	98,583	43,590	56,284	0	198,457
Phosphorus (tons)	9,650	5,332	3,801	0	18,784
Wind erosion (tons)	1,691	20,949	15,568	132	38,340

*Treatment with erosion control practices and nutrient management practices on all cropped acres.
Note: Calculations do not include land in long-term conserving cover.
Note: Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Expected regional results assuming all undertreated acres were treated

As shown in figure 71, the potential for reducing overall field-level losses with additional conservation practices is high in this region. Table 36 presents estimates of how treatment of only the 7.6 million critical undertreated acres in the region would reduce *overall* edge-of-field losses *for the region as a whole*. These results were obtained by combining treatment scenario model results for the 7.6 million acres with model results from the baseline conservation condition for the remaining acres.

Compared to the baseline conservation condition, treating the 7.6 million critical undertreated acres with soil erosion control practices *and* nutrient management practices would, for the region as a whole (table 36)—

- reduce wind erosion averaged over all cropped acres in the region by 27 percent;
- reduce waterborne sediment loss in the region to an average of 0.8 tons per acre per year, a 24-percent reduction from the baseline conservation condition;
- reduce total nitrogen loss by 12 percent, on average:
  - reduce nitrogen loss with windborne sediment by 24 percent,
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) by 22 percent, and
  - reduce nitrogen loss in subsurface flows by 10 percent;
- reduce phosphorus lost with windborne sediment averaged over all cropped acres in the region by 39 percent;
- reduce phosphorus lost to surface water (sediment adsorbed and soluble) by 20 percent; and
- reduce environmental risk from loss of pesticide residues in surface water by 25 percent for aquatic ecosystems and by 7 percent for humans.

Compared to the baseline conservation condition, treating all 17.9 million undertreated acres (97 percent of cropped acres in the region) with soil erosion control practices *and* nutrient management practices would, for the region as a whole (table 37)—

- reduce wind erosion averaged over all cropped acres in the region by 47 percent,
- reduce waterborne sediment loss in the region to an average of 0.2 tons per acre per year, an 86-percent reduction from the baseline conservation condition;
- reduce total nitrogen loss by 27 percent, on average:
  - reduce nitrogen loss with windborne sediment by 55 percent,
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) by 76 percent, and
  - reduce nitrogen loss in subsurface flows by 16 percent;
- reduce phosphorus lost with windborne sediment averaged over all cropped acres in the region by 66 percent;
- reduce phosphorus lost to surface water (sediment adsorbed and soluble) by 60 percent; and
- reduce environmental risk from loss of pesticide residues in surface water by 70 percent for both aquatic ecosystems and humans.

Nearly all of these reductions in sediment loss, wind erosion, pesticide residue loss, and nitrogen lost with surface water are due to the erosion control practices, as shown in table 37. The additional nutrient management practices accounted for all of the reduction in nitrogen loss in subsurface flows as well as additional reductions in total phosphorus loss. Nitrogen loss in subsurface flows would be reduced 16 percent when nutrient management practices are combined with erosion control practices, reversing the 24-percent increase in loss if only structural practices were used to control erosion. Total phosphorus loss would be reduced 39 percent using only erosion control practices, compared to 47 percent when combined with nutrient management practices. As also shown in table 37, the additional nutrient management used in the simulation reduced the amount of nitrogen applied within the region by 16 percent and the amount of phosphorus applied by 23 percent.

The effects of treating the 17.9 million undertreated acres for the region as a whole are graphically shown in figures 72 through 79. In these figures the model results for the baseline distribution are compared to the distributions for two levels of treatment with soil erosion control and nutrient management practices: (1) treatment of the 7.6 million critical undertreated acres, and (2) treatment of all 17.9 million undertreated acres. For perspective, the distribution of loss estimates if no conservation practices were in use, represented by the no-practice scenario, is also shown.

Model simulations indicate that for wind erosion the percentage of acres exceeding 4 tons per acre per year (the "acceptable level" used in chapter 5 as part of the process to identify undertreated acres) would be reduced from 54 percent in the baseline to 46 percent after treating the 7.6 million critical undertreated acres and further reduced to 31 percent of cropped acres if all 17.9 million undertreated acres were treated (fig. 72).

For waterborne sediment loss (fig. 73), the percentage of acres exceeding 2 tons per acre per year would be reduced from 16 percent in the baseline to 1 percent after treating all 17.9 million undertreated acres.

Figure 74 shows that the distribution of soil organic carbon is affected little by additional soil erosion control and nutrient management practices for undertreated acres in the region, particularly in soils already gaining carbon in the baseline. Soils losing carbon in the baseline scenario tended to lose less carbon under the treatment scenarios, but treatment is expected to contribute to carbon gains of more than 100 pounds per acre per year for fewer than 10 percent of cropped acres.

The effect of additional conservation treatment for undertreated acres on nitrogen loss is shown in figures 75, 76, and 77. Nitrogen lost with surface runoff is less than 10 pounds per acre throughout the region for 90 percent of acres with baseline treatment, compared to 91 percent of acres after treatment of the 7.6 critical undertreated acres and nearly 100 percent after treatment of all 17.9 million critical undertreated acres.

For nitrogen loss in subsurface flows, the percentage of acres exceeding 25 pounds per acre per year would be reduced from 22 percent in the baseline to only 20 percent with treatment of all 17.9 million undertreated acres (fig. 76). Reductions in total nitrogen loss, which also includes nitrogen loss with windborne sediment, nitrogen volatilization, and denitrification, would be reduced by larger amounts with additional treatment, as shown in figure 77.

The percentage of acres with phosphorus losses to surface water exceeding 2 pounds per acre per year would be reduced from 12 percent in the baseline to 5 percent (fig. 78) by treating all 17.9 million undertreated acres.

Figure 79 shows the effects of additional conservation treatment on irrigation water use in the Texas Gulf Basin. The gap between the curves for the baseline conservation condition and the no-practice scenario reflects the movement away from less efficient ditches and gravity irrigation used in the past to more efficient modern pressure irrigation systems. Implementing the treatment scenario on all irrigated acres would further reduce irrigation water use by an average of 3.6 inches per acre per year, compared to the baseline, on the 5.5 million irrigated acres in the region.

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. As shown in figure 80, the distribution of nitrogen removed at harvest is about the same for the curve representing the baseline scenario and the curves representing additional treatment.

Table 36. Conservation practice effects for the region as a whole* after additional treatment of 7.6 million critical undertreated acres (acres with a *high* need for conservation treatment) in the Texas Gulf Basin

	Baseline conservation condition	Treatment with erosion control practices		Treatment with erosion control and nutrient management practices	
Model simulated outcome	Average annual amount	Average annual amount	Percent reduction	Average annual amount	Percent reduction
Water flow					
Surface water runoff (inches)	4.3	3.6	16%	3.6	16%
Subsurface water flow (inches)	1.4	1.5	-5%	1.5	-5%
Erosion and sediment loss					
Wind erosion (tons/acre)	8.5	5.9	31%	6.3	27%
Sheet and rill erosion (tons/acre)	0.9	0.7	20%	0.7	20%
Sediment loss at edge of field due to water erosion (tons/acre)	1.1	0.8	24%	0.8	24%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-176	-153	13%	-155	12%
Nitrogen					
All nitrogen sources (pounds/acre)	67.4	67.0	1%	64.0	5%
Atmospheric deposition	4.0	4.0	0%	4.0	0%
Bio-fixation by legumes	1.2	1.4	-9%	1.4	-10%
Nitrogen applied as commercial fertilizer and manure	62.1	61.6	1%	58.6	6%
Nitrogen in crop yield removed at harvest (pounds/acre)	38.5	40.1	-4%	40.1	-4%
Total nitrogen loss for all loss pathways (pounds/acre)	40.9	38.7	5%	36.1	12%
Nitrogen lost with windborne sediment (pounds/acre)	8.5	6.2	27%	6.5	24%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	3.3	2.6	22%	2.6	22%
Nitrogen loss in subsurface flows (pounds/acre)	16.7	17.5	-4%	15.1	10%
Phosphorus					
Phosphorus applied (pounds/acre)	11.25	11.39	-1%**	10.29	9%
Phosphorus in crop yield removed at harvest (pounds/acre)	5.94	6.24	-5%	6.24	-5%
Total phosphorus loss for all loss pathways (pounds/acre)	2.13	1.60	25%	1.55	27%
Phosphorus lost with windborne sediment (pounds/acre)	1.16	0.74	36%	0.70	39%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	0.85	0.68	20%	0.68	20%
Pesticides					
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	6.07	5.04	17%	5.04	17%
Average annual surface water pesticide risk indicator for aquatic ecosystems	2.49	1.90	24%	1.86	25%
Average annual surface water pesticide risk indicator for humans	0.87	0.80	7%	0.80	7%

* Results presented for the region as a whole combine model output for the 7.6 million treated acres with model results from the baseline conservation condition for the remaining acres.
** Phosphorus 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 part of the decrease in nitrogen and phosphorus in the crop yield at harvest.
Note: Percent reductions are with respect to the baseline conservation condition.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 37. Conservation practice effects for the region as a whole* after additional treatment of 17.9 million undertreated acres (acres with a *high* or *moderate* need for conservation treatment) in the Texas Gulf 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)	4.3	1.6	63%	1.6	63%
Subsurface water flow (inches)	1.4	2.5	-77%	2.5	-78%
Erosion and sediment loss					
Wind erosion (tons/acre)	8.5	4.1	52%	4.6	47%
Sheet and rill erosion (tons/acre)	0.9	0.4	50%	0.4	50%
Sediment loss at edge of field due to water erosion (tons/acre)	1.1	0.2	85%	0.2	86%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-176	-118	33%	-121	31%
Nitrogen					
All nitrogen sources (pounds/acre)	67.4	66.4	1%	57.9	14%
Atmospheric deposition	4.0	4.0	0%	4.0	0%
Bio-fixation by legumes	1.2	1.7	-35%	1.7	-38%
Nitrogen applied as commercial fertilizer and manure	62.1	60.7	2%	52.2	16%
Nitrogen in crop yield removed at harvest (pounds/acre)	38.5	42.4	-10%	42.2	-10%
Total nitrogen loss for all loss pathways (pounds/acre)	40.9	37.3	9%	30.0	27%
Nitrogen lost with windborne sediment (pounds/acre)	8.5	3.6	58%	3.9	55%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	3.3	0.8	75%	0.8	76%
Nitrogen loss in subsurface flows (pounds/acre)	16.7	20.7	-24%	14.1	16%
Phosphorus					
Phosphorus applied (pounds/acre)	11.25	11.53	-2%**	8.71	23%
Phosphorus in crop yield removed at harvest (pounds/acre)	5.94	6.73	-13%	6.71	-13%
Total phosphorus loss for all loss pathways (pounds/acre)	2.13	1.29	39%	1.14	47%
Phosphorus lost with windborne sediment (pounds/acre)	1.16	0.43	63%	0.39	66%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	0.85	0.41	52%	0.34	60%
Pesticides					
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	6.07	2.35	61%	2.37	61%
Average annual surface water pesticide risk indicator for aquatic ecosystems	2.49	0.80	68%	0.75	70%
Average annual surface water pesticide risk indicator for humans	0.87	0.26	70%	0.26	70%

* Results presented for the region as a whole combine model output for the 17.9 million treated acres with model results from the baseline conservation condition for the remaining acres.
** Phosphorus 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 part of the decrease in nitrogen and phosphorus in the crop yield at harvest.
Note: Percent reductions are with respect to the baseline conservation condition.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Figure 72. Estimates of average annual wind erosion for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Texas Gulf Basin

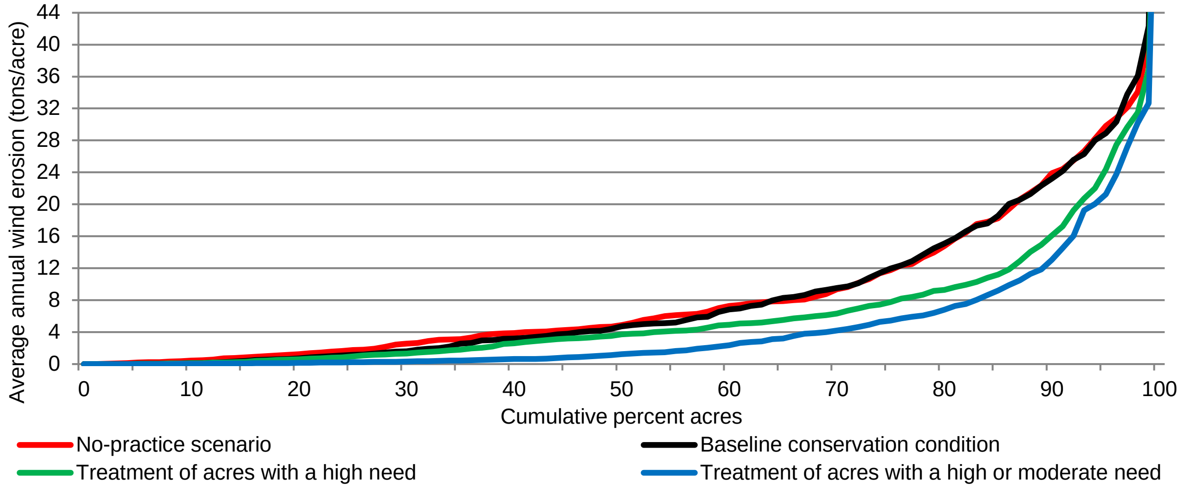


Figure 73. Estimates of average annual sediment loss for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Texas Gulf Basin

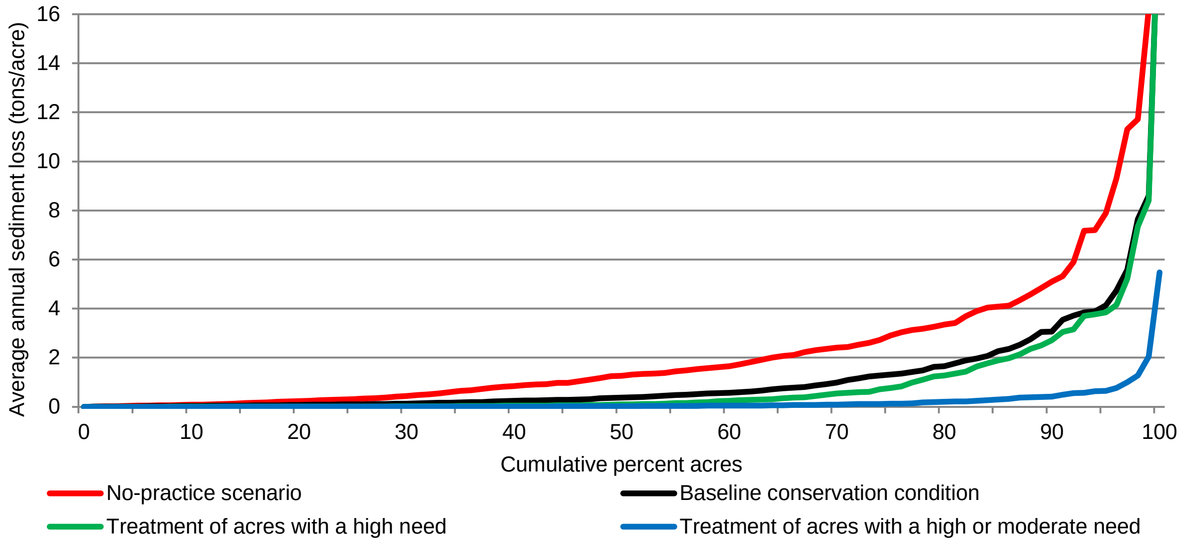


Figure 74. Estimates of average annual change in soil organic carbon for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Texas Gulf Basin

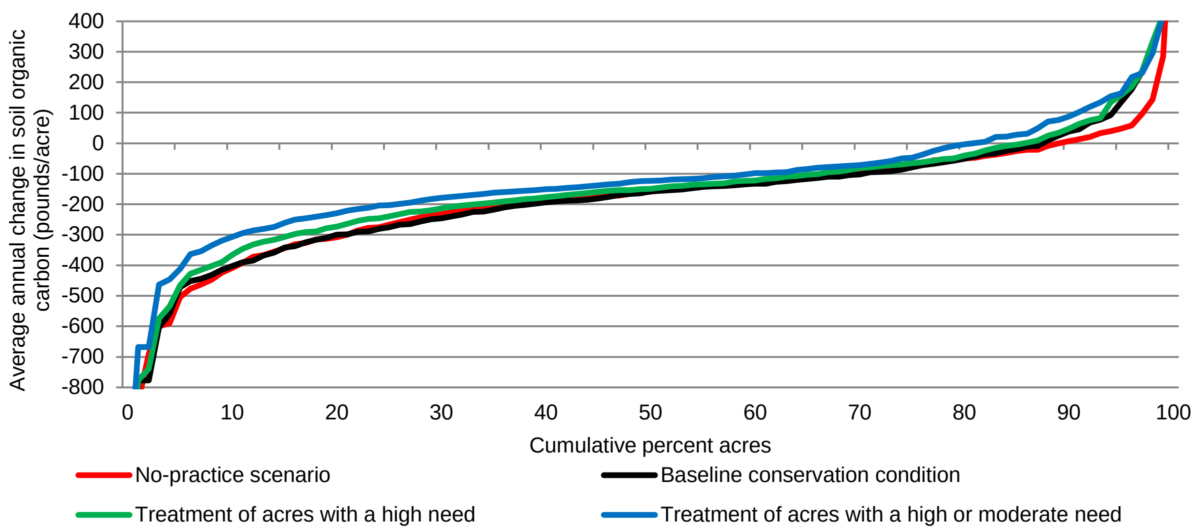


Figure 75. Estimates of average annual loss of nitrogen with surface runoff for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Texas Gulf Basin

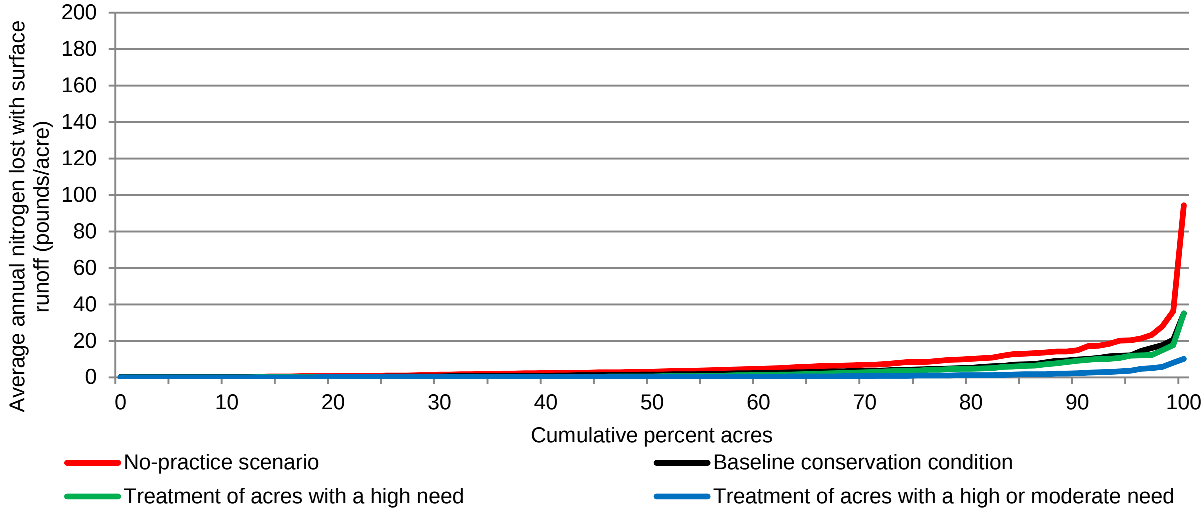


Figure 76. Estimates of average annual loss of nitrogen in subsurface flows for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Texas Gulf Basin

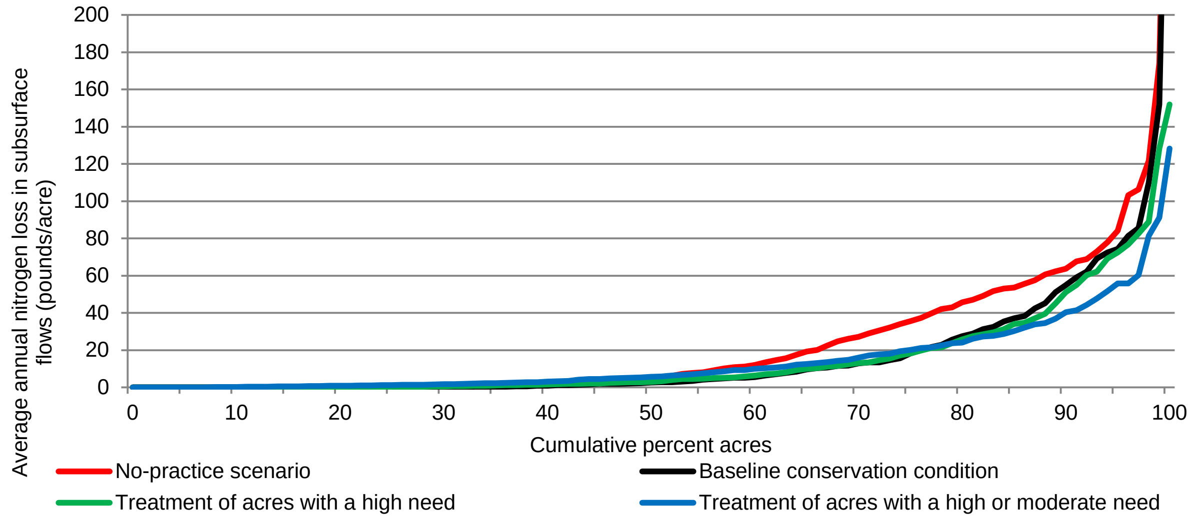


Figure 77. Estimates of average annual total nitrogen loss for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Texas Gulf Basin

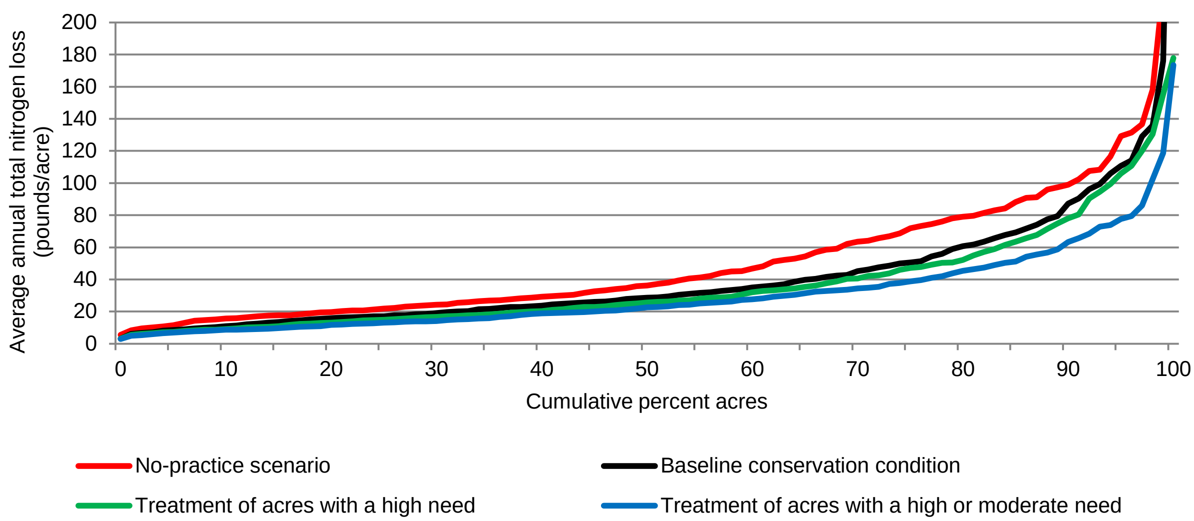
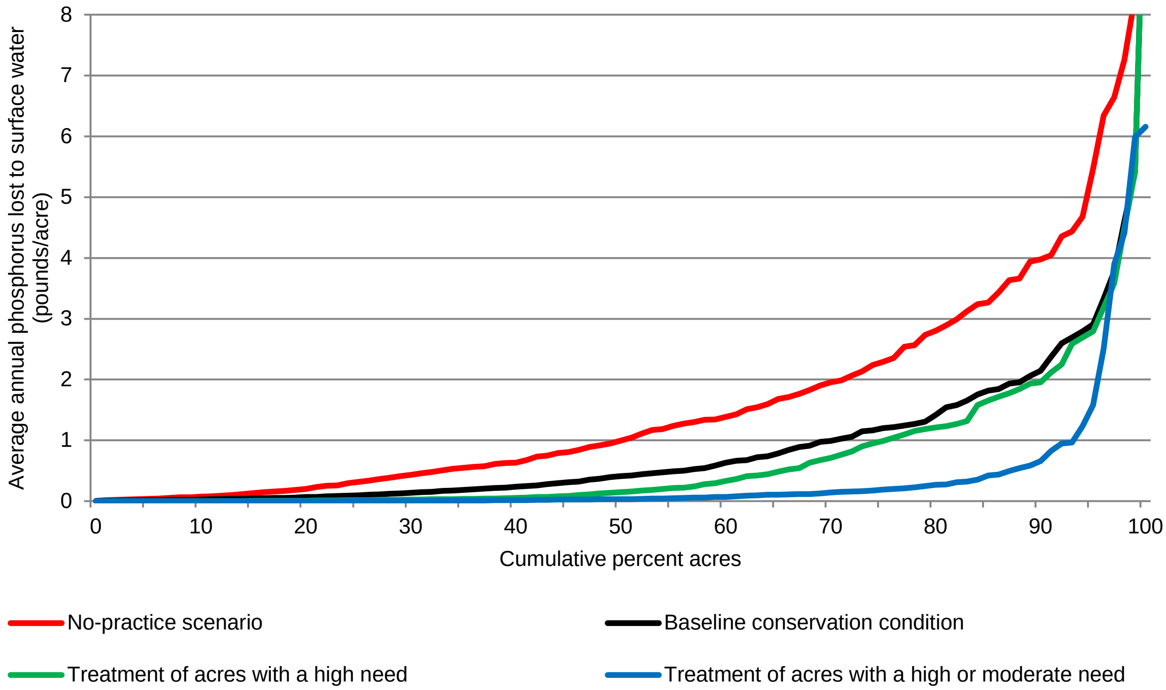


Figure 78. Estimates of average annual phosphorus lost to surface water (sediment attached and soluble)* for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Texas Gulf Basin



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

Figure 79. Estimates of average annual irrigation water application for the treatment scenarios compared to the baseline conservation condition and the no-practice scenarios, Texas Gulf Basin

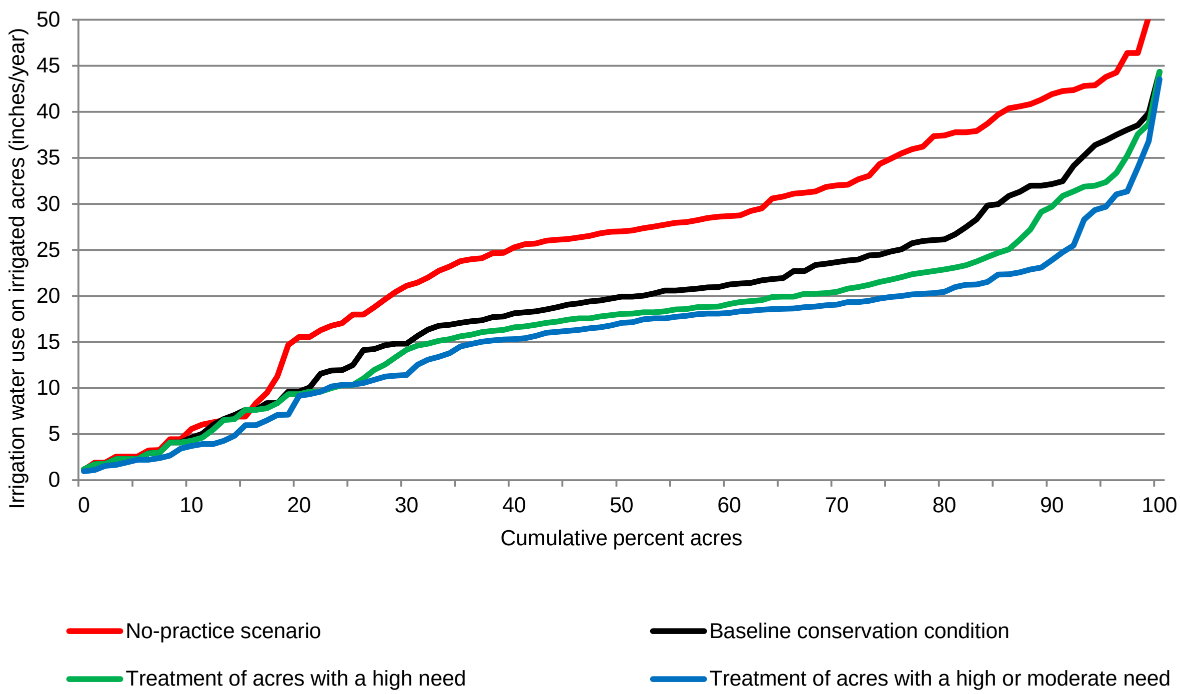
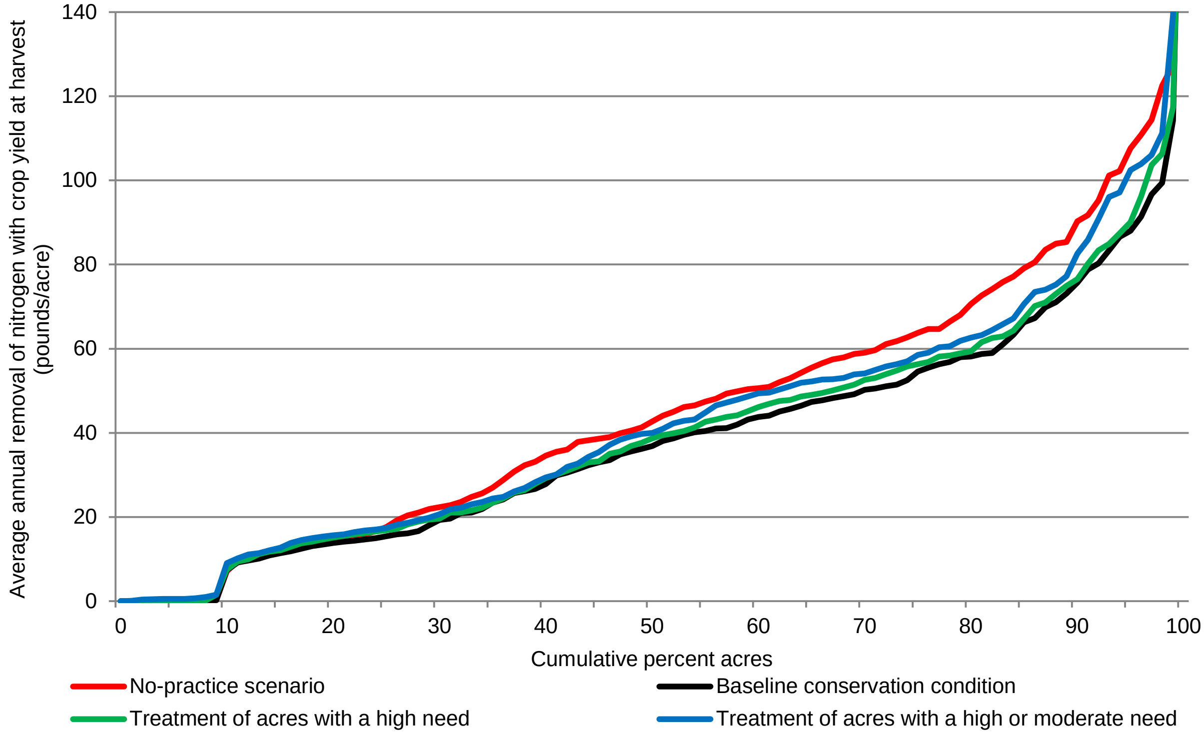


Figure 80. Estimates of average annual removal of nitrogen with crop yield at harvest for acres treated with erosion control and nutrient management compared to the baseline conservation condition and the no-practice scenario, Texas Gulf Basin



Chapter 7
Offsite Water Quality Effects of Conservation Practices

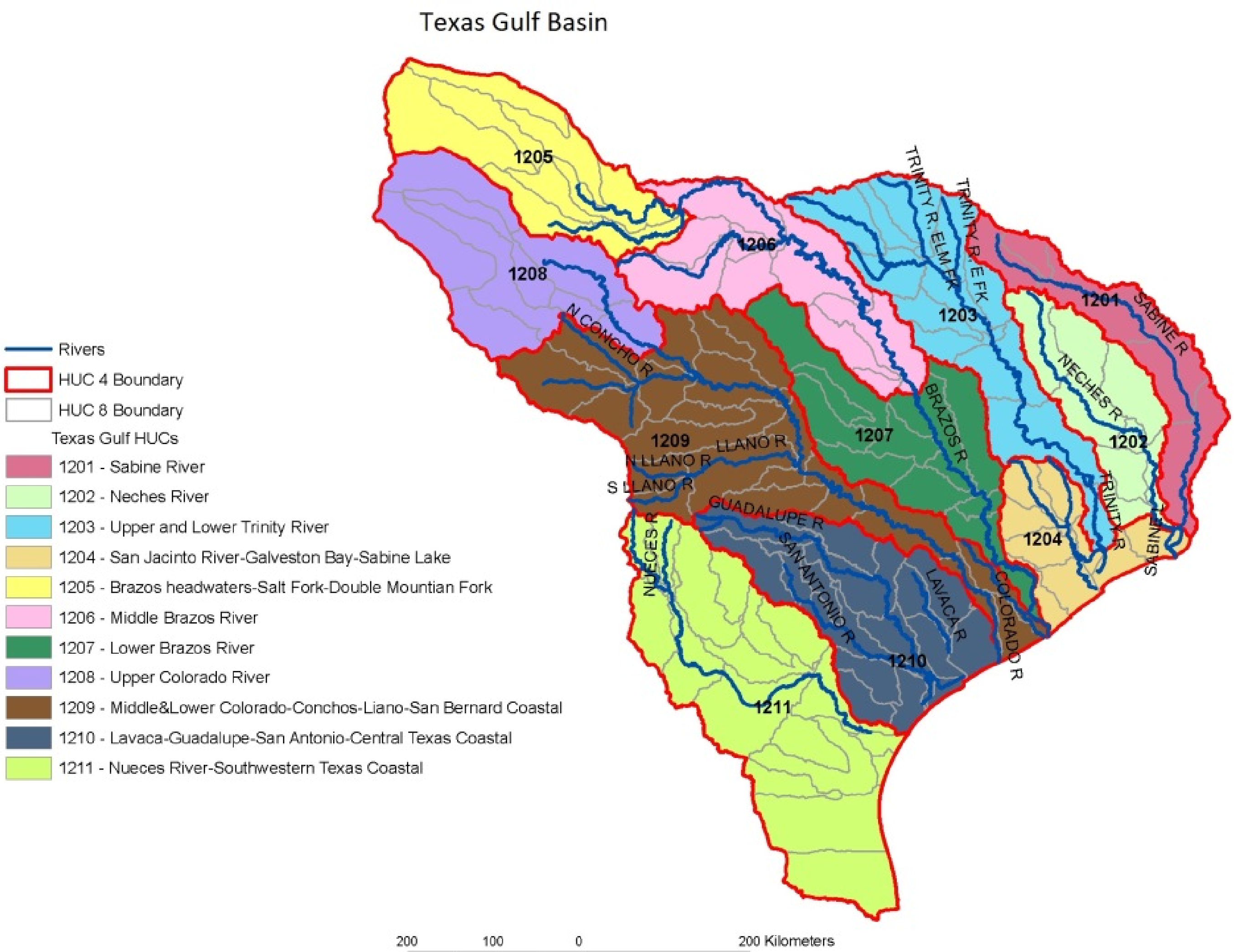
Field-level losses of sediment, nutrients, and atrazine estimated using APEX were integrated into a large-scale water quality model to estimate the extent to which conservation practices reduce—

- loads delivered to rivers and streams within the basin,
- instream loads at various points within the basin, and
- loads exported from the region to the Gulf of Mexico.

Loading estimates are reported for each of the 11 subregions (4-digit hydrologic unit code) in the Texas Gulf Basin, shown in figure 81, with two exceptions:

1. The Sabine River Basin (code 1201), the Neches River Basin (code 1202), and the San Jacinto River-Galveston Bay-Sabine Lake subregion (code 1204) have too few CEAP sample points to report results separately. Results for these three subregions are therefore aggregated with results for the Upper and Lower Trinity Basin (code 1203) for reporting.
2. The Lower Brazos River Basin (code 1207) also has too few CEAP sample points to report results; results are combined with results for the Middle Brazos River Basin (code 1206) for reporting.

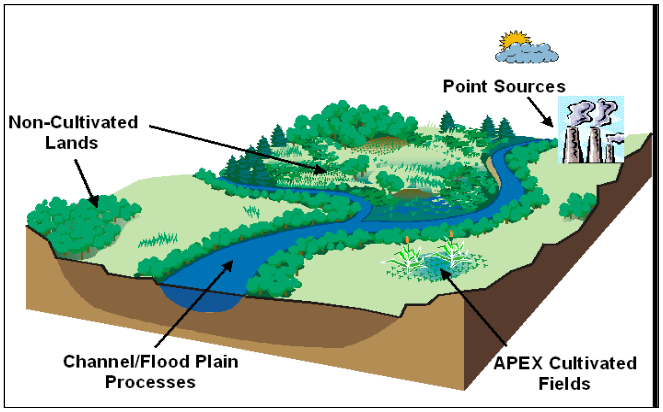
Figure 81. Subregions (4-digit HUC groupings of 8-digit HUCs) within the Texas Gulf Basin



The National Water Quality Model—HUMUS/SWAT

Offsite estimates of water quality benefits were assessed using HUMUS/SWAT, a combination of the SWAT model 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, nutrients, and pesticides from the land to receiving streams and the flow downstream to the next watershed and ultimately to estuaries and oceans (fig. 82).

Figure 82. Sources of water flows, sediment, and agricultural chemicals simulated with HUMUS/SWAT



Like APEX, SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007).[28] The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle simulates upland processes, which includes 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 simulates channel processes, including the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

Upland processes

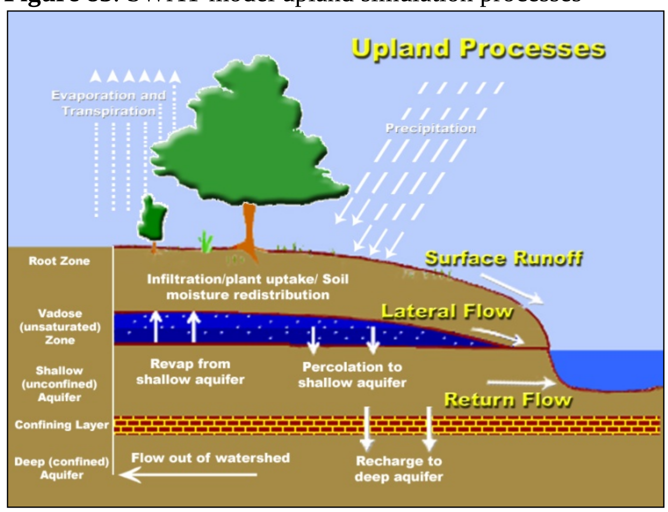
The water balance is the driving force for transport and delivery of sediment, nutrients, and pesticides from fields to streams and rivers. For this study, upland processes for non-cultivated cropland were modeled using SWAT, while source loads for cultivated cropland are estimated by APEX.

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

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

Upland processes were modeled for each of these HRUs in each watershed (8-digit HUC) (fig. 83). The model simulates surface runoff estimated from daily rainfall; percolation modeled with a layered storage routing technique combined with a subsurface flow model; lateral subsurface flow; groundwater flow to streams from shallow aquifers; potential evapotranspiration; snowmelt; transmission losses from streams; and water storage and losses from ponds.

Figure 83. SWAT model upland simulation processes



Agricultural sources

Upland processes for cultivated cropland (including land in long-term conserving cover) were modeled using APEX as described in previous chapters. The weighted average of per-acre APEX model output for surface water delivery, sediment, nutrients, and pesticides was multiplied by the acres of cultivated cropland in the HUMUS database and used as SWAT model inputs for cultivated cropland for each 8-digit Hydrologic Unit Code (HUC). The acreage weights for the CEAP sample points were used to calculate the per-acre loads. (In most cases in this region the 8-digit watersheds had too few CEAP sample points to reliably estimate edge-of-field per-acre loads. In these cases, the 6-digit per acre loads and sometimes the 4-digit per-acre loads were used to represent cultivated cropland.)

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

Various types of agricultural land management activities were modeled in SWAT for land use categories other than cultivated cropland. For permanent hayland, the following management activities were simulated.

- Hay was fertilized with nitrogen according to the crop need as determined by an auto-fertilization routine, which was set to grow the crop without undue nitrogen stress.
- Legume hay was grown in a 4-year rotation and phosphorus was applied at the time of planting (every fourth year) at a rate of 50 pounds per acre, followed by applications of 13 pounds per acre every other year.
- Recoverable manure from animal feeding operations was applied to 2 percent of the hayland acres at rates estimated from probable land application of manure using the methods described in USDA/NRCS (2003). These calculations indicated that 2 percent of hayland acres in the Texas Gulf Basin could have received manure from animal feeding operations.
- Three hay cuttings were simulated per crop year for grass hay, and four hay cuttings were simulated per year for legume hay.
- For hayland acres that land-use databases indicated were irrigated, water was applied at a frequency and rate defined by an auto-irrigation routine.

For pastureland and rangeland, the following management activities were simulated.

- Continuous grazing was simulated by algorithms that determined the length of the grazing period, amount of biomass removed, and the amount of biomass trampled. Grazing occurs whenever the plant biomass is above a specified minimum plant biomass for grazing. The amount of biomass trampled daily is converted to residue.
- Manure nutrients from grazing animals were simulated for pastureland and rangeland according to the density of grazing livestock as reported in the 2002 Census of Agriculture. Non-recoverable manure was estimated by subtracting recoverable manure available for land application from the total manure nutrients representing all livestock populations. Non-recoverable manure nutrients include the non-recoverable portion from animal feeding operations. Estimates of manure nutrients were derived from data on livestock populations as reported in the 2002 Census of Agriculture, which were available for each 6-digit HUC and distributed among the 8-digit HUCs on a per-acre basis.
- Recoverable manure from animal feeding operations was applied to 7 percent of the pastureland acres at rates estimated from probable land application of manure using the methods described in USDA/NRCS (2003). These calculations indicated that 7 percent of pastureland acres in the Texas Gulf Basin could have received manure from animal feeding operations.
- Supplemental commercial nitrogen fertilizers were applied to pastureland according to the crop need as determined by an auto-fertilization routine, which was set to grow grass without undue nitrogen stress.

Horticulture land was fertilized with 100 pounds of nitrogen per acre per year and 44 pounds of phosphorus per acre per year. For the irrigated horticultural acres, water was applied at a frequency and rate defined by an auto-irrigation routine.

Land application of biosolids from wastewater treatment facilities was not simulated. Manure nutrients from wildlife populations were not included in the model simulation.

A summary of the total amount of nitrogen and phosphorus applied to agricultural land in the model simulation, including nitrogen and phosphorus applied to cultivated cropland in the APEX modeling, is presented in table 38.[29]

Windborne sediment and nutrients

In areas of the country where wind erosion is a significant resource concern, as in the Texas Gulf Basin, windblown sediment can be an important source of instream loads. The wind-eroded material is deposited on many different landscapes and land uses including other agricultural fields, filter or buffer areas, ditches, roadways, flood plains, and even directly into rivers and streams. In most cases windblown sediment will consist of unconsolidated material, which is easily transported into rivers and streams with surface water runoff. Because windblown material usually consists of fine and very fine soil particles, the portion that originates from cropland is usually rich in nutrients.

There are no published estimates of the magnitude of instream loads that originate from windborne sediment. Recognizing, however, that this is an important source of sediment and sediment-bound nutrients in areas prone to wind erosion, a rough estimate was calculated and incorporated into the model simulation. Windblown sediment materials were estimated conservatively by increasing the waterborne sediment loads delivered to the outlet of each 8-digit HUC by 10 percent. Nutrients carried with these windblown sediments were assumed to be in the same proportion as in the water-eroded materials. Sediment and sediment-bound nitrogen and phosphorus loads estimated using this approach are presented in table 39.[30]

Estimates of windborne sediment and sediment-bound nutrients were not made for land uses other than cultivated cropland. However, other land uses may be significant contributors to windborne sediment.

[29] For information on how manure nutrients were calculated for use in HUMUS modeling, see "Manure Loadings Used to Simulate Pastureland and Hayland in CEAP HUMUS/SWAT Modeling," referenced on page 7.

[30] Wind erosion rates and the field-level losses of windborne nitrogen and phosphorus were also estimated for cropped acres using the APEX model, as presented in chapter 4. The loads added at the outlet of 8-digit HUCs represented, on average for the region, 16.7 percent of the sediment lost with wind erosion at the edge of the field for cropped acres, 41.0 percent of the nitrogen lost with windborne sediment at the edge of the field, and 55.9 percent of the phosphorus lost with windborne sediment at the edge of the field.

Table 38. Summary of commercial fertilizer and manure nutrients applied to agricultural land in HUMUS/SWAT (pastureland, rangeland, hayland, and horticulture) and APEX (cultivated cropland) models, Texas Gulf Basin

Subregion	Commercial nitrogen fertilizer (tons/year)	Nitrogen from manure (tons/year)	Total nitrogen (tons/year)	Commercial phosphorus fertilizer (tons/year)	Phosphorus from manure (tons/year)	Total phosphorus (tons/year)
Cultivated cropland						
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	73,281	3,647	76,929	11,170	1,249	12,420
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	95,999	14,495	110,494	17,268	6,955	24,224
Lower and Middle Brazos River Basin (codes 1206, 1207)	101,894	20,498	122,393	13,689	7,510	21,199
Upper Colorado River Basin (code 1208)	42,297	4,820	47,117	9,912	2,066	11,978
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	41,915	6,645	48,560	6,076	2,861	8,937
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	65,217	2,181	67,398	10,392	909	11,300
Nueces River-Southwestern Texas Coastal (code 1211)	92,473	4,885	97,358	11,529	1,764	13,293
Total	513,077	57,172	570,249	80,036	23,314	103,350
Hayland						
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	46,419	4,616	51,035	114	2,127	2,241
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	0	1	1	3	1	3
Lower and Middle Brazos River Basin (codes 1206, 1207)	27,215	1,232	28,447	71	561	633
Upper Colorado River Basin (code 1208)	0	0	0	3	0	3
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	6,914	176	7,090	29	77	106
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	13,451	1,149	14,600	27	518	545
Nueces River-Southwestern Texas Coastal (code 1211)	7,561	134	7,694	28	61	89
Total	101,560	7,307	108,868	275	3,345	3,620
Pastureland and rangeland						
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	21,608	89,187	110,795	12,985	53,184	66,169
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	6,295	25,179	31,473	2,580	10,321	12,902
Lower and Middle Brazos River Basin (codes 1206, 1207)	18,757	75,109	93,866	11,161	44,678	55,838
Upper Colorado River Basin (code 1208)	2,114	8,456	10,570	1,172	4,689	5,861
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	9,638	38,559	48,196	5,422	21,690	27,111
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	9,754	40,936	50,690	5,979	24,768	30,746
Nueces River-Southwestern Texas Coastal (code 1211)	7,497	30,095	37,592	4,483	17,964	22,447
Total	75,662	307,520	383,183	43,782	177,294	221,076
Horticulture						
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	2,436	0	2,436	1,072	0	1,072
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	138	0	138	61	0	61
Lower and Middle Brazos River Basin (codes 1206, 1207)	3,050	0	3,050	1,343	0	1,343
Upper Colorado River Basin (code 1208)	155	0	155	68	0	68
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	2,216	0	2,216	975	0	975
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	1,372	0	1,372	604	0	604
Nueces River-Southwestern Texas Coastal (code 1211)	2,325	0	2,325	1,023	0	1,023
Total	11,692	0	11,692	5,147	0	5,147

Table 38--continued. Summary of commercial fertilizer and manure nutrients applied to agricultural land in HUMUS/SWAT (pastureland, rangeland, hayland, and horticulture) and APEX (cultivated cropland) models, Texas Gulf Basin

Subregion	Commercial nitrogen fertilizer (tons/year)	Nitrogen from manure (tons/year)	Total nitrogen (tons/year)	Commercial phosphorus fertilizer (tons/year)	Phosphorus from manure (tons/year)	Total phosphorus (tons/year)
			Total for all agricultural land			
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	143,744	97,450	241,195	25,341	56,560	81,902
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	102,432	39,675	142,106	19,912	17,277	37,190
Lower and Middle Brazos River Basin (codes 1206, 1207)	150,916	96,839	247,756	26,264	52,749	79,013
Upper Colorado River Basin (code 1208)	44,566	13,276	57,842	11,155	6,755	17,910
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	60,683	45,380	106,062	12,502	24,628	37,129
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	89,794	44,266	134,060	17,002	26,195	43,195
Nueces River-Southwestern Texas Coastal (code 1211)	109,856	35,114	144,969	17,063	19,789	36,852
Total	701,991	372,000	1,073,990	129,239	203,953	333,191

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

Table 39. Summary of windborne sediment and nutrients included as loadings to rivers and streams in the HUMUS/SWAT model simulations,* Texas Gulf Basin

Subregion	Sediment (tons/year)	Nitrogen (tons/year)	Phosphorus (tons/year)
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	99,693	128	16
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	10,046,986	12,258	2,531
Lower and Middle Brazos River Basin (codes 1206, 1207)	1,451,467	1,658	286
Upper Colorado River Basin (code 1208)	3,524,682	3,209	681
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	1,173,862	2,237	269
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	111,404	133	25
Nueces River-Southwestern Texas Coastal (code 1211)	9,824,062	12,384	2,151
Total	26,232,155	32,006	5,959

* Windborne loadings were introduced as sources at the 8-digit HUC outlets.

"Legacy Phosphorus" Not Accounted for in Modeling

"Legacy phosphorus" from cultivated cropland sources results from the over-application of phosphorus on farm fields in past years. Excess phosphorus may be the result of over-application, or may be due to inclement weather or drought during the growing season, which inhibits the plants from taking up the phosphorus at rates they would under a more normal growing year. When excessive amounts of fertilizer or manure are chronically applied to a farm field, soil phosphorus levels increase dramatically. It may take decades for phosphorus levels to return to background levels once these practices are halted. Use of soil testing to determine the need for phosphorus applications can prevent further over-application, but there remains legacy phosphorus locked into the soil profile within the field, along the edge of the field and drainageways, and in streambeds that cannot be offset by current management activities. Legacy phosphorus can also come from sediment sources other than cultivated cropland.

The transport of sediment—and the phosphorus bound to those particles—from farm fields to rivers and streams can take many years. Eroded soil particles leaving a farm field can be deposited where runoff slows or ponding occurs before reaching a stream or river. Once the sediment has entered streams, some of the soil particles settle out and can remain in the streambed or settle on the floodplain when the water is high and slow moving. These sediments remain in place until a storm creates enough surface water runoff to re-suspend the previously eroded soil, or until streamflow cuts into streambanks made up of deposits of previously eroded soil. Windborne sediment transported into waterways can similarly be a mixture of newly eroded and previously eroded materials.

Consequently, measured phosphorus levels in rivers and streams include not only phosphorus lost from farm fields as a result of current farming activities but also "legacy phosphorus" from prior farming activities as well as prior deposits from non-farming sources. Some of this sediment-adsorbed "legacy phosphorus" can be solubilized by chemical reactions within the water body and measured as soluble phosphorus.

The simulation models used in this study do not account for these "legacy phosphorus" levels. There is recognition, however, that "legacy phosphorus" can be an important contributor to current levels of instream phosphorus loads, including soluble phosphorus loads.

Urban Sources

Urban sources include (1) loads from point sources discharged from industrial and municipal wastewater treatment plants and (2) loads from urban land runoff.

Discharges from industrial and municipal wastewater treatment plants can be major sources of nutrients and sediment in some watersheds. Point sources of water flow, total suspended sediment, total phosphorus, and Kjeldahl nitrogen were estimated using county-level data on population change to adjust 1980 estimates of point source loadings published by Resources for the Future (Gianessi and Peskin 1984) to the year 2000. The original Resources for the Future assessment covered 32,000 facilities, including industries, municipal wastewater treatment plants, and small sanitary waste facilities for the years 1977 to 1981. A GIS-based procedure was used to convert county data to the 8-digit HUC level. Point source loads are aggregated within each watershed and average annual loads input into SWAT at the watershed outlet.

Urban runoff is estimated separately for three categories of cover within an urban HRU: (1) pervious surfaces such as lawns, golf courses, and gardens, (2) impervious surfaces hydraulically connected to drainage systems such as paved roads and paved streets draining to storm drains, and (3) impervious surfaces not hydraulically connected to drainage systems such as a house roof draining to a pervious yard that is not directly connected to drains (composite urban surface consisting of impervious roof surface and pervious yard surface).

Pervious surfaces are simulated in the same manner as other grass areas (such as pasture). Surface runoff from pervious surfaces is calculated using the NRCS Runoff Curve Number (RCN), an empirical parameter used in surface hydrology for predicting direct runoff or infiltration. Nitrogen fertilizer (40 pounds per acre per year) is applied on grassed urban areas such as lawns and grassed roadsides using an auto-fertilizer routine to grow grass without undue nitrogen stress. The grass is considered irrigated as needed based on plant stress demand using an auto-irrigation routine.

For estimating surface water runoff from impervious urban areas, a runoff curve number of 98 was used for surfaces connected hydraulically to drainage systems. A composite runoff curve number was used for impervious surfaces not hydraulically connected to drainage systems. Sediment and nutrients carried with stormwater runoff to streams and rivers were estimated using the build-up-wash-off algorithm developed by Huber and Dickinson (1988).

The concept behind the build-up-wash-off algorithm is that over a period of time, dust, dirt, and other constituents are built up on street surfaces during dry periods. During a storm event the materials are washed off. The algorithms were developed from an EPA national urban water quality database that relates storm runoff loads to rainfall, drainage area, and impervious area.

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

A summary of the total amount of nitrogen and phosphorus applied to non-agricultural land in the model simulation is presented in table 40. Nutrients from septic systems were not included in the model simulations as data on locations of septic systems, populations using the septic systems, and types of septic systems were not available.

Atmospheric nitrogen deposition

Atmospheric deposition of nitrogen can be a significant component of the nitrogen balance. Nitrogen deposition data (loads and concentrations) were developed from the National Atmospheric Deposition Program/National Trends Network database (NADP 2004). When a rainfall event occurs in the model simulation, the amount of rainfall is multiplied by the average ammonium and nitrate concentrations calculated for the watershed to account for wet deposition. An additional amount of ammonium and nitrate are added on a daily basis to account for dry deposition. A summary of the total amount of nitrogen deposition included as inputs to the HUMUS/SWAT model simulation is presented in table 40.

Table 40. Summary of nutrients applied to urban land, nutrients originating from point sources, and wet and dry atmospheric deposition of nitrogen used as inputs to the HUMUS/SWAT model, Texas Gulf Basin.

	Urban land	Point sources		Wet and dry atmospheric deposition
Subregion	Nitrogen fertilizer (tons/year)	Nitrogen (tons/year)	Phosphorus (tons/year)	Nitrogen (tons/year)
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	35,707	134,249	29,994	75,548
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	3,863	32	8	7,966
Lower and Middle Brazos River Basin (codes 1206, 1207)	8,813	5,595	914	35,568
Upper Colorado River Basin (code 1208)	3,156	468	85	10,655
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	5,216	5,261	681	28,661
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	8,113	16,121	3,145	18,952
Nueces River-Southwestern Texas Coastal (code 1211)	10,334	12,147	2,363	24,308
Total	75,201	173,874	37,191	201,658

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

Routing and channel processes

SWAT simulates stream/channel processes including channel flood routing, channel sediment routing, nutrient and pesticide routing, and transformations modified from the QUAL2E model (fig. 84).

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

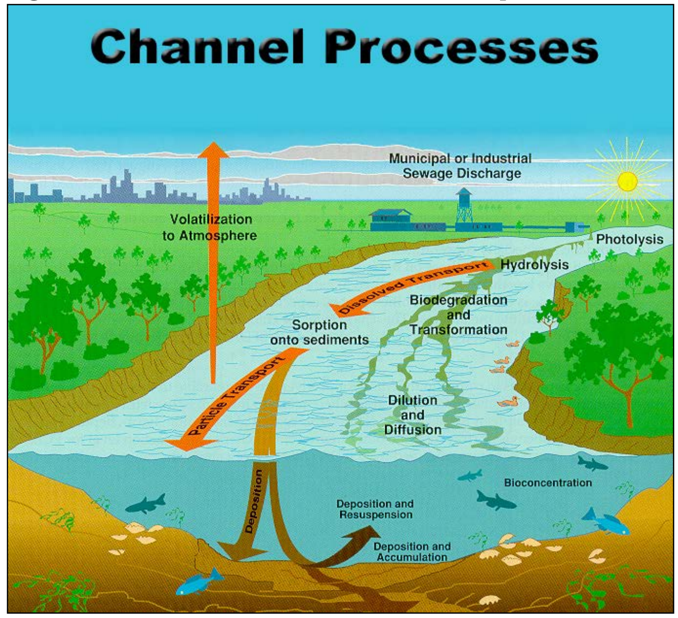
Sediment routing—deposition, bed degradation, and streambank erosion. Sediment transport in the stream network is a function of two processes, deposition and degradation. SWAT computes deposition and degradation simultaneously within the reach. Deposition is based on the fall velocity of the sediment particles and the travel time through each stream. Stream power is used to predict bed and bank degradation; excess stream power results in degradation. Bed degradation and streambank erosion are based on the erodibility and vegetative cover of the bed or bank and the energy available to carry sediment (a function of depth, velocity, and slope). The maximum amount of sediment that can be transported from a reach segment is a function of the peak channel velocity. Available stream power is used to re-entrain loose and deposited material until all of the material is removed.[31]

Nutrient routing. Nutrient transformations in the stream are controlled by the instream water quality component of the model. The model tracks nutrients dissolved in the stream and nutrients adsorbed to the sediment. Dissolved nutrients are transported with the water, while those adsorbed to sediments are deposited with the sediment on the bed of the channel.

Pesticide routing. As with nutrients, the total pesticide load in the channel is partitioned into dissolved and sediment-attached components. While the dissolved pesticide is transported with water, the pesticide attached to sediment is affected by sediment transport and deposition processes. Pesticide transformations in the dissolved and adsorbed phases are governed by first-order decay relationships. The major instream processes simulated by the model are settling, burial, resuspension, volatilization, diffusion, and transformation.

[31] There are no national estimates of streambank erosion that can be uniformly used to calibrate this component of the model. Parameters governing instream sediment processes are adjusted in concert with those governing upland sediment yields such that HUMUS predictions at calibration sites mimic measured sediment data. Sediment data collected at a single stream gauging site is a combination of upland and instream sources, which cannot be proportioned by source. Collectively a network of sediment monitoring sites may be used to develop a sediment budget for a watershed which may include a stream bank component. When such studies are available for a HUMUS region they are used as ancillary data during model calibration.

Figure 84. SWAT model channel simulation processes



Reservoirs

Reservoirs alter the dynamics of a free-flowing river, resulting in different rates of sediment deposition and chemical transformations. SWAT includes routines for reservoirs that account for the hydrological aspects of reservoirs. Basic reservoir data such as storage capacity and surface area were obtained from the dams database.

Reservoir outflow. A simple target volume approach was used in this study to simulate reservoir outflow. The algorithm attempts to keep reservoir storage near the principal spillway volume during the flood season but allow water storage to accumulate above the principal storage during the non-flood season.

Sediment routing. The concentration of sediment in the reservoir is estimated using a simple continuity equation based on volume and concentration of inflow, outflow, and water retained in the reservoir. Settling of sediment in the reservoir is governed by an equilibrium sediment concentration and the median sediment particle size. The amount of sediment in the reservoir outflow is the product of the volume of water flowing out of the reservoir and the suspended sediment concentration in the reservoir at the time of release.

Reservoir nutrients. The model assumes that (1) the reservoir is completely mixed, (2) phosphorus is the limiting nutrient, and (3) total phosphorus is a measure of the trophic status. The phosphorus mass balance equation includes the concentration in the reservoir, inflow, outflow, and overall loss rate.

Reservoir pesticides. The model partitions the system into a well-mixed surface water layer underlain by a well-mixed sediment layer for simulating the fate of pesticides. The pesticide is partitioned into dissolved and particulate phases in both the water and sediment layers. The major processes simulated by the model are loading, outflow, transformation, volatilization, settling, diffusion, resuspension, and burial.

Fifty seven reservoirs of varying size were simulated in the region in the HUMUS model. Collectively these reservoirs trapped 26 million metric tonnes of sediment annually; however, reservoirs may exacerbate downstream bank erosion, thus the actual impact may be significantly less. These reservoirs also trap 105,000 metric tonnes of nitrogen and 27,000 metric tonnes of phosphorus each year. It is important to note that phosphorus trapped in reservoirs is not necessarily removed from these systems permanently. Reservoirs' sediments may become a source of soluble phosphorus under anoxic conditions common in eutrophic water-bodies and may be a contributor to "legacy phosphorus" issues.

Calibration

Delivery of surface water (surface runoff) and subsurface water (baseflow) simulated from upland processes (HRUs and CEAP sample points) was spatially calibrated for each 8-digit watershed. This process ensures that simulated runoff or water yield (surface runoff plus baseflow) was in agreement with long-term average runoff or water yield obtained for the Texas Gulf Basin from the USGS. Hydrologic parameters in APEX (used for simulating cultivated cropland) and SWAT (used for simulating non-cultivated land) were adjusted separately for each 8-digit watershed to minimize differences in the long-term water yield. The time series calibration of streamflow was conducted for the period between 1961 and 2006 at eight gauging stations, depending on the length of data available. Predicted annual streamflows were compared against the monitored streamflows for the calibration period. Most of the flow calibration was carried out with minimal or no parameterization for the annual streamflows. [32] When necessary, the channel losses, seepage, and evaporation losses in reservoirs were adjusted to match the predicted flow time series with that of observed data.

For sediment calibration, observations were taken from USGS monitoring stations. Most of the sediment observations were grab-sample concentrations of suspended sediment. These, along with monitored daily flow data, were processed using the USGS's Estimator software to estimate annual average sediment load. The estimated annual average sediment loads at seven gauging stations in the Texas Gulf Basin were used to calibrate the predicted sediment loads from HUMUS/SWAT. Upland soil erosion and sediment yields were calibrated by adjusting the soil erodibility factor and residue cover. Instream sediment loads were calibrated using parameters controlling stream power and sediment-carrying capacity of channels. Delivery ratios from field to 8-digit watershed outlet and 8-digit watershed to river were adjusted to match predicted sediment load with that of observations for each gauging station. Where necessary, parameters affecting settling of sediment in reservoirs were adjusted.

Total nitrogen and total phosphorus loads were calibrated at eight gauging stations. Nitrate-Nitrogen, Nitrite-Nitrogen, Total Kjeldahl Nitrogen, and Orthophosphate were calibrated in stations where observed data were available. Nutrient loads were estimated from grab-sample concentrations using the same procedure outlined for sediment.

Upland nutrient loads were calibrated using parameters controlling nutrient uptake by plants, leaching to groundwater, and mineralization. Instream nutrient loads were calibrated using parameters affecting benthic nutrient source rates, mineralization, hydrolysis, and settling of particulate nutrients. Where necessary, parameters affecting settling of nutrients in reservoirs were also adjusted.

Adequate data were not available for calibration of atrazine loads.

The "background" scenario

An additional scenario was conducted to represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by simulating with APEX a grass-and-tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.[33] All other SWAT modeling inputs remained the same for this scenario. Thus, "background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Source Loads and Instream Loads

All source loads are introduced into SWAT at the outlet of each watershed (8-digit hydrologic unit code [HUC]). Flows and source loads from upstream watersheds are routed through each downstream watershed, including reservoirs when present.[34]

A sediment delivery ratio was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The sediment delivery ratio used in this study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC).

[32] For a complete documentation of calibration procedures and results for the Texas Gulf Basin, see "Calibration and Validation of CEAP HUMUS," referenced on page 7.

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[33] In a natural ecosystem, the vegetative cover would include a mix of species, which would continually change until a stable ecosystem was established. APEX allows for multiple species and simulates plant competition over time according to plant growth, canopy cover, vegetative form, and relative maturity or growth stage. The initial mix of species at the beginning of the 47-year simulation was similar to the mix of grasses and trees used to establish long-term conserving cover. Mixes included at least one grass and one legume. Over the 47-year simulation, the mix of grasses and trees shifted due to plant competition. The grass species typically dominate in the simulation until shaded out by tree cover. For further details on how the background simulation was conducted, see "Assumptions and Procedures for Simulating the Natural Vegetation Background Scenario for the CEAP National Cropland Assessment," referenced on page 7.

[34] For a complete documentation of HUMUS/SWAT as it was used in this study, see "The HUMUS/SWAT National Water Quality Modeling System and Databases," referenced on page 7.

The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU.[35]

In addition to the sediment delivery ratio, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment-attached pesticide concentrations transported with sediment to the watershed outlet divided by their concentrations at the edge of the field. As sediment is transported from the edge of field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

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

There are four points in the modeling process at which source loads or instream loads are assessed, shown in the schematic in figure 85 for sediment.

1. Edge-of-field loads from cultivated cropland—aggregated APEX model output as reported in the previous chapter.
2. Delivery to the watershed outlet from cultivated cropland—aggregated edge-of-field loads after application of delivery ratios. Loadings delivered to streams and rivers differ from the amount leaving the field because of losses during transport from the field to the stream. Delivery ratios are used to make this adjustment.
3. Delivery to the watershed outlet from land uses other than cultivated cropland as simulated by SWAT, after application of delivery ratios. Point sources are included.
4. Loadings in the stream or river at a given point. Instream loads include loadings delivered to the watershed outlet from all sources as well as loads delivered from upstream watersheds, after accounting for channel and reservoir processes.

[35] For a complete documentation of delivery ratios used for the Texas Gulf Basin, see "Delivery Ratios Used in CEAP Cropland Modeling," referenced on page 7.
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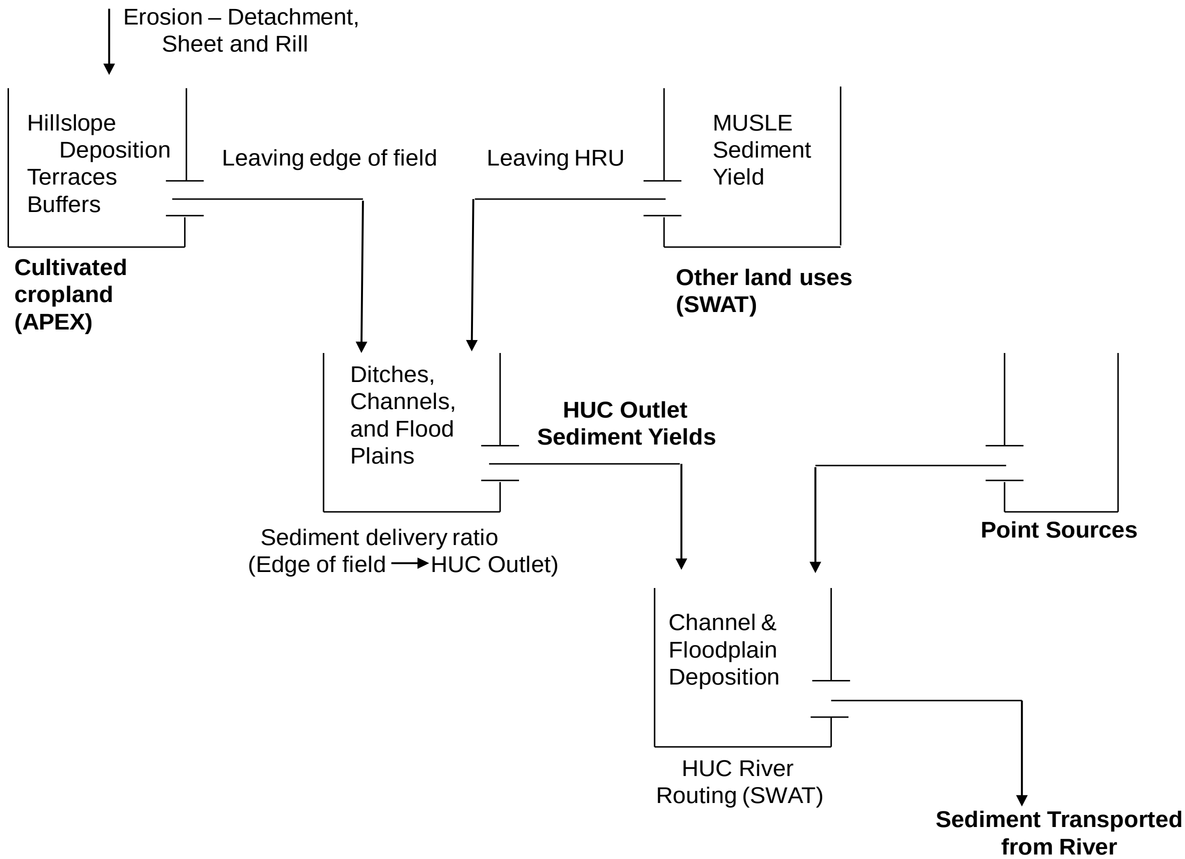
Figure 85. Schematic of sediment sources and delivery as modeled with HUMUS/SWAT for the Texas Gulf Basin



Modeling Land Use in the Texas Gulf Basin

The USGS National Land-Cover Database for 2001 (Homer et al. 2007) was the principal source of acreage estimates for HUMUS/SWAT modeling. The 2003 National Resources Inventory (USDA/NRCS 2007) was used to adjust NLCD cropland acreage estimates to include acres in Conservation Reserve Program (CRP) General Signups, used here to represent cropland in long-term conserving cover. Consequently, cultivated cropland acres used to simulate the water quality effects of conservation practices differ slightly from the cropped acres reported in the previous chapters, which were estimated on the basis of the CEAP Cropland sample.

Estimates of the acreage by land use, exclusive of water, used in the model simulation to estimate the effects of conservation practices in this chapter are presented in table 41 and figure 86. Grazing land (rangeland and pastureland) makes up slightly more than half of the acres in the basin. Cultivated cropland makes up 15 percent, and forest and other land uses makes up about 22 percent. Urban land makes up 7.5 percent of the land base. Hayland is a minor land use in this region (less than 3 percent of the land base).

Cultivated cropland acres are distributed throughout the region but are most concentrated in the northwestern part of the basin (northwestern Texas) (tables 4 and 41 and fig. 2). The Brazos headwaters–Salt Fork–Double Mountain Fork Basin (code 1205) has the most acres of cultivated cropland—29 percent of the cultivated cropland in the region. Three additional subregions account for another 42 percent of the cultivated cropland: the Upper Colorado River Basin (code 1208), the Nueces River–Southwestern Coastal Basin (code 1211), and the Middle Brazos River Basin (code 1206) (table 4).

The amount of cultivated cropland within each subregion is an important factor in sediment and nutrient loads in rivers Cultivated cropland accounts for 30 percent or more of the land base in 2 of the 11 subregions (table 4 and fig. 2):

- Brazos headwaters–Salt Fork–Double Mountain Fork Basin (code 1205), with 53 percent,
- Upper Colorado River Basin (code 1208), with 32 percent,

Cultivated cropland is a minor land use in five subregions, where it accounts for only a small percentage of the total area within the subregion (less than 10 percent)
(table 4 and fig. 2):

- Upper and Lower Trinity Basin (code 1203), with 8 percent,
- Middle and Lower Colorado–Conchos–Llano–San Bernard Coastal (code 1209), with 7 percent,
- San Jacinto River–Galveston Bay–Sabine Lake (code 1204), with 6 percent,
- Sabine River Basin (code 1201), with 2 percent, and
- Neches River Basin (code 1202), with 1 percent.

The amount of land in long-term conserving cover, which represents about 13 percent of the cultivated cropland acres in this region, is also an important driver of sediment and nutrient loads. There are two subregions where land in long-term conserving cover is 15 percent or more of cultivated cropland acres (table 4):

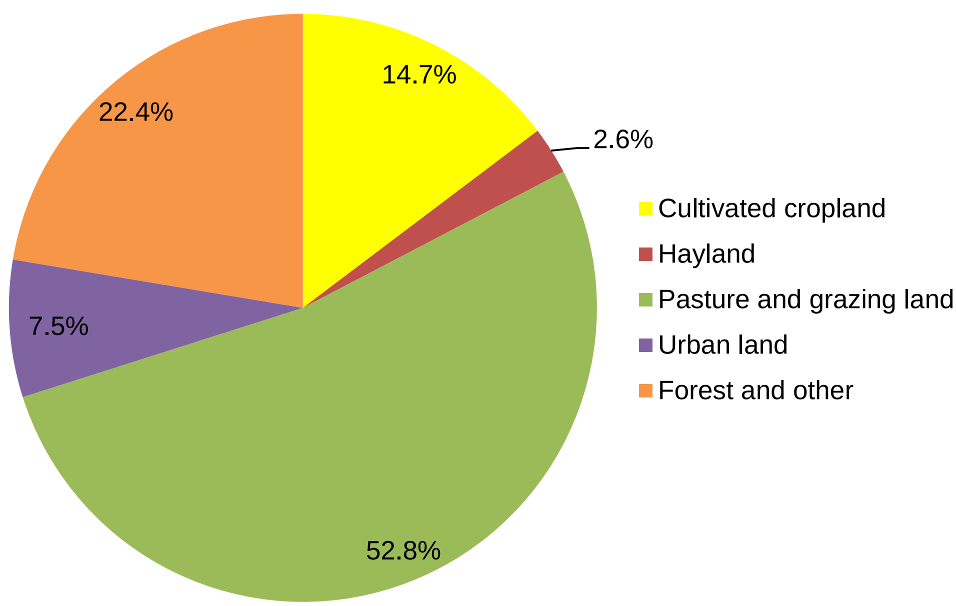
- Upper Colorado River Basin (code 1208), with 28 percent, and
- Brazos headwaters–Salt Fork–Double Mountain Fork Basin (code 1205), with 18 percent.

Table 41. Acres by land use, exclusive of water, used in model simulations to estimate instream sediment, nutrient, and atrazine loads for the Texas Gulf Basin

Subregions	Cultivated cropland (acres)*	Hay land not in rotation with crops (acres)	Pasture and grazing land not in rotation with crops (acres)**	Urban land (acres)	Forest and other (acres)***	Total land exclusive of water (acres)
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	1,365,051	1,442,975	9,490,893	3,658,168	13,272,234	27,807,857
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	4,909,188	604	3,840,595	481,729	101,419	9,321,543
Lower and Middle Brazos River Basin (codes 1206, 1207)	2,866,274	789,569	10,819,591	1,385,973	4,019,908	19,641,327
Upper Colorado River Basin (code 1208)	3,253,497	544	6,418,936	450,343	113,204	10,217,485
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	1,248,198	200,297	12,731,989	899,531	2,947,178	17,857,042
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	1,297,634	403,578	5,607,667	895,816	3,257,091	10,853,539
Nueces River-Southwestern Texas Coastal (code 1211)	2,176,723	217,751	12,458,585	999,174	2,314,178	17,695,169
Regional total	17,116,566	3,055,319	61,368,256	8,770,734	26,025,213	113,394,859

*Acres of cultivated cropland include land in long-term conserving cover as well as hay land and pastureland in rotation with crops.
**Includes grass and brush rangeland categories.
***Includes forests (all types), wetlands, horticulture, and barren land.
Note: Estimates were obtained from HUMUS databases on land use, and thus cultivated cropland estimates do not exactly match the acreage estimates obtained from the NRI-CEAP sample.

Figure 86. Percent acres for land use/cover types in the Texas Gulf Basin, exclusive of water



Loads Delivered from Cultivated Cropland to Rivers and Streams

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 is delivered to streams and rivers. Some material is bound up in various parts of the landscape during transport. Loads delivered from cultivated cropland and other sources to rivers and streams within the Texas Gulf Basin are presented in this section. Instream loads for all sources, which incorporate instream degradation processes and streambed deposition and accumulation of the sediment, nutrients, and pesticides *after* delivery to streams and rivers, are presented in the following section.

The water quality effects of conservation practices in use during 2003–06 on loads delivered from cultivated cropland to rivers and streams were assessed by comparing HUMUS/SWAT model simulation results for the baseline conservation condition to simulation results for the no-practice scenario. For the no-practice scenario, only the conditions for cultivated cropland were changed, as described previously. All other aspects of the simulations—including sediment and nutrient loads from point sources and land uses other than cultivated cropland—remained the same.

The field-level model results for the treatment scenarios with additional erosion control practices and nutrient management (chapter 6) were used with the HUMUS/SWAT model to determine the *potential for further reductions* in loads delivered from cultivated cropland to rivers and streams throughout the region with additional conservation treatment. Percent reductions relative to the baseline conservation condition were estimated for each of two treatment scenarios:

1. Treatment of the critical undertreated acres, which have a “high” need for additional treatment for one or more resource concerns (41 percent of cropped acres in the region)
2. Treatment of all acres with a “high” or “moderate” need for additional treatment for one or more resource concerns (97 percent of cropped acres in the region).

Acres not receiving treatment in the simulation retained baseline values. Thus, the distribution of undertreated acres within the region influences the extent to which individual subregions benefit from additional treatment, since additional treatment was simulated only for the undertreated acres. The distribution of undertreated acres within the Texas Gulf Basin is presented in Appendix B, table B5.

In summary, findings for the Texas Gulf Basin indicate that for the baseline conservation condition, sediment, nutrient, and atrazine loads ***delivered to rivers and streams from cultivated cropland sources*** *per year, on average, are—*

- *15 million tons of sediment (66 percent of loads from all sources);*
- *202 million pounds of nitrogen (31 percent of loads from all sources);*
- *9 million pounds of phosphorus (7 percent of loads from all sources); and*
- *10,600 pounds of atrazine.*

Conservation practices in use on cultivated cropland in 2003–06, including land in long-term conserving cover, have reduced sediment, nutrient, and atrazine loads ***delivered to rivers and streams from cultivated cropland sources*** *per year, on average, by —*

- *60 percent for sediment;*
- *41 percent for nitrogen;*
- *55 percent for phosphorus, and*
- *36 percent for atrazine.*

Model simulations further showed that if all of the undertreated acres (97 percent of cropped acres) were fully treated with the appropriate soil erosion control and nutrient management practices, loads ***delivered to rivers and streams from cultivated cropland sources*** *in the region would be reduced, relative to the baseline conservation condition, by—*

- *84 percent for sediment,*
- *32 percent for nitrogen,*
- *63 percent for phosphorus, and*
- *80 percent for atrazine.*

Sediment

Baseline condition. Model simulation results show that about 15 million tons of sediment are exported from farm fields in the Texas Gulf Basin and delivered to rivers and streams each year, on average, under conditions represented by the baseline conservation condition (table 42), which simulates farming activities and conservation practices in use during the period 2003 to 2006. About 0.88 ton per cultivated cropland acre is delivered to rivers and streams per year, on average, for the region (table 42).

The amount of sediment delivered to rivers and streams annually ranges from 2.7 to 3.2 million tons for the four subregions and combinations of subregions with the largest amounts (table 42):

- the Nueces River–Southwestern Texas Coastal (code 1211), with 21 percent of the regional total,
- Lower and Middle Brazos River Basin (codes 1206, 1207), with 19 percent of the regional total,
- the Brazos headwaters–Salt Fork–Double Mountain Fork Basin (code 1205), with 19 percent of the regional total, and
- the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204), with 18 percent of the regional total.

On a per-acre basis, sediment delivery to rivers and streams is highest for the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake area (codes 1201, 1202, 1203, 1204) with an average of 1.95 tons delivered per acre of cultivated cropland, and lowest for the Upper Colorado River Basin (code 1208) with an average of only 0.25 ton delivered per acre of cultivated cropland (table 42).

Sediment delivered to rivers and streams from cultivated cropland represents about 66 percent of the total sediment load delivered from all sources in the region (table 43, fig. 87). This percentage ranges, however, from a low of 38 percent in the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake area (codes 1201, 1202, 1203, 1204) to 80 percent or more in these three subregions (table 43):

- the Brazos headwaters–Salt Fork–Double Mountain Fork Basin (code 1205), with 96 percent,
- the Upper Colorado River Basin (code 1208), with 91 percent, and
- the Nueces River–Southwestern Texas Coastal (code 1211), with 84 percent.

For the region as a whole, urban nonpoint source runoff is the second largest source of sediment delivered to rivers and streams, representing 16 percent of the load (table 43). In the combined region with the smallest share of the regional sediment loads delivered to rivers and streams from cropland—the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake area (codes 1201, 1202, 1203, 1204)—nonpoint source runoff from urban areas accounts for 35 percent of the sediment delivered to rivers and streams (table 43). This set of combined subregions includes the two largest cities in the basin—Houston and the Dallas-Fort Worth metroplex.

Pastureland and rangeland account for 13 percent of the sediment loads delivered to rivers and streams within the region (table 43, fig. 87). Pastureland and rangeland sediment contributions range from 1 to 23 percent of subegional delivered sediment loads (table 43).

Hayland, urban point sources, and forest and other land covers are minor contributors to sediment loads in this region.

Effects of conservation practices. Sediment loads delivered to streams and rivers would have been over twice as large if soil erosion control practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of sediment from fields to rivers and streams by about 60 percent (table 44, fig. 88), on average. Reductions due to conservation practices range from lows of 30 and 32 percent for the Nueces River–Southwestern Texas Coastal (code 1211) and the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204) subregions to a high of 92 percent for the Upper Colorado River Basin (code 1208).

Potential gains from further conservation treatment. Model simulations show that use of additional erosion control practices on the critical undertreated acres in the region (41 percent of cropped acres) would reduce sediment loads delivered to rivers and streams from cultivated cropland by about 6 million tons per year, representing a reduction from baseline levels of 40 percent (table 45).

Expanding this treatment to all undertreated acres (97 percent of cropped acres) would reduce sediment loads delivered to rivers and streams from cultivated cropland by about 12.6 million tons per year, representing a reduction from the baseline level of 84 percent (table 45 and fig. 88). The largest gain in terms of tons saved would occur in the three basins with the highest sediment loads in the baseline conservation condition (table 45)—

- the Nueces River–Southwestern Texas Coastal (code 1211), with a reduction of 2.9 million tons,
- the Brazos headwaters–Salt Fork–Double Mountain Fork Basin (code 1205), with a reduction of 2.8 million tons, and
- the Lower and Middle Brazos River Basin (codes 1206, 1207), with a reduction of 2.5 million tons.

Figure 87. Percentage by source of average annual sediment loads delivered to rivers and streams for the baseline conservation condition, Texas Gulf Basin

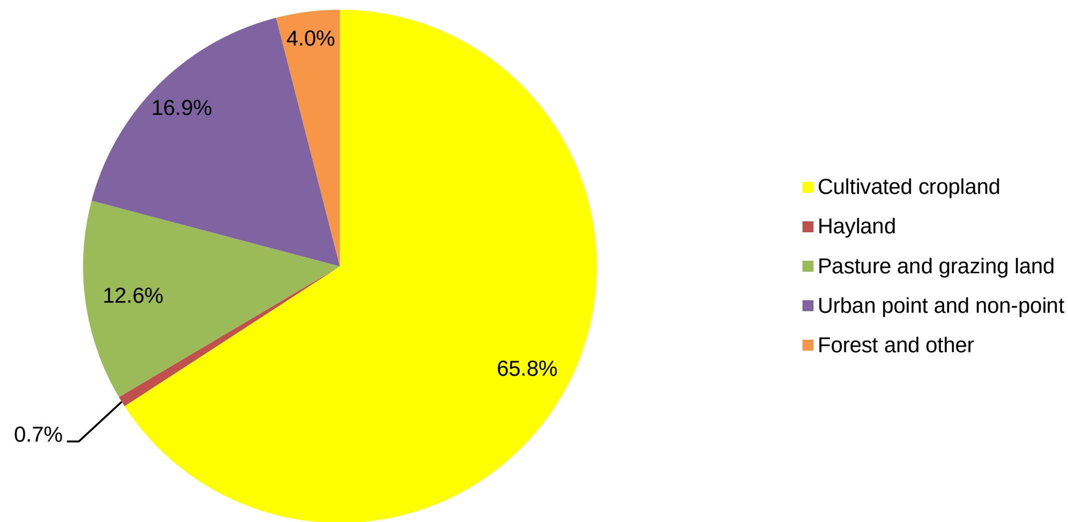


Table 42. Average annual sediment loads at the ***edge of field*** (APEX model output) and ***delivered from cultivated cropland to rivers and streams*** for the baseline conservation condition, Texas Gulf Basin

	Edge-of-field loads		Delivered to rivers and streams		
Subregions	Amount (1,000 tons)	Tons per cultivated cropland acre	Amount (1,000 tons)*	Percent of regional total	Tons delivered per cultivated cropland acre
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	4,334	3.17	2,665	18%	1.95
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	1,228	0.25	2,867	19%	0.58
Lower and Middle Brazos River Basin (codes 1206, 1207)	3,999	1.40	2,924	19%	1.02
Upper Colorado River Basin (code 1208)	293	0.09	814	5%	0.25
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	786	0.63	828	6%	0.66
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	2,700	2.08	1,747	12%	1.35
Nueces River-Southwestern Texas Coastal (code 1211)	1,669	0.77	3,200	21%	1.47
Regional total	15,008	0.88	15,045	100%	0.88

* Loads delivered to rivers and streams also include wind erosion loads from cultivated cropland, which are not included in the edge-of-field amount.
Note: Loads represent both cropped acres and land in long-term conserving cover.
Note: Columns may not add to totals because of rounding.

Table 43. Sediment loads ***delivered to rivers and streams*** by source, baseline conservation condition, Texas Gulf Basin

Subregions	All sources	Cultivated cropland*	Hayland	Pasture and rangeland	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 tons)			
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	7,068	2,665	103	1,173	2,453	142	531
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	2,972	2,867	0	32	31	0	41
Lower and Middle Brazos River Basin (codes 1206, 1207)	3,954	2,924	21	663	296	5	45
Upper Colorado River Basin (code 1208)	899	814	0	57	26	0	2
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	1,451	828	7	332	205	5	74
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	2,716	1,747	20	425	360	22	142
Nueces River-Southwestern Texas Coastal (code 1211)	3,800	3,200	1	205	307	8	79
Regional total	22,860	15,045	152	2,887	3,678	183	913
				Percent of all sources			
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	100	38%	1%	17%	35%	2%	8%
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	100	96%	0%	1%	1%	0%	1%
Lower and Middle Brazos River Basin (codes 1206, 1207)	100	74%	1%	17%	7%	<1%	1%
Upper Colorado River Basin (code 1208)	100	91%	0%	6%	3%	0%	0%
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	100	57%	<1%	23%	14%	<1%	5%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	100	64%	1%	16%	13%	1%	5%
Nueces River-Southwestern Texas Coastal (code 1211)	100	84%	<1%	5%	8%	<1%	2%
Regional total	100	66%	1%	13%	16%	1%	4%

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, horticulture, and barren land.

Table 44. Effects of conservation practices on average annual sediment loads ***delivered to rivers and streams from cultivated cropland,*** Texas Gulf Basin

Subregions	Baseline conservation condition (1,000 tons)	No-practice scenario (1,000 tons)	Reduction (1,000 tons)	Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	2,665	3,930	1,266	32%
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	2,867	9,918	7,051	71%
Lower and Middle Brazos River Basin (codes 1206, 1207)	2,924	4,704	1,780	38%
Upper Colorado River Basin (code 1208)	814	9,964	9,150	92%
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	828	1,838	1,010	55%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	1,747	2,976	1,229	41%
Nueces River-Southwestern Texas Coastal (code 1211)	3,200	4,552	1,352	30%
Regional total	15,045	37,882	22,838	60%

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

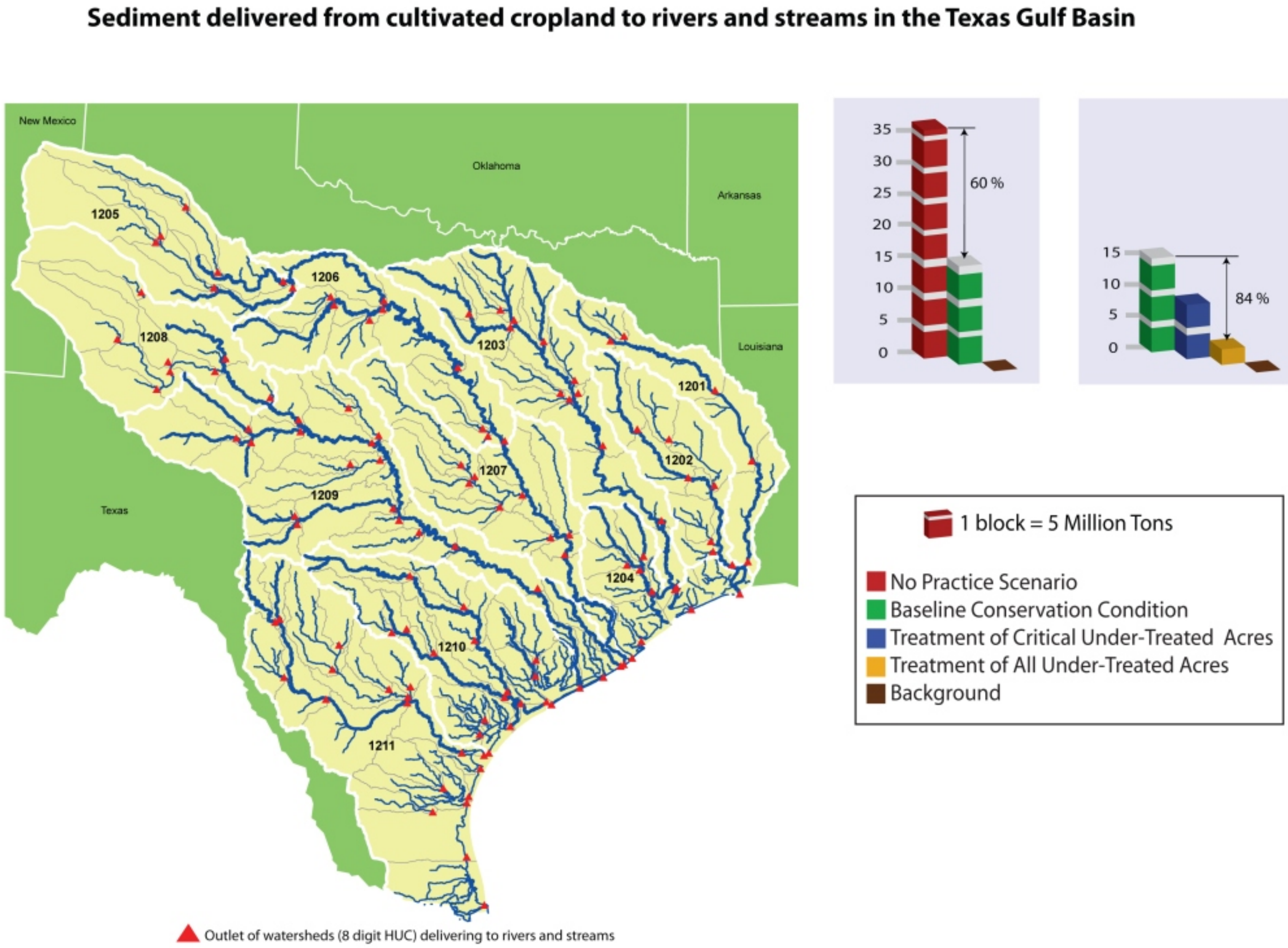
Table 45. Effects of additional conservation treatment with erosion control practices and nutrient management practices on average annual sediment loads ***delivered to rivers and streams*** from cultivated cropland, Texas Gulf Basin

		Treatment of critical undertreated acres			Treatment of all undertreated acres		
Subregions	Baseline conservation condition (1,000 tons)	Amount (1,000 tons)	Reduction (1,000 tons)	Percent reduction	Amount (1,000 tons)	Reduction (1,000 tons)	Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	2,665	2,550	115	4%	935	1,730	65%
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	2,867	829	2,039	71%	80	2,787	97%
Lower and Middle Brazos River Basin (codes 1206, 1207)	2,924	2,280	644	22%	472	2,452	84%
Upper Colorado River Basin (code 1208)	814	194	620	76%	25	789	97%
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	828	594	234	28%	214	614	74%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	1,747	1,665	82	5%	337	1,410	81%
Nueces River-Southwestern Texas Coastal (code 1211)	3,200	897	2,303	72%	334	2,866	90%
Regional total	15,045	9,009	6,036	40%	2,398	12,647	84%

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

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

Figure 88. Effects of conservation practices on average annual sediment loads delivered to rivers and streams, Texas Gulf Basin



Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.

Total Nitrogen

Baseline condition. Model simulation results show that of the 253 million pounds of nitrogen exported from farm fields in the Texas Gulf Basin (table 46), about 202 million pounds are delivered to rivers and streams each year, on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006. About 75 percent of the nitrogen delivered to rivers and streams from cultivated cropland originates in four subregions (table 46):

- the Nueces River-Southwestern Texas Coastal (code 1211), with 22 percent of the regional total,
- the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204), with 21 percent of the regional total,
- the Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210), with 17 percent of the regional total, and
- the Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205), with 15 percent of the regional total.

On a per-acre basis, nitrogen delivery to rivers and streams is, on average, 12 pounds per acre of cultivated cropland for the region, but is 20 or more pounds per cultivated cropland acre in three subregions, (table 46):

- the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204), with 31 pounds per cultivated cropland acre,
- the Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210), with 26 pounds per cultivated cropland acre, and
- the Nueces River–Southwestern Texas Coastal (code 1211), with 20 pounds per cultivated cropland acre.

Nitrogen delivered to rivers and streams from cultivated cropland represents about 31 percent of the total nitrogen load delivered from all sources in the region (table 47, fig. 89). This percentage ranges, however, from a low of 11 percent in the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204), to more than 50 percent in these three subregions:

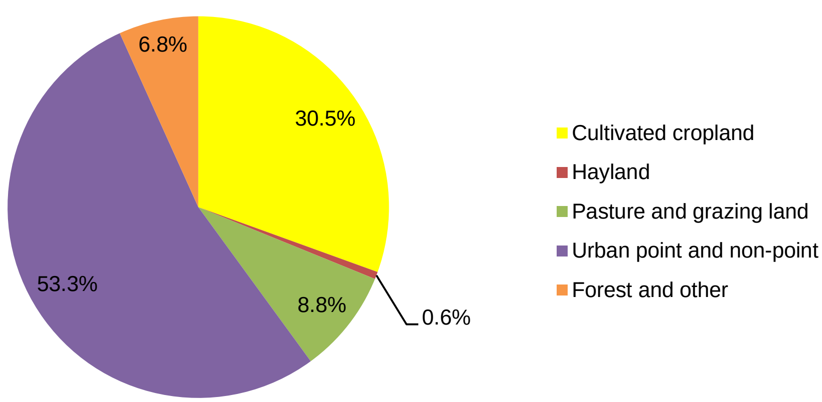
- the Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205), with 98 percent,
- the Upper Colorado River Basin (code 1208), with 89 percent, and
- the Nueces River-Southwestern Texas Coastal (code 1211), with 59 percent.

Urban point sources and non-point sources account for about 53 percent of the nitrogen delivered to rivers and streams in this region (table 47, fig. 89). Urban contributions are highest in the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204), where point sources account for about 242 million pounds of nitrogen per year, representing 65 percent of the nitrogen delivered to rivers and streams in that combination of subregions.

Pastureland and rangeland account for 9 percent of the nitrogen loads delivered to rivers and streams within the region, with variability among subregions ranging from 1 to 22 percent (table 47, fig. 89).

Hayland and forest and other land covers are minor contributors to nitrogen loads in most subregions.

Figure 89. Percentage by source of average annual nitrogen loads delivered to rivers and streams for the baseline conservation condition, Texas Gulf Basin



Effects of conservation practices. Nitrogen loads delivered to streams and rivers would have been much larger if conservation practices were not in use. Model simulations indicate that conservation practices have reduced the delivery of nitrogen from fields to rivers and streams by about 41 percent (table 48, fig. 90), on average. Reductions due to conservation practices vary throughout the region, ranging from a low of 13 percent for the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204) to highs of—

- 66 percent for the Brazos headwaters–Salt Fork–Double Mountain Fork Basin (code 1205), and
- 65 percent for the Upper Colorado River Basin (code 1208).

Potential gains from further conservation treatment. Model simulations show that use of additional erosion control and nutrient management practices on the critical undertreated acres in the region (41 percent of cropped acres) would reduce nitrogen loads delivered to rivers and streams from cultivated cropland by about 30.5 million pounds per year, representing a reduction from baseline levels of 15 percent (table 49).

Expanding this treatment to all undertreated acres (97 percent of cropped acres) would reduce nitrogen loads delivered to rivers and streams from cultivated cropland by 64 million pounds per year, representing a reduction from the baseline level of 32 percent (table 49 and fig. 90). The largest gain in terms of pounds saved would occur in the three subregions or combinations of subregions that had the largest loads delivered to rivers and streams in the baseline conservation condition (table 49):

- the Nueces River–Southwestern Texas Coastal (code 1211), with a reduction of 25.9 million pounds (a 58-percent reduction from the baseline level),
- the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204), with a reduction of 21.2 million pounds (a 50-percent reduction from the baseline level), and
- the Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210), with a reduction of 15.3 million pounds (a 45-percent reduction from the baseline level).

However, in two subregions—the Lower and Middle Brazos River Basins (codes 1206, 1207)—the model simulation showed an *increase* in nitrogen loads delivered to rivers and streams as a result of treatment of all undertreated acres with additional soil erosion control and nutrient management practices. The model simulation showed that the nitrogen load for these two subregions would increase by about 11.5 million pounds per year compared to the baseline conservation condition (table 49).

This result is due to a combination of factors that are not unique to these subregions but are manifested more in these subregions than other subregions in the Texas Gulf Basin.

First, the additional erosion control practices reduce runoff and increase subsurface flows, as discussed in chapter 4. In these two subregions, the additional practices reduced runoff by 3.5 inches per year and increased the flow to subsurface flows by 1 inch per year at the field level. In most cases the amount of nitrogen loss through surface loss pathways is greater than that in subsurface flows. In these two subregions, however, nitrogen loss in subsurface flow in the treatment scenario was the dominant nitrogen loss pathway. The field-level loss of nitrogen with surface runoff (sediment attached and soluble) in these subregions averaged 4 pounds per acre per year less with additional treatment compared to the baseline, representing a reduction due to additional treatment of 78 percent at the field level. But these benefits were offset by increases in the loss of nitrogen in subsurface flow pathways, which increased 10 pounds per acre per year at the field level due to the additional practices in these subregions. A portion of this additional nitrogen loss came from leaching of nitrogen stocks in the soil. The change in soil nitrogen fell from an average annual gain of about 1 pound per acre per year in the baseline to an average annual loss of 11 pounds per acre in the treatment scenario.

Second, there is a higher frequency of livestock grazing on small grain acreage in these subregions than in other subregions. Adding the structural practices reduces runoff losses and retains more moisture, which in turn enhances crop growth. The length of time that grazing occurs in the model simulation is determined by the amount of crop growth. Thus, the amount of grazing increases and the amount of manure produced by grazing livestock also increases in these subregions due to conservation practice use. A portion of this additional soluble nitrogen is then lost from the farm fields in these subregions, primarily through subsurface flow pathways.

Another factor may be that the model results seen here are in part an artifact of the conservation system protocols established for use in all CEAP regions. The goal of the improved treatment scenarios was to provide an estimate of the potential improvements using a simple approach to conservation treatment needs that was consistently applied to all 12 CEAP regions. The unique climate and agricultural systems of the watersheds in this region, however, may require a more refined set of treatment protocols to appropriately simulate a complete conservation plan that addresses both erosion and nutrient losses.

Nevertheless, the increase in nitrogen loads delivered to rivers and streams as a result of treatment of all undertreated acres in these subregions highlights the need for sound conservation planning at the local level to insure expected results.

Table 46. Average annual nitrogen loads at the ***edge of field*** (APEX model output) and ***delivered from cultivated cropland to rivers and streams*** for the baseline conservation condition, Texas Gulf Basin

	Edge-of-field loads		Delivered to rivers and streams		
Subregions	Amount (1,000 pounds)	Pounds per cultivated cropland acre	Amount (1,000 pounds)*	Percent of regional total	Pounds delivered per cultivated cropland acre
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	54,575	40	42,495	21%	31
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	30,970	6	30,640	15%	6
Lower and Middle Brazos River Basin (codes 1206, 1207)	30,630	11	24,860	12%	9
Upper Colorado River Basin (code 1208)	19,160	6	14,400	7%	4
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	14,140	11	11,110	6%	9
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	48,270	37	34,040	17%	26
Nueces River-Southwestern Texas Coastal (code 1211)	55,660	26	44,320	22%	20
Regional total	253,405	15	201,865	100%	12

* Loads delivered to rivers and streams also include wind erosion loads from cultivated cropland, which are not included in the edge-of-field amount.
Note: Loads represent both cropped acres and land in long-term conserving cover.
Note: Columns may not add to totals because of rounding.

Table 47. Nitrogen loads ***delivered to rivers and streams*** by source, baseline conservation condition, Texas Gulf Basin

Subregions	All sources	Cultivated cropland*	Hayland	Pasture and rangeland	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 pounds)			
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	370,164	42,495	3,071	26,746	26,784	242,132	28,925
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	31,418	30,640	0	392	292	59	36
Lower and Middle Brazos River Basin (codes 1206, 1207)	55,784	24,860	292	12,385	3,845	10,092	4,306
Upper Colorado River Basin (code 1208)	16,148	14,400	0	505	362	844	37
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	31,458	11,110	189	5,484	1,588	9,489	3,595
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	81,498	34,040	521	9,225	3,532	29,077	5,098
Nueces River-Southwestern Texas Coastal (code 1211)	74,922	44,320	28	3,593	2,396	21,908	2,675
Regional total	661,392	201,865	4,101	58,330	38,799	313,600	44,672
				Percent of all sources			
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	100	11%	1%	7%	7%	65%	8%
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	100	98%	0%	1%	1%	<1%	0%
Lower and Middle Brazos River Basin (codes 1206, 1207)	100	45%	1%	22%	7%	18%	8%
Upper Colorado River Basin (code 1208)	100	89%	0%	3%	2%	5%	0%
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	100	35%	1%	17%	5%	30%	11%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	100	42%	1%	11%	4%	36%	6%
Nueces River-Southwestern Texas Coastal (code 1211)	100	59%	<1%	5%	3%	29%	4%
Regional total	100	31%	1%	9%	6%	47%	7%

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, horticulture, and barren land.

Table 48. Effects of conservation practices on average annual nitrogen loads ***delivered to rivers and streams from cultivated cropland,*** Texas Gulf Basin

Subregions	Baseline conservation condition (1,000 pounds)	No-practice scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	42,495	48,669	6,174	13%
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	30,640	91,010	60,370	66%
Lower and Middle Brazos River Basin (codes 1206, 1207)	24,860	33,920	9,060	27%
Upper Colorado River Basin (code 1208)	14,400	41,450	27,050	65%
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	11,110	21,830	10,720	49%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	34,040	45,510	11,470	25%
Nueces River-Southwestern Texas Coastal (code 1211)	44,320	58,100	13,780	24%
Regional total	201,865	340,489	138,624	41%

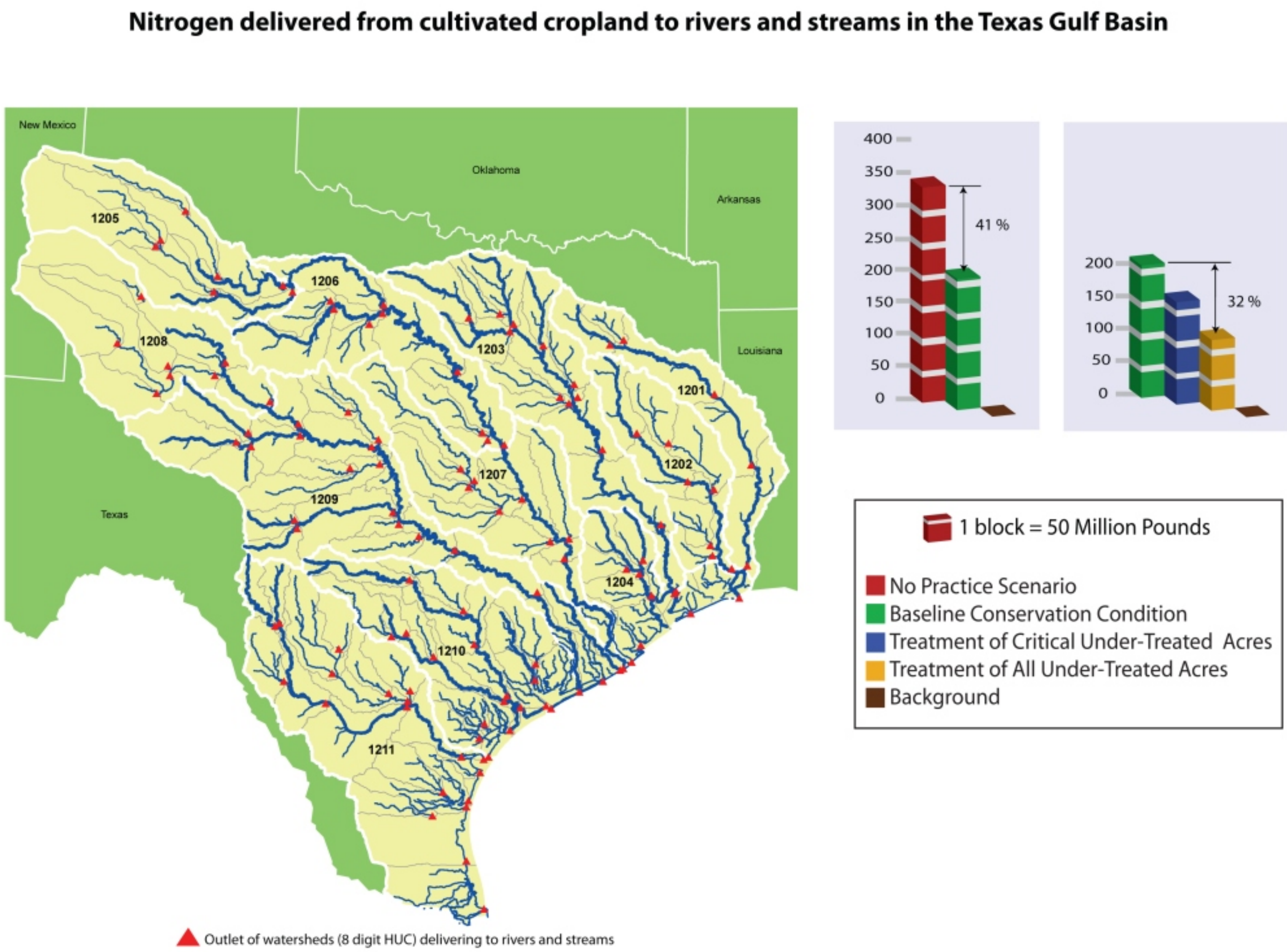
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Table 49. Effects of additional conservation treatment with erosion control practices and nutrient management practices on average annual nitrogen loads ***delivered to rivers and streams*** from cultivated cropland, Texas Gulf Basin

		Treatment of critical undertreated acres			Treatment of all undertreated acres		
Subregions	Baseline conservation condition (1,000 pounds)	Amount (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction	Amount (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	42,495	42,101	394	1%	21,259	21,236	50%
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	30,640	26,070	4,570	15%	23,230	7,410	24%
Lower and Middle Brazos River Basin (codes 1206, 1207)	24,860	23,868	992	4%	36,390	-11,530	-46%
Upper Colorado River Basin (code 1208)	14,400	13,450	950	7%	10,330	4,070	28%
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	11,110	9,978	1,132	10%	9,655	1,455	13%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	34,040	34,040	0	0%	18,780	15,260	45%
Nueces River-Southwestern Texas Coastal (code 1211)	44,320	21,840	22,480	51%	18,460	25,860	58%
Regional total	201,865	171,347	30,518	15%	138,104	63,761	32%

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.
Note: Critical undertreated acres have “high” need for additional treatment. All undertreated acres have either a “high” or “moderate” need for additional treatment.

Figure 90. Effects of conservation practices on average annual nitrogen loads delivered to rivers and streams, Texas Gulf Basin



Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.

Total Phosphorus

Baseline condition. Model simulation results show that of the 11.6 million pounds of phosphorus exported from farm fields in the Texas Gulf Basin (table 50), about 9.0 million pounds are delivered to rivers and streams each year, on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006. About 77 percent of the phosphorus delivered to rivers and streams from cultivated cropland originates in four subregions (table 50):

- the Lower and Middle Brazos River Basin (codes 1206, 1207), with 21 percent of the regional total,
- the Nueces River-Southwestern Texas Coastal (code 1211), with 20 percent of the regional total,
- the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204), with 18 percent of the regional total, and
- the Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205), with 18 percent of the regional total.

On a per-acre basis, phosphorus delivery to rivers and streams is, on average, 0.52 pound per acre of cultivated cropland for the region, but is about twice this high in two subregions, (table 50):

- the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204), with 1.16 pounds per cultivated cropland acre, and
- the Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210), with 0.95 pound per cultivated cropland acre.

Phosphorus delivered to rivers and streams from cultivated cropland represents about 7 percent of the total phosphorus load delivered from all sources in the region (table 51, fig. 91). This percentage ranges from a low of 2 percent in the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204) to highs in these two subregions:

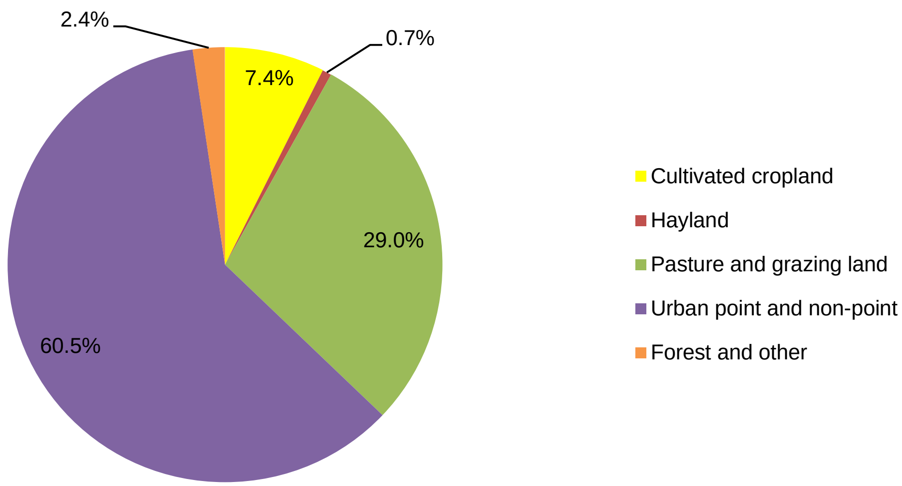
- Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205), with 82 percent, and
- the Upper Colorado River Basin (code 1208), with 48 percent.

Urban point sources and non-point sources account for about 61 percent of the phosphorus delivered to rivers and streams in this region (table 51, fig. 91). Urban contributions are highest in the combination of subregions with the largest urban centers in the watershed, the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204), where point sources account for about 54 million pounds of phosphorus per year, representing 72 percent of the phosphorus delivered to rivers and streams in that subregion and 45 percent of phosphorus loads from all sources in the entire region.

Pastureland and rangeland account for 29 percent of the phosphorus loads delivered to rivers and streams within the region (table 51, fig. 91). The percentage of phosphorus loads originating from pastureland and rangeland range from 14 percent in the Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205) to 71 percent in the Lower and Middle Brazos River Basin (codes 1206, 1207).

Hayland and forest and other land covers are minor contributors to phosphorus loads in all subregions.

Figure 91. Percentage by source of average annual phosphorus loads delivered to rivers and streams for the baseline conservation condition, Texas Gulf Basin



Effects of conservation practices. Model simulations indicate that conservation practices have reduced the delivery of phosphorus from fields to rivers and streams by a total of 11 million pounds per year, on average, representing a 55-percent reduction (table 52, fig. 92). Percent reductions due to conservation practices vary throughout the region, ranging from lows of 34 percent in the Nueces River-Southwestern Texas Coastal (code 1211) and the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204) to a high of 90 percent in the Upper Colorado River Basin (code 1208).

Potential gains from further conservation treatment. Model simulations show that use of additional erosion control and nutrient management practices on the critical undertreated acres in the region (41 percent of cropped acres) would reduce phosphorus loads delivered to rivers and streams from cultivated cropland by about 2.9 million pounds per year, representing a reduction from baseline levels of 32 percent (table 53).

Expanding this treatment to all undertreated acres (97 percent of cropped acres) would reduce phosphorus loads delivered to rivers and streams from cultivated cropland by 5.7 million pounds per year, representing a reduction from the baseline level of 63 percent (table 53 and fig. 92). The largest gain in terms of pounds saved would occur in three subregions (table 53):

- the Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205), with a reduction of 1.5 million pounds (a 94-percent reduction from the baseline level),
- the Nueces River-Southwestern Texas Coastal (code 1211), with a reduction of 1.3 million pounds (a 76-percent reduction from the baseline level), and
- the Lower and Middle Brazos River Basin (codes 1206, 1207), with a reduction of 1.2 million pounds (a 62-percent reduction from the baseline level).

Table 50. Average annual phosphorus loads at the ***edge of field*** (APEX model output) and ***delivered from cultivated cropland to rivers and streams*** for the baseline conservation condition, Texas Gulf Basin

Subregions	Edge-of-field loads: Amount (1,000 pounds)	Edge-of-field loads: Pounds per cultivated cropland acre	Delivered to rivers and streams: Amount (1,000 pounds)*	Delivered to rivers and streams: Percent of regional total	Delivered to rivers and streams: Pounds delivered per cultivated cropland acre
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	2,947	2.16	1,588	18%	1.16
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	1,013	0.21	1,626	18%	0.33
Lower and Middle Brazos River Basin (codes 1206, 1207)	2,942	1.03	1,885	21%	0.66
Upper Colorado River Basin (code 1208)	250	0.08	372	4%	0.11
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	669	0.54	498	6%	0.40
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	2,255	1.74	1,239	14%	0.95
Nueces River-Southwestern Texas Coastal (code 1211)	1,525	0.70	1,754	20%	0.81
Regional total	11,600	0.68	8,961	100%	0.52

* Loads delivered to rivers and streams also include wind erosion loads from cultivated cropland, which are not included in the edge-of-field amount.
Note: Loads represent both cropped acres and land in long-term conserving cover.
Note: Columns may not add to totals because of rounding.

Table 51. Phosphorus loads ***delivered to rivers and streams*** by source, baseline conservation condition, Texas Gulf Basin

Subregions	All sources	Cultivated cropland*	Hayland	Pasture and rangeland	Urban nonpoint sources**	Urban point sources	Forest and other***
				Amount (1,000 pounds)			
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	74,745	1,588	476	13,080	3,863	54,096	1,639
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	1,992	1,626	0	275	66	15	11
Lower and Middle Brazos River Basin (codes 1206, 1207)	14,857	1,885	106	10,480	527	1,650	209
Upper Colorado River Basin (code 1208)	770	372	0	221	21	154	1
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	6,218	498	82	3,544	376	1,228	490
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	13,666	1,239	156	5,638	594	5,672	366
Nueces River-Southwestern Texas Coastal (code 1211)	8,545	1,754	4	1,822	526	4,263	176
Regional total	120,794	8,961	824	35,061	5,973	67,078	2,892
				Percent of all sources			
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	100	2%	1%	18%	5%	72%	2%
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	100	82%	0%	14%	3%	1%	1%
Lower and Middle Brazos River Basin (codes 1206, 1207)	100	13%	1%	71%	4%	11%	1%
Upper Colorado River Basin (code 1208)	100	48%	0%	29%	3%	20%	<1%
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	100	8%	1%	57%	6%	20%	8%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	100	9%	1%	41%	4%	42%	3%
Nueces River-Southwestern Texas Coastal (code 1211)	100	21%	<1%	21%	6%	50%	2%
Regional total	100	7%	1%	29%	5%	56%	2%

* Includes land in long-term conserving cover, excludes horticulture.
** Includes construction sources and urban land runoff.
*** Includes forests (all types), wetlands, horticulture, and barren land.

Table 52. Effects of conservation practices on average annual phosphorus loads ***delivered to rivers and streams from cultivated cropland,*** Texas Gulf Basin

Subregions	Baseline conservation condition (1,000 pounds)	No-practice scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	1,588	2,423	835	34%
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	1,626	4,743	3,117	66%
Lower and Middle Brazos River Basin (codes 1206, 1207)	1,885	3,433	1,548	45%
Upper Colorado River Basin (code 1208)	372	3,656	3,284	90%
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	498	1,039	541	52%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	1,239	2,110	871	41%
Nueces River-Southwestern Texas Coastal (code 1211)	1,754	2,664	910	34%
Regional total	8,961	20,068	11,107	55%

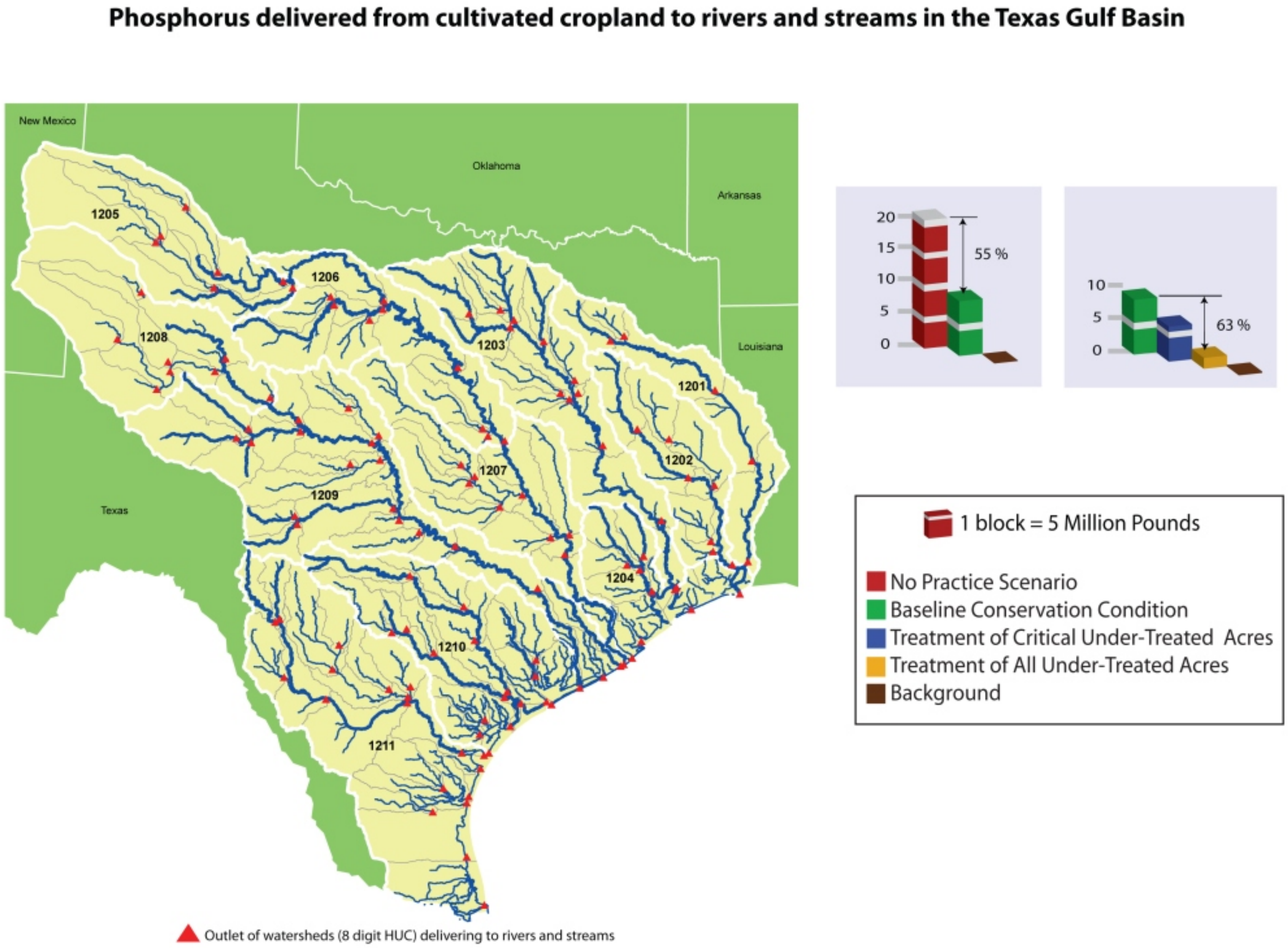
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Table 53. Effects of additional conservation treatment with erosion control practices and nutrient management practices on average annual phosphorus loads ***delivered to rivers and streams*** from cultivated cropland, Texas Gulf Basin

		Treatment of critical undertreated acres			Treatment of all undertreated acres		
Subregions	Baseline conservation condition (1,000 pounds)	Amount (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction	Amount (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	1,588	1,524	64	4%	1,009	579	36%
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	1,626	537	1,089	67%	102	1,524	94%
Lower and Middle Brazos River Basin (codes 1206, 1207)	1,885	1,544	340	18%	724	1,160	62%
Upper Colorado River Basin (code 1208)	372	130	242	65%	27	345	93%
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	498	379	119	24%	238	259	52%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	1,239	1,211	28	2%	761	478	39%
Nueces River-Southwestern Texas Coastal (code 1211)	1,754	737	1,017	58%	421	1,333	76%
Regional total	8,961	6,062	2,899	32%	3,282	5,679	63%

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.
Note: Critical undertreated acres have “high” need for additional treatment. All undertreated acres have either a “high” or “moderate” need for additional treatment.

Figure 92. Effects of conservation practices on average annual phosphorus loads delivered to rivers and streams, Texas Gulf Basin



Note: "Background sources" represent loads that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.

Atrazine

Although the full suite of pesticides was modeled for edge-of-field losses, atrazine was the only pesticide for which instream loads were assessed because it was the dominant contributor to mass loss of pesticide residues from farm fields and the primary contributor to environmental risk from pesticides in the region. First registered in the United States in 1959, atrazine is used to control broadleaf and grassy weeds. Cultivated cropland (primarily corn acres) was the only source for atrazine in the model simulations.

Atrazine is not used as heavily in the Texas Gulf Basin as in some of the other regions of the country. Based on the 2003–06 NRI-CEAP survey findings, about 19 percent of cropped acres in the Texas Gulf Basin had atrazine applied in one or more years. For comparison, atrazine was used on 52 percent of cropped acres in the eastern portion of the Missouri River Basin. The Ohio-Tennessee River basin had atrazine applied to 71 percent of the cropped acres, and the Upper Mississippi River Basin had atrazine applied to 60 percent of cropped acres. Atrazine was applied to 37 percent of cropped acres nationwide in 2003–06.

Baseline condition. Model simulation results show that of the 13,600 pounds of atrazine exported from farm fields in the Texas Gulf Basin (table 54), about 10,600 pounds are delivered to rivers and streams each year, on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006.

Approximately 83 percent of the atrazine delivered to rivers and streams is from three subregions or combinations of subregions:

- the Lower and Middle Brazos River Basin (codes 1206, 1207), delivering 4,500 pounds per year (43 percent of the regional total),
- the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204), delivering 2,440 pounds per year (23 percent of the regional total), and
- Middle and Lower Colorado-Conchos-Liano-San Bernard Coastal (code 1209), delivering 1,800 pounds per year (17 percent of the regional total).

Effects of conservation practices. Conservation practices—especially Integrated Pest Management (IPM) techniques and soil erosion control practices—can be effective in reducing the amount of atrazine lost from farm fields and delivered to rivers and streams. Model simulations indicate that conservation practices in this region have reduced the delivery of atrazine to rivers and streams by about 5,950 pounds per year, representing a reduction of 36 percent (table 55 and fig. 93), on average.

Potential gains from further conservation treatment. Model simulations show that use of additional erosion control and nutrient management practices on the critical undertreated acres in the region (41 percent of cropped acres) would reduce atrazine loads delivered to rivers and streams from cultivated cropland by about 520 pounds per year, representing a reduction from baseline levels of 5 percent (table 56). While this is a small benefit, it is not surprising as most of these acres needed additional treatment only for wind erosion, and were not located in areas where atrazine was used frequently.

Expanding this treatment to all undertreated acres (97 percent of cropped acres) would, however, significantly reduce atrazine delivered to rivers and streams from cultivated cropland. Overall, atrazine delivered to rivers and streams would be reduced by 8,430 pounds per year, representing an 80-percent reduction from baseline conditions (table 56 and fig. 93).

Table 54. Average annual atrazine loads at the ***edge of field*** (APEX model output) and ***delivered from cultivated cropland to rivers and streams*** for the baseline conservation condition, Texas Gulf Basin

Subregions	Edge-of-field loads: Amount (1,000 pounds)	Edge-of-field loads: Pounds per cultivated cropland acre	Delivered to rivers and streams: Amount (1,000 pounds)*	Delivered to rivers and streams: Percent of regional total	Delivered to rivers and streams: Pounds delivered per cultivated cropland acre
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	2.10	0.0015	2.44	23%	0.0018
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	1.14	0.0002	0.48	5%	0.0001
Lower and Middle Brazos River Basin (codes 1206, 1207)	3.48	0.0012	4.50	43%	0.0016
Upper Colorado River Basin (code 1208)	0.29	0.0001	<0.01	<1%	<0.0001
Middle and Lower Colorado-Conchos-Liano-San Bernard Coastal (code 1209)	1.53	0.0012	1.80	17%	0.0014
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	1.80	0.0014	0.71	7%	0.0005
Nueces River-Southwestern Texas Coastal (code 1211)	3.29	0.0015	0.67	6%	0.0003
Regional total	13.62	0.0008	10.60	100%	0.0006

* Loads delivered to rivers and streams also include wind erosion loads from cultivated cropland, which are not included in the edge-of-field amount.
Note: Loads represent both cropped acres and land in long-term conserving cover.
Note: Columns may not add to totals because of rounding.

Table 55. Effects of conservation practices on average annual atrazine loads ***delivered to rivers and streams from cultivated cropland,*** Texas Gulf Basin

Subregions*	Baseline conservation condition (1,000 pounds)	No-practice scenario (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	2.44	3.31	0.87	26%
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	0.48	2.42	1.94	80%
Lower and Middle Brazos River Basin (codes 1206, 1207)	4.50	4.50	<0.01	<1%
Upper Colorado River Basin (code 1208)	<0.01	0.05	0.05	100%
Middle and Lower Colorado-Conchos-Liano-San Bernard Coastal (code 1209)	1.80	1.99	0.20	10%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	0.71	2.80	2.09	75%
Nueces River-Southwestern Texas Coastal (code 1211)	0.67	1.50	0.83	55%
Regional total	10.60	16.55	5.95	36%

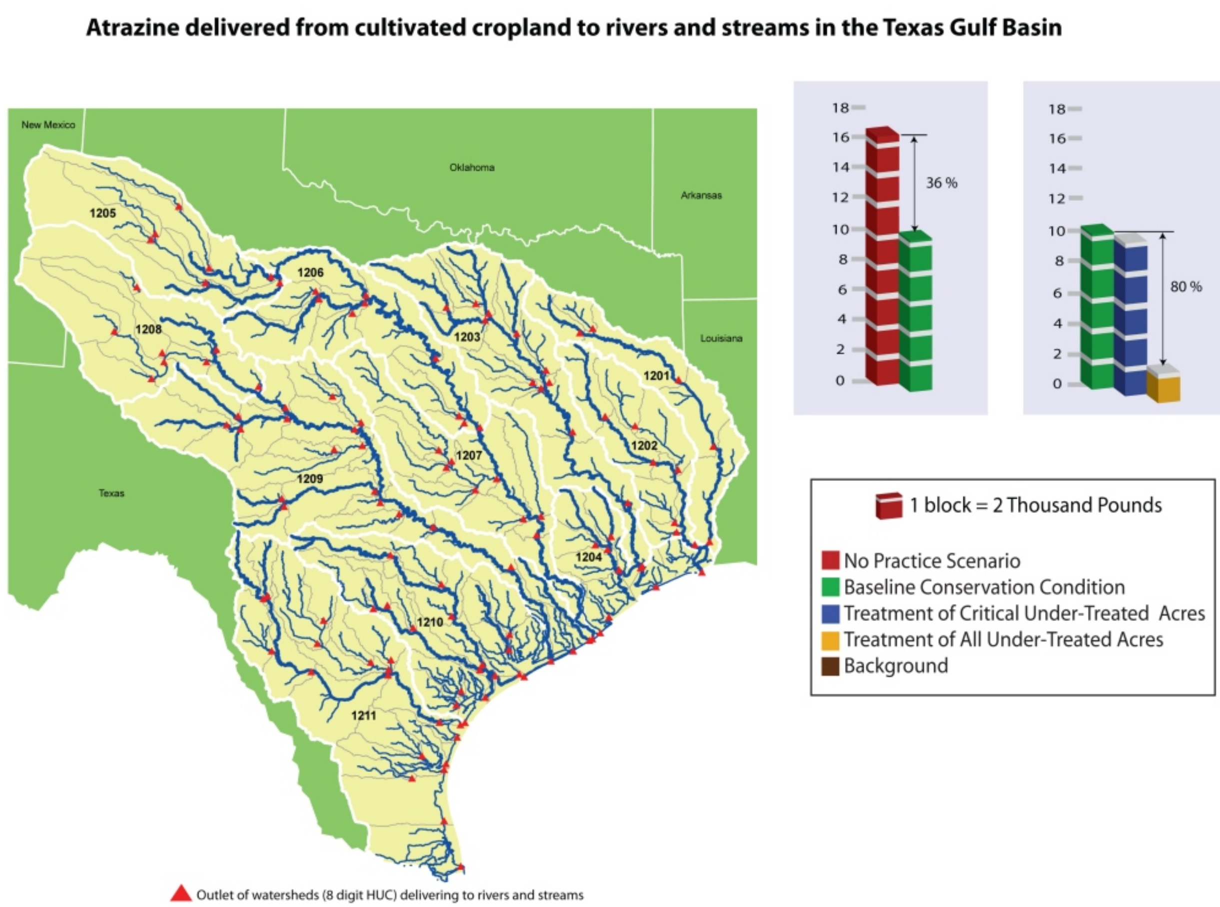
***** Only subregions with significant atrazine use are shown.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Table 56. Effects of additional conservation treatment with erosion control practices and nutrient management practices on average annual atrazine loads ***delivered to rivers and streams*** from cultivated cropland, Texas Gulf Basin

		Treatment of critical undertreated acres			Treatment of all undertreated acres		
Subregions	Baseline conservation condition (1,000 pounds)	Amount (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction	Amount (1,000 pounds)	Reduction (1,000 pounds)	Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	2.44	2.41	0.03	1%	1.00	1.43	59%
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)	0.48	0.42	0.06	12%	0.03	0.45	94%
Lower and Middle Brazos River Basin (codes 1206, 1207)	4.50	4.46	0.05	1%	0.58	3.92	87%
Upper Colorado River Basin (code 1208)	<0.01	<0.01	<0.01	<1%	<0.01	<0.01	<1%
Middle and Lower Colorado-Conchos-Llano-San Bernard Coastal (code 1209)	1.80	1.76	0.04	2%	0.15	1.65	92%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	0.71	0.71	0.00	0%	0.25	0.46	65%
Nueces River-Southwestern Texas Coastal (code 1211)	0.67	0.31	0.35	53%	0.15	0.51	77%
Regional total	10.60	10.07	0.52	5%	2.17	8.43	80%

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.
Note: Critical undertreated acres have “high” need for additional treatment. All undertreated acres have either a “high” or “moderate” need for additional treatment.

Figure 93. Effects of conservation practices on average annual atrazine loads delivered to rivers and streams, Texas Gulf Basin



Instream Loads from All Sources

Instream loads are estimated by starting with the loads delivered from all sources at the outlet of each 8-digit HUC and routing those loads downstream. Stream and channel processes are simulated, including flood routing, instream degradation processes, streambed deposition, streambank erosion, and reservoir dynamics. A portion of the sediment, nutrients, and pesticides delivered to rivers and streams is removed or trapped during these processes. Some of the nitrogen is lost during instream nitrification processes, and a portion of the sediment and sediment-bound nutrients and pesticides is deposited in streambeds and flood plains during transit. Large reservoirs can trap significant amounts of loads delivered to rivers and streams, keeping those loads from being transferred downstream. Sediment can also be added to instream loads through streambank erosion and streambed scouring.

The instream loads for outlets along the Gulf of Mexico include loads from upstream sources and additional loads contributed from within the subregion. In general these mainstem loads are smallest near the headwaters and largest near the outlets, as the loads tend to accumulate moving downstream. The presence of lakes and reservoirs along the mainstem of the river disrupt this trend when significant amounts of sediment are trapped within those water bodies. Sediment deposition in the major reservoirs along the main stems of the Colorado and Brazos Rivers, in particular, has a profound impact on sediment loading in the Gulf of Mexico. The vast majority of sediments from the northwestern portions of these basins is trapped in reservoirs and never reaches the Gulf of Mexico. Nutrients and pesticides bound to sediment particles can also be trapped in these reservoirs.

In summary, findings for the Texas Gulf Basin indicate that instream ***loads from all sources delivered from the region to the Gulf of Mexico*** *per year, on average, are—*

- *16.2 million tons of sediment (24 percent attributable to cultivated cropland sources);*
- *336 million pounds of nitrogen (26 percent attributable to cultivated cropland sources);*
- *80 million pounds of phosphorus (8 percent attributable to cultivated cropland sources); and*
- *6,300 pounds of atrazine (all assumed to be from cultivated cropland sources).*

Conservation practices in use on cultivated cropland in 2003–06, including land in long-term conserving cover, have reduced ***instream loads from all sources delivered from the region to the Gulf of Mexico*** *per year, on average, by—*

- *12 percent for sediment;*
- *10 percent for nitrogen;*
- *6 percent for phosphorus; and*
- *33 percent for atrazine.*

Additional conservation treatment of the 7.6 million critical undertreated acres in the region would be expected to further reduce ***instream loads from all sources delivered from the region to the Gulf of Mexico*** *per year relative to the baseline, on average, by—*

- *8 percent for sediment;*
- *4 percent for nitrogen;*
- *2 percent for phosphorus; and*
- *6 percent for atrazine.*

Additional conservation treatment of all undertreated acres in the region (97 percent of cropped acres) would be expected to further reduce ***instream loads from all sources delivered from the region to the Gulf of Mexico*** *per year relative to the baseline, on average, by—*

- *19 percent for sediment;*
- *8 percent for nitrogen;*
- *4 percent for phosphorus, and*
- *83 percent for atrazine.*

Sediment

Baseline condition. Sediment loads delivered to rivers and streams from all sources totaled about 22.9 million tons per year (table 43), averaged over the 47 years of weather as simulated in the model. Instream sediment loads delivered to the Gulf of Mexico, after accounting for instream deposition, reservoir dynamics, streambank erosion, and other transport processes, was less—about 16.2 million tons per year (table 57). The decrease in sediment loadings is attributed to the retention of sediment in lakes and reservoirs throughout the region.

About 24 percent of the instream sediment load delivered to the Gulf of Mexico is attributed to cultivated cropland sources in the model simulation. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the "background" scenario (no cultivation) from the total load from all sources in the baseline conservation scenario (table 57).

The largest contribution of instream sediment loads among the subregions is from the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204), with 5.0 million tons per year (table 57, fig. 94). However, only about 8 percent is from cultivated cropland sources; the rest comes from non-cropland sources within the subregions. The second largest contribution is from the Brazos River Basin (outlet at 1207, including upstream loads from subregions 1205 and 1206), with 4.4 million tons, of which 26 percent is attributable to cultivated cropland. The subregion with the largest contribution to instream loads *from cultivated cropland* is the Nueces River-Southwestern Texas Coastal (code 1211), with 3.1 million tons of sediment per year, of which 46 percent is attributable to cultivated cropland.

Effects of conservation practices. Model simulations of instream loads indicate that conservation practices have reduced the delivery of sediment from the Texas Gulf Basin to the Gulf of Mexico by about 12 percent overall (table 57 and figs. 94 and 95). Without conservation practices, the total sediment delivered to the Gulf of Mexico would be larger by 2.3 million tons per year.

Potential gains from further conservation treatment. Because of the relatively low levels of water-eroded sediment loss from farm fields throughout most of this region and the relatively large contributions of sediment from sources other than cultivated cropland, the potential for reductions in instream loads from further cropland conservation treatment is limited for this region, as shown in table 58 and figure 94.

Treatment of the 7.6 million critical undertreated acres in the region with additional erosion control practices would be expected to reduce instream loads delivered to the Gulf of Mexico by about 1.4 million tons, representing an 8-percent reduction compared to the baseline conservation condition.

Expanding this treatment to all undertreated acres (97 percent of cropped acres) would be expected to reduce instream loads delivered to the Gulf of Mexico by about 19 percent—totaling 3.0 million tons. The largest percent reduction would occur in the Nueces River-Southwestern Texas Coastal (code 1211)—39 percent.

Table 57. Average annual ***instream sediment loads*** (all sources) for the baseline conservation condition, no-practice scenario, and the erosion control with nutrient management treatment scenario, Texas Gulf Basin

	Baseline conservation condition			No practice scenario		
Subregions	Load from all sources (1,000 tons)	Background sources* (1,000 tons)	Percent of load attributed to cultivated cropland sources	Load from all sources (1,000 tons)	Reductions due to conservation practices (1,000 tons)	Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	5,017	4,641	8%	5,199	182	3%
Brazos River Basin (outlet at 1207, includes upstream loads from 1205 and 1206)	4,406	3,250	26%	5,508	1,102	20%
Colorado-Conchos-Llano-San Bernard Coastal (outlet at 1209, includes upstream loads from 1208)	841	627	25%	1,097	256	23%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	2,918	2,251	23%	3,125	207	7%
Nueces River-Southwestern Texas Coastal (code 1211)	3,053	1,637	46%	3,586	533	15%
Total load from all outlets delivered to the Gulf	16,235	12,406	24%	18,515	2,280	12%

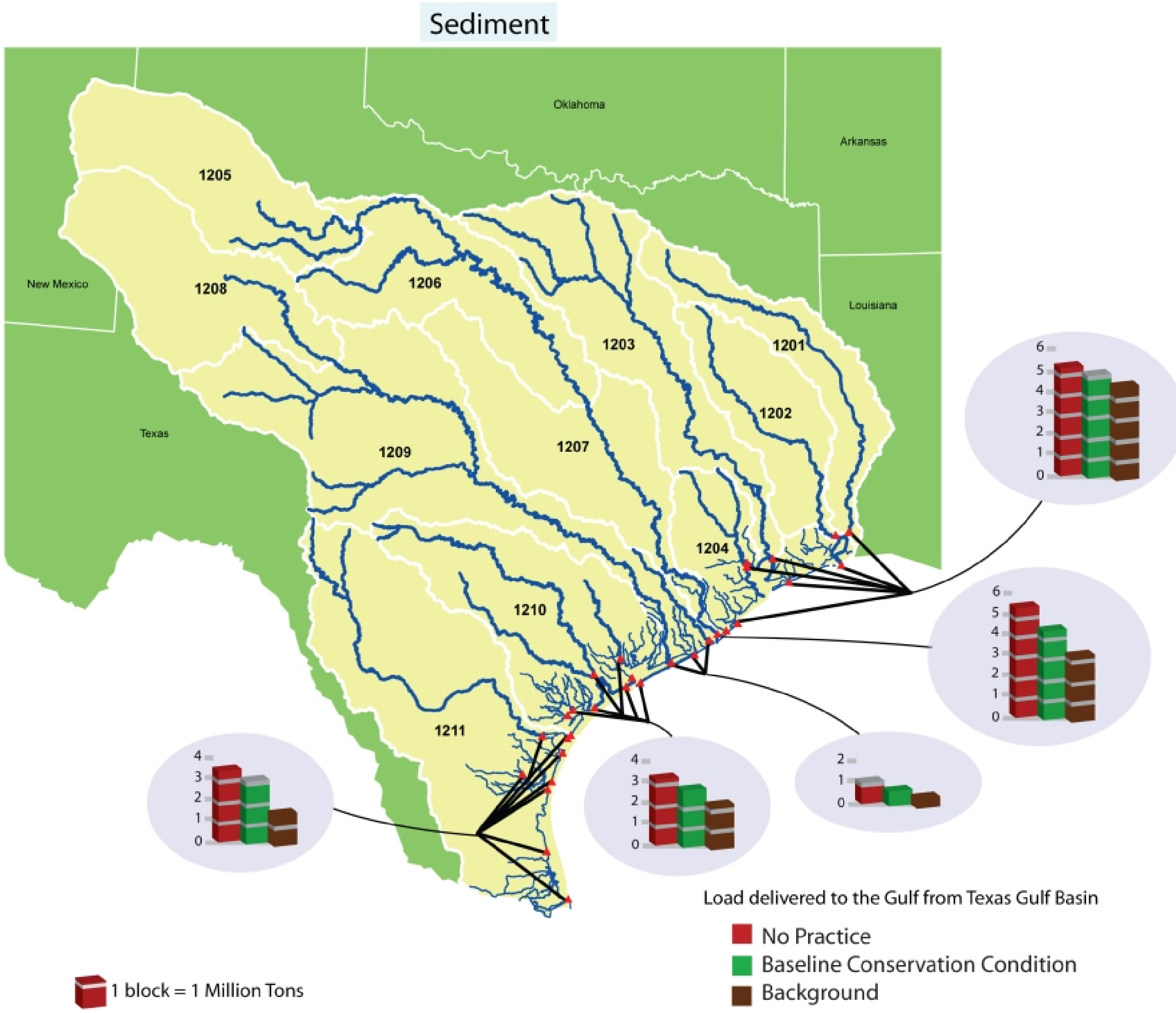
***** "Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 58. Effects of additional conservation treatment with erosion control practices and nutrient management practices on average annual ***instream sediment loads*** (all sources), Texas Gulf Basin

	Baseline conservation condition	Treatment of critical undertreated acres			Treatment of all undertreated acres		
Subregions	Load from all sources (1,000 tons)	Load from all sources (1,000 tons)	Reductions from baseline due to additional conservation treatment (1,000 tons)	Percent reduction	Load from all sources (1,000 tons)	Reductions from baseline due to additional conservation treatment (1,000 tons)	Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	5,017	5,013	4	0%	4,797	221	4%
Brazos River Basin (outlet at 1207, includes upstream loads from 1205 and 1206)	4,406	4,115	291	7%	3,391	1,015	23%
Colorado-Conchos-Llano-San Bernard Coastal (outlet at 1209, includes upstream loads from 1208)	841	799	42	5%	706	135	16%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	2,918	2,908	10	0%	2,458	460	16%
Nueces River-Southwestern Texas Coastal (code 1211)	3,053	2,046	1,007	33%	1,873	1,180	39%
Total load from all outlets to the Gulf	16,235	14,881	1,354	8%	13,224	3,011	19%

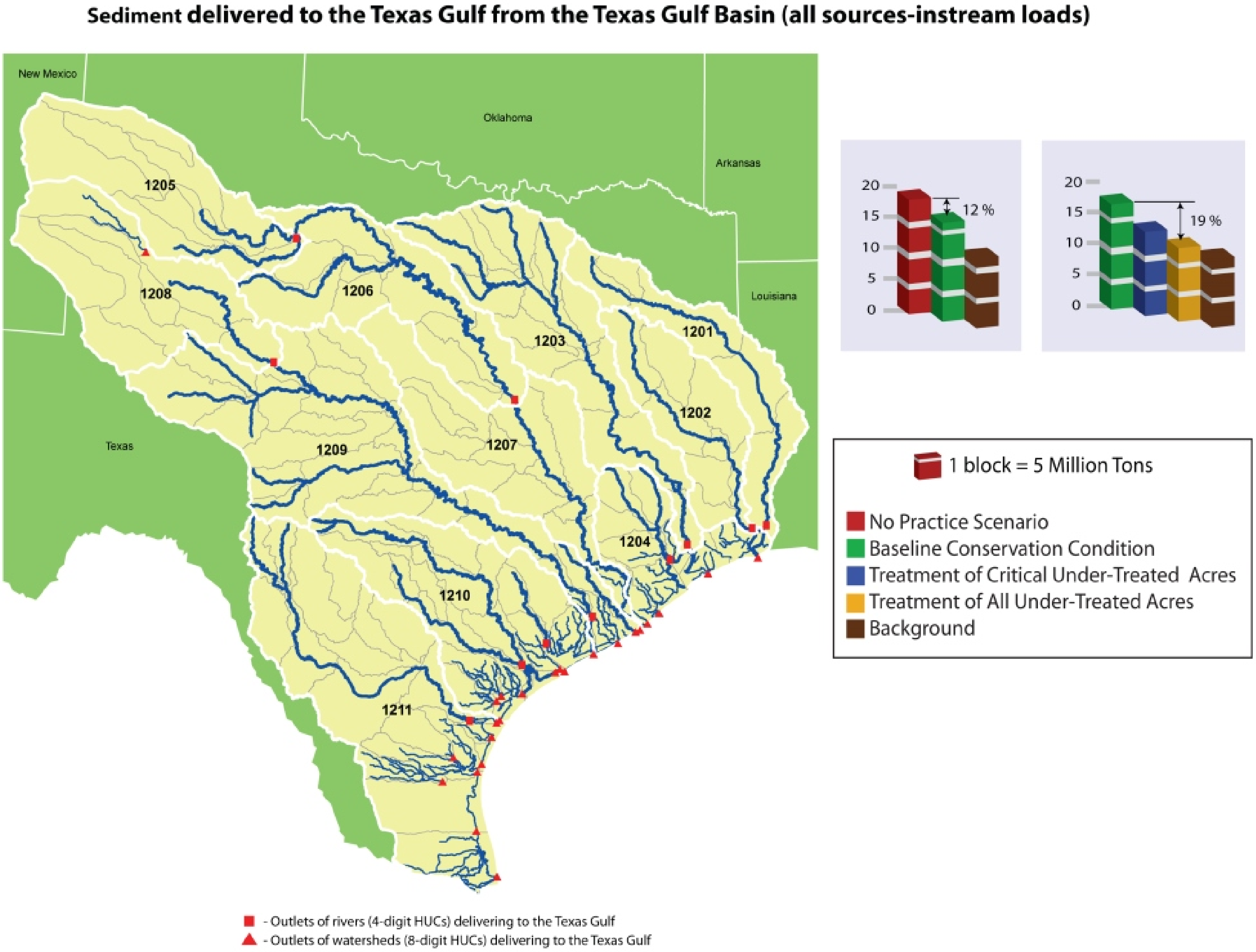
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Critical undertreated acres have "high" need for additional treatment. All undertreated acres have either a "high" or "moderate" need for additional treatment.

Figure 94. Effects of conservation practices on average annual instream sediment loads, Texas Gulf Basin



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

Figure 95. Effects of conservation practices on average annual instream sediment loads delivered to the Gulf, Texas Gulf Basin



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

Total Nitrogen

Baseline condition. Nitrogen loads delivered to rivers and streams from all sources totaled about 661 million pounds per year (table 47). Instream nitrogen loads delivered to the Gulf of Mexico, after accounting for instream deposition, reservoir dynamics, and other transport processes, was much lower, totaling about 336 million pounds per year, averaged over the 47 years of weather as simulated in the model (table 59).

About 26 percent of the instream nitrogen load delivered to the Gulf of Mexico is attributed to cultivated cropland sources in the model simulation. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the "background" scenario (no cultivation) from the total load from all sources in the baseline conservation scenario (table 59).

The largest contribution of instream nitrogen loads among the subregions is from the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204), with 199 million pounds per year (table 59, fig. 96). However, only about 7 percent is from cultivated cropland sources; the rest comes from non-cropland sources within the subregions, mostly from urban point sources. The second and third largest contributions are from the Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210), with 47 million pounds of nitrogen per year, and the Nueces River-Southwestern Texas Coastal (code 1211), with 46 million pounds per year. Over half of the loads from these two subregions, as well as those from the Brazos River Basin (outlet at 1207, including upstream loads from 1205 and 1206), are attributable to cultivated cropland sources.

Effects of conservation practices. Model simulations of instream loads indicate that conservation practices have reduced the delivery of nitrogen from the Texas Gulf Basin to the Gulf of Mexico by about 10 percent overall (table 59 and fig. 97). Without conservation practices, the total nitrogen delivered to the Gulf of Mexico would be larger by 37 million pounds per year. The Brazos River Basin (outlet at 1207, including upstream loads from 1205 and 1206) had the largest reduction due to use of conservation practices—15.9 million pounds of nitrogen per year, representing a 37-percent reduction from baseline loads.

Potential gains from further conservation treatment. Treatment of the 7.6 million critical undertreated acres in the region with additional erosion control and nutrient management practices would be expected to reduce instream nitrogen loads delivered to the Gulf of Mexico by about 12.5 million pounds, representing a 4-percent reduction compared to the baseline conservation condition (table 60).

Expanding this treatment to all undertreated acres (97 percent of cropped acres) would be expected to reduce instream nitrogen loads delivered to the Gulf of Mexico by about 8 percent—totaling 27.6 million pounds (table 60, fig. 97). The largest reductions would occur in the Nueces River-Southwestern Texas Coastal (code 1211), with a 29-percent reduction, and the Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210), with a 28-percent reduction.

According to the model simulation, instream loads delivered to the Gulf of Mexico from the Brazos River Basin (outlet at 1207, including upstream loads from 1205 and 1206), could increase by 20 percent due to additional conservation practice use (table 60). This is due to the increase in field-level nitrogen losses in subsurface flow pathways in the Lower and Middle Brazos River Basins (codes 1206 and 1207) as a result of additional conservation treatment in those basins, as discussed in the previous section on nitrogen loads delivered to rivers and streams.

Table 59. Average annual ***instream nitrogen loads*** (all sources) for the baseline conservation condition, no-practice scenario, and the erosion control with nutrient management treatment scenario, Texas Gulf Basin

Subregions	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: Load from all sources (1,000 pounds)	No practice scenario: Reductions due to conservation practices (1,000 pounds)	No practice scenario: Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	198,928	184,374	7%	201,387	2,459	1%
Brazos River Basin (outlet at 1207, includes upstream loads from 1205 and 1206)	27,020	11,750	57%	42,880	15,860	37%
Colorado-Conchos-Llano-San Bernard Coastal (outlet at 1209, includes upstream loads from 1208)	16,890	12,330	27%	20,780	3,890	19%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	47,270	19,640	58%	54,730	7,460	14%
Nueces River-Southwestern Texas Coastal (code 1211)	45,930	20,250	56%	53,310	7,380	14%
Total load from all outlets to the Gulf	336,038	248,344	26%	373,087	37,049	10%

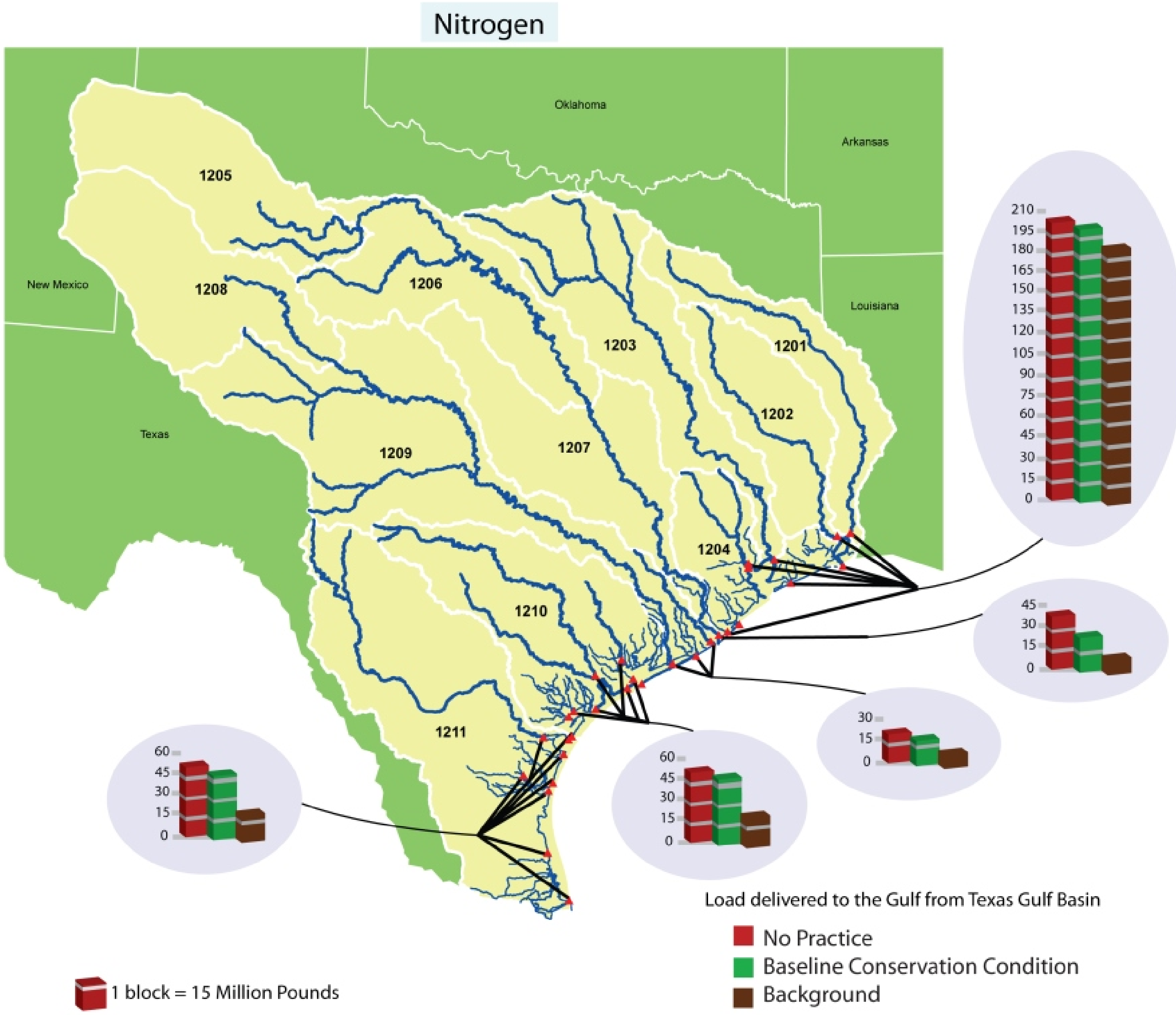
***** "Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 60. Effects of additional conservation treatment with erosion control practices and nutrient management practices on average annual ***instream nitrogen loads*** (all sources), Texas Gulf Basin

Subregions	Baseline conservation condition: Load from all sources (1,000 pounds)	Treatment of critical undertreated acres: Load from all sources (1,000 pounds)	Treatment of critical undertreated acres: Reductions from baseline due to additional conservation treatment (1,000 pounds)	Treatment of critical undertreated acres: Percent reduction	Treatment of all undertreated acres: Load from all sources (1,000 pounds)	Treatment of all undertreated acres: Reductions from baseline due to additional conservation treatment (1,000 pounds)	Treatment of all undertreated acres: Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	198,928	198,871	57	0%	193,090	5,838	3%
Brazos River Basin (outlet at 1207, includes upstream loads from 1205 and 1206)	27,020	25,000	2,020	7%	32,450	-5,430	-20%
Colorado-Conchos-Llano-San Bernard Coastal (outlet at 1209, includes upstream loads from 1208)	16,890	16,890	0	0%	16,570	320	2%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	47,270	47,270	0	0%	33,860	13,410	28%
Nueces River-Southwestern Texas Coastal (code 1211)	45,930	35,520	10,410	23%	32,420	13,510	29%
Total load from all outlets to the Gulf	336,038	323,551	12,487	4%	308,390	27,648	8%

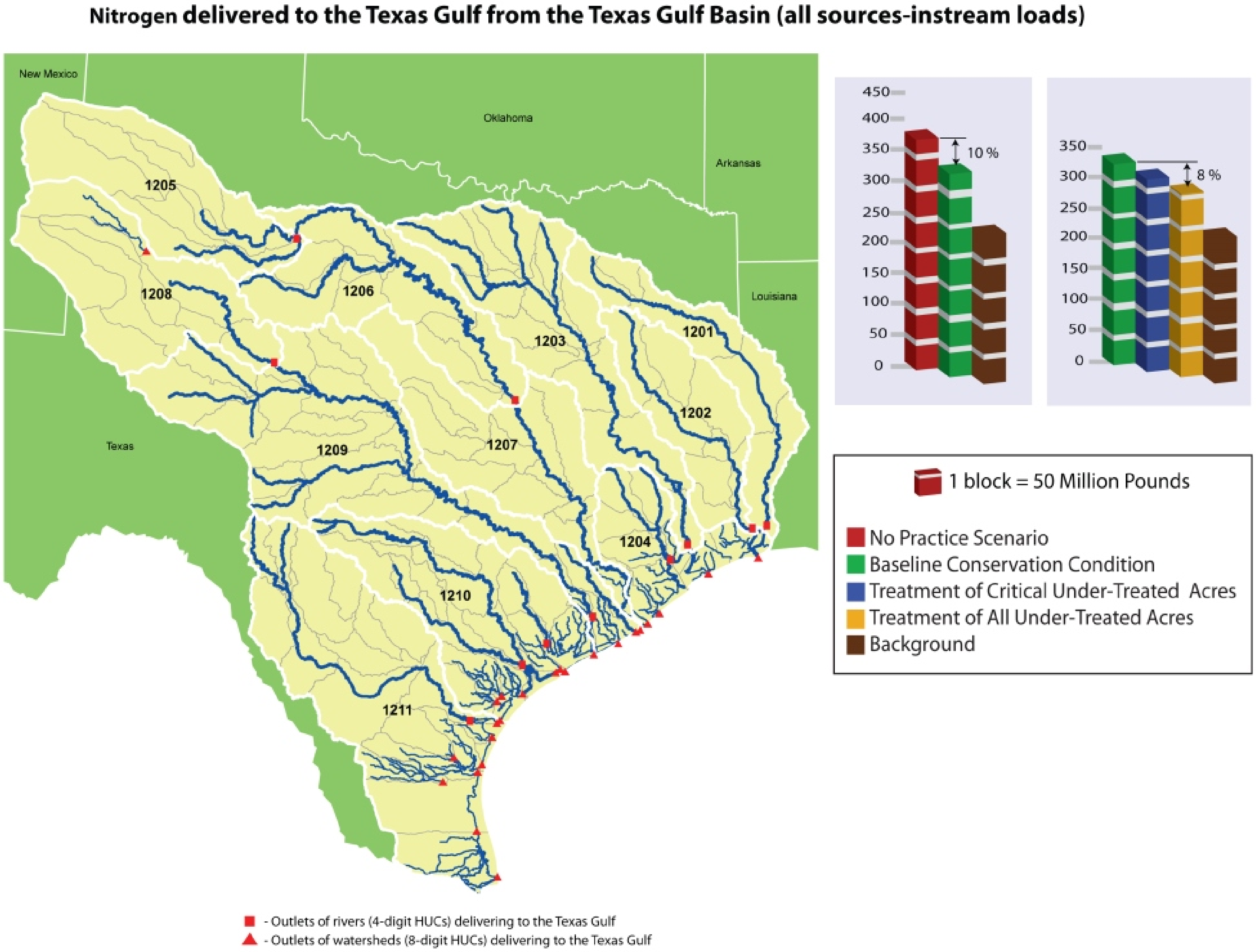
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Critical undertreated acres have "high" need for additional treatment. All undertreated acres have either a "high" or "moderate" need for additional treatment.

Figure 96. Effects of conservation practices on average annual instream nitrogen loads, Texas Gulf Basin



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

Figure 97. Effects of conservation practices on average annual instream nitrogen loads delivered to the Gulf, Texas Gulf Basin



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

Total Phosphorus

Baseline condition. Phosphorus loads delivered to rivers and streams from all sources totaled about 121 million pounds per year (table 51). Instream phosphorus loads delivered to the Gulf of Mexico, after accounting for instream deposition, reservoir dynamics, and other transport processes, was much lower, totaling about 80 million pounds per year, averaged over the 47 years of weather as simulated in the model (table 61).

About 8 percent of the instream phosphorus load delivered to the Gulf of Mexico is attributed to cultivated cropland sources in the model simulation. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the "background" scenario (no cultivation) from the total load from all sources in the baseline conservation scenario (table 61).

The largest contribution of instream phosphorus loads among the subregions is from the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204), with 50 million pounds per year (table 61, fig. 98). However, only a small portion—2 percent—is from cultivated cropland sources; the rest comes from non-cropland sources within the subregions, mostly from urban point sources. The subregions with the largest percentage of instream phosphorus load attributable to cultivated cropland are—

- the Brazos River Basin (outlet at 1207, including upstream loads from 1205 and 1206), with 26 percent of the load attributable to cultivated cropland, and
- the Nueces River-Southwestern Texas Coastal (code 1211), with 22 percent of the load attributable to cultivated cropland.

Effects of conservation practices.
Model simulations of instream loads indicate that conservation practices have reduced the delivery of phosphorus from the Texas Gulf Basin to the Gulf of Mexico by about 6 percent overall (table 61 and fig. 99). Without conservation practices, the total phosphorus delivered to the Gulf of Mexico would be larger by 5.5 million pounds per year.

The largest reduction among the subregions is for the Brazos River Basin (code 1207, including upstream loads from 1205 and 1206), where 3.4 million pounds per year of the instream phosphorus load have been reduced due to conservation practice use. Percent reductions vary from a low of 1 percent in the Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204) to a high of 28 percent in the Brazos River Basin.

Potential gains from further conservation treatment.
Treatment of the 7.6 million critical undertreated acres in the region with additional erosion control and nutrient management practices would be expected to reduce instream phosphorus loads delivered to the Gulf of Mexico by about 1.9 million pounds, representing a 2-percent reduction compared to the baseline conservation condition (table 62).

Expanding this treatment to all undertreated acres (97 percent of cropped acres) would be expected to reduce instream phosphorus loads delivered to the Gulf of Mexico by about 4 percent—totaling 3.6 million pounds (table 62, fig. 99). The largest percent reductions would occur in the Brazos River Basin (code 1207, including upstream loads from 1205 and 1206), with a 19-percent reduction, and the Nueces River-Southwestern Texas Coastal (code 1211), with a 17-percent reduction.

Table 61. Average annual ***instream phosphorus loads*** (all sources) for the baseline conservation condition, no-practice scenario, and the erosion control with nutrient management treatment scenario, Texas Gulf Basin

	Baseline conservation condition			No practice scenario		
Subregions	Load from all sources (1,000 pounds)	Background sources* (1,000 pounds)	Percent of load attributed to cultivated cropland sources	Load from all sources (1,000 pounds)	Reductions due to conservation practices (1,000 pounds)	Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	50,223	49,469	2%	50,524	301	1%
Brazos River Basin (outlet at 1207, includes upstream loads from 1205 and 1206)	8,665	6,443	26%	12,080	3,415	28%
Colorado-Conchos-Llano-San Bernard Coastal (outlet at 1209, includes upstream loads from 1208)	4,456	4,134	7%	4,863	407	8%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	9,556	8,492	11%	10,180	624	6%
Nueces River-Southwestern Texas Coastal (code 1211)	7,428	5,761	22%	8,210	782	10%
Total load from all outlets to the Gulf	80,328	74,299	8%	85,857	5,529	6%

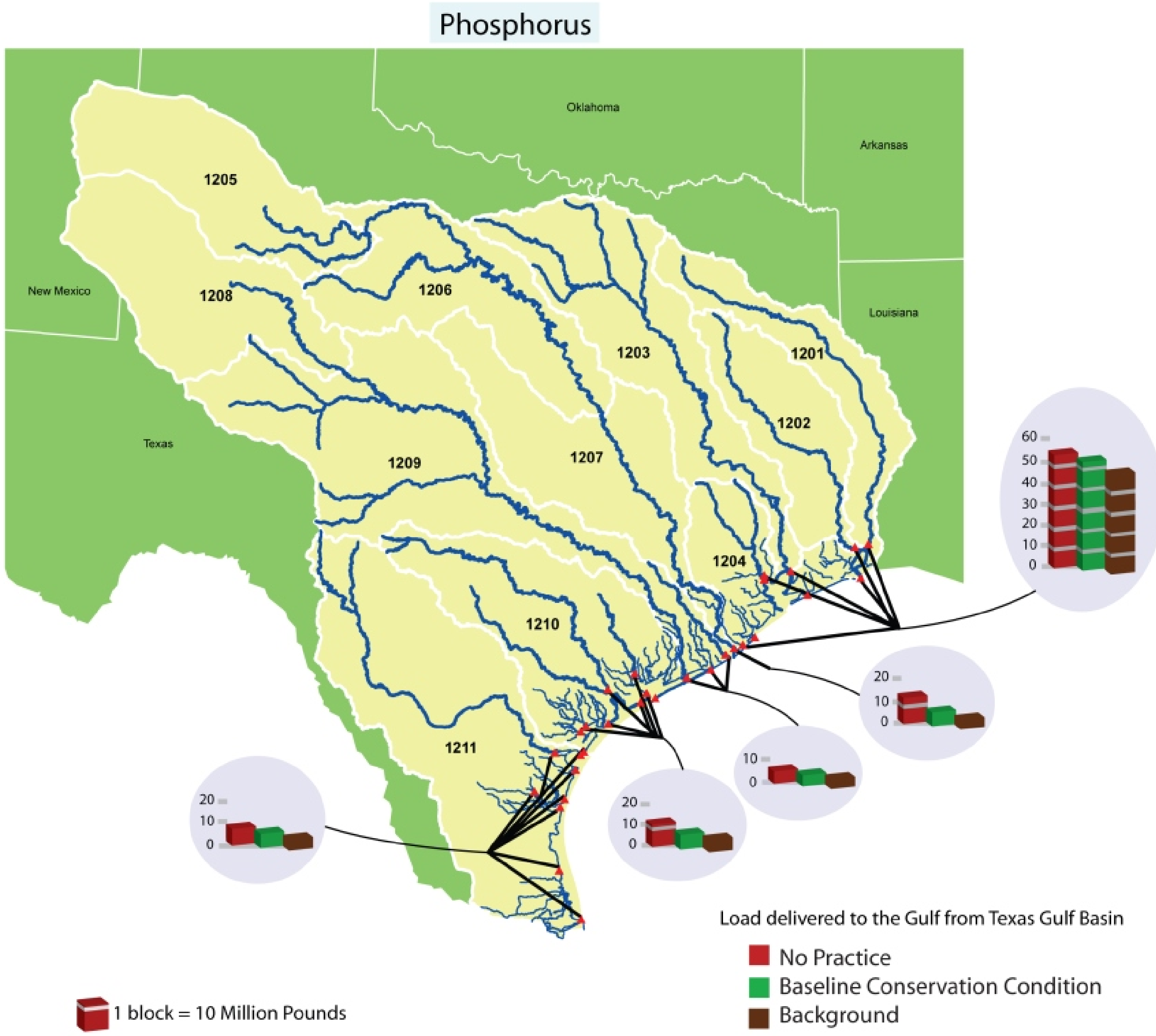
***** "Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 62. Effects of additional conservation treatment with erosion control practices and nutrient management practices on average annual ***instream phosphorus loads*** (all sources), Texas Gulf Basin

	Baseline conservation condition	Treatment of critical undertreated acres			Treatment of all undertreated acres		
Subregions	Load from all sources (1,000 pounds)	Load from all sources (1,000 pounds)	Reductions from baseline due to additional conservation treatment (1,000 pounds)	Percent reduction	Load from all sources (1,000 pounds)	Reductions from baseline due to additional conservation treatment (1,000 pounds)	Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	50,223	50,210	13	0%	50,033	190	0%
Brazos River Basin (outlet at 1207, includes upstream loads from 1205 and 1206)	8,665	7,868	797	9%	7,045	1,620	19%
Colorado-Conchos-Llano-San Bernard Coastal (outlet at 1209, includes upstream loads from 1208)	4,456	4,407	49	1%	4,351	105	2%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	9,556	9,539	17	0%	9,120	436	5%
Nueces River-Southwestern Texas Coastal (code 1211)	7,428	6,420	1,008	14%	6,191	1,237	17%
Total load from all outlets to the Gulf	80,328	78,444	1,884	2%	76,740	3,588	4%

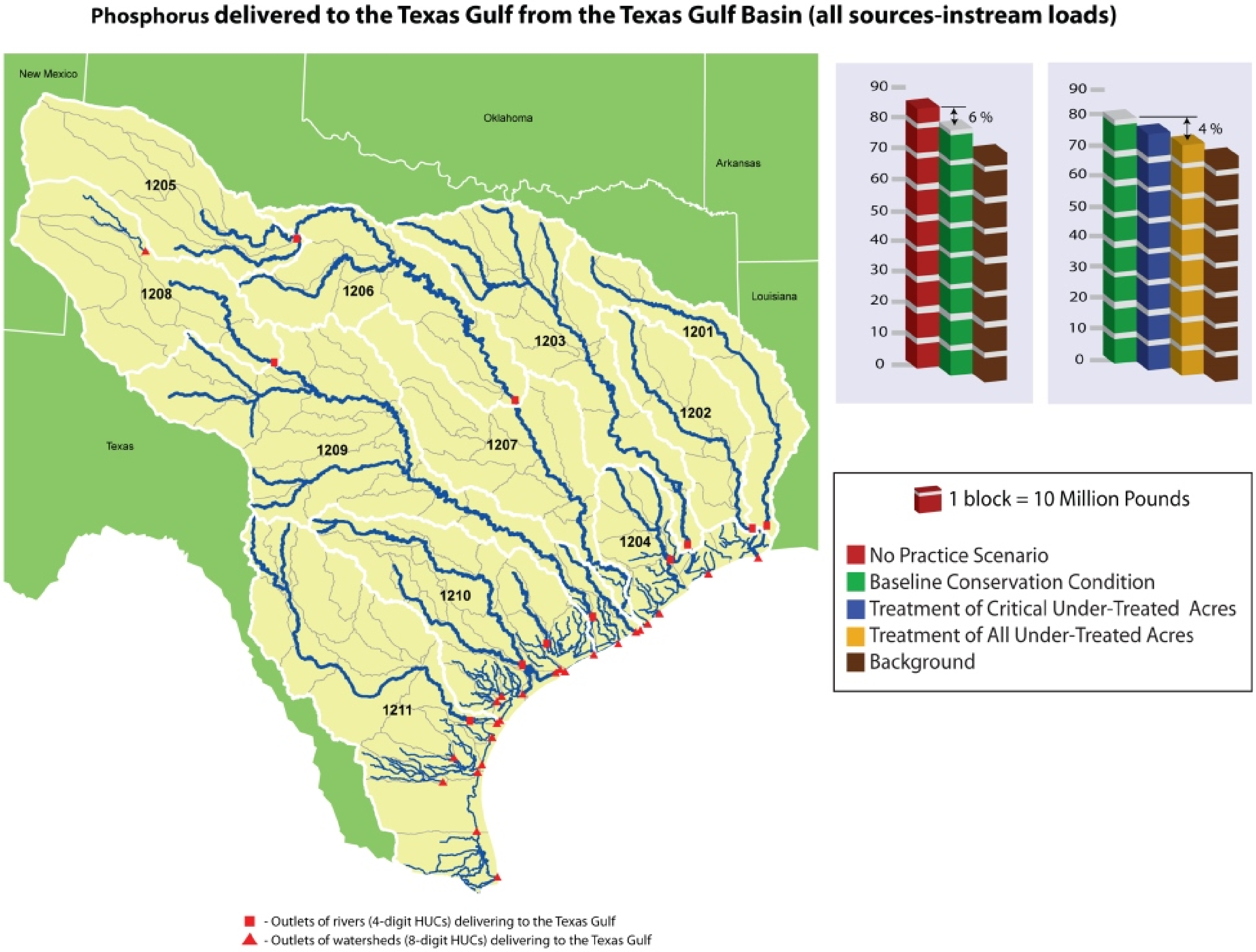
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Critical undertreated acres have "high" need for additional treatment. All undertreated acres have either a "high" or "moderate" need for additional treatment.

Figure 98. Effects of conservation practices on average annual instream phosphorus loads, Texas Gulf Basin



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

Figure 99. Effects of conservation practices on average annual instream phosphorus loads delivered to the Gulf, Texas Gulf Basin



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

Atrazine

Baseline condition. Atrazine loads delivered to rivers and streams from cultivated cropland totaled about 10,600 pounds per year (table 54). Instream atrazine loads delivered to the Gulf of Mexico from the Texas Gulf Basin, after accounting for instream deposition, reservoir dynamics, and other transport processes, was less, totaling about 6,300 pounds per year, averaged over the 47 years of weather as simulated in the model (table 63).

Effects of conservation practices.
Model simulations of instream atrazine loads indicate that conservation practices have reduced the delivery of atrazine from the Texas Gulf Basin to the Gulf of Mexico by about 33 percent overall (table 63). Without conservation practices, the total atrazine delivered to the Mississippi River would be larger by 3,100 pounds per year. About two-thirds of this reduction is for the Lavaca-Guadalupe-San Antonio-Central Texas Coastal subregion (code 1210), with a 77-percent reduction (table 63 and fig. 100). The lowest reduction is for the Colorado-Conchos-Llano-San Bernard Coastal subregion (outlet at 1209, includes upstream loads from 1208), with a 6-percent reduction compared to the baseline.

Potential gains from further conservation treatment.
Treatment of the 7.6 million critical undertreated acres in the region with additional erosion control and nutrient management practices would be expected to reduce instream atrazine loads delivered to the Gulf of Mexico by 6 percent compared to the baseline conservation condition (table 64).

Expanding this treatment to all undertreated acres (97 percent of cropped acres) would be expected to reduce instream atrazine loads delivered to the Gulf of Mexico by about 83 percent—totaling 5,200 pounds (table 64, fig. 101).

Table 63. Average annual ***instream atrazine loads*** for the baseline conservation condition and no-practice scenario, Texas Gulf Basin

Subregions	Baseline conservation condition load from cultivated cropland (1,000 pounds)	No-practice scenario load from cultivated cropland (1,000 pounds)	Reductions due to conservation practices (1,000 pounds)	Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	0.50	0.79	0.30	38%
Brazos River Basin (outlet at 1207, includes upstream loads from 1205 and 1206)	2.84	3.05	0.21	7%
Colorado-Conchos-Llano-San Bernard Coastal (outlet at 1209, includes upstream loads from 1208)	1.66	1.78	0.11	6%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	0.65	2.79	2.14	77%
Nueces River-Southwestern Texas Coastal (code 1211)	0.64	1.00	0.36	36%
Total load from all outlets to the Gulf	6.29	9.42	3.13	33%

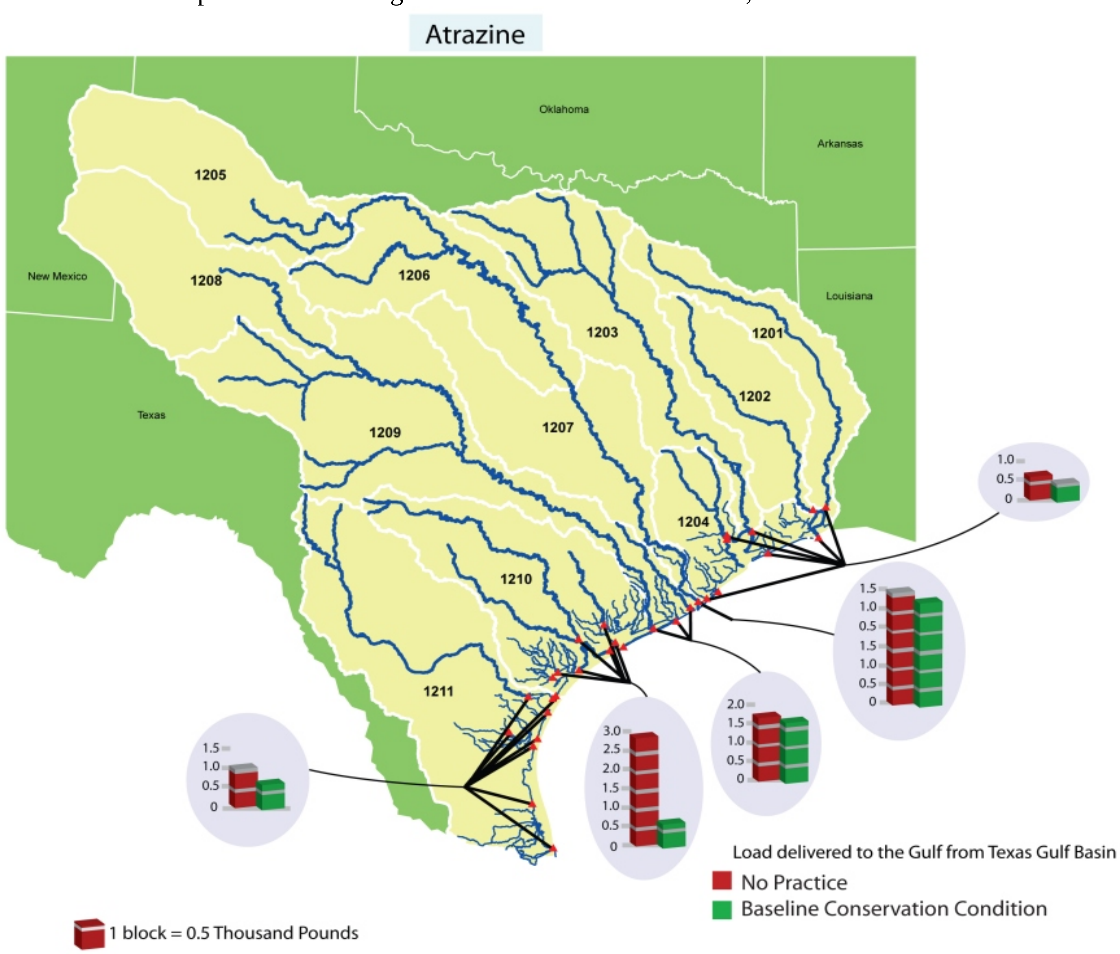
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.

Table 64. Effects of additional conservation treatment with erosion control practices and nutrient management practices on average annual ***instream atrazine loads*** (all sources), Texas Gulf Basin

	Baseline conservation condition	Treatment of critical undertreated acres			Treatment of all undertreated acres		
Subregions	Load from all sources (1,000 pounds)	Load from all sources (1,000 pounds)	Reductions from baseline due to additional conservation treatment (1,000 pounds)	Percent reduction	Load from all sources (1,000 pounds)	Reductions from baseline due to additional conservation treatment (1,000 pounds)	Percent reduction
Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)	0.50	0.49	0.00	1%	0.22	0.28	56%
Brazos River Basin (outlet at 1207, includes upstream loads from 1205 and 1206)	2.84	2.82	0.02	1%	0.36	2.48	87%
Colorado-Conchos-Llano-San Bernard Coastal (outlet at 1209, includes upstream loads from 1208)	1.66	1.65	0.02	1%	0.13	1.54	92%
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)	0.65	0.65	0.00	0%	0.23	0.42	65%
Nueces River-Southwestern Texas Coastal (code 1211)	0.64	0.29	0.35	54%	0.15	0.49	77%
Total load from all outlets to the Gulf	6.29	5.91	0.38	6%	1.08	5.21	83%

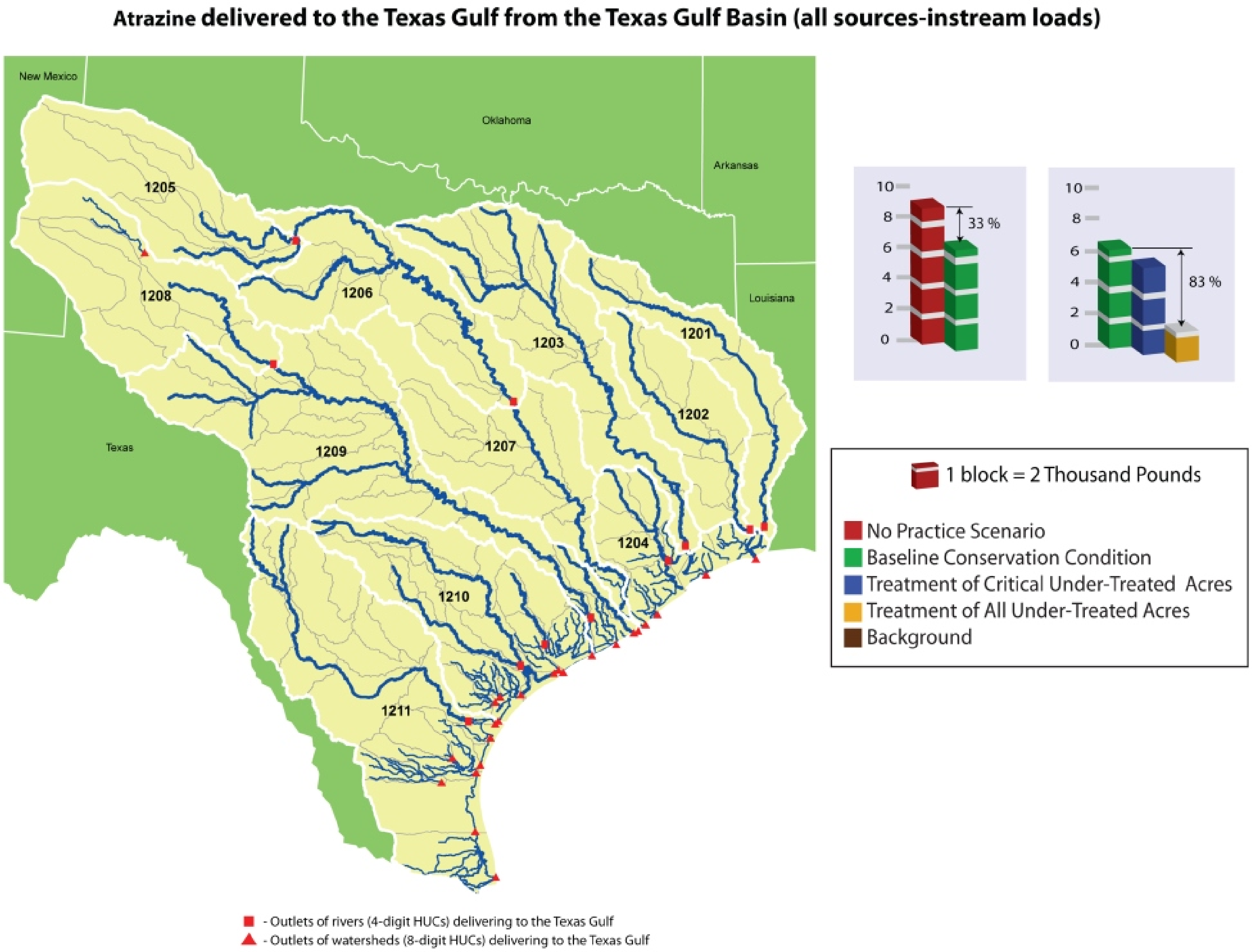
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Critical undertreated acres have "high" need for additional treatment. All undertreated acres have either a "high" or "moderate" need for additional treatment.

Figure 100. Effects of conservation practices on average annual instream atrazine loads, Texas Gulf Basin



Note: Cultivated cropland is the only source of atrazine included in the modeling; consequently, "background sources" are zero for atrazine.

Figure 101. Effects of conservation practices on average annual instream atrazine loads delivered to the Gulf, Texas Gulf Basin



Chapter 8

Summary of Findings

Field Level Assessment

The Baseline Conservation Condition

The baseline conservation condition represents model simulations of soil erosion, changes in soil organic carbon, and losses from farm fields of sediment, nitrogen, phosphorus, and pesticides through various loss pathways. Wind erosion accounts for most of the soil and nutrient losses from farm fields in this region. While conservation practices in use during 2003–06 have been effective in reducing wind erosion on some acres, model simulations show that average annual rates exceed 4 tons per acre for 59 percent of cropped acres. About 54 percent of total phosphorus lost from fields and 21 percent of total nitrogen lost from farm fields is lost with windborne sediment.

Evaluation of Practices in Use

The first Federal conservation efforts on cropland were focused primarily on water management and soil erosion control. Structural practices such as waterways, terraces, and diversions were installed along with supporting practices such as contour farming and stripcropping. Conservation tillage emerged in the 1960s and 1970s as a key management practice for enhancing soil quality and further reducing soil erosion. The conservation compliance provisions in the 1985 Farm Bill sharpened the focus to treatment of the most erodible acres—highly erodible land. This legislation created the Conservation Reserve Program as a mechanism for establishing long-term conserving cover on the most erodible cropland through multi-year contracts with landowners. More recently, the focus has shifted from soil conservation and sustainability to a broader goal of reducing all pollution impacts associated with agricultural production. Prominent among new concerns are the environmental effects of nutrient and pesticide export from farm fields.

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

- Structural practices for controlling water erosion are in use on 37 percent of cropped acres (table 7). On the 33 percent of the acres designated as highly erodible land, structural practices designed to control water erosion are in use on 35 percent.
- Structural practices for controlling wind erosion are in use on only 3 percent of cropped acres (table 7).
- Reduced tillage is used on about half the cropped acres in the region; 48 percent of the cropped acres meet criteria for no-till (5 percent), mulch till (30 percent), or reduced tillage (13 percent) (table 8).
- Only 13 percent of cropped acres in the region are gaining soil organic carbon (fig. 8).
- Producers use either residue and tillage management practices or structural practices, or both, on 66 percent of cropped acres (table 9).
- While most acres have evidence of some nitrogen or phosphorus management, the majority of the acres in the region lack consistent use of appropriate rates, timing, *and* method of application on each crop in every year of production (table 10).
    - About 17 percent of cropped acres have no nitrogen applied. An additional 44 percent of cropped acres meet criteria for timing of nitrogen applications on all crops in the rotation, 63 percent meet criteria for method of application, and 51 percent meet criteria for rate of application.
    - About 34 percent of cropped acres have no phosphorus applied. An additional 35 percent of cropped acres meet criteria for timing of phosphorus applications on all crops in the rotation, 52 percent meet criteria for method of application, and 19 percent meet criteria for rate of application.
    - Appropriate nitrogen application rates, timing of application, and application method for all crops during every year of production, however, are in use on only about 22 percent of cropped acres, in addition to the 17 percent of acres without any nitrogen application.
    - Good phosphorus management practices (appropriate rate, timing, and method) are in use on 10 percent of the acres on all crops during every year of production, in addition to the 34 percent of acres without any phosphorus application.
    - About 30 percent of cropped acres meet nutrient management criteria for both nitrogen *and* phosphorus management, including 17 percent of cropped acres not receiving either nitrogen or phosphorus applications.
- During the 2003–06 period of data collection, cover crops were used on only 2 percent of the acres in the region.
- The Integrated Pest Management (IPM) indicator showed that only about 5 percent of the acres were being managed with a relatively high level of IPM (fig. 11).
- Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of 2.5 million acres in the region, of which 60 percent is highly erodible.

Effects of Conservation Practices

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

- Reduced surface water runoff in the region by about 1.3 inches per year averaged over all acres, representing a 23-percent reduction (table 13);
- Reduced surface water runoff by 3.8 inches per year, on average, for irrigated acres and 0.2 inch per year for non-irrigated acres (table 13);
- Increased the volume of subsurface flows by an average of 0.15 inch per year (table 13).

- Reduced wind erosion by 0.18 ton per acre on cropped acres, representing a 2-percent reduction for the entire region (table 14);
- Reduced average sediment loss from water erosion by an average of 1.2 tons per acre per year, representing a 52-percent reduction (table 15);
- Resulted in an average gain in soil organic carbon of 8 pounds per acre per year (table 16);
- Reduced total nitrogen loss (volatilization, denitrification, windborne sediment, surface runoff, and subsurface flow losses) by an average of 10.7 pounds per acre per year, representing a 21-percent reduction (table 17):
  - Reduced nitrogen lost with windborne sediment by less than 1 percent;
  - Reduced nitrogen lost with surface runoff (soluble and sediment adsorbed) by 2.7 pounds per acre, representing a 45-percent reduction;
  - Reduced nitrogen loss in subsurface flows by an average of 6.7 pounds per acre, representing a 29-percent reduction;
- Reduced total phosphorus loss by an average of 1.0 pound per acre per year, representing a 33-percent reduction (table 19):
  - Reduced phosphorus lost with windborne sediment by an average of 0.26 pound per acre per year, representing an average reduction of 19 percent;
  - Reduced phosphorus lost to surface water by an average of 0.8 pound per acre per year, representing an average reduction of 49 percent; and
- Reduced pesticide loss from fields to surface water by 44 percent, resulting in (table 22)—
  - a 62-percent reduction in the edge-of-field surface water pesticide risk indicator (all pesticides combined) for aquatic ecosystems; and
  - a 49-percent reduction in the edge-of-field surface water pesticide risk indicator for humans.

Use of improved irrigation systems in the Texas Gulf Basin increases irrigation efficiency from 43 percent in the no-practice scenario to 65 percent in the baseline scenario. This change in efficiency represents an annual decreased need for irrigation water use of about 6.4 inches per year where irrigation is used (table 13).

At 2.5 million acres, land in long-term conserving cover is not a significant part of the agricultural landscape in most of the Texas Gulf Basin, but it is important in some subregions. The benefits of this conservation "practice" were estimated by simulating crop production on these acres without use of conservation practices. Model simulation results show that wind erosion and sediment loss due to water erosion have been almost completely eliminated for land in long-term conserving cover (tables 14 and 15). Compared to a cropped condition without conservation practices, total nitrogen loss has been reduced by 25 percent (table 18), total phosphorus loss has been reduced by 99 percent (table 19), and soil organic carbon has been increased by an average of 376 pounds per acre per year (table 16) on these acres.

Conservation Treatment Needs

The adequacy of conservation practices in use in the Texas Gulf Basin for the time period 2003–06 was evaluated to identify conservation treatment needs for five resource concerns:

- wind erosion,
- sediment loss with water erosion,
- nitrogen lost with surface runoff (attached to sediment and in solution),
- nitrogen loss in subsurface flows, and
- phosphorus lost to surface water (includes soluble phosphorus in lateral flow, soluble phosphorus in surface water runoff, and phosphorus lost with waterborne sediment).

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

Undertreated acres were identified by an imbalance between the level of conservation treatment and the level of inherent vulnerability. Findings for the Texas Gulf Basin indicate that (fig. 70)—

- 41 percent of cropped acres (7.6 million acres) have a **high** level of need for additional conservation treatment,
- 56 percent of cropped acres (10.3 million acres) have a **moderate** level of need for additional conservation treatment, and
- 3 percent of cropped acres (498,000 acres) have a **low** level of need for additional treatment and are considered to be adequately treated.

Acres with a "high" level of need for conservation treatment consist of the most critical undertreated acres in the region. These are the most vulnerable of the undertreated acres with the least conservation treatment and have the highest losses of sediment and/or nutrients.

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

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

Wind erosion is the most important conservation resource concern in the Texas Gulf Basin (fig. 69 and tables 29 and 30). About 40 percent of cropped acres have a high level of conservation treatment need for wind erosion and another 44 percent have a moderate level of need. Overall, 84 percent of cropped acres need additional treatment for wind erosion. About 41 percent of cropped acres need treatment *only* for wind erosion, and 43 percent need treatment for one or more resource concerns in combination with wind erosion (table 30).

For other resource concerns, the percentage of cropped acres in the Texas Gulf Basin with a high or moderate need for additional conservation treatment was determined to be (fig. 69 and table 29)—

- 42.5 percent for sediment loss (none with a high need for treatment),
- 1.7 percent for nitrogen loss with surface runoff (all with a high need for treatment),
- none for phosphorus lost to surface water, and
- 31.5 percent for nitrogen loss in subsurface flows (none with a high need for treatment).

Nearly all acres with a high level of need for conservation treatment *need additional treatment only for wind erosion*. Wind erosion for acres with a high need for additional treatment averaged 14.2 tons per acre per year, compared to 4.75 tons per acre per year for acres with a moderate need and 0.69 ton per acre for acres with a low need (table 31). Associated losses of nitrogen and phosphorus were also very high for these acres. About 11.7 pounds per acre of nitrogen and 1.8 pounds per acre of phosphorus are lost with windborne sediment, on average, for the 7.6 million acres with a high need for additional treatment.

Acres with a "moderate" level of need for conservation treatment in this region consist of undertreated acres that generally have excessive wind erosion rates and excessive losses of nitrogen in subsurface flows and sediment lost with water erosion. Many of these acres are located in the eastern portion of the region where precipitation is highest. Sediment loss for these acres averages 1.4 tons per acre per year, compared to average losses of less than 1 ton per acre per year for acres with a high or low need for additional treatment (table 31). Nitrogen loss in subsurface flows averages 19 pounds per acre per year, compared to average losses of less than 15 pounds per acre per year for with a high or low need for additional treatment. A portion of the acres needing additional treatment for wind erosion in this category also have high wind erosion rates, but overall not as high as for acres with a high need for additional treatment.

Only a few acres have a low level of need for additional conservation treatment in this region—less than 0.5 million acres. Wind erosion averages only 0.7 ton per acre per year, nitrogen loss in subsurface flows averages only 15 pounds per acre per year, and sediment loss with water erosion averages only 0.4 ton per acre per year for these acres (table 31). While gains can be attained by adding conservation practices to some of these acres with a low treatment need, additional conservation treatment would reduce average field losses by only a small amount.

Simulation of Additional Conservation Treatment

Model simulations were used to evaluate the potential gains from further conservation treatment in the Texas Gulf Basin. Three sets of additional conservation practices were simulated:

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

Model simulation was used to estimate the gains that could be attained when soil erosion control practices, nutrient management practices, and increased irrigation efficiencies are applied in this region. Diminishing returns from additional conservation treatment is demonstrated by comparing the average annual per-acre reductions in losses among three groups of acres.

Conservation treatment of the 7.6 million critical undertreated acres, nearly all of which need additional treatment only for wind erosion, would reduce wind erosion by an average of 5.5 tons per acre per year on those acres (table 35). In comparison, additional treatment of the 10.3 million acres with a moderate need for treatment would reduce wind erosion by about 3.0 tons per acre per year on those acres. Treatment of the remaining 0.5 million acres would reduce wind erosion by only about 0.5 ton per acre, on average.

Conservation treatment of the 7.6 million critical undertreated acres would also reduce windborne nitrogen loss by an average of 5.1 pounds per acre per year and reduce windborne phosphorus by an average of 1.1 pounds per acre per year on those acres. In comparison, additional treatment of the 10.3 million acres with a moderate need for treatment would reduce windborne nitrogen loss by an average of 4.6 pounds per acre per year and reduce windborne phosphorus by an average of 0.6 pound per acre per year on those acres. Treatment of the remaining 0.5 million acres would reduce losses by only 0.8 pound per acre per year for nitrogen and less than 0.1 pound per acre per year for phosphorus.

These diminishing returns are not evident or are less pronounced for other losses and loss pathways because of the predominance of wind erosion concerns in the critical undertreated set of acres and the small number of sample points representing acres with a low level of treatment need.

Compared to the baseline conservation condition, treating all 17.9 million undertreated acres (97 percent of cropped acres in the region) would, for the region as a whole (table 37)—

- reduce wind erosion averaged over all cropped acres in the region by 47 percent,
- reduce waterborne sediment loss in the region to an average of 0.2 tons per acre per year, an 86-percent reduction from the baseline conservation condition;
- reduce total nitrogen loss by 27 percent, on average:
  - reduce nitrogen loss with windborne sediment by 55 percent,
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) by 76 percent, and
  - reduce nitrogen loss in subsurface flows by 16 percent;
- reduce phosphorus lost with windborne sediment averaged over all cropped acres in the region by 66 percent;
- reduce phosphorus lost to surface water (sediment adsorbed and soluble) by 60 percent; and
- reduce environmental risk from loss of pesticide residues in surface water by 70 percent for both aquatic ecosystems and humans.

Except for wind erosion, about half of the potential field-level savings from conservation treatment, relative to losses simulated for the no-practice scenario, has been achieved in this region (fig. 71). The savings represented by practices in use in 2003–06 are 55 percent for sediment, 50 percent for nitrogen, and 51 percent for phosphorus. By treating the 7.6 million critical undertreated acres in the region with additional erosion control and nutrient management practices, an additional 12 percent in savings would be attained for sediment, 22 percent for nitrogen, and 28 percent for phosphorus. To achieve 100 percent of potential savings (i.e., an additional 32 percent for sediment, 28 percent for nitrogen, and 20 percent for phosphorus), additional conservation treatment for the remaining 10.3 million undertreated acres with a moderate need for additional treatment would be required.

The exception to this trend is the potential benefit for further treatment for wind erosion. The reductions in wind erosion represented by practices in place for the entire basin are only 4 percent of potential reductions. By treating the 7.6 million critical undertreated acres (acres with a high need for treatment) for wind erosion an additional 55 percent in savings could potentially be gained. To achieve 100 percent of the potential savings, would require treating the remaining 10.3 million moderate-need acres.

Conservation Practice Effects on Water Quality

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

Cultivated cropland represents about 15 percent of the land base in the Texas Gulf Basin. Of the total loads delivered to rivers and streams from all sources, cultivated cropland is the source for 66 percent of the sediment, 31 percent of the nitrogen, and 7 percent of the phosphorus.

Urban point and non-point sources delivered most of the nitrogen and phosphorus to the Gulf of Mexico, including 53 percent of the region's nitrogen and 61 percent of the region's phosphorus, while making up only 8 percent of the land base.

For the baseline conservation condition, sediment, nutrient, and atrazine loads **delivered to rivers and streams from cultivated cropland sources** per year, on average, are—

- 15 million tons of sediment;
- 202 million pounds of nitrogen;
- 9 million pounds of phosphorus; and
- 10,600 pounds of atrazine.

Conservation practices in use on cultivated cropland in 2003–06, including land in long-term conserving cover, have reduced sediment, nutrient, and atrazine loads **delivered to rivers and streams from cultivated cropland sources** per year, on average, by —

- 60 percent for sediment;
- 41 percent for nitrogen;
- 55 percent for phosphorus, and
- 36 percent for atrazine.

Model simulations further showed that if all of the undertreated acres (97 percent of cropped acres) were fully treated with the appropriate soil erosion control and nutrient management practices, loads **delivered to rivers and streams from cultivated cropland sources** in the region would be reduced, relative to the baseline conservation condition, by—

- 84 percent for sediment,
- 32 percent for nitrogen,
- 63 percent for phosphorus, and
- 80 percent for atrazine.

Instream loads are estimated by starting with the loads delivered from all sources at the outlet of each 8-digit HUC and routing those loads downstream. Stream and channel processes are simulated, including flood routing, instream degradation processes, streambed deposition, streambank erosion, and reservoir dynamics. A portion of the sediment, nutrients, and pesticides delivered to rivers and streams are removed or trapped during these processes. Some of the nitrogen is lost during instream nitrification processes, and a portion of the sediment and sediment-bound nutrients and pesticides are deposited in streambeds and flood plains during transit. Large reservoirs can trap significant amounts of loads delivered to rivers and streams, keeping those loads from being transferred downstream. Sediment can also be added to instream loads through streambank erosion and streambed scouring.

Model simulations showed that **instream loads from all sources delivered from the region to the Gulf of Mexico** per year, on average, are

- 16.2 million tons of sediment (24 percent attributable to cultivated cropland sources);
- 336 million pounds of nitrogen (26 percent attributable to cultivated cropland sources);
- 80 million pounds of phosphorus (8 percent attributable to cultivated cropland sources); and
- 6,300 pounds of atrazine (all assumed to be from cultivated cropland sources).

Conservation practices in use on cultivated cropland in 2003–06, including land in long-term conserving cover, have reduced **instream loads from all sources delivered from the region to the Gulf of Mexico** per year, on average, by—

- 12 percent for sediment;
- 10 percent for nitrogen;
- 6 percent for phosphorus; and
- 33 percent for atrazine.

Additional conservation treatment of the 7.6 million critical undertreated acres in the region would be expected to further reduce **instream loads from all sources delivered from the region to the Gulf of Mexico** per year relative to the baseline, on average, by—

- 8 percent for sediment;
- 4 percent for nitrogen;
- 2 percent for phosphorus; and
- 6 percent for atrazine.

Additional conservation treatment of all undertreated acres in the region (97 percent of cropped acres) would be expected to further reduce **instream loads from all sources delivered from the region to the Gulf of Mexico** per year relative to the baseline, on average, by—

- 19 percent for sediment;
- 8 percent for nitrogen;
- 4 percent for phosphorus, and
- 83 percent for atrazine.

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Appendix A: Estimates of Margins of Error for Selected Acre Estimates

The CEAP cultivated cropland sample is a subset of NRI sample points from the 2003 NRI (USDA/NRCS 2007). The 2001, 2002, and 2003 Annual NRI surveys were used to draw the sample. (Information about the CEAP sample design is in the documentation report "NRI-CEAP Cropland Survey Design and Statistical Documentation," referenced on page 7. The sample for cropped acres consists of 693 sample points in the Texas Gulf Basin. Acres reported using the CEAP sample are "estimated" acres because of the uncertainty associated with statistical sampling.

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

Margins of error are provided in table A1 for selected acres estimates found elsewhere in the report. The margin of error is a commonly used measure of statistical uncertainty and can be used to construct a 95-percent confidence interval for an estimate. The lower bound of the confidence interval is obtained by subtracting the margin of error from the estimate; adding the margin of error to the estimate forms the upper bound. Measures of uncertainty (e.g., margins of error, standard errors, confidence intervals, coefficients of variation) should be taken into consideration when using CEAP acreage estimates. The margin of error is calculated by multiplying the standard error by the factor 1.96; a coefficient of variation is the relative standard for an estimate, usually in terms of percentages, and is calculated by taking 100 times the standard error and then dividing by the estimate.

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

For reporting, results for some subregions were combined because of small sample sizes.

Table A1. Margins of error for acre estimates based on the CEAP sample for the Texas Gulf Basin

	Estimated acres	Margin of error
Use of structural practices (table 7)		
Overland flow control practices	6,085,816	948,228
Concentrated flow control practices	2,374,671	706,607
Edge-of-field buffering and filtering practices	307,144	381,651
One or more water erosion control practices	6,884,420	931,036
Wind erosion control practices	544,656	290,057
Use of cover crops	434,640	188,529
Use of residue and tillage management (table 8)		
Average annual tillage intensity for crop rotation meets criteria for no-till	935,455	397,800
Average annual tillage intensity for crop rotation meets criteria for mulch till	5,564,412	1,076,990
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	2,314,709	725,309
Continuous conventional tillage in every year of crop rotation	9,553,723	1,205,612
Conservation treatment levels for structural practices (fig. 7)		
High level of treatment	170,492	175,837
Moderately high level of treatment	1,714,933	729,166
Moderate level of treatment	4,998,996	688,826
Low level of treatment	11,483,879	1,272,760
Conservation treatment levels for residue and tillage management (fig. 8)		
High level of treatment	1,425,597	451,737
Moderately high level of treatment	144,330	203,272
Moderate level of treatment	7,880,723	1,254,729
Low level of treatment	8,917,649	1,090,033

Table A1. Margins of error for acre estimates based on the CEAP sample for the Texas Gulf Basin**—continued**

	Estimated acres	Margin of error
Conservation treatment levels for nitrogen management (fig. 9)		
High level of treatment	6,378,583	613,022
Moderately high level of treatment	6,201,263	1,063,510
Moderate level of treatment	4,985,326	1,220,044
Low level of treatment	803,127	472,774
Conservation treatment levels for phosphorus management (fig. 10)		
High level of treatment	8,195,106	934,034
Moderately high level of treatment	1,627,618	718,675
Moderate level of treatment	3,015,639	681,214
Low level of treatment	5,529,936	1,063,167
Conservation treatment levels for IPM (fig. 11)		
High level of treatment	984,634	587,012
Moderate level of treatment	6,015,507	1,041,097
Low level of treatment	11,368,158	1,176,115
Conservation treatment levels for water erosion control practices (fig. 58)		
High level of treatment	1,273,763	460,273
Moderately high level of treatment	209,529	222,015
Moderate level of treatment	7,865,601	1,295,618
Low level of treatment	9,019,407	1,055,260
Conservation treatment levels for nitrogen runoff control (fig. 59)		
High level of treatment	671,409	341,628
Moderately high level of treatment	3,310,153	588,669
Moderate level of treatment	10,929,682	1,191,052
Low level of treatment	3,457,055	1,179,224
Conservation treatment levels for phosphorus runoff control (fig. 60)		
High level of treatment	645,225	396,421
Moderately high level of treatment	3,672,689	778,247
Moderate level of treatment	7,639,799	1,165,295
Low level of treatment	6,410,586	1,006,052
Conservation treatment levels for wind erosion control (fig. 61)		
High level of treatment	64,907	88,568
Moderately high level of treatment	1,415,204	504,634
Moderate level of treatment	5,484,890	1,074,431
Low level of treatment	11,403,298	1,139,560
Soil runoff potential (fig. 62)		
High	40,174	176,323
Moderately high	2,276,957	569,476
Moderate	5,950,303	989,187
Low	10,100,865	732,906
Soil leaching potential (fig. 64)		
High	1,329,536	364,980
Moderately high	349,145	381,425
Moderate	9,650,046	784,982
Low	7,039,573	847,931
Soil wind erosion potential (fig. 66)		
High	1,127,034	326,797
Moderately high	4,698,190	721,610
Moderate	5,415,941	588,092
Low	7,127,134	748,869

Table A1. Margins of error for acre estimates based on the CEAP sample for the Texas Gulf Basin—continued

	Estimated acres	Margin of error
Level of conservation treatment need by resource concern		
Sediment loss (table 24)		
High (critical undertreated)	0	NA
Moderate (non-critical undertreated)	7,804,669	1,096,201
Low (adequately treated)	10,563,631	850,289
Nitrogen loss with surface runoff (sediment attached and soluble) (table 25)		
High (critical undertreated)	310,671	241,569
Moderate (non-critical undertreated)	0	NA
Low (adequately treated)	18,057,628	820,986
Nitrogen loss in subsurface flows (table 26)		
High (critical undertreated)	0	NA
Moderate (non-critical undertreated)	5,788,453	1,262,927
Low (adequately treated)	12,579,846	1,214,214
Phosphorus lost to surface water (table 27)		
High (critical undertreated)	0	NA
Moderate (non-critical undertreated)	0	NA
Low (adequately treated)	18,368,299	859,453
Wind erosion (table 28)		
High (critical undertreated)	7,291,232	755,770
Moderate (non-critical undertreated)	8,036,400	1,450,878
Low (adequately treated)	3,040,667	1,033,285
Level of conservation treatment need for one or more resource concerns (table 29)		
Texas Gulf Basin		
High (critical undertreated)	7,585,940	802,587
Moderate (non-critical undertreated)	10,283,869	1,231,293
Low (adequately treated)	498,490	424,407
Sabine, Neches, and Upper and Lower Trinity Basin (codes 1201, 1202, 1203)		
High (critical undertreated)	117,248	121,305
Moderate (non-critical undertreated)	1,171,032	260,063
Low (adequately treated)	39,619	69,132
San Jacinto River-Galveston Bay-Sabine Lake (code 1204))		
High (critical undertreated)	0	NA
Moderate (non-critical undertreated)	522,700	280,551
Low (adequately treated)	0	NA
Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)		
High (critical undertreated)	2,345,846	355,119
Moderate (non-critical undertreated)	1,693,757	401,503
Low (adequately treated)	7,797	15,992
Middle Brazos River Basin (code 1206)		
High (critical undertreated)	936,658	299,469
Moderate (non-critical undertreated)	1,217,764	318,532
Low (adequately treated)	74,378	93,804
Lower Brazos River Basin (code 1207)		
High (critical undertreated)	60,625	144,612
Moderate (non-critical undertreated)	1,429,396	482,615
Low (adequately treated)	193,779	340,153
Upper Colorado River Basin (code 1208)		
High (critical undertreated)	1,687,412	329,207
Moderate (non-critical undertreated)	880,288	261,747
Low (adequately treated)	0	NA

Table A1. Margins of error for acre estimates based on the CEAP sample for the Texas Gulf Basin—**continued**

	Estimated acres	Margin of error
Level of conservation treatment need for one or more resource concerns--continued		
Middle and Lower Colorado-Conchos-Liano-San Bernard Coastal (code 1209)		
High (critical undertreated)	647,597	400,798
Moderate (non-critical undertreated)	1,151,310	442,403
Low (adequately treated)	68,793	99,141
Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)		
High (critical undertreated)	29,293	63,929
Moderate (non-critical undertreated)	1,607,183	329,203
Low (adequately treated)	114,124	237,836
Nueces River-Southwestern Texas Coastal (code 1211)		
High (critical undertreated)	1,761,261	538,376
Moderate (non-critical undertreated)	610,439	386,715
Low (adequately treated)	0	NA

Appendix B: Model Simulation Results for the Baseline Conservation Condition for Subregions in the Texas Gulf Basin

Model simulation results presented in Chapter 4 for the baseline conservation condition are presented in tables B1–B5 for the subregions in the Texas Gulf Basin. For reporting, results for some subregions were combined because of small sample sizes. The column headings refer to the 4-digit Hydrologic Unit Codes (HUC), as shown below:

Subregion code	Subregion name
1201–1204	Sabine, Neches, Upper and Lower Trinity Basins, and San Jacinto River-Galveston Bay-Sabine Lake (codes 1201, 1202, 1203, 1204)
1205	Brazos headwaters-Salt Fork-Double Mountain Fork Basin (code 1205)
1206-1207	Lower and Middle Brazos River Basin (codes 1206, 1207)
1208	Upper Colorado River Basin (code 1208)
1209	Middle and Lower Colorado-Conchos-Liano-San Bernard Coastal (code 1209)
1210	Lavaca-Guadalupe-San Antonio-Central Texas Coastal (code 1210)
1211	Nueces River-Southwestern Texas Coastal (code 1211)

Table B1. Basin characteristics and average annual estimates of water flow, erosion, and soil organic carbon for the baseline conservation condition for cropped acres, by subregion, in the Texas Gulf Basin

Model simulated outcome	Texas Gulf Basin	1201–1204	1205	1206-1207
CEAP sample size for estimating cropped acres	693	75	233	109
Cropped acres (million acres)	18.368	1.851	4.047	3.913
Percent of acres in region	100	10	22	21
Percent of acres highly erodible	33	22	39	16
Percent of acres irrigated	30	29	60	7
Percent of acres receiving manure	3	2	7	2
Water sources (average annual inches)				
Non-irrigated acres				
Precipitation	28.2	38.7	19.3	30.3
Irrigated acres				
Precipitation	25.2	53.0	18.6	31.1
Irrigation water applied	19.3	3.1	20.7	23.6
Water loss pathways (average annual inches)				
Evapotranspiration	26.6	28.1	27.8	25.8
Surface water runoff	4.3	11.3	1.1	5.1
Subsurface water flow	1.4	4.2	0.8	0.7
Erosion and sediment loss (average annual tons/acre)				
Wind erosion	8.55	4.0	13.6	3.8
Sheet and rill erosion	0.86	1.7	0.3	1.1
Sediment loss at edge of field due to water erosion	1.09	2.8	0.3	1.5
Soil organic carbon (average annual pounds/acre)				
Loss of soil organic carbon with wind and water erosion	183	255	206	178
Change in soil organic carbon, including loss of carbon with wind and water erosion	-176	-221	-157	-152

Table B1. Basin characteristics and average annual estimates of water flow, erosion, and soil organic carbon for the baseline conservation condition for cropped acres, by subregion, in the Texas Gulf Basin—**continued**

Model simulated outcome	1208	1209	1210	1211
CEAP sample size for estimating cropped acres	117	59	40	60
Cropped acres (million acres)	2.568	1.868	1.751	2.372
Percent of acres in region	14	10	10	13
Percent of acres highly erodible	72	17	6	51
Percent of acres irrigated	34	19	21	32
Percent of acres receiving manure	0	2	0	3
Water sources (average annual inches)				
Non-irrigated acres				
Precipitation	18.4	29.1	36.4	26.4
Irrigated acres				
Precipitation	16.7	27.7	40.4	25.6
Irrigation water applied	26.0	22.2	8.4	21.2
Water loss pathways (average annual inches)				
Evapotranspiration	24.2	25.9	28.5	26.1
Surface water runoff	0.7	4.8	8.2	3.7
Subsurface water flow	0.5	1.7	2.0	1.8
Erosion and sediment loss (average annual tons/acre)				
Wind erosion	18.9	3.5	4.6	7.0
Sheet and rill erosion	0.2	0.8	1.7	0.7
Sediment loss at edge of field due to water erosion	0.2	1.0	2.1	0.8
Soil organic carbon (average annual pounds/acre)				
Loss of soil organic carbon with wind and water erosion	130	174	172	169
Change in soil organic carbon, including loss of carbon with wind and water erosion	-136	-172	-250	-202

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

Model simulated outcome	Texas Gulf Basin	1201–1204	1205	1206-1207
Nitrogen (average annual pounds/acre)				
Nitrogen sources				
Atmospheric deposition	4.0	5.6	3.7	4.3
Bio-fixation by legumes	1.2	1.9	0.5	1.2
Nitrogen applied as commercial fertilizer and manure	62.1	83.1	54.6	62.6
All nitrogen sources	67.4	90.6	58.8	68.1
Nitrogen in crop yield removed at harvest	38.5	44.8	38.0	33.4
Nitrogen loss pathways				
Nitrogen loss by volatilization	9.7	9.1	9.7	11.0
Nitrogen loss through denitrification	2.5	6.6	0.5	4.3
Nitrogen lost with windborne sediment	8.5	6.8	13.2	5.4
Nitrogen loss with surface runoff , including waterborne sediment	3.3	8.4	0.9	5.1
Nitrogen loss in subsurface flow pathways	16.7	35.4	10.1	8.1
Total nitrogen loss for all loss pathways	40.9	66.1	34.3	33.8
Change in soil nitrogen	-12.2	-20.7	-13.7	0.7

Table B2. Average annual estimates of nitrogen loss for the baseline conservation condition for cropped acres, by subregion, in the Texas Gulf Basin—**continued**

Model simulated outcome	1208	1209	1210	1211
Nitrogen (average annual pounds/acre)				
Nitrogen sources				
Atmospheric deposition	3.3	3.9	4.5	3.6
Bio-fixation by legumes	2.3	0.0	3.5	0.3
Nitrogen applied as commercial fertilizer and manure	36.7	52.0	77.0	82.1
All nitrogen sources	42.2	56.0	85.0	85.9
Nitrogen in crop yield removed at harvest	24.7	37.2	51.0	49.6
Nitrogen loss pathways				
Nitrogen loss by volatilization	8.3	9.7	9.8	9.7
Nitrogen loss through denitrification	0.3	2.8	3.9	1.0
Nitrogen lost with windborne sediment	10.2	5.5	7.5	8.6
Nitrogen loss with surface runoff , including waterborne sediment	0.3	4.0	5.4	2.1
Nitrogen loss in subsurface flow pathways	9.4	12.5	32.0	27.9
Total nitrogen loss for all loss pathways	28.6	34.5	58.7	49.3
Change in soil nitrogen	-11.2	-15.8	-24.8	-13.0

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

Model simulated outcome	Texas Gulf Basin	1201–1204	1205	1206-1207
Phosphorus (average annual pounds/acre)				
Phosphorus applied as commercial fertilizer and manure	11.25	13.42	11.97	10.84
Phosphorus in crop yield removed at harvest	5.94	6.35	5.96	4.94
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	1.16	0.65	2.12	0.53
Phosphorus lost to surface water, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage tiles and ditches and natural seeps	0.85	2.10	0.26	1.08
Soluble phosphorus loss to groundwater	0.12	0.30	0.09	0.10
Total phosphorus loss for all loss pathways	2.13	3.05	2.47	1.72
Change in soil phosphorus	2.56	3.04	3.15	2.84
Pesticides				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	1,376	755	1,951	888
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	6.1	14.4	2.5	6.69
Edge-of-field pesticide risk indicator				
Average annual surface water pesticide risk indicator for aquatic ecosystem	2.49	2.27	1.35	2.86
Average annual surface water pesticide risk indicator for humans	0.87	1.98	0.20	0.92
Average annual groundwater pesticide risk indicator for humans	0.06	0.01	0.06	0.14

Table B3. Average annual estimates of phosphorus loss and pesticide loss for the baseline conservation condition for cropped acres, by subregion, in the Texas Gulf Basin—**continued**

Model simulated outcome	1208	1209	1210	1211
Phosphorus (average annual pounds/acre)				
Phosphorus applied as commercial fertilizer and manure	9.33	9.57	12.91	11.21
Phosphorus in crop yield removed at harvest	3.57	5.71	7.80	8.64
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	2.01	0.48	0.84	0.78
Phosphorus lost to surface water, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage tiles and ditches and natural seeps	0.13	0.89	1.67	0.65
Soluble phosphorus loss to groundwater	0.03	0.22	0.12	0.11
Total phosphorus loss for all loss pathways	2.18	1.60	2.63	1.54
Change in soil phosphorus	3.68	1.68	2.34	0.39
Pesticides				
Average annual amount of pesticides applied (grams of active ingredient/hectare)	1,861	1,070	1,846	1,054
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	0.7	9.6	11.9	3.5
Edge-of-field pesticide risk indicator				
Average annual surface water pesticide risk indicator for aquatic ecosystem	1.83	4.97	3.99	1.67
Average annual surface water pesticide risk indicator for humans	0.06	0.84	3.09	0.28
Average annual groundwater pesticide risk indicator for humans	0.01	0.01	0.05	0.03

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

Category	1201–1204	1205	1206-1207	1208	1209	1210	1211
Percent of cropped acres within subregion at four conservation treatment levels for structural practices (see figure 7)							
High conservation treatment level	0	1	0	0	2	6	0
Moderately-high conservation treatment level	12	4	33	8	6	8	0
Moderate conservation treatment level	27	30	32	30	41	16	10
Low conservation treatment level	61	65	46	63	50	70	90
Percent of cropped acres within subregion at four conservation treatment levels for residue and tillage management (see figure 8)							
High conservation treatment level	2	12	8	14	5	1	4
Moderately-high conservation treatment level	1	0	1	0	0	0	3
Moderate conservation treatment level	70	38	46	27	56	45	30
Low conservation treatment level	28	50	45	58	39	53	62
Percent of cropped acres within subregion at four conservation treatment levels for nitrogen management (see figure 9)							
High conservation treatment level	18	47	36	44	41	21	20
Moderately-high conservation treatment level	25	32	36	36	30	31	41
Moderate conservation treatment level	46	17	23	19	28	41	36
Low conservation treatment level	10	4	5	1	2	7	4
Percent of cropped acres within subregion at four conservation treatment levels for phosphorus management (see figure 10)							
High conservation treatment level	39	40	57	52	44	30	40
Moderately-high conservation treatment level	11	6	6	3	13	14	17
Moderate conservation treatment level	24	19	12	18	18	13	13
Low conservation treatment level	27	36	24	27	26	43	30
Percent of cropped acres within subregion at four levels of soil runoff potential (see figure 62)							
High soil vulnerability potential	0	1	0	0	0	0	0
Moderately high soil vulnerability potential	26	1	22	1	18	20	6
Moderate soil vulnerability potential	67	6	36	8	29	70	45
Low soil vulnerability potential	6	92	42	90	52	10	49
Percent of cropped acres within subregion at four levels of soil leaching potential (see figure 64)							
High soil vulnerability potential	2	5	4	36	0	0	1
Moderately high soil vulnerability potential	0	1	3	0	3	0	6
Moderate soil vulnerability potential	12	90	44	59	58	14	51
Low soil vulnerability potential	86	5	48	5	38	86	43
Percent of cropped acres within subregion at four levels of soil wind potential (see figure 66							
High soil vulnerability potential	0	3	0	38	0	0	1
Moderately high soil vulnerability potential	0	34	7	51	12	0	64
Moderate soil vulnerability potential	0	63	26	11	45	0	32
Low soil vulnerability potential	100	0	68	0	43	100	3

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

Table B5. Percent of cropped acres for conservation treatment needs, by subregion, in the Texas Gulf Basin

Category	1201–1204	1205	1206-1207	1208	1209	1210	1211
Percent of cropped acres within subregion with conservation treatment needs for sediment loss							
High level of treatment need	0	0	0	0	0	0	0
Moderate level of treatment need	91	8	51	7	47	89	50
Percent of cropped acres within subregion with conservation treatment needs for nitrogen lost with runoff							
High level of treatment need	6	0	3	0	2	2	0
Moderate level of treatment need	0	0	0	0	0	0	0
Percent of cropped acres within subregion with conservation treatment needs for phosphorus lost to surface water							
High level of treatment need	0	0	0	0	0	0	0
Moderate level of treatment need	0	0	0	0	0	0	0
Percent of cropped acres within subregion with conservation treatment needs for nitrogen loss in subsurface flows							
High level of treatment need	0	0	0	0	0	0	0
Moderate level of treatment need	56	21	27	19	29	48	40
Percent of cropped acres within subregion with conservation treatment needs for wind erosion							
High level of treatment need	0	58	23	66	32	0	74
Moderate level of treatment need	40	42	55	34	48	63	25
Percent of cropped acres within subregion with conservation treatment needs for one or more resource concern							
High level of treatment need	6	58	25	66	35	2	74
Moderate level of treatment need	92	42	68	34	62	92	26
Undertreated (high or moderate level of treatment need)	98	100	93	100	96	93	100

END