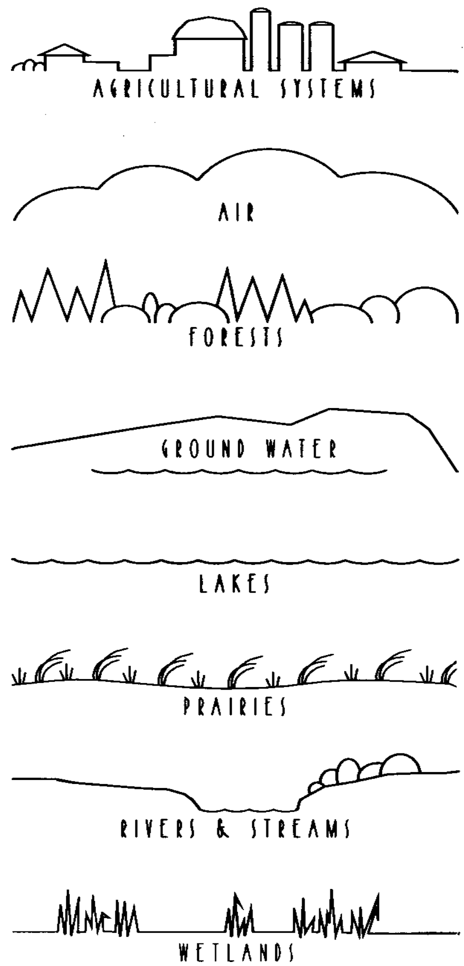
DEVELOPING ENVIRONMENTAL INDICATORS FOR MINNESOTA



Wetlands

The Environmental Indicators Initiative

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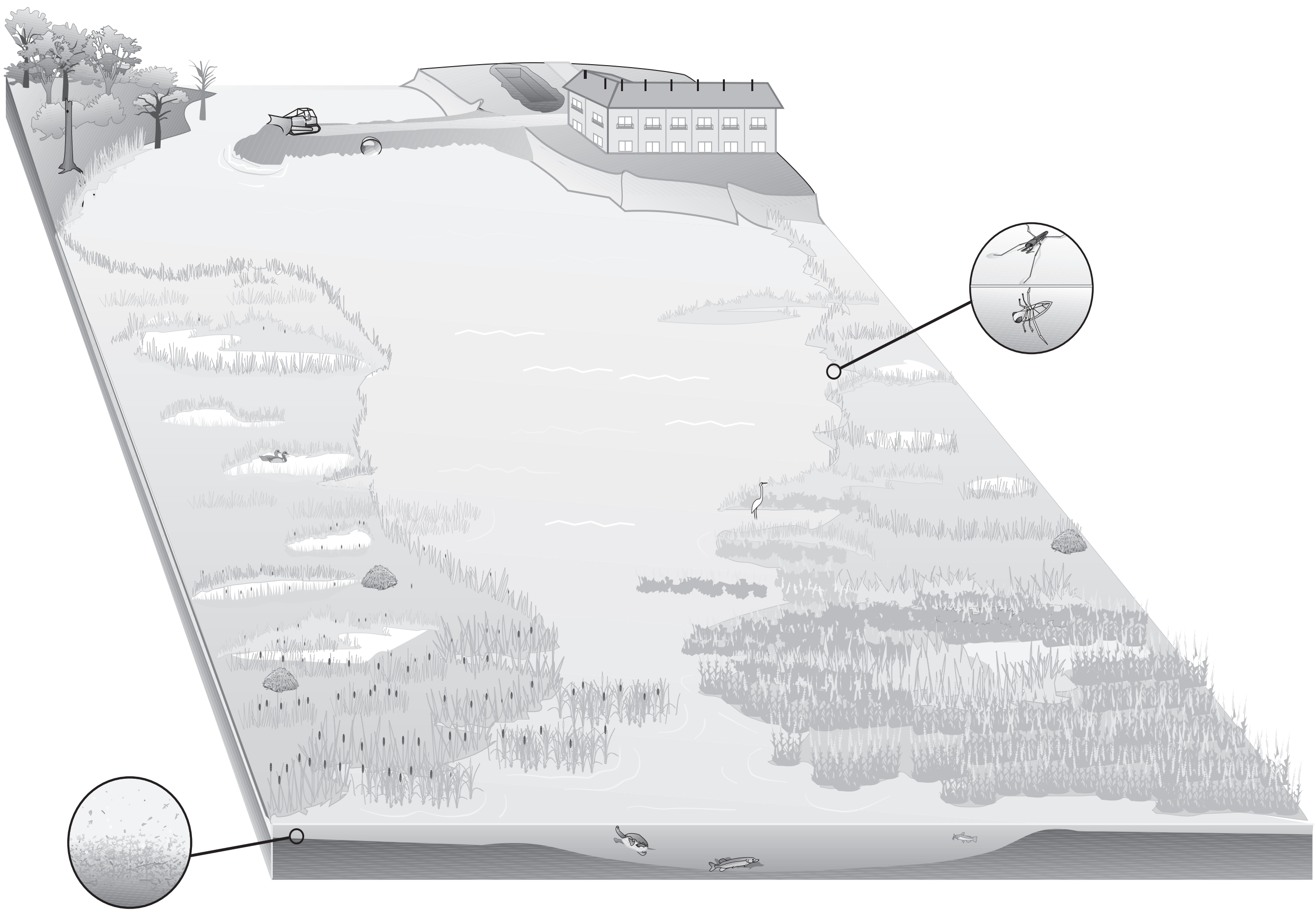

Citizens and decision makers use environmental indicators to help effectively manage and protect Minnesota's wetlands. Environmental indicators answer four questions.

What is happening to our wetlands?

Environmental condition can be assessed using indicators based on ecological characteristics of wetlands, including **variety of wetland birds, nutrients in water and sediment (change in pH, nitrogen, phosphorus)** and **water level fluctuations** in wetlands.

Why is it happening?

Indicators of *human activities* that affect wetlands include **conversion of natural habitat, altered water movement**, and **fertilizer and pesticide runoff**.

How does it affect us?

Changes in wetland health may diminish the flow of *benefits*. Indicators of how we are affected include **water quality**, **flood frequency**, and opportunities for **hunting** and **recreation**.

What are we doing about it?

Societal strategies to maintain or restore healthy wetlands include **land use planning, wetland restoration**, and **implementation of urban and rural best management plans**.

In this chapter we outline important benefits from wetland ecosystems, the key ecological characteristics that determine the health of wetlands, the pressures affecting wetlands today, the current status and trends relating to wetlands, and the most significant policies and programs that affect Minnesota wetlands. Throughout this chapter we give examples of indicators that provide important information about Minnesota wetlands.

HIGHLIGHTS

Benefits of Healthy Wetlands

- Flood attenuation
- Removal of sediments and nutrients from runoff
- Transformation of toxic chemicals
- Shoreline stabilization
- Fish and wildlife habitat
- Commercial uses (e.g., wild rice, paddy rice, bait industry)
- Recreation
- Education, science

Important Ecological Characteristics

- Hydrological regime is the single most important factor determining wetland structure and function.
- Differences in water levels, oxygen levels, productivity, soil organic matter, and plant and animal species result in different wetland types with varying benefits.
- Increases in nutrients and sediments entering wetlands stimulate productivity and cause shifts in plant communities, ultimately causing reduced diversity of types of wetlands and of wetland species.

Pressures

- Altered hydrology
- Wetland conversions (urban, roads, farms)
- Increased sediments
- Chemical inputs (roadways, lawns, golf courses, farms, etc.)
- Invasive species (purple loosestrife)

Status & Trends

- Nationally, wetlands cover 5% of land area but support 1/3 of rare, endangered species.
- Approximately 54% of presettlement wetlands remain; greatest losses are in prairie pothole region.
- Rates of loss are below the national average, but 26,500 acres were lost from 1982-92.
- From 1982-92, 38% of losses were due to agriculture, and 38% were due to urban development.
- Purple loosestrife infests 560 sites, but only 9 new sites were found from 1995-96.

Existing Policies & Programs

- Clean Water Act regulates dredge and fill activities in wetlands.
- Permit required for activities that alter water basins (Minnesota Waters Permit Program)
- Minnesota Wetland Conservation Act (1991) mandated 'no net loss.'
- Permanent Wetland Preserves Program encourages permanent conservation of existing wetlands.
- Comprehensive wetland conservation plan for the state
- Restoration of wetlands on farmlands promoted through several government programs (e.g., Swampbuster, Reinvest In Minnesota (RIM), Flood Risk Reduction Program, Wetland Reserve Program)

HOW WE BENEFIT FROM HEALTHY WETLANDS

Wetlands, an important part of Minnesota's natural heritage, provide valuable ecological services as well as direct social and economic benefits to Minnesotans. Wetlands are an integral part of the hydrologic cycle and play a very important role in the storage of floodwater. A measure of the benefits derived from wetlands is the cost of replacing functions once performed by wetlands now lost to development. A conservative estimate of costs to the state for replacing floodwater storage basins is $1.5 million a year, and about $125 million is spent each year for flood damage in rural and urban areas (Minnesota Wetlands Conservation Plan 1996). Flood impacts and the costs associated with them are generally lower in watersheds in which wetlands have been retained.

Wetland systems are also important filters of sediment, nutrients, and chemicals. The dense vegetation and organic soils of wetlands intercept materials that would otherwise enter rivers, streams, lakes, or groundwater, thus decreasing pollution in those systems and providing economic benefits that are often overlooked. Nearly $20 million has been spent in the past 10 years by state and federal agencies to remove sediment and nutrients from water that would normally have been filtered by Minnesota wetlands. Millions of dollars are spent annually by the U.S. Army Corps of Engineers for dredging Mississippi River sediment that was once intercepted by riverine wetlands (Minnesota Wetlands Conservation Plan 1996).

Wetlands add greatly to the state's biodiversity. Many terrestrial and aquatic animals depend on wetlands for habitat and feeding areas during some part of their life. Numerous unique plants occur in wetlands. In fact, wetlands support 31 percent of the plant species in the continental United States (Wilen and Tiner 1993). Wetlands sustain fish and waterfowl populations by providing protected, well-vegetated, nutrient-rich areas that are wet much of the time. Spawning and nursery grounds for fish and leeches contribute $50 million to Minnesota's economy each year (Minnesota Wetlands Conservation Plan 1996).

Each year more people enjoy wetlands and the plants and animals they support through hunting, fishing, hiking and nature observation. Over 1 million Minnesotans participate in wildlife observation, and over 2 million participate in fishing and hunting. These wildlife-related activities are valued at $40 million each year (Minnesota Wetlands Conservation Plan 1996). The natural areas and wildlife that are the focus of these activities are part of an integrated landscape in which wetlands are often a primary component.

Wetlands also provide direct economic benefits as sites for wild rice and paddy rice industries. These industries contribute $27 million annually to the state's economy.

ENVIRONMENTAL INDICATORS

What are environmental indicators, and how can they help us maintain healthy wetland ecosystems? Indicators are selected measures of the environment or of human activities that affect the environment. They help us understand the condition of our wetlands, alert us to potential problems, and point to ways to prevent or fix problems before they become crises. The following scenario demonstrates the value of environmental indicators.

Urban development expands into a rural landscape that includes a mix of agricultural lands and natural habitats with woodland corridors, wetlands, and clean lakes and streams. Ducks and herons are abundant in the wetlands scattered throughout the landscape, and the sounds of frogs and toads calling in the evening are familiar. As housing development expand into the area, woodlands and native vegetation around wetlands and streams are replaced with houses and manicured lawns. Improved roads, storm drainage systems, and service facilities alter the natural water levels and flows across the landscape. As natural habitats are converted and water flows are altered, changes occur in the wetlands. Large patches of exotic species, such as purple loosestrife, and invasive native species, such as cattails, replace the original diverse assemblage of wetland rushes, sedges, and herbs. These changes reduce the quality of the habitat for wildlife; animal populations, from ducks and herons to crayfish and frogs, begin to decline. The altered wetlands lose their capacity to filter nutrients from runoff and to moderate floods, essential services that protect water quality in adjacent lakes and streams. As the landscape's wetlands are gradually degraded, polluted lakes and streams with excessive algal blooms and declining fisheries become more common.

The wetland development scenario is representative of the complex issues affecting our wetlands. The Environmental Indicators Initiative framework provides insights into the relationships between human activities and environmental change and helps select indicators that measure progress toward solving complex problems. Some human activities adversely affect ecosystem health and diminish the flow of benefits. In the wetland scenario (Table 1), *human activities* that change the density and pattern of housing development impose several pressures on the environment. Indicators that measure these pressures include **conversion of natural habitat, the percentage of land in impervious surface, altered water movement, diversion of storm water to sewers,** and **levels of fertilizers, pesticides, and road salts entering area lakes and wetlands**. These pressures alter *environmental conditions*, which can be charted with indicators such as **abundance of native vegetation and invasive species, bird diversity, water quality in wetland and adjacent lakes and streams,** and **water-level fluctuations in wetlands**. These indicators of human activities and environmental condition help assess environmental trends and provide insights into complex cause-and-effect relationships.

This information may suggest the need for citizens to implement appropriate programs and *management strategies*, such as **promoting environmentally sensitive development (i.e., guiding development to those areas most able to handle growth and away from sensitive areas like prime agricultural land and natural areas), constructing infiltration ponds, applying lawn chemicals in an environmentally sensitive way, restoring backyard habitat,** and **reestablishing vegetated strips along waterways**. These management activities can help maintain or restore healthy wetlands and natural habitats by taking proactive measures to modify the pressures that cause environmental degradation.

Healthy wetlands provide residents with a number of important *benefits*, such as **flood control, clean water, fish and wildlife, hunting,** and **outdoor recreation**. These strategies are effective in large part because they address the human activities that cause declines in the health of the wetland. An integrated set of indicators helps us understand how our actions alter ecosystems and their ability to provide the benefits on which we depend.

Table 1 **WETLAND**

Examples of Wetland Indicators from an Urbanization Scenario

HUMAN ACTIVITIES	ENVIRONMENTAL CONDITION	SOCIAL STRATEGIES	BENEFITS
• Conversion of natural habitat • Percentage of land in impervious surface • Altered water movement • Runoff of fertilizers, pesticides, and road salts	• Abundance of native plants and invasive species • Variety of wetland birds • Water quality in wetlands and adjacent lakes and streams	• Environmentally sensitive development • Construction of settling ponds • Environmentally sensitive chemical use • Reestablishment of vegetative buffers	• Flood control • Clean water • Self-sustaining fish and wildlife populations • Outdoor recreation

ECOLOGY

Wetland ecosystems are areas where aquatic and terrestrial systems intergrade. Because of this, they exhibit some of the characteristics of each. Wetlands frequently are found around lakes and rivers but can occur anywhere in which water saturates soils and creates conditions that support characteristic wetland plants and inhibits others. The plants growing on these sites are adapted to the saturated (hydric) soils characteristic of wetlands. In general, low oxygen levels also limit the kinds and number of plants and animals that can inhabit many wetlands.

Hydrology

Wetland ecosystems are an integral component of the hydrologic cycle, serving as reservoirs that store water and facilitate its movement to other reservoirs. Water may remain in surface or groundwater bodies for long periods of time before returning to the atmosphere via evaporation and transpiration. As water moves between air and land, it accumulates minerals, nutrients, and other compounds that change its chemistry. Climate, geology, topography, and human activities all affect water movement and chemistry.

The hydrologic regime is the single most important factor determining the structure and function of wetlands (Mitsch and Gosselink 1993) and is a prime example of the importance of natural disturbance in ecosystems. The source and quality of water and the frequency, duration, and intensity of flooding strongly influence wetland plant and animal communities, levels of productivity, rates of material cycling, and soil conditions. Many wetlands occur where groundwater discharges at the surface as springs or seeps or where the water table is close to the surface. In some wetlands, however, water percolates down through soils and rocks and replenishes groundwater reserves. The source of water in most wetlands is a combination of precipitation, groundwater, and surface water. The dominant source of water helps determine wetland type. The distribution and diversity of wetlands in Minnesota are the results of differences in water availability, flooding regimes, and water chemistry. Wetlands lose water as it flows to lakes or rivers, percolates to groundwater reservoirs, is taken up by plants, or evaporates.

In most wetlands, water levels fluctuate seasonally in response to changes in water table levels that are driven by precipitation and evapotranspiration. Often, periods of low water or complete drying alternate with periods of saturated or flooded soils. Such fluctuations are most dramatic in wetlands dominated by precipitation and surface flow and are less pronounced in wetlands fed by groundwater. Periods of high water help support aquatic plant and animal communities and serve to replenish soil nutrients in riverine systems, and periods of drying stimulate nutrient cycling and decomposition.

One of the greatest challenges in the conservation of wetland ecosystems is maintaining the groundwater and surface-water sources that sustain them. Alterations in local and regional flow of water result from a variety of causes, including beaver dams, drought, floods, and human activity. Humans strongly influence surface water and groundwater components of the hydrologic cycle. For example, levees around rivers and streams, and drainage systems (ditches, channels, drainpipes, storm sewer systems) concentrate flow from the surface and hasten its movement into lakes and rivers. Dams on rivers and streams may cause flooding of upstream landscapes but withhold water from formerly flooded areas. Impermeable surfaces concentrate flow into localized areas. Groundwater wells for personal and industrial uses may lower groundwater levels by extracting water faster than it is replenished. Large-scale construction projects that divert water flow, changes to surface water bodies that feed groundwater reservoirs, and increases in impermeable cover that prevents downward percolation also affect groundwater.

Change in the hydrologic regime, compared to that which existed historically, is an important indicator of wetland ecosystem health. For example, reduced inputs of calcium-rich waters into a calcareous fen may result from natural variability in upwelling with no long-term effects. On the other hand, extreme or long-lasting changes may indicate that wetland health is threatened. As drying of the soils persists, the wetland plants adapted to calcium-enriched waters may not have adequate resources and may be replaced by a different plant community. Similarly, dramatic **changes in frequency or duration of water level fluctuations** in other wetlands also may be an indication of reduced wetland health. Water level changes may result from natural variability in climate, but they may also result from **increases in impermeable cover** that prevent percolation of storm water into soils and divert more water to the wetlands. Fluctuations that are more frequent and more extreme may create conditions that harm many

WETLAND TYPES

Many types of wetlands occur in Minnesota (Edgers and Reed 1987, Narrowing 1989).

Littoral wetlands occur as a fringe or emergent vegetation, including bulrushes, cattails, wild rice, and other grasses, surrounding lakes and ponds. Wave activity and water-level fluctuations are strong influences. Soils range from poor to fairly rich in organic material, depending on animal activity and on the availability of oxygen for microbes and invertebrates.

In **marshes** (including prairie potholes) standing water is present for much of the year. Water depth may range from a few inches to several feet, with fluctuations dependent on seasonal weather patterns. In very dry years marshes may dry completely. Emergent vegetation, such as cattails, sedges, and bulrushes, typically grows in mucky soils and may grow in solid stands or in a ring around the basin edge, with open water in the center.

Wet meadows and **sedge meadows** occur in association with small stream riparian wetlands and in closed basins with very shallow water or saturated soil. They are covered with herbs, grasses, and sedges. Persistent wetness contributes to a spongy accumulation of peat.

Calcareous fens are the rarest wetlands in the state. They occur where calcium- and magnesium-rich groundwater reaches the surface. Except under drought conditions or after alterations to groundwater hydrology, these sites remain saturated but lack deep standing water. Calcareous fens support a community of herbaceous vegetation that is not found in any other wetland type.

Bogs are a type of wetland characterized by a mat of Sphagnum moss, unique herbs, and sedges. In the older, more developed bogs, evergreen shrubs and trees are common. The saturated, acidic soils found in bogs inhibit breakdown of plant material and allow deep accumulations of peat. Bogs often receive a combination of groundwater, surface water, and precipitation inputs.

Shrub swamps and **wooded swamps** are saturated or seasonally flooded wetlands. Shrub swamps are dominated by tall shrubs, such as willow and dogwood or alder, along with grasses, sedges, and herbs. Organic-rich mucky to peaty soils are common. Shrub swamps may replace wet meadows and often occur in river and stream floodplains. Wooded swamps are associated with ancient lake basins (now filled in) or with old meanders of a river. They are dominated by conifers, such as tamarack and northern white cedar, or by hardwoods, such as elm, ash, and maple.

Floodplain forests are tightly linked to river systems. They are seasonally inundated during periods of high flow, such as spring runoff and flooding, but during much of the year they are well drained. The alluvial soils are reworked frequently, eroded and redeposited with changes in flow regimes. Floodplain forest are dominated by deciduous, hardwood trees such as American elm, eastern cottonwood, green ash, and silver maple, with an understory of tall herbaceous plants.

plants and may alter the character of a wetland dramatically.

Nutrient cycling

Breakdown and transformation of plant and animal material in wetlands provide nutrients for the plants growing there. These plants are, in turn, an important source of food for the many animals that use wetlands. Microorganisms and invertebrates are responsible for most of the initial conversions from plant and animal biomass to minerals and nutrients, and they also are important for transformation of other compounds entering the wetland.

Water flowing into a wetland from subsurface flows or from the surrounding landscape carries sediment, nutrients, pesticides, fertilizers, and other chemicals. Soil organisms absorb and metabolize many nutrients and minerals from the water. Over the long term, materials accumulate in the wetland soils and may remain there until the system is disturbed. The removal of chemical compounds improves the quality of the water that leaves the site but may degrade the wetland itself. To maintain the long-term health of wetlands, it is important to prevent excessive inputs of sediments and associated nutrients and pesticides into the wetland basin.

Monitoring levels of nutrients and contaminants in wetland soils and waters provides useful information about the health of the wetland and the animals that use it. Indicators such as **water pH** or **concentration of nitrogen and phosphorus** help us assess wetland nutrient status. An increase in the level of nutrients is often accompanied by a change in the pH and a change in the plant communities at a site and may result from inputs of nutrient-enriched groundwater or surface water from adjacent landscapes. Whatever the cause, **changes in the plant community** likely result in shifts in the community of animals (insects, mammals, amphibians, and birds) using the site. Because of the sensitivity of plants to nutrient availability, changes in the plant community can be an indication of altered wetland health.

Biological productivity

The regular availability of water and nutrients makes wetlands, particularly marshes, some of the most productive systems in the world. Each year, large quantities of new leaves, roots, stems, and seeds are produced in wetlands. Plant productivity and the metabolism and reproduction of soil organisms are influenced by oxygen availability and temperature. High water levels may limit oxygen availability but a variety of adaptations allow many plants to survive in low oxygen conditions. Some plants grow on tufts of other plants to remain above the water level, while others transfer oxygen down to roots from the surface, improving conditions not only for the plant but also for the microorganisms nearby.

Wetlands support a large number of animal species. Nationwide, about 150 bird species and 200 fish species depend on wetlands during some part of their life cycle (Niering 1987). The prairie pothole region, which includes parts of western Minnesota, accounts for only 10 percent of the nation's wetlands but produces 50 percent of the mallards, pintails, and green-wing teals. Grebes, pelicans, herons, egrets and many other non-game birds also use prairie wetlands (Tester 1995). The combination of emergent vegetation with open water provides diverse habitat and food resources, resulting in conditions conducive to many birds (Weller 1987). Frogs and toads depend on wetlands for breeding habitat. In fact, some northern Minnesota prairies and prairie wetlands are estimated to support tens of thousands of toads per square mile (Tester 1995). Littoral wetlands are highly productive systems as well, providing important nesting habitat for loons and other waterfowl and protected breeding grounds for many fish.

Environmental indicators that focus on **trends in biological productivity** help measure wetland health. Monitoring **changes in the size of populations of waterfowl and amphibians, changes in songbird bird diversity,** and **changes in the abundance of macroinvertebrates** (e.g., crayfish, aquatic insects) helps track wetland health.

Biological diversity

Although wetlands occupy only 5 percent of the national land base, they help sustain about one-third of all threatened and endangered plant and animal species. Species such as the northern bog lemming, the sandhill crane, and the gray wolf use bogs and fens for cover and for foraging. The northern cricket frog, Blanding's turtle, and numerous other threatened and endangered species depend on floodplain forests. Prairie marshes and littoral wetlands are important habitat for the dakota skipper and Karner blue butterflies, the horned grebe, Forster's tern, several rushes, and many other rare plants and animals.

In addition to supporting species at risk, wetlands support healthy populations of many unique and interesting plant and animal species, many of them restricted to wetlands. The star-nosed mole, the arctic shrew, pitcher plants, and numerous sedges, for example, depend on fens and bogs for survival. A host of birds, including grebes, pelicans, sandpipers, owls, and warblers, nest and feed in marshes and prairie potholes. Marshes and littoral wetlands are important fish spawning and nursery grounds. Voles, lemmings, and shrews build nests in the moss of bogs or the leafy and woody debris of swamps. Deer, moose, and other large animals browse in swamps and bogs. Floodplain forests and backwater areas are essential for reproduction, feeding, and protective cover for numerous mammals, fish, and birds, including those that use rivers as migratory flyways.

The diversity of organisms in Minnesota is in large part a function of the number and variety of wetlands occurring in the state. Maintaining the conditions that support Minnesota's wetland-dependent species requires that many types of wetlands in many locations be preserved. This is particularly evident in the prairie pothole region. Here, natural variability in regional and local hydrology results in irregular wet and dry cycles and unpredictable habitat availability. At any point in time, some wetlands support animal populations, while others do not because they are poorly vegetated or dry. An interconnected network of wetlands, including wetlands with a range of hydrologic characteristics, may best maintain waterfowl, amphibians, insects, fish, and mammals over the long term (Galatowitsch and van der Valk 1994). Such a network also helps to maintain diverse plant communities by promoting the dispersal of plants from one wetland to another and allowing revegetation after extreme drought, high levels of animal activity, or human disturbance.

Humans have converted many meadow and marsh wetlands with diverse plant communities to cattail or reed-canary grass wetlands. Although these wetlands support many species, the increase of more aggressive plant species occurs at the expense of other plants and animals. The long-term impact is an overall reduction in the biological diversity associated with wetlands of the state. Monitoring **changes in the abundance and distribution of key plants and animals** helps track the health of wetlands. In areas with increasing diversity of native littoral communities, we would expect a more diverse animal community and a wetland ecosystem that is more resilient after disturbances (Tilman et al. 1996). **Reduced biological diversity of native species** may signify declining conditions within the wetland or surrounding landscape that limit the ability of plant and animal species to thrive.

Linkages with other systems

Wetlands influence adjacent uplands and aquatic ecosystems. They provide feeding grounds and nesting material for both terrestrial and aquatic animals. Sediment and nutrients carried by wind or surface water are often intercepted by wetland ecosystems before entering adjacent water bodies. The rooted aquatic vegetation found along the edges of many lakes, rivers, and streams reduces streambank erosion and slows undercutting by stabilizing sediments, slowing the current velocity, and dampening wave action. Wetlands have the capacity to assimilate nutrients, sediments, and toxins transported from upland areas through binding with soils, uptake by plants, and transformation by microorganisms. When this capacity is exceeded, however, a result is the export of these materials to groundwater or to downslope water bodies. Because of connections with other landscape elements, the health of wetlands, and all aquatic systems, is a direct reflection of the health of the watershed. Environmental indicators for wetlands tell us not only about the health of wetlands but also about the health of the surrounding landscape.

PRESSURES ON WETLANDS

Wetland conversions

Wetland systems once covered more than 392 million acres in the United States. From 1780 to 1980, 53 percent of the wetlands within the lower 48 states were drained (Figure 1), filled, channelized, or otherwise converted for human use (Dahl 1990), the equivalent of 60 acres lost per hour for 200 years. Agricultural practices caused the majority of these losses, and urban development and road construction led to additional losses (Figure 2).

Historically, losses of wetlands in Minnesota followed the national trend and were due primarily to conversion of land for agriculture (Figure 3). Conversion of wetlands to urban development and roads, however, is increasing. Nationally, 20 percent of the loss of wetlands from 1982 to 1992 was due to agricultural activity, and 57 percent was attributed to urban development. During this same period, 38 percent of wetlands in Minnesota were lost to agriculture and about 38 percent to development (Figure 4; National Resources Conservation Service 1992). In recent years, increased numbers of lakeshore homes and recreational facilities on lakes have contributed to loss of littoral wetlands. The cumulative effects of removing wetlands include reduced fish and wildlife habitat and increased shoreline erosion, turbidity, and nutrient loading. In watersheds where no wetlands remain, flooding and degraded water quality are more likely.

Indicators can provide important information about watershed and wetland ecosystem integrity. **Changes in land use or plans for new land uses** can be an early indicator of likely impacts to wetland ecosystems. Indicators of **wetland acreage** should be accompanied by assessment of wetland functions (e.g., **changes in hydrologic regime, plant species diversity**).

Figure 2
Primary Reasons for Wetland Conversion in the USA from the Mid-1950s to Mid-1970s

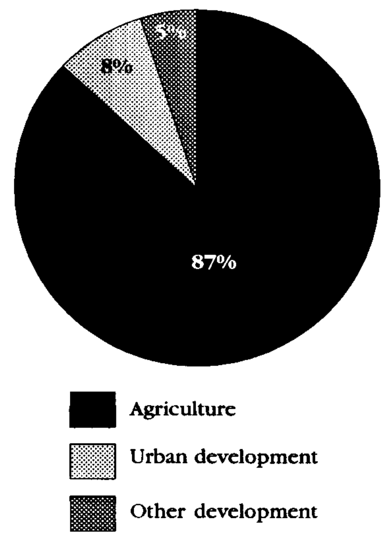

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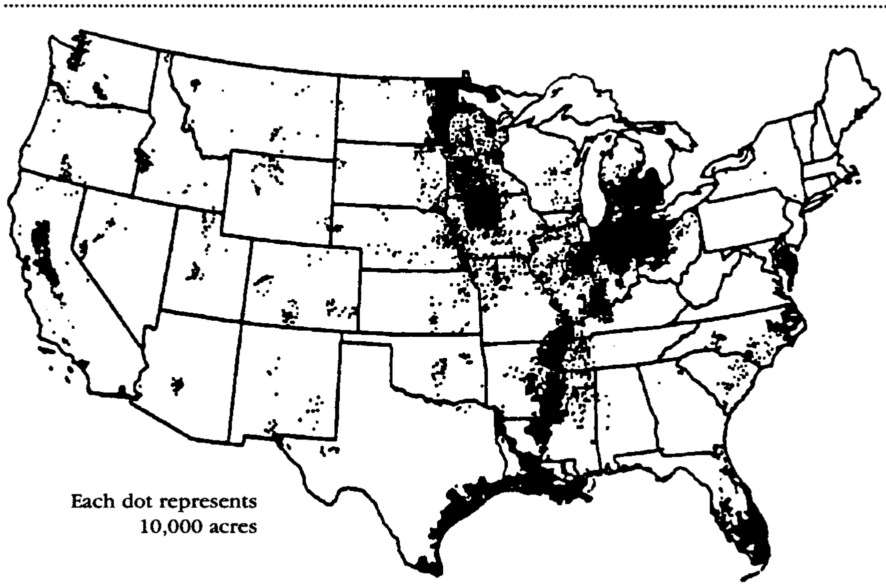
Figure 1
Land Organized into Drainage Enterprises

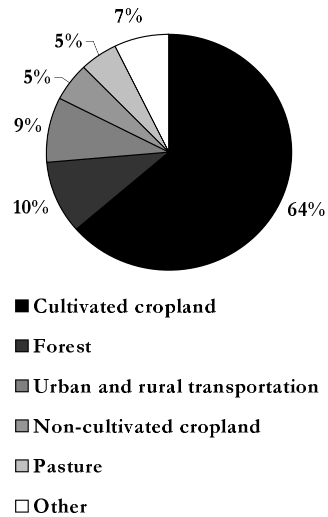


From USDA 1987

Sediment and chemical contaminants

Degradation of wetlands results from inputs of sediments, fertilizer, pesticides, fecal bacteria, oil, gasoline, salts, and other chemical substances carried in surface water, stormwater, wastewater, and wind. In many cases, nutrient enrichment results in the conversion of diverse wetland communities to less valuable cattail or reed-canary grass stands. Many

Figure 3
Land Use & Cover Associated with Wetland Loss in Minnesota

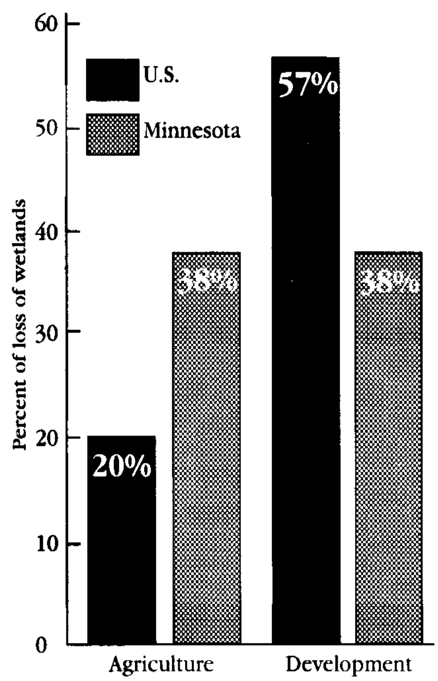


Figures based on NRCS 1992 data

contaminants are transferred from sediment or water into plants or animals that are then consumed by larger animals and humans. Bioaccumulated toxins interfere with reproduction and reduce the health of aquatic and semi-aquatic animals. Tracking changes in **soil and water contaminant levels** can help to pinpoint the cause of wetland decline. Monitoring **changes in amphibian and waterfowl populations** also helps track the effects of chemical contaminants in wetlands.

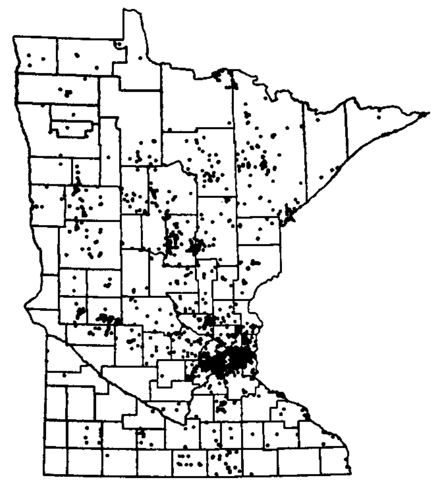
Biological pressures
Invasive species that outcompete native species alter the natural functioning of wetlands. In many wetlands, for example, cattails, sedges, and rushes are being replaced with uniform, dense stands of purple loosestrife. This attractive plant is aggressive and may cover large wetlands quickly. It replaces plants that are important as food and nesting cover and provides poor animal habitat (Skinner et al. 1994). Today, purple loosestrife occurs in wetlands across the state but is concentrated in wetlands and lakes in the Minneapolis-St. Paul metropolitan area (Figure 5). As of 1996, 560 wetlands were infested with purple loosestrife. The MDNR Purple Loosestrife Program attempts to control the spread of this plant with both chemical and biological methods. Only nine new wetlands were contaminated from 1995 to 1996 (Exotic Species Program 1996). The **occurrence and coverage of invasive species** that displace native plants and animals indicate potential or imminent decline in wetland health.

Figure 4
Loss of Wetlands to Agriculture and Development 1982-92



NRCS, 1992

Figure 5
Purple Loosestrife Infestations in Minnesota



From Skinner et al. 1994

Climate change
Global warming is expected to cause significant alterations in wetland location and functioning by increasing evaporation and altering water levels. Changes in the water balance and in nutrient cycling may result as temperatures increase, and these changes are likely to result in altered plant communities and the animal populations they support. New wetlands are likely to develop in northern climates, while southern wetlands are more likely to experience significant drying. As wetlands dry out, natural fires may threaten areas having large quantities of plant litter, releasing previously stored carbon and nitrogen to the atmosphere.

WETLAND STATUS AND TRENDS

National trends

Severe flood damage, reduced waterfowl populations, decreased fish and shellfish harvests, increased erosion of soil, and reduced water quality have stimulated a nationwide increase in awareness of the importance of wetland systems. Laws that protect wetland systems, and increased efforts at restoring and creating wetlands, have greatly reduced wetland losses in recent decades. Nationwide, losses of wetlands from 1982 to 1992 amounted to 50,000 acres per year, far lower than the 157,000 acres per year lost in the previous decade (Natural Resources Conservation Service 1995).

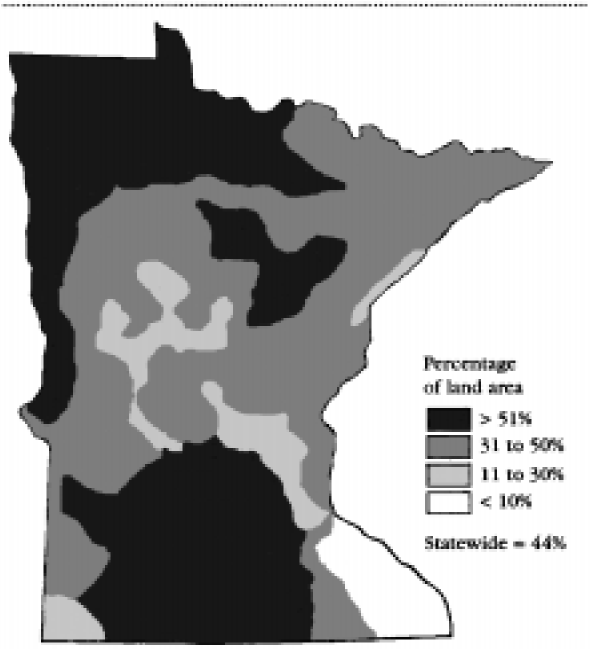
Status of Minnesota wetlands

Wetland Gains and Losses

Based on the distribution of hydric soils, it is estimated that 44 percent of Minnesota, nearly 22 million acres, was wetland before the arrival of European settlers (Figure 6a). Marshes and wet meadows occurred throughout much of the state. Bogs and fens were more common in the northern half of the state, prairie wetlands were most common in western and southwestern Minnesota, and floodplain forests and backwaters were most common along the Minnesota and Mississippi Rivers (Coffin 1988; Minnesota Wetlands Conservation Plan 1997). Only 10.6 million acres, or 54 percent of these wetlands, remain (Figure 6b, National Resources Conservation Service 1992).

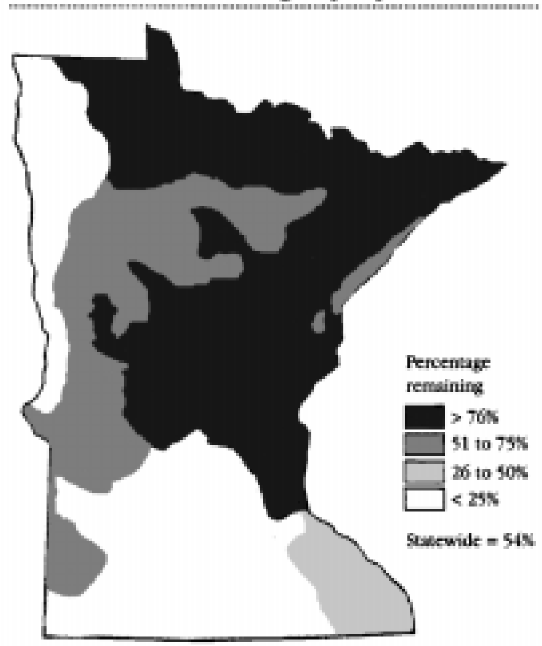
The proportion of original wetlands lost varies widely across the state. In northern Minnesota between 80 and 100 percent of presettlement wetlands still remain. Here, bogs, sedge meadows, and shrub swamps are common. In contrast, several counties in western and southern Minnesota have lost 100 percent of their presettlement wetlands (Minnesota Wetlands Conservation Plan 1997). On average, however, less than 50 percent of presettlement wetlands remain in this area (Figure 6b).

Figure 6a
Estimated Percentage of Land Area in Hydric Soils



Source: Estimates derived from data collected in the 1992 National Resources Inventory, Natural Resources Conservation Service.

Figure 6b
Estimated Percentage of Hydric Soils



The Minnesota Board of Water and Soil Resources annually reports to the Minnesota Legislature on the status of implementation of state laws and programs relating to wetlands. Data collected from the second year of full Wetland Conservation Act (WCA) implementation (January 1995-January 1996) found that of 7,673 proposed wetland projects, 71% (5,456) were resolved with no disturbance to a wetland (an estimated protection of 3,493 acres of wetlands). In addition, 381 wetland acres were replaced and 237 acres were drained or filled under the WCA ('unavoidable wetland impacts,' BWSR 1996) . However, significant wetland losses continue to occur through activities that require no approvals or permits, making them impossible to track (BWSR 1996). While Minnesota's regulatory programs are protecting wetlands, it is likely that losses still exceed gains in wetland acreage (Minnesota Wetland Conservation Plan 1997). Furthermore, newly created wetlands often do not function as well as natural wetlands—failing to achieve the goals for hydrology and for plant and animal communities.

Ecological Functions and Benefits

Quantitative and qualitative data on wetland functions (natural processes) and benefits is currently not available (Minnesota Wetland Conservation Plan, 1997; BWSR 1996). The Minnesota Routine Assessment Method For Evaluating Wetland Values (MNRAM), is a recently developed analytical method to evaluate wetland functions and values. MNRAM assigns a low, medium, high, exceptional, or not-applicable rating to a consolidated set of nine wetland functions and values (flood and storm water, shoreline protection, groundwater interaction, water quality protection, wildlife habitat, fishery habitat, floral diversity and integrity, aesthetics, recreation and education, and commercial uses). The methodology is now available for use statewide, and may be improved in future editions (Minnesota Wetlands Conservation Plan, 1997).

Wetland creation and restoration is intended to offset wetland losses and allow economic development. Few of these projects have been monitored for long-term ecosystem health, however, making it difficult to determine whether these wetlands perform the same ecological functions as do natural wetlands. Furthermore, long-term evaluation of wetland creation projects can be challenging because wetlands are created for a variety of purposes. Because wetlands are complex systems, comparisons across wetland types or from location to location are difficult (D'Alvanzo 1986).

Galatowitsch and van der Valk (1996) studied 62 wetlands in the southern area of the prairie pothole region (which includes counties in Minnesota, Iowa and South Dakota). Wetlands were restored by interrupting drainage tile lines, by plugging drainage ditches, or by blocking natural drainage ways. Restoration resulted in a pattern of wetland distribution very different from the predrainage pattern of many types of wetlands in a variety of sizes Galatowitsch and van der Valk, 1996). They concluded that wildlife species (e.g., common yellow throats, marsh wrens, swamp sparrows (Delphey and Dinsmore 1993 as sited in Galatowitsch and van der Valk 1996)) that require well-developed sedge meadow and shallow emergent vegetation, extensive wetland complexes, ephemeral/temporary wetlands and large wetlands are poorly served by current wetland restorations (Galatowitsch and van der Valk 1996).

Significant gains in Minnesota's wetland resource base will not be achieved through the mitigation required by regulatory programs, because the goal of those programs is to offset wetland losses (Minnesota's Wetland Conservation Plan, 1997) . Restoration, however, seeks a net gain of wetland functions and values in targeted areas of the state, and the maintenance or improvement of the ecological and hydrological integrity of watersheds. A variety of non-regulatory programs are designed to restore wetlands; their effectiveness can be enhanced through targeting areas for restoration programs and improving coordination among non-regulatory programs (Minnesota's Wetland Conservation Plan, 1997).

EXISTING POLICIES AND PROGRAMS

Recognition of the economic and ecological costs of wetland losses has stimulated a number of regulatory and non-regulatory initiatives and private and public programs at the state, national and international levels to protect and restore wetlands.

State initiatives

Minnesota has long been a leader in recognizing the importance of wetlands for long-term ecological health. Preservation of wetlands began in the 1950s, under the DNR's Save the Wetlands Program. Under this and similar programs more than 1,000 Wildlife Management Areas have been established, totaling nearly 900,000 acres. About one half of this land is wetland.

Public waters wetlands are protected under state laws governing all public waters. These include shallow marsh, deep marsh, and shallow open water wetlands that are 10 or more acres in size in unincorporated areas or 2 1/2 acres or larger in incorporated areas. Wetlands protected under the Wetland Conservation Act (WCA) are delineated according to the United States Army Corps of Engineers Wetland Delineation Manual (January 1987).

The 1991 Wetland Conservation Act established in state law the policy of 'no net loss' of existing wetlands. Under this law, those who propose to fill or drain wetlands are required to demonstrate that no feasible alternatives exist and to compensate for unavoidable wetland loss by restoring or creating other wetlands. Changes in the act in 1996 clarify the roles of state and local governments in wetlands issues and allow more flexibility in meeting the 'no net loss' goal in parts of the state with an abundance of wetlands. Additional changes increased exemptions for agricultural wetlands and reduced financial burdens on farmers (Helland 1996). The Wetland Conservation Act also established the Permanent Wetland Preserves Program (PWP) that offers compensation to landowners willing to place certain types of wetlands in a permanent conservation easement. These wetlands are then protected from grazing and cropping. PWP is administered by the Bureau of Water and Soil Resources and implemented by soil and water conservation districts at the local level. As of 1995, 276 easements have been acquired, perpetually protecting 11,225 acres of wetlands and surrounding uplands (BWSR 1996).

Not all wetlands are regulated under Minnesota or federal law. Exemptions exist for some kinds of current and historic land uses (Minnesota Wetlands Conservation Plan 1997).

Non-regulatory initiatives

The Minnesota Wetlands Conservation Plan (1997) used existing wetlands policies as the starting point to develop an umbrella wetlands policy framework. The framework strives to help coordinate state and federal agency responsibilities, create policy improvements, enhance information for decision making, and address concerns of landowners and local governments. The Plan was created through the combined efforts and contributions of a diverse group of citizens and professionals from throughout the state (Minnesota Wetlands Conservation Plan 1997).

The Reinvest in Minnesota (RIM) program attempts to protect and improve water quality by encouraging landowners to retire environmentally sensitive land from agricultural production. RIM reimburses farmers for placing their land in a permanent conservation easement, and provides assistance to the landowner to reestablish grass and tree cover and wetlands. Nearly 2,000 private landowners enrolled 45,000 acres of land (including 10,000 acres of wetland restoration easements) into the RIM Reserve Program between 1986 and 1993 (BWSR 1994).

The Minnesota Waterfowl Association (MWA) is a private, non-profit organization with a mission of protecting, preserving, and restoring habitat in the state for waterfowl and other wildlife populations. The MWA acquires land through donations, easements, and purchases, has active research and restoration programs, and provides many educational opportunities for youth.

National initiatives

The 1977 Clean Water Act (CWA) prohibits dredging or filling a wetland except as permitted by the Army Corps of Engineers. The CWA does not adequately protect wetlands against chemical contamination or degradation of plant and animal communities. It does, however, give authority to states to provide this protection under other provisions. The state of Minnesota has standards for water quality that help prevent such contamination and degradation.

The Conservation Reserve Program (CRP), authorized under the 1985 Food Security Act (FSA) and amended by the 1990 and 1996 Farm Bill, protects fragile farmland by encouraging farmers to stop growing crops on highly erodible and environmentally sensitive lands. The Wetland Reserve program (WRP) is another FSA program aimed at restoring and protecting wetlands on private property. WRP is a voluntary, incentives program that provides governmental payments to farmers who agree not to drain or alter wetlands on their land.

Other federal regulatory programs protect or conserve wetlands indirectly, including the Wetland Conservation 'Swampbuster' provision of the FSA, the National Pollution Discharge Elimination System (administered by MPCA), the Migratory Bird Conservation Act, and the Endangered Species Act.

International initiatives

The North American Waterfowl Management Plan (NAWMP) is an international agreement, signed in 1986 by the United States and Canada, and in 1994, by Mexico, for the conservation of wetland and waterfowl resources in those countries. Recognizing that waterfowl populations are an indicator of environmental health, the NAWMP is a strategic document for guiding the implementation of waterfowl population goals and wetland and associated grassland habitat goals. The Plan is implemented through joint ventures and their management boards–local partnerships among governments, private organizations, and individuals–that secure funding and implement projects to conserve and enhance waterfowl habitat at the local level (Minnesota Wetlands Conservation Plan 1997; Gerlach 1995).

Ducks Unlimited is an international, non-profit organization that restores, preserves, and creates waterfowl habitat in order to increase North America's waterfowl populations. Much of its work focuses on the prairie potholes, but includes other wetland types as well, totaling more than 7 million acres of wetlands. During the last decade, migration corridors, stopover habitat, and wintering habitat have received a great deal of attention.

EXAMPLE INDICATORS

Table 2 collects the indicators used in this chapter. The indicators are organized within the EII framework, which helps illustrate relationships among human activities, environmental condition, the flow of benefits, and strategies for sustaining a healthy environment. The indicators used in this chapter are examples that illustrate how indicators may help assess wetland health. The process of developing a comprehensive set of indicators that assess wetland health and inform environmental decisions is ongoing. Developing indicators will require input from stakeholders interested in their use, testing, refinement, and standardization.

Table 2

Example Indicators

HUMAN ACTIVITIES	ENVIRONMENTAL CONDITION	SOCIETAL STRATEGIES
Land conversions • Natural habitat conversion, land-use changes • Increase in impervious acres in watershed • Fertilizer, pesticide, and road-salt runoff • Sediment and nutrient inputs **Fragmentation** • Wetland isolation, relation to other wetland complexes and to surrounding natural communities **Altered water regime** • Draining, diversion, filling • Wetland extent and type diversity	**Productivity** • Diversity of wetland birds • Coverage of exotic and invasive species • Changes in the plant or animal community (plant biomass and annual production, wildlife population trends) • Decline of amphibian or waterfowl health **Biodiversity** • Changes in the abundance and distribution of key plants and animals (increase in exotics or endangered species) **Nutrient cycling** • Nutrients in water and sediments (change in pH, increased nitrogen or phosphorus, or algal blooms) • Changes in soil and water contaminant levels • Organic matter decomposition rate **Natural disturbance regimes** • Water level fluctuations • Frequency and duration of inundation	**Wetland planning & management** • Wetland restoration. • Environmentally sensitive chemical use. • Environmentally sensitive development. **Policy & legislative mandates** • 1991 Wetland Conservation Act mandates "no net loss" and strives for increased wetland acreage. 1996 revisions increased flexibility and reduce financial burdens on farmers. • Minnesota's Wetland Conservation Plan, builds on past policies and provides an "umbrella" wetlands policy framework to help coordinate different agency responsibilities, and address concerns of landowners and local governments.

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