

# Conservation and the Environment

Soil and water conservation engineering is the application of engineering and biological principles to the solution of soil and water management problems. The conservation of natural resources implies *utilization without waste* while maintaining a continuous profitable level of crop production and while improving environmental quality. Engineers must develop economical systems that meet these requirements.

The engineering problems involved in soil and water conservation may be divided into the following topics: erosion control, drainage, irrigation, flood control, and water resource development and conservation. Although soil erosion takes place even under virgin conditions, the problems to be considered are caused principally by human exploitation of natural resources and the removal of the protective cover of natural vegetation. Urban-rural interface problems are even more serious because of high population density and increased runoff caused by severe changes in land use.

Drainage and irrigation involve water and its movement on the land surface or through the soil mass to provide optimum crop growth. To provide water at places and times when it is not naturally available, surface reservoirs or other storage facilities must be developed for irrigation and domestic use. Where available, ground water supplies can be developed and maintained by recharge techniques. Flood control consists of the prevention of overflow on low land and the reduction of flow in streams during and after heavy storms. In water-short regions, soil water should be conserved by modified tillage and crop management techniques, level terracing, contouring, pitting, reservoirs, water harvesting, and other physical means of retaining precipitation on the land and reducing evaporative losses from the soil surface.

## Impact of Conservation Practices on the Environment

Some past civilizations have perished because they did not understand the impact of their agricultural practices or were unable to remedy their effects. For example, in some regions, high soil salinity reduced productivity to the point where food supplies were insufficient for the population to survive. Currently some argue that we do not have the incentive or economically viable technology to maintain long-term food production. Thus, it is important that we develop and apply the best conservation practices to protect the environment and conserve our soil and water resources for long-term sustainability.

Conservation practices can be beneficial or detrimental to the environment. For example, terracing rolling cultivated land can be beneficial by reducing erosion and sedimentation, or irrigation can be detrimental by increasing the salinity of downstream flow by the drainage water. Agricultural production of food and fiber is essential, but

preserving and enhancing the environment is also necessary as population pressures increase. When drinking water becomes contaminated with nitrates, pesticides, sediment, and other materials, the public is and should be concerned. The reduction in wildlife and disappearance of some species causes suspicion that something is detrimentally affecting the environment. Changing land use will modify the quantity and quality of terrestrial and aquatic habitats. Agricultural and wildlife interests are increasingly being coordinated by local, state, and federal governments. Many conservation practices are being changed to improve the environment with little or no cost to agriculture. Environmental costs are paid either by taxes, when supported by the government, or by higher prices, when supported by the private sector. With the adverse economic conditions in agriculture in the 1980s, low-input, sustainable agriculture programs were promoted. One of the many ways proposed to improve farming was to reduce fertilizers, pesticides, and other inputs, which could also enhance the environment. Others would argue that an increase in the use of fertilizers would increase production per hectare and require less land, so that erodible land could be taken out of cultivation and thus reduce erosion and pollution.

Erosion is one of the most serious problems because it pollutes the water with sediment, nutrients, and pesticides, increasing the cost of water treatment. Considerable effort has been made since the 1930s to develop conservation practices and to encourage reduced tillage and similar practices to keep crop residues and cover on the land. Although reduced tillage practices have been effective in reducing cost of production, pesticide use is generally increased with minimum or no tillage.

In general, the impact of drainage on the environment has been beneficial. The drainage of the lakebed area in the Midwest was instigated by medical doctors, who realized that it reduced malaria long before the mosquito was the known cause. The drainage of Central Park in New York City, which was one of the earliest drainage projects, was also done for health reasons. Obviously, subsurface drainage provides a desirable environment for the roots of agricultural crops and a stable base for roads and buildings. Without drainage much of our most productive crop land could not have been developed.

During the early development of the United States, agricultural interests prevailed and the drainage of swamps and other wetlands was done without question. In more recent years, drainage of these naturally wet areas was found to have some adverse effects on migrating terrestrial and aquatic life and other environmental aspects. As much as 50% of the wetlands have been drained, mostly in the Southeast, Midwest, and Pacific Coast states (USDA, 1989). Wetlands vary from permafrost in Alaska to the everglades in Florida to the desert wetlands in Arizona. In addition to providing habitat for fish and wildlife, wetlands enhance ground water recharge, reduce flooding, trap sediment and nutrients, and provide recreational areas. Federal legislation known as the Swampbuster Provision was passed to discourage wetland drainage.

Subsurface drainage water in humid areas and from irrigated lands generally contains higher concentrations of nitrate nitrogen, salts, and other chemicals than found in surface water or in the irrigation water. Wildlife interests often claim that open drainage ditches, when cleaned and straightened, reduce cover for wildlife. Because of this concern, some channel improvement projects have been redesigned to remove vegeta-

tion on only one side of the ditch and restrict cleanout and reshaping work to the opposite side. In large channels, low, small dams can be constructed to provide water pools for better fish habitat.

Irrigation in the central U.S. has been significantly changed by center-pivot irrigation. More land was converted to irrigation because of the center-pivot's ability to move over rolling terrain. One environmental benefit is that field corners have not been irrigated, but planted to trees and other vegetation. These corner areas have become wildlife sanctuaries and the wildlife population has greatly increased.

Irrigation projects, as in the West, have a major impact on the social and political structure of the entire community. Water storage and stream diversion facilities for irrigation, as well as stream flow and ground water use, influence minimum stream flow, depth of ground water, fish and wildlife populations, natural vegetation and crops grown, recreation activities, roads and public utilities, and other unique and site-specific factors. One example of a serious environmental problem is the chemical pollution (selenium and boron) from irrigation drainage water, such as occurred at the Kesterson National Wildlife Refuge in California (see Chapters 14 and 15). Blockage of the drainage system was mandated by the court. The Left Bank Outfall Drain in lower Pakistan, which is a constructed channel more than 250 km in length carrying only saline drainage water to the sea, illustrates the magnitude of the pollution problem. The Salton Sea in California is an example of an evaporation disposal site for drainage water. In the construction of the Aswan dam in Egypt, many people were displaced and archaeological sites were covered with water. Similar impacts exist where large dams are built for flood control. Because of such problems as described above, environmental impact statements, which necessitate more overall planning effort, are now mandatory for most projects that impact soil or water resources. Details of various conservation practices and their environmental impacts are included in most chapters and Chapter 2 has been devoted specifically to water quality.

## 1.1 Engineers in Soil and Water Conservation

Sound soil and water conservation is based on the full integration of engineering, atmospheric, plant, and soil sciences. Agricultural and Biological Systems engineers, because of their training in soils, plants, biology, and other basic agricultural subjects, in addition to their engineering background, are well suited to integrate these sciences. To develop and execute a conservation plan, engineers must have knowledge of the soil, including its physical and chemical characteristics, as well as a broad understanding of soil-plant-water-environment interactions. They have a unique role because their efforts are directed toward the creation of the proper environment for the optimum production of plants and animals. In addition to the agricultural application of their knowledge, they are playing an increasing role in the rural-urban sector, especially relating to air and water pollution control.

To be fully effective in applying technical training, engineers must be acquainted with the social and economic aspects that relate to soil and water conservation. They must have a full understanding of the various local, state, and federal government policies, laws, and regulations. They should also become familiar with ground and satel-

lite mapping techniques, geographic information systems (GIS), weather records and prediction systems, soil survey reports, and other physical data. To apply the vast amount of information available, engineers should be knowledgeable and able to use computers for solving job-related problems. Some of the presently available software will be referenced later.

## 1.2 Conservation Ethics

The increasing world population will dictate the necessity of conserving natural resources now and in future years. Fossil fuels, soils, minerals, timber, and many other materials are being exhausted at a rapid rate. The average 70-year-old American in a lifetime will use 1 000 000 times his or her weight in water, 10 000 times in fossil fuels and construction materials, and 3000 times in metal, wood, and other manufactured products (Wolman, 1990). Recycling of paper, glass, metals, and other items is being practiced, partly because of the increasing costs of waste disposal and partly because of public support and appreciation for conservation. The decreasing population of wildlife and the disappearance of many species are evidence that much of the problem is related to air and water pollution as well as loss of habitat. In agriculture, soil erosion from farmland is not only one of the major causes of water pollution, but the loss of the land itself reduces the production of food and fiber. Government incentive programs since the 1930s have been helpful, and research efforts have developed many useful agronomic, tillage, and mechanical practices. Exploitation of the soil and other natural resources for economic benefit has been practiced since the early pioneers developed this country. Private enterprise systems encourage this concept, but it is not in the best interest of society. Natural resources should be passed on to future generations in as good or better condition than previous generations have left them. Conversion of prime farmland to urban development and other nonfarm uses without regard to future food needs continues because farmland cannot compete with other higher value uses. Political solutions to these problems are not likely, but we can continue to promote and teach appropriate conservation ethics.

## 1.3 Environmental Regulations

Agricultural production has increased through more efficient farming systems and the use of fertilizers and pesticides. These on-site practices have had off-site impacts such as increasing the nitrogen content of ground and surface water supplies, as well as increasing the chemical content of streams and lakes from pesticides in runoff. Because most of the population is in urban areas, this has reduced the availability or quality of their already limited water supplies. To reduce the impact of various agricultural practices, environmental regulations have been established. Each state is authorized or required to establish Best Management Practices (BMPs). These practices establish guidelines based on Best Available Technology (BAT) that will minimize the pollution of our soil and water resources. For example, guidelines recommend the timing and amount of fertilizer to be applied to various crops that will just meet crop needs and thus reduce the nitrogen content of runoff and percolation. As further crite-

ria, Total Maximum Daily Loads (TMDLs) have been established for sediment and various chemicals in streams and rivers.

## 1.4 Hydrologic Cycle

Engineering for soil and water conservation and environmental control is based on understanding the processes of the hydrologic cycle. The hydrologic cycle (Figure 1.1) is composed of the processes of precipitation, evaporation, infiltration, runoff, transpiration, percolation to ground water, and interflow. Precipitation is the primary source of our useable water supply. The measurement or prediction of precipitation is required for most of the designs for soil and water conservation. Evaporation is the major depletion of water once it falls as precipitation. Infiltration fills the soil profile and adds to ground water storage. Runoff must be measured or predicted to estimate and control soil erosion, to predict flood events, and to estimate the availability of surface water supplies. Transpiration is difficult to measure and is combined with evaporation and called evapotranspiration. Evapotranspiration is important for irrigation and drainage design. Ground water supplies are replenished by percolation. Interflow is the lateral flow of water to streams or lakes. More detailed descriptions of the major processes in the hydrologic cycle are discussed in Chapters 3, 4, and 5.

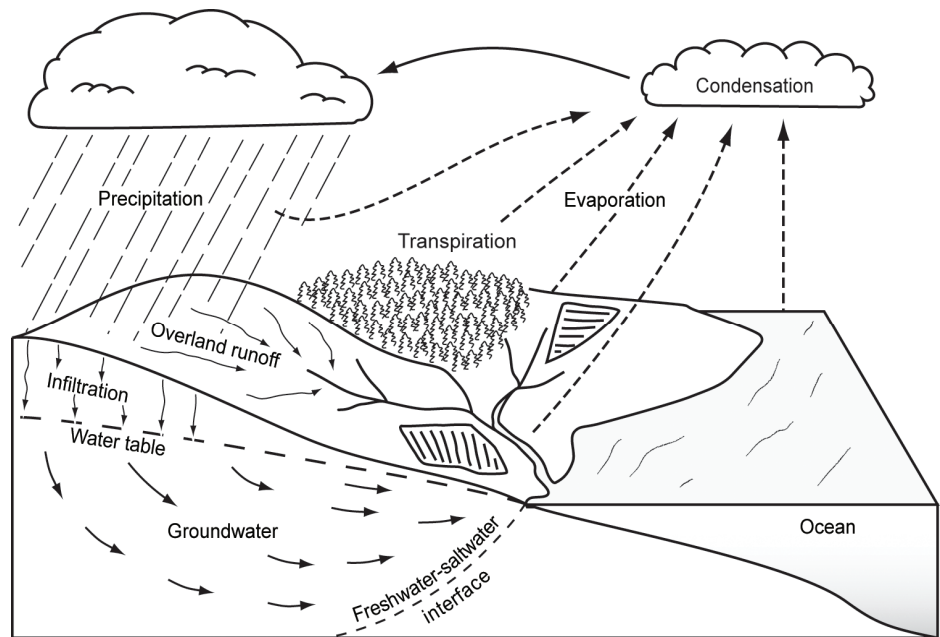


Figure 1.1 The hydrologic cycle. (Source: Adapted from Heath, 1980.)

## Major Conservation Practices

This text considers conservation practices for erosion control, drainage, irrigation, and flood control and water supply.

### 1.5 Soil Erosion

Erosion is a serious problem worldwide. The control of soil erosion by water and wind is essential to maintain crop productivity, reduce sedimentation, and reduce pollution in streams and lakes. The amount of soil eroded by water from fields and pastures in the United States is estimated to be equivalent to about 1 m from 200 000 ha of farmland each year. Additional losses are caused by wind erosion. Not only is soil lost by erosion, but a proportionally higher percentage of plant nutrients, organic matter, pesticides, and fine soil particles is lost than in the original soil. One of the most dramatic wind erosion events was the dust storm of 1934, which swept across the U.S. from the Great Plains to the Atlantic Coast. In the United States, federal legislation has provided technical assistance and financial incentives for controlling erosion and reducing pollution.

### 1.6 Drainage

Drainage practices in the world date back thousands of years. Some notable examples of large drainage projects are the polders in Holland and the fens in England, which are lowlands reclaimed from the sea. Drainage has long been recognized as essential for permanent crop production in low flatlands in humid areas and in irrigated agriculture. In the humid Midwest, many drainage systems have been installed to develop and improve crop production. These systems may provide both surface and subsurface drainage. An estimated one-third of the irrigated land in the world is affected by sodicity and salinity. Subsurface drainage systems are required to reclaim salt affected soils and to prevent salinity problems by maintaining a low water table. In areas that experience periods of both excessive water and water shortages during a growing season, subsurface pipe drains are also used to deliver water to the soil profile.

### 1.7 Irrigation

Irrigation expanded worldwide after 1950 because of the increased need for more food and fiber and because of the development of new and more efficient methods. Much of the expansion began in arid regions where few crops can be grown without irrigation. Later expansion was in more humid areas to supplement rainfall for maximum crop production. Many large dams were constructed for water storage. More efficient well drilling methods and better pumps also significantly contributed to the water supply and pressure needs of sprinkler and microirrigation systems. Areas with productive soils, adequate drainage, and a reliable water supply were irrigated in arid,

semi-arid, and subhumid climatic regions. Relatively large quantities of water are required for crop production in arid areas with irrigation using up to 80% of the available water supply.

## 1.8 Flood Control and Water Supply

Flooding is one of the most significant natural phenomena causing loss of life, crops, and property, as well as creating health hazards, water pollution, and interruption of services, such as transportation, utilities, police, fire protection, and emergency operations. Flood damage in upstream areas occurs primarily on agricultural lands, whereas downstream floods cause major damage in metropolitan areas. This text considers conservation designs that reduce erosion and flooding in upstream areas. Many practices that reduce flooding add to the water supply by allowing more water to infiltrate, which may increase crop production as well, or reduce the peak flow by water storage. Stored water may also be used for on-farm irrigation.

## Internet Resources

NRCS photos, publications, specialty centers, and technical information:

[www.nrcs.usda.gov](http://www.nrcs.usda.gov)

NRCS Water and Climate Center publication *Conservation and the Water Cycle*:

[www.wcc.nrcs.usda.gov/factpub/aib326.html](http://www.wcc.nrcs.usda.gov/factpub/aib326.html)

Major Uses of Land in the United States, 1997:

[www.ers.usda.gov/publications/sb973/sb973.pdf](http://www.ers.usda.gov/publications/sb973/sb973.pdf)

## References

- Heath, R. C. 1980. *Basic Elements of Ground-Water Hydrology with Reference to Conditions in North Carolina*. U.S. Geological Survey Water Resources Investigations Open-File Report 80-44. USGS Open-File Services Section, Denver, Colorado.
- Postel, S. 1989. *Water for Agriculture Facing Limits*. Paper 93. World Watch Institute, Washington, D.C.
- USDA (U.S. Dept. Agriculture). 1989. *The Second RCA Appraisal. Soil, Water and Related Resources on Nonfederal Land in the United States*. Govt. Printing Office, Washington, D.C.
- Vesterby, M., and K. S. Krupa. 1997. *Major Uses of Land in the United States*. Statistical Bull. No. 973. Resource Economics Division, Economic Research Service, U.S. Dept. Agriculture. Accessed June 2011 at [www.ers.usda.gov/publications/sb973/sb973.pdf](http://www.ers.usda.gov/publications/sb973/sb973.pdf).
- Wolman, M. G. 1990. The impact of man. *EOS, Trans. Am. Geophysical Union* 71(52): 1884-1886.

