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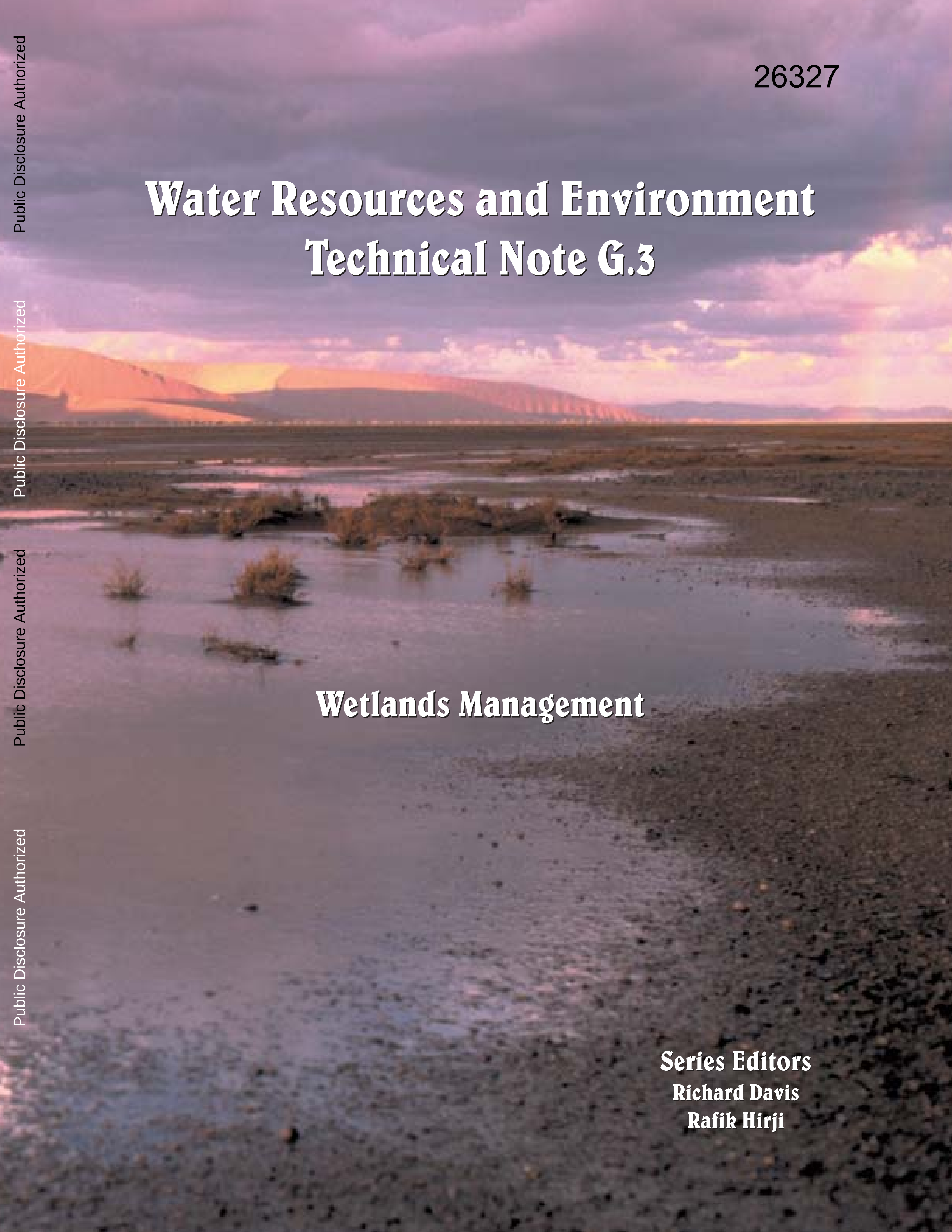

Water Resources and Environment Technical Note G.3

Wetlands Management

Series Editors
Richard Davis
Rafik Hirji

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Author
Joop de Schutter

Technical Adviser
Stephen Lintner

Editor
Robert Livernash

Production Staff
Cover Design: Cathe Fadel

Design and Production:
The Word Express, Inc.

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Wetlands in sand dunes,
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FOREWORD

The environmentally sustainable development and management of water resources is a critical and complex issue for both rich and poor countries. It is technically challenging and often entails difficult trade-offs among social, economic, and political considerations. Typically, the environment is treated as a marginal issue when it is actually key to sustainable water management.

According to the World Bank's recently approved Water Resources Sector Strategy, "the environment is a special 'water-using sector' in that most environmental concerns are a central part of overall water resources management, and not just a part of a distinct water-using sector" (World Bank 2003: 28). Being integral to overall water resources management, the environment is "voiceless" when other water using sectors have distinct voices. As a consequence, representatives of these other water using sectors need to be fully aware of the importance of environmental aspects of water resources management for the development of their sectoral interests.

For us in the World Bank, water resources management–including the development of surface and groundwater resources for urban, rural, agriculture, energy, mining, and industrial uses, as well as the protection of surface and groundwater sources, pollution control, watershed management, control of water weeds, and restoration of degraded ecosystems such as lakes and wetlands–is an important element of our lending, supporting one of the essential building blocks for sustaining livelihoods and for social and economic development in general. Prior to 1993, environmental considerations of such investments were addressed reactively and primarily through the Bank's safeguard policies. The 1993 Water Resources Management Policy Paper broadened the development focus to include the protection and management of water resources in an environmentally sustainable, socially acceptable, and economically efficient manner as an emerging priority in Bank lending. Many lessons have been learned, and these have contributed to changing attitudes and practices in World Bank operations.

Water resources management is also a critical development issue because of its many links to poverty reduction, including health, agricultural productivity, industrial and energy development, and sustainable growth in downstream communities. But strategies to reduce poverty should not lead to further degradation of water resources or ecological services. Finding a balance between these objectives is an important aspect of the Bank's interest in sustainable development. The 2001 Environment Strategy underscores the linkages among water resources management, environmental sustainability, and poverty, and shows how the 2003 Water Resources Sector Strategy's call for using water as a vehicle for increasing growth and reducing poverty can be carried out in a socially and environmentally responsible manner.

Over the past few decades, many nations have been subjected to the ravages of either droughts or floods. Unsustainable land and water use practices have contributed to the degradation of the water resources base and are undermining the primary investments in water supply, energy and irrigation infrastructure, often also contributing to loss of biodiversity. In response, new policy and institutional reforms are being developed to ensure responsible and sustainable practices are put in place, and new predictive and forecasting techniques are being developed that can help to reduce the impacts and manage the consequences of such events. The Environment and Water Resources Sector Strategies make it clear that water must be treated as a resource that spans multiple uses in a river basin, particularly to maintain sufficient flows of sufficient quality at the appropriate times to offset upstream abstraction and pollution and sustain the downstream social, ecological, and hydrological functions of watersheds and wetlands.

With the support of the Government of the Netherlands, the Environment Department has prepared an initial series of Water Resources and Environment Technical Notes to improve the knowledge base about applying environmental management principles to water resources management. The Technical Note series supports the implementation of the World Bank 1993 Water Resources Management Policy, 2001 Environment Strategy, and 2003 Water Resources Sector Strategy, as well as the implementation of the Bank's safeguard policies. The Notes are also consistent with the Millennium Development Goal objectives related to environmental sustainability of water resources.

The Notes are intended for use by those without specific training in water resources management such as technical specialists, policymakers and managers working on water sector related investments within the Bank; practitioners from bilateral, multilateral, and nongovernmental organizations; and public and private sector specialists interested in environmentally sustainable water resources management. These people may have been trained as environmental, municipal, water resources, irrigation, power, or mining engineers; or as economists, lawyers, sociologists, natural resources specialists, urban planners, environmental planners, or ecologists.

The Notes are in eight categories: environmental issues and lessons; institutional and regulatory issues; environmental flow assessment; water quality management; irrigation and drainage; water conservation (demand management); waterbody management; and selected topics. The series may be expanded in the future to include other relevant categories or topics. Not all topics will be of interest to all specialists. Some will find the review of past environmental practices in the water sector useful for learning and improving their performance; others may find their suggestions for further, more detailed information to be valuable; while still others will find them useful as a reference on emerging topics such as environmental flow assessment, environmental regulations for private water utilities, inter-basin water transfers and climate variability and climate change. The latter topics are likely to be of increasing importance as the World Bank implements its environment and water resources sector strategies and supports the next generation of water resources and environmental policy and institutional reforms.

Kristalina Georgieva
Director
Environment Department

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INTRODUCTION

Many wetlands around the world are being lost or are under threat. In many cases, losses are caused by direct development activities such as irrigation systems, conversion to agricultural land, reclamation for urban expansion, or aquaculture such as prawn culture in mangrove systems in South and Southeast Asia. In other cases, it is the result of off-site developments such as excessive upstream water use, exemplified by the loss of the Amu Darya and Syr Darya river delta ecosystems in the Aral Sea Basin; water pollution, such as the influence of the Aswan Dam on sediment deposition in the Nile Delta; or the introduction of invasive species. Water withdrawals are projected to increase by 18 percent in developed countries and by 50 percent in developing countries over the next 25 years, so these threats to wetlands are likely to worsen and have significant impacts on the natural environment and human welfare.

Existing wetlands, such as floodplains and river estuaries, are often highly productive and play a very important role in both ecological functioning and human subsistence.[1] The loss of wetlands is posing a significant threat to aquatic biodiversity; more than 800 species of plants and animals currently threatened with extinction are found in freshwater ecosystems.

The World Bank recognizes the importance of wetlands in its policies as well as in its operations. OP 4.04 (Natural Habitats) states that the Bank will not support the significant conversion of natural habitats unless there are no feasible alternatives for the project and its siting, and comprehensive analysis demonstrates that overall benefits from the project substantially outweigh the environmental costs. These habitats include freshwater lakes and rivers, coastal marshes, wetlands, and estuaries. The 1993 Water Resources Management Policy notes the need to "protect environmental resources in floodplains and wetlands," and the recent Water Resources Sector Strategy recognizes that wetlands provide valuable environmental services to dependent communities. An Update to the Environmental Assessment Sourcebook[2] provides advice on assessing wetland ecosystems. The Bank has supported regional wetland assessments–such as the 2000 map of Wetlands in Asia and the production of a booklet with Wetlands International–and has invested in projects that include wetland protection and restoration in most parts of the developing world. This Note provides technical support to the integration of wetlands management principles into water resources planning and development, as well as strategic instruments such as country environmental analysis.

In the next section, we describe the different types of wetlands and their occurrence in various biogeographic regions. We then describe the rapid loss of these wetlands around the world and the causes of this loss. Although some of this loss can be attributed to natural events, most of it arises from human activities such as land use conversion and diversion of river flows for agricultural development. The

Photo by Curt Carnemark, World Bank

Wetland, Seychelles

[1] World Bank (2002) states that the productivity of estuaries is around 50 times that of grasslands and 8 times that of wheat fields.

[2] World Bank (2002).

beneficial functions provided by wetlands are explained in the following section. The final section provides details of environmental protection (to avoid loss), planning, and management of wetlands. These include adherence to Bank safeguard policies, full stakeholder participation, the importance of assessing the value of services provided by wetlands, the costs of retaining wetlands in developments (including mitigation measures), and the selection of indicators and a monitoring program to implement them.

TYPES OF WETLANDS

The "Ramsar Convention[3]" has defined wetlands as:

areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 meters.

According to the Ramsar Convention and scientific literature, wetlands can be classified into three main types:

- Inland wetlands, including permanent and seasonal rivers, inland deltas and floodplains, permanent and seasonal lakes and ponds, marshes, freshwater swamp forests, and peatlands.
- Marine/coastal wetlands, including open coast, coral reefs, estuaries, tidal flats, mangrove forests, and coastal lagoons. These wetlands occupy about 8.6 million km^2, or 6.4 percent of the world's land surface (OECD, 1996). About 56 percent of these wetlands are located in the tropics and subtropics.
- Artificial or human-made wetlands, including reservoirs, aquaculture ponds, excavations and borrow pits, wastewater treatment ponds and irrigation canals, ditches, and rice fields.

The first two types can occur in a range of landscape settings, as shown in Table 1. The third type, artificial or constructed wetlands, will be discussed at the end of this document. Although the Ramsar definition allows for coral reefs and off-shore areas, we exclude them here and deal only with freshwater and coastal wetlands including tidal areas, estuaries, and mangrove areas.

Wetlands are always distinguished by the presence of water, either at the surface or within the root zone and usually have unique soil conditions that differ from adjacent areas. Wetlands support vegetation (hydrophytes) adapted to a dynamic hydrologic regime; consequently this vegetation tends to be flood-tolerant.

THREATS TO WETLANDS

There are few exact figures available on the extent of wetlands loss worldwide, although experts estimate that half of the world's wetlands have disappeared since 1900. Drainage for increased agriculture production is the principal cause (Table 2). It is estimated that in 1985 alone, drainage of wetlands for intensive agriculture caused between 55 and 65 percent of wetlands loss in Europe and North America and 30 percent in Asia, South America, and Africa. In the latter regions, the impact of agricultural drainage on wetlands is increasing rapidly as growing populations demand more space for food production.

Even protected wetlands are threatened or deteriorating. Disturbances were recorded in some 75 percent of the almost 957 sites designated as wetlands of international importance (Ramsar Sites) in 1998. Agricultural impacts, water flow regulation, pollution, and habitat destruction or deterioration were the predominant causes of degradation and deterioration of these sites.

Loss and degradation of wetlands from drainage, alterations to flow regimes, decreases in water quality (see Notes D.1-3) and invasion by alien species (see Note G.4) often have far-reaching ecological and economic consequences. This is illustrated by the following examples:[4]

[3] The 1971 Ramsar Convention on Wetlands of International Importance was established as the first global, intergovernmental conservation treaty for wetlands.
[4] Roggeri, H. (1995).

Table 1.
Main wetland types

	Character	Examples
Inland Wetland Floodplain	Floodplains occur in alluvial lowlands adjacent to rivers with large variations in discharges and seasonal or intermittent flooding. They are common in tropical rivers with extensive inland and/or deltaic systems and often possess shallow lakes and oxbows. Permanent shallow lakes are characterized by submerged aquatic plants or plants with floating leaves, and seasonal variations in water levels.	The Niger delta in Mali extends over 2 million hectares during the wet season; during the dry season, it covers only 400,000 hectares. Lake Chad is a shallow lake that includes swamps and marshes. Other examples are large parts of the Amazon, Lake Naivasha in Kenya, Lake Tempe in Indonesia, and the Inner Delta of the Magdalena River in Colombia.
Marsh	Marshes are normally dominated by emergent, rooted grassy vegetation (e.g. grass, reed) characterized by muddy, waterlogged soils. They generally develop in areas where the water level tends to vary considerably. Marshes never fully dry out.	The Sudd in Sudan is reputedly the world's largest marsh. Other examples include the Okavango Delta in Botswana, most of Lake Chad, and very large areas of the Amazon and Congo/Zaire River Basins.
Peatland	Peatlands develop when organic debris produced by swamp vegetation is not fully decomposed as a result of waterlogging, oxygen deficiency, high acidity, low temperatures, or nutrient deficiency. They have high average carbon content; typically 50 percent.	Peatlands are found in coastal tropical areas—the islands of Sumatra, Irian Jaya, and Sulawesi in Indonesia, and Negril Morass in Jamaica—and high-altitude areas such as the highlands of East Africa, Lesotho, and Papua Niuginni.
Swamp Forest	Swamp forests are mainly found along the lowest shores of water bodies, in depressions or on waterlogged soil. They develop where shallow stagnant water occurs during a large part of the year. Swamp forests never fully dry out.	Swamp forests are found in Southeast Asia (Indonesia, Papua Niuginni, Malaysia), Central Africa (Zaire, Congo, Gabon, and the Niger Delta), the Amazon Basin, and Central America (Costa Rica).
Coastal Wetland Mangroves	Mangroves are tidal forests consisting of plant formations typically developing on sheltered coastlines. They only occur in tropical and subtropical regions. Mangrove tree species thrive in shallow, variable tidal environments. They typically develop where fresh and marine waters meet; both influence local ecosystem conditions.	Mangroves are found along the coasts of Asia; Indonesia accounts for almost one third of the total. Other examples include the Sundarbans on the Bangladesh-Indian border, which is a well-preserved large-scale mangrove ecosystem; the coasts of Brazil; and several Caribbean and West African countries.
Estuary	Estuaries occur where river and marine ecosystems meet. They are characterized by variations in water salinity levels and often saline stratification. Estuaries usually include a large variety of wetland habitats, including mangroves and coastal lagoons in tropical and subtropical regions.	Found in all countries with coastlines.
Open Coast	Open coasts are not subject to the direct influence of rivers and lagoon systems. They may include habitats such as tidal flats and mudflats and, in tropical/semi-tropical areas, mangroves.	The Wadden Sea in Northern Europe is an example of a wetland on an open coast.

TABLE 2.
MAIN CAUSES OF WETLANDS LOSS

	Coastal Wetlands			Inland Wetlands				
	Estuaries	Open Coast	Mangroves	Floodplains	Freshwater marshes	Lakes	Peatlands	Swamp forest
Human Actions								
Direct								
Drainage for agriculture, forestry, and mosquito control	■	■	■	■	■	●	■	■
Dredging and stream channelization for navigation and flood protection	■	×	■	×	●	×	×	×
Filling for solid waste disposal, roads, and commercial, residential and industrial development	■	■	■	■	■	●	×	×
Conversion for aquaculture/mariculture	■	●	●	●	●	●	×	×
Construction of dykes, dams, levees, and seawalls for flood control, water supply, irrigation, and storm protection	■	■	■	■	■	●	×	×
Discharges of pesticides, herbicides, nutrients from domestic sewage and agricultural runoff, and sediment	■	■	■	■	■	■	×	×
Mining of wetland soils for peat, coal, gravel, phosphate, and other materials	●	●	×	●	×	■	■	■
Groundwater abstraction	×	×	×		■	×	×	×
Indirect								
Sediment diversion by dams, deep channels, and other structures	■	■	■	■	■	×	×	×
Hydrological alterations by canals, roads, and other structures	■	■	■	■	■	■	×	×
Subsidence due to extraction of groundwater, oil, gas, and other minerals	■	●	●	■	■	×	×	×
Natural Causes								
Subsidence	●	●	●	×	×	●	●	●
Sea-level rise	■	■	■	×	×	×	×	■
Drought	■	■	■	■	■	●	●	●
Hurricanes and other storms	■	■	■	×	×	×	●	●
Erosion	■	■	■	●	×	×	●	×
Biotic Effects	×	×	■	■	■	■	×	×

Absent or exceptional = ×
Present, but not a major cause of loss = ●
Common and important cause of wetland degradation and loss = ■

■ Flood problems in Colombo, Sri Lanka, worsened after nearby swamps were filled in. The drainage of wetlands had a similar effect on several towns in the lower Perak basin in Malaysia.

■ Drainage of peat swamps near Bushenyi in Uganda led to serious water supply problems;

the drained area is no longer able to store excess water and release it evenly during the dry season.
- Overgrazing and deliberate fires in the peat-forming swamps of Lesotho led to considerable erosion in the Orange and Tugela rivers.
- Flood levels downstream of the Bakalori Dam in the Sokoto valley, Nigeria, dropped by 50 percent, causing a 53 percent fall in the floodplain's cropped area. The loss of agricultural production from this modification of the flooding regime has been valued at $7 million annually.
- Construction of the Markela Dam on the Niger River in Mali has blocked fish migration routes to and from the wetlands and has led to a large decline in fisheries.

These environmental problems and associated costs occurred because of a poor appreciation of wetland ecosystems and the services they provide. Although there have been few attempts to place an economic value on the ecosystem services provided by wetlands, it is clear that the costs from the loss of wetlands can be substantial. For example, an assessment of floodplain productivity in Bangladesh concluded that a different operational regime for water flows in rivers and canals of the delta–in line with fish migration patterns–could probably double fish productivity.

FUNCTIONS AND BENEFITS OF WETLANDS

Most wetlands provide multiple resources, products, and services–depending on their biological, chemical, and physical characteristics and the interaction among these characteristics. Various methods have been developed to describe the functions, values, and benefits of wetlands. The Function Value Analysis method[5] assumes that the resources, services, and products provided by wetlands arise from the four basic functions listed in Table 3 and described below.

REGULATION FUNCTIONS

Regulation functions describe the capacity of ecosystems to regulate ecological processes that contribute to a healthy environment, such as local climate stabilization, water flow regulation, and groundwater recharge. These functions are characterized by not requiring any human intervention and are usually unnoticed until they are disturbed, such as increased flooding as a result of wetland drainage.

Wetlands provide crucial habitat to a wide range of species, including mammals, reptiles, amphibians, fishes, insects, waterfowl, crustaceans, plants and many other living organisms. Wetlands also provide nursery and migration habitat for bird and fish species. For example, the Kafue Flats in Zambia support a large population of the *Kafue lechwe*, a wetland antelope unique to this particular floodplain. The Niger inner delta hosts up to 1.5 million birds each year, which is 85 to 100 percent of water birds recorded in the Niger River Basin.

Maintenance of regional water balances is another important regulation function of wetlands. Retention of water in floodplains will decrease downstream flood damage by both reducing the height of flood peaks and diminishing the volume of floodwaters through groundwater infiltration and evaporation. Flood control by wetlands is now being rediscovered as a water management tool in many parts of the world, including developed countries such as those along the Rhine River in Western Europe. In arid regions, wetlands are a critical source of groundwater recharge (Note G.1). For example, each year the floodplains of the Hadejia River Basin in northern Nigeria supply around 1.4 x10^9 m^3

[5] Originally developed by de Groot, R.S. 1992. *Functions of Nature. Evaluation of Nature in Environmental Planning, Management and Decision Making.* The Netherlands: Wolters-Noordhoff. Further elaborated by Koudstaal, R. and R. Slootweg (1994).

Table 3.
Functions of wetlands ecosystems

Regulation	■ Flood attenuation and control ■ Prevention of saline water intrusion ■ Groundwater recharge and discharge ■ Protection against natural forces (e.g. climate influences) ■ Sediment retention ■ Storage and recycling of organic matter and nutrients ■ Storage and recycling of toxicants ■ Regulation of biological control mechanisms ■ Maintenance of migration and nursery habitats ■ Maintenance of other wetlands ■ Maintenance of biological diversity ■ Storage of carbon dioxide
Carrier	■ Human habitation and settlement ■ Cultivation: crops, animal husbandry, aquaculture ■ Energy (solar and hydropower) ■ Recreation and tourism ■ Navigation
Production	■ Water as a harvestable resource (drinking) ■ Naturally produced food and raw materials (e.g. fish, wood, shellfish, salt, etc.) ■ Fodder and fertilizer ■ Genetic resources ■ Medicinal resources ■ Biochemicals (oil, rubber, tannins, etc.)
Information	■ Aesthetic information ■ Spiritual and religious information ■ Historical information ■ Cultural and artistic information ■ Educational and scientific information

to the Chad aquifer. In some cases, wetlands support dry-season flows through a delayed release of floodwaters. For instance, the swamps and lakes of the White Nile supply 83 percent of the water flowing into the lower course of the Nile during the dry season.

The quality of surface and groundwater is also positively influenced by wetlands. The vegetation and topography of wetlands slows down water flows, allowing sediments to settle and nutrients to be removed by both plant uptake and attachment to sediments (Box 1). Wetlands can often remove pollutants more cheaply than can engineering solutions. In Sweden, for instance, the removal of nitrogen by a restored wetland cost $0.67 / kg in 1991, compared to $33/ kg for removal via a treatment plant. Wetlands such as rice paddies and swamps release a variety of gases such as nitrogen and methane into the atmosphere through microbially mediated processes and help maintain global cycling of carbon and other elements. Toxic materials, such as agricultural chemicals and some industrial wastes, are readily adsorbed/absorbed onto sediments, and so can also be removed from rivers when the velocity of water flows diminishes in wetlands. However, these toxicants can then cause ecological damage within the wetlands, unless the wetlands are specifically designed for pollutant removal (see section on Constructed Wetlands).

Photo by Curt Carnemark, World Bank

Elephant, Kenya

fluence the functioning of wetlands as a whole.

Agriculture that utilizes wetlands is very important in many tropical wetlands where communities have developed techniques to benefit from natural conditions, such as flood and flood-recession agriculture and swamp agriculture. Development programs often neglect existing agricultural production, yet it not only supports the livelihood of indigenous people, but it may also be efficient and sustainable. In the Senegal River floodplain, the daily remuneration is $1.04-2.00 for flood-recession sorghum, compared to $0.67-1.04 for rice grown in irrigation schemes.

Livestock farmers often lead their herds toward wetlands during the dry season, when upland grasses and water reserves are exhausted. The Utengule Swamp in the Usanga Plain of Tanzania is an important source of dry-season water supply for over 300,000 head of livestock. The draw-down zone of Lake Chad provides excellent grazing areas that may annually produce as much as 2 tons of dry matter per hectare. In Brazil, Paraguay, and Bolivia, the wetlands of the Pantanal support up to 8 million head of cattle and are some of the most valuable in the world.

Finally, as a result of their high humidity and evapotranspiration rate, extensive wetlands can influence the local and regional climate. They can have a cooling effect if located near highly developed areas, which might reduce impacts of "heat islands" arising from the heat generated by large urban centers.

CARRIER FUNCTIONS

Carrier functions represent the provision by wetlands of suitable space, substrate, or medium for human activities such as agriculture, aquaculture, animal husbandry, recreation, waterway navigation, tourist sites, and nature protection. Many of these uses change the natural environment and may in-

BOX 1: LAKE NAIVASHA: A CASE OF NATURAL POLLUTION CONTROL

Lake Naivasha in southern Kenya has experienced a population explosion from 50,000 to 250,000 people within the lake's catchment, a major expansion of intensive horticultural industries on the shores of the lake, and clearing and settlement in the headwaters of the lake's main river. The sewage treatment plant for the town of Naivasha has ceased to operate; raw sewage has been discharged directly into the lake since 1993.

In spite of this pollution, water quality in the lake appears to have remained remarkably unaffected, although it may have reached the limits of its assimilative capacity. Nutrient concentrations have remained relatively unchanged; pesticides and heavy metals are detectable in trace amounts only; and sedimentation is not a major problem. The lake apparently has been protected by fringing reed beds, often 20m thick. These have filtered sediments and attached pollutants from riverine and drainage inflows, including the raw sewage. There are constant threats to the reed beds from burning and plans for development of the shoreline. Any major loss of these filters would almost certainly see the lake become polluted, at significant cost to the local economy.

BOX 2.
ECOTOURISM IN THE UKRAINE DANUBE DELTA BIODIVERSITY PROJECT

The $1.5 million GEF-funded Danube Delta Biodiversity Project has supported the development of administrative facilities for the reserve, with a small hotel, simple guest houses on the Delta islands, and development of a bird-watching trail. The project also sponsored staff visits at reserves in Europe to learn good practices in self-financing. Since the project was completed in 1999, the Ukraine Danube Biosphere Reserve (DBR) has been developing revenue sources and creating jobs through ecotourism. The DBR has created a special division for ecotourism and offers lodging, food, guides, and auto and boat transport. In order to avoid dependence on the quality of outside tourism firms and to capture a greater share of tourism revenues, the DBR has obtained a license for conducting tourist activities itself. With the money earned thus far, they have built an observation tower and equipped their information center.

Source: World Bank. 2002. *ECA Biodiversity Strategy*. Washington: World Bank.

The use of wetlands for tourism and recreation is growing rapidly. Often wetlands protection activities are combined with ecotourism, which offers an opportunity for cost recovery for much of the investments in nature protection activities (Box 2). The Black River swamps in Jamaica draw 50,000 visitors per year, generate annual revenue of $1 million, and provide jobs for 200 people. In another example, the Okavango delta in Botswana and the Kafue Flats in Zambia draw large numbers of tourists because of the spectacular range of game.

PRODUCTION FUNCTION

Production functions are goods produced naturally in wetlands, as opposed to cultivated plants and animals. Only time and energy are necessary investments for their harvest. These goods include water itself, naturally produced food (meat, fruit, fish), raw materials (peat and firewood), and genetic and medicinal resources. The natural food, water, and energy supply that many communities depend upon for their existence is included in this category. For example, local communities harvest 115,000 tons of firewood per year from the Hadejia-Nguru floodplain in Nigeria. In the Sudd wetlands in Sudan, hunting provides 25 percent of the meat consumed by local people.

Fisheries are one of the most important activities supported by wetlands. Fish caught in wetlands provide an important source of protein for communities around the world. For example:

- The 1987 catch from the seasonal lakes of the Ogan-Komering floodplain in Sumatra was assessed at $15 million.
- In the Niger inner delta in Mali, some 100,000 fishermen provide around 90 percent of national fish production.
- In the Kulna-Jessore drainage rehabilitation project in southwest Bangladesh, fish production is more profitable than rice cultivation.

Wetlands, particularly coastal wetlands, also provide a critical spawning area for fish, invertebrates such as prawns, and other aquatic food. Box 3 describes the attempt to reestablish the productivity of an important fish spawning area in India.

INFORMATION FUNCTIONS

Wetlands also provide opportunities for spiritual enrichment and recreation. Information functions include aesthetic, spiritual and religious, historical and archaeological elements, cultural and artistic, educational, and scientific activities. Although the value of these functions can be difficult to quantify, it can be large.

Wetlands have played a significant role in the development of many civilizations; their historical importance is enormous. In some areas, many generations have grown up near and within wetlands, which are an important feature in their art, literature, and religions. The methods developed by these communities to make sustainable use of wet-

BOX 3.
THE MAHANADI DELTA, ORISSA, INDIA

Over the centuries, the delta and extensive floodplains of the Mahanadi River in the Indian state of Orissa have provided rich fishery resources supported by tidal estuaries with seasonal freshwater and saltwater conditions. The delta wetlands also provided extensive spawning grounds for freshwater prawns and fish. In the later part of the 20th century, the conversion of the delta into irrigated land and changes in the hydrology of the river, particularly the construction of the Hirakud dam upstream of the delta in 1958, have caused many aquatic species to virtually disappear.

Indian carp species (*Catla catla, Labeo rahita, L. calbasu and Cirrhina mrigala*) live in the delta and are totally dependent on monsoon floods for spawning. The more intense the flood, the more fry will be produced. Due to the Hirakud dam and the abstraction of water for irrigation, spawning is virtually absent during years of low rainfall when floods are controlled. Freshwater *Macrobrachium* prawns also reproduce in the brackish waters of the delta. The hatched juveniles migrate upstream into freshwater areas during a 3-month post-monsoon period. Maintenance of post-monsoon discharge is essential for this activity.

The replacement of the deteriorating Naraj Weir by the Naraj Barrage, under the World Bank-funded Orissa Water Resources Consolidation Project, provided an opportunity to improve the fish and prawn breeding potential of the delta. The new barrage will be provided with gates for flow regulation, which could make it possible to manage to some extent the inflows into different branches of the delta. A fish pass—with a width of 2 meters—will be included. The operating rules for the barrage state that, once irrigation requirements are met, the first monsoon floods should be as high as possible to enhance spawning of carp, and that a continuous flow will be maintained through the barrage after the monsoon to allow upstream migration of prawns. The operation of the barrage will be adjusted to maximize these spawning activities as knowledge of flow-biology relationships grows, subject to the requirement that irrigation needs are met.

Source: World Bank. 1998. *Integrating Freshwater Biodiversity Conservation with Development: Some Emerging Lessons*. Environment Department Paper No. 61. Washington: The World Bank.

land resources may have great learning potential for research and possible replication in other regions. For example, aquaculture and fishing techniques developed in the wetlands of Benin are striking examples of ingenious traditional techniques with potential for use in other regions. In Lake Titicaca, between Bolivia and Peru, the Uros people have lived for centuries on floating islands built of totora reeds. They use boats made from the same material for traveling between the islands. Fish, caught using artisanal methods, provide their animal protein. Even if these techniques are not replicable elsewhere, they contribute to human diversity and provide cultural benefits to humankind.

INCORPORATING WETLANDS MANAGEMENT INTO BANK PROJECTS

Projects that involve wetlands need to follow the same general principles as projects involving other environmental resources: the extent of impact needs to be assessed; the various stakeholders with an interest in the wetland need to be involved; options need to be developed involving different levels of mitigation; the costs of wetlands losses need to be estimated and compared to the benefits from the development under the different options; mitigation measures need to be agreed and incorporated into the project; and a monitoring program needs to be instituted to track the success of the implementation

IMPACT ASSESSMENT

The need for wetlands management arises in different types of Bank projects, including:

- Projects that affect the hydrology of wetlands, through such upstream activities as road construction, dam developments and irrigation schemes, lowering of water tables though groundwater exploitation for water supply, and flood control investments.

- Direct conversion of noncritical wetlands to agriculture, ports and harbors, navigation projects, and aquaculture, especially mangroves for mariculture. Under its Natural Habitat Policy, OP4.04, the Bank does not fund projects involving significant conversion of critical wetland habitat areas unless there are no feasible alternatives and the benefits substantially outweigh the costs.
- Projects that change the water quality and the biological composition of wetlands through pollution from agricultural runoff, urban and industrial discharges, introduction of exotic plant and animal species, acid rain, and sea-level rise.

The Bank's Operational Policy 4.01 applies to all Bank-funded projects likely to have significant environmental impacts on wetlands, including impacts caused by any of the above effects. Several other policies can also be triggered by projects that affect wetlands, including pest management (OP 4.09), water resources management (OP 4.36), indigenous people (OP 4.20), and involuntary resettlement (OP 4.30).

When a particular project is likely to impact a wetland, the following questions should be asked:

- Is the area on the Ramsar list, the list of biodiversity hotspots, or any national listing of areas requiring protection?
- Will there be significant changes in the ecological structure and functioning of the wetland?
- Is the project likely to increase nutrients, pesticides, and other pollutants, or induce physical disturbance to the wetland?
- Will any part of the wetland be converted to a different land use?
- What is the present socioeconomic value of the wetland? What would be the sustainable yield under better management? What is the replacement cost if the ecosystem services currently provided by the wetland are destroyed?
- Are local people willing and able to adapt their traditional practices to the likely changes in wetland functioning resulting from the project?

Borrowers are required to undertake an Environmental Assessment (EA) if the project receives an A or B environmental rating.[6] Issues arising from the proposed development will be identified in the EA, and appropriate mitigation measures will be included in either the EA or a separate Environmental Management Plan (EMP). If a project is likely to affect a wetland located off the site of the project area itself, an EA should take into account the existing and future relationships between a wetland and neighboring ecosystems. This may necessitate expansion of the geographical coverage of the EA and generation of sufficient hydrological, ecological, and socioeconomic linkages to capture and respond to all significant potential social and environmental impacts (Box 4).

The EA should contain baseline data for assessing the potentially positive and detrimental impacts of the proposed project. Because many wetlands function seasonally, the data should describe the uses and services of the wetland over each season. The EA should include assessments of the importance and value of the wetland to affected local communities and groups, such as women, fishing families, and livestock owners.

STAKEHOLDER PARTICIPATION

The Bank (and often national laws and procedures) requires involvement of stakeholders at an early stage of major project proposals in most countries. Usually the Ministry of Environment–but also typical development ministries such as Energy, Industry, Public Works, and local and regional water and environment management agencies–must be consulted regarding the application of these laws and procedures.

Specific attention must be given to ensuring that stakeholder groups, such as local communities dependent on the wetland functions and services, are included in the project planning at an early stage. Communities dependent on groundwater recharged

[6] See World Bank 2002.

Box 4.
The Kihansi Hydro Project and the Spray Toad

The Kihansi Hydro Project—a $260 million project to supply electricity to Tanzania—was financed by the World Bank, the Government of Tanzania, the European Investment Bank, and a number of bilateral donors. The project was completed in 2000. Water was diverted from the Kihansi gorge through a tunnel to drive the turbines. Consequently, flows in the gorge have been drastically reduced and the area of wetland in the gorge receiving spray has declined by 98 percent.

The project received an A rating and a full EA was carried out. The EA noted that the ecology of the gorge would be significantly impacted by the reduced water flows but, at that time, the existence of the Kihansi Spray Toad was unknown and the project went ahead. The toad was discovered in 1996 when further studies were being conducted for an EMP.

Various measures were initiated to save this unique toad. A captive breeding program has been carried out since 2000 at the Bronx Zoo. After some initial problems, toad numbers have now started to increase. A pilot artificial spray system has been installed in the gorge to mimic the effect of the falls and restore some of the original habitat, and hydrological and ecological monitoring has been set up in the area. A search has been mounted for other habitats of the Spray Toad. A new project is being developed to manage the environment in the wetland area. It includes components to build management capacity in government institutions and to educate the general public about environmental issues.

Source: World Bank. 2001. *Supporting the Web of Life: Biodiversity at the World Bank*. Washington: World Bank.

from seasonal wetland flooding are potentially just as affected by proposals that affect wetland hydrology as those living in the wetlands. Other groups such as NGOs, the general public, and business leaders may also be included if they have specific interests in the wetland.

Failure to involve groups that are highly dependent on wetlands can impose large, subsequent social costs on the project and may even lead to the cancellation of the project. The protests of ethnic groups against the construction of a large-scale waterway (Hidrovia) in Brazil led to the licensing process for this development being suspended. These groups had not been involved, even though the Brazilian constitution guarantees indigenous people the right to be consulted regarding water projects that would affect them (Box 5).

DEVELOPMENT OPTIONS

The choice of how much protection and how much development is appropriate for a wetland or system of wetlands will depend on a range of factors, including alternative uses for the land and water (both upstream and downstream) of the wetland, and the ecological functions supplied by the wetland. It should be guided by well-established principles of ecological management:[7]

- *Principle of Wise Use*. As formulated by the Ramsar Convention, wetlands should be sustainably utilized "for the benefit of humankind in a way compatible with the maintenance of the natural properties of the ecosystem."
- *Principle of Interdependence*. Wetlands cannot be considered independently or as an isolated ecosystem. They should be managed on a wider ecosystem basis, particularly the watershed within which they are located, which may cross political and social barriers and different sectors. This includes groundwater systems feeding the wetlands.
- *Principle of Multiple Use*. Sustainable wetland management means accepting and optimizing the different uses for wetlands and their associated watersheds.
- *Precautionary Principle*. "It is better to be safe than sorry." Avoid an activity with an assumed detrimental environmental impact, even when scientific evidence cannot yet prove that the impact will occur. And if detrimental impacts

[7] OECD, 1996.

BOX 5.
THE PANTANAL

Bordered by Brazil, Paraguay, and Bolivia, the Pantanal is one of the world's largest wetlands. It sustains flows in the Paraguay River in both the wet and dry seasons, and supports a diverse assemblage of birds (650 species), fish (400 species), and other biota. Tribal groups, numbering about 150,000 people, are highly dependent on these wetlands for their livelihoods, including food, transportation, and shelter. The wetlands also provide flood control and water purification services to millions of people downstream.

In the late 1980s, the governments of Argentina, Bolivia, Brazil, Paraguay, and Uruguay proposed a commercial waterway through the Pantanal to provide year-round navigational access from inland regions to the sea. The economic study that accompanied this proposal did not include the social and environmental costs arising from the proposed channel straightening, deepening, and stabilization. Subsequent studies showed that the losses arising from reduced wetland flooding and more rapid transmission of flood peaks would substantially offset the economic benefits. Perhaps more importantly, the indigenous groups affected by the proposal mounted a worldwide protest based on their exclusion from the planning of the project. As a result of these concerns, the Brazilian federal environmental agency suspended work on the plans within Brazil, and the Brazilian court system agreed that indigenous groups had not been consulted sufficiently as required in the constitution.

are to be expected from project activities, check that measures are taken to mitigate impacts, even if they are not certain.

- *No-Net-Loss Principle.* If a development destroys or impairs an area of wetland after an assessment shows that there were no feasible alternatives and the net benefits outweighed the costs, then the development plan should seek to retain the functions of the wetland as much as possible and establish an equivalent wetland elsewhere (Box 6). This is consistent with the Bank's O.P 4.04.
- *Principle of Restoration.* Wherever possible, previously degraded wetlands should be restored, if it can be shown through studies that some of the original functions of the wetland can be reestablished. The creation and restoration of wetlands is becoming technically and ecologically feasible for a few types of wetland, such as freshwater marshes (Box 7) and tidal marshes on low-energy coasts.

Project proposals can involve conversion of part or all of the wetland to an alternative use, or an upstream development that can affect the wetland through changes in flow (including groundwater flows), increases in pollution, and the possibility of the introduction of alien flora and fauna species. Normally a small number of development options are generated with input from the affected stakeholders. These options can then be assessed for their economic, social, and environmental effects.

ECONOMIC ANALYSIS

The choice of the preferred development option will depend partly on an economic analysis of the benefits and costs of the options, and partly on the social and environmental values of the wetland. The latter are seldom quantified and incorporated into the economic analysis, even in developed countries, although there is now good guidance on how to do so.[8] Nevertheless, quantification of major ecosystem services can provide important insights into which development option is appropriate. For example, an analysis of wetlands in northern Nigeria showed clearly that the economic losses to wetland users from diversion of water to an upstream irrigation scheme would at least be comparable to the economic benefits from the new irrigation area (Box 8). Other noneconomic costs, such as social disrup-

[8] World Bank (1998). Dixon, J.A., L.F. Scura, R.A. Carpenter, and P.B. Sherman. 1986. *Economic Analysis of Environmental Impacts.* London: Earthscan Publications. Also Chapter 6 in Belli, P., et al. (2000).

BOX 6.
WETLAND MITIGATION BANKING: AN INNOVATIVE APPROACH

Wetland mitigation banking provides an innovative, market-oriented approach to balancing the pressures for converting valuable wetlands to high-intensity uses with the need to preserve the ecosystem functions provided by wetlands. It is defined as the "restoration, creation, enhancement, and (in exceptional circumstances) preservation of wetlands and/or other aquatic resources, expressly for the purpose of providing compensatory mitigation in advance of authorized impacts to similar resources." If one wetland is to be destroyed through a change in land use, a fully compensating wetland is developed to replace the lost ecosystem services. These "new" wetlands are taken from wetland banks—typically large wetland areas with agreed ecosystem values—under regulatory agency approval.

Estimating the value of an ecosystem is not easy and, in practice, most credits and debits have been measured simply in terms of the area of various classes of wetlands. Although area is a crude measure of value, it still allows the loss of many small wetlands to be accumulated into the establishment of a larger, ecologically superior wetland that can be better managed.

The approach has proven to be popular in the United States, with over 100 banks now in operation. Most banks are operated by the same organizations, such as state highway departments that are carrying out the land use conversion. Until recently, there were few banks operated by the private sector where general developers could purchase compensatory wetland credits. Now, under encouragement from the federal government, several watershed-based wetland initiatives include private or publicly sponsored commercial banks.

In spite of its increasing popularity, there are some important unresolved issues with wetland mitigation banking. The timing of receipt of credits is central to full private sector involvement. If mitigation banks are constructed in advance of wetland losses, commercial bank entrepreneurs require that they receive financial credits before replacement wetlands are fully functioning or self-maintaining. Also, the replacement wetland needs to be sustainable in the long term if it is to be truly compensatory. This may require legally enforceable conditions on the long-term management of the replacement wetland. Finally, there are few satisfactory tools available for measuring the ecosystem services provided by a wetland, and so the issue of agreeing on compensation for a destroyed wetland is subject to considerable uncertainty and negotiation.

Source: Davis, M. 1995. "A More Effective and Flexible Section 404." *National Wetlands Newsletter* 17(4).

tion to groups dependent on the wetlands and disruption of water-bird habitat, were not quantified.

Economic analysis provides only one of the inputs to the decision regarding which development/conservation option to select. To be seen as fair and have local support, the decision will inevitably be a consultative process that must involve all stakeholders. Given the diversity of functions provided by wetlands and the inter-connectedness of wetlands with their surface watersheds and groundwater systems, it is essential that any interventions that may affect a particular wetland be based on a thorough understanding of the ecological functions of the wetland and the consequent sensitivity of those functions to changes likely to be induced by Bank-funded projects. This is an essential component of making sure that the parties involved in these trade-offs understand the probable consequences of different interventions.

MONITORING AND INDICATORS

Once a decision has been made about the preferred option, there will need to be monitoring of the impacts of the proposed development on the functioning of the wetland.[9] Indicators of wetland functioning should be developed as part of the implementation process. A monitoring program should be designed during project preparation to gather the information needed to quantify these indicators. The choice of indicators should be undertaken with input from local communities so they can become part of the ongoing implementation and tracking of the project.

Wetlands are responsive to many other factors apart from those arising from the development. Conse-

[9] See World Bank (1998b).

BOX 7.
RESTORING THE DELTAIC WETLANDS OF THE NORTHERN ARAL SEA

The decline of the Aral Sea began in the 1960s as increasing amounts of water were diverted—mainly for irrigation—from the inflowing rivers, the Amu Darya and Syr Darya. Between 1960 and 1996, the surface area of the sea declined by some 50 percent and the sea level dropped by 16 meters. In 1990, the Aral Sea split into a small Northern Aral Sea (NAS) and a Large Southern Aral Sea (LAS) as the waters receded.

Today, fish production in the Syr Darya delta and the NAS is virtually extinguished, as well as hay production that benefited in the past from natural flooding along streams, lakes, and wetlands. The ecological system has deteriorated, affecting both people and wildlife. Dust and salt storms occur often, and local climatic changes are taking place around the sea. It is becoming difficult to locate adequate and safe drinking water supplies, and human health problems have increased sharply. Tens of thousands of jobs were lost in the former fishing, agriculture, and service sectors. Huge tracts of agricultural lands were degraded by windborne and waterborne salt from the rivers, soil, groundwater, the desiccated seabed, and dried-up wetlands.

The delta area, wetlands, and lakes near the NAS could be rehabilitated by building a dike across the Berg Strait connecting the NAS to the LAS. Using limited local resources, this approach was tested by the creation of a temporary dike in the Berg Strait in 1992 and then again in 1996. It demonstrated that a partially restored NAS will have a much lower salinity than the LAS, thereby improving the environmental situation, improving fisheries potential, and in particular, enhancing the socioeconomic conditions in the area.

By rehabilitating the NAS, the project would address the root cause of the environmental degradation in the Syr Darya delta. This would improve agricultural, livestock, and fishery production in the river basin and the delta area. The main environmental benefits of the project include the restoration of the ecosystem and improvements in fishery reproduction conditions in the NAS and in the lakes. The positive impact of the NAS on microclimate and air quality would positively affect soil salinity, soil fertility in the delta area, human and animal health, vegetation, and wildlife.

A World Bank-funded project commenced in 2001 to construct the Berg Strait dike, rehabilitate some control structures on the Syr Darya River, upgrade the Chardara Dam, develop the fisheries industry in the NAS, and install a monitoring and assessment capability.

Source: Project Appraisal Document (P046045), Syr Darya Control and Northern Aral Sea Phase-I Project. Washington: World Bank.

quently, the monitoring program needs to be designed to allow the effects of exogenous factors, such as climate variability and climate change, to be separated from the effects of the development project.

BOX 8.
VALUING ECOSYSTEM SERVICES: THE HADEJIA-NGURU WETLANDS

The Hadejia-Nguru wetlands in northern Nigeria occur at the junction of the Hadejia and Jama'are rivers, downstream of existing and proposed irrigation schemes. During the rainy season, the wetlands are formed by annual flooding of inactive sand dunes. The wetlands are important for wildlife conservation and also support a range of economic activities, including wet-season and dry-season agriculture, fishing, fuelwood collection, livestock rearing, and forestry. Local people also use wild foods from the wetlands for sustenance, and obtain drinking water from shallow aquifers. Through the combined effects of drought and upstream water extraction, the wetlands have shrunk in recent years from 2,350 km^2 in 1969 to 413 km^2 in 1993.

One study put the economic value of the agricultural/fishing/firewood benefits provided by the wetlands at between 846 and 1275 Naira per hectare. A later study put the loss of groundwater recharge benefit for dry-season irrigators at 106,000 Naira per annum, and 1,146,000 Naira per annum for domestic water supply for a 1m drop in groundwater level. The latter study did not include all the environmental benefits provided by recharge, let alone other environmental benefits such as habitat provision for water birds and provision of wild foods for local populations. Overall, the studies show that even these losses from a reduction in downstream wetlands are comparable to, and usually greater than, the benefits from proposed upstream irrigation schemes.

Source: Acharya, G. 2000. Approaches to valuing the hidden hydrological services of wetlands ecosystems. *Ecological Economics* 35: 63-74.


Fishermen on the Shire River, Malawi

Photo by Jane Turpie

Indicators of change such as extent of poverty, annual withdrawals of ground and surface water, or threatened species as a percent of total native species can be used. The United Nations Commission for Sustainable Development has done much work on indicators to measure sustainable development.[10] Box 9 gives an example of indicators used to monitor the impacts of a wetlands management program implemented in the Baltic Sea Region with pilot projects in Russia, Latvia, Estonia, Lithuania, Poland, and Germany. It shows how a consistent structure can be set up to link causes of change—in this example, control of illegal forestry and fishing—with the impacts of those changes. It is important to ensure consistency between indicators used for the monitoring programs and indicators used during the environmental assessment (EA) process so that changes can be measured from an agreed baseline.

Data are gathered for these indicators through a monitoring program. Field monitoring by rangers, scientists, and local residents can be supplemented by modern technologies such as remote sensing and telemetric data management. Responsibility for monitoring should be clearly assigned to specific institutions or parties, which may be government agencies, NGOs, or private organizations with the capacity to undertake the data collection and interpretation.

[10] United Nations (1996).

BOX 9.
INTEGRATED COASTAL ZONE MANAGEMENT INDICATORS IN THE BALTIC SEA REGION

The HELCOM Management Programs for Coastal Lagoons and Wetlands, led by the WWF, includes pilot projects in lagoons in Estonia, Latvia, Lithuania, Russia, Poland, and Germany. The main goal of the project is to introduce Integrated Coastal Zone Management (ICZM) principles into the management of the Baltic Sea.

Some regions are highly polluted and industrialized, while others have high biodiversity values that are being threatened. Many of the problems have not been solved because of lack of institutional capacity. The OECD (Pressure, State, Response) framework was used in the monitoring programs. The indicators were identified through workshops and meetings with the stakeholders. Most important indicators are related to ecotourism; fisheries; hunting, birds, forest, and fauna; pollution and landfills; land and natural resources; and water quality, water treatment, and drainage.

A Driving Force Indicators (DFI) matrix (Table 4) shows how problems and their causes are related. In a second matrix (Table 5), the State and Response Indicators (SRI) are linked by “targets” and proposed “actions.” Part of the matrices from the Latvian example are used here to illustrate the principles of the approach.

Source: Gladh, L. WorldWide Fund for Nature, Sweden

Table 4.
Driving Force Indicator Matrix

Problems	Causes	Driver Indicators
Illegal forest cutting and fishing	Lack of controlling bodies Lack of coordination No management plans Unemployment	■ Unemployment rate ■ GDP per capita in agriculture ■ Coastal area with buildings/total area market

Table 5.
S-R Indicator Matrix

State Indicators	Targets	Actions	Response Indicators
■ Number of inspectors	Develop local business	Launch "business incubator"	■ Number of local enterprises using business incubator
■ Management plans elaborated YES/NO	Provide control and decisionmaking bodies for area	Establish administration of Kemeri National Park	■ Number of new inspectors
■ Employment in tourism		Establish administration for the project area	■ Number of training activities for local people
■ Employment in agriculture			
		Establish fund for the project area	■ Percent of local people familiar with nature protection idea
		Hire inspectors	

CONSTRUCTED WETLANDS

Wetlands can be constructed to provide specific ecosystem functions. In particular, they have been used for treating and recycling wastewater, resulting in improved water quality and often valuable wildlife habitat. Although wastewater treatment is the most common use of constructed wetlands, they can also be used for removal of toxicants and industrial wastes and for recharging groundwater systems.

Different wetland technologies are now available, such as various forms of ponds, land treatment and wetlands systems. Considerable experience has been gained over the years on improved methods for designing and operating constructed wetlands. This experience, together with results reported in the research literature, suggest that constructed wetlands offer considerable savings in wastewater treatment costs for small communities and even for upgrading of larger treatment facilities. In addition, these systems can provide valuable wetland habitat for waterfowl and other wildlife, as well as areas for public education and recreation.

Because of the build-up of contaminants in sediments and aquatic plant tissues, wetlands constructed for contaminant removal need to be actively managed. Nutrients and other contaminants will be released back into the water as the plants die and decompose unless the wetland management includes periodic harvesting and productive use or safe disposal of the plant material. Contaminants absorbed in the sediments also will be flushed out during large flow events unless the wetland is specifically designed to bypass large flows or the management plan includes removal and safe disposal of the sediments. The health of these wetlands needs to be closely monitored, because constructed wetlands can be subjected to large loads of toxic contaminants that can damage the flora and fauna of the wetland that provides the ecosystem services. Agricultural and industrial chemicals can cause the death of microbes and macrophytes unless the discharges into the wetlands are closely monitored and regulated.

CONCLUSION

Wetlands provide a wide range of ecological functions that support the livelihoods of local communities as well as provide regional and global benefits. They provide food and fiber locally, flood control and groundwater recharge regionally, and migratory bird habitat and nutrient recycling globally. In the few studies undertaken to date, the economic value of these functions is surprisingly high–comparable, in some studies, to the benefits from proposed development activities that would have affected the wetlands.

About half the world's wetlands were destroyed during the 20th century by agricultural development, urban expansion, pollution, and changes in river flows. There is an increasing appreciation in the developed world of the importance of retaining wetlands; options include construction of artificial wetlands for specific purposes (such as treatment of effluent), as well as innovative schemes to compensate for any wetlands destroyed by development. Projects financed by the World Bank can affect wetlands through inundation, conversion to alternate land uses, changes in flow regimes, increases in pollution, and drawdown of groundwater. Consequently, damage to wetlands can trigger a number of safeguard policies. The Bank does not support projects that would result in the significant conversion or loss of natural habitat, such as wetlands, unless there are no feasible alternatives, the benefits substantially outweigh the environmental costs, and suitable mitigation measures are put in place.

FURTHER INFORMATION

The following texts provide general background on wetlands:

Firehock, K. L., J.V. Middleton, K.D. Starinchak, C. Williams and L. Geoff. 1998. *Handbook for Wetlands Conservation and Sustainability*. Gaithersburg, MD: Izaak Walton League of America.

Acreman, M.C. and G.E. Hollis, eds. 1996. *Water Management and Wetlands in Sub Saharan Africa*. Gland, Switzerland: IUCN Wetlands Programme.

OECD. 1996. *Guidelines for Aid Agencies for Improved and Sustainable Use of Tropical and Subtropical Wetlands*. Paris: OECD.

Roggeri, H. 1995. *Tropical Freshwater Wetlands: Guide to Current Knowledge and Sustainable Management*. Dordrecht / Boston / London: Kluwer Academic Publishers.

Information on wetland assessment can be found in:

Koudstaal, R., and R. Slootweg. 1994. *Wise Use of Wetlands: A Methodology for the Assessment of Functions and Values of Wetlands*. Delft, The Netherlands: The Wetland Group.

Howe, C.P., G.F. Claridge, R. Hughes and Zuwendra. 1991. Manual of guidelines for scooping EIA in Tropical Wetlands. PHPA/AWB Sumatra Wetland Project Report No. 5. Asian Wetland Bureau. Bogor, Indonesia: Department of Forestry, Indonesia.

World Bank. 2002. *Wetlands and Environmental Assessment*. Environmental Assessment Sourcebook Update No 28. Washington: World Bank.

Two useful documents on assessing environmental values provided by wetlands are:

World Bank 1998a. *Economic Analysis and Environmental Assessment*. Environmental Assessment Sourcebook Update No. 23. Washington: World Bank.

Belli, P., J.R. Anderson, H.N. Barnum, J.A. Dixon and J-P Tan. 2000. Economic analysis of investment operations: analytical tools and practical applications. Washington: World Bank.

Information on monitoring and indicators can be found at:

World Bank. 1998b. Guidelines for Monitoring and Evaluation for Biodiversity Projects. Environment Papers No. 65. Washington: World Bank.

United Nations. 1996. *Indicators of Sustainable Development: Framework and Methodologies*. New York: UNCSD.

The following reference provides a good overview on constructed wetlands:

Hammer, D.A. ed. 1990. *Constructed Wetlands for Wastewater Treatment: Municipal, Industrial, Agricultural*. Chelsea, Michigan: Lewis Publishers.

Some useful websites dealing with wetlands include:

IUCN Wetlands Programme
http://www.iucn.org

Ramsar Convention Bureau
http://www.ramsar.org

World Wide Fund for Nature
http://www.panda.org

Wetlands International
http://www.wetlands.org

US Society of Wetland Scientists
http://www.sws.org/