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Technical Report NPS/NRWRD/NRTR-2007/XXX

Mississippi National River and Recreation Area

Minnesota

Water Resources Information and Issues Overview Report

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Water Resources Information and Issues Overview Report

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Technical Report NPS/NRWRD/NRTR-2007/XXX

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WATER RESOURCES DIVISION

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Executive Summary

This Water Resources Information and Issues Overview Report is one of several planning products offered by the National Park Service Water Resources Division that assists national park units with achieving or maintaining water resource integrity.

Mississippi National River and Recreation Area (MNRRA) is a riverine park unit spanning a culturally, geographically, and ecologically important 72-mile (116 km) reach of the Upper Mississippi River in Minnesota. The MNRRA corridor passes through the heart of the rapidly growing Twin Cities Metropolitan Area, encompasses parts of 25 communities, and draws in water from two major tributaries, the Minnesota and St. Croix Rivers. Because managing water resources in such a context is complex, in 2004 MNRRA staff requested technical assistance from the Water Resources Division (WRD) of the National Park Service (NPS). This document attempts to characterize water resources in MNRRA, reports the outcomes of a two-phase water resources scoping effort undertaken in 2005, and describes the subsequent analysis and conclusions of MNRRA and WRD staff.

This report has been organized into five major sections. The first, *Legislation, Management, and Coordination of Water Resources in MNRRA,* outlines the laws, regulations, and policies relevant to water resource management in MNRRA, and describes the varying roles of federal, state, regional, and local agencies in water resources management within the corridor.

The second section, *Regional Setting,* describes the area's physiography, its urban character and land use, its climatic conditions, and its major surface water and hydrogeologic features. It also provides context on navigational and commercial uses of the Mississippi River.

The third section, *Water Resources and Use,* reviews MNRRA's water resource features in greater detail, including coverage of surface and ground water hydrology, geomorphologic features and processes, surface and ground water quality, floodplains, wetlands, and riparian zones, aquatic biological resources (i.e., birds, mammals, fish, mussels, amphibians and reptiles, and algae and invertebrates), and visitor use and recreation.

The fourth section, *Water Resource Issues,* describes priority water resource issues identified by MNRRA partners during the 2005 scoping process. Among these are a range of water quality issues, including stormwater, state impaired waters, wastewater, contaminants, and drinking water concerns. Water quantity issues involving altered flow regimes, effects of urbanization, effects of floods and flood control as well as drought and drought mitigation, and water supply are also addressed. Concerns involving land and water management are treated on two levels – the local corridor/Metropolitan Area level and the greater watershed level. Given MNRRA's location in a complex urban setting, socio-environmental issues are also considered, including population growth, public perceptions of water quality, recreational impacts, and major economic drivers. Important biological issues, ranging from habitat and water quality degradation to aquatic invasive species, are explored in detail, along with the hydrologic, geomorphologic, and biological effects of river alteration. Finally, water resource needs related to ecosystem restoration and understanding as well as interagency coordination are identified.

The fifth and final section, *Considerations for Future Action,* identifies which of these water resource issues MNRRA may be best suited to address, taking into consideration the importance of the respective issues, the roles of partner agencies and institutions, and the intended function of the National Park Service in the MNRRA corridor. Key considerations include the following:

- Add a water resources professional to MNRRA staff, to improve MNRRA's ability to confer and coordinate with other agencies on water resource issues. Progress on all subsequent considerations will likely be difficult without the addition of this position.

- Serve as a convener for restoration issues in the MNRRA reach of the Mississippi River, by reviewing, prioritizing, and implementing key recommendations of the River Resources Forum, encouraging adaptive management, and participating actively in regional working groups.

- Increase NPS participation in local and regional water resource issues, such as impaired waters studies (particularly ongoing studies related to Lake Pepin and future studies related to new fecal coliform listings within MNRRA), stormwater management (for which there is an active public-private steering committee), land use and wastewater management beyond the seven-county Twin Cities Metropolitan Area (which is currently beyond Metropolitan Council jurisdiction but affects MNRRA resources), watershed education, and surface water use planning (as per the MNRRA Comprehensive Management Plan).

- Support data synthesis efforts specific to the MNRRA corridor, particularly with respect to water quality, land cover, and land use. Many agencies and organizations generate such data for the Upper Mississippi River, some of which is relevant to MNRRA. These data should be more effectively analyzed and synthesized in relation to the corridor.

- Fill aquatic information gaps in the MNRRA corridor, including comprehensive water resource assessments (targeting fish, benthic invertebrates, aquatic birds, and amphibians, as well as general habitat features), long-term monitoring activities (involving multiple ecological attributes and water quality), and research on effects of contaminants on aquatic biota (particularly contaminants from the Pig's Eye Dump and perflourochemicals from the Cottage Grove area).

It is hoped that this summary of water resource issues will provide a useful reference for MNRRA and other agencies within the MNRRA corridor, and that the above list of considerations may help guide water resource management activities by MNRRA and its partners in the future.

Introduction

Park Location and Description

The Mississippi National River and Recreation Area (MNRRA) was established in 1988 under Public Law 100-696, in order to protect and enhance a significant 72 mile (116 km) reach of one of the nation's most prominent rivers (Figure 1). The MNRRA corridor is situated in the upper reaches of the Mississippi River and stretches from just upstream of Anoka, Minnesota, through the Twin Cities Metropolitan Area, and to just downstream of the confluence with the St. Croix River, near Prescott, Wisconsin. Lock and Dam 1 and the Upper and Lower St. Anthony Falls Dams are situated within the MNRRA corridor; the pool above Upper St. Anthony Falls marks the uppermost extent of the Lock and Dam system and commercial navigation on the Upper Mississippi River. Other dams within MNRRA include the Coon Rapids Dam, near the upstream end of the corridor, and Lock and Dam 2, near the downstream end of the corridor. Land use in the contributing watersheds varies, with watersheds to the north generally characterized by forested or rural residential landscapes and watersheds to the west and south characterized by more agricultural and urban land uses.

The boundaries of the MNRRA corridor encompass approximately 54,000 acres (22,000 ha) of the Mississippi River and adjoining lands, of which only a handful of small floodplain islands is owned and managed by the National Park Service (NPS). Beyond these NPS lands, the corridor is a complex mix of privately owned and public lands administered by local governments, organizations, and state and federal agencies. In total, the MNRRA corridor passes through 25 different communities, ranging from rural townships to the urban centers of Minneapolis and St. Paul.

Primary water resources within the corridor include an important stretch of the Mississippi River, its confluences with the Crow, Rum, Minnesota, and St. Croix Rivers, a number of perennial and intermittent tributary streams, and significant floodplain wetlands and standing backwaters. The MNRRA corridor supports important fish and wildlife habitat, recreational opportunities, commercial navigation, hydropower generation, and drinking and industrial water supply. The park's enabling legislation emphasizes its role as a "coordinator and advisory organization", and instructs it to help develop policies and programs that preserve and enhance environmental values, outdoor recreation opportunities, scenic, historical, cultural, natural, and scientific values, and commercial and economic opportunities within the corridor.

Importance of Planning to Water Resources Management

Water is a particularly important and sensitive ecosystem component, and it plays a central role in the social, economic, environmental, and political mosaic of our national park units. Its physical availability and quality are critical determinants of a park's overall natural resource condition. Because of the important role of water in maintaining resource condition, it is the policy of the NPS to maintain, rehabilitate, and perpetuate the inherent natural integrity of water resources and water-dependent environments occurring within national park system units.

Proper management of water resources within the NPS is becoming more complex and challenging as threats to these resources, both internal and external to park boundaries, increase. Scientists and managers are increasingly called upon to respond to disruptions of water resources that threaten the quality of human life and environmental sustainability. Planning is an essential first step in addressing these threats and disruptions. The Planning Program of the Water Resources Division (WRD) of the NPS has assisted in the development of park-wide management strategies and ensured that park managers and policy makers have

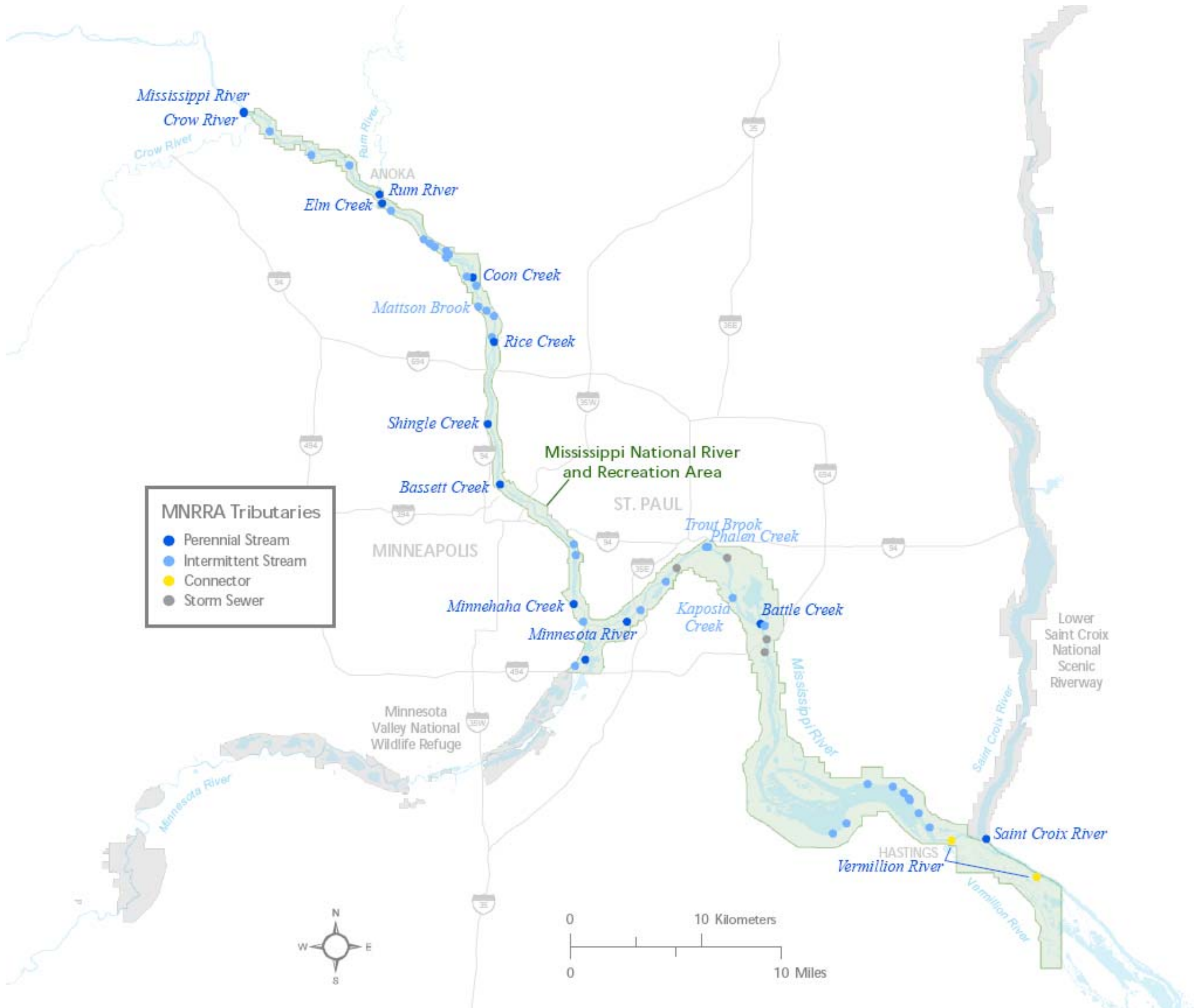


Figure 1. Map of MNRRA and surrounding area [DRAFT].

adequate and timely information to protect, utilize and enhance water resources. Several recurrent themes have emerged from the water resources planning process:

- Effective management solutions to water resource issues will be achieved only with the understanding that changes in environmental conditions are directly linked to socioeconomic patterns and processes, especially land use.
- Interactive partnerships among scientists, policy makers, and resource managers are essential for developing a comprehensive approach to integrating water sciences with management of water resources.
- Viewing water problems holistically and integrating research and management into a watershed context links the sciences involved in water research and management.
- The transfer of scientific information to regional/local leaders and the public should be done in a manner that will produce an informed and responsive citizenry, and
- Proposed recommendations are seemingly connected to issues that are related directly to societal needs, such as restoring and rehabilitating ecosystems, maintaining biodiversity, and understanding the effects of modified hydrologic flow.

Changes in NPS planning standards (2004 *Park Planning Program Standards*) have re-framed park planning through six discrete elements of planning; the water planning process and its products are designed to integrate into this framework (Figure 2). Outside of this framework, the Water Resources Information and Issues Overview report (not shown in Figure 2) is designed as a flexible document that addresses a park's specific needs with regard to water resources that are outside of the park planning framework. However, its contents may be used to support

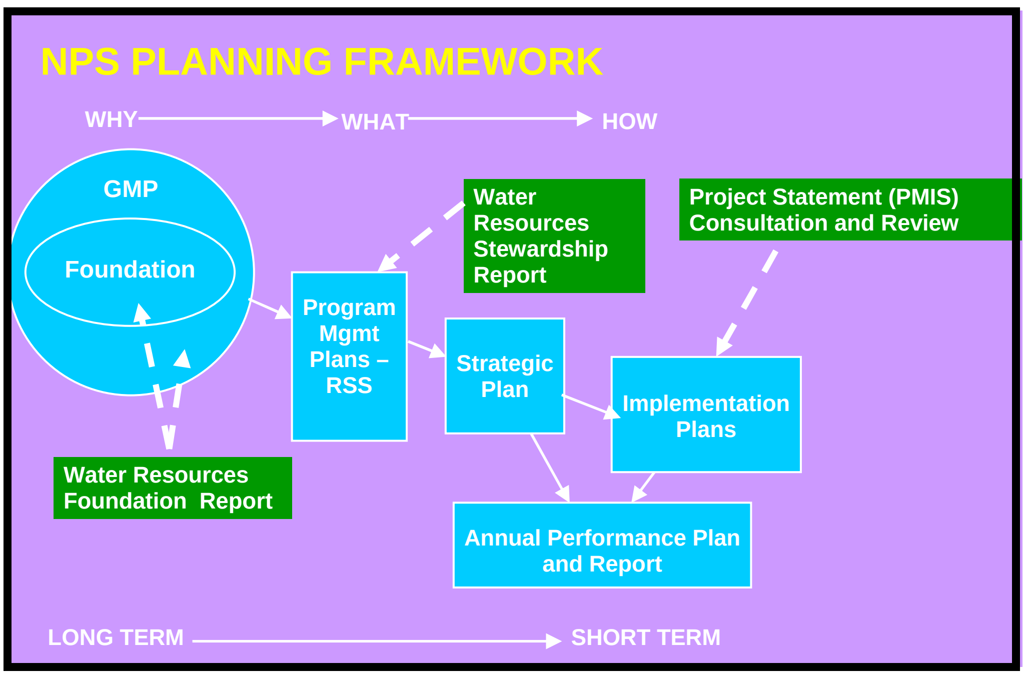


Figure 2. The NPS framework for planning and decision making (blue boxes). Green boxes represent WRD planning or assistance. RSS = Resource Stewardship Strategy; GMP = General Management Plan.

park planning efforts, particularly the GMP and/or Program Management Plans. For MNRRA, this Water Resources Information and Issues Overview is seen as an important collation and summarization of water resource information not only for the park but for all stakeholders, an identification of applicable federal, state, and local legislation and policy that affect the management of water resources, an assessment of current water resource status, stakeholder-based water resource issue identification and analysis, and an assessment of future actions or management directions.

Rationale for MNRRA's Water Resources Information and Issues Overview Report

Recognizing the complexity of water resource issues and the lack of aquatic specialists on staff, in 2004 MNRRA issued a technical assistance request to WRD. Aquatic professionals from WRD and the Midwest Regional Office of the NPS agreed to provide water resources guidance to MNRRA, and, with the help of park staff, initiated a water resources scoping process in spring 2005. The scoping process was intended to provide water resources insights from a broad range of stakeholders and to form the basis for this Water Resources Information and Issues Overview Report, similar to one recently completed for Missouri National Recreational River (Weeks et al. 2005).

A preliminary scoping meeting was held at MNRRA headquarters on May 31, 2005, with representatives from the major management agencies in the MNRRA corridor (i.e., National Park Service, U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, Minnesota Department of Natural Resources, and the Metropolitan Council). Water resource issues and relevant datasets and reports were identified. These were used to help structure the discussion for a much larger and more inclusive scoping workshop in September 2005. This Water Resources Issues Scoping Workshop was held in St. Paul, and included 43 participants from 28 different entities and organizations (see Appendix A for detailed summary). Participants engaged in group discussions and activities in order to refine and clarify the list of water resources issues identified in the May meeting. The revised list of issues fell into nine categories including water quality, land and water use and regulation, socio-environmental issues, biological issues, interagency and partnership coordination, effects of river alteration, economic impacts and analysis, water quantity, and ecosystem restoration and understanding. Later sections in this report focus on these issues and their management implications, and should serve to guide future management activities by NPS and its partners throughout the MNRRA corridor.

Legislation, Management, and Coordination of Water Resources in MNRRA

Many federal, state, and local agencies have an interest, mandated or otherwise, in the water resources at MNRRA. Protection of water resources requires an understanding of the various policy, regulatory, and management designations in order to facilitate coordination and cooperation among agencies and private landowners at MNRRA. Both federal and state agencies have authority for the enforcement of appropriate regulations. Water resource laws and regulations at the state and local levels are often patterned after federal laws, or serve in response to federal directives.

Federal Laws and Regulations

<u>Mississippi National River and Recreation Area [Public Law 100-696 (1988)]</u>
This is the authorizing legislation for the MNRRA which consists of the Mississippi River Corridor Critical Area encompassing that portion of the Mississippi River and adjacent lands generally within the Saint Paul-Minneapolis Metropolitan Area. The purposes of this legislation are: 1) to protect, preserve, and enhance the significant values of the waters and land of the Mississippi River corridor within the St. Paul-Minneapolis Metropolitan Area, 2) to encourage adequate coordination of all governmental programs affecting the land and water resources of the Mississippi River corridor, and 3) to provide a management framework to assist the State of Minnesota and its units of local government in the development and implementation of integrated resource management programs for the Mississippi River corridor. Other pertinent aspects of this legislation are the: 1) development of a comprehensive management plan for MNRRA, 2) assessment of federal lands and the approval of developments in MNRRA, 3) determination of land and water resource administration, and 4) authorization of federal grants to the State of Minnesota or its political subdivisions.

<u>National Park Service Organic Act of 1916</u>
This Act established the NPS and mandated that it “shall promote and regulate the use of the federal areas known as national parks, monuments, and reservations by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of future generations in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.”

<u>General Authorities Act of 1970</u>
This Act reinforced the 1916 Organic Act – all park lands are united by a common preservation purpose, regardless of title or designation. Hence, federal law protects all water resources in the national park system equally, and it is the fundamental duty of the NPS to protect those resources unless otherwise indicated by Congress.

<u>Redwood National Park Act (1978)</u>
This Act amended the General Authorities Act of 1970 to mandate that all park system units be managed and protected “in light of the high public value and integrity of the National Park System.” Furthermore, no activities should be undertaken “in derogation of the values and purposes for which these various areas have been established”, except where specifically authorized by law or as may have been or shall be directly and specifically provided for by Congress.

<u>National Parks Omnibus Management Act of 1998</u>
This Act attempts to improve the ability of the NPS to provide state-of-the-art management, protection, and interpretation of and research on the resources of the national park system by:

- Assuring that management of units of the national park system is enhanced by the availability and utilization of a broad program of the highest quality science and information;

- Authorizing the establishment of cooperative agreements with colleges and universities, including but not limited to land grant schools, in partnership with other federal and state agencies, to establish cooperative study units to conduct multi-disciplinary research and develop integrated information products on the resources of the national park system, or of the larger region of which parks are a part;

- Undertaking a program of inventory and monitoring of national park system resources to establish baseline information and to provide information on the long-term trends in the condition of national park system resources; and

- Taking such measures as are necessary to assure the full and proper utilization of the results of scientific study for park management decisions. In each case in which an action undertaken by the NPS may cause a significant adverse effect on a park resource, the administrative record shall reflect the manner in which unit resource studies have been considered. The trend in the condition of resources of the National Park System national park system shall be a significant factor in the annual performance.

National Environmental Policy Act (NEPA) of 1969
This Act requires federal agencies to evaluate the environmental impacts of their actions and to integrate such evaluations into their decision-making processes. NEPA's basic policy is to assure that all branches of government give proper consideration to the environment prior to undertaking any major federal action that significantly affects the environment.

Clean Air Act of 1970
This Act, as amended, regulates airborne emissions of a variety of pollutants from area, stationary, and mobile sources, establishes a nationwide program for the prevention and control of air pollution, and establishes National Ambient Air Quality Standards (NAAQS). Under the Prevention of Significant Deterioration provisions, the Act requires federal officials responsible for the management of Class I Areas (national parks and wilderness areas) to protect the air quality related values of each area and to consult with permitting authorities regarding possible adverse impacts from new or modified emitting facilities. The 1990 amendments to this Act were intended primarily to fill the gaps in the earlier regulations, such as acid rain, ground level ozone, stratospheric ozone depletion and air toxics. The amendments identify a list of 189 hazardous air pollutants. The USEPA must study these chemicals, identify their sources, determine if emissions standards are warranted, and promulgate appropriate regulations.

Clean Water Act of 1972 (Federal Water Pollution Control Act)
The Federal Water Pollution Control Act, more commonly known as the Clean Water Act, was first promulgated in 1972 and amended several times since (e.g., 1977, 1987, and 1990). This law is designed to restore and maintain the chemical, physical and biological integrity of the nation's waters, including the waters of the national park system. To achieve this, the act called for a major grant program to assist in the construction of municipal sewage treatment facilities, and a program of effluent limitations designed to limit the amount of pollutants that could be discharged. Effluent limitations are the basis for permits issued for all point source discharges, known as the National Pollutant Discharge Elimination System (NPDES).

As part of the act, Congress recognized the primary role of the states in managing and regulating the nation's water quality. Section 313 requires that all federal agencies comply with the requirements of state law for water quality management, regardless of other jurisdictional status or landownership. States implement the protection of water quality under the authority granted by the Clean Water Act through best management practices and through water quality standards. Standards are based on the designated uses of a water body or segment of water, the water quality criteria necessary to protect that use or uses, and an anti-degradation provision to protect the existing water quality.

Section 303 of the Clean Water Act requires the promulgation of water quality standards by the states. Additionally, each state is required to review its water quality standards at least once every three years. This section also requires the listing of those waters where effluent limitations are not stringent enough to implement any water quality standard [so called 303(d) list]. Each state must establish Total Maximum Daily Loads (TMDLs) for applicable pollutants for each of the waters on the 303 (d) list.

Section 404 of the Clean Water Act requires that a permit be issued for discharge of dredged or fill materials in waters of the U.S., including wetlands. The U.S. Army Corps of Engineers administers the Section 404 permit program with oversight and veto powers held by the U.S. Environmental Protection Agency. Under Section 410, the State must certify that any 404 action meets current state water quality standards.

The 1987 amendment to the Clean Water Act established a stringent nonpoint source control mandate. Subsequent amendments further developed this mandate by requiring that states develop regulatory controls over nonpoint sources of pollution and over storm water runoff from industrial, municipal, and construction activities.

Endangered Species Act of 1973

This 1973 Act requires the NPS to identify and promote the conservation of all federally listed endangered, threatened, or candidate species within any park unit boundary. This Act requires all entities using federal funding to consult with the Secretary of Interior on activities that potentially impact endangered flora and fauna. It also requires agencies to protect endangered and threatened species, as well as designated critical habitats. While not required by legislation, it is NPS policy to also identify state and locally listed species of concern and support the preservation and restoration of those species and their habitats.

Safe Drinking Water Act of 1974

This is the primary federal legislation (1974 with amendments in 1986 and 1996) protecting drinking water supplied by public water systems (those serving more than 25 people). The act provides for the establishment of primary regulations for the protection of the public health and secondary regulations relating to the taste, odor, and appearance of drinking water. The law established the current federal-state arrangement in which states may be delegated primary implementation and enforcement authority for the drinking water program; the 1986 amendments sought to accelerate contaminant regulation. The state-administered Public Water Supply Supervision (PWSS) program remains the basic program for regulating the Nation's public water systems.

Rivers and Harbors Act of 1899

Section 9 of this Act, prohibits the construction of any bridge, dam, dike or causeway over or in navigable waterways of the U.S. without Congressional approval. Administration of section 9 has been delegated to the Coast Guard. Structures authorized by state legislatures may be built if the affected navigable waters are totally within one state, provided that the plan is approved by the Corps of Engineers and the Secretary of Army.

Under section 10 of the Act, the building of any wharfs, piers, jetties, and other structures is prohibited without Congressional approval, and excavation or fill within navigable waters requires the approval of the Corps of Engineers.

Authority of the Corps of Engineers to issue permits for the discharge of refuse matter into or affecting navigable waters under section 13 was modified by the Federal Water Pollution Control

Act Amendments of 1972, as amended, which established National Pollutant Discharge Elimination System Permits.

Fish and Wildlife Coordination Act of 1934

The Fish and Wildlife Coordination Act, as amended, provides authority for the U.S. Fish and Wildlife Service to review and comment on the effects on fish and wildlife of activities proposed to be undertaken or permitted by the Corps of Engineers.

Amendments enacted in 1946 require consultation with the U.S. Fish and Wildlife Service and the fish and wildlife agencies of states where the "waters of any stream or other body of water are proposed or authorized, permitted or licensed to be impounded, diverted . . . or otherwise controlled or modified" by any agency under a federal permit or license. Consultation is to be undertaken for the purpose of "preventing loss of and damage to wildlife resources."

The 1958 amendments added provisions to recognize the vital contribution of wildlife resources to the Nation and to require equal consideration and coordination of wildlife conservation with other water resources development programs. The amendments also expanded the instances in which diversions or modifications to water bodies would require consultation with the U.S. Fish and Wildlife Service.

Wild and Scenic Rivers Act of 1968

The 1968 Wild and Scenic Rivers Act (WSRA) states that it is the policy of the United States that certain selected rivers of the Nation possess outstandingly remarkable scenic, recreational, geologic, fish, and wildlife, historic, cultural, or other similar values, and shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations." The WSRA defines "*free-flowing*" as: *existing or flowing in natural condition without impoundment, diversion, straightening, rip-rapping, or other modification of the waterway*. The existence, however, of low dams, diversion works, and other minor structures at the time any river is proposed for inclusion in the national wild and scenic rivers system shall not automatically bar its consideration for such inclusion: provided, that this shall not be construed to authorize, intend, or encourage future construction of such structures within components of the national and wild and scenic rivers system."

The Nationwide Rivers Inventory (NRI) is a listing of more than 3,400 free-flowing river segments in the United States that are believed to possess one or more "outstandingly remarkable" natural or cultural values judged to be of more than local or regional significance. Under a 1979 Presidential directive, and related Council of Environmental Quality procedures, all federal agencies must seek to avoid or mitigate actions that would adversely affect one or more NRI segments. The NRI is a source of information for statewide river assessments and federal agencies involved with stream-related projects. The Mississippi River in the Metropolitan Area from Lock and Dam 1 to the confluence with the St. Croix River, which includes approximately 36 miles (58 km) of MNRRA, was listed on the NRI in 1982 (see http://www.nps.gov/ncrc/programs/rtca/nri/). 'Outstandingly Remarkable Values' for this segment include recreation, scenery, geology, wildlife, and history.

Executive Order 11990: Wetlands Protection

This executive order directs the NPS to 1) provide leadership and to take action to minimize the destruction, loss, or degradation of wetlands, 2) preserve and enhance the natural and beneficial values of wetlands, and 3) to avoid direct or indirect support of new construction in wetlands unless there are no practicable alternative to such construction and the proposed action includes all practicable measures to minimize harm to wetlands.

Executive Order 11988: Floodplain Management

This executive order requires all federal agencies to take action to reduce the risk of flood loss, to restore and preserve the natural and beneficial values served by floodplains, and to minimize the impact of floods on human safety, health, and welfare. The objective of this executive order is

"…to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative." For non-repetitive actions, the executive order states that all proposed facilities must be located outside the limits of the 100-year floodplain. If there were no practicable alternative to construction within the floodplain, adverse impacts would be minimized during the design of the project.

Executive Order 13112: Invasive Species
This executive order requires the prevention of the introduction of invasive species and provides for their control and minimization of the economic, ecological, and human health impacts that invasive species cause. It complements and builds upon existing federal authority to aid in the prevention and control of invasive species.

Executive Order 13061 – American Heritage Rivers
This executive order establishes a program designed to assist communities in revitalizing their rivers and riverfront areas. Fourteen self-nominated rivers were designated in July 1998 as American Heritage Rivers. Each river is matched with a River Navigator, a federal employee who acts as a liaison between the communities along the river and programs that can provide technical and financial assistance to aid them in meeting their goals.

Fifty-eight communities along the Upper Mississippi River from Bemidji, Minnesota to St. Louis, Missouri (including the Twin Cities) comprise one of the 14 American Heritage Rivers designations.

State of Minnesota Laws and Regulations

At the state level, water law is organized into a series of statutes and rules. Minnesota Statutes 103A through 103G constitute water law in Minnesota. This chapter discusses water-related Minnesota statutes of importance to MNRRA. Implementation of these statutes via their associated rules is not discussed. However, the actual language of these statutes and associated rules is available at: http://www.leg.State.mn.us/leg/statutes.asp.

Minnesota Statute (MS) 84 – Department of Natural Resources
This chapter includes the powers and duties of the Department of Natural Resources commissioner and addresses issues related to public lands, parks, timber, water, minerals and wild animals of the State.

MS 103A – Water Policy Information
Regulatory policy is defined within this chapter. Policy related to wetlands, hydropower, ground water management, rainwater conservation, soil and water conservation, floodplain management, scenic river protection, marginal and erodable land and water law policy are defined and addressed in this statute.

MS 103B – Water Planning and Project Implementation
Water planning and project implementation are addressed – it specifically creates and defines plans, programs, districts, commissions, organizations and boards to protect water resources.

Metropolitan Surface Water Management Act (MS 103B.201-255) – This act was approved in 1982. The act was originally included in Chapter 509 (and was commonly referred to as 509 planning) and was later re-codified as MS 103B. This chapter mandates the development and implementation of watershed management plans by Watershed Management Organizations (WMO) for all 46 watersheds within the seven-county Twin Cities Metropolitan Area. This chapter further requires that each city or township in the Metropolitan Area develop and administer its own plan. Each city or township must demonstrate that its plan is consistent with all other plans in the affected watersheds. The Minnesota Department of Natural Resources, Minnesota Pollution

Control Agency, Department of Health, and Metropolitan Council must review and approve each city and township plan before it receives final approval by the Board of Soil and Water Resources.

Watershed management organizations can be administered under three different frameworks: as watershed districts, as joint powers agreements among municipalities, or under county government (with the exception of Hennepin and Ramsey counties which are unable to administer WMOs under county government). Within the metro area, 14 watershed management organizations are organized as watershed districts, 23 as joint powers agreements and several are organized under county government.

Metropolitan counties in 1987 were given the authority to prepare and adopt ground water plans through M.S. 103B.255. That authority provided a mechanism for counties to set priorities, address issues, and build local capacity for protection and management of ground water. All counties in the Metropolitan Area have approved ground water plans except Anoka County. Anoka County, though not participating in the official metropolitan ground water planning process, has prepared a ground water protection assessment.

Comprehensive Local Water Management Act (MS103B.301 to 355) – This chapter encourages counties to develop and implement comprehensive water management plans. While the plans are voluntary, various state grants and even some federal monies require a county to adopt a local water management plan that is updated periodically. There are 80 counties with water management plans outside of the Metropolitan Area, which has implications for broader watershed management.

<u>MS 103C – Soil and Water Conservation Law</u>
The Soil and Water Conservation Law authorized the creation of Soil and Water Conservation Districts. This chapter also covers cooperation between districts and other public agencies, addresses powers and duties of the Board of Water and Soil Resources (which has oversight for local activities related to this law) and covers project determination and assessments.

<u>MS 103D – Minnesota Watershed Act</u>
The Minnesota Watershed Act provides a means for local governments to engage in cooperative planning and policy activities on a watershed basis to solve and prevent local water-related problems. The Act gives county boards, city councils, or landowners within one or more watersheds the right to petition the Board of Water and Soil Resources to establish watershed districts. Watershed Districts are special purpose units of local government that are given broad authorities including adoption of rules with the power of law to regulate, conserve and control water use, acquire, construct and operate drainage systems, dams, dikes, reservoirs, and water supply systems, and enter upon lands within and without the district to make surveys and conduct investigations.

<u>MS 103F – Protection of Water Resources</u>
This chapter addresses the protection of water resources, specifically, among others, shoreland development, Wild and Scenic Rivers, and floodplain management.

Floodplain Management Law (MS 103F.101-155) – Minnesota's Floodplain Management Act (1969) addresses the reduction of flood damages though floodplain management activities. It stresses nonstructural measures such as floodplain zoning and flood proofing. The Act requires the Department of Natural Resources, in conjunction with other state agencies, to map floodplains, determine the probability of different flooding scenarios, identify measures to mitigate against flood damage and enforce compliance among local governments responsible for adopting local floodplain zoning ordinances.

Shoreland Management Act (M.S. 103F.201) – The Shoreland Management Act (1969) provides guidance for the wise development of lands bordering lakes and rivers. The Department of Natural Resources (DNR) administers the Shoreland Management Program. The Act defines river shorelands as land within 300 ft (91 m) of a public water course or the landward extent of the delineated floodplain, whichever is greater. The DNR classified the State's public waters for allowable intensity of shoreland development. The DNR developed minimum standards for each classification for land uses, structure placement, lot sizes, shoreland alterations, and construction of sanitary facilities. Counties and municipalities with shoreland areas covered by the Act must adopt and enforce shoreland zoning ordinances that meet or exceed the minimum standards as developed by the DNR, when and if directed to do so by DNR. Since all Mississippi River shore areas are covered by the standards in Executive Order 79-19 that created the Mississippi River Corridor Critical Area, and since those standards are more restrictive than statewide shoreland standards and cover a larger geographic area, DNR will not likely direct local governments to develop shoreland management ordinances for the Mississippi River.

Wild and Scenic Rivers Act (MS 103F.301-345) – The intent of this act is to preserve and protect rivers in Minnesota that have outstanding scenic, recreational, natural, historical, scientific and similar values. The act addresses eligibility, designates three protected classes (wild, scenic, and recreational), and outlines the procedure to be followed in the development of a management plan. Six river segments in the state have been protected under this act, including the Mississippi River from St. Cloud to Anoka. Six miles of this State Wild and Scenic River overlap with the first six miles of MNRRA within the cities of Ramsey and Dayton.

Clean Water Partnership Law (MS 103F.701-761) – This law addresses the protection and improvement of surface and ground water in the State through financial and technical assistance to local units of government. The purpose of this law is to control water pollution associated with land use and land management activities and to provide a legal basis for state implementation of federal laws controlling nonpoint source water pollution.

MS 103G – Waters of the State

This statute includes the commissioner's authority, public water use and designation, wetlands, work affecting public water, water diversion and appropriation, permit procedure, water level establishment and control, dam construction and maintenance, flowage easements, water aeration and deicing, harvest and control of aquatic plants, sunken log recovery, and streams.

MS 103H – Ground Water Protection Act

This chapter addresses ground water issues including sensitive area protection, development of best management practices, quality monitoring requirements, health risk limits, and pollution management.

MS 115 – Water Pollution Control; Sanitary Districts

Chapter 115 addresses issues concerning water pollution control, sanitary districts, municipal water pollution control, individual and alternative discharging sewage treatment systems, regional sanitary sewer districts, water supply systems, and wastewater treatment facilities.

State Water Pollution Control Act (MS 115.01-09) – This act addresses storm water issues and the National Pollutant Discharge Elimination System (NPDES). The Minnesota Pollution Control Agency has authority to establish and apply standards, procedures, rules, orders, variances, etc. to be consistent with the federal Clean Water Act, including NPDES. It outlines public notice for NPDES permit applications, provisions for storm water permits, general permits, compliance with non-degradation and mitigation requirements of agency water quality rules, and regulation of storm water discharges.

Regional Sanitary Sewer District Law (MS 115.16-67) – This act established sanitary sewer districts as a municipal corporation and subdivision of the State responsible for acquiring, constructing, improving, extending, operating, and maintaining facilities for the collection, treatment, and disposal of sewage and industrial and other wastes received from sewer systems of all municipalities within their corporate limits.

MS 116 – Pollution Control Agency
This act creates and addresses the powers of the Minnesota Pollution Control Agency.

MS 116A – Public Water and Sewer Systems
This chapter outlines the purpose for the establishment of pubic water and sewer systems and addresses the power of county boards to construct and maintain such facilities.

MS 116G Critical Areas Act and Executive Order 79-19
The legislature found that the development of certain areas possessing important historic, cultural, or aesthetic values or natural systems that perform functions of greater than local significance could result in irreversible damage to these resources, decrease their value and utility for public purposes, or unreasonably endanger life and property. The State should identify these areas of critical concern and assist and cooperate with local units of government in preparation of plans and regulations for wise use of these areas. This chapter discusses selection criteria, preparation, review, and approval of plans and regulations, development permits, and protection of landowners' rights.

The Mississippi River and its adjacent corridor in the Twin Cities Metropolitan Area were designated a State Critical Area in 1976 through Executive Order 120. The order was renewed in 1979 through EO 79-19 and subsequently made permanent; it has since been referred to as Executive Order 79-19. The purposes of designating the Mississippi River corridor a State Critical Area include preventing and mitigating irreversible damage to this resource, preserving and enhancing its natural, aesthetic, cultural and historical value for public use, and protecting the river as an essential element of the transportation, sewer and water and recreational systems. Local units of government and regional agencies are required to adopt critical area plans and regulations and capital improvement programs that comply with the executive order. The standards in the executive order that must be followed by local governments include: minimization of runoff, improvement of quality of runoff, minimization of site alternation, protection of bluffs, retention of existing vegetation, and site plan review and approval. The executive order designates the DNR (originally the Environmental Quality Council, but the authority was transferred in 1995) as the lead agency to coordinate the preparation, submission, revision and modification of land use plans, zoning ordinances, zoning amendments, capital improvement programs, and other regulations which are prepared by local units of government and regional and state agencies. In 1988, Congress used the same boundary as the Mississippi River Corridor Critical Area when it created MNRRA. In 1991, the legislature designated the MNRRA as a State Critical Area in accordance with MS116G. MNRRA's Comprehensive Management Plan (National Park Service 1995a) incorporates by reference the Mississippi River Corridor Critical Area and shares the same boundaries as the Critical Area.

MS 144.381-387 – Department of Health
This chapter also known as the Safe Drinking Water Act of 1977 describes the purpose and authority of the Department of Health. It addresses safe drinking water, approval of design, construction, and alteration of public water supplies, testing, inspection, emergency plans and record keeping of facilities.

MS 452.08 – St. Paul Water Utility
The city of St. Paul owns and operates its own water utility under the authority of this statute. This utility provides clean water to St. Paul and some of its outlying suburban communities. The utility operates intake, treatment, and distribution systems, and cooperates with local community groups to improve water quality and provide wildlife benefits in the Vadnais Lake Area Water Management Organization.

MS 473 – Metropolitan Land Planning Act
This chapter addresses the creation of the Metropolitan Council and regional issues including transportation, recreational open space, solid waste disposal, aviation, water supply, wastewater treatment, comprehensive planning, and housing and redevelopment.

MS 473H -- Metropolitan Agricultural Preserves Program
The Metropolitan Agricultural Preserves Act of 1980 established an agricultural land protection program in the Twin Cities Metropolitan Area. This law protects important agricultural land in the Twin Cities Metropolitan Area from competing land uses, protects the local agricultural economy and supports businesses, promotes orderly and planned growth and development of urban and rural land uses, and allows farmers to make long-term agricultural investments with the assurance that their land can continue in agricultural use without interference from urban pressures. Through this Act, local governments identify areas where agriculture is to be preserved, where non-farm growth will be permitted and what standards apply to each area. This statute also contains a provision that local governments may not enact ordinances or regulations that restrict or regulate normal agricultural practices within an agricultural preserve unless the restriction or regulation has a direct relationship to public health and safety.

The Metropolitan Council monitors participation in the Metropolitan Agricultural Preserves Program. Legislation directs the Metropolitan Council to prepare annual reports summarizing participation in the program, and to maintain maps illustrating lands certified for long term agriculture and lands covenanted as agricultural preserve.

National Park Service Policies and Director's Orders

The NPS Management Policies (National Park Service 2006) provide broad policy guidance for the management of National Park System units. These NPS policies and guidelines broadly require management of natural resources of the National Park System to maintain, rehabilitate, and perpetuate the inherent integrity of aquatic resources. Section 4.6 of the management policies specifically addresses water resource management including protection of surface waters and ground water, water rights, water quality, floodplains, wetlands, and watershed and stream processes. It is NPS policy to determine the quality of park surface and ground water resources and avoid, whenever feasible, the pollution of park waters by human activities occurring within and outside of parks. Specifically, the NPS works with appropriate governmental bodies to: achieve the highest possible standards available under the Clean Water Act for protection of park waters, take all actions necessary to maintain or restore surface and ground water quality within the parks to be in compliance with the Clean Water Act and all applicable laws and regulations, and develop agreements with other governing bodies, where appropriate, to obtain their cooperation in maintaining or restoring the quality of park water resources. NPS Management Policies also direct the NPS to: manage watersheds as complete hydrologic systems, minimize human disturbance to natural upland processes that deliver water, sediment, and woody debris to streams, and manage streams to protect stream processes that create habitat features, including floodplains, riparian systems, woody debris accumulations, terraces, gravel bars, riffles, and pools.

In accordance with these management policies, the NPS will protect watershed and stream features mainly by avoiding impacts to watershed and riparian vegetation and allowing natural fluvial processes to proceed unimpeded. When conflicts between park infrastructure and stream processes are unavoidable, park managers will first consider relocating or redesigning infrastructure, instead of manipulating streams. However, where stream manipulation is inevitable, the NPS will use techniques that protect natural processes to the greatest extent practicable. In addition, the NPS will allow natural shoreline processes to continue without interference. Where human uses or infrastructure have altered the nature or rate of natural shoreline processes, the NPS will investigate alternatives for mitigating such effects.

Director's Orders (DOs) and Procedural Manuals

National Park Service DOs and procedural manuals describe the recommended procedures for implementing service-wide policy. Those DOs and procedural manuals that pertain most directly to water resources are described below.

- DO #77-1 and Procedural Manual #77-1: Wetland Protection: The purpose of DO #77-1 is to establish NPS policies, requirements, and standards for implementing Executive Order 11990, *Protection of Wetlands* (42 FR 26961). The NPS adopts a goal of "no net loss of wetlands." In addition, the NPS will strive to achieve a longer-term goal of net gain of wetlands service-wide. DO #77-1 directs NPS units to conduct park-wide wetland inventories to help assure proper planning with respect to management and protection of wetland resources and sets forth the standard for defining, classifying, and inventorying wetlands. For proposed new development or other new activities or programs that are either located in or otherwise have the potential for adverse impacts on wetlands, the NPS will employ a sequence of: 1) avoiding adverse wetland impacts to the extent practicable, 2) minimizing impacts that could not be avoided, and 3) compensating for remaining unavoidable adverse wetland impacts via restoration of degraded wetlands. Where natural wetland characteristics or functions have been degraded or lost due to previous or ongoing human activities, the NPS will, to the extent appropriate and practicable, restore them to pre-disturbance conditions. Where appropriate and practicable, the NPS will not simply protect, but will seek to enhance natural wetland values by using them for educational, recreational, scientific, and similar purposes that do not disrupt natural wetland functions. A Wetland Statement of Findings (WSOF) must be completed in accordance with procedures described in Procedural Manual #77-1 (Wetland Protection), when any NPS wetlands are adversely impacted. Procedural manual #77-1 provides more detailed procedures by which the NPS will implement DO #77-1.

- DO #77-2 and Procedural Manual #77-2: Floodplain Management: DO #77-2 applies to all proposed NPS actions involving floodplain development that could adversely affect the natural resources and functions of floodplains or increase flood risks. In compliance with Executive Order 11988, *Floodplain Management*, it is NPS policy to preserve floodplain values and minimize potentially hazardous conditions associated with flooding. Specifically, DO #77-2 directs the NPS to:

  - protect and preserve the natural resources and functions of floodplains;
  - avoid the long- and short-term environmental effects associated with the occupancy and modification of floodplains;
  - avoid support of floodplain development and actions that could adversely affect the natural resources and functions of floodplains or increase flood risks; and
  - restore, when practicable, natural floodplain values previously affected by land use activities within floodplains.

  When it is not practicable to locate or relocate development or inappropriate human activities to a site outside and not affecting the floodplain, NPS will:

  - prepare and approve a Floodplain Statement of Findings (FSOF), in accordance with procedures described in Procedural Manual #77-2;

- take all reasonable actions to minimize the impact to natural resources of floodplains;
- use non-structural measures as much as practicable to reduce hazards to human life and property; and
- ensure that structures and facilities are designed to be consistent with the intent of the standards and criteria of the National Flood Insurance Program (44 CFR Part 60).

Procedural Manual #77-2 establishes NPS procedures for implementing floodplain protection and management actions for national park system units in accordance with DO #77-2. The manual defines regulatory floodplains and the information required to delineate floodplains, defines the information required to evaluate hazards associated with the modification or occupation of floodplains, and provides requirements for managing activities that impact floodplains.

- Reference Manual #77: Natural Resource Management: Reference Manual #77 offers comprehensive guidance to NPS employees responsible for managing, conserving, and protecting the natural resources found in national park system units. The Manual serves as the primary guidance on implementing Service-wide natural resource management in units of the national park system. Specific natural resources pertaining to water addressed in the manual include the management, protection, and use of: fish and fishery resources, freshwater resources, marine resources, nonnative species, shorelines, and marine, freshwater, and barrier island resources.

Management Agencies

Management of the Mississippi River and associated waters within MNRRA is dispersed. Several federal, state and local agencies are involved with different management activities. Some management functions are performed primarily by a single agency. Other functions are shared by federal and state agencies. Some functions, however, are spread across many jurisdictions, which can lead to conflicts, multiple interpretations of rules, and patchy management success.

Management by federal agencies

U. S. Army Corps of Engineers (ACOE)
The ACOE has a role in designing, building, and operating water resource and other civil works projects for the purposes of maintaining navigable waterways and flood protection. The agency issues permits for the placement of structures, dredging and filling of navigable waters under Section 10 of the Rivers and Harbors Act. It also regulates the discharge of dredged or other fill into all waters of the U. S. under Section 404, Clean Water Act. No section 404 permit may be issued by the ACOE without a section 401 certification from the Minnesota Pollution Control Agency that the discharge of dredged or fill material will not violate state water quality standards. The ACOE operates and maintains a 9-foot navigation channel from north Minneapolis (above St. Anthony Falls) downstream, including operating locks and dams as well as dredging and other in-river construction to maintain the navigation channel.

The ACOE also has enforcement authority to prohibit placement of any refuse or debris in a river or on the bank that may be washed into the river and obstruct navigation (Sec. 13, Rivers and Harbor Act).

The ACOE operates reservoirs on the upper Mississippi River based on guidelines established in an informal agreement with the State of Minnesota. The original authorized purpose for the Corps dams was to provide low flow augmentation for navigation on the Mississippi River as far south as the Twin Cities of St. Paul and Minneapolis. However, flood control, recreation, hydropower, water supply, and enhanced fish and wildlife production have subsequently been added as authorized project purposes.

National Park Service (NPS)
The NPS has responsibility for the 72-mile (116 km) Mississippi National River and Recreation Area in the Twin Cities Metropolitan Area, a unit of the national park system designated in 1988. The authorizing legislation for this national park unit mandates that the NPS review all federally funded or federally permitted activities in the corridor. The NPS has no direct management or regulatory authority except on the few acres of islands owned by it. The remainder of the 54,000-acre (nearly 22,000 hectare) MNRRA is under the jurisdiction of other federal, state and local government units, through existing authorities. The NPS works in partnership with the 21 cities, four townships and five counties within the MNRRA as well as state and federal agencies, nonprofit organizations, commercial interests and individuals to realize goals set forth in the comprehensive management plan (National Park Service 1995).

U.S. Coast Guard
The Coast Guard maintains the river channel buoy system and enforces safety standards and laws related to navigation-related vessels. They enforce some pollution laws, set bridge height standards, and inspect barges and recreational and commercial vessels.

U. S. Fish and Wildlife Service (USFWS)
The Fish and Wildlife Coordination Act of 1934 mandates that all federal agencies consult with the USFWS on permit and license applications involving water development projects. Section 7 of the Endangered Species Act mandates that all federal agencies consult with the USFWS to ensure that actions do not jeopardize federally listed species. The USFWS has direct management responsibility for the Minnesota Valley National Wildlife Refuge, adjacent to MNRRA, and the Upper Mississippi National Wildlife and Fish Refuge, 44 miles (71 km) downriver of MNRRA.

U.S. Environmental Protection Agency (EPA)
The EPA establishes standards for water quality management, drinking water safety, solid and hazardous waste disposal, toxic substance management, air quality control and general environmental quality review. Most enforcement is delegated to the states with EPA oversight. The EPA may veto a 404 permit, and it may initiate the lead federal role for certain cases. In Minnesota the primary enforcement role for water quality is filled by the Minnesota Pollution Control Agency.

Federal Energy Regulatory Commission (FERC)
FERC has jurisdiction over all non-federal hydroelectric power facilities that are located on or use water from a navigable stream, produce power that affects interstate or foreign commerce, are located on federal land, or use water impounded by a federal dam. The commission must issue a license before any such facility could be built. FERC operates under authority of the Federal Power Act (1920), the Public Utilities Regulatory Policies Act, the Electric Consumers Protection Act (1986) and the Energy Policy Act (1992). There are five dams within MNRRA that involve FERC licenses.

U.S. Geological Survey (USGS)
The USGS is primarily responsible for collecting data on natural resources and the physical environment. This includes information on geological and biological resources, water resources, maps and mapping, and earthquakes and other natural disasters. As such it is the lead research agency for the U.S. Department of Interior.

Management by the state of Minnesota

Minnesota Department of Agriculture
The Minnesota Department of Agriculture is the lead agency in soil and water conservation programs and other programs designed to protect agricultural land. It administers several laws that prevent surface and ground water pollution from agricultural practices, such as pesticide application. It also has regulatory authority in preventing and cleaning up ground water contamination from agricultural chemicals, including pesticides and fertilizers.

Minnesota Board of Water and Soil Resources (BWSR)
The BWSR is the State's administrative agency for 91 soil and water conservation districts, 46 watershed districts, 23 metropolitan watershed management organizations, and 80 county water managers. The agency's purpose, working through local government, is to protect and enhance the State's soil and water resources by implementing the State's soil and water conservation policy, comprehensive local water management, and the Wetland Conservation Act as it relates to 41.7 million acres (16.9 million hectares) of private land in Minnesota.

Water-related core functions and associated statutes for this agency are:

- Direct private land soil and water conservation programs through the action of soil and water conservation districts, counties, cities, townships, watershed districts and water management organizations (MS 103C, 103D, 103F);

- Link water resources planning with comprehensive land use planning (MS 103B);

- Provide resolution of water policy conflicts and issues (MS 103A.211, 103A.305, 103A.315, 103A.311);

- Implement the comprehensive local water management acts (MS103B.201, 103B.305, 103B.301); and

- Administer the Wetland Conservation Act (MS 103G).

Although the Board encourages integrated water planning, surface and ground water planning are essentially dealt with separately in the Metropolitan Area. Surface water planning is addressed through the plans of watershed management organizations/watershed districts, whereas ground water planning is addressed through the Comprehensive Local Water Management Act (MS 103B).

Minnesota Department of Health (MDH)
MDH is a public health agency that works with local public health agencies, federal health agencies, and other organizations to operate programs that promote clean water and related issues. It provides oversight for public water supply systems, develops and enforces safe drinking water standards, and administers the well-head protection program. An additional responsibility is the collection of information regarding the concentration of bioaccumulative chemicals in fish and publishing fish consumption advisories.

Minnesota Department of Natural Resources (MDNR)
The purpose of the MDNR is to: conserve and manage the State's natural resources, provide outdoor recreation opportunities, and provide for commercial uses of natural resources in a way that creates a sustainable quality of life. The agency manages the State's fisheries, forests and parklands and also has a significant role in managing the State's water resources, including administration of the floodplain and shoreland management programs.

The MDNR manages surface and ground water withdrawals in the State. State law requires an appropriation permit for withdrawals exceeding either 10,000 gallons per day (nearly 38,000 liters) or one million gallons (3.8 million liters) per year. The MDNR evaluates each water appropriation permit application to determine potential impacts on the water resource, other resource users, and fish and wildlife habitat, and assesses the efficiency of the proposed water use.

Minnesota statutes identify the priority of water uses during periods of limited water availability. Water uses, ranked according to highest priority, are as follows:

1. domestic water supply and power production that meets contingency planning requirements;
2. withdrawals of less than 10,000 gallons (38,000 liters) per day;
3. irrigation and processing of agricultural products;
4. power production that does not meet contingency planning requirements; and
5. non-essential water uses.

The MDNR bears responsibility for examination, maintenance, and repair of state-owned dams. It also inspects all private and public dams and associated structures and administers a grant program to local governments that provides up to 50 percent of the cost to repair locally owned dams.

The MDNR regulates activities pertaining to physical changes in the channel, current, or cross-section of protected waters including docks, boat ramps, shore protection, and drainage construction. Jurisdiction with regard to physical changes in protected water courses is limited to the elevation at the top of the channel bank. It also regulates protected riverine wetlands along with reservoirs and other types of wetlands. Under the current regulatory guidelines, the MDNR requires a permit for some activities.

The MDNR is the primary state agency involved in managing public lands located in river corridors. For example it maintains public access ramps and drop-in points for boating and canoeing on rivers in Minnesota.

The MDNR manages and develops spawning areas, constructs rough fish barriers, and obtains easements along streams for aquatic management and fishing access. A 1992 amendment to Minnesota's Outdoor Recreation Act provided the MDNR with the statutory authority to acquire property and easements for aquatic management. It identifies and acquires stream shoreland for access by anglers and fisheries management personnel, for important habitat areas, and for research on natural history.

The MDNR establishes standards for operating watercraft and approves local surface water use ordinances. All owners of watercraft must obtain and display a MDNR license.

The MDNR has three primary roles associated with the Mississippi River Corridor Critical Area Program. First, MDNR reviews existing ordinances that affect lands within the Critical Area for their compliance with State Critical Area standards and guidelines. Adoption or amendment of plans and ordinances affecting lands within the Critical Area are effective only after approval by the MDNR. Second, in communities where the Critical Area plans and ordinances have become effective, the local government unit must notify the MDNR area hydrologist at least 30 days before action is taken for all development applications or variances requiring a public hearing or discretionary action. Finally, in addition to the Critical Area Program, the MDNR will work with local units of government to ensure compliance with the floodplain management program and the state wild and scenic rivers program. The shoreland management program does not apply in the Critical Area, and the wild and scenic rivers program only applies in Dayton and Ramsey.

Minnesota Pollution Control Agency (MPCA)

The MPCA is responsible for state-wide water quality planning, development of state water quality standards, monitoring environmental quality, and enforcing environmental regulations.

While the EPA provides leadership in the area of water quality under the Clean Water Act, the MPCA designs programs and develops, administers, monitors and enforces standards to protect and enhance the State's surface and ground waters.

The MPCA regulates water pollution from both point and nonpoint sources. Point sources of water pollution include domestic and industrial facilities that discharge treated wastewater to surface water or land through distinct discharge points. The agency develops standards and administers programs to control nonpoint source pollution from farmland, feedlots, construction sites, septic systems, roadways, and other sources. Section 319 of the federal Clean Water Act established a national program to control nonpoint sources of water pollution. MPCA's *Nonpoint Source Management Program Plan* is a requirement for Minnesota to remain eligible to receive nonpoint source grant funds from the US Environmental Protection Agency under Section 319.

Under the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) Storm Water Program is a comprehensive national program for addressing polluted storm water runoff. Minnesota regulates the disposal of storm water through State Disposal System (SDS) permits. The MPCA issues combined NPDES/SDS permits for construction sites, industrial facilities and municipal separate storm sewer systems (MS4s).

As required by the Clean Water Act, MPCA publishes, every two years, an updated list of streams and lakes that are not meeting their designated uses because of excess pollutants. The list, known as the 303(d) list, is based on violations of water quality standards and is organized by river basin. For each pollutant that causes a water body to fail to meet state water quality standards, the federal Clean Water Act requires the MPCA to conduct a TMDL study.

<u>Environmental Quality Board (EQB)</u>
This Board develops state-wide policy and engages in planning activities relating to environmental issues affecting rivers and watersheds. Under the Minnesota Environmental Policy Act, the EQB has the authority to request an environmental review of certain projects affecting the State's rivers and watersheds. The EQB also promulgates and oversees regulations regarding the preparation of environmental impact statements and environmental assessment worksheets.

Management at the regional level

<u>Metropolitan Council</u>
The Metropolitan Council is a regional planning agency serving the seven-county Twin Cities Metropolitan Area. The Metropolitan Council looks across municipal and county lines, providing a focus on how regional issues of land use, growth patterns and regional services affect the Twin Cities' water resources. The Metropolitan Council coordinates the planning and development of major systems (e.g., bus and light rail system, wastewater, housing, parks, and regional water resources) in Minneapolis/St. Paul and their surrounding communities. With respect to river corridor development, the Metropolitan Council, which owns and operates the regional sewage system, works with developers and local governments to implement its water quality protection policies.

The Metropolitan Council reviews and comments on the watershed plans prepared by watershed management organizations as well as water management plans prepared by local units of government as a component of their local comprehensive plans. In addition, the Metropolitan Council provides technical assistance to counties, cities, and towns on issues relating to water resources.

With regard to the Mississippi River Corridor Critical Area, the Metropolitan Council reviews existing plans and ordinances that affect lands within the Critical Area, makes recommendations to DNR prior to approval, and provides technical assistance to communities in amending or adopting plans to become consistent with Executive Order 79-19.

State law (MS 473.145) directs the Metropolitan Council to prepare a comprehensive development guide for the Metropolitan Area. The development guide consists of the 2030 Regional Development Framework and four system plans for transportation, aviation, wastewater and regional recreation open space, and related policy statements, goals, standards, programs and maps describing how it will achieve its charge. The 2005 *Water Resources Management Policy Plan* replaces the 1996 plan (www.metrocouncil.org/planning/environment/WRMPP/WRMPP2005.htm). This policy plan was developed in response to MS 473.157.

Management at the local level

There are 21 cities and four townships in the five counties that encompass the MNRRA corridor. Local governments have broad planning and regulatory control over development in the corridor. Each of these political entities has regulatory power over land and water use through a variety of departments, agencies, commissions, etc. Minnesota state law gives these local governments primary authority over land use regulation. Local governments are often responsible for enforcement of standards written by state and county level agencies or the state legislature.

Counties
In Minnesota, counties are often responsible for the creation, implementation and enforcement of local water management plans.

Municipalities and Townships
These entities have regulatory authority over activities within their boundaries that are in addition to federal, state, county, and other local regulations and ordinances. Municipalities and townships are required to prepare plans to address water quality issues within their borders. These plans are prepared in support of the watershed management plans for the watershed management organization within which the city or township lies.

Soil and Water Conservation Districts
These districts are political subdivisions of the State whose boundaries generally coincide with county boundaries and whose purpose is to encourage private landowners to conserve soil and water resources through technical assistance, funding, and educational services. Management practices tend to emphasize prevention and reduction of soil erosion, sedimentation, and nonpoint source pollution.

Watershed Districts (WD) and Watershed Management Organizations (WMO)
Watershed districts are local units of government that work to solve and prevent water-related problems. The boundaries of districts follow those of a natural watershed and are governed by a board of managers appointed by the boards of county commissioners that have land in the district. A WMO is a watershed district wholly within the Metropolitan Area or a joint powers entity established wholly or partly in the Metropolitan Area by special law or agreement to perform some or all of the functions of a watershed district. The functions of WDs may include: development and implementation of a watershed management plan, review and approval of local water management plans, regulation of the use and development of land, and construction, repair, improvement and management of drainage systems. There are 23 WMOs and 14 WDs in the Metropolitan Area. The *Upper Mississippi Basin Information Document* (Minnesota Pollution Control Agency 2000b) provides detailed information on these WDs and WMOs.

In the Metropolitan Area, WMOs are responsible for the local water planning. WMOs prepare watershed management plans in response to the Metropolitan Surface Water Management Act and the Watershed Management Act (MS 103A-G). Minnesota Statutes 103D and 103B outline watershed district responsibilities and authorities. State agencies along with the Metropolitan Council review and comment on watershed management plans and provide comments to the BWSR for its use in approval of the plans. Local governments are also required to complete local water plans within two years after all of the WMOs that they are part of have approved watershed plans. The Metropolitan Council reviews local water plans and these plans are a required element of city and township comprehensive land use plans.

Related Management Plans and Programs

Comprehensive Management Plan for MNRRA (National Park Service 1995a)
This comprehensive management plan serves as the general management plan for MNRRA, providing guidance for managing the corridor for the next 10-15 years. The plan provides a policy framework for coordinated efforts to protect and interpret the nationally significant resources of the Mississippi River corridor and for analyzing other federal, state, or local plans and individual actions in the area. It is a conceptual, policy and program-level plan concentrating on corridor-wide concerns. Except for proposed NPS facilities, it does not address site-specific issues. Such issues will be addressed on a case-by-case basis by local communities using the broad visions, general concepts, and corridor-wide policies articulated in the Comprehensive Management Plan as a guide. Local governments have the flexibility to tailor the plan to their section of the river and address site-specific issues within the overall framework of the comprehensive management plan.

This plan adopts and incorporates by reference the State Critical Area program, wild and scenic rivers program, and other applicable state and regional land use management programs that implement the visions identified above. This plan does not create another layer of government but rather stresses the use of existing authorities and agencies to accomplish the policies and actions developed for the corridor.

The general concept for implementation prescribes a two-tier approach to achieving MNRRA plan consistency through local government planning and management.

> **Tier 1** -- The existing Mississippi River Corridor Critical Area Program will remain in place, and implementation of this program will be improved. Critical area program oversight will be transferred from the Minnesota Environmental Quality Board to the MDNR, and increased funding will be made available for program implementation in the MNRRA corridor. Local governments will be required to continue to administer a critical area ordinance and have a critical area plan in place.
>
> **Tier 2** -- Local governments could voluntarily move to a second tier of planning and management by updating their community plans and ordinances to incorporate the land use, resource protection, and open space policies described in the comprehensive management plan. Funding will be requested to assist local governments in updating their plans and ordinances to substantially conform to the new concepts and higher standards in the MNRRA plan, and technical assistance will be available from the Metropolitan Council for plan development and from the MDNR for ordinance development. Ordinance implementation will be overseen by the MDNR in the same way it oversees the critical area program.

Mississippi Scenic Riverway
The Mississippi River between the cities of St. Cloud and Anoka was designated as a State Wild and Scenic River in 1976, under authority of the Minnesota State Wild and Scenic Rivers Act (M.S. 103F.301-103F.345). This legislation directs the MDNR to conduct studies, develop criteria for classification and designation of rivers, and adopt rules to manage and administer the wild and scenic rivers system. The designation procedure requires a management plan to be prepared for each river within this system. The Mississippi Scenic Riverway Management Plan was updated in 2004 (http://files.dnr.state.mn.us/waters/watermgmt_section/wild_scenic/missplan_07-01-2004.pdf). Although this section of river was eligible for inclusion in the National Wild and Scenic Rivers System as a

state-administered segment, the state didn't seek the federal designation due to a high level of controversy at that time.

Mississippi River Resources Forum

The Mississippi River Resources Forum is a state and federal agency partnership for addressing resource issues concerning the Upper Mississippi River system within the St. Paul District, U.S. Army Corps of Engineers jurisdiction. Participating agencies include: the Corps, U.S. Fish and Wildlife Service, U.S. Coast Guard, U.S. Environmental Protection Agency, Natural Resources Conservation Service, National Park Service, and the Departments of Natural Resources and transportation from Minnesota, Wisconsin, and Iowa, and the Minnesota Pollution Control Agency.

Mississippi River Environmental Pool Plans

Environmental Pool Plans are descriptions of what river managers and the public have identified as the habitat and features necessary to reverse negative trends in habitat quality and move towards a more sustainable ecosystem. These plans ultimately provide guidance in the application of river management tools such as water level management, island stabilization and creation, backwater dredging, and channel modifications.

These plans were prepared by the Fish and Wildlife Group at the request of the River Resources Forum, and include plans for Pools 1-10 (http://www.mvp.usace.army.mil/rrf/eppfinal.pdf). The Forum endorsed the plan for Pools 2-10 in 2003; however, the Forum has not endorsed the plan for Pool 1. The Pool 1 Plan was believed to be unrealistic because it could not be achieved without sacrificing or significantly affecting other river uses such as congressionally mandated commercial navigation.

Upper Mississippi River System Environmental Management Program (EMP)

The Upper Mississippi River System Environmental Management Program, authorized by the Water Resources Development Act of 1986, is a federal-state partnership to monitor the natural resources of the river system. This partnership involves a variety of federal (U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, U.S. Geological Survey, and Natural Resources Conservation Service) and State (Illinois, Iowa, Minnesota, Missouri, and Wisconsin) agencies, non-governmental organizations, and the general public. This program provides a combination of monitoring, research, and habitat restoration activities, and originally consisted of five elements: Habitat Rehabilitation and Enhancement Projects (HREP), Long Term Resource Monitoring (LTRMP), Recreation Projects, Economic Impacts of Recreation, and Navigation Monitoring. Presently, EMP is only comprised of two elements – HREP and LTRMP.

Upper Mississippi River System Navigation and Ecosystem Sustainability Program (NESP)

The Upper Mississippi River-Illinois Waterway System Navigation Feasibility Study, conducted by the U.S. Army Corps of Engineers, was completed in September 2004 after more than 12 years of study. The resulting study's final recommendation includes the development of an implementation program underpinned by comprehensive adaptive management to achieve the dual purposes of ensuring a sustainable natural ecosystem and navigation system. The Navigation and Environmental Sustainability Program (NESP) is a long-term program of navigation improvements and ecological restoration for the Upper Mississippi River System over a 50-year period. This program's focus is threefold: 1) reduce or eliminate commercial traffic delays, 2) improve national and regional economic conditions, and 3) restore, protect, and enhance the environment.

The U.S. House of Representatives (in July 2005) and the U.S. Senate (in July 2006) have approved authorization of NESP, which would include $1.58 billion over 15 years for ecosystem restoration work in the river between Minneapolis and the mouth of the Ohio River. Some of that work would occur within MNRRA. In fall of 2006, a conference committee was working on resolving minor differences in the House and Senate versions of the bill.

NESP would also lead to creation of a River Manager's Council made up of representatives of nine federal agencies, five states and non-government organizations representing environmental, navigation, levee district, recreation and agricultural interests. This council would establish broad goals for managing the river system and prioritize ecosystem restoration projects.

Upper Mississippi River Basin Association (UMRBA)

The UMRBA was formed in 1981 as a successor to the defunct Upper Mississippi River Basin Commission. The UMRBA is an interstate (Minnesota, Missouri, Wisconsin, Illinois, and Iowa) organization that maintains communication and cooperation among the states on matters related to water planning and management. The five member states of the UMRBA are represented by gubernatorial appointees that usually have water resource management responsibilities. Six federal agencies also participate in the UMRBA as advisory members – the U.S. Army Corps of Engineers, Department of Agriculture (Natural Resources Conservation Service), Department of Homeland Security (Coast Guard and Federal Emergency Management Agency), Department of the Interior (Fish and Wildlife Service, Geological Survey), Department of Transportation (Maritime Administration), and U.S. Environmental Protection Agency.

The purpose of UMRBA is to facilitate dialogue and cooperative action regarding water and related land resource issues. In particular, UMRBA will:

- serve as a regional interstate forum for the discussion, study, and evaluation of river-related issues of common concern;
- facilitate and foster cooperative planning and coordinated management of the region's water and related land resources;
- create opportunities to exchange information among the states and federal agencies; and
- develop regional positions on river resource issues and serve as an advocate of the states' collective interests before Congress and the federal agencies.

Regional Setting

The Mississippi River is the second longest river (2,350 mi, or 3,782 km) in the U.S., after the Missouri River. It drains a large watershed area (1.2 million mi^2, 3.1 million km^2) covering approximately 40 percent of the country (all or part of 31 states), making it the third largest watershed in the world. It originates in Lake Itasca at an elevation of 1,475 ft (450 m) and flows through several glacial lakes above the Twin Cities of Minneapolis and St. Paul. Between the Twin Cities and St. Louis, several tributaries (e.g., the Minnesota, Illinois, and Des Moines Rivers) drain important agricultural lands. The Missouri River joins the Mississippi at St. Louis. It is the longest tributary, and constitutes more than 40 percent of the Mississippi drainage area, while furnishing about 20 percent of the total discharge. South of Cairo, Illinois and the confluence with the Ohio River, the Mississippi enters a wide, low valley that was once an embayment of the Gulf of Mexico. Here, the meandering channel route to New Orleans is almost three times as long as the valley. The Mississippi River enters the Gulf of Mexico (mean annual discharge of 640,000 ft^3/s, 18,123 m^3/s) about 100 mi (161 km) downstream of New Orleans through a 10,100 mi^2 (26,159 km^2) delta. Based on drainage area and mean annual discharge, the Mississippi River is the largest river in the U.S. (Iseri and Langbein 1974); via annual discharge the Mississippi is the sixth largest river in the world (Berner and Berner 1996).

The Upper Mississippi River System (the basin upstream of the mouth of the Ohio River) is the only river system in the U.S. formally recognized by Congress as a nationally significant ecosystem and a nationally significant commercial navigation system. As part of this recognition, the Water Resources Development Act of 1986 established a Long-Term Resource Monitoring Program (LTRMP), an element of the U.S. Army Corps of Engineers' Environmental Management Program, but implemented by the U.S. Geological Survey in cooperation with the five system states. A milestone for the LTRMP was the "Ecological Status and Trends Report of the Upper Mississippi River System 1998" which synthesized the first 10 years of study (U.S. Geological Survey 1999; http://www.umesc.usgs.gov/reports_publications/status_and_trends.html). In that report, Theiling (1999) summarized the human history of the Upper Mississippi River System. The most ecologically significant anthropogenic change to the Upper Mississippi River System was the construction of the 9-foot navigation channel and 29 locks and dams on the Mississippi River under the Rivers and Harbors Act of 1930. These navigation dams created a stair-stepped system of lake-like pools that enabled boats to negotiate obstacles and cross the elevation gradient and 670 miles (1,078 km) between Minneapolis and St. Louis (Figure 3). Upper and Lower St. Anthony Falls, Lock and Dam 1, and Lock and Dam 2 are in the Twin Cities Metropolitan Area and MNRRA.

The Mississippi River Basin, upriver from Lock and Dam 2 in the lower Twin Cities Metropolitan Area and extending north to the river source at Lake Itasca, covers approximately 22,450 mi^2 (58,145 km^2) (Figure 4). The Mississippi River flows approximately 579 miles (932 km) from Lake Itasca to Lock and Dam 2. If the basin area for the Minnesota River, a major tributary of the Upper Mississippi River, is included, the total basin area expands to 39,400 mi^2 (102,045 km^2). The MNRRA boundaries extend downriver to include the confluence with the St. Croix River. The St. Croix basin adds an additional 7,760 mi^2 (20,098 km^2) of area that influence the Mississippi River within MNRRA (Table 1).

Major tributaries of the Mississippi River upstream of MNRRA include the Leech Lake, Swan, Willow, Pine, Gull, Skunk, Clearwater and Elk Rivers. Within MNRRA, major tributaries are the Crow, Rum, Minnesota and St. Croix Rivers (Table 1).

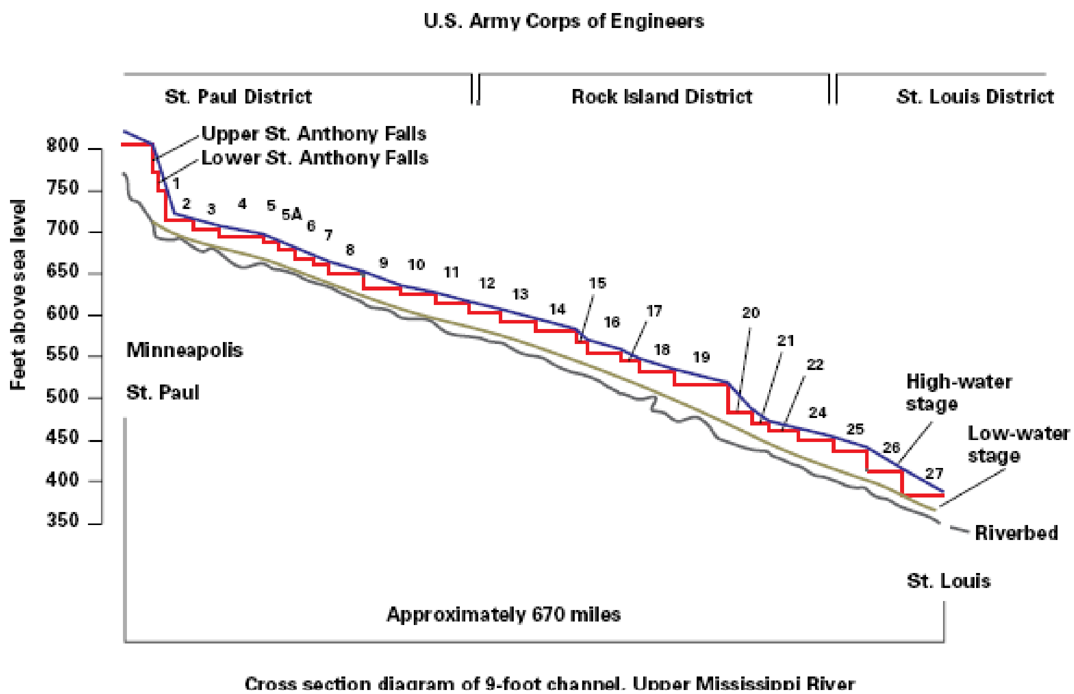


Figure 3. Elevation profile of the Upper Mississippi River System showing the increase in low-flow river stage caused by navigation dams (numbered 1-27). The river at flood stage exceeds stages required for navigation and is allowed to flow freely through and over dams (after Theiling 1999).

In Minnesota, the Mississippi River is impounded by 10 dams from the headwaters through the MNRRA corridor (Table 2). Reservoirs on Gull and Leech Lakes and the Pine River are part of the Upper Mississippi River Headwater Reservoir Project, along with Sandy Reservoir and two reservoirs on the Upper Mississippi River main stem, Pokegama and Winnibigoshish. The U.S. Army Corps of Engineers completed the Mississippi River Headwaters Dams in 1912 to augment flows in the Mississippi River for navigation. Today, these dams are operated for the general public good and tribal trust requirements, which include flood control, recreation, and fish and wildlife considerations (U.S. Army Corps of Engineers 2001). The Corps-operated headwaters reservoirs are drawn down in winter and store spring runoff to reduce flooding. River regulation at the main stem Mississippi River dams is very close to run-of-river. During all but the very lowest levels of the river discharge, river flow is more than adequate to meet all present water withdrawal needs (U. S. Army Corps of Engineers 2001).

The guidelines, regulations and general plan for operating the Mississippi River Headwaters reservoirs are contained, for the most part, in the 1963 Master Regulation Manual [revised in 1968 (U.S. Army Corps of Engineers 1969)]. However, the U.S. Army Corps of Engineers and the U.S. Forest Service will complete in 2006 a jointly sponsored, long-range operating plan study (Reservoir Operating Plan Evaluation, or ROPE) for the Headwaters reservoirs (see http://www.mvp.usace.army.mil/navigation/default.asp?pageid=143). The primary purpose of this study is to evaluate alternative plans for each of the federal reservoirs and attempt to improve system wide operations of all the reservoirs. An important aspect of this study will be an assessment of the opportunity to restore, to the extent possible, natural hydrologic variability.

Table 1. Some characteristics of major tributaries to the Mississippi River within the Metropolitan Area and MNRRA boundaries (from http://www.esg.montana.edu/gl/huc/07.html). HUC = Hydrologic Unit Code.

Tributary	HUC	Watershed Area mi^2 (km^2)	Perennial Stream Length mi (km)	Intermittent Stream Length mi (km)	Total Road Length mi (km)
Crow	07010204	2,764 (7,159)	710 (1,143)	1,151 (1,852)	6,729 (10,829)
Rum	07010207	1,561 (4,043)	600 (966)	462 (744)	3,221 (5,184)
Minnesota	07020012	16,951 (43,902)	720 (1,159)	391 (629)	5,544 (8,922)
Twin Cities (Metro)	07010206	1,081 (2,800)	333 (536)	3 (5)	8,405 (13,527)
St. Croix	07030005	7,760 (20,098)	731 (1,176)	786 (1,265)	6,737 (10,842)

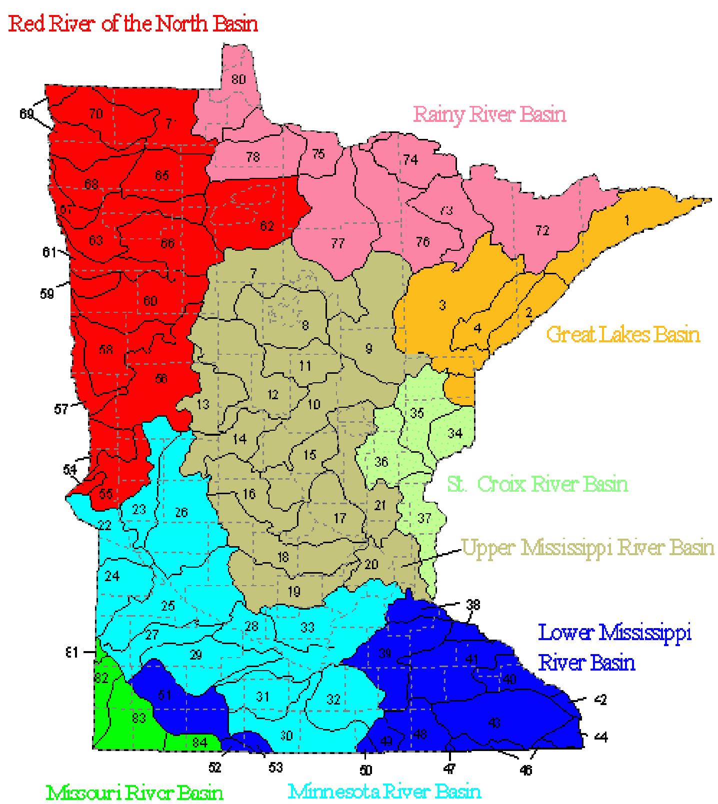


Figure 4. Major river basins and their sub-watersheds in Minnesota (used with permission from the Minnesota Department of Natural Resources; http://www.dnr.state.mn.us/watersheds/map.html). Minnesota's Upper Mississippi River Basin consists of the following watersheds: Mississippi River headwaters (No. 7); Leech Lake River (No. 8); Mississippi River, Grand Rapids (No. 9); Brainerd (No. 10); Pine River (No. 11); Crow Wing River (No. 12); Redeye River (No. 13); Long Prairie River (No. 14); Sartell (No. 15); Sauk River (No. 16); St. Cloud (No. 17; North Crow River (No. 18); South Crow River (No. 19); Mississippi River Metro (No. 20); Rum River (No. 21); St. Croix River (No. 34-37); Rush/Vermillion Rivers (No. 38); and Cannon River (No. 39).

Table 2. Dams on the main stem Upper Mississippi River upstream of and within the MNRRA corridor (after U.S. Army Corps of Engineers 2001). Dams marked with an '*' are part of the Mississippi River Headwaters Reservoirs Project of the U.S. Army Corps of Engineers.

Dam	Location	Owner/Operator	Primary Purpose
Upstream of the MNRRA corridor			
Stump Lake	Bemidji	Ottertail Power Co,	hydropower
Knutson	Cass Lake	U.S. Forest Service	recreation
Winnibigoshish*	Deer River	Corps of Engineers	flow augmentation, flood control, recreation
Pokegama Lake*	Grand Rapids	Corps of Engineers	flow augmentation, flood control, recreation
Blandin	Grand Rapids	Minnesota Power	hydropower
Potlatch	Brainerd	Potlatch Corp.	hydropower
Little Falls	Little Falls	Minnesota Power	hydropower
Blanchard	Royalton	Minnesota Power	hydropower
Champion	Sartell	Champion Int.	hydropower
St. Cloud	St. Cloud	City of St. Cloud	hydropower
Within the MNRRA corridor			
Coon Rapids	Coon Rapids	City of Coon Rapids	recreation, abandoned hydropower
Upper St. Anthony Falls	Minneapolis	Corps of Engineers, Xcel Energy	hydropower, navigation
Lower St. Anthony Falls	Minneapolis	Corps of Engineers, Xcel Energy	hydropower, navigation
Lock and Dam 1	St. Paul	Ford Motor Co., Corps of Engineers	hydropower, navigation
Lock and Dam 2	Hastings	Corps of Engineers, City of Hastings	hydropower, navigation

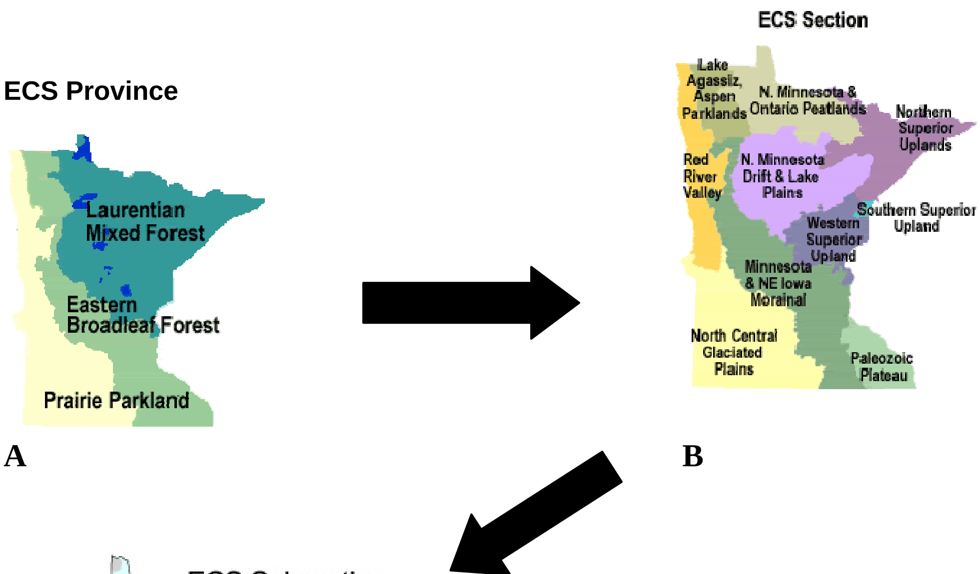
Physiography

Several broad classification schemes exist (Fenneman and Johnson 1946, Omernik 1987) that integrate climate, hydrology, topography, soils and vegetation. The Ecological Classification System is particularly noteworthy for Minnesota (http://www.dnr.state.mn.us/ecs/index.html). The Upper Mississippi River Basin in Minnesota contains three of the provinces of the Ecological Classification System (Figure 5a). Most of the basin is in the Laurentian Mixed Forest and Eastern Broadleaf Forest provinces. The Prairie Parkland province encompasses only the upper portion of the Minnesota River drainage.

The Laurentian Mixed forest province is the true forested region of Minnesota. It consisted of continuous conifer, conifer-hardwood mix, or hardwood forest vegetation before settlement. Topography is variable. Landforms range from lake and outwash plains to ground and end moraines. Soils are in the Alfisol, Entisol, or Histosol orders.

The Prairie Parkland province covers most of the area in Minnesota occupied by tall grass prairie before settlement. Topography is predominantly level to gently rolling. Major land forms include lake plains and ground moraines. Soils are generally in the Mollisol order.

The Eastern Broadleaf Forest Province is a transitional area between prairie to the west and true forest to the east. Topography varies from level in the plains to very steep in the southeastern portion of the province. Major landforms include lake plains, outwash plains, end moraines, ground moraines, and drumlin fields. Soils are in the Alfisol, Entisol, Histosol or Mollisol orders.



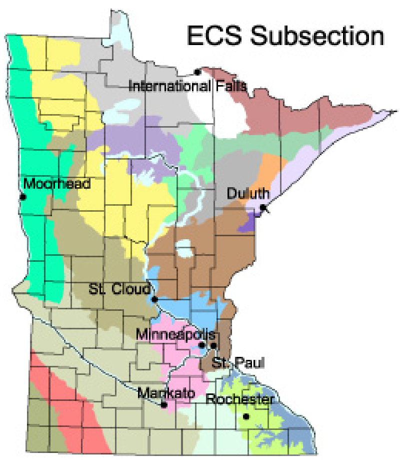


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Figure 5. Ecological classification System (ECS) for Minnesota from province (A) through section (B) to subsection (C) (used with permission from the Minnesota DNR; http://www.dnr.state.mn.us/ecs/index.html). Subsections (C) referred to in text are as follows: Anoka Sand Plan (blue); Big Woods (pink); St. Croix Moraines and Outwash Plains (brown); Oak Savanna (light green); and Blufflands (blue-gray).

The Twin Cities Metropolitan Area and MNRRA are primarily in the Minnesota and NE Iowa Morainal section of the Eastern Broadleaf Province (Figure 5b). This section has several subsections of importance to the Metropolitan Area and MNRRA (Figure 5c): 1) Anoka Sand Plain, 2) Big Woods, 3) St. Croix Moraines and Outwash Plains, and 4) Oak Savannah. The southern portion of MNRRA downriver of Lock and Dam 2 is in the Blufflands subsection of the Paleozoic Plateau (Figure 5c). Table 3 summarizes the important soil and vegetative characteristics of these subsections.

Twin Cities Metropolitan Area

The seven-county Metropolitan Area (Figure 6) currently has approximately 2.7 million people, based on the latest (April 2002) estimates by the Metropolitan Council. This represents a growth of 2.5 percent since the 2000 Census. The Metropolitan Area also added an estimated 32,400 households from 2000 to 2002, up from the 2000 Census count of 1,021,454. The northern parts of the Metropolitan Area are some of the fastest growing areas in the country (U.S. Army Corps of Engineers 2001).

Table 3. Soil and vegetative characteristics of the ECS subsections encompassed by the Twin Cities Metropolitan Area and MNRRA (from http://www.dnr.state.mn.us/ecs).

Subsection (general location within Metropolitan Area)	Soils	Vegetation
Anoka Sand Plain (northern)	Derived from fine sands and include primarily droughty, upland soils (Psamments) with some wet prairie (Aquolls) and organic (Hemists) soils	Pre-settlement – oak barrens and openings, brushland on large areas. Present – sod and vegetable crops extensively grown but oak openings and oak barrens abundant on sand plain.
Big Woods (western)	Derived from calcareous glacial till and include primarily soils developed under forests (Alfisols) with some soils developed under grassland (Mollisols).	Pre-settlement – Oak woodland and maple-basswood forest were common on irregular ridges. Present – greater than 75% of subsection is cropland with an additional 5-10% pasture; remaining is either upland forest or wetland.
St. Croix moraines and outwash plains (eastern)	Derived from mixed parent materials on moraines and sandy parent material on outwash plains and include primarily Alfisols with some Mollisols on outwash plains	Pre-settlement – Oak and aspen savanna were primary communities, with some tall grass prairie and maple-basswood forest Present – small areas of forest present in eastern portion of unit, but urban development continues.
Oak Savanna (southern)	Mosaic of Mollisols and Alfisols; common soils include Aquolls, Udolls (well drained prairie soils), Udalfs (well drained forest soils), and Aqualfs (wet forest soils	Pre-settlement vegetation – Bur oak savanna with areas of tallgrass prairie and maple-basswood forest Present – mostly farmed with some urban development.
Blufflands (southern)	Predominately Udalfs with localized Aquents along major river floodplains.	Pre-settlement – tallgrass prairie and bur oak savanna on ridge tops and dry slopes with red oak-white oak-basswood-black walnut forests in protected valleys and some prairie. Present – About 50% woodland, 30% cropped, and 20% pasture.

The 2000 Census revealed that the Metropolitan Area experienced its largest population growth in any decade in its history (http://www.metrocouncil.org/Census/KeyFacts/7-county.htm). The population growth of 353,333 recorded in the 1990s surpassed the growth of the 1960s (the previous record) by just over 4,000 (Table 4). The growth rate increased only slightly from the previous decade (15.3 versus 15.4 percent; Table 4), but it is below the high growth rates of the 1950s and 1960s. Across the seven counties, Scott County had the greatest population change (54.5 percent) from 1990 to 2000 followed by Carver (46.6), Dakota (29.3), Anoka (22.3), Washington (15.4), Hennepin (8.7), and Ramsey (5.2).

One of the major challenges for the Twin Cities Metropolitan Area in the next 25 years is population growth. The Metropolitan Council forecasts an increase of approximately 1 million more people by 2030 for the Metropolitan Area (Table 4). Households are projected to increase from 1,021,454 in 2000 to 1,179,000 in 2010, a 15 percent increase (Metropolitan Council 2004). The percentage increase is slightly higher than for population growth because of a continuing decline in the number of persons per household. The number of households in 2030 will reach 1,482,000.

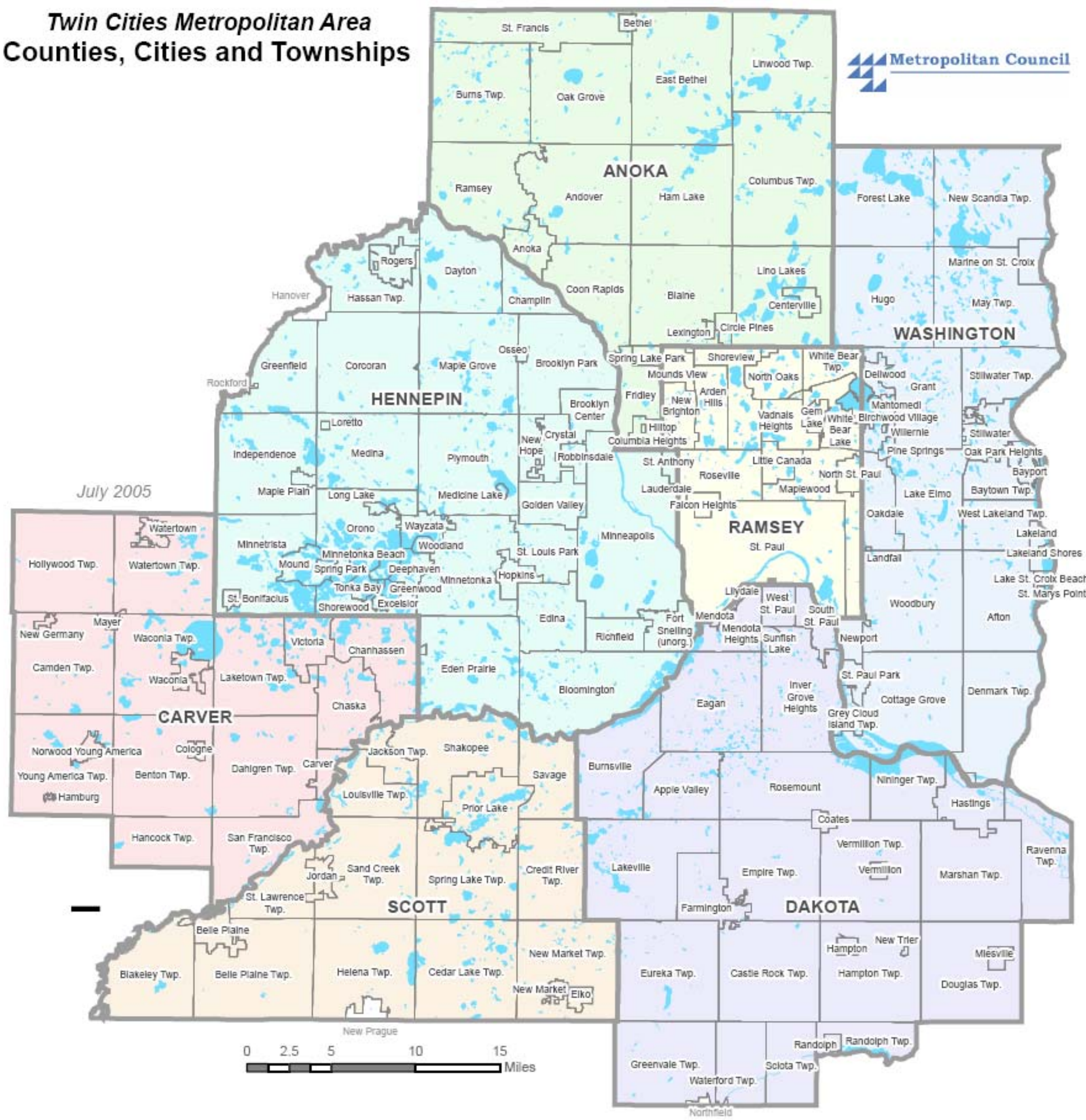

Figure 6. The seven-county Twin Cities Metropolitan Area (from http://www.metrocouncil.org).

The discussion of Twin Cities Metropolitan Area population growth is somewhat limited by Minnesota law, which defines the Metropolitan Area and limits the Metropolitan Council's jurisdiction to the seven counties of Hennepin, Ramsey, Washington, Anoka, Dakota, Scott and Carver. In reality, significant population increases are occurring in surrounding counties and the metropolitan region is actually much larger than the defined seven counties. Wright County, to the west, grew 31 percent from 1990 to 2000. Sherburne County, to the northwest, grew 54 percent in that period. Isanti County, to the north, grew 21 percent, and Chisago County, to the northeast, grew 35 percent during the 10-year period. Wisconsin's St. Croix and Pierce counties, to the east of the defined metropolitan area, grew rapidly as well. St. Croix County, the fastest-growing county in Wisconsin, grew 26 percent from 1990 to 2000 and another 22 percent from 2000 to 2005. Pierce County grew 12 percent from 1990 to 2000, and another 6 percent from 2000 to 2005.

Land Use

The population of the Twin Cities Metropolitan Area grew by approximately 25 percent between 1970 and 2000 (Table 4), while urban land area grew by 59 percent (http://www.epa.gov/urban/msp/indicators.htm). In the same time period, the area of agricultural lands decreased by 17 percent and the average amount of time Twin Cities' residents spent in congested traffic increased from 5 to 23 hours per year (http://www.epa.gov/urban/msp/indicators.htm). High percentages of agricultural and urban land uses depict areas in which land use practices may have profound effects on wildlife habitat, air and water quality, soil erosion, and quality of life. Agricultural best management practices and smart growth may help mitigate these human impacts. Table 5 shows the latest land use (2000) and the land use change from 1990 to 2000, and emphasizes the increase in urban lands and decrease in agricultural lands. Figure 7 graphically portrays the present land use within the Metropolitan Area.

Table 4. Historic growth and population forecasts for the Twin Cities Metropolitan Area (modified from Metropolitan Council 2004).

Decade	% Change	Population Change	Population at End of Decade
Trends			
1940-1950	18.5	185,136	1,185,694
1950-1960	28.7	339,306	1,525,297
1960-1970	22.9	349,315	1,874,612
1970-1980	5.9	111,261	1,985,873
1980-1990	15.3	302,856	2,288,729
1990-2000	15.4	353,333	2,642,062
Forecasts			
2000-2010	13.7	363,000	3,005,000
2010-2020	10.9	329,000	3,334,000
2020-2030	8.2	274,000	3,608,000

Climate

The climate of the Upper Mississippi River basin is greatly influenced by three major air masses, the Continental Polar, Maritime Tropical, and the Maritime Polar (http://www.npwrc.usgs/resource/habitat/rlandscp/genset.htm). The Continental Polar air mass from the Arctic brings cold, dry weather in the winter and cool conditions in the summer. The Maritime Tropical originates in the Gulf of Mexico and brings warm, moist winter weather and hot, humid summer conditions. The Maritime Polar air mass forms in the northern Pacific Ocean and carries large amounts of moisture; however, much of this is lost on the western slope of the Rocky Mountains. This air mass brings mild weather with little precipitation to the Metropolitan Area. Together, these air masses generate what is classified as a sub-humid continental climate that has wide and rapid diurnal and seasonal temperature fluctuations (Stark et al. 1996, Minnesota Pollution Control Agency 2000a).

Table 5. Changes in land use by area (acres and hectares) from 1990-2000 for the Twin Cities Metropolitan Area (from http://www.metrocouncil.org).

	1990		2000		Change (1990-2000)		
Land Use Categories	**Total (acres)**	**Total (hectares)**	**Total (acres)**	**Total (hectares)**	**Absolute (acres)**	**Absolute (hectares)**	**Relative (percentage)**
Residential Total	300,878	121,761	367,905	148,886	67,027	27,125	22%
Single Family Residential	262,028	106,039	313,355	126,810	51,327	20,771	20%
Farmsteads	16,739	6,774	19,759	7,996	3,020	1,222	18%
Multi-family Residential	22,111	8,948	34,791	14,079	12,680	5,131	57%
Mixed Use	N/A	N/A	3,429	1,388	N/A	N/A	N/A
Commercial	24,070	9,741	31,940	12,926	7,870	3,185	33%
Industrial Total	40,388	16,344	46,496	18,816	6,108	2,472	15%
Industrial & Utility	40,388	16,344	37,295	15,093	-3,093	-1,252	-8%
Extractive	N/A	N/A	6,439	2,606	N/A	N/A	N/A
Railway	N/A	N/A	2,762	1,118	N/A	N/A	N/A
Institutional	29,453	11,919	32,548	13,172	3,095	1,253	11%
Parks, Recreation & Preserves	126,759	51,298	163,286	66,080	36,527	14,782	29%
Major Vehicular Rights-of-Way	20,707	8,380	25,458	10,303	4,751	1,923	23%
Airports	7,446	3,013	6,766	2,738	-680	-275	-9%
Agriculture & Undeveloped Total	1,242,016	502,627	1,101,392	445,718	-140,624	-56,909	-11%
Agriculture	N/A	N/A	607,836	245,983	N/A	N/A	N/A
Undeveloped Land	N/A	N/A	493,556	199,735	N/A	N/A	N/A
Agricultural & Vacant	1,220,177	493,789	N/A	N/A	N/A	N/A	N/A
Industrial Parks not Developed	9,586	3,879	N/A	N/A	N/A	N/A	N/A
Public & Semi-Public Vacant	12,253	4,959	N/A	N/A	N/A	N/A	N/A
Open Water	111,238	45,016	124,331	50,315	13,093	5,299	12%
Total	1,902,955	770,100	1,904,140	770,579	1,185	480	0%

Annual normal temperatures (1971-2000) for the Metropolitan Area range from a low of 35.9° F (2.2° C) to a high of 54.7° F (12.6° C) with a mean of 45.4° F (7.4° C) (http://mcc.sws.uiuc.edu/index.jsp). The average monthly temperature ranges from 13.1° F (-10.5° C) in January to 73.2° F (22.9° C) in July (Figure 8). Annually, the number of days that the maximum temperature is ≤ 32° F (0° C) is 76.2. The average number of days that the minimum temperature is ≤ 32° F (0° C) is 154.2.

Average annual precipitation in the Metropolitan Area is 29.41 inches (74.70 cm) with a range of < 0.1 inches (0.25 cm) in January/February to 4.34 inches (11.02 cm) in June (Figure 9; http://mcc.sws.uiuc.edu/index.jsp). The period from December to February is the driest at 9.6 percent of the annual amount; May to September is the wettest period at 53.3 percent of annual precipitation (Figures 7 and 8). Annual average snow accumulation is 56.3 inches (143.0 cm), ranging from 0.1 inch (0.25 cm) in May to 13.7 inches (34.8 cm) in January.

Annual surface water runoff varies from approximately 3 inches (8 cm) in the west to more than 9 inches (23 cm) in the east (Minnesota Pollution Control Agency 1999). The mean annual evaporation in the Upper Mississippi River Basin varies from approximately 28 inches (23 cm) in the northeastern part to 40 inches (102 cm) in the southwest corner of basin (Farnsworth et al. 1982).

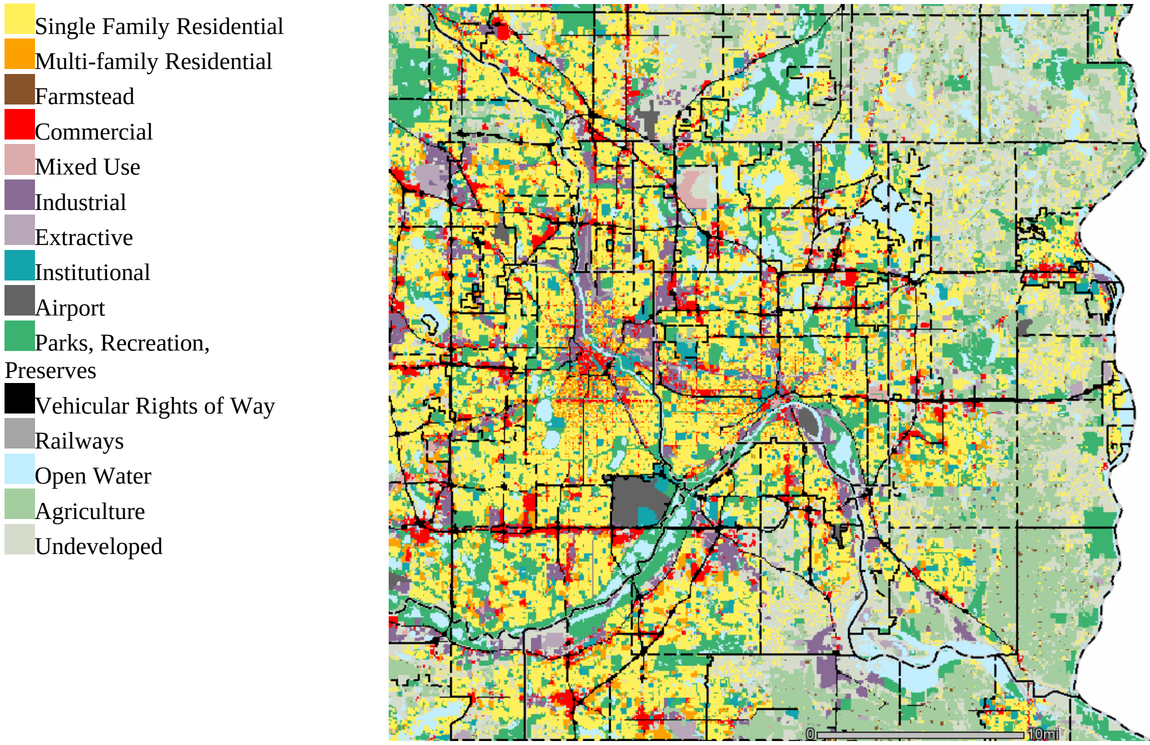

Figure 7. Distribution of land use categories across the Metropolitan Area (from http://es.metc.state.mn.us/eims/maps/related_maps.asp?optn=22).

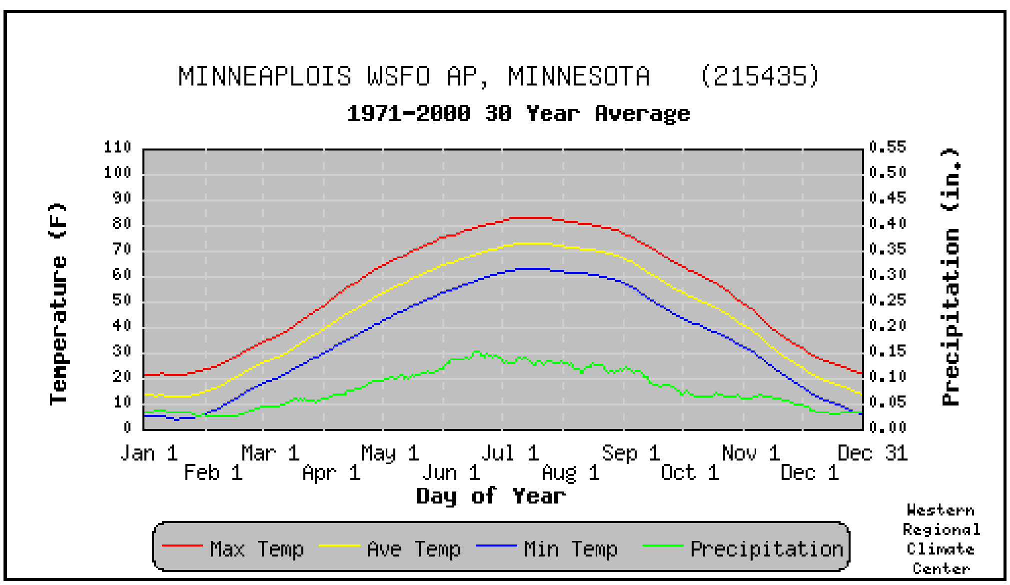

Figure 8. Daily average, maximum and minimum temperatures and average daily total precipitation for 1971-2000 in Minneapolis. Data are smoothed using a 29-day running average. After: http://mcc.sws.uiuc.edu/index.jsp.

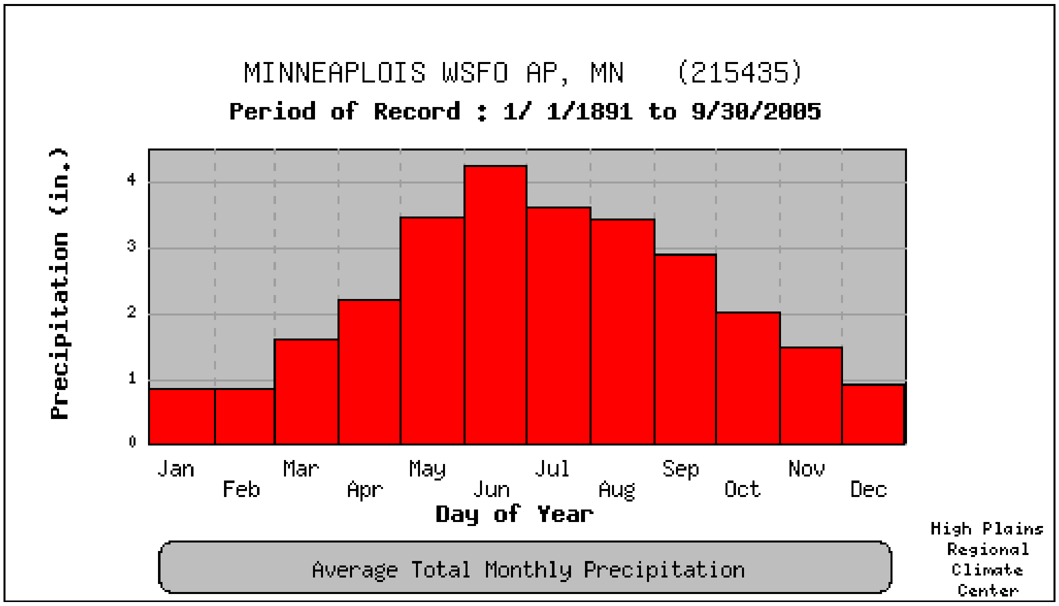

Figure 9. Average precipitation by month for the period of record 1891-2005 (from http://mcc.sws.uiuc.edu/index.jsp).

Surface Water

The overall hydrography of the Metropolitan Area is depicted in Figure 10. The Metropolitan Area watershed (Figure 4), besides the major tributaries listed in Table 1, contains many small, direct tributaries to the Mississippi River including (from north to south, with watershed areas in parentheses; Metropolitan Council 2004):

Elm Creek (85 mi^2, 220 km^2)
Coon Creek (94 mi^2, 243 km^2)
Shingle Creek (45 mi^2, 117 km^2)
Rice Creek (185 mi^2, 479 km^2)
Bassett Creek (40 mi^2, 104 km^2)
Minnehaha Creek (177 mi^2, 458 km^2)
Battle Creek (12 mi^2, 31 km^2)
Fish Creek (5 mi^2, 13 km^2)

Geology and Hydrogeology

Geology in the Twin Cities Metropolitan Area is subdivided into two basic classifications: unconsolidated glacial and alluvial sediments and consolidated bedrock formations of Paleozoic age (Stark et al. 1996, Seaberg 2000). The unconsolidated sediments, commonly called glacial drift, were deposited by glaciers of the Quaternary geologic period (Figure 11). Glacial deposits are essentially the result of the last glacial episode, the Wisconsinan, which lasted from 110,000 to 10,000 years before present. They were modified by subsequent erosion and soil formation processes. These glacial deposits form a widespread mantle of sediment that overlays bedrock materials. The overall thickness of glacial deposits ranges from 10 (3 m) to 400 ft (122 m).

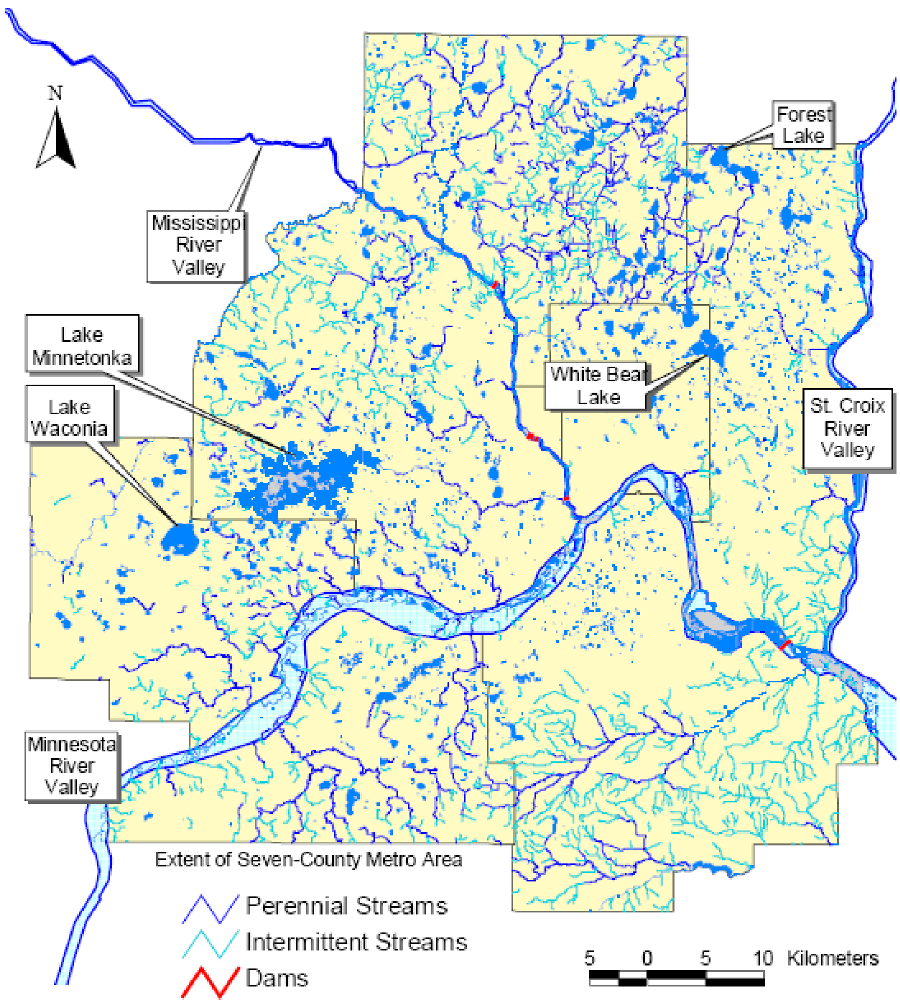

Figure 10. Twin Cities Metropolitan Area hydrography (from Seaberg 2000).

Consolidated bedrock formations are much older and lie beneath the glaciated drift. They include a thick overlapping sequence of sandstones, limestones, dolostones and shales (Figure 11). Most bedrock units in the Metropolitan Area were deposited during the Paleozoic era about 450 to 530 million years ago. The bedrock deposits in the Metropolitan Area are part of a regional geologic setting called the Hollandale Embayment (Stark et al. 1996, Seaberg 2000). The embayment sequence of sandstone, carbonate and shale bedrock layers underlies portions of Wisconsin, Minnesota and Iowa and acts as a huge ground water basin; deposits within the Embayment have varying water-holding capacities. A prominent secondary feature within the Embayment is the Twin Cities Basin. The Twin Cities Basin is a structural basin beneath the Metropolitan Area that contains up to 1,200 ft (366 m) of Paleozoic formations. Figure 12 provides a cross-sectional look at the geology of the Twin Cities Basin.

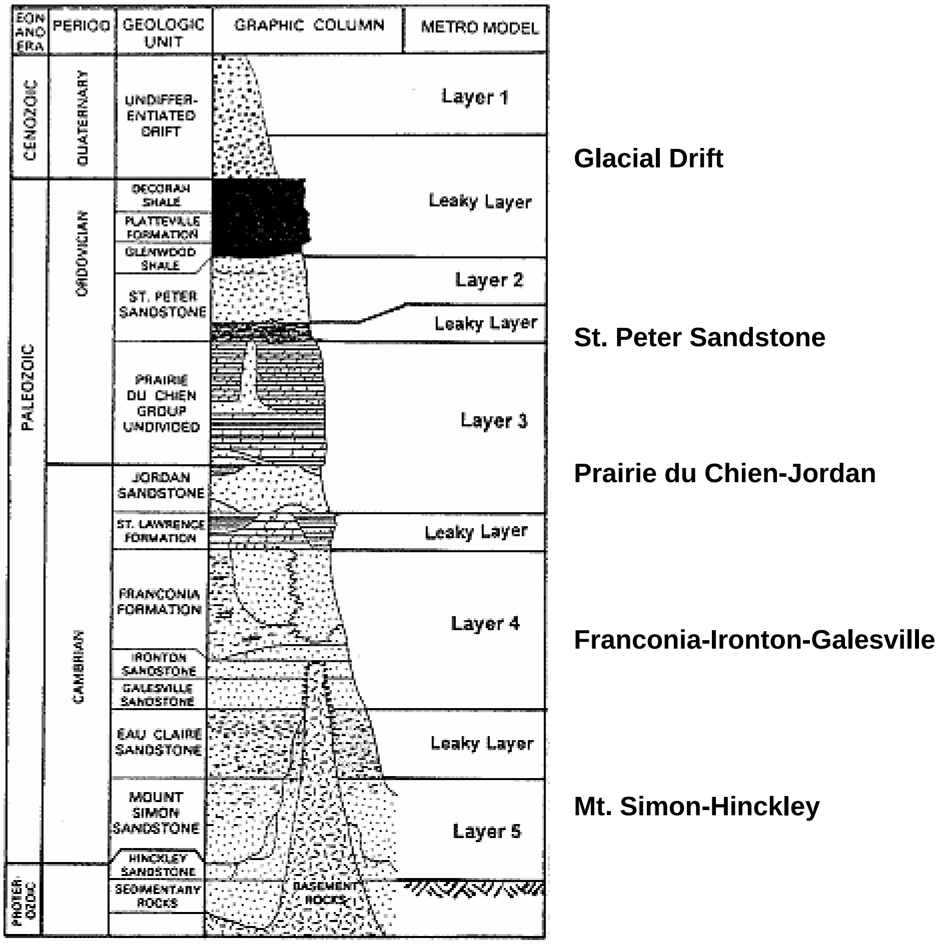

Figure 11. Stratigraphic column showing the sedimentary geology and hydrostratigraphy (aquifers) of the Twin Cities Metropolitan Area (modified from Seaberg 2000).

Aquifers

Coinciding with the geologic stratigraphy of Figure 11, there are two types of aquifers in the Twin Cities Metropolitan Area that are important sources of water: bedrock aquifers in rocks of Paleozoic age and sand and gravel (glacial drift) aquifers in deposits of Quaternary age. The shallow sand and gravel aquifers are the source of recharge to underlying bedrock aquifers.

The hydrogeology of the southern and eastern portions of the Metropolitan Area is dominated by Paleozoic bedrock geology consisting primarily of limestone, dolomite, and sandstone (Figure 13). The primary bedrock aquifers in the area include the St. Peter sandstone, the Prairie du Chien Group (carbonate), the Jordan sandstone, and the Franconia-Ironton-Galesville sandstone. The bedrock aquifers more or less act as continuous units with regional flow being to the major rivers. Surficial and buried sand and gravel aquifers may behave as a regional flow system in which the ground water flows toward the major rivers in the area. The Mt. Simon-Hinckley and Franconia-Ironton-Galesville aquifers are important sources of drinking water toward the northern and western portion of the metro area (Figure 12), where the Jordan aquifer is absent.

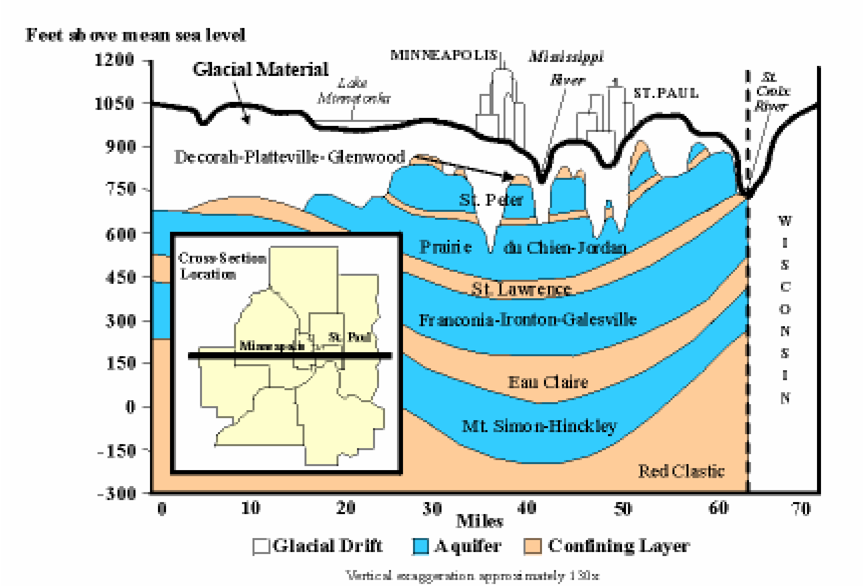

Figure 12. Generalized cross-section of the Twin Cities Basin under the Metropolitan Area (from Metropolitan Council 2004).

The St. Peter Aquifer consists of fine-to medium grained well-sorted quartzose sand, and is separated from the Upper Carbonate formations by the Decorah Shale and the Platteville and Glenwood formations which act as confining units (Figure 11). The St. Peter is easily eroded and is only rarely found at the land surface. This is an important aquifer in the central portion of the Metropolitan Area (Figure 12), occupying approximately 680 mi^2 (1,761 km^2) (Seaberg 2000).

The Prairie du Chien aquifer comprises two principal formations, the Oneota dolomite and the overlying Shakopee formation (Figure 11). These consist of thin to thick-bedded dolomite separated by the New Richmond sandstone. The formation may be as thick as 400 ft (122 m).

The Jordan Aquifer consists of a quartzose, fine-to medium grained sandstone, ranging from massive or thick-bedded to thin-bedded.

Traditionally, the Prairie du Chein and Jordan aquifers have been lumped together as one aquifer on the assumption that they are hydraulically well-connected. However, evidence suggests significant hydraulic separation may occur between the formations, particularly in areas where the Prairie du Chien group is overlain by younger bedrock units; these formations might require treatment as separate aquifers for local applications (Seaberg 2000). Together, they represent the most productive aquifer in the Metropolitan Area, supplying approximately 80 percent of the ground water pumped, and 50 percent of all water used. The Jordan Sandstone occupies over 1,820 mi^2 (4,714 km^2) and the Prairie du Chien about 1,520 mi^2 (3,937 km^2) of the Metropolitan Area (Figure 13).

The Franconia-Ironton-Galesville Aquifer is separated from the Jordan aquifer by the St. Lawrence Formation, which acts as a confining layer (Figure 11). These three aquifers are often treated as a single hydrologic unit. Each consists of sandstone, although there are scattered layers of shale and dolomite within the Ironton and Galesville sandstones. The aquifer covers most of the Metropolitan Area (Figure 13) except along the major rivers, where the formation is eroded and filled with glacial material. This is a significant aquifer particularly where the Priairie du Chien-Jordan Aquifer is absent (Figure 13).

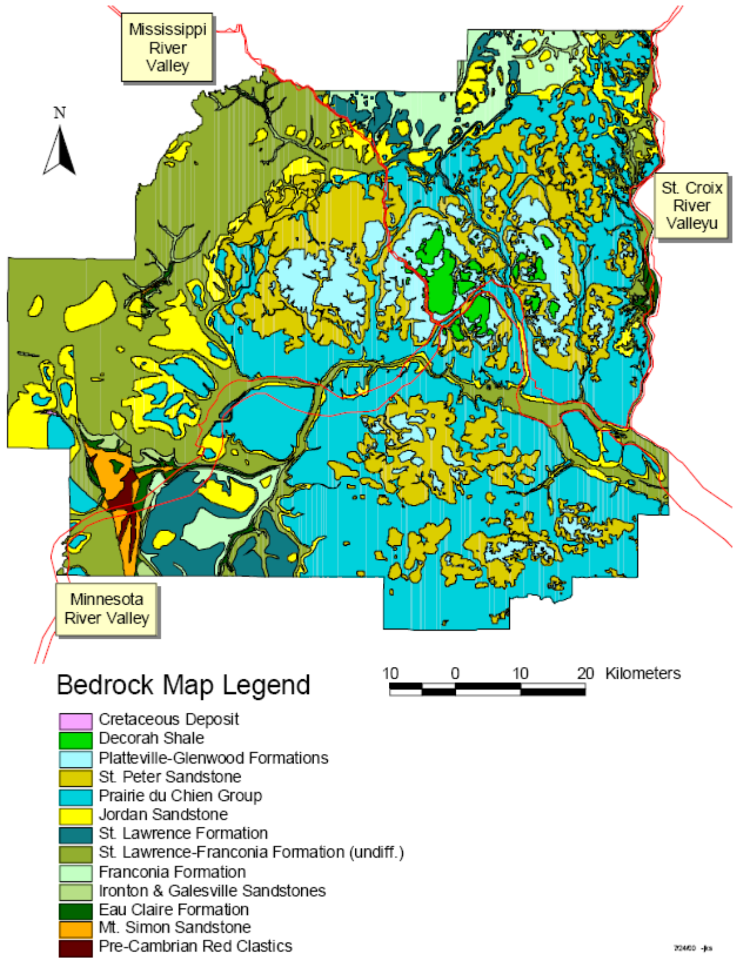

Figure 13. Areal distribution of bedrock geology in the Metropolitan Area (from Seaberg 2000).

The Mt. Simon-Hinckley Aquifer underlies almost all of the Metropolitan Area; together they comprise the second major aquifer in the area, supplying about 10 percent of the ground water production (Seaberg 2000). Originally, ground water flow within the Metropolitan Area was from the Mt. Simon-Hinckley aquifer upward towards the Prairie du Chien-Jordan Aquifer. However, the vertical gradient has been reversed due to pumping that has resulted in draw downs within the Mt. Simon-Hinckley aquifer of up to 240 ft (73 m) (Seaberg 2000).

There are few surficial drift aquifers in the southern and western portions of the Metropolitan Area. Surficial drift aquifers primarily occur in alluvium deposited along the major drainages, such as the Mississippi, Minnesota, Crow and St. Croix Rivers (Minnesota Geological Survey 1982). Surficial outwash deposits increase in frequency toward the northern part of the Metropolitan Area.

An important surficial aquifer that is present in the northern portion of the Metropolitan Area is the Anoka Sand Plain (Figure 14). It is largely continuous, extending to the north and northwest from the Metropolitan Area. In the absence of highly productive bedrock aquifers near the ground surface, the Anoka Sand Plain is widely used as a ground water resource (Seaberg 2000). The hydrogeology of the Anoka Sand Plain was described in more detail in Andrews et al. (1998).

The demand on surficial aquifers as a water supply source likely will increase due to rapid population growth in the Metropolitan Area. Population and water use demands are growing rapidly in the northwestern part of the area.

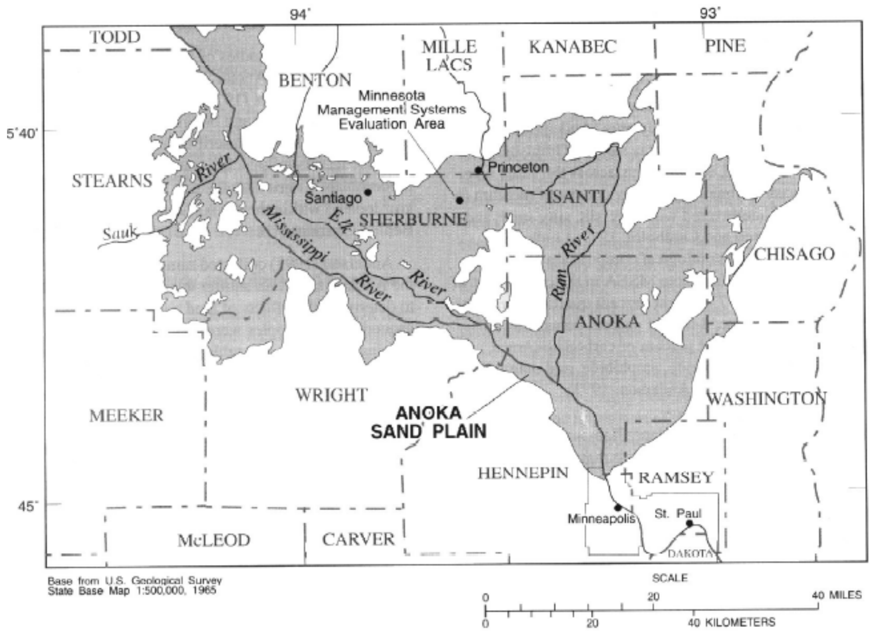

Figure 14. Location of the Anoka Sand Plain (from Seaberg 2000).

Well-sorted sand and gravel were deposited in bedrock valleys and as outwash plains by advancing and retreating glaciers (Seaberg 2000). These deposits, which are typically less than 30 ft thick, were subsequently buried by fine-textured material. Buried sand and gravel deposits comprise aquifers with limited potential supply for high capacity uses, but they yield sufficient quantities for domestic use. Buried drift aquifers occur throughout the Metropolitan Area, except in the southeast portion of the region, where bedrock occurs close to the land surface.

The Minnesota Pollution Control Agency has developed a regional-scale, multi-aquifer ground water flow model of the Twin Cities Metropolitan Area (http://www.pca.state.mn.us/water/groundwater/metromodel.html). Unfortunately, reduced funding has forced the agency to discontinue support for the Metro Model. Updates and revisions to the Metro Model have ceased, but all project resources accessible through the above website will remain available. Minnesota Pollution Control Agency will not support the Metro Model unless funds are specifically dedicated to the project through legislative appropriations.

Mississippi River Use

Locks and dams at the upper and lower St. Anthony Falls, Lock and Dam 1 in St. Paul and Lock and Dam 2 at Hastings enable commercial towboats, barges, and larger excursion vessels to navigate. Port facilities and barge fleeting areas are concentrated in Pool 2. Few port facilities exist in Pool 1 and the Upper Harbor (above St. Anthony Falls), as indicated in recent traffic figures (Table 6). Commercial river traffic in the Metropolitan Area is not forecasted to increase significantly in future years (U.S. Army Corps of Engineers 2004a). A number of port facilities in the Metropolitan Area are terminals for the bulk shipping of grain, fertilizer, petroleum products, chemicals, sand, gravel, and aggregate. About 10.4 million tons (9.4 million metric tons) of commodities were shipped through the Twin Cities harbors in 2004. The locks also pass many recreational boats, especially at Lock and Dam 2 (Table 6). The U.S. Army Corps of Engineers routinely surveys and dredges the channel as necessary. Dredged material is placed at upland sites, following the agency's Channel Maintenance Management Plan (http://www.mvp.asace.army.mil/navigation/default.asp?pageid=167&subpageid=321).

Table 6. Annual averages for commercial and recreational traffic through locks on the Mississippi River within the Metropolitan Area (after U.S. Corps of Engineers 2001).

Traffic	Lock/Dam 2	Lock/Dam 1	Lower St. Anthony Falls	Upper St. Anthony Falls
Commercial lockages	1,895	1,194	1,189	1,181
# of barges locked through	10,368	2,171	2,159	2,138
Recreational lockages	2,885	1,965	1,290	1,236
# of recreational boats locked through	11,592	5,729	2,407	2,492

Water Resources and Use

Hydrology

Surface water

Hydrologic features within the MNRRA corridor are central to the area's cultural history and to the development of St. Paul and Minneapolis as urban centers. Three distinct hydrologic and geomorphologic zones characterize the Mississippi River within MNRRA (Anfinson 2003). Gentle streambed gradients and low riverbanks typify the upper reach of MNRRA from Dayton and Ramsey down to St. Anthony Falls. Below St. Anthony Falls, the Mississippi enters its most confined reach on the entire River, a reach historically defined by high bluffs, strong currents, and tumbling rapids. Near St. Paul, the Mississippi is joined by the Minnesota River and the river valley widens to form floodplains and backwaters. Of these distinct reaches, the significance of the St. Anthony Falls reach cannot be easily overstated. The only major waterfalls on the Mississippi river, St. Anthony Falls represents a place of spiritual importance to Native Americans, and its unique hydrology made it the birthplace of powerful lumber and flour milling industries.

Over the past century, hydrology within MNRRA has been substantially altered by navigational improvements within the corridor as well as impoundments on Mississippi River headwater lakes. Navigation through the MNRRA corridor is now facilitated by wing dams, closing dams, and four major locks and dams: at Upper and Lower St. Anthony Falls, Lock and Dam 1 in St. Paul, and Lock and Dam 2 at Hastings (U.S. Army Corps of Engineers 2001). In addition to the locks and dams within MNRRA, six dams are situated on Mississippi River headwater lakes in north-central Minnesota.

Several long-term gaging sites on the Mississippi River provide insights into patterns of surface water hydrology at MNRRA. U.S. Geological Survey gage sites within MNRRA are located at the upstream end of the corridor near Anoka, Minnesota, in the middle of the corridor at St. Paul, Minnesota, and near the downstream end of the corridor at Prescott, Wisconsin. The Anoka site captures water entering the MNRRA corridor, and has the lowest average long-term flow of the three sites (8,306 ft^3/s, or 235 m^3/s) (Table 7, Figure 15). The St. Paul and Prescott gage sites incorporate additional stream flow from the Minnesota and St. Croix Rivers, respectively, and have average long-term flows of 12,872 ft^3/s (364 m^3/s) and 18,704 ft^3/s (530 m^3/s).

Table 7. Average discharges (in ft^3/s and m^3/s) for three U.S. Geological streamflow gaging sites located within the MNRRA corridor. Average flow calculated based on annual averages for each site, 1931-2004. From: http://waterdata.usgs.gov.

Site	USGS Site Code	Period of Record	Average Flow 1931-2004 (ft^3/s)	Average Flow 1931-2004 (m^3/s)
Mississippi River near Anoka	05288500	1931-2004	8,306	235
Mississippi River at St. Paul	05331000	1892-2003	12,872	364
Mississippi River at Prescott	05344500	1928-2004	18,704	530

In general, discharge has tended to increase at all three sites over their periods of record (Figure 15), with low-flow years in the mid-1930s and the late 1980s, and high flow events in 1965, 1969, 1997, and 2001. Long-term hydrologic monitoring data relevant to MNRRA were summarized by Schoenberg and Mitton (1990), providing monthly mean discharges for ten different gaging stations in the Upper Mississippi River Basin. Mitton (2002) noted record flows at nine gaging stations throughout the basin during the 2001 flood event, including the Mississippi River gage at St. Paul.

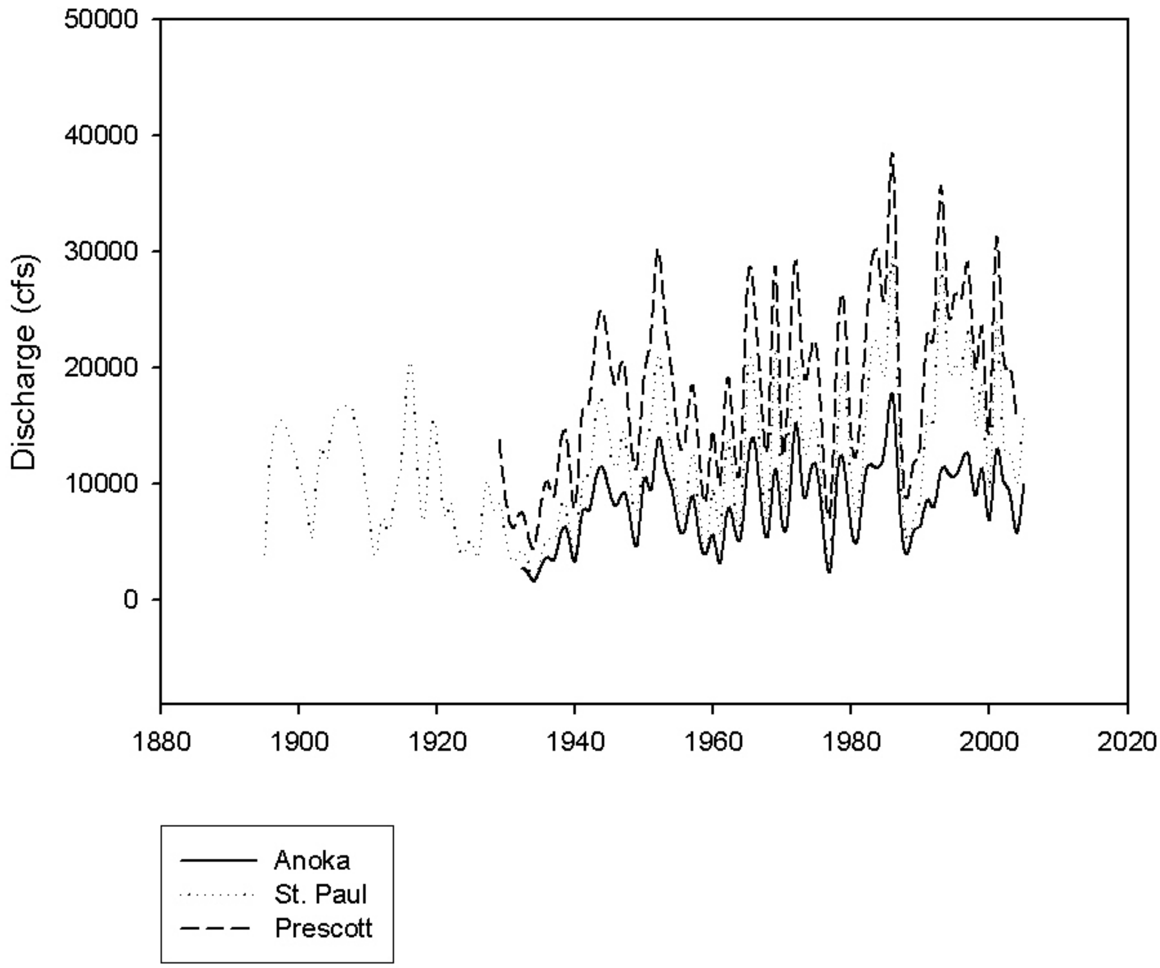

Figure 15. Discharge, in cubic ft per second, by year for three sites within the MNRRA corridor (Anoka, St. Paul, and Prescott), derived from U.S. Geological survey gaging data (http://waterdata.usgs.gov).

Over the long term, streamflow across the three MNRRA gaging sites follows similar seasonal patterns (Figure 16). Peak discharge generally occurs following snowmelt in March-May, with lower flows occurring in August-September. Slight rises are typical during the October-November period, with low flows again dominating during the winter December-February period.

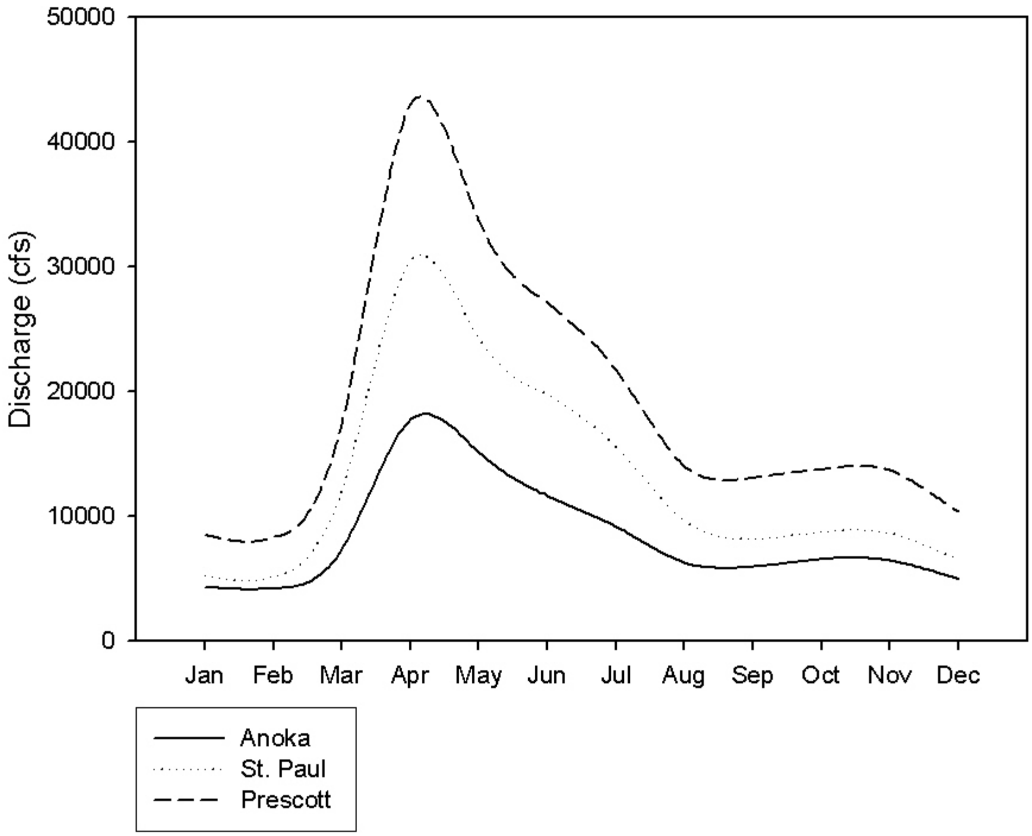

Figure 16. Discharge, in cubic ft per second, by month for three sites within the MNRRA corridor (1932-2003), derived from U.S. Geological survey gaging data (http://waterdata.usgs.gov).

Ground water

Ground water is an important water resource for MNRRA and the Twin Cities Metropolitan Area. It serves as a water supply source for public drinking water and industry, and contributes to streamflow in the Mississippi River, particularly in dry years. Horn (1983) estimated that over the last century 80 percent of ground water withdrawals in the area came from one aquifer, the Prairie du Chien-Jordan, and that most of this water was used for self-supplied industry. Ground water use increased from 1880 until the 1970s, when ground water conservation measures began to be implemented. Area aquifers appear to respond readily to changes in ground water withdrawals. For example, reductions in ground water pumping from 1970-1979 were linked to a 60 ft (18 m) increase in water levels in the Mount Simon-Hinckley aquifer, and water levels in the Prairie du Chien-Jordan aquifer varied by up to 25 ft (8 m) in response to local water pumping or recharge activities (Schoenberg 1984). From 1971-1980, most ground water withdrawals continued to come from the Prairie du Chien-Jordan aquifer, serving a mix of industrial and public water supply needs (Horn 1984).

Ground water-surface water interactions

Interactions between surface and ground water have also received attention in and around MNRRA. In order to assist water managers with their concerns about long-term ground water depletion, Ruhl et al. (2002) estimated recharge to unconfined aquifers and leakage to confined aquifers in the Twin Cities Metropolitan Area, noting that impervious land areas had little or no recharge potential, whereas surficial sand and gravel areas (e.g., Washington County near the St.

Croix River) had great recharge potential. Schoenberg (1989) and Payne (1995) estimated contributions of ground water to streamflow in the Mississippi and Minnesota Rivers, finding that seepage from bedrock aquifers affected flow particularly during dry years. Locations where ground water emerges from beneath river beds and along river margins have also been identified (Payne 1995).

Geomorphology

Glacial history and modern land use patterns influence the surficial hydrology and geomorphology seen in the Upper Mississippi River and its basin today (U.S. Geological Survey 1999). It is not clear when the Upper Mississippi River valley was initially formed (Anfinson 2003), but evidence suggests it formed in response to glacial events prior to the Wisconsin Glaciation. The major period of scouring occurred as the Wisconsin Glacier began its retreat about 15,000 years ago, sending meltwater south through the Mississippi and St. Croix River valleys. Soon after, the glacial River Warren swelled, emptying meltwater from glacial Lake Agassiz and forming what is now MNRRA's major tributary, the Minnesota River (Wiener et al. 1998). In the post-glacial times prior to European settlement, the Upper Mississippi River was characterized by a shallow main channel with runs, pools, and channel crossings, secondary and tertiary channels around main channel islands, and countless backwaters, including floodplain lakes. Today much of the Upper Mississippi River remains a great floodplain river, bounded by steep bluffs and consisting of many islands. Within the MNRRA corridor, the Mississippi River flows through a relatively wide and low-walled river valley above St. Anthony Falls, funnels through a deep, narrow gorge below St. Anthony Falls, and broadens to form side channels, floodplains, and backwaters near the Minnesota River confluence and downstream (Figure 17).

Figure 17. Aerial imagery depicting varying channel morphologies within the MNRRA corridor, derived from Google Earth, Europa Technologies in 2006. At left, a confined channel in the gorge reach of Pool 1, in Minneapolis/St. Paul. At right, a meandering channel, with side channels, in the Grey Cloud Islands area of Pool 2.

Within and beyond the MNRRA corridor, many of the Upper Mississippi River's natural geomorphologic processes have been affected by human activities. Floodplain, urban, and agricultural development, impoundment of river reaches by locks and dams, construction of channel-training structures like wing dams and closing dams, and ongoing bank stabilization and channel maintenance activities have all interrupted natural fluvial processes in the Upper Mississippi River (U.S. Geological Survey 1999, McGuiness 2001, Fremling 2005). Recently, the U.S. Army Corps of Engineers addressed sediment loading from the upstream end of MNRRA to Guttenburg, Iowa, noting that the Minnesota River, an agricultural tributary to the Mississippi

River within MNRRA, was a key sediment contributor for the entire Upper Mississippi River (Hendrickson 2003).

Water Quality

Surface water quality

Water quality within the MNRRA corridor has been the subject of public attention and management concern for more than a century, in part because of its importance to a large metropolitan population and its history of degradation. As early as 1900, the Mississippi River in the Twin Cities reach had become heavily polluted due to growing urban populations and inadequately treated municipal and industrial wastewater discharges (U.S. Environmental Protection Agency 2000). Construction of the lock and dam in Minneapolis in 1917 exacerbated these pollution problems by reducing the flushing effects of springtime peak flows. The result was severe oxygen depletion, extremely high bacteria levels, the formation of floating sewage sludge mats, and the generation of noxious gases. Tellingly, in 1928 the Minnesota and Wisconsin State Boards of Health declared the river in this zone “unfit for use as a water supply”, and noted that fish life had been exterminated. After failure of a chlorination unit at the public water supply plant resulted in a serious typhoid epidemic in 1935, the Twin Cities initiated what would be a series of wastewater treatment improvements (U.S. Public Health Service 1953).

Progressively more intensive wastewater treatment and sewer separation efforts have been implemented, and water quality in the MNRRA corridor has improved enormously since those early days (U.S. Environmental Protection Agency 2000). Aquatic life has reestablished and public use of the river has increased. Rapid population growth in the Twin Cities Metropolitan Area, however, has repeatedly overwhelmed wastewater treatment improvements, urban and industrial development continues, and agricultural activities in the Minnesota River Basin now contribute heavy loads of sediments, nutrients, and fecal coliform bacteria. As a result, water quality in MNRRA continues to be threatened by excess loading of nutrients and sediments, and contamination by fecal indicator bacteria, polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), pesticides, mercury, and other anthropogenic compounds.

As required by the Clean Water Act, Minnesota Pollution Control Agency publishes, every two years, an updated list of streams and lakes that are not meeting their designated uses because of excess pollutants. Several reaches of MNRRA and its contributing waters are currently listed as impaired due to such threats. For each pollutant that causes a water body to fail to meet state water quality standards, the federal Clean Water Act requires the Minnesota Pollution Control Agency to conduct a TMDL study. The TMDL plan is a pollution reduction plan that identifies the maximum amount of a pollutant a water body can receive without violating water quality standards. The TMDL process identifies both point and nonpoint sources of each pollutant and determines how much each source must reduce its contribution in order to meet the standard. The total of all contributions must be less than the maximum daily load. Subsequent to the TMDL, a detailed implementation plan is developed that focuses on source reduction strategies to meet water quality standards.

The most recent Minnesota TMDL list, approved by the U.S. Environmental Protection Agency in June 2006, lists nearly 150 reaches of streams in the Mississippi River Basin above the St. Croix River confluence as impaired (www.pca.state.mn.us/water/tmdl/). Included among these are 15 reaches of the Mississippi River within the MNRRA corridor itself. Impairments within MNRRA affect aquatic consumption, aquatic recreation, and aquatic life, and include pervasive mercury and PCB fish consumption advisories, fecal coliform exceedances above the Metropolitan Wastewater Treatment Plant, and turbidity exceedances below the confluence of the Minnesota River. Target completion dates for these TMDL studies range from 2009 to 2015. The most prominent TMDL study currently affecting MNRRA involves Lake Pepin, a natural impoundment of the Mississippi River just downstream of the park (see “Water quality issues – Impaired waters and TMDLs”).

Because maintaining good water quality within the MNRRA corridor is both important and complex, many agencies and entities have been involved in water quality monitoring and research efforts. Agencies engaged in these efforts include the Metropolitan Council, the Minnesota Pollution Control Agency, the Minnesota Department of Health, the Minnesota Department of Natural Resources, and the U.S. Geological Survey (Minnesota Science Center in Mounds View). In 1995, the National Park Service reviewed the STORET database for past water quality monitoring records in and near the MNRRA corridor and published a Baseline Water Quality Data Inventory and Analysis (National Park Service 1995b).

Results from the 1995 National Park Service report speak to the intensity of water quality monitoring and study in and near the MNRRA corridor. A total of 541 monitoring stations, 273,531 water quality observations, and 803 water quality parameters were identified in the STORET data retrieval, more than for any other national park unit in the Upper Midwest. Records of 43 active or inactive stream gages were found within the study area, with three active U.S. Geological Survey stream gages currently operating within the MNRRA boundaries.

Water quality trends in the MNRRA corridor have been analyzed on several occasions. Larson et al. (1976) analyzed data from five long-term monitoring stations, showing that dissolved oxygen concentrations changed little from the 1930s to the 1970s, but that biological oxygen demand and coliform bacteria had both increased at most sites due to increasing population in the Twin Cities area. As part of the NAWQA studies, Kroening and Andrews (1997) and Kroening and Stark (1997) analyzed trends within the Twin Cities area for the period of 1984 to 1993, documenting changes in nitrogen species that were likely due to changes in wastewater treatment practices. More recently, Kloiber (2004) analyzed water quality trends for three major rivers in the Twin Cities area, including one site within MNRRA at Anoka, for the period of 1976 to 2000. Trends at this site included declines in ammonium and total phosphorus and increases in nitrate concentrations (Table 8).

Table 8. Trend significance and direction for key water quality variables in the Minnesota, Mississippi, and St. Croix Rivers, 1976-2000, including the Anoka site within MNRRA (from Kloiber 2004).

Comparison of Trend Significance and Direction for the Minnesota, Mississippi, and St. Croix Rivers

Site	NH_4	BOD5	NO_x	TP	TSS
Minnesota River at Jordan					
Met Council 2004	↓	↓	↓	↔*	↓*
Kroening and Andrews 1997	↓		↔	↔	
MPCA 2002	↓	↓	↔	↔	↓
Mississippi River at Anoka					
Met Council 2004	↓		↑	↓	
Kroening and Andrews 1997	↓		↔	↔	
St. Croix River at Stillwater					
Met Council 2004	↓		↑	↔	
Kroening and Andrews 1997	↓		↔	↔	
Mississippi River at Red Wing					
Met Council 2004	↓		↑	↓	
Kroening and Andrews 1997	↓		↑	↔	

* - These trends were non-monotonic and may not be described well by the statistical test used.

The Metropolitan Council continues to monitor water quality at seven stations within the MNRRA corridor, including Anoka, Fridley, Lock and Dam 1, St. Paul, Newport, Grey Cloud, and Lock and Dam 2. Additionally, in 2006 the National Park Service’s Great Lakes Inventory and Monitoring Network began a program of monthly water quality monitoring at five locations in the MNRRA corridor. This monitoring is intended to occur every other year for the purpose of determining long-term trends in water quality conditions.

Ground water quality

The U.S. Geological Survey and others have surveyed and monitored chemical properties of the Twin Cities Metropolitan Area's ground water for several decades. In general, the area's aquifers yield calcium-bicarbonate types of ground waters, and dissolved solids increase from the northeastern to the southwestern reaches of the area (Maderak 1965). Few changes in fundamental ground water chemistry appear to have occurred between 1899 and 1963; however, shallow ground water in the area is susceptible to contamination due to agricultural and urban development (see "Water quality issues – contaminants").

Floodplains, Wetlands, and Riparian Zones

The MNRRA corridor features abundant Mississippi River floodplain habitats, including floodplain forests, wetlands, and riparian areas (Figure 18). Floodplains represent temporary storage spaces for floodwaters, and are most often defined by inundation frequency. A 100-year floodplain, for example, includes the land adjacent to the river channel up to the elevation expected to be flooded once every 100 years. Floodplain forests and wetland habitats are characterized by recurrent, sustained saturation, physical and chemical conditions in the substrate that indicate saturation, and the presence of organisms specifically adapted to tolerate flooding (National Research Council 1995). Wetlands are lands transitional between terrestrial and aquatic systems, where the water table is usually at or near the surface or the land is covered by shallow water (Keddy 2000). For NPS jurisdictional purposes, wetlands also include shallow lake edges and stream channels within the ordinary high water mark of the channel to a depth of two meters. For a more complete description of wetland types and wetland characteristics under NPS jurisdiction, refer to the U.S. Fish and Wildlife Service's *Classification of Wetlands and Deepwater Habitats of the U.S.* (Cowardin et al. 1979). Riparian ecosystems are generally defined as the stream channel between the low and high water marks, plus the terrestrial landscape above the high water mark, where vegetation may be influenced by elevated water tables or extreme flooding, and by the ability of the soils to hold water (Naiman and Decamps 1997).

Together, these habitats represent a species-rich and functionally important interface between terrestrial and aquatic environments. They provide structure and resources for river biota and are well known for their biodiversity. They provide crucial breeding, feeding, spawning, and migratory habitat for aquatic invertebrates, amphibians, fish, and aquatic wildlife, and they supply ecological functions and services: actively cycling nutrients and organic matter, acting as contaminant filters between land and water, providing protection from floods, and supplying woody debris and organic matter to the river environment.

Wetlands within the MNRRA corridor were recently estimated to exceed 25,000 acres (10,000 hectares) in area, comprising nearly half the total area of the corridor (Lafrancois and Glase 2005). A recent inventory at Crosby Farm Regional Park, within MNRRA, defined several useful wetland vegetation groups (Harris et al. 2005). Black ash seepage swamps were found in areas of ground water seepage along bluffs, whereas mature cottonwood (*Populus*)-silver maple (*Acer saccharinum*) forests were located on floodplain terraces between flood channels. These, and the very similar mature silver maple forests, provide high quality habitat for forest canopy birds. Silver maple forests occurred in the more frequently flooded river channels. Willow (*Salix*) swamps were found on wet, sandy soils along the edge of the Mississippi River and on sand bars. A handful of native sedge (*Carex*) meadows were identified, typically in areas less exposed to runoff from storm water, flooding from the Mississippi River, and water level fluctuations than other wetland types. Some disturbed floodplain forest types (e.g., cottonwood disturbed forest and box elder (*Acer negundo*) disturbed forest) were identified on terraces that were once cultivated; these likely provide little habitat for forest birds. Similarly, cattail (*Typha*)-bur reed (Sparganiaceae) marshes (emergent, species-poor marshes dominated by the exotic narrow leaf cattail, *Typha angunstifolia*) and reed canary grass wetlands (large wetlands overcome with the exotic reed canary grass, *Phalaris arundinaceae*) were found in disturbed areas and along the margins of backwater lakes.

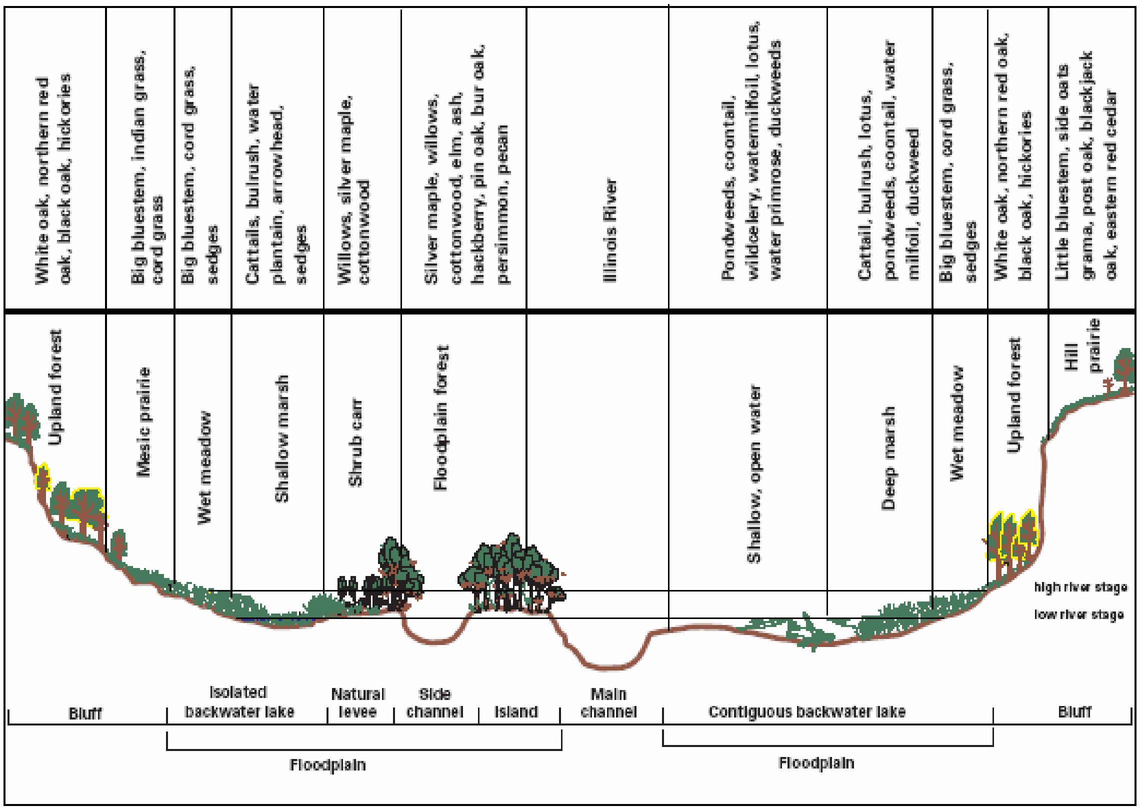

Figure 18. Cross-sectional representation of floodplain habitats likely to occur in the Upper Mississippi River (from U.S. Geological Survey 1999).

Other ecologically important backwater areas within MNRRA include a portion of Fort Snelling State Park (near the confluence of the Minnesota and Mississippi Rivers), Pig's Eye Lake (downstream of St. Paul), Spring Lake Regional Park (upstream of Lock and Dam 2), and the Vermillion River Bottoms (at the downstream end of the corridor). All provide important habitat for colonial water birds, migratory waterfowl, fish, amphibians, reptiles, and aquatic furbearers. The Minnesota Valley National Wildlife Refuge, adjacent to MNRRA and Fort Snelling State Park, is home to about 50 mammals, 30 species of reptiles and amphibians, and a colonial bird rookery of over 650 nests. Over 200 species of birds have been sighted within its boundaries. Pig's Eye Lake, while affected by organic and trace metal contaminants from a nearby dump site, is also adjacent to a state Scientific and Natural Area. A large great blue heron rookery (*Ardea herodias*, 1,600 nests) and bald eagle (*Haliaeetus leucocephalus*) nests exist in the Scientific and Natural Area, and the state-threatened paddlefish (*Polyodon spathula*) was observed in Pig's Eye Lake during high flow periods in the mid-1990s. Spring Lake Regional Park provides similar backwater functions and serves as a major waterfowl feeding and staging area. Finally, the Vermillion River Bottoms represents one of largest expanses of floodplain habitat on the Minnesota side of the Mississippi River, and is home to vast floodplain forests, many floodplain lakes and ponds, large emergent marshes, and wet meadows, willow swamps, mudflats, and flooded shrublands.

The MNRRA corridor includes many floodplain islands, only nine of which are currently owned by MNRRA. An inventory and management plan for these islands was recently completed, emphasizing biological attributes and level of previous habitat disturbance (Minnesota Department of Natural Resources 1999a). In all, the study documented 30 species of birds, four species of mammals, and two species of amphibians or reptiles inhabiting the islands. Floodplain islands in this reach of the Mississippi River are generally disturbed due to previous logging, pasturing, or residential development, and their long-term persistence is uncertain due to changes in sediment delivery and flow regimes resulting from the lock and dam system.

Aquatic Biological Resources

The Upper Mississippi River Valley is well known for its biological productivity and diversity. It provides an important migratory corridor for birds, produces a rich recreational and commercial fishery, supports diverse freshwater mussel assemblages, and provides, through its riverine wetlands and floodplain forests, important habitat for many other organisms (U.S. Geological Survey 1999). Aquatic birds, fish, freshwater mussels, and benthic macroinvertebrates have all received some study within MNRRA, and biological work from better-studied sites in the greater Upper Mississippi River likely applies to the downstream reaches of MNRRA.

Water-based birds

Within the MNRRA corridor, 105 species of water-based birds were listed as present or likely present in recent inventory efforts by the National Park Service (Appendix B-1). These birds may utilize open water habitats as well as wetlands or shorelines. Of the 105 species identified, 15 are listed as threatened, endangered, or species of special concern by the state of Minnesota, and the bald eagle is listed as federally threatened (Minnesota Department of Natural Resources 2006).

In response to improved water quality and the establishment of wildlife reserves, populations of water birds have been increasing within MNRRA. Observations of peregrine falcons (*Falco peregrinus*), bald eagles, mallard ducks (*Anas platyrhynchos*), and great blue herons are common in the floodplain wetlands within MNRRA, and black crowned night herons (*Nycticorax nycticorax*) have been observed feeding below Lock and Dam 1 (U.S. Environmental Protection Agency 2000). In addition, the abundance of great egrets (*Ardea alba*), great blue herons, and cormorants (*Phalacrocorax auritus*) nesting in the Pig's Eye Lake area has increased greatly since the 1970s-1980s (Figure 19, U.S. Environmental Protection Agency 2000). In fact, a recent study of waterbird use in Pool 2 of the Mississippi River showed that more than 36,000 waterbirds used the pool between March 30 and May 31, and more than 126,000 waterbirds used Pool 2 from September through December (Liddell and Cooper 1998). Throughout the summer months, 3,725 waterbirds were counted, with gulls by far the most abundant.

Water-based mammals

The MNRRA corridor is home to several species of aquatic or semi-aquatic mammals, including the American beaver (*Castor canadensis*), the river otter (*Lontra canadensis*), the mink (*Mustel vison*), and the muskrat (*Ondatra zibethicus*). While all are present within the corridor, little appears to be known about their population sizes and trends.

Fish

Fisheries surveys have been conducted since the early 20th century in the Upper Mississippi River, and offer important baseline information on community structure. In general, fish species composition within MNRRA is defined substantially by St. Anthony Falls, historically the only major barrier to fish migration in the Mississippi River. Over 100 fish species were historically found below the falls in the Minnesota and Wisconsin reach of the Upper Mississippi River, compared with only 60 or so species above the falls (Eddy et al. 1963). Similarly, results of a more recent study showed that fish composition in MNRRA's large contributing rivers (such as the Mississippi, Minnesota, and St. Croix) is largely affected by dispersal barriers, dams, and land use in the Twin Cities Metropolitan Area. Fish in the MNRRA reach of the Mississippi River tend to be lentic, planktivorous species with relatively high thermal tolerances (Goldstein et al. 1999).

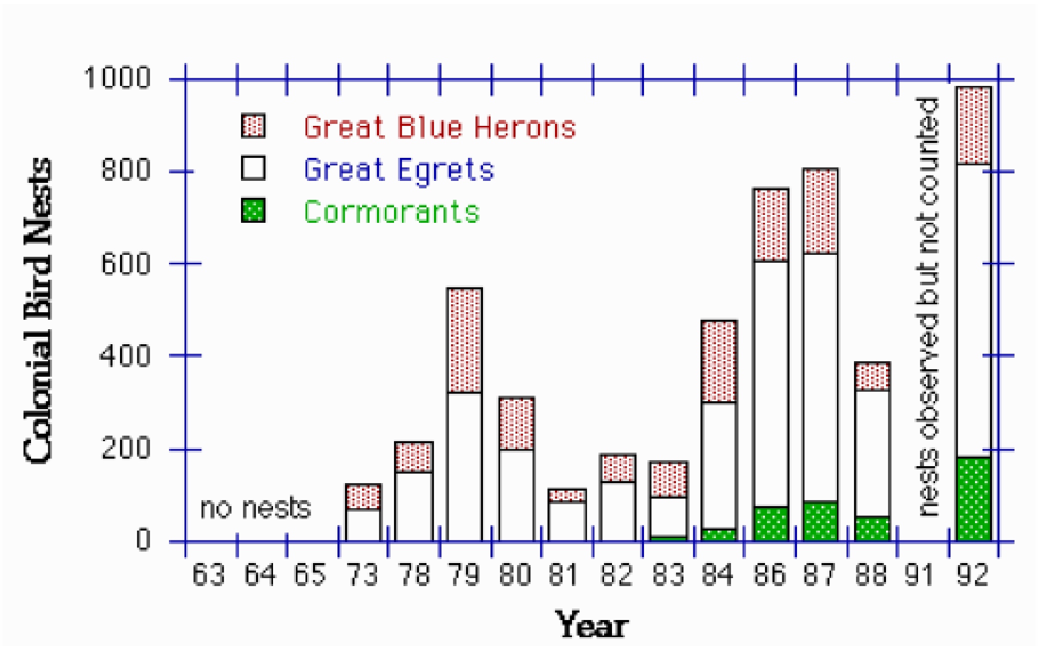

Figure 19. Trends in Great Blue Heron, Great Egret, and Cormorant nest counts for Pig's Eye Lake from 1963 to 1992 (U.S. Environmental Protection Agency 2000).

In the past, heavy wastewater loads and pollution from the Minnesota River have strongly affected MNRRA fishery resources; however, both water quality and the fishery have begun to recover. An outstanding walleye (*Sander vitreus*) and smallmouth bass (*Micropterus dolomieui*) fishery has become established in Pool 2, helped along by special angling restrictions implemented in the early 1990s. The Minnesota Department of Natural Resources continues to manage Pool 2 as a trophy fishery, limiting angler take to large fish suitable for taxidermy.

Currently over 100 fish species are considered present or likely present within the MNRRA corridor (Appendix B-2). Of these, six are listed as threatened or species of special concern in Minnesota, including paddlefish, lake sturgeon (*Ascipenser fulvescens*), blue sucker (*Cycleptus elongates*), least darter (*Etheostoma microperca*), black buffalo (*Ictiobus niger*), and yellow bass (*Morone mississippiensis*). Since 1990, reports of paddlefish within the MNRRA corridor have been isolated. Adult paddlefish were documented in the tailwaters of Lock and Dam 1 in 1990 and in Pool 2 near the Wacouta Bridge in 1992, several juvenile paddlefish were seen in Pig's Eye Lake during a very high water period in 1997, and an injured paddlefish was found floating upstream of Lock and Dam 2 in 2003 (Schmidt 2004). However, a tailwaters survey at Lock and Dams 1-3 in 2000 documented paddlefish only below Lock and Dam 3 (Schmidt 2004). Paddlefish apparently were common in deep backwater lakes of Pool 3, but accessibility of these deepwater habitats has since declined (Schmidt 1995).

In a recent fish survey of smaller streams in the Twin Cities area, 72 species from 18 families were collected, with tolerant omnivores and species like fathead minnows (*Pimephales promelas*), central mudminnows (*Umbra limi*), and green sunfish (*Lepomis cyanellus*) most common (Schmidt and Talmage 2001). Small agricultural streams in the area tend to support an assemblage of invertivorous fish, whereas forested streams tend to support an assemblage of fewer, mainly invertivorous and carnivorous fish species requiring cold clear water and cobble or boulder substrates (Goldstein et al. 1999). Urban streams in the area contain many lentic fish species tolerant of silt, low dissolved oxygen, and marginal habitats (Goldstein et al. 1999).

Freshwater mussels

Freshwater mussel work at MNRRA has included work on the federally endangered Higgins' eye mussel (*Lampsilis higginsii*, see "Ecosystem restoration and understanding – targeted restoration efforts" of native biota section below), a park-wide mussel inventory, and studies of trends in fingernail clam densities. In a survey of river miles 820-821 near Grey Cloud Island in Pool 2, Havlik (1997) documented a total of 14 live mussel species, an additional 11 present as empty shells, and only one living and one dead zebra mussel (*Dreissena polymorpha*). In general, live mussels were in excellent condition. In a more recent mussel inventory conducted along the entire MNRRA corridor at 138 sites, Kelner and Davis (2002) documented empty shells of two federally endangered mussels (the Higgins' eye and the winged mapleleaf, *Quadrula fragosa*), along with nearly 30 species of live mussels (Appendix B-3). Of these, over one-third are listed as threatened, endangered, or species of special concern in Minnesota.

The Kelner and Davis (2002) survey provided no evidence of zebra mussels above Lock and Dam 1 and only low densities in Pools 2 and 3. Additionally, recent and ongoing recruitment was verified for most native mussel species, indicating stable population age structure. Currently, Pool 2 supports Minnesota's largest known populations of state-endangered wartyback (*Q. nodulata*) and rock pocketbook (*Arcidens confragosus*), both of which continue to recruit new individuals (Davis 2004). Populations of fingernail clams (Sphaeriidae), on the other hand, appear to have declined significantly between historic and more recent records from the Upper Mississippi River, including sites in Pool 2 within MNRRA (Wilson et al. 1995).

Amphibians and reptiles

Given its abundance of riparian and wetland areas, the MNRRA corridor provides habitat for many amphibian and reptile species. The National Park Service Great Lakes Inventory and Monitoring Network recently compiled species lists for amphibians and reptiles within MNRRA. In this assessment, they noted that 14 species of frogs and salamanders were present or probably present in the corridor, along with 8 species of turtles and the northern water snake (*Nerodia sipedon sipedon*) (Appendices B-4 and B-5). The presence of several of these amphibian and reptile species within MNRRA was confirmed by the U.S. Geological Survey's Amphibian Research and Monitoring Initiative (ARMI) in a recent investigation (Mark Roth, personal communication, U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, WI, March 17, 2006). The common mudpuppy (*Necturus maculosus*), likely present in the MNRRA corridor, is host to the state-threatened salamander mussel (*Simpsonaias ambigua*) and was suggested as a "species of greatest conservation need" in Minnesota's recent Wildlife Action Plan (Minnesota Department of Natural Resources 2006).

Algae and invertebrates

Beyond birds, fish, and freshwater mussels, there have been few aquatic biological inventories or studies within the MNRRA corridor. However, ZumBerge et al. (2003) recently conducted an ecological investigation of periphyton and benthic invertebrate communities throughout the Upper Mississippi River basin. In the Upper Mississippi River itself, periphyton densities generally increased from upstream to downstream, whereas benthic invertebrate densities decreased from upstream to downstream.

Visitor Use and Recreation

Early European settlements in the present-day MNRRA corridor were generally fur trading and lumber milling communities with close ties to the Mississippi River (Anfinson 2003). As these communities developed, however, navigation interests, railroads, and road builders transformed the corridor, and water quality deteriorated as the river became a conduit for industrial and municipal wastes. Consequently, for much of the early 20th century Twin Cities residents had little interaction with the Mississippi River. In recent decades, progress on water quality, improvements to city riverfronts and river access, and increases in public education and outreach have strengthened public interest in the Mississippi River and the MNRRA corridor. Today, the corridor is home to a state park (Fort Snelling), ten regional parks (Mississippi West, Coon Rapids Dam, North Mississippi, Anoka County Riverfront, Central Mississippi Riverfront, Mississippi Gorge, Minnehaha, Hidden Falls-Crosby Farm, Lilydale-Harriet Island-Cherokee, Battle Creek), eighteen city parks, several nature reserves (Grey Cloud Dunes and Pine Bend Bluffs Scientific and Natural Areas, Spring Lake Park Reserve, and parts of Gores Pool Wildlife Management Area), and a network of hiking and biking trails. The River itself is used commonly by recreational boaters, anglers, and other visitors.

The comprehensive management plan for MNRRA (National Park Service 1995a) encourages more recreational use of the Mississippi River for “a variety of activities, including boating, fishing, canoeing, and sight-seeing” and promotes extensive riverside opportunities for “hiking, biking, jogging, picnicking, or just sitting in one of the many parks in the corridor…”. The plan also notes that additional quiet zones in the corridor will be encouraged, and tour boat operations and other visitor services will be promoted. A visitor use survey of the Minnesota River Valley area, which includes a portion of MNRRA, documented many of these uses (Minnesota Department of Natural Resources 2002). The highest percentages of respondents reported that they participated in hiking or walking (45 percent), taking self-guided nature walks (40 percent), visiting historic/cultural sites (43 percent), sightseeing (38 percent), and observing wildlife (35 percent). New visitor uses are also under consideration, including a proposal to create an artificial kayaking channel and whitewater park descending from Lower St. Anthony Falls (Minnesota Department of Natural Resources 1999b).

In addition to these activities, recreational boating is increasingly popular in the Upper Mississippi River. Recreational boat traffic at locks and dams in the MNRRA corridor increased substantially from the mid-1950s to the 1990s (U.S. Environmental Protection Agency 2000, Mississippi River Marina Cumulative Impacts Task Force 1990; Figures 20-21), and recreational permit applications for docks, beach improvements, wildlife improvements, marinas, boat houses, boat ramps and other improvements increased from just three in 1981 to 22 in 1989, across six Upper Mississippi River counties in and near the MNRRA corridor (U.S. Environmental Protection Agency 2000). By 1990, Upper Mississippi River use had increased so substantially that a multi-agency partnership agreement was formed to study recreational trends and resolve user conflicts.

Several regulatory agencies reviewed the potential effects of recreational marina expansions in Pools 1-4 of the Upper Mississippi River, and concluded that continued unplanned access expansion and unregulated boating would substantially degrade wildlife resources, water quality, and visitor experience (Mississippi River Marina Cumulative Impacts Task Force 1990). Within MNRRA, nearly 1,500 boats were recorded in marinas below Lock and Dam 1, with the highest densities of boats on the river found in the tailwaters of Lock and Dam 1 and the lowest densities found in the more channelized portion of Pool 2. While the Mississippi River has lower boating intensities than the St. Croix River and Lake Minnetonka (Figure 22, Minnesota Department of Natural Resources 1997), the Mississippi River Landscape Team (2004) noted that the number and size of recreational boats in the Mississippi River has continued to grow rapidly, resulting in increased wave height and frequency and erosion of streambanks. Further, in a recent study the U.S. Army Corps of Engineers projected that recreational usage of Pools 3 and 4 will continue to be higher than for any of the other navigational pools in the Upper Mississippi River system in the coming decades (Carlson and Bartell. 2000).

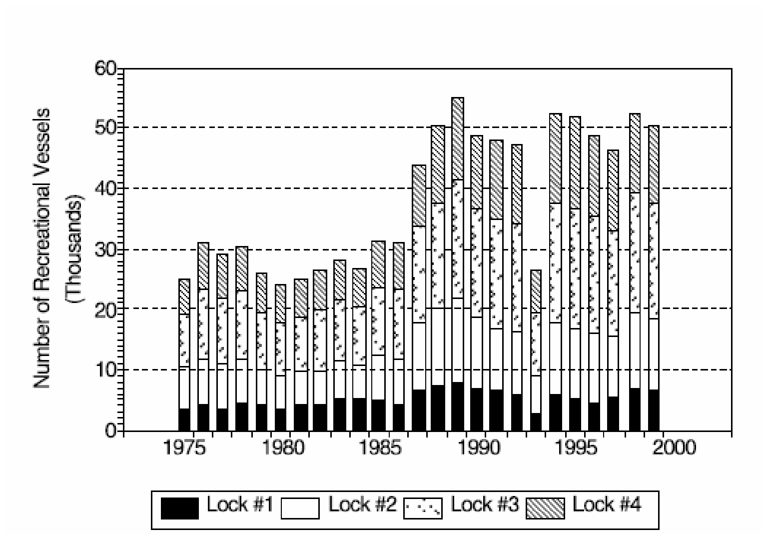

Figure 20. Trends in number of recreational vessels moving through locks within the MNRRA corridor, 1975-2000 (from U.S. Environmental Protection Agency 2000).

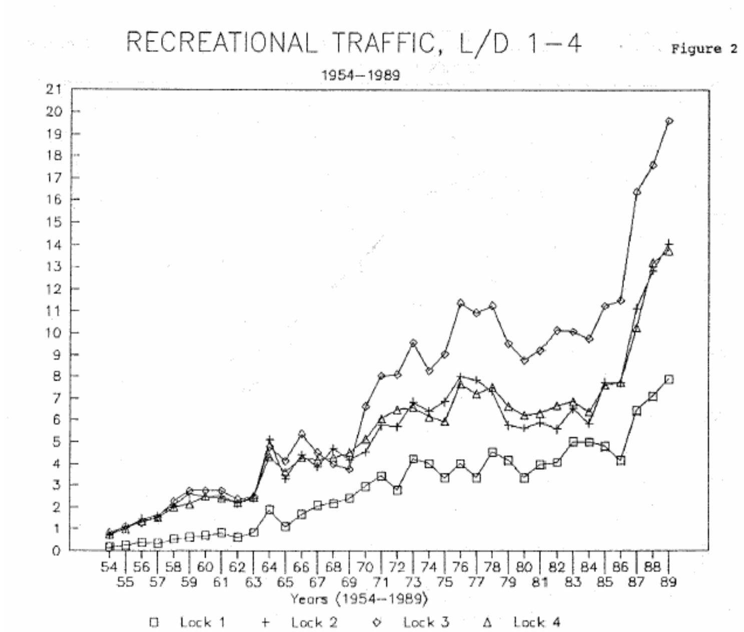

Figure 21. Number (in thousands) of recreational boats moving through locks within the MNRRA corridor annually, from 1954-1989 (from Mississippi River Marina Cumulative Impacts Task Force 1990).

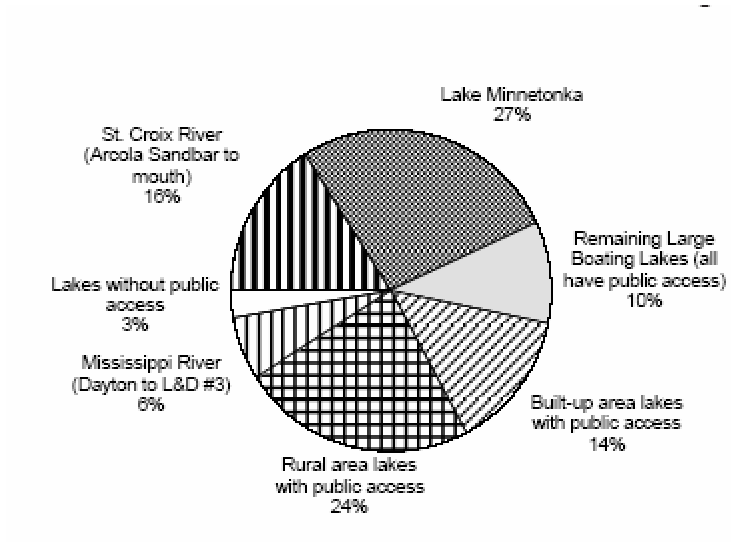

Figure 22. Estimated summer boating distribution for water resources in the Twin Cities Metropolitan Area (Minnesota Department of Natural Resources 1997).

Water Resource Issues

Water resource issues at MNRRA are wide-ranging, and their management is complex. To explore and prioritize these issues, in 2005 the National Park Service initiated a series of meetings with MNRRA partners and stakeholders. An initial list of water resource issues and concerns was identified during a small group meeting of state and federal agency representatives in May 2005. Primary issues identified included river regulation, ecosystem management, water quantity, water quality, biological concerns, and interagency coordination. These broad categories helped structure the discussion at a much larger water resources scoping meeting in September 2005 (see Appendix A for details), attended by 43 representatives of six cities and townships, two counties, four watershed districts, four state agencies, four federal agencies, four non-profit organizations, two private associations, the University of Minnesota, and the Metropolitan Council. This group expanded and refined the list of water resource issues to include more than 80 issues (Appendix A, Table 2). These issues fell within the following major categories, listed in order of importance as determined from participant votes (Appendix A, Table 3): water quality, land and water use and regulation, socio-environmental issues, biological issues, interagency and partnership coordination, effects of river alteration, economic impacts and analysis, water quantity, and ecosystem restoration and understanding. In this section, we explore in greater detail the water resource issues identified through this process. Due to overlap in content, economic impacts and analysis issues have been incorporated into the socio-environmental issues section.

Water Quality

Scoping workshop participants consistently gave water quality an importance rating of 9 or 10 (Appendix A, Figure 1), the highest of any of the issue categories, and generated a long list of related individual issues ranging from urban stormwater and wastewater to nonpoint source pollution and emerging contaminants. Taken together, water quality-related issues received more votes than any other category of issues (Appendix A, Table 2).

Stormwater issues

When precipitation falls on land, especially impervious surfaces, it carries soil and sediment from the landscape, as well as oil, grease, organic contaminants, nutrients, metals, litter, and bacteria into rivers, lakes, and wetlands. This stormwater runoff degrades water quality and can cause impairment of important surface and ground water resources. As part of the Clean Water Act, Congress mandated that a new program be implemented to address stormwater runoff – the National Pollutant Discharge Elimination System (NPDES) Stormwater Program. This program has been implemented in two phases: since the 1990s, Phase I has regulated large construction sites, some industrial facilities, and major metropolitan separate storm sewer systems. Phase II, implemented more recently in 2003, aims to regulate smaller construction sites, municipally owned or operated industrial activity, and smaller municipalities.

For MNRRA, the primary stormwater regulatory and permitting authority is the Minnesota Pollution Control Agency. Through its Stormwater Program, the Agency issues combined NPDES/State Disposal System permits. As part of the permit process, regulated parties must have stormwater pollution prevention plans, based on best management practices (BMPs), to address their discharges. Minnesota Pollution Control Agency currently issues three types of stormwater permits: construction, industrial, or municipal separate storm sewer system. In 2004, the Agency formed the Minnesota Stormwater Steering Committee, with representatives from nearly 30 public and private organizations. In its charter, the Steering Committee noted an immediate need to “enhance the effectiveness of existing and emerging state and local stormwater regulatory management programs, in order to build an efficient and understandable regulatory and implementation framework" (Minnesota Pollution Control Agency 2004). In particular, the Steering Committee aims to:

- Provide technical expertise and recommendations related to education, inspection, enforcement, monitoring of proposed regulatory initiatives, training programs, program management, and watershed management.
- Establish a forum to improve cooperation/coordination between and among agencies/entities.
- Develop links with other state or local water resource programs.
- Establish real and perceived fairness in sharing the burden of improving water quality among responsible groups and individuals.
- Address source control as well as runoff control.
- Establish subcommittees to address key areas.

The Steering Committee continues to develop the above goals, and has established eight subcommittees as focus groups: education and outreach, industrial stormwater, stormwater manual development, stormwater monitoring, nondegradation, stormwater research, watershed-based stormwater planning, and operations (charged with planning steering committee meetings). Through the efforts of these subcommittees, two important documents have recently been released in draft or final form. The Steering Committee's Manual Subcommittee partnered with consultants to develop a comprehensive state stormwater manual, finalized in 2005. The manual addresses stormwater management and provides detailed descriptions of best management practices (Minnesota Pollution Control Agency 2005a). It is expected to be a dynamic document, undergoing minor revisions twice-yearly and major revisions every two years.

The Watershed-Based Stormwater Planning Subcommittee released a draft framework for watershed-based permitting in Minnesota in March 2006. The authors of this framework noted that relationships among stormwater and watershed management regulatory programs at the state and federal levels are complex, and that a more integrated, streamlined approach was preferable. This position had previously been advanced by the U.S. Environmental Protection Agency, who issued the "Watershed-based NPDES Permitting Implementation Guidance" document in 2003. The framework aims to bring together various federal, state, and local stormwater and watershed management programs to more effectively and efficiently accomplish individual program goals and achieve overall stormwater management needs. One or more pilot projects, using the proposed framework, will eventually be initiated to refine the concept and process. If successful, this approach to integrating state watershed planning with federal stormwater pollution prevention planning, local water management planning, and local comprehensive planning will be the first of its kind nationwide (Tetra Tech, Inc. and Schilling Consultant Services 2006).

In addition to the above Minnesota Pollution Control Agency and Minnesota Stormwater Steering Commmittee's activities, a variety of other stormwater outreach, education, and research activities are underway. For example, the Metropolitan Council released an urban small sites best management practices manual (Barr Engineering Company 2001) to provide guidance in site development and redevelopment, taking into account concerns related to Minnesota's cold climate. The University of Minnesota Extension Service also features a Stormwater Education Program, offering educational resources to local units of government and design professionals and outreach resources to any interested organization. Local researchers are investigating nutrient absorption capacity of stormwater detention ponds (Perniel et al. 1998) and developing models to predict runoff volume and constituent loads in the Twin Cities area (Brezonik and Stadelmann 2002).

Continued stormwater management requires resources, and stormwater utilities have become an increasingly popular method for financing municipal stormwater activities. Stormwater utilities charge fees to property owners for using the local stormwater drainage system, forming a local revenue source that can be used for water quality improvements, development of local surface water management plans, implementation of best management practices, and storm sewer system maintenance. The Metropolitan Council recently determined that 45 of 140 communities in the Twin Cities Metropolitan Area have instituted stormwater utilities, with many more pending (Metropolitan Council 2000).

Despite important advances in stormwater management in the Twin Cities area, many concerns remain. Nearly all the older storm drains in the Metropolitan Area discharge to rivers with no treatment. Many newer urban storm water systems are being designed to capture sediment, but the rapid increase in impervious surfaces has overwhelmed many of the newer storm water systems (U.S. Army Corps of Engineers 2004b). MNRRA water resources scoping workshop participants noted that BMPs for trash and litter were still needed. Urban and suburban areas continue to develop rapidly, and these construction sites have both high erosion rates (due to vegetation removal) and high delivery rates (due to grading and ditching) (University of Wisconsin Extension 1997). Enforcement of stormwater management activities is difficult, time consuming, and frequently under-funded. Aplikowski et al. (2004) reported that while concentrations of most water quality variables in Twin Cities area stormwater were comparable to nationwide stormwater averages, Twin Cities area nutrient and biological oxygen demand levels appear to be higher. Finally, full integration of watershed and stormwater management across federal, state, and local boundaries, as proposed in the recent draft framework for watershed-based permitting, will likely be a lengthy and challenging process.

Impaired waters and Total Maximum Daily Loads (TMDLs)

Excess nutrients and sediments present important environmental and regulatory problems in the MNRRA corridor and the larger Upper Mississippi River Basin. In a recent summary of spatial patterns, the NAWQA Upper Mississippi River Basin Study Unit, Stark et al. (2000) noted that nutrient and sediment loading in the area is heavily influenced by land cover gradients and human land uses, a finding indicated by others as well (Have 1991, Stark 1997, and Kroening et al. 2002). High nutrient and sediment loads are found below the confluence of the heavily agricultural Minnesota River, for example, whereas the more forested St. Croix River basin contributes lower nutrient loads. While it appears that the nutrient load in MNRRA is dominated by nonpoint nutrient sources, such as fertilizer and manure (Kroening 1998), point source discharges from the Metropolitan Wastewater Treatment Plant have been historically significant and remain so in low flow years (Larson et al. 2002).

Temporal patterns of nutrient loading have been investigated throughout MNRRA's contributing watershed. Nutrient and sediment loading from tributaries varies seasonally, with peak nitrogen loading occurring in spring and summer for agricultural streams and in winter for forested streams (Kroening and Andrews 1997, Kroening and Stark 1997). Total phosphorus concentrations in these contributing streams tend to be greatest in spring and summer. In small storm-sewered urban streams tributary to MNRRA, rainfall appears to be the most significant factor controlling seasonal nutrient runoff and constituent loads. In small rural watersheds, runoff and loading are greatest during snowmelt and less closely related to rainfall patterns (Payne et al. 1982, Ayers et al. 1985).

Reaches of MNRRA and its contributing waters are currently listed as impaired (i.e., not meeting water quality standards) due to eutrophication, turbidity, or fecal coliform; all reaches are listed as impaired for mercury and PCBs (Table 9). The 2006 Minnesota TMDL inventory, recently approved by the U.S. Environmental Protection Agency, lists several reaches of the Mississippi River within MNRRA as impaired (Figure 23, www.pca.state.mn.us/water/tmdl/). Current fecal coliform impairments are reported for portions of the Mississippi River throughout MNRRA, including reaches from the Crow River to the Rum River, from Coon Creek to Upper St. Anthony Falls, from Lower St. Anthony Falls to Lock and Dam 1, and from the Minnesota River to the Metropolitan Wastewater Treatment Plant. Turbidity impairments are noted consistently from the confluence of the Minnesota River to the downstream end of the MNRRA corridor and beyond.

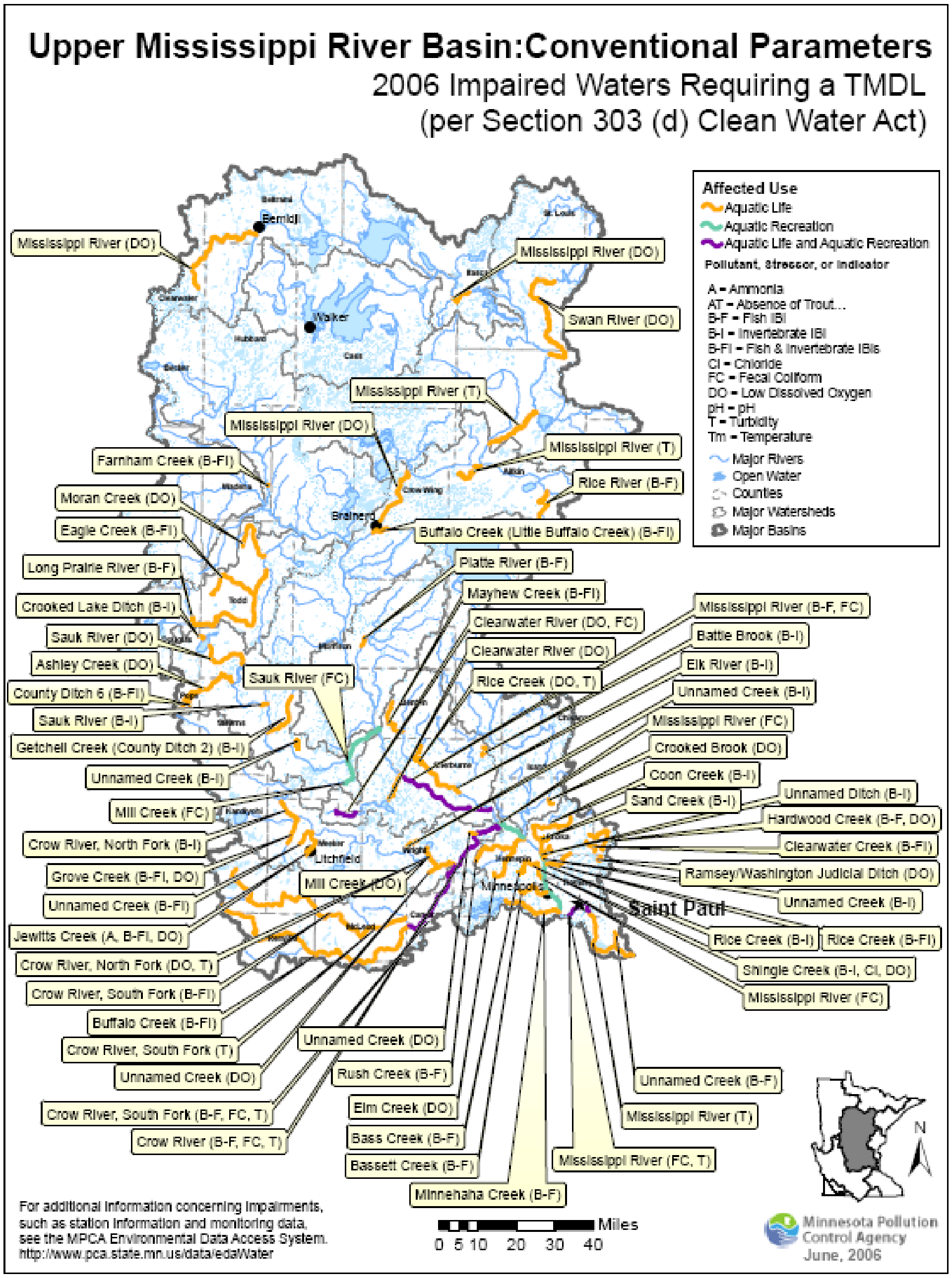

Figure 23. 2006 list of impaired waters in the upper Mississippi River Basin of Minnesota, Minnesota Pollution Control Agency (www.pca.state.mn.us/water/tmdl/).

The most prominent TMDL study currently affecting MNRRA involves Lake Pepin, a natural impoundment of the Mississippi River just downstream of the park. Lake Pepin is listed as impaired for turbidity and eutrophication due to high phosphorus and suspended sediment inputs from four primary sources in its large watershed: the Upper Mississippi above Lake Pepin, the St. Croix and Minnesota Rivers, and the Twin Cities Metropolitan Area (Senjem 2004). Of these, the Minnesota River contributes 80-90 percent of Lake Pepin's sediment and associated phosphorus loads, and recently underwent its own TMDL study for low dissolved oxygen concentrations. Lake Pepin experiences frequent and severe algal blooms, and sediment core studies indicate that sedimentation and in-filling are occurring rapidly (Engstrom and Almendinger 2000). The Lake Pepin TMDL Study was initiated in 2005, and is informed by a Stakeholder Advisory

Committee, a Science Advisory Panel, a Sediment Reduction Advisory Panel, a number of River Basin Teams, and the Internal Minnesota Pollution Control Agency Work Group, which is ultimately responsible for the TMDL study and implementation (Minnesota Pollution Control Agency 2006a). The TMDL process aims to establish appropriate goals for phosphorus and chlorophyll-a concentrations and develop a plan to meet the state water quality aquatic life standard for turbidity. Monitoring and modeling efforts are underway, but issues associated with load allocation, coordination with other pertinent TMDL studies, and legal and policy implications continue to present challenges.

Table 9. Impaired reaches of the Mississippi River, as per the 2006 Minnesota Pollution Control Agency inventory. "WC" = water column; "FCA" = fish consumption advisory.

Reach	Affected Use	Stressor
Crow R to NW city limits of Anoka	Aquatic recreation	Fecal coliform
NW city limits of Anoka to Rum R	Aquatic recreation	Fecal coliform
Coon Cr to Upper St Anthony Falls	Aquatic recreation	Fecal coliform
Lower St Anthony Falls to Lock & Dam #1 (RM 853.3 to RM 847.6)	Aquatic recreation	Fecal coliform
Minnesota R to Metro WWTP (RM 844 to 835)	Aquatic recreation	Fecal coliform
Minnesota R to Metro WWTP (RM 844 to 835)	Aquatic life	Turbidity
Metro WWTP to Rock Island RR Bridge (RM 835 to 830)	Aquatic life	Turbidity
Rock Island RR Bridge to Lock & Dam #2 (RM 830 to 815.2)	Aquatic life	Turbidity
Lock & Dam #2 to St Croix R (RM 815.2 to 811.3)	Aquatic life	Turbidity
Minnesota R to Metro WWTP (RM 844 to 835)	Aquatic consumption	Mercury WC
Metro WWTP to Rock Island RR Bridge (RM 835 to 830)	Aquatic consumption	Mercury WC
Rock Island RR Bridge to Lock & Dam #2 (RM 830 to 815.2)	Aquatic consumption	Mercury WC
Throughout	Aquatic consumption	Mercury FCA
Throughout	Aquatic consumption	PCB FCA

A number of TMDL studies addressing impairments related to turbidity, fecal coliform, chloride, dissolved oxygen, and biological integrity have been initiated in streams tributary to MNRRA as of 2006. Turbidity TMDL studies are underway for the Crow River, which joins the Mississippi River just upstream of the MNRRA boundary, and the Cannon and Vermillion Rivers, which join the Mississippi River near the downstream end of the MNRRA corridor. The Crow River is also undergoing a fecal coliform TMDL study. TMDL studies related to low dissolved oxygen conditions are underway for two smaller tributaries: Elm and Shingle Creeks. A TMDL study related to chloride concentrations is underway at Shingle Creek, and a fish biological integrity TMDL is ongoing at Minnehaha Creek.

These TMDL studies have important implications for MNRRA and its partners. The Lake Pepin TMDL study, in particular, is complicated by the large size of its watershed. Since more than half of Minnesota's waters drain into the Mississippi River and Lake Pepin, activities throughout much of the state may be relevant. In August 2005, the Minnesota Court of Appeals ruled that the state violated the Clean Water Act when it permitted two fast-growing Minnesota towns, Annandale and Maple Lake, to build a wastewater treatment facility on the Crow River, an impaired waterway that ultimately discharges to the Mississippi River in MNRRA. Under the Clean Water Act, discharges that would "cause or contribute to the violation of water quality standards" are not permitted before a TMDL study has been completed. Both the Crow River and Lake Pepin are listed as impaired, and neither water body has a TMDL in place. The Minnesota Pollution Control Agency has provided some guidance for existing facilities to follow until TMDLs are completed for these and other impaired waters in the state (Minnesota Pollution Control Agency 2006b). Because the Court of Appeals decision has wide-ranging implications for growth and development, the two cities and the Minnesota Pollution Control Agency have appealed the ruling to the state Supreme Court. The Minnesota Pollution Control Agency also is reviewing options to accelerate the Lake Pepin TMDL process.

Other efforts to limit phosphorus inputs to the state's waters include a new fertilizer law, implemented in January 2005, which restricts the use of lawn fertilizers containing phosphorus. The law expands on an earlier law restricting the use of phosphorus fertilizers in the Twin Cities Metropolitan Area. Under the new law, only phosphorus-free fertilizers may be applied on Minnesota lawns (Minnesota Department of Agriculture and others 2004).

Mercury contamination, due to inputs from wastewater, nonpoint source inputs, and atmospheric deposition, occurs throughout MNRRA and is the subject of a recent TMDL study. In October 2005, the State of Minnesota released its draft statewide mercury TMDL study for public review (Minnesota Pollution Control Agency 2006b). Because fish mercury concentrations differ in the two identified regions (i.e., they are higher in northeast vs. southwest Minnesota), mercury load reductions required to achieve the target fish mercury level of 0.2 mg/kg also differ. The recommended load reduction goal (93 percent of all anthropogenic sources) was selected to achieve fish mercury standards statewide. This goal would entail reducing Minnesota's year 2000 anthropogenic mercury emissions by an additional 78 percent. If approved by the U.S. Environmental Protection Agency, Minnesota will develop a detailed implementation plan.

Wastewater

Wastewater has been an important water quality concern in the MNRRA corridor for the past century, due to continued population growth in the Twin Cities area. By the early 1900s, inadequately treated municipal and industrial wastewater discharges in the Twin Cities area had heavily polluted the Mississippi River, resulting in severe oxygen depletion, fish kills, extremely high bacteria levels, the formation of floating sewage sludge mats, and the generation of noxious gases (U.S. Environmental Protection Agency 2000). In response to these concerns, in the 1930s the Twin Cities began what would be a long series of wastewater treatment improvements (Metropolitan Council 2005a). In the intervening decades, treatment facilities have been constructed, improved, and consolidated throughout the Twin Cities Metropolitan Area, with clear benefits for the Mississippi River.

The original Metropolitan Wastewater Treatment Plant (hereafter, Metro Plant) was a small primary treatment facility with chlorination, constructed in 1938 near Pig's Eye Lake in St. Paul. Its construction and use quickly improved water quality on the Mississippi, eliminating floating sludge mats and restoring a viable fishery. By the 1950s and 1960s, however, population in the Twin Cities had increased greatly, exceeding sewage treatment capacity and again compromising Mississippi River water quality. The Metro Plant added secondary treatment in 1966, and in 1970 Twin Cities wastewater treatment was consolidated under the Metropolitan Council, reducing the number of area treatment plants to nine technologically advanced facilities. Despite these advances and the 1970s legislation that set new fishable and swimmable goals for the Mississippi River, increased demand on the Metro Plant continued to threaten water quality.

In the 1980s the Metro Plant implemented advanced secondary treatment (transforming toxic ammonia into nitrate through nitrification), initiated a comprehensive industrial waste reduction program to reduce heavy metal inputs to the sanitary sewer system, began a 10-year combined sewer separation project to keep sewage overflows from entering the Mississippi with stormwater, and began dechlorinating wastewater before discharging to the Mississippi. The 1990s saw very good compliance with operation permits for the Metro Plant and others managed by Metropolitan Council, and continued efforts to reduce phosphorus and mercury discharge. By 2005, the Metro Plant and other metro area plants had implemented "BioP", or biological removal of phosphorus, to meet an effluent level of 1 mg/L for phosphorus. By far the largest treatment facility in Minnesota and one of the largest in the nation, the present-day Metro Plant treats about 75 percent of the area's wastewater, serving over 60 communities and over 600 permitted industries (Metropolitan Council 2005b).

The modern Metropolitan Area wastewater treatment system (operated by the Metropolitan Council) includes over 600 mi (966 km) of interceptors and eight wastewater treatment plants

(Table 10), treating approximately 300 million gallons (>1 billion liters) of wastewater daily from 103 communities and 800 industries (http://www.metrocouncil.org).

Currently five treatment plants discharge to the Mississippi River within the MNRRA corridor. These include several small treatment plants and one large facility (Metropolitan Council 2005b): 1) the Eagles Point Plant, which serves Cottage Grove and Woodbury, 2) the Hastings Plant, which serves the community of Hastings, 3) the Rosemount Plant, 4) the Empire Plant, which serves several Dakota County communities, and 5) the Metro Plant. Of these facilities, the Rosemount Plant is the region's smallest and is expected to close in 2007. Wastewater from this facility will be directed to the Empire Plant. Although the Empire Plant currently discharges to the Vermillion River, a new outfall pipe for discharge to the Mississippi River is planned.

Table 10. Summary statistics for the eight current Metropolitan Area wastewater treatment plants. Treatment volumes are given in millions of gallons a day (mgd) and millions of liters a day (mld). Length of interceptors is given in miles (mi) and kilometers (km) (from http://www.metrocouncil.org).

Plant	Current Treatment mgd (mld)	Design Capacity mgd (mld)	Length of Interceptors mi (km)
Metro	215 (814)	251 (950)	332 (534)
Seneca	25 (95)	39 (148)	46 (74)
Blue Lake	26 (98)	38 (144)	103 (166)
Empire	9 (34)	12 (45)	16 (26)
Eagles Point	2.1 (7.9)	10 (38)	10 (16)
St. Croix Valley	3.5 (13.2)	5.8 (22.0)	2 (3)
Hastings	1.7 (6.4)	2.9 (11.0)	0 (0)
Rosemount*	0.8 (3.0)	1.3 (4.9)	8 (13)

*will close in 2007 and be replaced by lift station and interceptor to Empire Plant.

While wastewater treatment in the Twin Cities has improved a great deal over the past century, related water quality concerns still exist, particularly in regard to excess phosphorus and nitrogen. Metropolitan area treatment facilities have reduced effluent phosphorus *concentration*s greatly, from very high levels to only 1 mg/L. Phosphorus *loads*, however, become more difficult to control as the population served increases. Phosphorus load limits, or mass caps, may be required to maintain good water quality in receiving waters. The implementation of advanced secondary treatment has reduced effluent concentrations of toxic ammonia and related threats to aquatic life, but this process has increased the concentrations of nitrates. Excess nitrates can stimulate nuisance algal growth, contribute to hypoxia issues in the lower Mississippi River and Gulf of Mexico, and be toxic in their own right at high enough concentrations. The issue of increasing nitrate concentrations as it relates to wastewater treatment has received little attention to date.

Metropolitan area treatment plants continue to struggle with contaminants such as mercury and PCBs, but have recently made good progress toward reducing mercury concentrations in wastewater. Since the late 1990s, the Metropolitan Council has been working with the Minnesota Dental Association to test new technologies to filter mercury in dental amalgam from wastewater before it reaches treatment facilities. If successful, this award-winning program will reduce mercury loads in the regional sewer system by nearly half. PCBs, though banned in the 1970s, are also still detected in Metropolitan Area wastewater. Concentrations at the Metro Plant appear to be declining, suggesting that only residual amounts flow in from the area's sewer lines.

Wastewater treatment capacity remains an important issue in the rapidly growing Twin Cities area. The $331 million separation of sanitary and storm sewers, which occurred from 1985 to 1995, helped ensure that the cities' sanitary sewers and wastewater treatment capacity were not overwhelmed during storm events (U.S. Environmental Protection Agency 2000). These Combined Sewer Overflow (CSO) events had significant impacts on water quality and led to legal action by the State of Wisconsin because of impacts downriver. The State of Minnesota entered into a settlement agreement with the State of Wisconsin in the 1980s in which Minnesota committed to separating storm and sanitary sewers in the three cities within 10 years. Today, almost all of the Metropolitan Area's sewers have been separated, including more than 95 percent of the City of Minneapolis' sewer systems (http://www.ci.minneapolis.mn.us/stormwter/overview/).

This sewer separation project greatly reduced the discharge of raw sewage to the Mississippi River via stormwater drains, but did not address the reverse issue – that of inflow and infiltration of ground and stormwater into sanitary sewer pipes via cracks, leaky joints, or deteriorated manholes. Inflow and infiltration results in the unnecessary treatment of clean water by wastewater treatment facilities, and may substantially reduce the wastewater treatment capacity of growing communities (Metropolitan Council 2006). The Metropolitan Council has been working with local governments to address this problem, and aims to keep clean water out of the sanitary system by disconnecting sump pumps and foundation drains connected to sanitary sewers and repairing leaky sewer pipes.

New wastewater concerns have also emerged as a result of rapid population growth in the northern suburbs of the Twin Cities. These suburbs are situated outside of the seven-county Twin Cities Metropolitan Area and, as such, are beyond the jurisdiction of the Metropolitan Council. Several river reaches were listed as impaired for fecal coliform bacteria in Minnesota's 2006 impaired waters list. These include the Crow River, which discharges to the Mississippi River at the upstream end of MNRRA, and several reaches of the Mississippi River within MNRRA, including the reach containing drinking water intakes for Minneapolis and St. Paul. Mississippi River reaches now listed as impaired for fecal coliform include: the Crow River to Rum River reach, the Coon Creek to Upper St. Anthony Falls reach, and the Lower St. Anthony Falls to the Metropolitan Wastewater Treatment Plant reach.

Contaminants

A variety of surface water contaminants has been detected within the MNRRA corridor due to industrial and municipal wastewater dischargers, stormwater runoff, urban/suburban development, and other sources. In a 1995 review of existing water quality data within MNRRA, the National Park Service reported occasional exceedances of water quality standards for 22 different parameters (National Park Service 1995b). Dissolved oxygen, pH, cyanide, chloride, cadmium, copper, lead, mercury, selenium, silver, and zinc exceeded their respective Environmental Protection Agency criteria for protection of freshwater aquatic life. Nitrite, nitrate, nitrite plus nitrate, cyanide, chloride, sulfate, arsenic beryllium, cadmium, chromium, lead, mercury, nickel, and zinc exceeded Environmental Protection Agency drinking water criteria. Concentrations of turbidity and fecal indicator bacteria (total and fecal coliform) exceeded screening criteria for aquatic life and bathing, respectively. Bioaccumulation of some of these contaminants in fish and other local biota remains a concern (see "Biological Issues - effects of contaminants"). Fish consumption advisories still exist throughout the MNRRA corridor due to mercury and PCB contamination. A recent TMDL study addresses mercury contamination statewide, recommending a 93 percent mercury emissions reduction goal for all anthropogenic sources from 1990 levels, and emission reductions of 2,553 lbs (1,158 kg) within Minnesota (Minnesota Pollution Control Agency 2006c).

One area of known contamination within the MNRRA corridor is the Pig's Eye Dump. Located in the Mississippi River floodplain southeast of downtown St. Paul in Pool 2, this 250-acre (101 ha) dump operated between 1956 and 1972, accepting approximately 8.3 million cubic yards (6.3 million cubic meters) of waste from Metro Area communities and businesses (Minnesota Pollution Control Agency 2001). From 1977-1985, the dump was used as an ash disposal site for burned sewage from the Metro Plant, and during the summer of 1988, the site caught fire and burned for two months. Because Pig's Eye Dump has not been properly covered and is situated in an active floodplain, the risk of erosion and exposure of buried waste due to flooding continues. The Minnesota Department of Health notes that the site represents a potential health hazard, and advises against consumption of nearby fish and deer (Minnesota Department of Health 2006). Monitoring efforts have shown that residential wells are not likely affected by contaminants from the dump, but Pig's Eye Dump remains the largest source of contaminants in the Upper Mississippi River Basin (River Resources Forum 2004) and is on the state Superfund list. The Minnesota Pollution Control Agency and the City of St. Paul continue to work on a costly cleanup project involving the removal of drums from the banks of Battle Creek, the rerouting of Battle Creek, the stabilization of shoreline where the dump meets Pig's Eye Lake, the stabilization of an area formerly used for lead-acid batteries, the covering of areas with insufficient soil cover, and the filling of an on-site pond to prevent contaminated runoff (Minnesota Pollution Control Agency 2001, 2005b). Some of the area is currently designated as green space or park land use, and the City favors further reclamation and redevelopment (City of St. Paul 2002).

In recent years concerns about organic wastewater contaminants with endocrine-disrupting properties have grown. These compounds originate from a broad range of household, industrial, and agricultural-use chemicals, pharmaceuticals, antibiotics, and sterols and hormones, and may adversely affect humans and aquatic biota (Daughton and Ternes 1999). Effects within MNRRA may include feminization of some fish species (see "Biological Issues – effects of contaminants" section, below, for more details). New filtration methods for removing these compounds from wastewater are being explored (e.g., Synder et al. 2003, Nghiem et al. 2005), but such technology is costly and unlikely to be implemented without a clear indication of biological risk.

Participants at the 2005 MNRRA Water Resources Scoping Workshop noted the importance of surface water-ground water interactions in the Twin Cities Metropolitan Area, and the risk of ground water contamination related to human activities on the land surface. In general, the area's sand and gravel surficial aquifers appear most vulnerable to contamination. Streams and wells in the Twin Cities Metropolitan Area show high sodium and chloride concentrations and frequent pesticide and VOCs detections (Andrews et al. 1995, Andrews 1996, Andrews et al. 1998). The highest well VOC concentrations tend to be found near spills, leaks, and landfills, and the most commonly detected VOC is trichloroethene, a degreasing agent. Aquifers with the highest modeled contamination susceptibility are generally associated with agricultural croplands and show high concentrations of pesticides and nitrates (Hanson 1998). Fong (2000) found correlations between ground water contaminants and land use, with high nitrate concentrations in agricultural wells, frequent detections of pesticides in agricultural and urban wells, and frequent detections of VOCs in urban areas.

Contamination of ground water with a particular family of chemicals, known as perflourochemicals (PFCs), is an emerging issue in the Twin Cities Metropolitan Area. From the late 1940s until 2002, the 3M Company used PFCs (i.e., perfluorooctane sulfate, or PFOS, and perfluorooctanic acid, or PFOA) at its Chemolite facility in Cottage Grove, Minnesota to make products that resist heat, oil, stains, and water (Minnesota Pollution Control Agency 2006d). For decades the facility discharged processed water containing PFCs to the Mississippi River within MNRRA, and disposed of production waste both on-site and at several area landfills, possibly including the Pig's Eye Dump. Results of limited environmental monitoring show that ground water beneath the Cottage Grove facility is contaminated with both PFOS and PFOA, in some locations at levels in excess of the Minnesota Department of Health-Based Values (HBVs) for ground water (U.S. Department of Health and Human Services 2005). The full extent of the contamination is unknown, but PFCs have been detected in excess of HBVs at some municipal and private residential wells near several disposal areas in the Twin Cities Metropolitan Area.

The effects of PFCs on human and wildlife health have not been widely investigated, despite their known persistence, ubiquity, and bioaccumlative potential (Minnesota Pollution Control Agency 2006d). With respect to human health, 3M has been monitoring PFC levels in the blood of workers exposed to the chemicals during manufacturing since the 1970s. While the workers do show elevated blood PFC concentrations, related epidemiological studies have not indicated an impact on worker mortality. Elevated levels of PFOS have also been detected in the blood, livers, and tissues of fish collected from the Mississippi River near the 3M Cottage Grove plant. Effects of elevated PFC burdens on local biota have not been investigated, but in animal lab toxicity studies high concentrations of PFOS and PFOA have adversely affected the liver and other organs, caused cancer in multiple sites, and caused developmental problems in the offspring of animals exposed to PFCs while pregnant. Based in part on these findings, the National Science Advisory Board's PFOA review panel recommended that the Environmental Protection Agency classify PFOA as a "likely carcinogen". Investigations into PFCs by the U.S. Environmental Protection Agency, the Minnesota Pollution Control Agency, and the Minnesota Department of Health continue. Additional sampling of Mississippi River sediments and fish is expected in the coming years.

Drinking water concerns

The Mississippi River provides a primary source of drinking water to the large and growing communities in the Twin Cities Metropolitan Area (Stark et al. 2005). The water intake for the cities of Minneapolis and St. Paul is located on the Mississippi River in Fridley, within the MNRRA corridor. For the city of Minneapolis, the Mississippi River represents the sole source of drinking water. For the city of St. Paul, Mississippi River water is supplemented with water from the Rice Creek Watershed and four municipal wells. Although drinking water quality in the area is generally good (City of Minneapolis 2005, St. Paul Regional Water Services 2005), water quantity and suitability for consumption remain important concerns for a variety of reasons.

The City of St. Paul pumps its Mississippi River water nine miles to a chain of four reservoir lakes, where it is stored before treatment. While the extra storage time allows sediments to settle, it also leads to taste and odor problems associated with lake algal blooms. The St. Paul Regional Water Services has attempted to improve St. Paul's water flavor in several ways, including restoring wetlands with the goal of reducing nutrient inputs and subsequent algal blooms. These attempts were met with limited success. In spring 2006, granular activated carbon filters, designed to remove the offending organic algal compounds, were installed and will likely be effective.

Taste and odor problems may be minor issues when compared with other drinking water concerns in the Twin Cities Metropolitan Area. Recent source water assessments for the cities of Minneapolis and St. Paul evaluated the likelihood that a contaminant will enter the public water supply and adversely affect human health (Minnesota Department of Health 2001a, b), concluding that the cities' surface source waters were highly vulnerable to contamination from multiple potential spill sources. Potential contaminants identified in these assessments included suspended solids, nutrients, oxygen-using materials, metals, pathogenic microorganisms, and several organic and inorganic chemical constituents. An inventory of potential oil and chemical spill sources within one mile of the Mississippi between the Mississippi River headwaters and St. Anthony Falls revealed more than 3,300 potential spill sources (Minnesota Department of Health 2001a, b).

Given the high number of potential spill sources and high susceptibility of surface drinking water intakes to contamination, source water protection and spill management planning have received some attention within MNRRA. In the early 1990s, a spill response report for the Mississippi River upstream of the Twin Cities was prepared (U.S. Army Corps of Engineers 1993), emphasizing the need for a River Defense Network and comprehensive spill response plan. To respond to this need, the cities of St. Cloud, Minneapolis, and St. Paul are developing Source Water Protection Plans through the Upper Mississippi River Source Water Protection Project, a Section 319 (of the Clean Water Act) project. As of August 2005, each city had delineated their Source Water Protection Area. Next steps include developing time of travel estimates, updating the inventory of potential contaminant sources, undertaking education and outreach activities, and developing implementation plans to protect source waters. The importance of this kind of planning was underscored in 2004, when 125,000 gallons (473,177 liters) of liquid cattle manure were accidentally released into a Mississippi River tributary just upstream of the St. Cloud water intakes (Stark et al. 2005). The U.S. Geological Survey provided time of travel estimates for the contaminant plume, allowing the water intakes in St. Cloud to be closed as the contaminant plume passed by.

Water Quantity

River flows and ecological function

From a broad perspective, river ecosystems provide: 1) provisioning services (products obtained from ecosystems), 2) regulating services (benefits obtained from regulation of ecosystem processes), 3) cultural services (nonmaterial benefits obtained from ecosystems), and 4) supporting services (nutrient cycling, primary production, flow variability, habitat/biodiversity) (World Wildlife Fund 2006). These latter services are critical because they provide the basis for all other benefits gained by the river. Supporting services differ from the other services in that their impacts on people are either indirect or occur over a long period of time. These services, particularly biodiversity, habitat, and hydrologic variability, are often affected most by dams and urban development (including water infrastructure).

A variety of ecosystem processes are supported by variations in flow (Table 11). The base flow of a river supports numerous ecological processes, and flow variations resulting from droughts and flood events support many more.

Effects of urbanization

> "An urban system casts a direct footprint that is easily ascertained by a view from above. However, there are few urban landscapes whose water needs can be supported based on the direct footprint of the urban system; water demand is met by appropriation of supply from nearby and possibly distant watersheds, and underlying aquifers. As a result the urban footprint typically greatly exceeds the direct footprint. Urbanization affects the ground water component of the water budget not only through use of water, but also through alteration of the quantity and quality of water that is recharged to the subsurface. Hence, urban water managers must manage a system that is itself altered by urbanization, and is therefore a moving target." (Johnson et al. 2004).

Under natural conditions, watersheds are in vegetative cover, and runoff is minimal because rainwater filters into the ground to the maximum extent, feeding rivers through springs and seepage during dry periods and recharging underground aquifers. But urbanization and associated suburban sprawl have changed the relationship between runoff and infiltration. The removal of perennial vegetation and the increase in impervious surfaces allows precipitation to run off of impervious surfaces much more rapidly and in much greater volume than under natural conditions. This decreases infiltration, reduces aquifer recharge and, therefore, reduces ground water flow into streams. A recent modeling effort estimated that the Twin Cities Metropolitan Area is losing between 9.0 and 31 billion gallons (34 and 117 billion liters) of water per year from infiltration (http://smartgrowthamerica.org/waterandsprawl.html). The higher rate and volume of runoff increases the magnitude and frequency of severe floods and produces higher stream velocities that cause severe erosion and sedimentation. This negatively impacts water quality, aquatic habitat, and infrastructure, such as roads, bridges, and water and sewer lines.

The increase in impervious surfaces within a watershed is the primary feature of urbanization that leads to increases in runoff and decreases in infiltration (Paul and Meyer 2001). As the percent of impervious surface cover within a watershed increases, runoff increases five-fold and infiltration decreases three-fold for 75-100 percent impervious cover (Figure 24). The increased runoff reduces unit water yield – more precipitation leaves urban watersheds as surface runoff.

Thus, ground water recharge is reduced, resulting in a reduction in baseflow for urban streams (Barringer et al. 1994). However, effluents from wastewater treatment plants, as well as septic drainage and interbasin transfers, may enhance baseflow. The percentage of impervious surface cover has been proven to be an accurate predictor of urban impacts on streams and rivers (McMahon and Cuffney 2000). Indeed, an impervious surface cover of 10-20 percent has been identified with many thresholds of degradation in streams (see Paul and Meyer 2001 for examples).

Table 11 . Ecological functions of different river flow levels [after Postel and Richter (2003) as presented in World Wildlife Fund (2006)].

Low (base) flows	**Normal level:** • Provide adequate habitat space for aquatic organisms • Maintain suitable water temperatures, dissolved oxygen, and water chemistry • Maintain water table levels in the floodplain and soil moisture for plants • Provide drinking water for terrestrial animals • Keep fish and amphibian eggs suspended • Enable fish to move to feeding and spawning areas • Support hyporheic organisms (those living in saturated sediments) **Drought level:** • Enable recruitment of certain floodplain plants • Purge invasive introduced species from aquatic and riparian communities • Concentrate prey into limited areas to benefit predators
High pulse flows	• Shape physical character of river channel, including pools and riffles • Determine size of stream bed substrates (sand, gravel, and cobble) • Prevent riparian vegetation from encroaching into channel • Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants • Aerate eggs in spawning gravels and prevent siltation • Maintain suitable salinity conditions in estuaries
Large floods	• Provide migration and spawning cues for fish • Trigger new phase in life cycle (e.g., in insects) • Enable fish to spawn on floodplain; provide nursery area for juvenile fish • Provide new feeding opportunities for fish and waterfowl • Recharge floodplain water table • Maintain diversity in floodplain forest types through prolonged inundation (different plant species have different tolerances) • Control distribution and abundance of plants on floodplain • Deposit nutrients on floodplain • Maintain balance of species in aquatic and riparian communities • Create sites for recruitment of colonizing plants • Shape physical habitats of floodplain • Deposit gravel and cobbles in spawning areas • Flush organic materials (food) and woody debris (habitat structures) into channel • Purge invasive introduced species from aquatic and riparian communities • Disburse seeds and fruits of riparian plants • Drive lateral movement of river channel, forming new habitats (secondary channels and oxbow lakes) • Provide plant seedlings with prolonged access to soil moisture

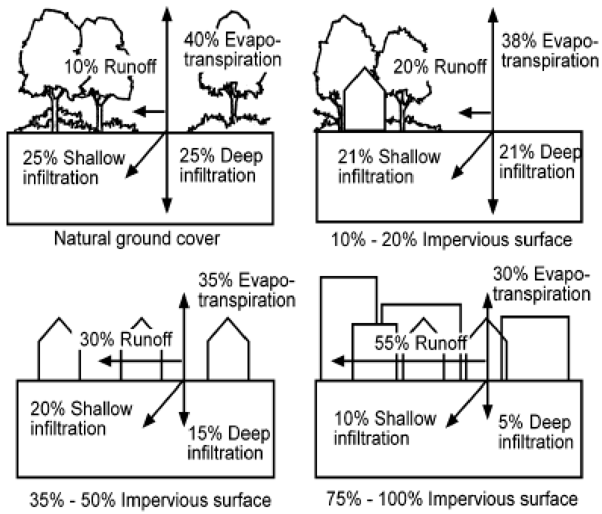

Figure 24. Changes in runoff and infiltration with increases in impervious surface cover (from Minnesota Pollution Control Agency 2000b).

As broadly mentioned above, various hydrological characteristics are altered by urbanization and its increase in impervious surface cover (Figure 25). In urban areas the difference in time between the center of precipitation volume and the center of runoff volume is shortened, resulting in floods that peak more rapidly and have higher discharges, and are shorter in duration. This results in flooding and erosion/sedimentation which may alter stream habitat and the structure/function of aquatic biological communities. In addition, the increase in runoff volume after urbanization (area under curves in Figure 25) increases the loadings of pollutants. Booth and Jackson (1997) delineated several related consequences of urbanization: for any given intensity and duration of rainfall, the peak discharge is greater (by factors of two to five; Hollis 1975), the duration of any given flow magnitude is longer (by factors of 5 to 10; Barker et al. 1991), and the frequency with which sediment-transporting and habitat-disturbing flows move down the channel network is increased dramatically (by factors of 10 or more; Booth 1991).

In terms of watershed morphometry, urbanization alters drainage density, a measure of stream length per watershed area (Booth and Jackson 1997). Because small streams are paved over, filled in, or placed in culverts, drainage density decreases (Dunne and Leopold 1978). However, construction of artificial channels may also affect drainage densities and lead to more links and nodes, thereby increasing flood velocity (Meyer and Wallace 2001).

A dominant view in river geomorphology states that rivers adjust their channels because of changes in sediment supply and bankfull discharge (1.5 year average recurrence interval; Leopold et al. 1964). Urbanization reduces sediment supply and bankfull flows are increased because of increases in impervious cover. The result is increased channel erosion as channel incision and widening occur to accommodate increased bankfull discharge and a reduced sediment budget.

<u>Floods and flood control</u>

Flooding is part of the natural cycle of the Upper Mississippi River system and plays an important role in maintaining ecosystem function and biodiversity (Poff et al. 1997). The environmental benefits of flooding also benefit society by maintaining desired ecosystem services (Bayley 1995). However, major modification of natural processes and ecosystems through human activity has created the potential for flood events to result in long-term undesirable changes to the environment (Montz and Tobin 1997). Science generally recognizes extreme flood events as beneficial natural disturbances, essential to maintaining a mosaic of dynamic, heterogeneous habitat types that support many species having differing environmental requirements, and thereby sustaining the high biological productivity and ecological integrity of rivers (Junk et al. 1989, Poff et al. 1997).

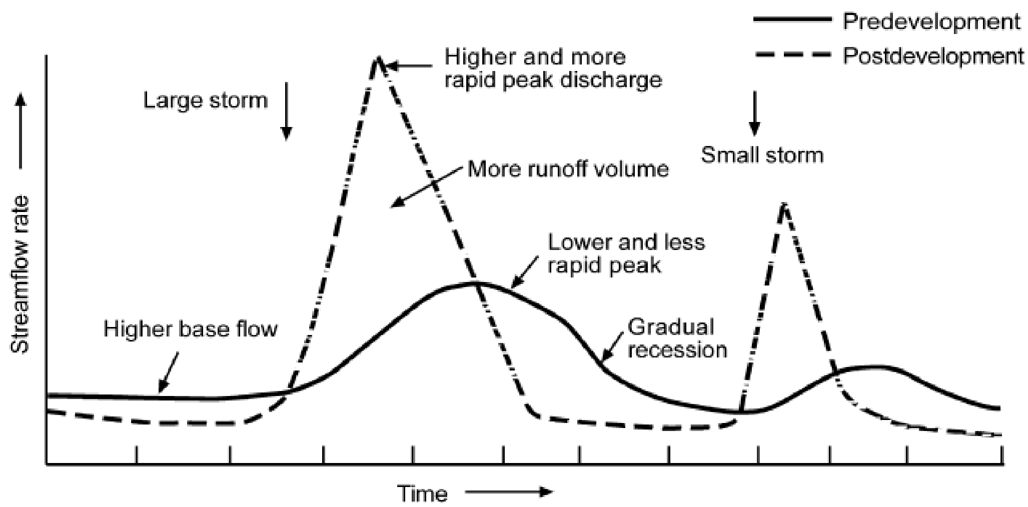

Figure 25. Generalized changes in the hydrology of running water as a result of urbanization (from Minnesota Pollution Control Agency 2000b, citing Schueler et al. 1992).

Floods are characterized by five critical components: the magnitude of discharge, the velocity of the discharge, the duration of the flood, timing or seasonality of the event and the frequency of the disturbance. Together these elements make up what is known as the flood regime. Flooding in the Twin Cities Metropolitan Area is primarily caused by spring snowmelt runoff or a combination of snowmelt and spring rainfall. Flood peaks occur from late March to well into June in years where late spring rainfall can exacerbate spring flooding. The largest floods on record have typically peaked in mid to late April. The four highest flood peaks on record beginning with the largest are 1965 (174,000 ft^3/s; stage height = 26.01ft, or 4,927 m^3/s; stage height = 7.93 m) 1969 (156,000 ft^3/s; stage height = 24.52 ft, or 4,417 m^3/s; stage height = 7.47 m), 2001 (142,000 ft^3/s; stage height 23.65 ft, or 4,021 m^3/s; stage height = 7.21 m), and 1997 (134,000 ft^3/s, or 3,794 m^3/s). A review of the annual flood peaks at the St. Paul gage (USGS 0533100) indicates that nine of the top 10 floods have occurred since 1950. In addition, since 1950 there has been an upward trend in the cumulative long-term departure from the mean flow for the period of record (U.S. Army Corps of Engineers 2004b). Trends in the Upper Mississippi basin challenge the traditional assumption that flood series are independent and identically distributed random variables and suggest that flood risk may be changing over time (Olsen and Stakhiv 1999).

The St. Paul gage was the most upstream station used in the Upper Mississippi River System Flow Frequency Study (U.S. Army Corps of Engineers 2004b). Hydrologic studies were conducted to determine the approximate effects of the Mississippi River Headwaters reservoirs on peak flows at the St. Paul gage. There was very little difference between modeled ‘regulated’ and ‘un-regulated’ flows at St. Paul. The final frequency curve for the St. Paul gage, based on the period of record from 1989-1998, is calculated in Figure 26. The 50 percent exceedance discharge of 38,500 ft^3/s is equivalent to a 2-year flood event, the 1 percent exceedance discharge of 148,000 ft^3/s is equivalent to a 100-year flood event, and the 0.2 percent exceedance discharge of 200,000 ft^3/s is equivalent to a 500-year flood event.

In heavily modified urban areas levees and flood walls have been constructed to minimize flooding; however, there is now mounting evidence that these structures are increasing flood magnitude and frequency (Poff 2002). For example, The U.S. Geological Survey (1999) found that in the last half of the 20th century, Mississippi River basin floods have increased as a direct result of the increased disconnection of the floodplain from the river by extensive leveeing. Moreover, Criss and Shock (2001) found that large tributary systems in the basin that lacked extensive leveeing did not flood so severely during this same time period. The need for flood protection often leads to environmental effects (Hickey and Salas 1995). Structural flood controls, especially levee systems and flood control reservoirs, deprive river systems of natural disturbance and stimulation. Main channels are separated from the natural floodplain, wetland areas are desiccated and destroyed, hydrologic regimes are altered, the geomorphic influence of floods is depressed, and natural biological cues are masked. Structural flood control is a deterrent to the health of natural systems, but remains a valued tool in flood management in highly urbanized areas.

An alternative approach to flood management is the use of so-called nonstructural approaches. Non-structural flood damage control relies on techniques that involve little or no channel manipulation, mechanical habitat alteration, or building of structures; Galat et al. (1998) called for their use on regulated rivers as a way to meet societal and ecological goals. This approach essentially emphasizes basic hydrological and ecological principles to reduce run-off to and increases natural storage in rivers to minimize flood damage to humans. Nonstructural flood control presents an opportunity to reduce the frequency and magnitude of extreme events and restore aquatic environments.

Drought and drought mitigation

Drought conditions are a direct result of climatic conditions and may be defined as a lack of precipitation over a period of time. The perception that the Twin Cities Metropolitan Area had adequate water supplies was greatly challenged by the 1987-89 drought, which saw the establishment of long- and short-term drought mitigation. As a result of that drought, the Metropolitan Area requested that the U.S. Army Corps of Engineers release additional flow from the Upper Mississippi reservoirs to ensure adequate supplies for the Twin Cities, the 1989 legislature charged the Metropolitan Council with preparing water use and supply plans for the Twin Cities Metropolitan Area, water restrictions were imposed by municipalities, the Governor appointed a task force specifically to make recommendations on how to meet future water demands in the event of low flow conditions on the Mississippi River, and the Minnesota Department of Natural Resources was mandated (MS Section 103G.293) to prepare a drought response plan. That plan was updated in July 2006 (http://files.dnr.state.mn.us/natural_resources/climate/drought/droughtp.pdf). The drought response plan provides a framework for preparing for and responding to future droughts in order to minimize conflicts and negative impacts on the Minnesota's natural resources and economy. That plan describes five responsibilities of the agency as drought conditions are approached or realized: 1) convene state drought task force, 2) intensify monitoring and assistance, 3) disseminate information to public, 4) suspend surface water appropriation permits, and 5) assist in the Governor's declaration of critical water deficiency and water use restrictions. Such low-flow monitoring activities were initiated in the Twin Cities during summer 2006 as a result of minimal precipitation and river discharge.

Under extreme low-flow events, the Mississippi River above St. Paul may experience large flow fluctuations from hydropower operations and the operation of reservoir control gates. Such fluctuations during extreme drought conditions exacerbate the already negative impacts on river ecology and water supply. A 1996 task force, including Minnesota Department of Natural Resources, U.S. Corps of Engineers and affected hydropower facilities, finalized the "System-Wide Low-Flow Management Plan for the Mississippi River above St. Paul", which was recently updated in 2004 (http://files.dnr.state.mn.us/natural_resources/climate/drought/Mississippi_River_Low_Flow_Management_Plan.pdf).

The purpose of this plan is to ensure run-of-river operations are maintained during low-flow periods in order to minimize artificial flow fluctuations and protect river resources and values. This plan establishes, where un-established, trigger flows (those flows that trigger implementation of the plan), reservoir operating bands, and ramping rates (rate of artificial flow change).

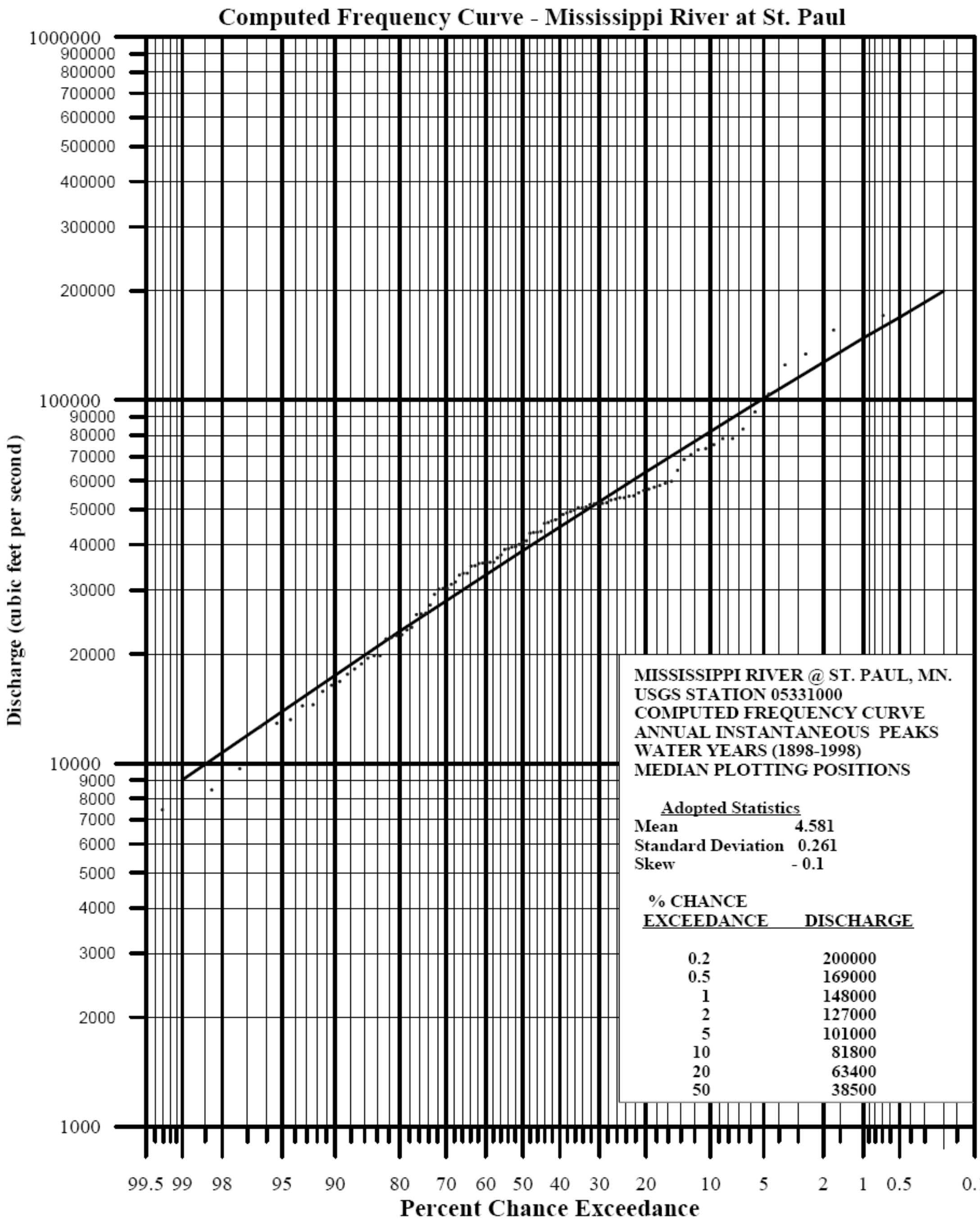

Figure 26. Computed frequency curve for the St. Paul gage over the period of record of 1989-1998 (U.S. Army Corps of Engineers 2004b).

The six reservoirs that make up the 'Mississippi River headwaters reservoirs' are operated by the U.S. Army Corps of Engineers, St. Paul District. The district has adopted a plan that calls for emergency releases from these reservoirs when necessary to meet human health and safety needs under certain conditions such as drought. Furthermore, the district has begun a re-evaluation of the operation of these headwaters reservoirs called the Reservoir Operations Plan Evaluation Study (ROPE).

Sustainability of water supplies

Given the rapid population growth in the Twin Cities Metropolitan Area, projected to increase by one million between 2000 and 2030 (Metropolitan Council 2004), there has been concern over the potential effects of increased ground water withdrawals in the region. As early as the 1970s, researchers noted that surface water resources of the Twin Cities area were not sufficient to meet all needs during a severe drought (Norvitch et al. 1973). Additionally, aquifers were already experiencing cones of depression during maximum withdrawals in summer months. The Metropolitan Council (2004) more recently reviewed water supply and demand for future planning in the Twin Cities Metropolitan Area. Their analysis showed that:

- Ground water is the primary source of water, supplying approximately 58 percent of the Metropolitan Area population and all or parts of 121 communities within the Metropolitan Area (Figure 27).

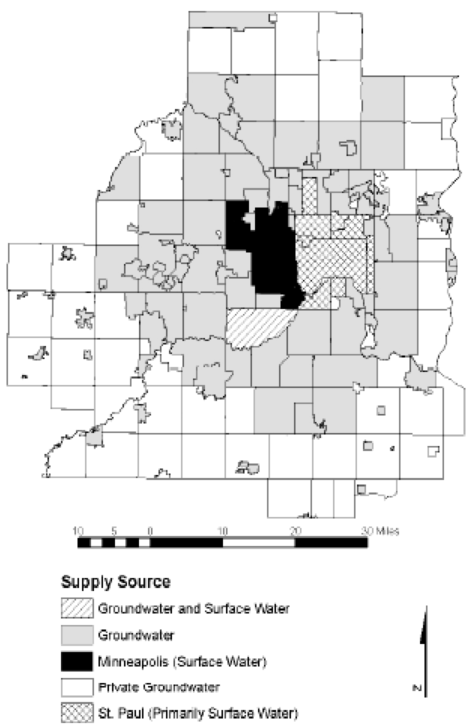

Figure 27. Water supply sources in Metropolitan Area (after Metropolitan Council 2004).

- Sixty-two percent of approximately 570 municipal wells in the Metropolitan Area originate in the Prairie du Chien-Jordan aquifer with the remainder spread relatively evenly across the Mt. Simon-Hinckley, glacial drift and Franconia-Ironton-Galesville aquifers. The highly productive Prairie du Chien-Jordan aquifer is present over a significant portion of the Twin Cities Metropolitan Area except for the northern and western portions (Figure 27). The surficial and Franconia-Ironton-Galesville aquifers are highly variable and not as productive as the Prairie du Chien-Jordan aquifer. The Mt. Simon-Hinckley aquifer is a potential water supply source, but its use is limited by law (MS103G.271). The combined total capacity of all municipal wells in 2002 was approximately 894 million gallons a day (3,384 million liters a day) with a total design capacity of 1,203 million gallons a day (4,554 million liters a day). Schoenberg (1990) estimated that a maximum of 500-800 million gallons a day (1,893-3,028 million liters a day) was available from the Metropolitan Area aquifer systems, but the study did not account for local conditions, increases to impervious surfaces, and climate change.

- The average-day withdrawal for the Twin Cities Metropolitan Area's municipal supply in 2002 was approximately 292 million gallons a day (1,105 million liters a day): 61 percent was used for residential use, 27.8 percent for commercial/industrial/institutional use, and 10.9 percent was unaccounted or un-metered. Additionally, of all non-municipal uses, power generation accounted for approximately 89 percent. Based on the Metropolitan Council's *Long-Term Water Supply Plan* (Elvrum 2001), residential, commercial, industrial and institutional water use is forecasted to reach 517 million gallons a day (1,957 million liters a day) in 2040. Water use for agriculture, water-level maintenance and once-through air conditioning is projected to decrease over the same period. Power generation water use is expected to remain relatively constant. Total water demand is expected to increase by 10 percent (100 million gallons a day) in 2040. Much of this increase is expected to be in developing suburban communities.

- The average residential water use for municipal supplies in the Twin Cities Metropolitan Area was 76.16 gallons per capita per day (288.30 liters per capita per day). There was no apparent trend in this use since 1980. Additionally, there was no apparent correlation between average lot size, average annual income, price of water or number of reported conservation programs in a community and per capita water use.

- Under drought conditions, water demand increases which reduces aquifer recharge. Major droughts have occurred in the Upper Mississippi River Basin during five periods since 1900: 1911-1914, 1921-1942, 1954-1961, 1976-1977, and 1987-1988 (U.S. Army Corps of Engineers 2001). The greatest impact occurred during the 1921-1942 drought followed by the 1976-1977 drought. However, the April-July period in 1988 saw the Mississippi River decreased to levels experienced only in 1934 and 1976. The ability to withdraw an adequate supply of water from the Mississippi River to meet demand during a protracted drought is uncertain. The Metropolitan Council (1990) identified a minimum instream flow need of 554 ft^3/s (16 m^3/s) at Anoka, based on the identified needs (Table 12).

Table 12. Minimum flow allocation at Anoka (Metropolitan Council 1990). ft^3/s = cubic feet per second; m^3/s = cubic meters per second.

Water Supply Needs	**Flow ft^3/s (m^3/s)**
Minneapolis water supply	125 (3.5)
St. Cloud water supply	50 (1.4)
St. Paul water supply	20 (0.6)
Brooklyn Center water	7 (0.2)
Xcel Energy power plant cooling water	2 (0.1)
Flow needed for lockages	350 (9.9)
Total	554 (15.7)

Other studies have examined future water use trajectories through detailed research and modeling. Lindgren (1990) and Schoenberg (1990) simulated ground water flow in the major aquifers of the area using a three-dimensional ground water flow model, showing substantial drops in the hydraulic heads of these aquifers if pumping were to increase by 125-200 percent over 1980 levels. The Twin Cities Ground Water Model (see Seaberg 2000), a computer simulation of regional ground-water flow for the seven-county Metropolitan Area, was developed by the Minnesota Pollution Control Agency as a cooperative venture among ground-water scientists in both the private and public sectors. This model could be useful in planning for future ground water supply needs.

Land and Water Use and Management

Within the MNRRA corridor and greater Twin Cities Metropolitan Area

Water resources at MNRRA are influenced strongly by human land uses occurring within and beyond the corridor boundaries. The park's Comprehensive Management Plan acknowledges that much of the land within the corridor either is or will soon be developed (National Park Service 1995a). Rapid changes in land use, largely involving a transition from agricultural to urban land uses, are occurring in the larger Twin Cities Metropolitan Area. Between 1970 and 2000, the area of urban lands in the Twin Cities Metropolitan Area swelled by 59 percent, while the area of agricultural lands decreased by 17 percent (http://www.epa.gov/urban/msp/indicators.htm). Land use in the most recent decade (from 1990 and 2000) reflected similar changes, with 22 percent gains in developed lands and 11 percent reductions in agricultural and undeveloped lands (http://www.metrocouncil.org). Concurrently, the area of parks, recreation areas, and preserves in the Twin Cities Metropolitan Area has increased by 23 percent. Such shifts in land use are occurring outside of the official seven-county Twin Cities Metropolitan Area as well, and are beyond the jurisdiction of regional planning bodies like the Metropolitan Council.

Within the MNRRA corridor, improved water quality and a desire to reconnect with the river have renewed development interests on the part of both citizens and municipalities. The Cities of Minneapolis and St. Paul are attempting to redefine their historically industrial relationship with the Mississippi River. Both cities have prepared riverfront development plans in recent years (BRW, Inc. 1999, City of Saint Paul 2002). The City of St. Paul's plan emphasizes the importance of the river corridor to the City's history and vitality, and lays out several strategies aimed to: 1) protect the river as a unique urban ecosystem, through blufffland preservation, protection of floodplains, wetlands, and shorelines, establishment of green corridors, and improved management of stormwater, 2) sustain the economic resources of the working river, through the continued support of commercial navigation and river-related businesses and housing, 3) enhance the City's quality of life by reconnecting to the river, through development of parks, open space, and trails, scenic vista protection, and preservation of cultural resources, and 4) enhance the corridor's built environment through use of traditional street and block patterns and consideration of view obstructions.

The City of Minneapolis historically has encouraged a variety of land uses along the Mississippi River above St. Anthony Falls. Material processing and transport industries dominated for decades, giving way more recently to parks and light-industrial development. More recently, the City of Minneapolis has shifted policy and begun to emphasize more sustainable park and residential land uses along the riverfront (BRW, Inc. 1999). The current master plan for the area recommends a contiguous open space system along the riverfront, complete with trails and bike lanes, restored shoreline habitat, points of interest, hospitality uses, and view corridors. It advocates establishing a non-profit entity to implement the master plan, closure of the Upper Harbor Terminal, rezoning of the area, a phase-out of heavy industrial uses, and the development of new riverfront residential communities.

Recognizing that only 4-6 percent of the Twin Cities area's native habitat remains, and that much of this is situated within MNRRA, several area entities are working to conserve the corridor's shorelands, blufflands, and other open spaces. The Trust for Public Land has a significant Twin

Cities Mississippi River Program and has initiated riverland protection projects at several sites. The Trust's projects include a shoreland conservation effort at the Minneapolis Upper River Site, a greenway and trail construction effort at the Bruce Vento Sanctuary site on St. Paul's East Side, a shoreline and bluff conservation effort at Pine Bend Bluffs Scientific and Natural Area down river from St. Paul, and a shoreline and floodplain conservation effort at the Vermillion River Bottoms. The Minnesota Department of Natural Resources' Metro Greenways program, initiated in 1998, also aims to protect disappearing natural areas in the Twin Cities Metropolitan Area. To date the program has assisted in the protection of more than 1,300 acres (526 ha) of sensitive natural areas and in the development of stewardship plans affecting more than 600,000 acres (242,812 ha). Friends of the Mississippi River offers a variety of educational programs related to open spaces, shoreline conservation, and native habitat restoration. Great River Greening restores endangered natural areas and open spaces by involving individuals and communities in stewardship activities in the Mississippi, Minnesota, and St. Croix River valleys and their watersheds.

The State of Minnesota has developed zoning rules related to shorelands and floodplains in order to "manage the effects of shoreland and water surface crowding, to prevent pollution of surface and ground waters of the state, to provide ample space on lots for sewage treatment systems, to minimize flood damages, to maintain property values, to maintain historic values of significant historic sites, and to maintain natural characteristics of shorelands and adjacent water areas" (http://www.revisor.leg.state.mn.us/arule/6120/). These shoreland rules were recently supplemented with a set of alternative shoreland management standards (Minnesota Department of Natural Resources 2005). Within the MNRRA corridor and Mississippi River Corridor Critical Area, more protective rules for shoreland zoning, defined by executive order during the establishment of the Critical Area, apply.

The role of MNRRA in land use decisions within and near the corridor is complex. The MNRRA Comprehensive Management Plan emphasizes coordination with local land use management entities and the Mississippi River Corridor Critical Area Program, which shares its boundaries with MNRRA. In the MNRRA Comprehensive Management Plan, land use policies are presented for the entire corridor, for riverfront areas, and for local site development areas. Several of the Plan's policies related to site development were chiefly intended to protect aesthetic values, but also have implications for water resources. Such policies address shoreline buffering, noting that developed areas should "provide uninterrupted vegetated shorelines where practical along the Mississippi and its tributaries". The policies also note a need to protect natural resources "using a system of preservation areas", such as riverfront areas, bluff areas, and setback areas. The policies also encourage wetland protection and restoration on lands within the corridor.

Despite the shoreland policies of the Minnesota Department of Natural Resources and those outlined in the MNRRA Comprehensive Management Plan, in many places MNRRA shorelands have been and continue to be modified for industrial, municipal, and residential purposes. In Minneapolis and St. Paul, much of the MNRRA shoreline has been hardened to accommodate docking, storage, and industrial facilities. In some northern suburbs, various techniques have been employed to stabilize shorelands on residential properties. Often such activities are conducted without regard to natural shoreland functions or softer engineering techniques, and occur above the ordinary high water mark, beyond the jurisdiction of regulating agencies.

In general, the MNRRA Comprehensive Management Plan and the Mississippi River Corridor Critical Area guidelines both stress that land use decisions within the corridor should seek a balance between resource protection, visitor use, and development needs. The MNRRA guidelines suggest that resource protection should prevail in cases of conflict. Striking this balance, in the face of rapidly changing land use and in cooperation with multiple agencies and several levels of government, is an important and ongoing management challenge for MNRRA.

The decision-making process for surface water uses in the MNRRA corridor is also complicated, and is less defined than for land use decisions. The MNRRA Comprehensive Management Plan

(National Park Service 1995a) identified a need for a Surface Water Use Management Plan, to be developed with involvement from the public and other interested agencies and organizations. Such a plan was intended to provide guidance on locations for commercial terminals, recreational marinas and barge fleeting in the corridor, evaluating the effects of barge activities and recreational boating on river sediments and shorelines, evaluating the economic impacts of surface water use, assessing water surface use conflicts, and assessing surface use capacity and the potential for different use zones. Although this plan was considered a high priority for the corridor (National Park Service 1995a), to date little progress has been made toward its completion.

Within the Upper Mississippi River watershed

The area within the MNRRA corridor boundaries occupies less than one percent of its total contributing watershed area. Consequently, although land use management along the MNRRA corridor is important to the park's water resources, land use management in the larger watersheds of the Upper Mississippi, Minnesota, and St. Croix Rivers is equally or more so. The issue of watershed use and management was emphasized by participants at the MNRRA water resources scoping workshop in September 2005, and reflects concerns previously voiced by many agencies and entities. The MNRRA Comprehensive Plan (National Park Service 1995a) and the U.S. Army Corps of Engineers Reconnaissance Study (U.S. Army Corps of Engineers 2001) each recognized a need for comprehensive watershed-based management of the Upper Mississippi River and MNRRA corridor.

Land use in the three major watersheds contributing to MNRRA differs greatly, with the Minnesota River basin dominated by cropland and other agricultural uses, the St. Croix River basin dominated by forests and pasturelands, and the Upper Mississippi River basin composed of mixed forest, agricultural, and urban land uses (Figure 28, Larson et al. 2002).

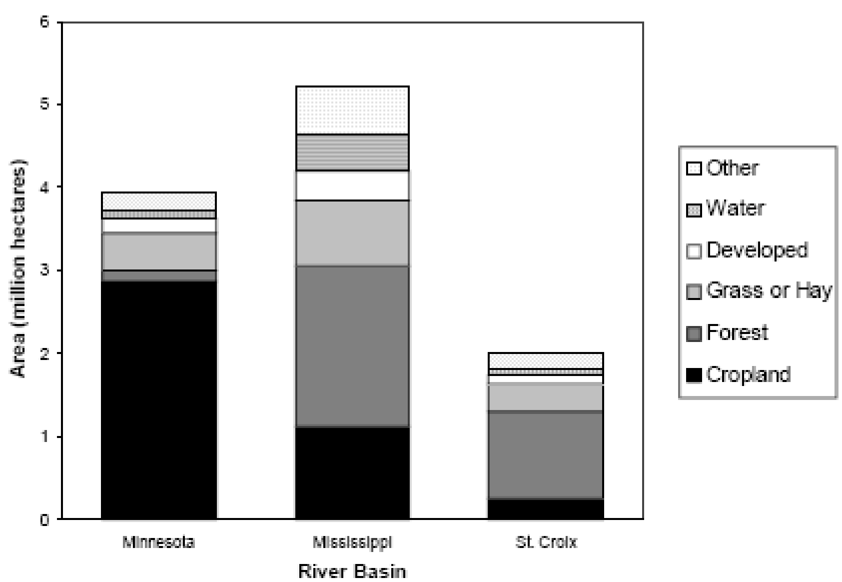

Figure 28. Major land uses and water cover in the Mississippi River Basin upstream of Prescott, Wisconsin, and in the Minnesota and St. Croix River Basins in 1997 (from Larson et al. 2002).

These patterns in land use are closely linked to nutrient and sediment levels in the Mississippi River. In fact, land use appears to be the primary factor influencing nutrients in streams of the NAWQA Upper Mississippi River Basin study unit (Kroening and Stark 1997), with the highest nutrient levels found in streams draining agricultural areas (e.g., the Minnesota River) and the lowest in streams draining forested areas (e.g., the St. Croix River). Land cover and use also affects sediment delivery to streams in the study unit, with the highest suspended sediment concentrations occurring in the Minnesota River due to soil conditions and agricultural activity (Stark 1997), and the lowest in the St. Croix River. Across all three major watersheds, the area of row-cropped land and the application of manure fertilizer has increased since the 1860s and the application of phosphorus fertilizer has increased dramatically since the 1950s (Mulla et al. unpublished manuscript). Significant increases in nutrient and sediment loading to two riverine lakes in these watersheds have accompanied these changes in land use (Engstrom and Almendinger 2000, Triplett et al. 2003).

Efforts are underway to improve land management practices in each of these major watersheds. Two current TMDL studies target land-linked nutrient and sediment issues at MNRRA. A turbidity TMDL study has been initiated for the Minnesota River Basin to reduce its heavy sediment loads and trim its contribution to the Mississippi River and Lake Pepin sediment burdens (Minnesota Pollution Control Agency 2005c). A major eutrophication and turbidity TMDL study underway for Lake Pepin aims to reduce nutrient and sediment loads throughout the Lake Pepin Basin (including the Upper Mississippi, Minnesota, and St. Croix River Basins). In a parallel effort, an interagency team recently proposed reducing St. Croix River phosphorus loads 20 percent by the year 2020 (St. Croix Basin Water Resources Planning Team 2004), recommending improvements in both land management practices and point source management.

Because human land uses are so closely linked to nutrient and sediment issues in the Upper Mississippi River Basin, improvements in land use practices throughout the basin should effectively reduce nutrient and sediment inputs to MNRRA and other receiving waters. On agricultural lands these improvements may include implementing conservation tillage, changing crop residue management, and increasing crop diversity to include pastures or permanent cover crops. On agricultural and other lands, riparian buffers, streambank stabilization, water storage, and other actions may be effective at reducing nutrient and sediment inputs. In urban and developing areas, which are notably abundant in the MNRRA corridor and surrounding areas, erosion control at construction sites and stormwater management will be especially important.

Many entities are involved in watershed planning and management within MNRRA and its contributing watersheds. Within the seven-county Twin Cities Metropolitan Area alone, nearly 20 Joint Powers Watershed Management Organizations and 14 Watershed Districts are in operation, with several other watersheds managed by Scott, Carver, and Dakota Counties (Figure 29). Fourteen of these entities share boundaries with the MNRRA corridor. Other prominent watershed management groups include the St. Croix Basin Water Resources Planning Team, an interagency group working cooperatively on water resources issues in the St. Croix watershed. Advocacy groups, friends groups, and nonprofit organizations in MNRRA contributing watersheds also provide training and outreach related to watershed management. Friends of the Mississippi River, for example, launched its Watershed Initiative in 2003, combining advocacy, land conservation, and public education with a focus on two tributary watersheds in the fast-growing fringes of the Twin Cities Metropolitan Area (the Vermillion River and Rice Creek). The Minnesota River Watershed Alliance, which began meeting in 2005, is another nonprofit group working to communicate the benefits of a healthy watershed to landowners and decision makers.

Enforcement

As described above, standards and best management practices exist for land use and development within the MNRRA corridor and the larger watershed. However, participants at the MNRRA water resources scoping workshop in September 2005 noted that enforcement capacity remained a significant issue. Ensuring compliance with land use rules and permit requirements in a rapidly developing metropolitan area is an ongoing concern.

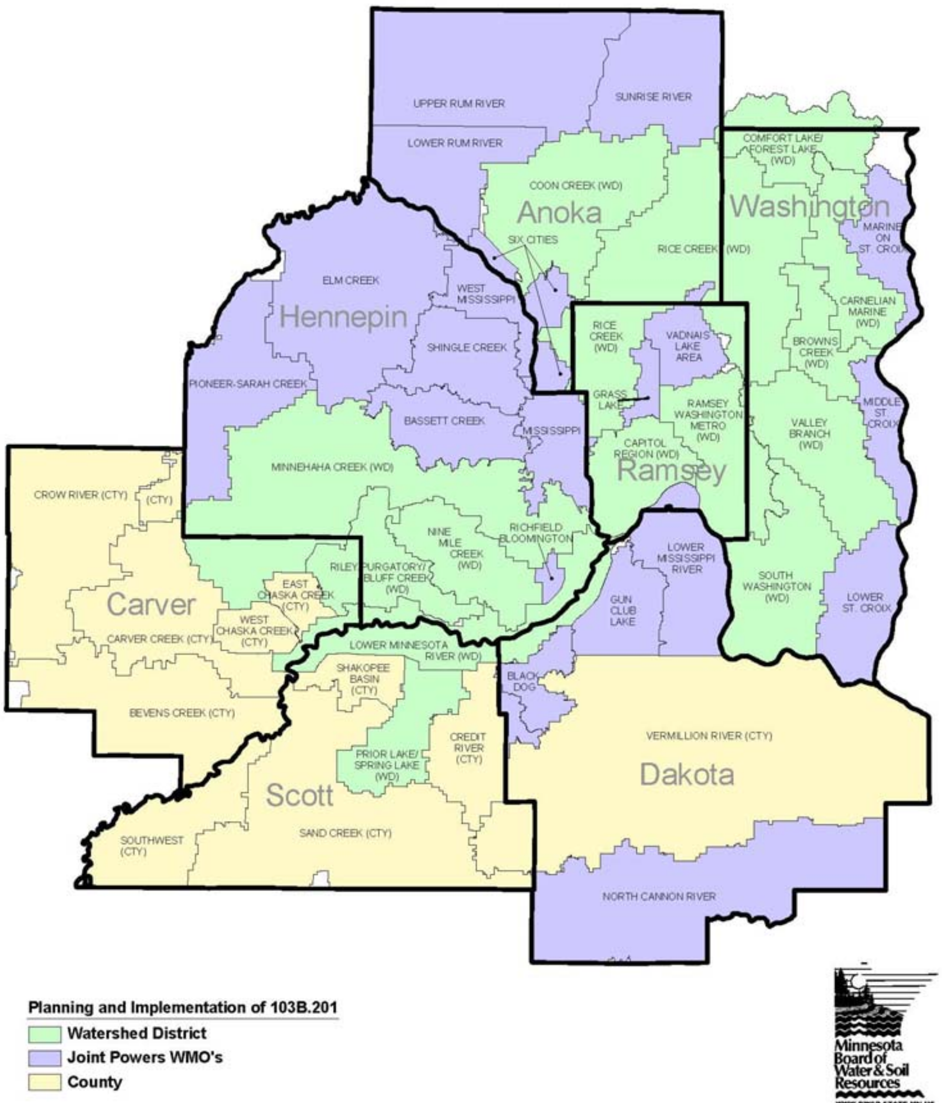

Figure 29. Watershed Management Organizations in the Twin Cities Metropolitan Area (from http://www.bwsr.state.mn.us/relatedlinks/).

Socio-Environmental Issues

Population growth

The MNRRA corridor lies within the Minneapolis-St. Paul metropolitan area, which is projected to experience significant population growth in the next 25 years (Minnesota Department of Administration 2005). This growth is expected to affect MNRRA in several ways. The seven-county metropolitan area under the jurisdiction of the Metropolitan Council is expected to grow 23 percent from 2005 to 2030, adding about 700,000 people to the area's current population of about 3 million. These new regional residents will need places to live, shop, work and recreate. They will consume additional drinking water and will produce additional waste. The population growth will not occur evenly throughout the area, but will tend to concentrate in the "collar" communities on the outer fringes of the Twin Cities Metropolitan area. In addition, the counties immediately outside the traditional seven-county Metropolitan Area will grow rapidly. This includes communities that will discharge wastewater into the Mississippi River immediately upstream of MNRRA.

The City of Ramsey is expected to grow 138 percent in the next 25 years, and the City of Dayton is expected to grow 512 percent. Those two cities abut the upstream limits of MNRRA and the upstream limit of the Metropolitan Council's jurisdiction. The Metropolitan Council provides wastewater treatment facilities for communities within its jurisdiction and at present carries wastewater from Ramsey and Dayton to the Metro Plant 43 mi (69 km) downriver.

The upstream limit of MNRRA is the mouth of the Crow River, and suburban growth near the Crow has already seen it reach its assimilative capacity for wastewater. Three communities that discharge wastewater to the Crow River near its confluence with the Mississippi are Rogers, which is expected to grow 574 percent in 25 years, Rockford, which is expected to grow 56 percent, and St. Michael, which is expected to grow 126 percent.

Also of concern is the rapid population growth along the Interstate 94 corridor between the Twin Cities and St. Cloud. This includes Wright County, which is expected to grow 56 percent, and Sherburne County, which is expected to nearly double from its 2000 population of 63,000 to a 2030 population of 122,000. Communities in the river corridor in these two counties include Becker, which is expected to grow 175 percent, Big Lake (123 percent), Elk River (86 percent), Albertville (142 percent), Monticello (72 percent) and Otsego (96 percent).

In addition to producing wastewater, this growing population in the vicinity of the upstream end of MNRRA will need places to recreate. Local parks along the river can expect significant increases in use, and how these new residents choose to recreate will be determined partly by their age. Residents in their teens and twenties, who often seek out the most active recreational pursuits, will increase in numbers far below the 23 percent increase in total population. The over-60 population, however, will soar. This suggests that perhaps more passive forms of recreation will be in greater demand. It is difficult to generalize about these trends, however, since the Baby Boom generation is proving to be far more physically active after age 50 than preceding generations. It might be safe to predict that there will be an increased demand for walking and biking paths along the river, and for passive activities like bird watching. As the population ages, boat use will likely tend toward larger, marina-based craft, and there may be a demand for an increase in marina slips in the corridor.

<u>Public perceptions of water quality</u>

The public and government agencies often perceive water quality issues differently. While agencies generally have the expertise to interpret data, the public brings a different perspective to information about water quality. It is public perceptions about water quality, right or wrong, that often drive actions by government decision-makers within MNRRA and elsewhere.

Fears about water quality and public health appear to drive public concerns about the Mississippi River in MNRRA. In a 1996 study, the top concern was pesticides in drinking water, cited by 78 percent of survey respondents. Second, at 77 percent, was pollution in the Mississippi affecting drinking water. A general statement about pollution of the river was eighth among respondent concerns, while the loss of fish and wildlife habitat ranked 10th out of 14 total areas of concern (MacWilliams 1996a).

Public understanding about sources of pollution to the Mississippi River appears to lag behind that of the scientific community. Although runoff from farms and cities is the most damaging source of pollution of the Mississippi River, the public first blames industry (35 percent) and sewage from cities and towns (19 percent). Only 9 percent of residents in the Upper Mississippi River region believe that farming is the biggest cause of pollution to the river (MacWilliams 1996b).

Despite significant improvements in Mississippi River water quality in recent decades, the public still believes water quality is bad and getting worse, threatening fish, wildlife, and public health. Eighty-one percent of survey respondents believe water quality is the biggest problem (Lake Research 1995). Similarly, a 2001 study of beach closings in Southern California found that the public's perception of beach water quality is often in disagreement with actual environmental conditions. Typically, a person's initial perception of water quality is based entirely on the aesthetic character of the water and surrounding environment. Aspects such as water color, clarity, odor, and the existence of litter and debris influence a person's opinion of water quality despite the fact that these aesthetic features often have little or no association with the actual physical, chemical, and biological quality of the aquatic system. Compounding these perception problems is the conclusion that 74 percent of local residents obtain their information about beach water quality from the media. The California study found a disparity between media coverage and scientific evidence, and drew the conclusion that the media doesn't always provide balanced information even when they have it (Jensen and McLellan 2005).

When the public is asked about the government's role in water quality issues, they often conclude agencies are not doing enough. In an Alabama survey, most citizens believed the current levels of environmental law enforcement are not strict enough and additional regulations are needed. Residents also concluded that agencies should include local citizen groups in decision-making processes. When respondents were asked why they were not more actively involved with water quality problems in their community, 69 percent said they were not sure where to start and 92 percent thought there should be more opportunities to receive environmental education (LaPrade and Knapp 1993).

<u>Recreation</u>

Recreational use of the MNRRA corridor takes many forms. There are many trails along the river that are used all year, and many people visit the river bank for a variety of recreational pursuits from picnicking to angling to simply relaxing. While many recreational activities have only a limited relationship to water resources, some, such as angling and recreational boating, have a direct connection.

Angling

In the 1960s, dissolved oxygen levels in lower Pool 2 frequently dropped to zero and aquatic life was nonexistent. Improvements in water quality since then, many related to improvements in wastewater treatment at the Metro Plant at Pigs Eye, have resulted in a dramatically improved aquatic ecosystem. Today, the Minnesota Department of Natural Resources manages Pool 2 as a trophy walleye fishery. Anglers have responded to this improvement, and the area downstream of downtown St. Paul gets significant use by boat anglers, even during times of the year when many other water resources in the region are covered with ice. High flows in the area between downtown St. Paul and the Interstate 494 bridge allow boat angling throughout late fall and often into the winter.

Despite the popularity of the MNRRA corridor with anglers, fish consumption advisories remain in effect. Some fish consumption advisories are related to water-borne contaminants, but others (such as PCBs) are related to contaminants that have accumulated in river bottom sediment over the years and are introduced into the environment only episodically, through sediment re-suspension.

Recreational boating

Recreational boating on the Mississippi, like most other areas, was relatively light prior to World War II. Following that war, economic prosperity, increased leisure time and technological advancements led to a rapid growth in recreational boating everywhere, including on the river. Boating use of the river grew dramatically through the 1970s, leveling off in the mid-1980s. Since the mid-1980s there has been little change in total boating numbers, but boats have grown larger and faster. In addition, the introduction of personal watercraft has led to significant use by that craft type.

When the Mississippi River was perceived as polluted, recreational boaters from marinas in Pool 2 usually traveled to the St. Croix River for weekend recreation. With improved water quality on the Mississippi, fewer boaters make that trip through Lock and Dam 2 and up the St. Croix each weekend. Significant recreational boat traffic through Lock and Dam 2 still occurs, however. With increased motorboat use staying in Pool 2, there is increased demand for overnight camping sites in the lower pool, especially between river mile 828 and the Grey Cloud/Spring Lake area. Conflicts between recreational motorboats and commercial navigation have increased somewhat in that area. There is significant rowing activity in upper Pool 2, generally upstream of downtown St. Paul, and conflicts between those users and recreational motorboats have increased.

Upper Pool 3 receives significant power boating activity, especially in the vicinity of the mouth of the St. Croix River. There is also significant traffic between the St. Croix and Pool 2, and between the St. Croix and a casino in lower Pool 3 near Red Wing. Pool 1 sees only modest recreational motorboating since the only access to that reach is through the locks. This pool sees fairly heavy rowing activity and modest canoe use. Above Upper St. Anthony Falls, motorboat activity is limited to the impoundment created by the dam, and again to the impoundment created by the Coon Rapids Dam. There are modest access opportunities to those two river segments and recreational boating is not heavy. In the Dayton/Anoka reach and again between Coon Rapids Dam and north Minneapolis, water levels are generally too low for watercraft other than canoes. There are no canoe rental operations in those areas and canoe use is fairly light.

In the late 1980s and early 1990s, the Minnesota Department of Natural Resources actively pursued construction of boat access points on the river, and access today is considered adequate to meet demand.

Power boating can cause shoreline erosion in some areas on the Mississippi River, but much of Pool 2 (where most of the high-speed boating occurs) is armored with riprap and traffic-related shoreline erosion is not as significant a problem as downriver in the Red Wing area.

<u>Economic drivers</u>

Commercial navigation

The St. Paul area in Pool 2 is the historic head of navigation and remains the northern-most port for the large 15-barge tows that ply the river between the Twin Cities and St. Louis. Seven percent of the nation's grain export leaves the Port of St. Paul each year, much of which is loaded on barges at terminals on the Minnesota River. This makes commercial navigation on the Mississippi River an important part of the region's economy.

While agricultural crops (mostly corn and soybeans) are the primary southbound products, northbound traffic into the Twin Cities includes a variety of products, with fertilizer, cement, coal and crude oil among the most common.

The large 15-barge southbound tows are usually formed at the turning basin near Holman Field in St. Paul, where there is also a nearby barge repair facility. Commercial traffic upriver from that point largely consists of traffic to and from the grain terminals on the lower Minnesota River, and two-barge tows to and from north Minneapolis in the Upper St. Anthony Falls pool. Northbound traffic to Minneapolis includes cement and gravel, while southbound traffic is largely scrap metal.

City planners in Minneapolis would like to close the commercial terminals there and convert the land to parks and housing, but some commercial operations are well established and land use conversion is probably many years away. If commercial traffic ceased in the Upper St. Anthony

Falls pool, the Corps of Engineers would likely consider mothballing lock operations at Lock and Dam 1, Lower St. Anthony Falls and Upper St. Anthony Falls. A modest amount of recreational traffic would likely not justify the cost of continued lock operations. In the St. Paul area, long-range forecasts predict no clear increase or decrease in traffic.

Barge fleeting, which involves long- and short-term parking of barges along the riverbank, occurs in specific areas along the river where pilings have been placed for tying up parked barges. The search for adequate fleeting space is an ongoing issue. One fairly large established fleeting site is located near Pigs Eye Lake, but it quickly fills with sediment and the St. Paul Port Authority, which manages the site, has struggled to find a design that would not involve frequent dredging.

Spills from river barges are a rare occurrence, and spills from trains or trucks into the river is statistically more likely. Truck and train spills can often be contained before impacting the river, however, while a spill from a barge would have a more direct effect on water resources.

Navigation channel maintenance

The U.S. Army Corps of Engineers maintains a nine-foot navigation channel from north Minneapolis to St. Louis. This has been defined as maintaining a channel adequate to handle vessels that draft nine feet, so adequate channel depths are somewhat greater than nine feet. The Corps of Engineers maintains minimum water levels in navigation channels through the operation of its locks and dams, by marking the navigable channel (which is actually done by the Coast Guard), and through periodic maintenance dredging.

The river's bed load accumulates at predictable places on the river, so periodic channel maintenance dredging occurs at certain locations and not others. For every historic dredge cut, the Corps of Engineers and natural resource management agencies, meeting as the River Resource Forum, have agreed on environmentally acceptable dredged material placement sites. Within MNRRA, most of those placement sites are transfer sites and the material is trucked away for construction fill.

Dredged material comes from the main river channel where bed load settlement is almost entirely coarse sand. Since contaminants tend to attach themselves only to fine sediment particles, dredged material from the river channel is generally clean material and of little contaminant concern.

Riverbank economic development

The urban Mississippi River within MNRRA has seen great changes in land use patterns over the decades. For decades, riverfront lands contained housing for the region's newest and poorest immigrants. Conversion of those neighborhoods to heavy industry began early in the 20th Century and was hastened by major flooding events in the early 1950s and late 1960s. By the late 20th Century, industry began closing up and left much riverfront land vacant and contaminated.

The last 15 years have seen a tremendous increase in interest in the Mississippi riverfront as a place to live. The public no longer perceives the river as the open sewer it once was, and the desire to live near water has greatly increased the value of riverfront lands. Residential condominium development on the riverfront in Minneapolis and St. Paul has occurred at a rapid pace, and other riverfront residential development projects have been proposed in the suburbs.

Biological Issues

Despite their intrinsic ecosystem and economic values, aquatic biological resources in the Upper Mississippi River have faced many threats since the area was settled by Europeans. Habitat degradation, deterioration of water quality, contamination by environmental toxins, and introductions of aquatic nuisance species have individually and cumulatively impaired biological resources throughout the Upper Mississippi River. In few reaches of the Mississippi River have these threats been more apparent than within the MNRRA corridor, where as recently as the 1960s aquatic life was largely extirpated due to abysmal water quality conditions (U.S. Environmental Protection Agency 2000). The MNRRA corridor represents an interesting biological case study, one of extreme biological degradation, remarkable biological recovery, and new biological challenges – all within the span of a single century.

Effects of habitat degradation

Land use and hydrologic modifications both within and beyond the MNRRA corridor affect physical aquatic habitat quality in MNRRA. River hydrology has been altered by the construction of the Lock and Dam System and other water control structures on the Mississippi River headwater lakes. Geomorphologic processes have been altered by a combination of hydrologic changes, shoreline modifications, and excess sediment loading. Each of these changes, coupled with water quality degradation and other stressors, affect the integrity of aquatic biota within MNRRA and the greater Mississippi River.

Fish communities of the Upper Mississippi River, for example, are affected by excess sedimentation above locks and dams, altered hydrographs, loss of islands and physical complexity in the floodplain, and structural barriers to migration (U.S. Geological Survey 1999, Fremling 2005). In the region's large rivers, such as the Mississippi, Minnesota, and St. Croix, fish species composition is particularly affected by dispersal barriers, dams, and the urban landscape of the Twin Cities Metropolitan Area (Goldstein et al. 1999, Minnesota Department of Natural Resources 2006). Fish in the MNRRA reach of the Mississippi River tend to be lentic, planktivorous species with relatively high thermal tolerances. In smaller streams of the Twin Cities Metropolitan Area, much of the fish habitat is modified and features little woody debris or cobble (Talmage et al. 1999) and fish-based biotic integrity scores are generally poor (Schmidt and Talmage 2001). Fish communities in these urban streams are affected by a combination of habitat and other factors, such as percent impervious surface, water chemistry, temperature, geomorphology, substrate, habitat, and migration barriers (Schmidt and Talmage 2001).

The Mississippi River downstream of the MNRRA corridor and stream sites across the larger Upper Mississippi River NAWQA study unit also show strong relationships between fish and habitat quality. Agricultural streams, affected by excess nutrients, increased temperature from loss of shade, habitat modifications due to stream channelization, and hydrologic modifications from dams and drain tiles, tend to support an assemblage of invertivores (Goldstein et al. 1999). In forested streams, fish assemblages tend to contain fewer species, mainly invertivores and carnivores requiring cold clear water and cobble or boulder substrates. Urban streams in the area contain many lentic fish species tolerant of silt, low dissolved oxygen, and marginal habitats (Goldstein et al. 1999). Many other studies have investigated how fish assemblages and spatial patterns relate to habitat and habitat alteration in the Mississippi River downstream of MNRRA (Holland-Bartels and Duval 1988, Johnson and Jennings 1998, Koel 2004). In addition to indirect effects of the lock and dam system on fish habitat, commercial navigation may directly affect fish assemblages through effects of barge passage on the distribution of fish eggs and larval forms (Holland 1986).

Changes in water quality, habitat, and hydrology have also affected aquatic and wetland vegetation in the Upper Mississippi River (U.S. Geological Survey 1999). In the lower reaches of the MNRRA corridor, aquatic vegetation has been affected by high sedimentation rates (which homogenize substrate diversity) and high suspended sediment concentrations (which reduce water clarity and light penetration). Since the 1890s, the area covered by floodplain, wetland, and aquatic vegetation has declined dramatically in Mississippi River pools, particularly in the open-water impounded areas just upstream from Locks and Dams (McGuiness 2001). In 2003, an ad hoc Vegetation Technical Committee of the Upper Mississippi River Conservation Committee noted that the quality of aquatic vegetation in Pools 2 through 4 was poor in comparison with Pools 5 through 8.

Freshwater mussels are among the most endangered groups of North American animals, and in the Upper Mississippi River system mussels are affected by commercial harvest, water quality degradation, habitat loss, and the zebra mussel invasion (U.S. Geological Survey 1999). Historically, 51 species of freshwater mussels have been documented in the Upper Mississippi River system. Within the last 35 years, however, only 44 freshwater mussel species have been documented, and most of these are listed as endangered, threatened, or species of special concern at the federal or state levels (Havlik and Sauer 2000). Much of the lost species richness has been linked to habitat changes resulting from construction of the Lock and Dam system, particularly in the pooled portions upstream of dams, where declines in habitat diversity have been most severe (Havlik and Sauer 2000).

<u>Effects of poor water quality</u>

Water quality at MNRRA is strongly linked to land use change in the contributing watersheds as well as point source contributions within the corridor. Prominent concerns for aquatic biota include high loads of sediments and nutrients, low transparency, and the presence of bioaccumulative and/or hormone-disrupting contaminants. Within MNRRA, Pool 2 has been especially impacted by changes in water quality over time, due to the discharge from the large Metro Plant and the influence of the sediment- and nutrient-laden Minnesota River. For decades, the pool supported little aquatic life.

As wastewater treatment improved, so did water quality within MNRRA. Monitoring data indicate notable reductions in phosphorus and ammonia concentrations, reductions in biological oxygen demand, and increases in oxygen levels in recent decades. Concurrent with these water quality improvements are promising signs of biological recovery in Pool 2. River-wide, benthic invertebrate densities appear to have declined in comparison with records from earlier in the 1900s, but mayfly abundance in Pools 2-4 has begun to recover downstream of the Twin Cities Metropolitan Area (Fremling 1989, U.S. Geological Survey 1999). Electrofishing efforts near wastewater discharges in St. Paul in 1981, 1986, and 1991 showed an increase in fish species richness and the abundance of certain fish species over time, as well as improved Index of Biological Integrity scores (U.S. Environmental Protection Agency 2000).

Some biological concerns related to water quality linger. For example, populations of fingernail clams have declined significantly between historic and more recent records from the Upper Mississippi River, including sites in Pool 2 within MNRRA. Wilson et al. (1995) suggested that these declines are caused by toxic conditions at the water-sediment interface (due to metals and ammonia) although no toxicity tests were conducted. Further, many organisms within MNRRA are threatened by persistent and emerging contaminant issues, discussed below.

<u>Effects of contaminants</u>

Persistent bioaccumulative toxins continue to render the fish unsuitable for human consumption, and may threaten populations of fish-eating birds. Although PCB levels and trace element concentrations have declined in water and bed sediments from 1985-1995 (Anderson and Perry 1999), PCB levels in walleye and common carp (*Cyprinus carpio*) from the Twin Cities area are still among the highest in the Upper Mississippi River (Lee and Anderson 1998), and trace elements in streambed sediments and fish livers appear to be highest at urban sites near MNRRA (Kroening et al. 2000). Fish consumption advisories exist throughout MNRRA for both PCBs and mercury.

Additionally, recent research has suggested a troubling trend of fish feminization in response to hormonally active wastewater compounds. In 1995, male common carp from a Metro Plant effluent channel were found to have elevated serum egg protein (vitellogenin) concentrations, suggesting the presence of hormonally-active chemicals (Folmar et al. 1996). Follow-up sampling revealed similar patterns in male walleye from the same effluent site (Folmar et al. 2001), but an experimental study reported mixed effects of exposing goldfish to Metro Plant sewage effluent (Schoenfuss et al. 2002). Despite some uncertainty about the biological implications, it is clear that endocrine-disrupting organic wastewater contaminants are widespread in Minnesota surface waters (Lee et al. 2004) and a matter of growing concern.

Effects of aquatic invasive species

The effects of chemical pollution have received a good deal of attention within the MNRRA corridor; however, biological pollutants such as aquatic invasive species have emerged as management priorities relatively recently. In 1991, the Minnesota Legislature directed the Minnesota Department of Natural Resources to establish an Invasive Species Program and to monitor and manage aquatic invasive species. The Program's primary goals involve prevention of new introductions to Minnesota waters, prevention of their spread within Minnesota, and management of their adverse ecological, societal, and economic impacts. On a larger scale, in 2001 the National Aquatic Nuisance Species Task Force invited an existing Mississippi River interstate entity to develop a Mississippi River Basin Panel (MRBP) on Aquatic Nuisance Species and prepare an organizational strategy for such a panel. The current MRBP joins other panels for the Great Lakes, Western States, Gulf of Mexico, and Northeastern States in forming a national network for aquatic nuisance species activities. In addition to its executive board, MRBP has formed several committees to address aspects of aquatic nuisance species in the Mississippi River basin; these include education/communication, research and risk assessment, and prevention and control.

Of the Upper Mississippi River's aquatic invasive species, the zebra mussel is perhaps its most notorious. Since their arrival in North America, zebra mussels have infested hard surfaces throughout the Great Lakes and Upper Mississippi River basins, harming native filter-feeding organisms, particularly freshwater mussels (Schloesser et al. 1996), altering ecosystem structure and function (Ludyanskiy et al. 1993), and causing an estimated $5 billion in damage to power plant and water treatment facility intake pipes (Lovell and Stone 2005). Transported via artificial waterway connections with Lake Michigan, the zebra mussel was first documented in the Mississippi River in 1991 and has become well established upstream through Pool 3 of the Mississippi River and the Lower St. Croix River (Figure 30). A recent survey of mussel fauna in the MNRRA corridor found low zebra mussel densities in Pools 2 and 3 of MNRRA, and no individuals in Pool 1 or the lower St. Anthony Falls Pool (Kelner and Davis 2002). The authors noted, however, that zebra mussels were likely present in Pool 1 and had been observed by the U.S. Army Corps of Engineers within the lock chambers at St. Anthony Falls. Although upstream transport of zebra mussels into MNRRA has been slow relative to other areas on the Upper Mississippi River, the 2005 discovery of zebra mussels in a Mississippi backwater lake north of the Twin Cities has elevated concerns about upstream source populations.

Several species of Asian carp, while not currently known from the MNRRA corridor, represent a fast-emerging invasive species issue in the greater Mississippi River basin (i.e., the grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molotrix*) and bighead carp (*H. nobilis*)). These voracious eaters were imported from Asia in the 1960s and 1970s to control aquatic vegetation and improve water quality in aquaculture ponds. They subsequently escaped or were deliberately introduced to the Upper Mississippi River system (Koel et al. 2000), and have spread rapidly in the Mississippi, Illinois, and Missouri Rivers. Although the most impressive numbers of these species currently occur well downstream of the MNRRA corridor, isolated catches have caused concern. In 2004, a bighead carp was caught in Lake Pepin, and in 2006, a grass carp individual was documented as far north as the Lower St. Croix River. Within only ten years of their first detection in the Missouri, Mississippi, and Illinois Rivers, the bighead and silver carp have come to dominate the fishery in some areas of the watershed.

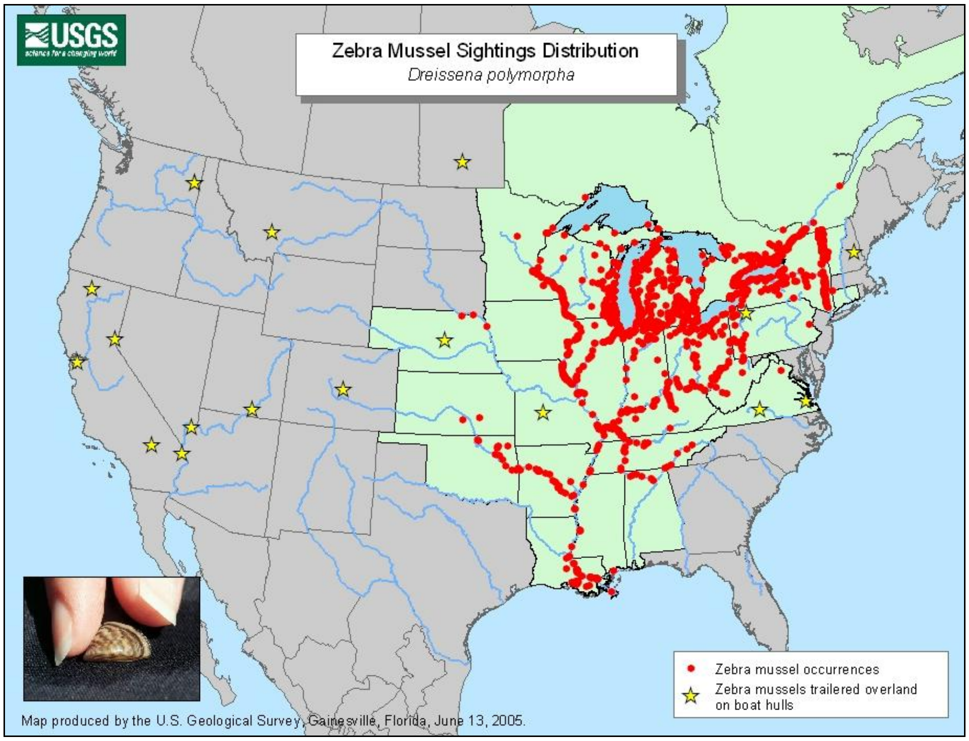

Figure 30. Zebra mussel distribution across North America in 2005, with sites in the MNRRA corridor (from U.S. Geological Survey, http://nas.er.usgs.gov/taxgroup/mollusks/zebramussel/).

The abundance of these carp constitutes a threat to river ecology and a nuisance to anglers, recreational users, and the commercial fishing industry. They consume enormous amounts of biomass, reproduce quickly, and grow to startling sizes, reaching 100 lbs (45 kg) in weight and 4 ft (1.2 m) in length. In other countries where the carp have been introduced, they have caused declines in planktivorous native fishes, with which they directly compete (Kolar et al. 2005). Other filter feeding species reliant on plankton, such as freshwater mussels, are likely also affected. Silver carp startle easily, and respond to boat motors and electrofishing devices by jumping out of the water and occasionally striking boat passengers. Their high abundances also foul nets and foil commercial fishing ventures on the invaded rivers.

Preventing the spread of these carp upstream in the Mississippi River or into the Great Lakes basin is a high priority for river managers, and potential dispersal barriers are under consideration. A major electrical barrier has been constructed on the Chicago Sanitary and Ship Canal to prevent upstream passage of the carp into the Great Lakes. On the Upper Mississippi River, various deterrents are being considered, including an electrical barrier, sonic bubble curtains, and pheromones. None has yet been implemented. In August 2006, an Asian carp symposium, co-sponsored by many science, conservation, and management entities, addressed issues of Asian carp prevention, containment, control, and impact management.

Invasive plant species in aquatic, floodplain, and riparian habitats also threaten biological integrity in the MNRRA corridor. The Minnesota Department of Natural Resources (1999a) documented several invasive plants on the floodplain islands managed by MNRRA, including the wetland plants purple loosestrife (*Lythrum salicaria*) and reed canary grass (*Phalaris arundinacea*) and the riparian forest shrubs European buckthorn (*Rhamnus cathartica*) and Tartarian honeysuckle (*Lonicera tartarica*). These species were also documented in a recent ecological inventory for Crosby Farm Regional Park, within MNRRA (Harris et al. 2005). Many of the recommended restoration efforts for the Crosby Farm area involve removal and control of invasive plant species, particularly buckthorn, reed canary grass, and the narrow leaf cattail (*Typha angustifolia*). In a broader survey throughout the MNRRA corridor, Larson and Larson (2005) noted that floodplain forests in MNRRA were particularly affected by garlic mustard (*Alliaria petiolata*), honeysuckle, reed canary grass, and buckthorn, and that many of the sampled areas featured adult buckthorn age classes. In floodplain forests at Fort Snelling, garlic mustard seedling cover was sizeable (26 percent).

Effects of River Alteration

Humans have had a long-standing presence in the Upper Mississippi River basin, but it was not until the past 150 years that their influence has become a dominant factor affecting river processes and biota. By the early 1800s, European immigrants had begun to use the river for transportation and commerce, with the first self-propelled watercraft entering the Upper Mississippi in 1823 (U.S. Geological Survey 1999). In the mid-1800s, the U.S. Army Corps of Engineers began a long series of navigation improvements, blasting channels through the Des Moines and Rock Island Rapids and clearing snags and hazards. Further improvements followed in 1866, with the construction of a 4-foot channel, in 1878, with construction of a 4.5-foot channel, and in 1907, with plans to construct a 6-foot channel. The current 9-foot navigation channel was authorized in 1930, resulting in the construction of 29 locks and dams on the Mississippi River from Minneapolis, Minnesota to St. Louis, Missouri by the 1960s. Above the Twin Cities, six dams were constructed on Mississippi River headwaters lakes by 1911, in order to augment Mississippi River flows for downstream navigation and hydropower generation (U.S. Army Corps of Engineers 2001), and the Coon Rapids Dam was constructed at river mile 866.2. Further alterations included the 1900 completion of the Chicago Sanitary and Ship Canal between Lake Michigan and the Illinois River, which permanently connected two of the continent's great drainage basins, and the construction of a vast system of levees.

Although these activities have undoubtedly improved conditions for commercial navigation, they have not been without environmental consequences. Many of these consequences have been discussed in other issue reviews (see above) and receive only general treatment in this section.

<u>Hydrologic effects</u>

Construction of the lock and dam system, the levee system, and a series of headwater dams has interrupted natural hydrologic features and processes in the Upper Mississippi River. The lock and dams have converted the free-flowing river to a series of 29 slackwater pools (McGuiness 2001). The navigation dams hold back sufficient water to maintain a nine-foot minimum depth for navigation, which generally results in higher than natural water levels and lower than natural flow variability during the ice-free navigation season. These effects are most pronounced in the lower portions of the navigation pools, where high water levels, slow current velocities, and complete inundation of backwater areas are common. By permanently inundating many bottomlands, the lock and dam system has also eliminated periodic low water levels and altered the extent of land flooded seasonally, a phenomenon implicated in loss of aquatic vegetation in Pool 2 and throughout the Upper Mississippi River (River Resources Forum 2004). The construction of levees, conversely, has removed large portions of the floodplain from contact with normal high waters and reduced flood storage capacity (U.S. Geological Survey 1999). Finally, headwater reservoir dam operations in north-central Minnesota have altered downstream Mississippi River hydrology, causing occasional water deficits in the MNRRA reach.

<u>Geomorphologic effects</u>

By the early 1900s, geomorphic features and processes had already been greatly affected by river alterations (U.S. Geological Survey 1999). Construction of closing structures had isolated side channels and backwaters from the main channel, and construction of wing dams had resulted in increased scouring in some channels and excess sedimentation in others. Dredging operations generate mountains of sand and dredged material, which have been placed in shallow areas and created border islands in some reaches. Backwaters have gradually accumulated fine sediments, particularly upstream of navigation dams, and islands have been lost due to wind- and boat-generated wave action. Within MNRRA, substantial sediment has been trapped above Lock and Dams 1 and 2 (River Resources Forum 2004), and one of the few floodplain islands managed by the National Park Service since 1988 has disappeared. Other geomorphologic changes on the Upper Mississippi River include shoreline development, which is particularly evident in the North Minneapolis and downtown St. Paul reaches of the MNRRA corridor, and floodplain filling, evident in the downtown St. Paul reach of the MNRRA corridor in the Holman Field area (River Resources Forum 2004). Due to such development, the MNRRA corridor from river mile 841 to river mile 836 represents one of the largest gaps in riparian habitat upstream of St. Louis, Missouri (River Resources Forum 2004).

<u>Biological effects</u>

Collectively, these hydrologic and geomorphologic alterations have served to reduce the diversity of habitats, alter patterns of fish passage, and facilitate transport of aquatic invasive species (U.S. Geological Survey 1999). Patterns of habitat degradation have included loss of critical islands, homogenization of bottom sediments and substrates, loss of channel diversity, and loss of aquatic vegetation and riparian habitat. Effects of the navigation system on fish passage are apparent throughout the Upper Mississippi River drainage, including the MNRRA corridor. Within MNRRA, a significant natural barrier to fish passage was overcome with the construction of the St. Anthony Falls Locks and Dams. Major barriers to fish passage now exist at the Coon Rapids Dam and at Lock and Dam 2, where the gates blocking fish movement are rarely raised (River Resources Forum 2004). Finally, commercial navigation and the infrastructure of locks, dams, and canals have facilitated the introduction and transport of aquatic invasive species. The zebra mussel, for example, readily invaded the Mississippi River because of its artificial connection with infested Lake Michigan waters (via the Illinois River), and spread rapidly upriver via commercial barges and other boat traffic.

Ecosystem Restoration and Understanding

The Upper Mississippi River System is nationally recognized as both an economic mainstay and a natural resource treasure. Although few are willing to sacrifice either of these ecosystem services, management agencies have become increasingly aware of the trade-offs between them. Ensuring sustainability of all of these desired attributes has been suggested as a long-term management goal for the Upper Mississippi River (Lubinski and Barko 2003). However, because many of the Upper Mississippi River's ecological functions are substantially degraded, ensuring their sustainability will require dedicated restoration efforts. Over the past two decades, the Upper Mississippi River System Environmental Management Program (EMP) has played an important role in river restoration, completing projects in tens of thousands of acres of aquatic and floodplain habitats. The continuing need for ecosystem restoration efforts was recognized in a recent Upper Mississippi River navigation feasibility study, in which a comprehensive program of both navigation improvements and ecosystem restoration actions was proposed (U.S. Army Corps of Engineers 2004a). Pool-specific restoration actions have been proposed in the Environmental Pool Plans document (River Resources Forum 2004).

<u>Whole-system restoration efforts</u>

Many tools have been considered for restoration projects in the Upper Mississippi River. The recent navigation feasibility study (U.S. Army Corps of Engineers 2004a) recommends a group of large-scale, construction-oriented options for ecosystem restoration, including island building, island protection, shoreline protection, fish passage improvements, floodplain restoration, water level management in pools and backwaters, backwater restoration via dredging, side channel restoration, wing dam/dike alteration, improvements to topographic diversity, and dam point control. Since its inception, the EMP program has completed many such projects on the Upper Mississippi River, including twenty-one projects above Lock and Dam 10 alone. No EMP project has been initiated within the MNRRA corridor to date, although restoration opportunities exist in Pools 1-3.

The River Resources Forum (2004) identified specific restoration needs for Pools 1-10, although it never adopted a restoration plan for Pool 1 because potential actions would negatively impact commercial navigation and hydropower operations. For Pools 2 and 3, the Forum recommended restoring depth diversity in channels and backwaters, protecting and restoring islands, restoring previously filled floodplain areas, managing water levels to improve aquatic vegetation, and restoring connectivity with side channels and backwaters to increase habitat diversity and improve fish passage. Supporting watershed management programs, reducing sources of water pollution, and eliminating exotic species were also listed as high priorities for restoration efforts within Pools 1-3.

Upstream of MNRRA, the U.S. Army Corps of Engineers is reviewing options to improve operations on the headwater dams. The study, known as the Reservoir Operating Plan Evaluation (ROPE) involves public input and an intensive reservoir system modeling effort. It may result in lake level changes, more natural flow releases for downstream river reaches, and restoration efforts in sections of the river system.

Targeted restoration efforts

To date, most biological restoration efforts on the Upper Mississippi River have been constructed under the Upper Mississippi River System Environmental Management Program (EMP). Since EMP projects within the National Wildlife Refuge system are 100 percent federally funded but must have a non-federal cost-share outside the refuge system, and because the Minnesota DNR has not acquired funds for cost-sharing projects, no restoration projects have been constructed within MNRRA. Participants in the September 2005 MNRRA water resources scoping workshop, however, noted a high potential for restoration of native biota within the MNRRA corridor. Currently, several efforts are aimed at 1) restoring remaining native plant communities in floodplain and riparian areas and 2) restoring rare and/or endangered fauna.

Many management agencies, municipalities, and conservation organizations are working to restore native vegetation within the Twin Cities Metropolitan Area, often through the removal of invasive plants. These activities frequently target bluff, riparian, and floodplain areas within MNRRA. Great River Greening, a nonprofit organization, is particularly active in area restoration activities. The organization works to restore natural areas and open spaces in the Mississippi, Minnesota, and St. Croix River basins, with an emphasis on native plantings and removal of invasive plants.

Reestablishing lost areas of aquatic vegetation has also become an important management focus in the Upper Mississippi River. The River Resources Forum (2004) noted that restoring periodic low water levels may help consolidate deposited sediments and stimulate recolonization of former marsh and aquatic plant communities. Beginning in summer 2001, the U.S. Army Corp of Engineers initiated a multi-year drawdown experiment on Pool 8, reducing pool water levels by over a foot and exposing 2,000 acres (809 ha) of bottomlands (http://www.umesc.usgs.gov/aquatic/drawdown_p8_veg.html). The experimental drawdowns effectively increased plant density, particularly on substrates exposed for a good portion of the growing season. A similar drawdown was conducted on Pool 5 in summer 2005, and drawdowns for other reaches of the Mississippi River, including Pool 2 in MNRRA, have been proposed. The River Resources Forum (2004) noted that lower water levels in Pool 2 could expose considerable areas of river bottom in the Grey Cloud Island area, the open areas across from Nininger, and the Spring Lake area.

Restoration targeting aquatic fauna has been more limited within MNRRA. The most prominent restoration activities at MNRRA have centered on the federally endangered Higgins' eye mussel. Found at MNRRA only as empty shells, the Higgins' eye mussel has commanded the attention of many management agencies for the past two decades. In the early 1980s, a recovery plan for the Higgins' eye was published, including lists of recovery criteria and essential habitat areas (Stern et al. 1982). The plan was subsequently revised and updated, in response to the zebra mussel invasion and the flood of 1993 (Hornbach et al. 1998). Most recently, the U.S. Fish and Wildlife Service (2004) issued a second revision of the Higgins' eye recovery plan, re-emphasizing the zebra mussel threat. Responses to other threats, including construction activities, contaminants, and poor water quality, were also outlined. The U.S. Fish and Wildlife Service and its partners continue to work toward Higgins' eye recovery in the Upper Mississippi River, developing artificial propagation techniques for use in restoration efforts and relocating cultured mussels to sites with few zebra mussels, including sites within MNRRA in Pools 1, 2, and 3 (Davis 2003).

The paddlefish, once abundant in the Mississippi River from Lake Pepin southward, has suffered impacts from poor water quality, commercial navigation projects, and over-fishing, and is currently listed as a state-threatened species in both Minnesota and Wisconsin. Since 1990, paddlefish have been reported sporadically from sites in the MNRRA corridor below Lock and Dam 1. However, a tailwaters survey at Lock and Dams 1-3 in 2000 documented paddlefish only below Lock and Dam 3 (Schmidt 2004). Recommendations for paddlefish restoration in the area include rearing and stocking programs, which have been successful for paddlefish in other states, construction of a passage channel at Lock and Dam 3 to improve paddlefish access to deep backwater habitats in Pool 3, and cooperative study and survey partnerships with the Minnesota and Wisconsin Departments of Natural Resources, the U.S. Fish and Wildlife Service's La Crosse Fisheries Resource Office, the U.S. Geological Survey, and regional universities (Schmidt 2004).

More general restoration efforts for fish and fish-dependent mussel fauna include improvements to fish passage. Ickes (2000) noted that several threatened or endangered fish of the Upper Mississippi River are likely affected by low-head Locks and Dams, including pallid sturgeon (*Scaphirhynchus albus*), lake sturgeon, paddlefish, skipjack herring (*Alosa chrysochloris*), blue sucker, goldeye (*Hiodon alosoides*), black redhorse (*Moxostoma duquesnei*), and yellow bass. In a survey of Upper Mississippi River fisheries experts, respondents felt that restricted passage had altered the geographic range, diversity, and community structure of area fish, and, consequently, native freshwater mussel fauna (Ickes 2000). The same respondents felt that improved fish passage was a very important aspect of ecosystem restoration, and emphasized that the amount of critical habitat in neighboring pools and the benefits to threatened and endangered species should be considered in prioritizing fish passage improvements. Alternatives for improving fish passage between Pools 2 and 3 are under investigation, including construction of a connecting channel on the northeast side of Lock and Dam 2 and removal of a closing dam at the inlet to the Vermillion River Bottoms (River Resources Forum 2004).

Other restoration efforts target the continuing habitat needs of migratory waterfowl and aquatic wildlife. Many entities are engaged in riparian restoration projects within the MNRRA corridor and its tributaries, and larger scale floodplain and island habitat restoration projects are also under consideration (River Resources Forum 2004).

<u>Information and understanding</u>

Data gathering and synthesis efforts have gained momentum on the Upper Mississippi River over the last two to three decades. Three major initiatives merit some mention here. First, since the late 1970s the Metropolitan Council has regularly monitored surface water quality in rivers, streams, lakes, and wastewater treatment plant outflows throughout the Twin Cities Metropolitan Area. The Council's long-term monitoring sites include seven on the Mississippi River within MNRRA; these records are important for evaluating local water quality trends and patterns. Second, the Long Term Resource Monitoring Program (LTRMP), authorized as part of the Water

Resources Development Act of 1986, aims to improve understanding of the Upper Mississippi River system, determine resource trends and impacts, develop management alternatives, and manage information. Program staff routinely collect data on water quality, fisheries, macroinvertebrates, and vegetation at sites throughout the Upper Mississippi River, and provide important data summary and synthesis documents (see, for example, U.S. Geological Survey 1999). Of the six LTRMP field stations, however, the one nearest MNRRA is located downstream of the park in Lake City, Minnesota. No LTRMP monitoring takes place within the MNRRA corridor. Last, in 1994 the NAWQA program established a study unit that stretches from the Mississippi headwaters at Lake Itasca to the outlet of Lake Pepin, encompassing the entire MNRRA corridor and its contributing watersheds. The NAWQA efforts should contribute greatly to managers' understanding of surface and ground water quality patterns throughout the study area and within MNRRA.

In spite of these important programs and accomplishments, participants at the 2005 MNRRA Water Resources Scoping Workshop emphasized that much remains to be learned about the Upper Mississippi River in general, and the MNRRA corridor in particular. Within MNRRA, already complex large river processes interact with major tributary inputs and a wide range of human influences, yet ecological research and modeling efforts for this reach of river lag behind those of other Upper Mississippi River pools. Additionally, good baseline data are unavailable for many groups of aquatic biota.

Interagency and Partnerships Coordination

It is clear from the above review that the MNRRA corridor faces a number of complex and inter-related water resource issues. Equally evident is that these issues are tended to by many water management organizations with overlapping and/or fragmented jurisdictions and a range of water resource management objectives (refer to Legislation, Management and Coordination of Water Resources in MNRRA, see Management Agencies).

At the local level, townships, municipalities, and counties play a role in land management through park development and land and water use decisions, along with Watershed Management Organizations and Soil and Water Conservation Districts. The Metropolitan Council plays an important part in regional water resources management, while prominent state water resource agencies include the Minnesota Pollution Control Agency, the Minnesota Department of Natural Resources, the Minnesota Department of Agriculture, the Minnesota Board of Water and Soil Resources, the Minnesota Department of Health, and the Minnesota Environmental Quality Board At the federal level, several additional agencies contribute to MNRRA water resource management. The U.S. Army Corps of Engineers is actively involved in the MNRRA corridor, with the U.S. Fish and Wildlife Service and the U.S. Environmental Protection Agency also serving important management roles. The Federal Energy Regulatory Commission has jurisdiction over some hydroelectric power facilities that are located on or upstream of MNRRA, and the U.S. Geological Survey plays an important role in local research and science.

The National Park Service entered this mix relatively recently, with the establishment of the MNRRA park unit in 1988. MNRRA has little direct management or regulatory authority within the corridor, but is mandated to review all federally funded or federally permitted activities in the corridor, and to work in partnership with municipalities, counties, state and federal agencies, nonprofit organizations, commercial interests, and individuals to achieve land use and resource protection goals. Due to its relatively recent establishment and its complex management directives, the park's role in water resources management is still developing and has remained somewhat unclear to partners.

Currently, the primary water resource activities of MNRRA staff involve reviewing permit applications related to structural developments and pollution discharges and consulting with other agencies and entities on environmental concerns. In general, however, the involvement of

MNRRA staff in the corridor's natural resource management activities has been limited. This minimal level of involvement indicates not a lack of support for water resources management in the corridor but rather a lack of sufficient staffing. MNRRA staff and water resources scoping workshop participants noted that MNRRA does not have an individual staff member dedicated to water resources issues and their management.

Potential changes in the coordination of river resource management and a significant increase in ecosystem restoration funding are on the horizon. In 2004, the U.S. Army Corps of Engineers completed a major study evaluating long-term needs for navigation improvement and ecological restoration in the Upper Mississippi River-Illinois Waterway System. The study recommended a comprehensive program of navigation and ecosystem improvements now known as the Navigation and Ecosystem Sustainability Program (NESP).

The U.S. House of Representatives (in July 2005) and the U.S. Senate (in July 2006) have approved authorization of NESP, which would include $1.58 billion over 15 years for ecosystem restoration work in the river between Minneapolis and the mouth of the Ohio River. Some of that work would occur within MNRRA. In fall of 2006, a conference committee was working on resolving minor differences in the House and Senate versions of the bill.

NESP would also lead to creation of a River Manager's Council made up of representatives of nine federal agencies, five states and nongovernmental organizations representing environmental, navigation, levee district, recreation and agricultural interests. This council would establish broad goals for managing the river system and prioritize ecosystem restoration projects.

Summary of Issues from Scoping Meeting

At the September 2005 MNRRA water resources scoping workshop, meeting participants helped prioritize the above water resource issues through voting and ranking exercises (Appendix A). First, participants were asked to rate the importance of addressing each issue *category*, on a scale of 1-10. Secondly, participants were asked to vote for *individual issues*, across all categories, that they felt were the top five most important to address in the MNRRA corridor. Thirdly, participants were asked to respond to questions concerning the difficulty or complexity of addressing each issue.

Water Quality, Land and Water Use and Regulation, and Biological Issues were rated as highly important in the MNRRA corridor, with many participants giving these issues a rating of nine or ten (Appendix A). Interagency and Partnerships Coordination was also rated high, with no participant giving it a rating of less than five. Participant opinion varied with respect to the remaining issue categories.

Across the more than 80 identified issues, the 11 highest ranking included water quality (13 votes), watershed management (11 votes), urban/suburban development (10 votes), land and water use and regulation (9 votes), restoration of native biota (9 votes), altered hydrologic regimes (8 votes), stormwater issues (7 votes), fragmented water management jurisdiction (7 votes), land use change in watershed (6 votes), need for a water-based NPS coordinator position (6 votes), and population growth (6 votes). A high proportion of the total votes fell to issues within the Water Quality and Land and Water Use and Regulation categories (35 and 32 votes, respectively, Appendix A).

Participants evaluated the difficulty or complexity of addressing each issue category by responding to a series of questions with a rating of 1-5. In general, a rating of 1 indicates the issue is relatively easy to address and 5 indicates it is very difficult (Table 13).

Results of this exercise were summarized across groups for presentation here (Table 14). In general, all of the issue categories were on the agenda of the agencies concerned. Water Quality and Quantity, in particular, were at the forefront, with Economic Impacts and Analysis receiving less agency attention. Participants concluded that nearly all issues were already confronting managers, or would within the next two to four years. All of the issues received high difficulty/complexity ratings for broadness of impact and number of government entities affected; participants noted that each issue affected many jurisdictions at many scales, and that in most cases six or more government entities would need to be involved in issue resolution. With respect to financial risks and opportunities, participants felt that risks and opportunities were very high for most issue categories; however, they noted that improving Interagency Partnerships and Coordination was relatively easier and less costly. Across issue categories, participants felt that the best approach for resolution was sometimes moderately well known but many cases unknown or disputed.

All of the issues were thought to have significant environmental consequences and possible high financial costs if left unaddressed, particularly Water Quality, Land and Water Use and Regulation, Biological Issues, and Water Quantity. Consequences of these issues for the general public, however, were thought to be more variable, with Water Quality, Land and Water Use and Regulation, and Water Quantity rated as most important to the public. The relative sensitivity of each issue varied. Participants noted that Ecosystem Restoration and Understanding issues were unlikely to be controversial, whereas issues of Water Quality and Land and Water Use and Regulation were more contentious.

In general, the results of this rating exercise suggest that all of the issue categories discussed at the scoping workshop are important, imminent, and part of the appropriate agencies' agendas. On the other hand, the water resource issues rated as most important in the MNRRA corridor (e.g., Water Quality and Land and Water Use and Regulation) are also among the most politically sensitive, complex, and difficult to address, presenting a lasting challenge to corridor managers.

Table 13. Questions posed to participants at the September 2005 water resources scoping workshop, concerning the difficulty/complexity of addressing key water resources issues within the MNRRA corridor.

1. **Is the issue on the agenda of the agencies and organizations who can take action?**
   [1=definitely, 5=definitely not]
2. **When will the issue come to a head?**
   [1=within 6 months, 2=1 year, 3=2 to 4 years, 4=5 to10 years, and 5=>10 years from now]
3. **How broad an impact will the issue have on agencies/organizations?**
   [1=one jurisdiction or organization, 5=many jurisdictions at many scales]
4. **How many government entities are affected by this issue and must be involved in its resolution?**
   [1=one government entity, 2=2 to 3 entities, 3=4 entities, 4=5-6 entities, 5=6 or more entities]
5. **How large is the financial risk/opportunity?**
   [1=minor, 3=moderate, 5=major]
6. **How apparent is the best approach for issue resolution?**
   [1=obvious, ready to implement, 3=broad parameters, few details, straightforward resolution, 5=wide open, unknown, or disputed]
7. **What are the probable resource consequences of not addressing this issue?**
   [1=low, 2=moderate, 3=some environmental detriment, some financial costs, 4=fairly serious, 5=very significant/lasting consequences, high financial costs]
8. **What are the probable consequences with the general public of not addressing this issue?**
   [1=inconvenience, inefficiency, 3=some private costs unevenly distributed, anger and frustration, 5=open hostility to change efforts, political solutions, lawsuits]
9. **How sensitive or "charged" is the issue relative to community, social, political, religious, and cultural values?**
   [1=benign, 3=touchy, 5=dynamite]

Table 14. Responses of September 2005 water resource scoping workshop participants, averaged across eight small groups, to questions concerning the difficulty/complexity of addressing key water resources issues within the MNRRA corridor. Lower values generally indicate the issue is less difficult or complex to address, whereas higher values indicate a higher degree of difficulty and complexity.

	Water Quality	Land and Water Use and Regulation	Biological Issues	Interagency and Partnership Coordination	Socio-Environmental Issues	Effects of River Alteration	Economic Impacts and Analyis	Water Quantity	Ecosystem Restoration and Understanding
1. Is the issue on the agenda of the agencies and organizations who can take action?	1	2	2	3	2	2	4	1	2
2. When will the issue come to a head (confront us)?	1	2	2	2	2	3	4	3	3
3. How broad an impact will the issue have on agencies/organizations?	5	5	5	5	5	4	5	5	4
4. How large is the financial risk/opportunity?	5	5	4	3	5	5	4	5	4
5. How apparent is the best approach for issue resolution?	3	3	4	4	4	4	4	4	3
6. How many government entities are affected by this issue and must be involved in its resolution?	5	5	5	5	5	5	5	5	4
7. What are the probable resource consequences of not addressing this issue?	5	5	5	4	4	4	4	5	4
8. What are the probable consequences with the general public of not addressing this issue?	5	5	3	3	4	2	3	5	2
9. How sensitive or 'charged' is the issue relative to community, social, political, religious, and cultural values?	5	5	3	3	4	3	3	3	2

Considerations for Future Actions

The MNRRA corridor flows through the heart of the Twin Cities Metropolitan Area and is situated at the confluence of several ecoregions and three contrasting river basins (the Mississippi, Minnesota, and St. Croix Rivers). It encompasses the uppermost reach of the lock and dam system on the Mississippi River, and contains some of its most urbanized and rapidly developing reaches. In its history are recorded some of the worst cases of water quality degradation on the Mississippi River, as well as some of the most remarkable ecological recoveries. The MNRRA corridor is home to dozens of local, state, and federal water management entities with complementary, overlapping, and occasionally conflicting management objectives and interests. At the same time, the corridor represents one of the most geomorphologically and culturally important reaches of Mississippi River, preserves important ecological habitats, and continues to provide opportunities for inspiration and recreation to a large urban population.

Managing water resources in the face of these geographic, historic, demographic, bureaucratic, and economic complexities is a continuing challenge in the MNRRA corridor. These challenges seem bound to continue, and several recent management documents reiterate this need to conserve historical and environmental features while simultaneously maintaining commercial navigation and a range of recreational uses on the River. Consider, for example, the MNRRA Comprehensive Management Plan (National Park Service 1995a), the Environmental Pool Plans (River Resources Forum 2004), and the Upper Mississippi River-Illinois Waterway System navigation feasibility study (U.S. Army Corps of Engineers 2004a). Clearly, there is a difficult balance to strike with respect to water resources management in the MNRRA corridor. Given all this, how can the National Park Service more effectively help achieve that balance?

- **Add a water resources professional to MNRRA staff.** In order for the National Park Service to more actively engage in water resources issues in the MNRRA corridor, a permanent, full-time water resources professional should be added to the park's natural resources staff. There may be some potential to share such a position with St. Croix National Scenic Riverway, a neighboring river park. Adding this position would greatly increase the visibility of the National Park Service in river management circles and would increase its capacity to achieve its mission within the MNRRA corridor. This position would represent a clear MNRRA point of contact with respect to water resource issues.

  The individual filling this position should have a scientific background in hydrology and aquatic ecology, but should also have superior communication skills and experience in coordinating management activities and collaborating on projects. This person would contribute substantially to management activities in the corridor, regularly interpret the broad range of scientific information generated within the corridor, and offer well-informed recommendations related to water resource issues in the larger Mississippi River basin. The following considerations for future actions will likely be difficult without the addition of this position.

- **Serve as a convener for Upper Mississippi River restoration issues.** During the MNRRA Water Resources Scoping Meeting in September 2005, participants noted that navigation pools above the Upper Mississippi River National Wildlife Refuge in Pool 5 have generally received less management and restoration attention than downstream navigation pools. Participants indicated that this was due, in part, to the lack of clear agency leadership in this reach of the Mississippi River, and suggested that the National Park Service could serve as an important convener for management issues in the MNRRA corridor and beyond.

  - *Review pool planning recommendations*. Through the River Resources Forum (2004), MNRRA staff helped develop desired future habitat conditions for Mississippi River Pools 1-10. Recommendations for the uppermost pools should be reviewed and considered for action by Forum partners, and updates and clarifications should be made where necessary. For example, the Forum has not yet endorsed the Pool 1 Plan because it describes a desired future condition incompatible with the commercial lock and dam system.

- *Prioritize pool planning recommendations*. The River Resources Forum report identifies many potential actions for achieving desired future conditions in each navigation pool. Managers at MNRRA, in cooperation with partners within and beyond the corridor, should determine which actions are the highest priorities for the uppermost navigation pools. Considerations may include both the need for the action and the achievability of the desired future condition.

- *Implement priority recommendations.* In its report, the River Resources Forum noted that the next step is for the river managing partners to "move forward with actual implementation actions." Once MNRRA and its partners have determined which actions are most important in the River's uppermost pools, implementation work should begin, taking into account the resources and responsibilities of the agencies and partners. MNRRA staff should encourage its partners to focus more restoration funds and activities on uppermost navigation pools, but should also determine which actions the National Park Service is best able to contribute to in terms of staff time or project funds. For example, plans for each of the navigation pools within MNRRA recommend "working cooperatively with private property owners" on land use issues and "supporting watershed management programs" to reduce nutrient and sediment inputs. Specific items under each of these recommendations could be considered for action by MNRRA staff.

- *Encourage adaptive management.* As implementation actions are completed, MNRRA and its partners should monitor the outcomes, evaluate successes and shortcomings, and make necessary adjustments. Are the actions having the desired effects? How can implementation actions be improved to ensure progress toward meeting desired future conditions?

- *Participate in regional working groups*. With staff additions, MNRRA could become more involved in broader Mississippi River working groups. Such involvement may include the Upper Mississippi River Conservation Committee (to facilitate management of fishery and wildlife resources within the corridor), the Mississippi Interstate Cooperative Resource Association (to facilitate interstate fisheries management), and the Mississippi River Basin Panel on Aquatic Nuisance Species (to help coordinate programs fighting species invasions).

- **Increase participation in local and regional water resource issues**. In addition to overarching Mississippi River management issues, the MNRRA corridor faces a number of more local water resources issues that could benefit from increased participation by the National Park Service. Several are described below.

    - *Total Maximum Daily Load (TMDL)s:* TMDL studies are underway for several of MNRRA's tributaries and receiving waters. The Lake Pepin TMDL study has perhaps the highest profile and the greatest likelihood to influence the future of water quality in the MNRRA corridor. Continued and increased participation on advisory and technical committees for these TMDL studies would be helpful. In addition, increased involvement from MNRRA staff could help expedite the still-distant TMDL process for fecal coliform in the corridor's upper reaches. MNRRA staff could coordinate with partners to generate TMDL-like information before the official TMDL study begins.

- *Stormwater management*. Stormwater management issues have received more attention in recent years due to the establishment of the public-private Stormwater Steering Committee. Staff from MNRRA should be actively involved in this committee, particularly with regard to its outreach and education goals.

- *Land use and wastewater management beyond Metropolitan Council jurisdiction.* The Metropolitan Council provides important land use planning services and wastewater treatment to communities within the seven-county Twin Cities Metropolitan Area. However, urbanization and land use changes beyond this area also affect water resources in the MNRRA corridor. Staff from MNRRA should play an active role in identifying and managing threats to water resources that are not addressed by the Metropolitan Council or other entities.

- *Watershed education and stewardship.* As a major player in local land use management, MNRRA should increase its participation in education and outreach activities related to watershed stewardship, water quality conservation, and sustainability. WaterShed Partners, a coalition of over 40 public, private, and non-profit organizations in the Twin Cities Metropolitan Area (including MNRRA), may provide good opportunities for collaborative outreach to local governments, area residents, community organizations, schools, and more.

- *Surface water use management plan.* The MNRRA Comprehensive Management Plan identified a high priority need for a surface water use management plan to help manage potentially conflicting surface water uses within the corridor (National Park Service 1995a). To date, no progress has been made on the plan. MNRRA should work to reinvigorate this process and to secure funding for such a plan through federal grant programs, cost-sharing opportunities, and coordination with partner agencies (National Park Service 1995a).

- **Support synthesis efforts specific to the MNRRA corridor.** Many agencies and organizations generate water resource data for the Upper Mississippi River, much of which pertains to only parts of the MNRRA corridor or to river reaches downstream of the MNRRA corridor. Furthermore, most of the information was generated in response to specific management questions of varying importance to MNRRA. In this report, we have attempted to synthesize the water resources information most relevant to MNRRA; however, more information is available and is being generated continually. There is a need to regularly compile information generated by partners within the corridor, particularly in terms of water quality, land cover, and land use. This information should be summarized frequently and interpreted with respect to MNRRA as a whole.

- **Fill aquatic information gaps in the MNRRA corridor.** Despite the number of natural resources agencies and organizations in the corridor and the wealth of water resources information available, important information gaps remain. Participants at the MNRRA Water Resources Scoping Workshop in September 2005 noted that certain biological data were lacking and that our understanding of ecosystem-level processes and functions lagged behind. This concern was echoed for MNRRA in a recent multi-park aquatic synthesis (Lafrancois and Glase 2005). The following considerations address these gaps.

    - *Conduct comprehensive aquatic resource assessments*. Aquatic inventories and assessments, specific to the MNRRA corridor, would be helpful. To date, freshwater mussels are the only aquatic taxa to have been inventoried specifically for the MNRRA corridor (see Kelner and Davis 2002). Additional inventory and assessment efforts should target fish, benthic invertebrates, aquatic birds, and amphibians, as well as habitat and geomorphological features.

- *Develop long-term ecosystem monitoring program.* The Long Term Resource Monitoring Program (LTRMP), implemented by the U.S. Geological Survey in La Crosse, Wisconsin, has yielded important insights related to Upper Mississippi River water quality and biology, but sites do not extend upstream of Lake Pepin. A similar monitoring program would be very useful for managing the uppermost navigation pools, including MNRRA. Some aspects of a long-term ecosystem monitoring program, such as water quality, are covered by the Metropolitan Council, through its river monitoring program, and the National Park Service, through its relatively new Inventory and Monitoring program. Other aspects, such as benthic invertebrates, macrophytes, and fish, are lacking. In cooperation with partners, MNRRA should seek to develop a program for monitoring multiple ecological attributes over the long term.

- *Encourage research on stressor-biota interactions.* The role of local and regional stressors (e.g., water quality degradation, aquatic invasive species, water level management, channel maintenance, etc.) in influencing aquatic biota and processes should continue to be evaluated. Potential research partners include local universities, management agencies, and the U.S. Geological Survey.

    - *Pig's Eye Dump*. This dump remains one of the most contaminated sites on the Upper Mississippi River, and is situated fully within the MNRRA corridor. In the past MNRRA has sought funding to evaluate the effects of contaminants from Pig's Eye Dump on fish and aquatic wildlife. To date, no funding has been awarded but the science needs remain. MNRRA staff should continue to work with interested investigators to facilitate this research.

    - *Perflourochemicals (PFCs).* It is known that PFCs, discharged to the Mississippi River by chemical facilities in the Cottage Grove area, are present in fish tissues in the MNRRA corridor. These chemicals are classified as “likely carcinogens”, but their effects on humans, fish, and wildlife are poorly understood and in need of further investigation. Because MNRRA is a non-industry, non-regulatory entity, it may be well positioned to facilitate research and outreach on this topic of public concern.

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Appendix A. Water Resources Scoping Meeting Summary

Mississippi National River and Recreation Area
Four Points Sheraton, St. Paul, Minnesota
September 8, 2005

MEETING PURPOSE: To discuss and hone a preliminary outline of water resources issues within the Mississippi National River and Recreation Area (MNRRA), then rank those issues in order of priority for attention. In the coming months, National Park Service staff will use this prioritization to prepare an informational overview report for MNRRA.

Background and Introductions

MNRAA Superintendent JoAnn Kyral extended a welcome to meeting participants, emphasized the importance of water resources in the MNRRA corridor, and introduced MNRRA Chief of Resource Management, Steve Johnson. Steve explained the rationale for the scoping meeting, noting that earlier park planning processes did not adequately address water resources and that there is no aquatic specialist on staff. To help sort out water resource management issues, Steve requested assistance from the National Park Service (NPS) Water Resources Division and the Midwest Regional Office. As a result, staff time from Brenda Moraska Lafrancois (aquatic ecologist) and David Vana-Miller (hydrologist) was allocated to water resource planning activities at MNRRA.

Brenda gave a short presentation on NPS water resource planning, and described the content of the proposed Information and Issues Overview Report. The report should identify water-related laws and policy, assess existing conditions relative to NPS management policies, analyze water resource trends, identify water resource issues, and evaluate stakeholder interests and policy-level concerns. MNRRA will use the report to focus management attention on its priority water resource needs.

Beth Carlson initiated a round of introductions. Meeting attendance was strong - 43 - and included representatives of six cities and townships, two counties, four watershed districts, four state agencies, four federal agencies, four non-profit organizations, two private associations, the University of Minnesota, and the Metropolitan Council. A full list of participant names and affiliations is attached (Table 1).

Initial Review of Water Resource Issues

Steve and Brenda reviewed an initial list of water resource issues identified at a small group meeting in May 2005. These issues were each ascribed to one of eight issue categories. In no particular order, the categories were: effects of river regulation, ecosystem management, water quantity, water quality, biological issues, socio-environmental issues, interagency coordination, and "other" (air quality and atmospheric deposition, land use change, and climate change).

Issue Clarification and Refinement

Meeting participants discussed the initial issues list and suggested additions and changes. Important adjustments included the revision of several category titles, the inclusion of some additional issues, and the development of two new categories to better address issues of watershed management and economics. The revised list of 10 categories included the following:

- Effects of River Alteration
- Ecosystem Restoration and Understanding
- Water Quantity
- Water Quality

- Interagency and Partnerships Coordination
- Socio-Environmental Issues
- Biological Issues
- Land and Water Use and Regulation
- Economic Impacts and Analysis
- Other (air quality and atmospheric deposition, funding and staffing needs, and climate change)

In total, more than 80 issues were identified across these categories. A complete listing of these issues is attached (Table 2).

Importance Rating and Voting

Meeting participants helped prioritize water resource issues through two dot voting exercises. First, participants were asked to rate the importance of addressing each category individually, on a scale of 1-10. Secondly, participants were asked to vote for issues they felt were the top five most important to address in the MNRRA corridor, across categories.

Water Quality, Land and Water Use and Regulation, and Biological Issues were rated as highly important in the MNRRA corridor, with many participants giving these issues a rating of nine or ten (Figure 1, attached). Interagency and Partnerships Coordination was also rated high, with no participant giving it a rating of less than five. Participant opinion varied with respect to the remaining categories.

Across the more than 80 identified issues and categories, the 11 highest ranking included water quality (13 votes), watershed management (11 votes), urban/suburban development (10 votes), land and water use and regulation (9 votes), restoration of native biota (9 votes), altered hydrologic regimes (8 votes), stormwater issues (7 votes), fragmented water management jurisdiction (7 votes), land use change in watershed (6 votes), need for a water-based NPS coordinator position (6 votes), and population growth (6 votes)(Table 2, attached). A high proportion of the total votes fell to issues within the Water Quality and Land and Water Use and Regulation categories (35 and 32 votes, respectively) (Table 3, attached).

Rating the Difficulty/Complexity of Issue Categories

In small groups, participants evaluated the difficulty/complexity of addressing each issue category by filling out a series of worksheets. Results of this assessment will be detailed in the Information and Issues Overview Report, and will help MNRRA managers decide which issues can be addressed most effectively by the park and its partners.

Next Steps

A draft of the Water Resources Information and Issues Overview report will be prepared in the coming months and submitted for internal NPS review by March 2006. Following the internal review, the draft report will be circulated to meeting participants for a 30-day review. Comments will be reviewed and incorporated, and the final report will be printed by September 2006. Participants were encouraged to contact Brenda (651.433.5953 x35, brenda_moraska_lafrancois@nps.gov) with any relevant documents, data, or insights from their respective agencies and organizations.

Table A-1. Participant list for September 2005 Water Resources Issues Scoping Workshop, sorted by agency or entity represented.

Agency	First name	Last name	Address	City	State	Zip	Phone	E-mail
Anoka County Parks	Tim	Sevcik	1350 Bunker Lake Blvd	Andover	MN	55304	763-767-2896	timothy.sevcik@co.anoka.mn.us
Audubon Upper Mississippi River Campaign	Dan	McGuiness	2357 Ventura Dr. #106	Woodbury	MN	55125	651-739-9332	dmcguiness@audubon.org
Builders Association of the Twin Cities	Nate	Duoss	2960 Centre Point Drive	Roseville	MN	55113	651-697-1954	nate@batc.org
Capitol Region Watershed District	Bob	Fossum	1410 Energy Park Dr. #4	St. Paul	MN	55108	651-644-8888	bob@capitolregionwd.org
City of Inver Grove Heights	Mark	Borgwardt	8150 Barbara Ave.	Inver Grove Hts	MN	55077	651-450-2581	mborgwardt@ci-inver-grove-heights.mn.us
City of Mendota Heights	Sue	McDermott	1101 Victoria Curve	Mendota Heights	MN	55118	651-255-1123	suem@mendota-heights.com
City of Ramsey	Amy	Geisler	15153 Nowthen Blvd.	Ramsey	MN	55303	763-433-9903	ageisler@ci.ramsey.mn.us
City of St. Paul	George	Johnson	25 W. 4th St.	St. Paul	MN	55102		george.johnson@ci.stpaul.mn.us
City of St. Paul	Larry	Soderholm	25 W. 4th St.	St. Paul	MN	55102	651-266-6575	larry.soderholm@ci.stpaul.mn.us
Confluence Consulting	Beth	Carlson	676 Sherwood Ave.	St. Paul	MN	55106	651-772-8412	ecarlson@pclink.com
Corps of Engineers	Dan	Wilcox	190 5th St. E.	St. Paul	MN	55101	651-290-5276	daniel.b.wilcox@mvp02.usace.army.mil
Friends of the Mississippi River	Whitney	Clark	46 E. 4th St. #606	St. Paul	MN	55101	651-222-2193	wclark@fmr.org
Grey Cloud Island Township	Bell	Tom	5868 Pioneer Road	St. Paul Park	MN	55071	651-459-4150	tnejbell@comcast.com
Lower Minnesota River Watshed Dist	Terry	Schwalbe	200 4th Ave. W	Shakopee	MN	55379	952-496-8842	terrys@lowermn.com
Metropolitan Council	Jack	Frost	230 E. 5th St.	St. Paul	MN	55101	651-602-1078	jack.frost@metc.state.mn.us
Metropolitan Council	Kent	Johnson	230 E. 5th St.	St. Paul	MN	55101	651-602-8117	kent.johnson@metc.state.mn.us
Minneapolis Water Works	Larry	Cole	4300 Marshall St. NE	Minneapolis	MN	55421	612-661-4923	larry.cole@ci.minneapolis.mn.us
Minnesota DNR	Wayne	Barstad	1200 Warner Road	St. Paul	MN	55106	651-772-7941	wayne.barstad@dnr.state.mn.us
Minnesota DNR	Mike	Davis	1801 S. Oak St.	Lake City	MN	55041	651-345-3331	mike.davis@dnr.state.mn.us
Minnesota DNR	Jack	Enblom	500 Lafayette Road	St. Paul	MN	55155	651-296-0785	jack.enblom@dnr.state.mn.us
Minnesota DNR	Scot	Johnson	1801 S. Oak St.	Lake City	MN	55041	651-345-5601	scot.johnson@dnr.state.mn.us
Minnesota DNR	Molly	Shodeen	1200 Warner Road	St. Paul	MN	55106	651-772-7915	Molly.Shodeen@dnr.state.mn.us
Minnesota DNR	Rebecca	Wooden	500 Lafayette Road	St. Paul	MN	55155		rebecca.wooden@dnr.state.mn.us
Minnesota DOT	Dick	Lambert	1110 Centre Point Curve	Mendota Heights	MN	55118	651-406-4805	dick.lambert@dot.state.mn.us
Minnesota Pollution Control Agency	Craig	Affeldt	520 Lafayette Road	St. Paul	MN	55155		craig.affeldt@state.mn.us
Minnesota Pollution Control Agency	Jim	Hodgson	7678 College Road	Brainerd	Mn	56425	218-828-6065	Jim.Hodgson@state.mn.us
Minnesota Pollution Control Agency	Norm	Senjem	18 Wood Lake Drive SE	Rochester	MN	55904	507-280-3592	Norman.Senjem@state.mn.us
Minnesota Waters	John	Helland	1269 2nd St. N. #200	Sauk Rapids	MN	56379		John.Helland@house.leg.state.mn.us
MN Board of Water & Soil Resources	Steve	Woods	520 Lafayette Road	St. Paul	MN	55155	651-297-7748	steve.woods@bwsr.state.mn.us

National Park Service	Nancy	Duncan	111 E. Kellogg Blvd	St. Paul	MN	55101	651-290-3030	nancy_duncan@nps.gov
National Park Service	Steve	Johnson	111 E. Kellogg Blvd	St. Paul	MN	55101	651-290-3030	steven_p_johnson@nps.gov
National Park Service	Brenda	Lafrancois	16910 152nd St.	Marine	MN	55047	651-433-5953	brenda_moraska_lafrancois@nps.gov
National Park Service	Jerrilyn	Thompson	115 Green, 1530 N. Cleveland	St. Paul	MN	55108	612-624-3699	jerrilyn_thompson@nps.gov
Ramsey-Washington Metro Watshd Dist	Cliff	Aichinger	2346 Helen St.	North St. Paul	MN	55109	651-704-2089	cliff@rwmwd.org
St. Paul Parks/Rec Department	Adam	Robbins	25 W. 4th St. #300	St. Paul	MN	55102	651-635-2457	adam.robbins@ci.stpaul.mn.us
St. Paul Regional Water Services	John	Blackstone	1900 Rice St.	St. Paul	MN	55113	651-266-6324	john.f.blackstone@ci.stpaul.mn.us
St. Paul Regional Water Services	Justine	Roe	1900 Rice St.	St. Paul	MN	55113		justine.Roe@ci.stpaul.mn.us
Three Rivers Park District	Brian	Vlach	3800 County Road 24	Maple Plain	MN	55359	763-694-7846	bvlach@threeriversparkdistrict.org
U.S. Geological Survey	Jeff	Stoner	2880 Woodale Drive	Mounds View	MN	55112	763-783-3100	stoner@usgs.gov
University of Minnesota	Jim	Perry	1980 Fallwell	St. Paul	MN	55108	612-625-4717	jperry@umn.edu
Upper Mississippi Waterway Assn.	Greg	Genz	P.O. Box 7006	St. Paul	MN	55107		gg92@att.net
USFWS	Gary	Wege	4101 E. 80th St.	Bloomington	MN	55425	612-725-3548	gary_wege@fws.gov
	Dave	Brostrom	2159 Berkeley Ave.	St. Paul	MN	55105	651-690-0690	brost004@umn.edu

Table A-2. Complete list of issues and issue categories, in descending order of importance according to number of votes acquired during the second round of dot voting. Issue categories are abbreviated as follows: BIO=Biological Issues, EIA=Economic Impacts and Analysis, ERU=Ecosystem Restoration and Understanding, IPC=Interagency and Partnership Coordination, LWU=Land and Water Use and Regulation, RAL=Effects of River Alteration, SEI=Socio-Environmental Issues, WQL=Water Quality, WQN=Water Quantity. The top 11 issues are shown in blue shading, and issues receiving at least one vote are shown in aquamarine. Issues receiving no votes are shown in white.

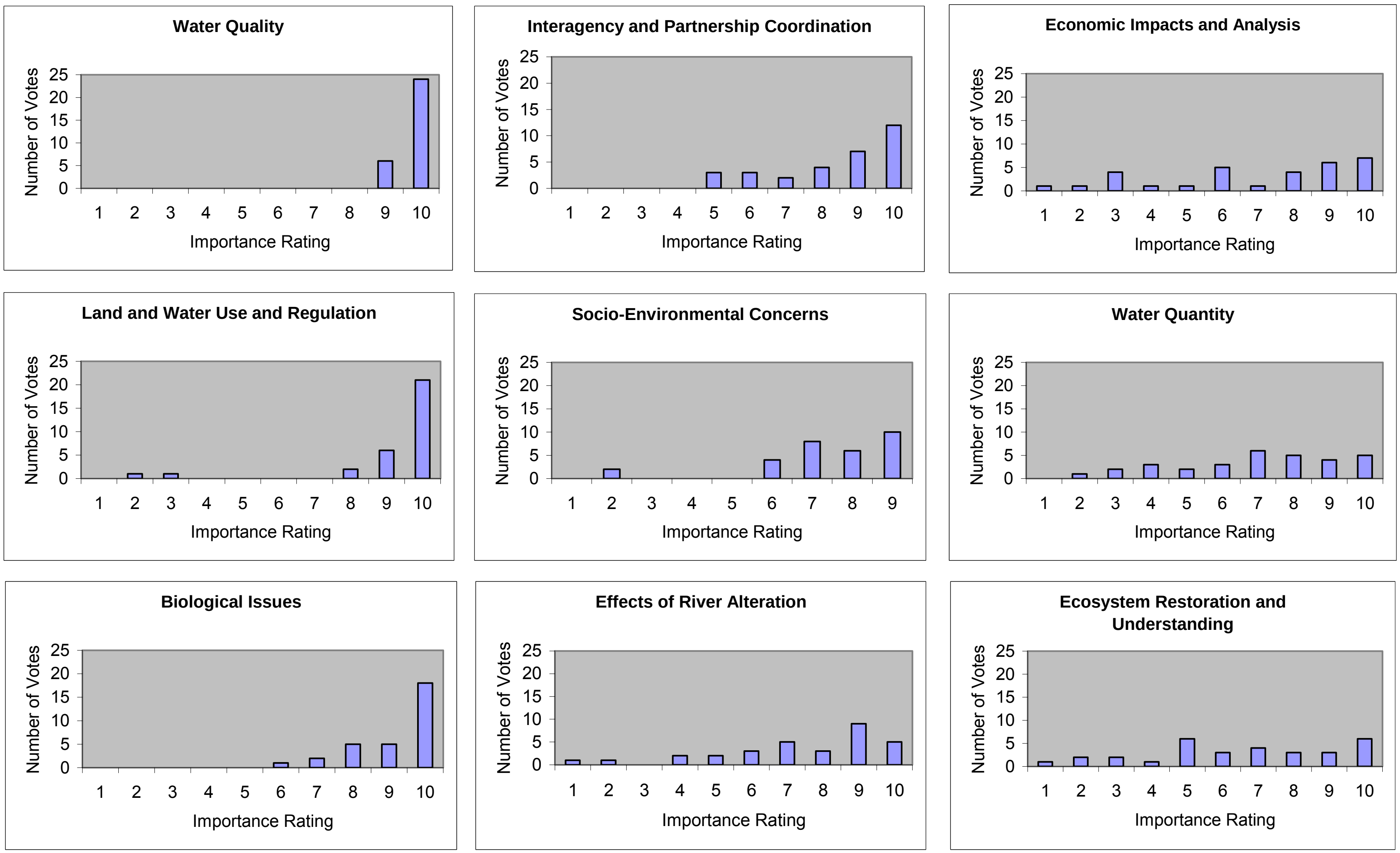
Issue	Category	# Votes
Water Quality	*WQL*	*13*
Watershed management	LWU	11
Urban/suburban development	LWU	10
Land and Water Use and Regulation	*LWU*	*9*
Restoration of native biota	BIO	9
Altered hydrologic regimes	RAL	8
Stormwater issues	WQL	7
Water management jurisdiction fragmented	IPC	7
Land use change in watershed	WQL	6
Need for a water-based NPS coordinator position	IPC	6
Population growth	SEI	6
Effects of TMDL's on MNRRA water quality	WQL	5
Public education	SEI	5
Bioaccumulative toxins	BIO	5
Need for baseline data	ERU	3
Needs and issues related to parks and open space	SEI	3
Enforcement capacity	LWU	2
Water Quantity	*WQN*	*2*
Water quantity altered	WQN	2
Nutrient management in agricultural watersheds	WQL	2
Interagency and Partnership Coordination	*IPC*	*2*
Socio-environmental Issues	*SEI*	*2*
Increasing consumptive uses	SEI	2
Biological Issues	*BIO*	*2*
Externalized costs	EIA	2
Real estate values	EIA	2
Geomorphologic changes	RAL	1
Ecosystem Restoration and Understanding	*ERU*	*1*
State drainage law	WQN	1
Relationship between surface and ground water	WQL	1
Disconnect between Clean Water Act and Safe Drinking Water Act	WQL	1
Recreational impacts	SEI	1
Economic drivers (e.g., tourism)	SEI	1
Commercial navigation	SEI	1
Conflicts between different river and land uses	SEI	1
Aquatic invasive species (e.g., zebra mussels, Asian carp)	BIO	1
Effects of poor water quality	BIO	1
Decline in riparian and submerged aquatic vegetation	BIO	1
Exotic plants and diseases affecting riparian vegetation	BIO	1
Commercial navigation	EIA	1

Valuation of these services	EIA	1
Effects of River Alteration	*RAL*	*0*
Water deficits due to upstream dam operations	RAL	0
Habitat loss	RAL	0
Barriers to fish passage	RAL	0
Facilitation of exotic species introduction	RAL	0
Dredging and dredge disposal	RAL	0
Flooding impacts	RAL	0
Slope control and erosion	RAL	0
Dam operations and water level management	ERU	0
Island construction	ERU	0
Wing dam notching	ERU	0
Pool planning process	ERU	0
Agricultural impacts/BMPs	LWU	0
Bluff protection standards	LWU	0
Requirements for ecosystem functions unknown	WQN	0
Surface water consumption rising	WQN	0
Consumptive uses diverse	WQN	0
Potential for increased hydropower use	WQN	0
Ground water over-tapped in places	WQN	0
Effects of flood control and drought mitigation	WQN	0
Nonconsumptive concerns (aesthetic, recreational)	WQN	0
Drought contingency planning	WQN	0
Water re-use and conservation	WQN	0
General wastewater concerns	WQL	0
Emerging wastewater contaminants	WQL	0
Continued urbanization along MNRRA corridor	WQL	0
General ground water contamination	WQL	0
Contaminants from Pig's Eye dump	WQL	0
Contamination of shallow ground water aquifers (Pool 2)	WQL	0
Many potential spill sources; no warning system	WQL	0
Court decision banning new discharges into impaired waters	WQL	0
Drinking water quality concerns	WQL	0
Trash and litter BMPs for stormwater	WQL	0
Sewer separation	WQL	0
Septics and septic management	WQL	0
NPS role in water resource management not always clear	IPC	0
Potential changes in coordination if NESP authorized	IPC	0
Recreational concerns (public access; water supply)	SEI	0
Conflicts between consumptive and non-consumptive uses	SEI	0
Increasing riverfront economic development and infrastructure	SEI	0
Public perceptions of water quality concerns	SEI	0
Aesthetics	SEI	0
Cultural and ethnic perceptions	SEI	0
Fish passage concerns	BIO	0
Protection of threatened and endangered species	BIO	0
Habitat needs for migratory waterfowl and aquatic wildlife	BIO	0
Economic Impacts and Analysis	*EIA*	*0*
Ecosystem services	EIA	0
Recreation services	EIA	0

Table A-3. Total number of votes received by issues within each category during the second round of dot voting. Issue categories are abbreviated as follows: BIO=Biological Issues, EIA=Economic Impacts and Analysis, ERU=Ecosystem Restoration and Understanding, IPC=Interagency and Partnership Coordination, LWU=Land and Water Use and Regulation, RAL=Effects of River Alteration, SEI=Socio-Environmental Issues, WQL=Water Quality, WQN=Water Quantity.

Issue Category	Code	# Votes
Water Quality	WQL	35
Land and Water Use and Regulation	LWU	32
Socio-Environmental Issues	SEI	22
Biological Issues	BIO	20
Interagency and Partnership Coordination	IPC	15
Effects of River Alteration	RAL	9
Economic Impacts and Analysis	EIA	6
Water Quantity	WQN	5
Ecosystem Restoration and Understanding	ERU	4

Figure A-1. Results of importance rating exercise, by category. Categories with votes skewed toward high ratings (i.e., Water Quality, Land and Water Use and Regulation, Biological Issues) were considered very important to address. More even vote distributions indicated a variety of opinions as to category importance.



Appendix B. Species Lists for the MNRRA Corridor

Appendix B-1. Birds.

Bird species present, probably present, historically present, and unconfirmed within Mississippi National River and Recreation Area, as determined by the National Park Service Great Lakes Inventory and Monitoring Network as of March 2006.

Standard Scientific Name	Standard Common Name	Aquatic Habitat	Park-Status	State Status	Federal Status
Actitis macularia	Spotted Sandpiper	Shoreline	Present		
Aechmophorus clarkii	Clark's Grebe	All	Present		
Aechmophorus occidentalis	Western Grebe	All	Present		
Agelaius phoeniceus	Red-winged Blackbird	Wetland	Present		
Aix sponsa	Wood Duck	All	Present		
Ammodramus leconteii	Le Conte's Sparrow	Wetland	Present		
Ammodramus nelsoni	Nelson's Sharp-tailed Sparrow	Wetland	Present	SPC	
Anas acuta	Northern Pintail	All	Present		
Anas americana	American Wigeon	All	Present		
Anas clypeata	Northern Shoveler	All	Present		
Anas crecca	Green-winged Teal	All	Present		
Anas discors	Blue-winged Teal	All	Present		
Anas platyrhynchos	Mallard	All	Present		
Anas rubripes	American Black Duck	All	Present		
Anas strepera	Gadwall	All	Present		
Ardea herodias	Great Blue Heron	All	Present		
Arenaria interpres	Ruddy Turnstone	Shoreline	Present		
Aythya affinis	Lesser Scaup	Water	Present		
Aythya americana	Redhead	Water	Present		
Aythya collaris	Ring-necked Duck	Water	Present		
Aythya marila	Greater Scaup	Water	Present		
Aythya valisineria	Canvasback	Water	Present		

Standard Scientific Name	Standard Common Name	Aquatic Habitat	Park-Status	State Status	Federal Status
Botaurus lentiginosus	American Bittern	Wetland	Present		
Branta canadensis	Canada Goose	All	Present		
Bubulcus ibis	Cattle Egret	Wetland	Present		
Bucephala albeola	Bufflehead	Water	Present		
Bucephala clangula	Common Goldeneye	Water	Present		
Buteo lineatus	Red-shouldered Hawk	Wetland	Present	SPC	
Butorides virescens	Green Heron	Wetland	Present		
Calidris alba	Sanderling	Shoreline	Present		
Calidris alpina	Dunlin	Shoreline	Present		
Calidris bairdii	Baird's Sandpiper	Shoreline	Present		
Calidris canutus	Red Knot	Shoreline	Present		
Calidris fuscicollis	White-rumped Sandpiper	Shoreline	Present		
Calidris himantopus	Stilt Sandpiper	Shoreline	Present		
Calidris mauri	Western Sandpiper	Shoreline	Unconfirmed		
Calidris melanotos	Pectoral Sandpiper	Shoreline	Present		
Calidris minutilla	Least Sandpiper	Shoreline	Present		
Calidris pusilla	Semipalmated Sandpiper	Shoreline	Present		
Casmerodius albus	Great Egret	Wetland	Present		
Catoptrophorus semipalmatus	Willet	Wetland	Present		
Ceryle alcyon	Belted Kingfisher	Water	Present		
Charadrius semipalmatus	Semipalmated Plover	Shoreline	Present		
Charadrius vociferus	Killdeer	Shoreline	Present		
Chen caerulescens	Snow Goose	Water	Present		
Chlidonias niger	Black Tern	All	Present		
Circus cyaneus	Northern Harrier	Wetland	Present		
Cistothorus palustris	Marsh Wren	Wetland	Present		
Cistothorus platensis	Sedge Wren	Wetland	Present		

Standard Scientific Name	Standard Common Name	Aquatic Habitat	Park-Status	State Status	Federal Status
Coturnicops noveboracensis	Yellow Rail	Wetland	Present	SPC	
Cygnus buccinator	Trumpeter Swan	All	Present	THR	
Cygnus columbianus	Tundra Swan	Water	Present		
Cygnus olor	Mute Swan	Water	Present		
Empidonax alnorum	Alder Flycatcher	Wetland	Present		
Empidonax traillii	Willow Flycatcher	Wetland	Present		
Euphagus carolinus	Rusty Blackbird	Wetland	Present		
Fulica americana	American Coot	All	Present		
Gallinula chloropus	Common Moorhen	Wetland	Present	SPC	
Gavia immer	Common Loon	All	Present		
Geothlypis trichas	Common Yellowthroat	Wetland	Present		
Grus canadensis	Sandhill Crane	Wetland	Present		
Haliaeetus leucocephalus	Bald Eagle	Water	Present	SPC	THR
Ixobrychus exilis	Least Bittern	Wetland	Present		
Larus argentatus	Herring Gull	Water	Present		
Larus delawarensis	Ring-billed Gull	Water	Present		
Larus eburnea	Ivory Gull	Water	Present		
Larus philadelphia	Bonaparte's Gull	Water	Present		
Larus pipixcan	Franklin's Gull	Water	Present	SPC	
Limnodromus griseus	Short-billed Dowitcher	Wetland	Present		
Limnodromus scolopaceus	Long-billed Dowitcher	Wetland	Present		
Limosa fedoa	Marbled Godwit	Wetland	Present	SPC	
Limosa haemastica	Hudsonian Godwit	Wetland	Present		
Lophodytes cucullatus	Hooded Merganser	Water	Present		
Melanitta fusca	White-winged Scoter	Water	Present		
Melanitta nigra	Black Scoter	Water	Present		
Melanitta perspicillata	Surf Scoter	Water	Present		

Standard Scientific Name	Standard Common Name	Aquatic Habitat	Park-Status	State Status	Federal Status
Mergus merganser	Common Merganser	All	Present		
Mergus serrator	Red-breasted Merganser	All	Present		
Nyctanassa violacea	Yellow-crowned Night-Heron	Wetland	Present		
Nycticorax nycticorax	Black-crowned Night-Heron	Wetland	Present		
Oxyura jamaicensis	Ruddy Duck	All	Present		
Pandion haliaetus	Osprey	Water	Present		
Pelecanus erythrorhynchos	American White Pelican	Water	Present	SPC	
Phalacrocorax auritus	Double-crested Cormorant	Water	Present		
Phalaropus lobatus	Red-necked Phalarope	All	Historic		
Phalaropus tricolor	Wilson's Phalarope	All	Present	THR	
Pluvialis dominica	American Golden Plover, American Golden-Plover, Lesser Golden-Plover	Wetland	Present		
Pluvialis squatarola	Black-bellied Plover	Wetland	Present		
Podiceps auritus	Horned Grebe	All	Present	THR	
Podiceps grisegena	Red-necked Grebe	All	Present		
Podiceps nigricollis	Eared Grebe	All	Present		
Podilymbus podiceps	Pied-billed Grebe	All	Present		
Protonotaria citrea	Prothonotary Warbler	Wetland	Present		
Rallus elegans	King Rail	Wetland	Present	END	
Rallus limicola	Virginia Rail	Wetland	Present		
Recurvirostra americana	American Avocet	Wetland	Present		
Seiurus motacilla	Louisiana Waterthrush	Wetland	Present	SPC	
Seiurus noveboracensis	Northern Waterthrush	Wetland	Present		

Standard Scientific Name	Standard Common Name	Aquatic Habitat	Park-Status	State Status	Federal Status
Stelgidopteryx serripennis	Northern Rough-winged Swallow	Water	Present		
Sterna caspia	Caspian Tern	All	Present		
Sterna forsteri	Forster's Tern	All	Present	SPC	
Sterna hirundo	Common Tern	All	Present	THR	
Tachycineta bicolor	Tree Swallow	Water	Present		
Tringa flavipes	Lesser Yellowlegs	Wetland	Present		
Tringa melanoleuca	Greater Yellowlegs	Wetland	Present		
Tringa solitaria	Solitary Sandpiper	Shoreline	Present		
Xanthocephalus xanthocephalus	Yellow-headed Blackbird	Wetland	Present		

Appendix B-2. Fish.

Fish species present, probably present, historically present, and unconfirmed within Mississippi National River and Recreation Area, as determined by the National Park Service Great Lakes Inventory and Monitoring Network as of March 2006. Species conservation status noted as "SPC" = special concern, "THR" = threatened, and "END" = endangered, at the state or federal level.

Standard Scientific Name	Standard Common Name	Park Status	State Status	Federal Status
Acipenser fulvescens	lake sturgeon	Present	SPC	
Alosa chrysochloris	blue herring, golden shad, green herring, river herring, skipjack, skipjack herring, skipjack shad	Historic	SPC	
Ambloplites rupestris	rock bass	Present		
Ameiurus melas	black bullhead	Present		
Ameiurus natalis	yellow bullhead	Present		
Ameiurus nebulosus	brown bullhead	Present		
Amia calva	bowfin	Present		
Ammocrypta clara	western sand darter	Probably Present		
Anguilla rostrata	American eel, american eel	Present		
Aphredoderus sayanus	pirate perch	Unconfirmed	SPC	
Aplodinotus grunniens	freshwater drum	Present		
Campostoma anomalum	central stoneroller	Present		
Campostoma oligolepis	largescale stoneroller	Present		
Carpiodes carpio	river carpsucker	Present		
Carpiodes cyprinus	quillback, quillback carpsucker	Present		
Carpiodes velifer	highfin carpsucker	Present		
Catostomus commersoni	white sucker	Present		
Coregonus artedii	cisco, lake herring	Present		
Cottus bairdii	mottled sculpin	Historic		
Crystallaria asprella	crystal darter	Present		
Ctenopharyngodon idella	grass carp, silver orfe	Unconfirmed		
Culaea inconstans	brook stickleback	Present		
Cycleptus elongatus	blue sucker	Present	SPC	
Cyprinella spiloptera	spotfin shiner	Present		
Cyprinella whipplei	steelcolor shiner	Historic		

Standard Scientific Name	Standard Common Name	Park Status	State Status	Federal Status
Cyprinus carpio	European carp, common carp	Present		
Dorosoma cepedianum	American gizzard shad, eastern gizzard shad, gizzard shad, hickory shad, mud shad, skipjack	Present		
Erimyzon sucetta	lake chubsucker	Historic		
Esox lucius	northern pike	Present		
Esox lucius X masquinongy	tiger muskie	Present		
Esox masquinongy	muskellunge	Present		
Etheostoma asprigene	mud darter	Present		
Etheostoma caeruleum	rainbow darter	Present		
Etheostoma chlorosomum	bluntnose darter	Historic		
Etheostoma exile	Iowa darter, iowa darter	Present		
Etheostoma flabellare	fantail darter	Present		
Etheostoma microperca	least darter	Present	SPC	
Etheostoma nigrum	johnny darter	Present		
Fundulus diaphanus	banded killifish	Probably Present		
Hiodon alosoides	goldeye	Present		
Hiodon tergisus	mooneye	Present		
Hybognathus hankinsoni	brassy minnow	Present		
Hybognathus nuchalis	Mississippi silvery minnow, mississippi silvery minnow	Probably Present		
Hybopsis amnis	pallid chub, pallid shiner	Historic		
Hypentelium nigricans	northern hog sucker	Present		
Hypophthalmichthys nobilis	bighead carp	Unconfirmed		
Ichthyomyzon castaneus	chestnut lamprey	Present		
Ichthyomyzon unicuspis	silver lamprey	Present		
Ictalurus furcatus	blue catfish	Unconfirmed		
Ictalurus punctatus	channel catfish, graceful catfish	Present		
Ictiobus bubalus	smallmouth buffalo	Present		

Standard Scientific Name	Standard Common Name	Park Status	State Status	Federal Status
Ictiobus cyprinellus	bigmouth buffalo	Present		
Ictiobus niger	black buffalo	Present	SPC	
Labidesthes sicculus	brook silverside	Present		
Lampetra appendix	American brook lamprey, american brook lamprey	Present		
Lepisosteus osseus	longnose gar	Present		
Lepisosteus platostomus	shortnose gar	Present		
Lepomis cyanellus	green sunfish	Present		
Lepomis gibbosus	kiver, pumpkinseed	Present		
Lepomis gulosus	No data	Present		
Lepomis humilis	orangespotted sunfish	Present		
Lepomis macrochirus	bluegill	Present		
Lota lota	burbot, ellpout	Present		
Luxilus cornutus	common shiner	Present		
Macrhybopsis aestivalis	speckled chub	Present		
Macrhybopsis storeriana	silver chub	Present		
Micropterus dolomieu	smallmouth bass	Present		
Micropterus salmoides	largemouth bass	Present		
Minytrema melanops	spotted sucker	Present		
Morone chrysops	white bass	Present		
Morone mississippiensis	yellow bass	Present	SPC	
Moxostoma anisurum	silver redhorse	Present		
Moxostoma carinatum	river redhorse	Present		
Moxostoma duquesnei	black redhorse	Unconfirmed		
Moxostoma erythrurum	golden redhorse	Present		
Moxostoma macrolepidotum	shorthead redhorse	Present		
Moxostoma valenciennesi	greater redhorse	Probably Present		
Nocomis biguttatus	horneyhead chub, hornyhead chub	Present		
Notemigonus crysoleucas	golden shiner	Present		
Notropis anogenus	pugnose shiner	Historic	SPC	
Notropis atherinoides	emerald shiner	Present		

Standard Scientific Name	Standard Common Name	Park Status	State Status	Federal Status
Notropis blennius	river shiner	Present		
Notropis buchanani	ghost shiner	Historic		
Notropis dorsalis	bigmouth shiner	Probably Present		
Notropis heterolepis	blacknose shiner	Historic		
Notropis hudsonius	spottail shiner	Present		
Notropis rubellus	rosyface shiner	Historic		
Notropis stramineus	sand shiner	Present		
Notropis texanus	weed shiner	Probably Present		
Notropis volucellus	mimic shiner	Present		
Notropis wickliffi	channel shiner	Present		
Noturus flavus	stonecat	Present		
Noturus gyrinus	tadpole madtom	Present		
Oncorhynchus mykiss	rainbow trout, redband trout, steelhead	Present		
Opsopoeodus emiliae	pugnose minnow	Present		
Perca flavescens	yellow perch	Present		
Percina caprodes	logperch	Present		
Percina maculata	blackside darter	Present		
Percina phoxocephala	slenderhead darter	Present		
Percina shumardi	river darter	Present		
Percopsis omiscomaycus	trout-perch	Present		
Pimephales notatus	bluntnose minnow	Present		
Pimephales promelas	fathead minnow	Present		
Pimephales vigilax	bullhead minnow	Present		
Polyodon spathula	American paddlefish, paddlefish	Present	THR	
Pomoxis annularis	white crappie	Present		
Pomoxis nigromaculatus	black crappie	Present		
Pylodictis olivaris	flathead catfish	Present		
Rhinichthys atratulus	blacknose dace	Present		
Rhinichthys cataractae	longnose dace	Present		
Salmo trutta	brown trout	Unconfirmed		
Salvelinus fontinalis	brook trout, charr, salter, sea trout	Unconfirmed		
Scaphirhynchus platorynchus	shovelnose sturgeon	Present		

Standard Scientific Name	**Standard Common Name**	**Park Status**	**State Status**	**Federal Status**
Semotilus atromaculatus	creek chub	Present		
Sander canadense	sauger	Present		
Sander vitreus	walleye	Present		
Umbra limi	central mudminnow	Present		

Appendix B-3. Mussels.

Mussel species present, probably present, historically present, and unconfirmed within Mississippi National River and Recreation Area, as determined by the National Park Service Great Lakes Inventory and Monitoring Network as of March 2006. Species conservation status noted as "SPC" = special concern, "THR" = threatened, "END" = endangered, and "CAND" = candidate for listing at the state or federal level.

Standard Scientific Name	Standard Common Name	Park Status	State Status	Federal Status
Actinonaias ligamentina	mucket	Present	THR	
Alasmidonta marginata	elktoe	Present	THR	
Amblema plicata	threeridge	Present		
Arcidens confragosus	rock pocketbook	Present	END	
Cumberlandia monodonta	spectacle case, spectaclecase	Historic	THR	CAND
Cyclonaias tuberculata	purple wartyback	Historic	THR	
Ellipsaria lineolata	butterfly	Present	THR	
Elliptio crassidens	elephant-ear, elephantear	Historic	END	
Elliptio dilatata	spike	Present	SPC	
Epioblasma triquetra	snuffbox	Historic	THR	
Fusconaia ebena	ebonyshell	Historic	END	
Fusconaia flava	Wabash pigtoe	Present		
Lampsilis cardium	plain pocketbook	Present		
Lampsilis higginsii	Higgins eye, Higgins' eye pearly mussel	Present	END	END
Lampsilis siliquoidea	fatmucket	Present		
Lampsilis teres	yellow sandshell	Historic	END	
Lasmigona complanata	white heelsplitter	Present		
Lasmigona compressa	creek heelsplitter	Present	SPC	
Lasmigona costata	fluted-shell, flutedshell	Historic	SPC	
Leptodea fragilis	fragile papershell	Present		
Ligumia recta	black sandshell	Present	SPC	
Megalonaias nervosa	washboard	Present	THR	
Obliquaria reflexa	three-horn wartyback, threehorn wartyback	Present		
Obovaria olivaria	hickorynut	Present	SPC	
Plethobasus cyphyus	sheepnose	Historic	END	CAND
Pleurobema sintoxia	round pigtoe	Present	THR	

Standard Scientific Name	Standard Common Name	Park Status	State Status	Federal Status
Potamilus alatus	pink heelsplitter	Present		
Potamilus ohiensis	pink papershell	Present		
Pyganodon grandis	giant floater	Present		
Quadrula fragosa	winged mapleleaf, winged mapleleaf mussel	Historic	END	END
Quadrula metanevra	monkeyface	Present	THR	
Quadrula nodulata	wartyback	Present	END	
Quadrula pustulosa	pimpleback	Present		
Quadrula quadrula	mapleleaf	Present		
Strophitus undulatus	creeper, squawfoot	Present		
Toxolasma parvus	lilliput	Historic		
Tritogonia verrucosa	pistolgrip	Historic	THR	
Truncilla donaciformis	fawnsfoot	Present		
Truncilla truncata	deertoe	Present		
Utterbackia imbecillis	paper pondshell	Present		

Appendix B-4. Amphibians.

Amphibian species present, probably present, and unconfirmed within Mississippi National River and Recreation Area, as determined by the National Park Service Great Lakes Inventory and Monitoring Network as of March 2006 ("Park-Status"), and amphibian species present or unconfirmed by the U.S. Geological Survey Amphibian Research and Monitoring Initiative (ARMI) as of March 2006.

Standard Scientific Name	Standard Common Name	Park-Status	ARMI
Ambystoma laterale	Blue-spotted Salamander	Probably Present	Unconfirmed
Ambystoma maculatum	Spotted Salamander	Unconfirmed	Unconfirmed
Ambystoma tigrinum tigrinum	Eastern Tiger Salamander	Probably Present	Present
Bufo americanus americanus	Eastern American Toad	Present	Present
Hemidactylium scutatum	Four-toed Salamander	Unconfirmed	Unconfirmed
Hyla chrysoscelis	Cope's Gray Frog, Cope's Gray Treefrog	Probably Present	Unconfirmed
Hyla versicolor	Gray Treefrog	Probably Present	Present
Necturus maculosus maculosus	Common Mudpuppy, Mudpuppy, Waterdog	Probably Present	Unconfirmed
Notophthalmus viridescens louisianensis	Central Newt	Probably Present	Unconfirmed
Plethodon cinereus	Eastern Red-backed Salamander, Red-backed Salamander, Redback Salamander	Unconfirmed	Unconfirmed
Pseudacris crucifer crucifer	Northern Spring Peeper	Probably Present	Unconfirmed
Pseudacris maculata	Boreal Chorus Frog	Probably Present	Unconfirmed
Pseudacris triseriata	Striped Chorus Frog, Western Chorus Frog	Present	Present
Rana catesbeiana	American Bullfrog, Bullfrog	Probably Present	Present
Rana clamitans melanota	Green Frog, Northern Green Frog	Present	Present
Rana palustris	Pickerel Frog	Unconfirmed	Unconfirmed
Rana pipiens	Northern Leopard Frog	Present	Present
Rana septentrionalis	Mink Frog	Unconfirmed	Unconfirmed
Rana sylvatica	Wood Frog	Probably Present	Unconfirmed

Appendix B-5. Reptiles.

Reptile species present, probably present, historically present, and unconfirmed within Mississippi National River and Recreation Area, as determined by the National Park Service Great Lakes Inventory and Monitoring Network as of March 2006, and reptile species present or unconfirmed by the U.S. Geological Survey Amphibian Research and Monitoring Initiative (ARMI) as of March 2006.

Standard Scientific Name	Standard Common Name	Park-Status	ARMI
Apalone mutica mutica	midland smooth softshell, midland smooth softshell turtle	Present	Unconfirmed
Apalone spinifera	Spiny Softshell, spiny softshell, spiny softshell turtle	Probably Present	Present
Chelydra serpentina serpentina	Common Snapping Turtle	Present	Present
Chrysemys picta bellii	Western Painted Turtle	Present	Present
Clemmys insculpta	ornate box turtle, wood turtle	Present	Unconfirmed
Cnemidophorus sexlineatus viridis	Prairie Racerunner	Present	Unconfirmed
Coluber constrictor flaviventris	Eastern Yellowbelly Racer	Present	Unconfirmed
Crotalus horridus	Timber Rattlesnake	Present	Unconfirmed
Diadophis punctatus	Ring-necked Snake, Ringneck Snake	Unconfirmed	Unconfirmed
Elaphe vulpina	Fox Snake	Present	Present
Emydoidea blandingii	Blanding's Turtle, blanding's turtle	Present	Unconfirmed
Eumeces fasciatus	Five-lined Skink	Unconfirmed	Unconfirmed
Eumeces septentrionalis septentrionalis	Northern Prairie Skink	Probably Present	Present
Graptemys geographica	Common Map Turtle, common map turtle	Probably Present	Present
Graptemys pseudogeographica	False Map Turtle, false map turtle	Probably Present	Present
Heterodon nasicus	Western Hog-nosed Snake, Western Hognose Snake	Present	Unconfirmed
Heterodon platirhinos	Eastern Hog-nosed Snake, Eastern Hognose Snake	Present	Unconfirmed
Lampropeltis triangulum triangulum	Eastern Milk Snake	Present	Unconfirmed
Nerodia sipedon sipedon	Northern Water Snake	Present	Present
Opheodrys vernalis	Smooth Green Snake	Historic	Unconfirmed
Pituophis catenifer sayi	Bullsnake	Present	Unconfirmed
Sistrurus catenatus catenatus	Eastern Massasauga	Unconfirmed	Unconfirmed
Storeria dekayi texana	Texas Brown Snake	Probably Present	Unconfirmed
Storeria occipitomaculata occipitomaculata	Northern Redbelly Snake	Present	Present
Thamnophis radix	Plains Garter Snake	Present	Unconfirmed

Standard Scientific Name	Standard Common Name	Park-Status	ARMI
Thamnophis sirtalis parietalis	Red-sided Garter Snake	Unconfirmed	Present
Thamnophis sirtalis sirtalis	Common Garter Snake	Present	Present

As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources, protecting our fish, wildlife, and biological diversity, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

Date, 2007