Module III - Water, Ecosystem Services, and Biodiversity

The purpose of this module is to link the Regional Environmental Review Program to the goals of the Division of Ecological and Water Resources.

The Division of Ecological and Water Resources works with others to:

- Protect, restore, and sustain **watershed functions** (land-water connections, surface water resources)
- Protect, restore, and sustain **biodiversity** and its adaptive potential
- Protect, restore, and sustain **groundwater** resources
- Provide and support excellent outdoor **recreation opportunities**
- Minimize the negative economic and ecological impacts of **invasive species**
- Support **sustainable natural resource economies**
- Help achieve **other DNR core objectives**
- Create and maintain a learning organization that implements the division's **guiding principles**

The Environmental Review Program is a key component in the Department of Natural Resources' efforts to improve Minnesota's **water**, **ecosystem services**, and **biodiversity**. DNR staff members involved in evaluating the effects of land- and water-use plans and economic development projects must take an integrated, systems-based, collaborative, and community-based approach to improving the habitat base and providing technical advice on actions that have the potential to adversely affect the environment. Staff must be ever mindful of the need to sustain (1) quantities and qualities of water that will ensure that Minnesota's people and other biota can survive and thrive in the midst of changing trends in energy, climate, and demographics; (2) levels of diversity that will provide native Minnesota species and biomes with the resilience and adaptive capacities they need to evolve and thrive in the midst of changing conditions; and (3) economically vital ecosystem services that will provide Minnesota with economic and ecological security into the future.

Minnesota's State Wildlife Action Plan (SWAP) has identified 292 species in greatest conservation need (SGCN) in Minnesota. SGCN are defined as native animals whose populations are rare, declining, or vulnerable to decline and are below levels desirable to ensure their long-term health and stability. These species are rare owing to many interconnected factors; however, after a careful review, the SWAP technical team asserted that habitat loss and deterioration are the primary causes of these species' rarity. Thus, SGCN represent not only the

potential loss of biodiversity at the species level but also signal stressors on Minnesota's ecosystems and a potential reduction in ecosystem services. See also Module IV, "Incorporating the State Wildlife Action Plan (SWAP) into the Environmental Review Process."

Environmental review can be challenging. DNR reviewers identify serious environmental issues and in the defense of the state's resources recommend changes or even question the need for a project. Environmental review should not be a combative process, however, but one in which the participants cooperate to achieve mutual benefits. More than anything else, DNR reviewers collaborate with many communities to provide the information needed to heighten public appreciation for and awareness of the complex systems-based ecological relationships and hydrologic systems that underlie DNR management decisions. Reviewers do not, however, simply provide environmental information; they strive to make that information central to all economic and social decisions. The goal is to prevent and everywhere possible reverse the degradation of water, ecosystem services, and biodiversity.

The following sections provide background information on water, ecosystem services, and biodiversity and develop the relationship between environmental review and these three resource topics.

WATER

Sustainable quantities and qualities of water that will ensure clean water is available for Minnesota's people and other biota to survive and thrive in the midst of changing trends in energy, climate, and demographics.

—Draft Design Ideas on a Strategic Framework (working paper for the Waters and Ecological Resources transformation), October 22, 2009

The waters of Minnesota include lakes, rivers, ponds, streams, groundwater, springs, cave waters, floodplains, and wetlands. The DNR has been charged with managing these waters. On January 15, 2010, the commissioner submitted a report evaluating and recommending options to provide for the long-term protection of the state's surface water and groundwater resources. That report identifies two powerful water policy laws enacted by the legislature that if implemented in combination with existing laws and rules, will begin to solve many of our water sustainability problems. If implementation rules and laws were adopted for these policy statutes, uniform application of the principles contained in *Minnesota Statutes*, section 103A.205 and *Minnesota Statutes,* section 103A.206 would reduce impairment and more sustainably manage the supply of all of Minnesota's waters. These two statutes serve as a reminder of the DNR's authority, through the environmental review program, to conserve water and enhance the quality of soil and water in the state.

Minnesota Statutes, section 103A.205 CONSERVATION POLICY FOR RAINWATER states:

> It is the policy of the state to promote the retention and conservation of all water precipitated from the atmosphere in the areas where it falls, as far as practicable. Except as otherwise expressly provided, all officers, departments, and other agencies of the state or political subdivisions having any authority or means for constructing, maintaining, or operating dams or other works or engaging in other projects or operations affecting precipitated water shall use the authority, as far as practicable, to effectuate the policy in this section.

Minnesota Statutes, section 103A.206 SOIL AND WATER CONSERVATION POLICY states:

> Maintaining and enhancing the quality of soil and water for the environmental and economic benefits they produce, preventing degradation, and restoring degraded soil and water resources of this state contribute greatly to the health, safety, economic well-being, and general welfare of this state and its citizens. **Land occupiers** [emphasis added] have the responsibility to implement practices that conserve the soil and water resources of the state. Soil and water conservation measures implemented on private lands in this state provide benefits to the general public by reducing erosion, sedimentation, siltation, water pollution, and damages caused by floods. The soil and water conservation policy of the state is to encourage land occupiers to conserve soil, water, and the natural resources they support through the implementation of practices that: (1) control or prevent erosion, sedimentation,

> siltation, and related pollution in order to preserve natural resources; (2) ensure continued soil productivity; (3) protect water quality; (4) prevent impairment of dams and reservoirs; (5) reduce damages caused by floods; (6) preserve wildlife; (7) protect the tax base; and (8) protect public lands and waters.

When taken in context, these two laws must be a major part of a solution to provide long-term protection for Minnesota's surface and groundwater resources. *Minnesota Statutes*, chapter 103 already offers multiple options that could deliver an effective implementation process guided by *Minnesota Statutes,* chapters 103B and 103C. (Source: *Long-Term Protection of the State's Surface Water and Groundwater Resources*. January 2010. Minnesota Department of Natural Resources)

Watersheds

DNR reviewers work with division experts, other DNR divisions, other agencies, local governments, organizations, and citizens to protect and improve the waters of Minnesota. Watershed protection is the key to sustaining the quantity and quality of the state's waters. Healthy watersheds provide desired quantities and qualities of water (for people and other biota).

The term *watershed*, or *catchment basin*, refers to "the entire physical area or basin drained by a distinct stream or riverine system, physically separated from other watersheds by ridgetop boundaries" (*Entering the Watershed, A New Approach to Save America's River Ecosystems* by The Pacific Rivers Council, 1993).

Gravity and topography are the two major factors that define a watershed. Gravity is the force that pulls all water downhill. Topography describes the form of the land: the hills, valleys, and other features that influence where and how water will flow. After saturating the ground, rain or meltwater trickles downhill in tiny rivulets that coalesce into larger ones that eventually combine into streams. These then merge into rivers that finally flow into the ocean, sometimes stopping temporarily in water bodies such as lakes. Gravity and topography help define these channels of water from the tiny to the huge and cause them to join together into stream networks.

Every channel (or lake) of a given stream network drains an area of land around it known as its watershed. As a stream network is made up of component channels, a given watershed also comprises component watersheds. These, in turn, are made up of still smaller component watersheds, and so on. Watersheds are described in terms of "hydrologic units."

Hydrologic Units

The United States Geological Survey (USGS) monitors the quantity and quality of surface and ground waters throughout the nation. The USGS organizes the United States into successively smaller hydrologic units that are classified into four levels: regions, sub-regions, accounting units, and cataloging units (also known as watersheds). The hydrologic units are arranged within each other, from the smallest (cataloging units) to the largest (regions). Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to eight digits based on the four levels of classification in the hydrologic unit system.

The first level of classification divides the nation into 21 major geographic regions. These geographic areas contain either the drainage area of a major river, such as the Missouri region, or the combined drainage areas of a series of rivers, such as the Texas-Gulf region, which includes a number of rivers draining into the Gulf of Mexico. Eighteen of the regions occupy the land area of the conterminous United States. Alaska is region 19, the Hawaii Islands constitute region 20, and Puerto Rico and other outlying Caribbean areas are region 21. Much of Minnesota is in the Upper Mississippi region, with portions in the Souris Red Rainy, Great Lakes, and Missouri regions.

The second level of classification divides the 21 regions into 221 subregions. A subregion includes the area drained by a river system, a reach of a river and its tributaries in that reach, a closed basin(s), or a group of streams forming a coastal drainage area.

The third level of classification subdivides many of the subregions into accounting units. These 378 hydrologic accounting units are nested within, or can be equivalent to the subregions.

The fourth level of classification is the cataloging unit, the smallest element in the hierarchy of hydrologic units. A cataloging unit is a geographic area representing part of all of a surface drainage basin, a combination of drainage basins, or a distinct hydrologic feature. These units subdivide the subregions and accounting units into smaller areas. There are 2,264 Cataloging Units in the nation.

A single-sheet hydrologic unit map of the U.S. is available published at a scale of 1:3,500,000 and the map measures 41- by 58-inches. This map is part of *The National Atlas of the United States of America* series. "Hydrologic Units" is available from USGS at a cost of $7.00 per sheet. Its stock number is TUS5681. The "Hydrologic Units" atlas map supersedes both the "Hydrologic Unit Map of the United States, East" (GHU0057-1T) and the "Hydrologic Unit Map of the United States, West" (GHU0057-2T). Additional information regarding this map is available at: http://www.nationalatlas.gov/wallmaps.html#hydro.

Adapted from Seaber, P. R., Kapinos, F. P., and Knapp, G. L., 1987, Hydrologic Unit Maps: U.S. Geological Survey Water-Supply Paper 2294, 63 p. A copy of USGS Water-Supply Paper 2294 may be ordered from USGS Information Services.

Watersheds allow us to evaluate the quality and quantity of water resources geographically. Only by knowing our local watershed and the system of watersheds in which it resides can we begin to understand why and where small changes can have huge impacts on the state's water. Human and natural modifications made in one watershed may be spread many miles downstream to another. Understanding this "domino-effect" is critical to the DNR's monitoring and managing of the state's water resources. (See the DNR webpage www.dnr.state.mn.us/watersheds for more information on watersheds.)

Many of Minnesota's waters have been modified by human activity. Physical alteration, habitat loss and degradation, water withdrawal, overexploitation, pollution, and the introduction of invasive species are the main threats to these ecosystems and their associated biological resources. The Statewide Conservation and Preservation Plan (SCPP) identifies the key drivers of change as land-use change, contaminants, consumptive use, and energy. The SWAP identifies habitat loss and degradation, invasive species, and pollution as major threats to SGCN and habitats on which they depend.

The DNR Watershed Assessment Tool (WAT) uses five components—hydrology, connectivity, geomorphology, biology, and water quality—to describe the similarities and differences among

watersheds. These five components are described below. Understanding the concepts and connections among the five components is essential for comprehensive assessment of watershed health.

Watershed Components

Hydrology is the component that drives the system. The continuous hydrologic cycle transfers water, energy, nutrients, and matter throughout the watershed. The power of moving water, whether a raindrop displacing soil or a flooding torrent reshaping the floodplain, keeps the system in a continuous state of flux.

Within the stream, hydrology refers to the source, amount, and rate of water, both spatially and temporally, in a stream channel. It impacts the development of aquatic and riparian vegetation, microhabitat features, as well as the other four components. Human activities such as draining wetlands, building roads, creating tile lines, and withdrawing water will alter stream hydrology and affect the hydrologic cycle within the watershed.

Connectivity is the component that holds the system together. It refers to the flow, exchange, and pathways of organisms, energy, and matter. Connections exist on all scales and in all directions. Connectivity often refers to the river's ability to access floodplains and wetlands during high water, but watershed connectivity also refers to terrestrial habitats being functionally and spatially accessible at the time they are needed for life cycle completion.

There are physical barriers to connectivity such as dams, but flow reduction from water withdrawal, chemical barriers such as zones of poor water quality, or biological barriers such as competition from invasive species or fragmented microhabitat can also have disruptive effects.

Biology is the component that describes the web of life within the watershed. Aquatic plant and animal species require various habitat components at various points in their lifecycle. The importance of pools, riffles, and runs are well studied for fish communities, particularly game fish. The presence, amount, and arrangement of these microhabitat features are directly related to the river's hydrology and geomorphology. Water quality and connectivity also impact the presence and persistence of aquatic species. Additionally, the mosaic of terrestrial plants and animals along the stream, in its floodplain, and in its valley are vital to the character of the watershed. Plants are critical components of nitrogen, carbon, and oxygen cycles, serving as production sites and conversion centers for life-sustaining elements. Throughout a stream's length, the vegetation along the riparian corridor intercepts flows of incoming runoff, nutrients, and contaminants.

Rather than attempt to quantify the complexity and scope of all the biological components within a watershed system, key indicator species and habitats are used to give an indication of abundance and diversity within the watershed.

Geomorphology speaks of the geologic template of landscape topography, soil type, and stream flow patterns that lay the foundation for the other components. The shape of the stream channel itself, such as meanders, oxbows, backwaters, and floodplain, reflects the dynamic nature of the stream system. These forces interact to create and maintain diverse habitat for many aquatic species. Stream geomorphology directly impacts a river's hydrology and water quality as well: an unaltered, complex geomorphology helps to attenuate sedimentation and river flooding downstream.

These landscape level processes interact with human land-use patterns to drive the system in new and often unexpected directions. Quantifying and describing these relationships moves us toward an understanding and an ability to anticipate the consequences of land-use decisions.

Water Quality is the component that describes the current condition of the water in the stream. It often refers to the stream's chemical balance, water temperature, sediment load, chemical pollutants, and nutrient load. Aquatic species may be adapted to a certain set of water-quality conditions, such as needing coldwater streams, or may be deleteriously impacted by unnatural water quality components, such as the input of estrogen-mimicking compounds.

Sediment and contaminant impaired waters are a symptom of unhealthy contributions from the surrounding watershed. These can be direct discharges into the stream, or mobilized from elsewhere in the watershed as a result of land-use practices and carried to the stream.

(Adapted from Minnesota Department of Natural Resources, 2006, Tomorrow's Habitat, Rivers Overview p. 275.) http://www.dnr.state.mn.us/cwcs/habitat_descriptions.html

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Watersheds characterize the way water moves through a landscape. The terrestrial portions of watersheds determine the quantity and quality of that water. What happens on the landscape affects water at every point downstream. Our actions yesterday, today, and tomorrow determine whether we will have plentiful supplies of clean water. The Division of Watersheds, Ecosystems and Biodiversity is involved in the protecting water and water quality through several DNR programs.

Surface Water – Lakes, Wetlands, and Streams

Minnesota is rich in surface waters. Lakes, streams, and wetlands cover a substantial surface area of the state—over 13 million acres. For most Minnesotans, lakes define the state, the "land of 10,000 lakes." Streams are flowing waters. The waters of lakes and wetlands flow as well, just more slowly than water in streams. Flowing or standing still, surface waters are conditioned by the geomorphology of their basins, by climate, and by human activity.

Lakes, like other ecological systems, do not have an unlimited capacity to withstand changes due to increases in housing development, recreational activities, and other human endeavors. At some level of development, lake resources become strained to their limit. Beyond that point, the resources, along with user satisfaction, will begin to decline. Evidence of deterioration becomes readily apparent in weed-choked lakes, crowded, poorly maintained shoreland development, and declining fishing success, among other things.

The potential for exceeding resource limits is inherent in the lake watershed as well as in the lake. The soil characteristics of the watershed and the size of the lake in relationship to the watershed are among the factors that govern the amount and quality of runoff flowing into the lake. The depth of the lake, water quality, and hydrologic residence time all mitigate the impact of added pollution.

Stream health is an integral part of watershed health and is determined by the combined factors of the stream's configuration, environment, resilience, and stewardship. For more information on stream health, see "*Understanding Our Streams and Rivers: Are Minnesota's Streams Healthy?"* on the DNR Stream Habitat Program webpage.
http://files.dnr.state.mn.us/publications/waters/understanding_our_streams_and_rivers.pdf

Stream habitats are widely distributed throughout the state. Stream habitat is shaped by a complex combination of forces: hydrology, geomorphology, connectivity, and water quality. The Environmental Review Program stresses the need to manage these forces to restore and protect stream integrity and to maintain and enhance key SGCN habitat.

Wetlands are defined as areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support (and that under normal circumstances do support) a prevalence of vegetation typically adapted for life in saturated soil conditions. Minnesota has more wetland acreage than any other state except Alaska, in spite of extensive losses due to conversion to agricultural and development uses since the mid-nineteenth century. There are approximately 10.6 million acres of wetlands in the state. The wetlands in Minnesota vary considerably in their type and distribution across the state (Minnesota Department of Natural Resources, 1997).

Wetlands provide important landscape functions. They prevent flood damage by storing storm water and spring runoff, protect shorelines from wave damage, recharge groundwater, and protect water quality. Wetlands support a great variety of plant and wildlife species, many of which are unique to wetland habitats. Without the depressional wetlands that dot the landscape there would be no waterfowl production, and opportunities for hunting ducks and geese would be greatly diminished. Fisheries also depend on lake and riverine wetlands for spawning and nursery habitat and the production of insects.

What happens on the land has a direct impact on lakes and streams. Much of the state's landscape has been converted from native prairies, wetlands, and forests to farmland and urban areas. This land-use change, along with pollution and the ditching and damming of streams, has resulted in increased erosion and deposition, altered hydrology, more frequent and destructive flooding, degradation of aquatic and riparian habitat, and decrease in species diversity.

The DNR works with riparian landowners and communities across the landscape to restore and protect riparian buffers and floodplains and take actions to improve water quality, reduce surface water runoff, reduce soil loss, improve habitat, restore biodiversity, and encourage sustainable development. Through environmental review, the DNR engages citizens, landowners, businesses, local governments, interested organizations, and other agencies to meet these goals.

Surface Water - Peatlands

Peatlands are a special surface-water feature. Minnesota's peatlands are regionally and internationally significant for a variety of reasons. One reason is their extent: Minnesota has more peatland area (over 6 million acres) than any other state except Alaska. These peatlands serve as an important water reservoir, the significance of which has yet to be fully understood.

In addition, Minnesota peatlands present in nearly pristine condition unique developmental stages and landforms for research by the world's scientific community. They demonstrate the intricate hydrological patterns and landforms that develop over large areas with diverse water chemistry, flow patterns, and developmental processes. As an added aid to research, Minnesota's peatlands are among the few in the world that are free of permafrost. Permafrost makes it harder

to investigate the groundwater and subtle drainage systems so essential to peatland formation and development.

Peatlands also offer excellent research opportunities regarding the complex adjustment of living organisms to their environment. Harsh environmental conditions in the peatlands present dramatic challenges to the survival and adaptation of plant and animal species. In addition, Minnesota peatlands occur at the edges of three biomes, resulting in unique species assemblages, including 24 species that are endangered, threatened, or of special concern in the state.

Minnesota's peatlands present other research advantages as well. Other peatlands have been utilized commercially (such as in northern Europe) or exist in areas even more difficult to reach (such as Siberia and the Hudson Bay Lowlands). In comparison, Minnesota peatlands are relatively accessible yet relatively free of development.

In recognition of their significance, the legislature enacted the Wetland Conservation Act of 1991 (WCA), which established 18 peatland Scientific and Natural Areas. (Source: Minnesota Department of Natural Areas, Scientific and Natural Areas Program. See the SNA website for more information about peatlands.) http://www.dnr.state.mn.us/snas/coniferous_peatlands.html

The world's peatlands cover approximately 3% of the earth's land area and are estimated to contain 350 to 535 gigatons of carbon, or between 20 to 25% of the world's soil organic carbon stock (Gorham 1991). If peatland conditions were to become drier, previously flooded peat could be exposed to anaerobic conditions, releasing large amounts of methane, a potent greenhouse gas. Additionally, peatland drainage, which occurs in many parts of the world, results in substantial emissions of carbon dioxide and nitrous oxide, two other greenhouse gases.

DNR reviewers regularly participate in programs that regulate the use of water and water bodies in the state. The following section summarizes the main state and federal regulatory programs with which reviewers must be familiar.

Water Supply and Public Waters

The DNR helps ensure the future of Minnesota's water resources by protecting public waters, managing the water supply, and providing information to decision makers. These early coordination and permit activities are environmental review functions.

Minnesota Statutes, section 103G.265 requires the Department of Natural Resources to "manage water resources to assure an adequate supply to meet long-range seasonal requirements for domestic, municipal, industrial, agricultural, fish and wildlife, recreational, power, navigation, and quality control purposes." The DNR Water Appropriation Permit Program exists to balance competing management objectives that include both development and protection of Minnesota's water resources.

Under *Minnesota Statutes*, section103G.245, subdivision 1, "the state, a political subdivision of the state, a public or private corporation, or a person, must have a DNR Public Waters Work Permit to:

(1) construct, reconstruct, remove, abandon, transfer ownership of, or make any change in a reservoir, dam, or waterway obstruction on public waters; or

(2) change or diminish the course, current, or cross section of public waters, entirely or partially within the state, by any means, including filling, excavating, or placing of materials in or on the beds of public waters."

Projects, including construction and operation methods, cause physical manipulation of the environment. Activities that directly affect Minnesota's waters include work in public waters, water appropriation (including dewatering), and bridge or culvert construction, repair, or replacement. Physical or hydrologic alterations include dredging, filling, stream diversion, outfall structure installation, diking, and impoundment of surface waters. The installation or abandonment of water wells, connection to or changes in public water supplies, and appropriation of ground or surface water also affect the state's waters. All development activities have the potential to change the quantity and quality of site runoff. Certain actions also may change the number or type of watercraft on a water body.

Clean Water Act (CWA) – Section 404

The U.S. Army Corps of Engineers Regulatory Programs include Section 10 of the Rivers and Harbors Act of 1899 and Section 404 of the Clean Water Act. The St. Paul District's regulatory jurisdiction covers the states of Minnesota and Wisconsin. The Corps has issued guidance for determining whether it has authority to regulate an activity. DNR reviewers can find this guidance on the St. Paul District website or by contacting the project manager for the county in which a wetland or other water is located.

Under Section 10, a Corps permit is required to do any work in, over, or under a Navigable Water of the U.S. Water bodies have been designated as Navigable Waters of the U.S. based on their past, present, or potential use for transportation for interstate commerce. These waters include many of the larger rivers and lakes, such as the Minnesota, St. Croix, and Mississippi rivers, and Lake Superior and the Mississippi headwaters lakes.

Under Section 404, a Corps permit is required for the discharge of dredged or fill material into waters of the U.S. Many water bodies and wetlands in the nation are waters of the U.S. and are subject to the Corps Section 404 regulatory authority.

To prevent loss of and damage to wildlife resources, the Fish and Wildlife Coordination Act of 1958 requires the Corps to consult with the U.S. Fish and Wildlife Service and the DNR, the state fish and wildlife agency, prior to issuing a permit to impound, divert, or otherwise control or modify a water body in the state.

Clean Water Legacy Program

The mission of the Clean Water Legacy Program is to meet current needs while ensuring a future in which Minnesota's waterways and watersheds remain an abundant source of clean water, support healthy aquatic ecosystems, and provide recreation opportunities. The goal of the program is to ensure that all of Minnesota's lakes, streams, and wetlands have water quality conditions that are acceptable for the various ways in which we use these waters.

The Minnesota Pollution Control Agency has the lead responsibility for implementing Clean Water Legacy efforts, but other state agencies, local units of government, private organizations, businesses, and Minnesota citizens also have important roles to play. The success of Clean Water Legacy efforts depends on strong partnerships and local involvement.

This program is based on a five-step approach:

- Assess the status of Minnesota's lakes, streams, and wetlands.
- Determine where water quality is not sufficient for how we want the waters to be used (i.e., identify those waters that are "impaired").
- Develop studies, called Total Maximum Daily Load studies, that identify maximum allowable pollutant levels and implementation plans that describe steps needed to restore "impaired" waters and to allow for a full range of uses.
- Implement actions to restore impaired waters and protect those waters that are not impaired.
- Monitor the status of Minnesota's waters to assess progress and focus future actions.

In the DNR regions, the Clean Water Legacy Specialist is the primary person responsible for implementing the Clean Water Legacy Program. The Regional Environmental Assessment Ecologist (REAE) is responsible for coordinating and communicating with this person to ensure that impaired waters concerns are fully addressed in environmental review processes.

Water pollution is defined as excessive concentrations of particular substances for sufficient periods of time to cause identifiable effects. Pollutants can be deposited by point sources, like effluent pipes, or by diffuse nonpoint sources, such as runoff from fields or disturbed sites. The following are common measures of pollution encountered in environmental review.

Physical parameters:
- Color
- Odor
- Temperature
- Solids (residues): suspended and dissolved, organic (volatile), inorganic (fixed)
- Turbidity
- Oil and grease

Chemical parameters associated with the organic content of water:
- Biochemical oxygen demand (BOD) - oxygen depletion
- Chemical oxygen demand (COD)
- Total organic carbon (TOC)
- Total oxygen demand (TOD)

Inorganic chemical parameters:
- Salinity
- Hardness
- pH
- Acidity
- Alkalinity
- Iron
- Manganese

Chlorides
Sulfates
Sulfides
Heavy metals (mercury, lead, chromium, copper, and zinc)
Nitrogen (organic, ammonia, nitrite, and nitrate)
Phosphorus

Bacteriological parameters:
Coliforms
Fecal coliforms
Specific pathogens
Viruses

Wetland Conservation Act of 1991 (WCA)

The DNR Wetlands Program was initiated with the passage of the state Wetlands Conservation Act (WCA) of 1991. A key component of WCA is the development of restored or created wetlands as replacement for wetlands that are drained or filled. In support of the WCA, the DNR has established a wetland review and conservation program to:

- Review wetland replacement plans and provide resource information and recommendations to local government decision makers.
- Provide technical assistance to local governments and landowners in developing wetland mitigation.
- Promote wetland conservation by providing science-based recommendations in the development of state wetland regulations, programs, and policies.

The first two tasks above are generally handled by DNR regional staff, primarily by the REAE and/or the designated DNR technical evaluation panel (TEP) representative, with oversight by the Regional Director. TEP representatives are drawn from several DNR disciplines and are responsible for WCA coverage in entire counties, parts of large counties, or several counties. The DNR maintains a statewide list of DNR TEP representatives or contacts, which the Board of Water and Soil Resources (BWSR) publishes on its website, along with other WCA information. The last task above is primarily handled by the Wetlands Program Consultant in the Central Office, with input from other division employees (Central Office, region, and field).

Minnesota Shoreland Management Program

The Minnesota Shoreland Management Program provides the backbone of statewide standards that local governmental units must adopt into their own land-use controls to provide for the orderly development and protection of Minnesota's shorelands (both rivers and lakes). The DNR provides technical assistance to local governmental units in the adoption and administration of their shoreland controls. This involves providing planning and zoning assistance to local governmental units by DNR Area Hydrologists and Shoreland Management staff.

Statewide minimum shoreland standards affect nearly all of Minnesota's lakes and rivers. These standards address issues of shoreland development and use such as sewage treatment, stormwater management, minimum lot size and water frontage, building and septic system setbacks, building heights, subdivisions, and alterations of land and vegetation close to the shore. By statute and

rule, local governments with priority shorelands are required to adopt and manage the statewide minimum shoreland standards through their local land-use controls and zoning ordinances. Many have also adopted stricter standards to deal with their own emerging land development issues.

Since January 2008, the Shoreland Rule Update project has worked with citizens to assess shoreland conservation standards by reviewing the science related to shoreland conservation, development, and management. The DNR concluded that revisions to the existing shoreland conservation standards are warranted; in fact, they are necessary to address important economic and environmental issues. The state is growing fast, and the rate of development of shorelands is predicted to increase. Many people are concerned about the consequences of poor development on water quality and fish and wildlife habitat. Better development practices can protect water quality while increasing property values. In addition, the existing shoreland standards need to be modernized to provide flexibility in use of various tools to address water quality declines and habitat losses and to reflect the diversity in local resource conditions and needs. The Shoreland Rule Update Project was guided by the mission statement from *Minnesota Statutes*, section 103F.201, which calls for the development of standards that (1) provide guidance for the wise development of shorelands of public waters and thus preserve and enhance the quality of surface waters, (2) preserve the economic and natural environmental values of shorelands, and (3) provide for the wise use of water and related land resources of the state.

The proposed standards include but are not limited to:

- Better water quality protection standards achieved by improved rainwater runoff management, increased drainfield setbacks, and higher shoreline buffer standards for undeveloped lots;
- Greater protections for vulnerable areas (e.g., sensitive lakeshore, trout streams, bluffs);
- Improved planned unit development standards;
- Specific resort standards that allow for expansion and improvements while addressing water quality and habitat concerns;
- Higher standards for new developments and new lots (e.g., impervious surface, natural areas, shoreline buffers);
- Advanced subdivision controls, including promotion of conservation subdivisions and other creative developments over conventional (lot and block) subdivisions;
- Revisions that allow easier local government implementation, while protecting natural resources and the interests of the general public.

Minnesota Floodplain Management Program

The natural floodplain is an important part of the water system. It affects storm runoff, water quality, spawning and breeding habitat, vegetative diversity, wildlife habitat, and aesthetic qualities of rivers and lakes. Any alteration of the floodplain should be carefully evaluated. A person's intended use should be appropriate to the site selected.

The DNR Floodplain Management Unit oversees the administration of the State Floodplain Management Program by promoting and ensuring sound land-use development in floodplain areas in order to promote the health and safety of the public, minimize loss of life, and reduce economic losses caused by flood damages. The Environmental Review Program interfaces with the Floodplain Management Program by providing analysis of proposed development in and beyond the floodplain. For example, by recommending project design that minimizes impervious surface and encourages storage of water on the project landscape, reviewers help to ensure that development does not increase flood stages and put people or property at risk.

Reviewers also encourage project decision makers to repair, restore, and protect ecosystem services within floodplains. For example, in the mid-1990s, the DNR and the U.S. Army Corps of Engineers prepared an environmental impact statement that evaluated the potential effects of 31 proposed flood control impoundments in the Red River watershed. Through the EIS, the two agencies sought to protect the functions of a natural floodplain while at the same time protecting human lives, property, and the economy of the region. As a result of the effort, the stakeholders were able to establish a dialogue through which they could create new strategies for achieving otherwise conflicting goals.

ECOSYSTEM SERVICES

> *Well-functioning ecosystem services that will provide Minnesota with economic and ecological security now and into the future (e.g., flood attenuation, soil preservation, water purification, habitat maintenance, and outdoor recreation).*
>
> —Draft Design Ideas on a Strategic Framework (working paper for the Waters and Ecological Resources transformation, October 22, 2009)

Reviewers work with DNR technical experts, other agencies, local governments, organizations, and citizens to protect and restore ecosystems and their services. Agency reviewers are encouraged to develop an explicit list of the services derived from each ecosystem and to use that list to help decision makers recognize the full range of impacts of a proposed project. This list can make the formulation and the analysis of alternatives more transparent and accessible. It also will help in establishing the significance or value of changes in the quality or quantity of services over time.

The concept of ecosystem services provides an approach to evaluating the ways in which ecological systems and changes to those systems induced by human actions affect human well-being. Ecosystems can also be valued, however, not only for the services they provide to humans directly or indirectly, but also for other reasons, including intrinsic natural values such as biodiversity (Proposed National Objectives for Water Resources Planning, December 3, 2009).

An ecosystem is a community of animals and plants interacting with one another and with their physical environment. Physical and chemical components such as soils, water, and nutrients support the organisms living within ecosystems. These organisms may range from large animals and plants to microscopic bacteria. Ecosystems include the interactions among all organisms in a given habitat, including people. The health and well-being of human populations depend on the services provided by ecosystems and their components—organisms, soil, water, and nutrients.

Ecosystems, whose functioning depends on biodiversity, provide the basic necessities of life, offer protection from natural disasters and disease, and shape human cultures and spiritual beliefs. *Ecosystem services are the benefits that people obtain from ecosystems*. They include provisioning services, regulating services, supporting services, and cultural services. The Millennium Ecosystem Assessment identified the following ecosystem services, many of which are highly interlinked. For example, primary production, photosynthesis, nutrient cycling, and water cycling all involve different aspects of the same biological processes.

Provisioning Services (Goods)

These are the products obtained from ecosystems, including:

- *Food.* This includes the vast range of food products derived from plants, animals, and microbes.
- *Fiber.* Materials included here are wood, jute, cotton, hemp, silk, and wool.

- *Fuel.* Wood, dung, and other biological materials serve as sources of energy.
- *Genetic resources.* This includes the genes and genetic information used for animal and plant breeding and biotechnology.
- *Biochemicals, natural medicines, and pharmaceuticals.* Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.
- *Ornamental resources.* Animal and plant products, such as skins, shells, and flowers, are used as ornaments, and whole plants are used for landscaping and ornaments.
- *Freshwater.* People obtain freshwater from ecosystems and thus the supply of freshwater can be considered a provisioning service. Freshwater in rivers is also a source of energy. Because water is required for other life to exist, however, it could also be considered a supporting service.

Regulating Services

These are the benefits obtained from the regulation of ecosystem processes, including:

- *Air quality regulation.* Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.
- *Climate regulation.* Ecosystems influence climate both locally and globally. At a local scale, for example, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.
- *Water regulation.* The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands, or croplands with urban areas.
- *Erosion regulation.* Vegetative cover plays an important role in soil retention and the prevention of landslides.
- *Water purification and waste treatment.* Ecosystems can be a source of impurities (for instance, in freshwater) but also can help filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems and can assimilate and detoxify compounds through soil and subsoil processes.
- *Disease regulation.* Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.
- *Pest regulation.* Ecosystem changes affect the prevalence of crop and livestock pests and diseases.
- *Pollination.* Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.
- *Natural hazard regulation.* The presence of coastal ecosystems such as mangroves and coral reefs can reduce the damage caused by hurricanes and large waves.

Cultural Services

These are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including:

- *Cultural diversity.* The diversity of ecosystems is one factor influencing the diversity of cultures.
- *Spiritual and religious values.* Many religions attach spiritual and religious values to ecosystems or their components.
- *Knowledge systems* (traditional and formal). Ecosystems influence the types of knowledge systems developed by different cultures.
- *Educational values.* Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.
- *Inspiration.* Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.
- *Aesthetic values.* Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks and scenic drives, and in the selection of housing locations.
- *Social relations.* Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies.
- *Sense of place.* Many people value the "sense of place" that is associated with recognized features of their environment, including aspects of the ecosystem.
- *Cultural heritage values.* Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species.
- *Recreation and ecotourism.* People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

Supporting Services

Supporting services are those that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating, and cultural services in that their impacts on people are often indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people. (Some services, like erosion regulation, can be categorized as both a supporting and a regulating service, depending on the time scale and immediacy of their impact on people.) These services include:

- *Soil Formation.* Because many provisioning services depend on soil fertility, the rate of soil formation influences human well-being in many ways.
- *Photosynthesis*. Photosynthesis produces oxygen necessary for most living organisms.

- *Primary production*. The assimilation or accumulation of energy and nutrients by organisms.
- *Nutrient cycling.* Approximately 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems and are maintained at different concentrations in different parts of ecosystems.
- *Water cycling*. Water cycles through ecosystems and is essential for living organisms.

Example: Wetlands Provide Beneficial Services

Wetlands are the vital link between water and land. They are among the most biologically productive ecosystems in the world. Because of their strategic position within the landscape, wetlands can provide a wide variety of ecosystem services such as:

- Improving water quality by filtering sediment, nutrients, and pollutants
- Reducing flood damage
- Preventing bank and shoreline erosion
- Recharging ground and surface water supplies
- Providing vital fish and wildlife habitat
- Offering opportunities for recreation, education, and research
- Producing food, forest, and fuel products

From EPA 843-F-01-002g, September 2001, Wetland Monitoring and Assessment

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Biodiversity loss disrupts the functioning of ecosystems, making them more vulnerable to perturbations and less able to supply humans with needed services. According to the Convention on Biological Diversity, the loss of biodiversity often reduces the productivity of ecosystems, thereby shrinking nature's basket of goods and services, from which we constantly draw.

Human society and the natural environment (ecosystems) are interrelated in a complex and dynamic social-ecological system. The loss of ecosystem services comes at a cost to human society, that is, the cost of replacing otherwise "free" services with human-made systems, for example, water purification plants. We may be able to avoid further losses through careful planning and management of development. That is the link to environmental review.

Population growth, urban and rural development, and the production and consumption of goods place an increasing demand on local and global biological resources. For example, a healthy watershed will provide economically vital ecosystem services, such as flood attenuation, soil preservation, water purification, habitat maintenance, and quality outdoor recreation. Therefore, the DNR Environmental Review Program addresses ecosystem services.

BIODIVERSITY

> *Watershed health includes sustainable levels of biodiversity that will provide Minnesota species, habitats, and ecosystems with the resilience and adaptive capacities they need to thrive in the midst of changing conditions.*
>
> —Draft Design Ideas on a Strategic Framework (working paper for the Waters and Ecological Resources transformation, October 22, 2009

According to the Convention on Biological Diversity (CBD), biological diversity or biodiversity is

> the term given to describe the variety of life on Earth. It reflects the number, variety and variability of living organisms and how these change from one location to another and over time. Biodiversity includes diversity within species (genetic diversity), between species (species diversity), and between ecosystems (ecosystem diversity).

According to the Council on Environmental Quality (1993), biotic resources are important, both ecologically and economically. For example, at the ecosystems level, maintenance of structural diversity and functional integrity is essential to the continued provision of important ecological services. Healthy, functioning ecosystems are necessary to support commercially and recreationally important fish and wildlife populations. The aesthetic, ethical, and cultural values associated with unique forms of life lend additional support to the establishment of biological conservation as public policy.

Another important aspect of biodiversity is system redundancy that contributes to ecosystems' adaptive potential. System redundancy is analogous to a diversified investment portfolio. For ecosystems, it is insurance in times of stress. Biodiversity contributes to an ecosystem's resilience, its capacity to respond to stress and disturbance. Working with natural systems, we can be certain of one thing: conditions change. These changes can be the result of natural processes such as fires and floods or human activity like the construction of new roads and highways. Resilience is the capacity of a system to undergo change, adapt, and retain essentially the same functional and structural identity.

Resilience is a key concept in the assessment of the effects of human activity on natural systems. Brian Walker and David Salt, in *Resilience Thinking: Sustaining Ecosystems and People in a Changing World* (2006), list nine commandments that, if followed, would contribute to resilience in *social-ecological* systems, linked systems of humans and nature. DNR reviewers should keep these factors in mind. They are:

- Promote and sustain diversity, a major source of future options and a system's capacity to respond to change and disturbance.
- Embrace and work with ecological variability, rather than attempting to control and reduce it.

- Maintain or create a degree of modularity; avoid over-connecting systems.
- Recognize and focus on the controlling variables associated with thresholds.
- Maintain or tighten the strength of feedbacks so that thresholds can be detected before we cross them.
- Promote trust, well-developed social networks, and leadership to ensure the capacity of people to respond, together and effectively, to change any disturbance.
- Emphasize learning, experimentation, locally developed rules, and embracing change.
- Create overlapping ways of responding to a changing world; institutional redundancy increases response diversity and flexibility.
- Include all the unpriced ecosystem services in development proposals and assessments.

Components of Biological Diversity

Regional ecosystem diversity: The pattern of local ecosystems across the landscape, sometimes referred to as "landscape diversity" or "large ecosystem density."

Local ecosystem diversity: The diversity of all living and nonliving components within a given area and their interrelationships. Ecosystems are the critical biological/ecological operating units in nature. A related term is "community diversity," which refers to the variety of unique assemblages of plants and animals (communities). Individual species and plant communities exist as elements of local ecosystems, linked by processes such as succession and predation.

Species diversity: The variety of individual species, including animals, plants, fungi, and microorganisms.

Genetic diversity: Variation within species. Genetic diversity enables species to survive in a variety of different environments and allows them to evolve in response to changing environmental conditions.

The **hierarchical nature** of these components is an important concept. Regional ecosystem patterns form the basic matrix for, and thus have important influences on, local ecosystems. Local ecosystems, in turn, form the matrix for species and genetic diversity, which can in turn affect ecosystem and regional patterns.

Relationships and interactions are critical components as well. Plants, animals, communities, and other elements exist in complex webs, which determine their ecological significance.

Source: Council on Environmental Quality, 1993, p.1

Minnesota's State Wildlife Action Plan: *Tomorrow's Habitat for the Wild and Rare*

Habitat loss and fragmentation are key contributors to the loss of biological diversity at multiple scales: ecosystem diversity, species diversity and genetic diversity. Minnesota's SWAP, *Tomorrow's Habitat for the Wild and Rare*, identified 292 species in greatest conservation (SGCN) need in Minnesota. SGCN are defined as species whose populations are rare, declining, or vulnerable to decline and are below levels desirable to ensure their long-term health and

stability. Each of these 292 species was evaluated to determine the factors influencing their rarity, vulnerability, or decline (SWAP, 60). The result of the species problem analysis indicated that habitat loss and degradation are the most significant challenges facing SGCN. Other significant factors included invasive species and competition, pollution, and social tolerance/persecution or exploitation. In addition to the species assessment, a statewide look at the species-habitat relationships shows that prairies, rivers, and wetlands are the three habitats used by the most SGCN. These are the habitats that have also experienced some of the greatest loss and degradation in the state (SWAP, 30).

Environmental Review plays a critical role in protecting and maintaining biodiversity through the formal review process associated with the federal and state endangered species acts and the National Environmental Policy Act, and also through early project coordination and permitting. Refer to Module IV for more detailed information about implementing the SWAP in Environmental Review.

MCBS Site Biodiversity Significance Ranks

At the conclusion of work in a geographic region, Minnesota County Biological Survey (MCBS) ecologists assign a biodiversity significance rank to each survey site. These ranks are used to communicate the statewide native biological diversity significance of each site to natural resource professionals, state and local government officials, and the public. The biodiversity ranks help to guide conservation and management.

A site's biodiversity significance rank is based on the presence of rare species populations, the size and condition of native plant communities within the site, and the landscape context of the site (for example, whether the site is isolated in a landscape dominated by cropland or developed land, or whether it is connected or close to other areas with intact native plant communities).

There are four biodiversity significance ranks, outstanding, high, moderate, and below:

- **Outstanding** sites contain the best occurrences of the rarest species, the most outstanding examples of the rarest native plant communities, and/or the largest, most ecologically intact or functional landscapes.
- **High** sites contain very good-quality occurrences of the rarest species, high-quality examples of rare native plant communities, and/or important functional landscapes.
- **Moderate** sites contain occurrences of rare species, moderately disturbed native plant communities, and/or landscapes that have strong potential for recovery of native plant communities and characteristic ecological processes.
- **Below** sites lack occurrences of rare species and natural features or do not meet MCBS standards for outstanding, high, or moderate rank. These sites may include areas of conservation value at the local level, such as habitat for native plants and animals, corridors for animal movement, buffers surrounding higher-quality natural areas, areas with high potential for restoration of native habitat, or open space.

Reviewers of plans and projects should check the DNR website for more detailed information regarding MCBS Sites of Biodiversity Significance. During environmental review of projects

that might affect an MCBS site, reviewers should consult with the Regional Ecologist for better information about the site and ways to protect it.

Statewide Conservation and Preservation Plan (SCPP)

The SCPP, commissioned by the Legislative-Citizen Commission on Minnesota Resources (LCCMR), lays out a deliberative strategy for conserving and protecting Minnesota's natural resources with an emphasis on biodiversity, while ensuring a healthy public and healthy economy. The SCPP consists of two parts: a Preliminary Plan (released July 2007) and the Final Plan (released July 2008). It includes of a series of recommendations for the state to consider in holistic fashion. The recommendations are designed to conserve and protect Minnesota's natural resources in a comprehensive approach, while being mindful of demographic change, public health, the state's economy, and climate change. The SCPP makes several types of recommendations: integrated planning, critical land protection, land and water restoration and protection, sustainable practices, and economic incentives for sustainability.

SCPP Habitat Recommendations

- Protect priority (critical) land habitats
- Protect critical shorelands of streams and lakes
- Improve connectivity and access to outdoor recreation
- Restore and protect shallow lakes
- Restore land, wetlands, and wetland-associated watersheds
- Protect and restore critical in-water habitat of lakes and streams
- Keep water on the landscape
- Review and analyze drainage policy
- Overall research on land and aquatic habitats
- Research on near-shore habitat vulnerability
- Improve understanding of groundwater resources
- Improve understanding of watersheds response to multiple drivers of change
- Habitat and landscape conservation and training programs for all citizens

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The SCPP identifies the key drivers of change affecting wildlife as land-use change and fragmentation, development, and disease and invasive species. It identifies the key drivers affecting fish as aquatic invasive species, land disturbance, aquatic habitat loss, climate change, fish stocking, and contaminants. The review of plans and projects should consider the recommendations made in this plan.

The Final Plan can be found at www.environment.umn.edu/scpp and in Appendix B of the Environmental Review Guide.

Council on Environmental Quality Guidance

The Council on Environmental Quality (CEQ) is a division of the Executive Office of the President that coordinates federal environmental efforts in the United States and works closely with agencies and other White House offices in the development of environmental and energy policies and initiatives. The CEQ (1993) enumerated several principles for incorporating the consideration of biodiversity into environmental review. These principles are compatible with DNR efforts to integrate the SWAP with environmental review.

- Take a "big picture" or ecosystem view
- Protect communities and ecosystems
- Minimize fragmentation and promote the natural pattern and connectivity of habitats
- Promote native species and avoid introducing nonnative species
- Protect rare and ecologically important species
- Protect unique or sensitive environments
- Maintain or mimic natural ecosystem processes
- Maintain or mimic naturally occurring structural diversity
- Protect genetic diversity
- Restore ecosystems, communities, and species
- Monitor biodiversity impacts, acknowledge uncertainty, and be flexible

CLIMATE CHANGE

Many up-to-date climate models suggest that Minnesota's climate will grow warmer and probably drier during the twenty-first century. Change will affect the composition of the state's aquatic and terrestrial ecosystems, impacting plants and animals in ways we are only beginning to comprehend. Climate change is a major complicating factor in our ability to assess the potential effects of proposed projects and management activities.

Exactly how climate change will affect Minnesota's biological diversity at multiple scales is not yet known, but some ecosystems and species are already showing effects from climate change. Furthermore, states, including Minnesota, are preparing for the incorporation of climate change into their SWAPs, and the Association of Fish and Wildlife Agencies has prepared a Climate Change Guidance document to assist with this effort.

Land managers and project proposers need to consider how climate change will affect the outcomes of management decisions and projects. The DNR *Strategic Conservation Agenda* says the following about climate change:

> Climate change poses great challenges to natural resource management. It is impacting the health and productivity of lands and waters and the animals and plants that depend on them, and will exacerbate other threats from habitat loss and invasive species. It threatens the services natural lands provide—from clean water and forest products to outdoor recreation. . . .
>
> Minnesota ecosystems will be in transition over the next 50 to 100 years. Managers must find new ways to sustain the health, diversity, and productivity of ecosystems in the face of climate change. . . . Climate change is expected to cause major changes in lakes and streams. Warming waters could shrink the number of trout streams and lake trout and cisco lakes, push walleye and northern pike populations northward, and expand the distribution of bass and panfish populations.
>
> Minnesota's northwestern moose population has dropped to fewer than 100 animals, and the northeastern population also is declining. DNR biologists have correlated heat stress and increased mortality. If trends continue, moose could disappear from Minnesota within 40 years.
>
> Wetlands are projected to become drier, altering plant communities and degrading waterfowl and other wildlife habitat. The range of major northern tree species such as black and white spruce and balsam fir is projected to shift northeastward out of the state if warming trends continue over the next 100 years. Forests may become savannas, and hardwood forests may persist mainly on north-facing slopes in some areas.

Recreation will be affected by changed winter weather, loss of habitat, and shifts in fisheries and wildlife populations.

Our understanding of the effects of climate change improves with the continued application of science. For example, scientists only recently have determined that the nine environmental processes named below must remain within specific limits; otherwise the "safe operating space" within which humankind can exist on Earth will be threatened (Foley et al. 2010). These processes are:

- Biodiversity loss
- Land use
- Freshwater use
- Nitrogen and phosphorus cycles
- Stratospheric ozone
- Ocean acidification
- Climate change
- Chemical Pollution
- Aerosol loading in the atmosphere

The researchers have determined that the world has already crossed the boundary in three cases: biodiversity loss, the nitrogen cycle, and climate change. Of the nine processes, DNR reviewers can address biodiversity loss, land use, freshwater use, and nitrogen and phosphorus cycling.

The DNR uses a three-pronged strategy to address climate change through mitigation, adaptation, and monitoring. Reviewers of plans and projects should consider these three strategies whenever possible.

Mitigation: Climate change mitigation includes actions that reduce the sources or increase the sinks for greenhouse gases. The DNR is actively reducing fossil fuel consumption by its vehicles and facilities. We are investigating management strategies for DNR-administered peatlands, wetlands, forests, and other lands to enhance their natural capacity to store large quantities of greenhouse gases from the atmosphere. The DNR's Carbon Metrics Team is engaged in efforts to refine measurement and reporting protocols to track carbon storage and sequestration on natural lands. This is critical to participating in future "carbon credit" programs.

Adaptation: Even with aggressive mitigation, Minnesota's climate will continue to change over the next 50 to 100 years because of past actions. Management actions that improve ecosystem health, diversity, and productivity are key to enhancing ecosystem resilience to climate change and associated impacts. Planned adaptations to reduce the vulnerability of ecosystems and wildlife to expected climate change include efforts to create wildlife corridors, improve habitat connectivity, and expand habitat buffers to facilitate plant and animal migration as climate changes.

Monitoring and applied research: The DNR will begin coordinating monitoring systems and participating in research to detect climate change impacts on natural resources. The department will track the effectiveness of mitigation and adaptation efforts.

The DNR is committed to enhancing ecosystem resilience to climate change and creating "wildlife corridors, improving habitat connectivity, and expanding habitat buffers to facilitate plant and animal migration as climate changes." The agency's environmental review practitioners should ask whether proposed projects and other actions will enhance ecosystem resilience or contribute to its decline. By doing so, they can ensure that the environmental review program makes a positive contribution to climate change mitigation and adaptation.

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