Wetlands 4

Status

- Despite "no-net-loss" policy, wetland destruction and degradation continue.
- No single statute directly protects wetlands.

Climate Change Problem

- Climate change is likely to accelerate wetland loss.

What Is Most Vulnerable?

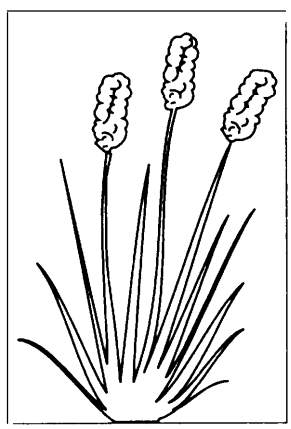
- Coastal wetlands (sea level rise).
- Western depressional wetlands (midcontinent warming and drying).
- Western riparian wetlands (midcontinent warming and drying).
- Tundra (largest warming at high latitudes).

Impediments

- Absence of clearly stated national policy for protecting wetlands.
- Different authorities and goals scattered across numerous Federal, State agencies.
- Federal policies have often failed to discourage, and have sometimes encouraged, wetland destruction.
- Inadequate criteria for decisionmaking; lack of an overarching priority plan for protection, restoration, and acquisition.
- No coordinated effort to monitor and evaluate wetlands.

Types of Responses

- Protect existing wetlands.
- Restore degraded or converted wetlands.
- Facilitate migration.
- Improve coordinated management and monitoring.



OVERVIEW

Wetlands are extremely complex and sensitive ecological systems that cover roughly 5 percent of the lower 48 States, but even today, the value of these systems is not always understood or appreciated.

Concern about steadily increasing losses of wetlands led the Federal Government to embrace a policy goal of no net loss of wetlands in **1989.** The policy specifies that destruction of wetlands should be offset by an equivalent restoration or creation of wetlands (see box 4-A). Efforts to move toward that goal have led to major controversies over how to define wetlands, the criteria and procedures necessary for mitigation, and the extent of Government involvement in regulating

Box 4-A–Wetland Mitigation and Restoration: Maintaining Wetland Functions and Values

During the 1950s to1970s,458,000 acres (183,200 hectares)[1] of wetlands were being lost each year, mainly to agriculture and urban and suburban development. That **pace has** been slowed to 100,000 to 200,000 acres per year, primarily due to legislative efforts. Wetlands serve many functions that are difficult to quantify in eoonomic terms; they are critical for storm-water retention, water quality control, and provision of wildlife habitat. Developing methods of restoring lost or degraded wetlands would help to alleviate problems resulting from their destruction, help achieve the Nation's goal of no net loss of wetlands in the short term, and increase the quantity and quality of wetlands in the long term.

Wetland mitigation is simplyalleviating any or all detrimental effectsthat may arise from harming a wetland. Mitigation includes enhancement, creation, and restoration; it may be done to formally complywith Section 404 of the Clean Water Act or for other reasons. Mitigation may involve the in-kind restoration or creation of **wetlands-in another** location--or the enhancement of services and functions of the wetland being harmed in place.Enhancement involves increasing one or more functions or values of an existing wetland (e.g., flood control, water quality improvement, and habitat provision). Creation refers to the complete conversion of an upland area into a wetland; it is the most difficult of the three and, so far, the least successful.

Wetland restoration involves the reestablishment of aquatic functions and related physical, chemical, and biological characteristics that were lost from a wetland. There are basically three categories of restoration techniques: 1) reestablishing and/or managing wetland hydrology, 2) eliminating or controlling wetland contaminants, and 3) reestablishing and/or managing the native plants. Sound plannig, project management and broad-based scientific knowledge regarding wetland processes are all critical elements in achieving a successful restoration. Wetland restoration is not easy because wetlands are complex ecosystems that Involve interactions between **a** multitude of species, and many of these relationships are not fully understood.

Wetland restoration is also a controversial practice for several reasons. The success of restoration techniques is not dear, mostly because there has been little investment in monitoring and evaluation (13). In addition, the measurement of success is elusive and complex. Success varies according to the value **and function** the project aims to restore. These functions range from providing wildlife habitat to flood control to water filtration. Determining success on the basis of these functions requires long-term evaluation as systems evolve **and** mature; some wetland system will respond more quickly and more positively to restoration than others. There are few documented, definitively successful cases; however, coastal marsh-restoration projects are generally more successful than restoration of inland freshwater marsh systems, mostly because coastal hydrology is better understood and, thus, more easily restored (13). Projects that have occurred outside the regulatory process have been more successful.[2] Factors such as unclear project goals, lack of monitoring, and an inadequate understanding of the wetland ecosystem have contributed to restoration failures,

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1To convert acres to hectares, multiply by *0.405.*

2 K.L. Erwin, Consulting Ecologist, Inc., personal **communication,** July *1993.*

Several Federal agencies are attempting to incorporate wetland-mitigation activities into their land-management plans. For the most part, these aim to retard wetland loss while doing little in the way of actual restoration (7). These efforts are heralded by the Army Corps of Engineers (the Corps), the Environmental Protection Agency (EPA), the Fish and Wildlife Service (FWS), and the National Marine Fisheries service (NMFS). The Corps is mainly concerned with replacing or providing substitutes for wetlands that have been reduced or subject to the adverse effects of water-resource development projects (7). EPA follows the Corps' criteria for evaluating discharges that have an adverse impact on surface- and groundwater systems, but has yet to issue any specific guidance on mitigation (7). FWS has developed a comprehensive mitigation policy that focuses on habitat value, and mandates that the degree of mitigation requested correspond to the value and scarcity of the habitat at risk. More importantly, the policy recommends that altering highly valued wetlands be avoided. NMFS has taken a proactive approach by participating in the early planning stages of wetland-restoration projects. In this way, the agency can offer guidance on identifying alternatives to wetland destruction, decreasing conflict anticipating problems, and minimizing potentially adverse effects on living marine resources and habitat.

In response to vast wetland losses, a *mitigation banking* program was developed as a mechanism for compensating unavoidable habitat losses associated with development activities (e.g., construction of roads and buildings) and administered primarily under the Clean Water Act (CWA; P.L. 92-500). The program includes the participation of agencies, nonprofit organizations, and private entities and involves off-site creation, restoration, and/or enhancement of wetlands. It is carried out by the private sector through the Section 404 permitting process and other similar State and local wetland regulations. The National Environmental Policy Act (NEPA; P.L. 91-1907) and the wetlands Executive Order (1 1990) encourage the exploration of alternatives to actions that would destroy wetlands. Mitigation, as an alternative, must address impacts and cannot be used simply to offset the acreage of wetland losses. Successful mitigation includes "replacing the loss of aquatic resource values by creating, restoring, and enhancing similar functions and values" (33 CFR, App. A, 334, July 1, 1992). This does not necessarily imply a one-to-one ratio of destroyed to mitigated acreage. Problems with enforcement, implementation, and monitoring of wetland mitigation have raised questions about the success of mitigation programs.

Restoration goals are bound to vary from region to region. For example, in urban areas, flood control and water filtering are highly valued functions of wetlands. Restoration of these functions does not require a fully vegetated wetland that supports fish and wildlife; the most important part of restoring these functions maybe simply to dear obstacles from the site and plant enough vegetation to anchor the soil. In other sites, including those in areas important for wildlife but where considerable habitat has been destroyed, a more complete restoration project to rehabilitate a broader range of functions maybe preferred. In some cases, technologies can be used to establish an artificial wetland for tertiary wastewater treatment. This application requires greater manipulation of the land and the installation of piping systems to regulate flow across the manually planted areas. Artificial wetlands are being successfully used to treat agricultural and urban wastewater in smaller communities across the country. As this technology is expanded, it may be more widely used as a low-cost, low-maintenance alternative to traditional wastewater treatment applications.

Using restoration as a way to offset loss of healthy wetland systems by creating new wetlands in another location often results in a trade to lower function and value. In some cases, though, a trade may make good sense. For example, allowing development on a small, isolated wetland in a highly urbanized area in exchange for protecting a larger tract that is in a migratory bird flyway could be beneficial in the long term. Several such projects are under way on the California and Oregon coasts, where migratory waterfowl habitat has been lost at rates that surpass those in the rest of the country.

In the San Francisco Bay area, for example, hundreds of acres of tidal marshland were restored after having been diked off and converted for cattle grazing, mostly during the 1930s. The original salt marsh was dominated

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Box 4-A-Wetland Restoration and Mitigation: Maintaining Wetland Functions and Values--(Continued)

by pickerel weed, which moved into "seasonal wetlands" toward upland areas, which are inundated by precipitation during the fall and winter months but dry out in the spring and summer. The restoration was a joint project between a private entity and the State.The private group was interested in developing the upland areas and, in exchange, created a restoration design that aimed to reestablish the original water-flow patterns in the degraded marsh, which allow vegetation to prosper; the design assumed that vegetation would colonize the area gradually, so an extensive planting program would not be needed. Sand and silt were excavated to create basins within the marsh, surrounded by a shelf that would support vegetation, and the dike was breached, allowing the bay waters to flow inland and reclaim the dormant marshland. Natural sedimentation processes could then occur, helping to resters the proper substrate conditions that would eventually support new tidal-marsh vegetation. The restoration is continuing naturally and, with monitoring, the wetland will probablybefunctional in a few years. In other cases, plants might have to be manually reestablished, and in inland or riparian-wetland situations, restoring the hydrology would be much more difficult. In all cases, however, it is important to perform a complete environmental assessment of the site before any fieldwork begins.

Wetlands are extremely complex systems that include a multitude of species of microbes, plants, birds, and other wildlife. Their interactions are highly developed; it has taken hundreds or thousands of years for these systems to achieve their level of ecological and functional diversity. Restoring destroyed wetlands or improving damaged ones requires not only a clear understanding of this dynamic and complex ecosystem, but also a well-ordered plan that attempts to account for difficulties that may arise during the restoration. A comprehensive monitoring program is necessary to track the restoration of a wetland's functions. Additional research is needed to improve restoration technology to help prevent the continued loss of the Nation's wetlands and to begin to regain some of what has already been lost.

SOURCES: K.L. Erwin, An Evaluation of Wetland Mitigation in the South Florida Water Management District (1990), Volume 1, report prepared for the South FloridaWater Management District, July 1991; K.L. Erwin, Consulting Ecologist, Inc., personal communication,July 1993,Interagancy Committee on Wetlands Restoration and Creation, A National Program for Wetlands Restoration and Creation, report to the Policy Coordinating Group Interagency Task Force on Wetlands, August 1992;J.AKusler and M.E. Kentula, Wetland Creation and Restoration: The Status of the Science (Washington, DC: Island Press, 1990); L. Roberts, "Wetland Trading is a Loser's Game, Say Ecologists," Science, vol. 260, June 25, 1993, pp. 1890-92; D. Salveson, Wetlands: Mitigating and Regulating Development Impacts (Washington, DC: The Urban Land Institute, 1990).

the use of private land where most wetlands exist (see box 4-B). As the debate continues on how to achieve the no-net-loss goal, the possibility of climate change, which may make halting the loss of wetlands even more difficult, looms on the horizon.

Four types of wetlands appear to be particularly vulnerable to climate change: coastal wetlands, depressional wetlands in arid or semiarid regions, riparian wetlands in the arid West and Southwest, and tundra wetlands. Coastal wetlands may be drowned by rising sea or altered by changing salinity. Arise of about 1.5 feet (about 0.5 meter)[1] could inundate more than 30 percent of coastal wetlands. Depressional wetlands maybe affected by lowered water levels-the likely result of higher temperatures, increased evaporation, and decreased precipitation in already dry areas. Drier conditions in the West also may threaten riparian wetlands that rely on water from rivers and streams. Tundra areas may shrink as increased temperatures allow the permafrost to thaw and drain.

Climate change may cause loss of wetlands, even as the need for wetlands becomes greater under climate change. For example, healthy

[1] To convert feet to meters, multiply by 0.305.

Box 4-B-How Wet Is a Wetland?: The Debate Over Which Wetlands to Regulate

The regulatory system has tied itself into knots attempting to meet the policy goal of "no net loss'' of wetlands. The simple-sounding goal is made complicated by the lack of an accepted definition for "wetland." Other issues have also yet to be reconciled, such as: How wet must a wetland be--and how often must it be wet? How can boundaries be drawn around it to distinguish a wetland that is covered by Federal regulatory programs (a jurisdictional wetland)from an adjacent area that is not? TheAdministration's efforts to clarify these issues set off a firestorm of controversy surrounding not only fundamental issues in wetland science, but also the relationships among science, politics, and policy.

In August 1991, a new policy program to meet the no-net-loss goal was announced. As part of that program the Environmental Protection Agency (EPA), the Army Corps of Engineers (the Corps), the Soil Conservation Service (SCS), and the Fish and Midlife Service (FWS) published in the *Federal Register* proposed new delineation manual, which was to be used for decisions about wetlands across all agencies. The manual stated that to be considered a wetland, an area must be flooded for 15 consecutive days, or saturated to the surfacefor 21 consecutive days, sometime during the growing season. This definition would exclude from regulation wetlands that are only sporadically inundated (e.g., in floodplains and prairie areas) and that may be dry for the greater part of the year. The manual imposed a high burden of proof, requiring that certain vegetation types, soils, and hydrology (water flow) be documented according to detailed rules of evidence.

The proposed manual set off an immediate uproar. Critics in the scientific and environmental communities claimed that there was no defensible scientific rationale for stating that wetlands must be flooded or saturated for so many days in a row, that the proposal would exclude up to half of the areas now regulated as wetlands, and that the manual--which was supposed to streamline the regulatory process--was actually more difficult, time-consuming, and expensive to use than the manual then in use. Supporters of the proposal, including farmers' and developers' organizations, favored the exclusion of "drier" wetlands, contending that the wetter ones were more important to protect. They argued that existing regulations were inconsistent, placed too great a burden on private landowners, and interfered in property rights, producing numerous horror stories of permits gone awryand causing untoward delays. By January 1992, EPA received more than 60,000 comments on the proposed manual. To date, no further revisions have been issued. in the interim, Congress requested a National Academy of Sciences study of wetlands delineation, and the agencies have fallen back on one or another version of manuals used in the past to determine what a wetland is.

Although particularly heated in 1991 and*1992,* the debate over what to regulate and how to recognize it dates back to 1972, when the Clean Water Act (P.L. 92-500) was passed. The act promoted protection of the Nation's water quality and established a permit program to regulate the dredging and filling of U.S. waters. The permit process was to be overseen by the Corps in its capacity for managing navigable waters. Four other Federal agencies-EPA, FWS, the National Marine Fisheries Service (NMFS), and SCS--alongwith State agencies ***were*** also allowed to review and comment on permit applications, but of the four, only EPA could veto a permit. When the Corps published regulations to implement the act it interpreted the mandate narrowly as including only traditionally navigable waters. Environmental groups sued, and a court order forced the Corps to issue new regulations in 1977 that covered a broad range of headwaters and wetlands. After considering 22 different definitions of wetlands, the Corps settled on the definition, also adopted by EPA, that is still used today in its regulatory decisions: "areas that are inundated or saturated by surface or ground water at a frequencyand duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation adapted for life in saturated conditions" (33 CFR328.6(6), 1991). Somewhat different definitions are used by other-s, such as FWS or the U.S. Department of Agriculture (USDA), whose purview includes wetlands.

Broad application of the CWA sometimes resulted in actions that private landowners protested were unfair takings of their property (see vol. 1, ch. 4). Each agency issued its own set of field guidelines on how to determine

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Box 4-B-How Wet Isa Wetland?: The Debate Over Which Wetlands to Regulate--(Continued)

what constitutes a jurisdictional wetland. Regulation varied considerablyfrom one jurisdiction to the next because separate regional offices of the decentralized Corps of Engineers interpreted or applied regulations differently, and some States were more active in overseeing wetland programs than others. Furthermore, changes by the Reagan administration intended to curtail the regulatory program by revising the Corps' procedures were opposed by many In EPA and FWS, leading to numerous conflicts over policy. By 1987, these differences made dear the need for a more coordinated national policy. Former EPA Administrator Lee Thomas requested that The Conservation Foundation, a private environmental organization, convene the Wetlands Forum in 1987 to try to resolve some of these issues. In 1983, this forum offered the idea for an interim goal of "no net loss" of wetlands with a long-term goal of a net gain in the quality and quantity of the Nation's wetlands.

A year later, the agencies were spurred to joint action. The Corps and EPA signed a memorandum of agreement detailing how they would meet the no-net-loss policy goal and encouraging more rigorous implementation of the Section 404 permit program. in addition, the Corps, EPA, FWS, and SCS adopted an Interagency delineation manual to be used by the four agencies in making regulatory andprogram decisions (33). The manual was developed by a panel of wetland scientists and set mandatory technical criteria and suggested field indicators. Although the interagency manual changed little in the Section 404 policy, it did result in a more coordinated and uniform application of the 404 program nationwide. Because it was not an official policy document, the manual was adopted without public notification and comment, which rankled those regulated.Th ey complained that the manual was too technical and difficult for people who had to delineate wetlands-in some jurisdictions, the landowners themselves. The groundswell of dissatisfaction was effectively consolidated by a series of public hearings convened across the country by the President's Council on Competitiveness. Protests gradually grew more vocal and more organized, and eventually led to the Administration decision to issue the revised manual that became the center of so much controversy in 1991.

Although the 1989 manual was accused by some of being too technical, it had at least won the support of the scientific community. The 1991 revision did not enjoysuch scientific support. During the revision, the chief ERA scientist onthe panel resigned, protesting that modifications demanded by the White House and some members of Congress were politically motivated rather than scientifically sound. Federal agencies such as the Office of Management and Budget and the Council on Competitiveness assumed major rolesinthe revision, further fueling suspicions by scientists and environmentalists and leading to a huge number of comments protesting the revised manual.

The regulatory question, "How wet is a wetland?" has still not been resolved. A revised manual is unlikely to be issued soon. In the meantime, EPA and the Corps have reverted to using the Corps' 1987 guidelines. The outcry over the manual has encouraged many States to become more active in their oversightof the Section 404 program, and some are preparing to assume primary responsibility for implementing the Federal programs, as many have done for air-pollution-control regulations. But whatever the resolution on the regulatory side, the debate has demonstrated the difficulty of reaching consensus on natural resource protection. The boundaries of a wetland will appear to be boated indifferent places depending on when in the moisture cycle it is examined: a wetland may not always be wet. Moreover, protecting only the obviously wet areas may fail to protect the ecosystem as a whole (2). Protection based on larger areas---watersheds or ecoregions bounded by their topography, hydrological systems, and biological characteristics---will be more likely to maintain the function of wetlands and other important ecosystems.

SOURCES: J.A. Kusler, "Wetlands Delineation: An Issue of Sciences or Politics'?' Environment vol.34, March 1992, pp. 7-11, 29-37; J, Alper, "War Over the Wetlands: Ecologists v. the White House,"Science, vol. 257, August 1992, pp. 1043-44; J.P. Cohn, 'How Wet Must a Wetland Be?" Government Executive, vol. 24, March 1992, pp. 20-25; C. Copeland, Federal Wetlands Manual Revisions:Summaryof Interagency Team Reports (Washington, DC: Congressional Research Service, Library of Congress, Feb. 25, 1992); U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, "Proposed Revision to the Federal Manual for Delineating Wetlands," *Federal Register, vol. 56, Aug.* 14,1991, pp. 404446-80.

wetlands can help control coastal erosion and flooding that may result from accelerated sea level rise (see vol. 1, ch. 4). Wetlands will help absorb and slow water runoff in urban areas that may result from more frequent and intense storms. In areas that become drier, concentrations of pollutants may be higher in runoff and surface water (see vol. 1, ch. 5). Wetlands will help falter out these pollutants and improve water quality. They may also become even more important as habitats for fish, waterfowl, invertebrates, and other wildlife under various warming scenarios.

Wetlands are not protected by any single Federal law or regulation, but by an amalgam of programs at all levels of government, many of which might be called on to cope with the impacts of climate change on wetlands. Federal programs over the past 50 years have focused on protecting existing wetlands through acquisition and, starting two decades ago, regulation. More recently, as the loss of wetlands has continued, interest has also turned toward restoring degraded and drained wetlands and creating new ones.

Section 404 of the Clean Water Act (CWA; P.L. 92-500) has played a limited but contentious role in the protection of wetlands. As one part of the broad CWA program to maintain the chemical, physical, and biological integrity of the Nation's waters, Section 404 regulates the discharge of dredged or fill material into waters of the United States, including wetlands. However, Section 404 effectively covers activities responsible for just one-fifth of the area of wetlands that disappears each year (112). Attempts to tighten direct Federal regulation of other wetlands have been constrained by the perception that strong restrictions on privately owned wetlands could, under appropriate circumstances, constitute a *taking*, which requires compensation (see vol. 1, ch. **5).** With nearly three-quarters of all remaining wetlands in private hands, an appropriate structuring of Federal incentives for activities on private lands is an essential complement to existing strategies for regulating wetlands (25). Incentive programs include direct payments, removal of various Federal subsidies, and *tradable rights* provisions such as mitigation banking (discussed below).

State and local regulations, including zoning and land-use controls, and efforts by private conservation organizations are essential to an overall strategy for protecting wetlands, both now and as the climate changes. However, because this report focuses on Federal programs, discussion of State and local activities is limited to considering how Federal programs might encourage or coordinate-or at least refrain from hindering-efforts at other levels.

A program designed to protect and regulate wetlands on almost any scale will be most effective if it incorporates an integrated approach to evaluating and managing wetlands within the context of the watersheds and hydrological systems in which they are located. Decisions on how to balance loss of wetlands against the need for development and other activities can best be made when decisionmakers have a clear understanding of the particular functions and values of a wetland within a given watershed-whether for wildlife habitat, flood control, water quality, or recreation, for example-and of how important that site is compared with other natural areas in the same vicinity that offer similar or complementary functions and values. An integrated approach to protecting wetlands will likely become even more important under a changing climate because the value of functions such as flood control and maintenance of water quality may increase in many areas due to changes in storms and hydrological regimes (see also vol. 1, chs. 4 and 5).

Whether wetlands change, migrate, or decline in response to climate change will depend largely on how humans decide to protect and restore wetlands now and in the future. Because loss of wetlands has already been extensive and degradation continues, many coastal wetlands and some inland wetlands are unlikely to be able to adapt to climate change--and a net loss of U.S. wetlands will occur. The existing Clean Water Act seeks to restore and maintain the physical, chemical, and

biological integrity of the Nation's waters. To achieve the act's goals, existing wetlands should be protected from destruction or degradation to the maximum extent practicable; formerly destroyed or degraded wetlands could be restored as part of watershed-based plans. Current and future protection policies must be tailored to anticipate the effects of climate change and to maximize the adaptability of the wetland systems that exist now.

This chapter summarizes the current location and status of wetlands in the United States, outlines the fictions and products they provide, and describes the legislative framework under which they are regulated and managed. The ways in which wetlands might be affected by climate change and whether they will be able to adapt to it are also addressed. Finally, the chapter suggests various policy responses that could help maintain a full range of functioning wetlands.

U.S. WETLANDS TODAY

■ What Are Wetlands?

Wetlands are dynamic systems, characterized as much by constant processes of change as by any truly constant features (see box 4-C). Wetlands are often difficult to recognize or define precisely because the boundary between wet and dry in the continuum from open water and lands that are always wet *(aquatic ecosystems)* to upland areas *(terrestrial ecosystems)* that are often dry is rarely discrete. In general, however, most scientists agree that wetlands can be defined by the composition of the vegetation, the soil characteristics, and the presence of water at or

Box 4-C-Wetland Types and Distribution

Wetlands are usually categorized according to their characteristic vegetation, their location(coastal or inland), and the salinity of the water they contain (ranging from fresh to brackish to salt water). Ecologists have developed a comprehensive technical classification of U.S. wetlands (22); these areas are described in the broadest categories in general vernacular terms below.

Coastal salt marshes grow along relatively calm, low-lying coasts of the Gulf of Mexico, the Atlantic, and sores parts of the Pacific (with the greatest expanses occurring on coasts in the Southeast), and are alternately inundated and drained by the rise and fall of the tides. The relatively small number of plant species that can tolerate the extremes in temperature and the continuous changes in water level and salinity consist primarily of Spartina grasses.

Mangrove swamps along the Atlantic and Gulf coasts in Florida (southwestern Florida harbors the largest expanses) and in a few patches in Louisiana and Texas contain any of several species of salt-tolerant trees and take the place of salt marshes in areas that are mostly free from frost

Tidal freshwater marshes occur in the upper reaches of tidal zones in estuaries along the Atlantic, Gulf, and Pacific coasts, but are most common in the mid-Atlantic region, Texas, and Florida Vegetation includes both **grasses and** broadleaf species and maybe extremely diverse and productive in the upper reaches of the marsh.

Freshwater nontidal wetlands comprise 95 percent of the Nation's vegetated wetlands. They may occur at any latitude but are not common at very high altitudes. Water depths of these wetlands usually range from 6 inches to 3 feet (from 0.15 to 0.90 meters)[1] and vegetation is generally characterized by soft-stemmed plants, grasses, sedges, and rushes. These include common plants such as waterlilies, cattails, reeds, arrowheads, and pickerel weed. Most of these wetlands serve vital storm-water and water-quality-control functions.

Inland depressional marshes may be either freshwater or saline. The freshwater marshes are most commonly found in depressions in the Great Plains States (prairie potholes), in Florida, and in California (vernal pools) and

1 To convert inches to meters, **multiply by *0.025;*** to convert **feet to meters, multiply by 0.305.**

have water depths ranging from several inches to 3 feet. Vegetation consists of soft-stemmed plants--grasses, sedges, and rushes, such as waterlilies, cattails, reeds, and wildrice-that emerge above the water surface. The saline marshes occur primarily along shallow lake basins and other depressions in the arid western United States, and include playas and rain-basin wetlands. These marshes are generally saturated with water and maybe 2 or 3 feet deep during the growing season. Plant life includes hard-stemmed or alkali bulrushes, widgeon grass, and sago. Many of these wetlands are semipermanent or seasonal, and some are found only occasionally during wet years.

Peatlands, including bogs and fens, are found throughout the Upper Midwest and in the Northeast, as well as in North Carolina and Honda, in shallow lake basins and flat uplands and along slow-moving streams. The soil, which is often composed of peat and maybe covered by moss, is generally saturated with water and may support both woody and herbaceous plants. Typical vegetation in northern bogs includes cranberries, leather-leaf, Labrador tea, and cotton grass, whereas southeastern bogs (known as pocosins) harbor pitcher plants, pond pine, Cyrilla, Persea, ***Gordonia,*** sweet bay, and Virginia chain fern. Bogs are typically valued for their production of renewable resources such as blueberries and cranberries, and can also be used as a source of peat and sphagnum moss for use in agriculture and horticulture. In some areas, the water-purifying properties of bogs are also important. Bogs are home to various insectivorous plants, which are valued for their scientific interest and as exotic house plants. Several varieties of these plants, including hooded and golden pitcher plants, are threatened or endangered species.

Tundra is a wet grassland found in cold climates, either at high altitudes on mountains *(alpine tundra) or* at northern latitudes *(arctic tundra).* Up to 25 percent of the State of Alaska is covered by arctic tundra and alpine tundra cart be found in the Rocky Mountains in the West and in the White Mountains in New England. Tundra generally has a deep layer of water-saturated soil that is permanently frozen (pemafrost), covered by a thick, often water-saturated mat of living and decaying vegetation including lichens, sphagnum mosses, grasses, sedges, and dwarf woody plants.

Shrub *swamps* are found along slow-moving streams and floodplains throughout the Southeast and Upper Midwest. The soil, which is often saturated during the growing season and may flood up to 6 inches deep, supports vegetation such as alder, willows, and dogwood.

Wooded swamps may be found alongside sluggish streams, in floodplains or shallow lake basins, and on flat uplands in the Southeast and Upper Midwest. The Soil is generally water-saturated during most of the growing season, and may be covered by up to 2 feet of water during periods of heavy rain or flooding. Typical northern vegetation includes tree species such as tamarack, white cedar, balsam, red maple, and black ash, often accompanied by a thick covering of moss, whereas further to the west, willows, red alder, and western hemlock are more common. In the South, vegetation may feature water and overcup oak, tupelo gum, swamp black gum, and cypress.

Bottomlands and other riparian habitats are found in low-lying floodplain areas adjacent to rivers throughout the eastern and southern United States as well as the arid West. These areas are not always recognized as wetlands because they are not necessarily water-saturated throughout the full growing season and they may only have standing water after an occasional flood. In the South, the lowest areas are characterized by hardwood trees such as bald cypress, tupelo gum, and water elm Higher areas that are less-frequently flooded support red maple, sweet gum, and various types of oak. The most infrequently flooded sites contain shagbark hickory, swamp chestnut oak, and post oak. In the West, riparian habitats are widely scattered along the permanent and intermittent rivers and streams that course through the arid and semiarid terrain; common trees include willows, alders, cotton woods, salt cedar, and mesquite.

SOURCES: R. Brewer, *The Science of Ecology(Philadelphia: Saunders* College Publishing, 1988); U.S. Department of the Interior (DOI), Fish and Wildlife Service (FWS), An *Overview of Major Wetland Functions and* Values, FWS/OBS-84/18 , contractor paper prepared by J.H. Sather and R.D. Smith (Washington, DC: U.S. DOI, FWS, September 1984); US. Congress, Office of Technology Assessment, Wetlands: Their *Use and Regulation,* OTA-0-206 (Washington, DC: U.S. Government Printing Office March 1984); R.S. Warren, "Coastal Wetland Vulnerabilities to Climate Change," contractor report prepared for the Office of Technology Assessment, July 1992.

near the soil surface for some part of the year. These elements are set forth in the definition of wetlands used by the U.S. Fish and Wildlife Service (FWS) as the basis for the National Wetlands Inventory (22) (several similar but distinct definitions are used by other agencies for regulatory purposes (see box 4-D)):

Wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface. The single feature that most wetlands share is soil or substrate that is at least periodically saturated with or covered by water . . . **Wetlands are lands**

Box 4-D--Why Care About Wetlands?

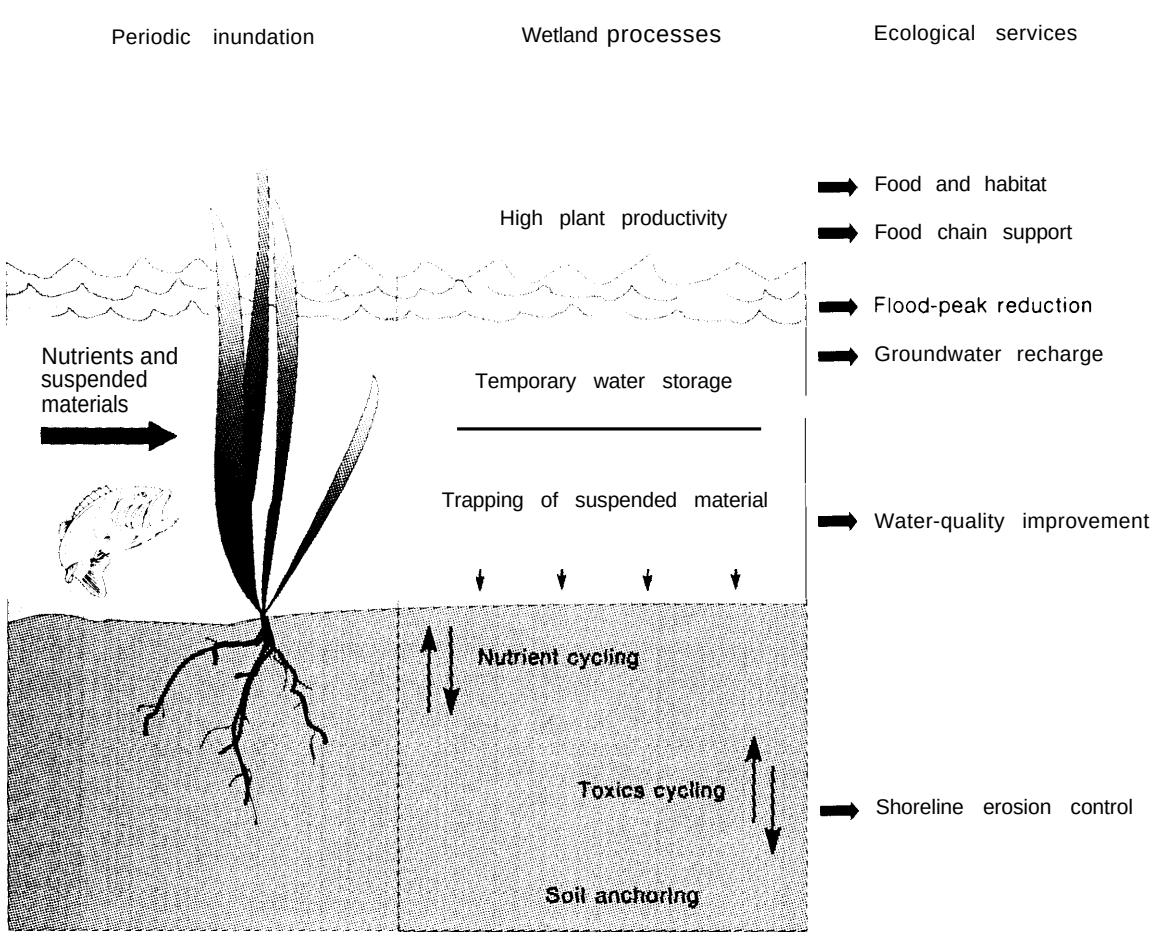
Wetlands are a resource of tremendous yet sometimes unrecognized, economic importance. The jobs of commercial fishers rely on wetlands---75 percent of the commercially landed fish **and** shellfish are dependent on ***wetlands*** (14). Sport fishing and waterfowl hunting, both of which depend on wetlands, generate several billion dollars of economic activity annually, offering significant stimulation to local economies. Commercial trappers make their living from wetlands, with over a third of the furs harvest in the United States coming from mammals that live and grow in wetlands. **Millions of dollars in** flood damage and pollution control may be averted by the presence of healthy wetlands. Wetlands provide crucial habitat for many endangered species. They also provide an environment highly valued for its aesthetic and recreational enjoyment

The degree to which and the frequency with which a wetland performs these various functions depend largely on where it is located. For example, although all wetlands perform some water filtration, this function is valued more where runoff waters are polluted than in pristine areas. Similarly, although nearly all wetlands provide wildlife habitat, the significance of that habitat varies. Some Wetlands provide major societal benefits only occasionally, such as the floodplains and t emporary ponds that may store or slow runoff during heavy rains or flooding, but may not even appear to be wetlands during dry years. Furthermore, value is in the eye of the beholder. A resident of a flood-prone area may value nearby wetlands because they attenuate floods and may eliminate the need to construct walls or ditches to control floods, whereas **a mare** distant resident may value the same wetland more for its aesthetic and recreational values.

The loss of these functional values usually comes at **an expense to the surrounding area Removing or** degrading a wetland that serves an important flood-control function will require investment in additional storm-water controls or replacement of property and resources damaged by floods. Degradation **of a wetland that serves a prims water-filtration function will** require additional investment in wastewater treatment facilities in the long term. By the same token,loss of valuable wetland wildlife habitat will result in a decrease in species. Though it is difficult to quantify these values, their loss certainly results in reverberating effects on surrounding communities and the landscape.

Economic values of wetlands are difficult to calculate and vary widely among different types of wetlands and the particular functions and products they provide. An array of approaches has been used to assess the values. Some studies have examined one or several services that wetlands provide to society, such as removing pollutants, providing flood control, or slowing coastal erosion, then have calculated the dollar value necessary to construct and operate sewage treatment plants or flood-control barriers that would perform equivalent services; the value of a wetland is assumed to be equal to the cost of replacing these services. Such studies have arrived at replacement values ranging from hundreds to hundreds of thousands of dollars per acre (70, 71, 89, 116). However, market values of wetlands rarely reflect the full replacement values indicated in such studies. Furthermore, despite numerous attempts, many values defy quantification. The value of habitat provided by wetlands for endangered species, for example, cannot easily be translated into dollar figures, but can only be hinted at through often-criticized surrogate pricing methods, such as surveys of the public's willingness to pay. Wetlands clearly make huge indirect contributions to the national economy through their roles in supporting the

Relationship Between Wetland Processes and Values



SOURCE: U.S. Congress, Office of Technology Assessment, *Wetlands: Their Use and Regulation,* OTA-O-208 (Washington, DC: U.S. Government Printing Office, March 1984).

multi-billion dollar U.S. fisheries and recreation industries, but pinpointing the proportion of valueadded by wetlands to these industries is difficult. Although scientists and economists may not agree on such dollar values, moat do agree that wetlands provide important functions, services, and products. Some of the major ones are outlined below.

Fisheries habitat—inland and coastal wetlands are essential to maintaining fish and shellfish populations. Billions of dollars a year are generated by the associated sport and commercial fisheries. About three-quarters of the commercial marine harvest consists of fish and shellfish that depend on wetlands--with regional estuarine dependency ranging from 98 percent for the Chesapeake Bay and 78 percent for the Gulf Coast to 76 percent in Alaska and 52 percent in the Pacific Northwest (14). In 1980 in Louisiana alone, the crayfish harvest amounted to $11 million (56). The Department of Commerce estimated in 1987 that the fish products from coastal wetland areas contribute more than $10 billion per year to the gross national product (GNP; 100). The value of marine

(Continued on *next page*)

Box 441-Why Care About Wetlands?--(Continued)

Economic Values of Wetlands

Function or service	Selected dollar value estimates per year
Fisheries habitat	Commercial fisheries harvest: $10 billion; marine recreational fishing: $13.5 billion
Waterfowl habitat	Recreational hunting: $638 million
Recreational activities	Spending on recreation: $55 billion
Flood and erosion control	$2,025/acre [a]
Pollution filtering	$400/acre
Timber and specialty crops	Standing timber value: $8 billion; cranberry, blueberry, wild rice harvest value: unknown
Trapping	Fur-bearing-mammal harvests: $295 million; alligator hides: $1.7 million

[a]To convert acres to hectares, multiply by 0.405.

SOURCE: Office of Technology Assessment, 1993.

recreational fishing (both shellfish and finfish) has been estimated at $13.5 billion (3). In addition, nearly all freshwater fish depend on wetlands for food and spawning grounds.

Waterfowl habitat--Wetlands are crucial to the existence of many birds. They are especially important as breeding grounds, feeding grounds, and wintering areas for migratory waterfowl. The hunting of waterfowl is a major wetland activity. In 1980,5.3 million people spent $638 million hunting waterfowl (WVS estimate cited in ref. 56).

Recreational activities--Wetlands support a range of recreational activities such as boating, birdwatching, and hiking in addition to hunting and fishing. The majority of these activities depend on wetlands with healthy vegetation (108). Wildlife refuges that contain wetlands, such as the Okefenokee Swamp in Georgia and Sanibel Island in Florida are among the most frequently visited of the lands managed by the U.S. Fish and Wildlife Service (FWS) (95).[1] FWS estimated that in 1980, recreational users spent $148 million observing and photographing fish and wildlife in the United States (56). A 1985 survey of fishing, hunting, and wildlife conducted by FWS estimated that overall "141 million Americans participated in wildiife-associated recreation, and spent $55 billion" (108), and an estimated 17 million sport anglers spent $8.2 billion (78).

Flood and erosion control--Inland wetlands decrease erosion by slowing runoff and by trapping sediment. They also limit flood damage by serving as a buffer zone and by absorbing the energy from overflows. Coastal wetlands act to slow erosion by buffering wave action and by trapping and anchoring sediment to the shore. Like inland wetlands, they also aid in flood control, reducing the destructive energy of waves and storm surges. The value of flood control and shoreline protection can be estimated by calculating the potential costs avoided. For example, a 1972 study by the Army Corps of Engineers determined that protecting 8,422 acres (3,389 hectares)[2] of wetlands adjacent to the Charles and Neponset River watersheds in Massachusetts could prevent more than $17 million in flood damages (106). In the Midwest, the Mississippi has been artificially controlled for years to provide land for agricultural and other uses, and its flood-control capacity has been dramatically decreased, resulting in exorbitant damage costs.

Pollution filtering--Wetlands contribute to water quality by trapping sediment and pollutants before they enter waterways. These areas are particularly helpful in reducing excess burdens of nitrogen and phosphorus that may otherwise cause harmful overgrowths of algae. A study in Georgia estimated that one 2,500-acre marsh, if given the opportunity, could have performed around $1 million in water pollution control per year. This suggests a value of $400 per acre per year for that wetland's pollution-control services.

1 J.W. Beaver, Biological Scientist, Florida Game and Fresh Water Fish Commission, personal communication, May 13-14, June 1,1932.

2To convert acres to hectares, multiply by 0.405.

Timber and specialty crops--Bottomland wetland forests of the southeastern United States have a standing value of some $8 billion. Hardwood timber harvests from bottomland forests can be accomplished with minimal harm to wetlands. Other wetland areas in the South support rice farming and aquaculture. Wetlands in the Northeast and North Central States provide cranberries and blueberries, and some North Central wetlands also ***grow wild rice. Grasses*** in wetlands also serve as livestock feed in many areas of the country, particularly along rivers and streams in the arid West.

Trapping--Both the coastal and inland wetlands provide valuable habitat for fur bearers and reptiles. Fur-bearing mammals that live in wetlands include beavers, muskrats, raccoons, minks,*and* otters; FWS estimated the harvest of these mammals from wetlands to be $295 million in 1980 (nearly one-third of the industry's total). The sale of alligator hides that year generated an additional $1.7 million (56).

Endangered species habitat-More than one-third of the United States's threatened and endangered species use wetlands as their primary habitat (69), and numerous others rely on wetlands during some part of their life cycles. Wetlands are necessary for the survival of such species as the American crocodile, the whooping crane, the wood stork, the bald eagle, the manatee, the insectivorous hooded pitcher plant, and many others.

Carbon sink--Because of their high productivity, many wetland systems are very effective at storing, or sequestering, carbon. Soils in tundra (and other northern ecosystems) may store up to one-third of the global pod of carbon now stored in soils (which could, if released to the atmosphere, speed up climate change) (72). Coastal wetlands, such as salt marshes, also store significant amounts of carbon (27).

Other cultural and aesthetic values---Wetlands hold many sites of historical and archaeological value and offer opportunities for education and scientific study. The combination of land and water gives wetlands a unique aesthetic appeal (120).

SOURCES: U.S. Congress, Office of Technology Assessment (OTA), *Wetlands:* Their Use and Regulation, OTA-0-206 (Washington, DC: U.S. Government Printing Office, March 1984); U.S. Department of Commerce, Letter of Comment, dated Nov. 27, 1987, on the Sept. 1, 1987, Draft Wetlands Priority Plan; U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), *National* Marine Fisheries Service (NMFS), Fisheries of the United States, 1990, Current Fishery Statistics No. 9000 (Silver Spring, MD: Fisheries Statistics Division, NMFS, NOAA May 1991).

> 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. . . [W]etlands must have ***one*** or more of the following three attributes: 1) at least periodically, the land supports predominantly hydrophytes [plants that can grow in water-saturated soil]; 2) the substrate is predominantly undrained hydric soil [soil that displays properties associated with having been saturated with water]; 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,

How to apply this definition, or some variation of it, has generated considerable controversy, particularly in attempts to define the boundaries of wetlands subject to Federal regulation (see box 4-E).

Wetlands can be classified according to many different characteristics, such as whether they are inland or coastal, fresh or saline. However classified, wetlands cannot be considered in isolation from the landscapes and the larger context of the hydrological systems in which they exist, such as the estuarine and inland landscapes shown in figure 4-1 (68, 120; see also ch. 2). Because wetlands are intricately connected to the quantity and quality of water flowing through a watershed, they are susceptible to any climate-induced changes in temperature and precipitation that affect the amount, speed, or temperature of water in the system. Their close link to hydrological cycles also means that they both affect and are affected by human activities in surrounding areas. For example, wetlands that occur in sites where an aquifer discharges water at the surface may be affected if the aquifer is depleted or reduced by decreased precipitation, runoff, and increased evaporation, or by human activities such as

Box 4-E-Is a Wetland a Place or a Process?

Part of the difficulty of regulating and protecting wetlands is that they are, by nature, dynamic systems. Wetlands may follow a progression from being fully or partially saturated, through a period during which vegetative material gradually accumulates, to being saturated less frequently, allowing for different species to move in. Many are only seasonally or periodically wet. Or the opposite may occur---a wetland may gradually or suddenly become saturated as a result of changes in water flow or levels in a lake, river, or estuary and eventually convert to open water. A recent report by the National Academy of Science (68) states:

> Along the edges of rivers, newly deposited sediments will be readily invaded by opportunistic plants and animals. Initial colonists are unlikely to be the same species as those of the floodplain forest that eventually develops. Along the edges of continents, mud fiats are formed by alluvial outwash **and are** gradually colonized by salt marsh grasses and succulents, which in turn trap sediments that raise the topography and attract additional plant and animal species. Along the edge **of an acidic lake, sphagnum moss and** herbaceous plants develop a mat that eventually supports bog shrubs and bog forest trees. in all these habitats, the nutrient content of the soil and the biomass of plants and animals increase through time, along with increases in species diversity and ecosystem complexity.

Yet U.S. policyhas tended to treat wetlands,like many other natural lands, as if they were static systems that will stay in the same place indefinitely if only further development is prevented. The Government has designated National Parks, National Wildlife Refuges, National Estuarine Research Reserves, and National Marine Sanctuaries as places where wetlands will be protected, but these areas are often surrounded by intensive land use **and development,** which may limit the ability of wetlands to continue their processes of growth **and** evolution (see vol. 1, ch. 4). in many parts of the Nation today, the natural processes of wetland evolution can no longer take place: "Before the widespread impact of man, new wetlands would have regularly opened up---due to the changing flow of a river for example--replacing those lost by succession or changes in drainage patterns.... In our modern, human-dominated world, however, where rivers and coastlines are constantly being molded to suit our whims, the natural recruitment of new wetlands is lost, depriving wildlife of a vital habitat . . ." (41).

Where does climate change fit into the picture? By speeding up the rate at which the elements of the environment change---the temperature, precipitation, and water-flow patterns, for example--climate change will require that the processes of evolution and the migration of species that inhabit wetlands take place more rapidly to keep up. In areas where there remains room to grow, where human activities have not yet blocked the paths for a natural progression of wetlands, the wetlands maybe able to adapt in time. But regardless of the initial causes of loss or degradation, in places where human activities have raised impenetrable barriers, the natural processes of wetlands may simply be squeezed out.

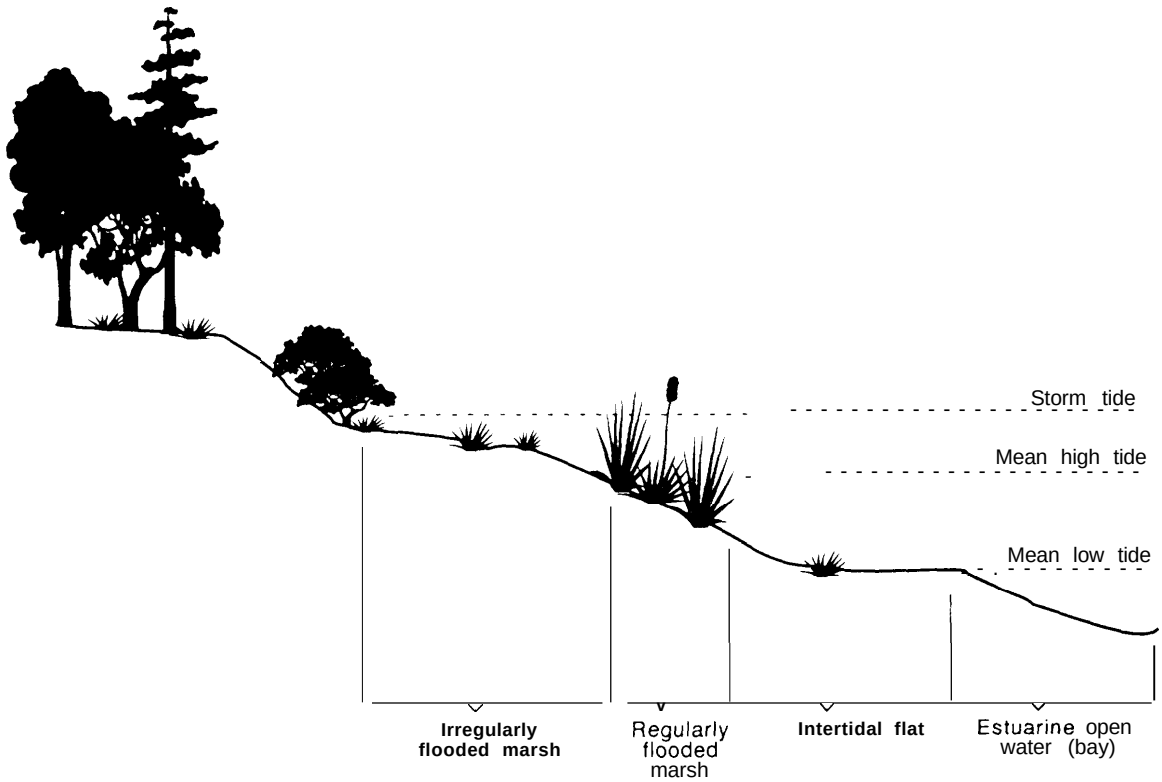
SOURCES: E. Goldsmith, N. Hildyard, P. McCully, and P, Bunyard, Imperiled Planet:Restoring Our Endangered Ecosystems (Cambridge, WThe MIT Press, 1990); National Research Council (NRC), Committee on Restoration of Aquatic Ecosystems --Science, Technology, and Public Policy, Water Science and Technology Board, Commission on Geosciences, Environment and Resources, Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy(Washington, DC: National Academy Press, 1992).

pumping water for irrigation and municipal use. Likewise, destruction of a wetland may cause downstream changes in flooding or water quality and degrade the quality of habitat for fish and wildlife. Attempts to manage, protect, or restore wetlands must take into account the numerous and intricate interactions among different parts of the landscape and must recognize that wetlands make up just one part.

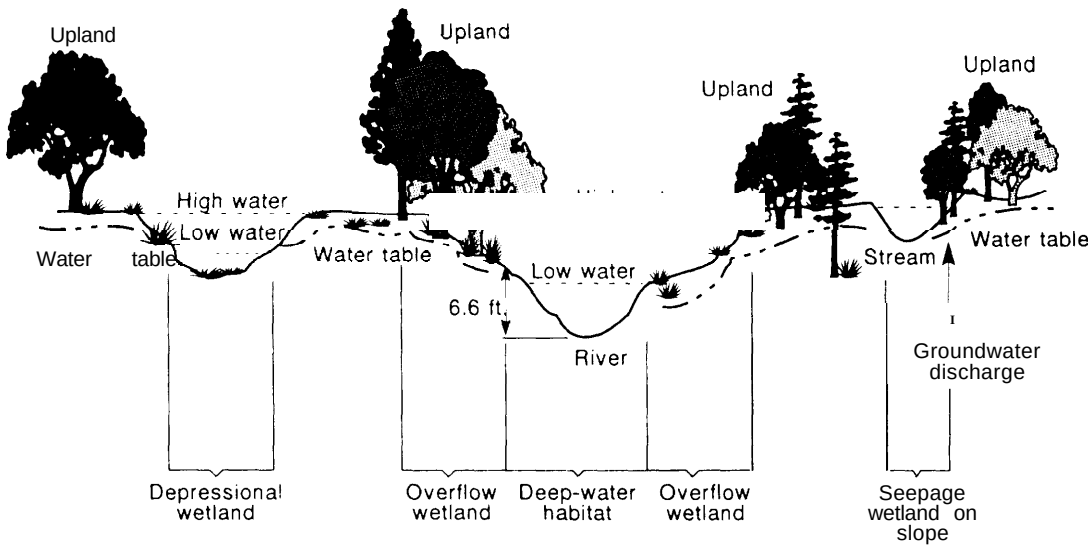
■ Why Are Wetlands Important?

Wetlands provide diverse products of considerable commercial value, playing a key role in the production of goods such as finfish, shellflsh, fur, waterfowl, timber, blueberries, cranberries, wild rice, and peat (see box 4-D). Wetlands also nurture biological productivity, slow surface-water flows, transform nutrients and toxic chemicals, and provide habitat that often harbors high

Figure 4-l-Cross-Sectional Diagrams of a Northeastern Salt Marsh and a Riparian Wetland System



NOTE: Intertidal flats are only intermittently inundated, depending on tidal movement; irregularly flooded marshes are usually brackish because they serve as a transition zone between the coastal marsh and the upland.



NOTE: Overflow wetland areas are transitional between the wetland and the upland, are periodically Inundated, and provide a vital flood-control function; depressional wetlands, or glacial pools, which are often filled in *for* agricultural use, occur in the prairie-pothole region in the Midwest. To convert feet to meters, multiply by 0.305.

SOURCE: R.W. Tiner Jr., *Wetlands* of the *United* Stares: *Current Status* and *Recant Trends,* National Wetlands Inventory (Washington, DC: U.S. Department of the Interior, U.S. Fish and Wildlife Service, March 1984).

biodiversity (described in more detail in ch. 2). These ecological functions are often associated with functions that are more directly valued by humans, such as flood control, erosion reduction, and improved water quality. Wetlands are also considered valuable for their aesthetic appeal and their recreational and educational opportunities. More recently, wetlands have become valued for their ability to store carbon (see ch. 2). They are critical habitat for about one-third of the Nation's threatened and endangered species (57); some species use them periodically (daily or seasonally) for food and water, whereas others reproduce in wetlands, and still others spend their entire life cycles there.

The many values of wetlands are closely interrelated (see box 4-D). For example, the aquatic plants in estuarine wetlands provide food and shelter for numerous finfish and shellfish, including many species valued for commercial, sport, and subsistence fishing. The vegetation and associated animal life also attracts waterfowl, which may lure hunters, birdwatchers, photographers, weekend boaters, and students on field trips. Such uses may profit local businesses and manufacturers that provide recreational services and products such as boats, binoculars, cameras, hiking boots, guns, and fishing gear (68, 95, 106, 120).

Where Are Wetlands Found?

In the mid-1980s, approximately 103 million of nearly 2 billion acres (41 million of 0.8 billion hectares)[2] of the conterminous States were occupied by wetlands (24). Roughly 5 percent of the lower 48 States is covered by wetlands, which is less than half the area of wetlands estimated by FWS to have covered those States during colonial times (23, 24). About 95 percent of total wetlands are inland freshwater wetlands[3] and only 5 percent are saltwater in coastal areas and estuaries. Approximately 75 percent of all wetlands in the conterminous States are privately owned (108), and the remainder belong to parks, wilderness areas, forests, and refuges held by Federal, State, and local agencies. Alaska has approximately 170 million acres of wetlands, comprising around 45 percent of the interior area of the State; approximately half of this consists of arctic tundra. Hawaii contains approximately 7,000 acres of wetlands, less than 0.2 percent of its total land area (23). The different types of wetlands and their geographical distribution are summarized in box 4-C and displayed in figure 4-2.

Why Are Wetlands Becoming Degraded?

Climate change is only one of numerous human-influenced environmental factors that impose increasing pressures and demands on natural ecosystems, including wetlands. These factors can be primarily chemical, physical, or biological in nature, or any combination. Like many natural areas, wetlands are degraded by air and water pollution, including industrial air emissions, contaminated waters from urban or industrial landfills, runoff laden with agricultural chemicals, contaminated irrigation water, and salinization from road salt. Inland and coastal wetland areas alike may be affected by water diversions and the altered water and sediment flows that result from channelization and navigation projects, flood-control structures, upstream withdrawals, and the pumping of water from aquifers

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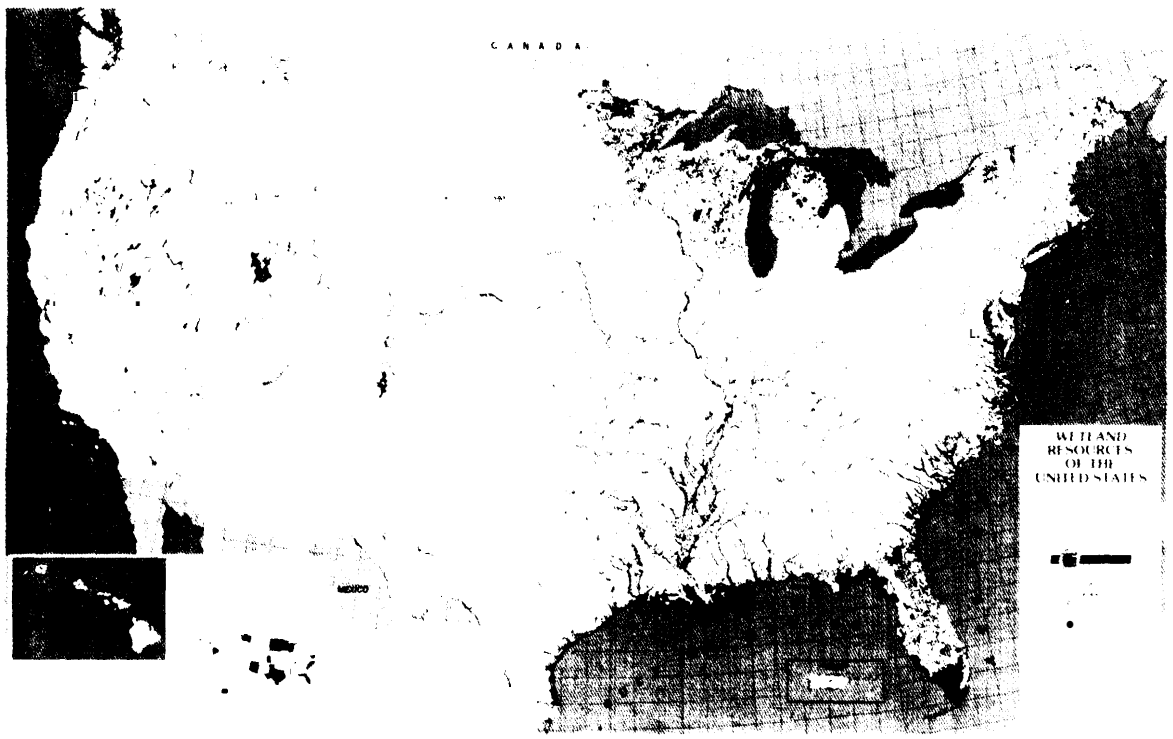
2 To convert acres to hectares, multiply by 0.405.

3 FWS defines coastal wetlands narrowly to include primarily tidal wetlands. A recent report by the National Oceanic and Atmospheric Administration (NOAA) on coastal wetlands used the same database but defined coastal wetlands more broadly to include "wetlands within watersheds or drainage areas directly surrounding estuarine waters or within counties adjacent to marine waters" (101). According to this definition NOM calculates that coastal wetlands account for nearly one-third of the Nation's total area of wetlands (almost 27.4 million acres), and that wetlands occupy 16 percent of the total land in coastal areas.

Figure 4-243 General Distribution of Wetlands in the United States



NOTE: Shaded portions incorporate general wetland areas,

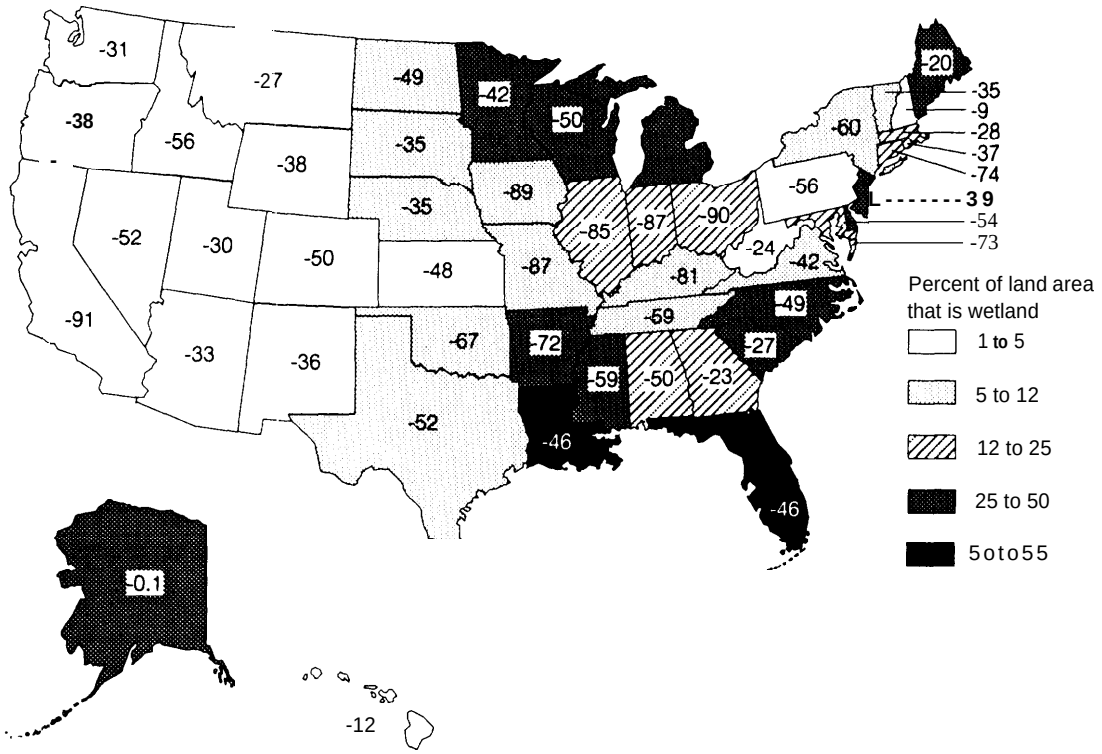
SOURCE: R.W. Tiner, Jr., *Wetlands of the United States: Current Status* and *Recent Trends*, National Wetlands Inventory (Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service, March 19S4).

for municipal and industrial use.[4] Construction of public-works projects (e.g., roads, airports, power plants, and darns) and private buildings (housing developments, office buildings, and marinas), and land-management practices (grazing, logging, and mining) in or near wetlands may all degrade or destroy them. These activities can also alter stream flow and sedimentation patterns by cutting off vital freshwater or sedimentation flow or by changing the balance of freshwater and salt water in estuarine areas (95, 112). Alterations of water levels and hydrological systems may in fact cause the most damage to wetlands (54).

Wetlands that are already degraded are often more susceptible to encroachment of *nonindigenous* (nonnative or exotic) species that may cause severe and sometimes irreversible damage to the habitat of native species. Coastal wetlands may be further affected by altered wave and current patterns created by the construction of dikes, sea walls, and other structures built to protect the coast, as well as by activities such as

[4] Although channelization and dredging projects may exert more-obvious pressures on wetlands, an increasing but less-obvious threat to inland marshes and swamps is the development of new well fields to supply municipal water in areas where the population is growing or in coastal areas (such as in Florida) where salt water has seeped into freshwater aquifers that were pumped down. Loss of wetlands due to well fields has not attracted research and monitoring efforts and is unlikely to be adequately accounted for in wetland inventories, but could become even more of a problem if climate change increases the intensity of well-field development (K.L. Erwin, Consulting Ecologist, Inc., personal communication, December 1992).

Figure 4-3-Wetland Acreage Lost in the United States, 1780s to 1980s



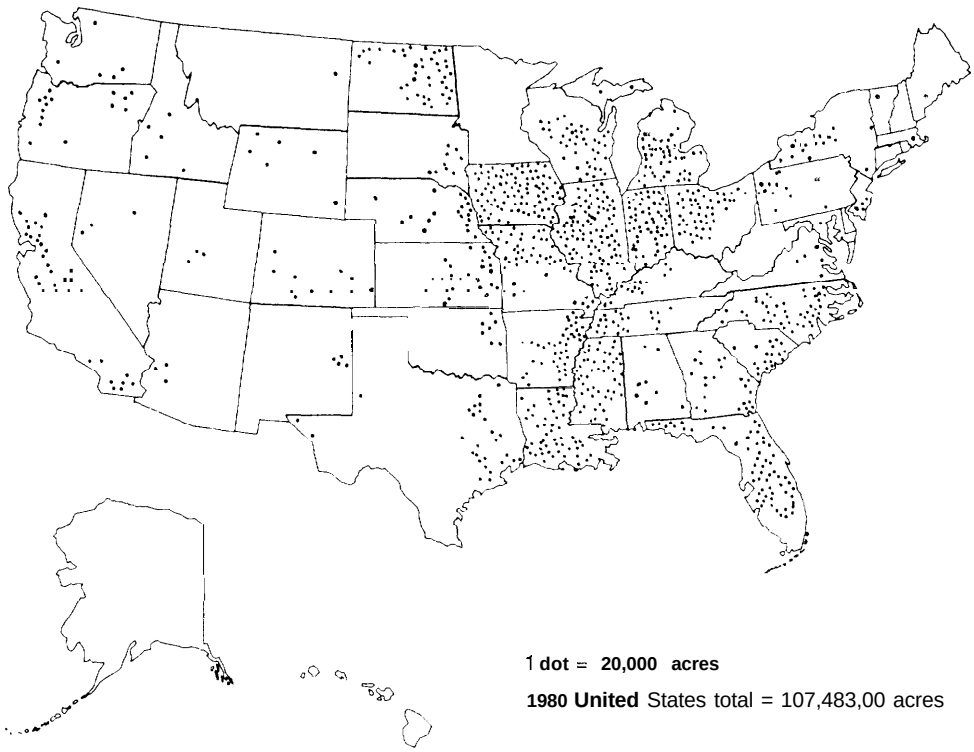
SOURCE: T.E. Dahl, Wetlands *Losses in the United States, 1780s to 1980s,* report to Congress (Washington, DC: Department of the Interior, Fish and Wildlife Service, 1990).

channelization, boat traffic, and subsidence following pumping associated with the off-shore extraction of nonrenewable resources (oil, gas, and groundwater) (46, 108, 113). FWS estimates that in the 1780s, wetlands covered more than 25 percent of the land area of 11 States; by the 1980s, as shown in figure 4-3 and box 4-D, only two States still contained 25 percent or more wetlands (23).

More than 80 percent of the destruction of wetlands aggregated over the past two centuries (1780s to 1980s) has been attributed to converting inland wetlands to agricultural uses, and agriculture remained the leading cause of loss from the mid-1970s through the mid-1980s. Figure 4-4 shows the extent and location of wetlands drained and converted to agricultural use as of 1985.[5] Although agricultural conversions have slowed, many wetlands could still be converted to agriculture. Around 5.2 million acres of wetlands are considered to have high or medium potential for

[5]Of the approximately 11 million acres of wetlands destroyed from the 1950s through 1970s, 87 percent were converted to agricultural uses (24)-an average rate of 480,000 acres per year-that were encouraged by various tax incentives and technical support. Between the mid-1970s and mid-1980s, however, the conversion of wetlands slowed to an average of 260,(X)0 acres per year, according to FWS estimates, due in part to decreasing rates of agricultural drainage and increased Federal Government regulation. Although agricultural conversions declined, they still accounted for 54 percent of the decade's losses (140,400 acres per year on average), while ''other" land uses (that is, "lands that had been drained and cleared of vegetation but not put to an identifiable use' claimed 41 percent, and urban land uses were responsible for the remainder (24). New program have compensated for some losses of wetlands to agriculture by restoring some wetlands; the U.S. Department of Agriculture's Swampbusterprogram (described later in this chapter) added approximately 90,000 acres to the Nation's wetlands inventory from 1987 to 1990 (24).

Figure 4-4-Extent and Location of Artificially Drained Agricultural Land in the United States, 1985



NOTE: To convert acres to hectares, multiply by 0.405.

SOURCE: U.S. Department of Agriculture (USDA), Economic Research Service, "Farm Drainage in the United States: History, Status, and Prospects," Miscellaneous Publication 1455, G.A. Pavelis (cd.) (Washington, DC: USDA, December 1987).

conversion; the lands most likely to be converted are small wetlands that interfere with farming activities and larger forested wetlands that could be drained.[6] The U.S. Department of Agriculture (USDA) reports that "although some wetlands have been converted directly to agricultural uses, about half were originally forested and may have entered agricultural use after being cut over for timber" (99). This practice may be slowing due to economic trends (see box 6-D).

Even where wetlands remain because they have been protected, they are often fragmented into small acreages surrounded by agriculture or residential development. The fragmentation of wetlands and associated habitat interferes with many long-term processes associated with normal wetland functions, so their ecological functions are often diminished and their value as wetlands deteriorates (see box 5-D). Wetlands remain, however, an important component of federally protected natural areas, with 380 of 408 National Wildlife Refuges including substantial tracts of wetlands. Chapter 5 discusses in greater detail the issues surrounding federally protected lands of all types.

6 "High potential for conversion" means that "similar lands were being converted in the years preceding the inventory' (99).

SURVIVAL OF WETLANDS UNDER CLIMATE CHANGE

How Could Climate Change Affect Wetlands?

Scientists have not precisely quantified the intricate interactions between wetlands and climate. No single factor determines whether wetlands will be at risk from climate change or whether they can benefit. The variables that are predicted to change include temperature, precipitation, carbon dioxide (CO> concentrations, and sea level. Some predicted impacts are described in chapter 2 and summarized in boxes 4-F and 4-G and table 4-1.

Climate change will affect the ecological and other functions of wetlands, but the rate and magnitude of losses of functions and products may differ, and may not be closely linked. As described in chapter 2, the public's perception of the impacts on wetlands will be based primarily on products and nonecololgical functions. Fully accounting for and predicting the potential damages will require not only precise regional predictions about the rate and magnitude of climate change, but also site-specific information on the functions and products of wetlands and their links to climate. Because such information is scarce and precise regional climate predictions do not yet exist, this section offers a qualitative rather than a quantitative view of whether, and how, wetlands can adapt to climate change and discusses what will make certain wetlands vulnerable to climate stresses (see table 4-l).

Climate change could affect the distribution and condition of U.S. wetlands by reducing the area they cover and potentially altering the assemblages of plant and animal species they support; both changes could affect the functions and products for which wetlands are protected (see box 4-D and ch. 2). The time frame over which climate change will affect wetlands, and the manner in which their functions and products are altered, will vary widely from one region to the next.[7] In the short term (5 to 25 years), wetlands may be most affected by extreme weather events, such as unusually severe storms, floods, droughts, and fires, which may disrupt the growth of vegetation (see box 4-H). Although all of these are normal, natural events that shape wetlands, their impacts may be particularly severe in areas already disturbed by human activities. Over the longer term (25 to 100 years), changes will likely include shifts in species composition as space opened by disturbance from extreme events is occupied by new species. In areas that become drier, the edges of wetlands will start to recede, while the structure of wetlands

The Florida coast hosts many mangroves that are havens for a variety of wildlife and migratory waterfowl. These dynamic wetlands also serve to protect the shoreline from erosion and help to maintain water quality.

[7] The Office of Technology Assessment convened a 2-day workshop in May 1992 to identify wetlands vulnerable to climate change and to consider management strategies that could alleviate impacts. Participants included scientists and managers responsible for various aspects of research and policy on wetlands. The workshop yielded few conclusions about which wetlands and which functions and products may be lost first, other than a general observation that the subsiding coasts of the Gulf of Mexico are likely to be in trouble sooner and more seriously than the rockier coasts of the Pacific and North Atlantic. Although the workshop did not aim for consensus in any formal way, nearly all participants agreed that most functions of wetlands that humans value are vulnerable now because so many wetlands have already been destroyed and their functions and products have diminished.

Box 4-F--Louisiana and Sea Level Rise: A Preview of What's to Come?

While coastal States up and down the Atlantic seaboard wrestle with what to do about impending sea level rise, the question is more than academic for Louisiana. A glimpse of the future is already here. Louisiana lost around 50 square miles (32,000 acres, or 12,800 hectares)[1] of its coastal wetlands every year between 1986 and 1978 as delta land subsided and the sea level rose, accounting for 86 percent of the entire Nation's annual losses of coastal wetlands. Since 1978, the annual loss has slowed to approximately 25 square miles. The figure below shows the dramatic decline of wetlands surrounding the mouth of the Mississippi from 1958 to 1978.

Wetland Changes in the Mississippi River Active Delta (1958-78)

NOTE: The light shading designates marsh and forested wetlands, and the darkest shading designates upland and dredge-deposit areas. Between 1956 and 1978, there was a decrease of more than 50 percent in marsh and forested wetlands (about 100,000 acres lost in all) and an increase of almost 300 percent (about 12,000 acres gained) in upland and dredge-deposit areas. One inch equals 50 miles (1 millimeter equals 3 kilometers); to convert acres to hectares, multiply by O.405.

SOURCE: U.S. Fish and Wildlife Service, National Wetlands Research Center, Slidell, LA, 1993.

The alarming erosion of Louisiana's coasts places at risk wetlands of great importance to fish and wildlife. Louisiana's coastal wetlands support nearly 30 percent of the Nation's commercial fish and shellfish harvests, provides the winter home for 20 to 25 percent of North America's puddle ducks, and yield North America's largest fur and alligator harvests. But Louisiana's coastal wetlands are important to Americans in other ways as well. The wetlands can reduce damage to property from hurricane-related tidal surges, provide flood storage when the Mississippi swells during large storm events, and remove pollutants from coastal waters.

Why the rapid decline? The coastal ***lands of*** Louisiana, like those in parts of neighboring Texas and Mississippi, were formed over millennia as sediment carried by the Mississippi River and its tributaries from States as far north as Minnesota, as far west as Montana, and as far east as Pennsylvania was deposited in the delta. The Mississippi spewed water, silt, dirt, and sand, until the debris had piled up so high that water no longer flowed easily seaward; the river then snaked around, changing its course, until it found the next path of least resistance. The loose sediments of these delta lands were gradually compacted and sank lower toward and into the sea,

1 To convert acres to hectares, multiply by 0.405.

(Continued on next page)

Box 4-F-Louisiana and Sea level Rise: A Preview of What's to Come?--(Continued)

eroding easily in the face of waves and storms, until wetland vegetation took root. Vegetation anchored the soil and built up organic material **and trapped** sediment and land started to accumulate again in coastal marshes. This dynamic process of deposition and growth continued until around a century ago, when human actions to control floods and improve navigation on the Mississippi began to drastically alter the hydrological patterns and interfere with the patterns of coastal and wetland growth. The consequences of human attempts to control alluvial processes are often dramatic, as was seen when the Mississippi scaled its artificial barriers and inundated hundreds of thousands of acres in its floodplain in July 1993--reclaiming, at least temporarily, many former wetlands.

The primary cause of Louisiana's wetland losses has been the construction of Federal and nonfederal flood-control levees along the Mississippi River that have virtually eliminated the inflow of fresh water and sediment into the delta marshes. Engineering projects designed to maintain navigation on the Mississippi River confine water flow to deep, straight channels, forcing the sediment-laden water to bypass the wetlands and deposit its silt into deeper Gulf of Mexico waters. Humanmade channels, built through the wetlands for navigation and for easy access to off-shore oil rigs, increase the encroachment of salt water into interior wetlands, killing the salt-intolerant vegetation and accelerating the loss of organic matter and the conversion of wetlands to open water. Wave action from boats traveling along the channels accelerates the erosion of the shorelines.

The more rapid sealevel rise predicted with climate change, combined with continuing subsidence, will further increase the rate and extent of wetland loss. Commercial fishers may actually see an initial increase in their harvests and profits. Shrimp production may increase rapidly during the early stages of wetland decline as open-water habitat increases, as marshes fragment, and as organic matter is released quickly by decaying vegetation, providing food sources for aquatic organisms. However, the initial boost of productivity will likely be followed by a long and potentially rapid decline. if sea level changes rapidly, some commercial fisheries may be lost entirely (see box 2-C).

What can be done to slow the loss? Many scientists who study wetlands view engineering activities with suspicion because they have been the cause of past damage. However, further engineering maybe necessary to reverse the damage that has already been done. The Army Corps of Engineers has already experimented with various techniques for offsetting the losses, and it should continue to evaluate their effectiveness to determine whether they should be implemented more widely. The techniques include: 1) implementing projects to divert fresh water to maintain the proper salinity, and to divert sediment to inhibit subsidence and to help create new wetlands in shallow open water; 2) backfilling and plugging certain dredged canals to prevent saltwater intrusion; 3) establishing salt-tolerant vegetation in areas where the natural vegetation is threatened by salt water; 4) effectively using maintenance dredge materials to restore proper marsh elevations for wetland vegetation; 5) improving management of water levels and salinities by using levees and water-control structures to preserve and enhance existing wetlands and to restore degraded wetlands; 6) restoring wetlands drained for grazing purposes; and 7) reducing the widespread use of forced drainage of wetland areas, thereby reducing sediment compaction and subsidence. Although levees and water-control structures are useful for controlling water level and salinity, they prevent or restrict the mobility of aquatic organisms, and interfere with hydrology and sedimentation patterns-the very reason why Louisiana marshes, and some others, are so degraded today, and also why the Mississippi River appears to have reclaimed its floodplain.

SOURCES: Louisiana Wetlands Protection Panel (LWPP), Saving *Louisiana's Coastal Wetlands: The* Need for a Long-Term Plan of Action, EPA-230-02-87-026, report of a panel convened by U.S. Environmental Protection Agency (EPA) and Louisiana Geological Survey at Grand Terre Island, LA, Sept. 17-19,1985 (Washington, DC: U.S. EPA, April 1987); J. McPhee, The *Control of Nature (New York:* Farrar, Straus, Giroux, 1989); U.S. Department of the Interior (001), Fish and Wildlife Service (FWS), Wetlands: Meeting the President's Challenge---1990 Wetlands Action Plan (Washington, DC: U.S. DOI, U.S. FWS, 1990); V. Van Sickle-Burkett et al., National Wetlands Research Center, U.S. Fish and Wildlife Service, tables describing coastal wetland vulnerabilities to climate change, prepared for U.S. Office of Technology Assessment, May 1992.

Box 4-G-How Could Climate Change Affect Wetlands?

Temperature---Increased air temperatures may speed evaporation of surface water from wetlands (and from runoff and water bodies that supply wetlands) and could increase the rate at which wetland plants lose water through evaporation and transpiration if the warmer temperatures are not accompanied by increased rainfall. Drying is most likely to occur at the edges of wetlands and could reduce the size or extent of inland wetlands. Warmer temperatures will increase the rates at which plants decompose, affecting the amount of organic material buried on the marsh floor. Warming could also increase the frequency and severity of drought and fires in seasonal wetlands, which could lead to major changes in and loss of vegetation and habitat. Warming in tundra areas could thaw the upper layer of the permafrost, making it more susceptible to drying, and could lead to significant reductions in the areas of both arctic ***and alpine*** tundra (120). Changes in the diurnal and seasonal distribution of temperature (such as warmer nights during winter and earlier spring thaws) will affect whether **and,** if so, how wetlands benefit from warmer temperatures. For example, mangroves may expand northward, replacing brackish marshes on the northern coast of Florida and throughout the Gulf of Mexico wherever frosts and freezes become less frequent. Warmer temperatures in large bodies of water could boost productivity in the associated wetlands but would affect the mix of species that could thrive,

Precipitation and soil moisture--Hydrology is an Important factor in determining levels of productivity, decomposition, and nutrient cycling in wetlands. Whether precipitation increases or decreases, ail of these functions will be affected. Shifts in hydrological effects may develop in a stepwise manner, with new climate patterns first affecting current vegetation (through shifts in soil moisture), then plant cover, and finally the permeability of soils. Alterations of plant cover and soil permeability may then act in a feedback loop to further modify the hydrological cycle.

Increases in precipitation may cause shifts in vegetation but are not likely to cause as much disturbance to wetlands as are drier conditions. In fact, increased precipitation along the Atlantic coastal plain, which is predicted by some models (64), could benefit Atlantic coast wetlands by transporting increased sediment from upstream to coastal areas, and by maintaining high freshwater flows to help offset saltwater intrusion-both of which may help lessen the potential destruction of coastal wetlands by sea level rise.

Reduced precipitation is more likely to be harmful than is increased precipitation, especially in semiarid or water-limited regions, leading to reduced riparian areas and desertification on semiarid flatlands. A drier continental interior, predicted by many climate models (49, 64; see also ch. 2), will mean less water and sediments moving down the Mississippi River and even greater problems for the coastal swamps and marshes of the Mississippi River Delta. It will also likely exacerbate problems associated with saltwater intrusion up the Columbia River and rivers associated with estuaries such as Puget Sound, San Francisco Bay, and the Tijuana River. Throughout estuarine and coastal systems, lower precipitation will exacerbate ail the impacts and problems associated with sea Ievel rise.

Increased carbon dioxide (CO_2)--Concentrations of atmospheric $C0_2$ are expected to reach twice the pre-industrial concentration (around 275 ppm) by the middle of the next century (49). The effects of this change on the productivity and composition of natural plant communities, including those in wetlands, are difficult to predict. The fertilizing effect of elevated CO_2 concentrations has been shown to boost productivity in Chesapeake Bay salt marshes (5, 26,27, 130), but the effect does not appear to occur for sustained periods in arctic tundra (44, 72), and other types of wetlands have yet to be tested for the effect. Some of the best long-term, open-environment experiments on the effects of increased $C0_2$ have been done on tidal wetlands. These studies do not provide definitive answers but suggest that elevated $C0_2$ concentrations tend to favor C_3 species over plants using the C_4 pathway for photosynthesis (see ch. 2 for a discussion of C_3 and C_4 plants). Most coastal wetland grasses are C_4 plants, whereas most sedges, rushes, forbs, and the weedy grass **Phragmites *australis are C_3 plants, as*** **are all** mangrove species. With rising CO_2, therefore, the C_3 species, which now tend to ***be***

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Box H-How Could Climate Change Affect Wetlands?--(Continued)

relatively less abundant, especially in more saline areas, may tend to become more important members of the plant community of the salt marsh--but the magnitude of this change and its effects on salt marsh functions are impossible to predict.

Accelerating sea level rise--Sea level has been rising at a gradual rate of 4 inches (10 centimeters)[1] per century for the past 3,000 years. At this rate, intertidal low marshes were able to accrete sedimentsts and produce peat at a rate that allowed the vertical marsh growth to keep up with or exceed the sea level rise. Behind the intertidal zone, marsh surface elevations rose **above** mean high tide, creating anew "high-marsh" niche flooded only by spring tides, where marsh vegetation could grow. As sea level rises, high-marsh vegetation moves landward, over the gradually submerging uplands. For a particular marsh to survive in the face of rising sea level requires-at a minimum--room for landward expansion as well as sufficient sediments to support a rate of surface accretion that on average, tracks the sea level rise. The extent of sea level rise expected to occur with thermal expansion of the oceans due to global warming--5 to 11 inches by 2050---may exceed the ability of tidal wetlands to accrete sediments and produce roots fast enough to keep up with the rising **sea level.** Vegetation may change and productivity may decrease; in some areas, wetlands maybe converted to open water.

In addition to the possibility that a rising sea may inundate coastal wetlands, it may also increase the distance that salt water intrudes into estuaries, rivers, and even coastal aquifers. Saltwater intrusion may be magnified if precipitation within a watershed decreases at the same time that sea level increases, or if upstream water withdrawals for human use reduce water flows. Saltwater intrusion could affect brackish and fresh tidal wetlands and freshwater coastal swamps, either converting thereto salt marsh or damaging vegetation **enough that those** areas are converted to open water.

1 To convert **inches to** centimeters, multiply by 2.540.

SOURCE: Office of Technology Assessment, 1993.

along the lowest-lying coasts may begin to change (i.e., become larger or disappear) as they are inundated.

While some wetlands may lose species and area because of either increased drying or inundation associated with climate change, others could prosper or expand. For example, the fertilizing effect of elevated CO_2 concentrations (described in ch. 2) boosts productivity in Chesapeake Bay salt marshes (5, 26, 27, 130). However, the fertilization effect does not appear to extend to tundra (44, 72). The extent of the fertilization effect in other wetland types has yet to be tested. In many cases, land use in adjacent areas will be a determiningg factor in whether any benefits can be realized. Wetlands buffered by undeveloped natural areas may have room to move and grow, whereas wetlands in areas where land is fragmented among many competing uses will be less likely to benefit. Wetland expansion might be accompanied by changes in vegetation, which could alter the products of, and the functions currently performed by, a given wetland.

Even where climate change benefits wetlands, however, expansion of wetlands in one region will not necessarily compensate for reductions in distant or dissimilar wetlands because the functions and values differ so widely. For example, in part of the Southeast, rainfall is predicted to increase enough to compensate for higher evaporation rates as the temperature warms, so parts of the region may become wetter. Riparian areas **and** bottomland hardwood wetlands could expand under these conditions. At the same time, vast areas of arctic tundra may be at risk as warming in the upper latitudes allows the permafrost underlying the wetlands to melt and drain (described in more detail below). Gains in southeast-

Table 4-l—Wetland Vulnerabilities to Climate Change

Wetland type	Vulnerability	Key climate factor, functions at risk
Coastal salt marshes	High	Sea level rise and coastal erosion from storm surges could inundate these areas faster than they can migrate At risk fish, shellfish, flood and *erosion control, habitat*
Mangrove swamps	Medium	Increased winter temperatures could favor growth, but sea-level rise, storm surges, and saltwater intrusion could cause net reduction *At risk* fish, *shellfish, habitat, flood and erosion control*
Tidal freshwater marshes	High	Decreased precipitation (lower water flow in rivers entering estuaries) combined with sea level rise could diminish or convert to salt marshes or open water *At risk fish, shellfish, flood and erosion control, habitat*
Inland freshwater marshes (including prairie potholes)	High	Increased temperatures, decreased precipitation could dry out shallower marshes such as prairie potholes *At risk key migratory bird breeding grounds*
Inland saline marshes	Medium to high	Increased temperatures, decreased precipitation could dry out shallower fringes At risk: *waterfowl and wildlife habitat.*
Bogs	Low to medium	In the Southeast, a wetter climate could aid bogs In the Northeast and Midwest, decreased precipitation could further degrade contaminated bogs *At risk: cranberries, blueberries, water quality*
Tundra	High	Warmer temperatures in alpine and arctic zones could melt **and dry permafrost** *At risk key source of carbon storage, wildlife habitat*
Shrub swamps	Low to medium	Higher precipitation in the Southeast could allow for expansion, lower precipitation in the Midwest would diminish the fringe areas, *At risk flood and erosion control, water quahty, habitat*
Wooded swamps	Low to medium	Higher precipitation in the Southeast could allow for expansion; lower precipitation in the Midwest would diminish the fringe areas *At risk: flood and erosion control, water qua/@, habitat.*
Bottom lands and other riparian habitat	High (in the Southwest)	Increased temperatures, lowered precipitation and runoff would reduce riparian habitat in the arid Southwest. At risk *fish and wildlife habitat, flood and erosion control, water quality, grazing*

SOURCE: Office of Technology Assessment, 1993 (adapted from Office of Technology Assessment Wetlands Advisory Panel Workshop, May 1992)

Box4-H--Will Climate Change Increase Conflicts Over Riparian Wetlands in the Arid West?

Like cases in the desert, riparian wetlands in the arid West offer lush vegetation and cool shade, presenting a respite from the hot sun and dry climate that attracts humans as well as wildlife. Riparian areas occupy just 1 percent of the arid lands in the West, but provide food and habitat for three-quarters of the wildlife species in those areas, including half of ail bird and vertebrate spades in the region (40, 103, 104). Rafting, fishing, **and canoeing** on western rivers **and streams make** an enormous contribution to local economies in the West. The river-outfitting industry in Colorado alone generates $70 million annually (77). Riverside and streambed wetlands are valued by ranchers as a haven for cattle, which seek out the cool shade of cottonwood and willow **and the** high-quality forage. After heavy rains, riparian vegetation filters sediment from runoff water, helping to build and maintain stream banks, protecting against erosion, and offering a buffer against floods. Riparian wetlands even play an important role in how a watershed functions: the vegetation shields water and soil from the sun, slowing evaporation (19).

Yet despite their many functions, riparian wetlands are under constant threat, even In the existing climate. As wet areas in a landscape where water is scarce, they are often overused. The Environmental Protection Agency (EPA) estimates that overgrazing has been the most geographically extensive cause of riparian wetland degradation and loss (15). Overgrazing, either by too many animals or for too long a period of time, prevents new plants from taking root and holding down the soil. As a result, stream banks erode, channels become shallow and laden with sediments, water quality and quantity decrease, and, eventually, the stream may flow only intermittently or not at all. Riparian wetlands may also be destroyed by the destructive Iand-clearing practices associated with mining and logging. Removing vegetation often leads to erosion that washes sediment into rivers and streams, filling wetlands and allowing them to dry up.

Even more threatening to riparian areas has been the diversion of water from rivers and streams for competing uses, either by direct pumping or by projects designed to **channel the water.** Water rights are hotly contested in many parts of the West, with water from many rivers already allocated in greater amounts than normally flow, and the need for water to remain instream (i.e., in the river rather than pumped out or directed) for fish, wildlife, and wetlands is not always recognized. Farmers channel or pump from streams to fields for agricultural use, while cities siphon off water for drinking and other purposes. These water diversions leave less water for riparian areas downstream, and because riparian vegetation depends more on flowing water than on precipitation, Iess water in the stream bed translates to Iess or even totally lost vegetation (28, 38). All told, more than 80 percent of riparian wetlands have been destroyed by human activity, with an associated loss of habitat and decline of wildlife populations (40, 51, 117).

Climate change could impose greater water stress on already-degraded wetlands, both from lower precipitation and from ever-increasing competition with human activities. Climate models predict that conditions will be hotter and drier in the already-arid West (49). A warmer climate may bring rain rather than snow in the winter, allowing precipitation to run off immediately rather than to remain in snowpacks that melt in spring as the growing season begins. The earlier runoff could mean that drier conditions would start earlier in the year, making summer **and fall water shortage and quality** problems worse in many parts **of** the West (84). As water becomes more scarce, the competition and potential conflicts over water use could increase. Drought-stricken farmers and expanding cities alike may demand more water development projects to makeup for lower precipitation, and ranchers may be more inclined to encourage grazing in riparian areas (or demand grazing rights on publicly owned properties) as surrounding rangelands decline. Riparian wetlands, along with the fish and wildlife that inhabit them, may well lose out among the competing demands and decreasing water flows.

Although most riparian wetlands are protected from the physical disturbances of dredge and fill activities (Section 404 of the Clean Water Act (P.L. 92-500)), they receive little legal protection against the upstream water diversions that might ultimately cause their destruction. Some fish and wildlife agencies and other conservation

groups have recently begun to purchase water rights for instream flows to protect riparian wetlands and wildlife, including fish. In the West, however, water is allocated according to the prior appropriation doctrine, which gives priority to those who first diverted water from a river and put it to use--"first in time, first in right." (See vol. 1, ch. 5.) In most cases, the water rights purchased for natural areas are "junior" to those owned by farmers and cities, so in a water crisis, water for natural areas would be among the first to be lost. The Wild and Scenic Rivers Act (P.L. 90-542) protects instream flows for certain designated rivers, but water rights for National Parks and wilderness areas have yet to be claimed by the Federal Government. Even these protections, which are already controversial, may become more so as water becomes more since.

SOURCES: E. Chancy, W. Elmore, and W.S, Platts, L/vestal Grazing on Western Riparian Areas, report prepared for the U. S. Environmental Protection Agency (Eagle, ID: Northwest Resources Information Center, Inc., 1990); U.S. Department of the Interior, Bureau of land Management, *Riparian-Wetland Initiative for* the 1900's, BLM/WO/GI-91/001-4340 (Washington, DC: Bureau of Land Management, September 1991); U.S. General Accounting Office, Rangeland *Management: Forest Service* Not *Performing Needed Monitoring of Grazing Allotments,* GAO/RCED-91-148 (Washington, DC: General Accounting Office, May 1991).

ern wetlands could not compensate for the loss of habitat and carbon storage provided by arctic tundra wetlands. Likewise, expansion of inland wetlands within a coastal watershed as sea level rises may be important to the estuary, but those wetlands would not perform the same nursery functions for fish and shellfish as do the wetlands right at the coast. Regardless of the benefits, then, climate change may still pose a threat to many functions and products of wetlands.

Although climate change may affect wetlands directly, many scientists and policy makers consider the activities currently degrading and destroying wetlands-agriculture, development, pollution, and changing water and sediment flows—to be the biggest threats to wetlands and their economically important functions in the future. Climate change would add to the stresses posed by these activities: a decrease in runoff in the Northeast could worsen water quality; competition with urban and industrial water uses would probably reduce the water available for wetlands; and increased pressure for water diversions might further alter water and sediment flows to wetlands (84). Thus, in many areas, the direct effects of climate change may not overtake existing sources of degradation and loss as the dominant threat to wetlands in the near term, but will likely exacerbate current trends of loss and degradation.

Because the United States has already lost more than half of the wetlands it contained 200 years ago (over 100 million acres), the potential for climate change to spur further losses and degradation could pose a significant threat to valued functions of wetlands (103). If losses continue at current rates, FWS estimates, the Nation may lose another 4 percent (approximately 4 million acres) of remaining wetlands in the conterminous States by the year 2000--and this estimate does not account for any additional losses in area or function due to climate change (108). Losses of inland wetlands will likely continue to make up the bulk of total losses of wetlands because that is where most U.S. wetlands lie, but coastal wetlands may suffer larger proportional losses in a changing climate because of the threat posed by a rising sea level.

B Can Wetland Species Adapt to Climate Change?

No single factor determines whether the various plant and animal species that make up a wetland can adapt to climate change or whether a particular wetland system will lose some or all of its functions and products. In any given site, wetland species may respond in three interrelated ways as the environment changes around them: they may change, migrate, or decline. Which response prevails will depend on where a wetland

lies in the landscape, its size, its hydrology, the health of its vegetation, and other physical, biological, and anthropogenic factors that have shaped it over time, combined with the rates at which regional patterns of temperature, precipitation, and evaporation change.

Change

Depending on the rate and magnitude of climate change, wetlands and the species that inhabit them may adapt to new climate conditions. New plants may become dominant, and different animal species may be associated with them (66). In a given wetland, a moderate change in precipitation may induce a gradual change in plant species composition but cause little harm to wildlife habitat, recreational use, or floodplain protection. A greater change might convert a year-round wetland into a, seasonal one, affecting vegetation and impairing wildlife habitat and recreational value, but perhaps allowing continued floodplain protection.

Migration

Wetland vegetative species may migrate to surrounding, similar areas if such areas exist and if migration pathways are not blocked by topographical or anthropogenic barriers. For example, coastal and estuarine wetland vegetation will begin to take root further inland as the sea level rises. Whether the vegetation becomes established successfully will depend on the rate at which water levels rise, the steepness of the coast, and the presence of barriers, such as rocky areas and human-built structures. Wetlands fringing the playa lakes of the Southwest may retreat or become degraded along the water line if increased evaporation in a hotter and drier climate causes water levels to drop, and farmers may then till up to or through the fringe. In many areas, adjacent human activity severely limits the ability of wetlands to move or flourish.

The likelihood of successful migration will differ for coastal and inland wetlands. In coastal areas, vegetation attempting to take root upslope of the rising sea may face competition from plants already in place that have well-established root systems and that may not give way easily. In inland areas where drying and drought occur, plants attempting to move downslope to follow declining water levels in rivers or depressions will not likely face the same kind of competition; the submerged plants that might have competed will likely die when the water recedes. In both coastal and inland areas where channels have been dug, however, migration will be difficult or impossible because the sharp slope at the channel's edge may present an insurmountable barrier.

Even where room to grow is available, there are limits to migration. As noted in chapter 2, it is unlikely that entire assemblages of plants and animals can simply pick up and move together in lockstep. Some species will migrate quickly, others slowly, others not at all. Patterns of competition and predation may be significantly altered, affecting which species will survive migration. Long-term studies of degraded or damaged wetlands suggest that change may take place slowly, one species at a time, and that not all species recover.[8] Random events, such as weather and chance dispersal of seeds, affect the probabilities of migration and survival, Any migration may be accompanied by a loss of biodiversity along with the loss of some of the wetland's functions and products.

DeclIne

Wetlands in some sites may disappear entirely or become so severely degraded that they lose the functions and products by which they are now characterized. If climate change is rapid or severe, some wetland species may not be able to adapt. Coastal wetlands not degraded by human activities have kept pace with a sea level rise of

[8] B. Bedford, Director, Association of Ecosystem Research Centers, and Professor of Ecology, Cornell University, personal communication, Nov. 4.1991.

approximately 0.04 inch (1 millimeter) per year (the rate at which many marshes are able to accumulate material) for the past 3,000 years, but at significantly faster rates, they would drown (114). Likewise, alpine and arctic tundra wetlands may shrink and, in some sites, disappear if the amount and speed of climate change are too great. The ability of many wetlands to survive has been diminished by land-use patterns that have fragmented or degraded them so much that they have little capacity to migrate or evolve.

Which Wetlands Are Vulnerable to Climate Change?

Some wetlands may continue to perform their most valued functions even if they are degraded by climate change. For example, changes in habitat quality in an urban wetland might not be considered a particularly large impact. On the other hand, maintenance of the flood-control function may be considered vital. Thus, as long as some vegetated areas remain to slow incoming flood waters, the valued functions of this wetland might not be considered vulnerable to climate change. If coastal wetlands decline, however, many of their important functions, including providing habitat for fish and buffering the shoreline, may suffer. Although both functions could to some extent be replaced by artificial constructs (e.g., fish hatcheries and ponds could be created to produce fish commercially), such measures would incur large and continuing costs and would involve other tradeoffs. These measures could not replace such functions as nurturing biodiversity and providing recreational opportunities. Thus, coastal wetlands might be considered vulnerable because they cannot easily adapt to sea level rise and because many of the functions and products that they provide are threatened.

Overall, four types of wetlands are likely to face difficulties in adapting to climate change and can thus be considered highly vulnerable: 1) coastal wetlands, 2) depressional wetlands in arid or semiarid areas (i.e., prairie potholes in the North Central States and vernal pools in California), 3) riparian wetlands in the arid West and Southwest, and 4) tundra wetlands (see table 4-l). *Coastal and estuarine wetlands maybe* drowned by a rising sea or altered by the changing salinity levels. *Depressional wetlands are* susceptible to the lowered water tables that will likely result from the higher temperatures, increased evaporation, and decreased summertime precipitation predicted for these already arid or semiarid areas. *Riparian wetlands in the* arid West, which rely on water flowing through rivers and streams, could also be threatened by drier conditions and increased competition for water. *Tundra* may shrink as increased temperatures allow the permafrost to thaw and drain. In addition, wetlands of any type that are already degraded by pollution, water diversions, or fragmentation may be particularly vulnerable (119, 123). These vulnerabilities are described in more detail below.

Prairie potholes such as these in the Lostwood National Wildlife Refuge, North Dakota, are scattered throughout the Midwest (North Dakota, South Dakota, Montana, Iowa, and Minnesota). They have been subjected to increased drainage due to agricultural demands, yet they serve as prime habitat for nesting waterfowl, and support countless other species as well.

Coastal *Wetlands*

Accelerated sea level rise combined with tropical storms (even if storm frequency does not

increase) will exacerbate "the current losses of coastal wetlands. Wetlands along the low-lying coasts of the Southeast, from North Carolina in the Atlantic to Texas in the Gulf of Mexico, are already subsiding due to *compaction* (i.e., compression of estuarine or deltaic sediments by new layers of sedimentary deposits). These areas may be either flooded or washed away as prevailing water levels rise (see ch. 2). Lands in the Mississippi River Delta are expected to suffer the highest rates of coastal erosion and loss of wetlands (see vol. 1, ch. 4). Indeed, erosion of coastal wetlands is already proceeding rapidly in Louisiana, and increasing rates of loss are expected with accelerated sea level rise (see box 4-F). Approximately half of the 5.5 million acres of coastal wetlands that remain in the United States are found along the Gulf of Mexico (16), making the potential for loss great.

Accelerated sea level rise will also be accompanied by *saltwater intrusion-that* is, salt water moving inland into estuaries and rivers-which may further alter or destroy coastal wetlands that depend on fresh water or a balance of fresh and salt water (see vol. 1, chs. 4 and 5, for further discussion). This effect may be especially damaging to tidal freshwater wetlands that lie near the upper reaches of tides in many coastal rivers. The higher and rockier coasts bordering the North Atlantic and Pacific Oceans are less likely to experience losses of wetlands, in part because these rocky coasts harbor fewer to begin with. However, some important estuarine systems in these areas, including Puget Sound, San Francisco Bay, and Tijuana Estuary, may be highly vulnerable because of local subsidence, erosion, and water diversions that have dramatically altered water and sediment flows. Each of these areas has already lost many wetlands to water diversion and competing land uses. Further losses might irreparably harm the already-diminished functions and products (83, 126).[9]

The key to whether coastal wetlands will be able to adapt to climate change is migration--the ability to move inland to keep pace with the rising sea (114) (see vol. 1, ch. 4). Although topography, geology, and the coast-shaping processes that accompany storms are important limiting factors to migration, human responses to sea level rise will perhaps be even more important. Societal measures taken to protect the coasts will help determine the pattern and rate of loss; such measures could range from no additional protection (which is unlikely in developed areas) to efforts to protect not only major coastal developments but more rural areas as well. Wetlands along highly developed coasts, including much of the Atlantic coast from Maryland to Massachusetts, may become quite vulnerable to climate change because control structures such as sea walls and bulkheads already form barriers to migration. As the sea level rises, the public may desire to take even more aggressive measures, such as constructing dikes, to protect human life and property values in densely settled areas. Even along undeveloped coasts, the land just above sea level into which wetlands could migrate is generally smaller than the area of wetlands at risk from climate change (91). Thus, coastal wetlands may simply be squeezed out between the rising sea and the flood-control structures that are already in place or that may be constructed to protect coastal properties.

Several functions and products are at risk if coastal wetlands are diminished and altered by climate change. In ecological terms, Atlantic tidal marshes are remarkably homogeneous in species composition from Florida to Maine, so it may appear that some losses will not pose a significant threat to overall fictions and products. However, regional populations of many species have developed adaptive characteristics that may not be common in the species as a whole, so declines in any region still reduce the genetic diversity

[9] D. J. Canning, Shorelands and Coastal Zone Management Program, Washington State Department Of Ecology, personal communication, Nov. 11, 1992.

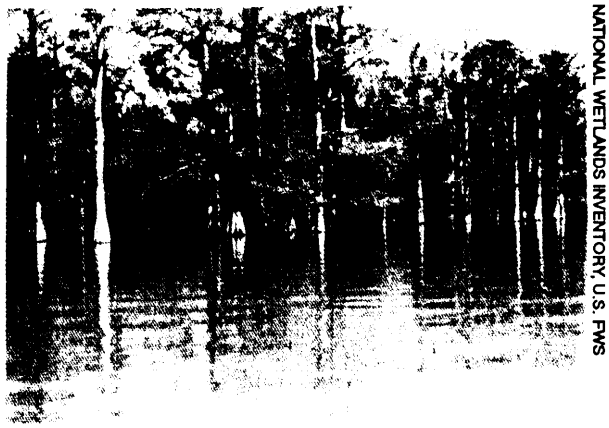
within individual species. Furthermore, some fish populations spawn and feed in specific estuaries; significant losses in one estuary could have large ripple effects on the fishery as a whole.

Coastal wetlands play a vital part in supporting the commercial fish and shellfish industries. Nationwide, estuarine wetlands provide essential food and habitat for three-quarters of the commercial catch of fish and shellfish, valued at $5.5 billion per year dockside, not counting the value added from processing (see box 4-D). The shrimp harvest in Louisiana alone is worth some $100 million. Degradation and destruction of coastal wetlands due to sea level rise may initially boost the production of fish and shellfish. However, the near-term productivity boost may be followed by a longer-term decline if new vegetation cannot take root and survive. The potential impacts on the fish and shellfish industries and the people who rely on them for jobs and livelihood could be substantial (see box 4-F) (64, 113, 129). In the Chesapeake Bay, landings of migratory fish species, including shad, herring, and bass, declined 66 to 96 percent from the mid- 1960s through the mid- 1980s. Oyster harvests declined 96 percent in the past century, and the bay has lost half its wetlands, including 90 percent of all its seagrass meadows, which form prime nursery habitat. Although many other factors, including pollution and overfishing, have contributed to this decline, the loss of habitat in wetlands is considered to be a primary cause (14, 16).

Loss of coastal wetlands will also reduce their capacity to control floods, reduce shoreline erosion, and filter pollution from runoff water as it passes from land to sea. The costs of these losses in function are hard to quanttify and are intricately related to other coastal issues (see vol. 1, ch. 4).

Depressional Wetlands

Shallow depressional wetlands in arid and semiarid parts of the West (including the prairie potholes of the Great Plains; the *playas,* flats, and



NATIONAL WETLANDS INVENTORY, U.S. FWS

Southern bottomland hardwood wetlands-this one in the Lower Mississippi Alluvial Plain--are one of the Nation's most important and most at-risk resources. They are home to millions of migratory birds and countless other species of wildlife, and they play vital roles in controlling floods and in maintaining water quality.

rainwater-basin wetlands of Utah, Nevada, Nebraska, Kansas, Oklahoma, and Texas; and the vernal pools of California) are particularly vulnerable to hotter, drier conditions. Most depressional wetlands are oases of habitat for birds and wildlife in the midst of an otherwise dry landscape. Some form important feeding grounds for waterfowl that migrate from Canada to the Gulf of Mexico, whereas others provide year-round habitat for numerous wildlife species. California's vernal pools are particularly valuable as habitat for several endangered species (128). The prairie-pothole region is valued for the recreational opportunities it provides to hunters and bird-watchers (see box l-F).

Higher temperatures and increasing frequency or severity of drought will speed evaporation and lower water levels in these wetlands or reduce the time during which they remain wet. These alterations in the water regime could cause extensive changes in vegetation, and reduce the quantity and quality of food and habitat for migratory waterfowl (6).[10] Larger wetlands are likely to

[10] K, A. Pioani, Ecosystems Research Center, Cornell University, personal communication, November 1992.

better withstand the effects of drying and maintain the range of diverse habitat conditions that will continue to support a wide range of species. Smaller ones will change the most under warmer and drier conditions; as they become shallower, they will become choked with cattails and other cover plants that will leave less open water for waterfowl breeding. In addition, some smaller wetlands may convert from year-round to seasonal wetlands, which would significantly change their use as habitat. Spring precipitation maybe one of the most important factors in determining the degree to which smaller and semipermanent depressional wetlands are affected by drier conditions.[11]

Protection of prairie potholes was the impetus for the passage of the Migratory Bird Hunting and Conservation Stamp Act in 1937 (P.L. 94-215), which levied fees on hunters to support the purchase of some pothole areas; these purchases signaled the start of a national system of wildlife refuges (see ch. 5). Numerous laws and land acquisitions since then have sought to protect the wildlife and recreational values of the prairie-pothole region. However, competition for land and water resources may further increase under climate change, particularly if climate change leads to expansion of agriculture in the region (see vol. 1, ch. 6).

The ability of western depressional wetlands to sustain waterfowl and other species that rely on them during climate change will depend in large part on the Nation's success in protecting them against other threats and restoring areas that have already been damaged. The key to maintaining depressional wetlands throughout the arid West will be to conserve water to help maintain water tables at their present levels, to find supplemental supplies where possible, and to restore degraded or drained wetlands where possible. Other possible conservation strategies include maintaining existing wetlands, increasing protection of deeper areas that may provide better habitat and are more likely to persist in dry years, and coordinating protection of wetlands within regions so that if some are lost others in the general vicinity may remain.

Western Riparian Wetlands

Riparian areas in the arid West are also highly vulnerable to the hotter and drier conditions predicted for much of the interior West. Predicted increases in temperatures and evaporation rates in this region, combined with reduced rainfall during the growing season, could greatly reduce the runoff entering streams and rivers. Some small or seasonal streams and their associated wetlands could disappear altogether.

Riparian wetlands in the West are highly valued for the habitat they provide to waterfowl, fish, and wildlife. Those habitats now comprise less than 1 percent of the western landscape, yet they support a vast recreational industry including hunting, fishing, and boating. Riparian wetlands are often the only forested areas in western flatlands, and they are critical for breeding, hunting, and cover for many mammal and bird species that inhabit these areas. They offer lush grazing grounds for deer and other wildlife and range-fed cattle. USDA estimates that over 80 percent of riparian habitat has been lost due to grazing and diverting water for irrigation and municipal uses (98). Climate change and increasing competition for scarce water resources could accelerate the loss of riparian habitat and could lead to diminished wildlife and fish populations, degraded rangeland, and reduced recreational values.[12] The potential for conflicts among different uses of riparian land and water is discussed in more detail in box 4-H.

Like coastal wetlands, riparian wetlands have some capacity to adapt to a changing climate by migrating along river edges up- and downstream

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11 Ibid.

12 C. Segelquist, U.S. Fish and Wildlife Service, National Ecology Research Center, Riparian and Wetland Ecology Project, personal communicator July 15, 1992.

as well as up- and down-slope to follow the water. However, in those areas subject to hotter and drier conditions, rivers are likely to shrink, so migration will likely involve retreat rather than expansion.

Tundra

Alpine and arctic tundra peat lands with water-saturated soils are highly vulnerable to climate change. Warmer temperatures will allow the permafrost layer, on which tundra relies for sustaining moisture, to thaw and drain.[13] As the upper layers of permafrost dry, the tundra vegetation and soils will start to decompose, releasing stored carbon into the air and potentially adding to the feedbacks that spur global warming (see ch. 2). Permafrost melting and decomposition of tundra soils may also cause the surface to subside, which could affect the stability of roads and pipelines built on tundra. Where arctic tundra is situated near the coast, these processes may also lead to increased loss of coastal land as frozen peat melts and slumps into the sea.

Because tundra serves important and diverse functions, its economic value is difficult to judge (see box 4-D). Along with the other northern soils, the tundra sequesters approximately one-fifth of the world's total soil carbon (44, 72, 80). Arctic tundra provides critical habitat and breeding grounds for migratory waterfowl, including certain geese, swans, and ducks, some of which migrate to the Arctic from as far away as the Southern Hemisphere. Organic matter from tundra peat is an important food source for fresh- and saltwater fisheries. In Alaska, arctic tundra provides habitat for the caribou, wolves, foxes, and waterfowl that contribute to the subsistence of the indigenous human population (see ch. 1, box l-G).

Alpine and arctic tundra both have limited capacity to adapt to climate change. As temperatures warm, alpine tundra is likely to shrink as lower-altitude and lower-latitude edges dry. Species now found in alpine and arctic tundra are unlikely to adapt easily in dry areas where the permafrost has been the primary means of maintaining moisture. As soon is it becomes warmer, it will become drier, and the tundra vegetation will decline. Although large areas of relatively pristine arctic wetlands remain protected by their isolation from many of the activities that have harmed wetlands in the rest of the Nation, this does not make them less vulnerable to the risks and impacts of climate change. Few policies other than successful efforts to slow greenhouse warming are likely to stem the loss.

POLICY CONTEXT

The Challenge for Policy

Since 1989, the Federal Government has embraced the policy goal of no net loss of wetlands, but steps to achieve it have not been fully implemented. The impetus for a no-net-loss policy arose from the widespread perception that historical losses of wetlands due to human activities have reduced the ability of remaining wetlands to provide the numerous functions and products for which they are valued, and that further losses would threaten the integrity of wetlands and the larger ecological systems in which they are found. A policy aimed at achieving net gains, promoted initially in 1987 by the National Wetlands Policy Forum (NWPF), received further endorsement in 1992 from the National Research Council (NRC), the policy-research branch of the National Academy of Sciences (NAS), which

[13] In tundra systems, permafrost acts as an impermeable layer between water on the soil surface (the active zone, where vegetation grows during brief Summer thaws) and the soil layers below. When the permafrost melts, the barrier is broken, and water from the surface can then seep into the lower layers, causing the active zone to drain and dry. Drying will likely be most severe in "cold desert' areas of tundra, where precipitation is scarce but moisture has accumulated in the active zone over thousands of years because it was prevented from draining. Not all tundra has accumulated enough moisture to support wetlands, but in areas that do have peat wetlands, those with a relatively thin permafrost layer may be most vulnerable to climate change.

recommended that 10 million acres of wetlands be restored by 2010 (68).

The no-net-loss policy does not prohibit some loss of wetlands to development or other uses if that loss cannot be avoided. What it does seek to ensure is that the overall quantity and quality of wetlands will remain stable. Efforts to restore and create wetlands must be undertaken on some sites to compensate for degradation and losses elsewhere (88).

Climate change may make it more difficult to halt the loss of wetlands and safeguard the multitude of functions and products they provide. This is particularly true in areas where wetlands are surrounded by development, limiting the areas into which wetland plants and animals can migrate. Changes in climate could cause far-reaching alterations in the complex ecological and hydrological systems that make up wetlands. For example, in the North Central States, increased temperatures and evaporation rates could cause many prairie-pothole wetlands to shrink or disappear, leading to further declines in already-diminished continental waterfowl populations (6). In the arid West, drier conditions combined with increased competition for water for human consumption and agricultural use could diminish the riparian and depressional wetlands (those along rivers and in low-lying areas) that now serve as habitat for diverse flora and fauna (84). Increased evaporation could also diminish water flow through streams and rivers in the Northeast and reduce water levels in the Great Lakes, leading to diminished water quality and eutrophication that could degrade wetlands. Rainfall may increase enough in the Southeast to offset the increased evaporation rates that accompany increased temperatures, potentially expanding the sites where wetland vegetation could grow, but gains may be limited by existing land uses and development. In coastal areas, a 20-inch (0.5-meter)[14] rise in sea level could inundate 35 percent of coastal wetlands nationwide by 2100 (84, 73, 74, 91). These and other changes may pose an enormous challenge for Federal efforts aimed at preventing further loss of wetlands.

Yet the same changes in climate will make maintenance of wetlands all the more important. Along coasts where climate change will likely lead to accelerated sea level rise, healthy wetlands can help control coastal erosion and flooding (see vol. 1, ch. 4). In urban areas, large amounts of water-impermeable paved and built surfaces have lead to an increase in runoff during storms, which could become more frequent in some areas as climate changes. Wetlands may help absorb and slow this runoff and prevent flooding. Wetlands filter water and improve water quality, which may become increasingly important in areas where climate change leads to drier conditions and thus to higher concentrations of pollutants in runoff and surface water (see vol. 1, ch. 5). Habitat provided by wetlands harbors diverse species of fish, waterfowl, invertebrates, and other wildlife; climate change may pose further threats to some species by eliminating habitat in some areas, making the remaining wetlands even more vital to efforts to protect endangered species (see ch. 5).

Wetland Management

Whatever is done to address the problems associated with wetland protection, restoration, and migration, those efforts will be more effective if the Nation addresses the problems caused by fragmentation-both of the landscape (see ch. 5) and of Federal agencies that oversee wetlands. Management decisions affecting wetlands are made by many different agencies, authorized by piecemeal legislation, often with conflicting goals or criteria for decisionmaking. All of the many scientists and managers consulted by the Office of Technology Assessment (OTA) emphasized the need for more integrated, coordinated management, planning, and decisionmaking for wet-

[14] To convert inches to meters, multiply by 0.025.

lands. Three aspects of coordination demand attention now:

- clarifying the goals for which wetlands are managed and amending or eliminating Federal programs that conflict with those goals;
- developing and applying a method for identifying which wetlands should receive the highest priority for preservation and restoration within particular watersheds; and
- using approaches that would coordinate management across resources and across watersheds or ecosystems (see ch. 1).

Integrated management should include intensive and broad-based monitoring to assess the rates at which features of wetlands are being affected by climate change, to evaluate the effectiveness of efforts to protect and restore wetlands, and to gauge the impacts of the degradation and loss of wetlands on the functions and products they provide. Monitoring is essential for identifying where limited funds should be directed.

Wetlands cannot be managed effectively in isolation. Many of the functions and products that make wetlands important-wildlife and fisheries habitat, flood control, biodiversity, and so on—depend on the integrity of a broad system of wetlands and water resources. Further, as described above, wetlands within watersheds are often linked by surface- or groundwater flows, so disturbance to one may affect others. For example, water diversions upstream of a wetland can degrade or destroy the wetland's vegetation and habitat quality by altering water and sediment flows, and overuse of groundwater for municipal or agricultural purposes may disturb wetlands throughout a given aquifer.

By considering wetlands along with the range of pressures on other resources, planners and managers can make better decisions about the most ''valuable' areas to be protected and restored in a given region. With the threat of climate change and the possibility that the characteristics of wetlands may change, a coordinated strategy for maintaining the functions and products of wetlands becomes all the more important.

The options presented in this chapter are based on maintaining the national commitment to protect the existing net quantity and quality of wetlands and, where wetlands have severely diminished or been degraded, to restore them. To maintain that commitment in the face of climate change, policy makers should focus on these four objectives, discussed in the following section:

1. Protect remaining wetlands. Mitigate the rate of loss by strengthening the protection and maintenance of existing wetlands, to increase the chances that wetlands will remain in locations from where they can migrate or adapt.
2. Restore what has been lost. Encourage restoration of wetlands to compensate for past and expected future losses.
3. Facilitate adaptive migration. Prepare for and assist in the migration of wetland species, which may be needed under a changing climate and accelerated sea level rise.
4. Improve coordinated management and monitoring.[15] Address the problems Of legal and institutional fragmentation. The absence of clearly stated authority for protecting wetlands, inadequate criteria for decisionmaking and lack of a coordinated effort to monitor and evaluate the quantity and quality of wetlands and the water systems that support them must be evaluated.

The Existing Regulatory Framework Governing Wetlands[16]

Regulation of wetlands has increased over the past two decades with the growing recognition of

[15] Coordinated management of wetlands cannot easily be accomplished without also considering management of water supplies (see vol. 1, ch. 5).

[16] This section draws heavily on material published in references 95, 108, 112 and on a contract paper prepared for OTA (120).

Tidal marshes are intermittently flooded, depending on tidal movement, and include the splash zone of coastal waters. These areas provide a filtering zone for freshwater systems whose outlets are on the coast. They also provide vital habitat for countless species of migratory birds.

the valuable functions and products they may provide. Wetlands are protected, acquired, managed, and restored under a complex array of Federal and State statutes, regulations, and programs, along with common-law public-trust doctrines, local land-use and zoning laws, actions by private landholders, and an increasing body of case law.

No single agency leads the effort to protect and regulate wetlands, and none has the protection of wetlands as its primary goal. Instead, major wetland programs are distributed among six Federal agencies: the U.S. Army Corps of Engineers (the Corps), the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (FWS), USDA's Agricultural Stabilization and Conservation Service (ASCS) and Soil Conservation Service (SCS), and the National Marine Fisheries Service (NMFS) in the National Oceanic and Atmospheric Administration (NOAA). Numerous other Federal agencies, including the National Park Service (NPS), the Bureau of Land Management (BLM), the Forest Service (USFS), NOAA'S Office of Ocean and Coastal Resource Management, and the Department of Defense (for wetlands on military bases and reserves), contribute to some aspect of the protection or management of wetlands.

Wetlands are not subject to any single comprehensive Federal law, but are covered by an amalgam of six statutes that address wetlands directly, more than 19 additional statutes with some impact on wetlands, two Executive Orders, and the various programs and regulations spawned by these statutes and orders. Moreover, approximately 100 bills addressing some aspect of wetlands were introduced in the 102d Congress. In addition, as described briefly below, many States and some municipal areas have enacted laws to protect wetlands; in some cases, these laws may be stricter than the Federal programs.

The major elements of the Federal "policy space'—that is, the existing institutions, legislation, and regulations--are described in detail in box 4-I. These programs can be categorized according to three types of government actions: direct Federal action, including regulation, acquisition, restoration, management, and oversight of wetlands; indirect Federal action that encourages the protection and restoration of wetlands through incentives to private property owners; and coordination and research activities that seek to provide information to managers and promote interaction among these individuals.

Direct *Federal Action*

Regulation and permitting are perhaps the most visible direct Federal controls on wetlands. The principal authority for Federal regulatory protection of private wetlands derives from the Federal jurisdiction over navigation. Section 404 of the Clean Water Act requires permits for discharges of dredge or fill materials into *navigable waters,* which originally included only those through which boats could travel but have been interpreted more recently to include almost all wetlands. This law gives the Corps and EPA a major role in wetland regulation at the Federal level. Most large-scale construction activities affecting wetlands are regulated under Section

Box 44—The Wetlands Policy Space

Regulatory activities and permitting programs--The Army C orps of Engineers, through Section 10 of the Rivers and Harbors Act of 1899, was given regulation and oversight authority of a permit program covering any dredge **and fill activities affecting navigable waters** in the United States. "Navigable waters" has been broadly defined by the Corps to include coastal and freshwater wetlands,[1] and starting in 1968, the Corps expanded the permit criteria beyond the original assessment of impacts on navigation to include assessments of impacts on fish **and** wildlife, conservation, pollution, aesthetics, ecology, flood-damage protection, recreation, water supply and quality, and others.

Although the Rivers and Harbors Act set forth the original regulatory authority, Section404 of the Federal Water Pollution Control Act (P.L. 92-500) of 1972, as amended by the Clean WaterAct of1977 (P.L. 92-217), has become the principal Federal program that regulates activities in wetlands. Section 404 requires that any landowner proposing to undertake activities that would result in the discharge of dredged material into U.S. waters, including wetlands, must first apply for and obtain a permit from the Corps. The application is reviewed in consultation with Fish and Wildlife Service **(FWS), the** Environmental Protection Agency (ERA), the National Marine Fisheries Service (NMFS), and the State where the activity is to take place. Permit applications are evaluated according to the extent of public and private need for the proposed project, whether alternative locations or less environmentally damaging methods could be used to achieve the stated project goals and result in less environmental impact, and the significance of the environmental impact the project may have.

Despite the Corps' broad interpretation of the extent of waters covered by permit requirements, the purview of the Section 404 program is limited in several ways. Numerous activities are exempted from Section 404 jurisdiction, including normal farming, forestry, ranching activities that do not convert natural wetlands to anew use (e.g., cropland), maintenance of flood-control structures, construction of bridges and dams, **and maintenance of** farm ponds, irrigation systems, and drainage ditches. Other activities fall under "general permits," which authorize activities expected to have minor impacts without the need for individual permits, as long as specified procedures for minimizing impacts are followed. On the basis of these limitations, the General Accounting Office (GAO) estimates that Section 404 "regulates only about 20 percent of the activities that destroy wetlands"(112).

Although States have the opportunity to assume primary responsibility for administering parts of the Section 404 program, only Michigan has done so. Many States are using their authorities under Section 401 to modify or deny Section 404 permits as a way to further protect wetlands under the Clean Water Act

Land acquisition--Federai legislation to acquire wetlands dates back to the Migratory Bird Hunting and Conservation Stamp Act (P.L. 94-215), passed in 1934. The act requires that waterfowl hunters purchase "duck stamps"; proceeds from stamp sales are placed into the Migratory Bird Conservation Fund to be used to acquire habitat for migratory birds. Since the inception of the program, more than $240 million worth of stamps have been

1 In1975,theCorps issued regulations defining "navigable waters"to include the following:"coastal waters, **wetlands, mudflats, swamps, and** similar **areas;** freshwater lakes, rivers, **and streams** that are used, were used in thepast, or are susceptible to use to transport interstate commerce, including all tributaries to these waters; Interstate waters; certain specified intrastate waters, the pollution of which would affect interstate commerce; and freshwater wetlands, including marshes, shallows, swamps and similar areas that are contiguous or adjacent to the above described lakes, rivers and streams, and that are periodically inundated and normally characterized by the prevalence of **vegetation** that requires saturated **soil** conditions for growth and reproduction" (34).

(Continued on next page)

Box 44-The Wetlands Policy Space--(Continued)

sold and 2.5 million acres (about 1 million hectares)[2] of habitat purchased Although some habitat purchases have been upland nesting areas, most acquisitions have targeted wetlands, particularly those in the prairie-pothole region of the North Central United States. In addition to purchasing land, the program seeks to preserve additional wetlands by acquiring perpetual easements under which landowners exchange their rights to drain, fill, burn, or level **wetlands** for a one-time or annual payment. Although most easement programs have targeted agricultural land, the Migratory Bird Hunting and Conservation Stamp Act authorizes the use of easements more generally. By the end of FY 1989, the program had spent approximately $49 million to obtain easements on 1.2 million acres of wetlands in the prairie-pothole region.

A more recent land-acquisition statute is the North American Wetlands Conservation Act of 1989 (P.L. 101-233), which established a cooperative effort between the United **States,** and Mexico **aimed at conserving or** restoring 6 million acres of wetlands in the prairie-pothole region to help revitalize **waterfowl populations. This act** authorized appropriations of up to $15 million for purchase of, and easements on, wetlands that will accomplish the goal. Although a substantial portion of the money is to be spent on projects in **Canada and Mexico, some 25 to 50 percent of the total may be spent in the** United States. Some funds are to be raised by excise taxes on ammunition, sporting arms, and archery equipment, as well as by fines for violations of the Migratory Bird Hunting and Conservation Stamp Act.

Various other programs support acquisition of wetlands.The Land and Water Conservation Fund Act of 1965 (LAWCON; P.L. 88-578) initiated a fund, bankrolled by fees from offshore drilling, to be used for the purchase of natural areas, including wetlands. Amendments in 1986added explicit authorization for LAWCON funds to be used to purchase wetlands, and further stipulated that States be required to consider wetlands in their **State Comprehensive Outdoor Recreation Plans, which they must complete** to qualify for grants from the LAWCON pool. FWS has used land acquisitions under this program to add to the National Wildlife Refuge System and to acquire crucial habitat areas for protecting endangered species. Critics charge that in recent years, LAWCONfunds have been underutilized and have not **adequately met the** mandate to acquire natural areas.

The Emergency Wetlands Resources Act of 1986 (P.L. 99-845) called for the development of a National Wetlands Priority Conservation Plan to direct the Federal Government's various wetland-protection efforts toward the most valuable areas. The plan was developed by FWS and issued In 1989. The act also authorized funds to acquire wetlands consistent with the plan, and provided various revenue mechanisms to support **wetland-protection and** -acquisition activities.

Several Federal programs support wetland preservation through easements. The Water Bank Act (P.L. 91-559), passed in 1970, established a fund to help preserve, maintain, and restore wetlands. Administered by the U.S. Department of Agriculture's (USDA's) Soil Conservation Service (SCS), water-bank funds are used* negotiate easements from farms who agree not to drain, fill, burn, level, or otherwise destroy wetlands or adjacent upland areas. Farmers receive annual payments ranging from $5 to $55 per acreforthe duration of the 10-year agreement (subject to review after the fourth year), after which the contracts maybe renewed. The Water Bank (Program has concentrated on acquiring easements in the prairie-pothoie region, where it had nearly 550,000 acres enrolled as of July 1991, at an annual cost of $8 million. The Conservation Reserve and Wetlands Reserve Programs described in the next section, also negotiate easements for the protection of wetlands.

[2] To convert acres to hectares, multlply by 0.405

[3] These figures are from reference 95. According to reference 112, the program had spent $102 million to acqulre fee-simple title to 584,000 acres of wetlands in the prairie-pothole region under the Small Wetlands Acquisition Program by the end of FY 1989.

Restoration—Perhaps because more than half of the Nation's wetlands have already been converted to other uses, particularly agricultural, recent policy initiatives have expanded the wetland-protection mandate beyond the early framework of preservation and regulation to include restoration. Several programs attempt restoration of agricultural land. Under the Conservation Reserve Program (CRP), authorized by the Food and Security Act of 1985 (P.L. 99-198), USDA can enter into contracts to pay farmers to remove highly erodible or environmentally valuable lands from production for 10 to 15 years in exchange for annual payments. A provision making farmed wetlands eligible for the conservation reserve was added in 1989. As of July 1991, nearly 34.5 million acres of farmland were enrolled in the CRP. USDA's Soil Conservation Service (SCS) estimates that approximately 410,000 acres were wetlands, for which rental payments were around $20.1 million annually. The wetlands Reserve Program (WRP), established by the Food, Agriculture, Conservation, and Trade Act of 1990 (P.L. 101-824), was established with the goal of restoring up to 1 million acres of wetlands that had been converted to agriculture. USDA's Agricultural Stabilization and Conservation Service (ASCS) makes annual payments for easement under which the farmer agrees to restore the wetlands. In addition, ASCS will provide up to 75 percent of the cost of restoring once-farmed wetlands placed under permanent easement and 50 percent of the cost of restoration for wetlands under 30-year easements.

The mitigation provisions of Section 404 of the Clean Water Act require that applicants for Section 404 permits offset unavoidable wetland impacts through the restoration or creation of wetlands. One party (often a government agency) restores or creates wetlands, t hus establishing marketable credits t hat are held in a bank. The bank can then arrange the sale of credits to Section 404 permit applicants to offset damage to wetlands that may be caused by the permitted activit y, often at a ratio greater than one-to-one. Achieving no net loss of wetlands requires greater than 100 percent replacement to compensate for areas where restoration does not succeed and for the time lag between restoration activities and the return of some measure of function. The permit applicant must purchase enough credit to offset potential wetland losses More t he permitted project begins and wetlands are destroyed. Under current policies, mitigation banking can be used only where loss of wetlands cannot be avoided and where there is no suitable site for restoration on the same property. If key areas for wetland migration are identified through the National Wetlands Priority Plan (described below), a wetland banking program could attempt to target those areas and allow mitigation credits for coastal development.

Other programs that support the restoration of wetlands are the Federal Aid in Wildlife Restoration Act of 1937 (P.L. 99-398), commonly known as the Pittman-Robertson Act and the Federal Aid in Fish Restoration Act of 1950 (P.L. 100-448), the Dingel l-Johnson Act. Through the Pittman-Robertson Act, FWS provides grants to States to cover up to 75 percent of the costs of acquiring, restoring, and maintaining wildlife areas, including wetlands. The act is funded by Federal excise tax on firearm and ammunition sales. The Dingell-Johnson Act uses Federal excise taxes on bait and fishing equipment to fund State projects up to 75 percent for "comprehensive fish and wildlife resource plans," including maintenance and restoration of wetland areas that provide needed habitat.

Coordinated planning and management--Because responsibility y for wetlands is divided among numerous laws, programs, and agencies, several policies have been put in place to coordinate planning and management. Some of these cover wetlands specifically, and others address wetlands within the larger context of natural resources such as water resources, coastal areas, and wildlife and endangered species habitat.

At least four laws and one Executive Order explicitly call for coordination among wetlands-planning and -management agencies. The Emergency Wetlands Resources Act of 1988 (P.L. 99-845) seeks to increase cooperation among the numerous agencies at the Federal, State, local, and private levels that protect, manage, and conserve wetlands. The act calls for FWS to develop a National wetlands Priority Conservation Plan, which would help decision makers at all levels of government identify the most valuable wetlands for protection. The act

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Box 44–The Wetlands Policy Space-(Continued)

also requires that State Comprehensive Outdoor Recreation Plans address wetlands, that FWS complete its wetland inventory mapping by 1988 (24), and t hat FWS conduct a study of how Federal programs affect wetlands. The Water Resources Development Act of 1990 (P.L. 101-640) embodies the call for no net loss of the Nation's remaining wetlands as part of the Army Corps of Engineers water-resources-development program. The act mandated that the Corps develop, in consultation with EPA, FWS, and other interested agencies, an action plan for achieving the no-net-loss goal for wetlands. The Coastal Wetlands Planning, Protection, and Restoration Act (P.L. 101 -646) established a planning process for protecting and restoring Louisiana coastal wetlands, and has been used to support various restoration projects. Executive Order 11990, Protection of Wetlands, was issued in 1977 to direct all Federal agencies to take action in carrying out their individual activities to minimize destruction, loss, and degradation of wetlands and to preserve and enhance wetlands and wetland functions and products.

Other programs that call for coordinated planning and management of wetlands as part of a larger set of natural resource issues include the Coastal Zone Management Act (P.L. 92-583), described in more detail under incentives (below and in vol. 1, ch. 4), the Fish and Wildlife Coordination Act (P.L. 89-72), the Endangered Species Act (P.L. 93-205), the National Environmental Policy Act (P.L. 91-190), and Executive Order 11988 (Flood Plain Management). The Fish and Wildlife Coordination Act requires that wildlife management be considered equal to other purposes in the construction of water-development projects, and authorizes FWS and NMFS to evaluate the potential impacts on fish and wildlife of Federal construction activities and projects being evaluated for Section 404 permits. The National Environmental Policy Act calls for a review of the environmental impacts of all proposed Federal projects, such as road construction and dam building, some of which pose significant threats to wetlands. The Endangered Species Act sets forth a procedure for listing threatened and endangered species and for designating the areas they need as habitat. Federal agencies are prohibited from undertaking or subsidizing any projects that will destroy habitat of the listed species. Because one-third of all listed endangered species depend on wetlands, this prohibition prevents some development in wetlands. Executive Order 11988 requires that all Federal agencies avoid supporting development in floodplain areas, either directly or indirectly; because many wetlands lie in floodplains, this directive could help protect wetlands.

Incentives and disincentives-Approximately 87 percent of the loss of wetlands in the past decade is attributed to agricultural conversions (108). Various Federal programs-including tax incentives, low-interest Farmers Home Administration (FmHA) loans, technical assistance, and commodity and price-support program--during the 1950s through the 1970s either directly or indirectly encouraged conversion of wetlands to agricultural uses. Thus, it is not surprising that many of the incentive and disincentive programs now seeking to protect and restore wetlands target agricultural lands. Furthermore, incentive and disincentive programs are in many cases the Federal Government's only chance to encourage conservation of the 74 percent of the Nation's remaining wetlands that are privately owned. The CRP and t he WRP, described above, offer direct payments to farmers as an incentive to set aside and restore former wetlands.

The Swampbuster program, initiated by the Food Security Act of 1985 (P.L. 99-198) and expanded by the Food, Agriculture, Conservation, and Trade Act of 1990 (P.L. 101-508), hinges on disincentives. As originally written, the Swampbuster program prohibited subsidies only if wetlands were converted (e.g., drained, filled, plowed, and burned)-after December 23, 1986-directly for the purposes of growing commodity crops (crop subsidies are explained in detail in vol. 1, ch. 6). This approach left a large loophole: farmers did not have to cultivate wetlands directly in a subsidized crop in order to boost their commodity acreage; rather, they could plant the wetland in an unsubsidized crop, such as forage, to free up other land to increase acreage for subsidized commodities. The 1990 amendments strengthened the program by calling for denial of crop subsidies if conversions of wetlands were used to boost acreage in commodity crops, even if the wetlands were not directly cultivated (1 12). Farmers caught in violation of Swampbuster regulations lose eligibility for all Federal farm

benefits, including commodity programs, crop insurance, and disaster payments, for that year and all subsequent years. As of August 1991, ASCS had withheld approximately $3.7 million in benefits because of Swampbuster violations (112).

Although agriculture has been a major focus of incentive and disincentive programs, legislation has sought to reduce or eliminate incentives for conversion of wetlands in other areas as well. The Coastal Barrier Resources Act (COBRA; P.L. 100-707) prohibits Federal expenditures or financial assistance (in the form of loans, grants, guarantees, insurance, payments, rebates, subsidies, and so on) to be used for development of coastal barrier islands. The act aims to reduce harm to human life, property, and natural resources, and because many coastal barriers are accompanied by wetlands, the withdrawal of Federal incentives to development may result in the protection of coastal wetlands. First established in 1982, the program was considerably expanded by 1990 amendments; the approach it espouses-withholding Federal subsidies-is now widely considered to be a good way to achieve environmental protection at low cost.

The Coastal Zone Management (CZM) Act of 1972 (P.L. 92-583, as amended) was designed to protect, restore, and develop coastal-zone resources and to encourage States to address ecological and aesthetic values, along with economic considerations, in managing their coastal areas. The CZM Act set forth a program in which States develop CZM plans according to certain guidelines imposed by the Federal Government. Because the requirements for CZM plans explicitly mandate the protection of ecological values of coastal resources (which include wetlands), and requirements for the plans already cover issues such as beach protection and shoreline erosion, the CZM program offers an appropriate mechanism through which the Federal Government could encourage the adoption of setbacks, which could allow wetlands room to migrate inland as sea level rises. (For a more detailed discussion, see vol. 1, ch. 4.)

An indirect incentive for wetland conversion that is being reined in is the National Flood Plain Insurance Program (NFIP). Established in 1968 by the National Flood Insurance Act (P.L. 90-448), the intent of the program was to encourage sound development policies in flood-prone areas. The act sought to accomplish this by requiring that communities develop and implement plans to regulate construction in flood plains in exchange for eligibility for Federal disaster-relief funds. Although the intent was to minimize floodplain development (and many wetlands occur in coastal and inland floodplains), the effect was sometimes to encourage development by providing subsidized insurance. The Federal Emergency Management Agency (FEMA), which administers the program, has called for stricter regulations of development in t he most flood-prone areas. (See vol. 1, ch. 4, for more information about flood insurance and other emergency-assistance programs.)

Research, inventory, and monitoring-Research on and monitoring of wetlands is conducted by several different Federal agencies under various programs, as well as by researchers in land-grant and sea-grant institutions, private institutions, and conservation organizations. Over the past two decades, long-term research and monitoring of wetlands has been conducted through programs such as FWS's National Wetlands Inventory and National wetlands Research Center; the National Science Foundation's long-Term Ecological Research (LTER) and Land Margin Ecological Research (LMER) programs; EPA's office of Research and Development and Wetlands Research Program; the National Oceanic and Atmospheric Administration's National Estuarine Research Reserve System, National Estuary Inventory, Estuarine Habitat Program, and sea level monitoring; the Corps' Waterways Experiment Station, Wetlands Research Program, and Dredged Materials Program; USDA's National Resource Inventory (conducted by SCS); various water- and weather-monitoring programs carried out by the U.S. Geological Survey and the National Weather Service; and others. New efforts include FWS's Gap Analysis Project (GAP) and EPA's Environmental Monitoring and Assessment Program (EMAP), which are described in chapter 5.

SOURCES: U.S. Congress, Office of Technology Assessment, *Wetlands: Their Use and Regulation,* OTA-O-206 (Washington, DC: U.S. Government Printing Office, March 1984); D.E. Willard et al., "Wetland Vulnerabilities to Climate Change," contractor paper prepared for the Office of Technology Assessment, August 1992; U.S. General Accounting Office (GAO), *Wetlands Overview: Federal and State Policies, Legislation, and Programs,* GAO/RCED-92-79FS (Washington, DC: U.S. GAO, November 1991).

404; many normal, ongoing agriculture and forestry practices are specifically exempted. The program does not cover draining of wetlands unless the activity involves a discharge, nor does it explicitly cover isolated wetlands (i.e., nonnavigable ones) unless there is a connection to interstate commerce (e.g., use by migratory waterfowl). overall, the program protects coastal, and particularly tidal, wetlands relatively well, but the exemptions exclude from coverage activities responsible for approximately 80 percent of the destruction of wetlands (1 12).

Federal acquisition of wetlands deemed particularly valuable for wildlife is done through outright purchase or through the establishment of easements, as authorized by legislation including the Migratory Bird Hunting and Conservation Stamp Act (also referred to as the Duck Stamp Act), the Emergency Wetlands Resources Act of 1986 (P.L. 99-645), and other laws related to the National Wildlife Refuge System. The National Wildlife Refuges now contain some 30 million acres of wetlands. Smaller acquisitions have been made through the National Estuarine Research Reserve System (NERRS), which now holds 425,000 acres of estuarine wetlands and adjacent waters and uplands, and the Marine Sanctuaries Program, which contains some wetlands along with open waters in eight sanctuaries. Additional wetlands have been acquired as part of areas purchased for parks or designated as wild and scenic rivers or wilderness areas (see ch. 5).

Restoration and management of wetlands are carried out through diverse programs. The Coastal Wetlands Planning, Protection, and Restoration Act (P.L. 101-646), passed in 1990, established a restoration cost-sharing program open to coastal States, with a particular--but not exclusive-emphasis on restoring coastal wetlands in Louisiana. NOW'S Damage Assessment and Restoration Program conducts habitat restoration and research in coastal wetlands that have been severely contaminated. The Conservation Reserve and Wetlands Reserve Programs, established by Title XII of the Food Security Act of **1985** (P.L. 99-198) and the Food, Agriculture, Conservation and Trade Act of 1990 (P.L. 101-624) both allow USDA to enter into contracts with farmers to set aside and pay up to 50 to 75 percent of the cost of restoration. Ongoing programs conducted by the Army Corps of Engineers, which is responsible for constructing and maintaining dams, flood-control structures, and navigable rivers and harbors, have given the agency a role in affecting wetlands through engineering techniques such as sedimentation control and use of dredged materials to create or restore wetlands.

Indirect Federal Action

Various incentive programs encourage wetland protection and restoration, and some disincentives have been established to discourage activities that degrade or destroy wetlands. The Water Bank Act (P.L. 91-559) provides payments to farmers as an incentive to refrain from draining wetlands important to migratory waterfowl. The "Swampbuster" provision of the Food Security Act of 1985 withdraws Federal benefits (i.e., crop subsidies and disaster insurance) from farmers who drain wetlands. The Coastal Barrier Resources Act (COBRA; P.L. 100-707) denies such benefits as flood insurance and infrastructure support to development projects that would alter coastal barrier islands to the point where they would be unable to provide certain fictions, such as erosion control. The Tax Reform Act of 1986 (P.L. 99-514) disallowed deductions for farm expenses incurred in draining wetlands (e.g., by constructing drainage ditches).

Coordination and *Research*

At least four laws and one Executive Order explicitly call for coordination among agencies responsible for wetland planning and management, and at least seven agencies plus numerous private and conservation organizations conduct research on and limited surveys of wetlands. The "Coordinated Planning and Management" and "Research, Inventory, and Monitoring" sections

in box 4-I describe these programs. Despite these and other programs, however, no coordinated long-term Federal effort tracks the overall quality of wetlands nationwide.

State, Local, *and Private Programs*

In addition to the many Federal programs, States, municipalities, and private conservation organizations also share responsibilities for protecting wetlands. States and municipalities play a major role in regulation through their implementation of land-use controls and planning. Loca1 land-use efforts, such as storm-water management and setbacks (see vol. 1, ch. 4) from wetlands and adjacent areas, can be effective in maintaining wetlands and their functions. Many States have also adopted various measures that address coastal, inland, or all wetlands within their boundaries, either specifically or in the context of water-quality control and broader mandates to protect natural areas (see table 4-2).

State and local parks and refuges are key to preserving the natural values of wetlands (see ch. 5). Private conservation groups such as The Nature Conservancy, the Audubon Society, and Ducks Unlimited, in addition to numerous regional and local land trusts, join the effort to protect and maintain wetlands.

Because many different organizations at all levels of government, along with private agencies, conduct programs that affect wetlands, any Federal efforts to respond to the impacts of climate change on wetlands must recognize and interact with the full range of programs. In many cases, State and local agencies have the ability to form partnerships with Federal agencies to accomplish things that Federal agencies by themselves cannot.

POLICY OPTIONS

OTA has identified many actions that the Federal Government could take to help protect existing wetlands, restore degraded areas, facilitate migration, and promote coordinated management and monitoring. These actions, summarized in table 4-3, run the gamut from incremental changes in existing programs to major policy revisions or additions. Many of the strategies are interconnected, comprising different approaches for accomplishing the same goal. To cope most effectively with the potential impacts of climate change on wetlands, the best approach would be to undertake the strategies together. A specific set of options, based on measures that are particularly feasible or urgent and on opportunities that may arise in upcoming legislative reauthorizations, should be pursued. Those options are suggested in the final section of this chapter, "First Steps."

Protect Existing Wetlands

Minimizing the current rate of loss should be the first priority of any comprehensive plan to help wetlands adapt to climate change. As noted above, the Nation has already lost more than half its wetlands. Maintaining what is left is a necessary first step to ensure that some wetlands will persist regardless of the rate and severity of climate change. An active protection strategy will yield benefits even if climate change proceeds more slowly or less severely than predicted. The goal of protecting existing wetlands has received widespread and bipartisan support and, despite the difficulties in achieving it thus far, that goal should remain. Climate change only makes protection efforts more urgent.

Direct Federal Action

Option 4-1: *Implement and oversee the no-net-1oss policy. The* no-net-loss policy has not yet been incorporated into the legal and regulatory framework in inexplicit and accountable way. In 1991, the Administration issued a plan for protecting wetlands that would include strengthening acquisition programs, revising the wetland-delineation manual, and improving regulation of wetlands under Section 404 of the Clean Water Act (25, 112). Although a few of the specific provisions of the plan were implemented, many of the more significant changes were not, due in

Table 4-2—Responding to Climate Change Impacts on Wetlands: Summary of Reported State Wetland Protection Programs[a]

State	Coastal permit program	Freshwater nontidal program	Comprehensive coastal and inland program	Formal policy, regulation, or guidelines for issuing Section 401 certification for wetlands
Alabama	●	—		●
Alaska	—	—		●
Arizona	NA	—		●
Arkansas	NA	—	—	—
Connecticut	NA	—	●	●
Delaware	●		—	—
Florida	●	■	●	●
Georgia	●	—	—	—
Hawaii	—	—	—	●
Illinois	—	—	◆	—
Indiana		—	—	●
Iowa	NA	—	—	●
Kansas	NA	—	—	●
Kentucky	NA	—		●
Louisiana	●		—	●
Maine	●	■	●	—
Maryland	●	◆	—	●
Massachusetts	●	■	●	●
Michigan	●	●	●	●
Minnesota	—	—	—	●
Mississippi	●	—	—	●
Missouri	NA	—		●
Nebraska	NA	—		●
Nevada	NA	—	—	●
New York	●	●	●	●
North Carolina	●		—	●
North Dakota	NA	—		—
Ohio	—	—		●
Oklahoma	NA	—	—	●
Oregon	●	●	●	●
Pennsylvania	●	■	●	●
Puerto Rico	—	—		●
Rhode Island	●	●		●
South Carolina	●			●
South Dakota	NA	■	—	—
Tennessee	NA	●	—	●
Texas	—	—	—	●
Vermont	NA	●	●	●
Virginia	●	—		●
Washington	—	—		●
West Virginia	NA	—	—	●
Wisconsin	●	■	●	

a●=Program in place; +=program in place, legislation enacted but not yet implemented, regulations to be developed; D=program in place, can be delegated to local or regional authorities; —=no data; NA=not applicable.

SOURCE: U.S. Environmental Protection Agency (EPA), National Water Quality *Inventory* 1990 Report to Congress (Washington, DC: U.S. EPA, 1992).

Table 4-3--Examples of Laws and Agencies That May Be Affected by Various Policy Options[a]

Option	Affected laws and/or agencies	Option	Affected laws and/or agencies
Protect existing wetlands		**Improve coordinated management and monitoring**	
Implement and oversee the no-net-loss policy,	CWA-reconstituted WRC	Identify, assign priorities to wetlands important now, under climate change,	LAPS, GAP, C-CAP, NWPCP, NAWMP, EMAP
Expand coverage and strengthen enforcement of CWA Section 404.	COE, EPA, FWS, NMFS	Clarify national goals for wetland protection,	CWA; EO 11990
Acquire key wetlands that may be lost soon	FWS, NPS, NOAA	Ensure that Federal policies do not inadvertently lead to loss of wetlands.	CWA, CZMA, COE, ASCS, SCS, OEP, Swampbuster
Design Federal projects to incorporate climate change predictions and safeguard water and sediment flow to wetlands	NEPA, COE, BOR	Promote integrated resource management at the watershed level by offering financial and other incentives.	NFIP, CZMA
Augment and coordinate monitoring of wetlands	All **agencies coordinated under interagency task forces;** FWS, EPA, USGS, NMFS	Use legislative reauthorizations to explore new ways to protect biodiversity and ecosystems and to integrate preservation and restoration.	CWA, ESA, DOI, NPS, NBS
Require direct payments	WRP, Water Bank Act	Support research on the impacts of climate change on wetlands	EPA, NOAA, FWA, NMFS
Require traded obligations	U.S. Tax code, CWA, Swampbuster		
Eliminate Federal incentives for wetland destruction.	ASCS and SCS cost-sharing; COBRA		
Restore degraded or converted wetlands		**Facilitate migration**	
Fully fund existing restoration programs.	WRP	Require building setbacks from coastal and riparian wetlands	CZMA, NFIP
Require that restoration projects set goals and monitor and evaluate success.	CWA	Identify wetlands most able to migrate and sites to which they could migrate.	LAPS, GAP, C-CAP, NWPCP, NAWMP, EMAP
Use opportunities to restore and preserve reclaimed wetlands,	FmHA CEP; DOD base closures	Acquire lands important for migration (including buffer zones).	Duck Stamp Act, LWCF, WRA, WRP and CRP
Remove hard engineering structures that degrade wetlands; restore normal water and sediment flow,	COE, BOR, FERC review	Reduce Federal subsidies such as CZMA funds and flood insurance in **areas that have not established setback or "planned-retreat" policies.**	CZMA, NFIP
Utilize dredged-materials program to facilitate wetland restoration,	COE		
Target key areas for wetland restoration programs.	CWA, COE, EPA, FWS, NMFS		

a ASCS=Agricultural Stabilization and Conservation Service; BOR=Bureau of Reclamation; C-CAP= Coastwatch-Change Analysis program; CEP=Conservation Easement Program; CoBRA=Coastal Barrier Resources Act; COE=U.S. Army Corps of Engineers; CRP=Conservation Reserve Program; CWA=Clean Water Act; CZMA=Coastal Zone Management Act; DOD=U.S. Department of Defense; FWS=U.S. Fish and Wildlife Service; EMAP=Environmental Monitoring and Assessment Program; EPA= Environmental Protection Agency; ESA=Endangered Species Act; EO=Executive Order; FERC=Federal Energy Regulatory Commission; FmHA=Farmers Home Administration; GAP=Gap Analysis Program; LAPS=Land Acquisition Priority System; LWCF=Land and Water Conservation Fund; NAWMP=Norfh American Waterfowl Management Plan; NFIP=National Flood Insurance Program; NEPA=National Environmental Policy Act; NOM= National Oceanic and Atmospheric Administration; NMFS=National Marine Fisheries Service; NPS=National Park Service; NWPCP=National Wetlands Priority Conservation Plan; OEP=Office of Environmental Policy; SCS=Soil Conservation Service; USGS=U.S. Geological Survey; WRA=Emergency Wetlands Resources Act; WRC=Water Resources Council; WRP=Wetlands Reserve Program,

SOURCE: Office of Technology Assessment, 1993.

large part to the controversy that surrounded the proposals. Two previous Executive Orders addressing activities that could destroy wetlands are also still in effect (No. 11990, Protection of Wetlands, and No. 11988, Floodplain Management); although many agencies have promulgated rules and regulations in accordance with these directives, no oversight mechanism exists.

Implementation and oversight of the no-net-1oss policy could be achieved in several ways. The Water Resources Council (WRC), which operated from 1967 until 1982 to recommend coordinated water policies and oversee the integrated plarnning efforts of river basin commissions, could be funded again with oversight of wetlands as a key function.[17] (See vol. 1, ch. 5, for more discussion of the WRC.)

Alternatively, an interagency committee or task force, composed of representatives from each agency whose activities affect wetlands, could be appointed and directed to) oversee wetland policy and to maintain an inventory of the quantity and quality of wetlands. The leadership of the task force could rotate among the members, or the task force could be placed under the coordination and oversight of the new White House Office of Environmental Policy (OEP), which could play a role similar to that of the Council on Environmental Quality in the past. Both types of bodies would be primarily advisory. A third alternative would be to appoint a single lead agency to oversee the implementation, but such a designation may cause contention among the several agencies that could legitimately claim a leading role. This coordinated effort could oversee wetland research and data gathering as well.

No matter which institution is selected to implement and oversee the no-net-loss policy, no single regulatory program can by itself accomplish the goal. That will require coordinated effort by many agencies under many programs, including programs that affect wetlands only indirectly. Furthermore, active Federal oversight of the no-net-loss policy will not eliminate problems that stem from unclear goals for wetland protection (discussed in more detail below), but it could help to minimize them.

Option 4-2: *Expand coverage and strengthen enforcement of CWA Section 404. The* no-net-loss policy is also constrained by the fact that the Clean Water Act Section 404 permitting program (described in box 4-I and ch. 5) covers activities responsible for approximately 20 percent of the destruction of wetlands (112). Permits cover only activities that involve discharges of dredged or fill material, but not activities such as water diversions, draining, channeling, and clearing that may also destroy wetlands but that do not involve a discharge. These constraints allow for incremental losses that appear small, but have a large cumulative effect (1 15). Even where permits do offer the Federal Government a powerful lever with which to control impacts on wetlands, goals for protecting wetlands are not clearly stated in Section 404. Thus, expanding the coverage of Section 404 to include more activities and small wetlands could greatly increase protection of existing wetlands (88).

Even where Section 404 could cover a given area and activity, program implementation is decentralized and has not been uniform across regions. Other limitations are the large number of permit applications that must be reviewed each year (approximately 15,000 individual permits) and the limited resources with which to conduct the review and to monitor compliance. The Section 404 permit program could be enhanced by increasing finding and by requiring that individual permit decisions be selectively reviewed by an oversight body, as recommended above, for consistency and adherence to the goals of wetland protection,

Option 4-3: *Target acquisition programs to wetland types that may be lost soon. Several*

17 The Council, authorized by the Water Resources Planning Act of 1965 (PL. 89-80), was never officially dismantled, but the funding was discontinued. Reconstituting the Council would require appropriations rather than new legislation.

programs seek to preserve wetlands by either acquiring the land outright or acquiring perpetual easements under which landowners exchange their rights to drain, fill, bum, or level wetlands for a one-time or annual payment (see box 4-I). These acquisition programs are, however, constrained by limited funds. For example, FWS has about $150 million per year to spend on all acquisitions (not just on wetlands), and funds are limited in other programs as well.

Federal acquisition programs are not likely to be expanded given the currently tight restrictions on all new Federal expenditures. Thus, it is essential that ongoing acquisitions made with existing funds focus on important areas currently in danger of being lost. Developing a list of high-priority wetlands within an integrated-resource-management framework (described below) will help direct funds to areas and wetland types that are either insufficiently protected now or that could be especially vulnerable to climate change.

Option 4-4: *Design Federal projects to incorporate climate change predictions and to safeguard water and sediment flow to wetlands. The* environmental impact statements (EISS) required under the National Environmental Policy Act (NEPA; P.L. 91-190) are intended to ensure that the potential environmental impacts of projects that the Federal Government oversees are carefully considered and disclosed to the public. However, wetlands have continued to be degraded in many areas despite the EIS process, in part because wetlands are easily affected by alterations in water and sediment flow in adjacent areas-even if the wetland itself is not dredged or filled. Since 1989, the Army Corps of Engineers has had a policy of evaluating current and potentially accelerated rates of sea level rise as part of its planning process (94). NEPA, or its implementing regulations, could be amended to require that all future Federal projects consider the effects of the proposed action on the water and sedimentation regimes that supply wetlands, both now and under climate change.

Option 4-5: *Augment and coordinate monitoring of wetlands.* Although numerous research and monitoring programs cover some aspect of wetlands, no single program comprehensively addresses the quantity and quality of wetlands today. The National Wetlands Inventory (NWI) conducted by FWS has been invaluable in recent efforts to understand patterns of wetland loss. However, its statistical sampling methods can only reveal gross changes in the amount of wetlands. NWI cannot supply information on the status or quality of the wetlands not sampled. The ongoing National Water Quality Assessment conducted by the U.S. Geological Survey (USGS) measures water-quality patterns nationwide but does not relate water quality to loss or degradation of wetlands. EPA's Environmental Monitoring and Assessment Program (EMAP) was initiated in 1987 to assess and report on the status and trends of ecological conditions in U.S. natural resource systems. EMAP includes a wetland program that aims to evaluate and monitor the quantity and quality of wetlands on a regional scale. The program is still in the pilot stage, but it could provide a sound basis for coordination if a consensus can be reached on data-collection protocols and dissemination. The Department of the Interior's (DOI'S) Gap-Analysis Program (GAP), described in a later section, also offers potential for coordinated monitoring. Finally, the National Biological Survey (NBS), a program recently initiated by DOI, may prove invaluable to coordinated monitoring and management among agencies (see ch. 5). The goals of NBS are to combine biological research activities within DOI into an independent, non-advocacy biological science arm.[18]

The Federal Government could strengthen the protection of wetlands by reducing the overlap of these and other existing research and monitoring efforts. Coordinated monitoring could help iden-

IS E. T. LaRoe, Director, Cooperative Research Unit Center, U.S. Fish and Wildlife Service, personal communication, March 1993.

tify **areas** that should be protected now, and could provide a baseline against which to gauge the future impacts of climate change. Increased funding for programs such as EMAP, GAP, and NBS, along with other monitoring and inventory efforts, would aid in coordinating these efforts among the agencies (see ch. 5).

Indirect Federal Action

The Federal Government could attempt to make it difficult to destroy wetlands and profitable to preserve them. Numerous programs over the years have offered direct or indirect subsidies or incentives to private landowners for construction in wetlands and flooddplains. Among these are the U.S. Tax Code, which for decades allowed tax write-offs for the construction of drainage and irrigation systems (often resulting in the conversion of wetlands to agricultural uses); various crop-support and commodity programs (see vol. 1, ch. 6); and federally supported disaster and flood insurance, which may have the unintended effect of promoting development in flood-prone areas. (Disaster and flood insurance are discussed in more detail in vol. 1, chs. 4 and 5.) To minimize the loss of wetlands, subsidies and tax incentives for protecting wetlands should be created or expanded while subsidies and incentives for converting wetlands should be reduced or eliminated.

Option 4-6: *Pay to protect wetlands on private property. This* kind of program pays landowners to refrain from destroying wetlands. Under programs such as the Water Bank Act and the Duck Stamp Program (under the Migratory Bird and Conservation Stamp Act), Congress has given agencies authority to pay farmers who agree not to drain, plow, burn, or otherwise harm wetlands on their property. Funding for such programs could be increased or at least maintained at the authorized levels.

Option 4-7: *Allow trading of regulatory or tax obligations for wetland protection.* A reduction in existing regulatory or tax obligations can be traded for wetland protection. For example, the Federal Government could create tax incentives for granting conservation easements on wetlands, or for outright donations of wetlands to conservation agencies. The Tax Reform Act of 1986 decreased the deductions possible for charitable giving, which includes the granting of conservation easements to Federal or State agencies. Introducing the tax incentives for wetland preservation could assist protection efforts. The Open Space Preservation Act of 1991 (H.R. 2149), introduced during the 102d Congress, sought to accomplish this goal.[19]

Some form of traded obligations might also be used as part of watershed-based efforts to achieve pollution control. The acquisition and restoration of wetlands near water bodies could be used as one element in a comprehensive water-quality program. Such wetlands could serve as water-filtering buffers to help control non-point-source pollution from agricultural lands and urban areas. Many communities have had to support expensive tertiary treatment processes at their sewage treatment plants in order to meet the stricter water-quality standards under the Clean Water Act, even though non-point-source pollution constitutes a significant part of the problem. Despite investments of $260 billion (1990 dollars) in the construction of sewage treatment plants during the 1970s and early 1980s, the non-point-source-pollution problems in many water bodies, such as the Chesapeake Bay, have still not been resolved (68).

Municipalities and States that are able to acquire, restore, and maintain sufficient amounts of wetlands to attain measurable improvements in water quality might be permitted to delay or scale down installation of additional sewage-treatment capabilities within the same watershed. Effluent

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[19] H. R. 2149 proposed to 'exclude from the gross estate the value of land subject to a qualified Conservation easement if certain conditions are satisfied and to defer some of the scheduled reduction in estate tax rates. '

from sewage treatment plants or storm-water drainage should not be discharged directly into existing wetlands, although some municipalities have constructed wetlands specifically for that purpose. Alternatively, some portion of the Federal grants to States for constructing treatment plants could be used for purchasing wetlands located in areas within the watershed (see vol. 1, ch. 5, options 5.1 and 5.2). Any program designed to use wetlands to help control non-point-source pollution would have to carefully avoid degrading existing wetlands.

Option 4-8: *Eliminate incentives to destroy wetlands. The* Swampbuster program (see box 4-I) is a prime example of reducing Federal benefits-in this case, crop subsidies and disaster payments— in order to protect wetlands. Swampbuster could be expanded to cover any activities adjacent to wetlands, such as ditching and diverting water for irrigation purposes, that result in destruction of wetlands.

For wetlands on federally owned land, including a significant share of the riparian wetlands in the West, the Federal Government could use fees charged for grazing permits to create an incentive for lessees to protect riparian areas from overuse by cattle. Offering a fee reduction or rebate to lessees who implement certain measures for restoring riparian wetlands might be an alternative way to protect wetlands on Federal land.

A far-reaching proposal that has received considerable attention since it was proposed by DOI in 1983 is to "CoBRAcize wetlands," that is, to adopt an approach for all wetlands similar to that used in the Coastal Barrier Resources Act, which eliminates Federal subsidies that indirectly support destruction of coastal barrier islands (see box 4-I and vol. 1, ch. 4). COBRA denies flood insurance, new Department of Veterans Affairs and Farmers Home Administration (FmHA) loans, Urban Development Action Grants, Community Development Block Grants, road-building monies, and other Federal support to development projects that would alter the natural functions of coastal barrier islands. The program increases environmental protection while saving the Government money, provides an alternative to land acquisition as a means of protection, does not interfere with any State or local programs, and avoids the issue of property takings (50).

Restore Degraded or Converted Wetlands

Recent reports documenting the extent to which wetlands have been destroyed over the past two centuries have stimulated the development and use of methods to restore them (see box 4-A). Restoration of wetlands has already been done with varying degrees of success, and the goal of restoring them to compensate for historic losses has been promoted by both the National Wetlands Policy Forum (NWPF) and the National Research Council (NRC). NRC recommended that the Nation undertake a program to restore 10 million acres of degraded wetlands by the year 2010 (68).

Within the Federal Government, restoration is practiced in two distinct contexts. On public lands, wetlands may be restored, created, or enhanced as part of the overall management strategy of wildlife refuges and other natural areas, or as a way to aid in flood control and maintenance of water quality.[20] In the regulatory setting, restoration may be performed for the purpose of mitigation-that is, the Government may require developers to restore or create wetlands in exchange for receiving a CWA Section 404 permit if damage to wetlands cannot be avoided. There are still many questions concerning the success rates of these practices.

[20] As currently used by wetland scientists, *restoration* means "returned from a disturbed or totally altered condition a previously existing natural or altered condition by some action of man," whereas *enhancement means "the increase in* one or more values of all or a portion of an existing wetland by man's activities, often with the accompanying decline in other wetland values." For example, efforts to enhance the value of a wetland as habitat for migratory waterfowl may include pumping water into the wetlands or controlling water levels; although this may make the area more attractive for ducks, it may affect other functions such as flood control *or* biodiversity. Creation is "the conversion of a persistent non-wetland area into a wetland through some activity of man" (R.R. Lewis, in ref. 59).

Little comprehensive monitoring has been performed to document the success of restoration efforts in either context (37, 59). The evaluations that have been done suggest that restoration has been most successful in coastal and estuarine wetlands. It has been somewhat less so in riparian areas, forested or shrub-dominated freshwater wetlands, and other areas where the hydrology is not well-understood. Restoration is problematic for isolated prairie potholes, which are typically fed by groundwater. Flood-control and waterfowl-production functions are the most readily restored; rejuvenating fisheries and other biological functions, as well as pollution filtering and aesthetics, is typically more difficult (59). Restoration projects may fail because people do not understand well enough how these systems work, the construction supervision is improper, the location of the project is innapropriate, or management plans for the area once it has been restored are lacking.

It is probably impossible to fully recreate or restore a wetland, or any other natural system. Any attempts at restoration in exchange for unavoidable alterations to wetlands must ensure that the uncertainty about the success of the project is taken into consideration. Nonetheless, within the broader context of managing and conserving wetlands under changing climate conditions, restoration is likely to become an increasingly important part of the effort.[21] A coordinated management policy would seek to preserve and restore a range of wetlands from coastal to inland areas within a watershed.

Various programs enacted over the past decade have sought to restore wetlands to make up for past degradation and 1oss.[22] The Wetlands Reserve Program (WRP), established in 1990, aims to set aside and restore up to 1 million acres of wetlands that had been converted to agriculture (see box 4-I). The Coastal Wetlands P1anning, Protection, and Restoration Act set forth a program and authorized funds for protecting and restoring coastal wetlands, particularly in Louisiana. The act also provided funds for restoration projects on approximately 6 million acres of wetlands important for migratory waterfowl—with an emphasis on the prairie-pothole region-as called for in the Fish and Wildlife Service's North American Waterfowl Management Plan. Mitigation-banking efforts under Section 404 can incorporate restoration of wetlands, referred to here as *wetland banking. This ap*proach to wetland conservation allows wetlands to be destroyed-when destruction is unavoidable-in exchange for restoring comparable wetlands elsewhere. Federal funds slated for improving grazing lands or other resources could be targeted for wetland restoration and enhancement.[23] Alternatively, because receipts from grazing fees are dwarfed by revenues from timber and recreation on Federal land, perhaps more of these monies could be channeled to protection and enhancement of the riparian wetlands in arid regions.

Option 4-9: *Fully fund existing restoration programs.* Farmers selected to participate in the WRP must develop restoration plans for lands to be set aside as part of the wetland reserve. The Federal Government pays up to $50,000 per year to landowners for property easements and shares 50 percent of the restoration costs on lands covered by 30-year easements. For lands under permanent easement, the Federal Government

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21 Efforts to create wetlands may also be necessary, although generally restoration is preferable because it is more successful and less costly (37, 59).

22 No@ however, that restoration goals may vary within and among regions. For example, in urban areas, flood control and water filtering are highly valued functions of wetlands. Restoration of these functions does not require a fully vegetated wetland that supports fish and wildlife; the most important part of restoring these functions maybe simply to clear obstacles from the site and plant enough vegetation to anchor the soil. In other sites, including those in areas important for wildlife but in which considerable habitat has been destroyed, a more complete restoration project to rehabilitate a broader range of functions, including wildlife habitat, may be preferred.

23 Currently, 5(.) percent of Bureau of Land Management and Forest Service grazing- fee receipts are targeted for improving rangelands under the Federal Land Policy and Management Act of 1976 (P.L. 94-579).

reimburses 75 percent of the costs. The WRP goal to set aside and restore up to 1 million acres of wetlands over a period of 5 years has been hampered by funding cutbacks. The WRP program received $46 million in funding during its fist year (1991), but in 1992, Congress eliminated all funding for the WRP for FY 1993 (55). In the 1995 Federal budget, funding has been restored to $65 million, with a goal of enrolling some 75,000 acres in the program during the year. Additional wetland-reserve easements may be purchased with emergency funds authorized for Mississippi flood relief.

Other restoration efforts include the Army Corps of Engineers' Wetlands Research and Dredged Materials Programs, which use dredged material for wetland-restoration projects; NOAA's Habitat Restoration Program, a program directed specifically at coastal wetlands; and the interagency Coastal America program based in Washington, DC, which operates at the national, regional, and local levels to coordinate restoration and mitigation projects. If these programs were to address wetlands that lie somewhat above the present sea level, they might be able to provide a buffer against the loss of coastal wetlands to accelerated sea level rise.

Option 4-10: *Increase Government oversight of restoration and mitigation; require that projects set goals to monitor and evaluate success. Typical goals in* restoring wetlands include the maintenance of enough vegetation to aid flood control or water retention and the restoration of some habitat for fish and wildlife. Fully restoring all natural functions of a wetland has proved very difficult to do, and each case presents different challenges. However, among the goals that can reasonably be expected for all projects are sustainability and adaptability: the restored wetland should be able to survive the range of current conditions and adapt to at least small changes in climate. Clear goals and a comprehensive understanding of wetland processes will increase the probability of the success of restoration efforts.

The Federal Government could enhance restoration efforts by increasing oversight of and guidance to the States and local agencies that ultimately manage the process. Different strategies are needed for efforts on public land (restoration) and private land (mitigation). For restoration projects on public land, an interagency committee could be convened to administer the program. For mitigation projects on private lands, CWA regulations could include explicit directions calling for goals to be clearly identified at the outset of any project, as well as for long-term monitoring to be conducted to ensure that the goals are achieved. In addition, there would have to be mechanisms for collecting, storing, and analyzing data and for evaluating the success of the project over time.

The Federal Government can also set standards for contractors who perform restoration and can train the regulators who oversee the projects. One approach for managing the restoration of wetlands under Section 404 mitigation requirements is to have private parties pay into a restoration fund and let the Government contract out the work to approved technicians. The private parties benefit because they have an interest in the project's success, and the approach would also facilitate Government oversight because contractors who did not perform to standards could be barred from participating in future projects.[24]

Option 4-11: *Use opportunities to restore and preserve reclaimed wetlands. The 1987* Agricultural Credit Act (P.L. 100-233) established the Farmers Home Administration Conservation Easement Program (FmHACEP), which authorizes USDA to grant or transfer easements for the preservation of lands that have reverted to the FmHA through farm foreclosures or voluntary conveyance. The program is not aimed at wetlands, but it could be used to assist restoration of wetlands that have been converted to agriculture. Not all repossessed lands merit easements because agricultural use often transforms wetlands past the point of return by draining, channeling,

24 K. L. Erwin, Consulting Ecologist, Inc., personal communication November 1992.

and filling, but full use of the program could bolster restoration efforts.

Another potential opportunity for reclaiming and restoring wetlands is provided by military-base closures. Decisions on the disposition of land in closed military installations could include consideration of whether wetlands exist or could be restored, particularly in sites containing functions, species, or habitat that are not well-represented in existing preserves, or in areas where the flood- and erosion-control functions would be highly valued.

Option 4-12: *Remove hard engineering structures that degrade wetlands, where feasible, and attempt to restore normal water and sediment flow.* A vital first step in restoring many degraded wetlands is to restore normal water and sediment flows in river and hydrological systems that have been altered. Construction of water-supply and -control structures has in the past often led to unforeseen damage to wetlands both upstream and downstream. This became vividly apparent with the Mississippi River flooding in the summer of 1993. The system of levees along the banks of the Mississippi has isolated it from the wetlands that once absorbed and slowed food waters. The levees have made the river deeper and swifter, with the consequence that when a breach occurs-as happened repeatedly during the recent flooding-the resulting flood is much more destructive than it would otherwise have been.

In some areas, there may be opportunities to remove structures not vital to the protection of developed areas. Both the Corps and the Bureau of Reclamation could review whether existing structures associated with the degradation of wetlands are still necessary and appropriate. Given the extensive damage due to the flooding of the Mississippi, Congress might consider removing some of the levees, allowing certain undeveloped areas to seine as floodwater-detention areas, and restoring wetlands within these areas. These flood-detention areas might also be targeted for conservation-reserve and wetland-reserve expenditures (see option 4-13 and the "first steps" at the end of the chapter).

The Corps, for example, has already begun to modify the structures that forced Florida's meandering Kissimmee River into a straight channel, which led to destruction of wetlands and wildlife habitat. Alleviation of impacts from water-diversion projects should receive high priority because restoring natural water regimes in a wetland plays an essential role in restoring the functions. Efforts to conserve the coastal wetlands of Louisiana, described in box 4-F, illustrate some approaches to restoring water and sediment flow. For example, the Mississippi River Gulf Outlet is a navigation channel that could be considered for modification because it is no longer used, but its presence allows salt water to flow into and harm freshwater wetlands (1 13).

Option 4-13: *Use the Dredged Materials Program to facilitate wetland restoration.* During the past decade, the by Corps of Engineers has dredged an average of 334 million cubic yards (255 million cubic meters)[25] of material annually, from rivers, harbors, and estuaries, to maintain navigable waterways and for other purposes. Some of this material could be used to replace sediments in subsiding coastal wetland areas or in areas that may be inundated if sea level rises. One estimate suggests that 103 square miles (270 square kilometers)[26] could be covered to a thickness of 3 feet each year with uncontaminated dredged material.[27] However, the use of dredged material to restore wetlands is controversial because some of this materialism contaminated and could be harmful to wetland vegetation and wildlife. The Corps has been directed to dispose of dredged material in the least costly manner, which is usually at sea. However, if the States

25 To convert cubic yards to cubic meters, multiply by 0.765.

26 To convert square miles to square kilometers, multiply by 2.590.

27 L. Vallianos, Policy and Special Studies Division, Institute for Water Resources, U.S. Army Corps of Engineers, personal Communication July 19, 1993.

wish to put the dredged material to some use, the Federal Government will contribute half of the increased costs of disposal if States pay the other half. If the Federal Government wishes to promote the use of uncontaminated dredged material for wetland restoration and enhancement, it may want to increase the subsidy it currently gives to the States.

Indirect Federal Action

Option 4-14: *Target key sites for a wetland-restoration program.* Wetland restoration has been attempted inside and outside the regulatory process. More of an effort must be made in the preliminary stages of projects to develop sound construction and implementation plans. Equally important are the development and application of monitoring and evaluation plans.

Small-scale successes in restoration projects could be used as models for larger-scale efforts, and an expanded regional restoration program could be created to target high-priority areas within watersheds for restoration. It could incorporate planning and management for restoration on public lands, as well as restoration for Section 404 permits. This way, a full array of wetlands could be maintained and restored, which would offer the broadest range of adaptive possibilities. A broader strategy for restoring wetlands, termed *wetland banking,* could be keyed to the watershed level to create a market for wetland restoration in cases where destruction of wetlands cannot be avoided. Wetland banks allow for the marketing of credits for wetland restoration and creation as part of the CWA Section 404 program (see box 4-A). A watershed-level wetland bank may be better able to protect functions and products of wetlands than could numerous individual on-site mitigation efforts.

So far, wetland banks, have been used very little, and most of them have been setup by State transportation departments rather than by private industry.[28] Still, they offer greater potential for Federal or regional government oversight than do site-by-site mitigation efforts. As noted earlier, individual mitigation projects are difficult to enforce effectively, and the goals of mitigation projects have often not been stated clearly enough to determine whether the project succeeded (31).

Current Section 404 practice requires that a wetland be restored to the extent practicable, as determined by the Army Corps of Engineers and EPA. However, specific criteria that can be used to measure the success of a project designed to restore wetland functions is often lacking. Furthermore, under standard permit requirements, individual mitigation efforts are to be undertaken ''on site' and 'in kind' wherever possible--that is, wetlands are to be restored on or near the original site, with the attempt to duplicate the characteristics of the original wetland. However, if these objectives are not applied carefully within the context of the overall watershed, they can inadvertently lead to the development of numerous small, isolated, and fragmented restoration projects (such as a pond surrounded by shopping-mall parking lots or tucked between the buildings of an office complex). Larger, better-connected projects are preferable and more likely to succeed. Regional wetland-restoration projects might best preserve habitat values. Some resource managers have suggested, for example, that restoring wetlands adjacent to the Everglades would be a better strategy than on-site mitigation for wetland losses in the urban corridor of coastal South Florida because it would reestablish historic water flows and effectively recreate a larger, contiguous wetland.

Failure to recognize that various wetlands and their functions are not interchangeable has led to the downfall of some mitigation projects. A regional wetland-restoration strategy could avoid some of the problems of case-by-case mitigation by encouraging mitigation projects on the watershed level-on the basis of an evaluation of the overall distribution and functions of wetlands

[28] M. J. Bean, Senior Attorney, Environmental Defense Fund, personal communication, Oct. 16, 1992.

within the watershed-and by targeting mitigation to areas that need it the most. By allowing developers to pay into a bank, rather than contracting mitigation projects individually, a wetland-banking system could allow greater Government oversight and more rigorous standards for restoration. Finally, by combining the planning and management of Section 404 mitigation with the restoration projects that take place on Federal lands, the Government could achieve greater integration of its wetland-protection and -restoration goals.

Standards for mitigation banking have been proposed as guidelines in some regions by the Corps and EPA but have not been uniformly imposed.[29] Additional Federal guidance could link mitigation to a watershed-based priority plan that seeks to maintain an array of wetlands. Participation in regional wetland-restoration schemes should not take the place of avoiding impacts to wetlands. Where destruction of a particular wetland cannot be avoided, however, regional restoration projects could offer additional leverage for implementing wetland-restoration goals on a watershed basis. The regional restoration schemes could require that more wetland areas be restored or created than destroyed.

Facilitate Migration

The biggest issue facing coastal wetlands is whether they will have room to migrate as the sea level rises.[30] Because so many coastal wetland areas already have a limited potential to grow, the remaining areas for coastal wetland migration could be identified and protected, either through direct acquisition or through a program of easements. Vegetation in riparian wetlands may also need to migrate toward new sites along rivers and streams. Regional predictions of climate change effects will probably not be available for a decade or so, which will make identification of lands needed for wetland migration difficult. However, if planners and managers do not initiate efforts now to identify where wetlands will be lost first and where wetlands might be able to relocate, the Nation may be ill-prepared to take advantage of the advances in global climate modeling to protect its natural resources. (See ch. 2 for a discussion of climate models.) While this information is being developed, sensible land-use policies-particularly in coastal areas--can be implemented to allow wetlands to persist as well as to reduce property loss and Federal payments such as disaster relief and subsidized flood insurance (see also vol. 1, ch. 4).

Many measures that could assist migration of wetlands will involve State and municipal land-use laws and plarnning efforts. Although the participation of States and municipalities is vital, the following sections focus on Federal actions, including those that might provide incentives for appropriate programs at the State and local levels.

Direct Federal Action

Option 4-15: *Require building setbacks from coastal and riparian wetlands.* A national policy requiring buildings to be set back a given distance from the coast according to actual or estimated sea level rise-as practiced by the State of Maine and described in more detail in volume 1, chapter 4-would not only allow room for wetlands to migrate, but could have the additional benefit of protecting or minimizing the loss of coastal buildings.

Option 4-16: *Identify the wetlands that are most able to migrate and sites to which they could migrate.* Identification of key areas for wetland migration in both coastal and riparian areas could be done through modifications of the various priority-setting mechanisms described below under "Improve Coordinated Management, Monitor-

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29 Ibid.

30 Of course, even with sufficient land, the vegetation of wetlands may change from one type to another, Or some of the functions may be dimini shed, but without sufficient land for migration, loss of wetlands is guaranteed.

ing, and Research. ” To date, none of these programs has included climate change considerations, although existing statutes would provide sufficient authority to do so. However, a congressional directive, perhaps with appropriations attached for the purchase of land for wetland migration, might ensure that agencies consider the need for land for migration.

Although accurate predictions of how climate change will affect wetlands and where they might migrate must await further research (outlined below), rough guesses of vital migration areas can be made now. EPA has already conducted several studies that combine various estimates of sea level rise with data on coastal topography and existing development to predict where coastal wetlands will be inundated (4, 52, 53, 73, 75). Periodic reassessments should be made as new information is obtained.

Option 4-17: *Acquire lands important for migration (including buffer zones). In the* absence of precise information on where wetland species might migrate, priority should be given to acquiring and protecting buffer zones around existing wetlands. This would be a logical first step in wetland protection. Buffers can help guard the present functions of wetlands, including flood control and the provision of wildlife habitat, and can also allow room for wetlands to grow in any direction in the event of climate change. Estimates of how far a buffer should extend from the wetland boundary vary, with a suggested range of 100 to 500 feet, depending on the area and the functions. Existing acquisition programs could be directed to incorporate suitable buffers with every purchase of wetlands or, at a minimum, with the purchase of wetlands most at risk from climate change.

A potential stumbling block is that acquisition programs focus on areas that are valuable now, rather than on those that could become valuable in the future. Although some areas important for future migration also have a high present value, such as the remainin g coastal uplands in Florida, this may not be true of all sites. Setting priorities that balance a known present value with an uncertain future value would be quite difficult but could be accomplished through effective watershed-management plans, as discussed below and in volume 1, chapter 5.

Indirect *Federal Action*

Option 4-18: *Reduce Federal subsidies, such as Coastal Zone Management (CZM)funds and flood insurance, in areas that have not established setback or “planned-retreat” policies. The* State of Maine recently adopted, as part of its coastal-dune regulations, a rule known *as planned retreat,* which ‘‘allows use of coastal property for constructing a building, provided the building is removed at some future time when the shoreline (high water line) has advanced to the building location” (86). Such planned-retreat policies are generally aimed at protecting coastal structures from costly damage, but these policies may also provide significant benefits for coastal wetlands. The Federal Government may best rely on State and local setbacks because land-use-control measures (such as zoning) generally lie within the purview of States or local areas. States’ abilities to require or induce private-property owners to allow coastal wetlands to migrate with a rising sea, rather than to construct bulkheads, walls, and other structural protections, will hinge on the balance of private-property rights with the public-trust doctrine (which is rooted in case law and varies from State to State). However, the planned-retreat rule could be added to the Federal CZM program requirements, which explicitly mandate the protection of ecological values of coastal resources (including wetlands) and already cover issues such as beach protection and shoreline erosion. Of course, CZM cannot require States to take action, but it can offer a financial incentive.

Another way for the Federal Government to promote buffer zones is to eliminate funding for activities that encourage development in areas adjacent to wetlands or in floodplains (e.g., by using the COBRA approach as described in option 4-8). One potential weakness of the COBRA

approach is that it addresses new construction and land uses. Existing activities, no matter how heavily subsidized by Federal programs in the past, are not covered by the act.

The Community Rating System (CRS) is a recent Federal Emergency Management Agency (FEMA) initiative that provides an incentive for communities to implement activities that exceed the minimum requirements of the National Flood Insurance Program (NFIP) (see vol. 1, ch. 4). Program participants can receive discounts in flood insurance premiums of up to 45 percent by promoting activities that protect floodplains and reduce flood losses. These activities include relocating structures at risk, removing debris from waterways, and preserving open space.

The CRS could be expanded to include the restoration of floodplains, which occupy a large part of the U.S. landscape and include many of the Nation's most productive wetlands and most fertile soil. Their functions include storing and conveying water, moderating floods, retarding erosion and sedimentation, maintaining water quality, recharging groundwater, and providing wildlife habitat. Under expansion of the program, credits could be given for actions that help to restore these functions.

Improve Coordinated Management, Monitoring, and Research

All three strategies presented above-protect existing wetlands, restore: degraded ones, and facilitate migration-will be more effective and efficient if applied within a regulatory and management framework that clearly identifies priorities and goals and that is coordinated across relevant programs and institutions to achieve those goals. This theme of coordination, which is important not just for wetlands but for all natural resources, is discussed in chapter 1; recommendations specific to wetlands, which can involve gradations from direct to indirect action, are described below.

Direct or Indirect Federal Action

Option 4-19: *Identify and assign priorities to the wetlands that are most important to protect and restore.* Identifying and ranking the wetlands that are the most important to protect now and in the future would help efforts to protect and restore wetlands. A listing of priorities that includes climate change considerations could be used to direct regulation, acquisition, and incentive programs throughout all levels of government. To be most effective, lists should be compiled for each major watershed and should be developed in consultation with all relevant stakeholders.

None of the Federal priority-setting mechanisms now used to direct wetland acquisition and restoration-the Land Acquisition Priority System (LAPS), the National Wetlands Priority Conservation Plan (NWPCP), the North American Waterfowl Management Plan (NAWMP), the Gap-Analysis Program (GAP) and the Coastwatch-Change Analysis Program (C-CAP--explicitly address the potential effects of climate change and its implications for setting priorities.

LAPS is a decisionmaking process used by FWS to set priorities for all of its land acquisitions, including wetlands. NWPCP, required by the Emergency Wetlands Resources Act of 1986, was developed by FWS to set criteria for identifying important wetlands to be acquired by Federal and State Governments. NAWMP, developed by FWS under the authority of the North American Wetlands Conservation Act of 1989, sets priorities for wetland conservation and restoration in the prairie-pothole region.

GAP is a land-use-analysis program at FWS that seeks to identify priorities for protecting endangered species. It addresses this and other goals by examining patterns of land use and ownership and comparing them with species habitat, vegetation, and other ecological features of the land (see ch. 5).

Run by the NOAA Estuarine Habitat Program, C-CAP provides information on the location, health, and loss rates of coastal habitats. To help set priorities for restoration, C-CAP has devel-

oped a standard protocol for rapid assessment of changes in habitat quality in coastal wetlands and the adjacent uplands.

These programs could be tied together and expanded for use in all Federal, State, and local efforts, including those involving regulatory, incentive, disincentive, acquisition, and restoration activities. In addition, they could be used to help identify indicators of climate change and methods of addressing these changes. Priorities could be reviewed periodically as new and more region-specific information on potential climate impacts is developed.

A potential problem with any general priority or ranking scheme for wetlands is that it assumes **that the** functions and products of different types are understood well enough to be compared and ranked accurately. Such schemes can easily fall prey to problems of focus and scale. For example, in coastal areas, FWS might need to evaluate whether top priority should be given to acquiring areas most at risk from sea level rise or to maintaining an interconnected network of lands. For inland wetlands, including riparian and depressional systems, it will also be important to identify water sources linked to the health of wetlands and to acquire water as well as land rights, where necessary.

Option 4-20: *Clarify national goals for wetland protection.* Climate change makes the need for clearly stated policy goals pressing. However, the Federal no-net-loss policy for wetlands is not clearly expressed in the regulatory framework, nor has it been completely embodied in Federal actions that provide incentives or disincentives to private activities that affect wetlands. Laws and programs should balance the need to preserve existing wetlands in the places where they are now with where they may or may not be in the future due to climate change.

One way to clarify wetland-protection goals is to use the opportunity offered by the upcoming reauthorization of the Clean Water Act to make its wetland-protection mandate explicit. Section 404 could be expanded, new sections could be added, or the focus of the entire statute could be changed from water quality to sustainable water use with watersheds. Another possibility would be to formulate a single new piece of legislation that would address wetlands specifically-a Federal omnibus wetland act. Some States have adopted such legislation. For example, Florida's Henderson Wetland Act of 1984 provides equal protection for all the State's waters and expands the State's jurisdiction over protection.

Option 4-21: *Ensure that Federal policies do not inadvertently lead to loss of wetlands. Many* Federal programs affect wetlands by encouraging different patterns of land use and development. The Emergency Wetlands Resources Act of 1986 called for the Department of the Interior (DOI) to conduct and publish a comprehensive review of the impacts of Federal programs on wetlands. One part of that review has been completed and released (102), but the second volume has yet to be published. Volume I discusses the lower Mississippi alluvial plain and prairie potholes. Volume II was to include: the Everglades, coastal Louisiana, Galveston Bay, Puerto Rico, California's Central Valley, western riparian areas, and Alaska. DOI should be urged to complete and issue Volume II promptly. Once the review is available, Congress may wish to consider amending programs that conflict with protection.

Option 4-22: *Promote integrated resource management at the watershed level.* Greater coordination and integration of programs and institutions would allow more-efficient management of wetlands. The Federal Government should explore ways to institute watershed-based management programs that would consider wetlands along with other natural resources. There is currently a great deal of interest in watershed management, and S. 1114, the Water Pollution Prevention and Control Act of 1993, contains a major section promoting it. Watershed management essentially recognizes that the many uses of water are tied together and that problems and their solutions are most effectively considered on a system-wide basis.

Managing wetlands within a watershed context would require an improved understanding of the types and amount of wetlands needed within any given watershed to support ecological functions and to maintain the entire system in a healthy state. This approach would require inventories of land, water, and wetlands so that models can be developed for estimating how changes in some parts of the system (whether caused by climate or by human activity) would affect functions elsewhere.

Many efforts already exist that could form part of an integrated management program, and numerous studies have recommended the need for such an approach (see ch. 1 and vol. 1, ch. 5). Programs with some form of integrated planning have been attempted in States including California, Florida, Georgia, Oregon, and Massachusetts. These programs should be reviewed so that any Federal action would complement-and avoid inadvertent interference with-successful programs at the State level.

Option 4-23: Use legislative *reauthorizations to integrate preservation and restoration. The* Clean Water Act and, to a lesser extent, the Endangered Species Act (P.L. 93-205) are vital elements of national wetland policies. Both are up for reauthorization. The controversy surrounding the Clean Water Act stems partially from the lack of consensus about what the wetland mandate should be. Also, the effectiveness of the species-by-species approach used in the Endangered Species Act has been questioned by critics as well as by some who fully support its goals. Reauthorization offers an opportunity to explore new ways to protect and restore biodiversity and ecosystems, both in wetlands and elsewhere.

Under the Clean Water Act, pilot projects in watershed management could be initiated in small watersheds where wetlands are either threatened or already degraded. Wetland-restoration projects could be systematically monitored and evaluated to explore whether restoration techniques can rejuvenate a full range of wetland functions and support the original diversity of flora and fauna in addition to accomplishing more case-specific goals, such as providing habitat for waterfowl.

Option 4-24: *Support long-term research and monitoring on the impacts of climate change on wetlands.* Efforts to identify which lands will be most valuable as the climate changes-and, in particular, estimating where migration of wetlands might occur-face a daunting lack of detailed regional climate predictions and a poor theoretical understanding of how climate and other hydrological and ecological changes will affect wetlands. Key areas of investigation that are needed include:

- establishing a baseline of wetland conditions nationwide and a long-term monitoring network to document rates and types of change;
- assessing how wetlands have already been altered in areas where the water regime has changed in ways similar to those predicted for climate change;
- determining g water needs for healthy wetlands and the hydrological connections between wetlands and groundwater;
- evaluating salt movement through estuaries, coastal aquifers, and inland surface- and groundwater systems;
- researching the adaptability of key wetland species (both plants and animals);
- assessing how extreme events such as storms and droughts affect the functioning of wetlands; and
- developing and evaluating restoration and creation technologies.

Some of these topics are already the focus of research efforts at the Fish and Wildlife Service's National Wetlands Research Center and the Army Corps of Engineer's Wetlands Research Program at the Corp's Waterways Experiment Station in Vicksburg, Mississippi. EPA's Environmental Monitoring and Assessment Program has also proposed monitoring some pertinent indicators of the condition of wetlands. The NBS (see ch. 5)

could also incorporate wetland assessment into its broader mandate.

FIRST STEPS

This chapter has described how the current policies for protecting wetlands in the United States fall short of meeting the stated no-net-loss policy goal. Because climate change will exacerbate existing stresses on wetlands as sea level rises in coastal areas and as some interior wetlands dry out, the problems encountered under current wetland-protection policies will become more acute. Thus, policies designed to facilitate adaptation of wetlands in the future must, at a minimum, seek to accomplish four goals:

1. establish a clear national policy for wetland protection,
2. integrate protection across agencies and across other natural resources,
3. establish and implement a priority plan for acquisition and protection, and
4. enhance protection of especially vulnerable wetlands.

The Federal Government cannot use all policy tools to address these problems with equal assurance of success. Because 74 percent of all wetlands are on privately owned lands, the potential for direct Federal intervention is limited. Given the available policy levers (regulation, acquisition, incentives, and research), the limited funds for programs, and the level of scientific understanding of the impacts of climate change on wetlands, OTA has identified the following strategies as potential "frost steps" to respond to climate change and the threats it poses to wetlands. This list comprises policies that should be initiated based on concerns about climate change now.

- Revise the Clean Water Act. The Clean Water Act (CWA), which is up for reauthorization, could be revised in various ways to improve the protection of wetlands. The absence of a clear and explicit mandate hampers wetland protection. Regulatory activity under Section 404, for example, is limited because of ambiguity about its applicability to wetlands that are periodically inundated or saturated-rather than wet all year. Furthermore, because existing statutory language emphasizes only the protection of surface-water quality, drainage activity that may destroy wetlands is not regulated unless it results in the discharge of materials into protected waters. Congress could revise the statutory language of CWA to spell out a clear goal of protecting wetlands and to extend regulation to all activities that destroy wetlands. A bill introduced during the 103d Congress, S. 1304, proposes revisions along these lines.

  Another potential target for revision is the provision for mitigation banking. If properly managed, regionally coordinated mitigation projects could offer both greater regulatory flexibility and more-effective restoration within watersheds. CWA could be modified to establish uniform standards for mitigation activity and to require that activities be comprehensively monitored and evaluated for success. Success should be determined by the restoration of the destroyed wetland's unique function and value as well as at least equivalent lost-wetland area.

  The act could also be expanded to promote comprehensive watershed management. Regional watershed management could be fostered by revising CWA to set up coordinating mechanisms and incentives. Wetland protection and restoration could be linked to regulations covering non-point-source pollution to create a more integrated approach to achieving mandatory water-quality levels. The bills now under consideration include a watershed-management component, but the key will be to ensure that wetlands are incorporated into this broader water-quality framework.

- Develop and implement priority plans to coordinate wetland protection across agencies. Federal agencies including the Fish and Wildlife Service (FWS), the Environmental Protection Agency (EPA), the Army Corps of Engineers (Corps), and the U.S. Department of Agriculture (USDA) have developed different methods for making decisions about wetland protection. Methods for monitoring, delineating, and assigning priority for acquisition or restoration vary according to the particular goals and responsibilities of each agency. These differences have led to enormous actual and perceived disparities in the protection of wetlands.,

  The various Federal agencies (e.g., the Corps, EPA, FWS, and USDA) should coordinate the designation of wetlands that are deemed to be high priority for protection, restoration, or acquisition. Development of regional priority plans and oversight of their implementation could be supervised by a multiagency task force composed of representatives from all Federal agencies that have responsibilities for wetlands. Alternatively, the White I-louse Office of Environmental Policy (OEP) could provide coordination and oversight. Once in place, Federal agencies could be directed to use this uniform priority plan in making decisions on CWA Section 404 permitting, land acquisition, easements, and restoration (through Swampbuster, Wetlands Reserve, and other programs). Such a plan should be updated periodically to reflect changing circumstances, including the anticipated effects of climate change.
- Ensure that Federal policies and incentives are consistent with wetland protection. Although Executive Order 11990, issued in 1977, directs Federal agencies to consider how their policies will affect wetlands, there are still many opportunities to revise existing Federal programs to enhance wetland protection.

Congress should urge the Fish and Wildlife Service to complete its review of the impact of Federal programs on wetlands that was mandated by the 1986 Emergency Wetlands Resources Act. Prompt completion of the report could assist further efforts to identify programs that could be modified to reduce their impacts on wetlands.

Even without the review, some programs appear to be prime candidates for modification. For example, Congress could amend the Coastal Barrier Resources Act to expand its coverage to include a broad range of coastal wetlands. Extending the act would not only help protect wetlands, but would also reduce Federal expenditures and, by slowing development in high-hazard coastal areas, could cut down on damage to human lives and property during coastal storms. Congress could also act to increase incentives to private landowners to set aside and restore wetlands. For example, Congress could maintain full funding for the Wetlands Reserve Program in future appropriations. Tax benefits for landowners who grant conservation easements on or make outright donations of wetlands to Federal, State, or local conservation organizations could be increased, as called for in H.R. 2149 (102d Congress).

Increased coordination across Federal programs could also promote wetland protection. Wetlands could be included among the issues considered in the Western Water Policy Review enacted by the 102d Congress (see vol. 1, ch. 5), perhaps considering ways to link conservation of riparian wetlands to measures promoting water-use efficiency. Agencies should be urged to take full advantage of the Farmers Home Administration (FmHA) Conservation Easement Program to review lands under FmHA loan defaults and to acquire title or easements to high-priority wetlands. Similarly, lands on decommissioned military bases should be reviewed for