Minnesota Rivers
a primer

Mary E. Renwick
Susanna Eden

Water Resources Center
University of Minnesota

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by

Mary E. Renwick
Susanna Eden
Water Resources Center
University of Minnesota

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Water Resources Center
College of Natural Resources
University of Minnesota
St. Paul, MN 55108

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Preface

Natural waters play a central role in the lives of Minnesotans. The State's great rivers — the Red River of the North, Mississippi, St. Croix and Minnesota — provide water for many purposes: hydropower, irrigation, drinking water, recreation, fishing resources, as well as waste disposal. Minnesota boasts substantial river resources with over 92,000 miles of rivers. It contains the headwaters for three major U.S. river systems: the Mississippi, the Red River of the North and the St. Lawrence.

Given the prominence of rivers in the lives of Minnesotans, these resources need to be managed wisely. A prerequisite for rational management of any natural resource is an understanding of the characteristics of the resource, the current and potential stresses acting upon it, and the way the resource responds, or is expected to respond, to such stresses. The purpose of this primer is to provide the reader with a basic understanding of how river systems function, their specific uses, and management and monitoring of Minnesota river systems. A brief profile of the State's rivers is also provided. Future publications will provide detailed profiles of the State's four great rivers including the Red River of the North, Mississippi, St. Croix and Minnesota.

This primer is intended as a basic reference for those interested in Minnesota's river systems. It is written for both a general audience with no background in river sciences as well as individuals with training and experience in rivers science and management. It is organized into five chapters. Many factors, including geologic, hydrologic, climactic and human land-use conditions, determine how a river functions. Understanding a river system involves understanding the complex interaction of these factors. Chapter 1 provides an overview of the principal components of river systems. Chapter 2 details Minnesota's river systems. The various uses of Minnesota river water are detailed in Chapter 3. Who controls Minnesota's rivers? This question is explored in Chapter 4, which introduces how policy, planning and management activities affect Minnesota rivers. Monitoring plays an essential role in policy, planning and management activities related to streams and rivers. Chapter 5 provides an overview of monitoring activities affecting Minnesota's rivers and streams and the agencies responsible for collecting, analyzing, reporting and storing the information.

CHAPTER 1

RIVER SYSTEM FUNCTIONS: A RIVER SCIENCES PRIMER

INTRODUCTION

Many factors, including physical, climatic, chemical and biological conditions, determine how a river functions. Understanding a river system involves understanding the complex interactions of these factors. This chapter provides an overview of the principal components of river systems. The discussion focuses initially on the basic components of a cross-section of the river system including the stream channel, the floodplain, and the transitional upland fringe. The discussion then focuses on how characteristics of a river system change from its headwaters to its mouth. Particular attention is given to identifying longitudinal changes in watershed functions, channel formation and other characteristics. The next section examines stream processes, such as hydrologic, hydraulic, geomorphic, and physical and chemical processes, and the last section discusses other important features of stream corridors, such as biological communities and system equilibrium.

BASIC PHYSICAL COMPONENTS OF THE STREAM CORRIDOR: A CROSS-SECTIONAL VIEW

Before examining the dynamic interactions of flowing water in the stream corridor, it is important to understand the basic structural components of the corridor itself. This section identifies the key structural components of the stream corridor cross-sectionally.

Most stream corridors contain three main components: the stream channel, the floodplain and the transitional upland fringe (Figure 1.1). The stream channel contains flowing water for at least a portion of the year. The floodplain, the land adjacent to stream channel, receives floodwaters and concomitant sediment when the stream channel overflows. The nature and size of floodplain vary both along river systems and between river systems. Depending on the surrounding topography, the floodplain may include land on one or both sides of the channel, and the area may vary considerably along a river. The transitional upland fringe is defined as the upland area on one or both sides of the floodplain that delineates the floodplain from the surrounding landscape.

Stream Channel

Flowing water and the sediment it carries form, maintain and modifie the stream channel. Although the form of a stream channels can vary greatly, from meandering gentle streams to fast flowing rivers, it tends to take on a rounded u-shape. When scientists study a stream cross-sectionally, they invariably examine two key attributes of the system — stream flow and channel size. Stream flow is the volume and velocity of water entering the channel. Precipitation is the original source of all stream flow; the pathways it takes after falling to the

Figure 1.1 The Major Cross-Sectional Components of the Stream Corridor. Photo courtesy of the University of Minnesota Extension Service

earth affect the quantity, quality and timing of the stream flow. The two basic flow pathways are storm flow and base flow. Storm flow is precipitation that reaches the channel very soon after precipitation via overland or underground routes. Base flow is precipitation that percolates to the ground water and moves slowly through the substrate before reaching the channel. Base flow provides stream flow during periods of little or no precipitation. The measure of stream flow used by those studying river systems is known as the discharge rate, which is the volume of water moving down the channel per unit of time. It is measured in cubic feet per second (cfs) in the U.S. Discharge rates depend both on the average velocity at which the water is moving downstream and the size of the channel through which the water is flowing.

Channel size is determined by stream flow and sediment load. Sediment load refers both to the amount of sediment the stream is transporting and depositing and to its characteristics. These characteristics are described in more detail below. A *stream balance equation* formally describes the dynamic relationship between channel size and sediment load and stream flow. This equation states that the channel is in equilibrium when the sediment load is balanced with stream flow. If changes in either sediment load or stream flow occur, the balance will be lost temporarily. These changes will modify the channel over time, by either building up or scouring the riverbed, to bring the system back into equilibrium. The stream balance equation is useful for conceptualizing the potential impacts on a channel resulting from changes in runoff or sediment loads from the watershed.

MOVING ALONG THE STREAM CORRIDOR: A LONGITUDINAL VIEW

Structural Changes in the Stream Corridor from its Headwaters to Outlet

The physical structure of the channel and floodplain changes as a river travels from its headwaters to its outlet. Channel width and depth increase downstream as the drainage area and discharge increase. A simplified longitudinal model captures these observed changes by disaggregating the river into three zones: headwaters zone, transfer zone, and depositional zone (Figure 1.2). The headwaters zone generally has the steepest slope. As the water moves over these slopes, sediment erodes and is carried downstream. In the transfer zone, which receives sediment from upstream, the gradient decreases. The river widens as smaller streams merge. In the depositional zone, the gradient flattens from a build-up of sediment over time. The river widens further and meanders toward its mouth.

These same three zones are also evident on a much smaller scale within the watersheds of contributing streams. A watershed is defined as the "area of land that drains water, sediment, and dissolved materials to a common outlet at some point along a stream channel" (Dunne and Leopold, 1978). The size and structure of watersheds vary significantly due to geologic, morphologic, vegetative, soil and climatic differences. Differences in topographic and geologic structure also influence watershed drainage patterns.

Stream Order Models

As water moves along pathways of least resistance in the watershed, it forms streams that join larger and yet larger streams. The resulting river is branched like a tree; the particular form of the branching depends on the watershed through which the water flows. A method of classifying the hierarchy of natural channels according to their position in the drainage system, referred to as stream order, permits comparison of the behavior of a river with others similarly situated. It is useful for developing and testing generalizations and predictions about river processes. Several modifications exist of the original stream-order system developed by Horton in 1945. In the most commonly cited and used system (Strahler, 1957), small headwater streams are designated Order I. Streams formed by the confluence of two Order I streams are referred to as Order II, and so on, with larger numbers indicating larger rivers with multiple tributary streams (Figure 1.3). Stream order is used primarily by hydrologists to construct models of stream flow. Stream order correlates generally with gradient, drainage area, channel width, and discharge; but because of multiple intervening factors, the statistical variance of the correlations is large.

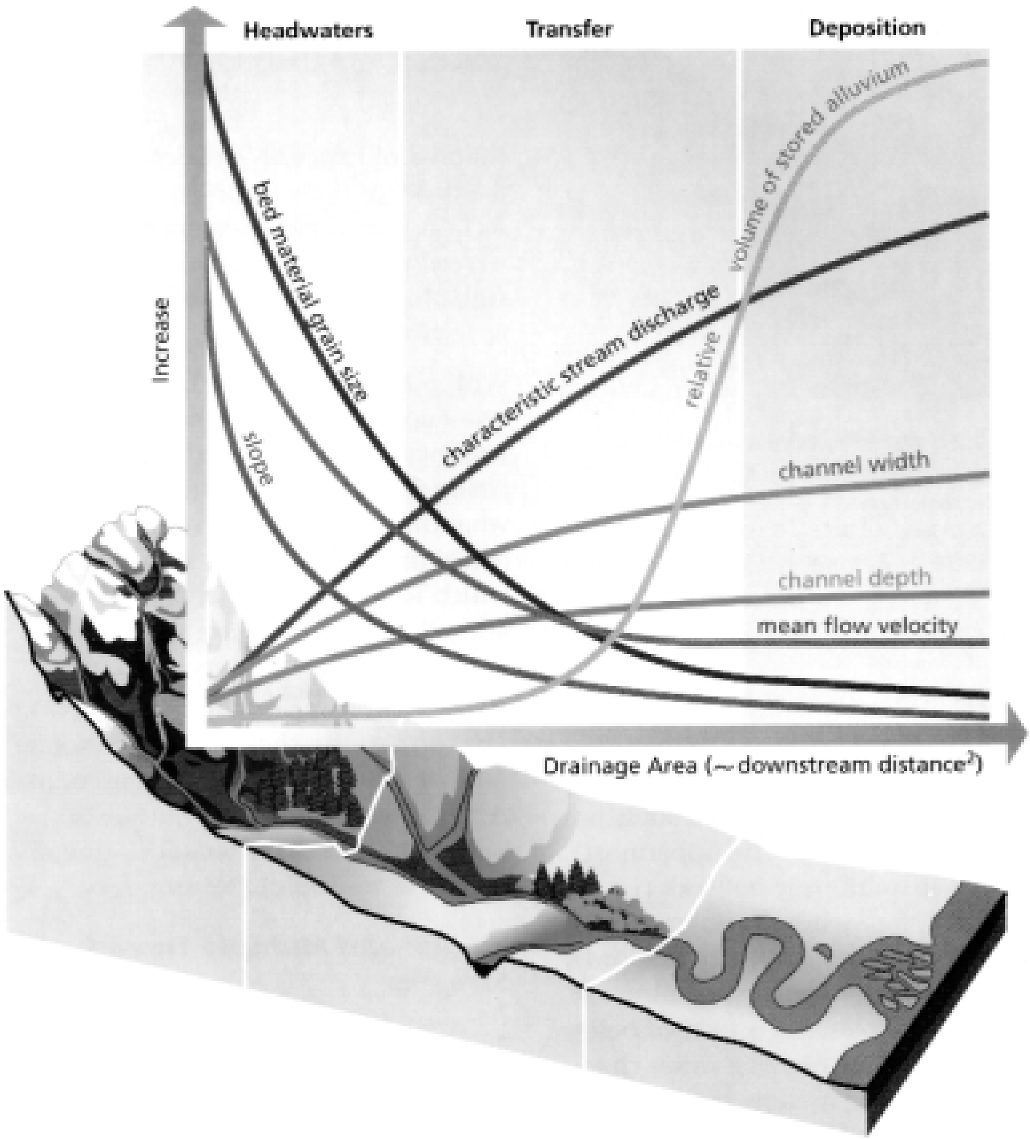

Figure 1.2 The Three Longitudinal Zones and Channel Characteristics. Reprinted with permission of Federal Interagency Stream Restoration Working Group (1998).

Longitudinal Changes in Stream Ecosystems

Beyond structural changes in the stream channel, there are observable changes in stream ecosystems from the headwaters to the mouth. The characteristics of biological communities vary in different reaches of a river system. Observation of abrupt changes in species associated with changes in stream size, channel width, gradient, stream flow and temperature supports the concept of stream zones, as described above.

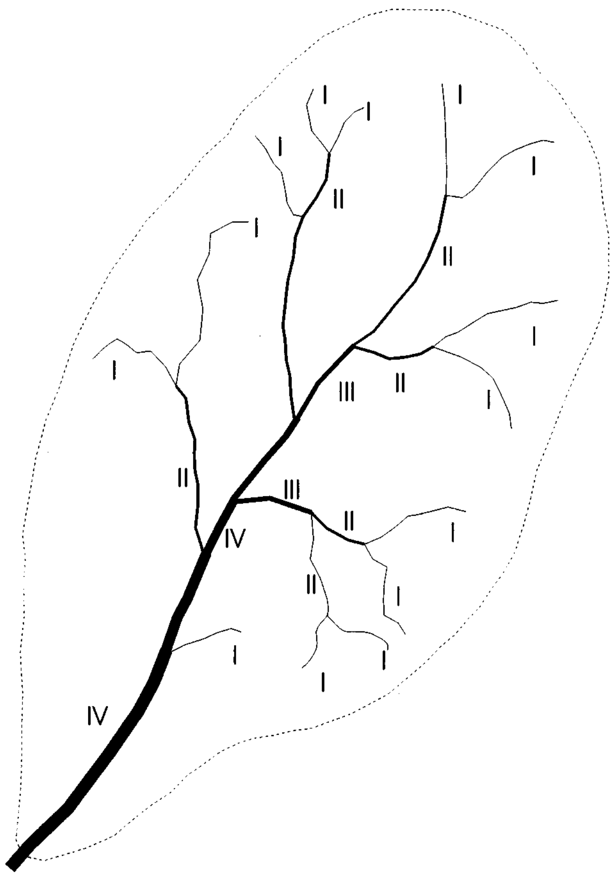

Figure 1.3 Stream Order Classification. By permission, Ojakangas, Richard W. 1982. Minnesota's Geology. With Charles L. Matsch. Drawings, charts, and graphs by Dan Beedy. Minneapolis : University of Minnesota Press. p. 114.

The best known longitudinal model for rivers, the River Continuum Concept (RCC), attempts to generalize and explain observed longitudinal changes in stream ecosystems (Figure 1.4). It proposes that rivers exhibit continuous longitudinal changes and identifies the relationships between the progressive changes in stream structure, such as channel size and stream flow, and the distribution of species (Table 1.1). According to the RCC, characteristics of particular reaches are associated not only with discrete factors such as water temperature, but with their positions along the length of the river. The model is especially useful at the basin and stream scale, because it accounts for observed longitudinal shifts in biotic communities.

The RCC as originally defined was most successful in describing rivers that emerge in forested mountains and descend into regulated channels on the floodplain. Since its initial development, the RCC has been expanded to include several alternative models. Rivers that regularly overtop their banks and inundate the floodplain have been characterized by a 'Flood Pulse' model that describes habitat characteristics and biotic communities along a temporal continuum. A temporal dimension is embedded in the RCC because the main features of a time-based river

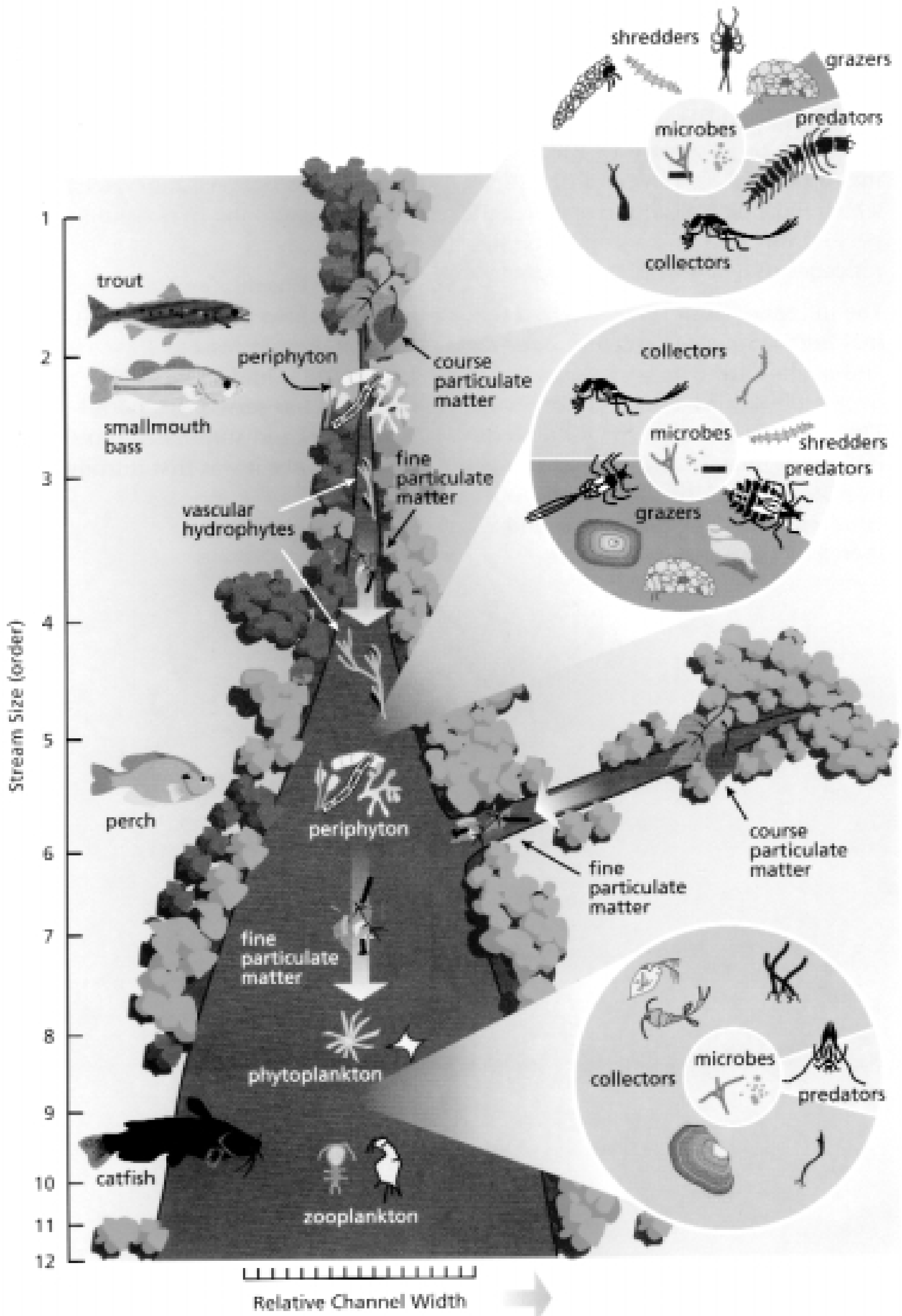

Figure 1.4 River Continuum Concept. Reprinted with permission of the Federal Interagency Stream Restoration Working Group (1998).

Table 1.1 Commonly Observed Changes Associated with River Continuum Concept. Adapted from Ward. 1992. A Mountain River, Chapter 23 in River Handbook, P. Calow and G.E. Petts, eds. pp. 499.

Simplified RCC	Upper reaches	Middle reaches	Lower reaches
Stream order	1 - 3	3 - 6	6 and above
Substrate	coarse	sand, gravel	fine
Current	fast		slow
Oxygen	saturated		periodic deficits
Sunlight	low	high	low
Temperature	max. <20°C, fairly constant	highly variable	max. >20°C, variable
Particulate matter	coarse		fine
Nutrients	low	high	low
Dominant energy source	leaf litter	primary producers	transport detritus
Dominant primary producers	primary producers rare	attached	plankton
Dominant invertebrates	shredders, collectors	grazers (scrapers), collectors	collectors
Fish habitat and food preferences	cool water, swift current insects	fish and insects	slow current plankton, bottom matter
Biological diversity	low	high	low

model (e.g., duration of inundation) vary longitudinally in a predictable fashion.

An alternative model adopted by some ecologists is referred to as “patch dynamics”. According to this model, stream habitat and species distribution exhibit patchiness. Stream communities are not determined by the nature of a given zone or stream reach but are viewed as random phenomena (Townsend, 1989). The patch dynamics concept reflects relatively short-term observations on a stream-reach scale at which the nature and distribution of biotic communities appear unpredictable. It is complementary with the RCC because most running waters that show local patch effects will exhibit predictable longitudinal patterns over larger scales and longer time periods (Brezonik, 1996).

KEY STREAM PROCESSES AND OTHER IMPORTANT SYSTEM CHARACTERISTICS

The observed structure in a particular stream corridor is a result of hydrologic, geomorphic and physical and chemical processes operating within the river corridor as well as the influence of biological functions and overall system equilibrium. This section examines how these processes and characteristics influence the structure of the stream corridor.

Hydrologic and Hydraulic Processes

The hydrologic cycle illustrates the cyclic transfer of water from precipitation through storage and runoff, to surface and ground water, and eventually back to the atmosphere through evaporation and transpiration, as shown in Figure 1.5 (Federal Interagency Stream Restoration Work Group, 1998). When precipitation reaches the earth it moves along one of three possible routes described by the hydrologic cycle. It evaporates/transpires back into the atmosphere, infiltrates the soil profile, or runs across the earth's surface into a water body. These pathways influence how water moves in the stream corridor. The relationship between the amount of water that falls on the watershed and the water that flows in the river channel (discharge) is determined by three major factors: (1) the nature, timing, and location of the water input in the watershed, (2) water demands of the system — interception, evaporation and evapotranspiration, and (3) flow pathways and water storage in the watershed. A dynamic interaction occurs between climatic variables, such as precipitation and temperature, and physical attributes, such as hydraulic gradient (slope or head) and watershed topography.

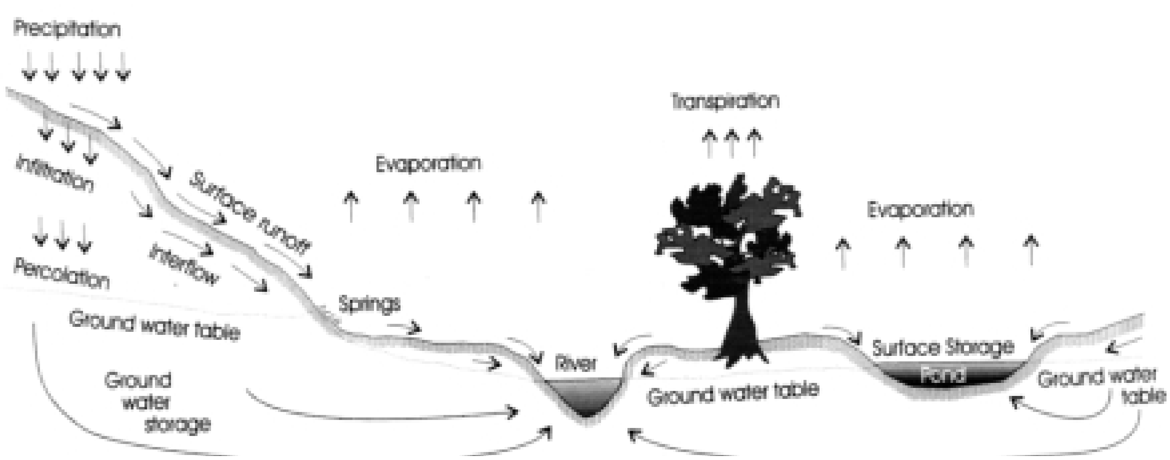

Figure 1.5 Hydrologic Cycle. Adapted from Adapted from Black, P. 1990. Watershed Hydrology. p. 267.

Water inputs to the river system come ultimately from precipitation — rain or snow — via overland and underground routes. The nature, timing and location of the water input influence the force of a river's flow. For example, precipitation in the form of snowfall does not reach the river as runoff until it melts in the spring.

Water demands on the system due to interception, evaporation and transpiration also influence river flow. In the U.S., more than two-thirds of precipitation evaporates back into the atmosphere. Some precipitation is intercepted by vegetation and other surfaces and evaporates into the atmosphere from the interception sites. How quickly the water evaporates from the interception sites after a precipitation event depends on climatic conditions. Evapotranspiration describes the movement of water back into the atmosphere through the diffusion of water vapor from vegetation, known as transpiration, and through evaporation of moisture contained in the soil.

Precipitation that is not evaporated or intercepted succumbs to the law of gravity and becomes runoff. Gravity pulls the water down from the surface of leaves, along the stems of plants, over land, through soil pores and rock fractures, downhill as far as it will go to oceans and land-locked lakes. It may seep underground and flow for short distances to emerge, for example, as a spring, or it may remain beneath the earth's surface for years or even millennia. The nature of the watershed's topography, soils and vegetation influences its capability to store water. Forested watersheds with active wetlands can store large quantities of water, slowing and damping the peak flood pulse and acting as a kind of flood control system.

Geomorphic Processes

Geomorphology is the study of the earth's surface forms and the processes and mechanisms that create these forms (Federal Interagency Stream Restoration Work Group, 1998). The hydrologic processes that characterize flowing water provide the mechanisms for the geomorphic processes discussed in this section. The three fundamental geomorphic processes associated with flowing water are erosion, sediment transport and sediment deposition.

As water flows along pathways in its watershed, it shapes the terrain through erosion, transport and deposition of sediments. Climate, topography, geology and land use influence the amount of sediment flowing through the watershed. Intense precipitation, steep slopes, easily erodible rock and soil, and land clearing all tend to increase sediment yields. In Minnesota, flowing water carries off more than 60 million tons of upland topsoil each year (Tester, 1995).

Stream transported sediment is classified either as suspended load or bedload. Suspended load consists of small particles such as clays, silts, and fine sands that are easily carried suspended in the flowing water. Bedload consists of large particles such as coarse sands, gravels and boulders that move by rolling, sliding, or hopping along the bed. River bed materials, referred to as the substrate, tend to vary downstream according to how easily the particles are transported (Figure 1.6). Beds of headwater streams usually contain large particles such as gravel and boulders that are too heavy for the stream to move. Downstream, the size of particles decreases, as large rocks are broken and worn down, and smaller particles such as finer sands and silts are sorted out, carried off and eventually deposited in the river's delta. Natural and artificial obstructions in a stream cause localized changes in the stream's ability to transport particles.

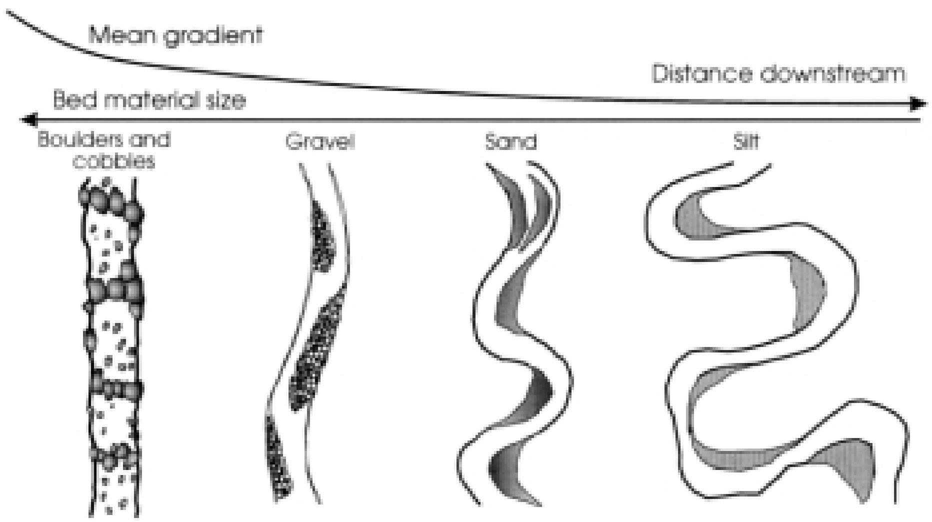

Figure 1.6 Sediment Transport. Adapted from Church, M. 1992. Channel Morphology and Typology. Chapter 6 in The River Handbook, vol. 1, P. Calow and G.E. Petts, eds. pp. 130, 136.

The amount of sediment a river can transport depends on stream energy or power. Stream energy is a function of the velocity of its flow, the gradient of the channel and the channel depth. Other factors such as surface roughness also influence sediment transport. When stream energy is just sufficient to transport the sediment supplied to the river, the river is said to be in equilibrium, or graded. If an imbalance exists between the amount of sediment supplied to the river and stream's power to transport the sediment, the channel characteristics will change over time to bring the river system into equilibrium. When sediment supplied exceeds stream carrying capacity, sediment deposition builds up (or aggrades) the stream bed, increasing its slope downstream and thereby increasing stream power. In contrast, when a river can carry more sediment than it receives, 'excess' stream energy scours (or degrades) the channel, decreasing downstream slope and stream energy.

Physical and Chemical Processes

The physical characteristics and chemistry of water change as water comes in contact with air, soil, rocks, bacteria, vegetation and biological communities. This section provides a brief description of the physical materials and chemical processes influencing stream water quality.

As water moves along pathways in a watershed, eroded soil and plant materials enter the flowing water. Addition of these materials, in conjunction with chemical and biological processes operating within the river, influences the physical and chemical properties of the flowing water (Figure 1.7). External (or allochthonous) materials entering the river include eroded soils, salts carried by rain or leached from rock and soil, and leaves and woody material washed or dropped into the stream. Internal (or autochthonous) processes operating within the river include physical breakdown of rocks and plant materials, microbial decomposition of organic matter, cycling of carbon and dissolved nutrients in the presence of sunlight by plants and animals, and chemical transformations of inorganic ions under changing conditions of temperature, pH, and oxygen concentration.

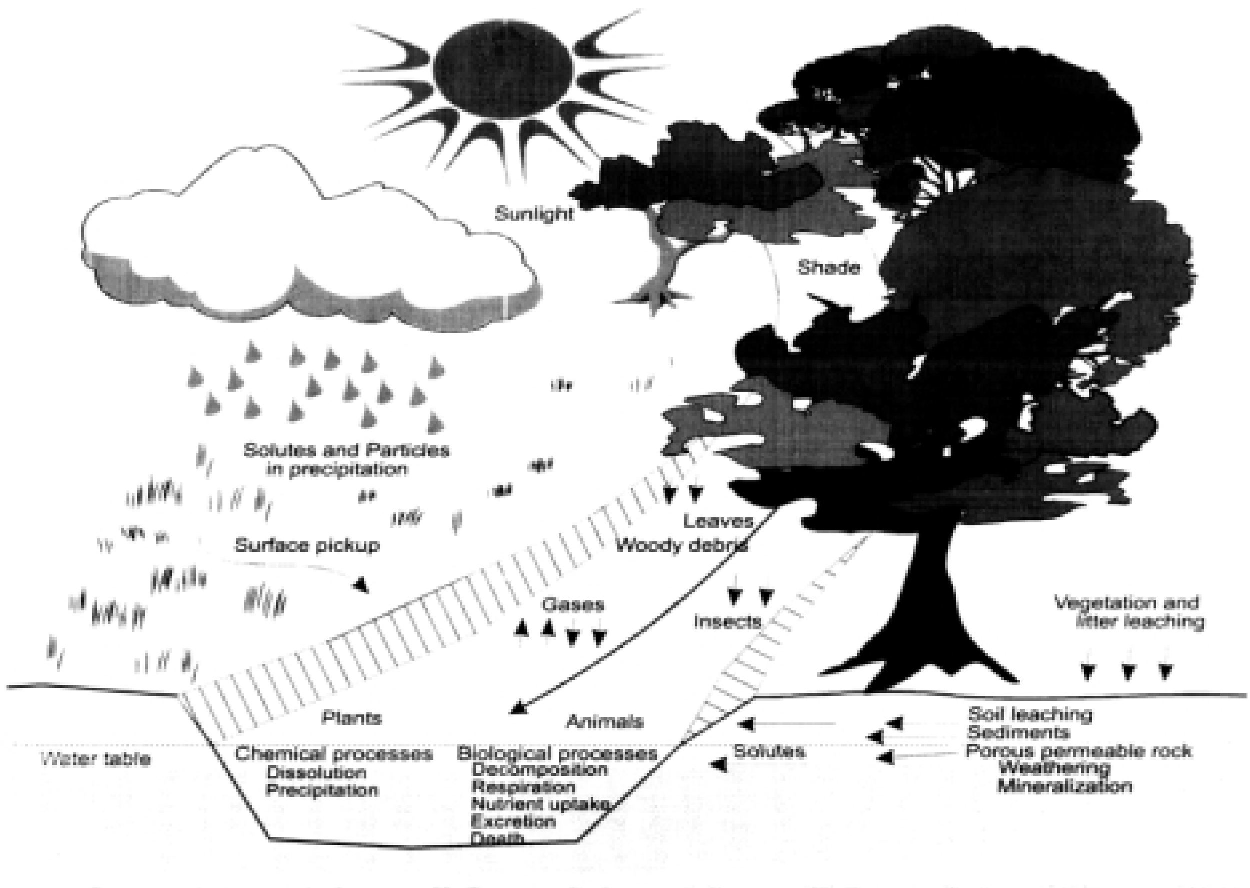

Figure 1.7 Materials and Processes Contributing to the Physical and Chemical Properties of a Stream

The chemical constituents resulting from these external and internal processes may be suspended or dissolved in the stream water. Suspended particles are classified either as sediment or colloids, depending upon their size. Suspended particles measuring 0.1 mm or greater in diameter are considered coarse sediment and they will settle rapidly out of still water. Smaller suspended particles include silts, clays, and organic particles (sometimes called organic detritus) derived from plants and animal activity. Bacteria and suspended algae (phytoplankton) also are in this size range (see next section). Clay-sized particles (< 63 m) settle very slowly, even in still water, unless they become coagulated into larger particles. Colloidal particles are smaller than about 0.5 m in diameter. Although colloids are too small to be seen with the naked eye, they provide surfaces for absorption of dissolved chemicals and affect water color and clarity (turbidity).

Dissolved constituents include organic compounds, gases, and inorganic ions (salts) such as calcium, magnesium, and sodium. Some inorganic chemicals, such as phosphorus, are common in all natural stream waters and are beneficial and even necessary for life. For example, phosphorus is an essential nutrient for plant life. These solutes are considered pollutants only when their levels are elevated to the point where they threaten the health of the ecosystem. Elevated concentrations of trace constituents are usually linked to anthropogenic factors, such as industrial discharges or runoff carrying agricultural fertilizers.

Stream water chemistry can vary both daily and seasonally. Much of this variability results from changes in the proportions of stormflow and baseflow, which often have very different chemical properties. Water chemistry also is affected by changes in the amount of flow. While periods of high flows decrease the concentration of some point source pollutants through dilution, they also may increase nonpoint source pollutants, such as those from atmospheric deposition, that accompany higher runoff.

Biological Community

The morphometric and physical properties of a stream determine the availability of suitable habitat for biota. The unidirectional flow of water is one of the most important factors controlling survival in rivers. River-adapted organisms must have strategies to protect themselves from being flushed downstream. Other factors that determine the suitability of habitat are flow regime, water quality, temperature, sunlight, oxygen, food, and protection from predators.

The organisms in an ecosystem are interconnected to form a food web. The food relationships commonly observed among stream biota are shown in Figure 1.8. In rivers, the primary producers that compose the base of the food web include aquatic plants (macrophytes) and algae. Some types of algae, known as periphyton, attach to surfaces in the stream channel, whereas others, known as phytoplankton, are suspended in the water. Primary producers use energy from sunlight to turn dissolved inorganic nutrients (nitrogen, phosphorus, carbon) into organic matter through photosynthesis. Organisms that feed on this plant tissue convert it to animal tissue, waste and energy. Decomposition of organic materials occurs as other organisms break down dead plant and animal tissue and wastes.

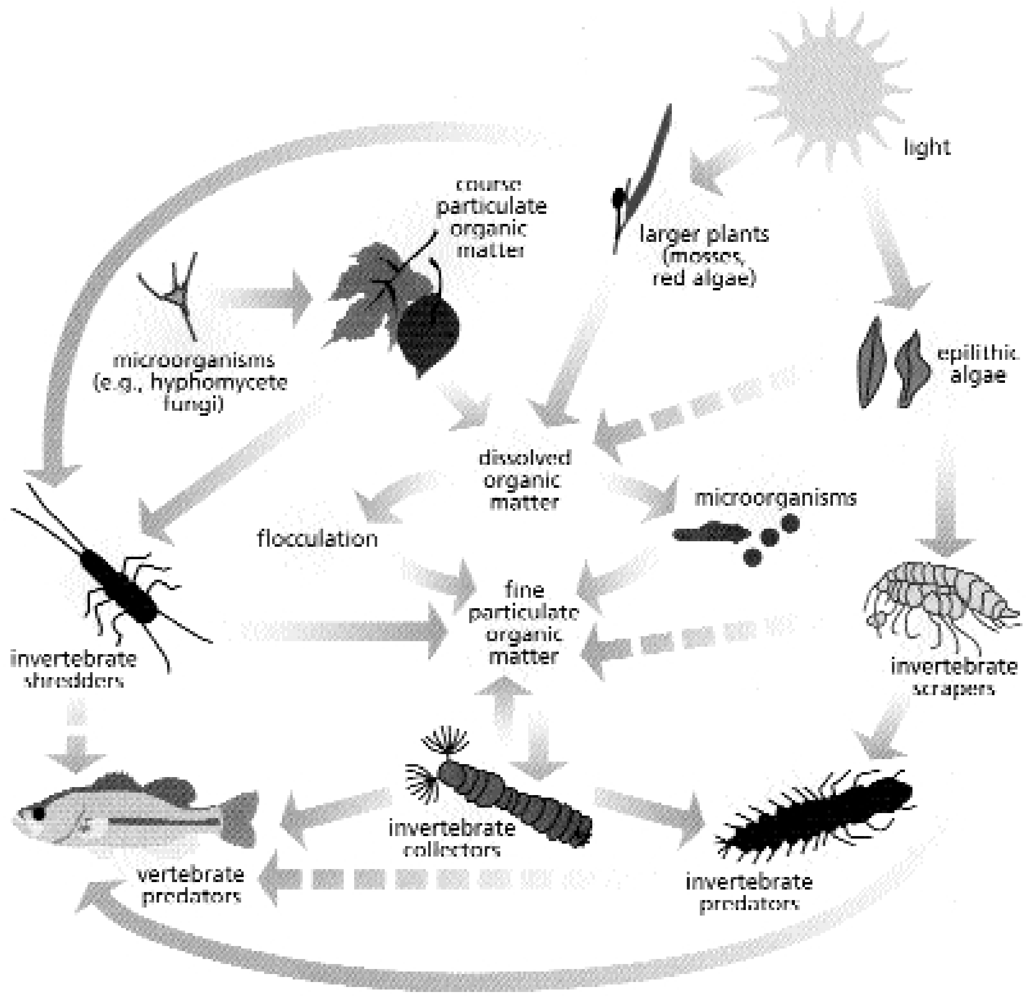

Figure 1.8 Stream Biota. Reprinted with permission of the Federal Interagency Stream Restoration Working Group (1998).

The relationship between the rate of primary production and the rate of decomposition influences the availability of habitat for stream biota. If primary production exceeds decomposition, the stream reach is described as autotrophic. If decomposition exceeds primary production, as occurs in most streams, the stream reach is described as heterotrophic. Most of the organic matter for the food web in heterotrophic stream reaches comes from external sources, such as the leaves of riparian trees and soil organic matter.

Primary producers that anchor themselves to the bottom substrate, such as large aquatic plants and attached algae, are more abundant in stream reaches where sunlight is unobstructed by riparian shade or suspended sediment. These producers tend to thrive in mid-reaches with substrates composed of coarser materials, ranging from sands to gravels. Other primary producers, such as phytoplankton, remain suspended in water and prefer slow-moving flow conditions found near stream banks, behind obstructions, and in the backwaters of lowland rivers.

Organisms that feed directly on non-living coarse particulate organic matter (detritus) include bacteria, fungi, and some invertebrates known as shredders. These organisms proliferate in forested headwater streams, where detritus is plentiful and where the substrate allows for attachment. Other organisms, such as scrapers and grazers, feed directly on primary producers and thrive where the plants they feed on are most abundant. Both shredders and scrapers produce fine particulate organic material, bits of shredded and partly decomposed detritus and wastes. Invertebrates that feed on fine particulate organic material (collectors) flourish in lowland reaches where they collect food supplied by upstream activities. Fish and other vertebrate predators feed on collectors, shredders and other invertebrate predators.

Fish species have adapted to different stream habitats over time by modifying their forms, habits, and reproductive strategies. For example, the small agile bodies of fish in high-gradient upland streams allow them to accelerate quickly and move through the swift and rolling flow of these streams. In response to seasonal variability of water levels, from periods of flood to periods of low or no flow, some species mature rapidly and have short life spans. They usually require higher oxygen content and lower temperatures ($<20^{0}$C) than downstream species. Low gradient floodplain rivers provide a greater variety of environments and therefore are populated by a wider variety of organisms. Fish in these rivers may be larger and are tolerant of wider ranges of temperature, higher temperatures, and lower oxygen concentrations.

For some fish, upland streams provide habitat for spawning and for young, while the lowland river is home to adults. In floodplain rivers where seasonal flood pulses provide a full range of flowing to still-water habitats, fish use shallow, seasonally flooded pools for reproduction and maturation.

Self-Correcting Mechanisms and Dynamic Equilibrium

Stream corridors exhibit a dynamic form of stability, known as dynamic equilibrium. Dynamic equilibrium refers to the ability of system to persist within a range of conditions (Federal Interagency Stream Restoration Work Group, 1998). Maintaining this balance requires the presence of a series of self-correcting mechanisms in the ecosystem. A disturbance to the stream ecosystem triggers a response from these self-correcting mechanisms allowing maintenance of the dynamic equilibrium.

Disturbances result from both naturally occurring and human-induced events. Climatic factors often play a role in naturally occurring disturbances and generally involve below- or above-normal precipitation and concomitant runoff. Human-induced disturbances often relate to changing land use patterns associated with development activities within the watershed.

Disturbances and the river system's response to them occur at both temporal and spatial scales, and a crude correlation can be drawn between them (Figure 1.9). At the stream reach scale, for example, cumulative effects of wave action from recreational boating over decades can be a major cause of bank erosion along popular reaches. At the river basin scale, the composite effect of major land-use changes in a watershed over a century, such as clearing of hardwood forests and substitution of agricultural crop production, may cause substantial chronic disturbances with long-term consequences for the river system.

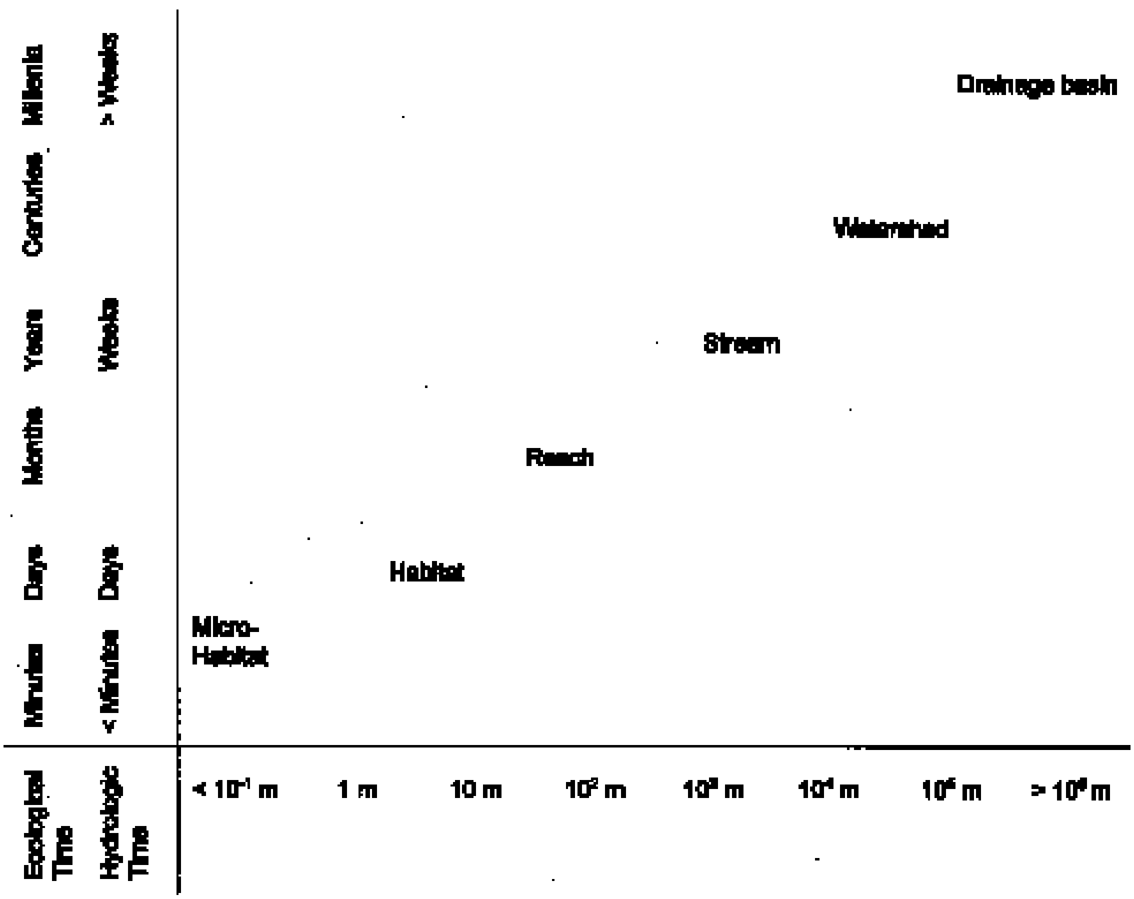

Figure 1.9 Temporal and Spatial Factors Influence Ecosystem Response

While many stream ecosystems can tolerate fairly significant disturbances and maintain dynamic equilibrium, threshold levels exist. When thresholds are exceeded, the system becomes unstable. As the ecosystem adjusts over time, it moves towards a new dynamic equilibrium that may be different than the one that existed prior to the disturbance. In some instances, disturbances alter the system to such an extent that it cannot recover unless the cause of the disturbance is removed or actions are taken to restore stream functions. At present, the relationships between threshold levels and the associated range of conditions required for ecosystem stability are not well understood. Research efforts in this area currently focus on identifying and quantifying threshold levels.

CHAPTER 2

AN OVERVIEW OF MINNESOTA'S RIVERS

INTRODUCTION

Minnesota contains eight major river basins with 92,000 miles of river. Eighty-one major watersheds compose these eight river drainage basins: Red River, Rainy River, Lake Superior, Upper Mississippi, Lower Mississippi, St. Croix, Minnesota, and Missouri (Figure 2.1).[1] A continental divide in Northeastern Minnesota partitions the surface flows from these eight river drainage basins into three major flow ways that constitute headwaters areas for the Hudson Bay, the Atlantic Ocean and the Gulf of Mexico.

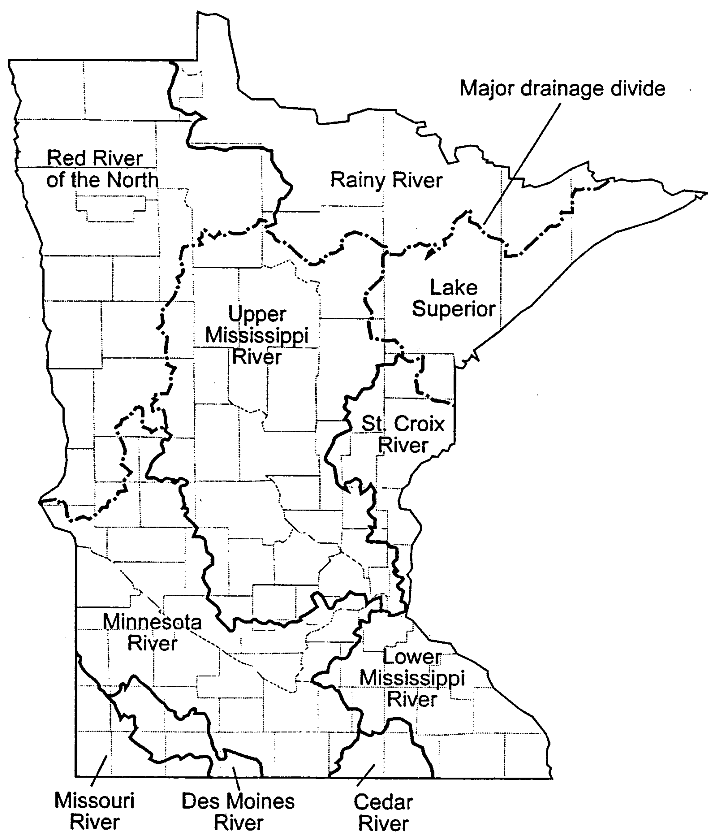

Figure 2.1 Major Watersheds in Minnesota. Rivers Council of Minnesota, 1999.

[1] As described in Chapter 1, a watershed is the land area that contributes surface flow to a single river system. Watersheds are nested such that the watershed of a large river is composed of several smaller tributary river basins, each of which is composed of several stream basins.

GEOMORPHOLOGIC FEATURES

A generally low relief surface characterizes the topography through which Minnesota's streams and rivers flow, as shown in Figure 2.2. The areas of greatest relief are located along the north shore of Lake Superior and in southeastern and southwestern Minnesota where streams descend into the Mississippi and Minnesota rivers, respectively. The state's topographical features, created largely during the most recent glacial periods, reflect a long period of geologic stability.

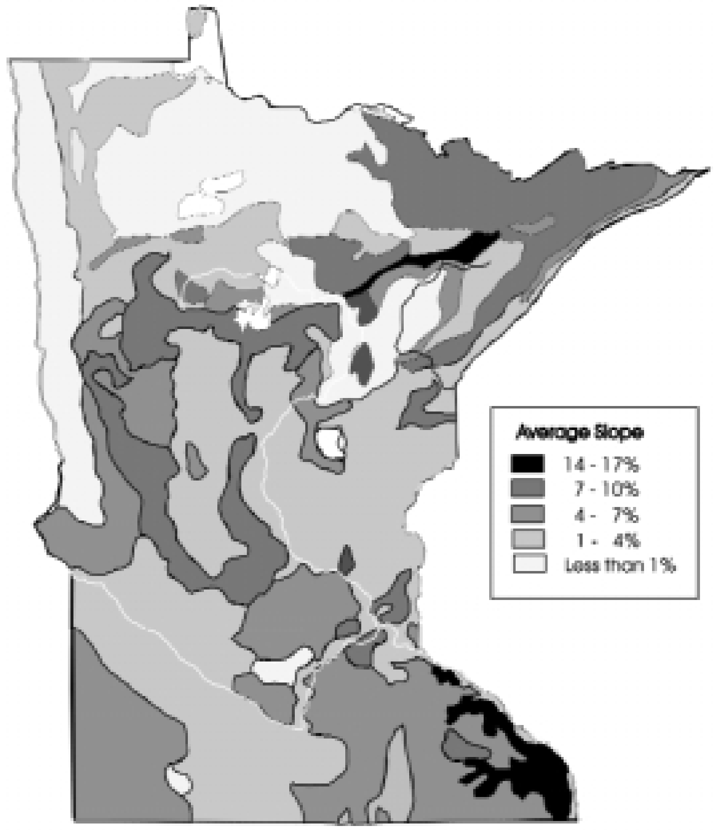

Figure 2.2 Topographic Regions of Minnesota. Adapted from MEQB-Lakes (1994). Minnesota Lake and Watershed Data Collection Manual, p. 69.

Minnesota's soils developed within the last 15,000 years from glacial sediments. A blanket of glacial sediments and meltwater deposits covers the state's older bedrock. The depth of glacial sediments is thickest (up to 150 meters) in northwestern Minnesota and thinnest in the Arrowhead and the southeastern Mississippi River valley regions. The variation in soil types across the state reflects differences in local erosion patterns and deposition of sediments during and after recent glacial periods. In general, however, soils tend to be rich in minerals because they are relatively new.

HYDROLOGIC CYCLE and STREAM FLOW

Water inputs into Minnesota's streams and rivers come primarily from runoff associated with precipitation. The majority of the state's annual precipitation (65 to 75 percent) occurs from May through October. Average precipitation varies widely across the state—from an average of 19 inches in the northwestern corner to 32 inches in the southeastern corner (Figure 2.3). Normal snowfall from November through April totals roughly 46 inches. Average annual runoff also varies widely across the state—from less than two inches in the west central border region to greater than 15 inches in the Arrowhead region (Figure 2.4). These differences reflect geographic trends in precipitation and other climatic conditions. Although snowfall accounts for only about 15% of annual precipitation, it contributes significantly to the amount and timing of peak stream runoff (Baker et al., 1979). High flows also occur as a result of intense summer thunderstorms.

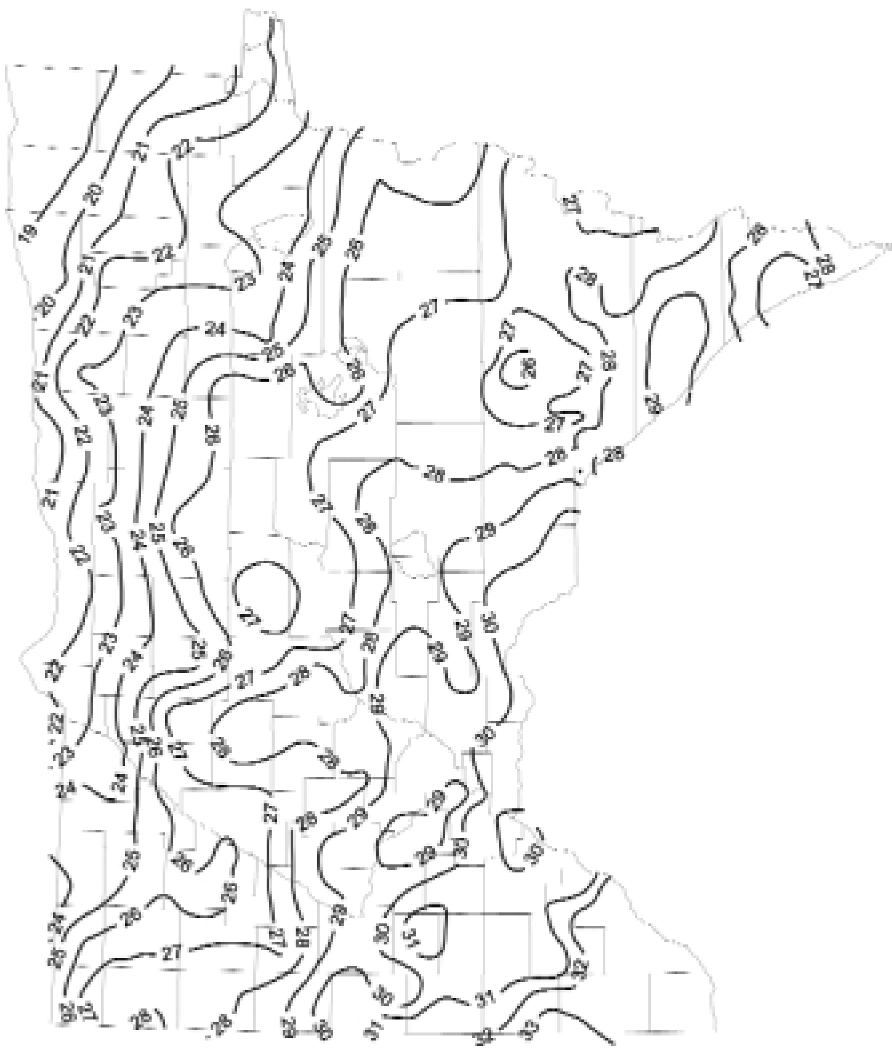

Figure 2.3 Average Annual Precipitation in Minnesota: 1961-1990. Courtesy of State Climatology Office, DNR-Waters Division, September, 1999.

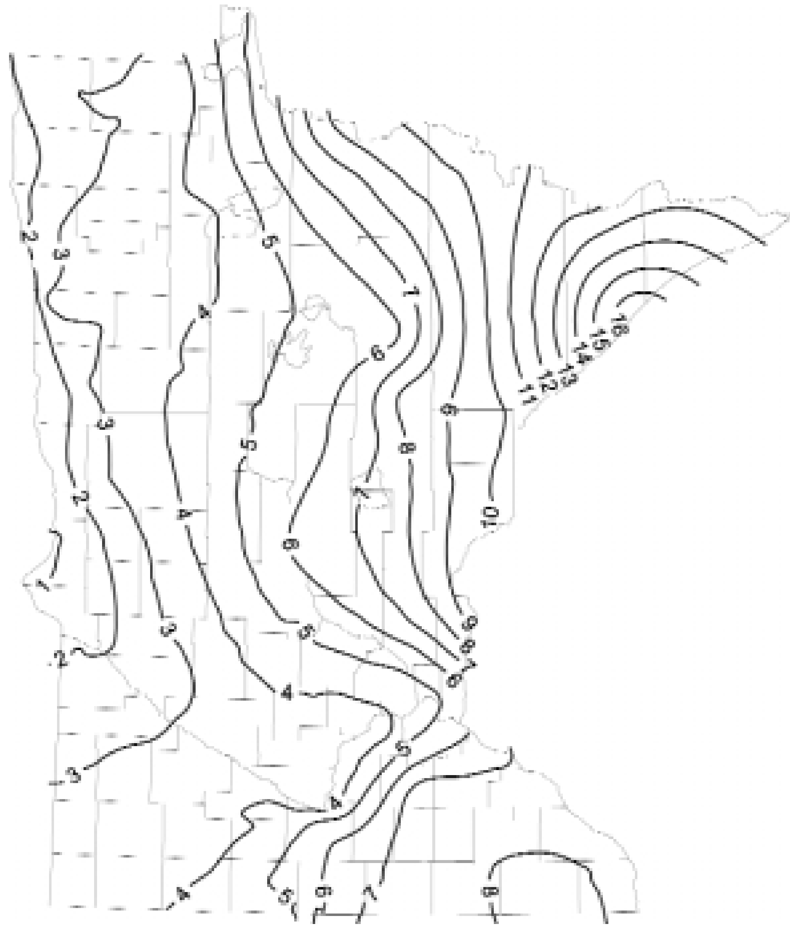

Figure 2.4 Annual Mean Runoff in Minnesota Measured in Inches: 1961-1990. Courtesy of State Climatology Office, DNR-Waters Division, September, 1999.

When precipitation reaches the earth it moves along one of three routes. It evaporates/transpires back into the atmosphere, infiltrates the soil profile or runs across the earth's surface into a body of water. According to the U.S. Geological Survey, about 78 percent (30 trillion gallons) of Minnesota's annual precipitation either evaporates or is transpired by natural vegetation (USGS, 1991). The remaining 22 percent of total precipitation (8 trillion gallons) either infiltrates the soil profile or runs off.

The topographical features and soil characteristics influence water storage capacity in the watershed. Forested watersheds with active wetlands can store substantial quantities of water and operate as a flood control mechanism by slowing and dampening peak flood impulse. In contrast, watersheds prone to flooding contain large areas of bare flat land that cannot store significant amounts of water.

Among the eight river basins in Minnesota, differences in the geomorphology of the flow pathways and water storage capacities in the watershed influence stream flows and the potential for flooding. The Rainy River and Lake Superior basins in northeastern Minnesota possess limited water storage capabilities because most tributaries flow over impermeable bedrock covered by only a thin layer of glacial drift. Despite limited storage capability of the soil profile, flows in the Rainy River basin remain relatively stable due to the substantial holding capacity of headwater lakes and wetlands. In contrast, very limited storage capacity in headwater areas in the Lake Superior basin makes these areas prone to flash flooding.

In the Red River basin, extensive areas of wetland, peat bogs, and marshes in northern tributary headwaters provide natural flood protection. However, the flat topography of the lower basin makes flooding a major problem in Red River valley. Spring flood waters can extend for miles, flowing over agricultural and municipal lands. Increased vulnerability of this area to floods stems from both stream channelization and draining of upland areas and prairie marshes. The most damaging floods on record occurred in 1950, 1966, 1979 and 1997. The 1979 flood resulted in property damage totaling $43.7 million. According to the 1998 Minnesota Recovery Disaster Task Force Anniversary Report, expenditures to remedy 1997 flood-induced damages totaled more than $830 million. Funding sources include $125 million from the state flood recovery fund, $573 million from the Federal flood recovery fund, and $132 million of private flood recovery funds.

The rivers of central Minnesota drain the Upper Mississippi basin. Natural regulation provided by extensive areas of lakes and swamps at the headwater areas contributes to stable stream flows. In addition, a series of headwater reservoirs regulates flows in the Upper Mississippi for navigational and other purposes. Flooding is a major problem along tributaries in the Lower Mississippi Basin of southeastern Minnesota. Spring snow melt and torrential summer thunderstorms may produce flash floods, a problem exacerbated by clearcutting on steep slopes for lumber and cattle grazing in the past.

In the Minnesota River Basin, which flows from west to east through the southern third of the state, stream flows have been modified greatly by human activities over the past 150 years. Over 90 percent of the land contained in the basin is under agricultural production. To support agricultural activities, the basin been extensively ditched, channelized, and drained by a vast network of drainage ditches and subsurface tiles.

PHYSICAL and CHEMICAL PROPERTIES

Concentrations of chemical constituents commonly found in rivers affect plant and animal life, as well as other water users. Figure 2.5 shows the typical concentrations of major ions found in large rivers of Minnesota at selected sampling sites. In addition to major ions, common metal, other elements and trace amounts of organic compounds from human activities are found in Minnesota's rivers. Mercury, phosphorus, and polychlorinated biphenyls (PCBs) have been found in concentrations high enough to trigger concern for some rivers.

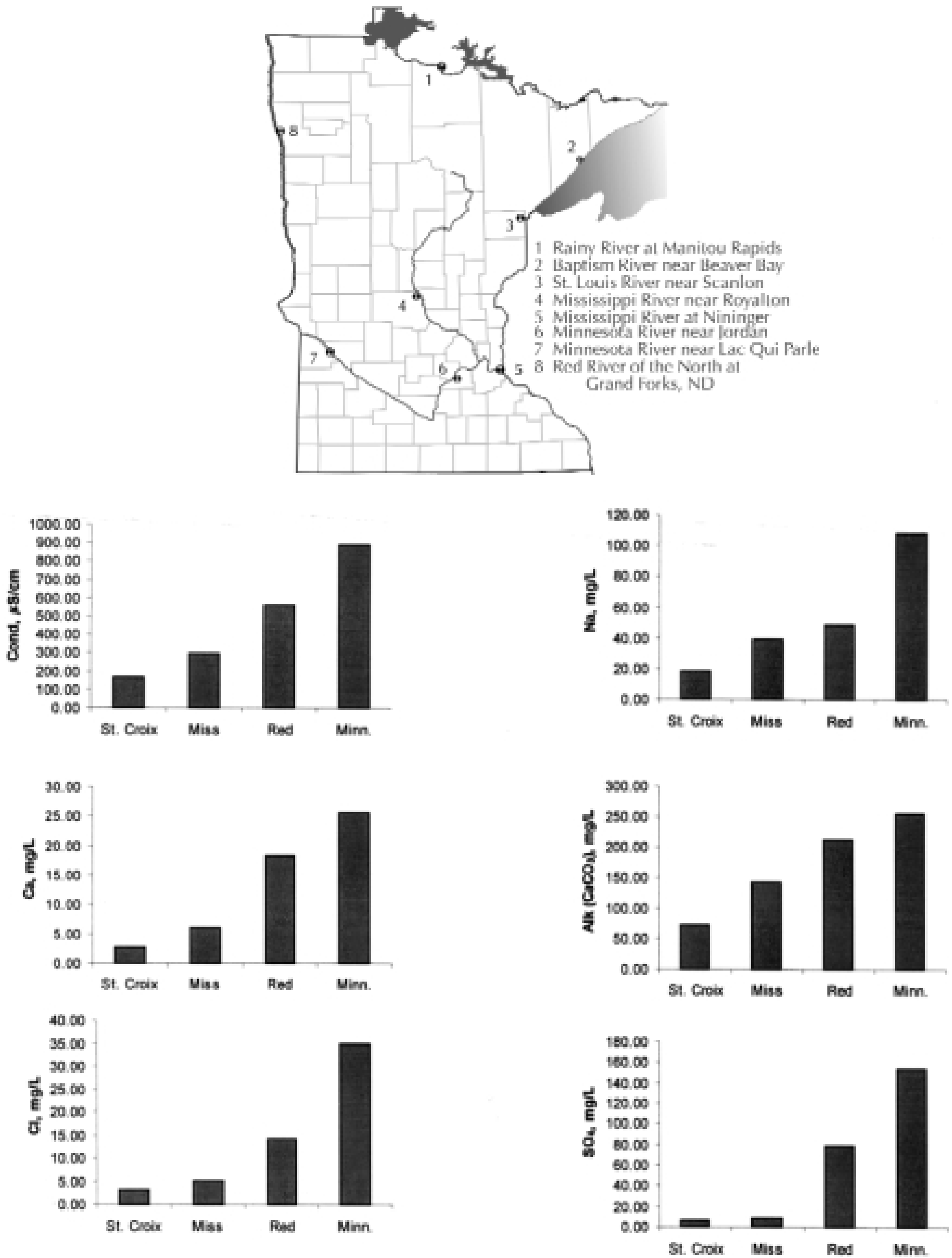

Figure 2.5 Average Concentrations of Major Ions Found in Minnesota Rivers.
USGS NASQAN Station data, 1999.

Overview of Water Quality in Selected Basins

Lake Superior Basin. Most of the streams in the Lake Superior Basin have near-pristine water quality, but wood processing facilities and urban centers have increased concentrations of some pollutants in the St. Louis and Rainy Rivers. Nitrogen, sulfate, chloride and suspended sediment concentrations are generally low. Low alkalinity values and dissolved solids concentrations are the result of low solubility of the thin soils and crystalline bedrock in the area.

Red River Basin. In the Red River Basin, dissolved solids and alkalinity are high because of geologic and climatic conditions. Sediments left behind by ancient glaciers and lakes are 200-300 feet thick. During low flow periods, highly mineralized groundwater seeps into the river and increases the load of dissolved solids. Concentrations of dissolved chemical constituents normally fall during spring runoff and after thunderstorms because of dilution. Total nitrogen and phosphorus concentrations are elevated in the south due to agricultural run-off. Some persistent pesticides, such as atrazine and 2,4-D, also have been detected although pesticide concentrations rarely approach drinking or ambient water-quality standards.

Minnesota River Basin. In the Minnesota River, alkalinity is generally high because of calcareous (limestone) glacial sediments. The river is turbid (carries large amounts of sediment) and high in sulfate and carbonate. As in the Red River Basin, highly mineralized groundwater contributes to the river's dissolved solids load. Contamination from agricultural chemicals also is a major problem.

St. Croix River Basin. The St. Croix is relatively unpolluted. It is slightly colored by humic matter from bog sources, but has low turbidity. Levels of water quality variables are good relative to other waters in the region and generally fall within standards set for the St. Croix River. Concentrations of a few metals, such as mercury, iron, and manganese, exceed standards, but iron and manganese are high because of natural sources.

Mississippi River Basin. In the Mississippi River, concentrations of chemical constituents generally increase from the source to the Iowa border. Differences in agricultural and urban development cause nitrogen concentrations to differ greatly among the sub-basins that make up the upper river system. Headwater streams drain an area that has little agriculture. Areas with more agriculture have higher concentrations of associated pollutants, but these generally do not exceed the limit for untreated drinking-water.

Trends in Water Quality. Trends in stream water quality over time are detected by statistical analysis of monitoring data. No clear statewide trends exist for Minnesota rivers over the last 20 years. Trend analyses show local increases in concentration of some constituents and decreases in others (USGS, 1999). Increases are probably due (primarily) to population pressures, unimproved treatment facilities, nonpoint control practices, and agricultural activities. Increases in chloride concentrations in the Minnesota River probably resulted from road deicing and may be associated with population increases (USGS, 1993). A decreasing trend in dissolved nutrients in the Minnesota River may be attributable to reductions in agriculture activities because of the droughts of the 1980s. Increasing dissolved oxygen concentrations in the Mississippi River south of Minneapolis-St. Paul, for example, resulted from reduced input of oxygen-demanding substances from the metropolitan sewage treatment facility and better control of urban nonpoint runoff.

LAND USE PATTERNS and ECOREGIONS

Various plant and animal species prefer different habitat conditions and therefore establish distinct communities in areas that provide preferred conditions. Prior to the influence of human activities, conditions in Minnesota favored establishment of mixed prairie and hardwood forests in the southwestern quarter of the state, grading through mixed pine and hardwood into pine forests in the northeast, with peat bogs developing in the northwest. Human activities, such as clearing of forests and draining of wetlands for agriculture, have altered the native landscape significantly. Current land use patterns in the state are shown in Table 2.1. Land uses range from dense managed forests in the northeast to heavily tilled cropland in western and southern parts of the state. In the central portion of the state there is a mixture of land uses, including cropland, woodland and prairie.

Table 2.1 Land Use in Minnesota. Land Management Information Center (1999), St. Paul, MN.

Description	Acreage	Percent
Cultivated land	22,694,200	42.0
Forested	14,434,482	26.7
Bog/marsh/fen	5,728,056	10.6
Hay/pasture/grass land	4,977,451	9.2
Water	3,211,643	5.9
Urban and rural development	1,472,267	2.7
Brushland	1,326,796	2.5
Mining	147,175	0.3
State Total	53,992,070	100.0

Climate, topography, and land-use patterns, along with soil and water conditions, form habitat for plants and animals. Large areas that contain similar communities of plants and animals are called ecoregions. Ecoregions are determined based on mapped information on land use, soil types, land surface form, and potential natural vegetation. Streams draining watersheds within the same ecoregion are believed to exhibit similar characteristics, such as physical habitat, hydrology, water chemistry, and biotic communities. According to the classification system for ecoregions developed by the U.S. Environmental Protection Agency, seven ecoregions are found in Minnesota: Red River Valley, Northern Minnesota Wetlands, Northern Lakes and Forests, North Central Hardwood Forests, Northern Glacial Plains, Western Corn Belt and Driftless Area. Land uses, topography, soil types and other information for each of the seven ecoregions are described in Figure 2.6.

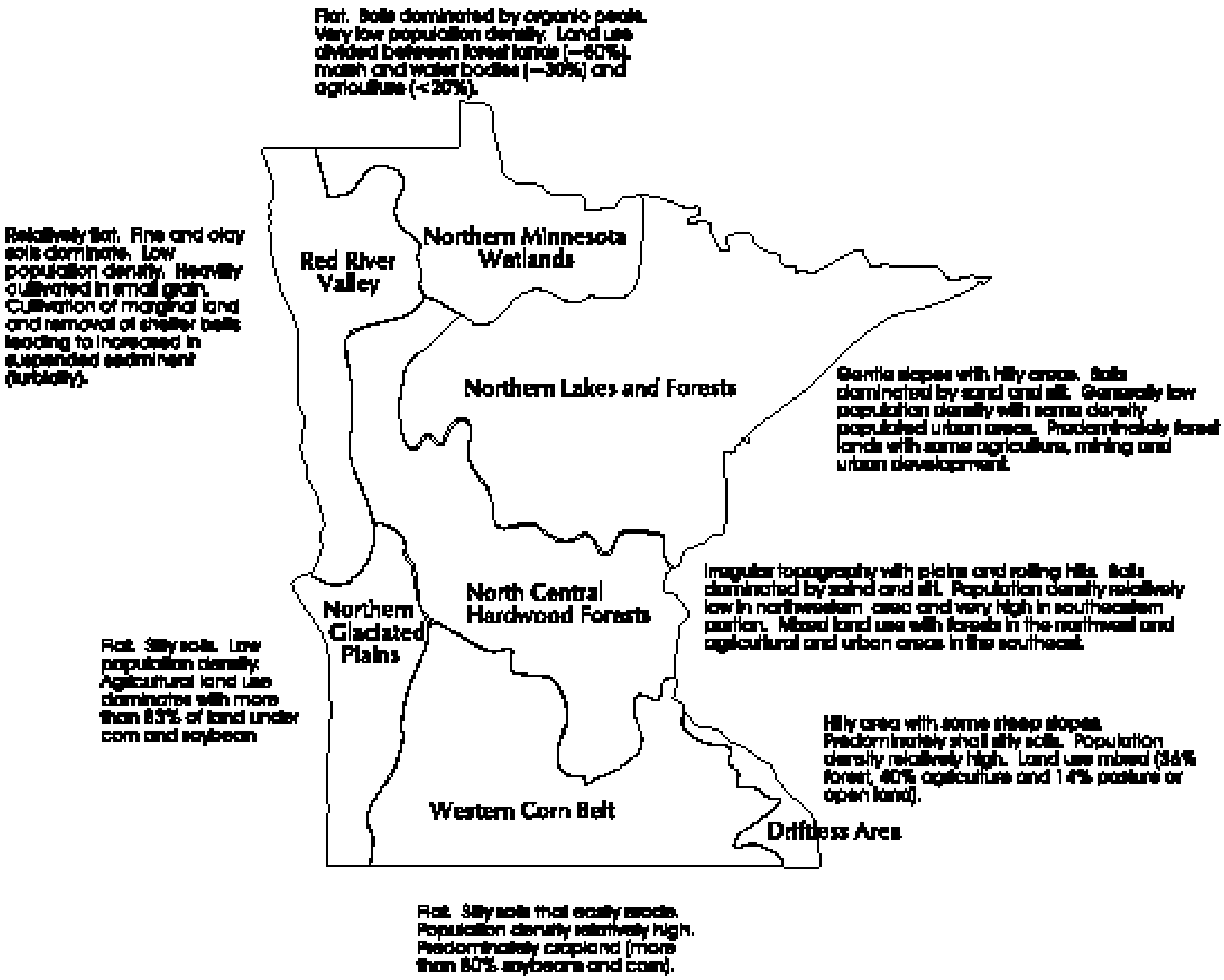

Figure 2.6 Minnesota's Seven Ecoregions

CHAPTER 3

STREAM WATER USES

INTRODUCTION

This chapter explores both the offstream and instream uses of stream water resources in Minnesota. Offstream uses involve withdrawing water, as for municipal and industrial uses, while instream uses require that water be left in the stream, as for commercial navigation and recreational boating. Conflict among users often erupts on rivers with many competing users due to the interdependence of offstream and instream uses. Offstream uses covered in this chapter are: municipal, thermoelectric, industrial and agricultural uses. Instream uses discussed are: hydropower, commercial navigation, commercial fishing and hunting, recreational boating, other recreational uses and *in situ* uses such as for natural amenities and waste disposal.

OFFSTREAM WATER USES

The U.S. Geological Survey (USGS) estimates total water use by geographic area and type of use for the United States every five years. The 1995 estimated withdrawals for offstream water uses in Minnesota totaled 3,390 million gallons per day (mgd) (Table 3.1)[1]. Offstream withdrawals may be for consumptive or non-consumptive use. Consumptive use is defined as water withdrawn from its source and not returned directly to the source (M.S. 103G.005, subd 8). In contrast, water diverted for non-consumptive use is immediately returned to its source after use.

Approximately 79 percent of withdrawals in 1995 came from surface water sources. Although some water is withdrawn from lakes, notably Lake Superior, the majority comes from rivers. Thermoelectric plants constitute the largest single offstream user with 60 percent of total withdrawals, followed by public water supply (14 percent), mining (9 percent) and irrigation (5 percent). Thermoelectric power production returns most of the water withdrawn to surface sources and is considered a non-consumptive use. Groundwater withdrawals make up 55 percent of total withdrawals when non-consumptive use for power generation is excluded.

The Minnesota Department of Natural Resources (DNR) provides annual information on actual withdrawals by users holding water appropriation permits. Under state law, users withdrawing more than 10,000 gallons per day or one million gallons per year must obtain an appropriation permit. Permit holders must report to the DNR each year the volume of water withdrawn, accurate to within 10 percent. Based on these individual reports, the DNR calculates total permitted withdrawals for the state by type of use (DNR, 1997).

[1] Under M.S. 103G.005, subd. 8, all groundwater withdrawals not returned to the same aquifer are considered consumptive use. Surface withdrawals are considered consumptive use if they are not directly returned to the originating source so that it is immediately available for further use (DNR, 1997).

Table 3.1 Estimated Total Water Use for Minnesota by Type of Use in 1995

Type of Use	Surface	Ground water	Total
	.... million gallons/day (mgd)		
Public Supply	154	331	485
Domestic	0	88	88
Commercial	20	46	66
Irrigation	37	120	157
Livestock	0	62	62
Industrial	83	58	140
Mining	292	6	298
Thermoelectric	2,090	2	2,090
Total*	2,680	714	3,390

Source: http://www.usgs.gov/public/watuse/
* Figures may not add up to totals because of rounding

Table 3.2 shows Minnesota's total permitted water use for the 1986-95 period. Over this period, total permitted usage trended upward due predominantly to increased thermoelectric demands. Based on available information, permitted use data represent a relatively good proxy for total usage. A comparison of the 1995 U.S. Geological Survey's total estimated water use of 3,390 mgd with the 1995 DNR total permitted use of 3,277 mgd reveals the two measures of total use are very close. These data also suggest that there are very few small diverters (those withdrawing less than 10,000 gallons per day).

Thermoelectric Power Generation Water Use

The largest volume of surface water withdrawals reported for the 1986-95 period was for nuclear and stream power plant cooling. During this period, Minnesota's power plants withdrew an average of 1.86 billion gallons of surface water per day. Usage trended upward over the period, increasing 28 percent between 1986 and 1995 (Table 3.2). Approximately 90 percent of total withdrawals for power plants return to their originating source and therefore are defined as non-consumptive use. This means that in 1995 while power plant withdrawals made up about 78% of total surface water withdrawals, consumptive use by power plants was less than 8 percent of total consumptive use (Table 3.1). Sixty-nine percent of reported water use in the state took place in the eight counties where power plant cooling was identified as the primary use. For example, water for cooling power plants in Goodhue and Wright counties accounted for 28 percent of total 1995 reported use for the state (DNR, 1997).

Table 3.2 Permitted Water Use in Minnesota by Type of Use: 1986–95

Type of Use	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
	……………………………….. million gallons/day (mgd) ………………………………									
Public Supply	466	526	556	477	449	466	479	449	488	477
Irrigation	82	184	282	236	195	164	173	82	153	156
Industrial/Mining	208	189	258	329	279	315	433	348	329	441
Other	115	104	115	132	145	142	159	173	175	156
Thermoelectric	1,477	1,745	1,816	1,819	1,912	1,901	1,860	1,978	2,096	2,047
Total*	2,348	2,748	3,027	2,992	2,981	2,989	3,104	3,030	3,241	3,277

Source: DNR Division of Waters, “1995 and 1996 Water Year Data Summary,” May 1997.
* Figures may not add up to totals because of rounding

Public Supply Water Use

Public supply includes water distributed to domestic, commercial, small industrial, and public users such as city parks, government buildings and hospitals. It does not include self-supplied domestic users or those served by small water companies (fewer than 25 customers). Withdrawal to meet the demands of this user group varies seasonally in Minnesota. Water usage increases in the summer months because of landscape irrigation and other outdoor uses of water. A rapid increase in demand for public water supplies has accompanied significant growth in Minnesota since the 1950s. While reliance on surface water sources increased until 1980, the majority of public supplies now come from groundwater. Increased dependence on groundwater to meet drinking and other public supply needs has raised new issues for water utility managers related to water quality and long-term sustainability of current withdrawal rates.

Industrial Processing Water Use

Industrial water use includes milling activities, paper and forest product operations, and food processing. It does not include smaller industrial facilities that receive water from public water suppliers. According to 1995 U.S. Geological Survey data, industrial use constituted 4 percent of total estimated water use and 11 percent of total consumptive use (Table 3.1). Surface water sources contribute 60 percent of the water used in industry. The mining industry is the third largest water user in the state with nine percent of total withdrawals and the second largest consumptive user with 23 percent of total.

Annual permitted water use data for industrial processing reported by the Minnesota DNR provide aggregated industrial and mining use data. In 1995, mining-related water-use activities accounted for 65 percent of reported industrial usage, pulp/paper processing for 16 percent and agricultural processing for 7 percent (DNR, 1997). Total water usage for industrial processing increased 33 percent between 1994 and 1995 because of increased mining demands in Lake County (Table 3.2). Counties with the highest industrial processing water use, ranked in decreasing order of use, include: Lake (mine processing), Cook (mine processing), Koochiching (pulp/paper processing), St. Louis (mine processing), Itasca (pulp/paper processing) and Ramsey (general and agricultural processing).

Agricultural Water Use

In 1995, agricultural use accounted for five percent of Minnesota's total usage and 13 percent of consumptive use (Table 3.2). Although agricultural use is relatively small, most applied water is used consumptively. Most of this water (76%) comes from groundwater sources (Table 3.1).

Irrigation is the primary agricultural use. The DNR's irrigation category includes major crops, orchard, and nursery irrigation, as well as some uses that are not agricultural, such as landscaping, cemetery, and golf course irrigation. Major crops accounted for 77 percent of total use in 1995 (DNR, 1997). Virtually every county in the state reports irrigation water use to the DNR. Otter Tail and Sherburne Counties reported the highest irrigation water use in 1995 with 17 percent and 12 percent of total irrigation use, respectively.

Livestock watering and other on-farm water uses make up most of non-irrigation use. Non-irrigation uses generally do not require a DNR permit because they constitute a relatively minor usage. The U.S. Geological Survey estimated 1995 livestock usage at 62 million gallons per day or five percent of consumptive use (Table 3.1).

Other Offstream Water Uses

Other uses as defined by the Minnesota DNR include air conditioning, water level maintenance, fisheries, construction dewatering, pollution confinement and other specialty uses (DNR, 1997). In 1995, these uses represented only five percent of total permitted use.

INSTREAM USES

Instream uses depend upon the water in the stream channel. These uses often require alteration, stabilization, or protection of the channel itself to create desired flow conditions. Measuring instream uses raises complex issues. Unlike offstream uses, for which the quantity of water withdrawn provides a measure of the level of use, instream uses can be measured in many different ways. In addition, the extent of *in situ* use, such as for fish and wildlife habit, is extremely difficult to quantify. Instream uses, such as hydropower and commercial fishing, may generate revenue for the user or provide other non-market related values, such as protecting endangered species. This section identifies and describes major instream uses of Minnesota's streams and rivers.

Hydropower

Minnesota's rivers have 32 active hydropower dams with a combined electrical capacity of about 215 megawatts, about 2 percent of the state's total electricity production. The State of Minnesota and the Federal Energy Regulatory Commission (FERC) regulate all hydropower dams (DNR, 1995). Most generate power for profit; only six use the power directly for manufacturing. Minnesota Power Company owns and operates the largest hydropower plant in the State with a capacity of 72.6 megawatts. Otter Tail Power Company owns the smallest hydropower plant with a 0.4-megawatt capacity.

Commercial Navigation

Approximately 230 miles of river in Minnesota are designated as navigable riverways for commercial vessels and belong to the national Shallow Draft Navigation System. This system consists of 22,000 miles of river channel across the United States. The Mississippi River contains 80 percent of navigable channels and terminals, and the St. Croix and Minnesota Rivers each have 10 percent (Table 3.3).

The Army Corps of Engineers maintains channel conditions and related lock and dam facilities. They dredge channels along the upper river system in Minnesota to ensure a depth of at least nine feet. A fully loaded barge requires a minimum depth of nine feet to maneuver safely in the channel. Regular dredging keeps the channels open in areas where fast moving tributaries discharge into the main river and deposit large amounts of sediment. The Corps also operates the lock and dam facilities that lift and lower river vessels. The locks in Minnesota were designed and built to accommodate barges up to 290 feet long with a 50-foot width and a maximum cargo-carrying capacity of 3,000 tons.

Table 3.3 Miles of Channel and Terminals on Upper Mississippi River System in Minnesota

River	Miles of channel	# of Terminals	
		Grain	Other
Mississippi	183.8	15	33
Minnesota	21.8	4	6
St. Croix	24.5	0	3
Total	230.1	19	41

Commercial navigation includes both freight and passenger traffic. Freight traffic generates significant economic returns to the state. A substantial amount of freight moves through Minnesota's 58 active river terminals, including: grain, coal, liquid and dry fertilizer, iron and steel, sand and gravel, crude oil and petroleum products, newsprint, and all types of heavy general cargo.

Historically, grain constituted at least one half of annual freight tonnage. Over 60 percent of Minnesota's grain exports are shipped by river (MDOT, 1993). In addition, grain shipments from North and South Dakota, western Wisconsin, and northern Iowa move through Minnesota's river terminals. Between 1972 and 1992, these terminals handled an average of 11 percent of the grain exported from Gulf Coast terminal or roughly 7 percent of total annual grain exports from the United States (MDOT, 1993).
Commercial passenger use of the state's riverways is relatively limited compared with freight traffic. Passenger traffic includes both large cruise and local excursion boats. Large cruise boats make occasional visits to the city of St. Paul in the summer months. For example, in 1992 seven cruise boats docked near downtown St. Paul. Each cruise boat visit generates an estimated $500,000 in revenue to the city. Many excursion boats carry passengers on trips of one day or less. A total of 17 vessels holds the required U.S. Coast Guard certification to carry passengers. Active passenger terminals on the Mississippi River are located in Minneapolis, St. Paul, Red Wing, Lake City, and Winona. Active passenger terminals on the St. Croix are located in Afton, Bayport, Stillwater, and Taylors Falls. The only active terminal on the Minnesota River is in Shakopee. Excursion boats carry nearly a quarter of a million passengers each season in Minnesota. For example, the Paddleford Pacquet Company in St. Paul carries more than 100,000 passengers annually, over half of whom reside outside the metropolitan area (MDOT, 1993).

Commercial Fishing and Trapping

Commercial fishing and trapping activities depend upon Minnesota's river resources. Commercial fish harvested from Minnesota rivers include: carp, sucker, sheepshead, and other varieties of non-game (rough) fish from the upper river. The St. Paul District generates about

$720,000 annually from commercially caught fish. Other commercial fishing activity on the Upper Mississippi River includes minnow and turtle trapping. Minnesota has long been a major supplier of turtle meat.

Commercial clamming produces shells for export to the Asian cultured pearl industry. This industry finds Minnesota clamshells desirable because of their unique color and luminescence. In 1990, shells harvested from the Otter Tail River in west central Minnesota were valued at between $30,000 and $40,000 (Tester, 1995). Minnesota and Wisconsin limit clam harvests to help protect the resource. Since 1991, all Minnesota rivers except the Mississippi below Red Wing have been closed to commercial shell harvesting.

Minnesota's commercial trapping activity remains limited. Trappers seek out raccoon, muskrat, mink, and beaver on backwaters and tributary streams. In 1992, furs taken on the navigable portion of the state's rivers were valued at an estimated $2 million (MDOT, 1993).

Recreational Boating

Recreational boating constitutes one of the largest uses of Minnesota's rivers. Many Minnesotans consider boating access to the state's rivers to be a basic right. The state contains 2,850 miles of designated canoe and boating river with some 2,300 state-maintained public access ramps and drop-in points (Figure 3.1).

In 1992, small recreational boats made up almost 50 percent of the traffic in locks on the river navigation system operated by the U.S. Army Corps of Engineers in Minnesota. The boats range in size from canoes to speedboats to houseboats. The Minnesota DNR provides 22 public boat launching ramps on the navigable portions of the Minnesota, St. Croix, and Mississippi rivers. The U.S. Army Corps of Engineers, the U.S. Fish & Wildlife Service and the Minnesota Department of Transportation maintain 15 ramps, and another 74 are owned and operated by commercial businesses, towns, sports organizations, churches, and other non-profit groups. In addition, the Minnesota portion of the Mississippi River contains 104 private boat launches and canoe drop-in sites. Numerous marinas for large recreational boats also exist. They range in size from as few as six boat slips to as many as 600. Forty-eight boat rental operations and 21 private yacht clubs further contribute to recreational boating traffic on Minnesota's rivers.

Other Recreational Uses

Minnesota's streams and rivers provide many other recreational uses such as fishing, hunting and wildlife viewing. According to a 1996 U.S. Department of Interior Fish and Wildlife Service survey, people spent an estimated 27,002,000 person-days fishing on Minnesota's lakes and rivers (U.S. Dept. of Interior, 1997). Anglers spent an estimated $69 per person-day on average for fishing-related travel, equipment and other expenditures in 1996[2]. In the same year, wildlife watchers engaged in 6,807,000 person-days of wildlife watching and spent an estimated $53 per person-day for equipment, food, lodging, transportation and other travel-related costs (U.S. Dept. of Interior, 1997).

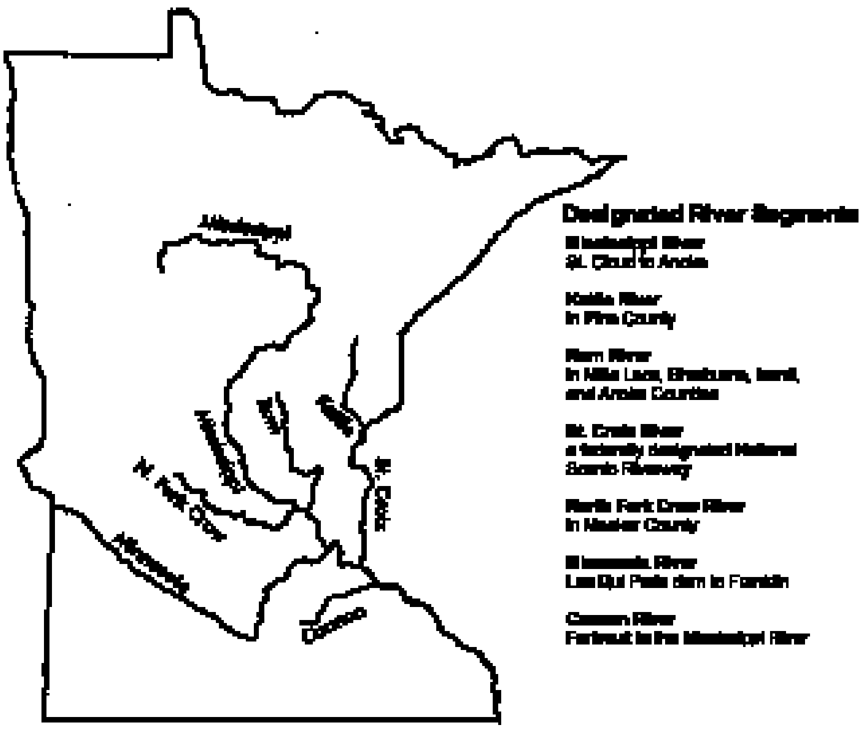

Figure 3.1 Minnesota's Designated Canoeing and Boating Streams. Minnesota Dept. of Natural Resources, Division of Trail and Waterways.

In Minnesota as a whole, hunters spent 6,984,000 person-days and an average of $258 per person-day for equipment, food, lodging, transportation, and other trip costs associated with hunting in 1996. River-bottom lands associated with the Upper Mississippi River system provide over 185 thousand acres of hunting area for upland birds, small game, and deer. Hunters spend an average of 350,000 person-days each year in the Mississippi River-bottom forests. In addition, duck hunters spend over 275,000 person-days on the water (U.S. Fish and Wildlife Service, 1997). Clearly, recreational use of water resources contributes significantly to the state as well as local economies.

Natural Amenity Uses

Non-game wildlife. The navigable portion of the Upper Mississippi River in Minnesota contains thousands of acres of state and federally managed fish and wildlife areas. Besides protecting habitat, these areas provide recreational services. For example, the Upper Mississippi River National Fish and Wildlife Refuge, which contains 32,900 acres and extends from Wabasha, Minnesota to Rock Island, Illinois, has the largest annual public use of any fish and wildlife refuge in the national refuge system. In Minnesota, 685,000 acres of refuge and park land fall under the auspices of the state. In some refuges, management plans encourage

[2] Average estimated based on total angler expenditures of $1,874,835,000 divided by 27,002,000 angler days for the State of Minnesota (U.S. Department of Interior, 1997).

regulated hunting, fishing, and camping activities. In others, management plans prohibit human activity (at least seasonally) to achieve species protection objectives.

Species preservation. Several species designated as endangered or threatened on state and federal lists depend on river habitats for survival. Table 3.4 lists river-dwelling vertebrate animal species on the state's endangered and threatened list that depend on river habitats. The state list also includes 25 endangered and threatened species of mollusk and one endangered species of the caddis fly. Minnesota's threatened and endangered river plants include floating marsh marigold, sweet-smelling Indian plantain, kitten-tails, glade mallow, and the dwarf trout lily, which is native only to southeast Minnesota and appears on the federal endangered species list.

Waste disposal

Sewage disposal systems use rivers to dilute treated effluent and move it downstream. Figure 3.2 shows major wastewater treatment plants that discharge into Minnesota's rivers. Most cities located along a river depend on river water dilution for at least part of their disposal requirements. For example, the Twin Cities' Metropolitan Plant discharges treated wastewater into the Mississippi River with about 3 parts per million (ppm) phosphorus. A study conducted for the Plant in 1992 concluded that reducing phosphorus discharge from 3 ppm to 1 ppm would cost $180 million in capital costs and add $20 million annually to operating costs. The plant currently avoids these costs by relying on the Mississippi for phosphorus dilution.

Table 3.4 Minnesota's Endangered and Threatened Vertebrate Animal Species Dependent upon River Habitat

Species	Status	Habitat
Northern Cricket Frog	Endangered	Small, pebbly streams in grasslands and near marshes and ponds
Massasauga (snake)	Endangered	River bottom lands
Paddlefish	Threatened	Open water of large rivers, river lakes, and backwaters
Wood Turtle	Threatened	Small, fast-moving, clear-water streams with hard bottoms (sand, gravel, or rock) grassy margins, and elevated sandbars for nesting, in relatively undisturbed areas in forests
Blandings Turtle	Threatened	Calm, shallow water with rich, aquatic vegetation, and sandy uplands for nesting
Bald Eagle	Federal: Threatened	Lakes and rivers in forested areas with large trees

Source: Information from Coffin and Pfannmuller, eds. (1988) Minnesota's Endangered Flora and Fauna and DNR. 1996. Minnesota's List of Endangered, Threatened and Special Concern Species (Effective 7/1/96) Natural Heritage and Non-Game Research Program.

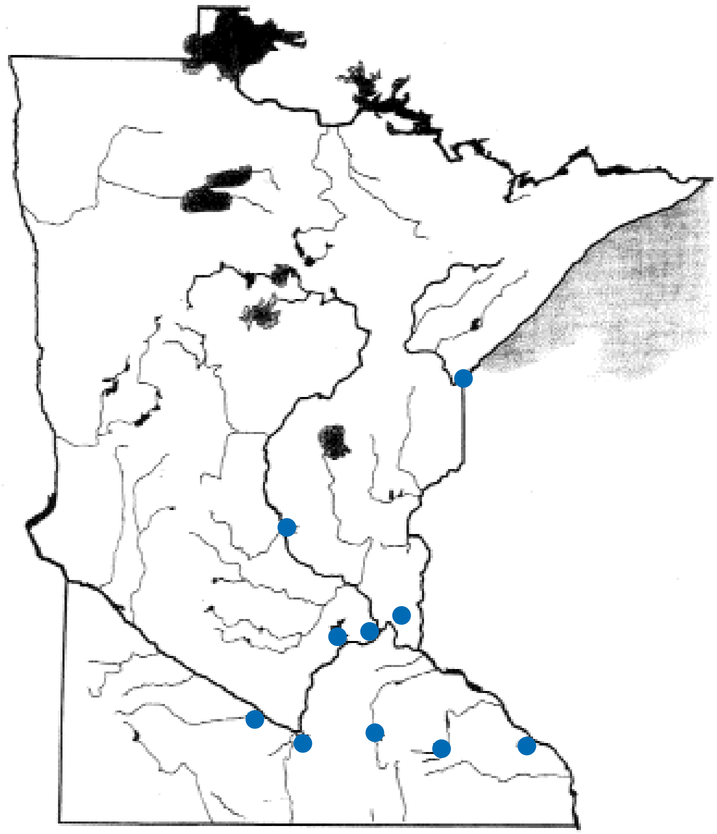

Figure 3.2 Wastewater Treatment Plants Processing More than 5 mgd.

CHAPTER 4

WHO CONTROLS MINNESOTA'S RIVERS?

POLICY, PLANNING, AND MANAGEMENT

INTRODUCTION

This chapter provides an introduction to policy, planning and management activities related to Minnesota's rivers. Policy and planning efforts occur at state, regional and local levels. The management of Minnesota's water resources is highly dispersed. A conglomeration of federal, state, and local agencies manages different river functions. The role of various agencies and their management activities are explored in this chapter.

POLICY AND PLANNING

Statewide Policy and Planning

The Minnesota Environmental Quality Board (EQB) develops statewide policy and engages in planning activities relating to environmental issues affecting rivers and watersheds. The EQB also plays a role in resolving conflicts among state agencies with regard to programs, rules, permits, and procedures significantly affecting the environment. Under the Minnesota Environmental Policy Act, the EQB retains the authority to request an environmental review for certain projects affecting the state's rivers and watersheds. The EQB consists of representatives from ten state agencies and the governor's office and five individuals from the general public. The ten participating state agencies are the Departments of Agriculture, Health, Natural Resources (DNR), Commerce, Trade and Economic Development and Transportation; Pollution Control Agency (PCA); Board of Water and Soil Resources (BWSR); Minnesota Planning; and the Office of Environmental Assistance. A small professional staff supports EQB activities.

If implementation of EQB policy decisions requires changes in state laws, BWSR, in conjunction with DNR and PCA commissioners, recommends such changes to the legislature. When questions arise regarding specific water policy issues, the governor, state or federal agencies, district court judges or affected individuals may assert the right to petition the BWSR to intervene. If the BWSR agrees to intervene, it conducts a public hearing and makes recommendations based on evidence presented at the hearing.

In addition to statewide activities, Minnesota participates in interstate planning and policy related to the Upper Mississippi and the St. Croix rivers. The Upper Mississippi River Basin Association, with members representing Minnesota, Iowa, Illinois, Missouri, and Wisconsin, coordinates policy development, planning, and implementation on issues related to use of the Upper Mississippi River system. The Association also commissions and conducts studies on common water resource concerns.

Minnesota state law also addresses several policy, planning, and management activities related specifically to wild and scenic rivers, floodplains, and shoreline. These laws include the Minnesota Wild and Scenic Rivers Act of 1990, The Minnesota Floodplain Management Act of 1969, and the Shoreline Management Act of 1969.

Minnesota's Wild and Scenic Rivers Act. Minnesota's Wild and Scenic Rivers Act, provides statutory protection for rivers and adjacent lands that possess outstanding scenic, recreational, natural, historical and scientific attributes. River areas protected by the Act fall into three classifications: wild, scenic or recreational. Rivers designated as wild flow freely through primitive adjacent lands. These rivers generally exhibit excellent water quality. Rivers receiving protection under the scenic category flow freely through predominately undeveloped adjacent lands, while rivers designated as recreational may flow through relatively developed adjacent lands. Classification of a river as recreational does not require the river to be free-flowing. Recreational channels may include modifications such as dams and diversions and receive protection under the Act.

The Minnesota DNR administers Minnesota's wild and scenic rivers system program. DNR's responsibilities include identifying and proposing rivers for wild and scenic designation, establishing a management plan, and specifying minimum standards. All aspects of use and development of protected rivers and adjacent lands become regulated. Ownership influences management activities on lands adjacent to protected areas of a river. On public lands, the state retains the administrative authority to ensure that management activities remain consistent with the management plan. On private lands, local governments facilitate protection and preservation goals through zoning ordinances. These ordinances must meet the minimum management standards specified by the DNR. The Wild and Scenic Rivers Act requires local governments to "... preserve and protect, reduce the effects of overcrowding and poorly planned development, to prevent pollution, to provide space for sanitary facilities, to preserve natural beauty and quietude, and to maintain property values, and promote the general welfare (Minn. Rules 6105.0080).[1] In addition, the DNR has the authority to approve variances granted by local governments.

Watercourses designated as "State Wild and Scenic Rivers" under Minnesota law include portions of the Mississippi, Minnesota, St. Croix, Crow, Rum, Kettle and Cannon rivers (see Table 4.1 and Figure 4.1).

In 1968, when the United States Congress approved the National Wild and Scenic Rivers System, it designated the St. Croix River as one of the eight rivers initially protected under the Act. The protected portion of the river runs from its headwaters in Wisconsin to Taylors Falls. In 1972, the protected area was expanded to include the Lower St. Croix from Taylors Falls to the Mississippi. This scenic river is managed according to the federal Wild and Scenic Rivers Act, the federal Lower St. Croix Act and the Lower St. Croix National Scenic Riverway

[1] Minn. Rules 6105.0080.

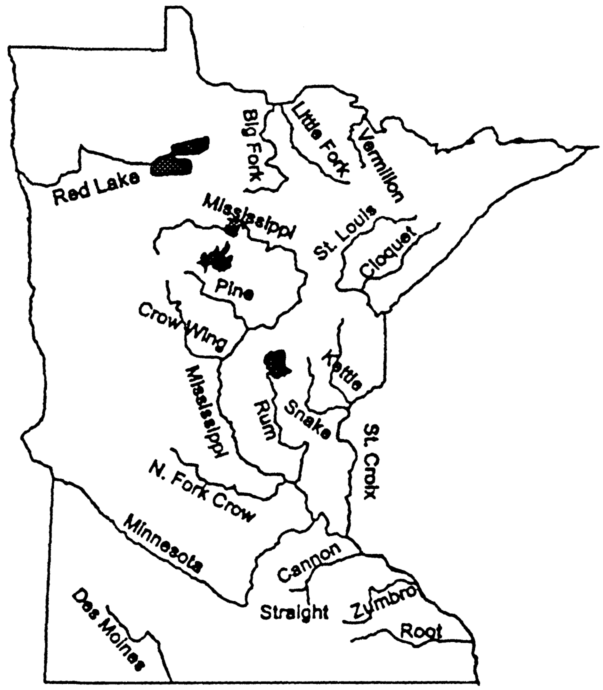

Figure 4.1 Minnesota's Wild, Scenic and Recreational Rivers and Lower St. Croix National Scenic Rivers. Minnesota Dept. of Natural Resources, Division of Waters and Trailways.

Table 4.1 Protected River Areas in Minnesota

River	Protected Area
Mississippi	from St. Cloud to the city of Champlin
Minnesota	from Lac Qui Parle Dam to near the city of Franklin
St. Croix	from the Wisconsin border to the Mississippi
Crow	north fork portion of the river in Meeker County
Rum	from Ogechie Lake to the city of Anoka
Kettle	in Pine County
Cannon	from the city of Faribault to the Mississippi

Cooperative Management Plan. The state of Minnesota recognized and concurred with the designated federal protection status. The Minnesota and Wisconsin DNRs provide administrative leadership and operate in partnership with the National Park Service and local governmental units. To date, the St. Croix remains the only Minnesota river among the 212 U.S. rivers on the federal Wild and Scenic Rivers list.

Floodplain Management Act. Floodplains receive floodwaters and the sediment they carry when stream channels overflow. Minnesota's Floodplain Management Act of 1969 provides the State authority to regulate land uses on floodplains to minimize potential flood damage. The Act requires the DNR, 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.

The sizes of floodplains vary both along river systems and among river systems. Depending on surrounding topography, the floodplain may include land on one or both sides of the channel, and the area may vary considerably along a river. Mapping a floodplain involves identifying the land area covered by flood waters under various flooding scenarios. For planning and management purposes, the outer perimeter of the floodplain is determined by the worst possible flood that would occur (on average) over a 100-year period. Historical data, provided by the Natural Resources Conservation Service (NRCS) and the Army Corps of Engineers, are used to estimate this 100-year event. Floodplain mapping includes delineation of the floodway and flood fringe. The floodway, the land immediately adjacent to the stream channel, provides a natural conduit for flood waters. During flooding, it becomes part of the river, carrying much of the floodwater downstream. The flood fringe extends from the outer border of the floodway to the edge of the floodplain. Shallow, slow-moving flood water covers this area during a 100-year flood event.

When data availability permits development of floodplain maps, local communities must adopt floodplain zoning ordinances. These zoning ordinances include management rules and guidelines established by the DNR, which retains responsibility for enforcing compliance by local governments. These rules and guidelines strongly encourage the use of non-structural protection mechanisms in lieu of levees, dikes and dams. Floodplain management rules also specify the type of development allowed on the floodway and flood fringe. For example, to ensure unobstructed flow of flood waters, management rules permit only open land uses with low flood vulnerability, such as agriculture or parks. On the flood fringe, proposed structures must comply with flood protection elevation, flood proofing construction codes and other applicable ordinances.

The National Flood Insurance Program requires flood insurance policies on new structures in floodplain areas recognized by the Federal Emergency Management Agency (FEMA) prior to granting loans. FEMA, the agency responsible for administering federal flood relief programs, maintains a data base on lands vulnerable to flooding in the United States.

Shoreland Management Act. In 1969, the Minnesota State Legislature passed the Shoreland Management Act to ensure preservation and wise development of land bordering lakes and rivers. The DNR Division of Waters, Land Use Management Section, administers the Shoreland Management Program. The Act defines river shorelands as land within 300 feet of a public watercourse 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. These classifications are remote, forested, transition, agricultural, urban, and tributary. For each classification, the DNR developed minimum standards 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 developed by the DNR. To assist localities with the development of appropriate ordinances, the DNR developed a Model Shoreland Ordinance. The DNR reviews local ordinances to ensure that the minimum standards are met. If a county or municipality fails to adopt a satisfactory ordinance, the DNR retains the authority to require adoption and implementation of the Model Shoreland Ordinance. As of March 1996, approximately 170 cities and 85 counties in Minnesota had implemented shoreland zoning ordinances.

Regional Policy and Planning

In Minnesota, many organizations and agencies play a role in regional policy and planning activities related to streams and rivers. Given space constraints, this section describes only a few of these organizations and agencies.

Under state law, two or more local governmental units can form a regional river basin joint powers organization if each unit agrees to work cooperatively with the other member units to protect, preserve or enhance an identified river resource. Some of the current joint powers organizations include: the Red River Watershed Management Board, Area II Minnesota River Basin Projects, Inc., Redwood-Cottonwood Rivers Control Area, Upper North Branch Root River Watershed, Whitewater Joint Powers Board, Minnesota River Joint Powers Board, Southeastern Water Resources Board, and Mississippi Headwaters Board.

The Mississippi Headwaters Board (MHB) is a well-established regional river basin joint powers organization. The Board maintains responsibility for protecting the natural, cultural, scenic, scientific, and recreational values of the first 400 miles of the Mississippi River. The MHB includes representatives from the eight headwaters counties: Aitkin, Beltrami, Cass, Clearwater, Crow Wing, Hubbard, Itasca, and Morrison.

In 1967, the state legislature authorized the creation of the Metropolitan Council as a regional planning authority for the Twin Cities Metropolitan Area. The Council coordinates planning and development of major systems in Minneapolis, St. Paul and their surrounding communities. Its areas of responsibility include water quality protection and river corridor development. The Council's Environmental Services division, which owns and operates the regional sewage system, assists with implementation of water quality protection policies. For river corridor development, the Council works with developers and local governments to implement its policies.

Local Water Policy and Planning

Most Minnesota communities participate in water policy and planning activities that affect local water resources. This section focuses on four key pieces of legislation designed to facilitate community involvement in local water policy and planning activities in Minnesota: Soil and

Water Conservation Law, Minnesota Watershed Act, Metropolitan Surface Water Management Act, and the Comprehensive Local Water Management Act. In 1987, the state legislature authorized the Board of Water and Soil Resources (BWSR) to provide oversight for local activities related to these laws. Prior to 1987, oversight responsibilities were shared by three independent entities: the Soil and Water Conservation Board, Southern Minnesota Rivers Basin Advisory Council, and the Water Resources Board.

Soil and Water Conservation Law. The Soil and Water Conservation Law authorized the creation of Soil and Water Conservation Districts (SWCDs). SWCDs encourage land owners and tenants to implement management practices to preserve natural resources, protect soil productivity, and control flooding. Management practices tend to emphasize prevention and reduction of soil erosion, sedimentation, and nonpoint pollution. Ninety-one SWCDs presently operate in Minnesota.

Minnesota Watershed Act. Managing natural resources by watershed allows an integrated, holistic approach to resource conservation. 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 BWSR to establish a watershed district. Watershed districts are authorized to construct projects, identify and assess properties that benefit, levy taxes, acquire property by eminent domain, and regulate activities that affect the district's objectives. Forty-two watershed districts currently exist in Minnesota.

Metropolitan Surface Water Management Act. The Metropolitan Surface Water Management Act requires the development and implementation of watershed management plans by Watershed Management Organizations (WMOs) within the seven-county Twin Cities Metropolitan Area. The Act further requires that each city or township in the Metropolitan Area develop and administer its own plan. To ensure the plans all work together to protect local watersheds, each city or township must demonstrate that its plan is consistent with all other plans in the affected watersheds. The DNR, PCA, Department of Health, and Metropolitan Council must review and approve each city and township plan before it receives final approval by the BWSR. There are 38 WMOs in the Metropolitan Area. Thirteen are organized as watershed districts, 23 are organized based on joint powers agreements and two are county operated WMOs. Joint powers agreements are agreements made among affected units of government.

Comprehensive Local Water Management Act. The Comprehensive Local Water Management Act encourages Minnesota counties outside the Twin Cities Metropolitan Area to develop and implement comprehensive water plans. Comprehensive plans must cover the entire county and conform with any existing plans enacted by watershed districts within the county. Comprehensive plans must also address existing local, city or township plans. However, once a comprehensive plan for the county receives approval, local plans conform with it. The BWSR reviews plans for conformance with state laws and regulations and resolves disputes over the interpretation of plans that may arise between and among the various units of local government. All 80 counties currently have comprehensive water plans and revise them every five years.

MANAGEMENT OF MINNESOTA'S RIVERS

River management in Minnesota is dispersed. A variety of federal, state, and local agencies is involved with different management activities (Table 4.2). Key management agencies include: U.S. Army Corps of Engineers, U.S. EPA, Minnesota DNR, Minnesota PCA, Minnesota EQB, BSWR, and the Metropolitan Council. Counties, watershed districts, and soil and water conservation districts also have important river management roles. Some management functions are performed primarily by a single agency. For example, navigation on the Upper Mississippi River system is controlled by the U.S. Army Corps of Engineers, and the DNR has sole responsibility for issuing water withdrawal permits. Some functions are shared by federal and state agencies. The Army Corps of Engineers and the DNR both regulate alterations to river channels; the EPA and PCA have complementary roles protecting water quality. Some functions, however, are dispersed among many jurisdictions, which has led to interjurisdictional conflicts, multiple interpretations of rules, and patchy management success. This section focuses on river management activities in Minnesota and the agencies responsible for administering them. Appendix B contains a listing of each agency's address and telephone number.

Regulating Withdrawals of Water from Rivers and Reservoirs

The DNR's Water Appropriation Permit Program office manages surface and ground water withdrawals in the state. State law requires an appropriation permit for withdrawals exceeding either 10,000 gallons per day or one million gallons per year (MN Stat. 6115.0620). The DNR 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. Local governments may review and comment on permit applications for withdrawals within their jurisdiction prior to the DNR's granting the permit. The DNR maintains the right to restrict withdrawals to protect the resource.

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 per day;
(3) irrigation and processing of agricultural products;
(4) power production that does not meet contingency planning requirements;
(5) industrial and commercial water uses, and;
(6) nonessential water uses.

Table 4.2 Federal, State and Local Agencies and Their River Management Activities

Management Activity	Federal				State				Local	
	U.S. EPA	U.S. Fish & Wildlife Service	U.S. Park Serv.	U.S. Coast Guard	MN Dept. of Nat. Res.	MN Board of Soil & Wtr Res.	MN Dept. of Health	MN Pollution Control Agency	Local Govt./ Other Agencies	Other
Regulate withdrawals of water from rivers and reservoirs					X					
Construct, maintain and operate public dams, reservoirs and navigation related facilities	X				X				X	X
Regulate construction and other alterations to river channels and related wetlands	X				X					
Manage public lands in stream corridor for recreational, fish and wildlife and other natural values			X	X	X					
Regulate commercial and recreational navigation vessels					X				X	
Water quality		X				X	X	X	X	

Constructing, Maintaining and Operating Public Dams, Reservoirs and Navigation Related Facilities

Federal, state and local governmental agencies, as well as private individuals, own and operate dams, reservoirs, and navigation of facilities on Minnesota's rivers. These dams and associated reservoirs provide a variety of services, such as: flood control, hydroelectric power, recreation, fish and wildlife habitat and irrigation (see Figure 4.2).

RESERVOIR	CAPACITY (acre feet)	PURPOSE(S)
1 Leech Lake	1,000,000	Flood Control/Recreation
2 Lake Winnibigoshish	1,072,000	Flood Control/Recreation
3 Mud and Goose Lake	44,000	Wildlife
4 Pokegama	129,600	Flood Control/Recreation
5 Prairie Lake	15,840	Hydroelectric
6 Big Rice Lake	13,465	Lake Control/Irrigation
7 Pine River Reservoir	193,500	Flood Control/Recreaction
8 Gull Lake Reservoir	111,000	Flood Control/Recreation
9 Sylvan Lake	10,430	Hydroelectric
10 Rice Lake	16,300	Hydroelectric
11 Sandy Lake	109,200	Flood Control/Recreation
12 Rice River Pool	38,000	Waterfowl
13 Rice Lake Pool	13,820	Waterfowl
14 Indian Head Flowage	12,750	Hydroelectric/Recreation
15 Blanchard Dam	15,500	Hydroelectric
16 Sauk River	10,000	Hydroelectric
17 Sauk Lake	19,600	Recreation
18 Lake Florida Slough	14,500	Fish and Wildlife
19 Lac Qui Parle Reservoir	122,800	Flood Control/Recreation
20 Marsh Lake	121,300	Flood Control
21 Big Stone Lake/ Whetstone River	122,500	Flood Control/Recreation
22 Byllesby Reservoir	25,000	Recreation
23 Zumbro Lake	35,000	Hydroelectric

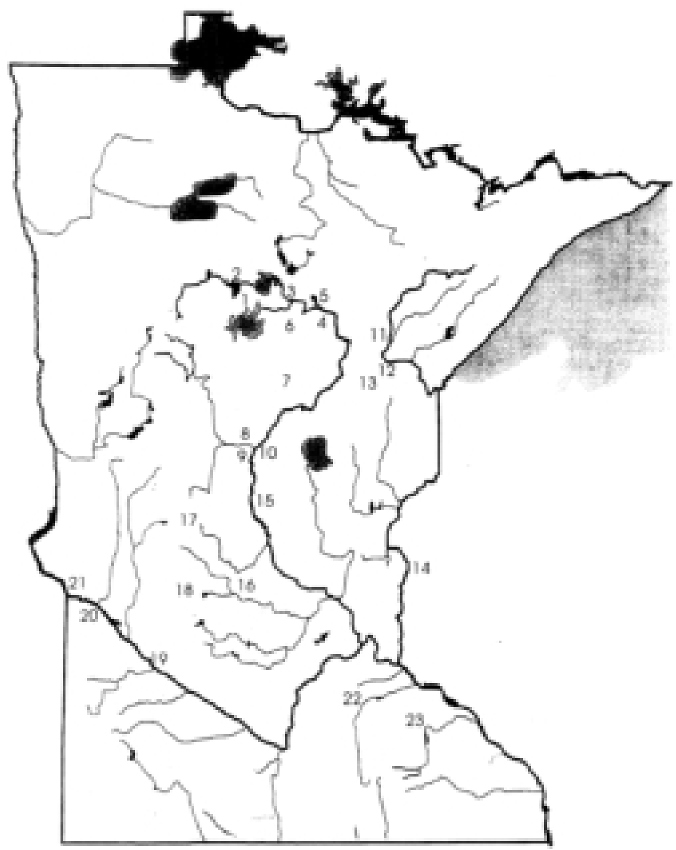

Figure 4.2 Minnesota's Main Reservoirs and Dams. UMRBC, 1981.

The U.S. Army Corps of Engineers (Corps) operates and maintains the navigation system on the Upper Mississippi River, including the headwaters reservoirs, locks, dams, channels, levees, and pools associated with the locks and dams on the river below St. Anthony Falls. The Corps maintains a nine-foot-deep channel by periodic dredging, and makes modifications to the system as deemed necessary.

The Corps operates the reservoirs based on guidelines established in an informal agreement with the state of Minnesota. The headwaters reservoirs, constructed primarily for flood control and to ensure sufficient flows for navigation, serve primarily to maintain lake levels for recreation. Reservoir level maintenance also provides benefits for the Leech Lake Band of Chippewa's wild rice production and harvesting. A lower priority objective is to augment river flow when low-flow conditions threaten Twin Cities' water supply and waste water systems. The Corps also operates flood control and low-flow augmentation projects on other Minnesota rivers, such as the Minnesota, Otter Tail, Bois de Sioux, and Red Lake rivers.

The DNR's Surface Water and Hydrographics Section within the Waters Division bears responsibility for examination, maintenance and repair of approximately 315 state-owned dams. Local governments and private landowners own and maintain dams built to protect agricultural land and towns from flooding. The federal Natural Resources Conservation Service built many of these dams and then turned them over to local or private ownership. In addition, private companies and local governments operate dams and related reservoirs for power generation. The DNR inspects all private and public dams and associated structures and administers a grant program to local governments that provides up to 50% of the cost to repair locally owned dams.

Regulating Construction and Other Alterations to River Channels and Related Wetlands

Both the Corps and the DNR regulate construction and other activities that modify river channels and related wetlands. The Corps regulates activities affecting the navigation capacity of designated navigable water waterways in the U.S. under Section 10 of the Rivers and Harbors Act. Permitted activities must not cause substantial adverse effects on navigation or the environment. Designated navigable waterways in Minnesota include: Big Fork River, Bois De Sioux River, Kawishiwi River, Kettle River, Little Fork River, Minnesota River, Mississippi River and Headwaters Reservoirs, Pigeon River, Pike River, Rainy River, Red River of the North, Red Lake River, Rum River, Snake River, St. Croix River, St. Louis River, Vermillion River, and the streams of the International Boundary Waters. The Corps also regulates activities related to placing dredged materials or other types of fill into any U.S. body of water or wetlands area, under Section 404 of the Clean Water Act. By this authority, the Corps holds jurisdiction over virtually every water body and wetland in Minnesota.

The DNR regulates activities pertaining to physical changes in the channel, current, or cross-section of protected waters including docks, boat ramps, shore protection, beach development, and drainage construction. Jurisdiction with regard to physical changes in protected watercourses is limited to the elevation at the top of the channel bank (Figure 4.3). The DNR also regulates protected riverine wetlands along with protected lakes, reservoirs, and other types of wetlands. Under the current regulatory guidelines, the DNR requires a permit for some activities. However, activities that do not require a permit generally must conform to established standards.

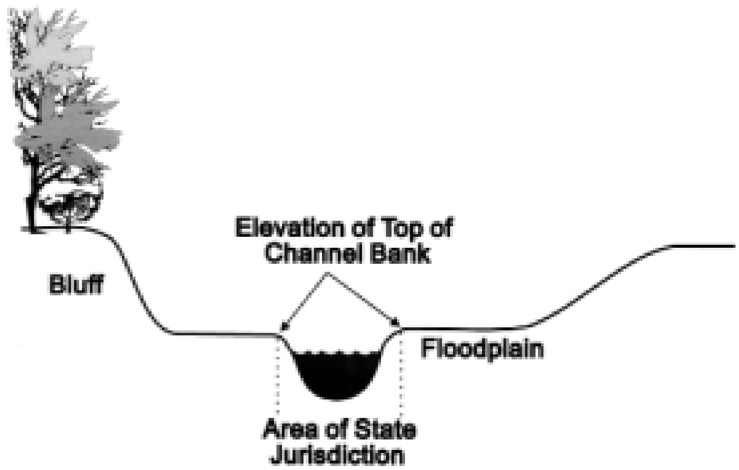

Figure 4.3 Area of State Jurisdiction Regarding Physical Alterations to Streams

Managing Public Lands in Stream Corridor for Recreational, Fish and Wildlife and Other Natural Values

The U.S. Fish and Wildlife Service, the National Park Service, and the Minnesota DNR manage public lands located along Minnesota's stream corridors for a variety of uses including: habitat protection and other natural amenity uses, boating, fishing, camping and other recreational uses.

The National Park Service manages the Mississippi National River and Recreation Area (MNRRA), which Congress added to the National Park System in 1988. The MNRRA consists of 72 miles of the Mississippi River and 54,000 acres of adjacent corridor lands within the Twin Cities Metropolitan Area. It contains more than 350 local, regional and state parks and national wildlife areas. A 22-member commission coordinates activities with the MNRRA. The U.S. Fish and Wildlife Service has responsibility for wildlife management on over 32,900 acres of land bordering the Mississippi in Minnesota.

The National Park Service also administers the St. Croix National Scenic Riverway and the Lower St. Croix National Scenic River under the National Wild and Scenic Rivers System. Other governmental agencies and organizations participate in managing the Upper River in accordance with the requirements of the National Wild and Scenic Rivers Act and state-adopted rules (see section on Wild and Scenic Rivers). The Minnesota and Wisconsin Departments of Natural Resources collaborate with the U.S. National Park Service in management activities on the Lower River (the southerly 52 miles).

The Minnesota DNR is the primary state agency involved in managing public lands located in river corridors. For example, the DNR Trails and Waterways Unit maintains almost 2,300 public access ramps and drop-in points for boating and canoeing on rivers and lakes in Minnesota. It also provides recreational amenities (campsites, picnic areas, and portages) on 19 designated canoe and boating routes comprising 2,850 river miles. The DNR Parks and Recreation Division operates and maintains 66 state parks with a total area of 220,000 acres.

The DNR Division of Fisheries and Wildlife manages and develops spawning areas, improves trout streams, constructs rough fish barriers, and obtains easements along streams for aquatic management and fishing access. The DNR manages more than 1,000 state wildlife management areas, containing about 685,000 acres, to preserve and enhance habitat for game and nongame animals. The Upper Mississippi system contains approximately 530,000 acres of wildlife refuge and management land. A 1992 amendment to Minnesota's Outdoor Recreation Act provided the DNR Division of Fisheries and Wildlife with statutory authority to acquire property and easements for aquatic management. It identifies and acquires lake and stream shoreland for access by anglers and fisheries management personnel, for protection of important habitat areas such as spawning and feeding and nesting sites, and for research on natural history. Aquatic management areas in Morrison County were acquired recently to protect adult river muskie habitat.

Regulating Commercial and Recreational Navigation Vessels

Federal, state and local communities all play roles in regulating navigational activities in Minnesota. The U.S. Coast Guard provides and maintains channel buoys, marker lights, and other navigational aids on U.S. waters to ensure compliance with navigation-related public safety standards. The Minnesota DNR establishes standards for operating watercraft and approves local water surface use ordinances. All owners of watercraft, with few exceptions, must obtain and display a license issued by the DNR to operate on Minnesota's rivers.

Local county agencies enforce many of the DNR's navigation-related standards. The DNR reviews the budgets of local county offices responsible for enforcement of DNR's standards, including search and rescue operations, to assure that the county maintains an appropriate level of service in these areas. Localities have some authority to limit or prohibit the use of watercourses within their jurisdictions. For example, they may designate particular stream reaches exclusively for swimming or unpowered watercraft (e.g., canoes) or impose watercraft speed limits.

Protecting and Enhancing Water Quality

Federal, state and local governmental agencies all play roles in water quality management in Minnesota. Key agencies include the U.S. Environmental Protection Agency (U.S. EPA), the Minnesota Pollution Control Agency (PCA), the Minnesota Department of Natural Resources (DNR), and the Minnesota Board of Soil and Water Resources (BSWR). Management efforts focus on protecting and enhancing water quality primarily by controlling and preventing sources of pollution. The mechanisms used to control and prevent pollution depend on whether targeted pollutants emanate from point or nonpoint sources. Point source polluters are identifiable because the source of the pollutants can be pinpointed. Examples of point sources of pollution include discharge pipes from municipal wastewater treatment and industrial processing plants. In contrast, nonpoint source pollutants come from a variety of sources such that the origin of the pollutants cannot be pinpointed. Examples of nonpoint sources of pollution include contaminated runoff and seepage from agricultural, construction, forestry, and mining activities as well as from urban pavement.

While the U.S. EPA provides leadership in the area of water quality under the Clean Water Act, the PCA in Minnesota designs programs and develops, administers, monitors and enforces standards to protect and enhance the quality of the state's surface water resources. Provisions contained in federal statutes related to the 1972 Clean Water Act, and subsequent amendments in 1977 and 1987, encourage each state to administer standards, provided the state's standards meet or exceed those set by the EPA. Within the PCA's northern, southern, and metro districts and in the environmental outcomes division, water quality staff assist individuals and organizations in meeting pollution control mandates.

The Water Quality Division's Monitoring and Assessment Section develops water quality standards, including numerical standards for 53 toxic pollutants (at the time of this writing) and detailed procedures for establishing standards for additional toxic pollutants. River water quality is assessed based on the number of violations of both conventional and toxic pollutant standards. The PCA reports these assessments to the EPA and Congress every two years in accordance with section 305(b) of the federal Clean Water Act.

The PCA's Point-Source Compliance Section issues wastewater treatment permits for municipalities and businesses, tracks compliance and enforces permit conditions. It administers point source discharge permits under both the National Pollutant Discharge Elimination System permit and the Minnesota State Disposal System permit program. Before the PCA will grant or renew a discharge permit, the point source discharger must demonstrate both the intention and ability to comply to effluent limits. The PCA reviews and selects proposals for funding. The BWSR also assists local governments by developing model rules and ordinances for point and nonpoint source pollution prevention and control, based on U.S. Soil Conservation Service technical guidelines, for use by local governments.

The Clean Water Act, as amended in 1987, mandates development of a Nonpoint Source Pollution Assessment Report and Management Program in each state. In Minnesota, the PCA's Nonpoint-Source Compliance Section develops standards and administers programs to control nonpoint source pollution from farmland, feedlots, construction sites, septic systems, roadways, and other sources. Controlling and preventing nonpoint source pollution raises difficult management issues because specific polluters often cannot be identified directly. Management efforts are coordinated by an interagency Project Coordination Team composed of representatives of 13 state and federal agencies and directed towards activities known to cause nonpoint pollution.

The Board of Soil and Water Resources (BWSR) addresses river pollution issues related to sediment and agricultural or urban nonpoint sources. The BWSR operates as a state administrative agency for local Soil and Water Conservation Districts (SWCDs), which assist local owners in protecting community soil and water resources. SWCDs provide assistance in developing and funding projects. They identify lands that contribute substantial amounts of nonpoint source pollution and ask landowners to participate in projects to reduce soil erosion and pollutant flow from their property. The state provides up to 75% of the funding for these projects for eligible participating landowners. The PCA's Watershed Assistance Section oversees and integrates efforts related to monitoring, assessment and point and nonpoint pollution control and prevention to protect and restore water resources within Minnesota's nine major drainage basins.

Other initiatives in Minnesota designed to prevent and control nonpoint source pollution and enhance water quality include the Metropolitan Surface Water Management Act (1982), the Comprehensive Local Water Management Act (1985), the Individual Sewage Treatment Systems Act (1994), and the Clean Water Partnership Program (1987). Under the Clean Water Partnership Program, the PCA provides grants to local government for water quality protection and improvement projects.

The Minnesota DNR plays only a minor role in regulatory issues related to water quality. However, through its land-use planning and zoning policies it influences developmental decisions and concomitant potential for point and nonpoint source pollution to Minnesota's waterways. Through monitoring and inspections programs, the DNR Ecological Services Section enforces federal and state laws regarding the use of aquatic pesticides in public waters. It also investigates major pollution spills and fish and wildlife kills, and collects specimens for toxic substance and pesticide analyses.

The DNR also engages in education and outreach programs designed to enhance and protect river resources. The DNR's Trails and Waterways Unit administers the state's Adopt-A-River Program, which solicits public involvement in river cleanup and provides organizations with information and guidance on organizing and carrying out river cleanup projects. It also publishes a newsletter on progress achieved on "adopted" rivers. To reduce and prevent point and nonpoint pollution from lands adjacent to Minnesota rivers, the DNR developed voluntary Best Management Practice (BMP) guidelines for use by landowners.

Moving Toward a More Integrated Management Approach for Minnesota's Rivers

While the current approach to river management has achieved some notable successes in sustaining or restoring some river values, opportunities for improvements exist. Many advocate restructuring the current fragmented system and adopting a watershed management model that acknowledges the natural linkages and boundaries of the system. They argue that since rivers are inextricably linked with their watersheds, management efforts must extend to shorelands, floodplains, and upland areas. The watershed management approach takes a holistic view of a river system by recognizing that all lands within the contributing watersheds, by reason of their position, use, topography, soils, geology, or other characteristics, may significantly impact the river.

In recent years, some state and regional agencies and grassroots organizations have undertaken a number of watershed-focused initiatives, but much work remains. Efforts to adopt watersheds as units of management run into resistance from established jurisdictions determined to maintain decision-making power. In addition, efforts to control land use through regulation often are met with stiff resistance because regulation reduces individual control over private property. While voluntary programs that encourage stewardship activities or provide incentives to protect and enhance Minnesota's river resources may create a relatively effective alternative to regulation, limits exist to these types of programs. To maintain and enhance the quality of its river resources, Minnesota must find a solution to this watershed management conundrum.

CHAPTER 5

MONITORING AND DATA ON MINNESOTA'S RIVERS

INTRODUCTION

Monitoring is essential to policy, planning, and management of Minnesota's streams and rivers. Monitoring efforts focus on both the quantity of water flowing in Minnesota's streams and rivers and its quality. Numerous federal, state and local agencies, as well as some non-governmental organizations, engage in monitoring activities. This chapter provides an overview of monitoring activities affecting Minnesota's rivers and streams and the agencies responsible for collecting, analyzing, reporting and storing the information. The discussion focuses first on flow-related monitoring activities and then examines water quality-related endeavors.

RIVER AND STREAM FLOW MONITORING

Flow-related monitoring activities permit tracking of stream flow conditions and forecasting extreme events such as floods and droughts. Monitoring data accumulated over many years enable managers to describe flow characteristics, assess in-stream flow needs, define available supplies, and ensure adequate water availability to meet long-term needs. These data also contribute to understanding how stream flow conditions in the state affect water quality and ecosystems.

Formal water quantity-related monitoring began in Minnesota with rainfall record-keeping in the early 1800s. The collection of stream-flow data began in 1909 when the U.S. Geological Survey (USGS) and Minnesota state agencies entered into cooperative agreements for the systematic collection of stream-flow records. State agencies that assist in collecting data through cooperative agreements with the USGS include the DNR, PCA, and Department of Transportation (MDOT); watershed management organizations, native American tribal government organizations, and watershed and conservation districts also have such agreements.

In the late 1930s, the USGS began a national stream gaging program with the establishment of a network of state-USGS gaging stations. Gaging stations measure the stream's stage (water level) and discharge rate (rate of flow). This national network is the principal tool used to measure surface-water supplies in each state. Stream gages with continuous stage-recording devices provide an ongoing record of stage and individual measurements of discharge. Agencies also obtain high-flow data by discrete measurements at "partial-record stations."

The size of the stream-gage network in Minnesota reached its peak in 1975 with 150 continuous-recording gage sites. In 1989, technological advances allowing 'real-time' electronic data collection and transmission at stations enhanced network capabilities. However, because of federal and state budgetary cuts, only 104 continuous-recording gaging stations have been in operation since 1993. Only 43 of the 81 major watersheds in Minnesota contain continuous recording gages. The locations of gaging stations operated by the USGS and DNR are shown in Figure 5.1.

The National Weather Service River Forecast Center uses stream gage data in order to model flows and forecast river flooding. About 95% of the gaging sites used by the NWS are shared with state agencies and the USGS. Where continuous data are not available, the NWS collects data manually. Data at these sites are collected on a daily basis during critical periods of high flow. The NWS uses its data to issue daily flow reports and to forecast future flows. It stores the data for only 30 days; however, the information is available to other agencies. The U.S. Army Corps of Engineers (Corps) also relies on stream flow monitoring data in the operation of its reservoirs, locks, and dams. It partially funds sites it shares with the USGS in the Upper Mississippi River Basin.

Flow Data Analysis, Reporting and Storage

Stream-flow data for Minnesota consists of information on stages (water levels) and discharge rates (flow in cubic feet per second). These data, in conjunction with other factors that may affect the relationships between stage and discharge rates, such as weather records, are used to construct stage-discharge relation curves or tables. Stage-discharge curves and tables are used to provide estimates of daily mean discharge rates from daily mean stage data.

The Water Resources Division of the USGS stores the data from Minnesota's gaging stations in the national USGS Streamflow database called WATSTORE. The USGS publishes an annual report for the state entitled "Water Resources Data - Minnesota," for each water year. The USGS water year, beginning October 1 and ending September 30, is identified by the calendar year in which it ends. Annual flow data also are available on-line from the USGS at http://h2o.er.usgs.gov/.

The Stream Flow Unit of the Minnesota DNR gathers and analyzes data on rivers and streams throughout Minnesota. The unit produces a weekly report on stream flow conditions during the open water season for water managers and other concerned interests. Data from these reports come from a variety of federal, state, and regional agencies and volunteer gage readers. The DNR also prepares special reports when conditions within certain rivers and streams approach significantly low- or high-flow levels. The DNR identifies several threshold levels for each gaging station and time of year: Q90 - stream flow is at least this high 90 percent of the time; Q75 - stream flow is at least this high 75 percent of the time; Q25 - stream flow is as high as this only 25 percent of the time, and; Q10 - stream flow is as high as this only 10 percent of the time (Table 5.1).

When flows fall below the Q90 level, the river is considered to be in a critically low flow condition, and it is closely monitored as long as flows remain below the threshold. The DNR Division of Waters may restrict appropriation of water from the river to maintain adequate flow for in-stream needs such as fish and wildlife and ensure adequate supplies for higher priority users such as municipal supplies and for power generation. At the other end of the spectrum, critically high levels, those exceeding the Q10 level, indicate potential flood conditions that threaten damage to property. Flood flows are generally defined using the flood stages identified by the NWS or other agencies. In watersheds where a flood stage has not been identified, the highest monthly Q10 is used as an interim estimate of flood flow.

Table 5.1 Definition of DNR Threshold Stream Flow Values

Critically Low	< *annual Q90* (Q90 = streamflow is at least this high 90% of the time at this station during the open water season)
Low	< *monthly Q75* (Q75 = streamflow is at least this high 75% of the time at this station during this month)
Normal	*monthly Q75 - Q25*
High	> *monthly Q25* (Q25 = streamflow in this month at this station has been as high as this only 25% of the time)
Critically High	> *monthly Q10* (Q10 = streamflow in this month at this station has been as high as this only 10% of the time)

Based on historical monitoring data.

Using the Stream and Watershed Information System under development at the Minnesota Land Management Information Center (LMIC), interested people can compare and analyze different kinds of water and land related data. The Legislative Commission on Minnesota Resources funded its development in 1991. Presently, Geographic Information System (GIS) data have been created, and some data from monitoring agencies have been integrated to the map layers. Data can be obtained online at the LMIC website (www.lmic.state.mn.us).

WATER QUALITY MONITORING

Information on Minnesota's river water quality comes from monitoring activities undertaken by federal, state and local agencies and by non-governmental organizations. This section first describes the general uses of water quality data and how it is collected and analyzed. The remainder of this section focuses on specific federal, state and local water quality efforts.

Water quality sampling is undertaken to establish baseline conditions and monitor trends, to monitor compliance with environmental regulations, and to study specific issues or locales. Monitoring data that describe ambient conditions are used to establish baselines and trends. Consistent, long-term ambient monitoring assists in the detection problems or threats to resources before they become obvious or irreversible. Ambient monitoring also provides the information needed to evaluate the effectiveness of management programs and projects. Compliance monitoring data are used to evaluate the effectiveness of point source contaminant controls. Discharge permits generally require permit holders to collect and report data on the quality of water discharged to ensure it meets state and federal quality guidelines.

Special monitoring programs also are established to develop basic water quality information in relation to a particular issue of concern. These programs generally run for a limited period and data from such efforts may not be useful for drawing conclusions about temporal trends. However, they can be more useful when integrated with compliance and ambient data.

Monitoring the state's surface water quality entails collection and analysis of water samples from locations throughout Minnesota. In theory, monitoring stations are chosen to reflect water conditions in all regions of the state. Minnesota's ambient water quality monitoring program began in 1953. Although the number and location of sampling sites have varied, extensive data are available for 42 sites. Over the past 40 years, the PCA monitored each of these sites for 20 or more years. The PCA also oversees monitoring of discharge sites for municipal and industrial facilities, such as wastewater treatment plants, to ensure compliance with permit conditions. The local operator of the treatment plant does most compliance monitoring, and it involves testing the effluent to determine that it meets discharge limits, rather than testing in the stream for impacts. The state also tests rivers for the presence of pesticides and nutrients to track compliance with regulations. The types of analyses conducted depend on specifics of the applicable law or permit. The state does a limited amount of fish tissue monitoring in rivers, usually in the most heavily-fished ones. When fish tissue analyses indicates a potential problem, sediments are sampled and analyzed to identify the source of contamination.

Monitoring agencies use several approaches to measure water quality: chemical analyses of water and sediment samples, biological surveys and toxicity testing, and analyses of fish and wildlife tissue to measure accumulation of toxic pollutants. Routinely measured parameters that affect designated uses of streams and rivers fall into six categories: sediment (total suspended solids and turbidity), nutrients (dissolved oxygen, biochemical oxygen demand, nitrate and phosphorus), major ions (total dissolved solids, chloride and sulfates), pathogens (fecal coliform bacteria), toxic substances (metals and organic compounds), and other basic water quality parameters (pH and temperature) (Table 5.2). Analyses of fish tissue to measure accumulation of toxic pollutants include PCBs, dioxin, organochlorine pesticides, and mercury. To identify potential human health threats to those consuming fish exposed to toxic pollutants, only the commonly eaten parts are analyzed. To measure the incidence of bioaccumulation of toxic pollutants, organs and fat that are known to accumulate contaminants are analyzed.

Other indicators of stream water quality include bioassays for toxicity and biological community assessments. Bioassays test the ability of organisms, like Daphnia (a relatively large-bodied zooplankton) and fathead minnows, to live in effluent, ambient water or sediment over a fixed time period. Biological community assessments provide a holistic indicator of stream water quality on a seasonal basis by evaluating the structure of the biological community in a specific area using data on the type and population of observed aquatic species.

Table 5.2 Commonly Measured River Water Quality Parameters

Category	Parameter	Human source	Environmental Effect
Sediment loading	• Total suspended solids (TSS)	• Suspended sediment is the product of erosion, either natural or the result of land-cover disturbances related to human activities.	• After runoff periods, fine particles can settle to the bottom of streams smothering fish eggs, larvae, and aquatic insects. TSS transports other pollutants with it. Sediment can fill reservoirs within a matter of years.
	• Turbidity is suspended silt and finely divided organic matter that scatters and absorbs light. It is perceived as cloudy water.	• High turbidity is associated with nonpoint sources of suspended solids washed into rivers and streams during rain storms.	• High turbidity is aesthetically displeasing, degrades habitat for some fish species such as smallmouth bass, decreases light penetration needed for plant growth, increases water temperature by absorbing more solar radiation, may significantly increase water treatment costs, and may decrease sport-fishing success.
Nutrient loading	• Dissolved Oxygen (DO)	• Low dissolved oxygen is usually caused by inadequate treatment and discharge of organic wastes or decomposing vegetation.	• Adequate dissolved oxygen is necessary for the survival and propagation of fish and other aquatic life and for the prevention of offensive odors.
	• Biochemical Oxygen Demand (BOD)	• Inadequate waste water treatment and runoff carrying fertilizers and animal wastes are common sources of BOD.	• Oxygen demanding pollutants increase oxygen consumption of the river. Lack of oxygen kills aquatic life.
	• Ammonium (NH_4^+) and Ammonia (NH_3)	• Ammonium is a natural part of the nitrogen cycle in surface waters, but high concentrations usually indicate inadequate wastewater treatment, discharge of organic wastes, or decomposing vegetation.	• Nitrification (conversion of ammonium to nitrate) consumes great quantities of oxygen. Ammonia, the un-ionized basic counterpart of ammonium, is toxic to fish.
	• Nitrite+nitrate (NO_2^-+ NO_3^-) are oxidized forms of nitrogen that make up most of the nitrogen in well-aerated streams.	• Nitrate is found in agricultural fertilizers and often is the main nitrogen form in agricultural runoff.	• Nitrate fertilizes the river, promoting growth of algae and weeds, either in the river itself or in downstream lakes. It also may make water unsuitable for public supply.
	• Total Phosphorus	• Runoff from agricultural areas, over-fertilization, and effluent from sewage treatment plants are the main sources of phosphorus contamination in Minnesota streams.	• Phosphorus increases the growth of aquatic plants and can promote heavy algal blooms and excessive weed growth. It reduces water clarity and creates unsuitable conditions for many species of fish.
Major Ions	• Total Dissolved Solids (TDS) is sometimes measured indirectly as conductivity.	• Dissolved solids in stream water result primarily from rock weathering, but also can be introduced as a byproduct of human activities.	• Dissolved solids can make water unsuitable for some uses and can harm aquatic organisms.

Stream Water Quality Monitoring Programs

A number of federal, state, regional and local governmental agencies monitors the quality of Minnesota's streams and rivers including the USGS, PCA, DNR, the Metropolitan Council Environmental Services (MCES), and certain local units of government. In addition, a number of citizen groups engages in monitoring activities. Each agency designs its monitoring program to meet its specific needs.

Federal Programs: The Water Resources Division of the U.S. Geological Survey (USGS) currently operates two nationwide stream water-quality monitoring networks, the Hydrologic Benchmark Network and the National Stream Accounting Network (NASQAN). Samples from stations in each program are sampled approximately four or five times during the year and analyzed for the parameters listed in Appendix C. A 20-year record of data exists for most sites. The USGS stores all water-quality data in their WATSTORE database available via STORET, the U.S. EPA's large water-quality database. Requests for small amounts of data from STORET (total costs under $25) may be obtained by contacting the EPA Region 5 Freedom of Information Officer. Data can also be obtained online or from the PCA. There are no fees for this service, except for unusually large data retrievals, and the wait time for most data requests is approximately two weeks. (Contacts for data requests are listed in Appendix B.)

The nationwide Hydrologic Benchmark Network Program provides information on baseline water quality conditions. The network consists of a set of stations located in small, pristine drainage basins. Because point source pollution is not a problem in these areas, this program has been especially useful in describing the effects of non-point atmospheric deposition of pollutants on streams. Only one Hydrologic Benchmark Network station is located in Minnesota on the Kawishiwi River near Ely. Another station, located on the North Fork of the Whitewater River, closed in 1993.

The National Stream Accounting Network (NASQAN) was established in 1973 to obtain information on the quality and quantity of water draining into the oceans, describe geographic variability in water quality, detect temporal trends, and provide a nationally consistent database. Most NASQAN stations are located at the mouths of rivers and tributaries. As a result, this program's stations are broadly representative of their basins, but they cannot provide specific, detailed data to characterize the basins. This has limited the ability of the program to analyze geographic patterns in water quality. In the early 1990s, this program experienced a significant reduction in size declining from ten NASQAN stations in Minnesota in 1993 to four in 1994. Existing stations are located on the Minnesota River at Jordan, the Mississippi River at Royalton and Nininger, and the St. Louis River at Scanlon. Figure 5.1 shows the locations of the NASQAN stations, the USGS Hydrological benchmark stations and other USGS water quality monitoring stations.

Figure 5.1 Locations of NASQAN, USGS Hydrological Benchmark and other water quality monitoring stations. U.S. Geological Survey, 1993.

To assess the quality of the nation's surface and ground water, the National Water-Quality Assessment Program (NAQWA) began in 1991. The program was designed to describe the status and identify trends in water quality and identify natural and anthropogenic factors affecting water quality. The scope of the program is large, covering approximately 60 to 70% of the water used by the entire U.S. population. This information will provide water managers and policy makers with a better understanding of the geographic differences water quality and concomitant causes.

Two basins that lie partially within Minnesota are being studied as part of NAWQA: the Red
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area. ... oject in
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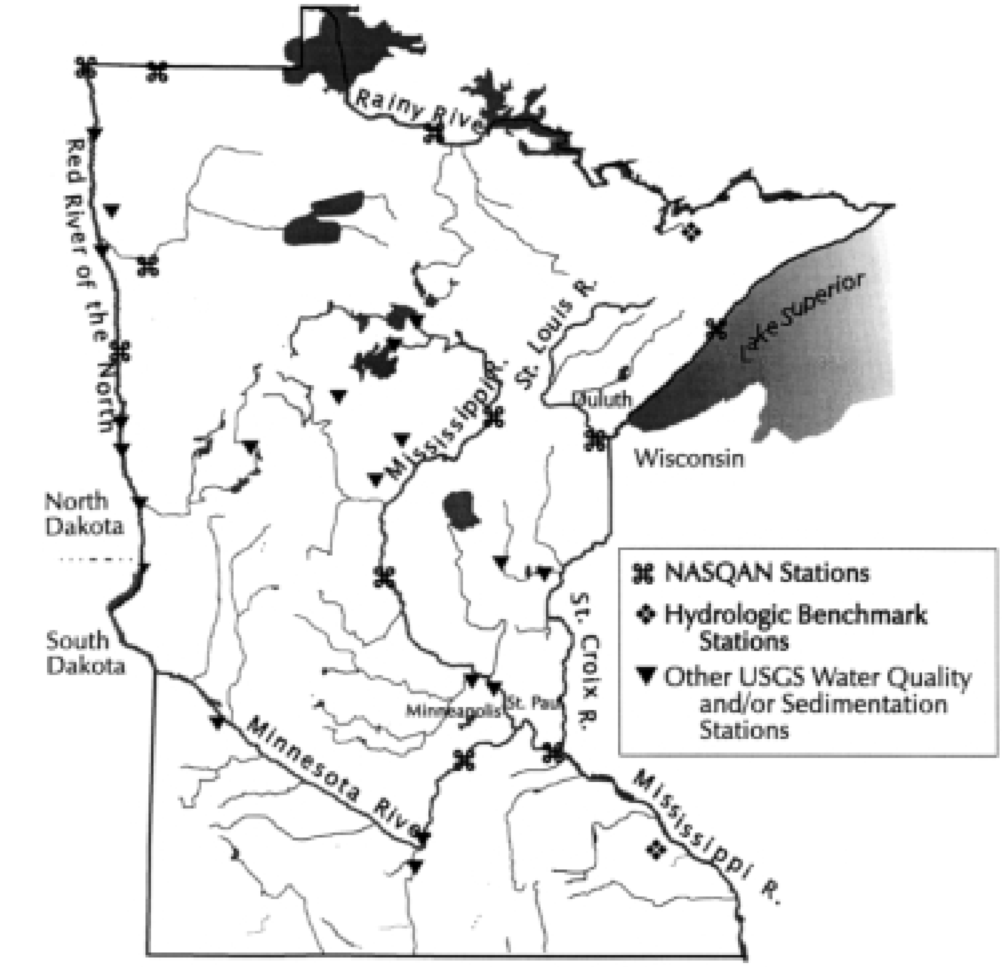

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The PCA cautions the users of its biennial reports that sites are not selected by a random process, and frequency of sampling and choice of parameters vary from site to site. Therefore the water quality assessment "cannot be considered or used to represent the overall water quality" of Minnesota's rivers and streams (PCA, 1994). The PCA initiated a random-site, statistically-based monitoring effort in 1996 to give a valid, unbiased assessment of overall water quality in Minnesota. At program initiation, 80 sites in the St. Croix basin were monitored for basic water chemistry, habitat, fish, and macro invertebrates.

Table 5.3 Fish Contaminant Advisory Levels

Use Category	Contaminant		
	TCDD* (ng/kg)	PCB** (µg/g)	Hg (µg/g)
Fully Supporting (unrestricted consumption)	<.032	<.025	< 0.150
Partially Supporting (moderate consumption)	.032 - .060	.025 - .470	0.150 - 2.810
Not Supporting (no consumption advised)	>.060	>.470	>2.810

*Tetrachlorodibenzodioxin, commonly known as dioxin
**Polychlorinated biphenyls
PCA, 1994. *Minnesota Water Quality*.

The PCA monitors rivers water quality routinely in compliance with state law and section 305(b) of the Clean Water Act. Section 305(b) requires that each state submit a biennial report to Congress on their progress toward meeting the goals of the act. Approximately 6% of Minnesota's total river miles are assessed each year. The program has been aimed primarily at monitoring point source pollution. For many years, 78 stations were monitored, the majority of which were located on the state's largest rivers. Tributary sampling sites generally are located near their mouths. Monitoring activities also included an additional 15 stream sites from a specific geographic area of emphasis; this rotates every three years from the southern to northeastern to northwestern portions of the state (PCA, 1992).

In 1996, the PCA routine monitoring program consisted of 90 sites statewide which were monitored for 10 months each year for two years of a five-year cycle. The Minnesota Department of Health analyzes the samples for standard and site-specific water-quality parameters. (Parameters are listed in Appendix C.)

The PCA recently made several changes in its monitoring program, including reduced reliance on routine, fixed-station monitoring and increased efforts on "longitudinal surveys" of streams of particular interest and "statistically-based monitoring." The PCA's monitoring activities include "basin assessments" that take into account relationships within a watershed, including nonpoint sources of pollution. In addition, to measure a river's ability to support its aquatic community, biological monitoring is being used to complement chemical monitoring. The PCA's water quality data are stored on the EPA's STORET database. Monthly data exist for the 1968 through 1978 period. Prior to 1968, sampling was sporadic, and since 1978, samples have not been collected in December, January, and February.

Local Programs. The Metropolitan Council Environmental Services (MCES), and its predecessor organizations, have monitored river water quality in the Twin Cities since the 1930s. Monitoring activities have focused on determining the adequacy of wastewater treatment to ensure public safety and the survival of fish and other aquatic life. The MCES routinely samples 27 sites, mostly on the Mississippi and Minnesota Rivers. Additional sites are located on the St. Croix, Vermillion, and Rum rivers. Sampling stations are usually placed upstream and downstream of the MCES-operated treatment facilities.

All sites are sampled continously using automatic sample devices. Analytical measurements are based on a set of water-quality parameters to track compliance with state standards. Additional parameters such as nutrients, biochemical oxygen demand (BOD), and chlorophyll-*a*, are also analyzed. Data are available from 1976 and are stored internally at the MCES.

Several citizen monitoring programs, such as the River Water Program, engage in water quality monitoring activities in Minnesota. If the data collected by these programs meet scientific protocols, the PCA enters the data into STORET.

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APPENDICES

APPENDIX A. RIVER FACTS

Caution data users. The following information was compiled from various sources, and entries are approximations. Drainage area, river length, gradient, and discharge were measured or estimated by separate agencies for different purposes and may not be complementary.

Rainy River Drainage Basin

Rainy River:

Kawishiwi River (Basswood): Lake Co., 1,376 sq.mi., 70 mi. from White Iron Lake, 340 ft. drop, mean q=1,100cfs; max q=16,000 cfs.

Vermilion River (Namakan): St. Louis Co., 1,034 sq.mi., 40 mi, from Vermilion Lake, 240 ft. drop, mean q=600 cfs; max q=4,000 cfs.

Little Fork River: St. Louis, Koochiching and Itasca Co., 1,843 sq.mi., 157 mi. from Lost Lake Swamp, 300 ft. drop, mean q=1,000cfs, max q=25,000cfs

Big Fork River: Koochiching and Itasca Co., 2,063 sq.mi., 213 mi from Jessie Lake, 250 ft. drop, mean q=950cfs, max q=20,000cfs

Red River of the North Drainage Basin

Red River of the North:

Bois de Sioux River: Traverse, Otter Tail, Grant and Wilkin Co., 1880 sq.mi. (564 in MN),

Mustinka River: Otter Tail, Grant, Stevens, Wilkin, and Traverse Co., 878 sq.mi., 69 mi. from Orwell Reservoir, 160 ft. drop, mean q=50cfs

Otter Tail River: Clearwater, Becker, Otter Tail, and Wilkin Co., 1,952 sq.mi, 189 mi. from Big Rock Lake, 540 ft. drop, mean q=300cfs, max q=2,000cfs

Buffalo River: Becker, Otter Tail, Wilkin, and Clay Co., 1,108 sq.mi., 130 miles , 635 ft. drop, mean q=150 cfs; max q=1500 cfs

Wild Rice River: Clearwater, Becker, Clay, Mahnomen, and Norman Co., 1,629 sq.mi., 168 mi. from lakes, 700 ft. drop, mean q=260cfs

Marsh River: Norman Co., 300 sq.mi., 47 mi., 100 ft. drop, mean q=90cfs, receives overflow from Wild Rice River

Sand Hill River: Polk Co., 484 sq.mi., 95 mi., 480 ft. drop, mean q=70cfs; max q=5,000 cfs

Red Lake River: Beltrami, Clearwater, Marshall, Pennington, Red Lake, and Polk Co., 5,754 sq.mi. (1,974 sq.mi. in Red Lakes), from 244 mi. From lakes, 345 ft. drop, mean q=1,100cfs, max q=30,000cfs

Thief River: Beltrami, Marshall, Pennington Co., 1,076 sq.mi., mean q=160cfs; max q=5,000 cfs

Clearwater River: Clearwater, Beltrami, Pennington, Polk, and Red Lake Co. 1,385 sq.mi., mean q=300cfs; max q=10,000 cfs.

Snake River: Marshall Co., 1,785 sq.mi., 81 mi.

Middle River: Marshall Co., 324 sq.mi., 67 mi.; mean q=40 cfs; max q=4,000 cfs

Tamarac River: Marshall Co., 333 sq.mi., 56 mi.

Two Rivers: Roseau and Kittson Co., 1,076 sq.mi., 72 mi., mean q=100cfs

Roseau River: Roseau and Kittson Co., 1505 sq.mi. (440 in Canada), 113 mi. (15 in Canada), mean q=300cfs; max q=4,000 cfs (at Canadian border)

Lake Superior Drainage Basin

Nemadji River: Carlton and Pine Co., 270 sq.mi., 32 mi., 500 ft. drop

St. Louis River: St. Louis, Carlton, Aitkin, and Lake Co., 3,647 sq.mi., 190 mi., 1,100 ft. drop, mean q=2,500cfs, max q=38,000cfs

Whiteface River: St. Louis Co., 600 sq.mi., 80 mi. from Whiteface Reservoir, 430 ft. drop, mean q=400cfs

Cloquet River: Lake and St. Louis Co, 794 sq.mi., 97 mi. from Cloquet Lake, 300 ft. drop, mean q=500cfs
Brule River: Cook Co., 282 sq.mi., 40 mi. from Brule Lake
Pigeon River: Cook Co., 610 sq.mi. (235 sq.mi. in U.S.), 60 mi. from South Lake, 950 ft. drop; mean q=500 cfs; max q=11,000 cfs
Baptism River: Cook Co., 140 sq.mi.; mean q=170 cfs; max q=10,000 cfs

Upper Mississippi Sub-basin above St Anthony Falls
Leech Lake River: Cass Co., 49 mi.
Pine River: Cass and Crow Wing Co.; 785 sq.mi.; 71 mi.
Crow Wing River: Hubbard Becker, Cass, Wadena, Otter Tail, Douglas, Todd, Crow Wing, and Morrison Co., 3,764 sq.mi., 115 mi., mean q=1,300cfs, max q=16,600cfs
Shell River: Becker, Wadena, and Hubbard Co., 40 mi. from Shell Lake, mean q=250cfs
Leaf River (Red Eye River): Becker, Otter Tail, Todd, and Wadena Co., 899 sq.mi.; 61 mi.; mean q=150cfs
Long Prairie River: Douglas, Todd, Cass, and Morrison Co., 862 sq.mi., 118 mi from northeast Douglas Co., mean q=200cfs
Gull River: Morrison Co., mean q=100cfs
Sauk River: Douglas, Todd, and Stearns Co., 1042 sq.mi.; 115 mi. from Lake Osakis, 340 ft. drop, mean q=280cfs; max q=9,000 cfs
Elk River: Benton and Sherburne Co., 50 mi from northern Benton Co.; 630 sq.mi.; 200 ft. drop, mean q=280cfs; max q=7,500 cfs
Crow River: Pope, Stearns, Kandiyohi, Meeker, Renville, McLeod, Carver, Wright, and Hennepin Co., 2,752 sq.mi., 175 mi. from Grove Lake (North Fork), plus 25 mi. of mainstem, mean q=750 cfs, max q=22,000cfs
Rum River: Crow Wing, Aitkin, Mille Lacs, Morrison, Benton, Sherburne Isanti, and Anoka Co. 1,558 sq.mi. (200 in Mille Lacs Lake), 163 mi. from Mille Lacs, 145 ft. drop, mean q=600cfs, max q=10,000cfs

Minnesota River Sub-basin
Minnesota River:
Pomme de Terre River: Otter Tail, Grant, Stevens, and Swift Co., 909 sq.mi., 125 mi.; 350 ft. drop, mean q=110cfs, max q=5,500cfs
Lac qui Parle River: Lincoln, Yellow Medicine, and Lac qui Parle Co., 749 sq.mi. in Minn. (343 in SD), 110 mi.; 800 ft. drop, mean q=140cfs, max q=17,000 cfs
Chippewa River: Otter Tail, Douglas, Grant, Stevens, Pope, Swift, Kandiyohi, and Chippewa Co., 2,072 sq.mi., 154 mi., 585 ft. drop, mean q=300cfs, max q=11,000cfs
Hawk Creek: Chippewa and Renville Co., 503 sq.mi., 65 mi. from , mean q=150cfs
Yellow Medicine River: Lincoln, Lyon, Yellow Medicine Co., 665 sq.mi., 80 mi. from Lake Shaokatan, 850 ft. drop, mean q=130cfs, max q=17,000cfs
Redwood River: Lincoln, Pipestone, Murray, Marshall, Yellow Medicine, and Redwood Co., 716 sq.mi., 122 mi., 1,000 ft. drop, mean q=130cfs, max q=20,000cfs
Cottonwood River: Marshall, Murray, Cottonwood, Redwood, and Brown Co., 1,316 sq.mi., 140 mi. from Rock Lake, 750 ft. drop, mean q=340cfs, max q=28,700
Blue Earth River: Brown, Cottonwood, Jackson, Martin, Faribault, Freeborn, Steele, Waseca, Watonwan, and Blue Earth Co., 3,161 sq.mi. (3,106 in Minn.), 109 mi, 285 ft. drop, mean q=1,500cfs, max q=68,000cfs
Watonwan River: Brown, Cottonwood, Jackson, Martin Watonwan, and Blue Earth Co., 848 sq.mi., 107 mi.; mean q=380cfs, max q=14,000cfs
Le Sueur River: Steele, Freeborn, Waseca, Faribault, and Blue Earth Co., 1,103 sq.mi., 98 mi.; 400 ft drop, mean q=500cfs, max q=25,000cfs

Upper Mississippi River Sub-basin in Minnesota below Fort Snelling

Upper Mississippi River:

St Croix River: Pine, Chisago, Isanti, Anoka, and Washington Co., 7,650 sq.mi., (3,500 in Minn.), 154 mi. from Gordon Dam in Wisc. (125 from border). 325 ft. drop, mean q=5,000cfs; max q=60,000 cfs

Kettle River: Carlton, Aitkin, Kanabec, and Pine Co., 1,050 sq.mi., 79 mi. from Corona Bog, 500 ft. drop, mean q=750cfs

Snake River: Mille Lacs, Aitkin, Kanabec, and Pine Co., 1,009 sq.mi., 98 mi.; 500 ft. drop, mean q=600cfs, max q=15,000cfs

Vermillion River: Scott and Dakota Co., 47 mi.,

Cannon River: LeSueur, Rice, Waseka, Steele, Dakota, Goodhue Co., 1,479 sq.mi., 117 mi.; 400 ft. drop, mean q=560cfs, max q=40,000cfs

Zumbro River: Steele, Dodge, Goodhue, Wabasha Co., 1,423 sq.mi., 109 mi from , 600 ft. drop, mean q=650cfs, max q=30,000cfs

Whitewater River: Olmstead, Wabasha, and Winona Co., 15 mi. mainstem only from confluence of the forks, 75 ft. drop (mainstem only-forks much greater), mean q=200cfs?, max q=20,000cfs??

Root River: Mower, Olmsted, Winona, Fillmore, and Houston Co., 1,659 sq.mi.;138 mi; 550 ft. drop; mean q=1,000cfs, max q=50,000cfs

Mississippi River (tributaries flowing into Iowa)

Upper Iowa River: Mower and Fillmore Co., 218 sq.mi.; 49 mi.

Cedar River: Freeborn, Dodge, and Mower Co., 711 sq.mi., 51 mi. (40 mi. in MN)

Shell Rock River: Freeborn Co., 570 sq.mi. (246 sq.mi. in MN), 12 mi. in MN

Des Moines River: Murray, Lyon, Cottonwood, and Jackson Co., 1,545 sq.mi., 123 mi. in Minn.; 235 ft. drop, to Iowa border, mean q=350cfs, max q=20,000 (To Missouri River)

Little Sioux River: Jackson Co., 312 sq.mi. in MN

Rock River: Pipestone and Rock Co., 913 sq.mi., 86 mi.; 450 ft. drop, max q=3,500 cfs near Iowa border

Data sources: LMIC (S. Maeder) compiled from DNR River Kilometer Index GIS River Trace Files and DNR 1993 WSHED23 Major/Minor GIS Coverage; USGS *Water Resource Data*—Minnesota, 1993 (2 vols.); and Waters, Thomas, 1977, *Streams and Rivers of Minnesota*, University of Minnesota Press, Minneapolis.

APPENDIX B. AGENCY CONTACTS AND DATA SOURCES

STATE OF MINNESOTA

Board of Water and Soil Resources
Ronald D. Harnack, Executive Director
One W. Water St., St. Paul, MN 55107
(612) 296-3767
INFORMATION OFFICER 297-1893
The board's staff can assist the public with questions concerning local water and soil management authorities and responsibilities. Copies of laws and rules, sample petitions, informational materials, and general information and assistance at no charge.

Department of Agriculture
90 W. Plato Blvd., St. Paul 55107
INFORMATION 297-2200
Minnesota River Ag Team (MNRAT), (612) 296-1482/282-5140

Department of Health
Environmental Health Division
Director, Patricia A. Bloomgren
121 E. 7th Place, Minneapolis, 55414
INFORMATION (612) 215-0870
Drinking Water Protection, 215-0746
Licensing and regulation of water supply systems, public water supply operators, plumbers, individual sewage disposal systems.

Department of Natural Resources
500 Lafayette Rd., St. Paul, MN 55155-4001
INFORMATION CENTER, 296-6157
Fish and Wildlife Division, 297-1308
  Ecological Services Section, 296-2835
Fisheries Section, 296-3325
Wildlife Section,296-0703
Information and Education Bureau, 396-3336
Library, 297-4929
Trails and Waterways Unit, 297-1151
Waters Division, 296-4800
  State Climatologist, 296-4214

Department of Transportation
Office of Railroads and Waterways
925 Kelly Annex, 395 John Ireland Boulevard, St. Paul, MN 55155
Ports and Waterways Section, (612) 297-5179

Environmental Conservation Library
Minneapolis Public Library and Information Center
300 Nicollet Mall, Minneapolis, MN 55401
(612) 372-6570
Depository for state environmental assessments and impact statements.

Environmental Quality Board
Michael Sullivan, Executive Director
300 Centennial Office Bldg., 658 Cedar St., St. Paul, MN 55155
(612) 296-2603
Charged with coordinating and integrating water policy development and water planning in Minnesota.The EQB Water Planning Committee carrries out specific water planning functions of the Board.

Legislative Commission on Minnesota Resources
John R. Velin, Director
65 State Ofc. Bldg., 100 Constitution Ave., St. Paul 55155
(612)296-2406
Recommends funding for programs every two years.

Metropolitan Council
230 E. 5th St., St. Paul, MN 55101
PUBLIC INFORMATION (612) 291-6359
Data Center, (612) 291-8140
Library, (612) 291-6310
Water Management 291-6402
Data and information about the seven-county Twin Cities Areas, including natural resources.

Metropolitan Council Environmental (Wastewater) Services
INFORMATION 229-2129
Communications, Tours, and Public Relations, 229-3279
Collects and treats wastewater in the Twin Cities area. Provides information services through as speaker's bureau, video presentations, general information publications, newsletter, and numerous technical reports and documents, including water quality monitoring, available from the Office of Communications.

Minnesota Agricultural Statistics Service
500 Commerce Bldg., 8 E. 4th ST., St. Paul 55101
INFORMATION (612) 296-2230

Minnesota Geological Survey
Director, David L. Southwick
2642 University Ave., St. Paul 55113
Maps & Publications, (612) 627-4782
Waterwell Records, 627-4784

Minnesota Planning
Office of Strategic & Long Range Planning
Director, Linda Kohl
658 Cedar St., St. Paul, MN 55155
INFORMATION (612) 296-3985
State Demographer, 296-4100
Staff support for EQB. Information and assistance to local governments on the environment and natural resources.
Land Management Information Center (LMIC)
INFORMATION 296-1211

Minnesota-Wisconsin Boundary Area Commission
Administrative Director, Dan Mcguiness
619 Second St., Hudson, WI 54016
(612) 436-7131 or (715) 386-9444
Serves as coordinator and chairman of the Upper and Lower St. Crox National Riverway Management Commissions on major segments of the National Wild and Scenic Rivers System, a cooperative venture of the Minnesota and Wisconsin Departments of Natural Resources and the National Park Service. Information on the St. Croix and Mississippi Rivers.

Mississippi Headwaters Board
Molly MacGregor, Director
Cass County Courthouse, 300 Minnesota Ave., Walker, 56484

Pollution Control Agency
520 Lafayette Rd., St. Paul, MN 55155
INFORMATION (612) 296-6300
Public Information Office, (621) 296-7283
Water Quality Division, (621) 296-7202

University of Minnesota
Minnesota Extension Service
GENERAL INFORMATION (612) 625-1915

UNITED STATES

Army Corps of Engineers
1421 U.S. Post Office Bldg., 180 E. Kellogg Blvd., St. Paul, MN 55101-9808
(612) 220-0200

Coast Guard
Marine Safety Detachment Marine Inspection-Marine Environmental Protection
180 E. Kellog Blvd., St. Paul 55101
(612) 290-3991

Environmental Protection Agency
Region 5, 77 W. Jackson Blvd., Chicago, IL 60604
Freedom of Information Officer, (312) 886-6686
Water Division, 886-3000

Fish and Wildlife Service
4101 East 80th St., St. Paul, MN 55425-1665
(612) 725-3548

Geological Survey
St. Paul District Office
2280 Woodale Drive, Mounds View, MN 55112
(612) 783-3100

Natural Resource Conservation Service
600 Farm Credit Svcs. Bldg., 375 Jackson St., St. Paul, MN 55101-1854
(612) 290-3675

INFORMATION AND DATA ON-LINE

MN Planning
http://www.mnplan.state.mn.us/
Land Management Information Center
http://www.lmic.state.mn.us/welcome.html

Minnesota River Basin Agricultural Resources & Research http://www.soils.agri.umn.edu/research /mn-river/index.html

National Weather Service
National Climatic Data Center
http://www.ncdc.noaa.gov/homepg/online.html
Midwestern Climate Center
http://mcc.sws.uiuc.edu

U.S. Army Corps of Engineers
St. Paul District
http://www.ncs.usace.army.mil/

U.S. Environmental Protection Agency
Office of Water
Information Resources & Services
http://www.epa.gov/ow/index.html
STORET DATA SYSTEM
http://www.epa.gov/OWOW/STORET/

U.S. Geological Survey
http://h2o.er.usgs.gov/
Minnesota Surface-Water Data Retrieval
http://h2o.usgs.gov/swr/MN/
USGS in Minnesota - NAWQA
http://www.cr.usgs.gov/

APPENDIX C. WATER QUALITY PARAMETERS

MINNESOTA POLLUTION CONTROL AGENCY
Routine Water Quality Monitoring Program (1992-93)

Temperature-C - field
Dissolved Oxygen - field
Fecal coliform
BOD5
Suspended Solids
pH
Conductivity
Nitrite + Nigrate
Total Phosphorus
Total Kjeldahl Nitrogen
Ammonia Nitrogen
Organic Nitrogen
Additional Monthly Analyses at Selected Stations
Chloride
Phenols
Total Lead
Calcium (as CACO3)
Total Sodium
Total Sulfate
Reactive Silicate (silica)
Turbidity
COD
TOC
Ortho Phosphorus
Total Solids
Total Vol. Solids
Dissolved Vol. Solids
Water Level Gage Reading
Total Alkalinity
E-coli
Magnesium
Total potassium
Asbestos fiber
Additional Analyses at Selected Stations
BOD5-Carbonaceous

MET COUNCIL ENVIRONMENTAL SERVICES
Comprehensive River Monitoring
Conventional Pollutant Sampling*
Auto
Temperature
Dissolved Oxygen
pH
Ammonia-N

Turbidity
Fecal Coliform
Nitrite-N
Nitrate-N
Carbonaceous BOD5
Total BOD5
Total Phosphorus
Suspended Solids
Volatile Suspended Solids
Total Dissolved Solids
Total Chlorophyll-a
Viable Chlorophyll-a
Conductivity
Ortho-phosphorus
Particulate Phosphorus
Total Kjeldahl-N
Particulate Kjedldhl-N

Quarterly
Dissolved: Chloride, Sulfate, Sodium, Potassium, Calcium,Magnesium
Alkalinity
Carbon Dioxide
Bicarbonate
Carbonate
Ultimate BOD Series
Grease and Oil

Toxics Monitoring*

Total: Antimony, Arsenic, Beryllium, Cadmium, Chromium, Copper, Cyanide, Lead, Mercury, Nickel, Phenol, Selenium, Silver, Thallium, Zinc

Dissolved: Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Zinc
Total Organics: Volatiles, Acids, Base/Neutrals, Pesticides, PCBs

* For Biomonitoring parameters, see Water Quality Summary Reports available from MCES contacts listed above.

U.S. GEOLOGICAL SURVEY
National Stream-Quality Accounting Network**
Instantaneous Discharge, cfs
Specific Conductance, field and lab, US/CM
pH - field and lab
Temperature, ?C
Turbidity, NTU
Barometric Pressure, mm of HG
Dissolved Oxygen
Fecal Coliform, cols/100ml
Fecal Streptococci, cols/100ml
Dissolved Calcium
Dissolved Magnesium
Dissolved Sodium
Dissolved Potassium
Alkalinity as CACO3 - field and lab
Carbonate
Bicarbonate
Dissolved Sulfate
Dissolved Chloride
Dissolved Fluoride
Dissolved Silica
Residue solide at 180? C
Dissolved Nitrite
Dissolved NO2+NO3
Dissolved Ammonium
Total Ammonia
Total Phosphorus
Dissolved Phosphorus
Dissolved Orthophosphorus
Dissolved Aluminum, Barium, Cobalt, Iron, Lithium, Manganese, Molybdenum, Nickel, Selenium, Silver, Strontium, Vanadium
Dissolved Organic Carbon
Suspended Organic Carbon
Suspended Sediment

** These same parameters are measured for Hydrologic Benchmark Monitoring, plus several radiological parameters. See U.S. Geological Survey data sources listed above for radiological parameters.