United States
Department of
Agriculture

Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Pacific Northwest Basin

National Resources Conservation Service
Conservation Effects Assessment Project

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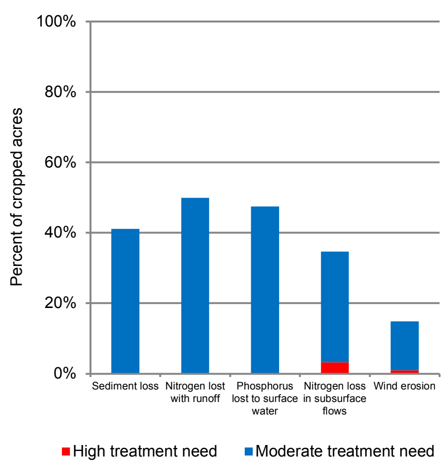

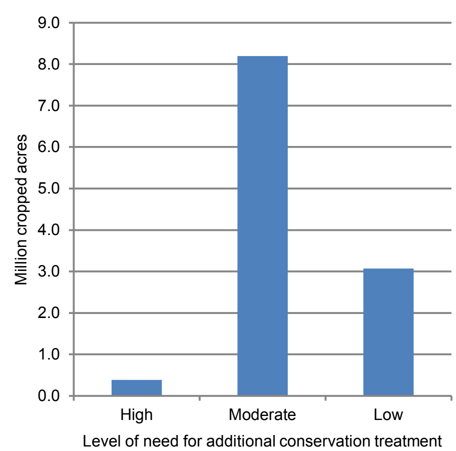

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Cover photos by (clockwise from top left) **Glenn Shea, Mark Olson, Dan Ogle, Ron Nichols,** USDA Natural Resources Conservation Service

CEAP—Strengthening the science base for natural resource conservation

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

CEAP activities are organized into three interconnected efforts:

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

Research and assessment efforts were designed to estimate the effects and benefits of conservation practices through a mix of research, data collection, model development, and model application. A vision for how CEAP can contribute to better and more effective delivery of conservation programs in the years ahead is addressed in Maresch, Walbridge, and Kugler (2008). Additional information on the scope of the project can be found at http://www.nrcs.usda.gov/technical/nri/ceap/.

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

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Foreword

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

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

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

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

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

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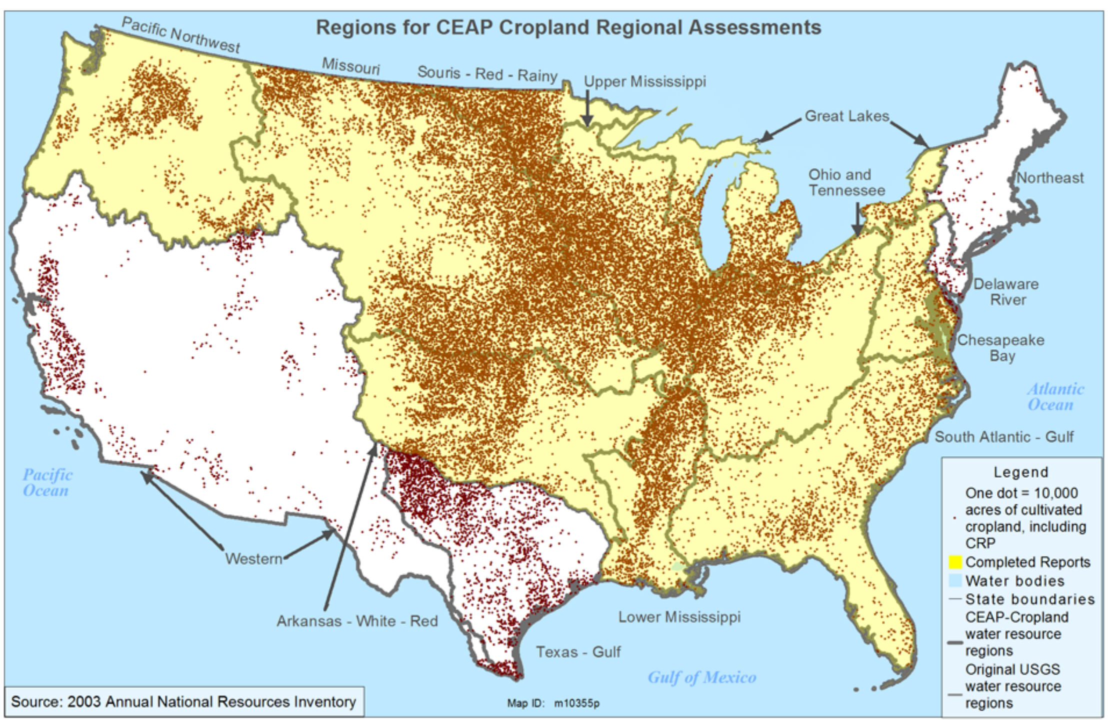


Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Pacific Northwest Basin

Contents

Documentation Reports

There are a series of documentation reports and associated publications by the modeling team posted on the CEAP website at: http://www.nrcs.usda.gov/technical/nri/ceap. (Click on "Cropland" and then click on "documentation reports and associated publications.") Included are the following reports that provide details on the modeling and databases used in this study:

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

Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Pacific Northwest Basin

Executive Summary

Agriculture in the Pacific Northwest Basin

The Pacific Northwest Basin consists of the drainage in the northwestern United States that discharges into the Pacific Ocean. The basin includes all of Washington, most of Oregon and Idaho, part of western Montana, and small parts of Wyoming, California, Utah, and Nevada. It covers 277,000 square miles (178 million acres).

Land cover in the basin is dominated by forestland and rangeland. Cultivated cropland accounts for only about 9 percent of the area. Rangeland accounts for 42 percent of the area, and forestland accounts for 40 percent of the area. Urban areas make up about 3 percent of the basin. The major metropolitan areas are Seattle, WA, and Portland, OR.

The 2007 Census of Agriculture reported 107,000 farms in the Pacific Northwest Basin, about 5 percent of the total number of farms in the United States. About 57 percent of Pacific Northwest Basin farms primarily raise crops, about 38 percent are primarily livestock operations, and the remaining 5 percent produce a mix of livestock and crops. According to the 2007 Census of Agriculture, the value of Pacific Northwest Basin agricultural sales in 2007 was about $16.8 billion, representing 6 percent of the National total. About 60 percent was from crops and 40 percent was from livestock.

The Pacific Northwest Basin accounted for about 7 percent of all U.S. crop sales in 2007, totaling $10 billion. Wheat and hay are the principal crops grown, accounting for 61 percent of harvested crop acreage in 2007. Potatoes, barley, and sugarbeets are also important crops in the region.

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

The primary focus of the CEAP Pacific Northwest Basin study is on the 16 million acres of cultivated cropland, including land in long-term conserving cover. The study was designed to—

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

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

The assessment was done using a common set of criteria and protocols applied to all regions in the country to provide a systematic, consistent, and comparable assessment at the national level. The sample size of the farmer survey—18,700 sample points nationally with 918 sample points in the Pacific Northwest Basin—is sufficient for reliable and defensible reporting for most subregions in the eastern portion of the basin, which include 92 percent of the cropped acres in the region. Other subregions, however, had to be combined for reporting because of the low density of cultivated cropland.

Voluntary, Incentives-Based Conservation Approaches Are Achieving Results

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

Conservation Practice Use

The farmer survey found, for the period 2003–06, that producers use either residue and tillage management practices or structural practices, or both, on 92 percent of the cropped acres.

- Structural practices for controlling water erosion are in use on 33 percent of cropped acres. Eighteen percent of cropped acres are designated as highly erodible land; structural practices designed to control water erosion are in use on 40 percent of these acres.
- Reduced tillage is common in the region; 80 percent of the cropped acres meet criteria for either no-till (21 percent) or mulch till (59 percent). All but 10 percent of the acres have evidence of some kind of reduced tillage on at least one crop in the rotation.

The use of nutrient management practices is more widespread in this region than other regions. The farmer survey found that the majority of acres have evidence of some nitrogen or phosphorus management. For example:

- About 72 percent of cropped acres meet criteria for timing of nitrogen applications on all crops in the rotation, 68 percent meet criteria for method of application, and 64 percent meet criteria for rate of application. An additional 1 percent of cropped acres have no nitrogen applied.
- About 61 percent of cropped acres meet criteria for timing of phosphorus applications on all crops in the rotation, 62 percent meet criteria for method of application, and 55 percent meet criteria for rate of application. An additional 17 percent of cropped acres have no phosphorus applied

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

- Appropriate nitrogen application rates, timing of application, and application method for all crops during every year of production are in use on 44 percent of cropped acres.
- Good phosphorus management practices (appropriate rate, timing, and method) are in use on 43 percent of the acres on all crops during every year of production.
- About 40 percent of cropped acres meet nutrient management criteria for both nitrogen and phosphorus management, including acres with no nutrient applications.

Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of 2.3 million acres in the region, of which 73 percent is highly erodible land.

Conservation Accomplishments at the Field Level

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

- reduced wind erosion by 25 percent;
- reduced waterborne sediment loss from fields by 37 percent;
- reduced nitrogen lost with windborne sediment by 23 percent;
- reduced nitrogen lost with surface runoff (attached to sediment and in solution) by 40 percent;
- reduced nitrogen loss in subsurface flows by 48 percent;
- reduced total phosphorus loss (all loss pathways) from fields by 46 percent; and
- reduced pesticide loss from fields to surface water, resulting in a 65-percent reduction in edge-of-field pesticide risk (all pesticides combined) for aquatic ecosystems and a 30-percent reduction in edge-of-field surface water pesticide risk for humans.

In this region, conservation practices on cropped acres have little effect on soil organic carbon levels for most cropped acres. Conservation practice use in the region has resulted in an average annual gain in soil organic carbon of only 2 pounds per acre per year on cropped acres.

For land in long-term conserving cover (2.3 million acres), soil erosion and sediment loss have been almost completely eliminated. Compared to a cropped condition without conservation practices, total nitrogen loss has been reduced by 85 percent, total phosphorus loss has been reduced by 94 percent, and soil organic carbon has been increased by an average of 179 pounds per acre per year.

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, including land in long-term conserving cover, are expected to reduce loads delivered from cultivated cropland to rivers and streams in the region. Edge-of-field losses of sediment, nitrogen, and phosphorus were incorporated into a national water quality model to estimate the extent to which conservation practices have reduced amounts of these contaminants delivered to rivers and streams throughout the region. Transport of sediment, nutrients, and pesticides from farm fields to streams and rivers involves a variety of processes and time-lags, and not all of the potential pollutants leaving fields contribute to loads delivered to rivers and streams.

Model simulation results for the Pacific Northwest Basin indicate that for the baseline conservation condition, sediment and nutrient loads delivered to rivers and streams from cultivated cropland sources per year, on average, are—

- 11.3 million tons of sediment;
- 235 million pounds of nitrogen; and
- 13.8 million pounds of phosphorus.

Conservation practices in use on cultivated cropland in 2003–06, including land in long-term conserving cover, have reduced sediment and nutrient loads delivered to rivers and streams from cultivated cropland sources per year, on average, by—

- 53 percent for sediment;
- 57 percent for nitrogen;
- 60 percent for phosphorus.

The effects of conservation practices are also estimated for instream loads from all sources. The percent reductions in total instream loads, however, are small in this region because conservation practices affect only the cultivated cropland component of the total instream load. Conservation practices in use on cultivated cropland in 2003-06, including land in long-term conserving cover, have reduced annual instream loads *from all sources* delivered from the Pacific Northwest Basin to the Pacific Ocean, on average, by—

- 5 percent for sediment,
- 16 percent for nitrogen, and
- 8 percent for phosphorus.

The evaluation of conservation practices and associated estimates of sediment, nitrogen, and pesticide losses from farm fields are based on practice use derived from a farmer survey conducted during the years 2003–06. Since then, implementation of the 2008 Farm Bill expanded conservation funding in the region. As a result, farmers have increased the use of proper nutrient management, cover crops, integrated pest management, and other practices. It is therefore possible that the effects of conservation practice use within this region are greater today than was determined during this study.

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

The assessment of conservation treatment needs identifies significant opportunities to further reduce contaminant losses from farm fields. The study found that, because of the current use of conservation practices, very few acres in the region have a **high** need for additional treatment—only 390,000 acres (3 percent of cropped acres in the region). Acres with a **high** level of need consist of the most vulnerable acres with the least conservation treatment and the highest losses of sediment or nutrients. However, most of the cropped acres in the Pacific Northwest Basin were determined to have a **moderate** need for additional conservation treatment—8.19 million acres (70 percent of cropped acres). Acres with a **moderate** level of need for conservation treatment consist of under-treated acres that generally have lower levels of vulnerability and/or have more conservation practice use than do acres with a high level of need. The remaining 3 million cropped acres (26 percent) have a **low** need for additional treatment and are considered to be adequately treated.

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

- 41 percent for sediment loss (no acres with a high need for treatment),
- 50 percent for nitrogen loss with runoff (no acres with a high need for treatment),
- 48 percent for phosphorus lost to surface water (no acres with a high need for treatment),
- 35 percent for nitrogen loss in subsurface flows (3 percent with a high need for treatment), most of which returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow, and
- 15 percent for wind erosion (1 percent with a high need for treatment).

Most undertreated acres in the Pacific Northwest Basin need additional treatment for multiple resource concerns. Only 24 percent of the undertreated acres need additional treatment for a single resource concern, primarily for nitrogen leaching (11 percent). About 58 percent of undertreated acres need treatment for three or more resource concerns, the most common of which is the need to treat for sediment loss, nitrogen runoff, and phosphorus runoff (29 percent). There is no single "most critical" conservation concern in this region. Rather, most undertreated acres have a need for better erosion control (sediment loss and/or wind erosion) *and* consistent use of nutrient management—appropriate rate, form, timing, *and* method of application of nitrogen and phosphorus.

Model simulations show that adoption of additional erosion control and nutrient management practices on the 8.6 million acres with a **high** or **moderate** treatment need would, compared to the 2003–06 baseline, further reduce edge-of-field losses in the region by—

- 85 percent for sediment loss,
- 22 percent for nitrogen lost with windborne sediment,
- 59 percent for nitrogen lost with surface runoff,
- 49 percent for nitrogen loss in subsurface flows,
- 36 percent for phosphorus lost with windborne sediment, and
- 59 percent for phosphorus lost to surface water (sediment-attached and soluble).

These field-level reductions would, in turn, further reduce loads delivered to rivers and streams within the region. Model simulations show that if **all** of the undertreated acres (8.6 million acres) were fully treated with the appropriate soil erosion control and nutrient management practices, loads <u>from cultivated cropland delivered to rivers and streams</u> in the region would be reduced, relative to the baseline conservation condition—

- 73 percent for sediment,
- 47 percent for nitrogen, and
- 41 percent for phosphorus.

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

- innovations in implement design to enhance precise nutrient application and placement, including variable rate technologies and improved manure application equipment;

- enhanced-efficiency nutrient application products such as slow or controlled-release fertilizers (for example: polymer-coated products, sulfur-coated products, etc.) and nitrogen stabilizers (for example: urease inhibitors and nitrification inhibitors);
- drainage water management that controls discharge of drainage water and treats contaminants, thereby reducing the levels of nitrogen and even some soluble phosphorus loss;
- constructed wetlands receiving surface water runoff and drainage water from farm fields prior to discharge to streams and rivers; and
- improved crop genetics that increase yields without increasing nutrient inputs.

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

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

Not all acres require the same level of conservation treatment. The more vulnerable acres, such as highly erodible land and soils prone to leaching, inherently lose more sediment or nutrients; therefore greater benefit can be attained with additional conservation treatment. Acres with characteristics such as steeper slopes and soil types that promote surface water runoff are more vulnerable to sediment and nutrient losses beyond the edge of the field. Acres that are essentially flat with permeable soil types are more prone to nutrient losses through subsurface flow pathways, most of which return to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

Moreover, model simulations show that treatment of erosion alone in this region can sometimes exacerbate the nitrogen leaching problem because reducing surface water runoff increases infiltration and, therefore, movement of soluble nitrogen into subsurface flow pathways. Soil erosion control practices are effective in reducing the loss of nitrogen in surface runoff, but for 7 percent of cropped acres the re-routing of surface water runoff to subsurface flow along with incomplete nutrient management results in a net increase in total nitrogen loss from the field.

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

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

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

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

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

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

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

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

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

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

Chapter 1
Land Use and Agriculture in the Pacific Northwest Basin

Land Use

The Pacific Northwest Basin consists of the drainage in the northwestern United States that discharges into the Pacific Ocean. The basin includes all of Washington, most of Oregon and Idaho, parts of western Montana, and small parts of Wyoming, California, Utah, and Nevada. It covers 277,000 square miles (178 million acres).

Land cover in the basin is dominated by forestland and rangeland (table 1, fig. 1). Cultivated cropland accounts for only about 9 percent of the area. (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].) Rangeland accounts for 42 percent of the area, and forestland accounts for 40 percent of the area.

Urban areas make up about 3 percent of the basin. The major metropolitan areas are Seattle, WA, and Portland, OR. Water and wetlands make up about 3 percent of the area. The remaining 3 percent consists of barren land, pastureland, and hayland.

Table 1. Land cover and use in the Pacific Northwest Basin

Land use	Acres*	Percent of area (including water)	Percent of land base (excluding water)
Cultivated cropland and land enrolled in the CRP General Signup**	16,138,215	9	9
Hayland not in rotation with crops	1,941,738	1	1
Pastureland not in rotation with crops	1,487,943	1	1
Rangeland—grass	13,593,488	8	8
Rangeland—brush	60,552,666	34	35
Horticulture	568,025	<1	<1
Forestland			
Deciduous	1,080,700	1	1
Evergreen	65,956,053	37	38
Mixed	2,585,199	1	1
Urban	5,135,106	3	3
Wetlands			
Forested	1,174,995	1	1
Non-Forested	985,995	1	1
Barren	2,409,964	1	1
Subtotal	173,610,086	98	100
Water	3,919,106	2	
Total	177,529,192	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.

Agriculture

The 2007 Census of Agriculture reported 107,000 farms in the Pacific Northwest Basin, about 5 percent of the total number of farms in the United States (table 2). Land on farms, which can include any of the land use categories shown in table 1 except urban and water, was about 45 million acres, representing 26 percent of the area within the region and 5 percent of all land on farms in the Nation. According to the 2007 Census of Agriculture, the value of Pacific Northwest Basin agricultural sales in 2007 was about $16.8 billion, representing 6 percent of the Nation's total. About 60 percent was from crops and 40 percent was from livestock.

About 57 percent of Pacific Northwest Basin farms primarily raise crops, about 38 percent are primarily livestock operations, and the remaining 5 percent produce a mix of livestock and crops (table 3).

As in other regions of the country, most of the farms are small. About 88 percent of farms have less than 500 acres, 8 percent have 500 to 2,000 acres, and only 4 percent of the farms have more than 2,000 acres (table 3). In terms of 2007 gross sales, 78 percent had less than $50,000 in total farm sales and 12 percent had $50,000 to $250,000 in total farm sales (table 3). Farms with total agricultural sales greater than $250,000 accounted for 10 percent of the farms in the region. About 46 percent of the principal farm operators indicated that farming was their principal occupation.

Crop production

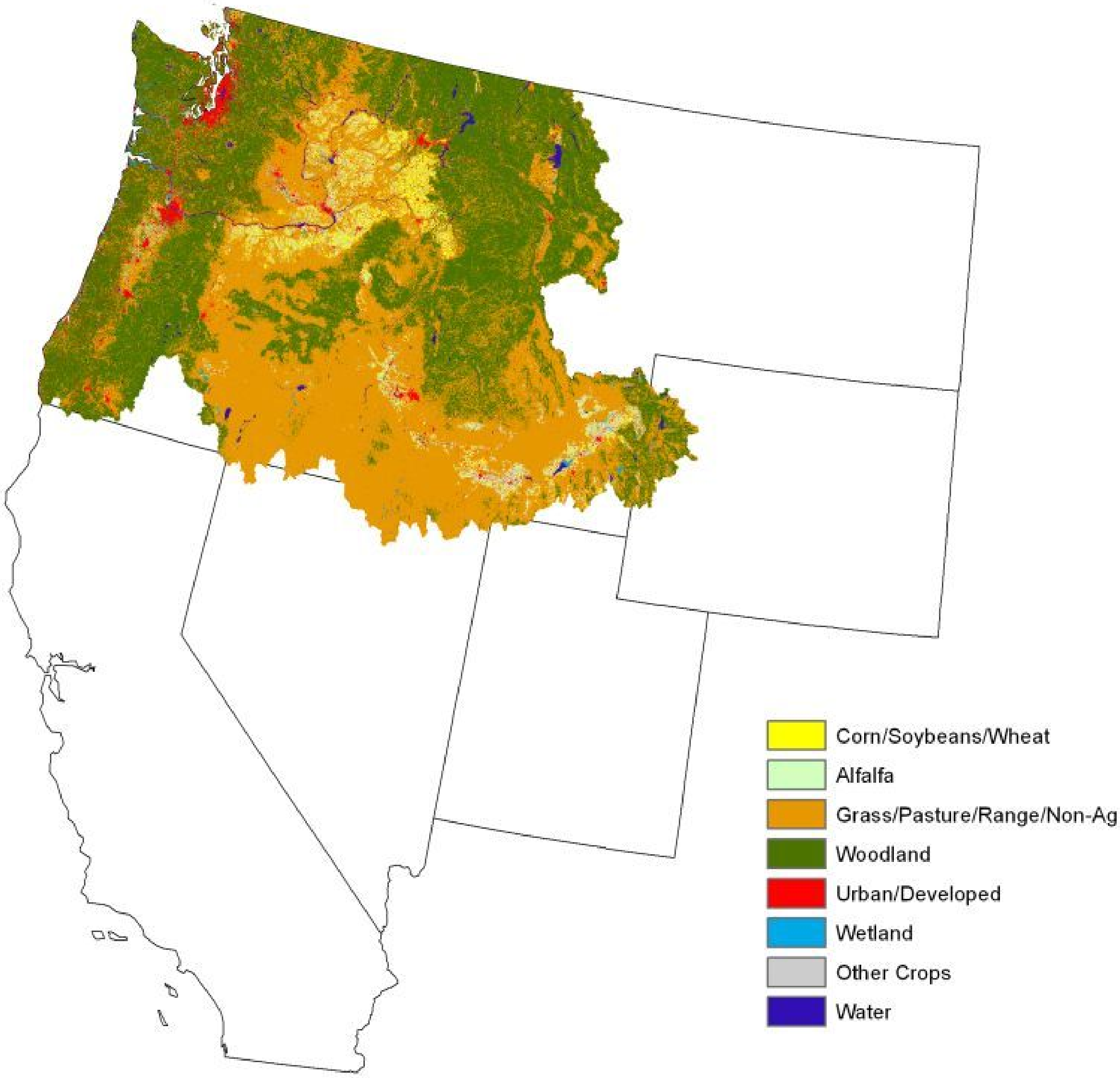
The Pacific Northwest Basin accounted for about 7 percent of all U.S. crop sales in 2007, totaling $10 billion (table 2). Wheat and hay are the principal crops grown, accounting for 61 percent of harvested crop acreage in 2007. Potatoes, barley, and sugarbeets are also important crops in the region. Nearly half of all potato acres in the Nation are in this region (540,000 acres in 2007). Farmers in the region also produced 28 percent of the national barley crop on 812,000 acres and 19 percent of the national sugarbeet crop on 177,000 acres.

Commercial fertilizers and pesticides are widely used throughout the region (table 2). In 2007, 9.6 million acres of cropland were fertilized, 8.7 million acres of cropland and pasture were treated with chemicals for weed control, and 3 million acres of cropland were treated for insect control. About 682,000 acres had manure applied in 2007.

Irrigation use is common in the region; half of the harvested acres were irrigated in 2007.

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

Figure 1. Land cover in the Pacific Northwest Basin



Source: National Agricultural Statistics Service (NASS 2007).

Livestock operations

Livestock production in the region is dominated by cattle and dairy production. Dairy operations in the region produced 10 percent of all dairy sales in the United States in 2007, totaling $3 billion in value (table 2) and accounting for 45 percent of total livestock sales in the region. Cattle sales in the region totaled $2.9 billion in value in 2007 (table 2) and accounted for 43 percent of total livestock sales in the region.

Of the 4.6 million livestock animal units in the region in 2007, 2.8 million animal units were cattle, horses, sheep, and goats, excluding fattened cattle and dairy cows. (An animal unit is 1,000 pounds of live animal weight, calculated as a yearly average for each farm using information reported in the 2007 Census of Agriculture.) Dairy cows and fattened cattle accounted for an additional 1.7 million animal units.

Based on livestock populations on farms as reported in the 2007 agricultural census, 4,882 of the farms in the region (5 percent of all farms in the region) could potentially be defined as animal feeding operations (AFOs) (table 3). AFOs are livestock operations typically with confined poultry, swine, dairy cattle, or beef cattle. About 900 of the livestock operations (2 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 400 meet livestock population criteria for a large CAFO.

An additional 18,205 farms have significant numbers of pastured livestock (17 percent of farms in the region).

Table 2. Profile of farms and land in farms in the Pacific Northwest Basin, 2007

Characteristic	Value	Percent of national total
Number of farms	107,211	5
Land on farms, acres	45,396,461	5
Average acres per farm	423	
Cropland harvested, acres	11,687,520	4
Cropland used for pasture, acres	1,594,756	4
Cropland on which all crops failed, acres	142,417	2
Cropland in summer fallow, acres	2,021,703	13
Cropland idle or used for cover crops, acres	3,043,108	8
Woodland pastured, acres	3,441,141	12
Woodland not pastured, acres	1,460,581	3
Permanent pasture and rangeland, acres	20,450,780	5
Other land on farms, acres	1,554,455	5
Principal crops grown		
Wheat harvested, sum acres harvested	4,103,067	8
Alfalfa hay harvested, acres harvested	1,925,495	10
Tame and wild hay harvested, acres harvested	1,073,355	3
Barley harvested, acres harvested	811,596	23
Potatoes harvested, acres harvested	537,779	48
Sugarbeets harvested, acres harvested	176,906	14
Irrigated harvested land, acres	5,834,210	11
Irrigated pastureland or rangeland, acres	1,146,835	23
Cropland fertilized, acres	9,600,426	4
Pastureland fertilized, acres	604,064	2
Land treated for insects on hay or other crops, acres	3,044,378	3
Land treated for nematodes in crops, acres	395,386	5
Land treated for diseases in crops and orchards, acres	1,369,933	6
Land treated for weeds in crops and pasture, acres	8,723,761	4
Crops on which chemicals for defoliation applied, acres	605,547	5
Acres on which manure was applied	682,277	3
Total grains and oilseeds sales, million dollars	2,073	3
Total vegetable, melons sales, million dollars	1,911	13
Total nursery, greenhouse, and floriculture sales, million dollars	1,407	8
Total other crops and hay sales, million dollars	4,614	15
Total crop sales, million dollars	10,004	7
Total dairy sales, million dollars	3,071	10
Total hog and pigs sales, million dollars	19	<1
Total poultry and eggs sales, million dollars	354	1
Total cattle sales, million dollars	2,937	5
Total sheep, goats, and their products sales, million dollars	55	8
Total horses, ponies, and mules sales, million dollars	64	3
Total other livestock sales, million dollars	305	12
Total livestock sales, million dollars	6,805	4
Animal units on farms		
All livestock types	4,613,226	4
Swine	15,958	<1
Dairy cows	1,210,004	10
Fattened cattle	492,629	4
Other cattle, horses, sheep, goats	2,815,667	5
Chickens, turkeys, and ducks	59,036	1
Other livestock	19,932	5

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 Pacific Northwest Basin, 2007

	Number of farms	Percent of farms in Pacific Northwest Basin
Farming primary occupation	48,901	46
Farm size:		
<50 acres	63,627	59
50–500 acres	30,734	29
500–2,000 acres	8,455	8
>2,000 acres	4,395	4
Farm sales:		
<$10,000	64,065	60
$10,000–50,000	19,606	18
$50,000–250,000	12,557	12
$250,000–500,000	4,275	4
>$500,000	6,708	6
Farm type:		
Crop sales make up more than 75 percent of farm sales	60,773	57
Livestock sales make up more than 75 percent of farm sales	41,078	38
Mixed crop and livestock sales	5,360	5
Farms with no livestock sales	41,285	39
Farms with few livestock or specialty livestock types	42,839	40
Farms with pastured livestock and few other livestock types	18,205	17
Farms with animal feeding operations (AFOs)*	4,882	5

Source: 2007 Census of Agriculture, National Agricultural Statistics Service, USDA

* AFOs, as defined here, typically have a total of more than 12 animal units consisting of fattened cattle, dairy cows, hogs and pigs, chickens, ducks, and turkeys.

Watersheds

A hydrologic accounting system consisting of water resource regions, major subregions, and smaller watersheds has been defined by the U.S. Geological Survey (USGS) (1980). Each water resource region is designated with a 2-digit Hydrologic Unit Code (HUC), which is further divided into 4-digit subregions and then into 8-digit cataloging units, or watersheds. The Pacific Northwest drainage is represented by 12 subregions.

Cultivated cropland is not a dominant land use in any of the 12 subregions (table 4 and fig. 2). Most cultivated cropland in the region (81 percent) is found in four subregions—

- the Snake Headwaters-Upper Snake River Basin (code 1704), with 3.7 million acres of cultivated cropland,
- the Upper Columbia River Basin (code 1702), with 3.2 million acres of cultivated cropland,
- the Middle Columbia River Basin including John Day-Deschutes (code 1707), with 3.2 million acres of cultivated cropland, and
- the Lower Snake River Basin including Salmon-Clear Water (code 1706), with 3.0 million acres of cultivated cropland.

Four subregions have very small amounts of cultivated cropland, each with less than 1 percent of the region’s cultivated cropland (table 4 and fig. 2)—

- the Lower Columbia River Basin (code 1708),
- the Washington-Oregon Coastal basins (code 1710),
- the Puget Sound Basin (code 1711), and
- the Oregon closed basins (code 1712).

Together these four subregions have only 250,000 acres of cultivated cropland, accounting for only 1.5 percent of the cultivated cropland in the region.

The concentration of cultivated cropland within each subregion is an important indicator of the extent to which sediment and nutrient loads in rivers and streams are influenced by farming operations. The subregion with the highest concentration of cultivated cropland in the Pacific Northwest Basin is the Upper Columbia River Basin (code 1702 (table 4 and fig. 2), where cultivated cropland represents 22 percent of the total area in the subregion. The concentration of cultivated cropland is 16 to 17 percent in two other subregions—the Middle Columbia River Basin including John Day-Deschutes (code 1707) and the Snake Headwaters-Upper Snake River Basin (code 1704).

Cultivated cropland includes land in long-term conserving cover, which represents about 13 percent of the cultivated cropland acres in this region (table 4). Subregions where land in long-term conserving cover is most concentrated are—

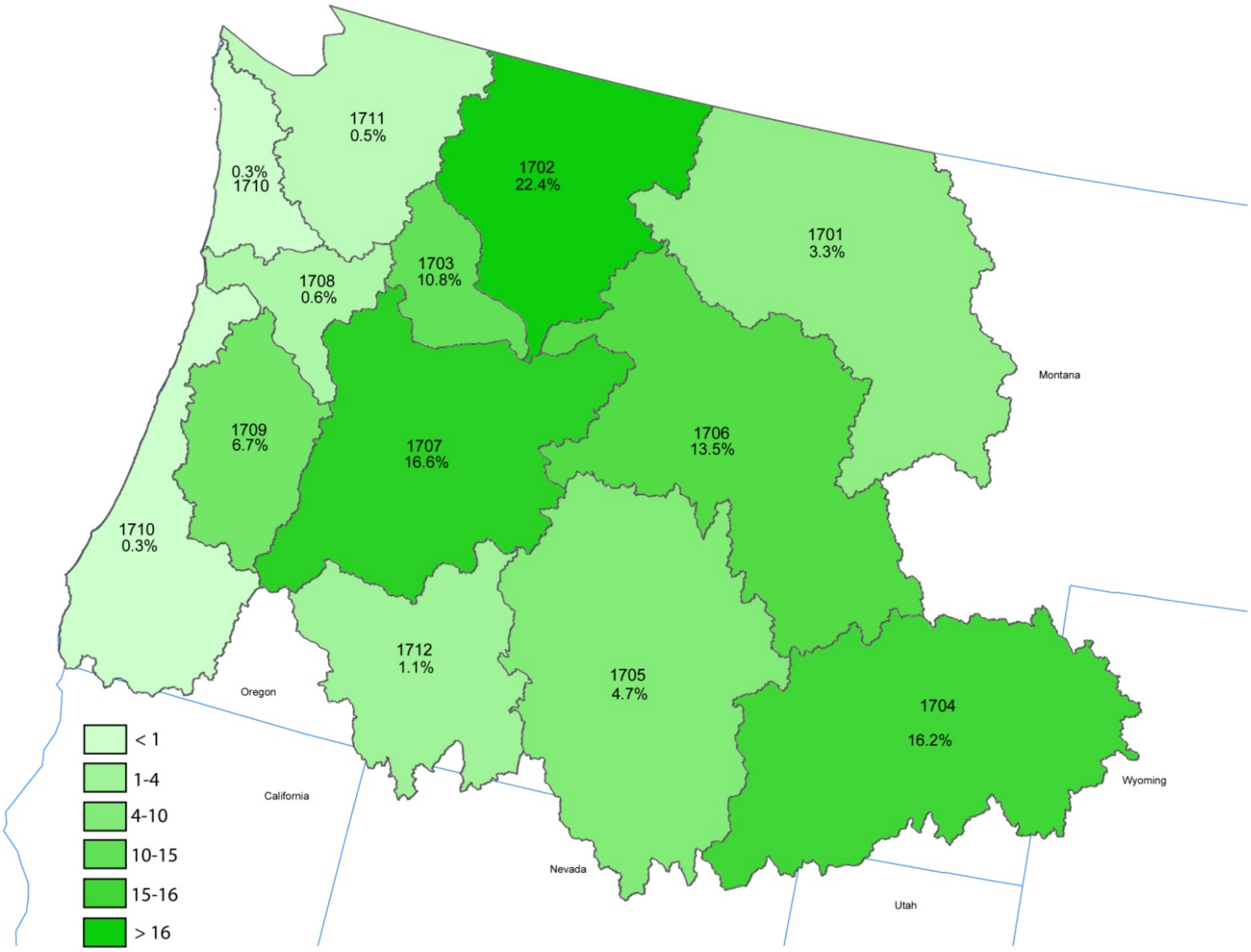
- the Middle Columbia River Basin including John Day-Deschutes (code 1707), where land in long-term conserving cover accounts for 20 percent of cultivated cropland within the subregion, and
- the Upper Columbia River Basin (code 1702), where land in long-term conserving cover accounts for 16 percent of cultivated cropland within the subregion.

Table 4. Cultivated cropland use in the 12 subregions in the Pacific Northwest Basin

Subregion	Total area (acres)	Cultivated cropland (acres)*	Percent cultivated cropland in subregion	Percent of cultivated cropland in Pacific Northwest Basin	Percent of cultivated cropland acres in long-term conserving cover
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin (code 1701)	23,229,321	760,433	3	5	8
Upper Columbia River Basin (code 1702)	14,248,348	3,194,966	22	20	16
Yakima River Basin (code 1703)	3,962,751	426,305	11	3	10
Snake Headwaters-Upper Snake River Basin (code 1704)	22,943,259	3,710,638	16	23	13
Middle Snake River Basin (code 1705)	23,687,913	1,114,258	5	7	6
Lower Snake River Basin including Salmon-Clear Water (code 1706)	22,424,592	3,021,713	14	19	11
Middle Columbia River Basin including John Day-Deschutes (code 1707)	19,119,304	3,173,192	17	20	20
Lower Columbia River Basin (code 1708)	3,968,805	23,041	<1	<1	<1
Willamette River Basin (code 1709)	7,357,499	489,277	7	3	<1
Washington-Oregon Coastal (code 1710)	14,855,243	43,414	<1	<1	<1
Puget Sound Basin (code 1711)	10,590,506	57,141	<1	<1	<1
Oregon closed basins (code 1712)	11,141,653	123,837	1	<1	12
Total	177,529,192	16,138,215	9	100	13

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 12 subregions in the Pacific Northwest 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—

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

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

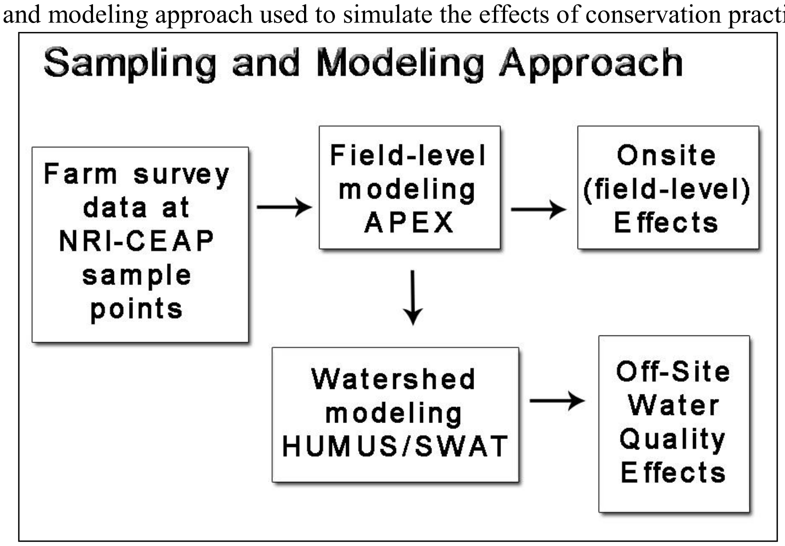
Sampling and Modeling Approach

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

- A subset of 918 National Resources Inventory (NRI) sample points provides a statistical sample that represents the diversity of soils and other conditions for cropped acres in the Pacific Northwest Basin. The sample also includes 822 additional NRI sample points designated as CRP acres to represent 2.3 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 918 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 Pacific Northwest Basin. The SWAT model (Soil and Water Assessment Tool) was used to simulate nonpoint source loadings from land uses other than cropland and to route instream loads from one watershed to another.

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

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



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

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

The effects of conservation practices are obtained by taking the difference in model results between the two scenarios (fig. 4). 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.[1] 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).

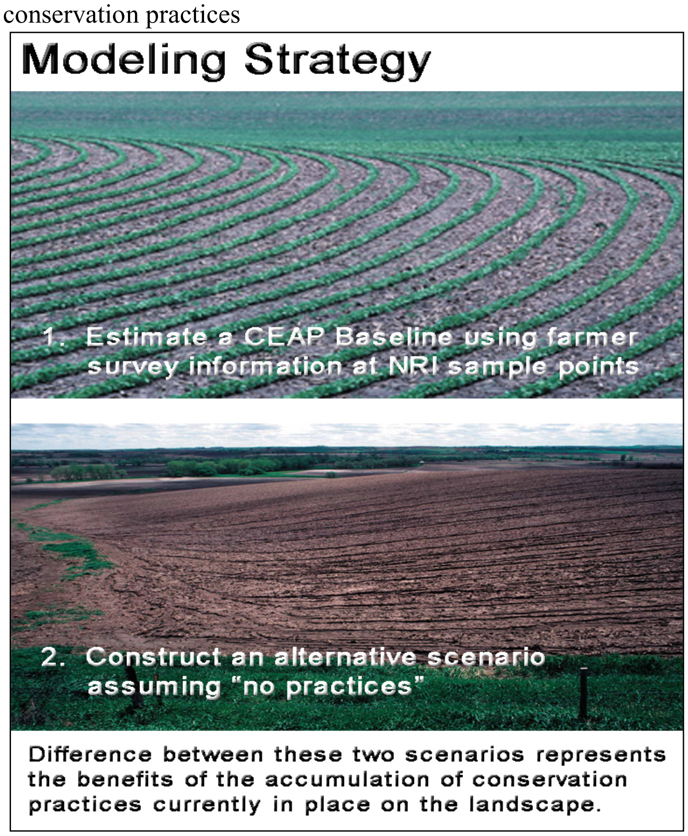
The NRI and the CEAP Sample

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



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

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

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

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

The NRI-CEAP Cropland Survey

A farmer survey—the NRI-CEAP Cropland Survey—was conducted to obtain the additional information needed for modeling the 918 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 11,649,900 cropped acres in the region has a lower bound of 11,127,477 acres and an upper bound of 12,172,323 acres (table 5). (The lower bound is the estimate minus the margin of error and the upper bound is the estimate plus the margin of error.)

The NRI-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 Pacific Northwest Basin, sample sizes for six subregions were too small to reliably report edge-of-field results because of the small amount of cultivated cropland acres within each subregion. Five of these subregions were combined with each other or other subregions as follows:

- the Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin (code 1701) was combined with the Yakima River Basin (code 1703), both of which are tributaries to the Upper Columbia River Basin and had too few sample points for separate reporting;
- the Lower Columbia River Basin (code 1708) had only one sample point, which was combined with the Willamette River Basin (code 1709) for reporting; and
- the Washington-Oregon Coastal basins (code 1710) and the Puget Sound Basin (code 1711), all of which drain directly into the Pacific Ocean without upstream

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

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

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

tributaries and had too few sample points for separate reporting.

An additional subregion, the Oregon closed basins subregion (code 1712), had no CEAP sample points and so no cropped acres or edge-of-field model results are estimated for this subregion.

NRI-CEAP estimates of cropped acres for the subregions and combined subregions within the Pacific Northwest Basin are presented in table 5 along with the 95-percent confidence intervals. These estimates of cropped acres differ from cultivated cropland estimates presented in tables 1 and 4 primarily because those tables also include 2.3 million acres of land in long-term conserving cover and 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.

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

Subregion and subregion groupings	Number of CEAP samples	Estimated acres	Percent	95-percent confidence interval: Lower bound (acres)	95-percent confidence interval: Upper bound (acres)
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	57	812,000	7	532,011	1,091,989
Upper Columbia River Basin (code 1702)	111	2,469,500	21	1,951,062	2,987,938
Snake Headwaters-Upper Snake River Basin (code 1704)	249	2,431,900	21	2,196,526	2,667,274
Middle Snake River Basin (code 1705)	82	617,600	5	401,877	833,323
Lower Snake River Basin including Salmon-Clear Water (code 1706)	123	2,258,200	19	1,855,836	2,660,564
Middle Columbia River Basin including John Day-Deschutes (code 1707)	167	2,080,100	18	1,745,402	2,414,798
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	103	868,200	7	721,992	1,014,408
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	26	112,400	1	62,271	162,529
Total	918	11,649,900	100	11,127,477	12,172,323

Note: Estimates are from the NRI-CEAP Cropland Survey. No NRI-CEAP sample points were obtained in the "Oregon closed basins" subregion (code 1712); thus no cropped acres are estimated for this subregion.

Cropping Systems in the Pacific Northwest 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.)

Rotations that include wheat or other close-grown crop dominate cropping systems in this region (table 6). Wheat grown without any other crops represents 43 percent of cropped acres in the region, according to the survey. Rotations that include vegetables account for 13 percent of cropped acres. Hay-crop mixes and cropping systems that include potatoes or sugarbeets are also important in this region.

Table 6. Estimated crop acres for cropping systems in the Pacific Northwest Basin

Cropping system	Number of CEAP samples	Estimated acres	Percent of total	95-percent confidence interval: Lower bound (acres)	95-percent confidence interval: Upper bound (acres)
Wheat only	329	4,959,655	43	4,282,440	5,636,870
Vegetables with or without other crops	111	1,506,077	13	1,170,104	1,842,050
Hay-crop mixes	72	1,043,193	9	677,597	1,408,789
Barley only	45	392,056	3	208,991	575,121
Corn and close grown crops	20	188,167	2	85,001	291,333
Potatoes with or without other crops	76	729,345	6	480,314	978,376
Sugarbeets with or without other crops	50	417,789	4	297,716	537,862
Remaining mix of row crops	34	276,437	2	145,177	407,697
Remaining mix of close grown crops	99	911,376	8	757,453	1,065,299
Remaining mix of row and close crops	82	1,225,806	11	857,200	1,594,412
Total	918	11,649,900	100	11,127,477	12,172,323

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 21 inches for cropped acres in the region. However, annual precipitation varies 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.

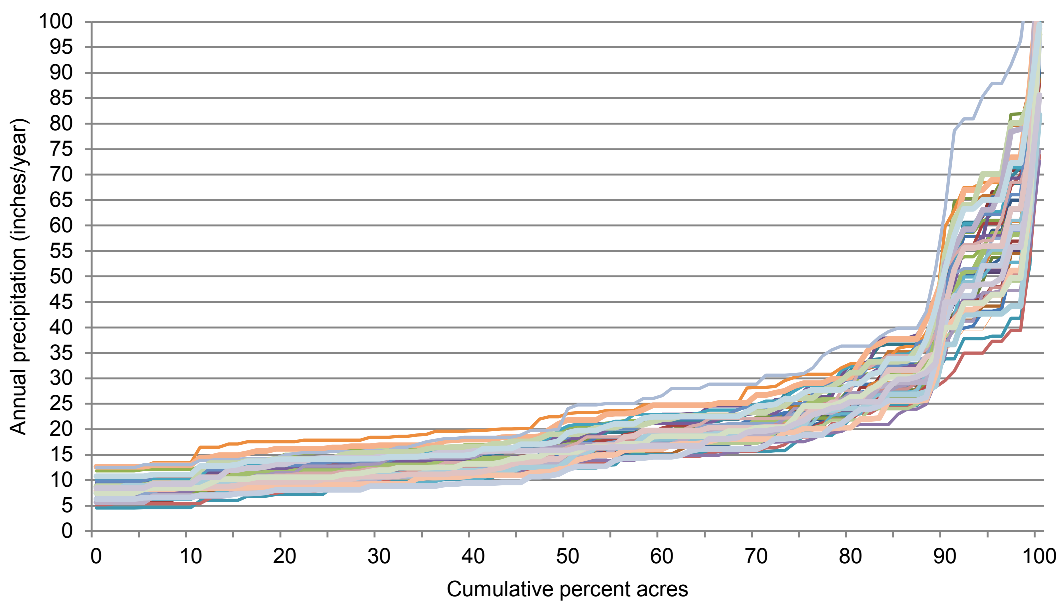
Precipitation in the western portion of the basin, represented by the four subregions located on or near the coast, is much higher than precipitation on cropland acres in the eastern portion of the basin. Precipitation for cropland acres in the western portion of the basin averaged 59 inches per year, compared to an average of 17 inches per year for the seven eastern subregions. The bulk of the cropped acres are located in the seven eastern subregions—92 percent of cropped acres (table 5).

Thus, the curves in figure 5 show a sharp increase in annual precipitation for the 8 percent of cropped acres with the highest precipitation, representing the annual precipitation for cropped acres in the four subregions nearest the coast. Conversely, the annual precipitation curves for the 92 percent of cropped acres with the lower values represent the variability among cropped acres within the seven eastern subregions.

These marked regional differences in precipitation are shown explicitly in figure 6. Year-to-year variability is more pronounced for the cropped acres in the four western subregions—the average annual precipitation amount (representing cropped acres) ranged over the 47 years from 39 inches in 1985 to 90 inches in 1996 (fig. 6). For the seven eastern subregions, the average annual precipitation amount for cropped acres ranged from 13 inches in 1976 to 24 inches in 1996.

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

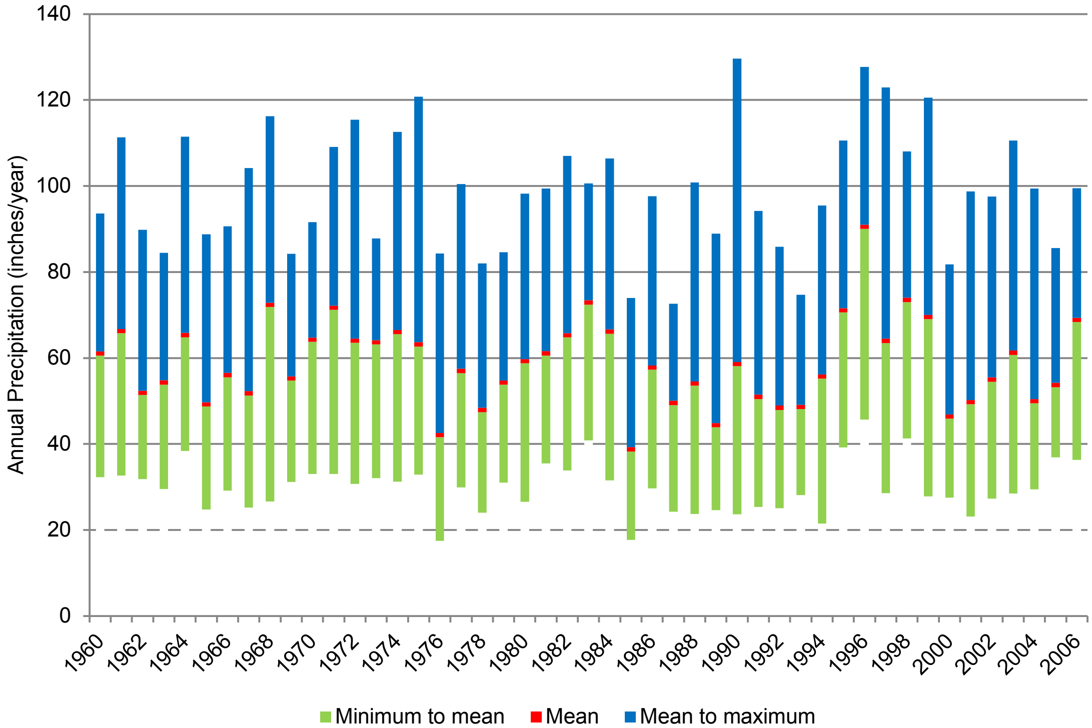
Figure 5. Cumulative distributions of annual precipitation used in the model simulations for cropped acres in the Pacific Northwest Basin



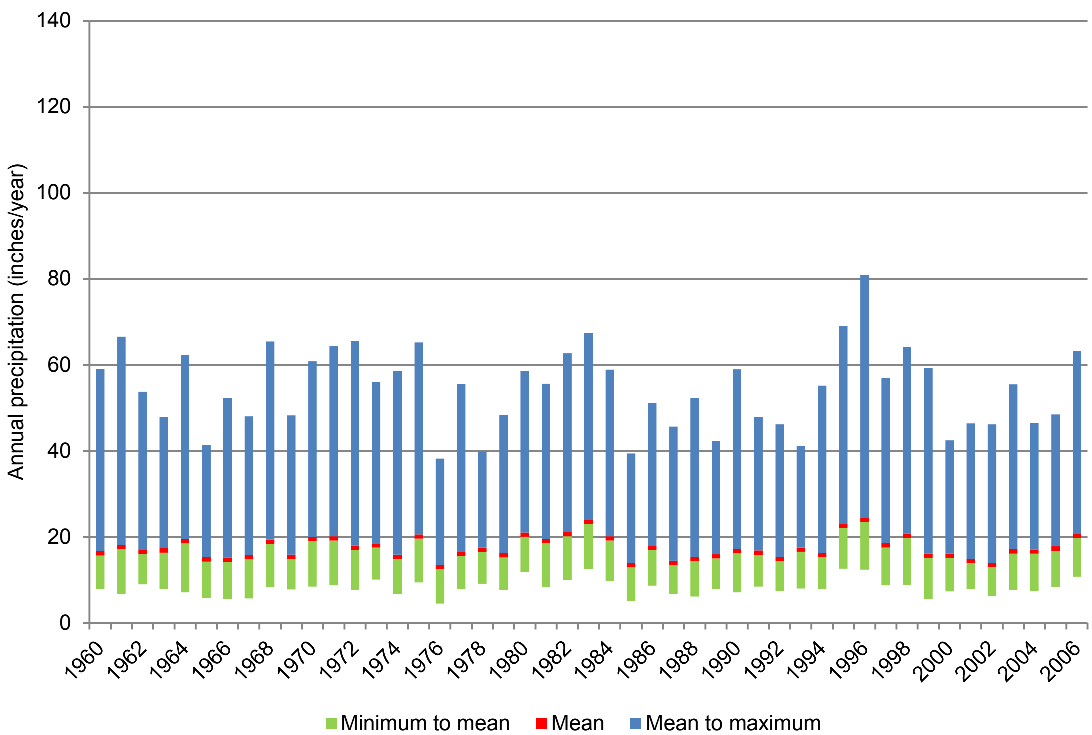
Note:. Each of the 47 curves shown above represents a single year of data and shows how annual precipitation varies over the region in that year, starting with the acres with the lowest precipitation within the region and increasing to the acres with the highest precipitation. The family of curves shows how annual precipitation varies from year to year. Annual precipitation over the 47-year simulation averaged about 21 inches for cropped acres throughout the region.

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

Four Subregions along the Coast Representing 8 Percent of Cropped Acres
(codes 0708, 0709, 0710, and 0711)



Remaining Subregions Representing 92 Percent of Cropped Acres
(codes 0701, 0702, 0703, 0704, 0705, 0706, and 0707)



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

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

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

Summary of Practice Use

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

- Structural practices for controlling water erosion are in use on 33 percent of cropped acres. On the 54 percent of the acres designated as highly erodible land, structural practices designed to control water erosion are in use on 40 percent.
- Reduced tillage is common in the region; 80 percent of the cropped acres meet criteria for either no-till (21 percent) or mulch till (59 percent). All but 10 percent of the acres had evidence of some kind of reduced tillage on at least one crop.
- About 30 percent of cropped acres are gaining soil organic carbon.
- Producers use either residue and tillage management practices or structural practices, or both, on 92 percent of cropped acres.
- The use of nutrient management practices is more widespread in this region than in other regions.
  - About 1 percent of cropped acres have no nitrogen applied. An additional 72 percent of cropped acres meet criteria for timing of nitrogen applications on all

crops in the rotation, 68 percent meet criteria for method of application, and 64 percent meet criteria for rate of application.
  - About 17 percent of cropped acres have no phosphorus applied. An additional 61 percent of cropped acres meet criteria for timing of phosphorus applications on all crops in the rotation, 62 percent meet criteria for method of application, and 55 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 are in use on 44 percent of cropped acres.
  - Good phosphorus management practices (appropriate rate, timing, and method) are in use on 43 percent of the acres on all crops during every year of production.
  - About 40 percent of cropped acres meet nutrient management criteria for both nitrogen and phosphorus management, including acres with no nutrient applications.
- During the 2003–06 period of data collection, cover crops were used on less than 1 percent of the acres in the region.
- The Integrated Pest Management (IPM) indicator showed that only about 12 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 2.3 million acres in the region, of which 73 percent is highly erodible land.

Structural Conservation Practices

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

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

Overland flow control practices are designed to slow the movement of water across the soil surface to reduce surface water runoff and sheet and rill erosion. NRCS practice standards for overland flow control include terraces, contour farming, stripcropping, in-field vegetative barriers, and field borders.[5] These practices are found on about 22 percent of the cropped acres in the region, including 27 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 12 percent of the cropped acres have one or more of these practices, including 17 percent of the highly erodible land (table 7).

Edge-of-field buffering and filtering practices, consisting of grasses, shrubs, and/or trees, are designed to capture the surface runoff losses that were not avoided or mitigated by the in-field practices. NRCS practice standards for edge-of-field mitigation practices include edge-of-field filter strips, riparian herbaceous buffers, and riparian forest buffers. CRP's buffer practices are included in this category. Edge-of-field buffering and filtering practices are in use on about 6 percent of all cropped acres in the region (table 7).

Overall, about 33 percent of the cropped acres in the Pacific Northwest Basin are treated with one or more water erosion control structural practices (table 7). The treated percentage for highly erodible land acres is slightly higher—40 percent.

At each sample point, structural conservation practices for water erosion control were classified as either a high, moderately high, moderate, or low level of treatment according to criteria presented in figure 7. Only about 3 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 7 percent have a moderately high level of treatment for structural practices. In contrast, 67 percent of the acres have a low treatment level for structural practices, which indicates that these acres do not have any structural practices for water erosion control. Included among the acres with a low treatment level are 38.5 percent of cropped acres with slopes greater than 2 percent.

(These treatment levels are combined with soil risk classes to estimate acres that appear to be undertreated for water erosion control in chapter 5.)

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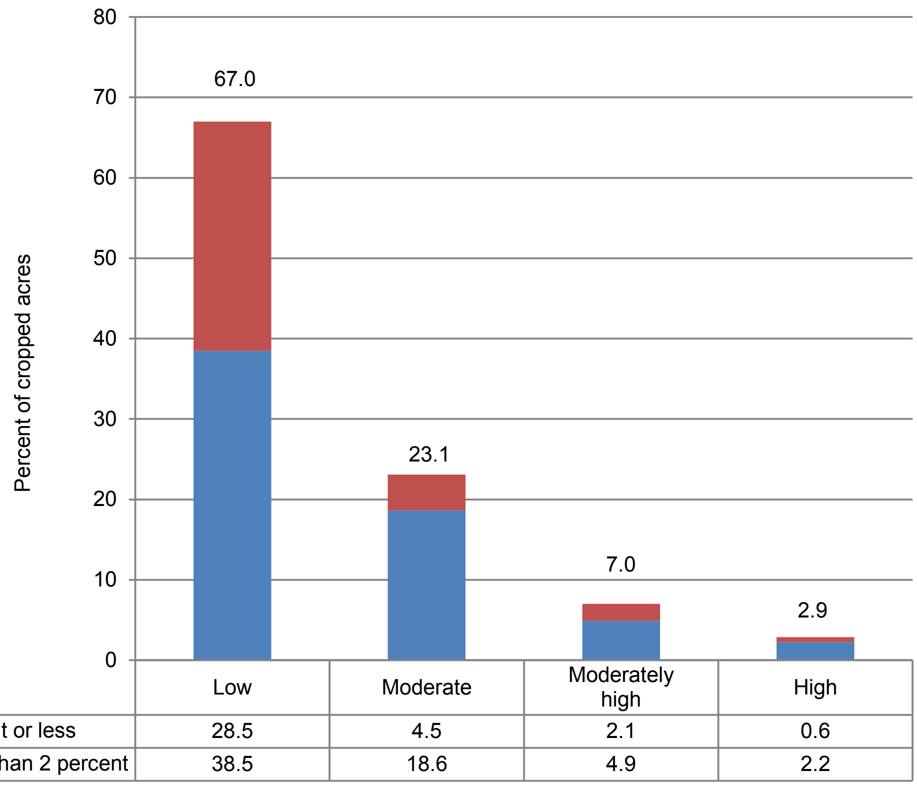
[5] Dikes and borders were incorporated into the model simulation for all sample points with rice as ponding of water is required for production. Dikes are typically used for flood protection and were not counted here as a field-level conservation practice in study.

Table 7. Structural conservation practices in use for the baseline conservation condition, Pacific Northwest Basin

Structural practice category	Conservation practice in use	Percent of non-HEL	Percent of HEL	Percent of cropped acres
Overland flow control practices	Terraces, contour buffer strips, contour farming, stripcropping, contour stripcropping, field border, in-field vegetative barriers	15	27	22
Concentrated flow control practices	Grassed waterways, grade stabilization structures, diversions, other structures for water control	7	17	12
Edge-of-field buffering and filtering practices	Riparian forest buffers, riparian herbaceous buffers, filter strips	8	5	6
One or more water erosion control practices	Overland flow, concentrated flow, or edge-of-field practice	25	40	33
Wind erosion control practices	Windbreaks/shelterbelts, cross wind trap strips, herbaceous windbreak, hedgerow planting	3	3	3

Note: About 54 percent of cropped acres in the Pacific Northwest 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, Pacific Northwest Basin



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

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

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

Wind erosion control practices are designed to reduce the force of the wind on the field. NRCS structural practices for wind erosion control include cross wind ridges, cross wind trap strips, herbaceous wind barriers, and windbreak/shelterbelt establishment. Wind erosion is a resource concern for many cropped acres in this region. However, only about 3 percent of the cropped acres in the region are treated for wind erosion using structural practices (table 7).

Residue and Tillage Management Practices

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

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

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

Overall, 80 percent of cropped acres in the Pacific Northwest Basin meet the tillage intensity rating for either no-till or mulch till (table 8). About 21 percent meet the criteria for no-till, and 59 percent meet the tillage intensity criteria for mulch till. About 11 percent of cropped acres do not meet criteria for mulch till or no-till but have reduced tillage on some crops in the rotation. Only 10 percent of the acres are conventionally tilled for all crops in the rotation.

To evaluate the use of residue and tillage management practices, practice use was classified as high, moderately high, moderate, or low for each sample point according to criteria presented in figure 8. (These residue and tillage management treatment levels were combined with the use of structural practices to estimate conservation treatment levels for water erosion control in chapter 5.) The high and moderately high treatment levels represent the 26 percent of cropped acres that meet tillage intensity criteria for either no-till or mulch till and are gaining soil organic carbon.

The high treatment level, representing 18 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 7.5 percent of cropped acres have a moderately high treatment level, where the *average annual* tillage intensity meets criteria for mulch till or no-till and the crop rotation is gaining soil organic carbon.

The bulk of the cropped acres—67 percent—have a moderate level of treatment. Most of these acres meet tillage intensity for no-till or mulch till but are losing soil organic carbon. Other acres have reduced tillage but do not meet criteria for no-till or mulch till, or they are gaining soil organic carbon but tillage intensity exceeds criteria for mulch till (fig. 8).

About 7.5 percent of the acres have a low treatment level, consisting of continuous conventional tillage for all crops in the rotation and loss of soil organic carbon.

Structural practices and residue and tillage management practices influence losses of sediment, nutrients, and pesticides due to water erosion. Most of the cropped acres (92 percent) in the Pacific Northwest Basin have one or both of these types of water erosion control practices (table 9). About 29 percent meet tillage intensity for no-till or mulch till *and* have structural practices, including 36 percent of HEL. About half of cropped acres meet tillage criteria for no-till or mulch till without structural practices in use. Only 2 percent have structural practices without any kind of residue or tillage management (table 9).

Conservation Crop Rotation

In the Pacific Northwest Basin, nearly all crop rotations meet NRCS criteria for conservation crop rotations (NRCS practice code 328). 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. In the Pacific Northwest Basin, only 6 percent of cropped acres are in continuous row cropping.

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

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

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

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

Residue and tillage management practice in use	Percent of non_HEL	Percent of HEL	Percent of all cropped acres
All cropped acres			
Average annual tillage intensity for crop rotation meets criteria for no-till*	19	22	21
Average annual tillage intensity for crop rotation meets criteria for mulch till**	55	62	59
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	12	9	11
Continuous conventional tillage in every year of crop rotation***	15	7	10
Total	100	100	100

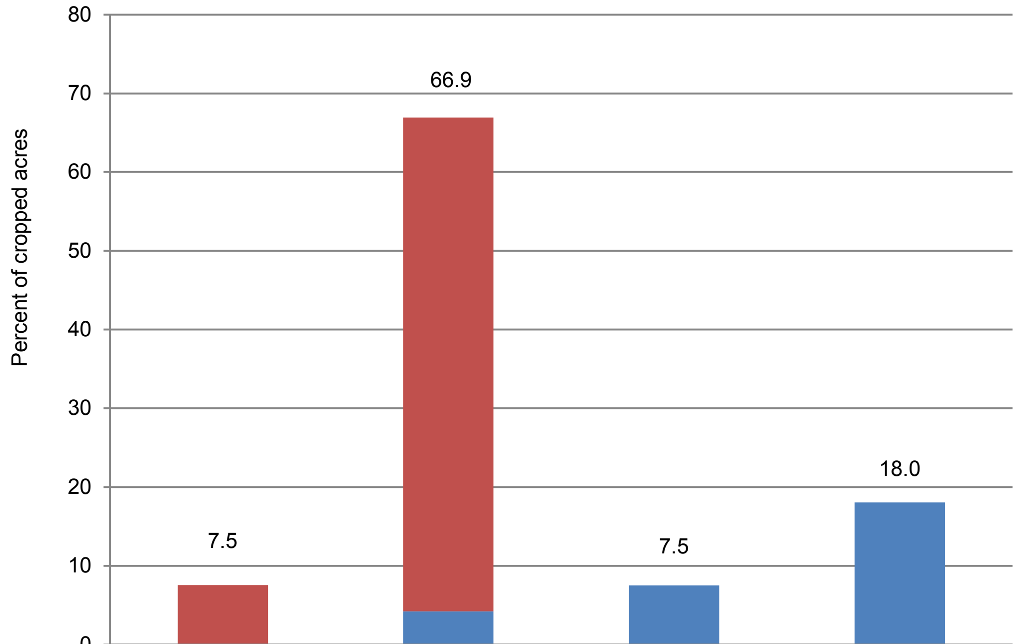
* Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is less than 30.
** Average annual Soil Tillage Intensity Rating (STIR) over all crop years in the rotation is between 30 and 100.
*** Soil Tillage Intensity Rating (STIR) for every crop year in the rotation is 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 54 percent of cropped acres in the Pacific Northwest Basin are highly erodible land (HEL).

Table 9. Percent of cropped acres with water erosion control practices for the baseline conservation condition, Pacific Northwest 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	16	13	14
No-till or mulch till with carbon loss, no structural practices	36	36	36
Some crops with reduced tillage, no structural practices	10	7	9
Structural practices and no-till or mulch till with carbon gain	9	13	11
Structural practices and no-till or mulch till with carbon loss	12	23	18
Structural practices and some crops with reduced tillage	2	2	2
Structural practices only	2	2	2
No water erosion control treatment	12	5	8
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, Pacific Northwest Basin



	Low	Moderate	Moderately high	High
Losing carbon	7.5	62.7	0.0	0.0
Gaining carbon	0.0	4.2	7.5	18.0

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

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

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

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

Since the 2003–06 survey, States in the Pacific Northwest 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, conservation practices are likely to be in wider use within the watershed than the CEAP survey shows for 2003–06.

Cover Crops

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

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

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

Some cover crops are planted for soil protection during establishment. In the Pacific Northwest Basin, cover crops were not commonly used as a conservation practice during the period covered by the farmer survey (2003–06). Less than 1 percent of the acres (5 sample points) met the above criteria for a cover crop.

Irrigation Management Practices

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

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

Proper irrigation involves applying appropriate amounts of water to the soil profile at the right times 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 increased the volume of water lost to evaporation in the pressurized sprinkling process. Modern sprinklers utilize improved nozzle technology to increase droplet size as well as reduce the travel time from the nozzle to the ground. Irrigation specialists consider the center pivot or linear move sprinkler with low pressure spray and low flow systems such as drip and trickle systems as the current state of the art.

According to the NRI-CEAP cropland survey for 2003–06, about 35 percent of cropped acres—4.1 million acres—receive irrigation water in the Pacific Northwest Basin for one or more crops.

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

Approximately 75 percent of the irrigation in the Pacific Northwest Basin is by pressure systems and 25 percent is irrigated with gravity systems. The most common pressure systems are center-pivot or linear-move systems with low pressure spray (36 percent of irrigated acres) followed by center-pivot or linear-move systems with impact sprinkler heads (15 percent of irrigated acres). There are also a number of side roll or wheel lines (13 percent of irrigated acres) as well as smaller numbers of hand move and solid set sprinklers, each on approximately 8 percent of the irrigated acres. In addition there are minor acreages of center pivot/linear move systems with near-ground emitters, big guns, and low flow systems.

The three common named gravity irrigation systems in the Pacific Northwest are a syphon tube system from lined ditch (8 percent of irrigated acres), gated pipe (4 percent of irrigated acres), and siphon tubes from unlined ditch (3 percent of irrigated acres). In addition, an additional 5 percent of the irrigated acres had other than a named gravity system, and an additional 1.5 percent of the irrigated acres using an open discharge. The open discharge category can include controlled direct discharge from a well, discharge from large irrigation structures, or discharge from alfalfa valves.

Approximately 37 percent of the irrigation systems in the Pacific Northwest Basin are capable of irrigation efficiencies that would be considered appropriate for state-of-the-art irrigation.

Nutrient Management Practices

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

Sound nutrient management systems can minimize nutrient losses from the agricultural management zone while providing adequate soil fertility and nutrient availability to ensure realistic yields. (The agricultural management zone is defined as the zone surrounding a field that is bounded by the bottom of the root zone, edge of the field, and top of the crop canopy.) Such systems are tailored to address the specific cropping system, nutrient sources available, and site characteristics of each field. Nutrient management systems have four basic criteria for application of commercial fertilizers and manure. [8]

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

Depending on the field characteristics, these nutrient management techniques can be coupled with other conservation practices such as conservation crop rotations, cover crops, residue management practices, and structural practices to minimize the potential for nutrient losses from the agricultural management zone. Even though nutrient transport and losses from agricultural fields cannot be completely eliminated, they can be minimized by careful management and kept within an acceptable level.

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

- All commercial fertilizer and manure applications are within 3 weeks prior to plant date, at planting, or within 60 days after planting. For fall-planted winter wheat, spring applications also were considered appropriate timing.
- The method of application for commercial fertilizer or manure is some form of incorporation or banding or spot treatment or foliar applied.
- The rate of nitrogen application, including the sum of both commercial fertilizer and manure nitrogen available for crops in the year of application, is—
  - less than 1.4 times the amount of nitrogen removed in the crop yield at harvest for *each* crop,[9] except for small grain crops; or
  - 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).
- 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

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

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

criteria are also met and when soil erosion and runoff are controlled.

As shown in table 10, the majority of acres in the Pacific Northwest Basin meet one or more of the criteria for nitrogen management. About 1 percent of cropped acres have no nitrogen applied. An additional 72 percent of cropped acres meet criteria for timing of nitrogen applications on all crops in the rotation, 68 percent meet criteria for method of application, and 64 percent meet criteria for rate of application.

Similar results were found for phosphorus management. About 17 percent of cropped acres have no phosphorus applied. An additional 61 percent of cropped acres meet criteria for timing of phosphorus applications on all crops in the rotation, 62 percent meet criteria for method of application, and 55 percent meet criteria for rate of application.

Fewer acres, however, meet all nutrient management criteria (table 10):

- In addition to the 1 percent of cropped acres without nitrogen applications, 44 percent of the acres meet all criteria for nitrogen applications;
- In addition to the 17 percent of cropped acres without phosphorus applications, 43 percent of the acres meet all criteria for phosphorus applications;
- 40 percent of cropped acres meet criteria for *both* phosphorus and nitrogen management, including acres with no nutrient applications.

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

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

About 35 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).

This level of nutrient management is higher than found in other regions of the country where corn or cotton is among the dominant cropping systems. Cropping systems prevalent in the Pacific Northwest consist mostly of close-grown crops and hay.

Only about 4 percent of cropped acres in this region had manure applied, according to the CEAP cropland survey for 2003–06.

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

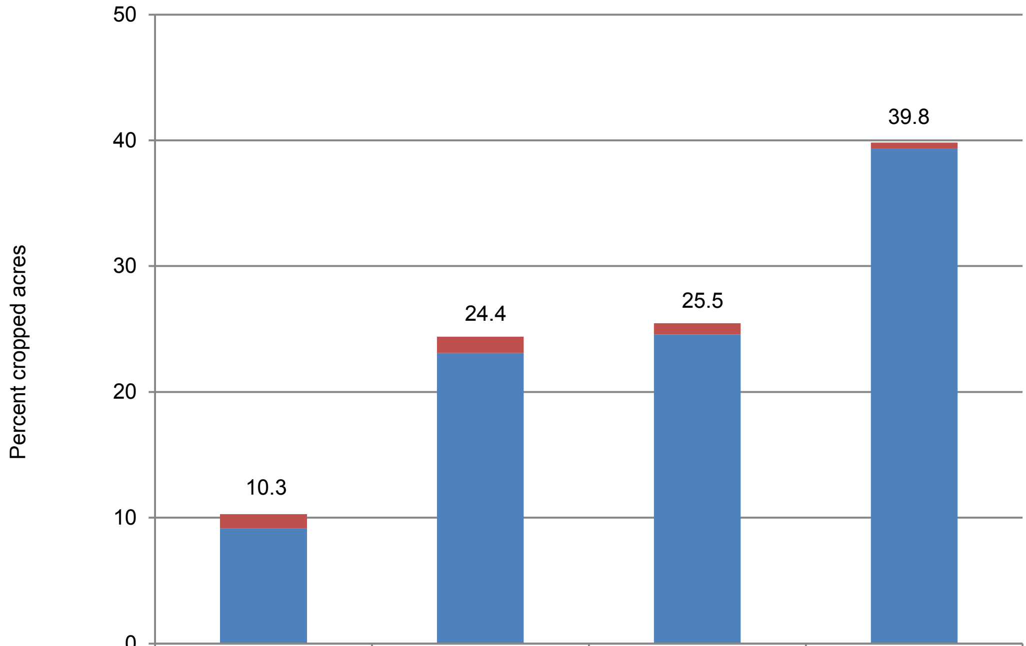
Based on these treatment levels, about 40 percent of the acres in the Pacific Northwest Basin have a high level of nitrogen management and about 60 percent have a high level of phosphorus management (figs. 9 and 10). About 26 percent of cropped acres have a moderately high treatment level for nitrogen and about 12 percent have a moderately high treatment level for phosphorus. About 20 percent of cropped acres have a low level of phosphorus management, compared to only 10 percent for nitrogen management.

Table 10. Nutrient management practices for the baseline conservation condition, Pacific Northwest Basin

	Percent of all cropped acres
Nitrogen*	
No N applied to any crop in rotation	1
For samples where N is applied:	
Time of application	
All crops have application of N (manure or fertilizer) within 3 weeks before planting or within 60 after planting	72
Some but not all crops have application of N (manure or fertilizer) within 3 weeks before planting or within 60 after planting	17
No crops in rotation have application of N (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	10
Method of application	
All crops in rotation have N applied with incorporation or banding/foliar/spot treatment	68
Some but not all crops in rotation have N applied with incorporation or banding/foliar/spot treatment	19
No crops in rotation have N applied with incorporation or banding/foliar/spot treatment	12
Rate of application	
All crops in rotation meet the nitrogen rate criteria described in text	64
Some but not all crops in rotation meet the nitrogen rate criteria described in text	27
No crops in rotation meet the nitrogen rate criteria described in text	8
Timing and method and rate of application	
All crops meet the nitrogen rate criteria, timing criteria, and method criteria described above	44
Some but not all crops meet the nitrogen rate criteria, timing criteria, and method criteria described above	36
No crops meet the nitrogen rate , timing criteria, and method criteria described above	19
Phosphorus*	
No P applied to any crop in rotation	17
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	61
Some but not all crops have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	16
No crops in rotation have application of P (manure or fertilizer) within 3 weeks before planting or within 60 days after planting	7
Method of application	
All crops in rotation have P applied with incorporation or banding/foliar/spot treatment	62
Some but not all crops in rotation have P applied with incorporation or banding/foliar/spot treatment	15
No crops in rotation have P applied with incorporation or banding/foliar/spot treatment	7
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	55
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	28
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	43
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	10
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	30
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	40
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	35
All sample points	100

* These estimates include adjustments made to the reported data on nitrogen and phosphorus application rates from the survey because of missing data and data-entry errors. In the case of phosphorus, the 3-year data period for which information was reported was too short to pick up phosphorus applications made at 4- and 5-year intervals between applications, which is a common practice for producers adhering to sound phosphorus management techniques. Since crop growth, and thus canopy development which decreases erosion, is a function of nitrogen and phosphorus, it was necessary to add additional nitrogen and phosphorus when the reported levels were insufficient to support reasonable crop yields throughout the 47 years in the model simulation. The approach taken was to first identify crop samples that have application rates recorded erroneously or were under-reported in the survey. The model was used to identify these samples by running the simulation at optimal levels of nitrogen and phosphorus for crop growth. The set of crop samples identified were treated as if they had missing data. Additional nitrogen or phosphorus was added to these crop samples so that the total nitrogen or phosphorus use was similar to that for the unadjusted set of crop samples. About 46 percent of the acres received a nitrogen adjustment for one or more crops. About 41 percent of the acres received a phosphorus adjustment for one or more crops. Nitrogen and phosphorus were added by increasing the existing applications (thus preserving the reported timing and methods), when present, or were applied at plant. (For additional information on adjustment of nutrient application rates, see "Adjustment of CEAP Cropland Survey Nutrient Application Rates for APEX Modeling," available at http://www.nrcs.usda.gov/technical/nri/ceap

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



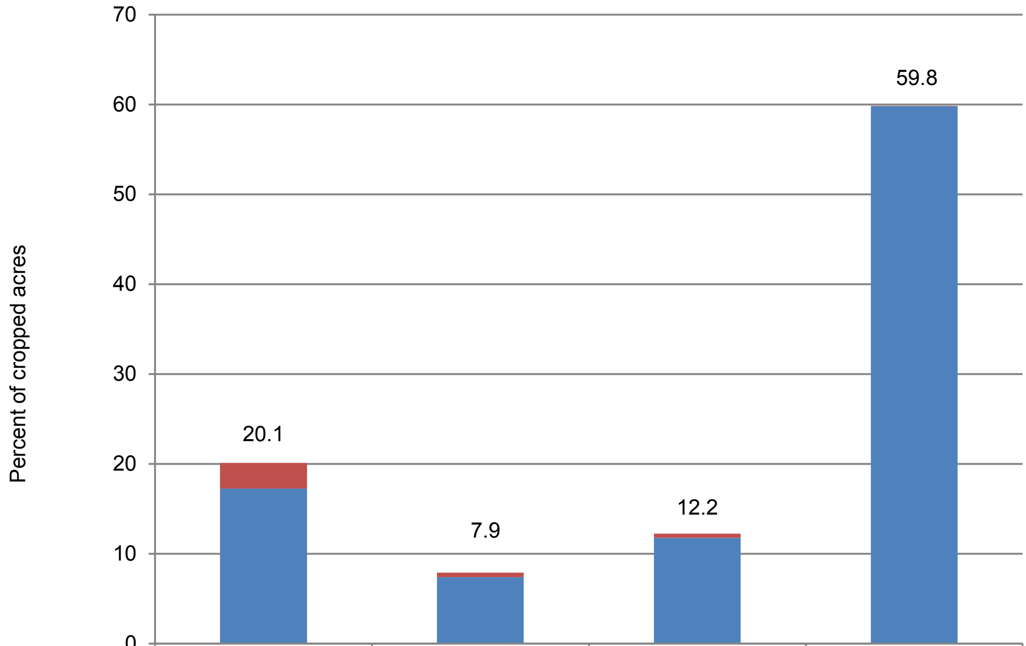
	Low	Moderate	Moderately high	High
Manure applied	1.1	1.3	0.9	0.5
No manure applied	9.2	23.1	24.6	39.4

Criteria for four levels of nitrogen management are:

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

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

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



	Low	Moderate	Moderately high	High
Manure applied	2.8	0.5	0.5	0.0
No manure applied	17.2	7.4	11.8	59.8

Criteria for four levels of phosphorus management are:

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

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

Pesticide Management Practices

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

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

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

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

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

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

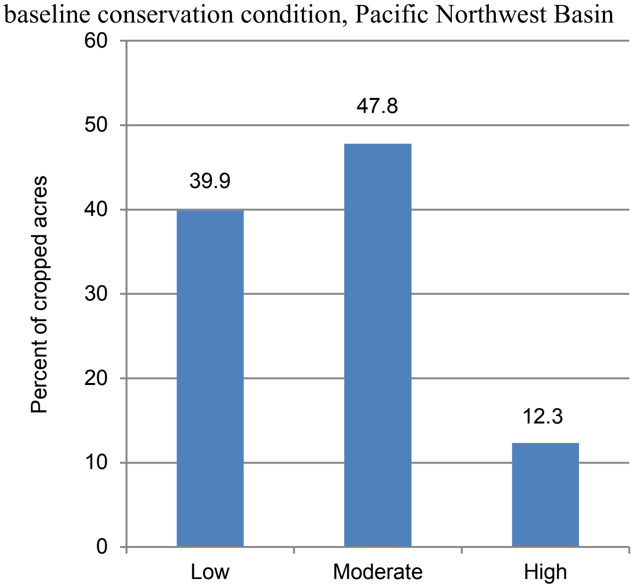
An IPM index was developed to determine the level of IPM activity for each sample point. The index was constructed as follows.

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

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

About 12 percent of the acres in the Pacific Northwest Basin have a high level of IPM activity (fig. 11). About 48 percent have a moderate level of IPM activity, and 40 percent have a low level of IPM activity.

Figure 11. Integrated Pest Management indicator for the baseline conservation condition, Pacific Northwest Basin



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

Table 11. Summary of survey responses to pest management questions, Pacific Northwest Basin

Survey question	Number samples with "yes" response	Percent of cropped acres
Prevention		
Pesticides with different action rotated or tank mixed to prevent resistance	413	46%
Plow down crop residues	293	31%
Chop, spray, mow, plow, burn field edges, etc.	466	47%
Clean field implements after use	456	53%
Remove crop residue from field	180	18%
Water management used to manage pests (irrigated samples only)	102	10%
Avoidance		
Rotate crops to manage pests	524	59%
Use minimum till or no-till to manage pests	264	30%
Choose crop variety that is resistant to pests	271	34%
Planting locations selected to avoid pests	74	9%
Plant/harvest dates adjusted to manage pests	98	12%
Monitoring		
Scouting practice: general observations while performing routine tasks	289	27%
Scouting practice: deliberate scouting	535	60%
--Established scouting practice used	201	23%
--Scouting due to pest development model	94	10%
--Scouting due to pest advisory warning	88	9%
Scouting done by: (only highest of the 4 scores is used)		
--Scouting by operator	325	39%
--Scouting by employee	33	2%
--Scouting by chemical dealer	168	18%
--Scouting by crop consultant or commercial scout	34	3%
Scouting records kept to track pests?	220	23%
Scouting data compared to published thresholds?	262	26%
Diagnostic lab identified pest?	102	11%
Weather a factor in timing of pest management practice	392	43%
Suppression		
Pesticides used?	870	94%
Weather data used to guide pesticide application	633	70%
Biological pesticides or products applied to manage pests	21	2%
Pesticides with different mode of action rotated or tank mixed to prevent resistance	413	46%
Pesticide application decision factor (one choice only):		
--Routine treatments or preventative scheduling	303	28%
--Comparison of scouting data to published thresholds	56	5%
--Comparison of scouting data to operator's thresholds	166	21%
--Field mapping or GPS	1	0%
--Dealer recommendations	222	26%
--Crop consultant recommendations	45	5%
--University extension recommendations	2	<1%
--Neighbor recommendations	0	0%
--"Other"	22	2%
Maintain ground covers, mulch, or other physical barriers	328	39%
Adjust spacing, plant density, or row directions	141	15%
Release beneficial organisms	9	1%
Cultivate for weed control during the growing season	292	29%
Number of respondents	918	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 2.3 million in the Pacific Northwest Basin (USDA/NRCS 2007). Approximately 73 percent of the cropland acres enrolled in the CRP in the Pacific Northwest 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 Pacific Northwest Basin, 67 percent of the CRP land is planted to introduced grasses and 21 percent to native grasses. An additional 11 percent has plantings specifically to support wildlife and about 1 percent is planted 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.

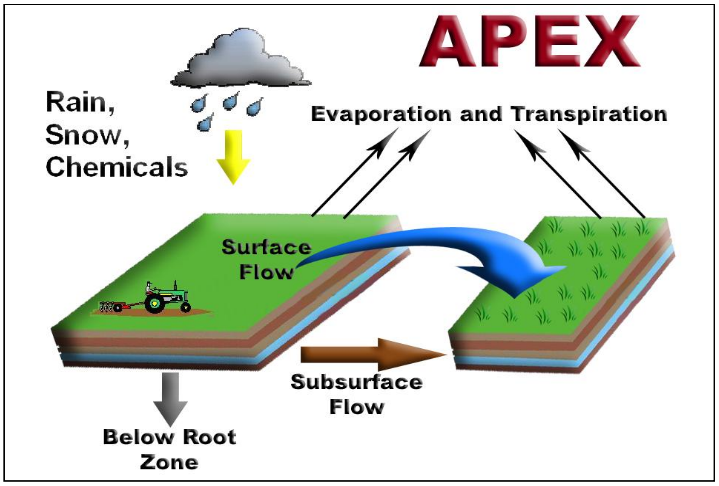
Chapter 4
Onsite (Field-Level) Effects of Conservation Practices

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).[11] The I_APEX model run management software developed at the Center for Agricultural and Rural Development, Iowa State University, was used to perform the simulations in batch mode.[12]

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

Figure 12. Daily hydrologic processes simulated by APEX



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

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

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

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

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

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

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

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

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

Simulating the No-Practice Scenario

The purpose of the no-practice scenario is to provide an estimate of sediment, nutrient, and pesticide loss from farm fields under conditions without the use of conservation practices. The benefits of conservation practices in use within the Pacific Northwest 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 Pacific Northwest Basin

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

No-practice representation of conservation tillage

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

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

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

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

No-practice representation of cover crops

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

No-practice representation of irrigation practices

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

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

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

In the no-practice scenario in the Pacific Northwest Basin there are approximately 71 percent gravity systems and 29 percent pressure systems. Primary systems in the no-practice scenario are: gated pipe (41 percent), portal system from unlined ditch (38 percent), side roll and wheel lines (11 percent), and center pivot or linear move with impact sprinklers (11 percent). In addition there are minor acreages of other systems such as solid set sprinklers, big guns, open discharges, and other non-specified systems.

No-practice representation of nutrient management practices

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

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

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

- increased to 2.0 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 small grain crops; and
- 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.

The ratio of 2.0 for non-legume crops other than small grains was determined by the average rate-to-yield-removal ratio for crops exceeding the application-removal ratio of 1.4. Where nitrogen was applied in multiple applications, each application was increased proportionately.

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

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

For the no-practice scenario, the amount of commercial phosphorus fertilizer applied was increased to 2.05 times the harvest removal rate for the crop rotation. The ratio of 2.05 for the increased phosphorus rate was determined by the average rate-to-yield-removal ratio for crops with phosphorus applications exceeding 1.1 times the amount of phosphorus taken up by all the crops in rotation and removed at harvest. Multiple commercial phosphorus fertilizer applications were increased proportionately to meet the 2.05 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 2.0 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, 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 pesticide residues pose to the surrounding environment.
3. Practice of Integrated Pest Management (IPM), including partial field applications and spot treatment.

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

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

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 Pacific Northwest Basin, there were 21 sample points with spot treatments, representing 3 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 Pacific Northwest Basin had partial field treatments of pesticides.

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

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

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

Potential for Using Model Simulation to Assess Alternative Conservation Policy Options

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

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

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

Effects of Practices on Fate and Transport of Water

Water is a potent force that interacts with or drives almost all environmental processes acting within an agricultural production system. The hydrologic conditions prevalent in the Pacific Northwest 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 for cropped acres over the 47-year simulation averaged about 21 inches in this region—59 inches for the four subregions along the coast and 17 inches for the seven eastern subregions. (See figs. 5 and 6.) About 35 percent of the cropped acres are irrigated, at an average application of 18 inches per year (table 13).

Most of the water that leaves the field is lost through evaporation and transpiration (evapotranspiration) on nearly all cropped acres (fig. 13). Evapotranspiration is the dominant loss pathway for 91 percent of cropped acres in this region. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.) On average, about 17 inches per year are lost through evapotranspiration, representing about 67 percent of total water loss (table 13). Model results indicate that evapotranspiration losses vary, however, according to soil characteristics and land cover; evapotranspiration ranges from about 20 percent to about 100 percent of the total amount of water that leaves the field on cropped acres in this region (fig. 14). Evapotranspiration is much higher, on average, for irrigated acres than for non-irrigated acres (table 13).

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

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (11.65 million acres)				
Water sources				
Non-irrigated acres				
Average annual precipitation (inches)	22.4	22.4	0.0	0
Irrigated acres				
Average annual precipitation (inches)	17.9	17.9	0.0	0
Average annual irrigation water applied (inches)*	17.6	20.8	3.2	15
Water loss pathways				
Average annual evapotranspiration (inches)	17.2	17.3	0.1	<1
Irrigated acres*	22.3	22.5	0.2	<1
Non-irrigated acres	14.5	14.5	0	0
Average annual surface water runoff (inches)	4.3	5.1	0.8	16
Irrigated acres*	4.1	6.1	2.0	33
Non-irrigated acres	4.4	4.5	0.1	3
Average annual subsurface water flows (inches)**	4.1	4.0	-0.1***	-1***
Irrigated acres*	4.9	5.0	-0.2	-3
Non-irrigated acres	3.6	3.4	-0.2	-5
Land in long-term conserving cover (2.3 million acres)				
Water sources*				
Average annual precipitation (inches)	16.4	16.4	0.0	0
Average annual irrigation water applied (inches)*	0.0	3.0	3.0	100
Water loss pathways				
Average annual evapotranspiration (inches)	13.1	14.2	1.1	8
Average annual surface water runoff (inches)	1.0	2.0	1.0	50
Average annual subsurface water flow (inches)**	2.3	2.6	0.3	12

* About 35 percent of the cropped acres in the Pacific Northwest Basin are irrigated (2.32 million acres). 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 0.1 inch per year (1 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 11subregions.

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

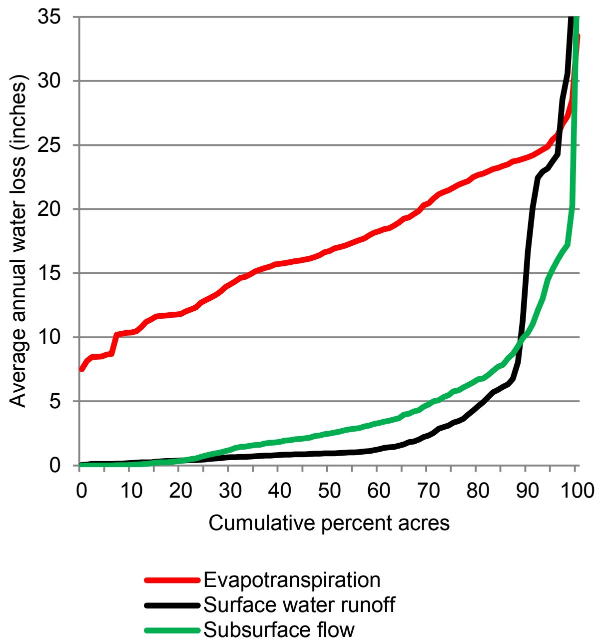
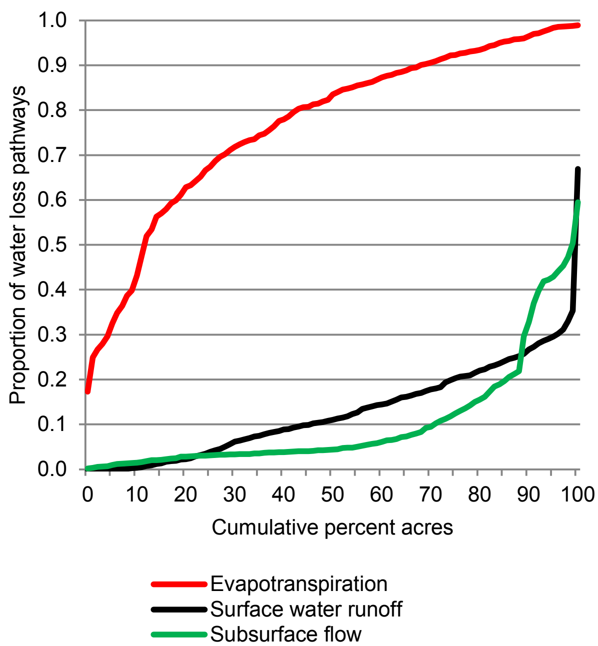


Figure 14. Cumulative distributions of the proportion of water lost through three loss pathways for cropped acres, Pacific Northwest Basin



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.

The remaining water is lost in surface water runoff and in subsurface flow pathways. 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.

When averaged over the entire region, surface water runoff is about the same as subsurface flows (figs. 13 and 14), each averaging about 4 inches. However, most of the surface water runoff and water loss in subsurface flows occurs in the western portion of the basin, as shown below.

Water loss pathways	Average annual baseline values for four western subregions (8 percent of cropped acres in region)	Average annual baseline values for seven eastern subregions (92 percent of cropped acres in region)
Average annual evapotranspiration (inches)	21.5	16.8
Average annual surface water runoff (inches)	27.1	2.2
Average annual subsurface water flow (inches)	13.7	3.2

Surface water runoff in the western portion of the basin averages 27.1 inches per year, compared to 2.2 inches per year in the eastern portion, which includes the bulk of the cultivated cropland acres. Subsurface water flow averages 13.7 inches per year in the western portion of the basin, compared to 3.2 inches per year in the eastern portion. On average, loss of water in subsurface flow pathways exceeds surface water runoff in the eastern portion of the basin, while surface water runoff exceeds subsurface flow in the western portion.

Subsurface water flows are higher for irrigated acres than for non-irrigated acres, as shown in table 13.

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 Pacific Northwest Basin, only about 8 percent of the cropped acres have some portion of the field that is tile drained, according to the farmer survey.

Effects of conservation practices

Cropped acres. Structural water erosion control practices, residue management practices, and reduced tillage slow the flow of surface water runoff and allow more of the water to infiltrate into the soil.[17] Model simulations indicate that conservation practices have reduced surface water runoff by about 1 inch per year averaged over all cropped acres, representing a 16-percent reduction on average (table 13).

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

Reductions in surface water runoff due to conservation practices range from less than zero to 7 inches per year (fig. 16).[18] The variability in reductions due to practices reflects different levels of conservation treatment as well as differences in precipitation and inherent differences among acres for water to run off.

The re-routing of surface water to subsurface flows results in an average gain in this region of only about 0.1 inch per year in subsurface flows in this region due to the use of conservation practices (table 13), representing a 1-percent increase. For 7 percent of cropped acres, however, re-routing of surface water to subsurface flows results in a gain of 1 to 7 inches per year in subsurface flow (fig. 17). Figure 17 also shows that use of conservation practices has reduced the volume of subsurface flow for about 20 percent of cropped acres in the region.

Use of improved irrigation systems in the Pacific Northwest Basin increases overall system efficiency from 49 percent in the no-practice scenario to near 56 percent in the baseline scenario. This change in efficiency represents an annual decreased need of water diversions of about 3 inches per year where irrigation is used (table 13).

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

[18] About 2 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.

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

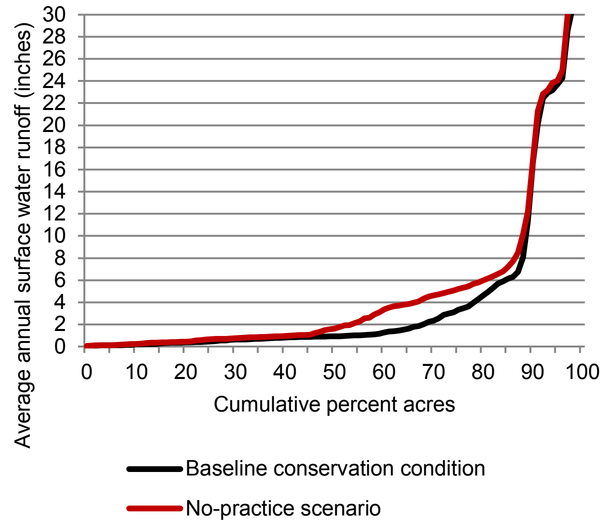


Figure 16. Estimates of average annual reduction in surface water runoff due to the use of conservation practices on cropped acres in the Pacific Northwest Basin

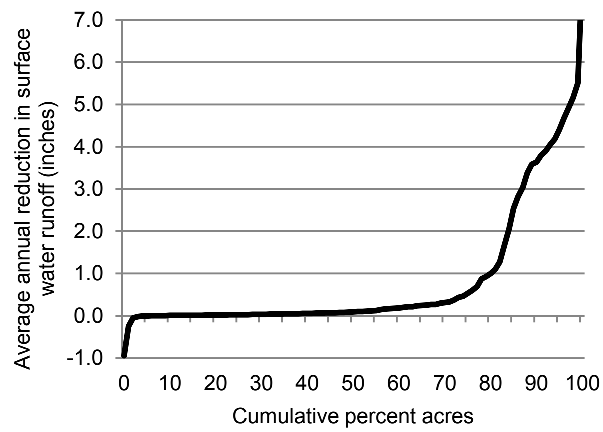
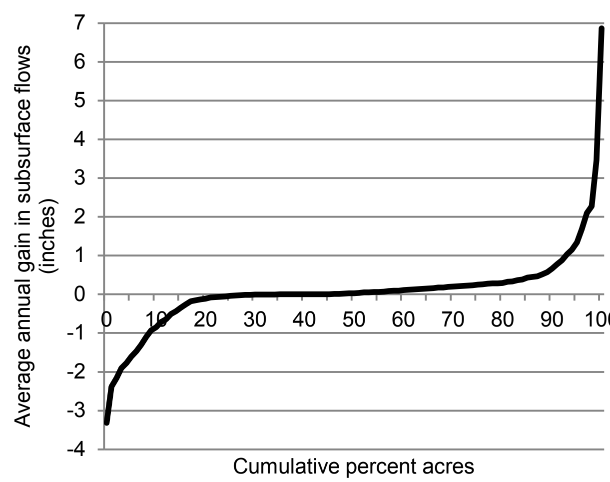


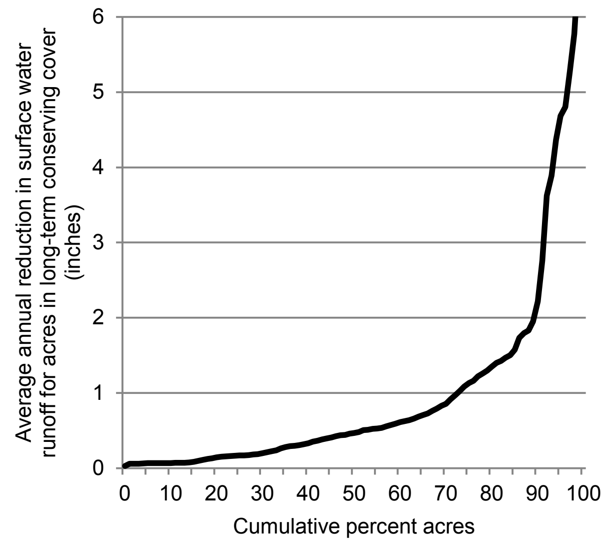
Figure 17. Estimates of average annual gain in subsurface flow due to the use of conservation practices on cropped acres in the Pacific Northwest Basin



Land in long-term conserving cover. Model simulations further show that land in long-term conserving cover (baseline conservation condition) in this region has, on average, much 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 1 inch per year in this region (table 13), and range from zero to about 6 inches per year (fig. 18).

Figure 18. Estimates of average annual reduction in surface water runoff due to conversion to long-term conserving cover in the Pacific Northwest 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 918 sample points used to represent cropped acres in the Pacific Northwest Basin and for each of the 822 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 918 surface water runoff estimates, weighted by the acres associated with each sample point. The 10th percentile for the baseline conservation condition is 0.19 inch per year, indicating that 10 percent of the acres have 0.19 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 0.45 inch per year. The 50th percentile—the median—is 0.94 inch per year, which in this case is slightly less than the mean value of 1.0 inch per year. At the high end of the distribution, 90 percent of the acres in this region have surface water runoff less than 16.7 inches per year; and conversely, 10 percent of the acres have surface water runoff greater than 16.7 inches per year.

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

Figure 16 shows the effects of conservation practices on surface water runoff using the distribution of the *reduction* in surface water runoff, calculated as the outcome for the no-practice scenario minus the outcome for the baseline conservation condition at each of the 918 cropped sample points. This distribution shows that, while the median reduction is 0.09 inch per year, 10 percent of the acres have reductions due to conservation practices greater than 3.6 inches per year and 2 percent of the acres actually have small increases in surface water runoff (i.e., negative reductions) as a result of conservation practice use.

Effects of Practices on Wind Erosion

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

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

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

Baseline condition for cropped acres

Wind erosion is an important resource concern in the eastern portion of the Pacific Northwest Basin. For all cropped acres, model simulations show that the average annual rate of wind erosion is 1.9 tons per acre (table 14)—2.1 tons per year in the eastern portion of the basin. Wind erosion is a relatively minor resource concern in the western portion of the basin where the average annual rate of wind erosion is only 0.02 ton per acre.

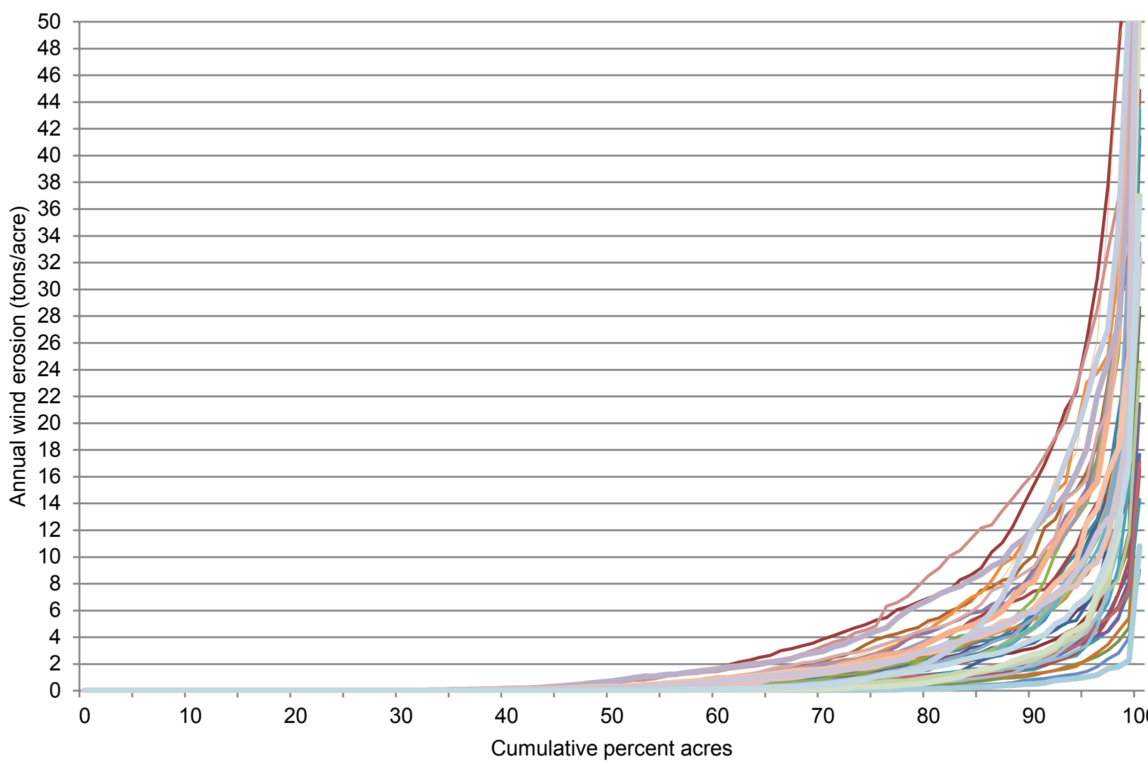
Table 14. Average annual wind erosion (tons/acre) for cultivated cropland in the Pacific Northwest Basin

	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres	1.90	2.53	0.62	25
Land in long-term conserving cover	<0.01	0.02	0.02	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 11subregions.

As shown in figure 19, wind erosion rates on about 30 percent of cropped acres in the region exceed 4 tons per acre per year in one or more years, and annual rates in some years can exceed 40 tons per acre for some acres. Nevertheless, wind erosion rates in the region are less than 0.5 ton per acre in every year on about half the cropped acres in the region (fig. 19).

Figure 19. Distribution of annual wind erosion rate for each year of the 47-year model simulation, Pacific Northwest 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 Pacific Northwest Basin. However, other practices common in the region, such as residue and tillage management, reduced tillage, and various water erosion control practices, are also effective in reducing wind erosion. Model simulations indicate that conservation practices have reduced the average wind erosion rate by 25 percent in the region (table 14). Reductions in wind erosion due to conservation practices are higher for some acres than others, reflecting both the level of treatment and the inherent erodibility of the soil (figs. 20 and 21).

Since grass or other cover has been established on land in long-term conserving cover, wind erosion on land in long-term conserving cover is negligible (table 14).

Figure 20. Estimates of average annual wind erosion for cropped acres in the Pacific Northwest Basin

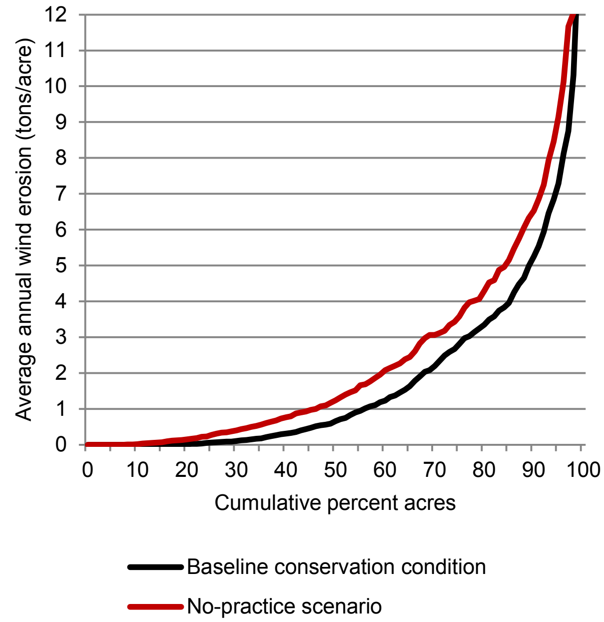
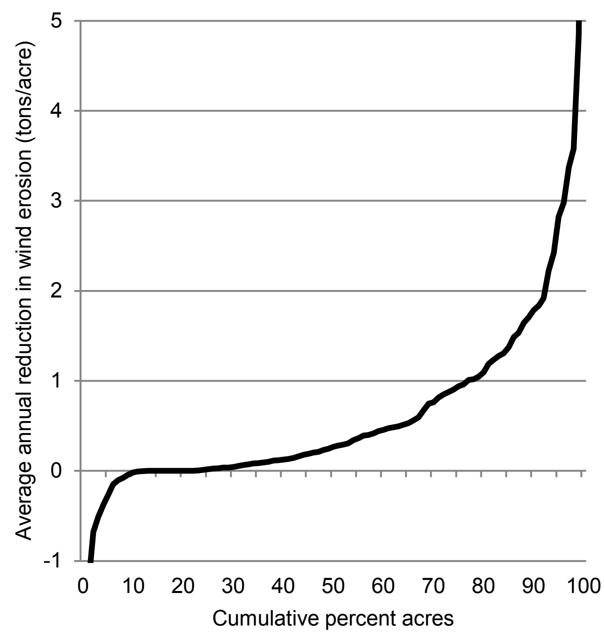


Figure 21. Estimates of average annual reduction in wind erosion due to the use of conservation practices on cropped acres in the Pacific Northwest Basin



Effects of Practices on Water Erosion and Sediment Loss

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

Sheet and rill erosion

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

Model simulations show that sheet and rill erosion on cropped acres in the Pacific Northwest Basin averages about 0.3 ton per acre per year (table 15)—1.1 tons per acre for the western portion of the basin and 0.2 ton per acre for the eastern portion. Sheet and rill erosion rates are much higher for highly erodible land, averaging 0.44 ton per acre per year compared to the average annual rate for non-highly erodible land of 0.14 ton per acre.

Model simulation results also show that conservation practices have reduced sheet and rill erosion on cropped acres in the Pacific Northwest Basin by an average of 0.13 ton per acre per year, representing a 30-percent reduction on average (table 15).

For land in long-term conserving cover, sheet and rill erosion has been reduced from 0.22 ton per acre per year if cropped without conservation practices to 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.

For this study, the APEX model was set up to estimate sediment loss using a modified version of MUSLE, called MUST (not MUSS, as was mistakenly reported in the CEAP reports on the Chesapeake Bay, the Great Lakes, and the Ohio-Tennessee River Basins).[19] The model variant called MUST uses an internal sediment delivery ratio to estimate the amount of eroded soil that actually leaves the boundaries of the field. A large percentage of the eroded material is redistributed and deposited within the field or trapped by buffers and other conservation practices and does not leave the boundary of the field, which is taken into account in the sediment delivery calculation. The estimate also includes some gully erosion and some ephemeral gully erosion. For this reason, sediment loss rates can exceed sheet and rill erosion rates.

Baseline condition for cropped acres. The average annual sediment loss from water erosion for cropped acres in the Pacific Northwest Basin is 2.5 tons per acre per year, according to the model simulation (table 15)—7.5 tons per acre for the western portion of the basin and 2.0 tons per acre for the eastern portion. As seen for sheet and rill erosion, sediment loss for highly erodible land is much higher than for non-highly erodible land. Sediment loss for irrigated acres is much lower, on average, than sediment loss for non-irrigated acres (table 15).

The average rate of sediment loss due to water erosion in the eastern portion of the basin is about the same as the average wind erosion rate—2 tons per acre per year. In the western portion, soil loss is almost exclusively due to water erosion.

On an annual basis, sediment loss varies from year to year, although high losses are restricted to a minority of acres each year. Figure 22 shows that, with the conservation practices currently in use in the Pacific Northwest Basin, annual sediment loss is below 2 tons per acre in all years for about 75 percent of the acres, including years with high precipitation. In contrast, sediment loss exceeds 4 tons per acre in one or more years on about 20 percent of the cropped acres in the region. The highest losses shown in figure 22 are for acres that have the highest inherent vulnerability to water erosion and have inadequate soil erosion control.

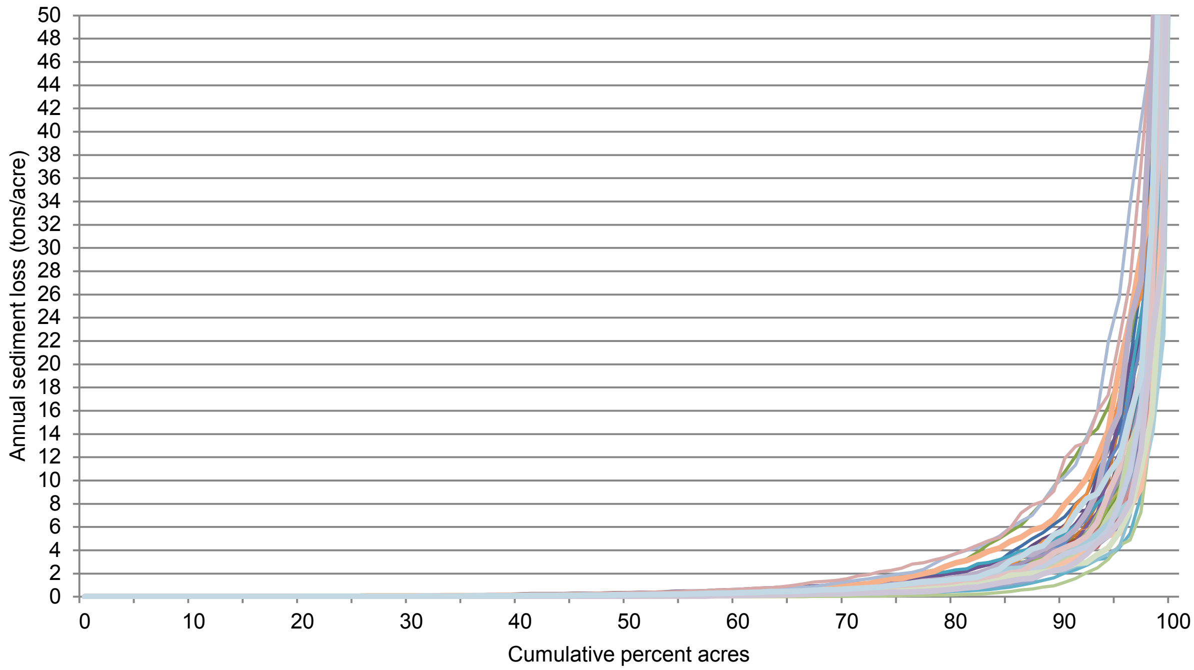
[19] APEX provides a variety of options for modeling erosion and sedimentation, including USLE, RUSLE, MUSS, MUSLE, and MUST. MUST is the most appropriate choice for simulation of sediment loss for small areas (less than 1 hectare, for example).

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

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (11.65 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.30	0.42	0.13	30
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	2.48	3.91	1.43	37
Irrigated acres (35 percent of cropped acres)				
Average annual sheet and rill erosion (tons/acre)*	0.16	0.20	0.04	18
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	1.29	3.41	2.13	62
Non-irrigated acres (65 percent of cropped acres)				
Average annual sheet and rill erosion (tons/acre)*	0.37	0.55	0.17	32
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	3.14	4.19	1.05	25
Highly erodible land (54 percent of cropped acres)				
Average annual sheet and rill erosion (tons/acre)*	0.44	0.59	0.16	26
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	3.54	5.51	1.97	36
Non-highly erodible land (46 percent of cropped acres)				
Average annual sheet and rill erosion (tons/acre)*	0.14	0.23	0.09	40
Average annual sediment loss at edge of field due to water erosion (tons/acre)**	1.24	2.03	0.79	39
Land in long-term conserving cover (2.3 million acres)				
Average annual sheet and rill erosion (tons/acre)*	0.01	0.22	0.21	96
Average annual sediment loss at edge of field due to water erosion (tons/acre)	0.06	2.65	2.59	98

* Estimated using the Revised Universal Soil Loss Equation.
**Estimated using MUST, which includes some sediment from gully erosion. See text.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 11subregions.

Figure 22. Distribution of annual sediment loss for each year of the 47-year model simulation, Pacific Northwest 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 Pacific Northwest Basin has reduced average annual sediment loss from water erosion by 37 percent for cropped acres in the region, including both treated and untreated acres (table 15). Without conservation practices, the average annual sediment loss for these acres would have been 3.9 tons per acre per year compared to 2.5 tons per acre average for the baseline conservation condition.

The effects of conservation practices on reducing sediment loss in this region are small for over half of the cropped acres but much larger for other cropped acres, as shown in figures 23 and 24. Figure 23 shows that about 17 percent of the acres would have more than 4 tons per acre per year sediment loss without practices, on average, compared to 11 percent with conservation practices. Conservation practices have reduced the average annual sediment loss by 2 tons per acre or more on 15 percent of the cropped acres, as shown in figure 24.

Conservation practices are more effective in reducing sediment loss for irrigated acres than non-irrigated acres (table 15), largely as a result of irrigation water management and control of surface water runoff (table 13). On average, sediment loss on irrigated acres has been reduced 2.13 tons per acre per year (62-percent reduction), compared to 1.05 tons per acre per year on non-irrigated acres (25-percent reduction) (table 15).

Cropped acres with structural practices have the highest per-acre reductions, ranging from an average of 2.1 tons per acre per year to 2.6 tons per acre per year depending on the extent to which tillage and residue management practices are also present (table 16). Acres with residue management but without any structural practices have much lower reductions, ranging from 0.8 ton per acre per year to 1.6 tons per acre per year.

Figure 23. Estimates of average annual sediment loss for cropped acres in the Pacific Northwest Basin

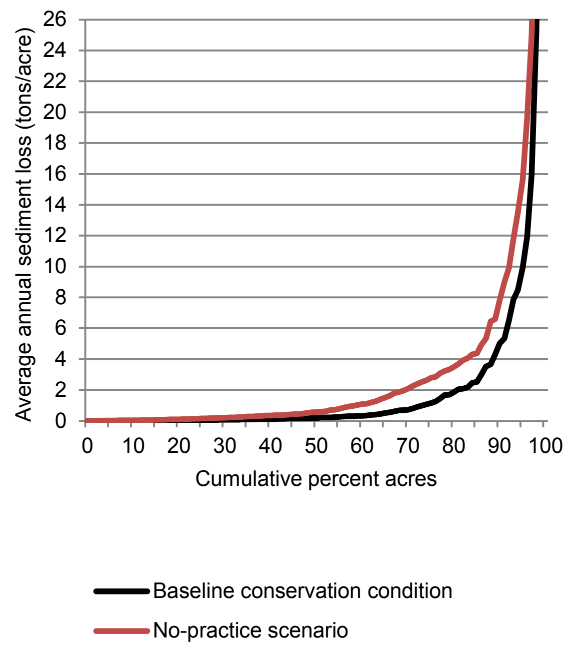


Figure 24. Estimates of average annual reduction in sediment loss due to the use of conservation practices on cropped acres in the Pacific Northwest Basin

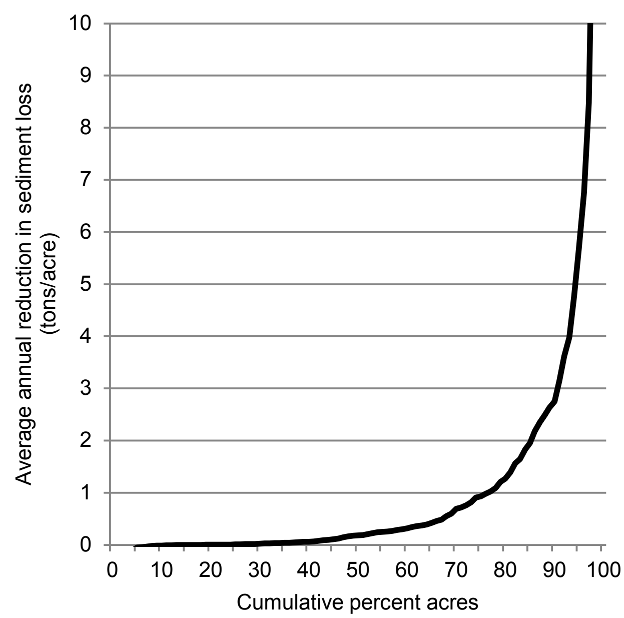


Table 16. Estimates of effects of combinations of structural practices and residue and tillage management on average annual sediment loss for cropped acres in the Pacific Northwest Basin

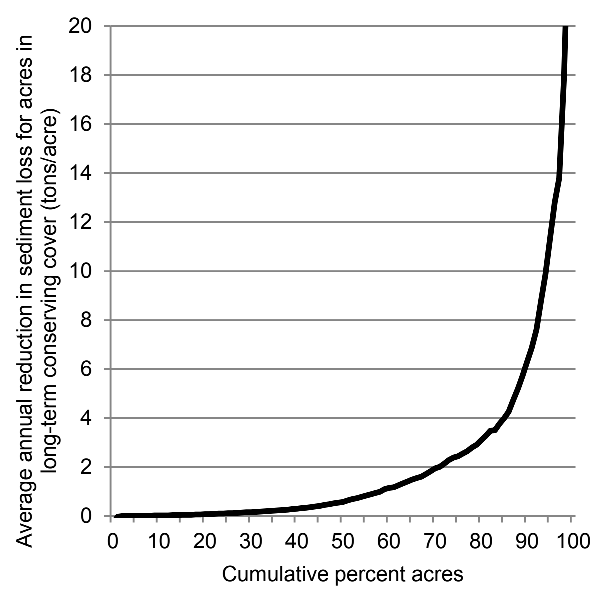
		Average annual sediment loss (tons/acre)			
Conservation treatment	Percent of cropped acres	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
No-till or mulch till with carbon gain, no structural practices	14	0.59	1.38	0.79	58
No-till or mulch till with carbon loss, no structural practices	36	3.29	4.16	0.87	21
Some crops with reduced tillage, no structural practices	9	1.75	3.31	1.56	47
Structural practices and no-till or mulch till with carbon gain	11	0.46	2.51	2.06	82
Structural practices and no-till or mulch till with carbon loss	18	4.17	6.48	2.31	36
Structural practices and some crops with reduced tillage	2	2.52	5.15	2.63	51
Structural practices only	2	1.28	2.66	1.38	52
No water erosion control treatment	8	2.34	4.17	1.83	44
All acres	100	2.48	3.91	1.43	37

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

Land in long-term conserving cover. Acres in long-term conserving cover have very little erosion or sediment loss, and thus show nearly 100-percent reductions when compared to a cropped condition (table 15). If these 2.3 million acres were still being cropped without any conservation practices, sediment loss would average 2.7 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 25. About 45 percent of the acres in long-term conserving cover have reductions of less than 0.5 ton per acre per year. In contrast, reductions greater than 6 tons per acre per year occur on about 8 percent of the acres with long-term conserving cover.

Figure 25. Estimates of average annual reduction in sediment loss due to conversion to long-term conserving cover in the Pacific Northwest Basin



Effects of Practices on Soil Organic Carbon

The landscape and climate for cropland acres of the Pacific Northwest Basin are in two distinct regions, the high rainfall Northwestern Forest, Forage, and Specialty Crop Land Resource Region (LRR) in the west and the much drier semi-arid to arid eastern portion, Northwestern Wheat and Range LRR. Both regions are characterized by dry summers and largely fertile soils from alluvium, glacial outwash, or windblown loess. The temperate, moist conditions of the western portion of the basin tend to allow these soils to readily accumulate soil organic carbon under natural vegetation and well managed crop rotations. The eastern portion required thousands of years of grassland vegetation to slowly accumulate its carbon stores and is a difficult climate for management to make significant gains in soil organic carbon accumulation.

The accumulation of soil organic carbon is a balance of moisture, temperature, and soil erodibility with crop residue production, tillage, and erosion control practices. Crop production practices tend to override any beneficial effects of climate for carbon sequestration and exacerbate carbon losses in less favorable climates. Approximately 23 percent of cropped acres have a crop rotation with low residue crops like vegetables, potatoes, and sugarbeets. These crops also tend to utilize more intense tillage methods and therefore make it very difficult for increases in carbon stores even when combined with higher residue crops. Another approximately 7 percent of cropped acres have a fallow period in which no crops are grown; this practice is also difficult for carbon improvements when combined with tillage for weed control. Other cultural practices found in this region include bailing or burning of residues from wheat or other high residue small grains, practices that are detrimental to soil organic carbon buildup.

Only 26 percent of cropped acres had a high or moderately high level for residue and tillage management with annual average gains in soil organic carbon (fig. 8). The majority of cropped acres (63 percent) had a moderate level of residue and tillage management indicating an imbalance between tillage and crop residue production and protection. Periodic increases in tillage for one or more crops in the rotation may also be reducing the acres gaining soil carbon by cancelling the gains of conservation tilled, high residue crop rotations.

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 66 pounds per acre per year, on average (table 17). Thirty percent of cropped acres are gaining soil organic carbon (fig. 26) at an average rate of 144 pounds per acre per year. In contrast, 70 percent of cropped acres are losing soil organic carbon at an average rate of 155 pounds per acre per year.

These estimates account for losses of carbon with sediment removed from the field by wind and water erosion. Loss of soil organic carbon due to wind and water erosion averages about 171 pounds per acre per year for the baseline conservation condition (table 17). Such losses are partially offset by gains on soil organic carbon due to incorporation of crop residues.

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 31 percent of cropped acres in the region would be considered to be maintaining—but not enhancing—soil organic carbon (fig. 26). When combined with acres enhancing soil organic carbon, a total of 61 percent of the acres in the region are either maintaining or enhancing soil organic carbon.

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

Model simulated outcome	Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (11.65 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	171	207	37	18
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)*	-66	-68	2**	--
Land in long-term conserving cover (2.3 million acres)				
Average annual loss of carbon with wind and water erosion (pounds/acre)	31	105	74	70
Average annual change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	131	-49	179**	

* 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. About 57 percent of cropped acres had a gain in soil organic carbon due to conservation practices, while 43 percent had decreases in soil organic carbon due to conservation practices (fig. 27)

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

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

Effects of conservation practices on cropped acres

In this region, conservation practices have little effect on soil organic carbon levels, as shown in figures 26 and 27. Without conservation practices, the annual change in soil organic carbon would be an average loss of 68 pounds per acre per year, compared to an average loss of 66 pounds per acre for the baseline (table 17). Thus, conservation practice use in the region has resulted in an average annual gain in soil organic carbon of only 2 pounds per acre per year on cropped acres.

The average annual gain in soil organic carbon due to practices varies among acres, however, depending on the extent to which residue and nutrient management is used, as well as the soil's potential to sequester carbon. Less than 10 percent of cropped acres in this region gain more than 100 pounds per acre of soil organic carbon due to conservation practice use (figure 27).

Figure 27 also shows that 43 percent of the acres have a higher annual soil organic carbon increase in the no-practice scenario than in the baseline conservation condition because of the higher fertilization rates, including manure application rates on a few acres, used in the no-practice scenario to simulate the effects of nutrient management practices. The higher residue impact of over-fertilization tends to cancel the detrimental impact of the increased tillage and removal of in-field structural practices in the no-practice scenario. This factor would be especially significant on soils with a lower risk of runoff losses.

The loss of carbon with wind and water erosion averaged 171 pounds per acre per year for the baseline, and slightly more at 207 pounds per acre for the no-practice scenario (table 17). Thus, on average for the region, conservation practice use results in a reduction of 37 pounds per acre per year in the loss of carbon with wind and water erosion, representing a 18-percent annual reduction on average.

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 gain in soil organic carbon of 2 pounds per acre due to conservation practice use is equivalent to an emission reduction of 38,164 U.S. tons of carbon dioxide for the Pacific Northwest Basin.

Figure 26. Estimates of average annual change in soil organic carbon for cropped acres in the Pacific Northwest Basin

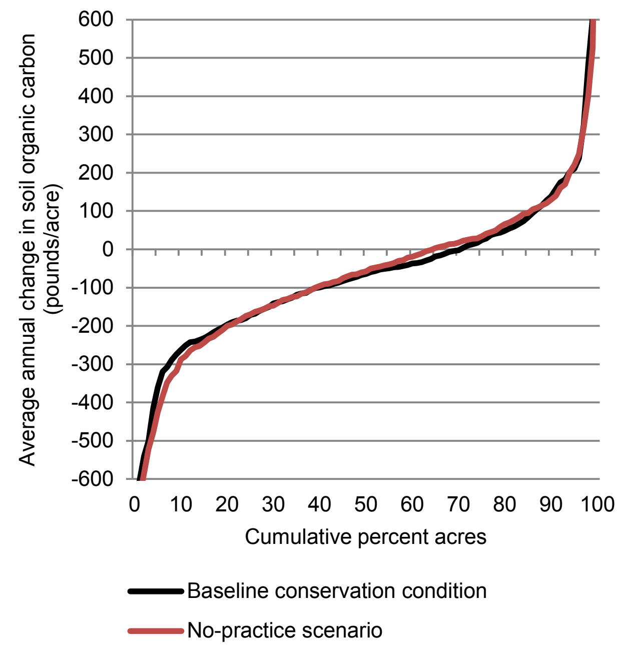
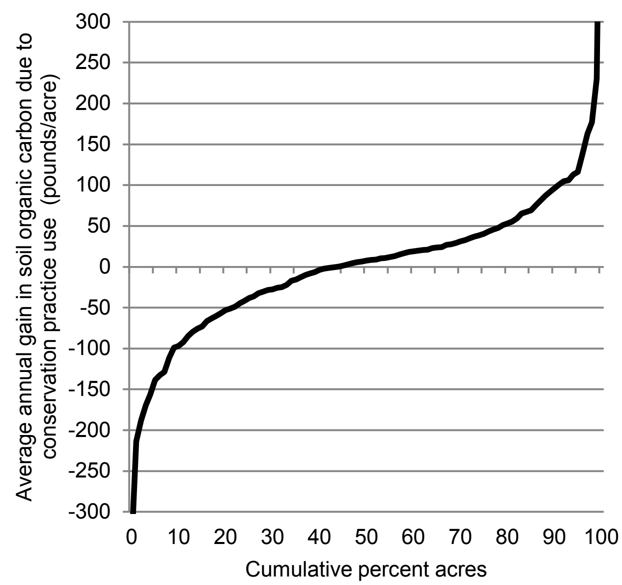


Figure 27. Estimates of average annual gain in soil organic carbon due to the use of conservation practices on cropped acres in the Pacific Northwest Basin



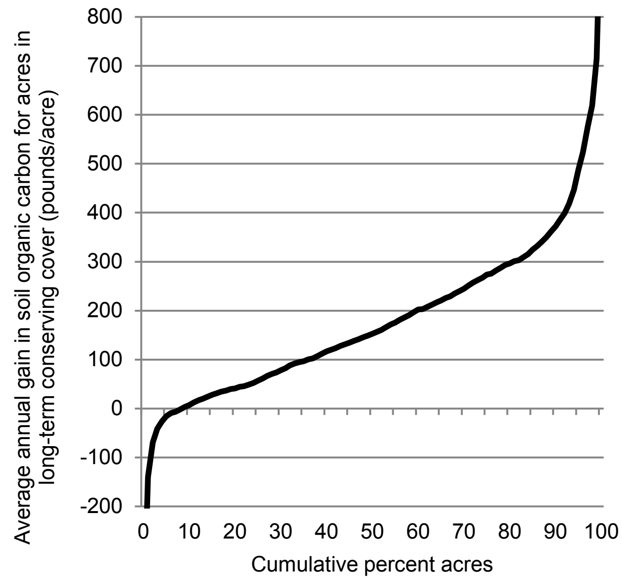
Note: See text for explanation of negative gains due to conservation practice use.

Land in long-term conserving cover

For land in long-term conserving cover, the annual change in soil organic carbon for the baseline conservation condition averages a gain of 131 pounds per acre per year (table 17). If these acres were still being cropped without any conservation practices, the annual average change in soil organic carbon would be a loss of 49 pounds per acre per year. Thus, the average gain in soil organic carbon due to the long-term conserving cover is 179 pounds per acre per year. This annual gain is much higher on some acres in long-term conserving cover, as shown in figure 28. This relatively low rate of change for land under permanent vegetation is largely a result of the natural slow rate of change in the dry eastern portion of the basin, which required thousands of years to build its inherent soil organic carbon under native grassland vegetation.

The gain of 179 pounds per acre is equivalent to an emission reduction of 739,619 U.S. tons of carbon dioxide for the region.

Figure 28. Estimates of average annual gain in soil organic carbon due to conversion to long-term conserving cover in the Pacific Northwest Basin



Note: Eight 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 104 pounds of nitrogen per acre per year for cropped acres in the Pacific Northwest Basin (table 18). Nitrogen applications, including manure applications, account for 87 percent of the nitrogen sources in this region. Sources of nitrogen vary significantly between the western and eastern portions of the basin, as shown below.

Water loss pathways	Average annual baseline values (pounds per acre) for four western subregions (8 percent of cropped acres in region)	Average annual baseline values (pounds per acre) for seven eastern subregions (92 percent of cropped acres in region)
Atmospheric deposition	1.6	1.2
Bio-fixation by legumes	5.2	12.4
Nitrogen applied as commercial fertilizer and manure	132.5	87.3
All nitrogen sources	139.3	101.0

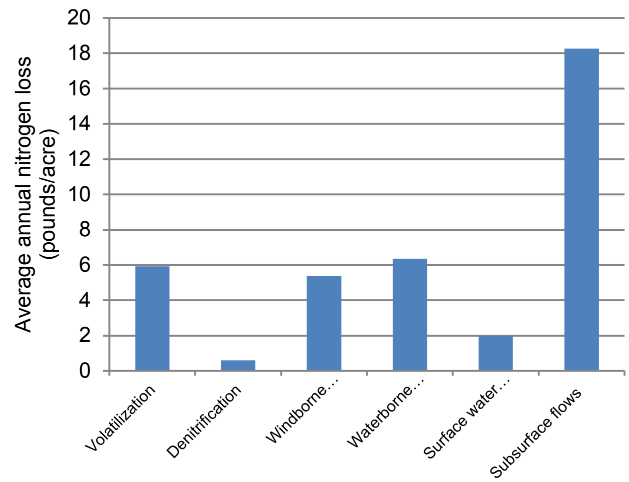
Model simulations show that about 75 pounds per acre of nitrogen are taken up by the crop and removed at harvest in the crop yield, on average (table 18), representing about 72 percent of all nitrogen sources. The amount of nitrogen removed at harvest in the crop yield is lower in the western portion of the basin, averaging 61.6 pounds per acre per year, than in the eastern portion of the basin, averaging 76.0 pounds per acre per year. Thus, in the eastern portion of the basin, 75 percent of all nitrogen sources are taken up by the crop and removed at harvest in the crop yield, on average, compared to only 44 percent in the western portion. As a consequence, a much larger share of the nitrogen sources in the western portion of the basin is lost from farm fields.

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 38.5 pounds per acre.[20] These nitrogen loss pathways are (fig. 29 and table 18)—

- nitrogen lost due to volatilization associated primarily with fertilizer and manure application (average of 5.9 pounds per acre per year);
- nitrogen returned to the atmosphere through denitrification (average of 0.6 pound per acre per year);
- nitrogen lost with windborne sediment (average of 5.4 pounds per acre per year);
- nitrogen lost with surface runoff (average of 8.3 pounds per acre per year), most of which is nitrogen lost with waterborne sediment; and
- nitrogen loss in subsurface flow pathways (average of 18.3 pounds per acre per year).

Most of the nitrogen loss in subsurface flows returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow.

Figure 29. Average annual nitrogen loss by loss pathway, Pacific Northwest Basin, baseline conservation condition



Nitrogen losses are much higher in the western portion of the basin for all loss pathways except nitrogen lost with windborne sediment, as shown below.

Nitrogen loss pathways	Average annual baseline values (pounds per acre) for four western subregions (8 percent of cropped acres in region)	Average annual baseline values (pounds per acre) for seven eastern subregions (92 percent of cropped acres in region)
Nitrogen loss by volatilization	9.3	5.6
Nitrogen loss through denitrification	2.3	0.5
Nitrogen lost with windborne sediment	<0.1	5.9
Nitrogen loss with surface runoff, including waterborne sediment	36.4	5.8
Nitrogen loss in subsurface flow pathways	37.1	16.5
Total nitrogen loss for all loss pathways	85.2	34.2

Model simulation results showed that nitrogen loss to specific loss pathways varies from acre to acre throughout the region (figs. 30 and 31). Loss of nitrogen in subsurface flows is the dominant loss pathway for 34 percent of the cropped acres in the region. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.) Nitrogen lost with windborne sediment and nitrogen loss by volatilization are each dominant for 23 percent of cropped acres. Nitrogen lost with waterborne sediment is the dominant loss pathway for 17 percent of cropped acres and nitrogen lost with surface water (soluble) is the dominant loss pathway for 3 percent of cropped acres.

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

Table 18. Field-level effects of conservation practices on nitrogen sources and nitrogen loss pathways for cropped acres (11.65 million acres) in the Pacific Northwest 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	1.2	1.2	0.0	0
Bio-fixation by legumes	11.8	11.0	-0.8	-8
Nitrogen applied as commercial fertilizer and manure	91.1	137.5	46.4	34
All nitrogen sources	104.2	149.7	45.5	30
Nitrogen in crop yield removed at harvest	74.8	92.0	17.2*	19
Nitrogen loss pathways				
Nitrogen loss by volatilization	5.9	9.5	3.5	37
Nitrogen loss through denitrification	0.6	0.8	0.2	26
Nitrogen lost with windborne sediment	5.4	7.0	1.6	23
Nitrogen loss with surface runoff, including waterborne sediment	8.3	13.8	5.5	40
Nitrogen loss with surface water (soluble)	2.0	5.0	3.0	61
Nitrogen loss with waterborne sediment	6.4	8.8	2.5	28
Nitrogen loss in subsurface flow pathways	18.3	35.0	16.7	48
Total nitrogen loss for all loss pathways	38.5	66.1	27.6	42
Change in soil nitrogen	-9.5	-8.6	0.8	--
Highly erodible land (54 percent of cropped acres)				
All nitrogen sources	97.5	140.2	42.7	30
Total nitrogen loss for all loss pathways	36.3	61.8	25.5	41
Non-highly erodible land (46 percent of cropped acres)				
All nitrogen sources	112.1	160.9	48.8	30
Total nitrogen loss for all loss pathways	41.1	71.2	30.1	42

* 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 11subregions.

Figure 30. Cumulative distributions of average annual nitrogen lost through six loss pathways, Pacific Northwest Basin, baseline conservation condition

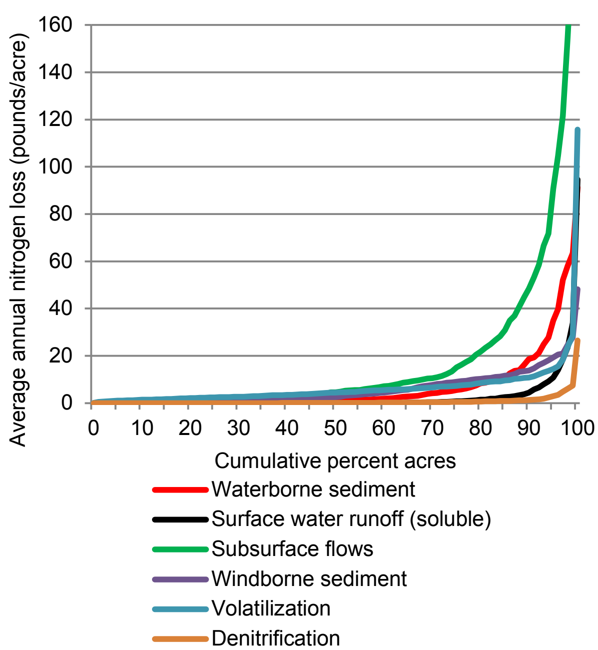
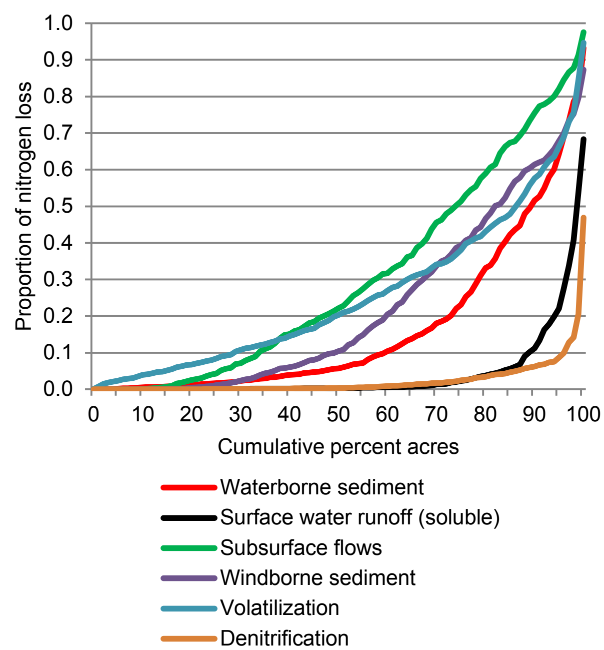


Figure 31. Cumulative distributions of proportions of nitrogen lost through six loss pathways, Pacific Northwest Basin



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.

Total nitrogen sources and total losses were slightly higher for non-highly erodible acres than for highly erodible acres (table 18).

Nitrogen loss in subsurface flows can be quite high for some acres (fig. 30). Average annual losses of nitrogen in subsurface flows exceed 50 pounds per acre per year for the 10 percent of acres with the highest losses. Over 50 percent of total nitrogen losses are lost in subsurface flows for about one-fourth of the cropped acres (fig. 31).

The distribution of average annual total nitrogen loss for the baseline is shown in figure 32, compared to the distribution of expected losses if no conservation practices were in use. Acres with the highest nitrogen losses have the highest inherent vulnerability combined with inadequate nutrient management. About one-fourth of cropped acres lose 40 pounds or more per acre per year. About half of cropped acres lose, however, less than 22 pounds per acre per year.

Model results for annual data indicate that some cropped acres in the Pacific Northwest Basin are much more susceptible to the effects of weather than other acres and lose high amounts of nitrogen in some years (fig. 33). About 15 percent of the acres lose more than 100 pounds per acre in at least some years, and 10 percent lose more than 60 pounds per acre in every year.

Figure 32. Estimates of average annual total nitrogen loss for cropped acres in the Pacific Northwest Basin

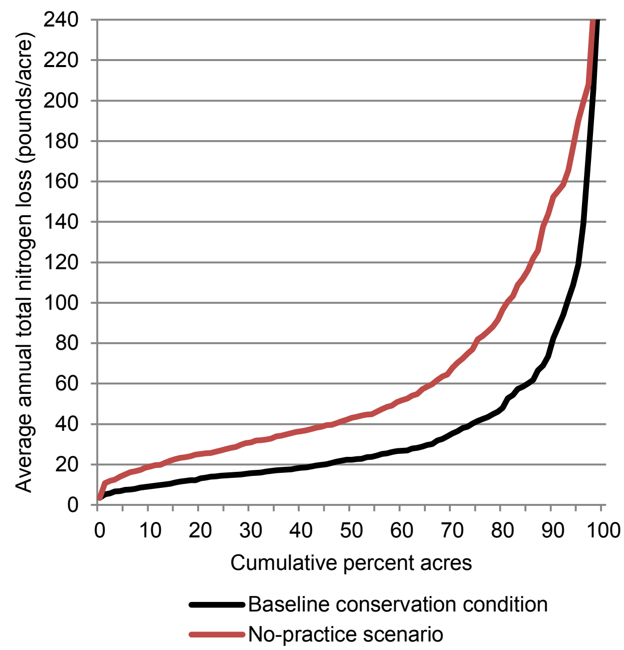
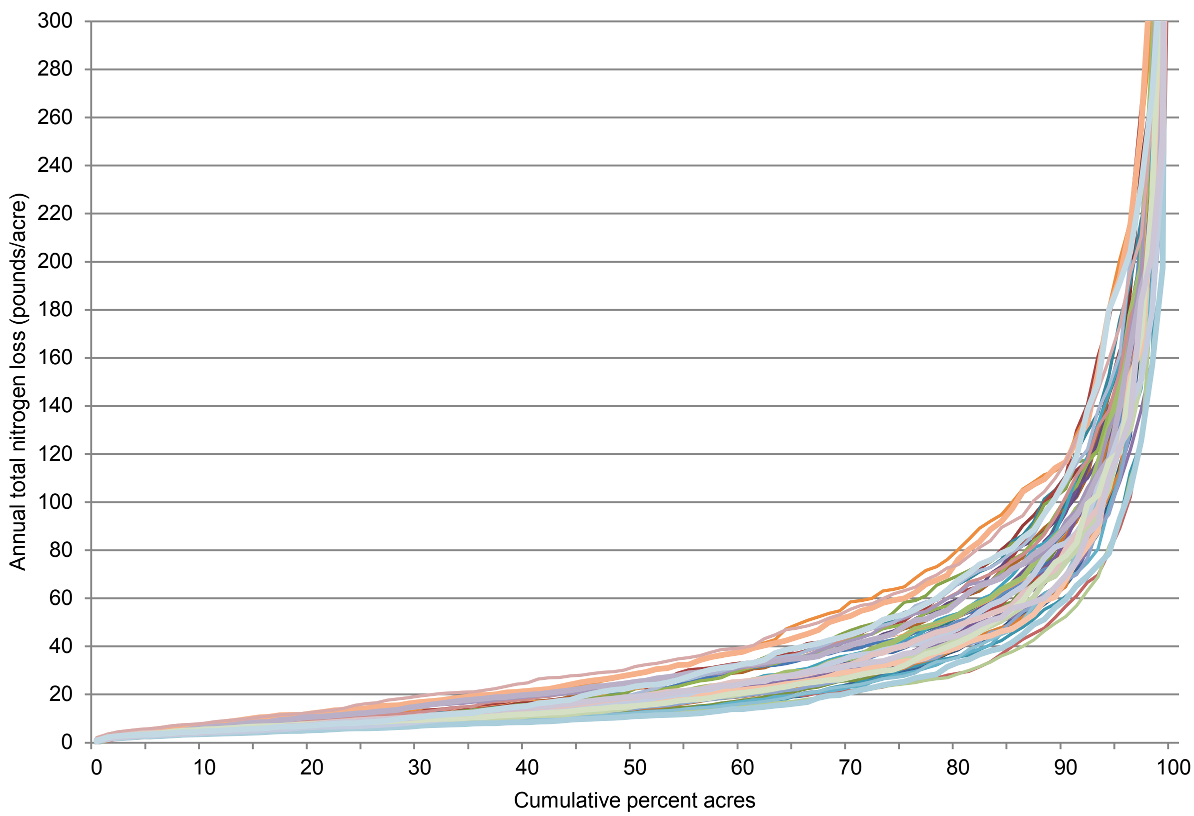


Figure 33. Distribution of annual total nitrogen loss for each year of the 47-year model simulation, Pacific Northwest Basin



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

Effects of conservation practices on cropped acres

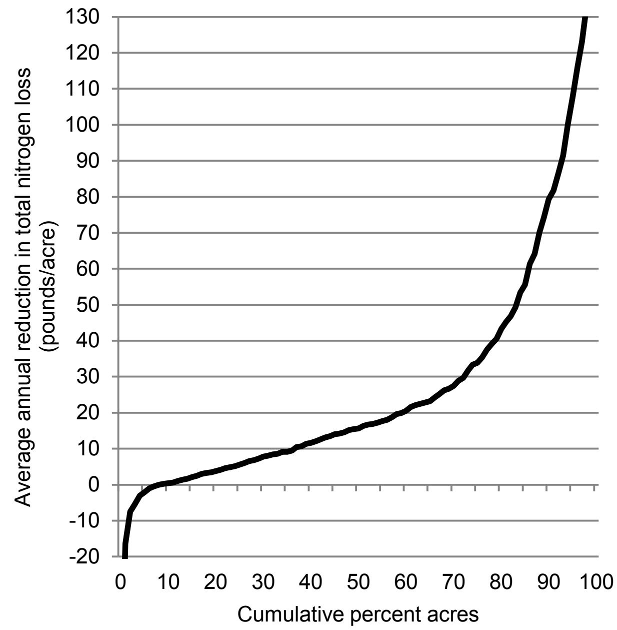
Total nitrogen loss, all pathways.

Model simulations show that the conservation practices in use in the region have reduced total nitrogen loss from cropped acres by an average of 28 pounds per acre per year, representing a 42-percent reduction, on average (table 18). Without conservation practices, about 53 percent of the cropped acres would have average annual total nitrogen loss exceeding 40 pounds per acre per year; with conservation practices, 25 percent of acres exceed this level of loss (fig. 32). The effects of conservation practices vary from small increases in nitrogen loss due to practices (negative reductions) to reductions greater than 100 pounds per acre per year (fig. 34). Acres with the highest reductions have higher levels of treatment and often higher levels of nitrogen use in the no-practice scenario.

About 7 percent of the cropped acres have an average annual *increase* in total nitrogen loss due to conservation practice use (fig. 34). This occurs on soils with relatively high soil nitrogen content and generally low slopes where surface water runoff is redirected to subsurface flow by soil erosion control practices. The higher volume of water moving through the soil profile extracts more nitrogen from the soil than under conditions without conservation practices. Cropping systems that include legumes, such as alfalfa hay, can also result in small overall losses in total nitrogen due to conservation practice use. Cropping systems with legumes have a higher soil nitrogen stock in the baseline conditions because legumes produce proportionately less biofixation of nitrogen under the higher fertilization rates simulated in the no-practice scenario.

About 65 percent of the acres have average annual reductions in total nitrogen loss above 10 pounds per acre per year due to conservation practice use, and 20 percent have average annual reductions in total nitrogen loss above 40 pounds per acre per year due to conservation practice use (fig. 34).

Figure 34. Estimates of average annual reduction in total nitrogen loss due to the use of conservation practices on cropped acres in the Pacific Northwest 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 7 percent of the acres.

Nitrogen lost with surface runoff. Model simulations show that, on average, nitrogen lost with surface runoff has been reduced 40 percent due to use of conservation practices in the region (table 18). On average, conservation practices have reduced nitrogen lost with surface runoff from 13.8 pounds per acre without practices to 8.3 pounds per acre with practices. Without conservation practices, about 28 percent of the cropped acres would lose more than 15 pounds per acre per year, on average, compared to 15 percent of the acres in the baseline conservation condition (fig. 35). Figure 36 shows that about 19 percent of the cropped acres have reductions in nitrogen lost with surface runoff greater than 10 pounds per acre due to conservation practice use. In contrast, however, 45 percent of the acres have reductions less than 1 pound per acre, including 3 percent with small increases in nitrogen lost with surface water due to conservation practice use.

Nitrogen loss in subsurface flows. Conservation practices are effective in reducing nitrogen loss in subsurface flows on about half of the cropped acres in this region, but make little difference on the other half of cropped acres and even result in increases in nitrogen loss in subsurface flows for about 15 percent of cropped acres (figs. 36 and 37). (Increases in nitrogen loss in subsurface flows are represented in figure 36 as negative reductions.) On average, conservation practices have reduced nitrogen loss in subsurface flows from 35 pounds per acre without practices to 18 pounds per acre with practices, representing an average reduction of 17 pounds per acre per year (48-percent reduction) (table 18). Figure 36 shows that reductions in average annual nitrogen loss in subsurface flows due to conservation practices exceed 20 pounds per acre for 25 percent of the cropped acres.

The increases in nitrogen loss in subsurface flows due to conservation practices on 15 percent of the cropped acres (fig. 36) are largely due to relatively weak nutrient management practices on acres with erosion control treatment. A portion of the reduction in nitrogen lost with surface runoff is re-routed to subsurface loss pathways, resulting in gains or only small reductions in nitrogen loss in subsurface flows. This re-routing of surface water runoff to subsurface flow pathways results in additional nitrogen being leached from the soil, diminishing and sometimes offsetting the positive effects of conservation practices on other nitrogen loss pathways.

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

Figure 35. Estimates of average annual nitrogen lost with surface runoff (including waterborne sediment) for cropped acres in the Pacific Northwest Basin

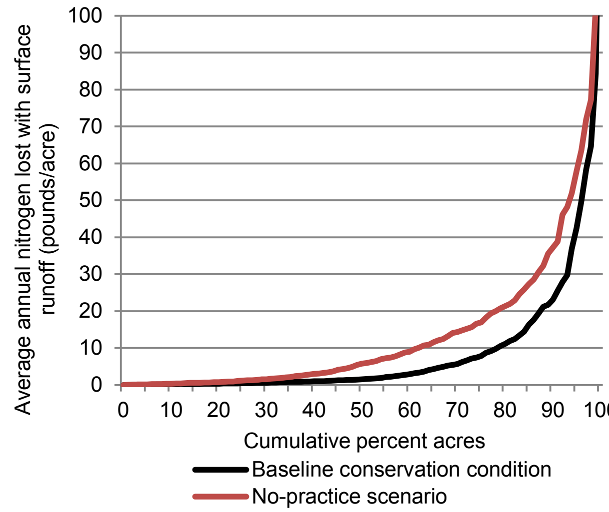


Figure 36. Estimates of average annual reduction in nitrogen lost with surface runoff and reduction in nitrogen loss in subsurface flows due to the use of conservation practices on cropped acres in the Pacific Northwest Basin

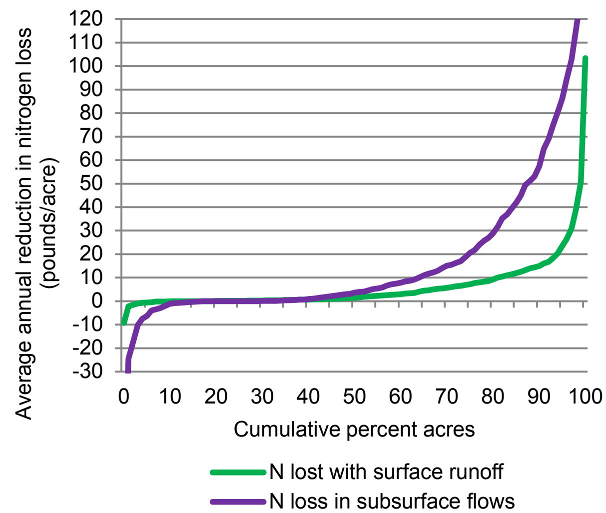
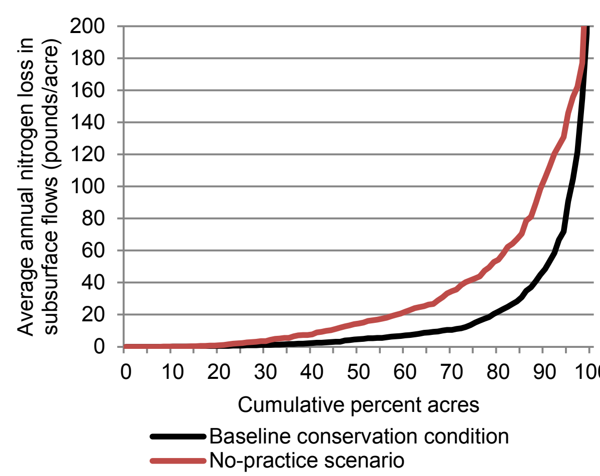


Figure 37. Estimates of average annual nitrogen loss in subsurface flows for cropped acres in the Pacific Northwest Basin



Tradeoffs in Conservation Treatment

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

- Terraces and conservation tillage are planned to solve a serious water erosion problem. However, in some areas there may be concern about seeps at the lower part of the field. The planned practices will solve the erosion problem, but could exacerbate the seep problem under some conditions. Ignoring that fact does not make for an adequate conservation plan.
- Conservation tillage is planned for erosion control on a cropland field with a high water table. The reduction in runoff may increase leaching of nitrates into the shallow water table. This potential secondary problem requires additional nutrient management practices to address the concern.
- Implementation of a nutrient management plan may reduce the amount of manure added to a field and thus reduce the loss of nutrients to surface or groundwater. However, this reduction in organic material added to the field may also reduce the soil organic matter or reduce the rate of change in soil organic matter.
- Figure 34 shows that about 7 percent of the acres have an increase in total nitrogen loss due to conservation practice use, although most of these increases are small. This result occurs primarily on soils with relatively high soil nitrogen content and generally low slopes where the surface water runoff is re-directed to subsurface flow by soil erosion control practices. The higher volume of water moving through the soil profile extracts more nitrogen from the soil than under conditions without conservation practices. For these fields, the nutrient management component of a farmer’s conservation plan would need to be enhanced to reduce or eliminate the negative effects of soil erosion control practices on nitrogen loss.

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

Land in long-term conserving cover

Total nitrogen loss has been reduced by 85 percent on the 2.3 million acres in long-term conserving cover, compared to conditions that would be expected had the acres remained in crops without conservation practices (table 19). Converting cropped acres to long-term conserving cover is very effective in reducing total nitrogen loss, as demonstrated in figure 38 and table 19. The reductions are much higher for some acres than others. Conversion of cropped acres to long-term conserving cover in the region has reduced total nitrogen loss from these acres from an average loss of 51 pounds per acre per year to about 8 pounds per acre per year, a reduction of 43 pounds per acre per year on average. Reductions exceed 100 pounds per acre for about 10 percent of acres converted to long-term conserving cover (fig 38).

Conversion of cropped acres to long-term conserving cover has also reduced subsurface losses from 29 pounds per acre per year to an average of less than 1 pound per acre (table 19). Nitrogen lost with surface runoff on these acres has been reduced from an average loss of 11 pounds per acre per year to 0.8 pound per acre per year.

Figure 38. Estimates of average annual reduction in total nitrogen loss for land in long-term conserving cover in the Pacific Northwest Basin

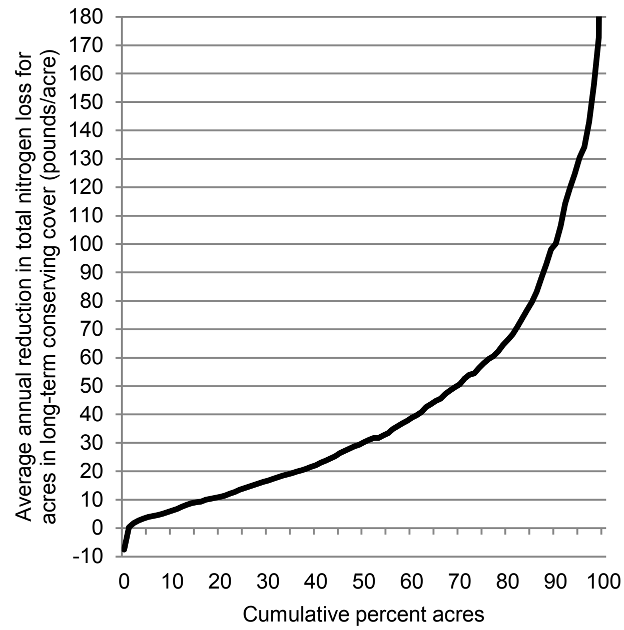


Table 19. Effects of conservation practices on nitrogen sources and nitrogen loss pathways for land in long-term conserving cover (2.3 million acres), Pacific Northwest Basin

Model simulated outcome	Average annual values in pounds per acre: Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Nitrogen sources				
Atmospheric deposition	1.4	1.4	0.0	0
Bio-fixation by legumes	9.5	2.2	-7.3*	-333*
Nitrogen applied as commercial fertilizer and manure	0.0	109.5	109.5	100
All nitrogen sources	10.9	113.0	102.1	90
Nitrogen in crop yield removed at harvest	0.0	67.0	67.0	100
Nitrogen loss pathways				
Nitrogen loss by volatilization	6.2	10.7	4.5	42
Nitrogen loss through denitrification	0.7	0.6	-0.1	-12
Nitrogen lost with windborne sediment	0.0	0.1	0.1	100
Nitrogen loss with surface runoff, including waterborne sediment	0.8	10.6	9.8	93
Nitrogen loss with surface water (soluble)	0.0	2.7	2.7	99
Nitrogen loss with waterborne sediment	0.8	7.8	7.1	90
Nitrogen loss in subsurface flow pathways	0.1	28.9	28.8	100
Total nitrogen loss for all pathways	7.8	50.8	43.1	85
Change in soil nitrogen	2.8	-5.2	-7.9	--

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text.
* As reported in chapter 3, the simulated conservation cover was a mix of species and all points included at least one grass and one clover species. This legume is the source of the 9.5 pounds per acre of nitrogen in the baseline scenario. The crops simulated for the no-practice scenario on these acres were almost never legume crops in this region, and so the results show a gain in nitrogen (negative reduction) from bio-fixation due to conversion to land in long-term conserving cover.

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 Pacific Northwest Basin, about 15.1 pounds per acre of phosphorus were applied as commercial fertilizer or with manure to cropped acres, on average, in each year of the model simulation (table 20). About 68 percent of the phosphorus applied is taken up by the crop and removed at harvest—10.3 pounds per acre per year, on average, for the region.

As seen for nitrogen, however, the percent of phosphorus applied that is removed with the crop yield at harvest is lower for cropped acres in the western portion of the basin than in the eastern portion, leaving a larger share of the phosphorus available for field-level losses in the western portion of the basin. Of the 24.6 pounds per acre of phosphorus applied in the western portion of the basin, 9.8 pounds per acre per year are removed with the crop yield at harvest—40 percent of the amount applied. In the eastern portion of the basin, 14.2 pounds per acre of phosphorus are applied and 10.3 pounds per acre per year are removed with the crop yield at harvest—73 percent of the amount applied.

Total phosphorus loss for all loss pathways averaged 4.1 pounds per acre per year in the baseline conservation condition (table 20). These phosphorus loss pathways are—

- phosphorus lost with windborne sediment (average of 1.5 pound per acre per year);
- phosphorus lost with waterborne sediment (average of 1.9 pound per acre per year);
- soluble phosphorus lost to surface water, including soluble phosphorus in surface water runoff, and soluble phosphorus that infiltrates into the soil profile but quickly returns to surface water either through quick return lateral flow or intercepted by drainage systems (average of 0.7 pounds per acre per year); and
- soluble phosphorus that percolates through the soil profile into the groundwater (average of less than 0.02 pound per acre per year).

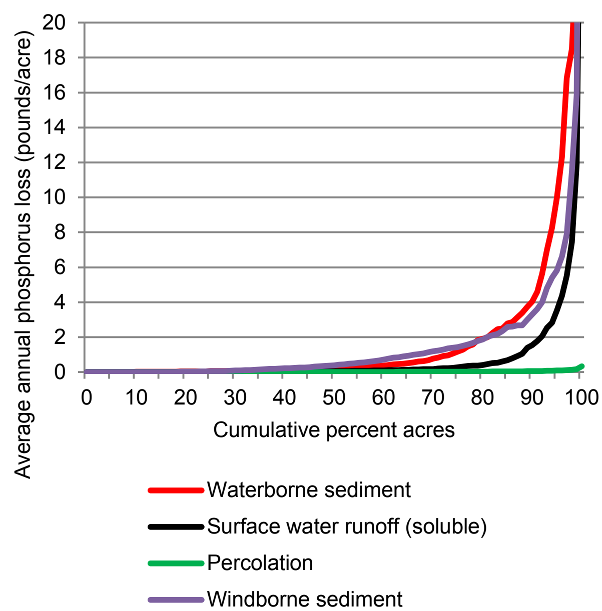
Phosphorus losses are higher in the western portion of the basin for all loss pathways except phosphorus lost with windborne sediment, as shown below.

Phosphorus loss pathways	Average annual baseline values (pounds per acre) for four western subregions (8 percent of cropped acres in region)	Average annual baseline values (pounds per acre) for seven eastern subregions (92 percent of cropped acres in region)
Phosphorus lost with windborne sediment	<0.1	1.6
Phosphorus lost to surface water (sediment attached and soluble)	14.3	1.5
Soluble phosphorus lost to surface water	5.5	0.2
Phosphorus loss with waterborne sediment	8.8	1.3
Soluble phosphorus loss to groundwater	0.1	<0.1
Total phosphorus loss for all loss pathways	14.4	3.1

In the western portion of the basin, most phosphorus lost from farm fields is lost to surface water runoff as soluble phosphorus and with waterborne sediment. In the eastern portion, most phosphorus lost from farm fields is lost with windborne sediment and waterborne sediment. A very small amount of soluble phosphorus is lost through percolation into groundwater.

Figure 39 shows how losses for the four loss pathways vary among cropped acres throughout the region.

Figure 39. Estimates of average annual phosphorus lost through various loss pathways, Pacific Northwest Basin, baseline conservation condition



The percentage of phosphorus lost in each of the principal loss pathways also varies from acre to acre, as shown in figure 40 for cropped acres.

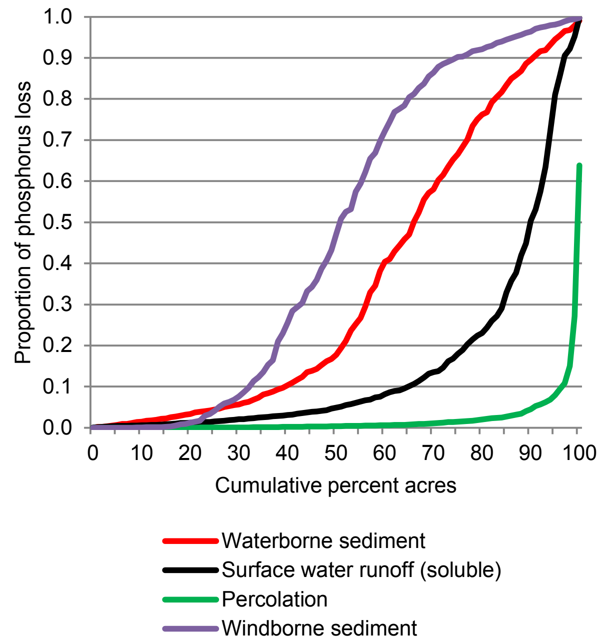
Phosphorus lost with windborne sediment is the dominant loss pathway for 51 percent of cropped acres in the region. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.) Phosphorus lost with waterborne sediment is the dominant loss pathway for 37 percent of cropped acres. Soluble phosphorus lost with surface water runoff and lateral flow (including discharge to drainage tiles, ditches, and seeps) was the dominant loss pathway for 12 percent of cropped acres. Soluble phosphorus lost through percolation into groundwater is the dominant loss pathway for less than 1 percent of cropped acres.

As observed for nitrogen, the amounts of phosphorus applied and total phosphorus losses are slightly higher for non-highly erodible acres than for highly erodible acres (table 20).

Total phosphorus loss varies considerably from year to year and from acre to acre, as shown in figure 41. About 60 percent of the acres lose less than 4 pounds per acre per year through the various loss pathways under *all* weather conditions (fig. 41). In contrast, about 10 percent of cropped acres lose more than 4 pounds per acre in all years. Phosphorus losses can exceed 12 pounds per acre in some years on up to 15 percent of cropped acres.

The *average annual* phosphorus lost to surface water for the baseline is shown in figure 42. Acres with the highest phosphorus losses have the highest inherent vulnerability combined with inadequate nutrient management and runoff controls. About 85 percent of cropped acres lose, on average, less than 4 pounds per acre per year, while 5 percent lose 13 pounds or more per acre per year, on average.

Figure 40. Cumulative distributions of the proportion of phosphorus lost through various loss pathways, Pacific Northwest 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 20. Field-level effects of conservation practices on phosphorus sources and phosphorus loss pathways for cultivated cropland in the Pacific Northwest Basin

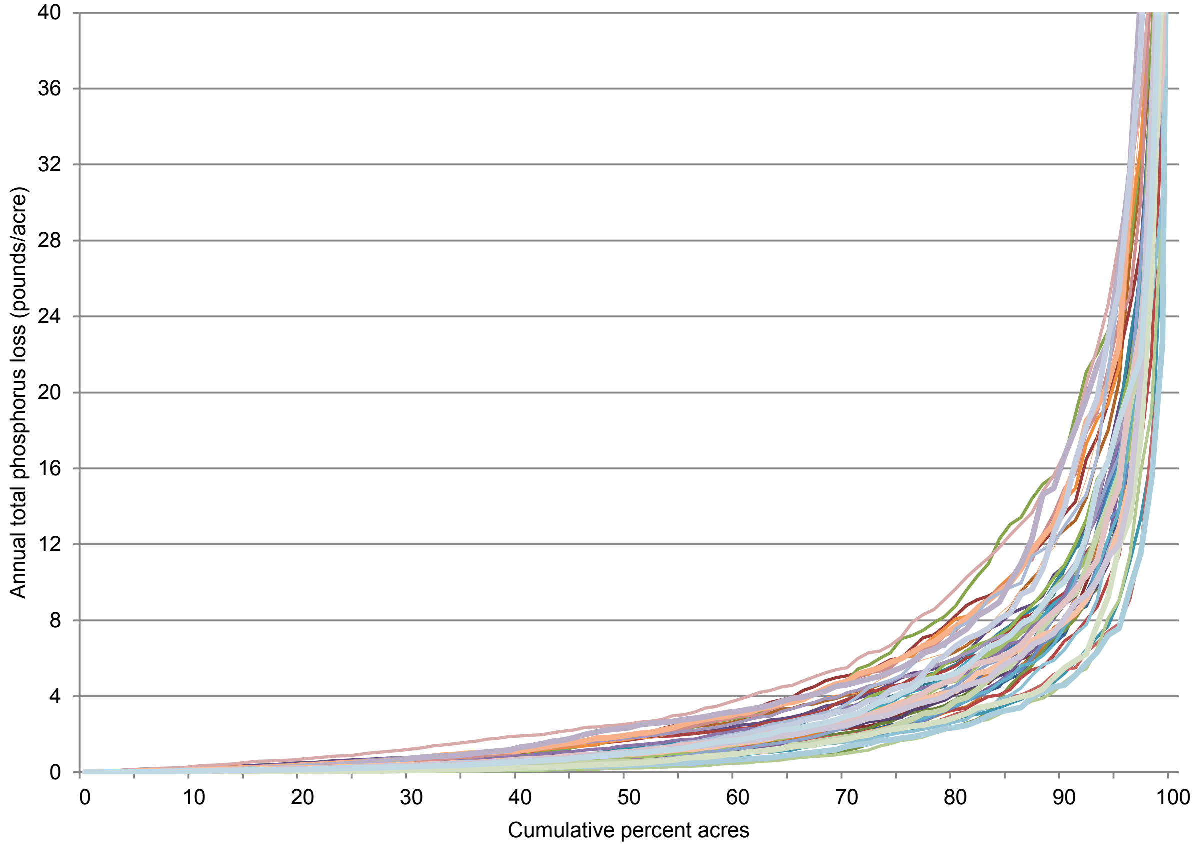
Model simulated outcome	Average annual values in pounds per acre Baseline conservation condition	No-practice scenario	Reduction due to practices	Percent reduction
Cropped acres (11.65 million acres)				
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	15.1	24.2	9.1	38
Phosphorus in crop yield removed at harvest	10.3	12.5	2.2	18
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	1.45	2.33	0.88	38
Phosphorus lost to surface water (sediment attached and soluble)*	2.61	4.81	2.20	46
Soluble phosphorus lost to surface water*	0.70	1.42	0.72	50
Phosphorus loss with waterborne sediment	1.91	3.40	1.49	44
Soluble phosphorus loss to groundwater	0.02	0.03	<.01	17
Total phosphorus loss for all loss pathways	4.08	7.17	3.09	43
Change in soil phosphorus	0.59	4.51	3.92	--
Highly erodible land (54 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	13.3	22.7	9.5	42
Total phosphorus loss for all loss pathways	4.0	7.5	3.5	47
Non-highly erodible land (46 percent of cropped acres)				
Phosphorus applied as commercial fertilizer and manure	17.2	25.9	8.7	34
Total phosphorus loss for all loss pathways	4.2	6.8	2.6	38
Land in long-term conserving cover (2.3 million acres)				
Phosphorus sources				
Phosphorus applied as commercial fertilizer and manure	0.0	16.5	16.5	100
Phosphorus in crop yield removed at harvest	0	9	9	100
Phosphorus loss pathways				
Phosphorus lost with windborne sediment	0.00	0.02	0.02	100
Phosphorus lost to surface water (sediment attached and soluble)*	0.16	2.87	2.71	94
Soluble phosphorus lost to surface water*	0.06	0.56	0.50	89
Phosphorus loss with waterborne sediment	0.10	2.31	2.21	96
Soluble phosphorus loss to groundwater	0.02	0.02	0.00	9
Total phosphorus loss for all loss pathways	0.18	2.91	2.73	94
Change in soil phosphorus	-0.20	4.57	4.77	--

* 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.

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

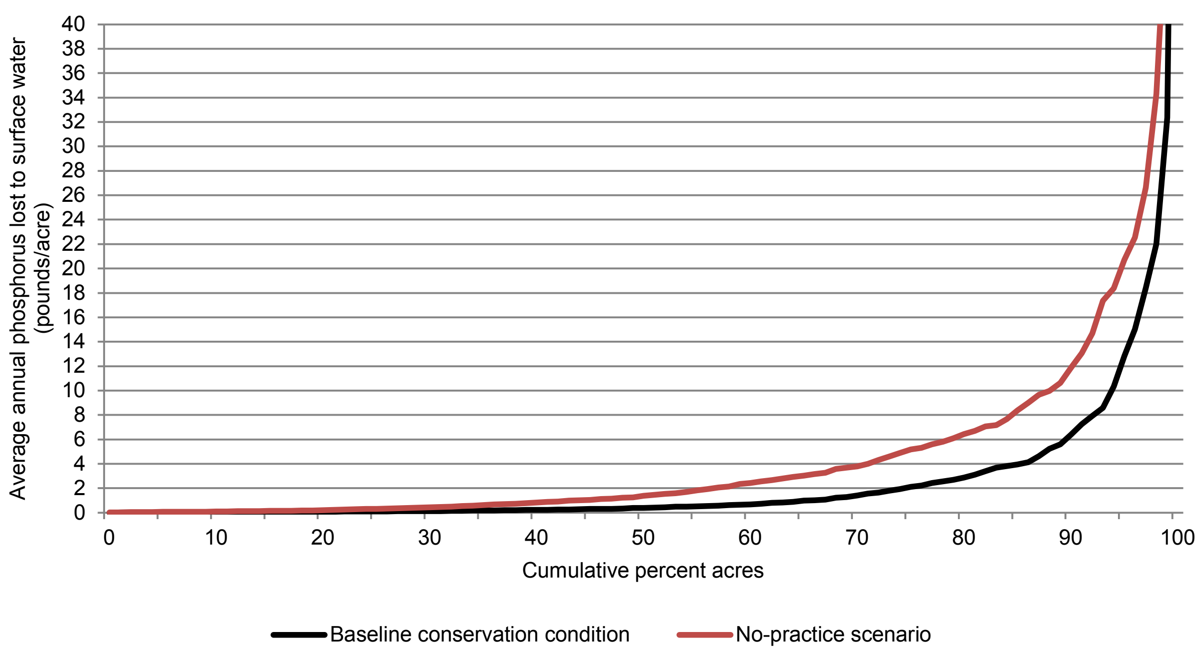
Note: Model simulation results for the baseline conservation condition are presented in appendix B for the 11subregions.

Figure 41. Distribution of annual total phosphorus loss for each year of the 47-year model simulation, Pacific Northwest 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 42. Estimates of average annual phosphorus lost to surface water (sediment attached and soluble)* for cropped acres in the Pacific Northwest Basin



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

Effects of conservation practices on cropped acres

Conservation practices have reduced phosphorus lost to surface water for cropped acres by 46 percent, reducing the average loss from 4.8 pounds per acre per year if conservation practices were not in use to 2.6 pounds per acre per year for the baseline conservation condition (table 20). The largest reductions were for phosphorus lost with waterborne sediment. On average, conservation practices have reduced phosphorus loss with waterborne sediment by 1.49 pounds per acre per year, representing a 44-percent reduction. Conservation practices have reduced phosphorus lost with windborne sediment by 0.88 pounds per acre per year, representing a 38-percent reduction. Soluble phosphorus lost to surface water has been reduced 0.72 pounds per acre per year due to conservation practice use, representing a 50-percent reduction (table 20).

The effects of conservation practices on phosphorus lost to surface water (soluble and sediment attached) are shown in figures 42 and 43 for cropped acres. Without conservation practices in use, 30 percent of cropped acres would exceed 4 pounds per acre per year of phosphorus lost to surface water, on average, compared to 15 percent with conservation practice use as represented in the baseline conservation condition (fig. 42).

The effects of conservation practices on phosphorus lost to surface water vary considerably throughout the Pacific Northwest Basin, as shown in figure 43. At the high end, reductions exceed 5 pounds per acre for about 11 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 5 percent of the acres, however, conservation practice use results in *increases* in phosphorus lost to surface water, although the increases exceeded 0.5 pound per acre for only 2 percent of the acres. (Increases in phosphorus lost to surface water are represented in figure 43 as negative reductions.) In some cases these increases in phosphorus loss are the result of small increases in surface water runoff due to conservation practice use (see fig. 16 and the footnote on the same page). In other cases, however, increases in phosphorus loss due to conservation practices resulted from a combination of practices and landscape conditions that cause phosphorus levels to concentrate near or on the soil surface, where it is more vulnerable to surface runoff. On these types of landscapes, improved phosphorus management along with light incorporation and maintenance of crop residue on the soil surface may be necessary to reduce soluble phosphorus loss.

Land in long-term conserving cover

For land in long-term conserving cover, total phosphorus loss is 94 percent less than it would have been if crops had been grown and no conservation practices used, reducing total phosphorus loss by 2.7 pounds per acre per year, on average (table 20). Reductions are less than 2 pounds per acre per year for the majority of acres, but range to over 9 pounds per acre per year for the 7 percent of acres with the highest reductions (fig. 44).

Figure 43. Estimates of average annual reduction in phosphorus lost to surface water (sediment attached and soluble) due to conservation practices on cropped acres in the Pacific Northwest Basin

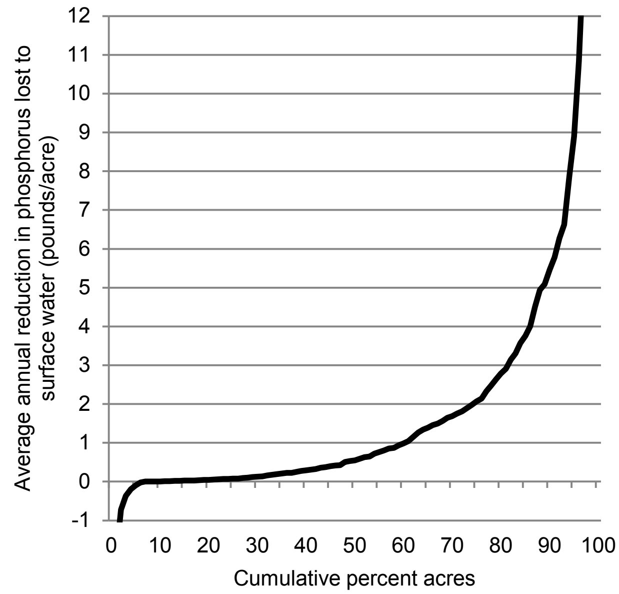
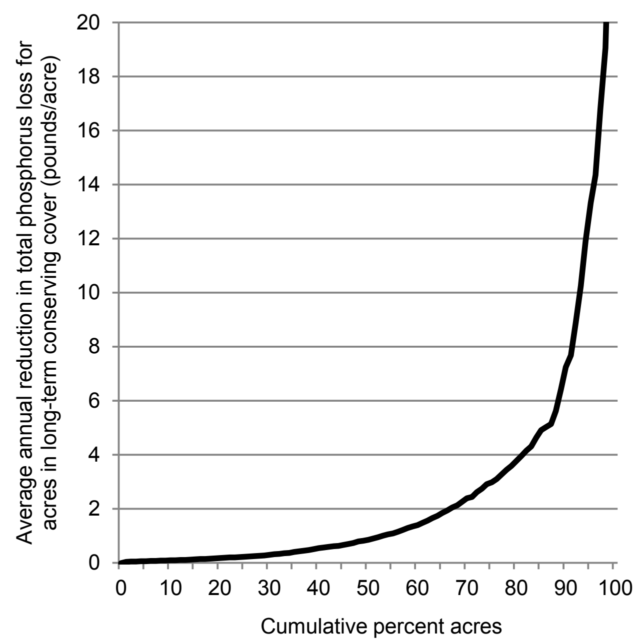


Figure 44. Estimates of average annual reduction in total phosphorus loss due to conversion to long-term conserving cover in the Pacific Northwest Basin



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.

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

Model simulations incorporated pesticide use information from the CEAP survey conducted in 2003–06 (active ingredient, application rate, application method, and time of application). A total of 190 different pesticides are used in the region, as reported in the survey. The most commonly applied pesticides are presented in table 21. The two pesticides applied in the largest amount for the entire region were metam-sodium and the fungicide 1,3-dichloropropene, together totaling 69 percent of the total weight of all pesticides applied. The herbicides glyphosate isopropylamine salt and EPTC accounted for 3 percent and 2 percent of the total weight of all pesticides applied, respectively.

Baseline condition for pesticide loss

The APEX model tracks the mass loss of pesticides dissolved in surface water runoff, adsorbed to sediment lost through water erosion, and dissolved in subsurface flow pathways.[21] The distribution of losses through each of these three pathways is contrasted in figure 45. Eighty percent of cropped acres in this region have very small amounts of pesticide residues lost from farm fields—less than 3 grams per hectare total pesticide weight of all pesticide residues lost.

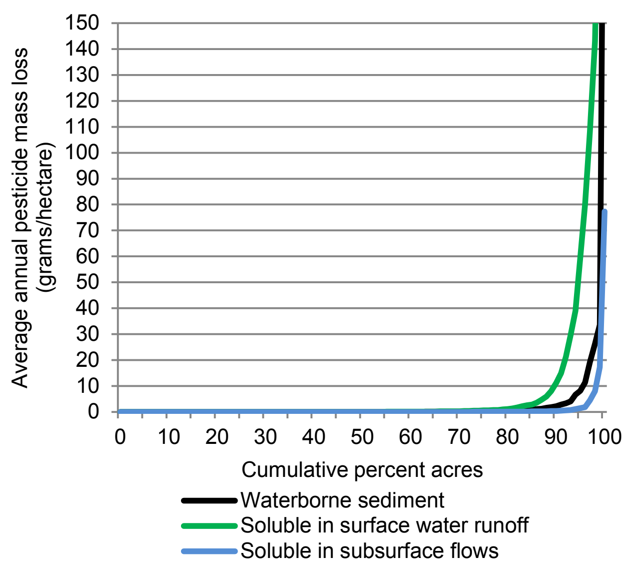
All three pathways are important in the transport of pesticide residues from farm fields. The dominant loss pathway for 40 percent of cropped acres was pesticides lost with surface water runoff. (The dominant loss pathway was determined for each sample point as the pathway with the highest loss.) Subsurface flows were the dominant pesticide loss pathway for 28 percent of the acres, and waterborne sediment was the dominant pesticide loss pathway for 24 percent of the acres. The remaining 8 percent of the acres had no pesticide loss.

The average annual amount of pesticide lost from farm fields in the Pacific Northwest Basin is about 13 grams of active ingredient per hectare per year (table 22).[22] Most of this is lost from cropped acres in the western portion of the basin, where the average annual amount of pesticide lost from farm fields is about 118 grams of active ingredient per hectare per year. In stark contrast, the amount of pesticide residues lost from farm fields in the eastern portion of the basin averages only 4 grams of active ingredient per hectare per year.

The most common pesticide residues lost from farm fields in model simulations for the Pacific Northwest Basin are the herbicide diuron (21.6 percent of total mass loss), the herbicide ethofumesate (10 percent), the herbicide flufenacet (9.9 percent), the herbicide metribuzin (6.3 percent), the herbicide MCPA-dimethylamine salt (6 percent), and the herbicide glyphosate isopropylamine salt (6 percent of total mass loss). These six pesticides account for 59 percent of all pesticide residues lost from fields in the model simulations for the Pacific Northwest Basin (table 21).

The herbicide atrazine, commonly used on corn acres and often found as a contaminant of surface water and groundwater in other regions of the country, only accounted for 0.5 percent of the total weight of pesticides applied in this region and only 2.5 percent of the total weight of pesticides lost from farm fields. The survey found that atrazine was applied to only 3 percent of cropped acres in the Pacific Northwest Basin.

Figure 45. Estimates of average annual pesticide loss (mass loss of all pesticides combined) for three loss pathways, Pacific Northwest 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. Dominant pesticides applied in model simulations and contributing to losses, Pacific Northwest Basin

Pesticide (active ingredient name)	Pesticide type	Percent of total applied in the region
Pesticide application*		
Metam-sodium	Multi-target	47.1
1,3-Dichloropropene	Fungicide	22.0
Glyphosate isopropylamine salt	Herbicide	3.3
EPTC	Herbicide	2.1
Mancozeb	Fungicide	1.4
Chlorothalonil	Fungicide	1.3
2,4-D, 2-ethylhexyl ester	Herbicide	1.2
2,4-Dichlorophenoxyacetic acid	Herbicide	1.1
2,4-D, dimethylamine salt	Herbicide	0.9
Sulfur	Fungicide	0.9
MCPA, 2-ethylhexyl ester	Herbicide	0.8
MCPA	Herbicide	0.8
Alachlor	Herbicide	0.8
Metribuzin	Herbicide	0.8
Pendimethalin	Herbicide	0.8
Oxamyl	Insecticide	0.7
Aldicarb	Insecticide	0.7
Diuron	Herbicide	0.7
Ethofumesate	Herbicide	0.6
Bromoxynil octanoate	Herbicide	0.6
Phorate	Insecticide	0.6
Ethoprop	Nematicide	0.5
Bromoxynil	Herbicide	0.5
Propanil	Herbicide	0.5
Atrazine	Herbicide	0.5
Total		91.0
		Percent of total pesticide loss in the region**
Pesticide loss from farm fields*		
Diuron	Herbicide	21.6
Ethofumesate	Herbicide	10.0
Flufenacet	Herbicide	9.9
Metribuzin	Herbicide	6.3
MCPA, dimethylamine salt	Herbicide	6.0
Glyphosate isopropylamine salt	Herbicide	5.6
2,4-D, 2-ethylhexyl ester	Herbicide	5.1
2,4-D, dimethylamine salt	Herbicide	3.6
Metam-sodium	Multi-target	3.1
Sulfur	Fungicide	2.8
Atrazine	Herbicide	2.5
Pendimethalin	Herbicide	2.2
EPTC	Herbicide	2.0
2,4-Dichlorophenoxyacetic acid	Herbicide	1.6
S-Metolachlor	Herbicide	1.4
Dicamba	Herbicide	1.3
Dicamba, dimethylamine salt	Herbicide	1.3
Propiconazole	Fungicide	1.3
Metaldehyde	Molluscicide	1.1
MCPA	Herbicide	1.1
2,4-DP, dimethylamine salt	Herbicide	0.8
Paraquat dichloride	Herbicide	0.8
Oxyfluorfen	Herbicide	0.6
Chlorpyrifos	Insecticide	0.5
Chlorothalonil	Fungicide	0.5
Total		93.0

* Pesticides not listed each represented less than 0.5 percent of the total mass weight applied or lost in the region. Percents may not add to total due to rounding.
** Includes loss of pesticides dissolved in surface water runoff, adsorbed to sediment loss from water erosion, and dissolved in subsurface flow pathways.

Table 22. Field-level effects of conservation practices on pesticide loss and associated edge-of-field environmental risk for cropped acres in the Pacific Northwest 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)	3,540	3,893	354	9
Pesticide loss				
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	13.2	21.1	7.9	37
Edge-of-field pesticide risk indicator				
Average annual surface water pesticide risk indicator for aquatic ecosystems	1.76	5.02	3.27	65
Average annual surface water pesticide risk indicator for humans	0.86	1.24	0.38	30
Average annual groundwater pesticide risk indicator for humans	0.41	0.66	0.25	38

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 11subregions.

Effects of conservation practices on pesticide residues and risk

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

Model simulations show that conservation practices—primarily water erosion control practices—are effective in reducing the loss of pesticide residues from farm fields in the Pacific Northwest Basin. Use of conservation practices has reduced the loss of pesticides (summed over all pesticides) by an average of 7.9 grams of active ingredient per hectare per year, a 37-percent reduction from the 21.1 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. The environmental impact is specific to the toxicity of each pesticide to non-target species that may be exposed to the pesticide.

Pesticide risk indicators were therefore developed to represent risk at the edge of the field (bottom of soil profile for groundwater). These edge-of-field risk indicators are based on the ratio of average annual pesticide concentrations in water leaving the field to safe concentrations (toxicity thresholds) for each pesticide. As such, these risk indicators do not have units. The pesticide risk indicators were developed so that the relative risk for individual pesticides could be aggregated over the 190 pesticides included in the model for the Pacific Northwest Basin.[23]

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

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

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

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

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

The dominant pesticides contributing to each of the three risk indicators are presented in table 23. Based on the model simulations, the dominant pesticides contributing to the edge-of-field risk indicator score for aquatic ecosystems in this region are the herbicides 2,4-D, 2-ethylhexyl ester, diuron, atrazine, flufenacet, and metribuzin, and the insecticide chlorpyrifos. These six pesticides each have 1 percent or more of cropped acres in the region with an average annual edge-of-field risk indicator greater than 1. The frequency at which the two risk indicators for humans exceeded 1 was much lower, and occurred for fewer pesticides (table 23).

Figure 46 shows that for most acres and most years the overall risk for aquatic ecosystems is low, in part because of the conservation practices in use. But the edge-of-field concentrations can be high relative to "safe" thresholds for some acres, mostly in the western portion of the basin. The pesticide risk indicator for aquatic ecosystems averaged 1.76 over all years and cropped acres (table 22) for the baseline conservation condition. (The 1.76 value indicates that average annual pesticide concentrations in water leaving cropped fields in the Pacific Northwest Basin are 1.76 times the “safe” concentration for non-target plant and animal species when exposed to concentrations at the edge of the field.) The median value, however, is only 0.01 (fig. 47). About 87 percent of the cropped acres in the region have an average annual edge-of-field surface water pesticide risk indicator for aquatic ecosystems less than 1 for the baseline conservation condition (fig. 47).

Pesticide Risk Indicators

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

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

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

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

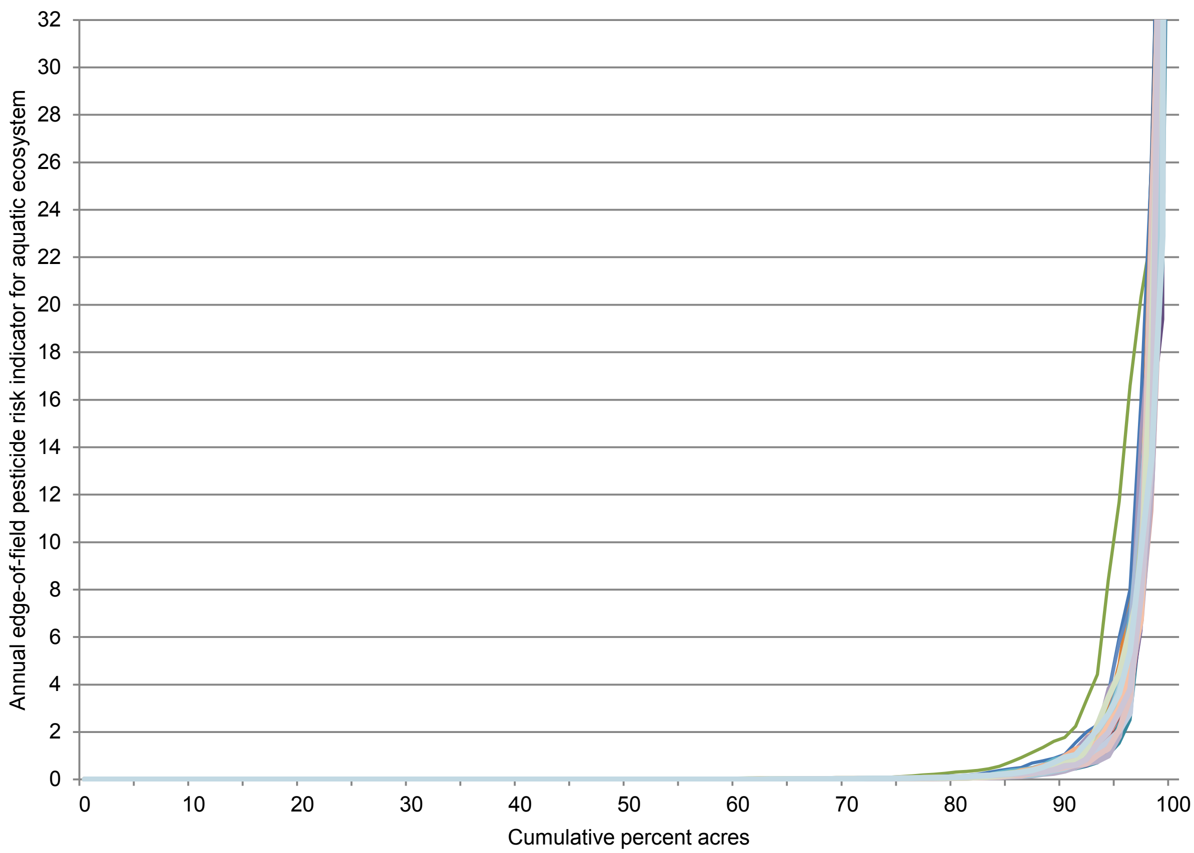
Two aquatic toxicity thresholds were used in estimating potential risk:

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

Table 23. Dominant pesticides determining edge-of-field environmental risk, Pacific Northwest Basin

Pesticide (active ingredient name)	Pesticide type	Percent of cropped acres in the region with average annual edge-of-field risk indicator greater than 1
Risk indicator for aquatic ecosystem		
2,4-D, 2-ethylhexyl ester	Herbicide	3.6
Diuron	Herbicide	1.8
Atrazine	Herbicide	1.6
Flufenacet	Herbicide	1.3
Chlorpyrifos	Insecticide	1.1
Metribuzin	Herbicide	1.0
Aldicarb	Insecticide	0.8
Metam-sodium	Multi-Target	0.7
Dimethoate	Insecticide	0.6
S-Metolachlor	Herbicide	0.5
All other pesticides combined		4.1
Risk indicator for humans, surface water		
Metam-sodium	Multi-Target	1.1
MCPA, dimethylamine salt	Herbicide	0.7
Diuron	Herbicide	0.7
Dimethoate	Insecticide	0.7
Atrazine	Herbicide	0.5
All other pesticides combined		1.2
Risk indicator for humans, groundwater		
Atrazine	Herbicide	1.1
Metam-sodium	Multi-Target	0.4
All other pesticides combined		0.5

Figure 46. 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, Pacific Northwest Basin



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

The pesticide risk indicators for humans were much lower, averaging 0.86 for surface water and 0.41 for groundwater (table 22). The median values are less than 0.01 for surface water and for groundwater. Only about 4 percent of the cropped acres have an average annual edge-of-field surface water pesticide risk indicator for humans greater than 1 for the baseline conservation condition (fig. 48).

The use of conservation practices in the Pacific Northwest Basin has reduced the pesticide risk indicator for aquatic ecosystems by 65 percent (table 22), averaged over all years, all pesticides, and all cropped acres. The surface water pesticide risk indicator for humans has been decreased by 30 percent and the groundwater pesticide risk indicator for humans has been decreased by 38 percent due to conservation practice use (table 22).

Figure 49 shows the distribution of the reductions due to conservation practices in the two surface water pesticide risk indicators. Most acres have indicator scores so low that conservation practices reduce the indicators only a small amount. Significant risk reductions for aquatic ecosystems occur on about 15 percent of the acres, while significant risk reductions for humans occur on only about 10 percent of the acres. The benefits of conservation practices were significant for both aquatic ecosystem risks and human risks on the acres that had those risks, but because aquatic ecosystem risks were more widespread than human risks, conservation practices have greater potential benefit for aquatic ecosystems than for human drinking water.

Figure 47. Estimates of average annual edge-of-field surface water pesticide risk indicator for aquatic ecosystem in the Pacific Northwest Basin

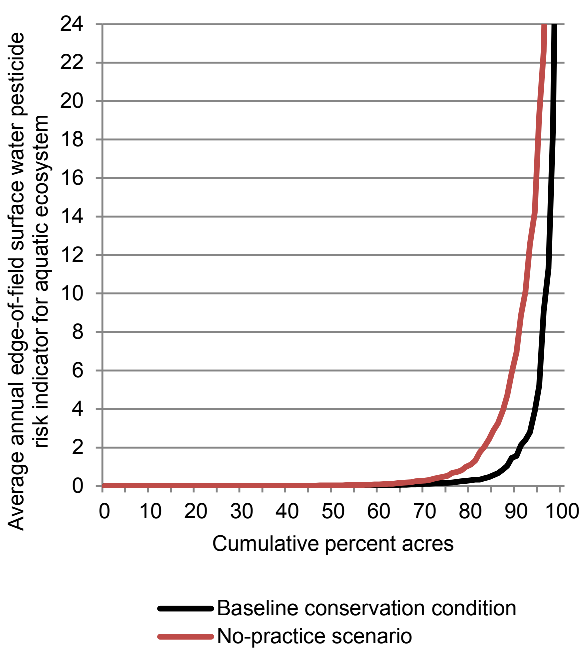


Figure 48. Estimates of average annual edge-of-field surface water pesticide risk indicator for humans in the Pacific Northwest Basin

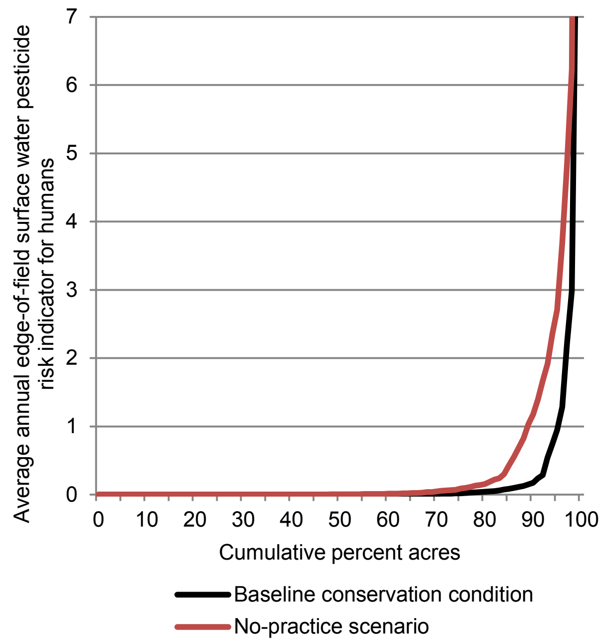
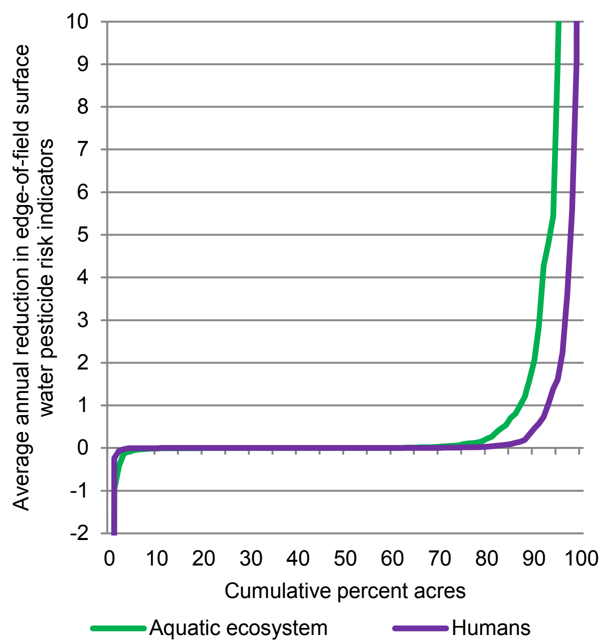


Figure 49. Estimates of average annual reductions in the edge-of-field surface water pesticide risk indicators for aquatic ecosystems in the Pacific Northwest Basin



Note: Negative reductions in pesticide loss (and therefore risk) similar to negative reductions in soluble phosphorus losses occur on some landscapes as a result of reduced tillage (see discussion related to figure 43 on phosphorus reductions.)

Chapter 5
Assessment of Conservation Treatment Needs

The adequacy of conservation practices in use in the Pacific Northwest 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.

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

1. sediment loss due to water erosion;
2. nitrogen loss with surface runoff (nitrogen attached to sediment and in solution);
3. nitrogen loss in subsurface flows;
4. phosphorus lost to surface water (phosphorus attached to sediment and in solution, including soluble phosphorus in subsurface lateral flow pathways); 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. A portion of the pesticide residues are controlled by soil erosion control practices; meeting soil erosion control treatment needs would provide partial protection against loss of pesticide residues from farm fields. Integrated Pest Management (IPM) practices are also effective in reducing the risk associated with pesticide residues leaving the farm field. Determination of adequate IPM, however, is highly dependent on the specific site conditions and the nature and extent of the pest problems.

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

The 8.58 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.

In summary, findings for the Pacific Northwest Basin indicate that—

- *3.3 percent of cropped acres (390,000 acres) have a* ***high*** *level of need for additional conservation treatment,*
- *70.3 percent of cropped acres (8.19 million acres) have a* ***moderate*** *level of need for additional conservation treatment, and*
- *26.3 percent of cropped acres (3.07 million acres) have a* ***low*** *level of need for additional treatment and are considered to be adequately treated.*

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. 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 Pacific Northwest 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 50. A high level of water erosion control treatment is in use on about 5 percent of cropped acres, primarily on non-highly erodible land. About 13 percent have a moderately high level of conservation treatment. About 45 percent of cropped acres have a moderate level of conservation treatment for water erosion control, about half of which are highly erodible. The remaining 36 percent of cropped acres have a low level of conservation treatment for water erosion control in this region.

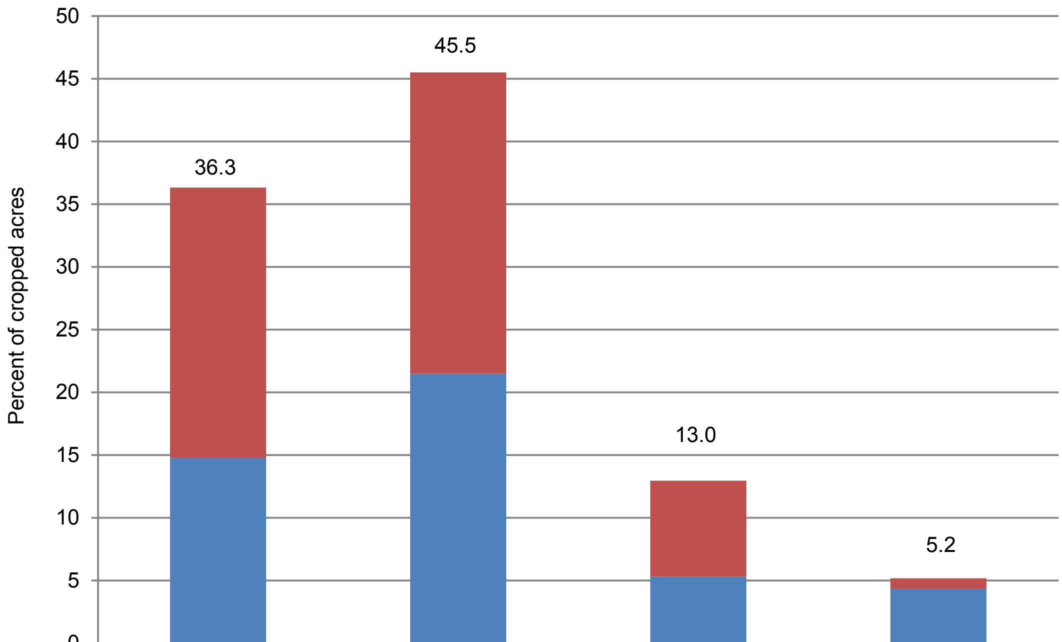
For nitrogen loss with surface runoff, conservation treatment levels were defined by a combination of structural practices, residue and tillage management practices, and nitrogen management practices, as defined in figure 51. A high level of treatment for nitrogen runoff is in use on only 2 percent of cropped acres. About 23 percent have a moderately high level of conservation treatment. The bulk of cropped acres—57 percent—have combinations of practices that indicate a moderate level of treatment. About 18 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 52. A high level of treatment for phosphorus runoff is in use on only 2 percent of the acres. About 26 percent of cropped acres have combinations of practices that indicate a moderately high level of treatment. About 56 percent of cropped acres have a moderate level of treatment, and 16 percent of cropped acres have a low level of phosphorus management.

The nitrogen management level presented in figure 9 (see chapter 3) was used to evaluate the adequacy of conservation treatment for nitrogen loss in subsurface flows. A high level of treatment for nitrogen loss in subsurface flows is in use on 40 percent of the acres, and about 26 percent of cropped acres have a moderately high level of treatment. About 24 percent of cropped acres have a moderate level, and 10 percent have a low level of nitrogen treatment.

For wind erosion, a combination of structural practices and tillage intensity was used to evaluate the adequacy of conservation treatment, as defined in figure 53. A high level of treatment for wind erosion is in use on only 1 percent of the acres. About 22 percent of the acres have a moderately high level of treatment. Fifty-seven percent of cropped acres have a moderate level of treatment, and 20 percent of the acres have a low level of treatment for controlling wind erosion in this region.

Figure 50. Percent of cropped acres at four conservation treatment levels for water erosion control in the baseline conservation condition, Pacific Northwest Basin



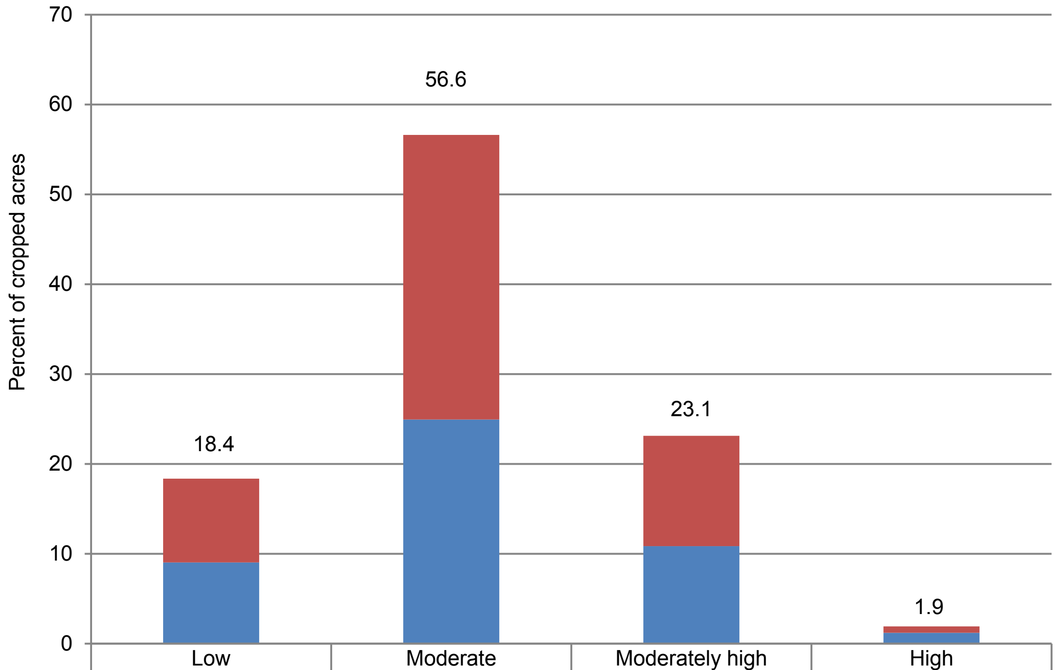
	Low	Moderate	Moderately high	High
HEL	21.6	24.0	7.6	0.8
Non-HEL	14.8	21.5	5.3	4.4

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

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

Note: About 54 percent of cropped acres in the Pacific Northwest Basin are highly erodible land.

Figure 51. Percent of cropped acres at four conservation treatment levels for nitrogen runoff control in the baseline conservation condition, Pacific Northwest Basin



	Low	Moderate	Moderately high	High
HEL	9.3	31.7	12.3	0.7
Non-HEL	9.0	24.9	10.8	1.2

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

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

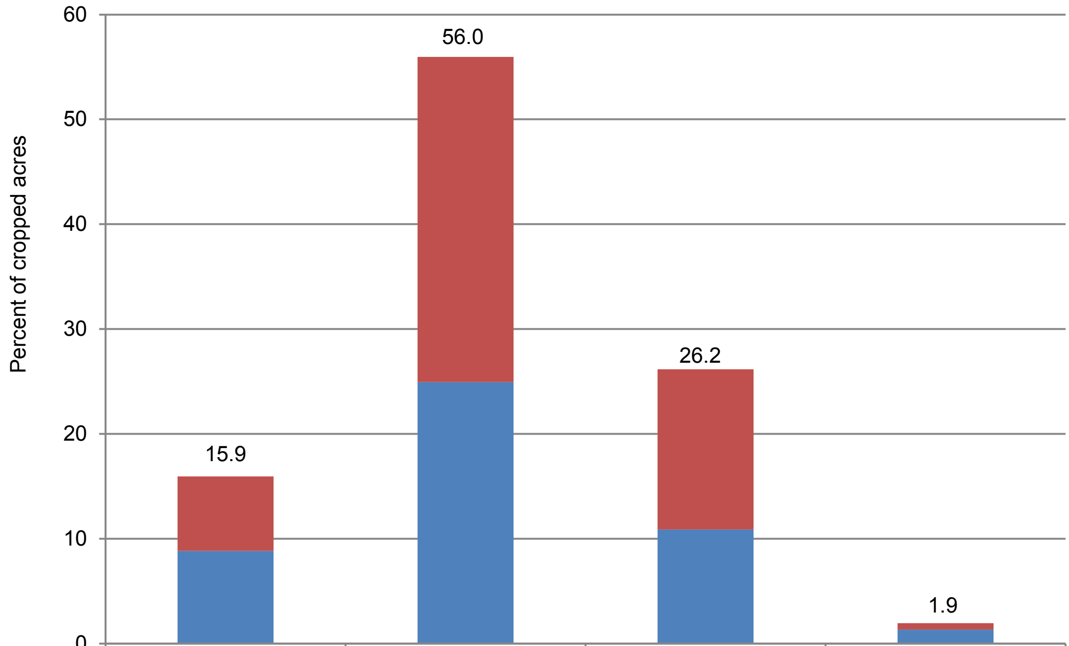
- **High treatment**: Sum of residue and tillage management score and nitrogen management score is equal to 8. (High treatment level for both structural practices and nitrogen management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores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

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

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

Note: About 54 percent of cropped acres in the Pacific Northwest Basin are highly erodible land.

Figure 52. Percent of cropped acres at four conservation treatment levels for phosphorus runoff control in the baseline conservation condition, Pacific Northwest Basin



	Low	Moderate	Moderately high	High
HEL	7.1	31.0	15.3	0.6
Non-HEL	8.8	24.9	10.9	1.3

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

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

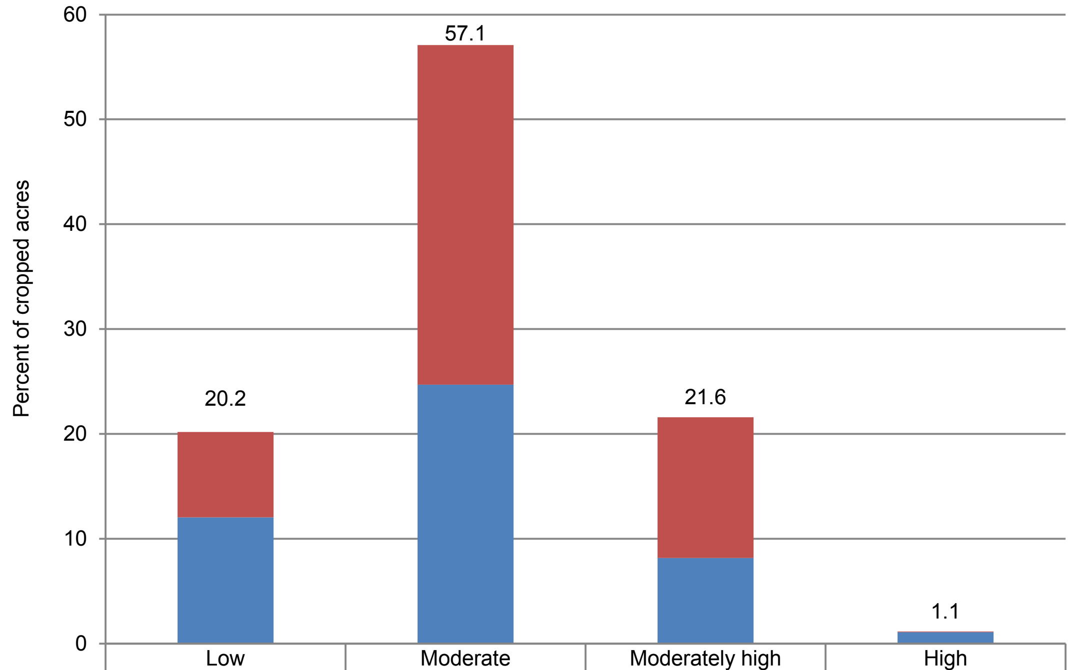
- **High treatment**: Sum of residue and tillage management score and phosphorus management score is equal to 8. (High treatment level for both structural practices and phosphorus management practices).
- **Moderately high treatment**: Sum of scores equal to 6 or 7.
- **Moderate treatment**: Sum of scores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

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

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

Note: About 54 percent of cropped acres in the Pacific Northwest Basin are highly erodible land.

Figure 53. Percent of cropped acres at four conservation treatment levels for wind erosion management, baseline conservation condition, Pacific Northwest Basin



	Low	Moderate	Moderately high	High
HEL	8.1	32.4	13.4	0.1
Non-HEL	12.0	24.7	8.2	1.1

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 54 percent of cropped acres in the Pacific Northwest Basin are highly erodible land.

Inherent Vulnerability Factors

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

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

The criteria for the soil runoff potential are presented in figure 54, followed by the spatial distribution of the soil runoff potential within the Pacific Northwest Basin in figure 55. The criteria and spatial distribution for the soil leaching potential are presented in figures 56 and 57. The criteria and spatial distribution for the soil wind erosion potential are presented in figures 58 and 59.

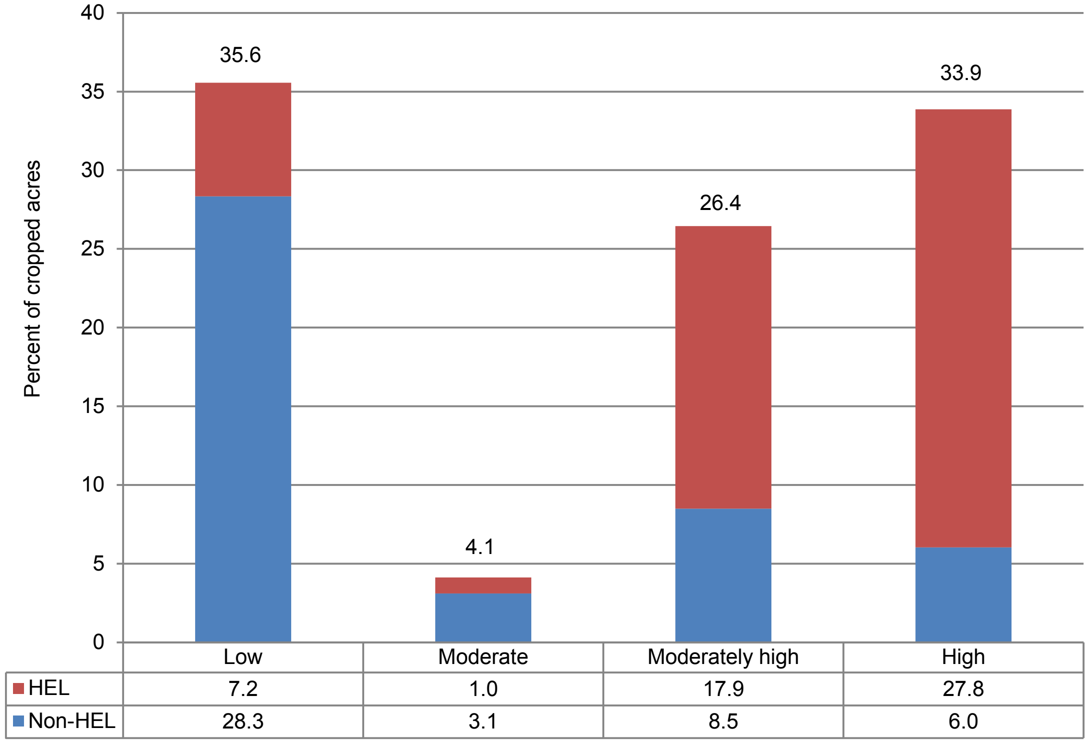
The maps show the vulnerability potentials for all soils and land uses in the region. For the assessment of conservation treatment needs, however, only the vulnerability potentials for cropped acres were used.

Most cropped acres in the Pacific Northwest Basin have a high or moderately high vulnerability to runoff. About 34 percent of cropped acres have a high soil runoff potential, and 26 percent have a moderately high soil runoff potential (fig. 54). About 4 percent of cropped acres have a moderate soil runoff potential. Thirty-six percent of cropped acres have a low soil runoff potential, including most of the non-highly erodible acres in the region (fig. 54).

In contrast, most cropped acres in the region are only moderately vulnerable to leaching (figs. 56 and 57). Only 3.5 percent of cropped acres have a high soil leaching potential, and only 1.6 percent have a moderately high soil leaching potential. The bulk of cropped acres—89 percent—have a moderate soil leaching potential. About 6 percent of cropped acres have a low leaching potential.

Most cropped acres in the region have moderately high vulnerability to wind erosion. Only about 3 percent of cropped acres have a high soil wind erosion potential, but 61 percent of cropped acres have a moderately high soil wind erosion potential (fig. 58). About 20 percent of cropped acres have a moderate soil wind erosion potential, and 17 percent of cropped acres have a low soil wind erosion potential.

Figure 54. Soil runoff potential for cropped acres in the Pacific Northwest 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

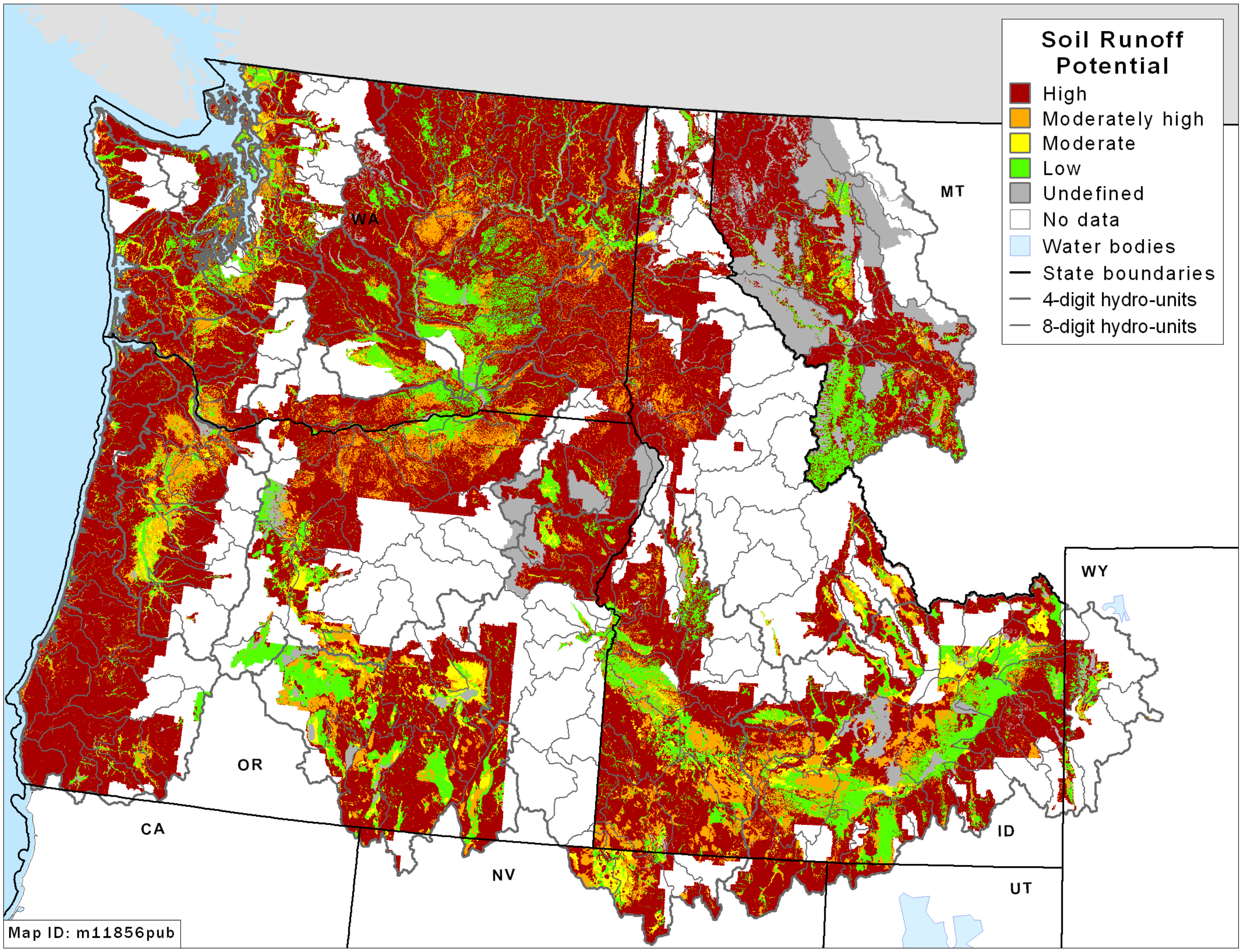
Hydrologic soil groups are classified as:

- **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.

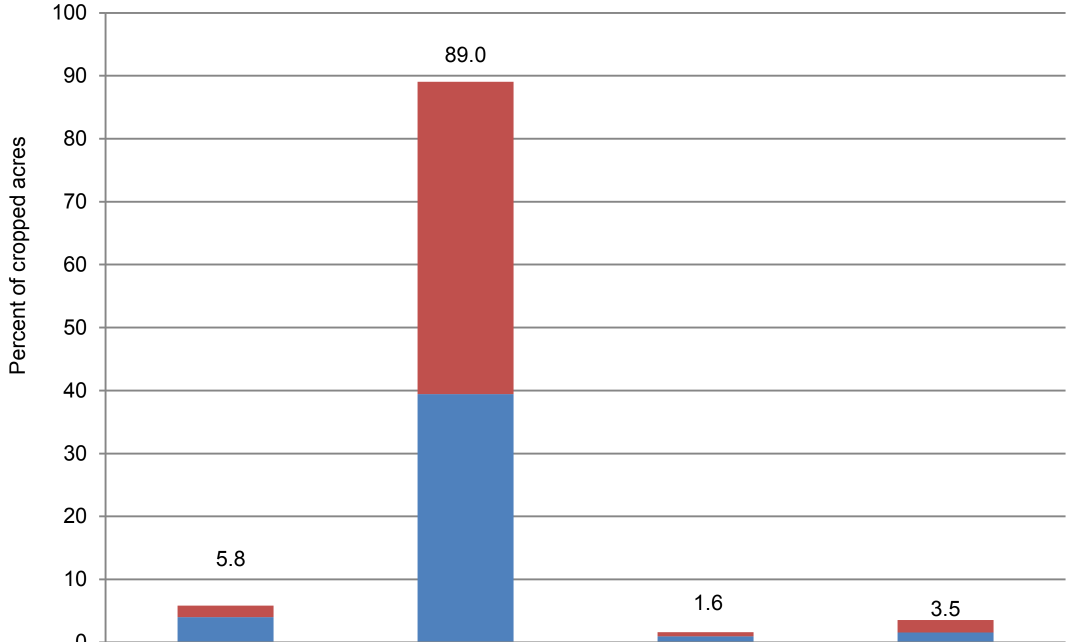
Note: About 54 percent of cropped acres in the Pacific Northwest Basin are highly erodible land.
Note: See appendix B, table B4, for a breakdown of soil runoff potential by subregion.

Figure 55. Soil runoff potential for soils in the Pacific Northwest Basin



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

Figure 56. Soil leaching potential for cropped acres in the Pacific Northwest Basin



	Low	Moderate	Moderately high	High
HEL	1.8	49.6	0.6	2.0
Non-HEL	4.0	39.4	1.0	1.6

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.

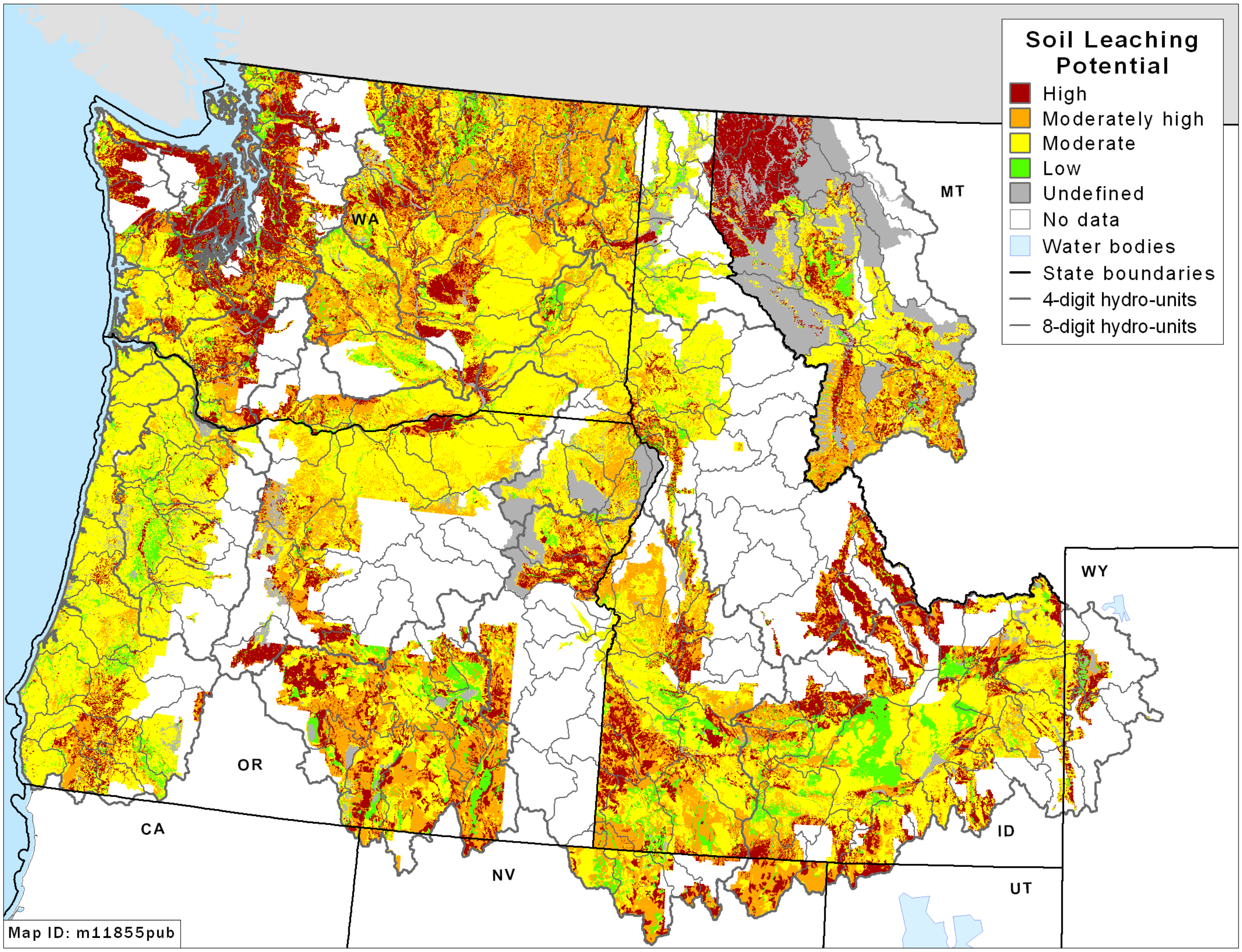
Hydrologic soil groups are classified as:

- **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.

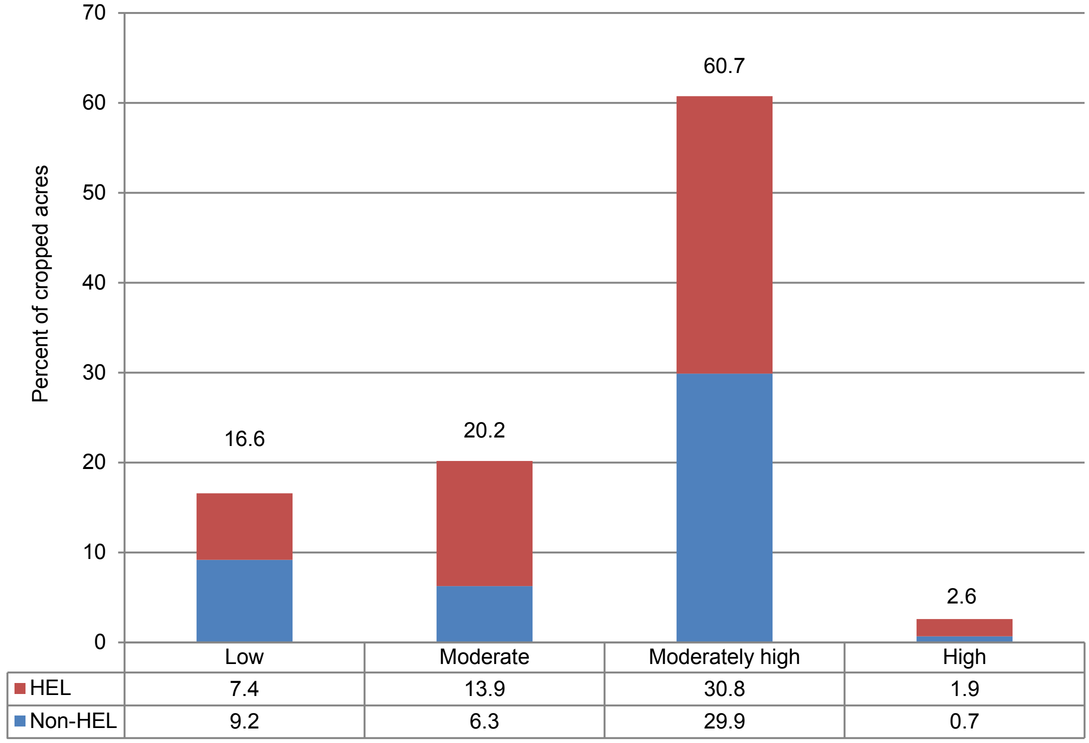
Note: About 54 percent of cropped acres in the Pacific Northwest Basin are highly erodible land.
Note: See appendix B, table B4, for a breakdown of soil leaching potential by subregion.

Figure 57. Soil leaching potential for soils in the Pacific Northwest Basin



Note: The soil leaching potential shown in this map was derived using the criteria presented in figure 56 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Figure 58. Soil wind erosion potential for cropped acres in the Pacific Northwest Basin



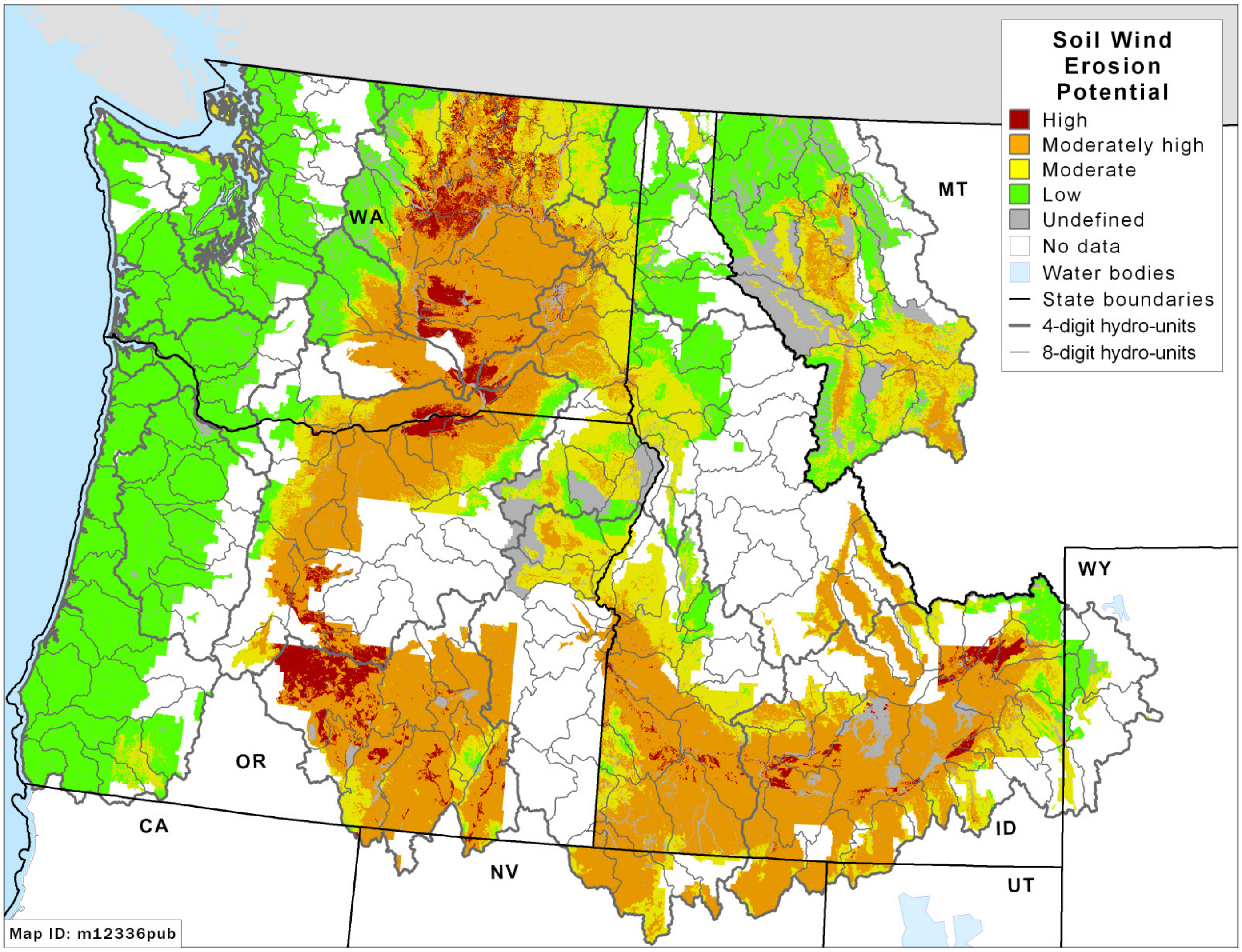
Criteria for four classes of wind erosion potential were derived using a combination of annual precipitation, percent slope, and the I-factor from the wind erosion equation*, as shown in the table below:

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 <u>or</u> 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 <u>or</u> 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 54 percent of cropped acres in the Pacific Northwest Basin are highly erodible land.
Note: See appendix B, table B3, for a breakdown of soil wind erosion potential by subregion.

Figure 59. Soil wind erosion potential for soils in the Pacific Northwest Basin



Note: The soil wind erosion potential shown in this map was derived using the criteria presented in figure 58 applied to soil characteristics for SSURGO polygons. All soils and land uses are represented.

Evaluation of Conservation Treatment

The "matrix approach"

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

The matrixes are presented for each of the 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 at all vulnerability potentials.

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

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

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

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

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

The criteria and steps in the process are as follows—

1. The percentage of acres that exceeded a given level of loss was estimated for each cell in the matrix as a guide to determining the extent of excessive losses. These are referred to as "acceptable levels." *Losses above these levels were treated as unacceptable levels of loss.* "Acceptable levels"[25] for field-level losses used in this study are—
   - Average of 2 tons per acre per year for sediment loss,
   - Average of 15 pounds per acre per year for nitrogen loss with surface runoff (soluble and sediment attached),
   - Average of 25 pounds per acre per year for nitrogen loss in subsurface flows,
   - Average of 4 pounds per acre per year for phosphorus lost to surface water (soluble and sediment attached), and
   - Average wind erosion rate 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.

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

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

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

- 97 percent of cropped acres for sediment loss,
- 94 percent of cropped acres for nitrogen loss with surface runoff,
- 93 percent of cropped acres for nitrogen loss in subsurface flows,
- 95 percent of cropped acres for phosphorus lost to surface water, and
- 92 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.

Why Was a Threshold Approach Not Used?

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

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

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

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

Soil runoff potential	Conservation treatment levels for water erosion control: Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	1,028,498	2,295,957	440,750	377,958	4,143,164
Moderate	116,613	187,318	45,225	131,480	480,636
Moderately high	1,474,593	1,233,268	326,333	46,350	3,080,543
High	1,613,176	1,585,279	697,454	49,649	3,945,557
All	4,232,879	5,301,821	1,509,761	605,438	11,649,900
Percent of cropped acres					
Low	9	20	4	3	36
Moderate	1	2	<1	1	4
Moderately high	13	11	3	<1	26
High	14	14	6	<1	34
All	36	46	13	5	100
Sediment loss estimates *without* conservation practices (no-practice scenario, average annual tons/acre)					
Low	1.99	1.39	0.53	0.74	1.39
Moderate	16.09	2.60	NA	NA	5.56
Moderately high	3.76	2.35	1.00	NA	2.86
High	7.60	8.27	2.09	NA	7.19
All	5.13	3.71	1.35	3.57	3.91
Sediment loss estimates for the baseline conservation condition (average annual tons/acre)					
Low	1.32	0.90	0.18	0.08	0.85
Moderate	8.66	1.70	NA	NA	3.23
Moderately high	2.30	0.81	0.18	NA	1.45
High	6.15	5.66	0.48	NA	4.91
All	3.70	2.33	0.32	0.68	2.48
Percent reduction in sediment loss due to conservation practices					
Low	34	35	66	89	39
Moderate	46	35	NA	NA	42
Moderately high	39	65	82	NA	49
High	19	32	77	NA	32
All	28	37	76	81	37
Percent of acres in baseline conservation condition with average annual sediment loss more than 2 tons/acre					
Low	8	9	1	0	7
Moderate	41	20	NA	NA	29
Moderately high	19*	13	0	NA	14
High	46	36	6	NA	35
All	28	18	3	10	19
Estimate of undertreated acres					
Low	0	0	0	0	0
Moderate	116,613	0	0	0	116,613
Moderately high	1,474,593	0	0	0	1,474,593
High	1,613,176	1,585,279	0	0	3,198,454
All	3,204,382	1,585,279	0	0	4,789,660

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

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

Note: NA indicates "not applicable" because there were no acres in the category.

* This group of acres was classified as under-treated acres because a lower level of soil vulnerability met the criteria for under-treated acres.

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

Soil runoff potential	Conservation treatment levels for nitrogen runoff control: Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	789,079	2,125,726	1,081,112	147,247	4,143,164
Moderate	110,256	233,725	136,656	0	480,636
Moderately high	681,569	1,857,352	509,606	32,015	3,080,543
High	557,121	2,379,823	966,764	41,849	3,945,557
All	2,138,025	6,596,626	2,694,137	221,111	11,649,900
Percent of cropped acres					
Low	7	18	9	1	36
Moderate	1	2	1	0	4
Moderately high	6	16	4	<1	26
High	5	20	8	<1	34
All	18	57	23	2	100
Estimates of nitrogen loss with surface runoff *without* conservation practices (no-practice scenario, average annual pounds/acre)					
Low	15.3	11.3	5.4	4.9	10.3
Moderate	34.5	31.4	17.3	NA	28.1
Moderately high	20.5	12.3	3.5	NA	12.6
High	31.0	17.4	7.8	NA	16.9
All	22.0	14.5	6.5	5.3	13.8
Estimates of nitrogen loss with surface runoff for the baseline conservation condition (average annual pounds/acre)					
Low	8.0	5.3	2.0	1.0	4.8
Moderate	24.5	23.4	5.8	NA	18.6
Moderately high	12.5	5.3	1.2	NA	6.2
High	25.1	13.0	4.5	NA	12.5
All	14.7	8.7	2.9	0.9	8.3
Percent reduction in nitrogen loss with surface runoff due to conservation practices					
Low	48	53	63	80	53
Moderate	29	26	66	NA	34
Moderately high	39	57	65	NA	51
High	19	25	42	NA	26
All	33	40	55	83	40
Percent of acres in baseline conservation condition with average annual nitrogen loss with surface runoff more than 15 pounds/acre					
Low	12	10	3	0	8
Moderate	47	44	17	NA	37
Moderately high	22*	12*	0	NA	12
High	49	25*	5	NA	23
All	27	17	4	0	16
Estimate of undertreated acres for nitrogen loss with surface runoff					
Low	0	0	0	0	0
Moderate	110,256	233,725	0	0	343,981
Moderately high	681,569	1,857,352	0	0	2,538,922
High	557,121	2,379,823	0	0	2,936,944
All	1,348,946	4,470,900	0	0	5,819,846

Note: Yellow and orange-shaded cells indicate undertreated acres; groups of acres with more than 30 percent of the acres exceeding acceptable levels were defined as undertreated acres. Orange-shaded cells indicate critical undertreated acres; critical undertreated acres were defined as groups of acres with more than 60 percent of the acres in excess of acceptable levels.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Percents may not add to totals because of rounding.
Note: NA indicates "not applicable" because there were no acres in the category.

* This group of acres was classified as under-treated acres because a lower level of soil vulnerability met the criteria for under-treated acres.

Table 26. Identification of undertreated acres for nitrogen loss in subsurface flows in the Pacific Northwest Basin

Soil leaching potential	Conservation treatment levels for nitrogen management: Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	301,000	143,534	124,306	106,958	675,798
Moderate	787,657	2,437,636	2,740,178	4,408,141	10,373,613
Moderately high	17,403	53,018	24,062	92,966	187,449
High	93,231	208,844	78,711	32,255	413,040
All	1,199,291	2,843,032	2,967,257	4,640,320	11,649,900
Percent of cropped acres					
Low	3	1	1	1	6
Moderate	7	21	24	38	89
Moderately high	<1	<1	<1	1	2
High	1	2	1	<1	4
All	10	24	25	40	100
Estimates of nitrogen loss in subsurface flows *without* conservation practices (no-practice scenario, average annual pounds/acre)					
Low	34.6	50.7	55.1	31.5	41.3
Moderate	74.9	44.4	31.9	15.6	31.2
Moderately high	98.3	57.2	37.1	18.9	39.5
High	137.9	142.1	70.9	26.6	118.6
All	70.0	52.2	34.0	16.1	35.0
Estimates of nitrogen loss in subsurface flows for the baseline conservation condition (average annual pounds/acre)					
Low	28.6	44.3	35.9	6.9	29.8
Moderate	38.4	33.5	8.0	4.9	15.0
Moderately high	89.4	45.0	23.1	4.8	26.4
High	103.8	103.8	6.0	12.6	78.1
All	41.8	39.4	9.3	5.0	18.3
Percent reduction in nitrogen loss in subsurface flows due to conservation practices					
Low	17	13	35	78	28
Moderate	49	25	75	69	52
Moderately high	9	21	38	75	33
High	25	27	92	53	34
All	40	24	73	69	48
Percent of acres in baseline conservation condition with average annual nitrogen loss in subsurface flows more than 25 pounds/acre					
Low	20*	49	24	10	25
Moderate	39	43	5	2	15
Moderately high	100	96	14	0	38
High	67	77	0	4	54
All	37	47	6	2	18
Estimate of undertreated acres for nitrogen loss in subsurface flows					
Low	301,000	143,534	0	0	444,534
Moderate	787,657	2,437,636	0	0	3,225,293
Moderately high	17,403	53,018	0	0	70,421
High	93,231	208,844	0	0	302,075
All	1,199,291	2,843,032	0	0	4,042,323

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

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

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

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

Soil runoff potential	Conservation treatment levels for phosphorus runoff control: Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	1,118,515	1,727,336	1,159,796	137,516	4,143,164
Moderate	123,125	265,418	92,093	0	480,636
Moderately high	414,414	1,991,403	628,376	46,350	3,080,543
High	201,928	2,534,805	1,166,975	41,849	3,945,557
All	1,857,982	6,518,963	3,047,240	225,715	11,649,900
Percent of cropped acres					
Low	10	15	10	1	36
Moderate	1	2	1	0	4
Moderately high	4	17	5	<1	26
High	2	22	10	<1	34
All	16	56	26	2	100
Phosphorus lost to surface water *without* conservation practices (no-practice scenario, average annual pounds/acre)					
Low	6.26	3.64	2.09	1.11	3.83
Moderate	12.01	11.66	3.07	NA	10.1
Moderately high	14.38	3.92	1.22	NA	4.74
High	12.23	5.97	2.63	NA	5.26
All	9.1	4.96	2.15	1.3	4.81
Phosphorus lost to surface water for the baseline conservation condition (average annual pounds/acre)					
Low	3.76	2.02	0.44	0.29	1.99
Moderate	7.85	6.49	1.34	NA	5.85
Moderately high	9.49	1.40	0.40	NA	2.27
High	7.39	3.87	0.91	NA	3.13
All	5.71	2.73	0.64	0.31	2.61
Percent reduction in phosphorus lost to surface water due to conservation practices					
Low	40	45	79	74	48
Moderate	35	44	56	NA	42
Moderately high	34	64	67	NA	52
High	40	35	66	NA	40
All	37	45	70	76	46
Percent of acres in baseline conservation condition with average annual phosphorus lost to surface water more than 4 pounds/acre					
Low	14	13	1	0	10
Moderate	47	52	11	NA	43
Moderately high	46	14*	2	NA	16
High	47	22*	1	NA	17
All	27	18	2	0	15
Estimate of undertreated acres for phosphorus lost to surface water					
Low	0	0	0	0	0
Moderate	123,125	265,418	0	0	388,543
Moderately high	414,414	1,991,403	0	0	2,405,817
High	201,928	2,534,805	0	0	2,736,733
All	739,467	4,791,626	0	0	5,531,094

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

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

Note: NA indicates "not applicable" because there were no acres in the category.

* This group of acres was classified as under-treated acres because a lower level of soil vulnerability met the criteria for under-treated acres.

Table 28. Identification of under-treated acres for wind erosion in the Pacific Northwest Basin

Soil wind potential	Conservation treatment levels for wind erosion control				
	Low	Moderate	Moderately high	High	All
Estimated cropped acres					
Low	355,343	768,768	714,503	91,026	1,929,640
Moderate	391,192	1,257,942	679,369	19,124	2,347,628
Moderately high	1,488,302	4,499,529	1,070,562	15,266	7,073,659
High	115,315	124,515	51,412	7,732	298,973
All	2,350,151	6,650,755	2,515,846	133,147	11,649,900
Percent of cropped acres					
Low	3	7	6	1	17
Moderate	3	11	6	<1	20
Moderately high	13	39	9	<1	61
High	1	1	<1	<1	3
All	20	57	22	1	100
Wind erosion estimates *without* conservation practices (no-practice scenario), average annual tons/acre					
Low	0.37	0.85	0.43	0.01	0.57
Moderate	1.38	1.03	0.52	NA	0.94
Moderately high	5.05	3.29	1.14	NA	3.33
High	9.71	5.67	12.36	NA	8.70
All	3.96	2.62	1.00	1.23	2.53
Wind erosion estimates for the baseline conservation condition, average annual tons/acre					
Low	0.35	0.60	0.13	0.00	0.35
Moderate	1.38	0.61	0.12	NA	0.59
Moderately high	4.75	2.44	0.24	NA	2.59
High	9.17	4.13	3.13	NA	5.97
All	3.74	1.91	0.24	0.42	1.90
Percent reduction in wind erosion due to conservation practices, average annual tons/acre					
Low	6	29	68	99	38
Moderate	0	41	77	NA	37
Moderately high	6	26	79	NA	22
High	6	27	75	NA	31
All	6	27	76	66	25
Percent of acres in baseline with average annual wind erosion more than 4 tons/acre					
Low	4	5	0	0	3
Moderate	10	0	0	NA	2
Moderately high	43	18	1	NA	21
High	100	49	0	NA	61
All	34	14	0	6	15
Estimate of under-treated acres for wind erosion					
Low	0	0	0	0	0
Moderate	0	0	0	0	0
Moderately high	1,488,302	0	0	0	1,488,302
High	115,315	124,515	0	0	239,830
All	1,603,616	124,515	0	0	1,728,132

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

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

Most of the cropped acres in the Pacific Northwest Basin were determined to have a moderate need for additional conservation treatment. Because of the current use of conservation practices, very few acres in the region have a high need for additional treatment. The proportion of cropped acres with a high or moderate need for additional conservation treatment was determined to be (fig. 60 and table 29)—

- 41 percent for sediment loss (no acres with a high need for treatment),
- 50 percent for nitrogen loss with runoff (no acres with a high need for treatment),
- 48 percent for phosphorus lost to surface water (no acres with a high need for treatment),
- 35 percent for nitrogen loss in subsurface flows (3 percent with a high need for treatment), most of which returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow, and
- 15 percent for wind erosion (1 percent with a high need for treatment).

Most undertreated acres in the Pacific Northwest Basin need additional treatment for multiple resource concerns (table 29). Only 24 percent of the undertreated acres need additional treatment for a single resource concern, primarily for nitrogen leaching (11 percent of the undertreated acres). About 58 percent of undertreated acres need treatment for three or more resource concerns, the most common of which is the need to treat for sediment loss, nitrogen runoff, and phosphorus runoff (29 percent of the undertreated acres).

There is no single "most critical" conservation concern in this region. Rather, most undertreated acres have a need for better erosion control (sediment loss and/or wind erosion) *and* consistent use of nutrient management—appropriate rate, form, timing, *and* method of application of nitrogen and phosphorus.

Figure 60. Percent of cropped acres that are undertreated in the Pacific Northwest Basin, by resource concern

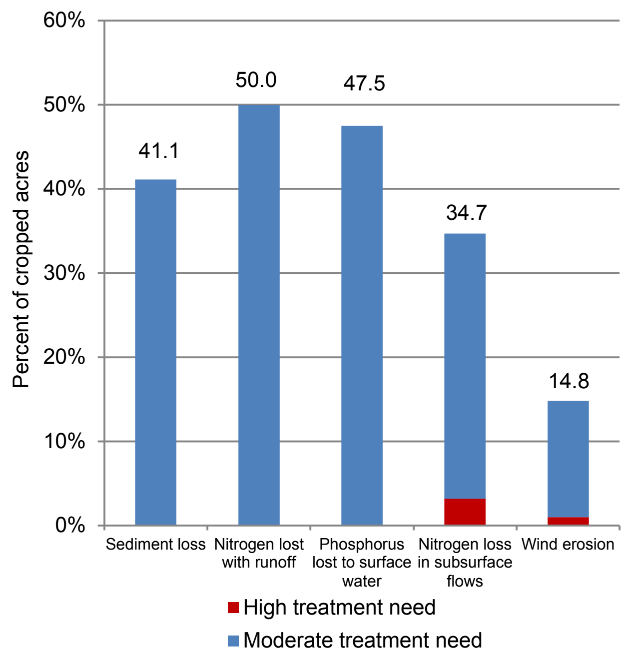


Table 29. Undertreated acres with resource concerns needing treatment in the Pacific Northwest Basin

Reason for treatment need	Estimated acres needing treatment	Percent of cropped acres	Percent of undertreated acres
Wind erosion only	539,113	4.6	6.3
Phosphorus runoff only	173,116	1.5	2.0
Nitrogen leaching only	911,626	7.8	10.6
Nitrogen leaching and wind erosion	701,189	6.0	8.2
Phosphorus runoff and nitrogen leaching	21,274	0.2	0.2
Nitrogen runoff only	86,878	0.7	1.0
Nitrogen runoff and phosphorus runoff	470,590	4.0	5.5
Nitrogen runoff, phosphorus runoff, and wind erosion	19,056	0.2	0.2
Nitrogen leaching and nitrogen runoff	238,846	2.1	2.8
Nitrogen leaching, nitrogen runoff, and wind erosion	11,912	0.1	0.1
Nitrogen runoff, nitrogen leaching, and phosphorus runoff	602,603	5.2	7.0
Nitrogen runoff, nitrogen leaching, phosphorus runoff, and wind erosion	16,423	0.1	0.2
Sediment loss only	374,872	3.2	4.4
Sediment loss and phosphorus runoff	41,252	0.4	0.5
Sediment loss and nitrogen leaching	56,487	0.5	0.7
Sediment loss, nitrogen runoff, and phosphorus runoff	2,496,076	21.4	29.1
Sediment loss, nitrogen runoff, phosphorus runoff, and wind erosion	282,524	2.4	3.3
Sediment loss, nitrogen runoff, and nitrogen leaching	130,271	1.1	1.5
Sediment loss, nitrogen runoff, phosphorus runoff, and nitrogen leaching	1,250,265	10.7	14.6
All five resource concerns	157,913	1.4	1.8
All undertreated acres	8,582,288	73.7	100

Notes: This table summarizes the undertreated acres identified in tables 24-28 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

After accounting for acres that need treatment for multiple resource concerns, the evaluation of conservation treatment needs for the Pacific Northwest Basin determined the following (fig. 61):

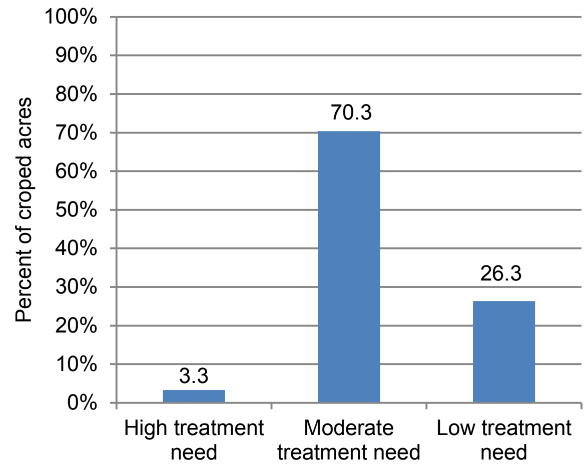
- 3.3 percent of cropped acres (390,000 acres) have a **high** level of need for additional conservation treatment,
- 70.3 percent of cropped acres (8.19 million acres) have a **moderate** level of need for additional conservation treatment, and
- 26.3 percent of cropped acres (3.07 million acres) have a **low** level of need for additional treatment and are considered to be adequately treated.

High level of need for conservation treatment. These are the most vulnerable of the under-treated acres with the least conservation treatment and have the highest losses of sediment and/or nutrients. In this region, only a few acres have a critical need for additional treatment—about 390,000 acres. These 390,000 acres have an average wind erosion rate of 4.7 tons per acre per year and lose (per acre per year, on average) 2.8 tons of sediment by water erosion, 7.7 pounds of phosphorus, and 123 pounds of nitrogen (table 30).

Moderate level of need for conservation treatment. Acres with a "moderate" level of need for conservation treatment consist of under-treated acres that generally have lower levels of vulnerability and/or have more conservation practice use than do acres with a high level of need. All but a few undertreated acres in this region—8.19 million acres—have a moderate need for additional treatment. These 8.19 million acres have an average wind erosion rate of 2.0 tons per acre per year and lose (per acre per year, on average) 3.2 tons of sediment by water erosion, 4.8 pounds of phosphorus, and 41 pounds of nitrogen (table 30).

Low level of need for conservation treatment. Acres with a low level of need for conservation treatment consist of acres that are adequately treated with respect to the level of inherent vulnerability. In the Pacific Northwest Basin, these 3.07 million acres have an average wind erosion rate of 1.2 tons per acre per year and lose (per acre per year, on average) 0.6 tons of sediment by water erosion, 1.8 pounds of phosphorus, and 20 pounds of nitrogen (table 30). While gains can be attained by adding conservation practices to some of these acres with a low treatment need, additional conservation treatment would reduce average field losses by only a small amount.

Figure 61. 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 Pacific Northwest Basin



What is "Adequate Conservation Treatment?"

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

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

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

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

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

Table 30. Baseline conservation condition model simulation results for subsets of undertreated and adequately treated acres in the Pacific Northwest Basin

Model simulated outcome, average annual values	Acres with a *low* need for treatment	Acres with a *moderate* need for treatment	Acres with a *high* need for treatment	All acres
Cultivated cropland acres in subset	3,067,612	8,194,387	387,901	11,649,900
Percent of cropped acres	26.3%	70.3%	3.3%	100.0%
Water flow				
Surface runoff (inches)	2.7	4.8	5.0	4.3
Subsurface water flow (inches)	3.6	4.2	5.6	4.1
Erosion and sediment loss				
Wind erosion (tons/acre)	1.25	2.01	4.72	1.90
Sheet and rill erosion (tons/acre)	0.06	0.39	0.33	0.30
Sediment loss at edge of field due to water erosion (tons/acre)	0.56	3.18	2.83	2.48
Soil organic carbon				
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-9	-87	-71	-66
Nitrogen				
Nitrogen sources (pounds/acre)				
Atmospheric deposition	1.2	1.3	1.0	1.2
Bio-fixation by legumes	21.5	8.4	8.1	11.8
Nitrogen applied as commercial fertilizer and manure	67.8	93.1	235.5	91.1
All nitrogen sources	90.5	102.7	244.6	104.2
Nitrogen in crop yield removed at harvest (pounds/acre)	76.3	72.3	115.0	74.8
Nitrogen loss				
Loss of nitrogen through volatilization (pounds/acre)	5.7	5.8	11.0	5.9
Nitrogen returned to the atmosphere through denitrification (pounds/acre)	0.5	0.6	0.8	0.6
Loss of nitrogen with windborne sediment (pounds/acre)	4.3	5.6	8.9	5.4
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	3.3	10.2	8.2	8.3
Nitrogen loss in subsurface flows (pounds/acre)	6.5	19.0	94.4	18.3
Total nitrogen loss for all pathways (pounds/acre)	20.3	41.3	123.3	38.5
Phosphorus				
Phosphorus applied (pounds/acre)	10.2	15.5	44.4	15.1
Phosphorus in crop yield removed at harvest (pounds/acre)	9.8	10.2	16.0	10.3
Phosphorus loss				
Loss of phosphorus with windborne sediment (pounds/acre)	0.8	1.5	5.1	1.5
Loss of phosphorus to surface water, including both soluble and sediment attached (pounds/acre)*	1.0	3.2	2.5	2.6
Total phosphorus loss for all pathways (pounds/acre)	1.8	4.8	7.7	4.1
Pesticide loss				
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	8.1	14.7	21.3	13.2
Surface water pesticide risk indicator for aquatic ecosystem	0.7	1.9	6.3	1.8
Surface water pesticide risk indicator for humans	0.1	0.9	6.8	0.9

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

Conservation treatment needs by cropping systems

Six of the 10 cropping systems in this region have a disproportionately high percentage of acres that need additional treatment, shown in table 31, although they are only weakly disproportionate. These six cropping systems include most of the cropping systems with row crops.

Four of the 10 cropping systems have a disproportionately low percentage of under-treated acres (table 31), including wheat, barley, and hay-crop mixes.

All cropping systems, however, have substantial percentages of cropped acres that need additional conservation treatment.

Conservation treatment needs by subregion

Undertreated acres in the Pacific Northwest Basin are generally distributed evenly throughout the subregions. Undertreated acres are most concentrated in the Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709) (table 32). Eighty-four percent of the 868,200 cropped acres in this combination of two subregions need additional conservation treatment, compared to 74 percent for the region.

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

Table 31. Percent of undertreated acres (acres with a *high* or *moderate* level of treatment need) by cropping system, Pacific Northwest Basin

Cropping system	Percent of cropped acres in Pacific Northwest Basin	Percent of undertreated acres in Pacific Northwest Basin	Percent of undertreated acres in cropping system
Disproportionately high percentage of undertreated acres			
Corn and close grown crops	2	2	96
Potatoes with or without other crops	6	8	89
Sugarbeets with or without other crops	4	4	84
Vegetables with or without other crops	13	14	82
Remaining row crops only	2	3	81
Remaining close grown crops only	8	8	79
Disproportionately low percentage of undertreated acres			
Barley only	3	2	47
Hay-crop mixes	9	6	53
Remaining mix of row and close crops	11	10	68
Wheat only	43	42	73
Total	100	100	74*

Note: Percents may not add to totals because of rounding.
* Percent of under-treated acres in the region.

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

Subregion	Percent of cropped acres in Pacific Northwest Basin	Percent of undertreated acres in Pacific Northwest Basin	Percent of undertreated acres in subregion
Disproportionately high percentage of undertreated acres			
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	7	8	84
Middle Snake River Basin (code 1705)	5	6	82
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	1	1	78
Middle Columbia River Basin including John Day-Deschutes (code 1707)	18	19	77
Lower Snake River Basin including Salmon-Clear Water (code 1706)	19	20	75
Disproportionately low percentage of undertreated acres			
Snake Headwaters-Upper Snake River Basin (code 1704)	21	19	65
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	7	7	70
Upper Columbia River Basin (code 1702)	21	21	73
Total	100	100	74*

Note: Percents may not add to totals because of rounding.
* Percent of undertreated acres in the Pacific Northwest Basin.

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

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

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

Three sets of additional conservation practices were simulated:

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

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

1. Treatment of all 8.6 million undertreated acres (acres with a high or moderate need for conservation treatment) with water erosion control practices only;
2. Treatment of the 390,000 critical undertreated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses; and
3. Treatment of all 8.6 million undertreated acres with nutrient management practices in addition to water erosion control practices to address nutrient losses.

In summary, the potential for achieving additional field-level savings from further conservation treatment is high in this region, especially for additional reductions in sediment loss. Conservation practices in use in 2003–06 achieved 39 percent of potential reductions in sediment loss, 60 percent for nitrogen, 58 percent for phosphorus, and 55 percent for wind erosion. By treating all 8.6 million undertreated acres in the region with additional erosion control and nutrient management practices, an additional 57 percent in savings would be attained for sediment, 36 percent for nitrogen, 39 percent for phosphorus, and 41 percent for wind erosion. To achieve 100 percent of potential savings (i.e., an additional 4 percent for sediment, 4 percent for nitrogen, 3 percent for phosphorus, and 5 percent for wind erosion), additional conservation treatment for the remaining 3.07 million acres with a low need for additional treatment would be required, which would result in very small conservation gains on a per-acre basis.

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

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

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

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

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

Nor were treatment scenarios designed to represent actual program or policy options for the Pacific Northwest 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 33) 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 (1.7 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.

Table 33. 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 Pacific Northwest Basin

Additional practice		Treated acres	Percent of total
Overland flow practice only		55,194	1
Terrace only		19,118	0
Filter only		2,567,654	30
Filter and overland flow practice		1,530,005	18
Filter plus terrace		400,126	5
Filter and overland flow practice and terrace		2,566,173	30
Overland flow practice and terrace		125,075	1
Buffer only		676,125	8
Buffer and overland flow practice		83,679	1
Buffer and terrace		98,803	1
Buffer and overland flow practice and terrace		319,098	4
One or more additional practice		8,441,049	98
No structural practices		141,239	2
	Total	8,582,288	100

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

Simulation of Additional Nutrient Management Practices

The nutrient management treatment scenario consists of additional nutrient management practices where needed *in addition to* the erosion control practices. The nutrient management practices simulated the application of nutrients at an appropriate rate, in an appropriate form, at appropriate times, and using an appropriate method of application to provide sufficient nutrients for crop growth while minimizing losses to the environment. Simulation of nutrient management required changes to nutrient applications for one or more crops on all but 6 percent of the acres (see table 10).

Specific rules for application timing

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

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

In the baseline condition, about 13 percent of the cropped acres in the Pacific Northwest Basin receive fertilizer applications in the fall for at least one spring-planted row crop in the rotation. The only fall application of nutrients simulated in the nutrient management treatment scenario was for fall-seeded crops that received a starter fertilizer at planting time.

Specific rules for method of application

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

Specific rules for the form of application

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

Specific rules for the rate of nutrient applied

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

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

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

Simulation of Irrigation Water Use Efficiency

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

The treatment scenarios had four components.

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

Implementation of the treatment scenario on all irrigated acres would result in an additional 2.6 million acres converted to center pivot or linear move sprinkler systems with low pressure head.

In the Pacific Northwest Basin, the representation of irrigation management in the treatment scenarios increased the average Virtual Irrigation System Efficiency (VISE) from 56 percent in the baseline conservation condition to 78 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 38 percent of irrigated acres,
- 10-20 percent on 21 percent,
- 20-30 percent on 29 percent,
- 30-40 percent on 8 percent, and
- 40-45 percent on 4 percent of irrigated acres.

Emerging Technologies for Reducing Nutrient Losses from Farm Fields

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

- innovations in implement design to enhance precise nutrient application and placement, including variable rate technologies;
- enhanced-efficiency nutrient application products such as slow or controlled release fertilizers (for example, polymer coated products, sulfur-coated products, etc.) and nitrogen stabilizers (for example, urease inhibitors, and nitrification inhibitors);
- 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 all 8.6 million undertreated acres

According to the model simulation, treatment of all 8.6 million undertreated acres (acres with a high or moderate level of treatment need) *with erosion control practices* would substantially reduce sediment loss from water erosion and wind erosion, as well as reductions in nitrogen and phosphorus losses with surface water runoff (table 34). Wind erosion would be reduced to an annual average of 1.4 tons per acre per year for these acres, representing a 36-percent reduction relative to the baseline condition. Sediment loss would be reduced to an annual average of about 0.3 ton per acre per year for these acres, a 92-percent reduction. Nitrogen loss with surface runoff would be reduced to 4.0 pounds per acre per year on average (60-percent reduction), and phosphorus lost to surface water would be reduced to 1.4 pounds per acre per year (35-percent reduction). However, the re-routing of surface water to subsurface flow pathways would decrease nitrogen loss in subsurface flows by only about 3 percent for these acres, on average.

The addition of nutrient management would have little additional effect on wind erosion or sediment loss, but would be effective in reducing nitrogen loss in subsurface flows and further reducing nitrogen and phosphorus lost to surface water (table 34). Nitrogen loss in subsurface flows for these acres would be reduced to an average of 10.3 pounds per acre per year, representing a 54-percent reduction compared to losses simulated for the baseline conservation condition. Nitrogen lost to surface water would be reduced to an average of 3.4 pounds per acre per year for these acres, representing a 66-percent reduction compared to the baseline condition. Phosphorus lost to surface water would be reduced to an average of 1.1 pounds per acre per year for these acres, representing a 66-percent reduction.

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

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 Pacific Northwest Basin:

1. the 390,000 undertreated acres with a "high" need for additional treatment,
2. the 8.19 million undertreated acres with a "moderate" need for additional treatment, and
3. the 3.07 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 would reduce wind erosion an average of 2.0 tons per acre per year for the 390,000 critical undertreated acres, compared to a reduction of 0.6 ton per acre per year for the 8.19 million non-critical undertreated acres. Additional treatment of the remaining 3.07 million acres would reduce wind erosion by only 0.2 ton per acre per year on those acres, on average (table 35).

Conservation treatment would reduce sediment loss an average of 2.5 tons per acre per year for the 390,000 critical undertreated acres and 2.9 tons per acre per year for the 8.19 million non-critical undertreated acres. In comparison, additional treatment of the remaining 3.07 million acres would reduce sediment loss by only 0.5 ton per acre per year on those acres, on average (table 35).

Diminishing returns were more pronounced for nitrogen and phosphorus loss. Total nitrogen loss would be reduced by an average of 80.7 pounds per acre per year on the 390,000 critical undertreated acres, compared to a reduction of 19.7 pounds per acre for the 8.19 million undertreated acres with a moderate need for treatment, and only 7.2 pounds per acre for the remaining 3.07 million acres.

Nitrogen loss in subsurface flows would be reduced by an average of 68.9 pounds per acre per year on the 390,000 critical undertreated acres and 9.5 pounds per acre per year on the 8.19 million acres with a moderate need for treatment, compared to a reduction of 2.8 pounds per acre for the remaining 3.07 million acres.

Total phosphorus loss would be reduced by an average of 4.9 pounds per acre per year on the 390,000 critical undertreated acres, compared to a reduction of 2.7 pounds per acre for the 8.19 million undertreated acres with a moderate need for treatment and only 0.6 pound per acre for the remaining 3.07 million acres.

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

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

Table 34. Conservation practice effects for additional treatment of 8.6 million undertreated acres (acres with a *high* or *moderate* need for conservation treatment) in the Pacific Northwest 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)	4.8	4.4	9%	4.4	9%
Subsurface water flow (inches)	4.2	4.2	1%	4.2	2%
Erosion and sediment loss					
Wind erosion (tons/acre)	2.1	1.4	36%	1.5	29%
Sheet and rill erosion (tons/acre)	0.4	0.2	42%	0.3	32%
Sediment loss at edge of field due to water erosion (tons/acre)	3.2	0.3	92%	0.3	91%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-86	-51	--	-109	--
Nitrogen					
Nitrogen sources					
Atmospheric deposition	1.3	1.3	<1%	1.3	0%
Bio-fixation by legumes	8.4	8.0	4%	8.6	-3%
Nitrogen applied (pounds/acre)	99.5	96.4	3%*	59.5	40%
All nitrogen sources	109.1	105.7	3%	69.4	36%
Nitrogen in crop yield removed at harvest (pounds/acre)	74.3	72.7	2%	55.9	25%
Total nitrogen loss for all loss pathways (pounds/acre)	45.0	36.7	18%	22.5	50%
Nitrogen lost with windborne sediment	5.8	4.3	26%	4.2	28%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	10.1	4.0	60%	3.4	66%
Nitrogen loss in subsurface flows (pounds/acre)	22.4	21.7	3%	10.3	54%
Phosphorus					
Phosphorus applied (pounds/acre)	16.8	16.7	<1%*	12.2	28%
Phosphorus in crop yield removed at harvest (pounds/acre)	10.5	10.2	2%	8.2	22%
Total phosphorus loss for all loss pathways (pounds/acre)	4.9	2.6	47%	2.1	57%
Phosphorus lost with windborne sediment	1.7	1.1	32%	1.0	42%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	3.2	1.4	55%	1.1	66%
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	15.0	11.7	22%	11.9	21%
Surface water pesticide risk indicator for aquatic ecosystems	2.1	1.4	35%	1.3	38%
Surface water pesticide risk indicator for humans	1.1	0.8	29%	0.6	44%

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

Note: Values reported in this table are for the 8.6 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 11.65 million cropped acres in the Pacific Northwest Basin

	Additional treatment for 0.39 million critical undertreated acres*			Additional treatment for 8.19 million non-critical undertreated acres*			Additional treatment for remaining 3.07 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)	5.0	4.9	0.2	4.8	4.4	0.4	2.7	2.4	0.3
Subsurface water flow (inches)	5.6	5.3	0.4	4.2	4.1	0.1	3.6	3.3	0.3
Erosion and sediment loss									
Wind erosion (tons/acre)	4.7	2.7	2.02	2.0	1.5	0.56	1.2	1.0	0.21
Sheet and rill erosion (tons/acre)	0.3	0.2	0.13	0.4	0.3	0.12	0.1	0.1	0.00
Sediment loss at edge of field due to water erosion (tons/acre)	2.8	0.3	2.52	3.2	0.3	2.89	0.6	0.1	0.51
Soil organic carbon									
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-71	-72	1**	-87	-110	24**	-9	-52	42**
Nitrogen									
Nitrogen sources									
Atmospheric deposition	1.0	1.0	0.0	1.3	1.3	0.0	1.2	1.2	0.0
Bio-fixation by legumes	8.1	10.5	-2.4	8.4	8.5	-0.2	21.5	20.8	0.7
Nitrogen applied (pounds/acre)	235.5	118.2	117.3	93.1	56.7	36.3	67.8	43.2	24.5
All nitrogen sources	244.6	129.7	114.9	102.7	66.5	36.2	90.5	65.2	25.3
Nitrogen in crop yield removed at harvest (pounds/acre)	115.0	89.1	25.8	72.3	54.3	18.0	76.3	60.2	16.1
Total nitrogen loss for all loss pathways (pounds/acre)	123.3	42.6	80.7	41.3	21.6	19.7	20.3	13.1	7.2
Nitrogen lost with windborne sediment	8.9	5.2	3.7	5.6	4.1	1.5	4.3	3.5	0.8
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	8.2	5.6	2.6	10.2	3.3	6.9	3.3	1.3	2.0
Nitrogen loss in subsurface flows (pounds/acre)	94.4	25.5	68.9	19.0	9.6	9.5	6.5	3.8	2.8
Phosphorus									
Phosphorus applied (pounds/acre)	44.4	22.2	22.2	15.5	11.7	3.8	10.2	8.9	1.3
Phosphorus in crop yield removed at harvest (pounds/acre)	16.0	13.9	2.1	10.2	7.9	2.3	9.8	7.7	2.1
Total phosphorus loss for all loss pathways (pounds/acre)	7.7	2.8	4.9	4.8	2.1	2.7	1.8	1.2	0.6
Phosphorus lost with windborne sediment	5.1	1.7	3.4	1.5	0.9	0.6	0.8	0.6	0.2
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	2.5	1.0	1.5	3.2	1.1	2.1	1.0	0.6	0.4
Pesticide loss									
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	21.3	17.0	4.3	14.7	11.7	3.1	8.1	7.3	0.8
Surface water pesticide risk indicator for aquatic ecosystem	6.3	5.1	1.2	1.9	1.2	0.8	0.7	0.7	<0.1
Surface water pesticide risk indicator for humans	6.8	6.0	0.8	0.9	0.4	0.5	0.1	0.1	<0.1

*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 soil and nutrient savings from additional conservation treatment in the Pacific Northwest Basin are contrasted to estimated savings for the conservation practices in use in 2003–06 in figure 62. 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 wind erosion, sediment loss, and nutrient loss between these two scenarios represents the maximum savings possible for conservation treatment, which totaled 43 million tons of sediment, 268,162 tons of nitrogen, 30,968 tons of phosphorus, and 6,643 tons of soil lost with wind erosion (fig. 62).

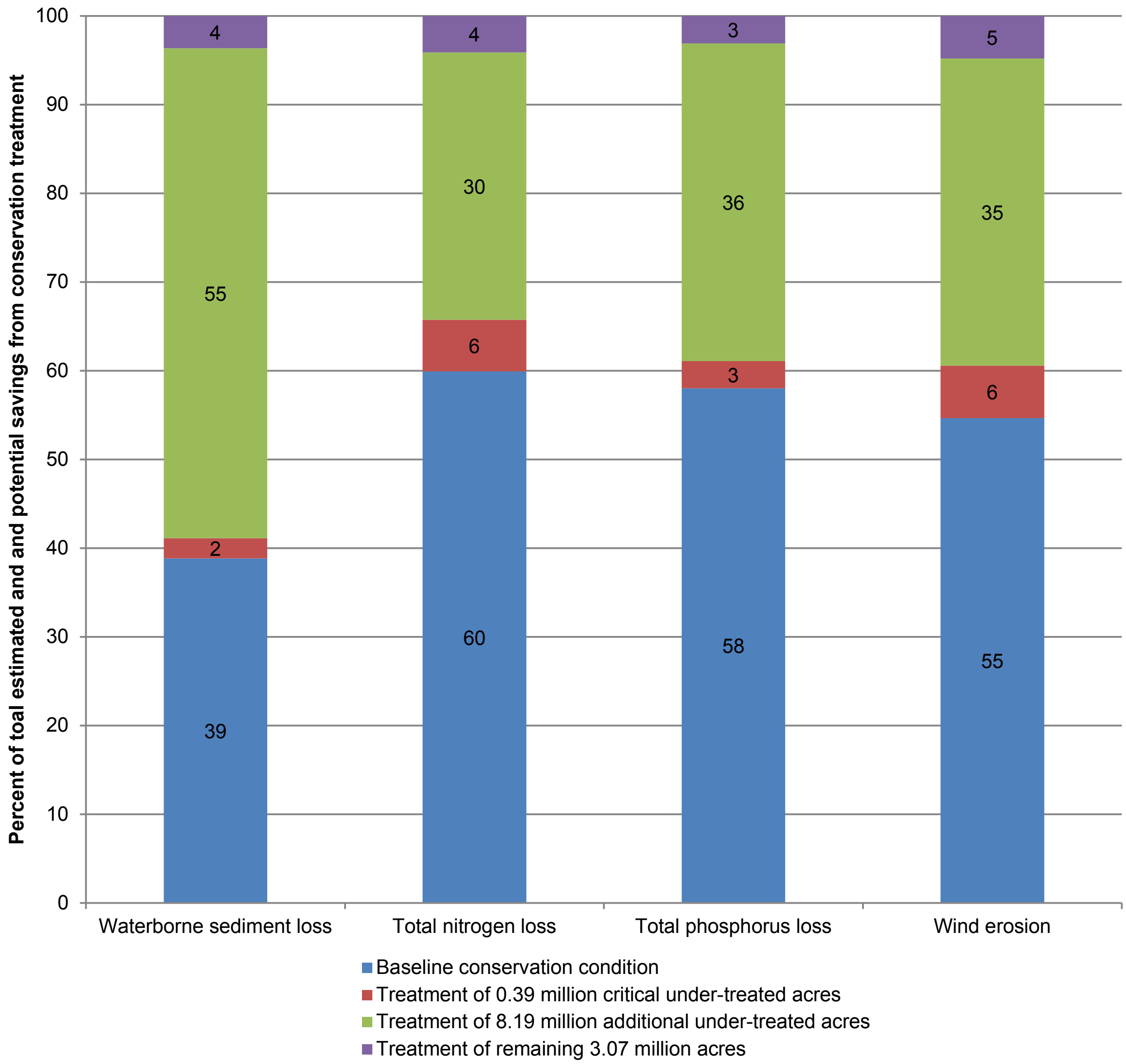
For sediment loss, about 39 percent of the potential savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition. Additional treatment of the 390,000 critical undertreated acres would account for another 2 percent of the potential sediment savings. Treatment of the 8.19 million undertreated acres with a moderate need for treatment would account for about 55 percent of the potential savings. Treatment of the 3.07 million adequately treated acres would account for the last 4 percent of potential sediment savings.

For nitrogen loss, 60 percent of the potential savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition. Additional treatment of the 390,000 critical undertreated acres would account for another 6 percent of the potential nitrogen savings. Treatment of the 8.19 million undertreated acres with a moderate need for treatment would account for about 30 percent of the potential savings. Treatment of the 3.07 million adequately treated acres would account for the last 4 percent of potential nitrogen savings.

For phosphorus loss, about 58 percent of the potential savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition. Additional treatment of the 390,000 critical undertreated acres would account for another 3 percent of the potential phosphorus savings. Treatment of the 8.19 million undertreated acres with a moderate need for treatment would account for 36 percent of the potential savings. Treatment of the 3.07 million adequately treated acres would account for the last 3 percent of potential phosphorus savings.

For wind erosion, about 55 percent of the potential savings are accounted for by the conservation practices already in use, as represented by the baseline conservation condition. Additional treatment of the 390,000 critical undertreated acres would account for another 6 percent of the potential wind erosion savings. Treatment of the 8.19 million undertreated acres with a moderate need for treatment would account for about 35 percent of the potential savings. Treatment of the 3.07 million adequately treated acres would account for the last 5 percent of potential wind erosion savings.

Figure 62. Comparison of estimated sediment, nitrogen, and phosphorus savings (field-level) that are due to practices in use in the baseline conservation condition and potential savings with additional water erosion control *and* nutrient management treatment of cropped acres in the Pacific Northwest Basin



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

	Estimated savings due to conservation practice use (baseline conservation condition)	Potential savings from treatment of 0.39 million critical undertreated acres*	Potential savings from treatment of 8.19 million additional undertreated acres*	Potential savings from treatment of remaining 3.07 million acres*	Total estimated and potential savings from conservation treatment
Sediment	16,672,298	978,014	23,708,124	1,567,048	42,925,484
Nitrogen	160,653	15,653	80,814	11,042	268,162
Phosphorus	17,971	945	11,090	963	30,968
Wind erosion	3,631	393	2,299	320	6,643

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

Expected regional results assuming all undertreated acres were treated

As shown in figure 62, the potential for reducing overall field-level losses with additional conservation practices is significant in this region. Table 36 presents estimates of how treatment of 8.6 million 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 8.6 million acres with model results from the baseline conservation condition for the remaining acres.

Compared to the baseline conservation condition, treating all 8.6 million undertreated acres with soil erosion control practices *and* nutrient management practices would, for the region as a whole (table 36)—

- reduce wind erosion rates in the region by 24 percent on average;
- reduce sediment loss in the region by 85 percent on average;
- reduce total nitrogen loss by 43 percent:
  - reduce nitrogen loss with windborne sediment by 22 percent,
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) by 59 percent, and
  - reduce nitrogen loss in subsurface flows by 49 percent;
- reduce phosphorus lost to surface water by 59 percent;
- reduce phosphorus loss with windborne sediment by 36 percent, and
- reduce surface water environmental risk from loss of pesticide residues by 34 percent for aquatic ecosystems and 43 percent for humans.

Nearly all of these reductions in wind erosion, sediment loss, and environmental risk from loss of pesticide residues are due to the erosion control practices, as shown in table 36. The additional nutrient management practices accounted for a significant portion of the reductions in total nitrogen and total phosphorus loss.

The effects of treating the undertreated acres *for the region as a whole* are graphically shown in figures 63 through 69. In these figures the model results for the baseline distribution are compared to the distributions for treatment of all 8.6 million undertreated acres. For perspective, the distribution of loss estimates if no conservation practices were in use, represented by the no-practice scenario, is also shown.

The distributions show how the number of acres with high losses *could be reduced dramatically in the region by treating the undertreated acres*. For example, 19 percent of the acres in the Pacific Northwest Basin exceed an annual average loss of sediment of 2 tons per acre per year in the baseline conservation condition. Model simulations indicate that treating all undertreated acres (8.6 million acres) would reduce the acres exceeding annual sediment loss of 2 tons per acre to 3 percent (fig. 63).

For wind erosion, 14 percent of the acres exceed an annual average wind erosion rate of 4 tons per acre per year in the baseline conservation condition. Model simulations indicate that treating all undertreated acres (8.6 million acres) would reduce the acres exceeding annual sediment loss of 4 tons per acre to 8 percent (fig. 64).

Soil organic carbon would be minimally affected by the additional soil erosion control and nutrient management practices. Figure 65 shows that the percentage of acres building soil organic carbon would actually decrease slightly from 30 percent for the baseline conservation condition to 25 percent with additional conservation treatment of all the undertreated acres.

For total nitrogen loss to all pathways, 25 percent of the acres in the baseline conservation condition exceed losses of 40 pounds per acre per year. Treating all undertreated acres would reduce the acres exceeding 40 pounds per acre to 9 percent (fig. 66).

Treatment of all 8.6 million undertreated acres with water erosion control and nutrient management would reduce the acres exceeding 15 pounds per acre of nitrogen lost with runoff from 15 percent for the baseline to 6 percent (fig. 67).

Seventeen percent of the acres in the region have nitrogen loss in subsurface flows greater than 25 pounds per acre per year for the baseline conservation condition. Treatment of all 8.6 million undertreated acres would reduce the percentage to 7 percent (fig. 68).

Acres exceeding 4 pounds per acre of phosphorus lost to surface water would be reduced from 15 percent for the baseline to 5 percent by treating all undertreated acres (fig. 69).

One of the objectives in constructing the treatment scenarios was to maintain the level of regional crop production. The removal of nitrogen at harvest serves as a useful proxy for crop yields and allows for aggregation over the mix of crops. The average annual amount of nitrogen removed at harvest would be reduced about 2 percent for the region as a whole if the 8.6 million undertreated acres were treated with additional soil erosion control practices (table 36). If the 8.6 million undertreated acres were treated with additional soil erosion control *and* nutrient management practices the average annual amount of nitrogen removed at harvest would be reduced about 18 percent for the region as a whole. Figure 70 shows that the distribution of nitrogen removed at harvest would be lower for the treatment scenario with nutrient management, but otherwise similar to the distribution for the baseline conservation condition.

Table 36. Conservation practice effects for the region as a whole* after additional treatment of 8.6 million undertreated acres (acres with a *high* or *moderate* need for conservation treatment) in the Pacific Northwest 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	4.0	7%	3.9	7%
Subsurface water flow (inches)	4.1	4.0	1%	4.0	1%
Erosion and sediment loss					
Wind erosion (tons/acre)	1.9	1.3	30%	1.4	24%
Sheet and rill erosion (tons/acre)	0.3	0.2	40%	0.2	31%
Sediment loss at edge of field due to water erosion (tons/acre)	2.5	0.3	86%	0.4	85%
Soil organic carbon					
Change in soil organic carbon, including loss of carbon with wind and water erosion (pounds/acre)	-66	-40	--	-83	--
Nitrogen					
Nitrogen sources					
Atmospheric deposition	1.2	1.2	0%	1.2	0%
Bio-fixation by legumes	11.8	11.6	2%	12.0	-2%
Nitrogen applied (pounds/acre)	91.1	88.9	3%	61.7	32%
All nitrogen sources	104.2	101.7	2%	74.9	28%
Nitrogen in crop yield removed at harvest (pounds/acre)	74.8	73.6	2%	61.3	18%
Total nitrogen loss for all loss pathways (pounds/acre)	38.5	32.4	16%	22.0	43%
Nitrogen lost with windborne sediment	5.4	4.3	20%	4.2	22%
Loss of nitrogen with surface runoff, including waterborne sediment (pounds/acre)	8.3	3.8	54%	3.4	59%
Nitrogen loss in subsurface flows (pounds/acre)	18.3	17.7	3%	9.3	49%
Phosphorus					
Phosphorus applied (pounds/acre)	15.1	15.0	0%	11.7	23%
Phosphorus in crop yield removed at harvest (pounds/acre)	10.3	10.1	2%	8.6	16%
Total phosphorus loss for all loss pathways (pounds/acre)	4.1	2.4	41%	2.0	51%
Phosphorus lost with windborne sediment	1.5	1.1	27%	0.9	36%
Loss of phosphorus to surface water, including waterborne sediment (pounds/acre)	2.6	1.3	50%	1.1	59%
Pesticide loss					
Mass loss of pesticides for all pathways (grams of active ingredient/hectare)	13.2	10.7	19%	10.9	17%
Surface water pesticide risk indicator for aquatic ecosystems	1.8	1.2	31%	1.2	34%
Surface water pesticide risk indicator for humans	0.9	0.6	28%	0.5	43%

* Results presented for the region as a whole combine model output for the 8.6 million undertreated acres with model results from the baseline conservation condition for the remaining acres.

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

Note: Percent reductions are with respect to the baseline conservation condition.

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

Figure 63. Estimates of average annual sediment loss for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Pacific Northwest Basin

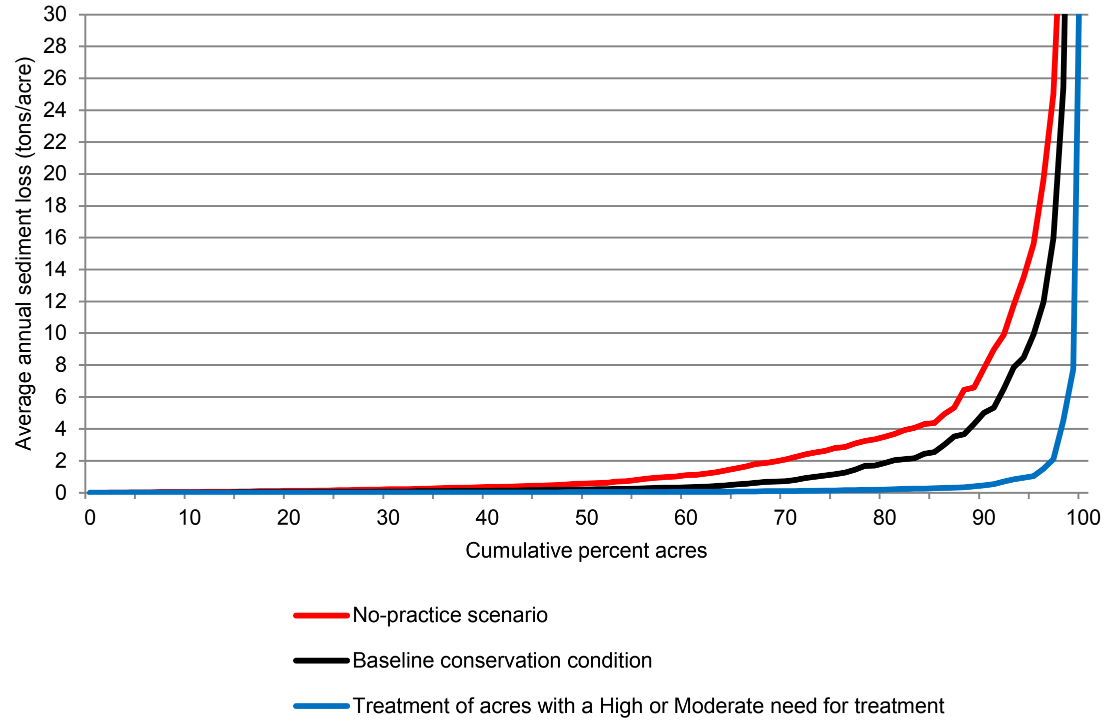


Figure 64. Estimates of average annual wind erosion for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Pacific Northwest Basin

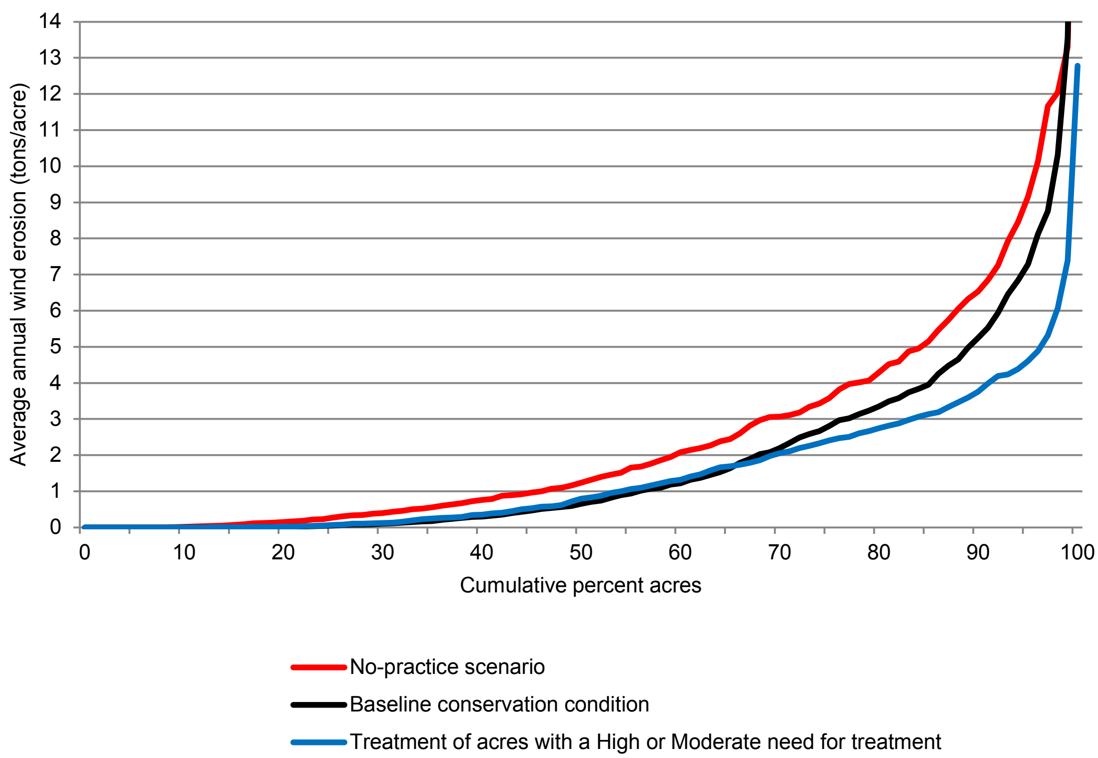


Figure 65. Estimates of average annual change in soil organic carbon for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Pacific Northwest Basin

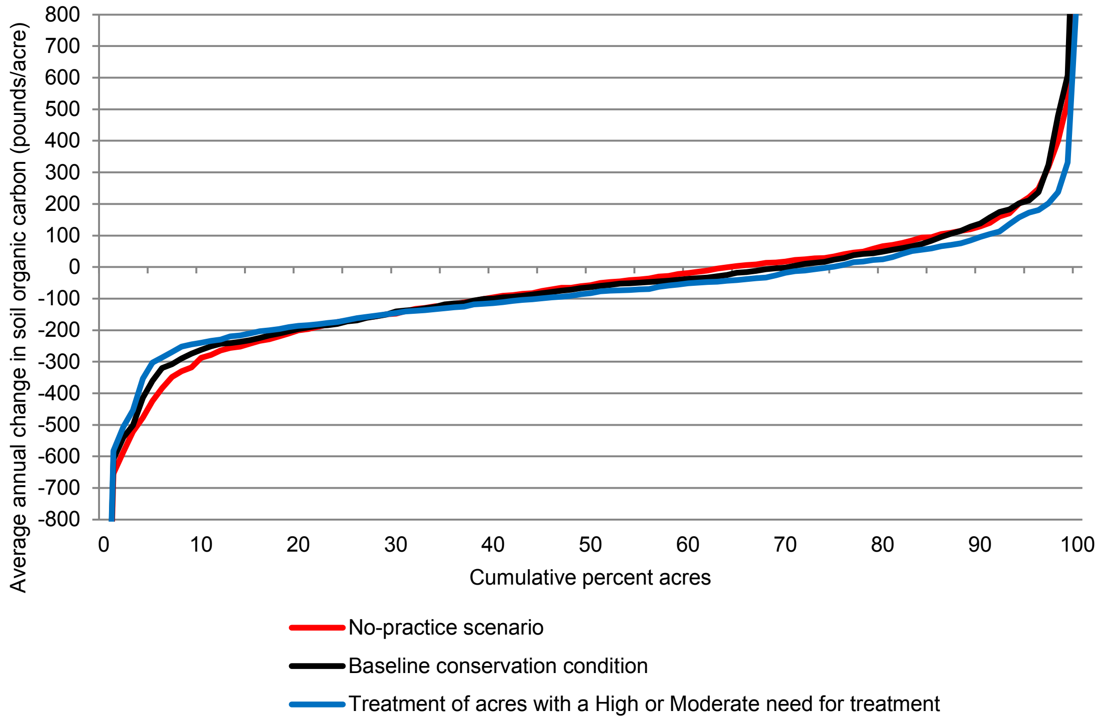


Figure 66. Estimates of average annual total nitrogen loss for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Pacific Northwest Basin

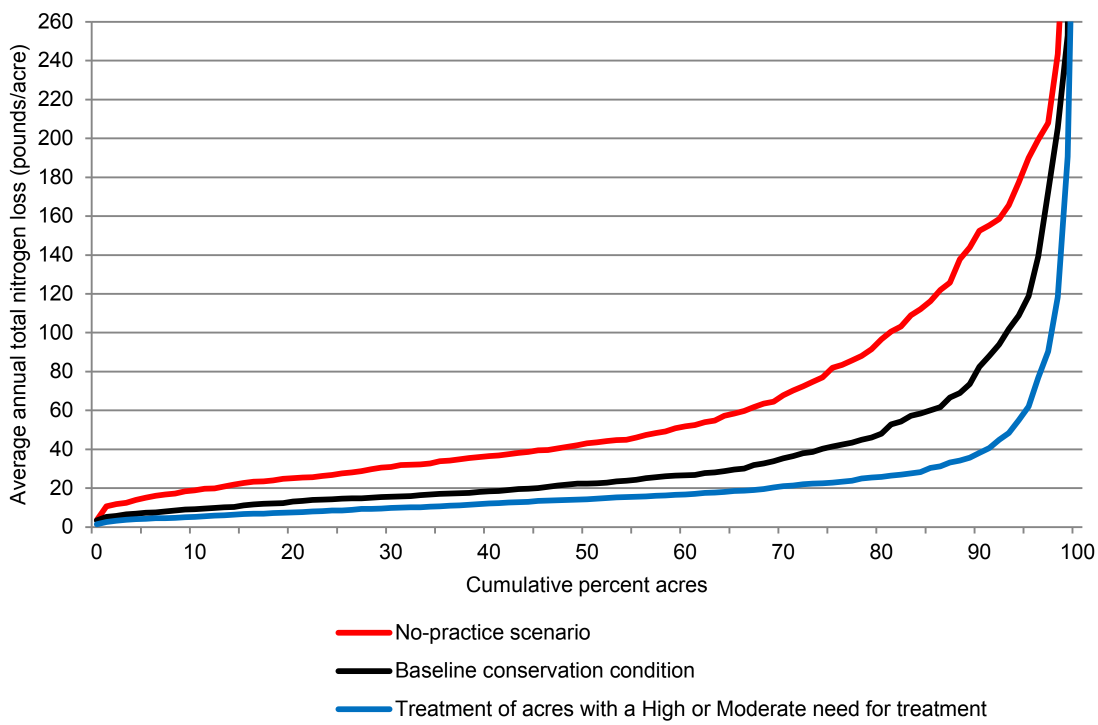


Figure 67. Estimates of average annual loss of nitrogen with surface runoff for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Pacific Northwest Basin

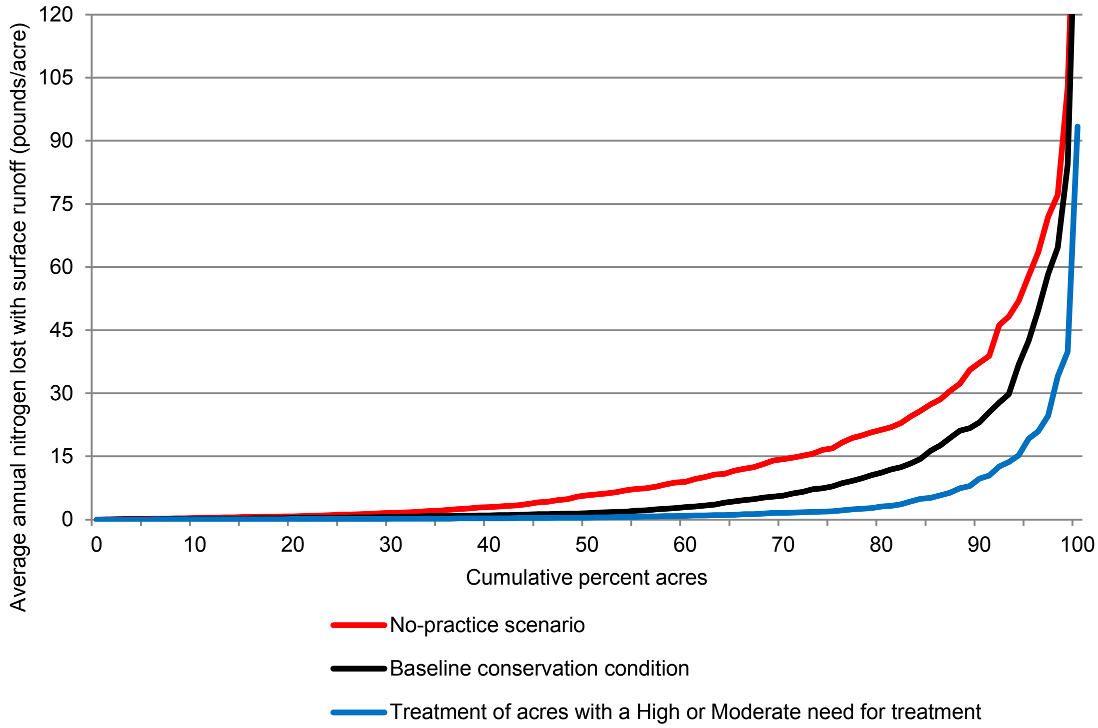


Figure 68. Estimates of average annual loss of nitrogen in subsurface flows for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Pacific Northwest Basin

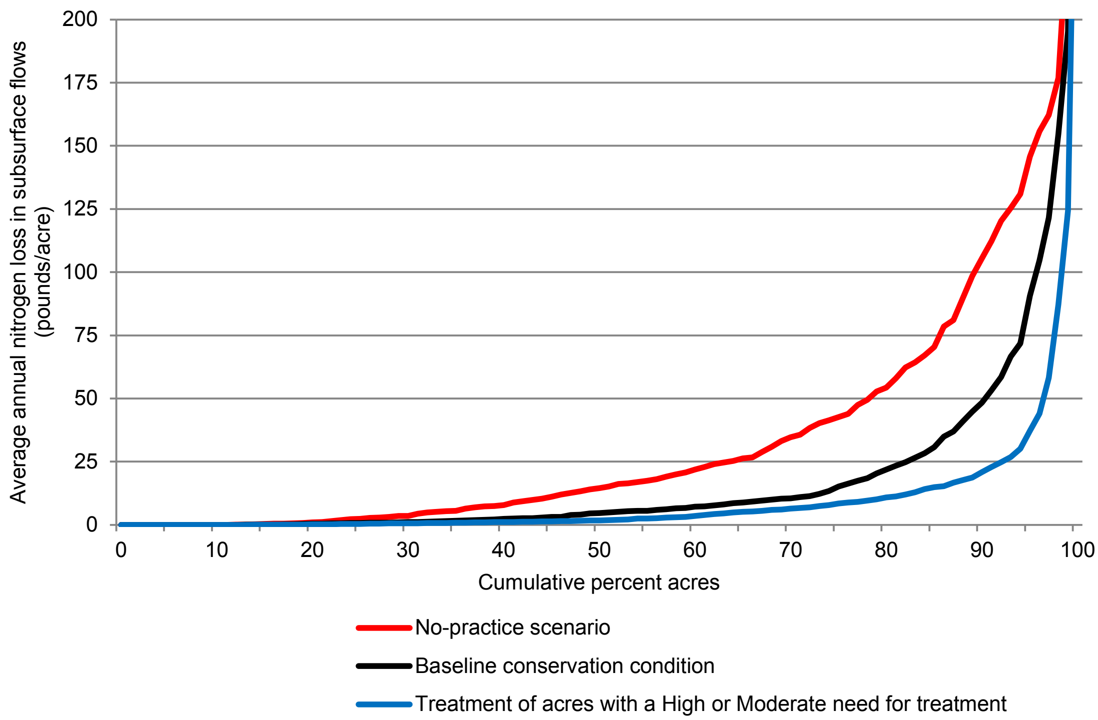
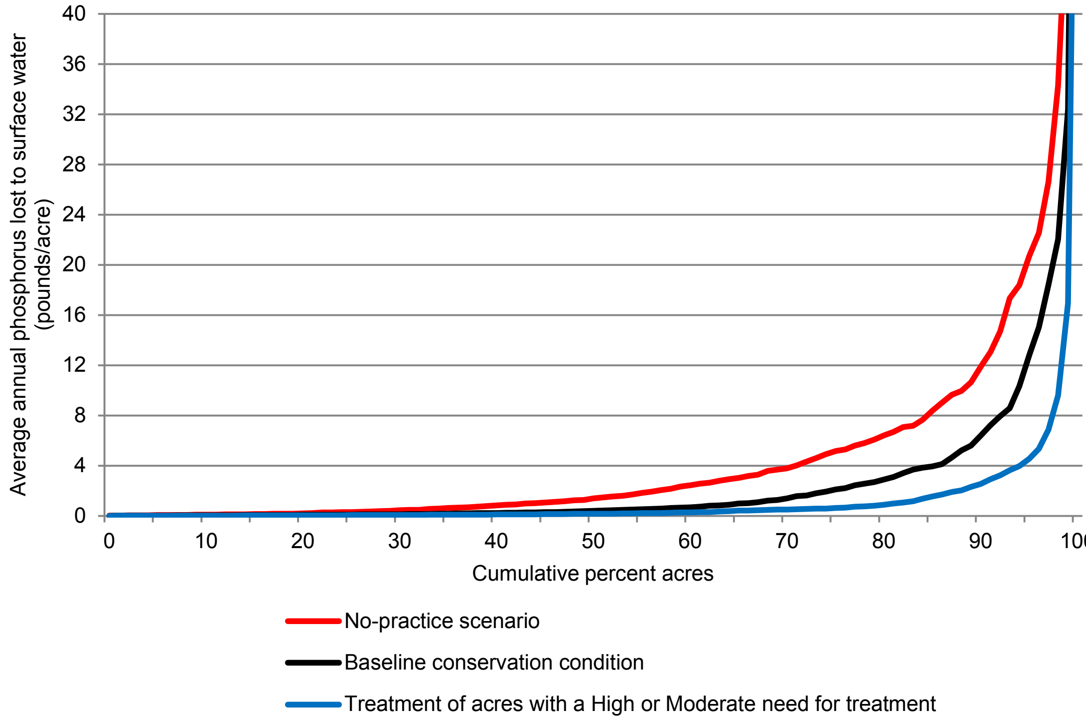
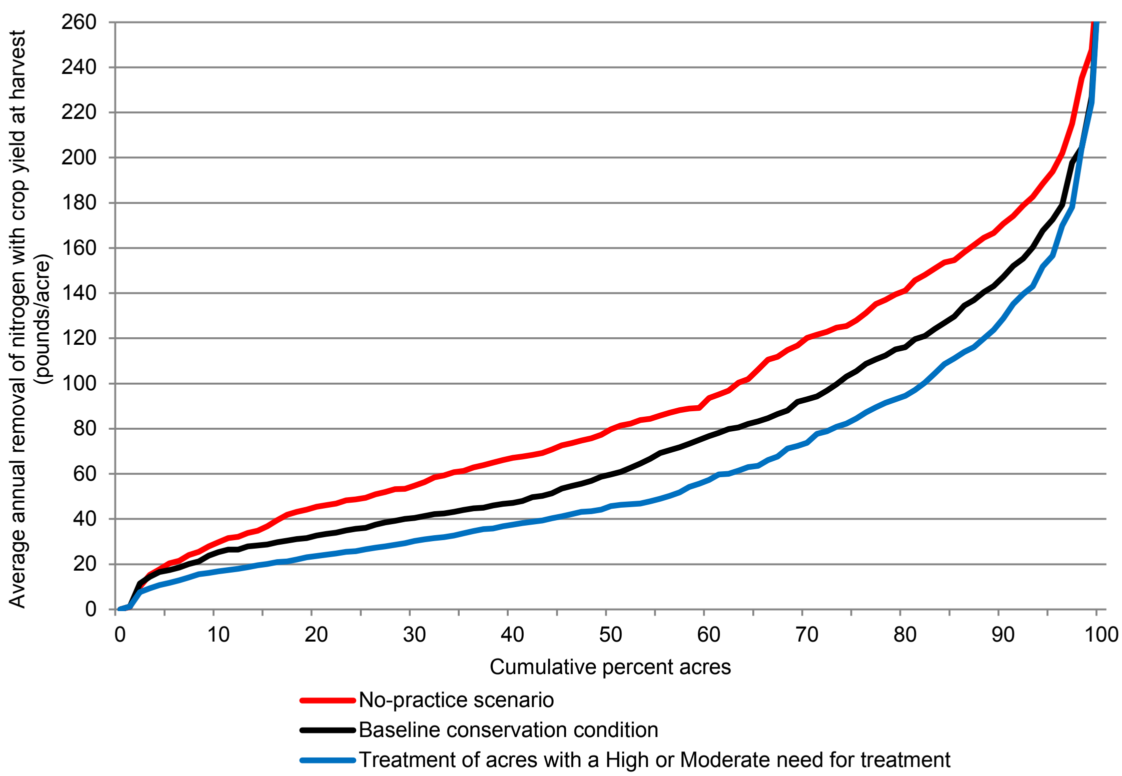


Figure 69. Estimates of average annual phosphorus lost to surface water (sediment attached and soluble)* for undertreated acres treated with water erosion control *and* nutrient management compared to the baseline conservation condition and the no-practice scenario, Pacific Northwest Basin



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



Chapter 7
Offsite Water Quality Effects of Conservation Practices

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

- loads delivered to rivers and streams within the basin, and
- loads exported from the region to the Pacific Ocean.

The 12 subregions that make up the Pacific Northwest Basin are shown in figure 71. As discussed in chapter 2, sample sizes for six subregions in the Pacific Northwest Basin were too small to reliably report edge-of-field results because of the small amount of cultivated cropland acres within each subregion.

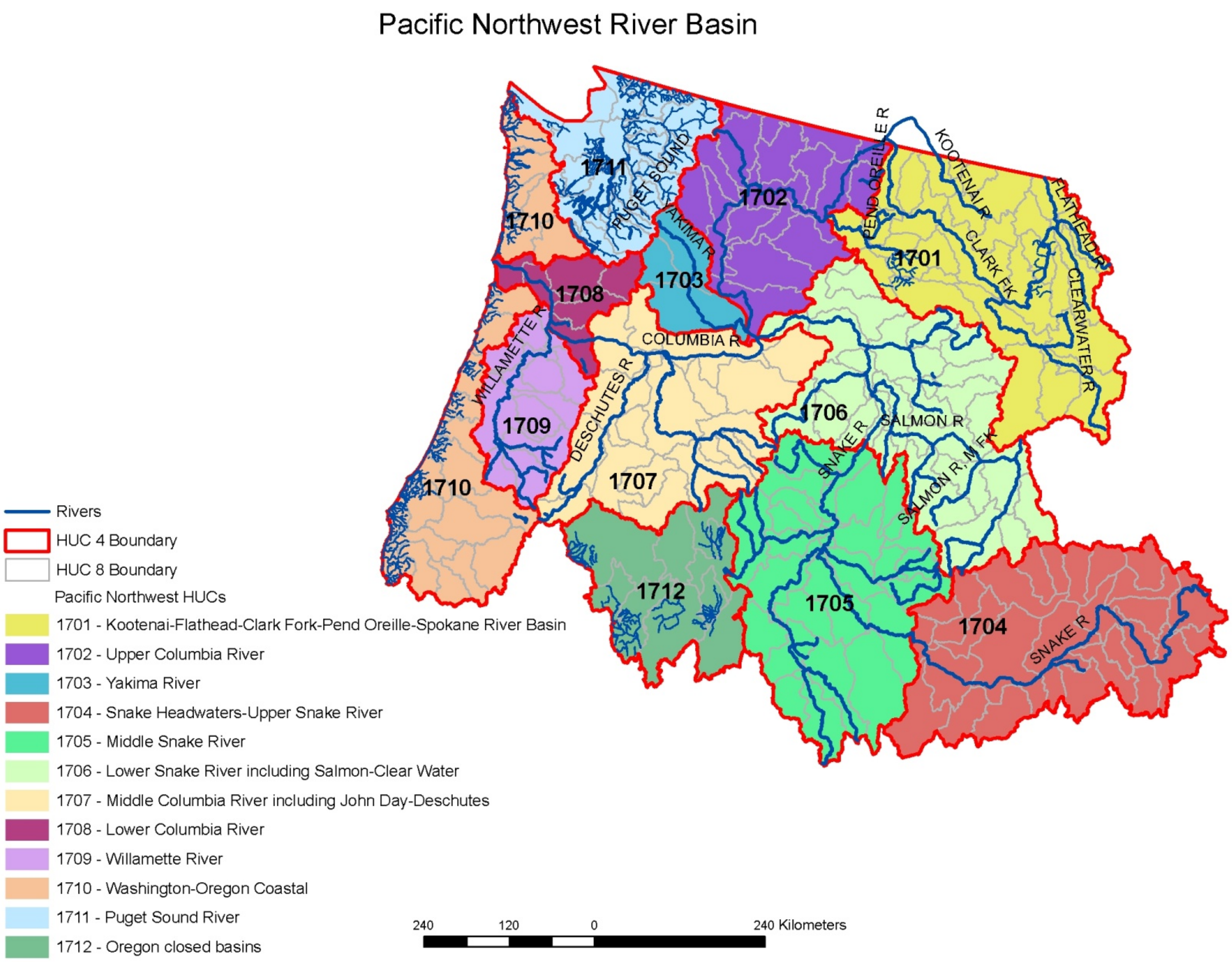
Offsite water quality results for five of these subregions are therefore combined with each other or with other subregions as follows:

- the Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin (code 1701) was combined with the Yakima River Basin (code 1703), both of which are tributaries to the Upper Columbia River Basin and had too few sample points for separate reporting;
- the Lower Columbia River Basin (code 1708) was combined with the Willamette River Basin (code 1709) for reporting; and
- the Washington-Oregon Coastal basins (code 1710) was combined with the Puget Sound Basin (code 1711), both of which drain directly into the Pacific Ocean without upstream tributaries.

The sixth subregion, the “Oregon closed basins” subregion (code 1712), had no CEAP cropland sample points and so no water quality results are estimated for this subregion.

Load estimates for the remaining five subregions were reported separately for each subregion.

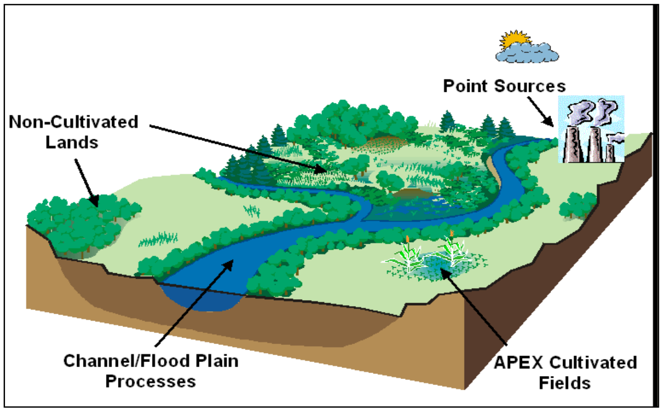
Figure 71. The 12 subregions in the Pacific Northwest Basin



The National Water Quality Model—HUMUS/SWAT

Offsite estimates of water quality benefits were assessed using HUMUS/SWAT, a combination of the SWAT model (Soil and Water Assessment Tool) and HUMUS (Hydrologic Unit Modeling for the United States) databases required to run SWAT at the watershed scale for all watersheds in the United States (Arnold et al. 1999; Srinivasan et al. 1998). SWAT simulates the transport of water, sediment, pesticides, and nutrients from the land to receiving streams and routes the flow downstream to the next watershed and ultimately to estuaries and oceans (fig. 72).

Figure 72. Sources of water flows, sediment, and agricultural chemicals simulated with HUMUS/SWAT



Like APEX, SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007).[26] The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

Upland processes

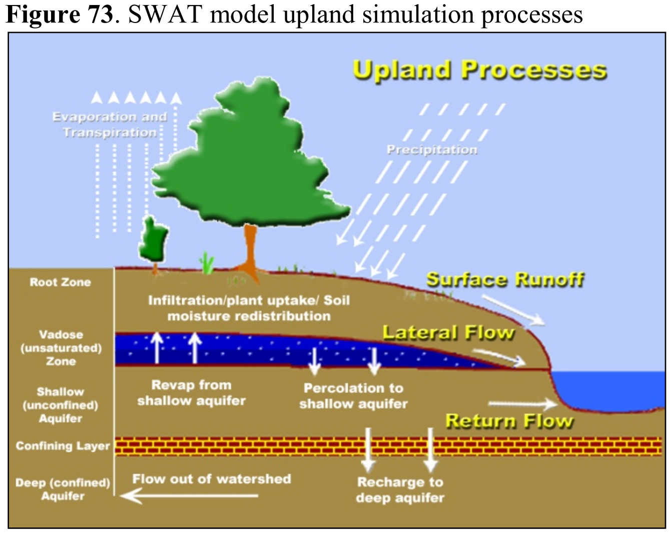
The water balance is the driving force for transport and delivery of sediment, nutrients, and pesticides from fields to streams and rivers. For this study, upland processes for non-cultivated cropland were modeled using SWAT, while source loads for cultivated cropland are estimated by APEX.

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

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

Upland processes were modeled for each of these HRUs in each watershed (8-digit HUC) (fig. 73). 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 73. SWAT model upland simulation processes



Agricultural sources

Upland processes for cultivated cropland (including land in long-term conserving cover) were modeled using APEX as described in previous chapters. The weighted average of per-acre APEX model output for surface water delivery, sediment, nutrients, and pesticides was multiplied by the acres of cultivated cropland in the HUMUS database and used as SWAT model inputs for cultivated cropland for each 8-digit Hydrologic Unit Code (HUC). The acreage weights for the CEAP sample points were used to calculate the per-acre loads. Some of the 8-digit watersheds in this region had too few CEAP sample points to reliably estimate edge-of-field per-acre loads. In these cases, the 6-digit per acre loads were used to represent cultivated cropland.

Various types of agricultural land management activities were modeled in SWAT. For permanent hayland, the following management activities were simulated:

- Hay was fertilized with nitrogen according to the crop need as determined by an auto-fertilization routine, which was set to grow the crop without undue nitrogen stress.

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

- Legume hay was grown in a 4-year rotation and phosphorus was applied at the time of planting (every fourth year) at a rate of 50 pounds per acre, followed by applications of 13 pounds per acre every other year.
- Recoverable manure from animal feeding operations was applied to 3 percent of the hayland acres at rates estimated from probable land application of manure from animal feeding operations, estimated using the methods described in USDA/NRCS (2003). (These calculations indicated that 3 percent of hayland acres in the Pacific Northwest Basin could have received manure from animal feeding operations.)
- Three hay cuttings were simulated per crop year for grass hay and four hay cuttings were simulated per year for legume hay.
- For hayland acres that land-use databases indicated were irrigated, water was applied at a frequency and rate defined by an auto-irrigation routine.

For pastureland and rangeland, the following management activities were simulated:

- Continuous grazing was simulated by algorithms that determined the length of the grazing period, amount of biomass removed, and amount of biomass trampled. Grazing occurs whenever the plant biomass is above a specified minimum plant biomass for grazing. The amount of biomass trampled daily is converted to residue.
- Manure nutrients from grazing animals were simulated for pastureland and rangeland according to the density of pastured livestock as reported in the 2002 Census of Agriculture. Non-recoverable manure was estimated by subtracting recoverable manure available for land application from the total manure nutrients representing all livestock populations. Non-recoverable manure nutrients include the non-recoverable portion from animal feeding operations. Estimates of manure nutrients were derived from data on livestock populations as reported in the 2002 Census of Agriculture, which were available for each 6-digit HUC and distributed among the 8-digit HUCs on a per-acre basis.
- Recoverable manure from animal feeding operations was applied to about 1 percent of pastureland acres at rates estimated from probable land application of manure obtained from animal feeding operations as estimated in USDA/NRCS (2003). (These calculations indicated that about 1 percent of pastureland acres in the Pacific Northwest Basin could have received manure from animal feeding operations.)
- Supplemental commercial nitrogen fertilizers were applied to pastureland (but not rangeland) according to the crop need as determined by an auto-fertilization routine, which was set to grow grass without undue nitrogen stress.

Horticulture land was fertilized with 100 pounds per acre of nitrogen per year and 44 pounds per acre of phosphorus. For the irrigated horticultural acres, water was applied at a frequency and rate defined by an auto-irrigation routine.

Land application of biosolids from wastewater treatment facilities was not simulated. Manure nutrients from wildlife populations are not included in the model simulation.

A summary of the total amount of nitrogen and phosphorus applied to agricultural land in the model simulation, including nitrogen and phosphorus applied to cultivated cropland in the APEX modeling, is presented in table 37.[27]

Urban Sources

Urban sources include (1) loads from point sources discharged from industrial and municipal wastewater treatment plants and (2) loads from urban land runoff.

Discharges from industrial and municipal wastewater treatment plants can be major sources of nutrients and sediment in some watersheds. Point sources of water flow, total suspended sediment, total phosphorus, and Kjeldahl nitrogen were estimated using county-level data on population change to adjust 1980 estimates of point source loadings published by Resources for the Future (Gianessi and Peskin 1984) to the year 2000. The original Resources for the Future assessment covered 32,000 facilities, including industries, municipal wastewater treatment plants, and small sanitary waste facilities for the years 1977 to 1981. A GIS-based procedure was used to convert county data to the 8-digit HUC level. Point source loads are aggregated within each watershed and average annual loads input into SWAT at the watershed outlet.

Urban runoff was 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 were simulated in the same manner as other grass areas (such as pasture). Surface runoff from pervious surfaces was calculated using the curve number approach. Nitrogen fertilizer (40 pounds per acre per year) was applied on grassed urban area such as lawns and grassed roadsides using an auto-fertilizer routine to grow grass without undue nitrogen stress. The grass was irrigated as needed based on plant stress demand using an auto-irrigation routine.

[27] For information on how manure nutrients were calculated for use in HUMUS modeling, see "Manure Loadings Used to Simulate Pastureland and Hayland in CEAP HUMUS/SWAT Modeling," available at: http://www.nrcs.usda.gov/technical/nri/ceap.

Table 37. Summary of commercial fertilizer and manure nutrients applied to agricultural land in HUMUS/SWAT (pastureland, rangeland, hayland, and horticulture) and APEX (cultivated cropland) models, Pacific Northwest 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			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	29,552	3,591	33,143	3,539	1,713	5,252
Upper Columbia River Basin (code 1702)	82,290	1,487	83,778	8,293	576	8,869
Snake Headwaters-Upper Snake River Basin (code 1704)	130,144	14,097	144,240	26,663	7,909	34,572
Middle Snake River Basin (code 1705)	44,707	9,366	54,073	6,862	4,545	11,407
Lower Snake River Basin including Salmon-Clear Water (code 1706)	78,476	369	78,845	7,619	150	7,768
Middle Columbia River Basin including John Day-Deschutes (code 1707)	71,481	368	71,849	7,790	143	7,934
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	51,838	1,079	52,916	8,291	306	8,597
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	9,036	3,006	12,043	2,561	882	3,443
Total	497,524	33,363	530,887	71,617	16,224	87,841
			Hayland			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	5,609	503	6,112	1,049	220	1,269
Upper Columbia River Basin (code 1702)	1,892	144	2,035	549	63	612
Snake Headwaters-Upper Snake River Basin (code 1704)	1,380	675	2,055	1,120	281	1,401
Middle Snake River Basin (code 1705)	2,956	619	3,576	659	229	888
Lower Snake River Basin including Salmon-Clear Water (code 1706)	1,433	24	1,458	201	13	214
Middle Columbia River Basin including John Day-Deschutes (code 1707)	1,986	418	2,403	122	164	286
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	5,172	1,786	6,958	72	781	853
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	7,511	2,445	9,956	140	1,046	1,186
Total	27,940	6,614	34,553	3,912	2,798	6,710
			Pastureland and rangeland			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	2,148	8,624	10,773	1,251	5,016	6,267
Upper Columbia River Basin (code 1702)	1,802	7,208	9,010	902	3,606	4,508
Snake Headwaters-Upper Snake River Basin (code 1704)	8,744	34,978	43,722	3,924	15,697	19,621
Middle Snake River Basin (code 1705)	7,038	28,151	35,189	3,637	14,547	18,184
Lower Snake River Basin including Salmon-Clear Water (code 1706)	2,082	8,328	10,409	1,262	5,047	6,309
Middle Columbia River Basin including John Day-Deschutes (code 1707)	3,176	12,706	15,882	1,726	6,905	8,632
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	1,900	8,002	9,902	846	3,551	4,397
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	3,422	14,403	17,825	1,483	6,229	7,713
Total	30,312	122,399	152,711	15,031	60,599	75,630

Table 37--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, Pacific Northwest Basin*

Subregion	Commercial nitrogen fertilizer (tons/year)	Nitrogen from manure (tons/year)	Total nitrogen (tons/year)	Commercial phosphorus fertilizer (tons/year)	Phosphorus from manure (tons/year)	Total phosphorus (tons/year)
			Horticulture			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	6,399	0	6,399	2,817	0	2,817
Upper Columbia River Basin (code 1702)	8,434	0	8,434	3,712	0	3,712
Snake Headwaters-Upper Snake River Basin (code 1704)	349	0	349	153	0	153
Middle Snake River Basin (code 1705)	827	0	827	364	0	364
Lower Snake River Basin including Salmon-Clear Water (code 1706)	298	0	298	131	0	131
Middle Columbia River Basin including John Day-Deschutes (code 1707)	3,603	0	3,603	1,586	0	1,586
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	6,161	0	6,161	2,712	0	2,712
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	2,878	0	2,878	1,267	0	1,267
Total	28,948	0	28,948	12,742	0	12,742
			Total for all agricultural land			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	43,709	12,717	50,027	8,656	6,949	12,789
Upper Columbia River Basin (code 1702)	94,418	8,839	94,823	13,457	4,245	13,989
Snake Headwaters-Upper Snake River Basin (code 1704)	140,617	49,749	190,018	31,860	23,888	55,595
Middle Snake River Basin (code 1705)	55,528	38,136	92,837	11,521	19,321	30,479
Lower Snake River Basin including Salmon-Clear Water (code 1706)	82,289	8,721	90,711	9,212	5,210	14,291
Middle Columbia River Basin including John Day-Deschutes (code 1707)	80,246	13,492	90,135	11,225	7,212	16,852
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	65,070	10,867	69,776	11,921	4,638	13,847
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	22,848	19,854	39,824	5,451	8,158	12,341
Total	584,724	162,376	718,151	103,303	79,621	170,181

*Excludes sources associated with the "Oregon closed basins" subregion (code 1712).
Note: The amounts reported in this table are as elemental nitrogen and elemental phosphorus (not fertilizer equivalents).

For estimating surface water runoff from impervious urban areas, a runoff curve number of 98 is used for surfaces connected hydraulically to drainage systems. A composite runoff curve number was used for impervious surfaces not hydraulically connected to drainage systems. Sediment and nutrients carried with stormwater runoff to streams and rivers were estimated using the build up-wash off algorithm developed by Huber and Dickinson (1988). The concept behind the build up-wash off algorithm is that over a period of time, dust, dirt and other constituents are built up on street surfaces during dry periods. During a storm event the materials are washed off. The build up-wash off algorithms are developed from an EPA national urban water quality database that relates storm runoff loads to rainfall, drainage area, and impervious area.

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

A summary of the total amount of nitrogen and phosphorus applied to nonagricultural land in the model simulation is presented in table 38. Nutrients from septic systems were not included in the model simulations as data on locations of septic systems, populations using the septic systems, and types of septic systems were not available.

Atmospheric nitrogen deposition

Atmospheric deposition of nitrogen can be a significant component of the nitrogen balance. Nitrogen deposition data (loads and concentrations) were developed from the National Atmospheric Deposition Program/National Trends Network database (NAPD 2004). When a rainfall event occurs in the model simulation, the amount of rainfall is multiplied by the average ammonium and nitrate concentrations calculated for the watershed to account for wet deposition. An additional amount of ammonium and nitrate are added on a daily basis to account for dry deposition. A summary of the total amount of nitrogen deposition included as inputs to the HUMUS/SWAT model simulation is presented in table 38.

Table 38. 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, Pacific Northwest Basin*

	Urban land	Point sources		Wet and dry atmospheric deposition
Subregion	Nitrogen fertilizer (tons/year)	Nitrogen (tons/year)	Phosphorus (tons/year)	Nitrogen (tons/year)
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	6,051	5,772	1,239	23,168
Upper Columbia River Basin (code 1702)	3,651	2,111	644	5,236
Snake Headwaters-Upper Snake River Basin (code 1704)	4,439	3,767	1,245	19,265
Middle Snake River Basin (code 1705)	3,024	2,327	621	14,730
Lower Snake River Basin including Salmon-Clear Water (code 1706)	2,196	1,628	328	19,621
Middle Columbia River Basin including John Day-Deschutes (code 1707)	4,180	1,847	563	7,742
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	8,389	16,498	3,030	10,481
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	19,546	65,351	13,983	21,835
Total	51,477	99,299	21,654	122,078

*Excludes sources associated with the “Oregon closed basins” subregion (code 1712).

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

“Legacy Phosphorus” Not Accounted for in Modeling

“Legacy phosphorus” results from the over-application of phosphorus on farm fields in past years. When excessive amounts of fertilizer or manure are applied to a farm field, soil phosphorus levels increase dramatically. It may take many years or even decades for phosphorus levels to return to background levels once these practices are halted. Use of soil testing to determine the need for phosphorus applications can prevent further over-application, but there remains other phosphorus material locked into the soil profile within the field, along the edge of the field and drainageways, and in streambeds that cannot be offset by current management activities.

In addition, the transport of sediment—and the phosphorus bound to those particles—from farm fields to rivers and streams can take many years. Eroded soil particles leaving a farm field can be deposited where runoff slows or ponding occurs before reaching a stream or river. Once the sediment has entered streams, some of the soil particles settle out and can remain in the streambed or settle on the floodplain when the water is high and slow moving. These sediments can remain in place for years until a storm creates enough surface water runoff to re-suspend the previously eroded soil, or until streamflow cuts into streambanks made up of deposits of previously eroded soil. Windborne sediment transported into waterways can similarly be a mixture of newly eroded and previously eroded materials.

Consequently, the phosphorus content of eroded soil from farm fields can be high even when excessive amounts of fertilizer or manure are no longer being applied, including eroded soil from land that is not currently farmed. The measured phosphorus levels in rivers and streams include not only phosphorus lost from farm fields as a result of current farming activities but also “legacy phosphorus” adsorbed to soil particles as a result of prior farming activities. Some of this sediment-adsorbed “legacy phosphorus” can be solubilized by chemical reactions within the water body and measured as soluble phosphorus.

The simulation models used in this study do not account for these “legacy phosphorus” levels. There is recognition, however, that “legacy phosphorus” can be an important contributor to current levels of instream phosphorus loads, including soluble phosphorus.

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. 74).

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

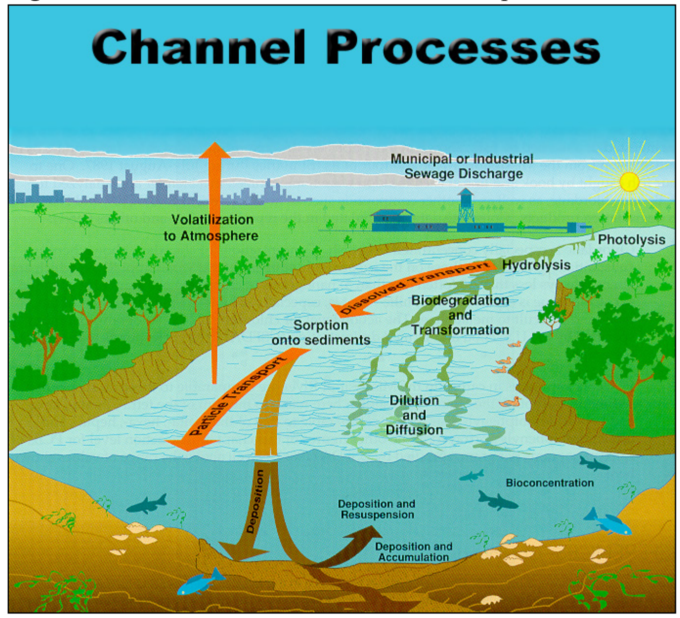
- **Sediment routing—deposition, bed degradation, and streambank erosion**. Sediment transport in the stream network is a function of two processes, deposition and degradation. SWAT computes deposition and degradation simultaneously within the reach. Deposition is based on the fall velocity of the sediment particles and the travel time through each stream. Stream power is used to predict bed and bank degradation; excess stream power results in degradation. Bed degradation and streambank erosion are based on the erodibility and vegetative cover of the bed or bank and the energy available to carry sediment (a function of depth, velocity and slope). The maximum amount of sediment that can be transported from a reach segment is a function of the peak channel velocity. Available stream power is used to re-entrain loose and deposited material until all of the material is removed.[28]

- **Nutrient routing**. Nutrient transformations in the stream are controlled by the instream water quality component of the model. The model tracks nutrients dissolved in the stream and nutrients adsorbed to the sediment. Dissolved nutrients are transported with the water, while those adsorbed to sediments are deposited with the sediment on the bed of the channel.

- **Pesticide routing**. As with nutrients, the total pesticide load in the channel is partitioned into dissolved and sediment-attached components. While the dissolved pesticide is transported with water, the pesticide attached to sediment is affected by sediment transport and deposition processes. Pesticide transformations in the dissolved and adsorbed phases are governed by first-order decay relationships. The major instream processes simulated by the model are settling, burial, resuspension, volatilization, diffusion, and transformation.

[28] There are no national estimates of streambank erosion that can be uniformly used to calibrate this component of the model. Parameters governing instream sediment processes are adjusted in concert with those governing upland sediment yields such that HUMUS predictions at calibration sites mimic measured sediment data. Sediment data collected at a single stream gauging site is a combination of upland and instream sources, which cannot be proportioned by source. Collectively a network of sediment monitoring sites may be used to develop a sediment budget for a watershed which may include a stream bank component. When such studies are available for a HUMUS region they are used as ancillary data during model calibration.

Figure 74. SWAT model channel simulation processes



Reservoirs

Reservoirs alter the dynamics of a free-flowing river, resulting in different rates of sediment deposition and chemical transformations. SWAT includes routines for reservoirs that account for the hydrological aspects of reservoirs. Basic reservoir data such as storage capacity and surface area were obtained from the dams database.

- **Reservoir outflow**. A simple target volume approach was used in this study to simulate reservoir outflow. The algorithm attempts to keep reservoir storage near the principal spillway volume during the flood season but allow water storage to accumulate above the principal storage during the non-flood season.

- **Sediment routing**. The concentration of sediment in the reservoir is estimated using a simple continuity equation based on volume and concentration of inflow, outflow, and water retained in the reservoir. Settling of sediment in the reservoir is governed by an equilibrium sediment concentration and the median sediment particle size. The amount of sediment in the reservoir outflow is the product of the volume of water flowing out of the reservoir and the suspended sediment concentration in the reservoir at the time of release.

- **Reservoir nutrients**. The model assumes that (1) the reservoir is completely mixed, (2) phosphorus is the limiting nutrient, and (3) total phosphorus is a measure of the trophic status. The phosphorus mass balance equation includes the concentration in the reservoir, inflow, outflow, and overall loss rate.

- **Reservoir pesticides**. The model partitions the system into a well-mixed surface water layer underlain by a well-mixed sediment layer for simulating the fate of pesticides. The pesticide is partitioned into dissolved and particulate phases in both the water and sediment layers. The major processes simulated by the model are loading, outflow, transformation, volatilization, settling, diffusion, resuspension, and burial.

Calibration

Both the SWAT and APEX models set up for the Pacific Northwest Basin were calibrated to capture the spatial variation in long-term average annual water yield for each 8-digit watershed. The observed water yield used for calibration was obtained from the USGS. Spatial calibration of water yield at each 8-digit watershed helped to capture the spatial variation in hydrology and the local water balance and streamflow calibration at gages. Time series calibration of streamflow was conducted at 6 gauging stations on the rivers in the Pacific Northwest Basin for the period between 1961 and 2006, depending on the length of data available. Predicted annual flows were compared against the gage data for the calibration period. Hydrologic parameters in APEX (used for simulating cultivated cropland) and SWAT (used for simulating non-cultivated land) such as curve number, soil water depletion coefficient, available water holding capacity, soil and plant evaporation compensation factors, and ground water related parameters were adjusted to match the water yield at the 8-digit watersheds and stream flow at the gages. When necessary, channel losses, seepage, and evaporation losses in reservoirs were adjusted to match the predicted flow time series with that of monitored data. Impoundments such as reservoirs and lakes in the Pacific Northwest Basin were represented in the model and their impact on trappings of sediment and nutrients were accounted.

Annual sediment loads were estimated using the grab sediment concentration and daily streamflow data collected at each calibration site using the USGS's Load Estimator software. Estimated annual sediment loads at six gauging stations were used to calibrate the SWAT model. APEX and SWAT model parameters related upland soil erosion and sediment yields (for cultivated and non-cultivated lands) such as soil erodibility factor, residue cover, lateral sediment concentration and slope were adjusted. Parameters controlling stream power, sediment carrying capacity of the channel, channel cover and erodibility factors in SWAT were adjusted for calibration of instream sediment loads at the gages. Where necessary, parameters affecting settling of sediment in reservoirs were adjusted. Delivery ratios from field to 8-digit watershed outlet and 8-digit watershed to river were adjusted to match the predicted sediment load with that of observations for each gauging station. Measures were taken to calibrate the proportion of the upland erosion versus channel erosion and transport/delivery of sediment through rivers and reservoirs to be reasonable.

Similar to sediment, various forms of annual nitrogen and phosphorus loads required for calibration were estimated. Nitrogen and phosphorus loads were estimated using daily streamflow and grab sample concentration data collected at the five calibration sites using the USGS's Load Estimator software. The source of most of these data was the USGS-NASQAN data monitoring program. Estimated total nitrogen and total phosphorus loads were used for calibration at six gauging stations in the SWAT model. Nitrate-nitrogen and nitrite-nitrogen (sum), total Kjeldahl nitrogen, and orthophosphate were calibrated at stations where monitoring data were available. For calibration of upland nutrients and nutrient losses from different land uses, parameters controlling nutrient uptake by plants, leaching of nitrogen and phosphorus through subsurface soil layers, groundwater nitrogen and phosphorus parameters, enrichment ratio of organic nutrients, nitrogen fixation coefficient, and nitrate leaching ratio were used as necessary in both models. 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.

Calibration results for this basin can be found in CEAP calibration documentation.[29] Further details on the CEAP model calibration can be found in Santhi et al. 2012 and White et al. 2014**.**

The "background" scenario

An additional scenario was conducted to represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by simulating with APEX a grass-and-tree-mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.[30] All SWAT modeling remained the same for this scenario. Thus, "background" loads include loads from all other land uses—hayland, pastureland, rangeland, horticulture, forestland, and urban land—as well as point sources.

Source Loads and Instream Loads

All source loads are introduced into SWAT at the outlet of each watershed (8-digit hydrologic unit code [HUC]). Flows and source loads from upstream watersheds are routed through each downstream watershed, including reservoirs when present.[31]

A sediment delivery ratio was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The sediment delivery ratio used in this study is a function of the ratio of the

[29] For a complete documentation of calibration procedures and results for the Pacific Northwest Basin, see "Calibration and Validation of CEAP HUMUS" at http://www.nrcs.usda.gov/technical/nri/ceap.

[30] In a natural ecosystem, the vegetative cover would include a mix of species, which would continually change until a stable ecosystem was established. APEX allows for multiple species and simulates plant competition over time according to plant growth, canopy cover, vegetative form, and relative maturity or growth stage. The initial mix of species at the beginning of the 47-year simulation was similar to the mix of grasses and trees used to establish long-term conserving cover. Mixes included at least one grass and one legume. Over the 47-year simulation, the mix of grasses and trees shifted due to plant competition. The grass species typically dominate in the simulation until shaded out by tree cover. For further details on how the background simulation was conducted, see "Assumptions and Procedures for Simulating the Natural Vegetation Background Scenario for the CEAP National Cropland Assessment" at http://www.nrcs.usda.gov/technical/nri/ceap.

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

time of concentration for the HRU (land uses other than cultivated cropland) or field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU.[32]

In addition to the sediment delivery ratio, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment-attached pesticide concentrations transported with sediment to the watershed outlet divided by their concentrations at the edge of the field. As sediment is transported from the edge of field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

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

There are four points in the modeling process at which source loads or instream loads are assessed, shown in the schematic in figure 75 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.

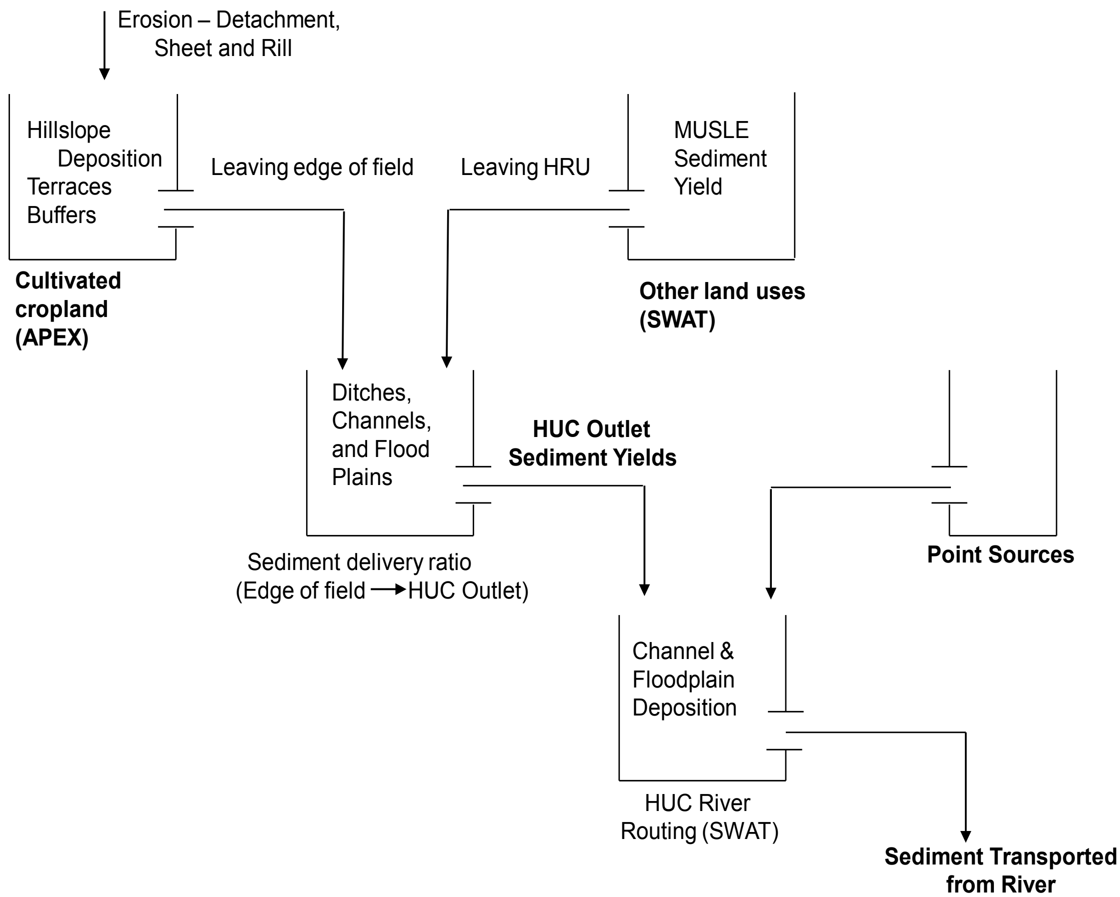
3. Delivery to the watershed outlet from land uses other than cultivated cropland as simulated by SWAT, after application of delivery ratios. Point sources are included.

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.

Loads for the herbicide atrazine, which was assessed using HUMUS/SWAT in previous CEAP reports, were not estimated for the Pacific Northwest Basin because of the low use of atrazine in the region. The survey found that atrazine was applied to only 3 percent of cropped acres in the Pacific Northwest Basin and accounted for only 2.5 percent of the total weight of pesticides lost from farm fields within the region.

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

Figure 75. Schematic of sediment sources and delivery as modeled with HUMUS/SWAT for the Pacific Northwest Basin



Modeling Land Use in the Pacific Northwest Basin

The USGS National Land-Cover Database for 2001 (Homer et al. 2007) was the principal source of acreage estimates for HUMUS/SWAT modeling. The 2003 National Resources Inventory (USDA-NRCS 2007) was used to adjust NLCD cropland acreage estimates to include acres in Conservation Reserve Program General Signups, used here to represent cropland in long-term conserving cover. Consequently, cultivated cropland acres used to simulate the water quality effects of conservation practices differ slightly from the cropped acres reported in the previous chapters that were based on the CEAP Cropland sample.

Estimates of the acreage by land use used in the model simulation to estimate the effects of conservation practices reported in this chapter are presented in figure 76 and table 39. Loads from cultivated cropland in the subregion "Oregon closed basins," code 1712, could not be estimated because no sample points were obtained in the CEAP sample. Results for this subregion are not included in tables and figures in this chapter so that direct comparisons can be made between land use acres and sediment and nutrient loads for the region.

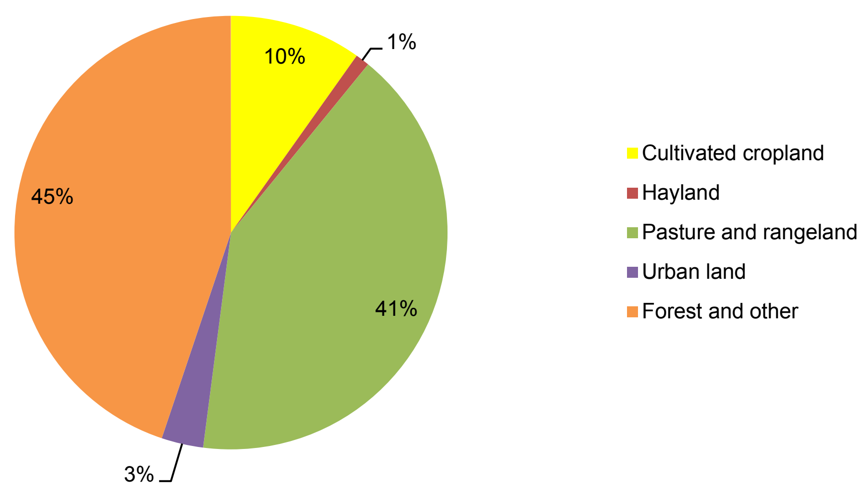
Cultivated cropland makes up only 10 percent of the land base in this region (fig. 76), and is not a dominant land use in any of the five subregions or three combinations of subregions.

Forest land accounts for 45 percent of the land base and pasture and rangeland account for 41 percent (table 39). One of these land uses is the dominant land use in each subregion and subregion combination.

The subregion with highest concentration of cultivated cropland is the Upper Columbia River Basin (code 1702), where 23 percent of the land base is cultivated cropland (table 39).

Cultivated cropland includes land in long-term conserving cover, which represents about 13 percent of the cultivated cropland acres in this region (table 4). This percentage varies, however, across the subregions, as shown in table 4.

Figure 76. Percent acres for land use/cover types in the Pacific Northwest Basin, exclusive of water



Note: Excludes acres in the "Oregon closed basins" subregion (code 1712).

Table 39. Acres by land use, exclusive of water, used in model simulations to estimate instream sediment and nutrient loads for the Pacific Northwest Basin

Subregions*	Cultivated cropland *	Hayland not in rotation with crops	Pasture and rangeland not in rotation with crops**	Urban land	Forest and other ***	Total land exclusive of water)
			Acres, excluding water			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	1,186,738	389,058	6,686,632	633,556	17,773,878	26,669,863
Upper Columbia River Basin (code 1702)	3,194,966	170,078	5,180,055	385,470	5,017,128	13,947,698
Snake Headwaters-Upper Snake River Basin (code 1704)	3,710,638	308,242	13,415,449	448,813	4,862,909	22,746,051
Middle Snake River Basin (code 1705)	1,114,258	226,597	18,286,732	295,937	3,616,304	23,539,828
Lower Snake River Basin including Salmon-Clear Water (code 1706)	3,021,713	82,660	7,739,741	233,380	11,242,511	22,320,005
Middle Columbia River Basin including John Day-Deschutes (code 1707)	3,173,192	85,487	9,191,268	434,836	6,057,753	18,942,535
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	512,318	191,456	2,409,021	866,118	7,104,888	11,083,801
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	100,555	249,465	4,006,404	1,762,950	17,215,321	23,334,696
Regional total	16,014,378	1,703,044	66,915,303	5,061,060	72,890,692	162,584,477
			Percent of total acres, excluding water			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	4	1	25	2	67	100
Upper Columbia River Basin (code 1702)	23	1	37	3	36	100
Snake Headwaters-Upper Snake River Basin (code 1704)	16	1	59	2	21	100
Middle Snake River Basin (code 1705)	5	1	78	1	15	100
Lower Snake River Basin including Salmon-Clear Water (code 1706)	14	<1	35	1	50	100
Middle Columbia River Basin including John Day-Deschutes (code 1707)	17	<1	49	2	32	100
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	5	2	22	8	64	100
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	<1	1	17	8	74	100
Regional total	10	1	41	3	45	100

*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. Excluded from the table are acres in the "Oregon closed basins" subregion (code 1712).

Loads Delivered from Cultivated Cropland to Rivers and Streams within the Region

HUMUS/SWAT accounts for the transport of water, sediment, pesticides, and nutrients from the land to receiving streams and routes the flow downstream to the next watershed and ultimately to estuaries and oceans. Not all of the sediment, nutrients, and pesticides that leave farm fields are delivered to streams and rivers. Some material is bound up in various parts of the landscape during transport. Loads delivered from cultivated cropland and other sources to rivers and streams within the Pacific Northwest Basin are presented in this section.

The water quality effects of conservation practices in use during 2003–06 on loads delivered from cultivated cropland to rivers and streams were assessed by comparing HUMUS/SWAT model simulation results for the baseline conservation condition to simulation results for the no-practice scenario. For the no-practice scenario, only the conditions for cultivated cropland were changed, as described previously. All other aspects of the simulations—including sediment and nutrient loads from point sources and land uses other than cultivated cropland—remained the same.

The field-level model results for the treatment scenarios with additional erosion control practices and nutrient management (chapter 6) were used with the HUMUS/SWAT model to determine the *potential for further reductions* in loads delivered from cultivated cropland to rivers and streams throughout the region with additional conservation treatment. Percent reductions relative to the baseline conservation condition were estimated for the 8.6 million acres with a "high" or "moderate" need for additional treatment for one or more resource concerns (70 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 Pacific Northwest Basin is shown in chapter 5, table 32.

*In summary, findings for the Pacific Northwest Basin indicate that for the baseline conservation condition, sediment and nutrient loads **delivered to rivers and streams from cultivated cropland sources** per year, on average, are:*

- *11.3 million tons of sediment (37 percent of loads from all sources);*
- *235 million pounds of nitrogen (27 percent of loads from all sources); and*
- *13.8 million pounds of phosphorus (16 percent of loads from all sources).*

*Conservation practices in use on cultivated cropland in 2003-06, including land in long-term conserving cover, have reduced sediment and nutrient loads **delivered to rivers and streams from cultivated cropland sources** per year, on average, by:*

- *53 percent for sediment;*
- *57 percent for nitrogen; and*
- *60 percent for phosphorus.*

Model simulations further showed that if the 8.6 million undertreated acres were fully treated with the appropriate soil erosion control and nutrient management practices, loads from cultivated cropland delivered to rivers and streams in the watershed would be reduced, relative to the baseline conservation condition:

- *73 percent for sediment;*
- *47 percent for nitrogen; and*
- *41 percent for phosphorus.*

Sediment

Baseline condition. Model simulation results show that of the 25.7 million tons of sediment exported from farm fields in the Pacific Northwest Basin (table 40), about 11.3 million tons are delivered to rivers and streams each year (table 41), on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006. About 0.71 ton of sediment per acre of cultivated cropland is delivered to rivers and streams per year, on average, within the region (table 41).

The majority of the sediment delivered to rivers and streams from cultivated cropland in this region originates in three subregions (table 41)—

- the Middle Columbia River Basin including John Day-Deschutes (code 1707), with 24 percent of the basin total,
- the Lower Snake River Basin including Salmon-Clear Water (code 1706), with 20 percent of the basin total, and
- the Snake Headwaters-Upper Snake River Basin (code 1704), with 18 percent of the basin total.

These three subregions together account for 62 percent of the sediment delivered to rivers and streams from cultivated cropland within the region. They account for a smaller proportion—47 percent—of the cultivated cropland acres in the region.

The subregion with the highest per-acre delivery of sediment—8.7 tons per acre—is the Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711), which has the least amount of cultivated cropland in the region but also has the highest annual precipitation.

Sediment delivered to rivers and streams from cultivated cropland represents about 37 percent of the total sediment load delivered from all sources in the region (table 42, fig. 77). In contrast, cultivated cropland acres make up only 10 percent of the land base in the region.

Cultivated cropland is the dominant source of sediment in five subregions (table 42)—

- the Middle Snake River Basin (code 1705), where cultivated cropland is the source of 75 percent of the sediment delivered to rivers and streams,
- the Lower Snake River Basin including Salmon-Clear Water (code 1706), where cultivated cropland is the source of 67 percent of the sediment delivered to rivers and streams,
- the Middle Columbia River Basin including John Day-Deschutes (code 1707), where cultivated cropland is the source of 65 percent of the sediment delivered to rivers and streams,
- the Upper Columbia River Basin (code 1702), where cultivated cropland is the source of 63 percent of the sediment delivered to rivers and streams, and
- the Snake Headwaters-Upper Snake River Basin (code 1704), where cultivated cropland is the source of 59 percent of the sediment delivered to rivers and streams.

Urban nonpoint sources are the dominant source of sediment in the Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709) (table 42), where urban nonpoint sources account for 30 percent of the sediment delivered to rivers and streams.. For the region, urban nonpoint sources account for only 12 percent of the total sediment load delivered from all sources (table 42, fig. 77).

Pasture and rangeland are the dominant sources of sediment in the Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703), accounting for 38 percent of the sediment delivered to rivers and streams. For the region, the pasture and rangeland accounts for 27 percent of the total sediment load delivered from all sources in the region (table 42, fig. 77).

Urban nonpoint sources are the dominant source of sediment in the Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709) (table 42) where urban nonpoint sources account for 30 percent of the sediment delivered to rivers and streams. For the region, urban nonpoint sources account for only 12 percent of the total sediment load delivered from all sources in the region (table 42, fig. 77).

Hayland and urban point sources account for only a tiny proportion of the sediment delivered to rivers and streams in the region—totaling about 1 percent for the region.

Effects of conservation practices. Model simulations indicate that conservation practices have reduced the delivery of sediment from fields to rivers and streams by about 53 percent (table 41, fig. 78), on average, in this region. Reductions due to conservation practices vary throughout the region from a low of 41 percent in the Lower Snake River Basin including Salmon-Clear Water (code 1706) to a high of 66 percent in the Upper Columbia River Basin (code 1702).

Potential gains from further conservation treatment. Model simulations show that use of additional erosion control practices on the 8.6 million under-treated acres in the region would further reduce sediment loads delivered to rivers and streams by 3.0 million tons per year, representing a reduction from baseline levels of 73 percent (table 43, fig. 78).

Potential reductions due to additional conservation treatment vary throughout the region from a low of 26 percent in the Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711) to a high of 87 percent in the Lower Snake River Basin including Salmon-Clear Water (code 1706).

Table 40. Average annual sediment loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Pacific Northwest Basin

Subregions*	Baseline conservation condition: Amount (1,000 tons)	Percent of basin total	Tons delivered per cultivated cropland acre	No-practice Scenario (1,000 tons)	Reductions in loads due to conservation practices: Reduction (1,000 tons)	Percent
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	1,386	5%	1.17	4,236	2,850	67%
Upper Columbia River Basin (code 1702)	712	3%	0.22	3,174	2,462	78%
Snake Headwaters-Upper Snake River Basin (code 1704)	3,275	13%	0.88	10,240	6,965	68%
Middle Snake River Basin (code 1705)	2,942	11%	2.64	5,756	2,814	49%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	6,645	26%	2.20	11,230	4,585	41%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	6,901	27%	2.17	12,410	5,509	44%
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	2,028	8%	3.96	4,937	2,909	59%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	1,782	7%	17.72	5,814	4,032	69%
Regional total	25,671	100%	1.60	57,797	32,127	56%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Some columns do not add to totals because of rounding.

Table 41. Average annual sediment loads ***delivered to watershed outlets*** (8-digit HUCs) ***from cultivated cropland*** in the Pacific Northwest Basin

Subregions*	Baseline conservation condition: Amount (1,000 tons)	Percent of basin total	Tons delivered per cultivated cropland acre	No-practice Scenario (1,000 tons)	Reductions in loads due to conservation practices: Reduction (1,000 tons)	Percent
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	555	5%	0.47	1,593	1,038	65%
Upper Columbia River Basin (code 1702)	716	6%	0.22	2,104	1,388	66%
Snake Headwaters-Upper Snake River Basin (code 1704)	1,982	18%	0.53	4,807	2,825	59%
Middle Snake River Basin (code 1705)	1,304	12%	1.17	2,300	996	43%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	2,296	20%	0.76	3,877	1,581	41%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	2,752	24%	0.87	4,810	2,058	43%
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	837	7%	1.63	1,969	1,132	57%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	870	8%	8.66	2,424	1,554	64%
Regional total	11,312	100%	0.71	23,884	12,572	53%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

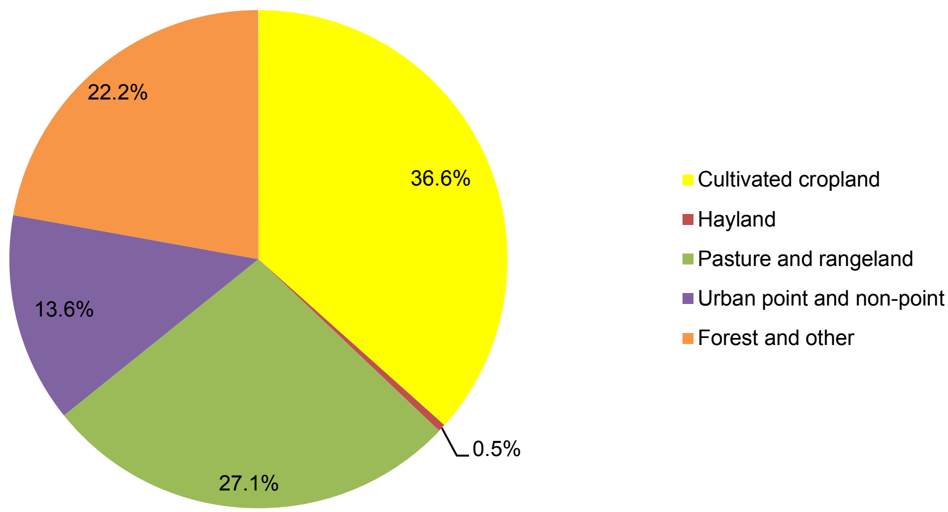
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 40 are due to the application of delivery ratios, which were used to simulate delivery of sediment from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.

Table 42. Average annual sediment loads ***delivered to watershed outlets*** (8-digit HUCs) from each source in the Pacific Northwest Basin, baseline conservation condition

Subregions*	All sources	Cultivated cropland**	Hayland	Pasture and rangeland	Urban nonpoint sources***	Urban point sources	Forest and other****
				Amount (1,000 tons)			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	2,659	555	28	1,000	212	18	846
Upper Columbia River Basin (code 1702)	1,144	716	13	125	82	6	202
Snake Headwaters-Upper Snake River Basin (code 1704)	3,343	1,982	3	1,027	30	7	292
Middle Snake River Basin (code 1705)	1,731	1,304	4	262	27	5	129
Lower Snake River Basin including Salmon-Clear Water (code 1706)	3,413	2,296	4	535	61	5	511
Middle Columbia River Basin including John Day-Deschutes (code 1707)	4,216	2,752	3	1,001	201	6	254
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	3,931	837	49	911	1,172	58	904
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	10,476	870	47	3,527	2,014	306	3,711
Regional total	30,912	11,312	152	8,389	3,800	410	6,849
				Percent of all sources			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	100%	21%	1%	38%	8%	1%	32%
Upper Columbia River Basin (code 1702)	100%	63%	1%	11%	7%	<1%	18%
Snake Headwaters-Upper Snake River Basin (code 1704)	100%	59%	<1%	31%	1%	<1%	9%
Middle Snake River Basin (code 1705)	100%	75%	<1%	15%	2%	<1%	7%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	100%	67%	<1%	16%	2%	<1%	15%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	100%	65%	<1%	24%	5%	<1%	6%
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	100%	21%	1%	23%	30%	1%	23%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	100%	8%	<1%	34%	19%	3%	35%
Regional total	100%	37%	<1%	27%	12%	1%	22%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).
** Includes land in long-term conserving cover, excludes horticulture.
*** Includes construction sources and urban land runoff.
**** Includes forests (all types), wetlands, horticulture, and barren land.

Figure 77. Percentage by source of average annual sediment loads delivered to rivers and streams in the Pacific Northwest Basin, baseline conservation condition*



* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

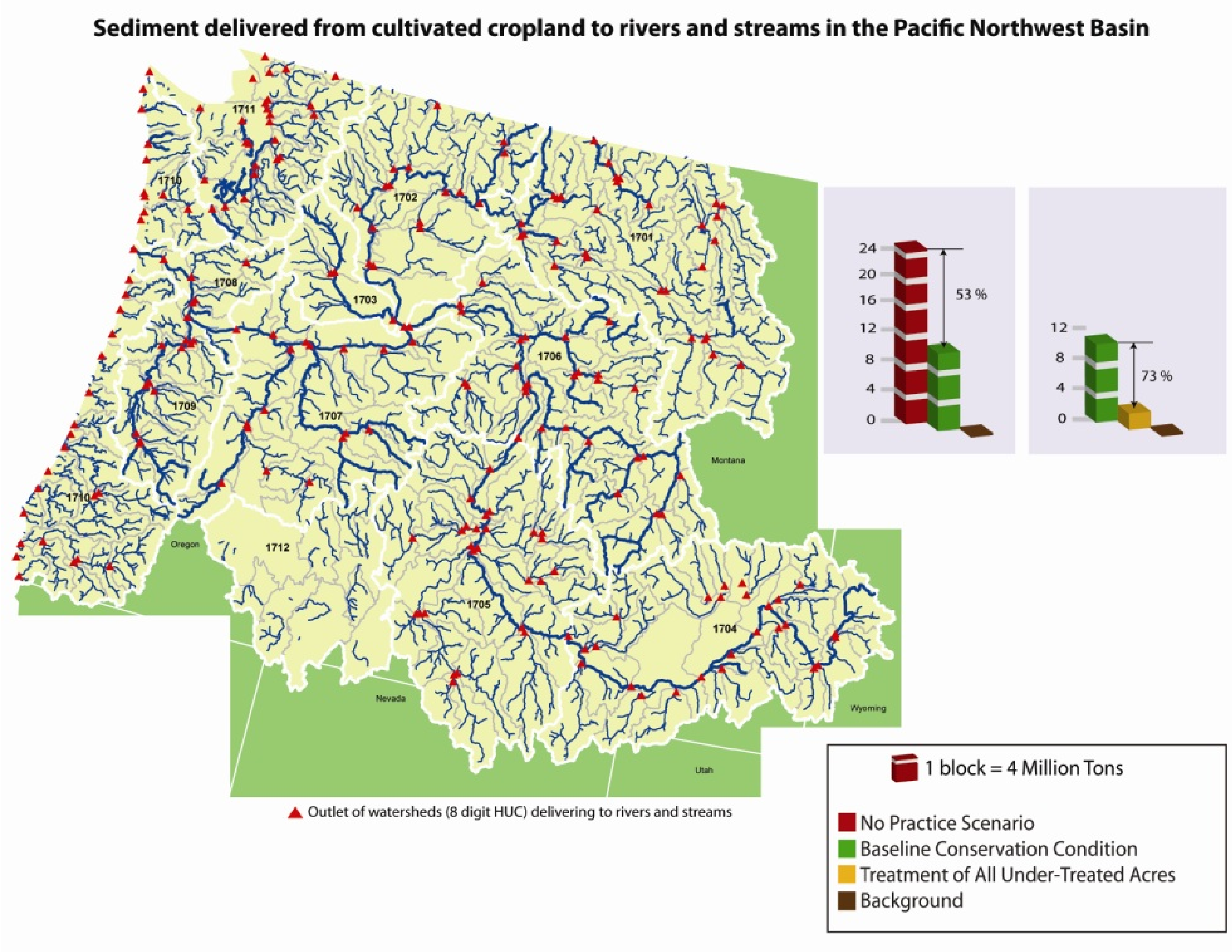
Table 43. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **sediment source loads** ***delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Pacific Northwest Basin

	Baseline conservation condition	Treatment of all 8.6 million undertreated acres	
Subregion*	Average annual load (1,000 tons)	Average annual load (1,000 tons)	Percent reduction
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	555	92	83%
Upper Columbia River Basin (code 1702)	716	99	86%
Snake Headwaters-Upper Snake River Basin (code 1704)	1,982	739	63%
Middle Snake River Basin (code 1705)	1,304	213	84%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	2,296	304	87%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	2,752	629	77%
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	837	327	61%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	870	644	26%
Regional total	11,312	3,047	73%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Figure 78. Effects of conservation practices on average annual sediment loads delivered to rivers and streams, Pacific Northwest Basin*



* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

Total Nitrogen

Baseline condition. Model simulation results show that of the 298 million pounds of nitrogen exported from farm fields in the Pacific Northwest Basin (table 44), about 235 million pounds are delivered to rivers and streams each year (table 45), 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 15 pounds of nitrogen per acre of cultivated cropland are delivered to rivers and streams per year, on average, within the region (table 45).

The majority of the nitrogen delivered to rivers and streams from cultivated cropland in this region originates in three subregions (table 45)—

- the Middle Snake River Basin (code 1705), with 22 percent of the basin total,
- the Middle Columbia River Basin including John Day-Deschutes (code 1707), with 20 percent of the basin total, and
- the Snake Headwaters-Upper Snake River Basin (code 1704), with 19 percent of the basin total.

These three subregions together account for 61 percent of the nitrogen delivered to rivers and streams from cultivated cropland within the region. They account for a much smaller proportion—38 percent—of the cultivated cropland acres in the region.

The subregion with the highest per-acre delivery of nitrogen—178 pounds per acre—is the Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711), which has the least amount of cultivated cropland in the region but also has the highest annual precipitation.

Sources of nitrogen are fairly evenly spread among the land use categories in this region. Nitrogen delivered to rivers and streams from cultivated cropland totals 235 million pounds per year, representing about 27 percent of the total nitrogen load delivered from all sources in the region (table 46, fig. 79). In contrast, cultivated cropland acres make up only 10 percent of the land base in the region. About equal amounts of nitrogen are delivered from pasture and rangeland sources (224 million pounds) and the "forest and other" land use category (228 million pounds per year). Another 180 million pounds per year are delivered from urban nonpoint and point sources in the region, representing about 21 percent of the total nitrogen load delivered from all sources in the region (table 46, fig. 79).

Cultivated cropland is the dominant source of nitrogen in five subregions (table 46)—

- the Middle Snake River Basin (code 1705), where cultivated cropland is the source of 56 percent of the nitrogen delivered to rivers and streams,
- the Middle Columbia River Basin including John Day-Deschutes (code 1707), where cultivated cropland is the source of 55 percent of the nitrogen delivered to rivers and streams,
- the Snake Headwaters-Upper Snake River Basin (code 1704), where cultivated cropland is the source of 50 percent of the nitrogen delivered to rivers and streams,
- the Upper Columbia River Basin (code 1702), where cultivated cropland is the source of 42 percent of the sediment delivered to rivers and streams, and
- the Lower Snake River Basin including Salmon-Clear Water (code 1706), where cultivated cropland is the source of 35 percent of the nitrogen delivered to rivers and streams.

The "forest and other" land use category is the dominant source of nitrogen in the remaining three subregion combinations (table 46).

Effects of conservation practices. Model simulations indicate that conservation practices have reduced the delivery of nitrogen from fields to rivers and streams by about 57 percent (table 45, fig. 80), on average, in this region. Reductions due to conservation practices vary throughout the region from a low of 24 percent in the Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709) to a high of 76 percent in the Snake Headwaters-Upper Snake River Basin (code 1704).

Potential gains from further conservation treatment. Model simulations show that use of additional erosion control and nutrient management practices on the 8.6 million under-treated acres in the region would further reduce nitrogen loads delivered to rivers and streams by 124 million pounds per year, representing a reduction from baseline levels of 47 percent (table 47, fig. 80).

Potential reductions due to additional conservation treatment vary throughout the region from a low of 17 percent in the Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711) to a high of 64 percent in the Middle Snake River Basin (code 1705).

Table 44. Average annual nitrogen loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Pacific Northwest Basin

Subregions*	Baseline conservation condition: Amount (1,000 pounds)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	14,774	5%	12.45	41,020	26,246	64%
Upper Columbia River Basin (code 1702)	21,100	7%	6.60	57,210	36,110	63%
Snake Headwaters-Upper Snake River Basin (code 1704)	50,290	17%	13.55	211,400	161,110	76%
Middle Snake River Basin (code 1705)	60,230	20%	54.05	110,300	50,070	45%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	40,730	14%	13.48	80,130	39,400	49%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	59,320	20%	18.69	102,100	42,780	42%
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	24,872	8%	48.55	33,455	8,583	26%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	26,414	9%	262.68	35,010	8,596	25%
Regional total	297,730	100%	18.59	670,625	372,895	56%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Some columns do not add to totals because of rounding.

Table 45. Average annual nitrogen loads ***delivered to watershed outlets*** (8-digit HUCs) ***from cultivated cropland*** in the Pacific Northwest Basin

Subregions*	Baseline conservation condition: Amount (1,000 pounds)	Baseline conservation condition: Percent of basin total	Baseline conservation condition: Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Reductions in loads due to conservation practices: Percent
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	10,783	5%	9.09	31,690	20,907	66%
Upper Columbia River Basin (code 1702)	20,070	9%	6.28	51,240	31,170	61%
Snake Headwaters-Upper Snake River Basin (code 1704)	44,260	19%	11.93	185,100	140,840	76%
Middle Snake River Basin (code 1705)	52,530	22%	47.14	95,440	42,910	45%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	22,840	10%	7.56	50,600	27,760	55%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	46,970	20%	14.80	80,730	33,760	42%
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	19,515	8%	38.09	25,527	6,012	24%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	17,850	8%	177.51	23,708	5,858	25%
Regional total	234,818	100%	14.66	544,035	309,217	57%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

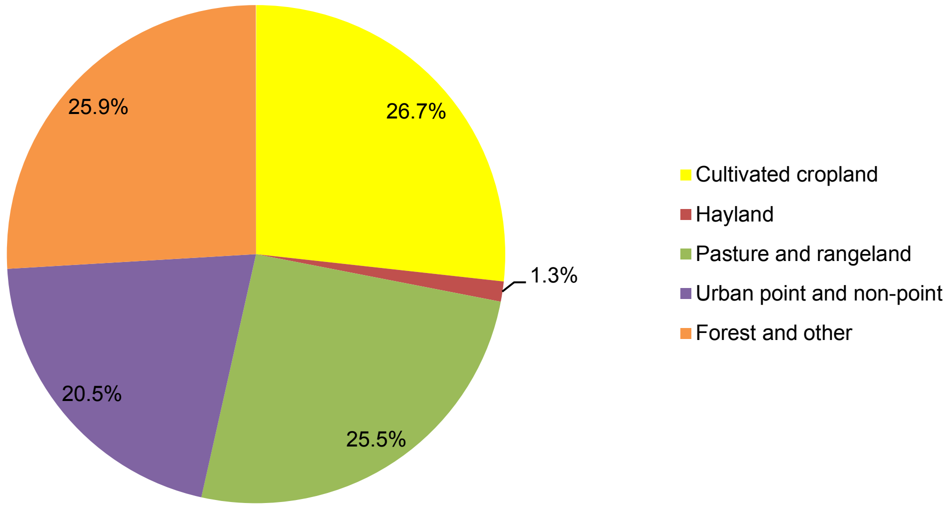
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 44 are due to the application of delivery ratios, which were used to simulate delivery of sediment from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.

Table 46. Average annual nitrogen loads ***delivered to watershed outlets*** (8-digit HUCs) from each source in the Pacific Northwest Basin, baseline conservation condition

Subregions*	All sources	Cultivated cropland**	Hayland	Pasture and rangeland	Urban nonpoint sources***	Urban point sources	Forest and other****
				Amount (1,000 pounds)			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	69,530	10,783	2,823	19,021	4,761	10,411	21,731
Upper Columbia River Basin (code 1702)	47,467	20,070	549	9,911	2,564	3,807	10,566
Snake Headwaters-Upper Snake River Basin (code 1704)	87,998	44,260	666	29,478	984	6,794	5,816
Middle Snake River Basin (code 1705)	94,236	52,530	728	29,275	1,394	4,197	6,113
Lower Snake River Basin including Salmon-Clear Water (code 1706)	64,867	22,840	460	22,672	1,981	2,935	13,978
Middle Columbia River Basin including John Day-Deschutes (code 1707)	84,918	46,970	371	18,615	4,319	3,330	11,314
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	138,657	19,515	2,538	28,745	13,449	29,755	44,654
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	290,159	17,850	3,274	65,999	22,886	66,616	113,535
Regional total	877,833	234,818	11,408	223,716	52,338	127,846	227,707
				Percent of all sources			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	100%	16%	4%	27%	7%	15%	31%
Upper Columbia River Basin (code 1702)	100%	42%	1%	21%	5%	8%	22%
Snake Headwaters-Upper Snake River Basin (code 1704)	100%	50%	1%	33%	1%	8%	7%
Middle Snake River Basin (code 1705)	100%	56%	1%	31%	1%	4%	6%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	100%	35%	1%	35%	3%	5%	22%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	100%	55%	<1%	22%	5%	4%	13%
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	100%	14%	2%	21%	10%	21%	32%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	100%	6%	1%	23%	8%	23%	39%
Regional total	100%	27%	1%	25%	6%	15%	26%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).
** Includes land in long-term conserving cover, excludes horticulture.
*** Includes construction sources and urban land runoff.
**** Includes forests (all types), wetlands, horticulture, and barren land.

Figure 79. Percentage by source of average annual nitrogen loads delivered to rivers and streams in the Pacific Northwest Basin, baseline conservation condition*



* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

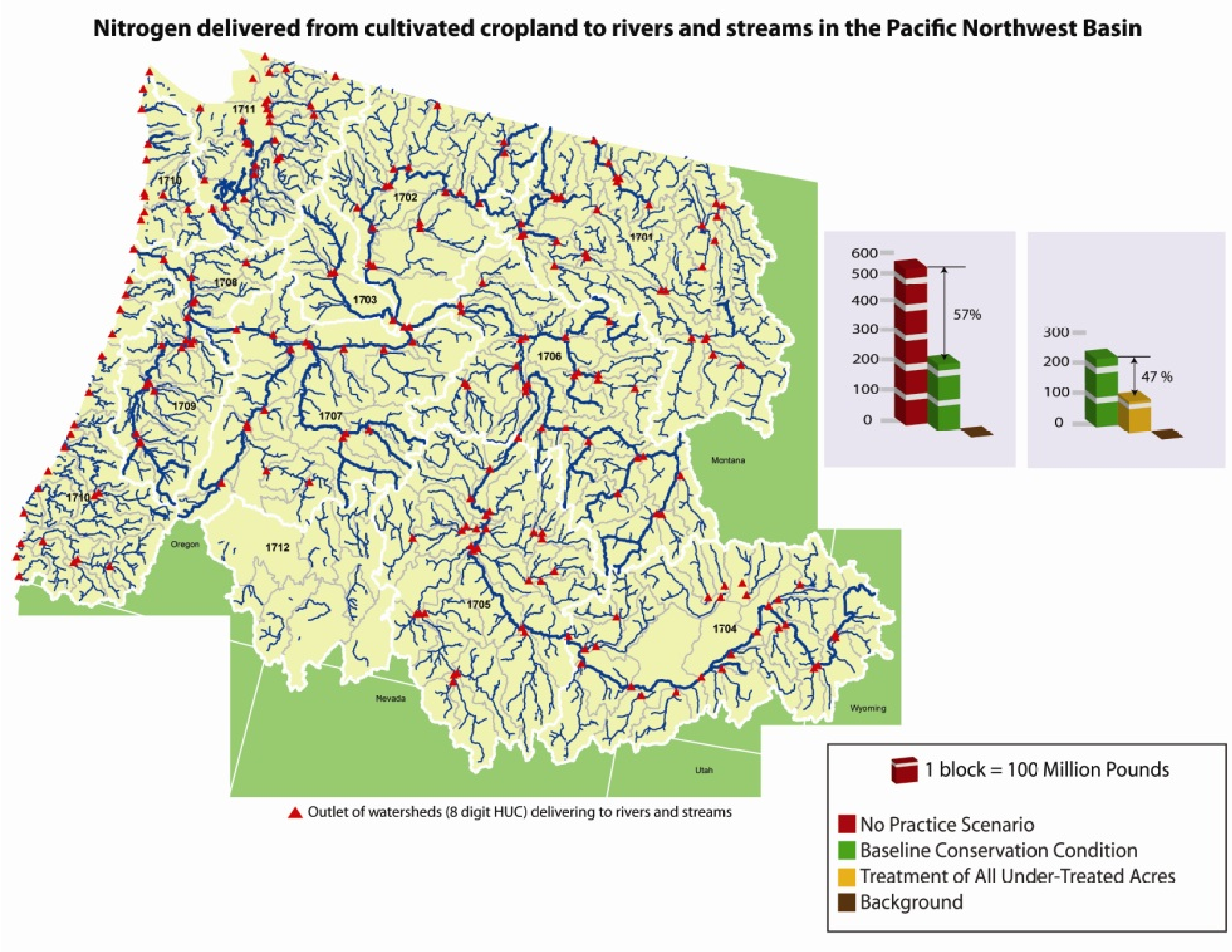
Table 47. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual **nitrogen source loads *delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Pacific Northwest Basin

	Baseline conservation condition	Treatment of all 8.6 million undertreated acres	
Subregion*	Average annual load (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	10,783	8,486	21%
Upper Columbia River Basin (code 1702)	20,070	8,987	55%
Snake Headwaters-Upper Snake River Basin (code 1704)	44,260	24,520	45%
Middle Snake River Basin (code 1705)	52,530	18,760	64%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	22,840	11,610	49%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	46,970	22,500	52%
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	19,515	14,027	28%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	17,850	14,826	17%
Regional total	234,818	123,716	47%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Figure 80. Effects of conservation practices on average annual nitrogen loads delivered to rivers and streams, Pacific Northwest Basin*



* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

Total Phosphorus

Baseline condition. Model simulation results show that of the 31 million pounds of phosphorus exported from farm fields in the Pacific Northwest Basin (table 48), about 14 million pounds are delivered to rivers and streams each year (table 49), on average, under conditions represented by the baseline conservation condition, which simulates farming activities and conservation practices in use during the period 2003 to 2006. About 0.9 pound of phosphorus per acre of cultivated cropland is delivered to rivers and streams per year, on average, within the region (table 49).

The majority of the phosphorus delivered to rivers and streams from cultivated cropland in this region originates in three subregions (table 45)—

- the Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711),with 19 percent of the basin total,
- the Snake Headwaters-Upper Snake River Basin (code 1704), with 18 percent of the basin total, and
- the Lower Snake River Basin including Salmon-Clear Water (code 1706), with 16 percent of the basin total.

These three subregions together account for 53 percent of the phosphorus delivered to rivers and streams from cultivated cropland within the region. They account for a much smaller proportion—31 percent—of the cultivated cropland acres in the region.

The subregion with the highest per-acre delivery of phosphorus—26 pounds per acre—is the Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711), which has the least amount of cultivated cropland in the region but also has the highest annual precipitation.

Phosphorus delivered to rivers and streams from cultivated cropland represents about 16 percent of the total phosphorus load delivered from all sources in the region (table 50, fig. 81). The dominant source of phosphorus for the region is urban point sources, representing 45 percent of the total phosphorus load delivered from all sources in the region. Pasture and rangeland sources account for 20 percent, the "forest and other" land use category accounts for 11 percent, and urban nonpoint sources account for 6 percent. Hayland accounts for only about 1 percent of the total phosphorus load delivered from all sources in the region.

Cultivated cropland is the dominant source of phosphorus in four subregions (table 50)—

- the Lower Snake River Basin including Salmon-Clear Water (code 1706), where cultivated cropland is the source of 54 percent of the phosphorus delivered to rivers and streams,
- the Middle Snake River Basin (code 1705), where cultivated cropland is the source of 52 percent of the phosphorus delivered to rivers and streams,
- the Snake Headwaters-Upper Snake River Basin (code 1704), where cultivated cropland is the source of 41 percent of the phosphorus delivered to rivers and streams, and
- the Middle Columbia River Basin including John Day-Deschutes (code 1707), where cultivated cropland is the source of 37 percent of the phosphorus delivered to rivers and streams.

Urban point sources are the dominant source of phosphorus in the other subregions (table 50).

Effects of conservation practices. Model simulations indicate that conservation practices have reduced the delivery of phosphorus from fields to rivers and streams by about 60 percent (table 49, fig. 82), on average, in this region. Reductions due to conservation practices vary throughout the region from a low of 20 percent in the Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711) to a high of 80 percent in the Upper Columbia River Basin (code 1702).

Potential gains from further conservation treatment. Model simulations show that use of additional erosion control and nutrient management practices on the 8.6 million under-treated acres in the region would further reduce phosphorus loads delivered to rivers and streams by 8 million pounds per year, representing a reduction from baseline levels of 41 percent (table 51, fig. 82).

Potential reductions due to additional conservation treatment vary throughout the region from a low of 25 percent in the Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709) to a high of 71 percent in the Middle Snake River Basin (code 1705).

Table 48. Average annual phosphorus loads ***delivered to edge of field*** (APEX model output) from cultivated cropland in the Pacific Northwest Basin

Subregions*	Baseline conservation condition: Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Percent
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	1,857	6%	1.56	6,506	4,649	71%
Upper Columbia River Basin (code 1702)	695	2%	0.22	4,638	3,943	85%
Snake Headwaters-Upper Snake River Basin (code 1704)	3,587	12%	0.97	15,170	11,583	76%
Middle Snake River Basin (code 1705)	3,720	12%	3.34	9,786	6,066	62%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	7,636	25%	2.53	16,070	8,434	52%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	4,253	14%	1.34	9,481	5,228	55%
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	3,935	13%	7.68	7,327	3,392	46%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	5,160	17%	51.32	6,891	1,731	25%
Regional total	30,843	100%	1.93	75,869	45,026	59%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Loads represent both cropped acres and land in long-term conserving cover. Some columns do not add to totals because of rounding.

Table 49. Average annual phosphorus loads ***delivered to watershed outlets*** (8-digit HUCs) ***from cultivated cropland*** in the Pacific Northwest Basin

Subregions*	Baseline conservation condition: Amount (1,000 pounds)	Percent of basin total	Pounds delivered per cultivated cropland acre	No-practice Scenario (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Percent
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	722	5%	0.61	2,574	1,852	72%
Upper Columbia River Basin (code 1702)	531	4%	0.17	2,596	2,065	80%
Snake Headwaters-Upper Snake River Basin (code 1704)	2,429	18%	0.65	8,964	6,535	73%
Middle Snake River Basin (code 1705)	1,926	14%	1.73	4,930	3,004	61%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	2,209	16%	0.73	5,043	2,834	56%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	1,498	11%	0.47	3,464	1,966	57%
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	1,861	13%	3.63	3,438	1,578	46%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	2,622	19%	26.08	3,294	672	20%
Regional total	13,799	100%	0.86	34,303	20,505	60%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

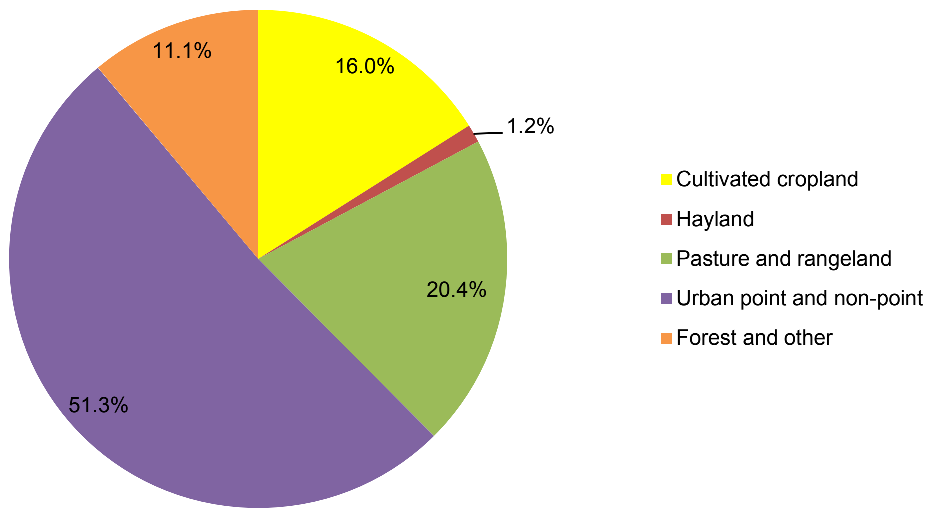
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. The differences between loadings in this table and table 48 are due to the application of delivery ratios, which were used to simulate delivery of sediment from the edge of the field to the watershed outlet (8-digit HUC). Some columns do not add to totals because of rounding.

Table 50. Average annual phosphorus loads ***delivered to watershed outlets*** (8-digit HUCs) from each source in the Pacific Northwest Basin, baseline conservation condition

Subregions*	All sources	Cultivated cropland**	Hayland	Pasture and rangeland	Urban nonpoint sources***	Urban point sources	Forest and other****
				Amount (1,000 pounds)			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	5,518	722	95	1,605	239	2,234	623
Upper Columbia River Basin (code 1702)	2,278	531	35	345	89	1,162	116
Snake Headwaters-Upper Snake River Basin (code 1704)	5,897	2,429	19	963	32	2,245	210
Middle Snake River Basin (code 1705)	3,715	1,926	10	592	28	1,120	39
Lower Snake River Basin including Salmon-Clear Water (code 1706)	4,079	2,209	8	977	69	592	224
Middle Columbia River Basin including John Day-Deschutes (code 1707)	4,100	1,498	12	1,199	227	1,016	149
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	13,499	1,861	338	2,585	1,406	5,466	1,844
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	46,815	2,622	487	9,255	3,042	25,220	6,188
Regional total	86,059	13,799	1,003	17,521	5,131	39,055	9,550
				Percent of all sources			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	100%	13%	2%	29%	4%	40%	11%
Upper Columbia River Basin (code 1702)	100%	23%	2%	15%	4%	51%	5%
Snake Headwaters-Upper Snake River Basin (code 1704)	100%	41%	<1%	16%	1%	38%	4%
Middle Snake River Basin (code 1705)	100%	52%	<1%	16%	1%	30%	1%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	100%	54%	<1%	24%	2%	15%	5%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	100%	37%	<1%	29%	6%	25%	4%
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	100%	14%	3%	19%	10%	40%	14%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	100%	6%	1%	20%	6%	54%	13%
Regional total	100%	16%	1%	20%	6%	45%	11%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).
** Includes land in long-term conserving cover, excludes horticulture.
*** Includes construction sources and urban land runoff.
**** Includes forests (all types), wetlands, horticulture, and barren land.

Figure 81. Percentage by source of average annual phosphorus loads delivered to rivers and streams in the Pacific Northwest Basin, baseline conservation condition*



* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

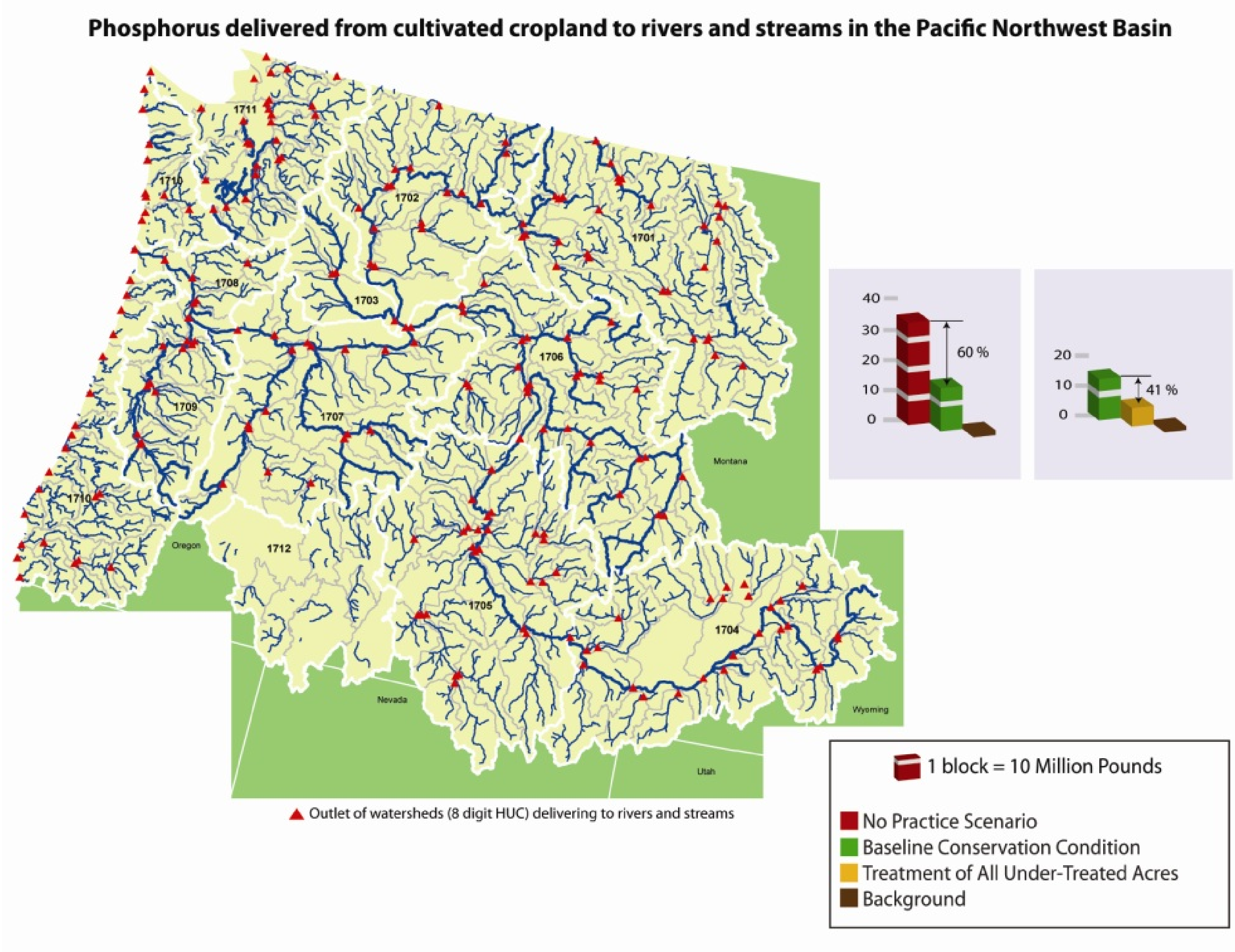
Table 51. Effects of additional conservation treatment with erosion control practices ***and*** nutrient management practices on average annual **phosphorus source loads *delivered to watershed outlets*** (8-digit HUCs) from cultivated cropland for the Pacific Northwest Basin

	Baseline conservation condition	Treatment of all 8.6 million undertreated acres	
Subregion*	Average annual load (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	722	473	34%
Upper Columbia River Basin (code 1702)	531	231	56%
Snake Headwaters-Upper Snake River Basin (code 1704)	2,429	1,699	30%
Middle Snake River Basin (code 1705)	1,926	561	71%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	2,209	992	55%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	1,498	933	38%
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)	1,861	1,397	25%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	2,622	1,835	30%
Regional total	13,799	8,122	41%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

Notes: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding. Critical undertreated acres have a high need for additional treatment. Undertreated acres have either a high or moderate need for additional treatment.

Figure 82. Effects of conservation practices on average annual phosphorus loads delivered to rivers and streams, Pacific Northwest Basin*



* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

Instream Loads from All Sources Delivered to the Pacific Ocean

Instream loads are estimated by starting with the loads delivered from *all sources* at the outlet of each 8-digit HUC and routing those loads downstream. Stream and channel processes are simulated, including flood routing, instream degradation processes, streambed deposition, streambank erosion, and reservoir dynamics. A portion of the sediment, nutrients, and pesticides delivered to rivers and streams is removed or trapped during these processes. Some of the nitrogen is lost during instream nitrification processes, and a portion of the sediment and sediment-bound nutrients and pesticides is deposited in streambeds and flood plains during transit. Large reservoirs can trap significant amounts of loads delivered to rivers and streams, keeping those loads from being transferred downstream. Sediment can also be added to instream loads through streambank erosion and streambed scouring.

Instream loads represent *all sources* of sediment, nutrients, and pesticides. In some river systems, the predominant source of instream loads is urban point sources, while in other river systems the predominant source of instream loads is cultivated cropland.

Baseline conservation condition

After accounting for instream deposition, reservoir dynamics, streambank erosion, and other transport processes, model simulations indicate that total instream loads from all of these sources deliver to the Pacific Ocean, on average, for the baseline conservation condition (tables 52, 53, and 54)—

- 15.7 million tons per year of sediment,
- 400 million pounds per year of nitrogen, and
- 62 million pounds per year of phosphorus.

The results of the "background scenario," described previously, were used to estimate the percentage of instream sediment and nutrient loads that would likely be attributable to cultivated cropland sources. The background scenario represents loads that would be expected if no acres in the drainage systems were cultivated. The amount attributed to cultivated cropland was determined by subtracting the instream loads in the "background" scenario from the total load from all sources in the baseline conservation scenario. Using this approach, the percentage of instream sediment and nutrient loads delivered to the Pacific Ocean that is attributed to cultivated cropland sources, based on the model simulation, is (tables 52, 53, and 54)—

- 4 percent for sediment,
- 13 percent for total nitrogen, and
- 9 percent for total phosphorus.

Effects of conservation practices

The effects of conservation practices are estimated for instream loads in the same manner as was done for loads delivered to rivers and streams. The percent reductions in total instream loads, however, are small in this region because conservation practices affect only the cultivated cropland component of the total instream load. As shown previously, cultivated cropland is the dominant source of sediment and nutrients in some subregions.

Conservation practices in use on cultivated cropland in 2003-06, including land in long-term conserving cover, have reduced annual instream loads from all sources delivered from the Pacific Northwest Basin to the Pacific Ocean, on average, by (tables 52, 53, and 54; figs. 83, 84, and 85)—

- 5 percent for sediment,
- 16 percent for nitrogen, and
- 8 percent for phosphorus.

Reductions are highest in the Snake Headwaters-Upper Snake River Basin (code 1704), where conservation practices have reduced annual instream loads from all sources, on average, by (tables 52, 53, and 54)—

- 42 percent for sediment,
- 66 percent for nitrogen, and
- 64 percent for phosphorus.

Potential gains from further conservation treatment

Estimates are also available for how much additional reduction in instream loads from all sources might be possible from further conservation treatment for all undertreated acres in the basin (acres with a high or moderate level of need for additional treatment). Additional conservation treatment included erosion control practices, irrigation management, and nutrient management.

Model simulation results indicate that additional conservation treatment of the 8.6 million under-treated acres would be expected to further reduce annual instream loads from all sources delivered to the Pacific Ocean relative to the baseline, on average, by (tables 55, 56, and 57; figs. 83, 84, and 85)—

- 2 percent for sediment;
- 5 percent for nitrogen;
- 3 percent for phosphorus.

Potential reductions are highest in the Middle Snake River Basin (code 1705), where additional conservation treatment of the under-treated acres would be expected to further reduce annual instream loads from all sources, on average, by (tables 55, 56, and 57)—

- 25 percent for sediment,
- 30 percent for nitrogen, and
- 32 percent for phosphorus.

Table 52. Average annual ***instream sediment loads*** (all sources) delivered to the Pacific Ocean from the Pacific Northwest Basin

Subregion*	Baseline conservation condition			No-practice scenario, average annual load (1,000 tons)	Reductions in loads due to conservation practices	
	Average annual load (1,000 tons)	Background sources** (1,000 tons)	Percent of load attributed to cultivated cropland sources		Reduction (1,000 tons)	Percent
Loads at subregion outlets within the Snake and Columbia Rivers drainage system						
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	4,107	3,900	5%	4,463	356	8%
Snake Headwaters-Upper Snake River Basin (code 1704)	705	558	21%	1,222	517	42%
Middle Snake River Basin (code 1705)	1,533	1,063	31%	1,816	283	16%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	5,291	5,097	4%	5,570	279	5%
Upper Columbia River Basin (code 1702)	2,774	2,656	4%	3,325	551	17%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	12,930	10,660	18%	14,810	1,880	13%
Willamette River Basin (code 1709)	1,164	979	16%	1,292	128	10%
Loads delivered to the Pacific Ocean						
Lower Columbia River Basin (code 1708)	6,664	6,449	3%	6,937	273	4%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	9,014	8,621	4%	9,649	635	7%
Total	15,678	15,070	4%	16,586	908	5%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).
**"Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Table 53. Average annual ***instream nitrogen loads*** (all sources) delivered to the Pacific Ocean from the Pacific Northwest Basin

Subregion*	Baseline conservation condition			No-practice scenario, average annual load (1,000 pounds)	Reductions in loads due to conservation practices	
	Average annual load (1,000 pounds	Background sources** (1,000 pounds)	Percent of load attributed to cultivated cropland sources		Reduction (1,000 pounds)	Percent
Loads at subregion outlets within the Snake and Columbia Rivers drainage system						
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	39,440	32,760	17%	56,000	16,560	30%
Snake Headwaters-Upper Snake River Basin (code 1704)	35,590	11,970	66%	103,700	68,110	66%
Middle Snake River Basin (code 1705)	65,400	29,710	55%	108,200	42,800	40%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	46,070	26,930	42%	74,020	27,950	38%
Upper Columbia River Basin (code 1702)	59,690	43,640	27%	86,430	26,740	31%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	100,000	55,770	44%	142,100	42,100	30%
Willamette River Basin (code 1709)	74,270	63,030	15%	77,220	2,950	4%
Loads delivered to the Pacific Ocean						
Lower Columbia River Basin (code 1708)	162,000	123,500	24%	188,900	26,900	14%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	238,500	223,770	6%	289,300	50,800	18%
Total	400,500	347,270	13%	478,200	77,700	16%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).
**"Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Table 54. Average annual ***instream phosphorus loads*** (all sources) delivered to the Pacific Ocean from the Pacific Northwest Basin

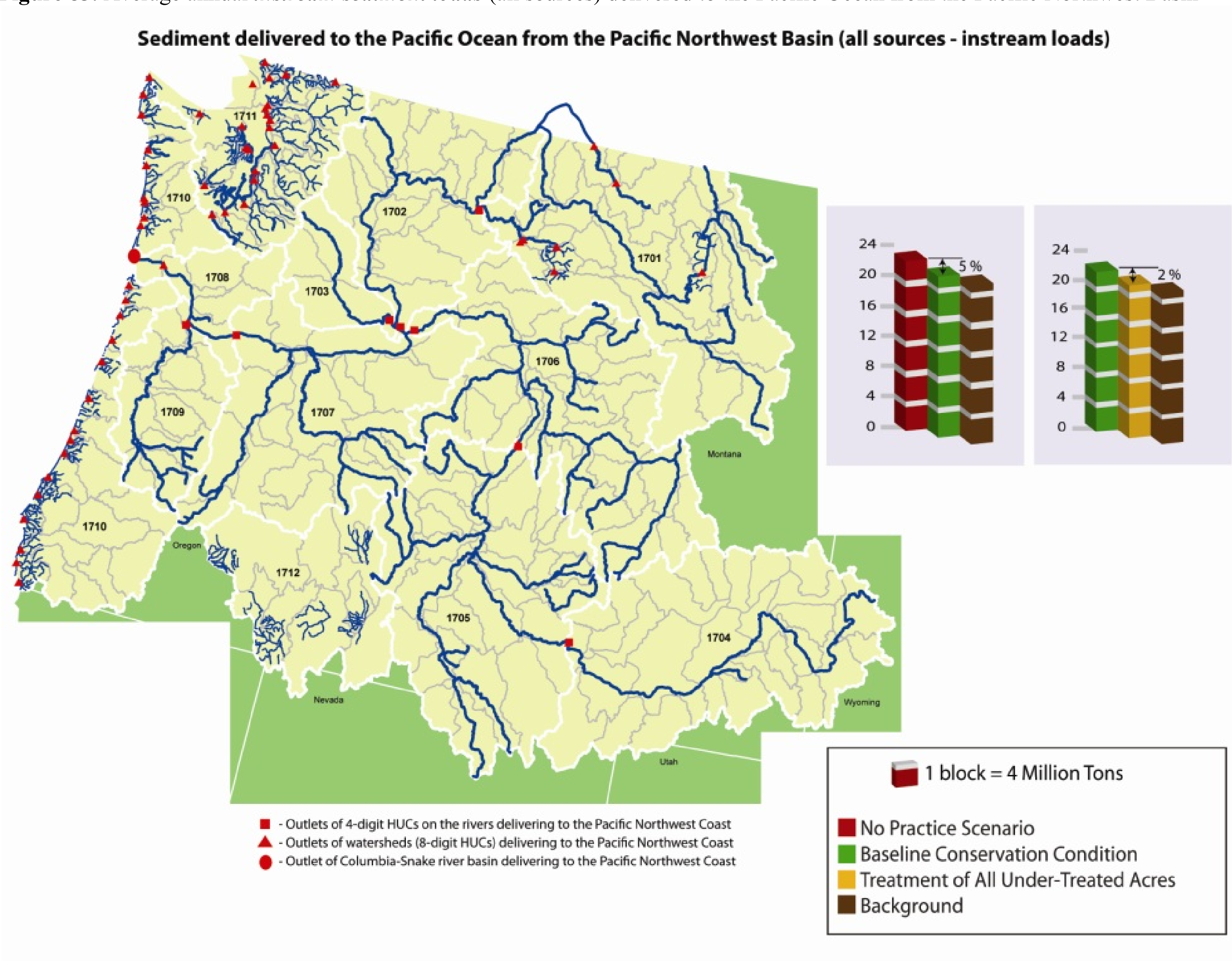
Subregion*	Baseline conservation condition: Average annual load (1,000 pounds	Background sources** (1,000 pounds)	Percent of load attributed to cultivated cropland sources	No-practice scenario, average annual load (1,000 pounds)	Reductions in loads due to conservation practices: Reduction (1,000 pounds)	Percent
Loads at subregion outlets within the Snake and Columbia Rivers drainage system						
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	3,813	3,303	13%	5,211	1,398	27%
Snake Headwaters-Upper Snake River Basin (code 1704)	1,705	746	56%	4,775	3,070	64%
Middle Snake River Basin (code 1705)	3,768	1,833	51%	7,257	3,489	48%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	4,503	2,315	49%	8,090	3,587	44%
Upper Columbia River Basin (code 1702)	5,793	5,285	9%	7,751	1,958	25%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	10,390	7,534	27%	15,550	5,160	33%
Willamette River Basin (code 1709)	5,887	5,126	13%	6,935	1,048	15%
Loads delivered to the Pacific Ocean						
Lower Columbia River Basin (code 1708)	18,450	14,910	19%	23,550	5,100	22%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	43,150	40,910	5%	43,670	520	1%
Total	61,600	55,820	9%	67,220	5,620	8%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

**"Background sources" represent loadings that would be expected if no acres in the watershed were cultivated. These estimates were derived by running an additional scenario that simulated a grass and tree mix cover without any tillage or addition of nutrients or pesticides for all cultivated cropland acres in the watershed.

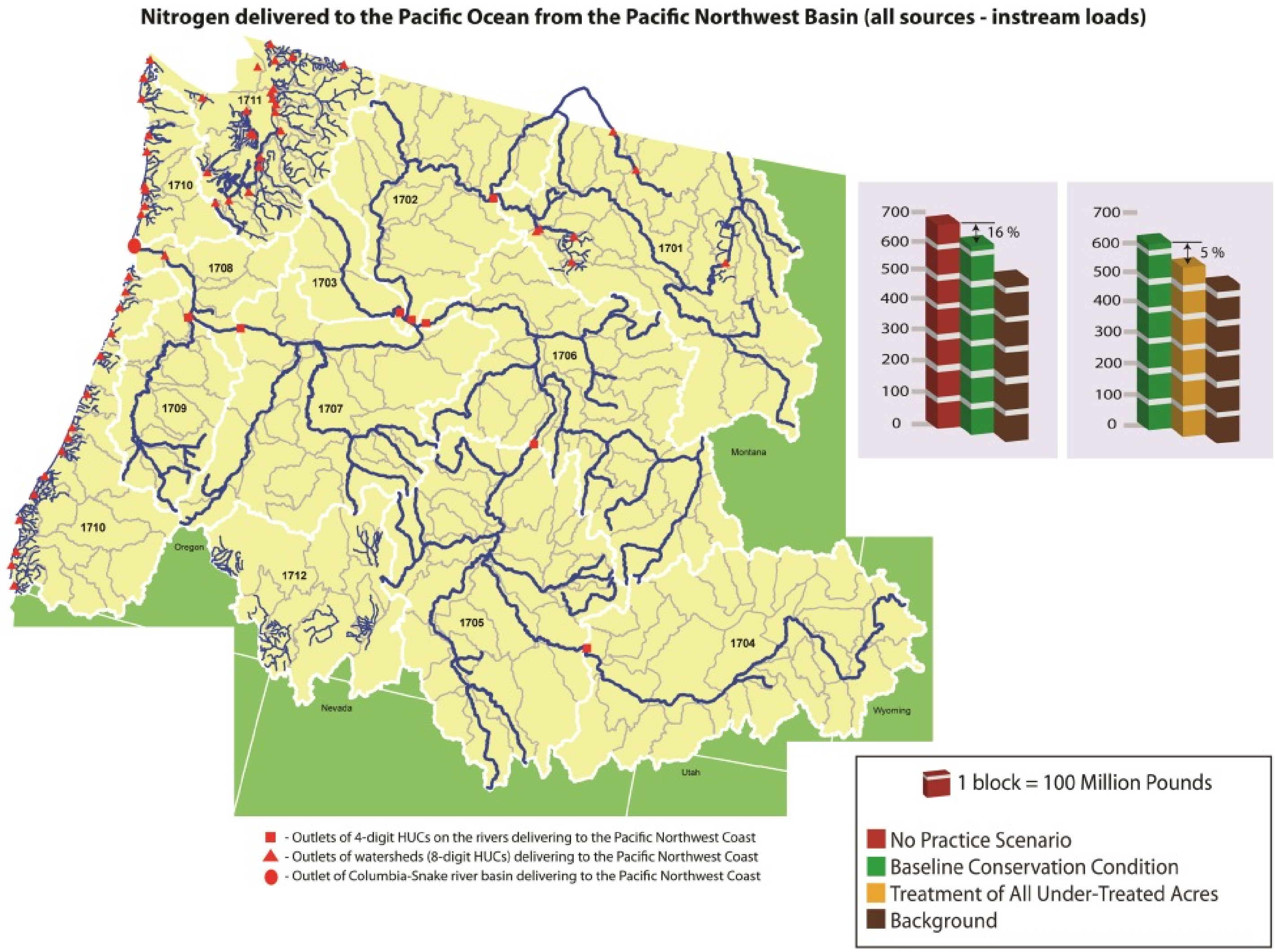
Note: Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Figure 83. Average annual ***instream sediment loads*** (all sources) delivered to the Pacific Ocean from the Pacific Northwest Basin



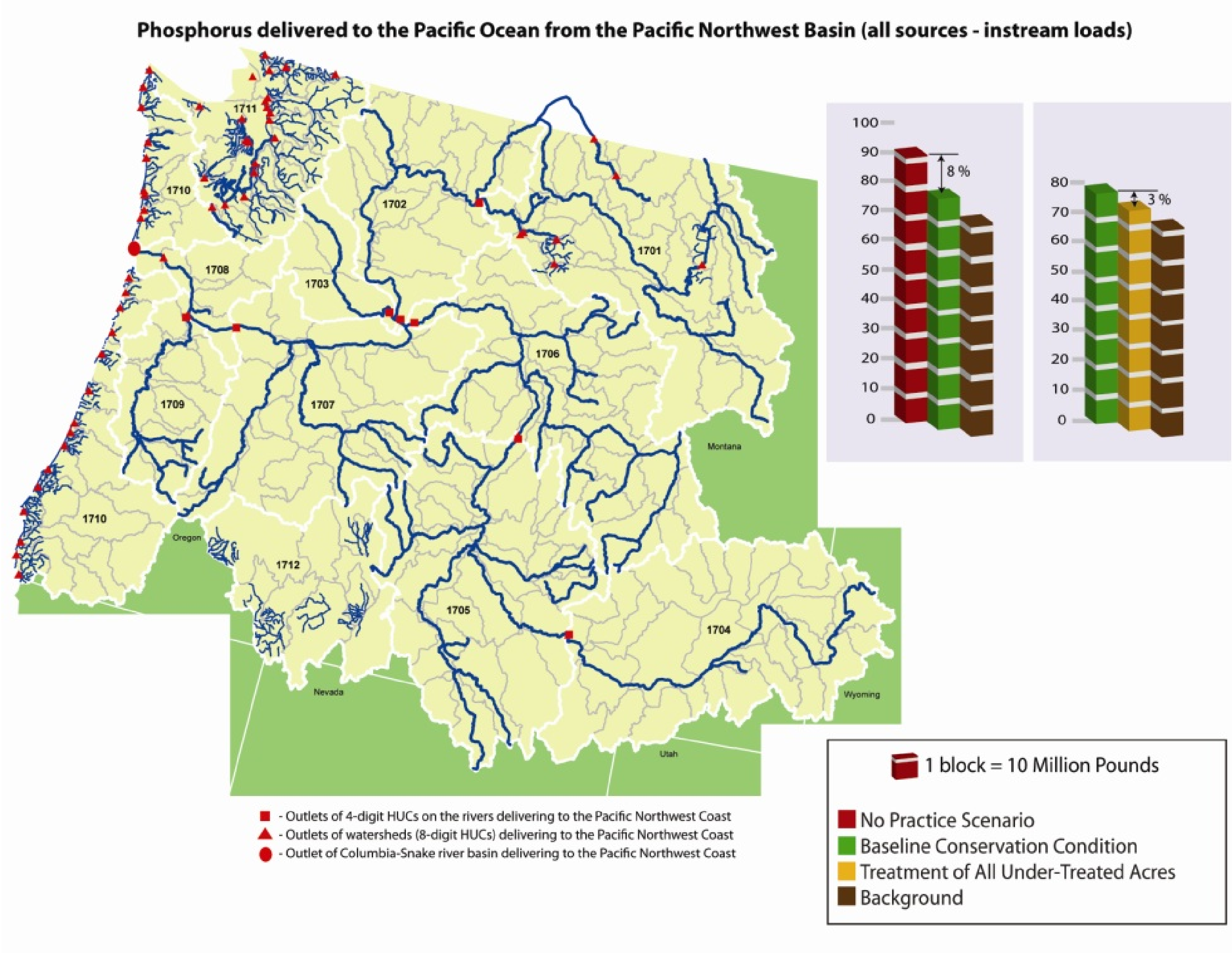
* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

Figure 84. Average annual ***instream nitrogen loads*** (all sources) delivered to the Pacific Ocean from the Pacific Northwest Basin



* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

Figure 85. Average annual ***instream phosphorus loads*** (all sources) delivered to the Pacific Ocean from the Pacific Northwest Basin



* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

Table 55. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream sediment loads*** from all sources delivered to the Pacific Ocean from the Pacific Northwest Basin

Subregion*	Baseline conservation condition	Treatment of all undertreated acres	
	Average annual load from all sources (1,000 tons)	Average annual load (1,000 tons)	Percent reduction
Loads at subregion outlets within the Snake and Columbia Rivers drainage system			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	4,107	3,925	4%
Snake Headwaters-Upper Snake River Basin (code 1704)	705	584	17%
Middle Snake River Basin (code 1705)	1,533	1,150	25%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	5,291	4,847	8%
Upper Columbia River Basin (code 1702)	2,774	2,684	3%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	12,930	10,970	15%
Willamette River Basin (code 1709)	1,164	1,037	11%
Loads delivered to the Pacific Ocean			
Lower Columbia River Basin (code 1708)	6,664	6,485	3%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	9,014	8,899	1%
Total	15,678	15,384	2%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).
Note: Under-treated acres have a high or moderate need for additional conservation treatment. Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Table 56. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream nitrogen loads*** from all sources delivered to the Pacific Ocean from the Pacific Northwest Basin

Subregion*	Baseline conservation condition	Treatment of all undertreated acres	
	Average annual load from all sources (1,000 pounds)	Average annual load (1,000 pounds)	Percent reduction
Loads at subregion outlets within the Snake and Columbia Rivers drainage system			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	39,440	38,580	2%
Snake Headwaters-Upper Snake River Basin (code 1704)	35,590	25,900	27%
Middle Snake River Basin (code 1705)	65,400	45,980	30%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	46,070	36,980	20%
Upper Columbia River Basin (code 1702)	59,690	51,630	14%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	100,000	77,010	23%
Willamette River Basin (code 1709)	74,270	70,750	5%
Loads delivered to the Pacific Ocean			
Lower Columbia River Basin (code 1708)	162,000	145,500	10%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	238,500	236,000	1%
Total	400,500	381,500	5%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).
Note: Under-treated acres have a high or moderate need for additional conservation treatment. Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Table 57. Effects of additional conservation treatment with erosion control practices *and* nutrient management practices on average annual ***instream phosphorus loads*** from all sources delivered to the Pacific Ocean from the Pacific Northwest Basin

Subregion*	Baseline conservation condition: Average annual load from all sources (1,000 pounds)	Treatment of all undertreated acres: Average annual load (1,000 pounds)	Treatment of all undertreated acres: Percent reduction
Loads at subregion outlets within the Snake and Columbia Rivers drainage system			
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)	3,813	3,635	5%
Snake Headwaters-Upper Snake River Basin (code 1704)	1,705	1,411	17%
Middle Snake River Basin (code 1705)	3,768	2,581	32%
Lower Snake River Basin including Salmon-Clear Water (code 1706)	4,503	3,309	27%
Upper Columbia River Basin (code 1702)	5,793	5,602	3%
Middle Columbia River Basin including John Day-Deschutes (code 1707)	10,390	9,067	13%
Willamette River Basin (code 1709)	5,887	5,764	2%
Loads delivered to the Pacific Ocean			
Lower Columbia River Basin (code 1708)	18,450	17,120	7%
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)	43,150	42,460	2%
Total	61,600	59,580	3%

* Excludes loads associated with the "Oregon closed basins" subregion (code 1712).

Note: Under-treated acres have a high or moderate need for additional conservation treatment. Percent reductions were calculated prior to rounding the values for reporting in the table and the associated text. Some columns do not add to totals because of rounding.

Chapter 8
Summary of Findings

Field Level Assessment

Evaluation of practices in use

The first Federal conservation efforts on cropland were focused primarily on water management and soil erosion control. Structural practices such as waterways, terraces, and diversions were installed along with supporting practices such as contour farming and stripcropping. Conservation tillage emerged in the 1960s and 1970s as a key management practice for enhancing soil quality and further reducing soil erosion. The conservation compliance provisions in the 1985 Farm Bill sharpened the focus to treatment of the most erodible acres—highly erodible land. This legislation created the Conservation Reserve Program as a mechanism for establishing long-term conserving cover on the most erodible cropland through multi-year contracts with landowners. More recently, the focus has shifted from soil conservation and sustainability to a broader goal of reducing all pollution impacts associated with agricultural production. Prominent among new concerns are the environmental effects of nutrient and pesticide export from farm fields.

The application of conservation practices in the Pacific Northwest Basin reflects this history of Federal conservation programs and technical assistance. An assessment, based on a farmer survey representing practice use and farming activities for the period 2003–06, found the following:

- Structural practices for controlling water erosion are in use on only 33 percent of cropped acres. On the 54 percent of the acres designated as highly erodible land, structural practices designed to control water erosion are in use on 40 percent (table 7).
- Reduced tillage is common in the region; 80 percent of the cropped acres meet criteria for either no-till (21 percent) or mulch till (59 percent) (table 8). All but 10 percent of the acres had evidence of some kind of reduced tillage on at least one crop.
- About 30 percent of cropped acres are gaining soil organic carbon (fig. 8).
- Producers use either residue and tillage management practices or structural practices, or both, on 92 percent of cropped acres (table 9).
- The use of nutrient management practices is more widespread in this region than in other regions (table 10).
  - About 1 percent of cropped acres have no nitrogen applied. An additional 72 percent of cropped acres meet criteria for timing of nitrogen applications on all crops in the rotation, 68 percent meet criteria for method of application, and 64 percent meet criteria for rate of application.
  - About 17 percent of cropped acres have no phosphorus applied. An additional 61 percent of cropped acres meet criteria for timing of phosphorus applications on all crops in the rotation, 62 percent meet criteria for method of application, and 55 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 are in use on 44 percent of cropped acres.
  - Good phosphorus management practices (appropriate rate, timing, and method) are in use on 43 percent of the acres on all crops during every year of production.
  - About 40 percent of cropped acres meet nutrient management criteria for both nitrogen and phosphorus management, including acres with no nutrient applications.
- During the 2003–06 period of data collection, cover crops were used on less than 1 percent of the acres in the region.
- The Integrated Pest Management (IPM) indicator showed that only about 12 percent of the acres were being managed with a high level of IPM (fig. 11).
- Land in long-term conserving cover, as represented by enrollment in the CRP General Signup, consists of 2.3 million acres in the region, of which 73 percent is highly erodible land.

Annual precipitation over the 47-year simulation averaged about 21 inches for cropped acres in the region. Precipitation in the western portion of the basin, represented by the four subregions located on or near the coast, averaged 59 inches per year, compared to an average of 17 inches per year for the seven eastern subregions. The bulk of the cropped acres are located in the seven eastern subregions—92 percent of cropped acres.

Effects of conservation practices

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

- reduced surface water flow from fields by 16 percent, re-routing water to subsurface flow pathways (table 13);
- reduced wind erosion by 25 percent, from 2.5 tons per acre without conservation practices to 1.9 tons per acre with conservation practices (table 14);
- reduced sediment loss from fields caused by water erosion by 37 percent, from 3.91 tons per acre without conservation practices to 2.5 tons per acre with conservation practices (table 15);
- reduced total nitrogen loss (volatilization, denitrification, surface runoff, subsurface flow, and windborne losses) from fields by 42 percent, from 66.1 pounds per acre without conservation practices to 38.5 pounds per acre with conservation practices (table 18):
  - reduced nitrogen lost with windborne sediment by 23 percent, from 7.0 pounds per acre without practices to 5.4 pounds per acre with conservation practices;
  - reduced nitrogen lost with surface runoff (attached to sediment and in solution) by 40 percent, from 13.8 pounds per acre without conservation practices to 8.3 pounds per acre with conservation practices;
  - reduced nitrogen loss in subsurface flows by 48 percent, from 35.0 pounds per acre without conservation practices to 18.3 pounds per acre with conservation practices;

- reduced total phosphorus loss from fields by 43 percent, from 7.2 pounds per acre without conservation practices to 4.7 pounds per acre with conservation practices (table 20); and
- reduced pesticide loss from fields to surface water, resulting in a 65-percent reduction in edge-of-field pesticide risk (all pesticides combined) for aquatic ecosystems and a 30-percent reduction in edge-of-field surface water pesticide risk for humans (table 22).

In this region, conservation practices have little effect on soil organic carbon levels for most cropped acres (figs. 26 and 27). Conservation practice use in the region has resulted in an average annual gain in soil organic carbon of only 2 pounds per acre per year on cropped acres (table 17).

For land in long-term conserving cover (2.3 million acres), soil erosion and sediment loss have been almost completely eliminated. Compared to a cropped condition without conservation practices, total nitrogen loss has been reduced by 85 percent, total phosphorus loss has been reduced by 94 percent, and soil organic carbon has been increased by an average of 179 pounds per acre per year (tables 15, 17, 19, and 20).

Conservation treatment needs

The adequacy of conservation practices in use in the Pacific Northwest Basin for the period 2003–06 was evaluated to identify conservation treatment needs for five resource concerns (see chapter 5):

- Wind erosion.
- Sediment loss from fields.
- Nitrogen lost with surface runoff (attached to sediment and in solution).
- Nitrogen loss in subsurface flows.
- Phosphorus lost to surface water (includes soluble phosphorus in lateral flow).

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

Undertreated acres were identified by an imbalance between the level of conservation treatment and the level of inherent vulnerability. Three levels of treatment need were identified:

- Acres with a "high" level of need for conservation treatment consist of the most critical undertreated acres in the region. These are the most vulnerable of the undertreated acres with the least conservation treatment and have the highest losses of sediment and/or nutrients.
- Acres with a "moderate" level of need for conservation treatment consist of undertreated acres that generally have lower levels of vulnerability and/or have more conservation practice use than acres with a high level of need. The treatment level required is not necessarily less, although it can be, but rather the sediment and nutrient losses are lower and thus there is less potential on a per-acre basis for reducing agricultural pollutant loadings with additional conservation treatment.
- Acres with a "low" level of need for conservation treatment consist of acres that are adequately treated with respect to the level of inherent vulnerability. While gains can be obtained by adding conservation practices to some of these acres, additional conservation treatment would reduce field losses by only a small amount.

Most of the cropped acres in the Pacific Northwest Basin were determined to have a moderate need for additional conservation treatment. Because of the current use of conservation practices, very few acres in the region have a high need for additional treatment. The proportion of cropped acres with a high or moderate need for additional conservation treatment was determined to be (fig. 60 and table 29)—

- 41 percent for sediment loss (no acres with a high need for treatment),
- 50 percent for nitrogen loss with runoff (no acres with a high need for treatment),
- 48 percent for phosphorus lost to surface water (no acres with a high need for treatment),
- 35 percent for nitrogen loss in subsurface flows (3 percent with a high need for treatment), most of which returns to surface water through drainage ditches, tile drains, natural seeps, and groundwater return flow, and
- 15 percent for wind erosion (1 percent with a high need for treatment).

Most undertreated acres in the Pacific Northwest Basin need additional treatment for multiple resource concerns (table 29). Only 24 percent of the undertreated acres need additional treatment for a single resource concern, primarily for nitrogen leaching (11 percent of the undertreated acres). About 58 percent of undertreated acres need treatment for three or more resource concerns, the most common of which is the need to treat for sediment loss, nitrogen runoff, and phosphorus runoff (29 percent of the undertreated acres).

After accounting for acres that need treatment for multiple resource concerns, all but 26 percent of the cropped acres need additional conservation treatment in this region (fig. 61):

- 3.3 percent of cropped acres (390,000 acres) have a **high** level of need for additional conservation treatment.
- 70.3 percent of cropped acres (8.19 million acres) have a **moderate** level of need for additional conservation treatment.

There is no single "most critical" conservation concern in this region. Rather, most undertreated acres have a need for better erosion control (sediment loss and/or wind erosion) *and* consistent use of nutrient management—appropriate rate, form, timing, *and* method of application of nitrogen and phosphorus.

Simulation of additional conservation treatment

Model simulations were used to evaluate the potential gains from further conservation treatment in the Pacific Northwest Basin (see chapter 6).

Three sets of additional conservation practices were simulated:

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

Model simulation was used to estimate the gains that could be attained when additional soil erosion control practices, nutrient management practices, and increased irrigation efficiencies are applied in this region (tables 34, 35, and 36).

- Conservation treatment would reduce wind erosion an average of 2.0 tons per acre per year for the 390,000 critical undertreated acres, compared to a reduction of 0.6 ton per acre per year for the 8.19 million non-critical undertreated acres. Additional treatment of the remaining 3.07 million acres would reduce wind erosion by only 0.2 ton per acre per year on those acres, on average (table 35).

- Conservation treatment would reduce sediment loss an average of 2.5 tons per acre per year for the 390,000 critical undertreated acres and 2.9 tons per acre per year for the 8.19 million non-critical undertreated acres. In comparison, additional treatment of the remaining 3.07 million acres would reduce sediment loss by only 0.5 ton per acre per year on those acres, on average (table 35).

- Total nitrogen loss would be reduced by an average of 80.7 pounds per acre per year on the 390,000 critical undertreated acres, compared to a reduction of 19.7 pounds per acre for the 8.19 million undertreated acres with a moderate need for treatment, and only 7.2 pounds per acre for the remaining 3.07 million acres (table 35).

- Nitrogen loss in subsurface flows would be reduced by an average of 68.9 pounds per acre per year on the 390,000 critical undertreated acres and 9.5 pounds per acre per year on the 8.19 million acres with a moderate need for treatment, compared to a reduction of 2.8 pounds per acre for the remaining 3.07 million acres (table 35).

- Total phosphorus loss would be reduced by an average of 4.9 pounds per acre per year on the 390,000 critical undertreated acres, compared to a reduction of 2.7 pounds per acre for the 8.19 million undertreated acres with a moderate need for treatment and only 0.6 pound per acre for the remaining 3.07 million acres (table 35).

Model simulations demonstrated that sediment and nitrogen losses with surface runoff could be effectively controlled in the region with additional erosion control practices. However, model simulations also showed that a suite of practices that includes both soil erosion control and consistent nutrient management is often *required* to adequately address both soil erosion *and* nutrient loss through all loss pathways. Treatment with combinations of soil erosion control practices and nutrient management makes applied nutrients more available for use by crops and thus significantly reduces the rerouting of soluble nitrogen and phosphorus to subsurface loss pathways.

Compared to the baseline conservation condition, treating all 8.6 million undertreated acres with soil erosion control practices *and* nutrient management practices would, *for the region as a whole* (table 36)—

- reduce wind erosion rates in the region by 24 percent on average;
- reduce sediment loss in the region by 85 percent on average;
- reduce total nitrogen loss by 43 percent:
  - reduce nitrogen loss with windborne sediment by 22 percent,
  - reduce nitrogen loss with surface runoff (sediment adsorbed and soluble) by 59 percent, and
  - reduce nitrogen loss in subsurface flows by 49 percent;
- reduce phosphorus lost to surface water by 59 percent;
- reduce phosphorus loss with windborne sediment by 36 percent, and
- reduce surface water environmental risk from loss of pesticide residues by 34 percent for aquatic ecosystems and 43 percent for humans.

Nearly all of these reductions in wind erosion, sediment loss, and environmental risk from loss of pesticide residues are due to the erosion control practices. The additional nutrient management practices accounted for a significant portion of the reductions in total nitrogen and total phosphorus loss.

The potential for achieving additional field-level savings from further conservation treatment is high in this region, especially for additional reductions in sediment loss (fig. 62). Conservation practices in use in 2003–06 achieved 39 percent of potential reductions in sediment loss, 60 percent for nitrogen, 58 percent for phosphorus, and 55 percent for wind erosion. By treating all 8.6 million undertreated acres in the region with additional erosion control and nutrient management practices, an additional 57 percent in savings would be attained for sediment, 36 percent for nitrogen, 39 percent for phosphorus, and 41 percent for wind erosion. To achieve 100 percent of potential savings (i.e., an additional 4 percent for sediment, 4 percent for nitrogen, 3 percent for phosphorus, and 5 percent for wind erosion), additional conservation treatment for the remaining 3.07 million acres with a low need for additional treatment would be required, which would result in very small conservation gains on a per-acre basis.

Loads Delivered to Rivers and Streams within the Region

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

Cultivated cropland makes up only 10 percent of the land base in this region (fig. 76), and is not a dominant land use in any of the subregions. Nevertheless, at the 2003–06 level of conservation practice use, cultivated cropland delivered a disproportionate amount of sediment and nutrients to rivers and streams within the region. Sediment and nutrient loads **delivered to rivers and streams from cultivated cropland sources** per year, on average, are (tables 41, 45, and 49):

- 11.3 million tons of sediment (37 percent of loads from all sources);
- 235 million pounds of nitrogen (27 percent of loads from all sources); and
- 13.8 million pounds of phosphorus (16 percent of loads from all sources).

Conservation practices in use on cultivated cropland in 2003–06, including land in long-term conserving cover, have reduced sediment and nutrient loads **delivered to rivers and streams from cultivated cropland sources** per year, on average, by (tables 41, 45, and 49):

- 53 percent for sediment;
- 57 percent for nitrogen; and
- 60 percent for phosphorus.

Model simulations further showed that if the 8.6 million undertreated acres were fully treated with the appropriate soil erosion control and nutrient management practices, loads from cultivated cropland delivered to rivers and streams in the watershed would be reduced, relative to the baseline conservation condition (tables 43, 47, and 51):

- 73 percent for sediment;
- 47 percent for nitrogen; and
- 41 percent for phosphorus.

Instream Loads from All Sources Delivered to the Pacific Ocean

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 is deposited in streambeds and flood plains during transit. Large reservoirs can trap significant amounts of loads delivered to rivers and streams, keeping those loads from being transferred downstream. Sediment can also be added to instream loads through streambank erosion and streambed scouring.

Instream loads represent *all sources* of sediment and nutrients. After accounting for instream deposition, reservoir dynamics, streambank erosion, and other transport processes, model simulations indicate that total instream loads from all of these sources deliver to the Pacific Ocean per year, on average, for the baseline conservation condition (tables 52, 53, and 54)—

- 15.7 million tons per year of sediment,
- 400 million pounds per year of nitrogen, and
- 62 million pounds per year of phosphorus.

The effects of conservation practices are estimated for instream loads in the same manner as was done for loads delivered to rivers and streams. The percent reductions in total instream loads, however, are small in this region because conservation practices affect only the cultivated cropland component of the total instream load. As shown previously, cultivated cropland is the dominant source of sediment and nutrients in selected subregions. Conservation practices in use on cultivated cropland in 2003–06, including land in long-term conserving cover, have reduced annual instream loads from all sources delivered from the Pacific Northwest Basin to the Pacific Ocean, on average, by (tables 52, 53, and 54; figs. 83, 84, and 85)—

- 5 percent for sediment,
- 16 percent for nitrogen, and
- 8 percent for phosphorus.

Reductions are highest in the Snake Headwaters-Upper Snake River Basin (code 1704), where conservation practices have reduced annual instream loads from all sources, on average, by (tables 52, 53, and 54)—

- 42 percent for sediment,
- 66 percent for nitrogen, and
- 64 percent for phosphorus.

Model simulation results indicate that additional conservation treatment of the 8.6 million under-treated acres would be expected to further reduce annual instream loads from all sources delivered to the Pacific Ocean relative to the baseline, on average, by (tables 55, 56, and 57; figs. 83, 84, and 85)—

- 2 percent for sediment;
- 5 percent for nitrogen;
- 3 percent for phosphorus.

Potential reductions are highest in the Middle Snake River Basin (code 1705), where additional conservation treatment of the under-treated acres would be expected to further reduce annual instream loads from all sources, on average, by (tables 55, 56, and 57)—

- 25 percent for sediment,
- 30 percent for nitrogen, and
- 32 percent for phosphorus.

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Appendix A: Estimates of Margins of Error for Selected Acre Estimates

The CEAP cultivated cropland sample is a subset of NRI sample points from the 2003 NRI (USDA/NRCS 2007). The 2001, 2002, and 2003 Annual NRI surveys were used to draw the sample. (Information about the CEAP sample design is in "NRI-CEAP Cropland Survey Design and Statistical Documentation," available at http://www.nrcs.usda.gov/technical/nri/ceap.)
The sample for cropped acres consists of 918 sample points in the Pacific Northwest Basin. Acres reported using the CEAP sample are "estimated" acres because of the uncertainty associated with statistical sampling.

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

Margins of error are provided in table A1 for selected acres estimates found elsewhere in the report. The margin of error is a commonly used measure of statistical uncertainty and can be used to construct a 95-percent confidence interval for an estimate. The lower bound of the confidence interval is obtained by subtracting the margin of error from the estimate; adding the margin of error to the estimate forms the upper bound. Measures of uncertainty (e.g., margins of error, standard errors, confidence intervals, coefficients of variation) should be taken into consideration when using CEAP acreage estimates. The margin of error is calculated by multiplying the standard error by the factor 1.96; a coefficient of variation is the relative standard for an estimate, usually in terms of percentages, and is calculated by taking 100 times the standard error and then dividing by the estimate.

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

Table A1. Margins of error for acre estimates based on the CEAP sample, Pacific Northwest Basin

	Estimated acres	Margin of error
Use of structural practices (table 7)		
Overland flow control practices	2,513,702	498,260
Concentrated flow control practices	1,440,871	325,256
Edge-of-field buffering and filtering practices	732,529	317,995
One or more water erosion control practices	3,843,186	607,895
Wind erosion control practices	323,245	190,386
Use of cover crops	48,120	68,717
Use of residue and tillage management (table 8)		
Average annual tillage intensity for crop rotation meets criteria for no-till	2,389,178	558,011
Average annual tillage intensity for crop rotation meets criteria for mulch till	6,845,788	625,247
Reduced tillage on some crops in rotation but average annual tillage intensity greater than criteria for mulch till	1,226,162	286,510
Continuous conventional tillage in every year of crop rotation	1,188,771	320,777
Conservation treatment levels for structural practices (fig. 7)		
High level of treatment	333,968	185,812
Moderately high level of treatment	818,008	384,072
Moderate level of treatment	2,691,210	420,854
Low level of treatment	7,806,714	754,912
Conservation treatment levels for residue and tillage management (fig. 8)		
High level of treatment	2,100,518	559,265
Moderately high level of treatment	873,777	298,506
Moderate level of treatment	7,797,015	660,276
Low level of treatment	878,590	288,780
Conservation treatment levels for nitrogen management (fig. 9)		
High level of treatment	4,640,320	655,242
Moderately high level of treatment	2,967,257	560,119
Moderate level of treatment	2,843,032	531,258
Low level of treatment	1,199,291	240,138

Table A1—continued.

	Estimated acres	Margin of error
Conservation treatment levels for phosphorus management (fig. 10)		
High level of treatment	6,969,307	552,936
Moderately high level of treatment	1,423,857	335,246
Moderate level of treatment	917,686	320,201
Low level of treatment	2,339,050	370,309
Conservation treatment levels for IPM (fig. 11)		
High level of treatment	1,436,589	438,118
Moderate level of treatment	5,567,016	487,369
Low level of treatment	4,646,295	641,367
Conservation treatment levels for water erosion control practices (fig. 49)		
High level of treatment	605,438	301,390
Moderately high level of treatment	1,509,761	391,031
Moderate level of treatment	5,301,821	660,273
Low level of treatment	4,232,879	670,813
Conservation treatment levels for nitrogen runoff control (fig. 50)		
High level of treatment	221,111	156,642
Moderately high level of treatment	2,694,137	491,621
Moderate level of treatment	6,596,626	661,344
Low level of treatment	2,138,025	439,866
Conservation treatment levels for phosphorus runoff control (fig. 51)		
High level of treatment	225,715	125,750
Moderately high level of treatment	3,047,240	532,822
Moderate level of treatment	6,518,963	641,648
Low level of treatment	1,857,982	285,618
Conservation treatment levels for wind erosion control (fig. 51)		
High level of treatment	133,147	121,680
Moderately high level of treatment	2,515,846	590,382
Moderate level of treatment	6,650,755	638,317
Low level of treatment	2,350,151	382,385
Soil runoff potential (fig. 54)		
High	3,945,557	592,813
Moderately high	3,080,543	538,442
Moderate	480,636	174,053
Low	4,143,164	445,257
Soil leaching potential (fig. 56)		
High	413,040	241,518
Moderately high	187,449	106,162
Moderate	10,373,613	595,140
Low	675,798	235,095
Soil wind erosion potential (fig. 58)		
High	298,973	208,164
Moderately high	7,073,659	691,122
Moderate	2,347,628	364,492
Low	1,929,640	282,770
Level of conservation treatment need by resource concern		
Sediment loss (table 24)		
High (critical undertreated)	0	--
Moderate (non-critical undertreated)	4,789,660	529,310
Low (adequately treated)	6,860,239	519,410

Table A1—continued.

	Estimated acres	Margin of error
Level of conservation treatment need by resource concern--continued		
Nitrogen loss with surface runoff (sediment attached and soluble) (table 25)		
High (critical undertreated)	0	--
Moderate (non-critical undertreated)	5,819,846	598,474
Low (adequately treated)	5,830,053	485,869
Nitrogen loss in subsurface flows (table 26)		
High (critical undertreated)	372,496	233,920
Moderate (non-critical undertreated)	3,669,827	530,184
Low (adequately treated)	7,607,577	700,832
Phosphorus lost to surface water (table 27)		
High (critical undertreated)	0	--
Moderate (non-critical undertreated)	5,531,094	605,565
Low (adequately treated)	6,118,806	536,467
Wind erosion (table 27)		
High (critical undertreated)	115,315	158,646
Moderate (non-critical undertreated)	1,612,817	343,019
Low (adequately treated)	9,921,768	535,362
Level of conservation treatment need for one or more resource concerns		
Pacific Northwest Basin		
High (critical undertreated)	387,901	229,085
Moderate (non-critical undertreated)	8,194,387	545,385
Low (adequately treated)	3,067,612	510,319
Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin (codes 1701 and 1703)		
High (critical undertreated)	14,479	21,349
Moderate (non-critical undertreated)	550,456	277,500
Low (adequately treated)	247,065	138,632
Upper Columbia River Basin (code 1702)		
High (critical undertreated)	136,969	118,479
Moderate (non-critical undertreated)	1,677,165	425,931
Low (adequately treated)	655,366	252,162
Snake Headwaters-Upper Snake River Basin (code 1704)		
High (critical undertreated)	50,965	50,617
Moderate (non-critical undertreated)	1,538,134	272,910
Low (adequately treated)	842,802	231,786
Middle Snake River Basin (code 1705)		
High (critical undertreated)	25,125	27,058
Moderate (non-critical undertreated)	480,379	195,645
Low (adequately treated)	112,095	76,075
Lower Snake River Basin including Salmon-Clear Water (code 1706)		
High (critical undertreated)	21,288	59,884
Moderate (non-critical undertreated)	1,663,648	422,559
Low (adequately treated)	573,265	261,475
Middle Columbia River Basin including John Day-Deschutes (code 1707)		
High (critical undertreated)	95,502	121,801
Moderate (non-critical undertreated)	1,511,773	326,573
Low (adequately treated)	472,826	200,303
Lower Columbia River Basin and Willamette River Basin (codes 1708 and 1709)		
High (critical undertreated)	43,574	81,409
Moderate (non-critical undertreated)	685,654	115,257
Low (adequately treated)	138,972	82,205

Table A1—continued.

	Estimated acres	Margin of error
Level of conservation treatment need for one or more resource concerns --continued		
Washington-Oregon Coastal and Puget Sound Basin (codes 1710 and 1711)		
High (critical undertreated)	0	--
Moderate (non-critical undertreated)	87,179	50,083
Low (adequately treated)	25,222	36,133

Appendix B: Model Simulation Results for the Baseline Conservation Condition for Subregions in the Pacific Northwest Basin

Model simulation results in chapter 4 for the baseline conservation condition are presented in tables B1-B3. Model simulation results in chapters 3 and 5 are presented in tables B4 and B5. Some subregions were combined because of small sample sizes, as discussed in the text. The column headings refer to the 4-digit Hydrologic Unit Codes (HUC), as shown below:

Subregion code	Subregion name
1701 and 1703	Kootenai-Flathead-Clark Fork-Pend Oreille-Spokane River Basin and Yakima River Basin
1702	Upper Columbia River Basin
1704	Snake Headwaters-Upper Snake River Basin
1705	Middle Snake River Basin
1706	Lower Snake River Basin including Salmon-Clear Water
1707	Middle Columbia River Basin including John Day-Deschutes
1708 and 1709	Lower Columbia River Basin and Willamette River Basin
1710 and 1711	Washington-Oregon Coastal and Puget Sound Basin

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 Pacific Northwest Basin

Model simulated outcome	Pacific Northwest Basin	1701 and 1703	1702	1704	1705	1706	1707	1708 and 1709	1710 and 1711
CEAP sample size for estimating cropped acres	852	215	113	56	192	73	75	42	86
Cropped acres (million acres)	11,649,900	812,000	2,469,500	2,431,900	617,600	2,258,200	2,080,100	868,200	112,400
Percent of cropped acres in region	100	7	21	21	5	19	18	7	1
Percent of acres highly erodible	54	53	43	47	26	83	70	20	9
Percent of acres irrigated	35	31	25	81	96	2	14	32	50
Percent of acres receiving manure applications	4	12	0	8	13	0	0	2	45
Water sources (average annual inches)									
Non-irrigated acres									
Precipitation	22.4	22.0	11.5	18.7	26.6	21.8	22.1	57.7	71.6
Irrigated acres									
Precipitation	17.9	23.5	8.9	14.3	14.8	21.0	16.2	59.3	54.1
Irrigation water applied	17.6	12.9	17.5	18.0	22.0	10.5	14.3	15.4	14.2
Water loss pathways (average annual inches)									
Evapotranspiration	17.2	17.1	12.8	21.2	23.5	16.7	14.7	21.8	19.1
Surface water runoff	4.3	3.5	0.5	1.8	3.4	2.2	3.6	26.6	30.9
Subsurface water flow	4.1	4.8	1.3	2.9	5.5	3.1	4.6	13.2	17.3
Erosion and sediment loss (average annual tons/acre)									
Wind erosion	1.90	0.85	3.53	3.30	1.91	0.51	1.15	0.01	0.06
Sheet and rill erosion	0.30	0.08	0.01	0.04	0.09	0.14	0.88	1.16	0.98
Sediment loss at edge of field due to water erosion	2.48	1.50	0.28	0.58	1.75	2.22	5.84	7.22	9.72
Soil organic carbon (average annual pounds/acre)									
Loss of soil organic carbon with wind and water erosion	171	138	140	138	137	175	171	380	301
Change in soil organic carbon, including loss of carbon with wind and water erosion	-66	8	-84	-79	-68	-40	-107	15	-277

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

Model simulated outcome	Pacific Northwest Basin	1701 and 1703	1702	1704	1705	1706	1707	1708 and 1709	1710 and 1711
Nitrogen (average annual pounds/acre)									
Nitrogen sources									
Atmospheric deposition	1.2	1.4	0.7	1.7	1.2	1.5	1.0	1.6	1.6
Bio-fixation by legumes	11.8	15.0	3.7	22.4	32.1	8.3	8.7	5.2	5.6
Nitrogen applied as commercial fertilizer and manure	91.1	81.6	67.9	118.6	175.1	69.8	69.1	121.9	214.3
All nitrogen sources	104.2	98.0	72.3	142.7	208.4	79.6	78.7	128.7	221.5
Nitrogen in crop yield removed at harvest	74.8	74.1	52.2	117.2	132.3	64.8	52.4	57.7	91.6
Nitrogen loss pathways									
Nitrogen loss by volatilization	5.9	5.6	7.4	5.5	9.7	4.0	4.3	9.8	5.5
Nitrogen loss through denitrification	0.6	0.7	0.2	0.4	1.0	0.6	0.4	2.3	1.9
Nitrogen lost with windborne sediment	5.4	3.5	10.1	8.7	5.5	1.5	3.4	0.0	0.1
Nitrogen loss with surface runoff , including waterborne sediment	8.3	6.5	1.4	2.8	6.7	10.5	8.8	36.7	34.5
Nitrogen loss in subsurface flow pathways	18.3	10.5	12.4	17.9	49.5	7.4	22.3	26.5	118.8
Total nitrogen loss for all loss pathways	38.5	26.7	31.4	35.3	72.3	23.9	39.2	75.4	160.8
Change in soil nitrogen	-9.5	-3.5	-11.6	-10.4	3.4	-9.4	-13.1	-4.1	-31.1

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

Model simulated outcome	Pacific Northwest Basin	1701 and 1703	1702	1704	1705	1706	1707	1708 and 1709	1710 and 1711
Phosphorus (average annual pounds/acre)									
Phosphorus applied as commercial fertilizer and manure	15.1	12.9	7.2	28.4	36.9	6.9	7.6	19.8	61.3
Phosphorus in crop yield removed at harvest	10.3	10.7	7.0	15.7	19.8	8.9	6.6	9.6	11.3
Phosphorus loss pathways									
Phosphorus lost with windborne sediment	1.45	0.62	1.94	3.13	2.19	0.47	0.74	0.01	0.24
Phosphorus lost to surface water, including waterborne sediment and soluble phosphorus in surface water runoff and lateral flow into drainage tiles and ditches and natural seeps	2.61	1.87	0.27	0.87	2.27	2.57	2.35	12.31	29.66
Soluble phosphorus loss to groundwater	0.02	0.03	0.01	0.02	0.03	0.01	0.03	0.06	0.10
Total phosphorus loss for all loss pathways	4.08	2.51	2.22	4.02	4.48	3.06	3.12	12.38	29.99
Change in soil phosphorus	0.59	-0.42	-2.08	8.69	12.74	-5.32	-2.15	-2.79	20.37
Pesticides									
Average annual amount of pesticides applied (grams of active ingredient/hectare)	3,540	401	5,147	4,641	6,996	1,768	3,205	1,861	2,869
Pesticide loss									
Average annual mass loss of pesticides for all pathways (grams of active ingredient/hectare)	13.2	1.6	2.5	1.6	8.3	1.7	8.6	129.1	31.9
Edge-of-field pesticide risk indicator									
Average annual surface water pesticide risk indicator for aquatic ecosystem	1.76	0.12	3.73	0.54	3.06	0.30	0.90	5.79	3.52
Average annual surface water pesticide risk indicator for humans	0.86	0.01	3.32	0.13	0.29	0.19	0.08	0.75	0.87
Average annual groundwater pesticide risk indicator for humans	0.41	<.01	1.60	0.03	0.01	0.04	0.15	0.24	0.61

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

Model simulated outcome	Pacific Northwest Basin	1701 and 1703	1702	1704	1705	1706	1707	1708 and 1709	1710 and 1711
Percent of cropped acres within subregion at four conservation treatment levels for structural practices (see figure 7)									
High conservation treatment level	3	14	2	2	0	3	2	3	1
Moderately-high conservation treatment level	7	2	9	3	10	10	8	9	0
Moderate conservation treatment level	23	18	14	11	<1	41	43	11	2
Low conservation treatment level	67	66	75	85	90	46	46	77	98
Percent of cropped acres within subregion at four conservation treatment levels for residue and tillage management (see figure 8)									
High conservation treatment level	18	22	12	14	8	27	20	25	3
Moderately-high conservation treatment level	8	11	2	8	9	8	3	27	0
Moderate conservation treatment level	67	66	82	65	48	60	75	44	54
Low conservation treatment level	8	1	4	13	35	5	2	3	43
Percent of cropped acres within subregion at four conservation treatment levels for nitrogen management (see figure 9)									
High conservation treatment level	40	37	51	27	20	53	52	3	17
Moderately-high conservation treatment level	25	28	18	41	26	25	15	25	26
Moderate conservation treatment level	24	25	28	20	43	19	30	11	45
Low conservation treatment level	10	10	3	12	12	3	3	61	12
Percent of cropped acres within subregion at four conservation treatment levels for phosphorus management (see figure 10)									
High conservation treatment level	60	62	77	29	34	80	85	6	11
Moderately-high conservation treatment level	12	13	13	17	23	12	2	13	17
Moderate conservation treatment level	8	13	3	16	11	2	8	4	24
Low conservation treatment level	20	12	7	39	32	5	5	76	48
Percent of cropped acres within subregion at four conservation treatment levels of soil runoff potential (see figure 54)									
High soil vulnerability potential	34	35	30	9	1	73	46	11	<1
Moderately high soil vulnerability potential	26	38	31	22	26	15	35	25	9
Moderate soil vulnerability potential	4	0	<1	7	4	0	0	28	39
Low soil vulnerability potential	36	27	39	62	69	12	19	36	52
Percent of cropped acres within subregion at four conservation treatment levels of soil leaching potential (see figure 56)									
High soil vulnerability potential	4	2	8	2	3	1	4	4	1
Moderately high soil vulnerability potential	2	4	2	3	1	0	<1	2	0
Moderate soil vulnerability potential	89	93	87	91	92	99	95	49	51
Low soil vulnerability potential	6	1	4	4	4	0	<1	44	48
Percent of cropped acres within subregion at four conservation treatment levels of soil wind erosion potential (see figure 586)									
High soil vulnerability potential	3	0	6	1	1	1	4	0	0
Moderately high soil vulnerability potential	61	22	92	82	74	45	56	0	0
Moderate soil vulnerability potential	20	55	2	14	24	35	27	0	7
Low soil vulnerability potential	17	24	0	3	1	19	13	100	93

Table B5. Percent of cropped acres for conservation treatment needs, by subregion, in the Pacific Northwest Basin

Model simulated outcome	Pacific Northwest Basin	1701 and 1703	1702	1704	1705	1706	1707	1708 and 1709	1710 and 1711
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	0	0
Moderate level of treatment need	41	52	47	19	24	60	50	19	19
Percent of cropped acres within subregion with conservation treatment needs for nitrogen lost with runoff									
High level of treatment need	0	0	0	0	0	0	0	0	0
Moderate level of treatment need	50	56	53	27	27	61	64	57	33
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	0	0
Moderate level of treatment need	47	54	46	29	26	58	57	61	45
Percent of cropped acres within subregion with conservation treatment needs for nitrogen loss in subsurface flows									
High level of treatment need	3	2	6	1	4	1	5	5	0
Moderate level of treatment need	32	33	25	31	51	21	28	67	57
Percent of cropped acres within subregion with conservation treatment needs for wind erosion									
High level of treatment need	1	0	2	1	1	1	2	0	0
Moderate level of treatment need	14	4	16	29	55	6	1	0	0
Percent of cropped acres within subregion with conservation treatment needs for one or more resource concern									
High level of treatment need	3	2	6	2	4	1	5	5	0
Moderate level of treatment need	70	68	68	63	78	74	73	79	78
Undertreated (high or moderate level of treatment need)	74	70	73	65	82	75	77	84	78

END