CHAPTER FOUR

The Rural River

Farmers and ranchers are less than 1 percent of the nation's population, yet they have the responsibility to manage and conserve roughly half the land in the lower 48 states—about 1,049 million acres.

For virtually every agricultural enterprise, a big part of the management and conservation challenge involves water, which is both a critical source of sustenance for crops and a vehicle for the movement of pollutants.

Surface water or groundwater used for irrigation accounts for about 34 percent of the total water withdrawn in the United States (including water applied both to agricultural crops and pastures and to recreational lands such as golf courses). Of the amount withdrawn for irrigation, about 90 percent of the total is in the West, where irrigation converts arid land into fertile cropland. In the East, irrigation is used to supplement natural precipitation, increase yields or the number of plantings per year, and reduce the risk of crop failures during droughts (See Table 4.1 and Figure 4.1).

In 1995, about 134 billion gallons per day was used for irrigation nationwide, with about 63 percent of the total withdrawn from surface water and the remainder from groundwater. Once withdrawn, about one fourth is lost in conveyance, half is consumed, and the remaining fourth is returned to surface water or groundwater supplies.

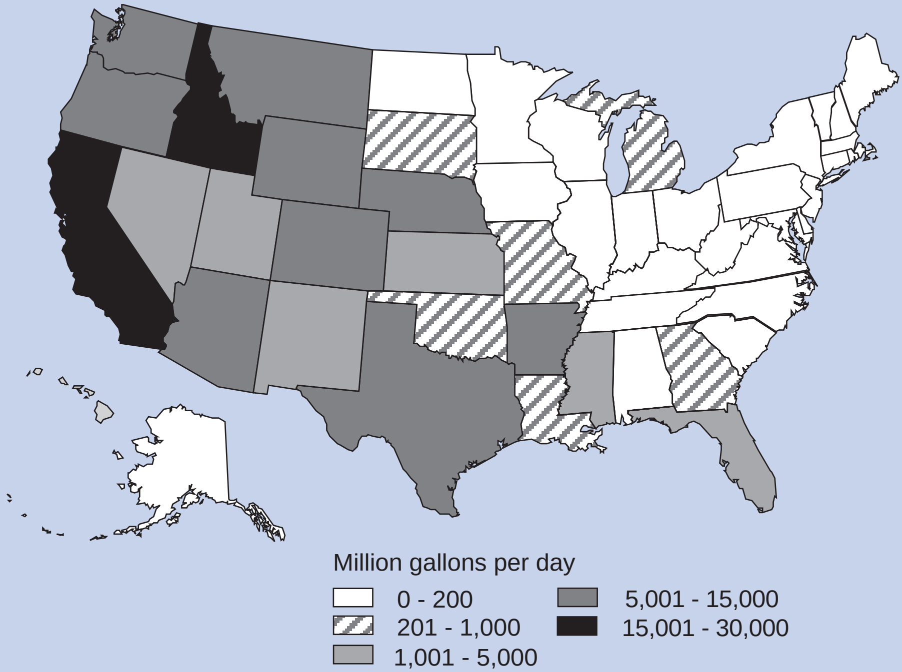
According to the National Water Quality Inventory, agriculture is by far the leading source of pollution in U.S. rivers and streams. But the extent of agricultural activities in a given watershed is not necessarily correlated with the severity or

Table 4.1 Diversion of Surface Water for Various Uses in Western and Eastern United States, 1990

Use	West	East
	percent	
Irrigation	76	24
Thermoelectric power	13	60
Municipal	8	9
Industrial	2	7
Livestock	1	0
Total	100	100

Source: Congressional Budget Office using data from W.B. Solley, R.R. Pierce, and H.A. Perlman, *Estimated Use of Water in the United States in 1990*, U.S. Geological Survey Circular 1081 (USGS, Reston, VA, 1993).

Figure 4.1 Amount of Water Used for Irrigation by State, 1995



Source: Solley, W.B., *Preliminary Estimates of Water Use in the United States, 1995,* Open File Report 97-645 (USGS, Reston, VA, 1997).

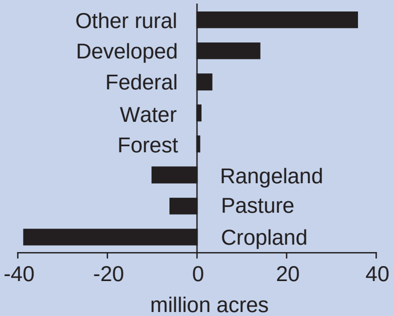
extent of water pollution problems. For example, there are many instances where the intensity of agricultural land use — such as the proliferation of poultry and concentrated animal feedlot production in the Southeast—is a leading factor in creating significant water quality problems.

CONSERVING THE LAND

Though agriculture still dominates the rural landscape, significant shifts are underway in the use of rural land across the nation (Figure 4.2).

For example, the number of mid-size farms has dwindled, while the number of small and large farms has increased. The pattern of increasing small ownerships, coupled with population growth as urban areas expand, has greatly increased the mixing and overlap of urban and rural land uses as evidenced by the value of agricultural production in proximity to metropolitan areas (Figure 4.3). Rural residential development now frequently mixes with prime farmland, which can make agricultural production more difficult and land management more complicated. Watersheds where the maintenance of healthy conditions formerly

Figure 4.2 Net Changes in Use of Nonfederal Land, 1982-1992

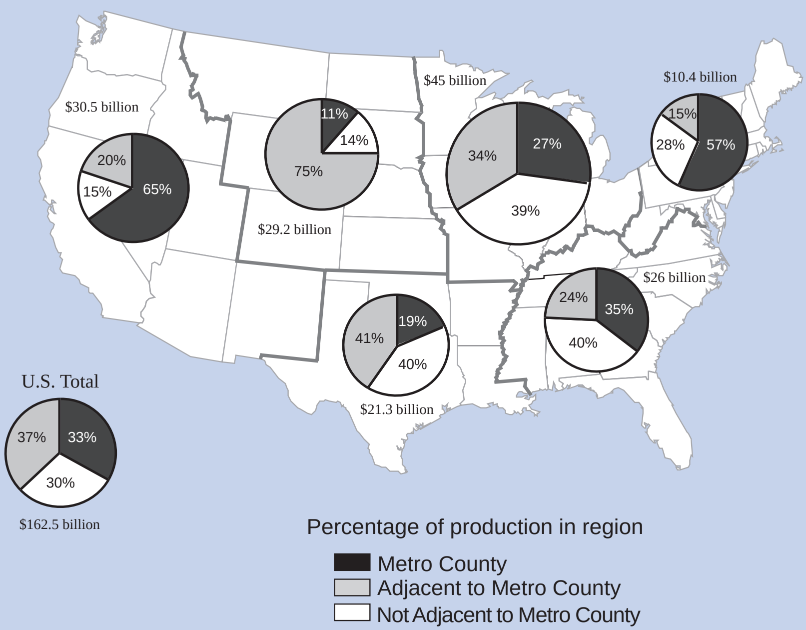


Source: USDA, Natural Resources Conservation Service, *Summary Report 1992 Natural Resources Inventory* (USDA, NRCS, Washington, DC, 1995).
Notes: Other rural land = primarily CRP acres, but also farmsteads, windbreaks, wetlands, and barren land.
Federal = land acquired for national forests, parks, etc.

depended on the stewardship of a few dozen farmers may now require the cooperation and involvement of hundreds of small landowners.

Between 1982 and 1992, some 60 million acres shifted from cropland to other uses, while about 21 million acres shifted from other uses into cropland, leaving a net loss in cropland of 39 million acres. An important contributor to this shift in use was the federal Conservation Reserve Program (CRP), under which farmers retire highly erodible land from active use. Over the 1982- 92 period, 35.4 million acres were enrolled in the CRP (See Part III, Table 7.19).

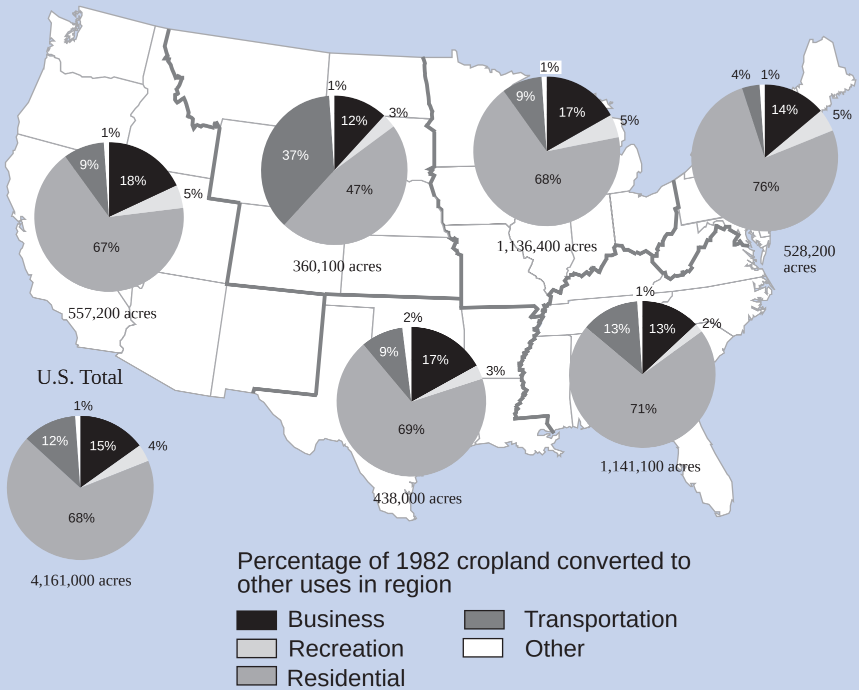
Figure 4.3 Value of Agricultural Production by Proximity to Metro Areas



Source: U.S. Department of Agriculture, Natural Resources Conservation Service, based on 1992 Census of Agriculture data, 1996.

Note: U.S. pie chart is not on same scale as regional pies.

Figure 4.4 Cropland Converted to Developed Land by Region, 1982-1992



Source: U.S. Department of Agriculture, Natural Resources Conservation Service, based on National Resources Inventory data, 1992.

Over the same period (1982-1992), about 4 million acres were converted to developed land (Figure 4.4). About two thirds of this total was converted to residential development. However, the rate of conversion to residential development has slowed compared to earlier decades.

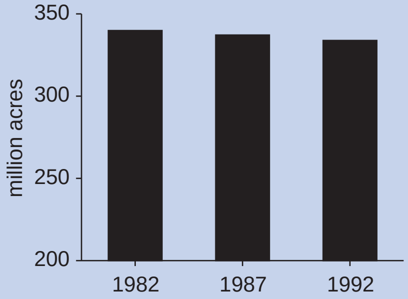
Saving Prime Farmland

The loss of prime farmland (Figure 4.5) has prompted the development of farmland preservation programs. Fifteen states, mostly in the Northeast, now pay farmers willing to keep their land in an agricultural use. Easements stay with the land even after its sale, guaranteeing that farmland stays farmland.

Since the mid-1970s, farmland preservation laws have protected nearly 420,000 acres of farmland at a cost of almost $730 million, or about $1,750 an acre. Funding for the programs has come mostly from sale of bonds and the levy of sales, property, and other taxes. An additional $195 million was available early in 1996 for further purchases, including $107 million in New Jersey alone.

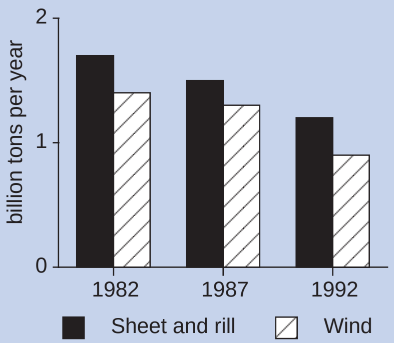
Maryland leads the way in farmland protection, spending $125 million to pur-

Figure 4.5 U.S. Prime Farmland, 1982-1992



Source: U.S. Department of Agriculture, Natural Resources Conservation Service, *Summary Report 1992 National Resources Inventory* (USDA, NRCS, Washington, DC, 1995).

Figure 4.6 U.S. Cropland Erosion by Type, 1982-1992



Source: See Part III, Table 7.6.

chase easements on 117,000 acres of farmland. Pennsylvania has spent more than $150 million to protect almost 75,000 acres; Massachusetts and New Jersey also have made substantial investments in the program.

The federal government is supporting farmland protection; a provision in the 1996 farm bill authorizes a farmland protection program with up to $35 million in funding. The program is designed to help state programs purchase conservation easements.

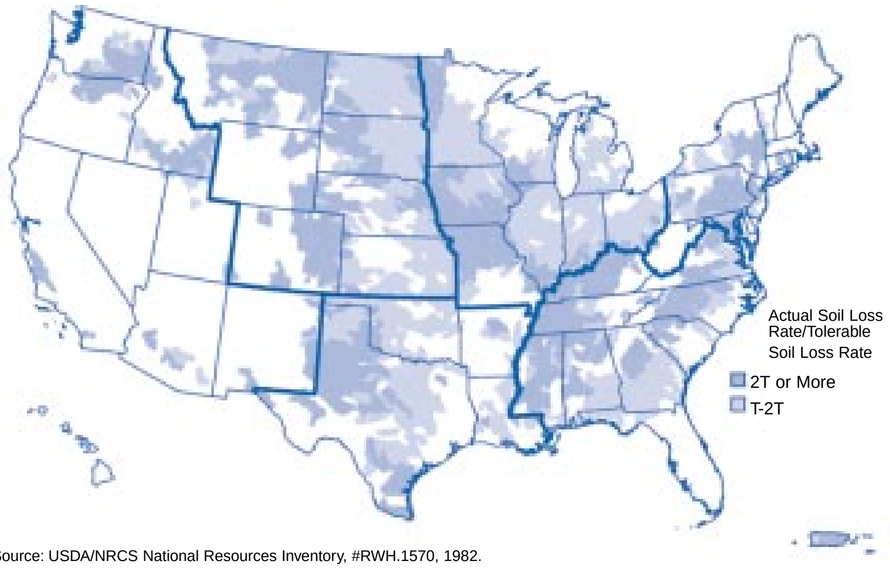
Reducing Soil Erosion

Since the Dust Bowl days of the 1930s, and particularly over the last two decades, American farmers have made remarkable progress in reducing soil erosion on cropland and rangeland. In 1982, erosive forces moved about 3.1 billion tons of cropland soil, including about 1.4 billion tons attributable to wind erosion and 1.7 billion tons carried away by water. By 1992, soil erosion on cropland had dropped to about 2.1 billion tons, including 900 million tons via wind and 1.2 billion tons via water (Figure 4.6).

Depending on soil type and a number of other factors, some soil erosion is tolerable. Over the 1982-92 period, cropland with tolerable levels of sheet and rill erosion increased from 73 to nearly 79 percent of all cropland, while tolerable rates for wind erosion increased from 79 to nearly 84 percent. Nevertheless, erosion remains above tolerable rates for a substantial fraction of the nation's cropland (Figures 4.7 and 4.8).

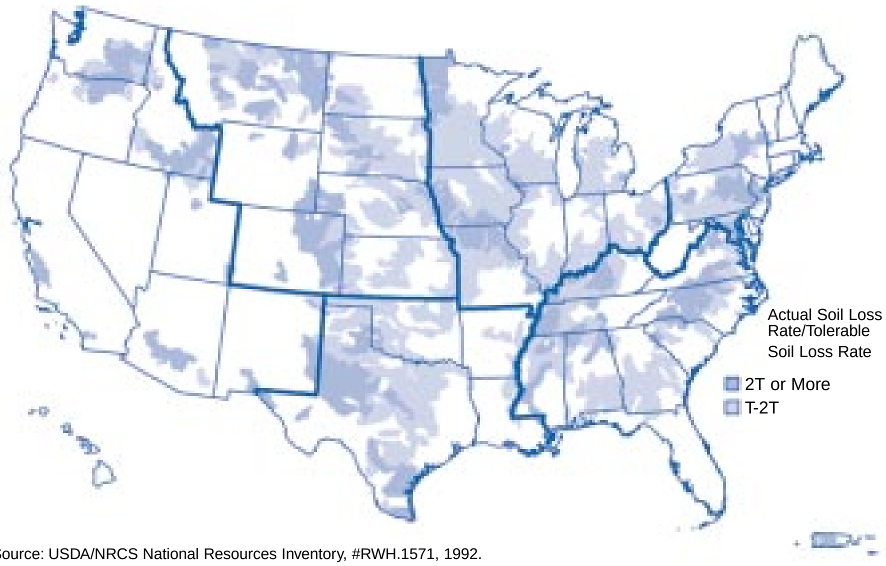
Taking highly erodible land out of production has helped reduce erosion tremendously. Under the Conservation Reserve Program, which has taken 36 million acres of highly erodible land out of production, farmers planted trees and grasses, installed windbreaks and wildlife ponds, and used a variety of other conservation practices. The CRP reduced erosion on retired acres from 12.5 tons per

Figure 4.7 Soil Erosion as a Proportion of the Tolerable Rate (T), 1982



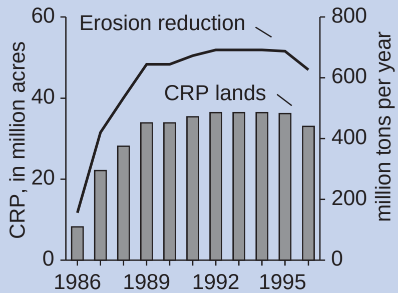
Source: USDA/NRCS National Resources Inventory, #RWH.1570, 1982.

Figure 4.8 Soil Erosion as a Proportion of the Tolerable Rate (T), 1992



Source: USDA/NRCS National Resources Inventory, #RWH.1571, 1992.

Figure 4.9 Erosion Reduction on Lands in the Conservation Reserve Program, 1986-1996



Source: USDA, Economic Research Service.
Note: Erosion reduction refers to the amount of soil not eroded due to CRP. Data are based on cumulative enrollment at the end of each calendar year.

acre in 1982 to 1.5 tons per acre in 1992. Total annual soil erosion reduction as a result of the CRP may be as much as 700 million tons (Figure 4.9). Furthermore, wildlife populations rebounded in many areas as grassland and forest habitat increased.

New farming practices also are helping reduce erosion. Conservation tillage, which reduces soil disturbance and maintains residue levels of at least 30 percent on a field surface, can both reduce soil erosion and increase soil organic matter. Over the 1989-96 period, conservation tillage on cropland increased 45 percent, from 71.7 to 103.8 million acres. Conservation tillage acres are concentrated in the Midwest and Northern Plains, the only regions where the practice is undertaken on more acres than conventional or reduced tillage (Figure 4.10).

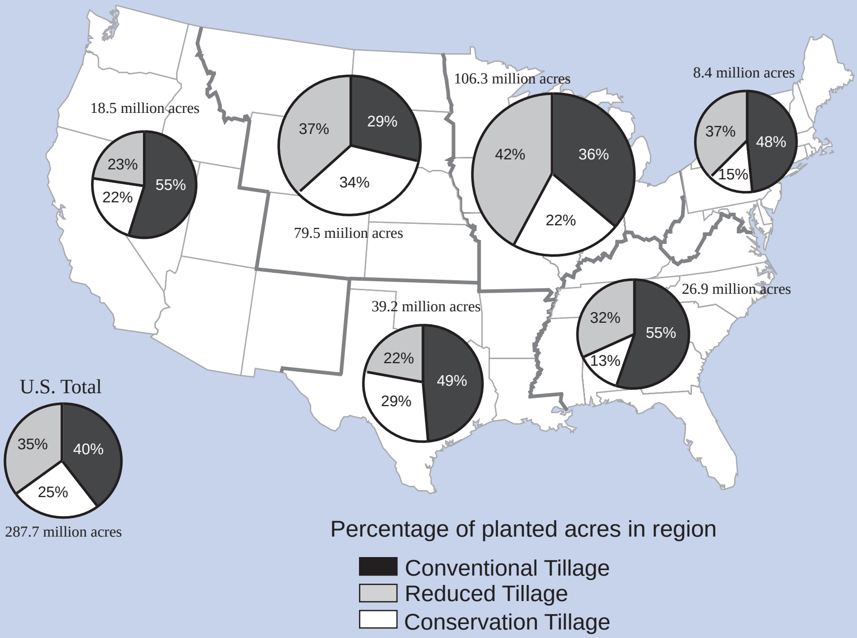
Conservation compliance plans, in which farmers plan and apply conservation systems to highly erodible cropland as a condition of eligibility for USDA farm benefit programs, have been developed on more than 140 million acres of cropland since the late 1980s. Implementation of these plans reduced the average annual soil loss on these acres from 11.7 to 6.9 tons per acre between 1992 and 1995. By 1992, erosion on about 42 million acres—almost 40 percent of all highly erodible cropland—had been reduced to below the tolerable level.

Is there a payoff to such conservation initiatives? In the Driftless Area of the Upper Mississippi Valley, including Coon Valley, Wisconsin, USDA started a program of conservation initiatives as early as 1933. At the time the project was established, it was estimated that soil erosion was nearly 15 tons per acre. In 1992, some 60 years later, the average annual erosion rate had declined to just over 6 tons per acre. This occurred even though the acreage in row crops, which is expected to have high erosion rates, had nearly doubled, while the acreage in small grains, which normally has lower erosion rates, had declined more than 80 percent.

Protecting and Restoring Wetlands

The conversion of wetlands to croplands has historically been one of the principal factors in the rapid loss of wetlands in the United States. Although wetlands in the conterminous United States are continuing to diminish, the rate of decline has slowed substantially.

Figure 4.10 U.S. Tillage Practices by Region, 1995



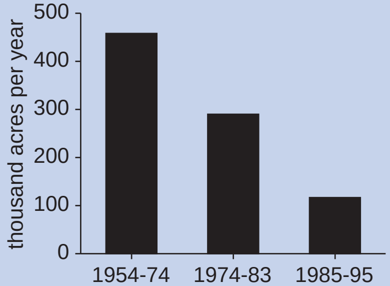
Source: U.S. Department of Agriculture, Natural Resources Conservation Service, based on Conservation Technology Information Center data, 1995.

Note: U.S. pie chart is not on same scale as regional pies.

There are now about 100.9 million acres of wetlands in the conterminous United States. Of this total, 95 percent are inland freshwater wetlands, while 5 percent are coastal or estuarine wetlands. Freshwater forested wetlands make up the single largest category.

According to the latest Interior Department estimates on trends in wetland losses, the average annual net loss of wetland area between 1985 and 1995 was 117,000 acres, or a total of about 1.2 million acres over the entire period. This is some 60 percent lower than the loss rate reported for the period between the mid-1970s and the mid-1980s (Figure 4.11).

Figure 4.11 Average Annual Rate of U.S. Wetlands Losses, 1950s to 1990s



Source: See Part III, Table 6.14.

The latest figures indicate a decline of almost 5 percent in forested wetlands since 1985. As forested wetlands are cleared, some of these wetlands are replanted to trees or allowed to revegetate and remain as wetlands. The net result is a change from one wetland type to another; for example, the wetland shrub category increased in area in the 1985-95 period, but this was mostly at the expense of forested wetlands.

Wetland restoration activities that convert uplands to wetlands are contributing an estimated 78,000 acres per year to the wetlands total. An estimated 150,000 acres of freshwater emergent marshes were restored or created on agricultural lands during this period, according to the Interior Department.

The Policy Response. The federal government has used a combination of carrots and sticks to slow the rate of wetlands losses and encourage restoration of wetlands wherever possible.

Farmers who own or manage wetlands are directly affected by two federal programs. Section 404 of the Clean Water Act requires individuals to obtain a permit before discharging dredged or fill material into waters of the United States, including most wetlands. The Swampbuster provisions of the Food Security Act withhold certain federal farm benefits from farmers who convert or modify wetlands.

Most routine ongoing farming activities do not require section 404 permits. Other farming activities that involve discharges of dredged or fill materials may not require a section 404 permit if the activity is part of an ongoing farming operation and cannot be associated with bringing a wetland into agricultural production or converting an agricultural wetland to a non-wetland area.

The Swampbuster program generally allows the continuation of most farming practices. The program discourages farmers from altering wetlands by withholding federal farm program benefits from any person who plants an agricultural commodity on a converted wetland that was converted by drainage, dredging, leveling, or any other means (after December 23, 1985), or converts a wetland for the purpose of or to make agricultural commodity production possible (after November 28, 1990).

Federal efforts to protect wetlands have proven quite controversial over the years. Since coming into office, the Clinton Administration has developed a 40-point program to enhance wetlands protection while making wetlands regulation more fair and flexible. Since the program was announced in August 1993, many proposals have been implemented—streamlining the wetlands permitting program, encouraging mitigation of wetland impacts through the permitting process, responding to the concerns of farmers and small landowners, improving cooperation with private landowners to protect and restore wetlands, and increasing the role of state, local, and tribal governments in wetlands protection.

To make the wetlands program more consistent and predictable for farmers, the Clinton Administration clarified that "prior converted croplands" are not subject to regulation under section 404. Nearly 53 million acres are covered by this action, which exempts lands that no longer perform the wetlands functions as they did in their natural condition.

For those farmers with wetlands on their property, the Administration has simplified the process by using a single wetlands determination by the Department of Agriculture for both Food Security Act and Clean Water Act programs.

In 1995, an approval process was set up that allows landowners to affect up to one half acre of non-tidal wetlands for construction of single-family homes without applying for an individual section 404 permit.

Wetlands Reserve Program. Numerous programs encourage restoration of wetlands. One of the most successful is USDA's Wetlands Reserve Program, a voluntary program that offers landowners a strong financial incentive to restore and protect wetlands.

The program gives landowners three options: a permanent easement, in which USDA will pay up to the agricultural value of the land and all the costs of restoring the wetlands and uplands; a 30-year easement, in which USDA will pay 75 percent of what would be paid for a permanent easement and 75 percent of the restoration costs; and a restoration cost-share agreement, in which USDA will pay 75 percent of the cost of restoring a wetland in exchange for a minimum 10-year agreement to maintain the restoration. The 1996 farm bill requires that one third of the acres be enrolled though the use of permanent easements, one third through 30-year easements, and one third through restoration cost-share agreements, to the extent practicable. To date, demand and interest in permanent easements has been much higher than in the other two options.

Any type of land that can be restored to a valuable wetland at a reasonable cost is eligible, except for wetlands drained in violation of the Swampbuster program or land converted to trees under the Conservation Reserve Program.

In response to the devastating floods in the Midwest in 1993, an Emergency Wetlands Reserve Program was started that offered landowners an alternative to agriculture on their floodprone lands. In 1994 and 1995, over 86,000 acres were enrolled in this program.

All told, both programs have enjoyed strong support by both farmers and conservationists. Since 1992, at least 400, 000 acres of restorable wetlands and adjacent upland were enrolled in both the Wetlands Reserve Program (WRP) and the Emergency Wetlands Reserve Program (EWRP).

Iowa River Corridors Project. In Iowa, the Emergency Wetlands Reserve Program has been instrumental in building a broader locally driven program to rationalize land uses along the state's river corridors.

During the discussions that took place after the devastating 1993 flood, many Iowans had ideas about what should take place on their lands beyond returning flood-prone lands to wetlands. There was strong local interest in making the best use of all land along the river, uplands as well as flood-prone bottomlands. This could include recreation, non-consumptive wildlife uses, alternative crops, changed management of forest and grasslands, and traditional row crop production.

Largely through the active involvement of local groups, 11 river corridor projects are now underway in Iowa. Many groups are taking an active role in the river corridor projects, providing funds, technical support, contacting landowners, providing assistance for enhancement, and much more. The Iowa Natural Heritage Foundation's attorney works essentially full-time on WRP/EWRP river corridors. Many other organizations—the Fish and Wildlife Service, Iowa Department of Natural Resources, county conservation boards, Iowa Natural Heritage Foundation, and Nature Conservancy—are providing funds to purchase easements. Local groups such as Pheasants Forever and Ducks Unlimited are often involved in these river corridor projects.

IMPROVING WATER MANAGEMENT

Conflicts over current and future allocations of surface water are an especially difficult challenge in the western states. Typically, such conflicts are between the historical use of water for agricultural use by farmers on the one hand, and the increasingly recognized needs for urban and environmental uses on the other.

Fish and wildlife species that depend on river ecosystems for their survival are declining in every major river basin in the West. Some 184 species—either threatened, endangered, or proposed for listing under the Endangered Species Act—are affected by the Bureau of Reclamation's operations. In addition, the water rights of many Native American tribes have yet to be quantified or allocated.

Since rising costs and other considerations now preclude construction of major new water supply projects in the West, new demands for water have to be met largely by reallocating water from existing uses, primarily agriculture.

In response, the Bureau of Reclamation has identified a variety of water management measures: fundamental measures, such as pricing and measurement systems; institutional measures, such as water shortage contingency plans; operational measures, such as distribution control; and facilities-related measures, such as water reuse systems.

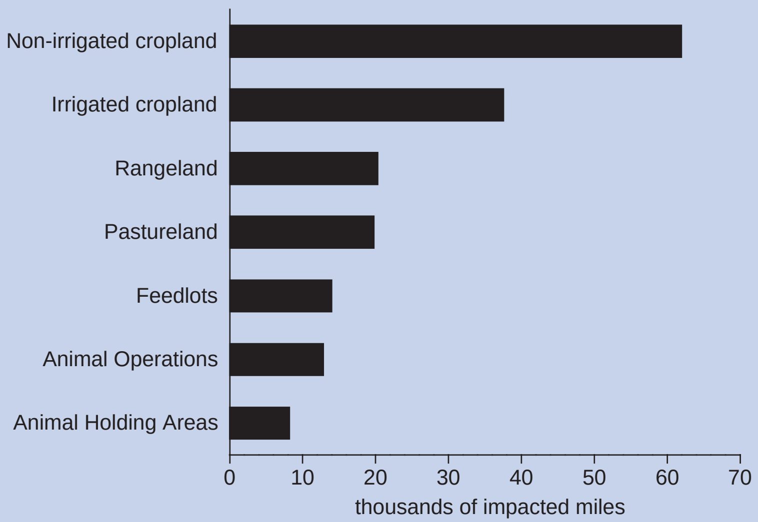
Fundamental measures include: a) improved water measurement, which should accommodate some form of volumetric pricing and billing for individual users and allow for tracking of water deliveries to individual users in order to accommodate a billing system based on deliveries; b) changes in water pricing to provide a stronger incentive for efficient water use; c) educational programs, which can help make water users aware of the benefits of water-use efficiency; and d) designating a conservation coordinator, which provides an important focal point for district water users.

Institutional water management measures include: a) water shortage contingency plans, which provide farmers with fairly certain information as to what they can expect in terms of water deliveries during drought periods; b) on-farm conservation incentives, such as tax incentives or low interest loans for improvements such as ditch lining, development of water reuse systems, installation of surge valves and gated pipes, sprinkler systems, field leveling, or soil treatments; c) water transfers, including permanent transfers, contingent transfers, tradeable shares or allotments, water banking, water wheeling, or transfers of reclaimed, conserved or surplus water; and d) land management, including land retirement, fallowing, or conversion to dryland farming.

Operational water management measures include: a) improved operating procedures, such as changes to a district's operating procedures that provide for increased delivery and storage flexibility; b) distribution control, such as installation of new structures or improvements to existing structures to more precisely manipulate flow rates and head levels; c) system-wide irrigation scheduling, which attempts to schedule water deliveries to match irrigation requirements; d) on-farm irrigation scheduling, such as using evapotranspiration estimates and soil moisture to provide a better estimate of true crop needs; and e) conjunctive use, which refers to the coordinated operation of surface water and groundwater resources to meet water requirements.

Facilities-related water management measures include: a) construction of regulatory reservoirs, which can help a district better match water deliveries to crop requirements; b) lining of canals and reservoirs, which can provide substantial

Figure 4.12 Agricultural Sources of Pollution in Surveyed U.S. Rivers and Streams, 1996



Source: U.S. Environmental Protection Agency, *National Water Quality Inventory: 1996 Report to Congress*, Table A4 (EPA, Washington, DC, 1998).

reductions in seepage losses; and c) water re-use systems, which are designed to capture system spills, seepage, and drainage waters for immediate or later use.

IMPROVING WATER QUALITY

Agriculture remains a vexing and significant source of pollution in rivers and lakes. According to the Environmental Protection Agency's 1996 National Water Quality Inventory, which assessed 19 percent of the nation's river and stream miles and 40 percent of lakes and ponds, agriculture is the most widespread source of pollution in the nation's waterways. Farms and ranches generate pollutants that degrade aquatic life or interfere with public use of 25 percent of all river miles surveyed. That is, agriculture is a source of pollution in one of every four surveyed river miles, whereas the next leading sources—municipal point sources and hydrologic modifications/habitat alteration—are problems in less than one in every 20 surveyed miles. Agriculture also is the leading source of impairment in lakes, affecting about 19 percent of surveyed lake acres.

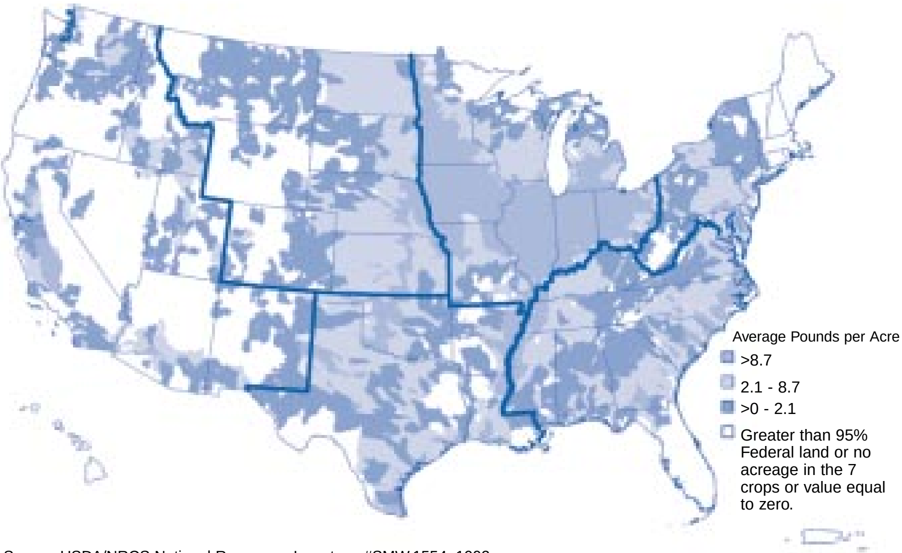
The states reported that nonirrigated crop production impaired the most river miles, followed by irrigated crop production, rangeland, pastureland, feedlots (facilities where animals are fattened and confined at high densities), animal operations (facilities other than large cattle operations—primarily poultry or swine), and animal holding areas (facilities where animals are confined briefly before slaughter) (Figure 4.12).

Nutrients—mainly nitrogen and phosphorus—are vital in the promotion of plant growth; if applied inappropriately or excessively, however, they are likely to move from the land into the water. Nitrate nitrogen is highly mobile; it can leach into groundwater, volatilize into the atmosphere, or be carried overland to nearby surface waters (Figure 4.13). Phosphate, while not as mobile as nitrate, tends to be carried on soil particles that erode off farmers' fields (Figure 4.14). When phosphorus reaches a saturation point in the soil it will also move freely in solution. Nitrate concentrations in streams and groundwater tend to be higher in agricultural areas than in undeveloped or urban areas (Figure 4.15). Phosphorus concentrations, on the other hand, tend to be higher downstream from urban sources because of point source contributions (Figure 4.16). See also Chapter Five, The Urban River.

Nitrogen and phosphorus interact with soils in different ways and numerous natural and manmade factors affect their potential transport and fate, including climate, soil type, proximity to water courses, tillage and conservation practices, and application rates and timing, among others.

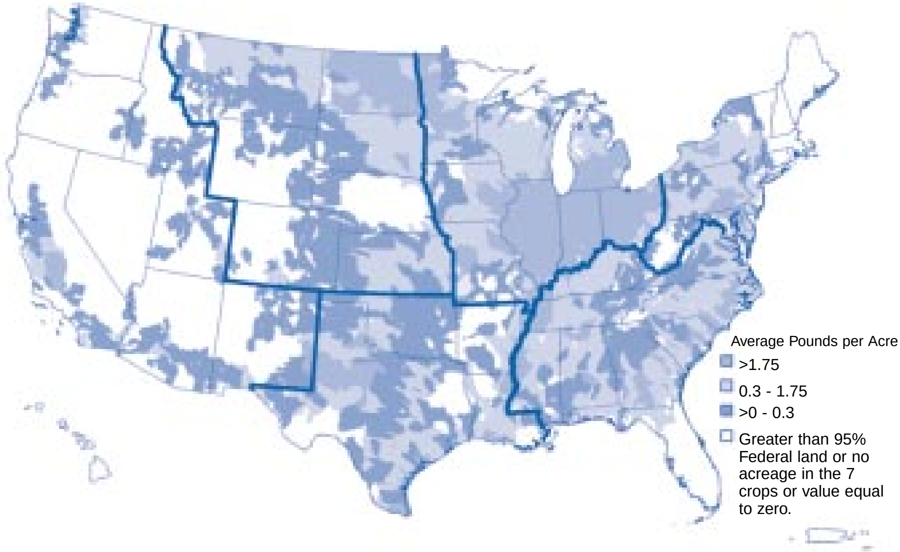
Agriculture accounts for about 80 percent of all pesticide use. Some crops, such as corn and cotton, are pesticide-intensive, while others such as wheat are not. Pesticides can leach through the soil into groundwater or run off the fields and into nearby water bodies. Runoff potential is somewhat greater in the Midwest (Figure 4.17), while leaching potential is greater in the humid Southeast (Figure 4.18).

Figure 4.13 Potential Nitrogen Fertilizer Loss from Farm fields, 1992



Source: USDA/NRCS National Resources Inventory, #SMW.1554, 1992.

Figure 4.14 Potential Phosphate Fertilizer Loss from Farm fields, 1992



Source: USDA/NRCS National Resources Inventory, #SMW.1555, 1992.

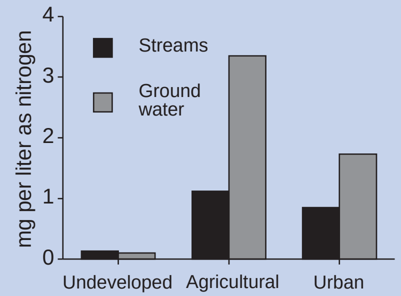
According to U.S. Geological Survey findings, the factors most strongly linked with increased likelihood of pesticide occurrence in wells are high pesticide use; high recharge; and shallow, inadequately sealed, or older wells. Frequencies of pesticide detection are almost always low in low-use areas, but vary widely in areas of high use. While pesticides are commonly present in low concentrations in groundwater beneath agricultural areas, they seldom are at levels exceeding water-quality standards. Low rates of pesticide detection often are found in high-use areas, indicating that other hydrogeoloic factors affect their occurrence in groundwater.

The frequency of pesticide detection may also be substantial in nonagricultural areas. In the Georgia portion of the Apalachicola-Chattahoochee-Flint River basin, pesticides applied to lawns, golf courses, parks, roadsides, swimming pools, and residential structures occur in urban watersheds. Concentrations of these compounds tend to be higher and are found for a greater part of the year than in agricultural watersheds.

An Emerging Problem: Animal Waste Pollution

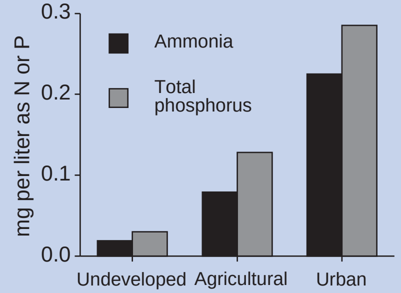
The production of broilers, turkeys, hogs, and non-dairy cattle is increasingly taking place in concentrated spaces with little cropland, raising serious concerns about the increasing risk of water pollution from animal waste spills, runoff from farm fields, and leakage from waste storage facilities. Animal waste pollution has been implicated as one of the causes of recent deadly outbreaks of the microorganism *Pfiesteria piscicida*.

Figure 4.15 Nitrate Concentrations in Streams and Ground Water by Land Use, 1979-1990



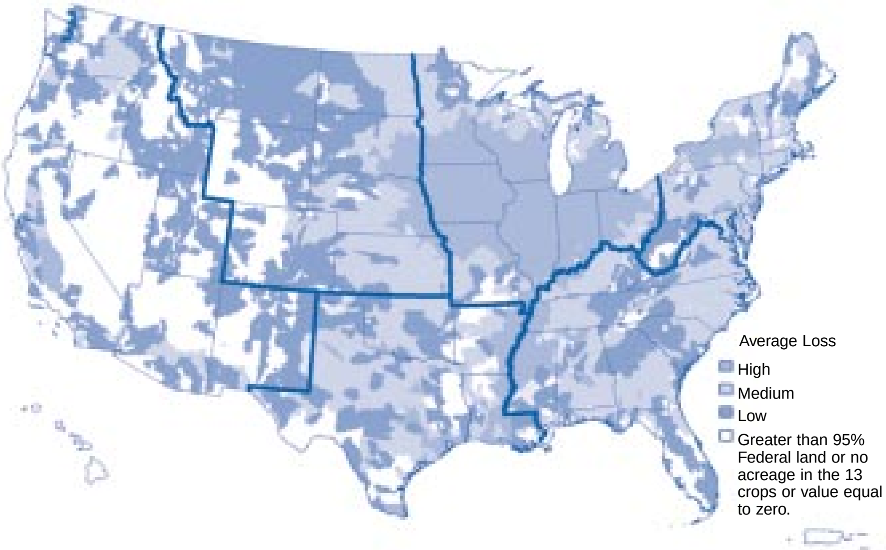
Source: Mueller, D.K. & D.R. Helsel, *Nutrients in the Nation's Waters -- Too Much of a Good Thing?* USGS Circular 1136 (USGS, Reston, VA, 1996).
Note: Data are median concentrations compiled from stations at the first 20 study units in the National Water Quality Assessment (NAWQA) Program.

Figure 4.16 Ammonia and Total Phosphorus Concentrations in Streams by Land Use, 1979-1990



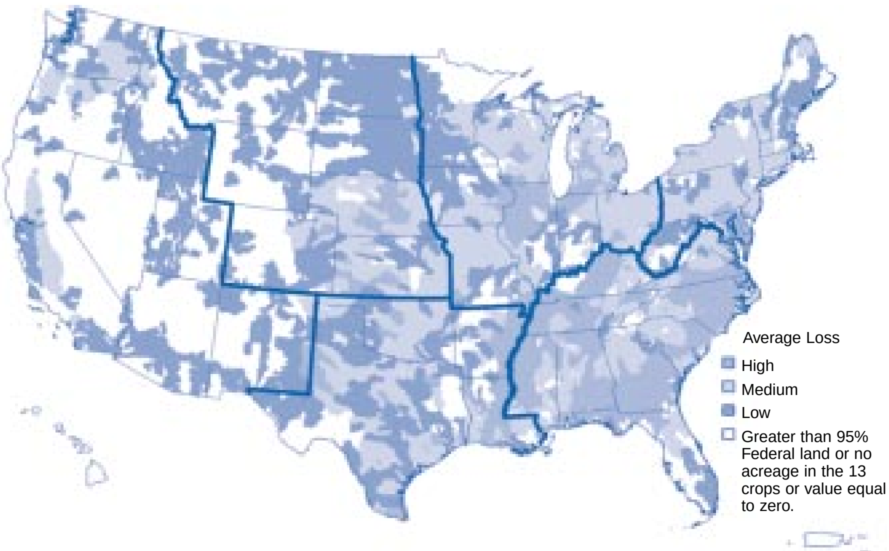
Source: Mueller, D.K. & D.R. Helsel, *Nutrients in the Nation's Waters -- Too Much of a Good Thing?* USGS Circular 1136 (USGS, Reston, VA, 1996).
Note: Data are median concentrations compiled from stations at the first 20 study units in the National Water Quality Assessment (NAWQA) Program.

Figure 4.17 Pesticide Runoff Potential for Field Crop Production, 1992



Source: USDA/NRCS National Resources Inventory, #SMW.1662, 1992.

Figure 4.18 Pesticide Leaching Potential for Field Crop Production, 1992



Source: USDA/NRCS National Resources Inventory, #SMW.1663, 1992.

The transition to more intensive livestock and poultry operations is quite dramatic. Over the past 15 years, the number of hog farms has dropped from about 600,000 to 157,000, yet the nation's hog inventory has increased. (Figure 4.19). The number of farms with broiler houses dropped by 35 percent between 1969 and 1992, but over the same period broiler production nearly tripled (Figure 4.20).

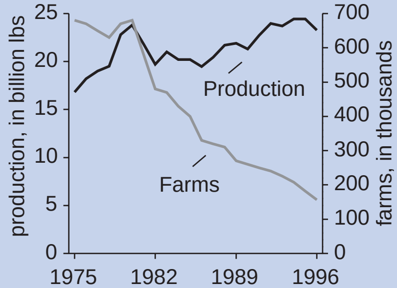
Of the nation's 450,000 confined feedlot operations, just 6,600—only about 1.5 percent—account for about 35 percent of total U.S. livestock production. Just 3 percent of the nation's hog farms produce more than 50 percent of the nation's hogs, while 2 percent of cattle feed operations account for over 40 percent of all cattle sold.

These operations are producing vast amounts of animal waste. Estimated annual U.S. manure production from animals totaled about 1.37 billion tons in 1997, or about 5 tons for every person in the nation. On the Delmarva Peninsula east of the Chesapeake Bay, 600 million chickens produce over 1.6 million tons of waste every year and as much nitrogen as from a city of 500,000 people.

The rising volume of animal waste is raising the risk of environmental impacts. Hogs and cattle generate liquid and solid waste. Water is used to flush this waste, typically into earthen lagoons or slurry tanks. Most of the solids (including much of the phosphorus) settle into a sludge at the bottom; most of the nitrogen remains dissolved in the water or volatilizes into the atmosphere. Poultry operations typically produce a dry litter with about 15-25 percent moisture content that is stacked or stored in metal or wooden structures or on the ground.

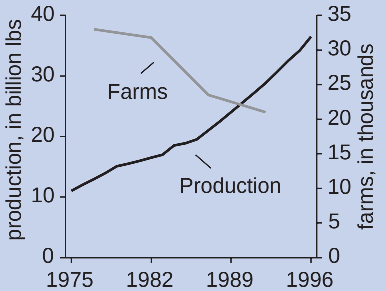
Animal waste, when applied in amounts greater than can be used by crops or retained by the soil, is susceptible to leaching and run-off into surface and groundwater. Waste spills from storage facilities also are a problem. An informal survey in a few livestock-producing states indicates that spills roughly doubled between 1992 and 1996. In North Carolina in 1995, 35 million gallons of

Figure 4.19 U.S. Hog Farms and Pork Production, 1975-1996



Source: USDA, NASS, *Agricultural Statistics* (annual).

Figure 4.20 U.S. Broiler Farms and Production, 1975-1996



Source: USDA, NASS, *Agricultural Statistics* (annual) and *Census of Agricultural* (quinquennial).

animal waste spilled into the state's waterways.

In areas with a large concentration of intensive livestock operations, many indicators of water quality are worsening. At one sampling site on the Neuse River in North Carolina, for example, average concentrations of nitrogen-bearing compounds and ammonia nitrogen doubled from the 1954-60 to the 1991-95 periods. Poultry and livestock operations may account for more than one third of the nitrogen that enters the Neuse River.

Pfiesteria seem to thrive in nutrient-enriched brackish waters such as the Neuse estuary, where the salt content is about 12 to 14 parts per thousand. In 1991, over one billion fish—mostly menhaden—died during a *Pfiesteria* attack in September and October. Another large fish kill occurred in August through November 1995.

Pfiesteria outbreaks occurred in Maryland's Pocomoke River in 1996 and again in 1997. During the October 1996 period of the attack, total nitrogen levels were at 10-year highs and salinity was at a 10-year low. Nitrogen and phosphorus levels in the Pocomoke River are higher than average when compared to other Chesapeake Bay tributaries, and nitrogen levels have been increasing since 1986. In August 1997, another *Pfiesteria* attack killed an estimated 30,000 fish, again mostly menhaden.

Maryland was the first state in the nation to link toxic outbreaks of *Pfiesteria* to concerns about public health. Symptoms reported among people with close exposure to *Pfiesteria* in its toxic form include memory loss, respiratory problems, and skin rashes. (See Chapter Six.)

Current Federal and State Actions. Under the Clean Water Act, no point source may discharge pollutants unless it is in accordance with a permit issued by EPA or a state under EPA's National Pollutant Discharge Elimination System (NPDES). The act's definition of point source includes concentrated animal feeding operations (CAFOs). EPA's regulations define a CAFO as an animal feeding facility in which animals are confined for 45 days or more out of a 12-month period, over which no crops or forage growth is sustained, and that meets one of the following additional conditions: a) it contains 1,000 animals units and has the potential to discharge pollutants into water by any means; b) it contains over 300 animal units and is discharging pollutants through a man-made device directly into a water body; or c) it is designated a CAFO after a site inspection determines that the operation is or has the potential to be a significant polluter, no matter its size.

Under the Safe Drinking Water Act, animal feeding operations that are identified as a source of groundwater contamination, or are within a designated wellhead protection area, or that are located near public water systems, may be subject to additional discharge limitations or management practices.

The Department of Agriculture does not have regulations that govern animal waste management. The Natural Resources Conservation Service provides conservation assistance to farmers that includes waste and nutrient management for livestock and poultry farms.

Many states have enacted new laws and regulations recently. For example, North Carolina and Kentucky recently imposed moratoria on the construction of most new livestock operations.

At the federal level, the Clinton Administration's new Clean Water Action Plan includes a commitment that EPA and USDA will jointly develop a unified national strategy to minimize the environmental and public health impacts of animal feeding operations. EPA is considering new Clean Water Act regulations, increased inspections of operations, and stepped-up enforcement against polluting operations. USDA and EPA are planning to establish comprehensive management systems for animal feeding operations that are environmentally sustainable.

The National Environmental Dialogue on Pork Production—which includes EPA, USDA, several state environmental and agriculture departments, and individual pork producers affiliated with the National Pork Producers Council—has recommended environmental regulations for swine operations. These recommendations will: apply to all sizes of operations; require new operations to comply with recognized engineering standards; limit manure application by crop nutrient needs and soil nutrient levels; require certification and training for facility operators; require setbacks from water bodies, residences, and other public facilities; and allow public notice and comment on proposed operations.

New Strategies for Better Water Quality

Better management practices are having a demonstrable effect in reducing agricultural pollution. Such practices include:

- Maintaining unplowed strips of grass and vegetation or natural wetland areas along stream banks to prevent soil and water runoff.
- Accurately determining fertilizer needs.
- Ensuring the efficient use and careful application of pesticides.
- Using practices such as crop rotation that interrupt destructive insects' life cycles to reduce the need for pesticides.

Over 100 different beneficial practices have been identified. The most widely adopted include conservation cropping, cover or green manure crops, conservation tillage, and animal manure management. Popular management practices include improved fertilizer timing and application and use of soil nitrogen tests.

In a demonstration project in Delaware, farmers adopted nutrient management practices on 44,000 acres, reducing nitrogen applications by 2,600 tons and phosphorus applications by 2,100 tons. In a survey of 16 demonstration projects in the early 1990s, USDA found that annual nitrogen application rates declined by 14 to 129 pounds per acre, while phosphorus applications were reduced by 3 to 106 pounds per acre. As of 1994, total annual reductions for the

Aerial spraying of North Carolina cornfields.

Photo Credit:
S.C. Delaney/EPA

16 projects were 22.3 million pounds of nitrogen and 10.3 million pounds of phosphorus.

The Maumee River Basin, Ohio. Between 1972 and 1982, phosphorus loadings into Lake Erie from municipal sources were reduced by 85 percent, and it was clear that further reductions in phosphorus would have to come from nonpoint sources such as agriculture.

Ohio's Maumee River was a prime candidate for such an initiative, since it was contributing about 46 percent of the phosphorus and 37 percent of sediment entering Lake Erie, while providing only 3 percent of the inflow. Cropland covers about 80 percent of the basin's 3.1 million acres.

Studies indicated that land use practices such as conservation tillage and winter cover residue had the best potential to reduce sediment and phosphorus runoff. State and federal officials settled on a strategy that emphasized lowering the cost a farmer pays for farm equipment that leaves more plant residue on the surface. In October 1991, the strategy was approved by EPA and awarded a $641,000 grant under section 319 of the Clean Water Act. The plan included targeting critical areas; listing residue enhancing equipment and land treatments approved for cost share; maximum cost-share amounts; and minimum acreage requirements for each cost-share item.

Soil and water conservation districts were permitted to approve or disapprove applications from local farmers, while a joint advisory board consisting of one representative from each county in the basin provided local input and direction. In the first year, some 513 farmers from 15 counties participated, committing an average of $10,000 each in pollution control equipment. The $641,000 in cost-share payments generated some $5 million in matching funds.

West Lake, Iowa. West Lake, the surface reservoir for the cities of Osceola and Woodburn in south-central Iowa, was in the late 1980s heavily polluted with sediment, pesticides, and nutrients. About two thirds of the lake's drainage area was cropland, primarily in a corn-soybean rotation.

Sediment was rapidly reducing the reservoir's capacity, damaging filtration and pumping equipment, increasing maintenance costs, and making additional water treatment necessary. In 1987, sampling by the Osceola water treatment plant detected atrazine and cyanazine levels above the federal drinking water standards; concentrations remained high in 1991.

In November 1990, the Clarke County Soil and Water Conservation District developed a watershed management plan that was supported by an EPA grant and funds from Iowa's Resource Enhancement and Protection Program. Under the plan, 41 landowners representing 2,500 acres of the most highly erodible cropland were offered incentives. They included financial payment for acres contracted into soil conserving practices, soil fertility analysis, sprayer calibration, evaluation of land use, assistance in implementing reduced or no-till systems, and fertility and crop pest consultation.

In 1991, project staff convinced a number of farmers to voluntarily reduce or eliminate their use of atrazine and cyanazine. For the farmers cooperating in this voluntary program, the number of gallons of atrazine applied dropped from 443 in 1991 to 8 in 1992. For the entire watershed, the use of atrazine was nearly cut in half, going from 1,159 gallons in 1991 to 638 gallons in 1992; cyanazine use dropped from 3,281 gallons in 1991 to 2,500 in 1992. Lake monitoring also showed that cyanazine and atrazine levels dropped substantially in 1992. According to participating farmers, voluntary compliance was quicker and more effective than waiting for mandatory regulatory compliance. The limited number of landowners and the relatively small size of the watershed also were factors in the program's success.

The project's integrated crop management component also provided recommendations for alternative solutions to atrazine use, including services such as soil tests and recommendations for managing pest outbreaks.

In 1992, the integrated crop management program designed a nutrient management strategy for 689 acres that resulted in substantial reductions in fertilizer. Reduced applications of phosphorus and potassium saved one farmer $18 per acre on 87 acres and another saved $15 per acre on 190 acres.

The project also resulted in a significant decrease in soil loss. In 1990, soil loss averaged 18.8 tons per acre; two years later, it was down to 7.5 tons per acre. Much of the reduction was due to the widespread adoption of no-till planting, terraces and sediment control structures, field borders, waterways, buffer strips, and cross-slope farming—all promoted through the project.

Central Platte Valley, Nebraska. Farmers in the Central Platte Valley in Nebraska have been using heavy doses of nitrogen fertilizers and intensive irrigation since the 1960s, largely for the production of corn. Combined with the area's coarse sandy soils and shallow water table, these practices led to significant nitrate contamination in groundwater. In some parts of the region, nitrate-nitrogen groundwater concentrations were reaching 18.9 parts per million—nearly twice the safe level of 10 ppm established by EPA—and in a few sites concentrations were as high as 40 ppm. Since groundwater provided essentially all the area drinking water, these levels of nitrate contamination posed a serious threat to the area's drinking water supplies.

In response to the problem and the mandates required by a 1986 state groundwater protection law, the Central Platte Natural Resources District in 1987 developed a comprehensive groundwater management plan. The plan—the first in the state designed to reduce nitrate contamination in groundwater—tailored its management directives according to the severity of the contamination problem.

In Phase I areas, with contamination in the 0-12.5 ppm range, producers were

A stream in rural Michigan.

Photo Credit:
Greg Baier/USGS

banned from applying nitrogen on sandy soils in fall and winter and were required to attend training classes to become certified to apply nitrogen fertilizers. In Phase II areas, with contamination in the 12.6-20 ppm range, producers must be certified, test soils and irrigation water annually for nitrate-nitrogen content, and file annual management reports. They are also prohibited from applying nitrogen to sandy soils in fall and winter. Compliance with recommended practices for nitrogen and irrigation water management is voluntary. In Phase III areas, with concentrations exceeding 20 ppm, producers must meet all Phase II requirements, are prohibited from applying nitrogen in fall and winter on all soil types, and must split spring applications of nitrogen or include an inhibitor.

Nitrate-nitrogen levels in groundwater, which had been increasing at an average rate of 0.5 ppm per year since 1960, began declining in 1989 at an average rate of more than 0.3 ppm per year. An average decline of more than 1.0 ppm was achieved in three years. Concentrations leveled off in 1991-92, apparently as a result of excessive leaching of nitrate-nitrogen due to unusually wet conditions.

An important part of the program's success was an education effort to convince farmers that the recommended nitrogen and irrigation practices would not harm their yield and would save money in the long run. In 1992, district farmers saved approximately $1.6 million by applying less fertilizer and still maintained acceptable levels of crop yields.

PROTECTING RIVER BANKS

The many opportunities for farmers to reduce nonpoint pollution through better management practices represent an important component of a broad effort to protect America's rivers. Another vital part of this effort is the protection and restoration of streambanks and the "riparian" lands adjacent to creeks, streams, and rivers.

In the Eastern half of the nation, streamside woodlands can play a vital role in reducing runoff of nutrients and sediment, in ameliorating the effects of some pesticides, and in improving food and habitat conditions for stream communities. For example, sediment is reduced by the many obstructions encountered in a forest; additional sediment is filtered out by the porous soil structure, vegetation, and organic litter.

Since about 85 percent of available phosphorus is bonded to the small soil particles that comprise sediment, phosphorus is also reduced by the filtering action of the streamside forest. Roughly 4 percent of the phosphorus is attached to soil particles that are too small to be filtered by these processes.

Nitrogen from fertilizer and animal waste is soluble in water as nitrate and can leach downward through the soil into groundwater or move laterally to contaminate surface waters. Under well-oxygenated soil conditions, bacteria and fungi in the streamside woodlands convert nitrogen in runoff and decaying organic debris into mineral forms (NO_3), which can be synthesized into proteins by plants or bacteria. When soil moisture is high, denitrifying bacteria convert dissolved nitrogen into various nitrogen gases, which are then returned to the atmosphere.

Pesticide residues borne by runoff can also be converted to non-toxic compounds by microbial decomposition, oxidation, reduction, hydrolysis, solar radiation, and other biodegrading forces at work in the soil and litter of the streamside woodlands.

Streamside woodlands play an important role in maintaining the health of aquatic ecosystems. In small, well-shaded upland streams, as much as 75 percent of the organic food base may be supplied by dissolved organic compounds or detritus such as fruit, limbs, leaves, and insects that fall from the forest canopy. The stream-bottom bacteria, fungi, and invertebrates that feed on this detritus form the basis of the aquatic food chain, and in turn they pass on this energy to larger fauna and eventually to fish.

Through their impact on water temperature, streamside woodlands also play an important role in improving rivers as habitat for trout and other fish. Lacking shade from a forest, stream water temperatures are dramatically increased by direct solar radiation, which has the double effect of decreasing the amount of dissolved oxygen in the water and increasing a trout's demand for oxygen. Furthermore, insects, the favorite food of trout, are abundant in stream reaches cooled by streamside forests.

Though comprising less than 1 percent of the region's total area, riparian areas in the West are nevertheless among the region's most productive and valuable lands.

These areas provide important habitat for many western wildlife species. In the Great Basin of southeastern Oregon, more than 75 percent of terrestrial wildlife species are dependent upon or use riparian habitats. In Arizona and New Mexico, 80 percent of all vertebrates depend on riparian areas for at least half of their life cycles. More than half of all bird species in the southwestern U.S. are completely dependent upon riparian areas.

By the late 1880s, about 19 million cattle and sheep were grazing in the arid West. The rapid expansion of livestock operations in the West took a heavy toll on many western riparian areas. Livestock tend to concentrate in riparian areas for extended periods of time, eat virtually all of the grassy and woody vegetation, and trample the streambanks while using the stream for drinking water. Over several decades, native perennial grasses were virtually eliminated from vast areas and were replaced by sagebrush, mesquite, juniper, and other exotic plants.

As rangelands deteriorated, wind and water erosion accelerated. Unchecked flood flows eroded unprotected streambanks and cut down streambeds. Water tables lowered, and perennial streams became intermittent or dry during much of the year. These conditions led to a drying out of the land that reduced the productivity of an estimated 225 million acres in the West.

Today, many streams throughout the West are littered with the remains of what were once vigorous aspen groves. Aspen reproduce by sending up shoots from roots, but if these young plants are constantly grazed, the parent trees will eventually die and aspens will disappear from the site.

Can Western riparian areas be successfully restored? A June 1988 report by the General Accounting Office (GAO) reviewed 22 riparian areas in 10 Western states that had been restored by the Bureau of Land Management or the Forest Service. GAO found that these successes—while limited in number compared to the scope of the problem—"demonstrate dramatically the extent of improvement that is possible." Furthermore, the report found no technical barriers to improving riparian areas and that the restoration approaches used on successful projects can essentially be applied to all riparian areas on federal rangelands.

GAO found that all these projects shared one technique in common—limiting the access of livestock to riparian areas. In some cases, the area was fenced off; in others, the number of livestock was limited or their grazing was restricted to certain periods of the year.

In some cases, improvements also were made in areas away from the streams in the uplands in order to provide water for livestock, lessen grazing pressure on the riparian areas, and improve the water runoff into streams. Some of these improvements included building water storage tanks and troughs with water piped to them from the stream or a spring; blasting potholes to collect water; burning unwanted vegetation to encourage growth of grass; and making improvements to springs to increase their flow. In each case, restoration depended primarily on managing livestock so that the native vegetation had more opportunity to grow and regenerate.

Since about 1980, the overall condition of western rangeland has stabilized and in some areas improved. But riparian areas, which are now widely recognized as crucial to the overall health of the range, remain largely in degraded condition.

Duck Creek/Henry's Lake, Idaho. Henry's Lake covers about 6,500 acres along the continental divide in eastern Idaho. The lake is fed by numerous large springs; several small tributary streams provide spawning habitat for cutthroat and brook trout. Juvenile fish migrate to the lake and attract anglers from around the United States. Over many decades, livestock had depleted streamside vegetation and trampled streambanks, summer water temperatures had increased, streambanks had eroded, and trout spawning gravels had been smothered in sediment.

To deal with the problem, concerned fishermen, summer home owners, local ranchers and business owners formed the Henry's Lake Foundation to raise money and manpower to revitalize the lake fishery and the dependent local economy. For its first project in 1985, the foundation raised money from its members to permanently exclude livestock from the riparian area along a half-mile reach of private land on Duck Creek, an important trout spawning and rearing stream that feeds into Henry's Lake. Foundation members took time off from jobs and vacations to build a fence to the landowner's specifications. The foundation paid the landowner a small fee to cover the cost of maintaining the fence.

Even after decades of grazing, the area fenced from livestock responded dramatically in the first growing season. Vegetation rapidly re-established on eroded streambanks and began the natural process of trapping sediments and narrowing and deepening the stream channel.

Three years into the pilot project on Duck Creek, the rancher, foundation, and Idaho Fish and Game Department cost-shared a pasture subdivision project that will provide increased livestock forage production and complete protection for the riparian area and stream channel.

The key to success was cooperation among fishermen, landowners, and businesses with a stake in restoring and maintaining the overall long-term economic productivity of the area. Fishermen were instrumental in overcoming traditional barriers between fishery and agricultural interests. The key was their willingness to cost-share mutually beneficial solutions instead of simply blaming riparian landowners for the problem. By forming a partnership with the landowner, the foundation avoided spending years and many thousands of dollars proving the obvious. They chose to invest their money and energy in implementing solutions that produced quick results instead of paper.

West Rocky Creek, Texas. West Rocky Creek is located at 1,800 feet elevation in the porous limestone Edwards Plateau in west Texas. Over many decades, heavy overgrazing destroyed native grasses in the area, which were succeeded by dense stands of mesquite and juniper. These deeper-rooted plants used groundwater below the depth grass roots could reach, depleting water that previously had recharged springs and streams. West Rocky Creek became intermittent in 1918 and dried up completely in the 1930s, though it flowed sporadically during periods of above-average rainfall.

In the early 1960s, five ranchers began a range rehabilitation program on their privately owned land with technical assistance and cost-sharing provided by USDA's Great Plains Conservation Program. Extensive, costly brush removal and grass reseeding plus improved grazing strategies were implemented on about half the 74,000-acre watershed. By 1970, springs that had been dry for decades began to flow again on all five ranches. West Rocky Creek began to flow year-round, yielding from 150-4,000 gallons per minute during the severe 1984 drought. Riparian vegetation re-established and streambanks and the stream channel stabilized.

Improving the productivity of the West Rocky Creek watershed produced significant downstream benefits to the city of San Angelo. The quantity and quality of water yielded to water supply reservoirs increased. Reduced sedimentation increased the economic life of reservoirs and decreased water treatment costs.

Continuing good grazing management was a key to the project's success. Some nearby sites received the same brush removal and reseeding treatments, but were improperly grazed. Those sites quickly deteriorated and eventually became reinfested with brush.

Huff Creek, Wyoming. Huff Creek is located at 6,600 feet elevation in the mountainous foothills of southwestern Wyoming. It is one of several streams within a 91,000-acre multiple permittee allotment in the Rock Springs District of the Bureau of Land Management.

In the mid-1970s the trout in Huff Creek were identified as a pure strain of Bonneville cutthroat, then under consideration for listing as a threatened species under the Endangered Species Act. To provide emergency protection, in 1976 and 1979 livestock were excluded from stream reaches totaling about one mile in length. Instream structures and rock riprap were installed to elevate the water table, improve trout habitat and reduce streambank erosion.

The area inside the fences responded dramatically. Streambanks healed and the stream channel narrowed and deepened. Within five years the riparian area had roughly doubled in width due to the elevated water table. Vegetation shifted back to grass, and the grass inside the fences stood over two feet high, whereas grass outside the fence was sparse, less than two inches tall, and dominated by sagebrush.

Seeing the demonstrated potential for increasing livestock forage, the livestock association decided to change its grazing strategy for the six-mile-long Huff Creek drainage. A rider was hired to herd stock in the north half of the allotment. Grazing in the Huff Creek valley bottom was delayed until late August through September. The lower half of the valley received light grazing because the herder accelerated the animals' natural drift pattern. Herding and strategically placed salt blocks improved livestock distribution and provided ungrazed forage for stock being trailed to winter pastures.

The number of calves and weight gains improved. In three years, riparian vegetation outside the fence looked the same as vegetation inside the fence. Huff Creek had narrowed by about one third, doubled in depth, and water temperatures had declined. The percentage of eroding streambanks decreased from about 80 percent to about 20 percent, and the number of Bonneville cutthroat increased by over 1,000 percent over 1978 levels.

DOWNSTREAM LINKAGES

One of the most difficult environmental challenges facing the nation concerns the numerous linkages between upstream pollution and downstream impacts. Increasingly, environmental managers are connecting the dots between upstream and downstream and finding creative new ways to work together.

For example, the city of Syracuse, New York, has one of the few unfiltered water supplies in the country and is facing the prospect of investing $40 to $50 million in a filtration plant to maintain its water quality. In hopes of avoiding this expense, the city is now prepared to spend $17 million over 10 years to protect water quality in Skaneatles Lake, the city's source of water.

The Skaneatles Lake Watershed Program helps area farmers install pollution-prevention practices on their farms, promotes land conservation programs on nonfarm areas, and works with other

Although the majority of farmland is managed by a large number of small farm operators, ownership and control of agricultural assets is increasingly concentrated in fewer and larger farms.

Photo Credit:
S.C. Delaney/EPA

agencies to educate watershed residents about protecting the lake's water quality. The program assigns the highest priority to farms posing the greatest threat to water quality. In the summer of 1996, preparations were underway to implement conservation plans for the seven farms with the most serious conservation needs.

The city of Syracuse will provide up to 100 percent cost-sharing for farmers to install management practices such as intensive rotational management, barnyard water management, and nutrient management. One crop farm that is adopting contour farming is expected to reduce soil erosion by some 322 tons on 240 acres.

The program also is beginning to work with local land trusts to encourage the acquisition of conservation easements, sponsoring seminars and providing technical assistance to nonfarm landowners, and collaborating with the Cornell Cooperative Extension Service to provide education to towns and businesses and to watershed homeowners.

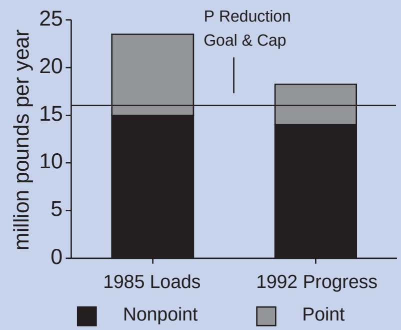
Another important link between upstream practices and downstream effects is the buildup of sediment from upstream sources in downstream harbors. Instead of dredging the harbor, port authorities could reduce or avoid such costs by reducing upstream soil erosion.

The Army Corps of Engineers and the Toledo Port Authority are trying the latter approach through a program that helps farmers reduce soil erosion on their land. In an unusual alliance, the Corps of Engineers, USDA's Natural Resources Conservation Service, and the Ohio Environmental Protection Agency are working together to reduce harbor sedimentation by a conservative 15 percent. Part of the funding for the project—$700,000—is coming from the Corps, while NRCS is providing offices, staff, and technical expertise.

NRCS and local conservation districts have set up Sediment Reduction Committees to work with farmers on soil erosion reduction initiatives. By the summer of 1996, a number of projects were underway, including adapting plans for conservation tillage, installing riparian corridors and windbreaks, planting grassy strips in gently sloping waterways, and holding field days to showcase new technologies and tools. In the program's next phase, NRCS will be working one-on-one with farmers to develop resource management plans.

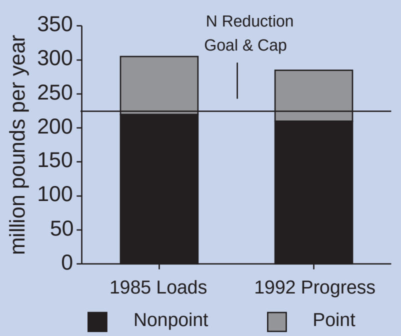
The connection between upstream pollution and downstream effects has also been an important part of the effort to restore the Chesapeake Bay. For example, farming practices along the Susquehanna River in Pennsylvania—miles upstream from the bay—have a profound impact on the health of the bay. The bay states—Pennsylvania, Maryland, and Virginia—have almost 1.5 million acres under nutrient management plans and have cut potential pollutants by 21 percent for phosphorus (Figure 4.21) and 5 percent for nitrogen (Figure 4.22).

Figure 4.21 Phosphorus Loads Delivered to the Chesapeake Bay by Source, 1985 and 1992



Source: U.S. Environmental Protection Agency, Chesapeake Bay Program, Chesapeake Bay Phase II Watershed Model, Annapolis, MD.

Figure 4.22 Nitrogen Loads Delivered to the Chesapeake Bay by Source, 1985 and 1992



Source: U.S. Environmental Protection Agency, Chesapeake Bay Program, Chesapeake Bay Phase II Watershed Model, Annapolis, MD.

REFERENCES

Chaney, Ed, Wayne Elmore and William S. Platts, *Managing Change: Livestock Grazing on Western Riparian Areas,* report prepared for the U.S. Environmental Protection Agency (Northwest Resource Information Center, Eagle, ID, 1993).

Clary, Warren P. and Bert F. Webster, *Managing Grazing of Riparian Areas in the Intermountain West* (USDA Forest Service, Intermountain Research Station, Ogden, UT, 1989).

Dove, Richard J., Testimony to U.S. House of Representatives Committee on Resources, Subcommittee on Fisheries Conservation, Wildlife, and Oceans (October 9, 1997).

Lipton, Eric, "Poultry Poses Growing Potomac Hazard," *The Washington Post* (June 1, 1997), p. A1.

U.S. Department of Agriculture, Natural Resources Conservation Service, *America's Private Land: A Geography of Hope* (NRCS, Washington, DC, 1996).

U.S. Department of Agriculture, Natural Resources Conservation Service, "Draft Strategic Plan for Fiscal Years 1996-2002" (NRCS, Washington, DC, 1997).

U.S. Department of Interior, Bureau of Reclamation, *Achieving Efficient Water Management* (December 1996), prepared for the Department of Interior by Hydrosphere Resource Consultants (available at http://ogee.do.usbr.gov/rwc/guide/).

U.S. Environmental Protection Agency, Office of Water, *Section 319 Success Stories* (EPA, Washington, DC, 1994).

U.S. Environmental Protection Agency, Office of Water, *National Water Quality Inventory: 1996 Report to Congress* (EPA, Washington, DC, 1998).

U.S. General Accounting Office, *Riparian Areas: Some Riparian Areas Restored but Widespread Improvement Will be Slow* (GAO, Washington, DC, 1988).

U.S. Senate Committee on Agriculture, Nutrition, and Forestry, "Animal Waste Pollution in America: An Emerging National Problem, Minority Staff report (December 1997).

Welsch, David J., Riparian Forest Buffers: Function and Design for Protection and Enhancement of Water Resources (USDA Forest Service, Radnor, PA, 1991).