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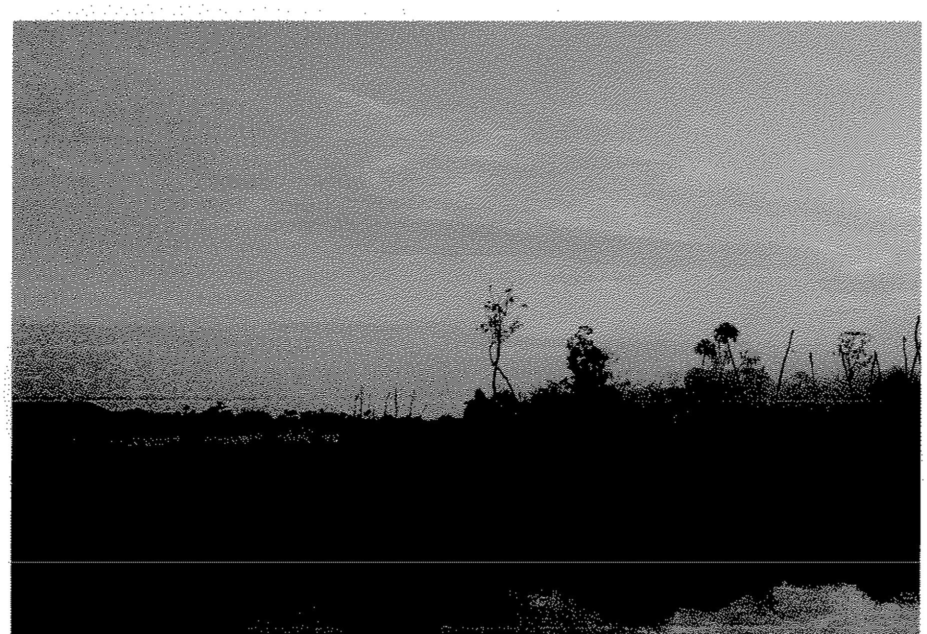
National Water Summary on Wetland Resources



By U.S. Geological Survey

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Foreword

National Water Summary on Wetland Resources is the eighth in a series of reports that describes the conditions, trends, availability, quality, and use of the water resources of the United States. This volume describes an often-overlooked water resource—wetlands. It gives a broad overview of wetland resources and includes discussions of the scientific basis for understanding wetland functions and values; legislation that regulates the uses of wetlands; wetland research, inventory, and evaluation; and issues related to the restoration, creation, and recovery of wetlands. In addition, it presents more-specific information—types and distribution, hydrologic setting, trends, and conservation—on the wetland resources of each State, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, and several Pacific islands over which the United States has jurisdiction.

Wetlands serve as a transitional environment between water bodies and dry land and represent a significant part of the Nation's natural resources. They contain economically important timber, fuel, and food sources; provide esthetic and recreational opportunities; and influence the quantity, quality, and ecological status of water bodies, which include rivers, aquifers, lakes, reservoirs, and estuaries. Wetlands owe their existence, in part, to precipitation, streams, lakes, ground water, and oceans and, in return, perform important functions that affect the quantity and quality of these water resources. Although wetlands are best known for their function as habitat for birds, fish, and other wildlife, their less well known hydrologic and water-quality functions provide such benefits as reducing the severity of flooding and erosion by modifying the flow of water or improving water quality by filtering out contaminants.

Public and scientific views of wetlands have changed greatly over time. Only a few decades ago, wetlands were generally considered to be of little or no value. Those who eliminated wetlands through draining or filling were thought of as performing a public service. The role of the wetlands as a breeding ground for disease (primarily malaria) and their inability to be exploited for agricultural production caused them to be viewed as an economic "bad" rather than as a public "good," as they are viewed today. Because of new scientific knowledge, as well as a change in values (as manifested in our Nation's environmental laws), efforts to eliminate wetlands are viewed in a negative light by many. In fact, government and private citizens are making investments in the preservation, remediation, or creation of wetlands.

Although we now understand some of the benefits of wetlands and government agencies have established programs to protect them, wetland-protection policies remain a controversial public issue. In keeping with its mission, the U.S. Geological Survey (USGS) has prepared this report with the intent of informing public officials, scientists, and the general public about wetlands. Our purpose is to increase and help improve the understanding of this valuable resource and to provide the scientific information base upon which wise decisions regarding the classification, use, modification, or restoration of wetlands can be made. The hydrologic, biological, and economic consequences of these decisions are substantial and often politically contentious. The USGS takes no position on these issues but hopes to make a positive contribution to the process whereby these decisions are made.

The USGS is an earth science information agency. It collects, manages, and disseminates data; conducts interpretive scientific studies and research; and publishes the results of these efforts in many forms. The work of the USGS is organized into four thematic areas—resources, hazards, environment, and information management. Wetlands are addressed in each of these areas. For example, some wetlands play an integral role in water-resource availability because they are major discharge areas for some aquifers. Some wetlands relate to the hazards theme through their role in the mitigation of floods. Wetlands are affected by environmental changes, such as changes in the source or distribution of water, and, in turn, cause changes in the environment, such as shifts in vegetation or in habitat for birds, fish, and other animals; studies of these changes tie into the environmental theme. And, finally, with respect to the information management theme, the process of classifying, monitoring, and understanding wetlands is dependent upon the hydrologic, geologic, and topographic data collected by the USGS.

The USGS has taken this opportunity to draw on the expertise of the many agencies and organizations that have missions directly or indirectly related to wetlands to provide a broad background for government officials, water-resource managers, and the general public. You will note that many of the chapters of this volume have authors from other agencies with key roles in research, classification, or management of wetlands. Production of this volume was a team effort, just as management of wetlands is a team effort. We thank our colleagues in the many other agencies that helped make this report possible. I would like to pay special tribute to the late Dr. Edward T. LaRoe of the National Biological Service, coauthor of the chapter on research. He was a leading wetland researcher and played a pivotal role in the evolution of all biological research in the U.S. Department of the Interior.

Though this volume merely touches on the many and varied aspects of wetlands, it provides a starting place for further study and a base upon which to begin to understand the values of wetlands to the Nation. We hope it is useful, and we welcome your comments on this volume, as well as on our other products.

Gordon P. Eaton

DIRECTOR

Hidden River near Homosassa Springs, Florida. *(Photograph by Judy D. Fretwell, U.S. Geological Survey.)*

There has been a lot said about the sacredness of our land which is our body, and the values of our culture which is our soul. But water is the blood of our tribes, and if its life-giving flow is stopped, or it is polluted, all else will die and the many thousands of years of our communal existence will come to an end.

Frank Tenorio, Governor, San Felipe Pueblo, 1978

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Wetland in Bridgeport Valley, California; Sierra Nevada Mountains in the background.
(Photograph by Steve Van Denburgh, U.S. Geological Survey.)

This wetland is part of a local park near Madison, Wisconsin.
(Photograph by Patricia S. Greene.)

Executive Summary

This National Water Summary on Wetland Resources documents wetland resources in the United States. It presents an overview of the status of our knowledge of wetlands at the present time—what they are, where they are found, why they are important, and the controversies surrounding them, with an emphasis on their hydrology. The "State Summaries of Wetland Resources" part of this National Water Summary describes wetland resources in each State, the District of Columbia (combined with Maryland), Puerto Rico, the U.S. Virgin Islands, and the Western Pacific Islands. The following discussion is a summary of the two parts of this book—"Overview of Wetland Resources" and "State Summaries of Wetland Resources."

OVERVIEW OF WETLAND RESOURCES

The Overview of Wetland Resources part of this National Water Summary consists of three sections—"Technical Aspects of Wetlands," "Wetland Management and Research," and "Restoration, Creation, and Recovery of Wetlands"—that contain 11 articles providing information on many technical and societal aspects of wetland resources. The following text summarizes the many facts about wetland resources that these articles report.

Technical Aspects Of Wetland Resources

Wetlands began disappearing soon after permanent European colonization of the United States. More than one-half of the 221 million acres of wetlands that existed at that time have disappeared; only 103 million acres remain today. Early in this Nation's history, it was believed that wetlands presented obstacles to development and that wetlands should be eliminated. Federal laws provided incentives for "reclaiming" wetlands. Only recently people have begun to recognize wetland values and attempted to find ways to preserve them, including changing Federal laws. These attempts have slowed the rate of wetland loss, but losses continue today. The history of wetland losses in the conterminous United States from the time of the first permanent European settlement and changes in societal attitudes toward wetlands are documented in "History of Wetlands in the Conterminous United States."

Although there is controversy over the precise, legal definition of a wetland, wetlands are scientifically defined by their hydrology, vegetation, and soils. The many different types of wetlands, found in many different geographic settings, have different functions. Wetlands can be grouped according to these differences using a nationally consistent terminology (Cowardin and others, 1979) to identify mapping units for Federal and State wetland inventories and to determine wetland status and trends that can aid in planning and management of the resource. The different types of wetlands and the classification systems describing them are presented in "Wetland Definitions and Classifications in the United States."

An understanding of the basic hydrologic processes that control the formation, persistence, size, and functions of wetlands is necessary for determining appropriate protective measures for particular wetlands and for determining the success of those measures. The source and distribution of water is a major factor in the differences in wetland types and distribution across the country. Both a favorable geologic setting and an adequate and persistent supply of water are necessary for the existence of a wetland. Different wetlands receive water from different sources; ground water, streams, lakes, tides, snow, and rain. The source of water largely determines its quality, which in turn is largely responsible for wetland vegetation. The wetland vegetation affects the value of the wetland to animals and people. Wetlands provide many beneficial water-related functions. Some wetlands provide flood control, some provide water for aquifers, others feed streams, some modify climate, others improve water quality, some help maintain the salt balance necessary for estuarine life, and still others control erosion. "Wetland Hydrology, Water Quality, and Associated Functions" describes the different water-related factors that determine what types of wetlands will be established and what functions each will perform.

One of the best known functions of wetlands is as habitat for birds. About one-third of the North American bird species use wetlands for water, food, shelter, or breeding. About 138 of the 1,900 bird species in the conterminous United States are wetland dependent. For wetland-dependent birds, habitat loss or degradation usually translates to population loss. Some international treaties—The Migratory Bird Treaty and the Ramsar Convention—are partly responsible for much of the formal wetland protection in this country. "Wetlands as Bird Habitat" discusses the relation of birds and wetlands and the effects of wetland losses on birds, and describes some efforts to reduce wetland loss.

Wetland Management And Research

Many of the benefits that wetlands provide accrue primarily to the general public instead of the private landowners. Landowners usually have few incentives to conserve wetlands that fulfill the needs of the general public. The Government, therefore, provides incentives and regulates and manages some wetland resources to protect the resources from degradation and destruction. Despite current recognition of wetland benefits, potentially conflicting interests still exist, and disagreement on how to protect wetlands has led to differences in local, State, and Federal guidelines. Current wetland-protection regulation commonly requires that wetland loss to development be offset by replacing wetlands by means of mitigation. Section 404 of the Clean Water Act and the "Swampbuster" program are two major Federal vehicles of wetland protection. Coastal wetlands are provided some protection by the Coastal Zone Management Act and the Coastal Barriers Resources Act. Major Federal legislation and initiatives that affect wetlands are discussed in "Wetland Protection Legislation."

The recent understanding of wetland values and the benefits that they provide has been broadened by the research efforts. In 1992, wetland research was being done by 18 Federal agencies—12 of which had expenditures of $1 million or more—as part of their mission or responsibilities defined by Congress. In 1992, Federal wetland research expenditures totaled about $63 million. Ecological processes and functions differ with wetland type; therefore, research needs and techniques also differ. Types of Federal wetland research fall into one of the following broad categories: wetland processes, wetland functions, human-induced stresses, delineation and identification, and management. Research needs also differ among agencies; nevertheless, efforts are coordinated to share information and to avoid duplication. Disappearing coastal and bottom-land hardwood wetlands are among the major areas of research. These and other areas of research are discussed in "Wetland Research by Federal Agencies."

Wetland mapping is a prerequisite for wetland inventory, regulation, management, protection, and restoration. Maps are used to analyze wetland trends and the effects of projects, policies, and activities on wetlands. The U.S. Fish and Wildlife Service has a major responsibility for the mapping and inventory of the Nation's wetlands as mandated by legislation enacted in the past 40 years. This responsibility is satisfied through the agency's National Wetlands Inventory program by producing maps, establishing a wetland data base, publishing and distributing reports on the status and trends of wetlands in this country, and by providing other products related to the identification, mapping, and inventory of wetlands. To date, the National Wetlands Inventory has produced more than 43,300 maps, covering more than 83 percent of the conterminous United States, 28 percent of Alaska, and all of Hawaii and the U.S. Territories. Other Federal agencies with wetland mapping and inventory activities, specific to their missions, are the Natural Resources Conservation Service (formerly known as the Soil Conservation Service)—freshwater wetlands with the potential for agricultural conversion; the National Oceanic and Atmospheric Administration—coastal wetlands associated with marine resources; and the U.S. Geological Survey—geographically significant wetlands. More information can be found in "Wetland Mapping and Inventory."

Placing a value on wetlands facilitates decisions on which sites should be developed to ensure that the most valuable wetlands are preserved. The value of a wetland lies in the benefits that its habitat, water-quality, and hydrologic functions provide to the environment or to people. Economic value can be placed on some wetland products, but true value goes beyond money. Some wetland values extend beyond the perimeter of the wetland and provide benefits on a local, regional, or global scale. Several systems of wetland evaluation have been or are being developed to assign numerical values to wetland functions in order to allow for the comparison of the worth of one wetland to another. The article "Wetland Functions, Values, and Assessment" discusses three different wetland evaluation methods—the Federal Highway Administration's "Wetland Evaluation Technique," the U.S. Environmental Protection Agency's "Environmental Monitoring Assessment Program—Wetlands," and the U.S. Army Corps of Engineers' "Hydrogeomorphic Approach."

Restoration, Creation, And Recovery

For the past few centuries wetlands have been drained or altered to accommodate human needs. This continues to happen, although at a slower rate than in the past. As people have begun to recognize what is lost when wetlands are destroyed, efforts have been made to restore lost wetlands or to create new ones. Restoration and creation of wetlands can help maintain the quality of wetlands and their surrounding ecosystems, and at the same time accommodate the human need for development. Although indications are that some replacement can be successful, full functional replacement has not yet been demonstrated. This is, in part, because of the youth of most restoration and creation projects and, in part, because of the lack of followup on most projects. Scientific knowledge about wetland restoration and creation differs by wetland type, function, and location. We know most about intertidal salt marshes and know much less about replacing forested wetlands because of the time needed for woody vegetation to mature. The more complex the hydrology and ecology of a system, the more difficult it is to restore the system; complete restoration might be impossible in some systems. The ecosystems least likely to be replaced are bogs and fens that have developed over thousands of years. "Wetland Restoration and Creation" discusses what is involved in restoring and creating wetlands and chances of being successful.

In August 1992, Hurricane Andrew caused massive destruction in southern Florida and in Louisiana—two States with some of the largest wetland acreages in the country. The storm passed directly over the Florida Everglades—the largest wetland complex in the United States—and the Atchafalaya River Basin, La., which contains the largest hardwood swamp in the United States. Although there were some immediate detrimental effects on plants and animals, the long-term effects seem to have been minimal in Florida. In Louisiana, the hurricane may have hastened the coastal erosion and wetland deterioration processes that were already at work. "Effects of Hurricane Andrew (1992) on Wetlands in Southern Florida And Louisiana" describes the effects of this major hurricane on these wetlands.

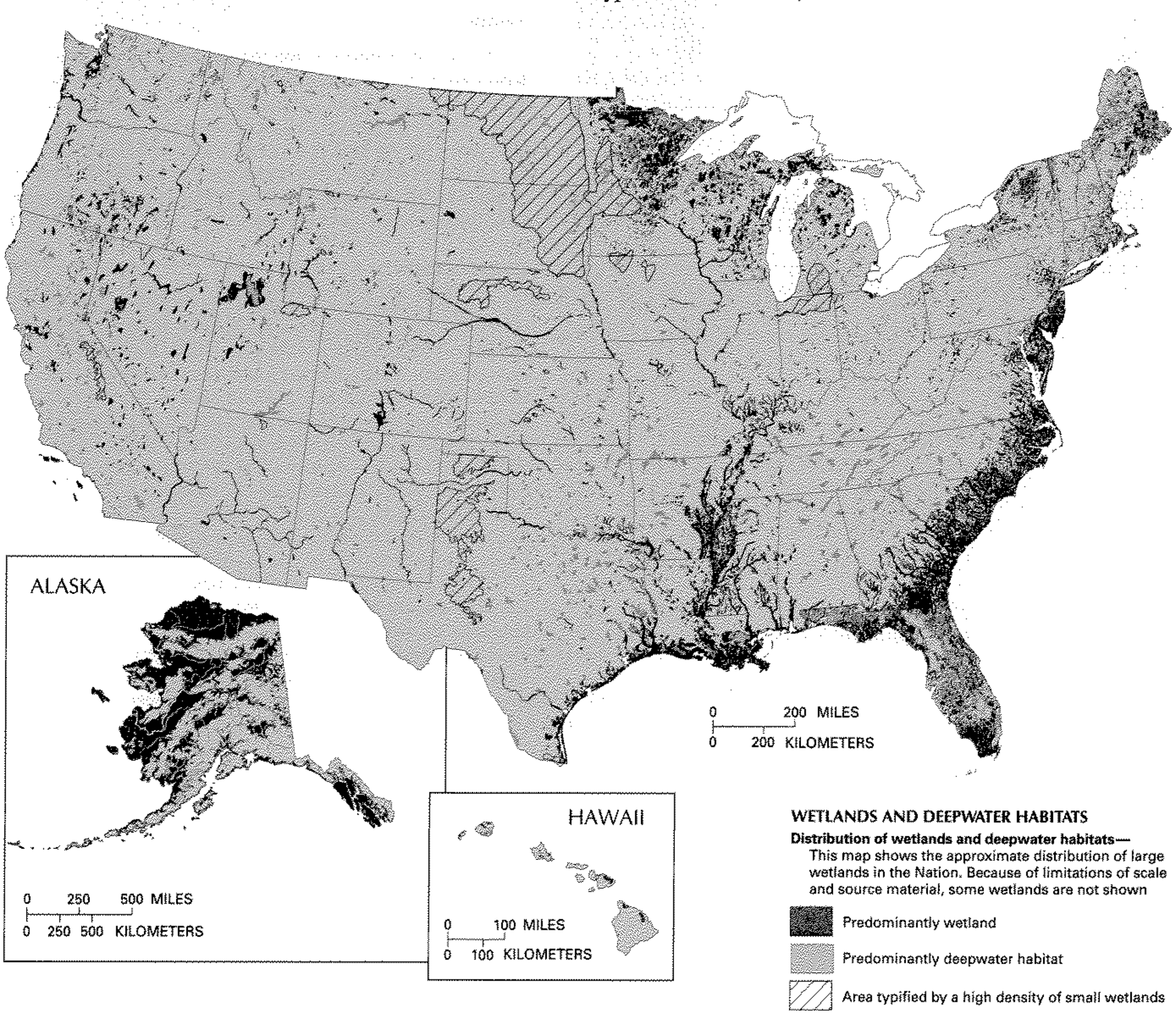
The Great Midwest Flood of 1993, in the Mississippi and Missouri River Basins, was the most devastating flood in United States' history. The areal extent, intensity, and long duration makes this flood unique in the 20th century. Effects of the flood were both detrimental and beneficial to wetlands. Trees were uprooted, islands were eroded, many wetland plants were destroyed, and several bird species fledged few young. Massive sedimentation buried mussels; mammals displaced from the flood plain suffered higher than normal mortalities on highways and railroads; the floodwaters transported large amounts of contaminants and nutrients into and down streams; nuisance plants replaced native vegetation; and turbidity made it difficult for some fish to feed. Nevertheless, some fish spawn and feed on inundated flood plains when temperature rise accompanies flooding—which was the case in this flooding. Also, some fish habitat was improved by the creation of deep scour holes and massive underwater debris piles that provide cover. Effects of the flooding are discussed in "Effects of the Great Midwest Flood of 1993 on Wetlands."

STATE SUMMARIES OF WETLAND RESOURCES

State Summaries of Wetland Resources in this National Water Summary provides an overview of the wetland resources of the 50 States, the District of Columbia (combined with Maryland), Puerto Rico, the U.S. Virgin Islands, and several Pacific islands over whose wetlands the United States has some form of jurisdiction. (The term "State" is used in the following discussion for all these geographic areas.) The State summaries contain the following sections:

Types and Distribution

Wetlands in the United States are of many types. Some of the more familiar names for different kinds of wetlands are swamp, marsh, bog, playa, tideflat, prairie pothole, and pond. Examples of lesser known, local names for different wetland types are cienega, pocosin, muskeg, wet pine flatwoods, and willow carrs. The "Types and Distribution" section of each State summary contains a brief discussion of the wetland types in the State and relates the common, locally known wetland names to the classification system used by Federal agencies to identify and delineate wetlands (see the article "Wetland Definitions and Classifications in the United States" in this volume for an extensive discussion of wetland types and classification).



WETLANDS AND DEEPWATER HABITATS

Distribution of wetlands and deepwater habitats— This map shows the approximate distribution of large wetlands in the Nation. Because of limitations of scale and source material, some wetlands are not shown

- Predominantly wetland
- Predominantly deepwater habitat
- Area typified by a high density of small wetlands

The "Types and Distribution" section of each State summary also contains a brief discussion of wetland distribution in the State and a map that shows the general distribution of major wetlands. The State maps were derived from a national map that was compiled by the U.S. Fish and Wildlife Service (fig. 1). Because the data used to compile the map differ in reliability from State to State, the distribution of wetlands shown should be considered approximate. Also, because small areas physically cannot be represented at the scale at which the map was compiled, only relatively large wetlands are shown.

Example of table 1 used in each State summary (in this case Maryland and the District of Columbia) showing selected wetland-related activities of government agencies and private organizations within the State.

[Source: Classification of activities is generalized from information provided by agencies and organizations. •, agency or organization participates in wetland-related activity; ..., agency or organization does not participate in wetland-related activity. MAN, management; REG, regulation; R&C, restoration and creation; LAN, land acquisition; R&D, research and data collection; D&I, delineation and inventory]

Agency or organization	MAN	REG	R&C	LAN	R&D	D&I
FEDERAL						
Department of Agriculture						
Consolidated Farm Service Agency	...	•	...	...	...	...
Natural Resources Conservation Service	...	•	•	...	•	•
Department of Commerce						
National Oceanic and Atmospheric Administration	•	•	...	...	•	•
Department of Defense						
Army Corps of Engineers	•	•	•	•	•	•
Department of the Interior						
Fish and Wildlife Service	•	...	•	•	•	•
Geological Survey	...	...	...	...	•	...
National Biological Service	...	...	...	...	•	...
National Park Service	•	...	•	•	•	•
Environmental Protection Agency	...	•	...	...	•	•
STATE						
Department of the Environment						
Water Management Administration	•	•	•	•	•	•
Department of Natural Resources						
Chesapeake Bay and Watershed Programs	•	...	•	...	•	•
Natural Heritage Program	•	...	...	...	•	•
Program Open Space	...	...	...	•	...	...
Office of State Planning	...	...	...	...	...	•
State Highway Administration	...	...	•	...	...	...
University of Maryland	...	...	...	...	•	...
DISTRICT OF COLUMBIA						
Department of Consumer and Regulatory Affairs	...	•	...	...	...	...
Department of Public Works	•	...	•	...	...	...
Metropolitan Council of Governments	...	•	...	...	...	...
Soil and Water Conservation District	•	•	•	...	...	...
SOME COUNTY AND LOCAL GOVERNMENTS	•	•	•	...	...	...
PRIVATE ORGANIZATIONS						
Chesapeake Bay Foundation	...	•	...	...	...	...
Environmental Concern, Inc.	...	...	•	...	•	...
Maryland Land Trust Alliance	•	...	...	•	...	...
The Nature Conservancy	•	...	...	•	...	...

Hydrologic Setting

Wetlands can form almost anywhere that water remains on or near the land surface for an extended period. Some wetlands are ephemeral, containing water for only a few weeks in spring, whereas others are permanently inundated. In arid regions, some wetlands are wet only in years when rainfall is much above normal.

The factors that determine where and when wetlands form include precipitation amount and timing, evaporation and transpiration rates, topography, and geologic characteristics (see "Wetland Hydrology, Water Quality, and Associated Functions" in this volume for a discussion of wetland hydrology). The "Hydrologic Setting" section of the State summaries provides an overview of the factors that determine wetland hydrology in each State.

Trends

The area of wetlands in the conterminous United States has decreased by about one-half since the founding of the Nation in the late 1700's (Dahl, 1990), and the decline is continuing. The "Trends" section of each State summary contains a brief accounting of wetland losses and gains and lists the major causes of wetland loss. (For a national perspective of wetland trends, see "History and Trends of Wetlands in the Conterminous United States" in this volume.)

Conservation

Wetland-conservation efforts are carried out by Federal, State, and local government agencies; many private organizations also work to conserve wetlands. The "Conservation" section of each State summary provides an account of the wetland-conservation activities on each of those levels. Included are primary Federal, State, and local regulations affecting wetlands, as well as a discussion of other aspects of wetland conservation, such as management, land acquisition, planning, mitigation, research, restoration and creation, delineation, inventory, education, and many more. (For a discussion of regulatory legislation pertaining to wetlands, see "Wetland Protection Legislation" in this volume.)

Each State summary contains a table (such as the accompanying table for Maryland and the District of Columbia) that lists selected wetland-related activities of Federal, State, and local government agencies and private organizations in the State. The information contained in the table and in the "Conservation" section was compiled in 1993; because of the often dynamic nature of government bureaucracies and agency responsibilities, the names of agencies and the activities listed for them can be considered reliable as of that date and no later.

References Cited

Cowardin, L.M., Carter, Virginia, Golet, F.C., and LaRoe, E.T., 1979, Classification of wetlands and deepwater habitats of the United States: U.S. Fish and Wildlife Service Report FWS/OBS–79/31, 131 p.

Dahl, T.E., 1990, Wetlands—Losses in the United States, 1780's to 1980's: Washington, D.C., U.S. Fish and Wildlife Service, 13 p.

State Summary Highlights

Following are a few notable facts about the wetlands of the 50 States, the District of Columbia, Puerto Rico, the Virgin Islands, and several islands of the Pacific Ocean, as reported in the State summaries:

Alabama

Wetlands cover about 10 percent of Alabama and range in size from small areas of less than an acre to the 100,000-acre forested tract in the Mobile-Tensaw River Delta. Most of the State's forested wetlands are bottom-land forests in alluvial flood plains. Coastal waters support extensive salt marshes. Wetland acreage in the area that is now Alabama has been reduced by about one-half in the last two centuries. Major causes of wetland loss or alteration have been agricultural and silvicultural conversions in the interior; dredging on the coast; industrial, commercial, and residential development; erosion; subsidence; and natural succession of vegetation.

Alaska

Alaska has more area covered by wetlands—about 170 million acres—than the other 49 States combined. More than 70,000 swans, 1 million geese, 12 million ducks, and 100 million shorebirds depend on Alaskan wetlands for resting, feeding, or nesting. Freshwater Alaskan wetlands include bogs, fens, tundra, marshes, and meadows; brackish and saltwater wetlands include flats, beaches, rocky shores, and salt marshes. Most of the State's freshwater wetlands are peatlands (wetlands that have organic soils), and cover as many as 110 million acres. Alaska's coastal wetlands are cooperatively protected and managed by local governments, rural regions, and the State.

Arizona

Less than 1 percent of Arizona's landscape has wetlands. Since the late 1800's, streams and wetlands throughout Arizona have been modified or drained, resulting in the loss of more than one-third of the State's original wetlands. The most extensive Arizona wetlands are in riparian zones and include oxbow lakes, marshes, cienegas, and bosques. Nonriparian wetlands include tinajas, playas, and caldera lakes. Extreme aridity and seasonally varying precipitation are the climatic characteristics that most significantly influence wetland formation and distribution in Arizona. Recreational use of wetlands provides economic benefits to the State.

Arkansas

About 8 percent of Arkansas is wetland. The most extensive areas are forested wetlands (swamps and bottom-land forests) along major rivers. Arkansas wetlands, especially those in the Mississippi River Valley, are a critical component of the series of wetlands along the Mississippi Flyway. Wetlands in the Cache-Lower White River system have been designated as one of nine "Wetlands of International Importance" in the United States. Arkansas has lost more wetland acres than any other inland State; most of the loss has been due to conversion to farmland. Arkansas has adopted a program that applies an antidegradation policy to substantial alteration of water bodies, including adjacent wetlands.

California

California's wetlands have significant economic and environmental value, providing benefits such as water-quality maintenance, flood and erosion attenuation, prevention of saltwater intrusion, and wildlife habitat. The Sacramento-San Joaquin Delta regularly harbors as much as 15 percent of the waterfowl on the Pacific Flyway. California has lost as much as 91 percent of its original wetlands, primarily because of conversion to agriculture. Flooded rice fields, which are converted wetlands, covered about 658,600 acres in the mid-1980's. Rice farmers, State and university researchers, and private organizations are cooperatively studying the feasibility of managing rice fields for migratory waterfowl habitat. Wetland protection is identified as a goal of The California Environmental Quality Act of 1970.

Colorado

Wetlands cover about 1 million acres of Colorado—1.5 percent of the State's area. Wetlands occur in all life and climatic zones, from the high mountains to the arid plains and plateaus. Wetland types in Colorado include forested wetlands, willow carrs, fens, marshes, alpine snow glades, and wet and salt meadows. Wetlands are vital to wildlife in the State, particularly in the arid regions. Colorado's wetland area has decreased by about one-half in the last two centuries, and losses are continuing due to a variety of land-development pressures; however, irrigation and changes in land-use practices have resulted in new wetlands, principally in the San Luis Valley and near Boulder.

Connecticut

Wetlands cover about 173,000 acres of Connecticut—5 percent of the State's land surface. Connecticut has lost an estimated one-third to three-fourths of its original wetlands over the 200-year period between the 1780's and 1980's. Forested wetlands, primarily red maple swamps, are the predominant wetland type, constituting 54 percent of the State's wetlands. Salt marshes, tidal flats, and beaches are the primary coastal wetlands. Wetland protection in Connecticut is carried out at the Federal, State, and (or) local government level, depending on the type and location of the wetland resource.

Delaware

Wetlands cover about 17 percent of Delaware. Wetlands in Delaware are diverse. Extensive estuarine wetlands line Delaware Bay and the Atlantic Ocean. Delmarva bays, which are seasonally flooded depressions in the Coastal Plain, contain marsh, shrub, and forest vegetation. More than one-half of Delaware's wetlands have been converted to nonwetland uses or otherwise altered since the 1780's. The State Wetlands Act controls development in tidal wetlands, and a proposed statute would establish a State-run nontidal-wetlands regulatory program. Delaware has established its own wetland classification, which has five categories that are based on a wetland's functions and values.

District of Columbia

The District of Columbia has about 250 acres of wetlands; all are palustrine or riverine. Most occur along the tidal reaches of the Potomac and Anacostia Rivers. About 87 percent of the District's wetlands have been drained or filled since the District was established in the 1790's. The National Park Service owns and maintains most wetlands in the District of Columbia. To alter wetlands, permits must be obtained from the U.S. Army Corps of Engineers and the Department of Consumer and Regulatory Affairs. Wetland conservation is accomplished on Federal and local levels and through the activities of private organizations.

Florida

Florida has about 11 million acres of wetlands, more than any of the other 47 conterminous States. The abundance of wetlands in Florida is due primarily to the low, flat terrain and plentiful rainfall. Most of Florida's wetlands are forested freshwater habitats on stream flood plains, in small depressions and ponds, and covering wet flatwoods. The Everglades, in southern Florida, is a large freshwater marsh that once received surface- and ground-water flows from the Kissimmee River-Lake Okeechobee Basin but which now depends on water releases from canals and water-retention areas. Florida has lost nearly one-half of its wetlands, primarily to agricultural drainage. The State protects wetlands by regulating development in wetland areas, acquiring wetlands and land adjacent to wetlands, and requiring local governments to produce long-range plans for wetland protection.

Georgia

Georgia has more than 7.7 million acres of wetlands. Georgia's wetlands are diverse, ranging from mountain seepage areas to estuarine tidal flats. This diversity is primarily due to the wide variety of landforms present, each of which can have different geologic and hydrologic characteristics. The greatest acreages of wetlands are in the coastal plain, where flood-plain wetlands are most extensive and tidal freshwater swamps and estuarine marshes meet. Most of Georgia's wetlands are forested freshwater habitats associated with streams. The Okefenokee Swamp in Georgia, one of the largest freshwater wetlands in the United States, is a mosaic of emergent marshes, aquatic beds, forested and scrub-shrub wetlands, and forested uplands.

Hawaii

Wetlands constitute less than 3 percent of the State, but they have had a major economic effect on Hawaiian society both before and after European contact. Wetlands are habitats for several species of birds and plants endemic to the Hawaiian Islands. Wetland formation in Hawaii is influenced by climate, topography, and geology; wetlands form where local hydrologic conditions favor water retention near the land surface. Although rainfall is high in many areas of the islands, steep topography and the high permeability of the volcanic rock that forms the islands result in rapid discharge of storm runoff to the ocean as surface-water and ground-water flow. Coastal wetland losses have been greatest on Oahu, where wetlands have been drained and filled for resort, industrial, and residential development.

Idaho

Most of Idaho's 386,000 acres of wetlands are in flood plains and riparian areas along streams and other water bodies. Since about 1860, when mining and farming began in the State, wetland acreage has decreased by 56 percent. The Idaho State Water Plan states that, insofar as is possible, the State should assume responsibility for wetland management and protection. Policy plans made by the Idaho Department of Fish and Game for 1991 to 2005 focus land-acquisition efforts on wetland areas where habitat protection is critical. Many private organizations and groups have participated in projects involving wetland acquisition and restoration.

Illinois

Wetlands cover about 3.5 percent of Illinois. The largest acreage of wetlands is in the bottom-land forests and swamps along the State's major rivers. Northeastern Illinois also has a large concentration of wetlands. Illinois has lost as much as 90 percent of its original wetlands over the last 200 years; most of the losses have been due to drainage for conversion to agricultural and other uses. The primary State law governing wetlands is the Interagency Wetland Policy Act of 1989, which sets a goal of no net loss of wetlands due to projects funded by the State. Wetlands can be owned and protected by the public as County Forest Preserve Districts.

Indiana

About 85 percent of Indiana's wetlands have been lost since the 1780's, primarily because of conversion to agricultural land. The current rate of wetland loss is about 1 to 3 percent of the remaining wetlands per year. Most of the wetlands remaining in Indiana, about 813,000 acres, are in the northeastern part of the State, including extensive wetlands in and near the Indiana Dunes National Lakeshore. The Department of Natural Resources is developing a State wetland conservation plan under a grant from the U.S. Environmental Protection Agency. Several River Basin Commissions are encouraging or pursuing wetland restoration as a flood-control measure with an added benefit of recreation potential.

Iowa

Iowa has diverse wetlands that include prairie-pothole marshes, swamps, sloughs, bogs, fens, and ponds. Wetlands cover about 1.2 percent of Iowa, but about 200 years ago more than 11 percent of the State's area was wetland. Conversion of wetlands to agricultural lands, largely in the prairie-pothole region, has been the primary cause of wetland loss. Wetland acreage has been slowly increasing since 1987 as a result of the Prairie Pothole Joint Venture, a cooperative Federal, State, county, and private-organization program. The Wetland Reserve Program of the 1990 Food, Agriculture, Conservation, and Trade Act has the potential to add a substantial number of additional acres.

Kansas

Kansas has about 435,000 acres of wetlands, which include sandhill pools along the Arkansas River, playa lakes in western Kansas, freshwater marshes such as those in Cheyenne Bottoms, and salt marshes such as those in Quivira National Wildlife Refuge. Kansas wetlands are important to migrating waterfowl and shorebirds, which depend on the few remaining wetlands in the Central Flyway. Kansas has lost about one-half its wetlands during the last 200 years, mostly due to conversion to cropland and depletion of surface and ground water due to irrigation withdrawals. Wetland preservation and restoration are being accomplished through cooperation among Federal and State agencies and private organizations.

Kentucky

Wetlands compose less than 2.5 percent of Kentucky's land area, but they have considerable environmental, socioeconomic, and esthetic value. Most Kentucky wetlands lie shoreward of rivers, lakes, and reservoirs and include cypress swamps, bottom-land hardwood forests, marshes, and ponds. More than one-half of Kentucky's original wetlands have been lost, primarily as a conversion to cropland and pastureland; most conversions have been in western Kentucky. The State fosters protection of wetlands through a system of registry and dedication agreements with private entities. Most of Kentucky's wetlands are privately owned.

Louisiana

Wetlands are a major source of income for the people of Louisiana, providing revenues from harvesting of fish and shellfish, trapping, and recreation. Most of the State's wetlands are freshwater swamps, but the area of coastal marsh is substantial: Louisiana's coastal marshes represent as much as 40 percent of the coastal marshes in the United States. Wetlands once covered more than one-half of the area that is now Louisiana, but wetland acreage has declined to less than one-third of the State's land surface over the last 200 years. The Louisiana Coastal Wetlands Conservation and Restoration Program implements specific projects to conserve, enhance, restore, and create coastal wetlands.

Maine

Maine's wetlands are diverse, ranging from inland swamps and peatlands to coastal salt marshes and mud flats. One-fourth of the State is wetland, and most wetlands are owned by individuals, timber companies, or other private landowners. Land-use changes have led to wetland losses. Early in Maine's history, expansion of fishing and farming communities along the coast resulted in the filling of many coastal wetlands. Wetlands along inland waterways were converted to agricultural use. Recent losses have been due to urbanization and other development. Wetland conservation in Maine is a combined effort by Federal, State, and local governments and private organizations and landowners.

Maryland

Maryland has about 591,000 acres of wetlands, one-half of which are tidal and one-half nontidal. Extensive estuarine wetlands exist on both sides of the Chesapeake Bay. The Delmarva Peninsula has many wetlands in Delmarva bays, topographic depressions whose wetness is controlled by the water table. About 64 percent of Maryland's wetlands have been converted to nonwetland uses since the 1780's. To obtain permits for altering wetlands in Maryland, a single State-Federal application is submitted to the Maryland Department of the Environment. Wetland conservation in Maryland is accomplished on the Federal, State, and local level and through the activities of private organizations.

Massachusetts

Wetlands cover about 590,000 acres of Massachusetts, about 12 percent of the State's area. Massachusetts has lost about 28 percent of its original wetlands since the 1780's. Agricultural and urban expansion have caused most of the losses. Forested wetlands, primarily red maple swamps, comprise more than one-half of the State's wetlands; estuarine and marine wetlands account for about one-fifth. Regulatory functions of wetland conservation in Massachusetts are performed at the Federal, State, and local government level, and private organizations are active in land acquisition and management, research, education, and policy review and planning.

Michigan

Wetlands cover about 15 percent of Michigan. They provide many benefits, including flood and erosion attenuation, water-quality maintenance, recreation, and wildlife habitat. Michigan's wetlands are largely associated with surface features that are the result of glaciation. Most Michigan wetlands are vegetated by forest or shrubs, but fresh marsh is abundant in coastal and inland areas. About one-half of the State's wetlands have been converted to other uses, primarily agriculture. The Goemaere-Anderson Wetland Protection Act of 1980 (Public Law 203) and other State statutes are the basis for Michigan's wetland-conservation program. The U.S. Environmental Protection Agency has oversight of the State program.

Minnesota

Minnesota has about 9.5 million acres of wetlands, about one-half the wetland acreage present in predevelopment times. Most wetland losses have been due to drainage for agriculture. Minnesota's wetlands are diverse, ranging from extensive northern peatlands to small prairie potholes. Minnesota has about 150,000 to 200,000 acres of wild rice beds. The centerpiece of Minnesota's efforts to protect wetlands is the Wetland Conservation Act of 1991, which sets a goal of no net wetland loss. The law fills the gap in wetland protection between larger, deepwater habitats that are already protected by Minnesota statute and agricultural wetlands that are addressed by the Federal "Swampbuster" provisions.

Mississippi

Wetlands occupy more than 13 percent of Mississippi. Bottom-land forests, swamps and freshwater marshes account for most of Mississippi's wetland acreage; coastal marshes also are extensive. Wetlands in Mississippi are a key part of the Lower Mississippi Valley Joint Venture program for the restoration of Mississippi Flyway waterfowl populations. Nearly three-fifths of the State's wetlands have been converted to nonwetland uses, primarily agriculture. Mississippi wetlands have been and continue to be a source of timber, and the cleared, fertile lands have become productive farmland. The Natural Heritage Program identifies and inventories priority wetlands.

Missouri

Missouri's wetlands occupy 643,000 acres, about 1.4 percent of the State's area. Swamps and other forested wetlands, marshes and fens, and shrub swamps constitute most of the wetland acreage. Missouri's location on the Mississippi Flyway makes the State a favored wintering area for hundreds of thousands of waterfowl and other birds, including bald eagles. Missouri has lost as much as 4.2 million acres (87 percent) of its original wetlands. Most wetland loss has been due to agricultural conversions, urban development, and flood-control measures. The State has developed a wetland-management plan to guide its efforts in the restoration and management of wetlands until the year 2000.

Montana

Wetlands cover only a small part of Montana, but their ecological and economic importance far outweighs their relative size. About 27 percent of the wetlands present before 1800 have been converted to other land uses, primarily cropland. Losses to cropland have been particularly great in north-central and eastern Montana, an area that is part of the Nation's most valuable waterfowl production area, the prairie pothole region of the northern Great Plains. Montana has no comprehensive wetland-protection program; however, the Water Quality Bureau of the Montana Department of Health and Environmental Sciences is developing enforceable water-quality and biological standards specific to Montana wetlands.

Nebraska

Nebraska has three wetland complexes recognized as being of international importance as migrational and breeding habitat for waterfowl and nongame birds: the Rainwater Basin wetlands in south-central and southeastern Nebraska, the Big Bend reach of the Platte River (directly north of the Rainwater Basin), and the Sandhills wetlands in north-central and northwestern Nebraska. Nebraska has lost about 1 million acres of wetlands in the last 200 years—about 35 percent of the State's original wetland acreage. Conversion to agricultural use was the primary cause for most of the losses, but urbanization, reservoir construction, highway construction, and other activities also contributed.

Nevada

Wetlands cover less than 1 percent of Nevada but are some of the most economically and ecologically valuable lands in the State. Benefits of wetlands include flood attenuation, bank stabilization, water-quality improvement, and fish and wildlife habitat. Desert wetlands include marshes in playa lakes, nonvegetated playas, and riparian wetlands; mountain wetlands include fens and other wetlands that form in small glacial lakes. More than one-half of Nevada's original wetlands have been lost, primarily due to conversion of wetlands to cropland and diversion of water for agricultural and urban use; many others have been seriously degraded by human activities. Some wetlands have been created by mine dewatering and sewage treatment.

New Hampshire

Wetlands occupy as much as 10 percent of New Hampshire and are an integral part of its natural resources. Swamps and peatlands comprise most of the State's wetlands. Many wetlands have been converted to nonwetland uses such as crop or pastureland. Others have been altered or degraded by urbanization, peat mining, timber harvesting, road building, all-terrain vehicle use, and other causes. New Hampshire regulates wetlands primarily through State law and the rules of the Wetlands Board; local conservation commissions have an advisory role in local wetland protection. During 1987 to 1993, the State acquired diverse wetlands by purchase and donation or protected wetlands through conservation easements.

New Jersey

New Jersey has about 916,000 acres of wetlands, most of which are in the coastal plain. Forested wetlands are the most common and widely distributed wetlands in the State. Salt marshes are the most common wetlands in coastal areas. Wetlands are ecologically and economically valuable to the State. Cranberry growing is a significant industry in New Jersey; more than 3,000 acres of cranberry bog wetlands were under private management in 1992. Between the 1780's and 1980's, New Jersey lost about 39 percent of its wetlands. Wetlands have been drained primarily for crop production and pasturage and filled for housing, transportation, industrialization, and landfills.

New Mexico

Wetlands cover about 482,000 acres (0.6 percent) of New Mexico; most are in the eastern and northern areas of the State. New Mexico's wetlands include forested wetlands, bottom-land shrublands, marshes, fens, alpine snow glades, wet and salt meadows, shallow ponds, and playa lakes. Riparian wetlands and playa lakes are especially valuable to migratory waterfowl and wading birds. New Mexico has lost about one-third of its wetlands, mostly due to agricultural conversion, diversion of water to irrigation, overgrazing, and urbanization. Other causes of loss or degradation have been mining, clear cutting, road construction, streamflow regulation, and invasion by nonnative plants.

New York

New York has about 2.4 million acres of wetlands. One-half of the 160 species identified as endangered or threatened by the Department of Environmental Conservation are wetland dependent. Counties in the Adirondack Mountains and those south and east of Lake Ontario have the largest percentages of wetland area; counties that make up New York City and Long Island, along the border with Pennsylvania, and in the Catskills have the smallest percentages. From the 1780's to 1980's, about 60 percent of New York's wetland area was lost, primarily because of conversion to agriculture and other land uses. Counties may facilitate wetland acquisition through the funding of bond acts.

North Carolina

About 5.7 million acres of North Carolina—17 percent of the State—is wetland. The Coastal Plain contains 95 percent of the State's wetlands. Before colonization by Europeans, North Carolina had about 11 million acres of wetlands. Nearly one-third of the wetland alterations in the Coastal Plain have occurred since the 1950's; most have resulted from conversion to managed forests and agriculture. The Roanoke River flood plain has one of the largest intact and least disturbed bottom-land hardwood forests in the mid-Atlantic region. About 70 percent of the rare and endangered plants and animals in the State are wetland dependent.

North Dakota

Wetlands once covered about 4.9 million acres of North Dakota—11 percent of the State. By the 1980's, the acreage had decreased to about 2.7 million acres, a loss of about 45 percent. Most of the losses have been caused by drainage for agricultural development. The rate of agricultural conversions in the future will likely depend on crop prices and other economic factors. Most of North Dakota's wetlands are prairie potholes, which provide nesting and feeding habitat for migratory waterfowl and wading birds. About one-half the Nation's duck population originates in the Prairie Pothole Region of North Dakota and other prairie States.

Ohio

Ohio's wetlands cover about 1.8 percent of the State. Swamps, wet prairies, coastal and embayment marshes, peatlands, and wetlands along stream margins and backwaters are the most common Ohio wetlands. Wetland area in Ohio has declined by 90 percent during the last 200 years, from about 5,000,000 acres to about 483,000 acres. Drainage of wetlands for agriculture has been the primary cause of wetland loss, but recreational use, fluctuating water levels, urban development, mining, logging, and fire also have contributed. Ohio designates all wetlands as State Resource Waters. As such, wetland water quality is protected from degradation that may interfere with designated uses.

Oklahoma

Wetlands cover about 950,000 acres (2 percent) of Oklahoma. Wetlands in Oklahoma include bottom-land hardwood forests and swamps; marshes and wet meadows; aquatic-bed wetlands characterized by submersed or floating plants in ponds, lakes, rivers, and sloughs; and sparsely vegetated wetlands such as intermittently flooded playa lakes. Most forested wetlands are in eastern Oklahoma, where precipitation is highest and evaporation lowest. Riparian wetlands and playa lakes in drier western Oklahoma are especially valuable to wildlife. Nearly two-thirds of Oklahoma's original wetlands have been lost as a result of agricultural conversions, channelization, impoundment, streamflow regulation, and other causes.

Oregon

Wetlands are economically and ecologically valuable to Oregon and can be found statewide. Oregon had nearly 1.4 million acres of wetlands as of the mid-1980's, a decline of more than one-third over the previous 200 years. Most of the losses were due to conversion to agricultural uses, primarily in the Willamette River Valley and Upper Klamath Basin. To improve the effectiveness and efficiency of Oregon's efforts to conserve, restore, and protect wetlands, the State has developed the Wetland Conservation Strategy. The strategy is based on the recommendations of advisory committees representing Federal, State, and local agencies and interest groups.

Pennsylvania

About 1.4 percent (404,000 acres) of Pennsylvania is covered by wetlands. Deciduous and forested wetlands are the most common types, followed by open water, marshes, shrub wetlands, and others. Wetlands are most densely distributed in the glaciated northwestern and northeastern parts of the State. Wetland area in Pennsylvania has decreased by more than one-half in the last 200 years. The primary causes of wetland loss or degradation have been conversion to cropland, channelization, forestry, mining, urban development, and the construction of ponds and impoundments. About 50 private conservancy organizations in the State work to protect and preserve natural lands, including wetlands, on a local level.

Puerto Rico

Wetlands in Puerto Rico are diverse, ranging from interior montane wetlands of the rain forest to intertidal mangrove swamps along the coast. Puerto Rico's wetlands are valuable natural resources that provide habitat for wildlife and a water supply for several large cities. Nearly all of Puerto Rico's wetlands have been modified by man—historically for sugar cane agriculture and more recently for housing development, transportation, tourist facilities, and other types of development. Wetland restoration efforts are underway at several locations throughout Puerto Rico; an example is the freshwater wetlands of Laguna Cartagena, once one of the most important waterfowl habitats on the island.

Rhode Island

Wetlands cover about 65,000 acres of Rhode Island, about 10 percent of the State's area. Forested wetlands, primarily red maple swamps, are the most abundant wetland type and account for nearly three-quarters of the State's wetlands. Once more common in Rhode Island, Atlantic white cedar wetlands are now found mostly in the southwestern part of the State. Wetlands are regulated primarily at the State-government level in Rhode Island; different agencies regulate coastal and freshwater wetlands. Local land-use controls are an additional wetland-protection measure. Many of Rhode Island's natural resources have been acquired and protected through cooperative efforts of private and public entities.

South Carolina

Nearly one-quarter of South Carolina is wetland—about 4.6 million acres. South Carolina's wetlands provide flood attenuation, erosion control, water-quality maintenance, recreational opportunities, and fish and wildlife habitat. South Carolina wetlands are important wintering areas for migratory waterfowl on the Atlantic Flyway. Wetlands in the State include wet pine flatwoods, pocosins, Carolina bays, beaver ponds, bottom-land forests, swamps, fresh and salt marshes, and tidal flats. About 80 percent of the wetlands are freshwater and forested. Wetland acreage in South Carolina has declined by more than one-quarter since the late 1700's, primarily as a result of human activities.

South Dakota

Wetlands occupy about 1.8 million acres (3.6 percent) of South Dakota. These wetlands are of great economic and esthetic value because they provide important habitat for wildlife (especially migratory waterfowl), hydrologic benefits that include water retention and flood attenuation, and numerous recreational opportunities. By far the most common wetland type in South Dakota is the prairie pothole, which occurs in glaciated eastern South Dakota. Wetland area in South Dakota has decreased by about 35 percent during the last 200 years—from about 2.7 million to about 1.8 million acres. Agricultural conversions, notably in the prairie pothole region, have accounted for most wetland losses.

Tennessee

Estimates of Tennessee's wetland area range from 640,000 to 1,400,000 acres. Although wetlands constitute a small percentage of Tennessee, they are ecologically and economically valuable to the State. Bottom-land forests are the most common Tennessee wetlands; they are most abundant in the flood plains of rivers in the western part of the State. Nearly three-fifths of Tennessee's original wetlands have been lost; major causes of loss or degradation in Tennessee have included agricultural conversions, logging, reservoir construction, channelization, sedimentation, and urbanization. The Tennessee Wetlands Acquisition Act of 1986 authorizes the acquisition of wetlands by use of real estate transfer taxes.

Texas

Wetlands cover about 7.6 million acres of Texas, 4.4 percent of the State's area. The most extensive wetlands are the bottom-land hardwood forests and swamps of East Texas; the marshes, swamps, and tidal flats of the coast; and the playa lakes of the High Plains. Wetlands provide flood attenuation, bank stabilization, water-quality maintenance, fish and wildlife habitat, and opportunities for hunting, fishing, and other recreational activities. Commercial fisheries benefit directly from coastal wetlands. Texas has lost about one-half of its original wetlands as a result of agricultural conversions, overgrazing, urbanization, channelization, water-table declines, construction of navigation canals, and other causes.

Utah

Wetlands cover only a small part of Utah but provide critical aquatic habitat in an arid environment as well as economic and other benefits. Utah wetlands include the shallows of small lakes, reservoirs, ponds, and streams; riparian wetlands; marshes and wet meadows; mud and salt flats; and playas. The largest wetlands in the State surround Great Salt Lake. Because of the importance of Great Salt Lake and its associated wetlands to migratory waterfowl and shorebirds, in 1991 the lake was designated a Hemispheric Reserve in the Western Hemisphere Shorebird Reserve Network. Streamflow regulation and agricultural, residential, industrial, and ski-area development have resulted in widespread wetland losses.

Vermont

Estimates of the area covered by wetlands in Vermont range from 4 to 6 percent of the State's total area. The largest wetlands are in the valleys of the northeast and in river flood plains and deltas in the Lake Champlain Valley. Vermont's wetlands provide flood and erosion control, water-quality maintenance, timber, and recreational opportunities. As much as 35 percent of Vermont's wetlands have been lost; major causes have been conversion to agriculture and residential and recreational development. The State is undertaking the Vermont Wetlands Conservation Strategy, a comprehensive review of current wetland conservation programs that will recommend actions to improve wetland conservation in Vermont.

U.S. Virgin Islands

Wetlands in the U.S. Virgin Islands comprise about 3 percent of the land surface. Wetlands are habitat for fish, shellfish, and birds, including endangered species such as the peregrine falcon and brown pelican. Freshwater is scarce in the islands, and wetlands there are mainly estuarine and marine types such as salt ponds, mangrove forests, sea grass beds, and coral reefs. Shoreline wetlands are vulnerable to destruction from construction of tourist facilities and water-dependent developments like marinas and to degradation by sedimentation and septic tank leachate. The Territorial Legislature adopted the Indigenous and Endangered Species Act of 1990, which establishes a policy of "no net loss of wetlands" to the maximum extent possible.

Virginia

Virginia has about 1 million acres of wetlands; one-quarter are tidal and three-quarters are nontidal. Forested wetlands (swamps) are the most common wetlands in the State. Both shores of the Chesapeake Bay have extensive estuarine wetlands. Conversion to nonwetland uses (agricultural, urban, industrial, and recreational), channelization and ditching, and other causes have resulted in the loss of about 42 percent of Virginia's wetlands since the 1780's. Development in wetlands is regulated in part by means of the Virginia Water Protection Permit. Local governments may adopt prescribed zoning ordinances and form citizen wetland boards to regulate their own tidal wetlands; the State retains an oversight and appellate role.

Washington

Wetlands cover only about 2 percent (939,000 acres) of Washington, but they benefit the State both ecologically and economically. Wetlands are nursery and feeding areas for anadromous fish such as salmon and steelhead trout. About 75 percent of the State's wetlands contain freshwater and include forested and shrub swamps, bogs, fens, marshes, wet prairies and meadows, vernal pools, and playas. About 25 percent are estuarine or marine and include marshes, tidal flats, beaches, and rocky shores. Estimates of wetland loss in Washington range from 20 to 50 percent; causes of loss or degradation include agricultural conversion, urban expansion, siting of ports and industries, logging, and invasion of nonnative plants and animals.

West Virginia

Wetlands constitute less than 1 percent of West Virginia's surface area but contribute significantly to the State's economic development and ecological diversity. Common West Virginia wetlands include swamps, peat bogs, marl wetlands, marshes, wet meadows, and ponds. The Canaan Valley and Meadow River wetlands together contain about 14 percent of the State's wetlands. The Canaan Valley wetland complex is the largest in the central Appalachian Mountains. West Virginia has lost about one-fourth of its original wetlands; primary causes have been agricultural conversions, channelization, pond and reservoir construction, and urbanization. Some wetlands have been created as a result of beaver activity.

Western Pacific Islands

Most of the wetlands in the Mariana, Samoan, Caroline, and Marshall Islands (referred to as the Western Pacific Islands in this report) are in coastal areas. Wetlands on the islands include mangrove swamps, marshes, and coral reefs. Wetlands are of economic importance on many islands because the staple food, taro, is grown in converted or constructed wetlands. On the larger islands, wetlands are important wildlife habitat. Available trend information indicates that on many islands there has been wetland loss or degradation due to agricultural conversion, urban expansion, or firewood cutting. Wetland activities on islands under United States jurisdiction are subject to Federal regulation.

Wisconsin

Wetlands cover more than 5 million acres (15 percent) of Wisconsin. Common wetlands include swamps and marshes in southern Wisconsin and peatlands in northern Wisconsin. Wetlands are most numerous in glaciated parts of the State; the unglaciated "driftless" section of southwestern Wisconsin has few wetlands, except in stream valleys filled with unconsolidated outwash and alluvium. Wetland acreage has decreased by nearly one-half over the last 200 years, primarily owing to agricultural development. In 1991 the State became the first to adopt water-quality standards for wetlands; the standards allow the State to control wetland development under section 401 of the Clean Water Act.

Wyoming

Wetlands cover about 1.25 million acres (2 percent) of Wyoming and are the most diverse ecosystems in the State's semiarid environment. The Laramie Plain Lakes wetland complex is home to the Wyoming toad, an endangered species. Trend information indicates that wetland acreage in Wyoming has decreased over time, primarily due to agricultural and urban development. However, agricultural diversions, whose original purpose was to flush salts and increase hay-meadow production, have enhanced wetlands along the Bear River; the Bear River wetland is one of the most productive and diverse bird habitats in Wyoming. The Wyoming Wetlands Act is the basis for wetland program development by the State.

Introduction

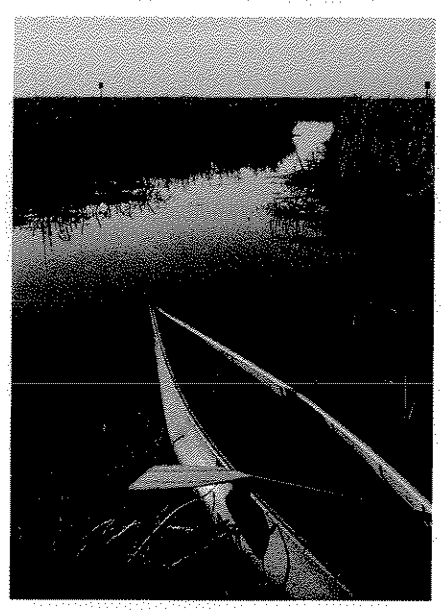
This volume, *National Water Summary on Wetland Resources*, is organized into two parts, a somewhat different format than the seven previous volumes (see inside front cover for previous volumes) in the *National Water Summary* series. (The "Hydrologic Conditions and Water-Related Events" included in the previous volumes are published separately, as U.S. Geological Survey Open-File Reports Numbers 96–107 and 96–145.)

This volume is the result of a coordinated effort to compile the most up-to-date information available on wetland resources. Although much has been written about the biological aspects of wetlands, much less has been written about the hydrology and the non-habitat functions of wetlands. This volume presents an overview of wetland resources from many different perspectives.

The first part of this volume, "Overview of Wetland Resources," discusses wetland resources from a national perspective and provides background information for the State summaries section. This section contains articles on the technical, management and research, and restoration, creation, and recovery aspects of wetland resources. These articles relate the history of wetlands in the United States; the definition of wetlands and a description of the U.S. Fish and Wildlife Service Classification System (Cowardin and others, 1979); hydrologic and water-quality factors that affect the distribution of wetlands and related functions commonly attributed to wetlands; the role of wetlands as habitat for birds; the roles of Federal agencies in wetland protection legislation and research; progress in inventory and mapping of wetlands; techniques for evaluating wetlands; human attempts to restore damaged wetlands and create new ones; and the recovery of wetlands following natural disasters.

The second part, "State Summaries of Wetland Resources," describes wetlands of each State, the District of Columbia (combined with Maryland), Puerto Rico, the U.S. Virgin Islands, and the Western Pacific Islands. Each State summary discusses wetlands in terms of value, types and distribution, hydrologic setting, and trends in acreage from predevelopment to modern times. Each State summary also provides an overview of public- and private-sector wetland-conservation efforts in that State and a table showing the wetland-related responsibilities of principal government agencies and private organizations within the State. Illustrations include a map depicting the areal distribution of principal wetlands and selected related features such as ecoregions, physiography, precipitation, runoff, evaporation, or other physical or climatic features that influence the presence or distribution of wetlands in that State. Some of the State summaries include a map or cross section depicting the hydrologic setting of wetlands and (or) a map showing predevelopment wetland distribution.

To supplement the information provided in this volume, bibliographic references are listed at the end of each article and State summary. An extensive list of suggested references for more information about topics discussed in the "Overview of Wetland Resources" is available in U.S. Geological Survey Open-File Report 96–169. This report also is available online at *http://h2o.usgs.gov/public/nwsum/bib/bib.html.* Most technical terms are defined in the glossary at the end of this volume, and a conversion table of water measurements precedes the glossary.



Horicon Marsh, Wisconsin, provides recreational opportunities. *(Photograph by Phillip J. Redman, U.S. Geological Survey.)*

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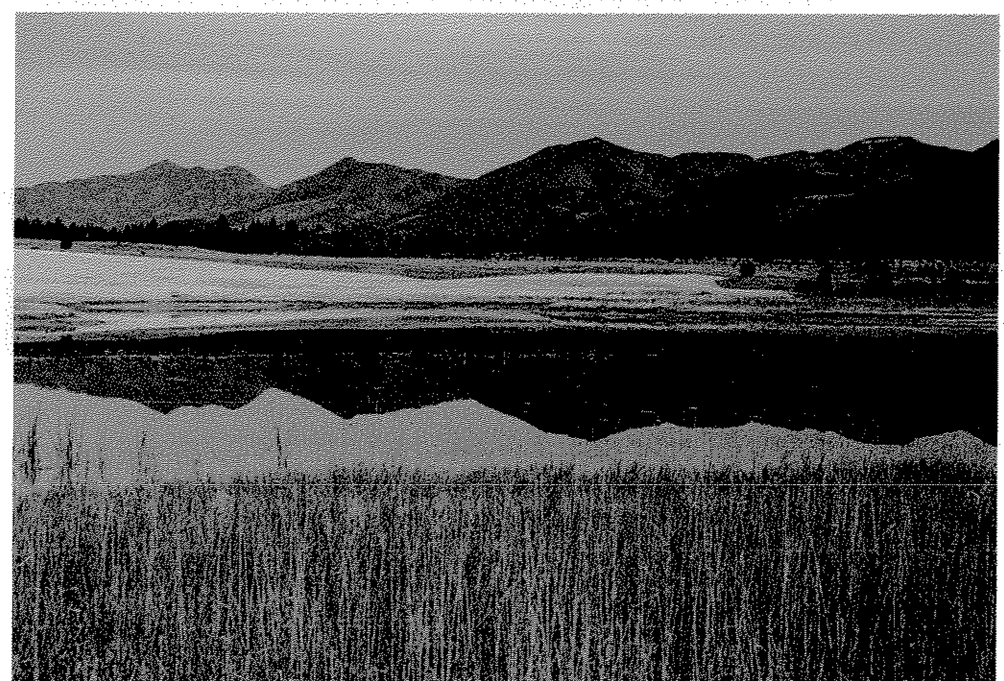
Overview of Wetland Resources



A restored wetland near Blackfoot River, Montana. *(Photograph by Kenneth J. Lanfear, U.S. Geological Survey.)*

Overview of Wetland Resources

Technical Aspects of Wetlands

History of Wetlands in the Conterminous United States

By Thomas E. Dahl[1] and Gregory J. Allord[2]

At the time of European settlement in the early 1600's, the area that was to become the conterminous United States had approximately 221 million acres of wetlands. About 103 million acres remained as of the mid-1980's (Dahl and Johnson, 1991). Six States lost 85 percent or more of their original wetland acreage—twenty-two lost 50 percent or more (Dahl, 1990) (fig. 2). Even today, all of the effects of these losses might not be fully realized.

Historical events, technological innovations, and values of society sometimes had destructive effects on wetlands. By examining the historical backdrop of why things happened, when they happened, and the consequences of what happened, society can better appreciate the importance of wetlands in water-resource issues. Society's views about wetlands have changed considerably—especially in the last half century. Interest in the preservation of wetlands has increased as the value of wetlands to society has become more fully understood. From a cultural standpoint, it is interesting to understand how changes in opinions and values came about, and what effects these changes had on wetland resources. From an ecological perspective, it is important to understand how the loss of wetlands affects fish, wildlife, and the environment as a whole.

EARLY 1600'S TO 1800—COLONIAL SETTLEMENT

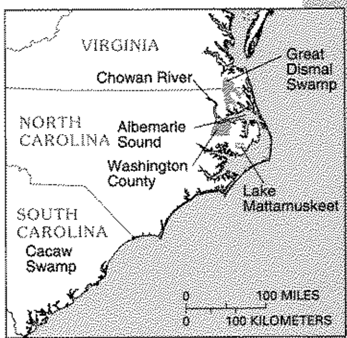
Wetland drainage began with permanent settlement of Colonial America. Throughout the 1600's and 1700's, colonization was encouraged by European monarchs to establish footholds in North America. The effects of this colonization on the landscape became obvious in the early to mid-1700's.

Much of our knowledge of early wetlands comes from maps and other documents that survived over time. The origins of settlers influenced both where people settled and how they mapped and used natural resources. Few records exist because the original English, French, and Spanish settlements were established before the land was surveyed. Settlements in the North tended to be clustered, whereas communities in the South were more widely scattered because of the predominance of agriculture. Many different land surveying systems resulted in an incomplete patchwork of ownership that ultimately caused many legal problems due to boundary errors and overlapping claims (Garrett, 1988). It was not until 1785 that the Land Ordinance Act established the United States Public Land Survey, which required surveying and partitioning of land prior to settlement. Although not

Interest in the preservation of wetlands has increased as the value of wetlands has become more fully understood.

Figure 2. States with notable wetland loss, 1780's to mid-1980's. *(Source: Modified from Dahl, 1990.)*

[1] U.S. Fish and Wildlife Service.
[2] U.S. Geological Survey.



The original extent of wetland acreage and the effect of widespread drainage is evident in Washington County, N.C. Originally, wetlands covered over 186,000 acres or about 85 percent of the land area of Washington County. Large-scale drainage began as early as 1788 with the construction of a canal 6 miles long and 20 feet wide to drain the wetlands north and east of Phelps Lake (Washington County Historical Society, 1979). A system of cross ditches leading into the main canal was designed to drain up to 100,000 acres of wetlands so that rice and corn could be grown (Tant, 1981). Today, about 34 percent of Washington County's original wetland acreage remains in scattered tracts.

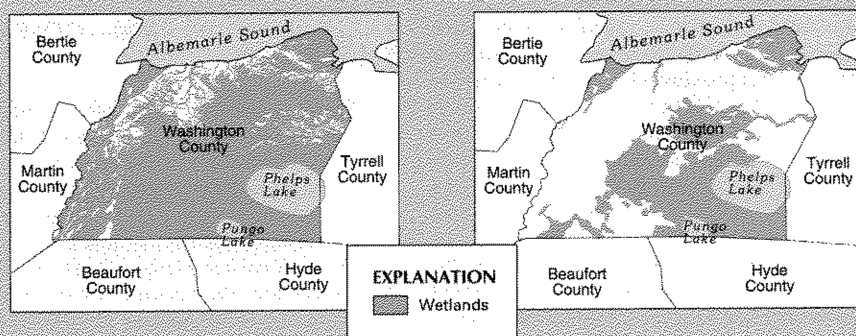


Figure 3. Extent of wetlands in Washington County, N. C., circa 1780 (left) and 1990 (right). *(Source: U.S. Fish and Wildlife Service, Status and Trends, unpub. data, 1994.)*

established to provide information on natural resources, surveys do provide some information about the distribution and location of wetlands.

Technical advances facilitated wetland conversion.

During the 1700's, wetlands were regarded as swampy lands that bred diseases, restricted overland travel, impeded the production of food and fiber, and generally were not useful for frontier survival. Settlers, commercial interests, and governments agreed that wetlands presented obstacles to development, and that wetlands should be eliminated and the land reclaimed for other purposes. Most pioneers viewed natural resources from wetlands as things to be used without limit (Tebeau, 1980). The most productive tracts of land in fertile river valleys in parts of Virginia had been claimed and occupied before 1700. The resulting shortage of choice land stimulated colonists to move south to the rich bottom lands along the Chowan River and Albemarle Sound of North Carolina on the flat Atlantic coastal plain. Initially, settlements consisted primarily of shelters and subsistence farms on small tracts of land. To extend the productive value of available land, wetlands on these small tracts were drained by small hand-dug ditches. During the mid- to late 1700's, as the population grew, land clearing and farming for profit began to affect larger tracts of land; many coastal plain wetlands were converted to farmland (fig. 3). Once drained, these areas provided productive agricultural lands for growing cash crops.

Oil-powered dredge digging a 30-foot-wide ditch to drain wetlands near Carroll, Iowa. *(Photograph courtesy of National Archives, 8-D-2214-2570.)*

Widespread wetland drainage was most prevalent in the southern colonies. In 1754, South Carolina authorized the drainage of Cacaw Swamp for agricultural use (Beauchamp, 1987). Similarly, areas of the Great Dismal Swamp in Virginia and North Carolina were surveyed in 1763 so that land could be reclaimed for water transportation routes. Farming on large plantations was common practice in the South and necessitated some drainage or manipulation of wetlands.

By the 1780's, immigrants had settled along the fertile river valleys of the Northeast and as far south as present-day Georgia. Wetlands in these river valleys suffered losses with this settlement (fig. 4). Small towns and farms were established in the valleys along the rivers of Massachusetts, Connecticut, New York, and Pennsylvania. Settlement extended to the valleys beyond the Appalachian Mountains in Virginia and followed the major rivers inland through the Carolinas by 1800.

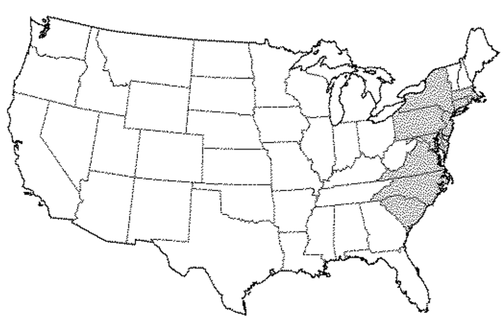


Figure 4. States with notable wetland loss, early 1600's to 1800.

1800 TO 1860—WESTWARD EXPANSION

The period between 1800 and 1860 was a time of growth in the United States. During these decades, numerous land acquisitions—the Louisiana Purchase (1803); Florida and eastern Louisiana ceded by Spain (1819); annexation of Texas (1845); the Oregon Com-

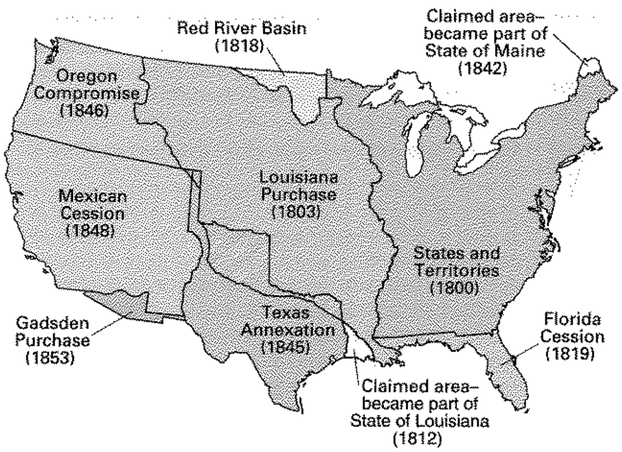


Figure 5. Major United States land acquisitions between 1800 and 1860. *(Source: U.S. Geological Survey, 1970.)*

promise (1846); and lands ceded from Mexico (1848)—greatly expanded the land area of the United States (Garrett, 1988) (fig. 5). With this land expansion, the population grew from 7.2 million in 1810 to 12.8 million in 1830 (U.S. Bureau of the Census, 1832). Land speculation increased with this rapid growth and marked a period when land and resources seemed to be available for the taking. It was a time of rapid inland movement of settlers westward into the wetland-rich areas of the Ohio and Mississippi River Valleys (fig. 2). Large-scale conversion of wetlands to farmlands started to have a real effect on the distribution and abundance of wetlands in the United States. Areas where notable wetland loss occurred between 1800 and 1860 are shown in figure 6.

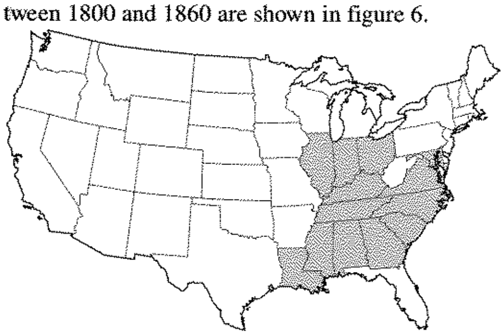


Figure 6. States with notable wetland loss, 1800 to 1860.

Technical advances throughout the 1800's greatly facilitated wetland conversions. The opening of the Erie Canal in 1825 provided settlers with an alternative mode and route of travel from New York to the Great Lakes States, increasing migration of farmers to the Midwest. The canal also provided low-cost transportation of timber and agricultural products from the Nation's interior to eastern markets and seaports (McNall, 1952). Another innovation, the steam-powered dredge, allowed the channelizing or clearing of small waterways at the expense of adjacent wetlands. Between 1810 and 1840, new agricultural implements—plows, rakes, and cultivators—enabled settlers to break ground previously not considered for farming (McManis, 1964). Mechanical reapers introduced in the 1830's stimulated competition in, and furthered refinements of, farm equipment marketed in the Midwest (Ross, 1956). These innovations ultimately took a toll on wetlands as more land was drained, cleared, and plowed for farming.

Wetland drainage continued. In the Midwest, the drainage of the Lake Erie marshes of Michigan and Ohio probably started about 1836. Cotton and tobacco farming continued to flourish in the Southern States and precipitated the additional drainage of thousands of acres of wetlands for conversion to cropland.

Wetlands also were being modified in other ways. The Horicon Marsh in Wisconsin was dammed and flooded in 1846 for a transportation route and to provide commercial fishing. Toward the middle of the century, lumbering was an important industry in the Midwest, supplying wood for construction and fuel for stoves and fireplaces. Much of the Nation's timber came from the swamp forests of Ohio, Indiana, and Illinois, which typically contained a mix of birch, ash, elm, oak, cottonwood, poplar, maple, basswood, and hickory.

In 1849, Congress passed the first of the Swamp Land Acts, which granted all swamp and overflow lands in Louisiana to the State for reclamation. In 1850, the Act was made applicable to 12 other States, and in 1860, it was extended to include lands in two additional States (Shaw and Fredine, 1956) (table 1). Although most States did not begin immediate large-scale reclamation projects, this legislation clearly set the tone that the Federal Government promoted wetland drainage and reclamation for settlement and development. This tone pervaded policy and land-use trends for the next century.

1860 TO 1900—AGRICULTURE MOVES WEST

The American Civil War (1861–65) affected wetlands because traversing swamps and marshes with heavy equipment presented major logistical problems for both armies. The design, engineering, and construction of transportation and communication networks were stimulated. Attention became focused on the development of routes around, through, or over water bodies and wetlands, and on production of accurate maps (fig. 7). These maps provided an early glimpse of some of the Nation's wetlands.

After the war, the Nation's attention focused on westward expansion and settlement. Railroads were important in the initial development of transportation routes. The railroads not only opened new lands, including wetlands, to development, but the railroad industry also was a direct consumer of wetland forest products. In the 1860's, more than 30,000 miles of railroad track existed in the United States (Stover, 1961). The railroads of Ohio consumed 1 million cords of wood annually just for fuel (Gordon, 1969). The additional quantity of wood used for ties is not known. From 1859 to 1885, intense timber cutting and land clearing eliminated many of Ohio's wetlands, including the Black Swamp (fig. 8).

The Black Swamp was in the northwestern corner of Ohio and was a barrier to travel and settlement.

Table 1. Acreage granted to the States under the authority of the Swamp Land Acts of 1849, 1850, and 1860

YEAR	STATE	ACRES
1849	Louisiana	9,493,456
	Alabama	441,289
	Arkansas	7,686,575
	California	2,192,875
	Florida	20,325,013
	Illinois	1,460,164
1850	Indiana	1,259,231
	Iowa	1,196,392
	Michigan	5,680,310
	Mississippi	3,347,860
	Missouri	3,432,481
	Ohio	26,372
	Wisconsin	3,360,786
1860	Minnesota	4,706,503
	Oregon	286,108
	TOTAL	64,895,415

Figure 7. Confederate States of America map of Southeastern United States with wetlands depicted for strategic rather than natural resources value. *(Source: National Archives, Record Group 94, Civil War Atlas, Plate CXLIV.)*

This forested wetland was estimated to have been 120 miles long and 40 miles wide, covering an area nearly equal in size to Connecticut (Gordon, 1969; Ohio Department of Natural Resources, 1988). The swamp, which was an elm-ash forested wetland typical of the region, contained a variety of commercially valuable trees (Eyre, 1980). Nothing was left of the Black Swamp by the end of the nineteenth century.

During the mid- to late 1880's, agriculture expanded rapidly westward along the major river systems. Several regions of abundant wetlands lay directly in the path of this expansion (Wooten and Jones, 1955), including:

- The prairie pothole wetlands of western Minnesota, northern Iowa, and North and South Dakota
- The bottom lands of Missouri and Arkansas in the lower Mississippi River alluvial plain
- The delta wetlands of Mississippi and Louisiana
- The gulf plains of Texas

By the 1860's, settlers started to farm and drain the prairie pothole region. At first, only a modest number of potholes were drained. By the late 1800's, however, the numbers had increased significantly.

As new kinds of machinery increased the ability to till more land, the conversion of wetlands to farmlands increased rapidly. Huge wheat farms, or "Bonanza Farms," were operating in the Dakota Territory (present-day North and South Dakota) by 1875. New mechanical seeders, harrowers, binders, and threshers, designed specifically for wheat production, were used to cultivate large tracts of land for these farms (Knue, 1988). Many wetlands were lost as a result of these operations.

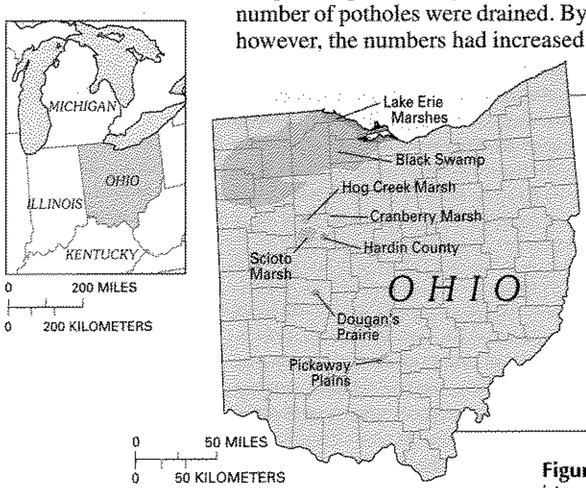
Improvements in drainage technology greatly affected wetland losses in the East and the Midwest. As the use of steam power expanded, replacing hand labor for digging ditches and manufacturing drainage tiles, the production and installation of drainage tiles increased rapidly. By 1880, 1,140 factories located mainly in Illinois, Indiana, and Ohio manufactured drainage tiles that were used to drain wetlands for farming (Pavelis, 1987). By 1882, more than 30,000 miles of tile drains were operating in Indiana alone. By 1884, Ohio had 20,000 miles of public ditches designed to drain 11 million acres of land (Wooten and Jones, 1955).

Wetland conversion in the Central Valley of California began in the mid-1800's, when farmers began diking and draining the flood-plain areas of the valley for cultivation (fig. 9). Other States had notable losses of wetlands between 1860 and 1900 (fig. 10).

1900 TO 1950—CHANGING TECHNOLOGY

The first half of the twentieth century was a time of ambitious engineering and drainage operations. Two World Wars, a rapidly growing population, and industrial growth fueled the demand for land as industry and agriculture propelled the United States to the status of a world leader. Technology was increasingly important in manipulation of the Nation's water resources. Two of the most notable projects that affected wetlands were California's Central Valley Project and the lock and dam system on the Mississippi River.

Although draining had begun one-half century earlier, wetland modification in the Central Valley accelerated early in the 20th century. By the 1920's, about 70 percent of the original wetland acreage had been modified by levees, drainage, and water-diversion projects (Frayer and others, 1989). In the 1930's,



HISTORIC WETLANDS	AREA IN ACRES	DATE DRAINED	SOURCE
Black Swamp	3,072,000	1859–1885	Ohio Dept. Nat. Res., 1988
Pickaway Plains	4,800	1821	Gordon, 1969
Scioto Marsh	16,000	1859, 1883	Gordon, 1969
Other marshes, Hardin County	9,000	1860's	Howe, 1900
Hog Creek Marsh	8,000	1868–1874	Gordon, 1969
Cranberry Marsh	1,000	Unknown	Gordon, 1969
Lake Erie Marshes	300,000	1936–1974	Bednarik, 1984
Dougan's Prairie	Unknown	1827	Middleton, 1917
TOTAL	3,410,800		

Figure 8. Location, estimated original acreage, and drainage date of Ohio's historic wetlands.

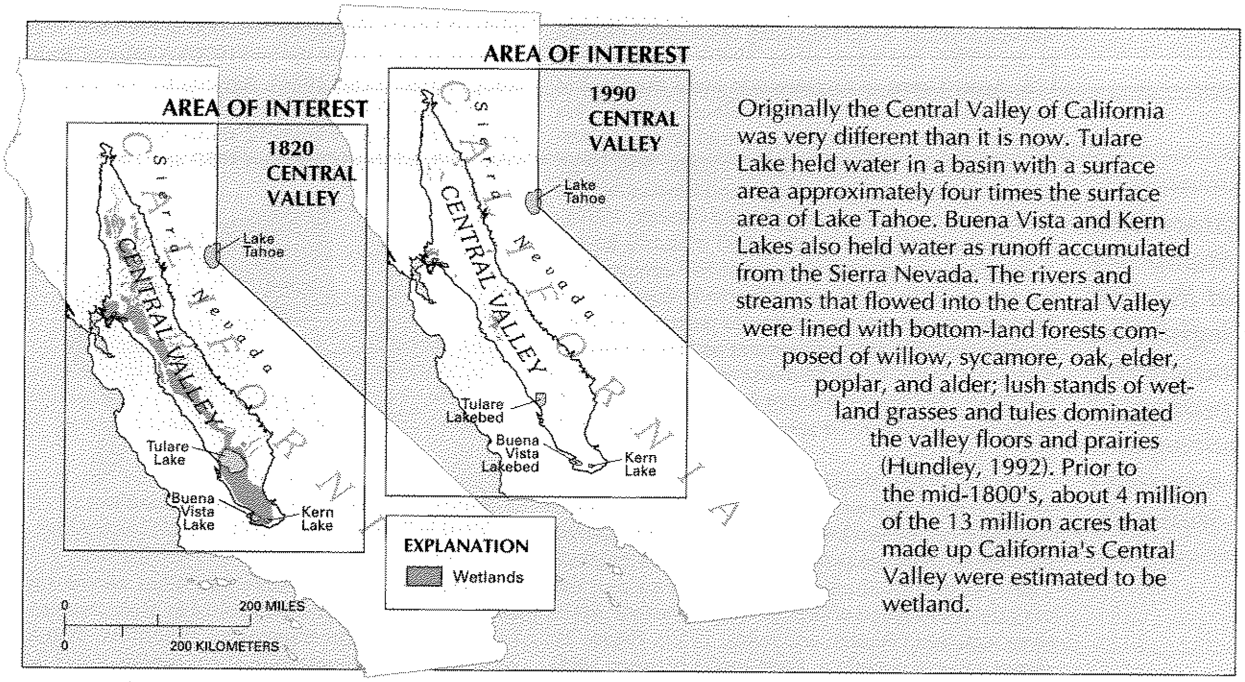


Figure 9. Wetlands of the Central Valley of California, circa 1820 (left) and 1990 (right). *(Source: U.S. Fish and Wildlife Service, Status and Trends, unpub. data, 1994.)*

large-scale flood-control projects, diversion dams, and water-control structures were being built on the tributary rivers entering the valley.

Wetland modification also continued farther east. Before the installation of the lock and dam system in 1924, the bottom lands of the Mississippi River corridor were primarily wooded islands separated by deep sloughs (Green, 1984). Hundreds of small lakes and ponds were scattered throughout extensive wooded areas. The river channel was subject to shifting sands and shallows, and changed constantly. Lake and dam structures were built to create a permanent navigable waterway. The water depth increased behind each dam to create a pool that extended upstream to the next dam. The first pool was filled in 1935 and the system was completed when the last pool was filled in 1959. The resulting changes to the river system eliminated large water-level fluctuations and helped stabilize water depth and flooding. Bottom lands no longer dried out in summer, and former hay meadows and wooded areas were converted to marshlands surrounding the pools. One type of wetland was

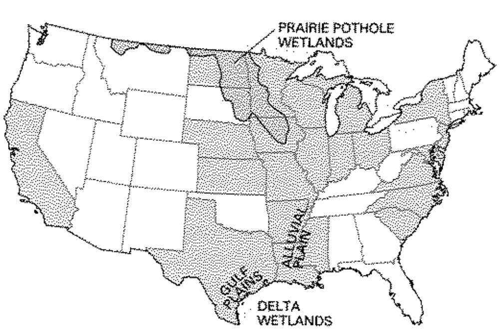


Figure 10. States with notable wetland loss, 1860 to 1900.

exchanged for another. Although some pools of the Upper Mississippi River have problems with silt deposition and restricted water circulation, these "created" wetland areas provide habitat for fur-bearing animals, waterfowl, and fish.

In other parts of the country, this era was marked by urban and agricultural expansion projects that drained both large and small wetlands. Some of the most ambitious projects were attempts to drain and cultivate Horicon Marsh in Wisconsin in 1904; commercial timber harvesting in southern Georgia, which began in 1908 as a precursor to attempts to drain the Okefenokee Swamp (Trowell, 1988); and in 1914, the draining of North Carolina's largest natural lake, Lake Mattamuskeet, to create farmland (U.S. Fish and Wildlife Service, undated). Early in the century, land developers dug drainage ditches in an attempt to drain a huge area for development in the vast peatlands north of Red Lake, Minn. (Glaser, 1987). On July 29, 1917, the Minneapolis Sunday Tribune ran a full page advertisement to attract homesteaders to the Red Lake area—"perhaps the last of the unsettled, uncut timberland in the middle of the country" (Wright, 1984). By 1930, nearly all of the prairie wetlands in Iowa, the southern counties of Minnesota, and the Red River Valley in North Dakota and Minnesota were drained (Schrader, 1955).

Attempts were underway to drain and farm large parts of The Everglades (a huge expanse of wetlands in southern Florida). By the 1930's, more than 400 miles of drainage canals were already in place (Lord, 1993). (See article "Wetland Resources of Florida" in the State Summaries section of this volume.) With the passage of the Sugar Act of 1934, additional wetlands in southern Florida were drained and put into sugarcane production. Sugarcane yields more than doubled from 410,000 to 873,000 tons between 1931 and 1941 (Clarke, 1977), largely at the expense of

Drainage tile operation, circa 1940's. Tiles provide a conduit for moving water from a wetland. *(Photograph courtesy of U.S. Department of Agriculture.)*

wetland acreage. Severe flooding in southern Florida in the 1920's and again in the 1940's prompted the U.S. Army Corps of Engineers to build the Central and Southern Florida Project for flood control. This massive undertaking, which required levees, water-storage areas, channel improvements, and large pumps, caused additional large modification to The Everglades' environment (Light and Dineen, 1994).

The Migratory Bird Hunting Stamp Act was one of the first pieces of legislation to initiate the process of acquiring and restoring America's wetlands.

Mechanized farm tractors had replaced horses and mules for farm labor during this half century. The tractors could be used more effectively than animals for drainage operations, and the old pasture land then became available for improvement and production of additional crops. In the Midwest and the North-central States, the use of tractors probably contributed to the loss of millions of acres of small wetlands and prairie potholes.

In the 1930's, the U.S. Government, in essence, provided free engineering services to farmers to drain wetlands; and by the 1940's, the Government shared the cost of drainage projects (Burwell and Sugden, 1964). Organized drainage districts throughout the country coordinated efforts to remove surface water from wetlands (Wooten and Jones, 1955). Figure 11 shows areas of notable wetland losses between 1900 and 1950.

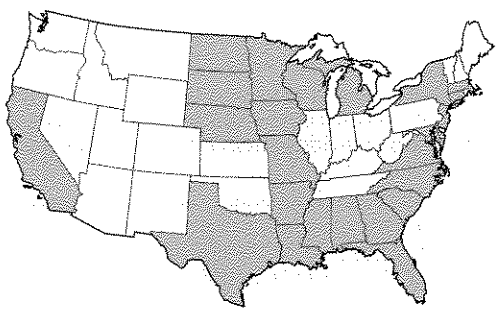


Figure 11. States with notable wetland loss, 1900 to 1950.

In 1934, in stark contrast to these drainage activities, Congress passed the Migratory Bird Hunting Stamp Act. This Act was one of the first pieces of legislation to initiate the process of acquiring and restoring America's wetlands.

1950 TO PRESENT—CHANGING PRIORITIES AND VALUES

By the 1960's, most political, financial, and institutional incentives to drain or destroy wetlands were in place. The Federal Government encouraged land drainage and wetland destruction through a variety of legislative and policy instruments. For example, the Watershed Protection and Flood Prevention Act (1954) directly and indirectly increased the drainage of wetlands near flood-control projects (Erickson and others, 1979). The Federal Government directly subsidized or facilitated wetland losses through its many public-works projects, technical practices, and cost-shared drainage programs administered by the U.S. Department of Agriculture (Erickson, 1979). Tile and open-ditch drainage were considered conservation practices under the Agriculture Conservation Program—whose policies caused wetland losses averaging 550,000 acres each year from the mid-1950's to the mid-1970's (Office of Technology Assessment, 1984). Agriculture was responsible for more than 80 percent of these losses (Frayer and others, 1983). Figure 12 shows States with notable wetland losses between 1950 and 1990.

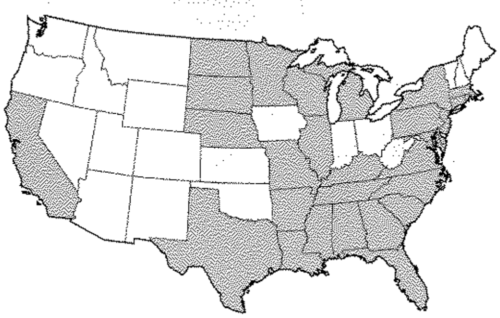


Figure 12. States with notable wetland loss, 1950 to 1990.

Since the 1970's, there has been increasing awareness that wetlands are valuable areas that provide important environmental functions. Public awareness of, and education about, wetlands has increased dramatically since the early 1950's. Federal policies, such as the "Swampbuster," have eliminated incentives and other mechanisms that have made the destruction of wetlands technically and economically feasible. New laws, such as the Emergency Wetland Resources Act of 1986, also curtail wetland losses. (See article "Wetland Protection Legislation" in this volume for information on legislation affecting wetlands.) Some of the more ambitious drainage projects of earlier years have been abandoned. Now, places like Lake Mattamuskeet, Horicon Marsh, and the Okefenokee Swamp, which once were targeted for drainage, have become National Wildlife Refuges that provide wetland habitat for a variety of plants and animals.

The effects of the Federal policy reversal on the rate of wetland loss are not clear. Estimates indicate that wetland losses in the conterminous United States from the mid-1970's to the mid-1980's were about 290,000 acres per year (Dahl and Johnson, 1991). This is about one-half of the losses that occurred each year in the 1950's and '60's. The preceding numbers do not include degraded or modified wetlands. Although the estimate above reflects a declining rate of loss, land development continues to destroy wetlands.

From about 1987 to the present, Federal efforts to restore wetlands have increased. Although there is no precise number for all of the wetland acres restored, the U.S. Fish and Wildlife Service (1991) estimated that between 1987 and 1990 about 90,000 acres were added to the Nation's wetland inventory.

Attempts are underway now to restore some of The Everglades. The remaining Everglades comprise about 2,300 square miles, three-fifths of which is impounded in managed water-conservation areas (Lord, 1993). This wetland system currently is experiencing mercury contamination and other water-quality problems, water-supply and diversion controversies, declining wildlife populations, increasing pressure from tourism, urban and agricultural expansion, and influx of nuisance plants.

The magnitude of environmental alterations in Florida, with numerous conflicting interests, exemplifies the dilemma of managing water resources and wetlands. What initially seemed to be a matter of water removal turned into an extremely complex and costly issue involving water-use objectives at all levels of government (Tebeau, 1980).

Today there are more than 100 dams within the California Central Valley drainage basins and thousands of miles of water-delivery canals. Water is diverted for irrigation, hydroelectric power, and municipal and industrial water supplies. Only 14 percent of the original wetland acreage remains. The Tulare Lake Basin has been virtually drained, leaving only remnant wetland areas and a dry lakebed, and Buena Vista and Kern Lakes rarely contain water (fig. 9).

Currently (1994), manipulation of water levels in wetlands rather than the complete removal of water as in the past, is a trend that affects wetlands. Partial drainage or lowering of the water levels to allow for certain uses is becoming prevalent in some parts of the country. Effects of this type of management are uncertain.

EXAMPLE OF CHANGING ATTITUDES—HORICON MARSH

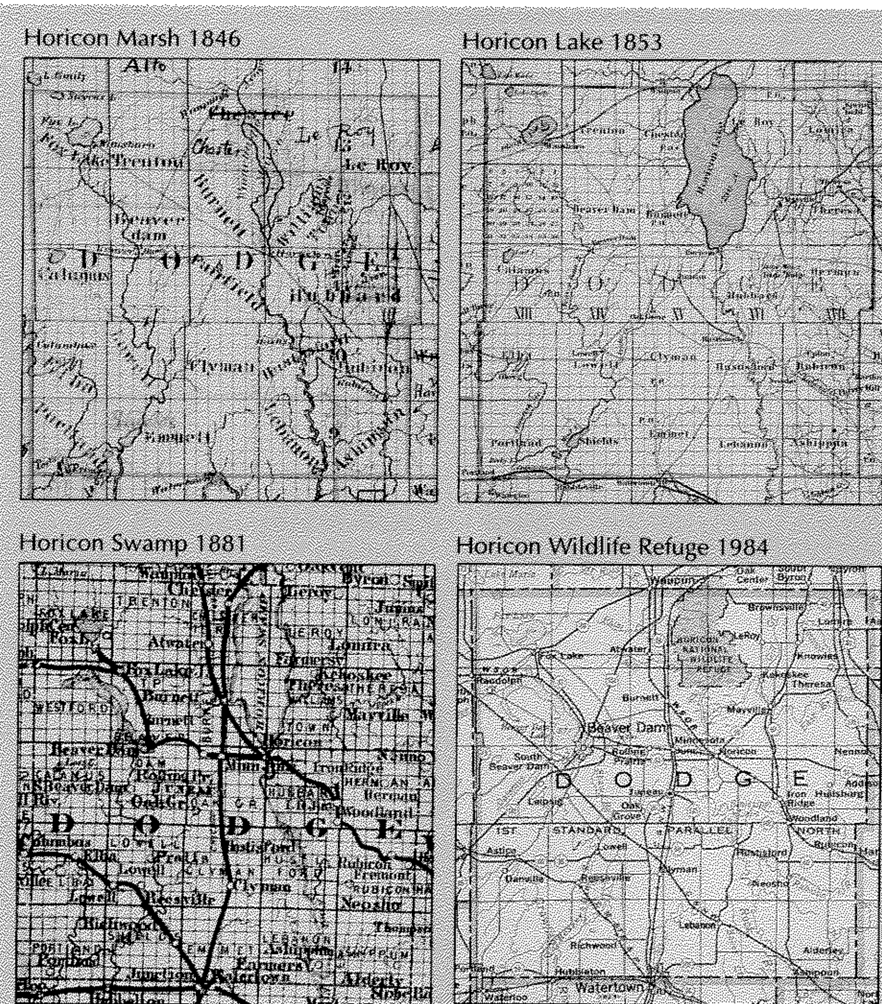


Figure 13. Horicon Marsh, Wis., evolved from original marsh (1846), to lake (1853), to swamp (1881), to wildlife refuge (1984). *(Source: Sequence is left to right, top to bottom, Historical Society of Wisconsin negative number WHi (X3) 50111, WHi (X3) 50212, WHi (X3) 50113; U.S. Geological Survey, 1984.)*

The history of the Horicon Marsh in Wisconsin is an example of how people's attitudes toward wetlands have changed through time (fig. 13). Horicon Marsh was dammed, flooded, and renamed Lake Horicon in 1846. At that time, it was the largest manmade lake in the world (about 4 miles wide by 14 miles long) (Wisconsin Department of Natural Resources, 1990). Lake Horicon was used for commercial transportation and for commercial fishing. In 1869, the dam was removed and the land returned to marsh. In 1883, two sportsmen's clubs, which leased the marsh area, reported that 500,000 ducks hatched annually in the marsh. They also reported that 30,000 muskrats and mink were trapped in the southern half of the marsh. Huge flocks of geese also were reported (Freeman, 1948). In 1904, attempts were made to drain the marsh and sell the reclaimed land for truck farms. Lawsuits resulting from inadequate drainage halted the reclamation effort.

In 1921, local conservationists began efforts to protect Horicon Marsh as a game refuge, and the State of Wisconsin created the Horicon Marsh Wildlife Refuge in July 1927. Later, to avoid legal confrontations with the local farmers, the State bought property and (or) water rights to the southern half of the refuge and the Federal Government purchased rights to the northern half. In 1990, Horicon Marsh was added to the sites recognized by the Convention on Wetlands of International Importance especially as Waterfowl Habitat.

Estimates indicate that today slightly more than 100 million acres of wetlands remain in the conterminous United States. Although the rate of wetland conversion has slowed in recent years, wetland losses continue to outdistance wetland gains.

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Technical Aspects of Wetlands

Wetland Definitions and Classifications in the United States

By Ralph W. Tiner[1]

"Wetland" is a generic term for all the different kinds of wet habitats—implying that it is land that is wet for some period of time, but not necessarily permanently wet. Wetlands have numerous definitions and classifications in the United States as a result of their diversity, the need for their inventory, and the regulation of their uses. This article provides an overview of wetland definitions and classification systems of major wetland types in the United States. It also introduces the U.S. Fish and Wildlife Service (FWS) classification system (Cowardin and others, 1979) that is used throughout this volume.

Wetlands typically occur in topographic settings where surface water collects and (or) ground water discharges, making the area wet for extended periods of time. Examples of some of these topographic settings, and some common names for wetland types associated with them are:

- Depressions (swales, sloughs, prairie potholes, Carolina bays, playas, vernal pools, oxbows, and glacial kettles)
- Relatively flat depositional areas that are subject to flooding (intertidal flats and marshes, coastal lowlands, sheltered embayments, shorelines, deltas, and flood plains)
- Broad, flat areas that lack drainage outlets (interstream divides and permafrost muskegs)
- Sloping terrain associated with springs, seeps, and drainageways; and relatively flat or sloping areas adjacent to bogs and subject to expansion by accumulation of peat
- Open water bodies (floating mats and submersed beds)

Cross sections of some typical wetland landscapes and the position of the wetland relative to specific topographic features are shown in figure 14.

All areas considered to be wetlands must have enough water at some time during the year to stress plants and animals that are not adapted to life in water or saturated soils. A variety of wetland plant communities and soil types have developed in the United States because of regional differences in hydrologic regimes, climate, soil-forming processes, and geologic settings. Consequently, many terms, such as "marsh," "bog," "fen," "swamp," "pocosin," "pothole," "playa," "salina," "vernal pool," "bottom-land hardwood swamp," "river bottom," "lowland," and others are applied to different types of wetlands across the country.

WETLAND DEFINITIONS

Wetlands have been defined for specific purposes, such as research studies, general habitat classification, natural resource inventories, and environmental regulations. Before the beginning of wetland-protection laws in the 1960's, wetlands were broadly defined by scientists working in specialized fields (Lefor and Kennard, 1977). A botanist's definition would emphasize plants; a soil scientist would focus on soil properties; and a hydrologist's definition would emphasize fluctuations of the water table.

Nonregulatory Definition

The FWS developed a nonregulatory, technical definition that could have several uses, ranging from wetland protection to scientific investigations. This definition emphasizes three important attributes of wetlands: (1) hydrology—the degree of flooding or soil saturation; (2) vegetation—plants adapted to grow in water or in a soil or substrate that is occasionally oxygen deficient due to saturation (hydrophytes); and (3) soils—those saturated long enough during the growing season to produce oxygen-deficient conditions in the upper part of the soil, which commonly includes the major part of the root zone of plants (hydric soils) (Cowardin and others, 1979; Tiner, 1991). To supplement this

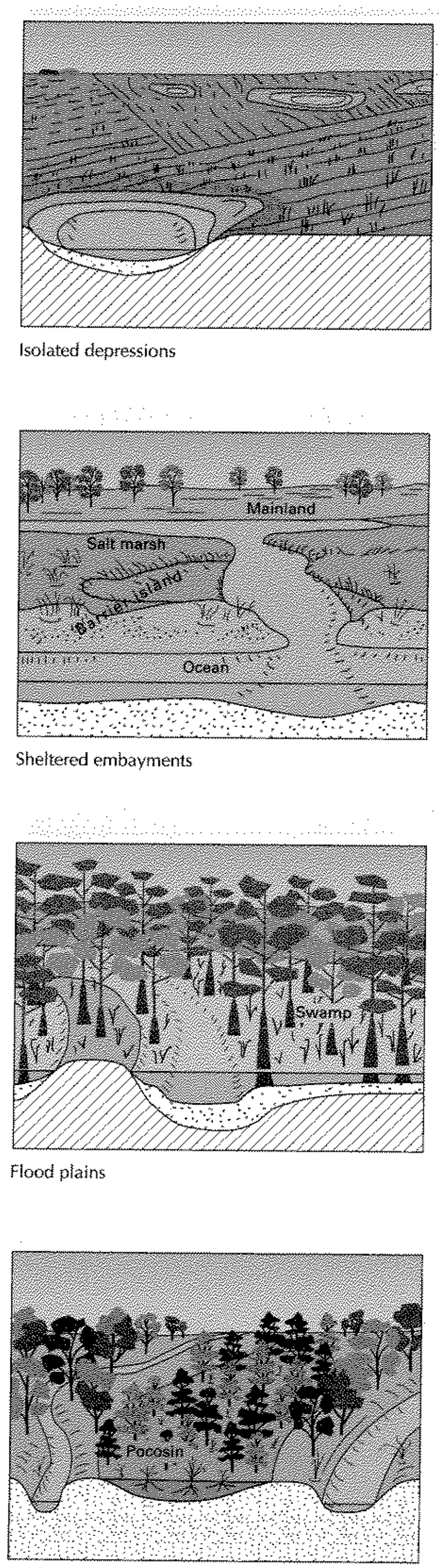
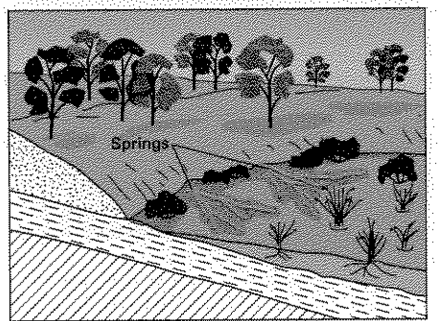
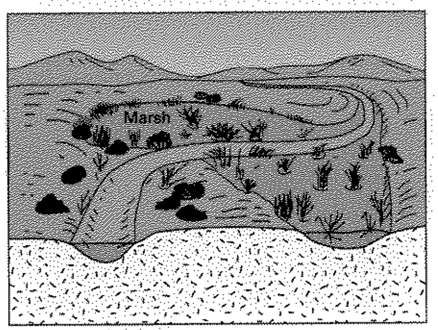


Figure 14. Cross sections of selected wetland landscapes showing typical positions of wetlands relative to topographic features.

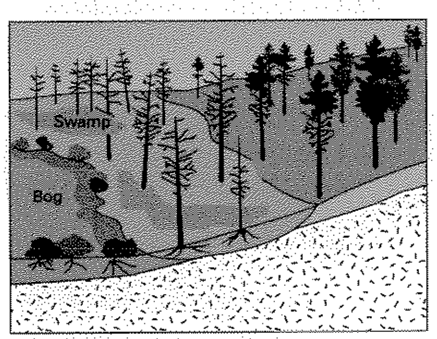
[1] U.S. Fish and Wildlife Service.



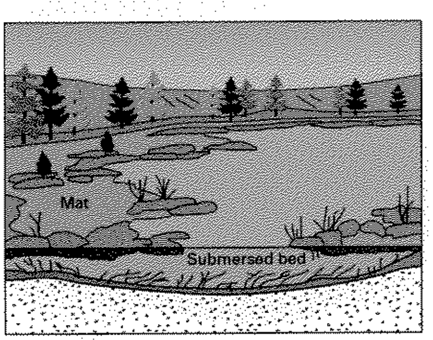
Seepage areas and springs



Basins with streams



Blanket bogs in boreal and arctic regions



Open water bodies with floating mats and submersed beds

Figure 14. Cross sections of selected wetland landscapes showing typical positions of wetlands relative to topographic features. —Continued.

definition and to help identify wetlands in the United States, the FWS prepared a list of wetland plants (Reed, 1988). In addition, the Soil Conservation Service[1] (SCS) developed a list of hydric soils (U.S. Soil Conservation Service, 1991).

On the basis of plant and soil conditions, wetlands typically fall into one of three categories: (1) areas with hydrophytes and hydric soils (marshes, swamps, and bogs); (2) areas without soils but with hydrophytes (aquatic beds and seaweed-covered rocky shores); and (3) areas without soil and without hydrophytes (gravel beaches and tidal flats) that are periodically flooded. The FWS definition generally does not include permanent deepwater areas as wetlands. However, permanent shallow waters that commonly support aquatic beds and emergent plants (erect, rooted, nonwoody plants that are mostly above water) are classified as wetlands.

Regulatory Definitions as Compared to Nonregulatory Definitions

In the 1960's and 1970's, State and Federal environmental laws gave some protection to wetlands. On the basis of different interests to be protected, however, each governing body developed a different definition of wetlands. Examples of some of these definitions are given in table 2. Only wet soils vegetated with hydrophytes are considered as wetlands by the three Federal agencies involved with regulation—the SCS, the U.S. Environmental Protection Agency (EPA), and the U.S. Army Corps of Engineers (Corps). The FWS uses a nonregulatory definition that is broader and includes aquatic beds in shallow freshwater and naturally nonvegetated areas. In the context of vegetated wetlands, all four agency definitions are conceptually the same in that they include hydrology, vegetation, and soils.

Most States have developed regulatory definitions to protect certain wetlands from exploitation. Therefore, State definitions are much broader than any of the Federal definitions. The State definitions tend to emphasize the presence of certain plants for identification purposes (table 2). However, the States did not produce a comprehensive list of "wetland plant species," making it difficult to use vegetation consistently to identify the limits of wetlands (Tiner, 1989 and 1993a).

WETLAND CLASSIFICATION

"Wetland classification," as used in this article, refers to the designation of different wetland types on the basis of hydrology, vegetation, and soils. The Federal Government's early attempts to classify wetlands were motivated largely by agricultural interests that sought to convert wetlands to cropland. The first classification systems put wetlands into a few general categories on the basis of location—river swamps, lake swamps, and upland swamps (Wright, 1907). Other classification systems were related to the degree of inundation—permanent swamps, wet grazing land, periodically overflowed land, and periodically swampy land (Dachnowski, 1920).

Later wetland classifications developed from a need to differentiate wetlands from other land-cover types for regional and national planning purposes, or because of ecological interest. Martin and others (1953) developed a "*Classification of Wetlands in the United States*" to serve as a framework for the 1954 national inventory to assess the amount and types of wetland waterfowl habitat. Although this system is still in use, the inadequate definition of wetland types has led to inconsistencies in application across the country (Cowardin and others, 1979).

When the FWS began a review of existing wetland inventories in 1974, they found more than 50 classification schemes (U.S. Fish and Wildlife Service, 1976). The only one of these that was nationally based was that of Martin and others (1953). Subsequently, the FWS worked with several prominent wetland scientists and mapping experts to identify necessary elements for a new classification system based on the concept of ecosystems (Sather, 1976). Four key objectives were established:

- Identify ecologically similar habitat units
- Classify these units systematically to facilitate resource-management decisions
- Identify units for inventory and mapping purposes
- Provide uniformity in concept and terminology throughout the country

[1] The SCS became the Natural Resources Conservation Service in 1994.

Table 2. Examples of wetland definitions used by Federal and State agencies in the United States

Organization (reference)	Wetland definition
FEDERAL	
U.S. Fish and Wildlife Service (Cowardin and others, 1979)	"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For the purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."
U.S. Army Corps of Engineers (33 CFR 328.3) U.S. Environmental Protection Agency (40 CFR 230.3)	"Wetlands are those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalance of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas."
U.S. Soil Conservation Service (National Food Security Act Manual 1988) (The Act is commonly known as the "Swampbuster")	"Wetlands are defined as areas that have a predominance of hydric soils and that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions, except lands in Alaska identified as having high potential for agricultural development and a predominance of permafrost soils."
STATE	
Connecticut (CT General Statutes, Sections 22a–36 to 45, inclusive, 1972, 1987)	"Wetlands mean land, including submerged land which consists of any of the soil types designated as poorly drained, very poorly drained, alluvial, and floodplain by the National Cooperative Soils Survey, as may be amended from time to time, by the Soil Conservation Service of the United States Department of Agriculture. Watercourses are defined as rivers, streams, brooks, waterways, lakes, ponds, marshes, swamps, bogs, and all other bodies of water, natural or artificial, public or private."
Connecticut (CT General Statutes, Sections 22a–28 to 35, inclusive 1969)	"Wetlands are those areas which border on or lie beneath tidal waters, such as, but not limited to banks, bogs, salt marshes, swamps, meadows, flats or other low lands subject to tidal action, including those areas now or formerly connected to tidal waters, and whose surface is at or below an elevation of one foot above local extreme high water." (Also includes a list of plants capable of growing in tidal wetlands.)
Rhode Island Coastal Resources Management Council (RI Coastal Resources Management Program as amended June 28, 1983)	"Coastal wetlands include salt marshes and freshwater or brackish wetlands contiguous to salt marshes. Areas of open water within coastal wetlands are considered a part of the wetland. Salt marshes are areas regularly inundated by salt water through either natural or artificial water courses and where one or more of the following species predominate:" (8 indicator plants listed). "Contiguous and associated freshwater or brackish marshes are those where one or more of the following species predominate:" (9 indicator plants listed).
Rhode Island Department of Environmental Management (RI General Law, Sections 2–1–18 et seq.)	Fresh water wetlands are defined to include, "but not be limited to marshes; swamps; bogs; ponds; river and stream flood plains and banks; areas subject to flooding or storm flowage; emergent and submergent plant communities in any body of fresh water including rivers and streams and that area of land within fifty feet (50') of the edge of any bog, marsh, swamp, or pond." Various wetland types are further defined on the basis of hydrology and indicator plants, including bog (15 types of indicator plants), marsh (21 types of indicator plants), and swamp (24 types of indicator plants plus marsh plants).
New Jersey (Pinelands Protection Act, N.J. STAT. ANN. Section 13:18–1 to 13:29.)	"Wetlands are those lands which are inundated or saturated by water at a magnitude, duration and frequency sufficient to support the growth of hydrophytes. Wetlands include lands with poorly drained or very poorly drained soils as designated by the National Cooperative Soils Survey of the Soil Conservation Service of the United States Department of Agriculture. Wetlands include coastal wetlands and inland wetlands, including submerged lands." "Coastal wetlands are banks, low-lying marshes, meadows, flats, and other lowlands subject to tidal inundation which support or are capable of supporting one or more of the following plants:" (29 plants are listed). "Inland wetlands" are defined as including, but not limited to, Atlantic white cedar swamps (15 plants listed), hardwood swamps (19 plants specified), pitch pine lowlands (10 plants listed), bogs (12 plants identified), inland marshes (6 groups of plants listed), lakes and ponds, and rivers and streams.
New Jersey (Coastal Wetland Protection Act - N.J. STAT. ANN. Section 13:18–1 to 13:9A–10)	"Coastal wetlands" are "any bank, marsh, swamp, meadow, flat or other low land subject to tidal action in the Delaware Bay and Delaware River, Raritan Bay, Sandy Hook Bay, Shrewsbury River including Navesink River, Shark River, and the coastal inland waterways extending southerly from Manasquan Inlet to Cape May Harbor, or at any inlet, estuary, or those areas now or formerly connected to tidal areas whose surface is at or below an elevation of 1 foot above local extreme high water, and upon which may grow or is capable of growing some, but not necessarily all, of the following:" (19 plants are listed.) Coastal wetlands exclude "any land or real property subject to the jurisdiction of the Hackensack Meadowlands Development Commission...."
Massachusetts (MA General Law Chapter 131, Section 40)	"The term 'freshwater wetlands' shall mean wet meadows, marshes, swamps, bogs, areas where groundwater, flowing or standing surface water or ice provides a significant part of the supporting substrate for a plant community for at least five months of the year; emergent and submergent plant communities in inland waters; that portion of any bank which touches any inland waters." Various wetland types are further defined on the basis of hydrology and indicator plants and include bogs (19 types of indicator plants), swamps (22 types of plants), wet meadows (12 types of plants), and marshes (22 types of indicator plants).

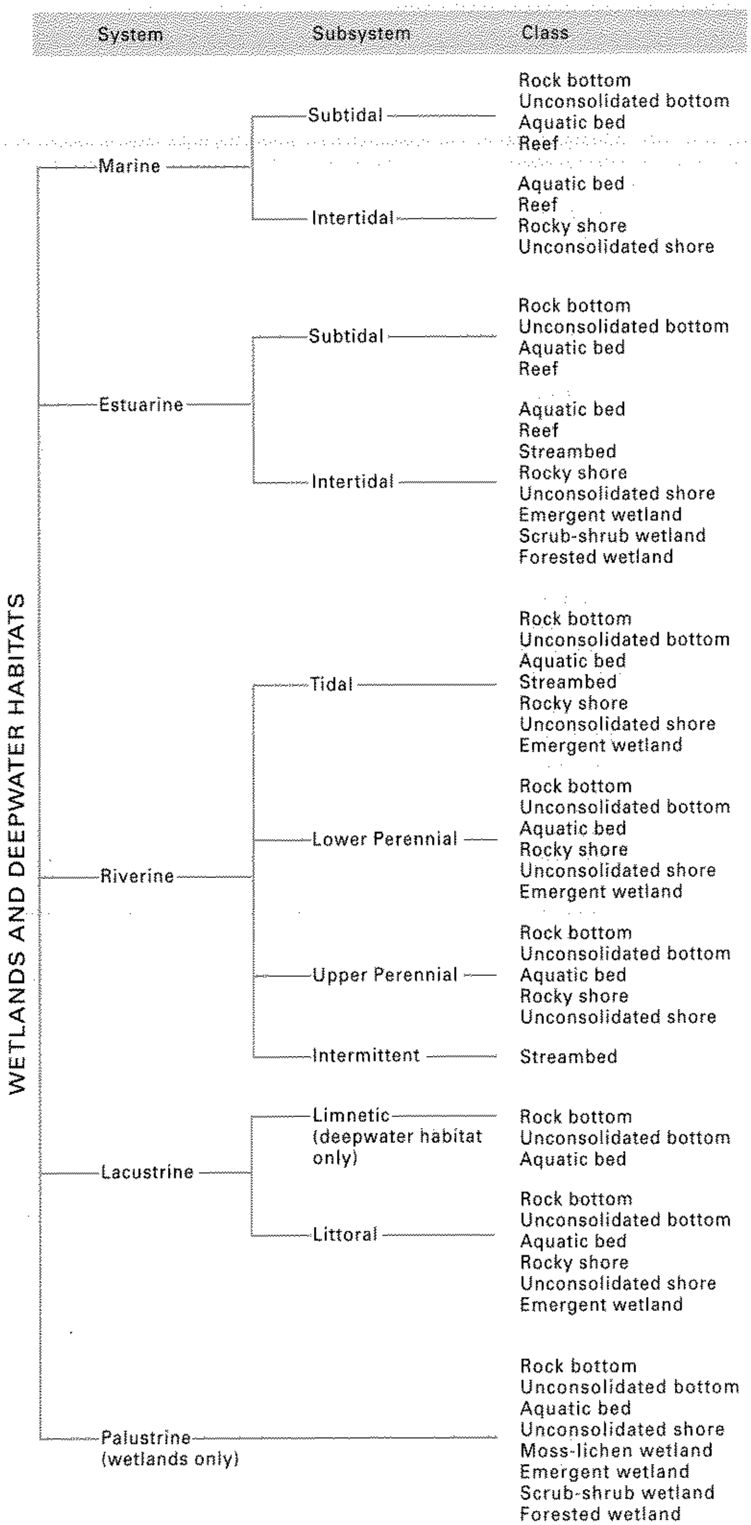


Figure 15. Classification hierarchy of wetlands and deepwater habitats showing systems, subsystems, and classes. *(Source: Cowardin and others, 1979).*

On the basis of these objectives, the FWS developed a new wetland classification system. The system was extensively field tested and reviewed by public and private sectors before being published as "Classification of Wetlands and Deepwater Habitats of the United States" (Cowardin and others, 1979). Since its publication, the system has become the national and international standard for identifying and classifying wetlands (Mader, 1991; Gopal and others, 1982).

THE U.S. FISH AND WILDLIFE SERVICE WETLAND CLASSIFICATION SYSTEM

A synopsis of the FWS wetland classification system is presented here. Each of the State summaries in this volume gives a general summary of the system, and a more comprehensive discussion can be found in Cowardin and others (1979). The system described here proceeds from general to specific, as shown in figure 15.

System.— Each system represents "a complex of wetlands and deepwater habitats, that share the influence of similar hydrologic, geomorphologic, chemical, or biological factors" (Cowardin and others, 1979, p. 4). Five systems are defined:

- Marine—open ocean and its associated coastline
- Estuarine—tidal waters of coastal rivers and empayments, salty tidal marshes, mangrove swamps, and tidal flats
- Riverine—rivers and streams
- Lacustrine—lakes, reservoirs, and large ponds
- Palustrine—marshes, wet meadows, fens, playas, potholes, pocosins, bogs, swamps, and small shallow ponds

The overwhelming majority of the Nation's wetlands fall within the Palustrine System; most of the remaining wetlands are in the Estuarine System.

Subsystem.—Each system, except the Palustrine, is divided into subsystems (fig. 15). The Marine and Estuarine Systems have two subsystems that are defined by tidal water levels: subtidal—continuously submersed areas; and intertidal—alternately flooded and exposed to air. The Lacustrine System has two subsystems that are defined by water depth: littoral—the shallow-water zone where wetlands extend from the lakeshore to a depth of 6.6 feet below low water or to the extent of nonpersistent emergent plants such as arrowheads, pickerelweed, wild rice, or bulrush, if they grow beyond that depth; and limnetic—the deepwater zone where low water is deeper than 6.6 feet (deepwater habitat). The Riverine System has four subsystems that represent different reaches of a flowing freshwater system: tidal—water levels subject to tidal fluctuations; lower perennial—permanent, slow-flowing waters having a well-developed flood plain; upper perennial—permanent, fast-flowing waters having very little or no flood plain; and intermittent—streambeds with flowing water for only part of the year.

Classes.—Each subsystem is divided into classes, which describe the general appearance of the wetland or deepwater habitat in terms of the dominant vegetative form, or composition of the substrate (table 3). For areas where vegetation covers 30 percent or more of the surface, five vegetative classes are

Table 3. Classes and subclasses of wetlands and deepwater habitats as defined by Cowardin and others (1979)

Class	Brief description	Subclasses
Rock bottom	Generally permanently flooded areas with bottom substrates consisting of at least 75 percent stones and boulders and less than 30 percent vegetative cover.	Bedrock; rubble
Unconsolidated bottom	Generally permanently flooded areas with bottom substrates consisting of at least 25 percent particles smaller than stones and less than 30 percent vegetative cover.	Cobble-gravel; sand; mud; organic
Aquatic bed	Generally permanently flooded areas that are vegetated by plants growing principally on or below the water surface.	Algal; aquatic; rooted vascular; floating vascular
Reef	Characterized by elevations above the surrounding substrate and interference with normal wave flow; they are primarily subtidal.	Coral; mollusk; worm
Streambed	Channel whose bottom is completely dewatered at low water periods.	Bedrock; rubble; cobble-gravel; sand; mud; organic; vegetated
Rocky shore	Wetlands characterized by bedrock stones or boulder with areal coverage of 75 percent or more and with less than 30 percent coverage by vegetation.	Bedrock; rubble
Unconsolidated shore	Wetlands having unconsolidated substrates with less than 75 percent coverage by stones, boulders, and bedrock and less than 30 percent native vegetative cover.	Cobble-gravel; sand; mud; organic; vegetated
Moss-lichen wetland	Wetlands dominated by mosses or lichens where other plants have less than 30 percent coverage.	Moss; lichen
Emergent wetland	Wetlands dominated by erect, rooted, herbaceous hydrophytes.	Persistent; nonpersistent
Scrub-shrub wetland	Wetlands dominated by woody vegetation less than 20 feet (6 meters) tall.	Deciduous; evergreen; dead woody plants
Forested wetland	Wetlands dominated by woody vegetation 20 feet (6 meters) or taller.	Deciduous; evergreen; dead woody plants

used—aquatic bed, moss-lichen wetland, emergent wetland, scrub-shrub wetland, and forested wetland. Aquatic beds may be either wetlands or deepwater habitats, depending on water depth.

Six other classes are used where vegetation generally is absent and where substrate and degree of flooding are distinguishing features—rock bottom, unconsolidated bottom, reef, streambed, rocky shore, and unconsolidated shore. Areas that are nonvegetated and permanently flooded are classed as either rock bottom or unconsolidated bottom. Areas that are periodically flooded are classed as streambed, rocky shore, or unconsolidated shore. Reefs are found in both permanently flooded (deepwater habitats) and periodically flooded tidal areas (wetlands).

Subclass.—Each class is divided further into subclasses (table 3) to define the substrate in non-vegetated areas or the dominant vegetation in vegetated areas. In vegetated areas, the subclasses are—persistent or nonpersistent emergents, mosses and lichens, or broad-leaved deciduous, needle-leaved deciduous, broad-leaved evergreen, needle-leaved evergreen, and dead woody plants. In nonvegetated areas the subclasses are—bedrock, rubble, cobble-gravel, mud, sand, and organic.

Dominance Type.—Below the subclass, dominance type can be applied to specify the dominant plant or animal in the wetland. This level allows one to distinguish between distinct plant communities (red maple forested wetland and pin oak forested wetland, or a tussock-sedge-dominated emergent wetland and cattail-dominated emergent wetland). In this way, individual wetlands can be grouped in ecologically similar units.

Modifiers.—The classification system also uses modifiers to describe hydrologic, chemical, and soil characteristics, and the effects of humans on the wetlands. The four specific modifiers used are—water regime, water chemistry, soil, and special. These modifiers can be applied to classes, subclasses, and dominance types.

The water-regime modifiers describe flooding or soil saturation and are divided into two main groups—tidal and nontidal. Tidal modifiers can be subdivided into two general categories—salt- and brackish-water and freshwater. The nontidal modifier—inland freshwater and saline—defines conditions where runoff, ground-water discharge or recharge, evapotranspiration, wind, and lake seiches (oscillation of the water) cause water-level changes. Both tidal and nontidal modifiers are briefly defined in table 4.

Water-chemistry modifiers are divided into two categories: salinity and pH. The salinity modifiers have been further divided into two groups: haline for estuarine and marine tidal areas dominated by sodium chloride and saline for nontidal areas dominated by salts other than sodium chloride. The salinity and

The FWS classification system has become the national and international standard for identifying and classifying wetlands.

Table 4. Water regime modifiers as defined by Cowardin and others (1979)

Group	Water type	Water regime and definition
Tidal	Salt- and brackish-water areas	Subtidal — Permanently flooded tidal waters
		Irregularly exposed — Exposed less often than daily by tides
		Regularly flooded — Daily tidal flooding and exposure to air
		Irregularly flooded — Flooded less often than daily and typically exposed to air
	Freshwater	Permanently flooded — Permanently flooded by tides and river overflow but with tidal fluctuation in water levels
		Semipermanently flooded — Flooded most of the growing season by river overflow but with tidal fluctuation in water levels
		Regularly flooded — Daily tidal flooding and exposure to air
		Seasonally flooded — Flooded irregularly by tides and river overflow
		Temporarily flooded — Flooded irregularly by tides and for brief periods during growing season by river overflow
Nontidal	Inland fresh-water and saline areas	Permanently flooded — Flooded throughout the year in all years
		Intermittently exposed — Flooded year-round except during extreme droughts
		Semipermanently flooded — Flooded throughout the growing season in most years
		Seasonally flooded — Flooded for extended periods in the growing season, but surface water is usually absent by the end of the growing season
		Saturated — Surface water is seldom present, but the substrate is saturated to the surface for most of the growing season
		Temporarily flooded — Flooded for only brief periods during the growing season, with the water table usually well below the soil surface for most of the season
		Intermittently flooded — The substrate is usually exposed and only flooded for variable periods without detectable seasonal periodicity (may be upland in some situations)
		Artificially flooded — Duration and amount of flooding is controlled by pumps or siphons in combination with dikes or dams

The FWS wetland classification system has provided a uniformity of wetland terminology.

fluctuations in salinity of water in a wetland and the type of salt causing the salinity determines what plant and animal species the wetland can support. The pH modifiers identify waters that are acid (pH less than 5.5), circumneutral (pH 5.5–7.4), and alkaline (pH greater than 7.4).

Soil modifiers are divided into two categories—organic and mineral. In general, if a soil has 20 percent or more organic matter by weight in the upper 16 inches, it is considered an organic soil. If it has less than this amount, it is a mineral soil.

Special modifiers are used to describe human or beaver activities. These modifiers are: excavated, impounded (obstruct outflow of water), diked (obstruct inflow of water), partly drained, farmed, and artificial (materials deposited by humans to create or modify a wetland).

Although an extensive treatment of wetlands is beyond the scope of this article, it would be incomplete without examples of the classification of some of the different wetland types. In figure 16, some of the major wetland types are listed by their common names and then classified by the FWS system. The variety of wetlands and their locations also are illustrated. For further information on wetland types, see Mitsch and Gosselink (1986), Niering (1984), Tiner (1984, 1987, 1993b), and Wilen and Tiner (1993).

CONCLUSIONS

The FWS wetland classification system places ecologically similar habitats into a hierarchal system that permits wetland classification down to dominance types, which are based on dominant plants or substrates. The system can be used to identify units for inventory and mapping for Federal and State wetland inventories. It also has provided a uniformity of wetland terminology. The FWS uses this classification to determine wetland status and trends—information useful to resource managers and planners at all levels of government.

Since the 1954 inventory by the FWS, wetlands have changed because of natural and human-related activities. Wetland characteristics and values have become better defined, more widely known, and more appreciated. As a result, Federal and State legislation has been passed to protect wetlands, and some States have completed wetland surveys (Cowardin and others, 1979) to aid in protecting and managing this resource.

EXPLANATION

Number	General wetland type	Location	System	Subsystem	Class	Subclass	Water regime
1	Willow swamp	Alaska Range east of Paxon, Alaska	Palustrine	—	Scrub-shrub	Broad-leaved deciduous	Seasonally flooded
2	Cattail marsh	Near Brainerd, Minn.	Palustrine	—	Emergent	Persistent	Seasonally flooded
3	Inland lakeshore marsh	Lake Durant, N.Y.	Lacustrine	Littoral	Emergent	Nonpersistent	Permanently flooded
4	Floating bog	Adirondacks, N.Y.	Palustrine	—	Scrub-shrub	Broad-leaved evergreen	Saturated
5	Salt marsh	Nantucket, Mass.	Estuarine	Intertidal	Emergent	Persistent	Tidal, Irregularly flooded
6	Maple-ash swamp	Sussex County, N.J.	Palustrine	—	Forested	Broad-leaved deciduous	Seasonally flooded
7	Brackish marsh	Cedar Key, Fla.	Estuarine	Intertidal	Emergent	Persistent	Tidal, Irregularly flooded
8	Cypress-gum swamp	Francis Marion National Forest, S.C.	Palustrine	—	Forested	Needle/broad-leaved deciduous	Semipermanently flooded
9	Pocosin	Francis Marion National Forest, S.C.	Palustrine	—	Scrub-shrub	Broad-leaved evergreen	Saturated
10	Cottonwood riparian forest	Near Reno, Nev.	Palustrine	—	Forested	Broad-leaved deciduous	Temporarily flooded
11	Wet meadow	Nisqually, Wash.	Palustrine	—	Emergent	Persistent	Seasonally flooded
12	Black spruce bog	Juneau, Alaska	Palustrine	—	Forested	Needle-leaved evergreen	Saturated
13	Prairie pothole	Devil's Lake area, N. Dak.	Palustrine	—	Emergent	Nonpersistent	Semipermanently flooded

Figure 16. Examples of the classification for major wetland types in the United States, following Cowardin and others (1979). *(Note that there are no subsystems for the Palustrine System. Photograph 1 by David Dahl; 4 by Bill Zinni; 12 by Jon Hall; all others by Ralph W. Tiner. All photographers are with the U.S. Fish and Wildlife Service.)*

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Technical Aspects of Wetlands

Wetland Hydrology, Water Quality, and Associated Functions

By Virginia Carter[1]

The formation, persistence, size, and function of wetlands are controlled by hydrologic processes. Distribution and differences in wetland type, vegetative composition, and soil type are caused primarily by geology, topography, and climate. Differences also are the product of the movement of water through or within the wetland, water quality, and the degree of natural or human-induced disturbance. In turn, the wetland soils and vegetation alter water velocities, flow paths, and chemistry. The hydrologic and water-quality functions of wetlands, that is, the roles wetlands play in changing the quantity or quality of water moving through them, are related to the wetland's physical setting.

Wetlands are distributed unevenly throughout the United States because of differences in geology, climate, and source of water (fig. 17). They occur in widely diverse settings ranging from coastal margins, where tides and river discharge are the primary sources of water, to high mountain valleys where rain and snowmelt are the primary sources of water. Marine wetlands (those beaches and rocky shores that fringe the open ocean) are found in all coastal States. Estuarine wetlands (where tidal saltwater and inland freshwater meet and mix) are most plentiful in Alaska and along the southeastern Atlantic coast and the gulf coast. Alaska has the largest acreage of estuarine wetlands in the United States, followed by Florida and Louisiana.

Inland (nontidal) wetlands are found in all States. Some States, such as West Virginia, have few large wetlands, but contain many small wetlands associated with streams. Other States, such as Nebraska, the Dakotas, and Texas, contain many small isolated wetlands—the lakes of the Nebraska Sandhills, the prairie potholes, and the playa lakes, respectively. Northern States such as Minnesota and Maine contain numerous wetlands with organic soils (peatlands), similar in origin and hydrologic and veg-

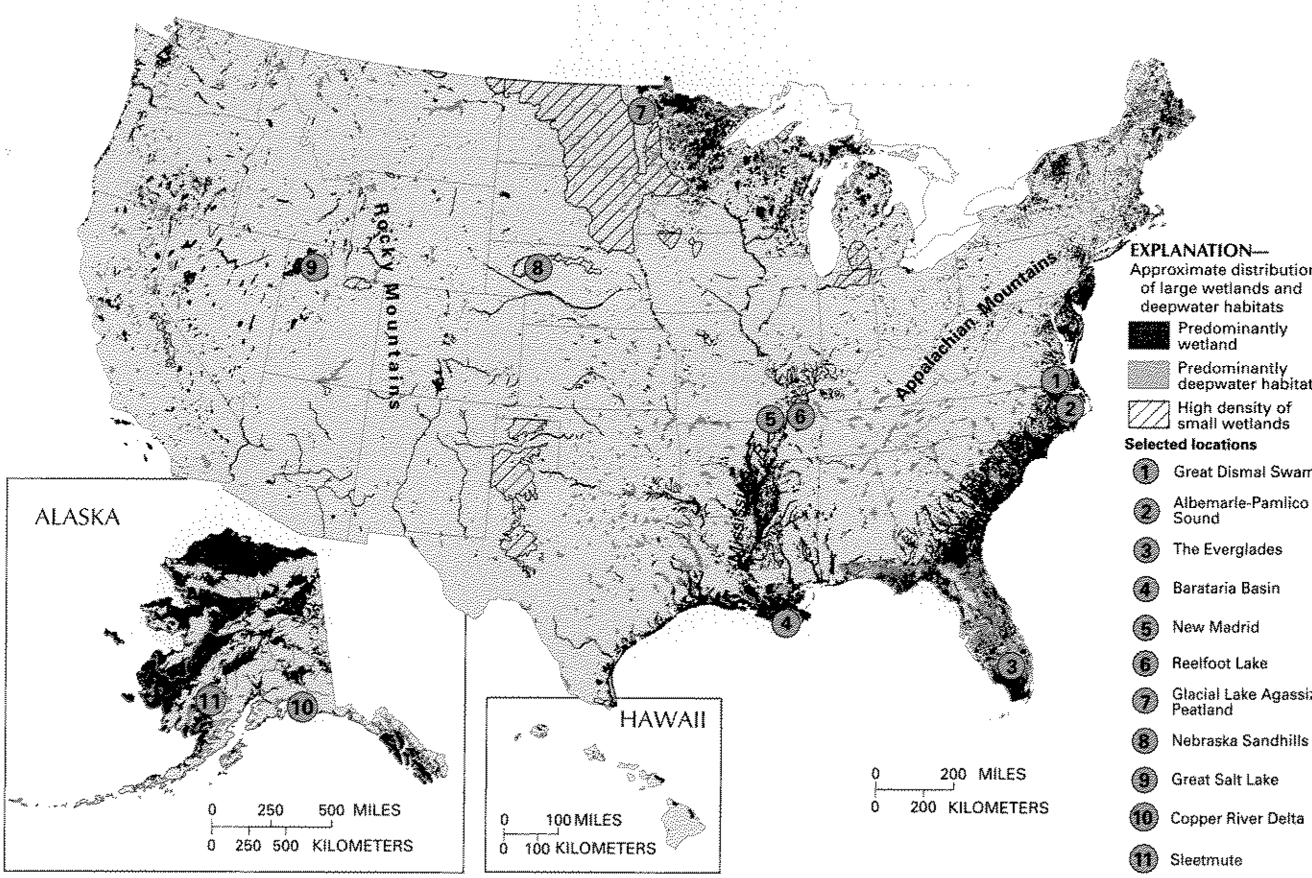
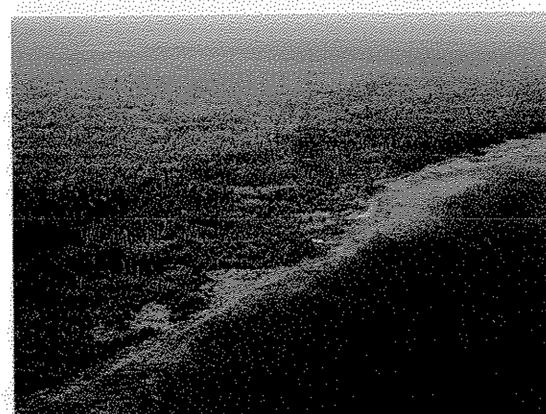


Figure 17. Major wetland areas in the United States and location of sites mentioned in the text. *(Source: Data from T.E. Dahl, U.S. Fish and Wildlife Service, unpub. data, 1991.)*

[1] U.S. Geological Survey.

Typical prairie pothole wetland in North Dakota. *(Photograph by Virginia Carter, U.S. Geological Survey.)*



Glacial Lake Agassiz peatland, Minnesota. *(Photograph by Virginia Carter, U.S. Geological Survey.)*

etative characteristics to the classic bog and fen peatlands of northern Europe. However, peatlands are by no means limited to Northern States—they occur in the Southeastern and Midwestern United States wherever the hydrology and chemical environment are conducive to the accumulation of organic material.

Wetlands occur on flood plains—for example, the broad bottom-land hardwood forests and river swamps (forested wetlands) of southern rivers and many of the narrow riparian zones along streams in the Western United States. Wetlands are commonly associated with lakes or can occur as isolated features of the landscape. They can form large complexes of open water and vegetation such as The Everglades of Florida, the Okefenokee Swamp of Georgia and Florida, the Copper River Delta of Alaska, and the Glacial Lake Agassiz peatland of Minnesota.

HYDROLOGIC PROCESSES IN WETLANDS

Hydrologic processes occurring in wetlands are the same processes that occur outside of wetlands and collectively are referred to as the hydrologic cycle. Major components of the hydrologic cycle are precipitation, surface-water flow, ground-water flow, and evapotranspiration (ET). Wetlands and uplands continually receive or lose water through exchange with the atmosphere, streams, and ground water. Both a favorable geologic setting and an adequate and persistent supply of water are necessary for the existence of wetlands.

The wetland water budget is the total of inflows and outflows of water from a wetland. The components of a budget are shown in the equation in figures 18 and 19. The relative importance of each component in maintaining wetlands varies both spatially and

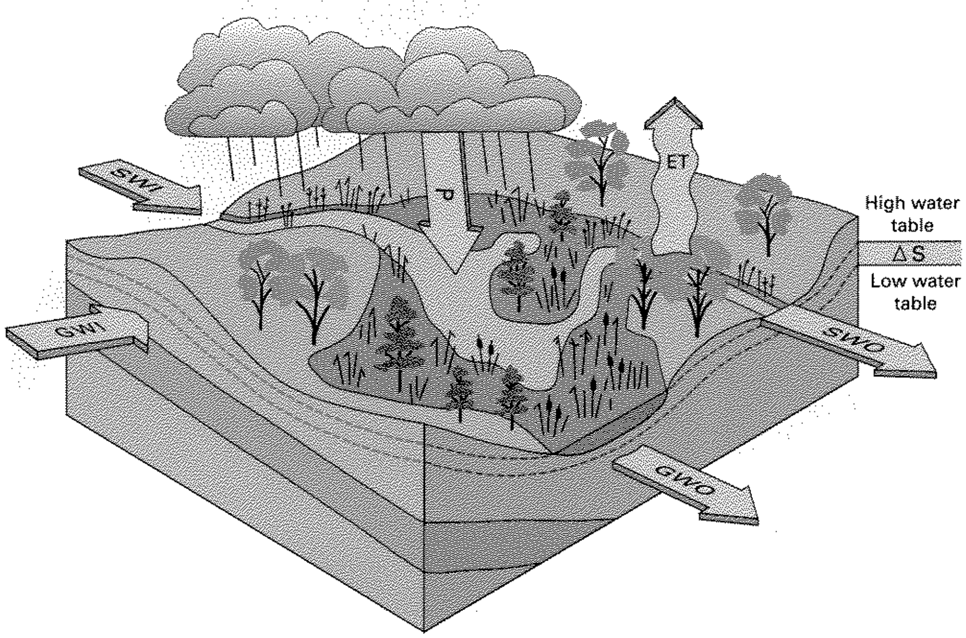


Figure 18. Components of the wetland water budget. ($P + SWI + GWI = ET + SWO + GWO + \Delta S$, where P is precipitation, SWI is surface-water inflow, SWO is surface-water outflow, GWI is ground-water inflow, GWO is ground-water outflow, ET is evapotranspiration, and ΔS is change in storage.)

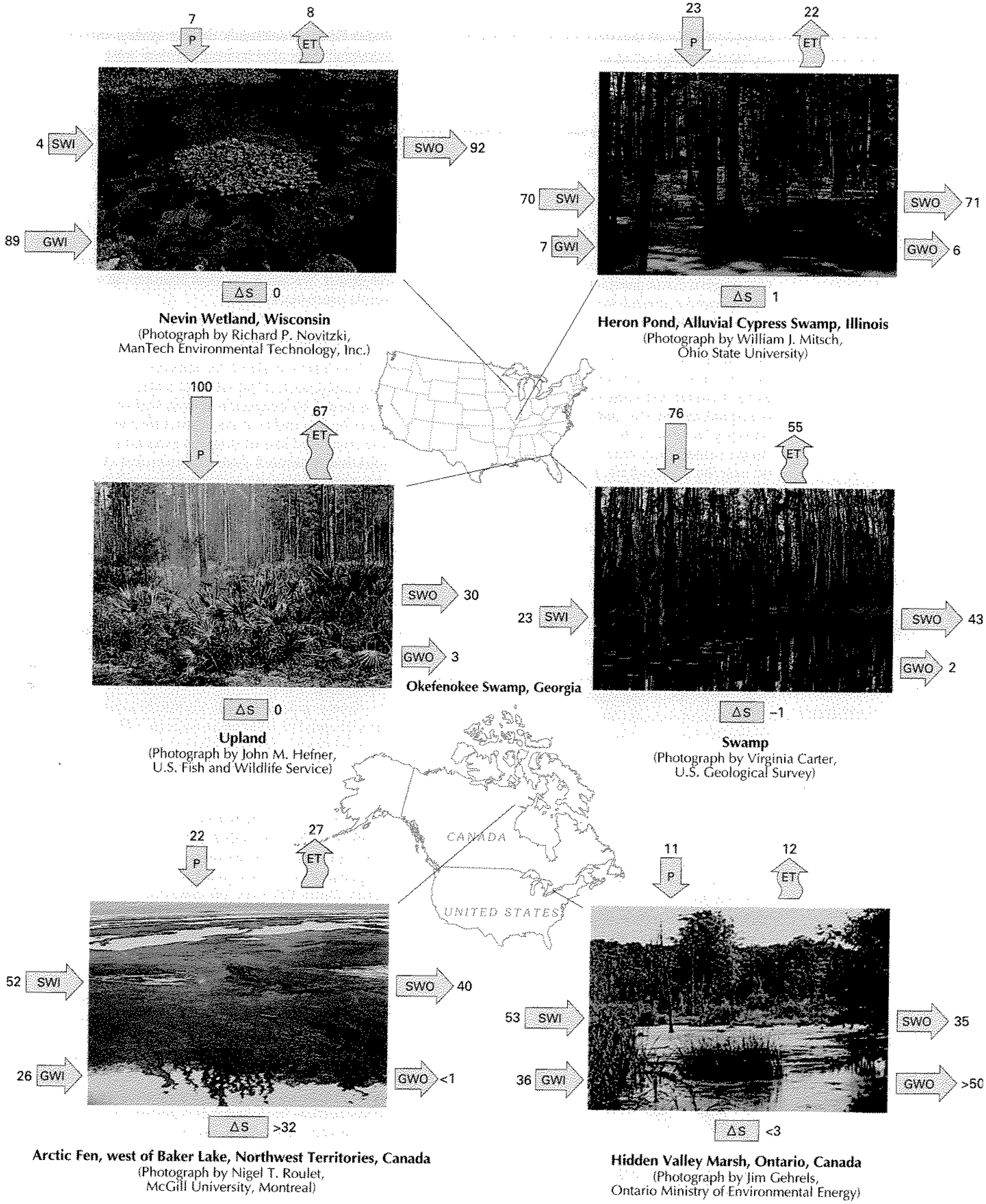


Figure 19. Water budgets for selected wetlands in the United States and Canada. (P + SWI + GWI = ET + SWO + GWO + ΔS, where P is precipitation, SWI is surface-water inflow, SWO is surface-water outflow, GWI is ground-water inflow, GWO is ground-water outflow, ET is evapotranspiration, and ΔS is change in storage. Components are expressed in percentages. Abbreviations used: < = less than; > = greater than.) *(Sources from left to right and top to bottom: Novitzki, 1978; Roulet and Woo, 1986; Rykiel, 1984; Rykiel, 1984; Mitsch and Gosselink, 1993; and Gehrels and Mulamoottil, 1990.)*

temporally, but all these components interact to create the hydrology of an individual wetland.

The relative importance of each of the components of the hydrologic cycle differs from wetland to wetland (fig. 19). Isolated basin wetlands, typified by prairie potholes and playa lakes, receive direct precipitation and some runoff from surrounding uplands, and sometimes receive ground-water inflow. They lose water to ET; some lose water that seeps to ground water, and some overflow during periods of excessive precipitation and runoff. These wetlands range from very wet to dry depending on seasonal and long-term climatic cycles. Wetlands on lake or river flood plains also receive direct precipitation and runoff and commonly receive ground-water inflow. In addition, they can be flooded when lakes or rivers are high. Water drains back to the lake or river as floodwaters recede. Wet and dry cycles in these wetlands commonly are closely related to lake and river water-level fluctuations. Coastal wetlands, while also receiving direct precipitation, runoff, and ground-water inflow, are strongly influenced by tidal cycles. Peatlands with raised centers may receive only direct precipitation or may be affected by ground-water inflow also. Surface-water inflows affect only the edges of these wetlands.

Water budgets provide a basis for understanding hydrologic processes of a wetland.

Determining water budgets for wetlands is imprecise because as the climate varies from year to year so does the water balance. The accuracy of individual components depends on how well they can be measured and the magnitude of the associated errors (Winter, 1981; Carter, 1986). However, water budgets, in conjunction with information on the local geology, provide a basis for understanding the hydrologic processes and water chemistry of a wetland, understanding its functions, and predicting the effects of natural or human-induced hydrologic alterations. Each of the components is discussed below.

Precipitation

Precipitation is any form of water, such as rain, snow, sleet, hail, or mist, that falls from the atmosphere and reaches the ground. Precipitation provides water for wetlands directly and indirectly. Water is provided for a wetland directly when precipitation falls on the wetland or indirectly when precipitation falls outside the wetland and is transported to the wetland by surface- or ground-water flow. For example, snow that falls on wetland basins provides surface-water flow to wetlands during spring snowmelt. Snowmelt may also recharge ground water, sustaining ground-water discharge to wetlands during summer, fall, and winter.

The distribution of precipitation across the United States is affected by major climatic patterns. In North America, maximum rainfall is found on the western slopes of mountain ranges in the West, along the east coast, and in Hawaii. Tropical areas such as Florida and Puerto Rico also receive large quantities of precipitation. By contrast, precipitation is minimal in the continental interior where the atmosphere is dry; the driest part of North America is the southwestern desert. Wetlands are most abundant in areas with ample precipitation.

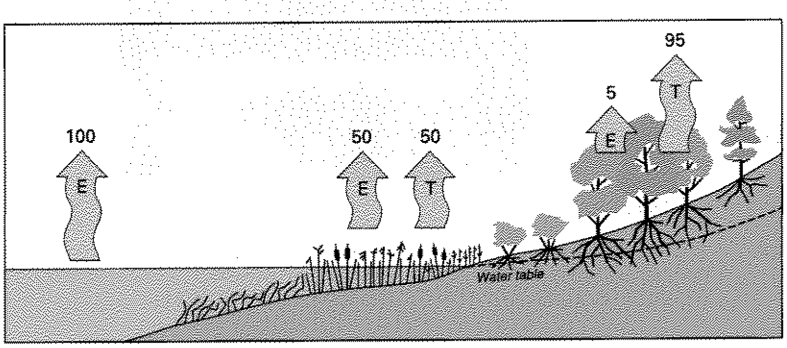


Figure 20. Percentage of transpiration and evaporation from various wetland components. (E, evaporation; T, transpiration.)

Evapotranspiration

The loss of water to the atmosphere is an important component of the wetland water budget. Water is removed by evaporation from soil or surfaces of water bodies and by transpiration by plants (fig. 20). The combined loss of water by evaporation and transpiration is termed evapotranspiration (ET). Solar radiation, windspeed and turbulence, relative humidity, available soil moisture, and vegetation type and density affect the rate of ET. Evaporation can be measured fairly easily, but ET measurements, which require measuring how much water is being transpired by plants on a daily, weekly, seasonal, or yearly basis, are much more difficult to make. For this reason scientists use a variety of formulas to estimate ET and there is some controversy regarding the best formula and the accuracy of these estimates (Gehrels and Mulamoottil, 1990; Carter, 1986; Dolan and others, 1984; Idso, 1981).

Evapotranspiration is highly variable both seasonally and daily (Dolan and others, 1984). ET losses from wetlands vary with plant species, plant density, and plant status (whether the plants are actively growing or are dormant). Seasonal changes in ET also relate to the water-table position (Ingram, 1983) (more water evaporates from the soil or is transpired by plants when the water table is closer to land surface) and also to temperature changes (more water evaporates or is transpired in hot weather than in cold). Daily ET rates are controlled chiefly by the energy available to evaporate water—there is generally less at night and on cool, cloudy days.

Surface Water

Surface water may be permanently, seasonally, or temporarily present in a wetland. Surface water is supplied to wetlands through normal streamflow, flooding from lakes and rivers, overland flow, ground-water discharge, and tides. Ground water discharged into wetlands also becomes surface water. Surface-water outflow from wetlands is greatest during the wet season and especially during flooding. Surface water may flow in channels or across the surface of a wetland. Flow paths and velocity of water over the surface of a wetland are affected by the topography and vegetation within the wetland.

Streamflow from wetlands that have a large component of ground-water discharge tends to be more evenly distributed throughout the year than streamflow from wetlands fed primarily by precipitation (fig. 21). This is because ground-water discharge tends to be relatively constant in quantity compared with precipitation and snowmelt.

In coastal areas, tides provide a regular and predictable source of surface water for wetlands, affecting erosion, deposition, and water chemistry. The magnitude of daily high and low tides is affected by the relative position of the sun and the moon—highest and lowest tides usually occur during full or new moons. Where tidal circulation is impeded by barrier islands (for example, in the Albemarle-Pamlico Sound in North Carolina, where tides are primarily wind-driven) or dikes and levees, tidal circulation may be small or highly modified. Strong winds and storms can cause extreme changes in sea level, flooding both wetlands and uplands.

Ground Water

Ground water originates as precipitation or as seepage from surface-water bodies. Precipitation moves slowly downward through unsaturated soils and rocks until it reaches the saturated zone. Water also seeps from lakes, rivers, and wetlands into the saturated zone. This process is known as ground-water recharge and the top of the saturated zone is known as the water table. Ground water in the saturated zone flows through aquifers or aquifer systems composed of permeable rocks or other earth materials in response to hydraulic heads (pressure). Ground water can flow in shallow local aquifer systems where water is near the land surface or in deeper intermediate and regional aquifer systems (fig. 22). Differences in hydraulic head cause ground water to move back to the land surface or into surface-water bodies; this process is called ground-water discharge. In wetlands that are common discharge areas for different flow systems, waters from different sources can mix. Ground-water discharge occurs through wells, seepage or springs, and directly through ET where the water table is near the land surface or plant roots reach the water table. Ground-water discharge will influence the water chemistry of the receiving wetland whereas ground-water recharge will influence the chemistry of water in the adjacent aquifer.

Wetlands most commonly are ground-water discharge areas; however, ground-water recharge also occurs. Ground-water recharge or discharge in wetlands is affected by topographic position, hydrogeology, sediment and soil characteristics, season, ET, and climate and might not occur uniformly throughout a wetland. Recharge rates in wetlands can be much slower than those in adjacent uplands if the upland soils are more permeable than the slightly permeable clays or peat that usually underlie wetlands.

The accumulation and composition of peat in wetlands are important factors influencing hydrology and vegetation. It was long assumed that the discharge of ground water through thick layers of well-decomposed peat was negligible because of its low permeability, but recent studies have shown that these layers can transmit ground water more rapidly than previously thought (Chason and Siegel, 1986). Peatland type (fen or bog) and plant communities are affected by the chemistry of water in the surface layers of the wetland; the source of water (precipitation, surface water, or ground water) controls the water chemistry and determines what nutrients are available for plant growth. Ground-water flow in extensive peatlands such as the Glacial Lake Agassiz peatland in Minnesota may be controlled by the development of ground-water mounds (elevated water tables fed by precipitation) in raised bogs where ground water moves downward through mineral soils before discharging into adjacent fens (Siegel, 1983; Siegel and Glaser, 1987). Movement of the ground water through mineral soils increases the nutrient content of the water.

Coastal wetlands and shallow embayments represent the lowest point in regional and local ground-water flow systems; ground water discharges into these areas, sometimes in quantities large enough to affect the chemistry of estuaries (Valiela and Costa, 1988;

The hydrology of a wetland is largely responsible for the vegetation of the wetland.

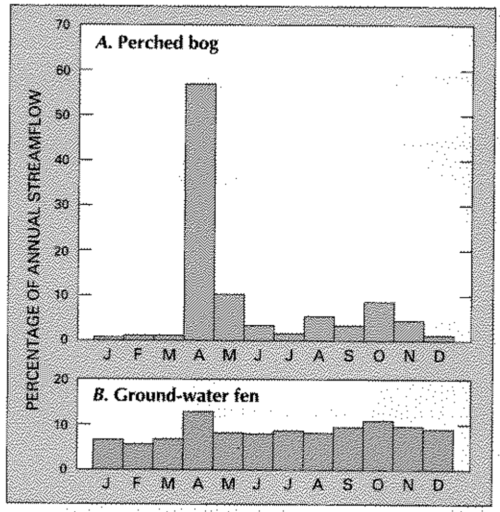


Figure 21. Monthly streamflow from two wetlands in northern Minnesota; ***A***, a perched bog whose inflow component is primarily precipitation, and ***B***, a fen whose inflow component is primarily ground water. *(Source: Modified from Boelter and Verry, 1977.)*

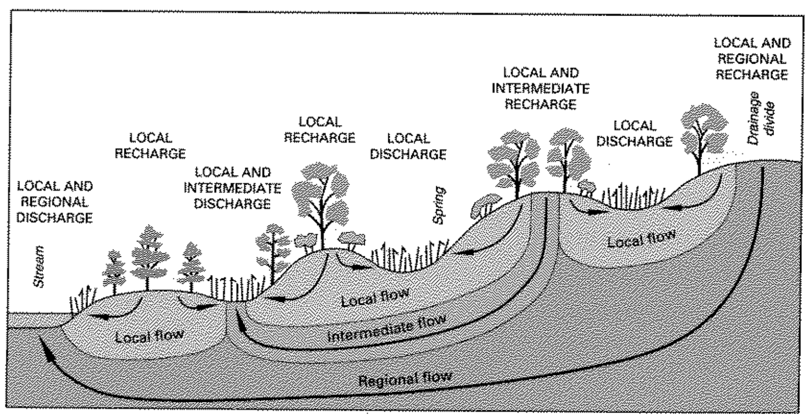


Figure 22. Ground-water flow systems. Local ground-water flow systems are recharged at topographic highs and discharged at immediately adjacent lows. Regional ground-water flow systems are recharged at the major regional topographic highs and discharged at the major regional topographic lows. Intermediate flow systems lie between the other two systems. *(Source: Modified from Winter, 1976.)*

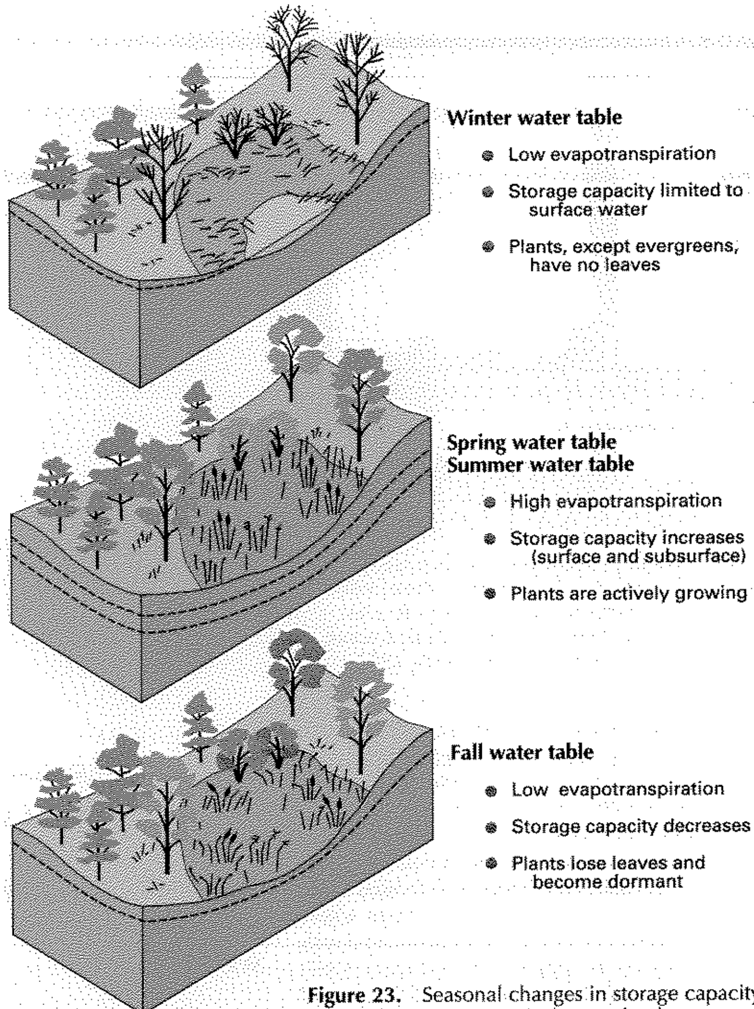


Figure 23. Seasonal changes in storage capacity and evapotranspiration (ET) in wetlands.

Valiela and others, 1990). The quantity of ground water discharged varies throughout the tidal cycle, affecting the water chemistry of the wetland soils (Harvey and Odum, 1990; Valiela and others, 1990).

Storage

Storage in a wetland consists of surface water, soil moisture, and ground water. Storage capacity refers to the space available for water storage—the higher the water table, the less the storage capacity of a wetland. Some wetlands have continuously high water tables, but generally, the water table fluctuates seasonally in response to rainfall and ET. Storage capacity of wetlands is lowest when the water table is near or at the surface—during the dormant season when plants are not transpiring, following snowmelt, and (or) during the wet season (fig. 23). Storage capacity increases during the growing season as water tables decline and ET increases. When storage capacity is high, infiltration may occur and the wetland may be effective in retarding runoff. When water tables are high and storage capacity is low, any additional water that enters the wetland runs off the wetland rapidly.

The vegetation affects the value of the wetland to animals and people.

SOME EFFECTS OF HYDROLOGY ON WETLAND VEGETATION

The hydrology of a wetland is largely responsible for the vegetation of the wetland, which in turn affects the value of the wetland to animals and people. The duration and seasonality of flooding and (or) soil saturation, ground-water level, soil type, and drainage characteristics exert a strong influence on the number, type, and distribution of plants and plant communities in wetlands. Although much is known about flooding tolerance in plants, the effect of soil saturation in the root zone is less well understood. Golet and Lowry (1987) showed that surface flooding and duration of saturation within the root zone, while not the only factors influencing plant growth, accounted for as much as 50 percent of the variation in growth of some plants. Plant distribution is also closely related to wetland water chemistry; the water may be fresh or saline, acidic or basic, depending on the source(s).

HYDROGEOLOGIC SETTINGS

The source and movement of water are very important for assessing wetland function and predicting how changes in wetlands will affect the associated basin. Linkages between wetlands, uplands, and deepwater habitats provide a framework for protection and management of wetland resources. Water moving into wetlands has chemical and physical characteristics that reflect its source. Older ground water generally contains chemicals associated with the rocks through which it has moved; younger ground water has fewer minerals because it has had less time in contact with the rocks. Which processes can and will occur within the wetland are determined by the characteristics of the water entering and the characteristics of the wetland itself—its size, shape, soils, plants, and position in the basin.

Because wetlands occur in a variety of geologic and physiographic settings, attempts have been made to group or classify them in such a way as to identify similarities in hydrology. For example, Novitzki (1979, 1982) developed a hydrologic classification for Wisconsin wetlands based on topographic position and surface water-ground water interaction; Gosselink and Turner (1978) grouped freshwater wetlands according to hydrodynamic energy gradients; and Brinson (1993) developed a hydrogeomorphic classification for use in evaluating wetland function. (See the articles "Wetland Definitions and Classifications in the United States" and "Wetland Functions, Values, and Assessment" in this volume.) Wetlands, like lakes, are associated with features where water tends to collect. They are commonly found in topographic depressions, at slope breaks, in areas of stratigraphic change, and in permafrost areas (fig. 24) (Winter and Woo, 1990).

Topographic Depressions

Most wetlands occur in or originate in topographic depressions—these include lakes, wetland basins, and river valleys (fig. 24*A*). Depressions may be formed by movement of glaciers and water; action of wind, waves, and tides; and (or) by processes associated with tectonics, subsidence, or collapse.

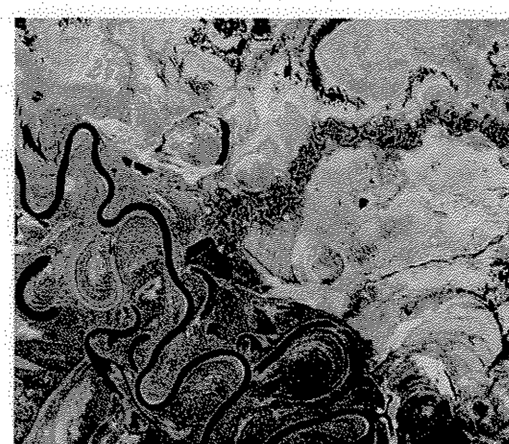
Glacial movement.—Glaciers shaped the landscape of many of the Northern States and caused wetlands to form in mountainous areas such as the Rocky Mountains and the northern Appalachians. As the glaciers advanced over the Northern United States they gouged and scoured the land surface, making numerous depressions, depositing unsorted glacial materials, and burying large ice masses. As the climate warmed, the glaciers retreated, leaving behind the depressions and the large masses of buried ice. As the temperatures continued to warm, the ice masses melted to form kettle holes. In many cases, water filled the depressions and kettle holes, forming lakes. As the lakes filled with sediments, they were replaced by wetlands.

Water movement.—Wetlands also are formed by the movement of water as it flows from upland areas toward the coast. The flow characteristics of water are partly determined by the slope of the streambed. On steeply sloping land, water generally flows rapidly through relatively deep, well-defined channels. As the slope decreases, the water spreads out over a wider area and channels usually become shallower and less defined. Shallow channels tend to meander or move back and forth across the flood plain. The changes in flow path sometimes result in oxbow lakes and flood-plain wetlands. When the river floods, the isolated oxbow lakes begin to fill with sediment, providing an excellent place for more wetlands to form. Obstruction to the normal flow of water also can cause the water to change course and leave gouges in front of or channels around the obstruction, or can cause water to be impounded behind the obstruction. Many lakes and wetlands are formed behind dams made by humans or beavers.

Wind, wave, and tidal action.—Wetlands are common in areas of sand dunes caused by wind, waves, or tides. Wetlands formed in the depressions between sand dunes are found in the Nebraska Sandhills, along the shoreline of the Great Lakes, and on barrier islands and the seaward margins of coastal States. In coastal States, tides, waves, and wind cause the movement of sand barriers and the closing of inlets, which often result in the formation of shallow lagoons with abundant associated emergent wetlands.

Tectonic activities.—Tectonic activity is responsible for depression wetlands such as Reelfoot Lake on the Mississippi River flood plain in Tennessee caused by the 1812 New Madrid earthquake. Earthquakes result when two parts of the Earth's crust move relative to each other, causing displacement of land. When this occurs, depressions may result along the lines of displacement or the flow paths of rivers may be changed, leaving isolated bodies of water. When a source of water coincides with these depressions, wetlands can form.

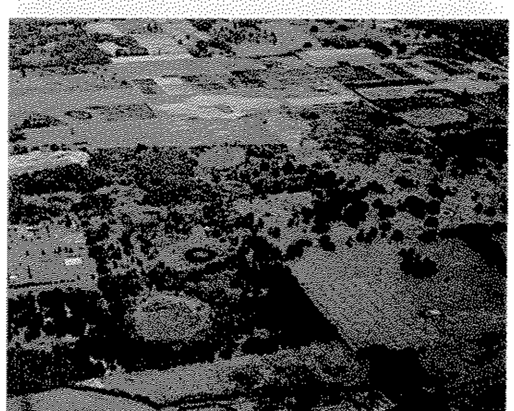
Subsidence and collapse features.—Land subsidence and collapse also can form depressions in which wetlands and lakes occur. In some areas, especially in the Southwest, pumping of ground water has caused the land above an aquifer to sink, forming depressions where water collects and wetlands develop. In karst topography (landscapes resulting from the solution of carbonate rocks such as limestone), such as is found in Florida, wetlands form in sinkholes. Collapse of volcanic craters produces



Infrared color photograph of oxbow lakes in the drainage area of Hoholitna River near Sleetmute, Alaska. *(Photograph courtesy of National Aeronautics and Space Administration.)*

Lotus in Reelfoot Lake, Tennessee. *(Photograph by Virginia Carter, U.S. Geological Survey.)*

Coastal marsh along San Francisco Bay, California. *(Photograph by Virginia Carter, U.S. Geological Survey.)*



This recently collapsed sinkhole, in central Florida, provides an ideal spot for a wetland to form. *(Photograph by Terry H. Thompson, U.S. Geological Survey.)*

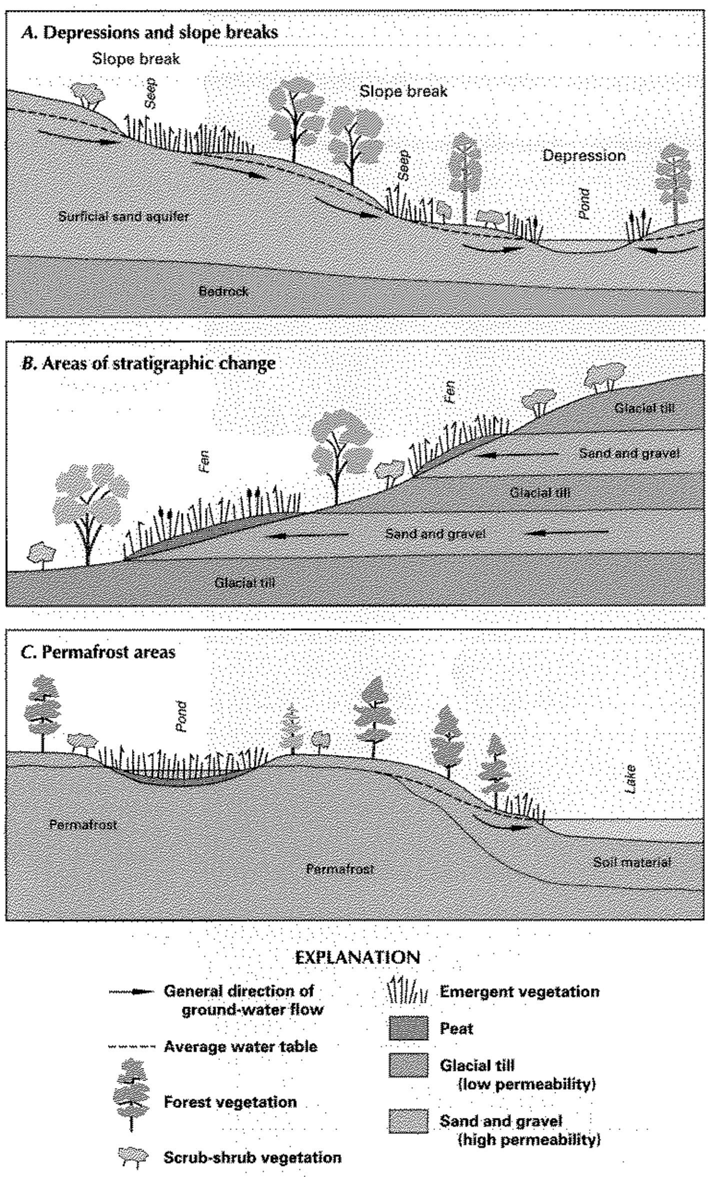


Figure 24. Cross sections showing principal hydrogeologic settings for wetlands; ***A,*** slope break and depression, ***B,*** area of stratigraphic change, and ***C,*** permafrost area.

calderas that fill with water and sediment and contain lakes or wetlands.

Slope Breaks

The water table sometimes intersects the land surface in areas where the land is sloping. Where there is an upward break or change in slope, ground water moves toward the water table in the flatter landscape (fig. 24*A*) (Roulet, 1990; Winter and Woo, 1990). Where ground water discharges to the land surface, wetlands form on the lower parts of the slope. Constant ground-water seepage maintains soil saturation and wetland plant communities. The Great Dismal Swamp of Virginia and North Carolina is maintained by seepage of ground water at the slope break at the bottom of an ancient beach ridge that runs along the western edge (Carter and others, 1994).

Areas of Stratigraphic Change

Where stratigraphic changes occur near land surface, the layering of permeable and less-permeable rocks or soils affects the movement of ground water. When water flowing through the more permeable rock encounters the less permeable rock, it is diverted along the surface of the less permeable rock to the land surface. The continual seepage that occurs at the surface provides the necessary moisture for a wetland (fig. 24*B*). Fens in Iowa form on valley-wall slopes where a thin permeable horizontal layer of rock is sandwiched between two less permeable layers and continual seepage from the permeable layer causes the formation of peat (Thompson and others, 1992).

Permafrost Areas

Permafrost is defined as soil material with a temperature continuously below 32°F (Fahrenheit) for more than 1 year (Brown, 1974); both arctic and subarctic wetlands in Alaska are affected by permafrost (figs. 24*C* and 25). Permafrost has low permeability and infiltration rates. As a result, recharge through permafrost is extremely slow (Ford and Bedford, 1987). In areas covered by peat, organic silt, or dense vegetation, permafrost is commonly close to the surface. In areas covered by lakes, streams, and ponds, permafrost can be absent or at great depth below the surface-water body. The surface or active layer of permafrost thaws during the growing season. In areas where permafrost is continuous, there is virtually no hydraulic connection between ground water in the surface layer and ground water below the permafrost zone. The imperviousness of the frozen soil slows drainage and causes water to stand in surface depressions, forming wetlands and shallow lakes.

In discontinuous permafrost areas (fig. 25), unfrozen zones on south-facing slopes (in the northern hemisphere) and under lakes, wetlands, and large rivers provide hydraulic connections between the surface and the ground water below the permafrost zone. Ground-water discharge to wetlands from deeper aquifers can occur through the unfrozen zone (Williams and Waller, 1966; Kane and Slaughter, 1973). In discontinuous permafrost regions, whether a slope faces away from or toward the sun can determine the presence or absence of permafrost and thus influence the location and distribution of wetlands (Dingman and Koutz, 1974). Permafrost is sensitive to factors that upset the thermal equilibrium. Thermokarst features (depressions in the land surface caused by thawing and subsequent settling of the land) may be caused by regional climatic change or human activities. These depressions formed by local thawing of permafrost are usually filled with wetlands.

WATER QUALITY IN WETLANDS

The water chemistry of wetlands is primarily a result of geologic setting, water balance (relative proportions of inflow, outflow, and storage), quality of inflowing water, type of soils and vegetation, and human activity within or near the wetland. Wetlands