Marsh River Watershed Monitoring and Assessment Report

Minnesota Pollution Control Agency

June 2017

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List of acronyms

AUID Assessment Unit Identification Determination

CI Confidence Interval

CR County Road

CSAH County State Aid Highway

CWA Clean Water Act

DNR Minnesota Department of Natural Resources

EPA U.S. Environmental Protection Agency

EQuIS Environmental Quality Information System

EX Exceeds Criteria (Bacteria)

EXP Exceeds Criteria, Potential Impairment

EXS Exceeds Criteria, Potential Severe Impairment

FWMC Flow Weighted Mean Concentration

HUC Hydrologic Unit Code

IBI Index of Biotic Integrity

IF Insufficient Information

K Potassium

LRVW Limited Resource Value Water

MDH Minnesota Department of Health

MPCA Minnesota Pollution Control Agency

MSHA Minnesota Stream Habitat Assessment

MTS Meets the Standard

N Nitrogen

Nitrate-N Nitrate Plus Nitrite Nitrogen

NA Not Assessed

NHD National Hydrologic Dataset

NH3 Ammonia

P Phosphorous

PCB Polychlorinated Biphenyls

SWAG Surface Water Assessment Grant

TALU Tiered Aquatic Life Uses

TKN Total Kjeldahl Nitrogen

TMDL Total Maximum Daily Load

TP Total Phosphorous

TSS Total Suspended Solids

USGS United States Geological Survey

WIMN What's In My Neighborhood?

WPLMN Water Pollutant Load Monitoring Network

Executive summary

The Marsh River Watershed lies within the Lake Agassiz Plain Ecoregion in northwestern Minnesota. This watershed drains a total of 362 square miles, spanning across Norman and Clay counties. No notable lakes occur within the watershed. However, there are multiple streams and small tributaries flowing into the Marsh River. The most notable tributary to the Marsh River is County Ditch 11.

In 2014, the Minnesota Pollution Control Agency (MPCA) began an intensive watershed monitoring (IWM) effort of lakes, rivers, and streams within the Marsh River Watershed. After finishing the monitoring effort in the summer of 2016, the lakes, rivers, and streams were assessed for aquatic life, aquatic recreation, and aquatic consumption use support. Six stream reaches were assessed. Sixty-seven percent of the assessed stream reaches fully support aquatic life, and 33% of the stream reaches do not support aquatic life. In addition to the aquatic life impairments in the Marsh River, it is impaired for aquatic recreation. The main contributors to the aquatic life impairments includes habitat degradation, flow permanence, and total suspended solids (TSS)/turbidity exceedances. No lakes were assessed within this watershed due to a lack of water quality data for waterbodies that meet the definition of a lake.

The Marsh River Watershed is home to more than 36 fish species, and 119 macroinvertebrate taxa. The abundance and diversity of aquatic life in the Marsh is due in part to the rivers close connection to the Red River of the North; together these streams function as an interconnected system to provide critical habitat for many species. The diversity of life in the Marsh River system is worth protecting and restoring. However, there are some major impediments to restoring fully supporting aquatic life. Drainage ditch networks, and the high gradient culvert located at the confluence of County Ditch 11 and the Marsh River, impede the natural fish runways from the Red River of the North and threaten the ability of these fishes to reach the Marsh River and its tributaries. Drainage of the tributaries within the Marsh River Watershed is so effective, that most of the tributaries go dry during the summer months. Establishing ways to control drainage, while allowing the stream to retain water and not impede fish passage, and creating buffers around all streams, rivers, and ditches would help protect and restore aquatic habitat for a greater diversity of aquatic life.

Following this report, the stressor identification team will identify the aquatic life stressors, and release a report on their findings. The development of a Watershed Restoration and Protection Strategy for the Marsh will follow, and will likely focus on the implementation of best management practices (BMPs) to restore the impaired waters of the Marsh River Watershed.

The Red River of the North at the outlet of the Marsh River Watershed is not assessed in this report; a another report on the entire Red River of the North Mainstem will be released at a later date.

Introduction

Water is one of Minnesota's most abundant and precious resources. The MPCA is charged under both federal and state law with the responsibility of protecting the water quality of Minnesota's water resources. MPCA's water management efforts are tied to the 1972 Federal Clean Water Act (CWA), which requires states to adopt water quality standards to protect their water resources and the designated uses of those waters, such as for drinking water, recreation, fish consumption, and aquatic life. States are required to provide a summary of the status of their surface waters and develop a list of waterbodies that do not meet established standards. Such waters are referred to as "impaired waters" and the state must make appropriate plans to restore these waters, including the development of Total Maximum Daily Loads (TMDLs). A TMDL is a comprehensive study determining the assimilative capacity of a waterbody, identifying all pollution sources causing or contributing to impairment, and an estimation of the reductions needed to restore a waterbody so that it can once again support its designated use.

The MPCA currently conducts a variety of surface water monitoring activities that support our overall mission of helping Minnesotans protect the environment. To successfully prevent and address problems, decision makers need good information regarding the status of the resources, potential and actual threats, options for addressing the threats, and data on the effectiveness of management actions. The MPCA's monitoring efforts are focused on providing that critical information. Overall, the MPCA is striving to provide information to assess, and ultimately, to restore or protect the integrity of Minnesota's waters.

The passage of Minnesota's Clean Water Legacy Act in 2006 provided a policy framework and the initial resources for state and local governments to accelerate efforts to monitor, assess, restore, and protect surface waters. This work is implemented on an on-going basis with funding from the Clean Water Fund created by the passage of the Clean Water, Land and Legacy Amendment to the state constitution. To facilitate the best use of agency and local resources, the MPCA has developed a watershed monitoring strategy, which uses an effective and efficient integration of agency and local water monitoring programs to assess the condition of Minnesota's surface waters, and to allow for coordinated development and implementation of water quality restoration and improvement projects.

The strategy behind the watershed monitoring approach is to intensively monitor streams and lakes within a major watershed to determine the overall health of water resources, identify impaired waters, and to identify waters in need of additional protection. The benefit of the approach is the opportunity to begin to address most, if not all, impairments through a coordinated TMDL process at the watershed scale, rather than the reach-by-reach and parameter-by-parameter approach often historically employed. The watershed approach will more effectively address multiple impairments resulting from the cumulative effects of point and non-point sources of pollution and further the CWA goal of protecting and restoring the quality of Minnesota's water resources.

This watershed-wide monitoring approach was implemented in the Marsh River Watershed beginning in the summer of 2014. This report provides a summary of all water quality assessment results in the Marsh River Watershed and incorporates all data available for the assessment process including watershed monitoring, volunteer monitoring, and monitoring conducted by local government units.

The watershed monitoring approach

The watershed approach is a 10-year rotation for monitoring and assessing waters of the state on the level of Minnesota's 80 major watersheds. The major benefit of this approach is the integration of monitoring resources to provide a more complete and systematic assessment of water quality at a geographic scale useful for the development and implementation of effective TMDLs, project planning, effectiveness monitoring, and protection strategies. The following paragraphs provide details on each of the four principal monitoring components of the watershed approach. For additional information see: Watershed Approach to Condition Monitoring and Assessment (MPCA, 2008) (http://www.pca.state.mn.us/publications/wq-s1-27.pdf).

Intensive watershed monitoring

The IWM strategy utilizes a nested watershed design allowing the sampling of streams within watersheds from a coarse to a fine scale (Figure 1). Each watershed scale is defined by a hydrologic unit code (HUC). These HUCs define watershed boundaries for waterbodies within a similar geographic and hydrologic extent. The foundation of this approach is the 80 major watersheds (8-HUC) within Minnesota. Using this approach, many of the smaller headwaters and tributaries to the main stem river are sampled in a systematic way so that a more holistic assessment of the watershed can be conducted and problem areas identified without monitoring every stream reach. Each major watershed is the focus of attention for at least one year within the 10-year cycle.

River/stream sites are selected near the outlet of each of three watershed scales, 8-HUC, aggregated 12-HUC and 14-HUC (Figure 1). Within each scale, different water uses are assessed based on the opportunity for that use (i.e., fishing, swimming, supporting aquatic life such as fish and insects). The major river watershed is represented by the 8-HUC scale. The outlet of the major 8-HUC watershed (purple triangle in Figure 2) is sampled for biology (fish and macroinvertebrates), water chemistry, and fish contaminants to allow for the assessment of aquatic life, aquatic recreation, and aquatic consumption use support. The aggregated 12-HUC is the next smaller subwatershed scale, which generally consists of major tributary streams with drainage areas ranging from 75 to 150 square miles. Each aggregated 12-HUC outlet (green dots in Figure 2) is sampled for biology and water chemistry for the assessment of aquatic life and aquatic recreation use support. Within each aggregated 12-HUC, smaller watersheds (14-HUCs, typically 10-20 mi^2), are sampled at each outlet that flows into the major aggregated 12-HUC tributaries. Each of these minor subwatershed outlets is sampled for biology to assess aquatic life use support (red dots in Figure 2).

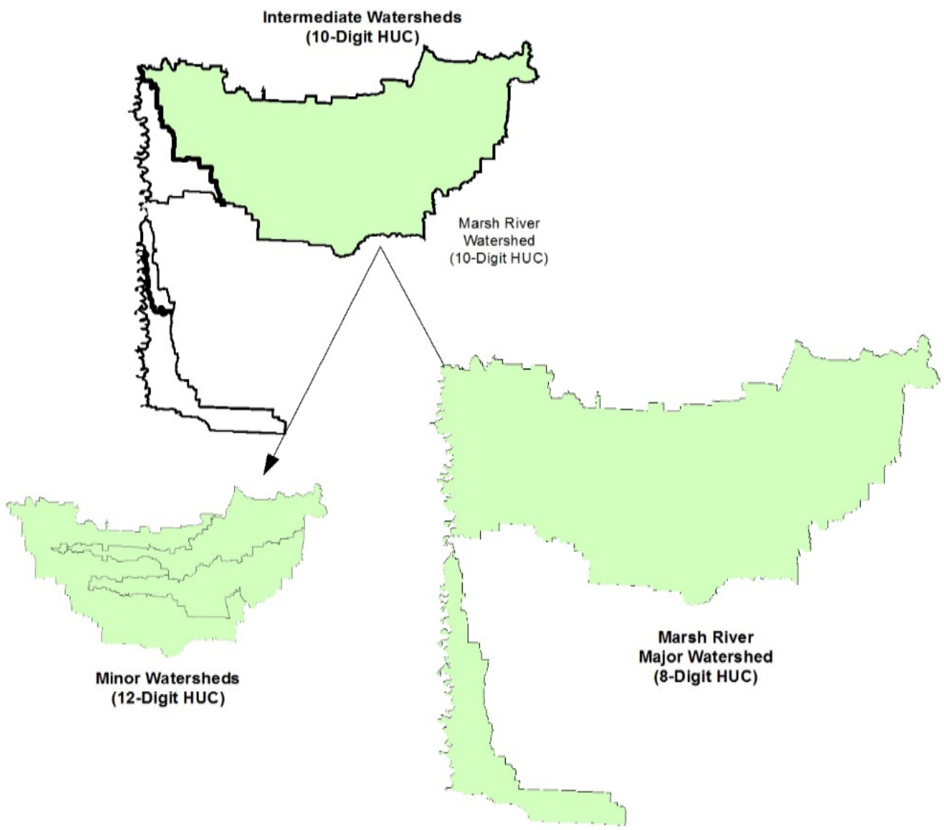

Figure 1. The intensive watershed monitoring design.

Lakes most heavily used for recreation (all those greater than 500 acres and at least 25% of lakes 100-499 acres) are monitored for water chemistry to determine if recreational uses, such as swimming and wading, are being supported and where applicable, where fish community health can be determined. Lakes are prioritized by size, accessibility (can the public access the lakes), and presence of recreational use. No lakes were monitored within the Marsh River Watershed.

Specific locations for sites sampled as part of the intensive monitoring effort in the Marsh River Watershed are shown in Figure 2 and are listed in Appendices 2.1 and 2.2.

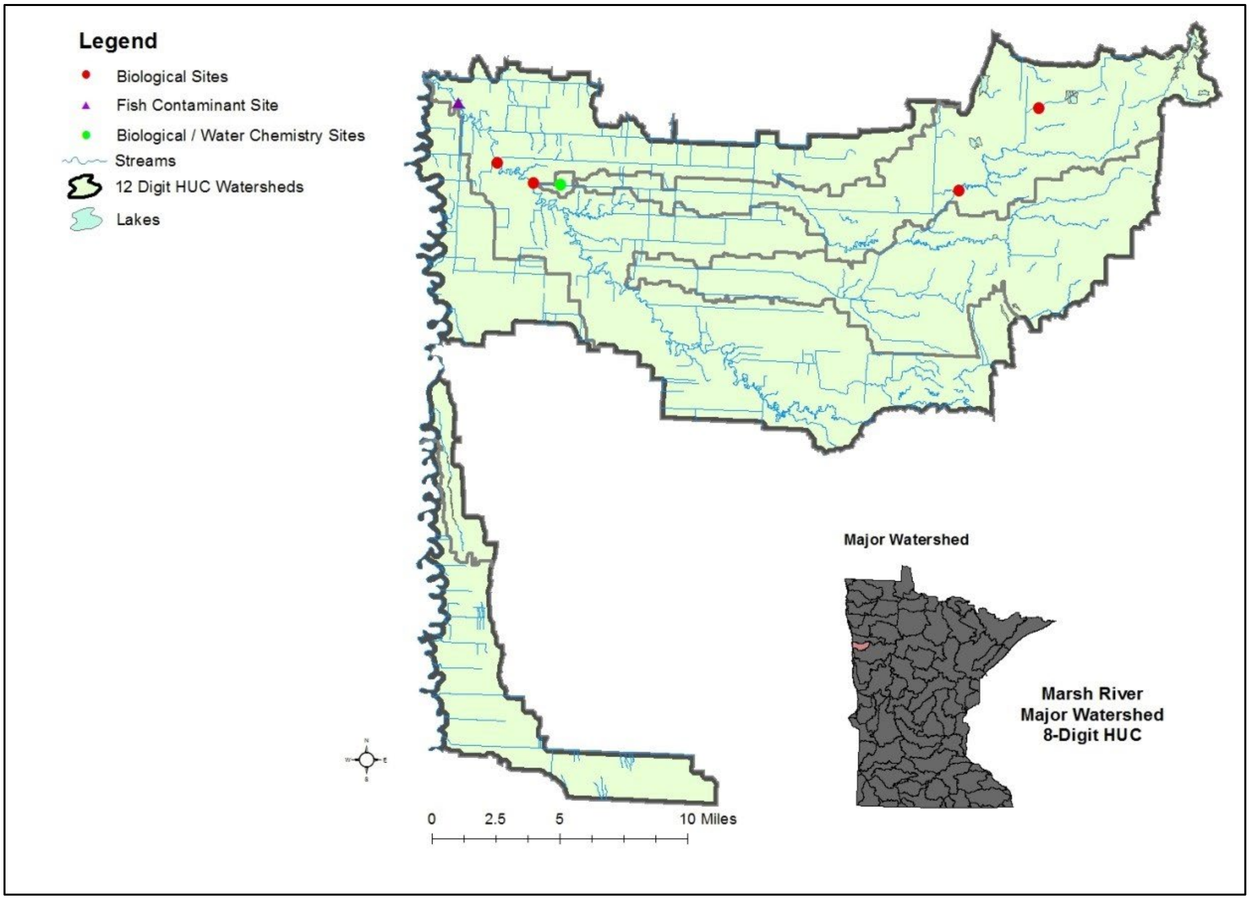

Figure 2. Intensive watershed monitoring sites for streams in the Marsh River Watershed.

Citizen and local monitoring

Citizen and local monitoring is an important component of the watershed approach. The MPCA and its local partners jointly select the stream sites and lakes to be included in the intensive watershed monitoring process. Funding passes from MPCA through Surface Water Assessment Grants (SWAGs) to local groups such as counties, soil and water conservation districts, watershed districts, nonprofits, and educational institutions to support lake and stream water chemistry monitoring. Local partners use the same monitoring protocols as the MPCA, and all monitoring data from SWAG projects are combined with the MPCA's to assess the condition of Minnesota lakes and streams. Preplanning and coordination of sampling with local citizens and governments helps focus monitoring where it will be most effective for assessment and observing long-term trends. This allows citizens/governments the ability to see how their efforts are used to inform water quality decisions and track how management efforts affect change. Many SWAG grantees invite citizen participation in their monitoring projects and their combined participation greatly expand our overall capacity to conduct sampling.

The MPCA also coordinates two programs aimed at encouraging long term citizen surface water monitoring: the Citizen Lake Monitoring Program and the Citizen Stream Monitoring Program. Like the permanent load monitoring network, having citizen volunteers monitor a given lake or stream site monthly and from year to year can provide the long-term picture needed to help evaluate current status and trends. Citizen monitoring is especially effective at helping to track water quality changes that occur in the years between intensive monitoring years. There were no citizens enrolled in the citizen monitoring programs during the 10-year data window, and citizen monitoring data were not used for assessment decisions in the Marsh River Watershed.

Assessment methodology

The CWA requires states to report on the condition of the waters of the state every two years. This biennial report to Congress contains an updated list of surface waters that are determined to be supporting or non-supporting of their designated uses as evaluated by the comparison of monitoring data to criteria specified by Minnesota Water Quality Standards (Minn. R. ch. 7050 2008; https://www.revisor.leg.state.mn.us/rules/?id=7050). The assessment and listing process involves dozens of MPCA staff, other state agencies, and local partners. The goal of this effort is to use the best data and best science available to assess the condition of Minnesota's water resources. For a thorough review of the assessment, methodologies see: Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List (MPCA, 2012). https://www.pca.state.mn.us/sites/default/files/wq-iw1-04.pdf.

Water quality standards

Water quality standards are the fundamental benchmarks by which the quality of surface waters are measured and used to determine impairment. These standards can be numeric or narrative in nature and define the concentrations or conditions of surface waters that allow them to meet their designated beneficial uses, such as for fishing (aquatic life), swimming (aquatic recreation) or human consumption (aquatic consumption). All surface waters in Minnesota, including lakes, rivers, streams and wetlands are protected for aquatic life and recreation where these uses are attainable. Numeric water quality standards represent concentrations of specific pollutants in water that protect a specific designated use. Narrative standards are statements of conditions in and on the water, such as biological condition, that protect their designated uses.

Protection of aquatic recreation means the maintenance of conditions safe and suitable for swimming and other forms of water recreation. In streams, aquatic recreation is assessed by measuring the concentration of E. coli bacteria in the water. To determine if a lake supports aquatic recreational activities, its trophic status is evaluated using total phosphorus (TP), Secchi depth, and chlorophyll-a as indicators. Lakes that are enriched with nutrients and have abundant algal growth are eutrophic and do not support aquatic recreation.

Protection of consumption means protecting citizens who eat fish from Minnesota waters or receive their drinking water from waterbodies protected for this beneficial use. The concentrations of mercury and polychlorinated biphenyls (PCBs) in fish tissue are used to evaluate whether or not fish are safe to eat in a lake or stream and to issue recommendations regarding the frequency that fish from a particular waterbody can be safely consumed. For lakes, rivers, and streams that are protected as a source of drinking water, the MPCA primarily measures the concentration of nitrate in the water column to assess this designated use.

Protection of aquatic life means the maintenance of a healthy aquatic community, including fish, invertebrates, and plants. Biological monitoring, the sampling of aquatic organisms, is a direct means to assess aquatic life use support, as the aquatic community tends to integrate the effects of all pollutants and stressors over time. To effectively use biological indicators, the MPCA employs the Index of Biotic Integrity (IBI). This index is a scientifically validated combination of measurements of the biological community (called metrics). An IBI is comprised of multiple metrics that measure different aspects of aquatic communities (e.g., dominance by pollution tolerant species, loss of habitat specialists). Metric scores are summed together, and the resulting index score characterizes the biological integrity or "health" of a site. The MPCA has developed stream IBIs for (fish and macroinvertebrates) since these communities can respond differently to various types of pollution. Because the rivers and streams in Minnesota are physically, chemically, and biologically diverse, IBIs are developed separately for different stream classes to account for this natural variation. Further interpretation of biological community data is provided by an assessment threshold or biocriteria against which an IBI score can be compared within a given stream class. In general, an IBI score above this threshold is indicative of aquatic life use support, while a score below this threshold is indicative of non-support. Additionally, chemical parameters are measured and assessed against numeric standards developed to be protective of aquatic life. For streams, these include pH, dissolved oxygen, un-ionized ammonia nitrogen, chloride, TSS, pesticides, and river eutrophication.

Protection for aquatic life uses in streams and rivers are divided into three tiers: Exceptional, General, and Modified. Exceptional Use waters support fish and macroinvertebrate communities that have minimal changes in structure and function from the natural condition. General Use waters harbor "good" assemblages of fish and macroinvertebrates that can be characterized as having an overall balanced distribution of the assemblages and with the ecosystem functions largely maintained through redundant attributes. Modified Use waters have been extensively altered through legacy physical modifications, which limit the ability of the biological communities to attain the General Use. Currently the Modified Use is only applied to streams with channels that have been directly altered by humans (e.g., maintained for drainage, riprapped). These tiered uses are determined before assessment based on the attainment of the applicable biological criteria and/or an assessment of the habitat. For additional information, see: http://www.pca.state.mn.us/index.php/water/water-permits-and-rules/water-rulemaking/tiered-aquatic-life-use-talu-framework.html).

Table 1. Table of proposed tiered aquatic life use standards.

Proposed Tiered Aquatic Life Use	Acronym	Proposed Use Class Code	Description
Warm water General	WWg	2Bg	Warm water Stream protected for aquatic life and recreation, capable of supporting and maintaining a balanced, integrated, adaptive community of warm or cool water aquatic organisms that meet or exceed the General Use biological criteria.
Warm water Modified	WWm	2Bm	Warm water Stream protected for aquatic life and recreation, physically altered watercourses (e.g., channelized streams) capable of supporting and maintaining a balanced, integrated, adaptive community of warm or cool water aquatic organisms that meet or exceed the Modified Use biological criteria, but are incapable of meeting the General Use biological criteria as determined by a Use Attainability Analysis
Warm water Exceptional	WWe	2Be	Warm water Stream protected for aquatic life and recreation, capable of supporting and maintaining an exceptional and balanced, integrated, adaptive community of warm or cool water aquatic organisms that meet or exceed the Exceptional Use biological criteria.
Coldwater General	CWg	2Ag	Coldwater Stream protected for aquatic life and recreation, capable of supporting and maintaining a balanced, integrated, adaptive community of cold water aquatic organisms that meet or exceed the General Use biological criteria.
Coldwater Exceptional	CWe	2Ae	Coldwater Stream protected for aquatic life and recreation, capable of supporting and maintaining an exceptional and balanced, integrated, adaptive community of cold water aquatic organisms that meet or exceed the Exceptional Use biological criteria.

A small percentage of stream miles in the state (~1% of 92,000 miles) have been individually evaluated and re-classified as a Class 7 Limited Resource Value Water (LRVW). These streams have previously demonstrated that the existing and potential aquatic community is severely limited and cannot achieve aquatic life standards either by: a) natural conditions as exhibited by poor water quality characteristics, lack of habitat or lack of water; b) the quality of the resource has been significantly altered by human activity and the effect is essentially irreversible; or c) there are limited recreational opportunities (such as fishing, swimming, wading, or boating) in and on the water resource. While not being protective of aquatic life, LRVWs are still protected for industrial, agricultural, navigation, and other uses. Class 7 waters are also protected for aesthetic qualities (e.g., odor), secondary body contact, and groundwater for use as a potable water supply. To protect these uses, Class 7 waters have standards for bacteria, pH, dissolved oxygen, and toxic pollutants.

Assessment units

Assessments of use support in Minnesota are made for individual waterbodies. The waterbody unit used for river systems, lakes, and wetlands is called the "assessment unit". A stream or river assessment unit usually extends from one significant tributary stream to another or from the headwaters to the first tributary. A stream "reach" may be further divided into two or more assessment reaches when there is a change in use classification (as defined in Minn. R. ch. 7050) or when there is a significant morphological feature, such as a dam or lake, within the reach. Therefore, a stream or river is often segmented into multiple assessment units that are variable in length. The MPCA is using the 1:24,000 scale high resolution National Hydrologic Dataset (NHD) to define and index stream, lake, and wetland assessment units. Each river or stream reach is identified by a unique waterbody identifier (known as its AUID), comprised of the U. S. Geological Survey (USGS) eight-digit hydrologic unit code (8-HUC) plus a three-character code that is unique within each HUC.

It is for these specific stream reaches that the data are evaluated for potential use impairment. Therefore, any assessment of use support would be limited to the individual assessment unit. The major exception to this is the listing of rivers for contaminants in fish tissue (aquatic consumption). Over the course of time it takes fish, particularly game fish, to grow to "catchable" size and accumulate unacceptable levels of pollutants, there is a good chance they have traveled a considerable distance. The impaired reach is defined by the location of significant barriers to fish movement such as dams upstream and downstream of the sampled reach and thus often includes several assessment units.

Determining use attainment

For beneficial uses related to human health, such as drinking water or aquatic recreation, the relationship is well understood and thus the assessment process is a relatively simple comparison of monitoring data to numeric standards. In contrast, assessing whether a waterbody supports a healthy aquatic community is not as straightforward and often requires multiple lines of evidence to make use attainment decisions with a high degree of certainty. Incorporating a multiple lines of evidence approach into MPCA's assessment process has been evolving over the past few years. The current process used to assess the aquatic life use of rivers and streams is outlined below and in Figure 3.

The first step in the aquatic life assessment process is largely an automated process performed by logic programmed into a database application where all data from the 10 year assessment window is gathered; the results are referred to as 'Pre-Assessments'. Data filtered into the "Pre-Assessment" process is then reviewed to ensure that data is valid and appropriate for assessment purposes. Tiered use designations are determined before data is assessed based on the attainment of the applicable biological criteria and/or an assessment of the habitat. Stream reaches are assigned the highest aquatic life use attained by both biological assemblages on or after November 28, 1975. Streams that do not attain the Exceptional or General Use for both assemblages undergo a Use Attainability Analysis (UAA) to determine if a lower use is appropriate. A Modified Use can be proposed if the UAA demonstrates that the General Use is not attainable as a result of legal human activities (e.g., drainage maintenance, channel stabilization) which are limiting the biological assemblages through altered habitat. Decisions to propose a new use are made through UAA workgroups, which include watershed project managers and biology leads. The final approval to change a designated use is through formal rulemaking.

The next step in the aquatic life assessment process is a comparison of the monitoring data to water quality standards. Pre-assessments are then reviewed by either a biologist or water quality professional, depending on whether the parameter is biological or chemical in nature. These reviews are conducted at the workstation of each reviewer (i.e., desktop) using computer applications to analyze the data for potential temporal or spatial trends as well as gain a better understanding of any extenuating circumstances that should be considered (e.g., flow, time/date of data collection, or habitat).

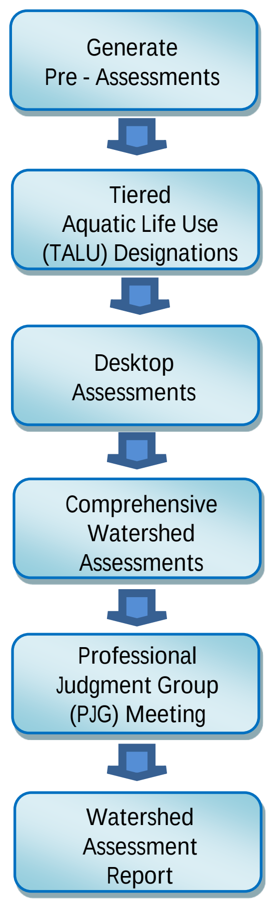

Figure 3. Flowchart of aquatic life use assessment process.

The next step in the process is a comprehensive watershed assessment meeting where reviewers convene to discuss the results of their desktop assessments for each individual waterbody. Implementing a comprehensive approach to water quality assessment requires a means of organizing and evaluating information to formulate a conclusion utilizing multiple lines of evidence. Occasionally, the evidence stemming from individual parameters are not in agreement and would result in discrepant assessments if the parameters were evaluated independently. However, the overall assessment considers each piece of evidence to make a use attainment determination based on the preponderance of information available. See the *Guidance Manual for Assessing the Quality of Minnesota Surface*

Waters for the Determination of Impairment 305(b) Report and 303(d) List (MPCA, 2016) https://www.pca.state.mn.us/sites/default/files/wq-iw1-04i.pdf for guidelines and factors considered when making such determinations.

The last step in the assessment process is the Professional Judgment Group meeting. At this meeting, results are shared and discussed with entities outside of the MPCA that may have been involved in data collection or that might be responsible for local watershed reports and project planning. Information obtained during this meeting may be used to revise previous use attainment decisions (e.g., sampling events that may have been uncharacteristic due to annual climate or flow variation, local factors such as impoundments that do not represent the majority of conditions on the AUID). Waterbodies that do not meet standards and, therefore, do not attain one or more of their designated uses are considered impaired waters and are placed on the draft 303(d) Impaired Waters List. Assessment results are also included in watershed monitoring and assessment reports.

Watershed overview

Located within the northwestern portion of Minnesota, the Marsh River Watershed is comprised of cropland, wetlands, and rich soils. The Marsh River Watershed has a total drainage of 361.7 square miles, spanning across Polk, Norman, and Clay counties. The Marsh River originates at the dike connection with the Wild Rice River, located 2 miles southeast of Ada, and flows northwest for 51.4 miles until it reaches its confluence with the Red River of the North, 2.1 miles northwest of Shelly. Most of the Marsh River Watershed experiences intermittent flow conditions. The main flow contribution into the Marsh River is through the dike system, but this flow is dependent upon the Wild Rice River reaching 95% total flow, in order to flow over the dike.

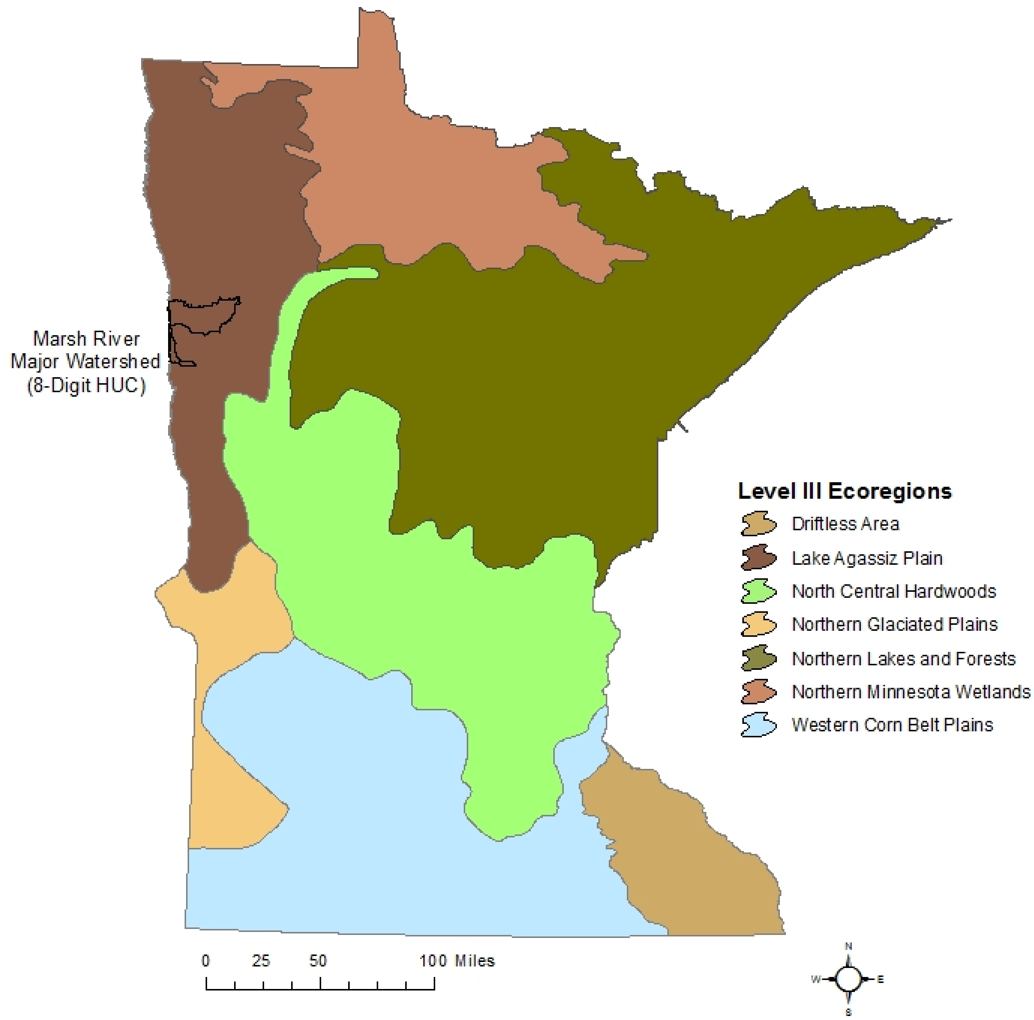

Figure 4. The Marsh River Watershed within the Lake Agassiz plain ecoregion of northwestern Minnesota.

This watershed lies within the Lake Agassiz Plains Ecoregion (Omernik et al., 1988, Figure 4). This area is largely utilized for agriculture, as it features rich soils (Figure 5) that formed from historic glacial Lake Agassiz. Following the last ice age, Lake Agassiz was a large glacial lake covering 200,000 square miles within North America (Waters, 1977). Larger than all of the Great Lakes combined, Lake Agassiz covered 17,000 square miles of Minnesota along the North Dakota-Minnesota border. As glaciers melted and formed Lake Agassiz, clay soils were spread throughout the lake bottom, forming the Red River Valley of the North and creating large flat plains of fertile soil (Waters, 1977).

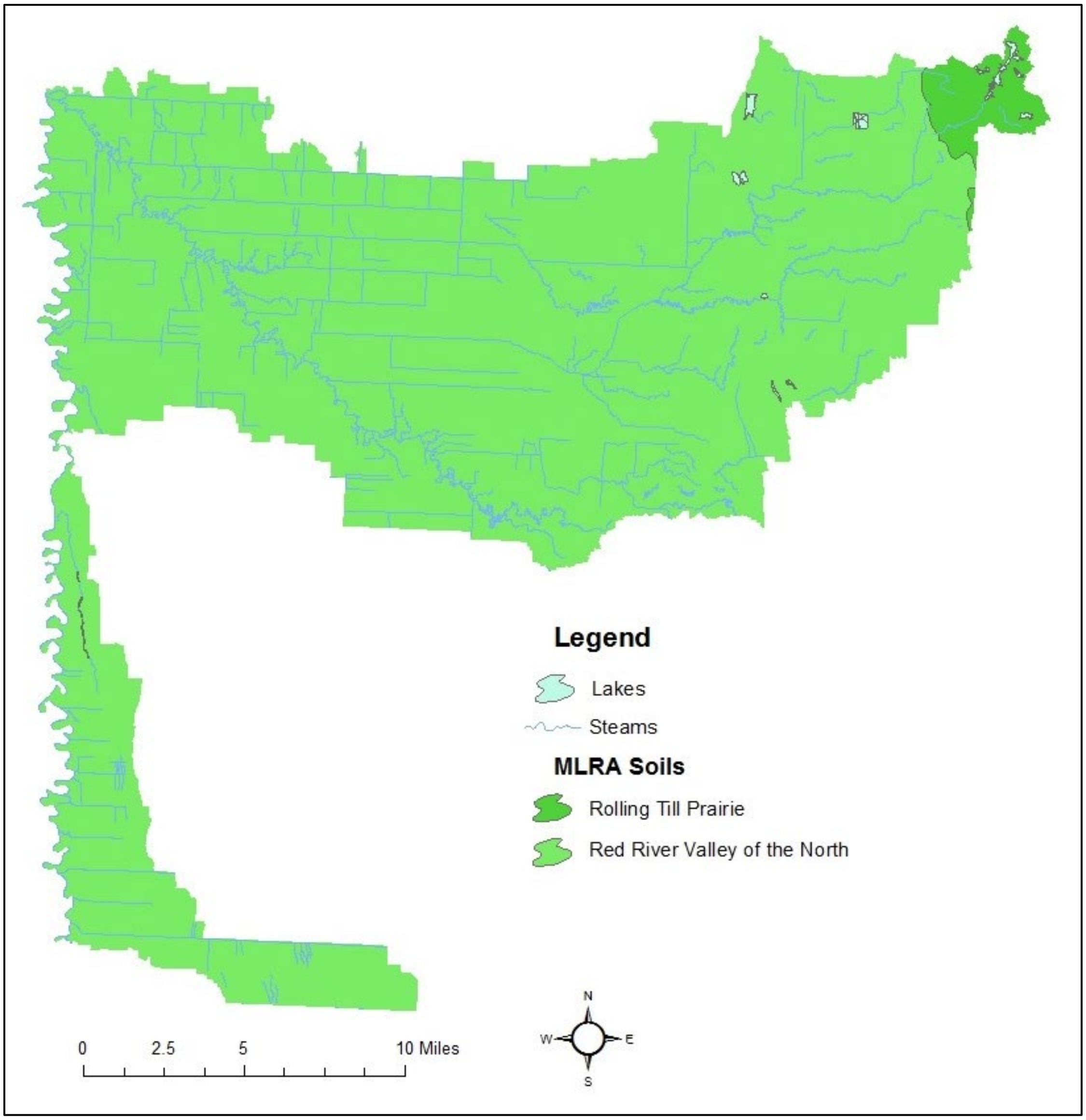

Figure 5. Major Land Resource Areas (MLRA) and springs in the Marsh River Watershed.

Land use summary

From the early 1900s, the Marsh River Watershed has been managed for optimal agricultural production (Offelen et al. 2002). During settlement in the area, flood management had been an area of concern. Early flood management practices included modifying natural stream channels to develop vast drainage systems for agriculture. This watershed wide alteration changed the natural hydrology of the entire watershed, causing an abrupt change within the whole ecosystem (Offelen et al., 2002). According to the NRCS (2007), there are 674 farms within the watershed that use 718,443 acres to produce crops and livestock (Figure 6). Each farm averages 190 acres.

Historically, logging practices also occurred within the area. The connection of the Marsh River with the Wild Rice River provided an efficient way of floating logs to a sawmill just east of Ada. More recently, this connection is used for flood management purposes. During high flow events, when the Wild Rice River reaches 95% flow, water flows over the dike allowing the excess water to flow down the Marsh River before reaching its confluence with the Red River of the North.

The Marsh River Watershed is sparsely populated as 7,278 people live within the watershed. Land ownership is dominated by private ownership. Nearly 100% of the watershed is privately owned; only a small fraction of land (0.63%) in the watershed is public (NRCS, 2007).

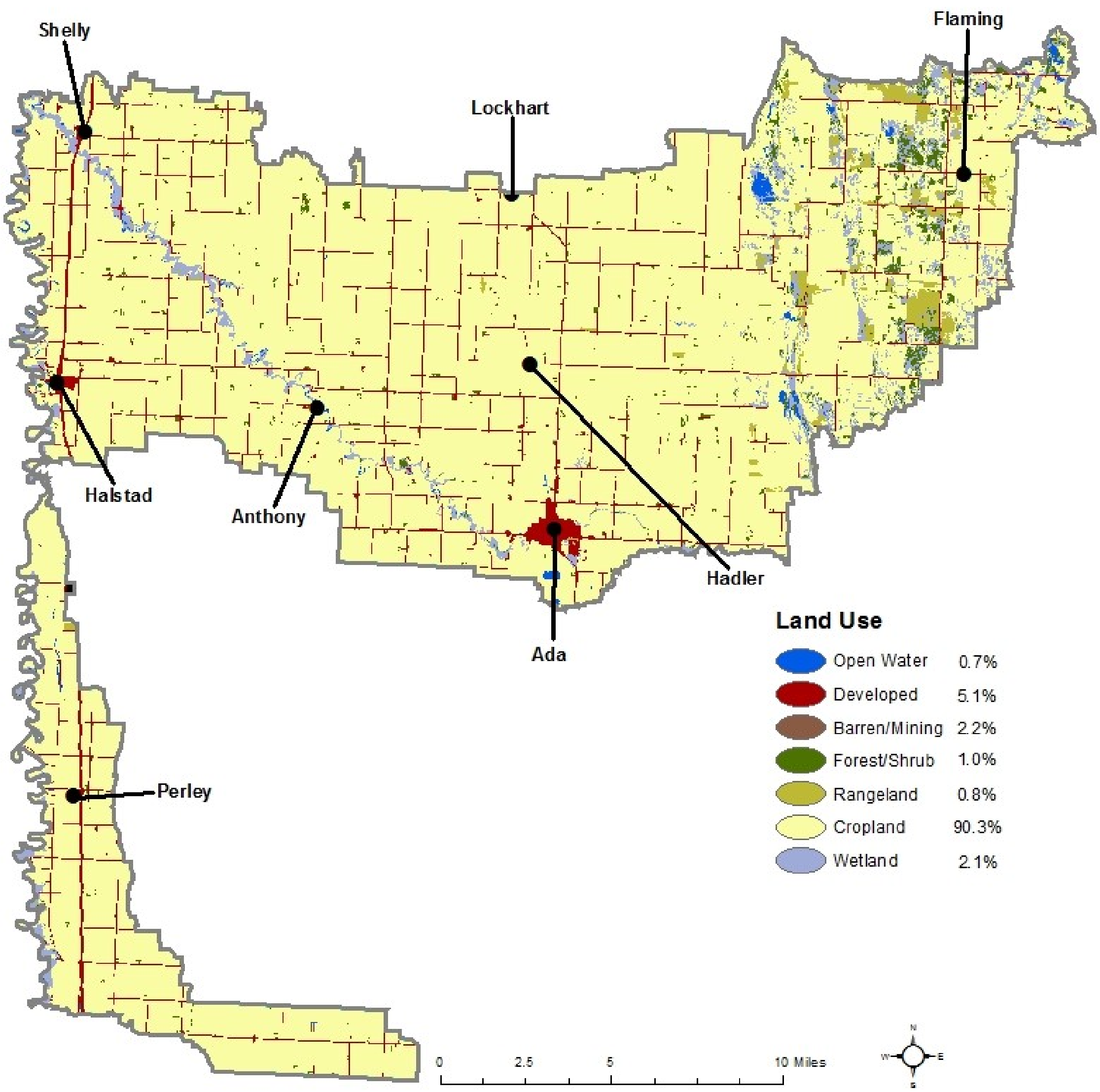

Figure 6. Land use in the Marsh River Watershed.

Surface water hydrology

Historically, the Marsh River Watershed was once inundated by glacial Lake Agassiz. Although 8,500 years have passed since Lake Agassiz has receded, the effects of the massive lake can be seen today. Abundant rich soils within the ancient lake bottom have given rise to modern agricultural opportunities.

The Marsh River flows northwest, draining approximately 362 square miles (NRCS, 2007). Small portions of the headwaters of the Marsh River have been channelized near its connection with the Wild Rice River, but the remainder of the river has not been channelized. Although a majority of the Marsh River has remained natural, nearly all of the tributaries within the watershed have been channelized, with the exception of Spring Creek. This channelization has historically taken place in an attempt to aid drainage, and aid flood management practices (Figure 7, Figure 8). Flood management is an issue that has impacted this region since settlement.

The headwaters of the Marsh River originate at the connection with the Wild Rice River, 2 miles southeast of Ada. The river flows for 51 miles before reaching its confluence with the Red River of the North, 2.1 miles northwest of Shelly. As the Marsh River flows northwest through the watershed, approximately three major tributaries contribute flow to the Marsh River. Identified from upstream to downstream, the major tributaries to the Marsh River include Judicial Ditch 51, County Ditch 45, and Spring Creek/County Ditch 11.

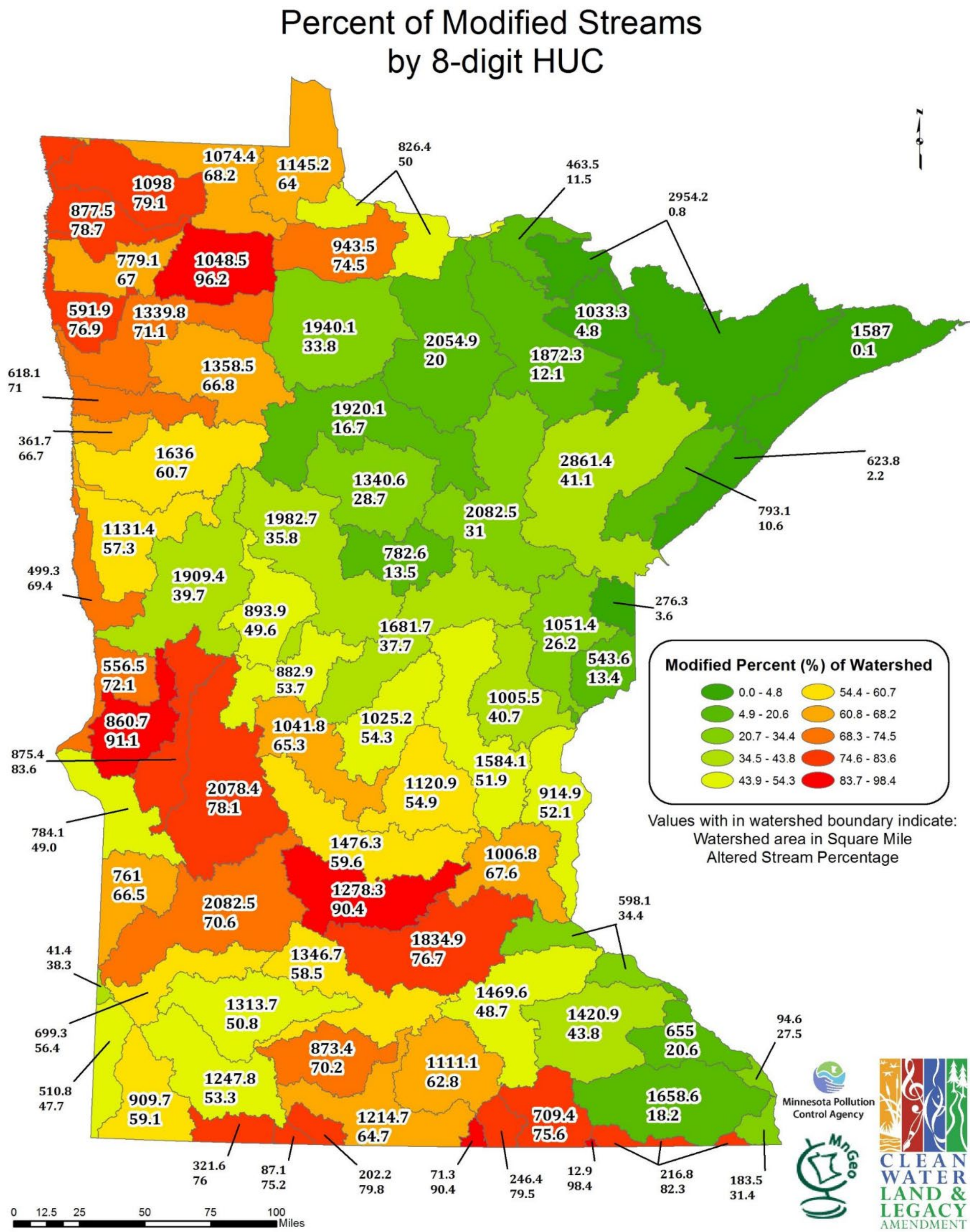

Figure 7. Map of percent modified streams by major watershed (8-HUC).

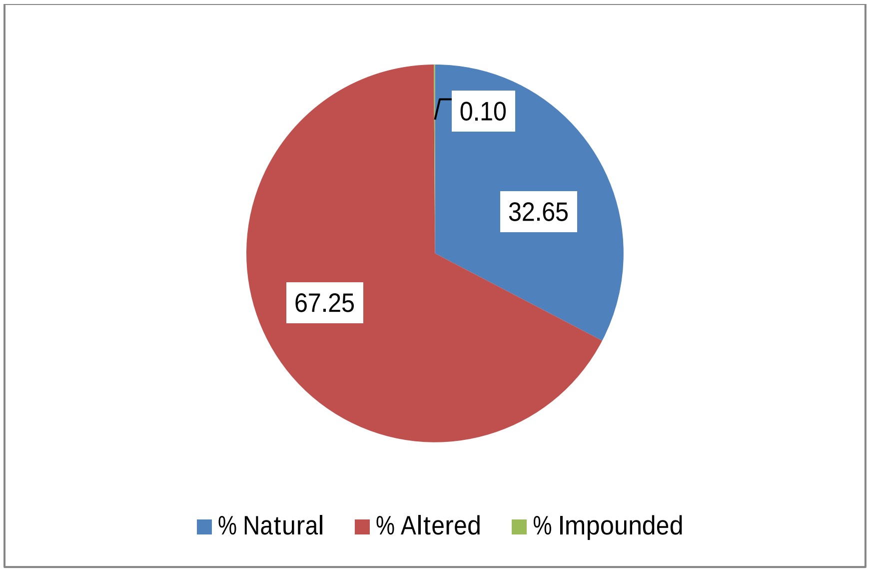

Figure 8. Comparison of natural to altered streams in the Marsh River Watershed (percentages derived from the State-wide Altered Water Course project).

Climate and precipitation

Minnesota has a continental climate, marked by warm summers and cold winters. The mean annual temperature for Minnesota is 4.6˚C (NOAA, 2016); the mean summer (June-August) temperature for the Marsh River Watershed is 20.6˚C; and the mean winter (December-February) temperature is -12.8˚ C (DNR: Minnesota State Climatology Office, 2010).

Precipitation is an important source of water input to a watershed. Figure 9 displays two representations of precipitation for calendar year 2014. On the left is total precipitation, showing the typical pattern of increasing precipitation toward the eastern portion of the state. According to this figure, the Marsh River Watershed area received 16 to 20 inches of precipitation in 2014. The display on the right shows the amount that precipitation levels departed from normal. The Marsh River Watershed area experienced precipitation that was 4 inches below normal in 2014.

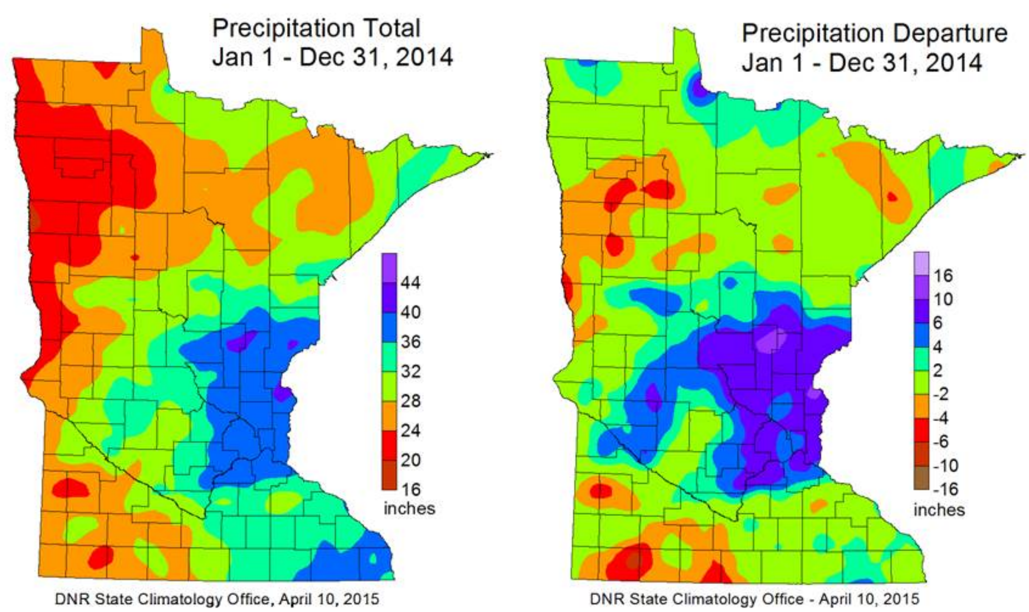

Figure 9. Statewide precipitation total (left) and precipitation departure (right) during 2014 (Source: DNR State Climatology Office, 2015)

The Marsh River Watershed is located in the northwest precipitation region. Figure 10 and Figure 11 display the areal average representation of precipitation in northwest Minnesota for 20 and 100 years, respectively. An areal average is a spatial average of all the precipitation data collected within a certain area presented as a single dataset. Though rainfall can vary in intensity and time of year, rainfall totals in the northwest region display no significant trend over the last 20 years. However, precipitation in northwest Minnesota exhibits a significant rising trend over the past 100 years ($p<0.01$). This is a strong trend and matches similar trends throughout Minnesota.

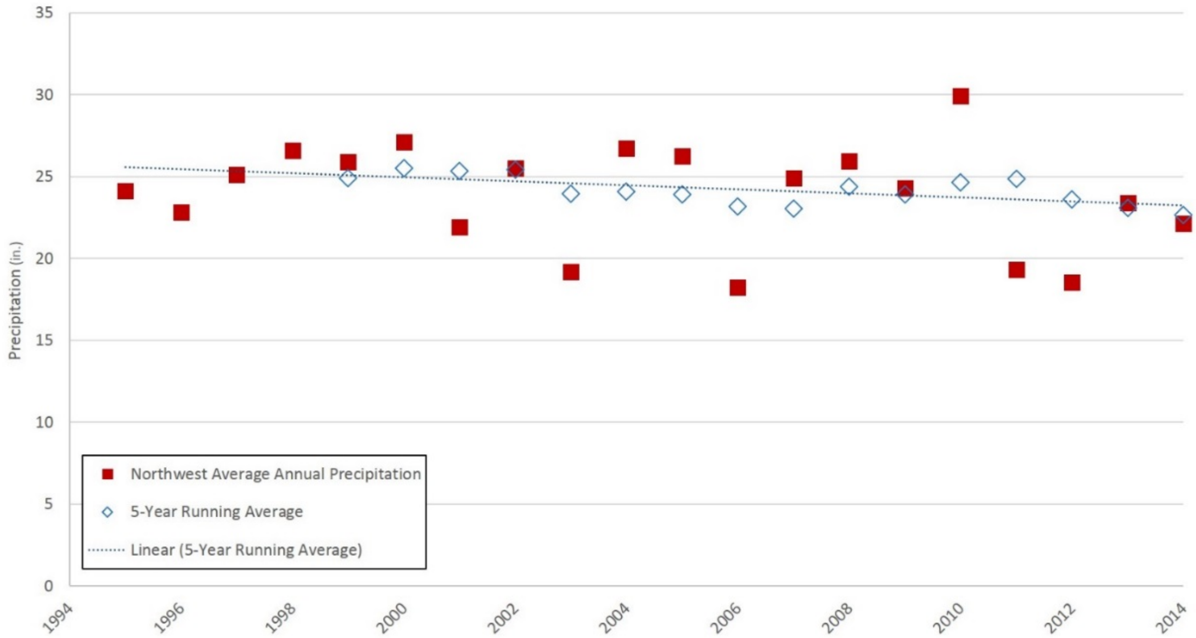

Figure 10. Precipitation trends in northwest Minnesota (1995-2014) with five-year running average (Source: WRCC, 2016)

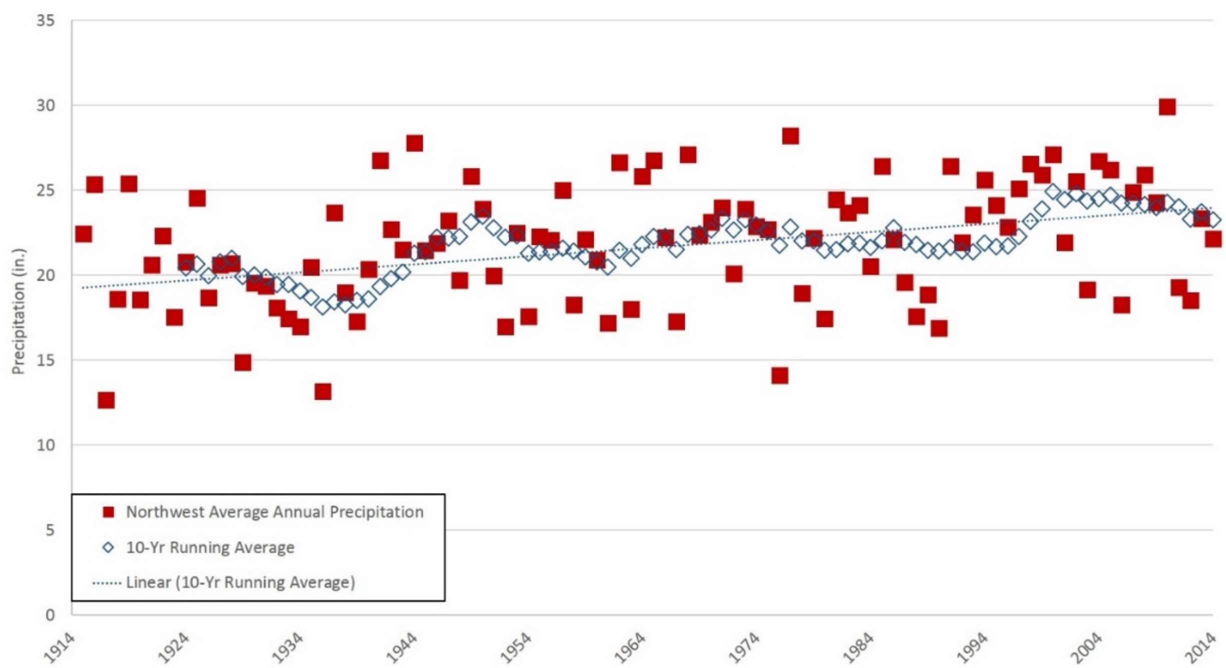

Figure 11. Precipitation trends in northwest Minnesota (1915-2014) with 10-year running average (Source: WRCC, 2016)

Hydrogeology and groundwater quality and quantity

Hydrogeology

Hydrogeology is the study of the interaction, distribution, and movement of groundwater through the rocks and soil of the earth. The geology of a region strongly influences the quantity of groundwater available, the quality of the water, the sensitivity of the water to pollution, and how quickly the water will be able to recharge and replenish the source aquifer. This branch of geology is important to understand as it indicates how to manage groundwater withdrawal and land use and can determine if mitigation is necessary.

Surficial and bedrock geology

Surficial geology is identified as the earth material located below the topsoil and overlying the bedrock. Glacial sediment is at the surface in a majority of the Marsh River Watershed and is the parent material for the soils that have developed since glaciation. The depth to bedrock ranges from approximately 230 feet to over 520 feet and is buried by deposits of the various ice lobes that reached this watershed during the last glacial period, as well as during previous glaciations in the last 2.58 million years. The deposits at the surface are associated with the Des Moines ice lobe. The geomorphology includes glacial lake sediment, lake modified till, stagnation and ground moraines (Des Moines Lobe-Erskine Moraine), and alluvium (Holocene) (Figure 12, left) (Hobbs & Goebel, 1982). The glacial sediment consists of sand, gravel, clay, and silt glacial lake sediment and calcareous till with a predominantly clayey texture.

Bedrock is the main mass of rocks that form the Earth, located underneath the surficial geology and can be seen in only a few places where weathering has exposed it. Precambrian bedrock lies under the extent of the Marsh River Watershed, displaying evidence of volcanic activity. The main terrane groups include the Wawa and Wabigoon Subprovince (mafic metavolanic rocks, schist of sedimentary protolith) and the Wawa Subprovince (mafic metavolcanic, calc-alkalic volcanic and volcaniclastic rocks) (Jirsa et al., 2011). Foliated to gneissic metamorphic rocks (tonalite, diorite, and granodiorite) are concentrated in the north central region while mafic plug-like intrusions are scattered throughout the watershed (Jirsa et al., 2011). The rock types that are found in the uppermost bedrock include basalt, gabbro, granite, greywacke, mafic metavolcanic rock and monzonite (Figure 12, right) (Morey & Meints, 2000).

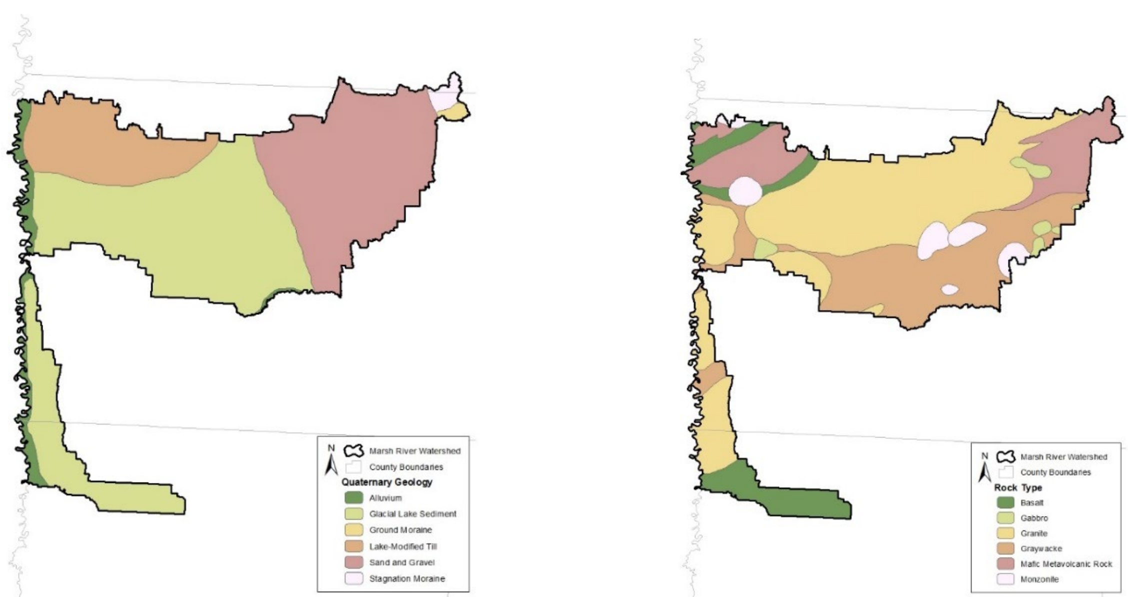

Figure 12. Quaternary geology (left) and bedrock geology rock types (right) within the Marsh River Watershed (GIS Source: Hobbs & Goebel, 1982; Morey & Meints, 2000)

Aquifers

Groundwater aquifers are layers of water-bearing units that readily transmit water to wells and springs (USGS, 2016a). As precipitation hits the surface, it infiltrates through the soil zone and into the void spaces within the geologic materials underneath the surface, saturating the material and becoming groundwater (Zhang, 1998). The water table is the uppermost portion of the saturated zone, where the pore-water pressure is equal to local atmospheric pressure. The geologic material determines the permeability and availability of water within the aquifer. Minnesota's groundwater system is comprised of three types of aquifers: 1) igneous and metamorphic bedrock aquifers, 2) sedimentary rock aquifers, and 3) glacial sand and gravel aquifers (MPCA, 2005). The Marsh River Watershed has fractured igneous and metamorphic bedrock aquifers lying beneath clayey unconsolidated sediments (DNR, 2016a). Except for the eastern-most tip of the watershed, the unconsolidated sediments are limited surficial and buried sand aquifers, with the Quaternary Buried Artesian Aquifer as the primary source for groundwater withdrawal (DNR, 2016a). The general availability of groundwater for this watershed can be categorized as moderate in the surficial sands, limited in the buried sands, and limited in the bedrock (DNR, 2016a)

Groundwater pollution sensitivity

Bedrock aquifers are typically covered with thick till, indicating that they would normally be better protected from contaminant releases at the land surface. It is also less likely that withdrawals from wells would have a direct and significant impact on local surface waterbodies. In contrast, surficial aquifers are typically more likely to 1) be vulnerable to contamination, 2) have direct hydrologic connections to local surface water, and 3) influence the quality and quantity of local surface water. The Minnesota Department of Natural Resources (DNR) is working on a hydrogeological atlas focused on the pollution sensitivity of the bedrock surface. It is being produced county-by-county, and is awaiting completion for those counties within the Marsh River Watershed. Until the hydrogeological atlas is finished, a 2016 statewide evaluation of pollution sensitivity of near-surface materials completed by the DNR is utilized to estimate pollution vulnerability up to 10 feet from the land surface. This display is not intended to be used on a local scale, but as a coarse-scale planning tool. According to this data, the Marsh River Watershed is estimated to have primarily ultra-low sensitivity over the majority of the watershed. There are areas of moderate to high pollution sensitivity in the eastern region of the watershed, most likely due to the presence of sand and gravel Quaternary geology (Figure 13) (DNR, 2016b).

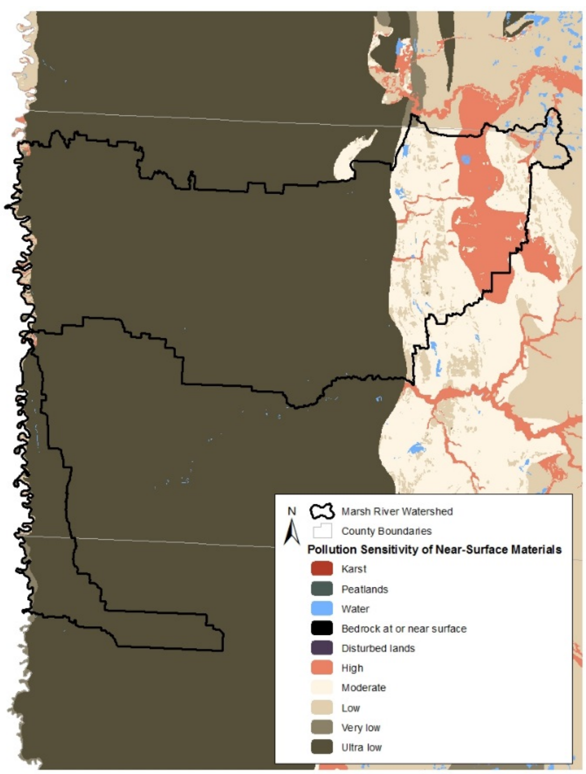

Figure 13. Pollution sensitivity of near-surface materials for the Marsh River Watershed (GIS Source: DNR, 2016b)

Groundwater potential recharge

Groundwater recharge is one of the most important parameters in the calculation of water budgets, which are used in general hydrologic assessments, aquifer recharge studies, groundwater models, and water quality protection. Recharge is a highly variable parameter, both spatially and temporally, making accurate estimates at a regional scale difficult to produce. The MPCA contracted the USGS to develop a statewide estimate of recharge using the SWB – Soil-Water-Balance Code.

The result is a gridded data structure of spatially distributed recharge estimates that can be easily integrated into regional groundwater studies. The full report of the project as well as the gridded data files are available at: https://gisdata.mn.gov/dataset/geos-gw-recharge-1996-2010-mean.

Recharge of these aquifers is important and limited to areas located at topographic highs, those with surficial sand and gravel deposits, and those along the bedrock-surficial deposit interfaces (Figure 14). Typically, recharge rates in unconfined aquifers are estimated at 20 to 25% of precipitation received, but can be less than 10% of precipitation where glacial clays or till are present (USGS, 2007). For the Marsh River Watershed, the average annual potential recharge rate to surficial materials ranges from 1.8 to 8.5 inches per year, with an average of 3.3 inches per year (Figure 15). The statewide mean potential recharge ranges from 0.025 to 17.8 with an average estimated at 4 inches per year with 85% of all recharge ranging from 3 to 8 inches per year (Figure 16). When compared to the statewide average potential recharge, the Marsh River Watershed receives a lower average potential recharge, most likely attributable to the variability of the surficial sediment distribution of the area.

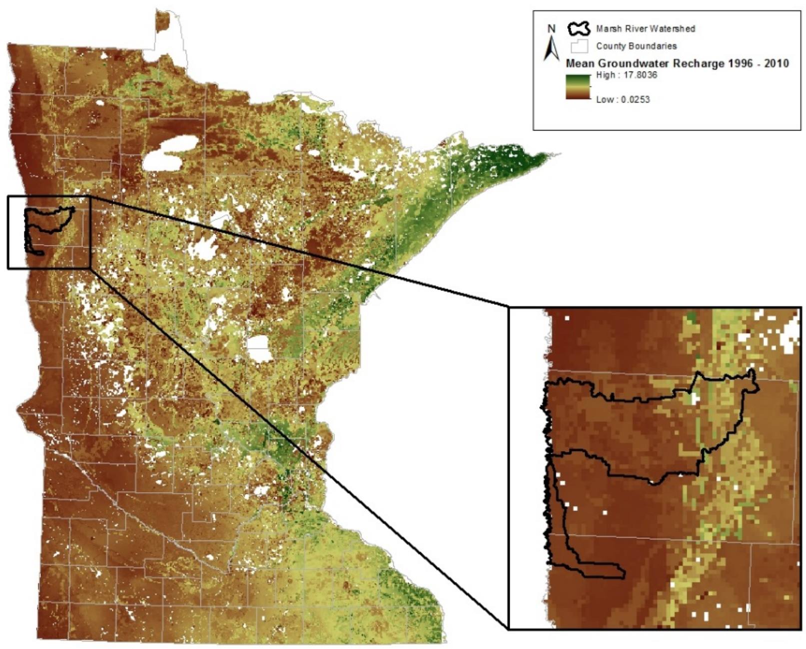

Figure 14. Average annual potential recharge rate to surficial materials in Marsh River Watershed (1996-2010) (GIS Source: USGS, 2015)

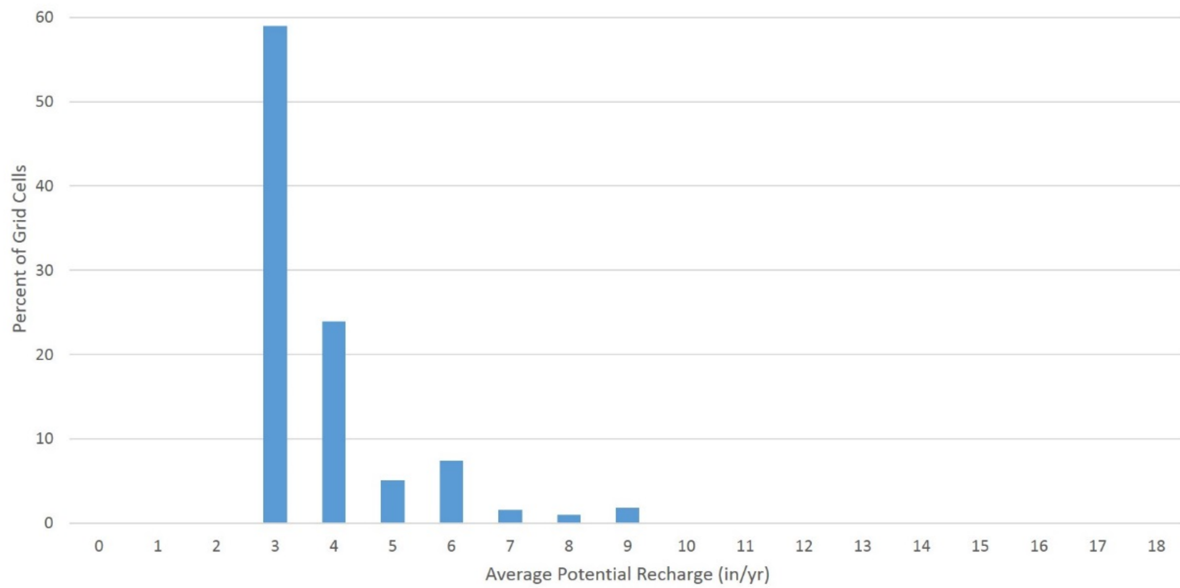

Figure 15. Average annual potential recharge rate percent of grid cells in the Marsh River Watershed (1996-2010)

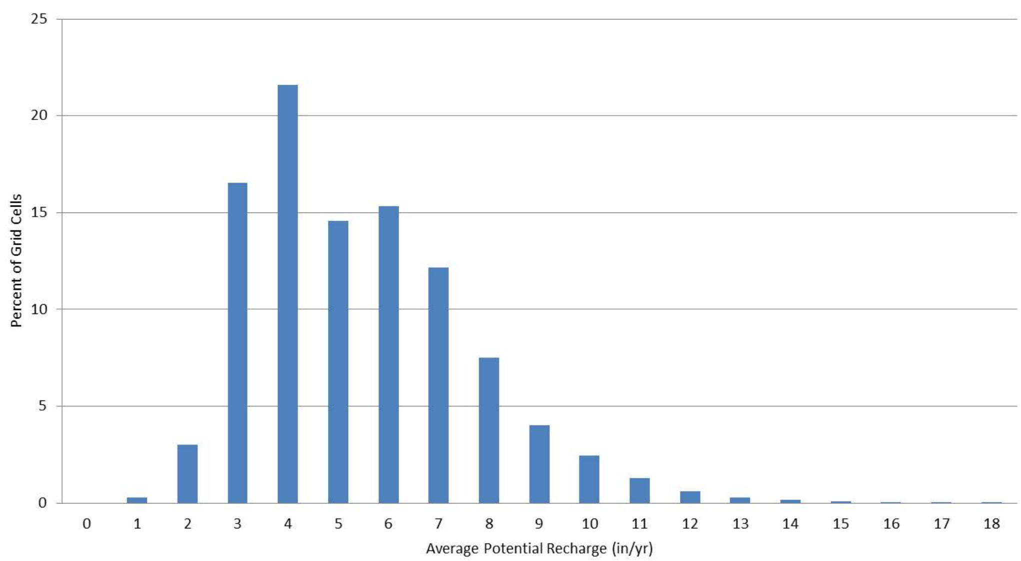

Figure 16. Average annual potential recharge rate percent of grid cells statewide (1996-2010)

Groundwater quality

Approximately 75% of Minnesota's population receives their drinking water from groundwater, undoubtedly indicating that clean groundwater is essential to the health of its residents. The MPCA's Ambient Groundwater Monitoring Program monitors trends in statewide groundwater quality by sampling for a comprehensive suite of chemicals including nutrients, metals, and volatile organic compounds. These ambient groundwater monitoring wells represent a mix of deeper domestic wells and shallow monitoring wells. The shallow wells interact with surface waters and exhibit impacts from human activities more rapidly. Available data from federal, state, and local partners are used to supplement reviews of groundwater quality in the region.

There are currently no MPCA ambient groundwater monitoring wells within the Marsh River Watershed. Figure 17 displays the locations of the closest ambient groundwater wells around the specified watershed. Due to the lack of data available, no ambient groundwater quality analysis was completed for the Marsh River Watershed.

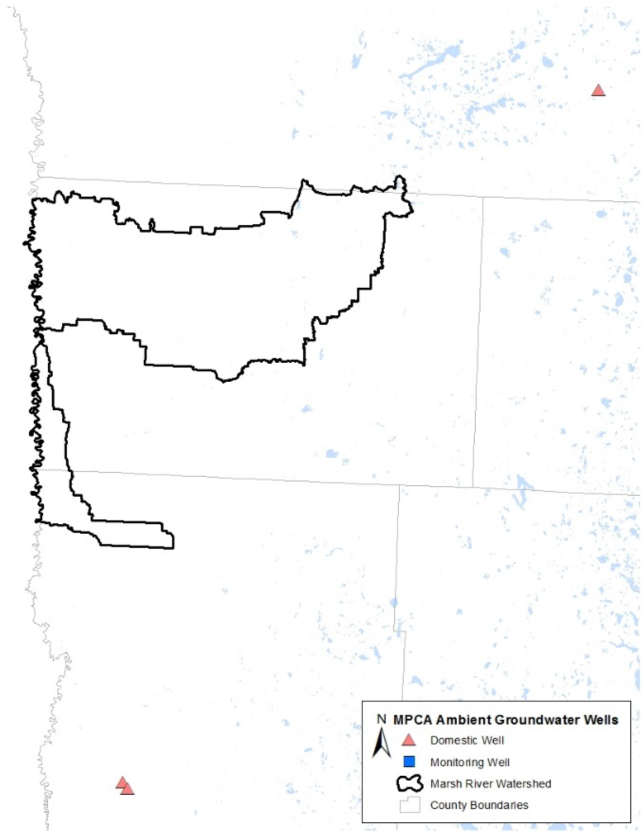

Figure 17. MPCA ambient groundwater monitoring well locations near the Marsh River Watershed.

Regional groundwater quality

From 1992 to 1996, the MPCA conducted baseline water quality sampling and analysis of Minnesota's principal aquifers. The Marsh River Watershed lies entirely within the Northwest Region, which was identified as having higher concentrations of chemicals in the sand and gravel aquifers when compared to other areas with similar aquifers. The greatest indicator of poor water quality in this region was the presence of Cretaceous bedrock, which is only found in the southern tip of this watershed. The number of exceedances of drinking criteria for arsenic, barium, boron, manganese, nitrate and selenium ranged from 1 to 12, depending on the aquifer (MPCA, 1999). Nitrate was identified as the chemical of greatest concern in this hydrogeologic region, with probable anthropogenic sources contributing to the elevated concentrations. Volatile organic compounds were also detected with chloroform as the most commonly detected compound, which is correlated with well disinfection (MPCA, 1999).

Another source of information on groundwater quality comes from the Minnesota Department of Health (MDH). Mandatory testing for arsenic, a naturally occurring but potentially harmful contaminant for humans, of all newly constructed wells has found that 10.7% of all wells installed from 2008 to 2015 have arsenic levels above the maximum contaminant level (MCL) for drinking water of 10 micrograms per liter (MDH, 2016a). In the Marsh River Watershed, the majority of new wells exceed the water quality standards for arsenic levels. When observing concentrations of arsenic by percentage of wells that exceed the MCL per county, the watershed lies within counties that range from 10 to greater than 20%, which is considered high. High levels of arsenic can sometimes be linked to anthropogenic causes, but most are likely related to the clay-rich material left behind by the Des Moines glacial lobe till (MDH, 2016a). By county, the percentages of wells identified with concentrations exceeding the MCL are as follows: Norman (42.1%), Clay (38.0%), and Polk (16.7%) Counties (MDH, 2016b) (Figure 18). It is important to reiterate that the percentages of arsenic concentration exceedances are per county, not specifically for Marsh River Watershed. For more information on arsenic in private wells, please refer to the MDH's website: https://apps.health.state.mn.us/mndata/arsenic_wells.

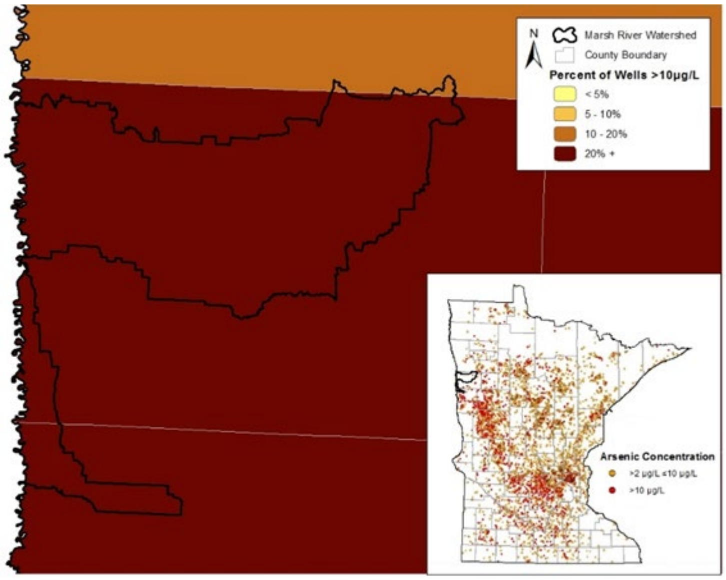

Figure 18. Percent wells with arsenic occurrence greater than the MCL for the Marsh River Watershed (2008-2015) (Source: MDH, 2016b)

A statewide dataset of potentially contaminated sites and facilities with environmental permits and registrations is available at the MPCA's website, through a web-based application called, "What's In My Neighborhood" (WIMN). This MPCA resource provides the public with a method to access a wide variety of environmental information about communities across the state. These data are divided into two groups. The first is potentially contaminated sites and includes contaminated properties, formerly contaminated sites, and those that are being investigated for suspicion of being contaminated. The second category is made up of businesses that have applied for, and received, different types of environmental permits and registrations from the MPCA. An example of an environmental permit would be for a business acquiring a permit for a storm water or wastewater discharge, requiring it to operate within limits established by the MPCA. In the Marsh River Watershed, there are currently 96 active sites identified by WIMN: 31 tanks and leaks, 23 hazardous waste sites, 21 feedlots sites, 17 water quality sites, 2 air quality sites, 1 investigation and cleanup site, and 1 solid waste site (Figure 19) (MPCA, 2016). For more information regarding WIMN, refer to the MPCA webpage at http://www.pca.state.mn.us/index.php/data/wimn-whats-in-my-neighborhood/whats-in-my-neighborhood.html.

Groundwater quantity

The DNR permits all high capacity water withdrawals where the pumped volume exceeds 10,000 gallons per day or 1 million gallons per year. Permit holders are required to track water use and report to the DNR annually. The changes in withdrawal volume detailed in this report are a representation of water use and demand in the watershed and are taken into consideration when the DNR issues permits for water withdrawals. Other factors not discussed in this report but considered when issuing permits include: interactions between individual withdrawal locations, cumulative effects of withdrawals from individual aquifers, and potential interactions between aquifers. This holistic approach to water allocations is necessary to ensure the sustainability of Minnesota's groundwater resources.

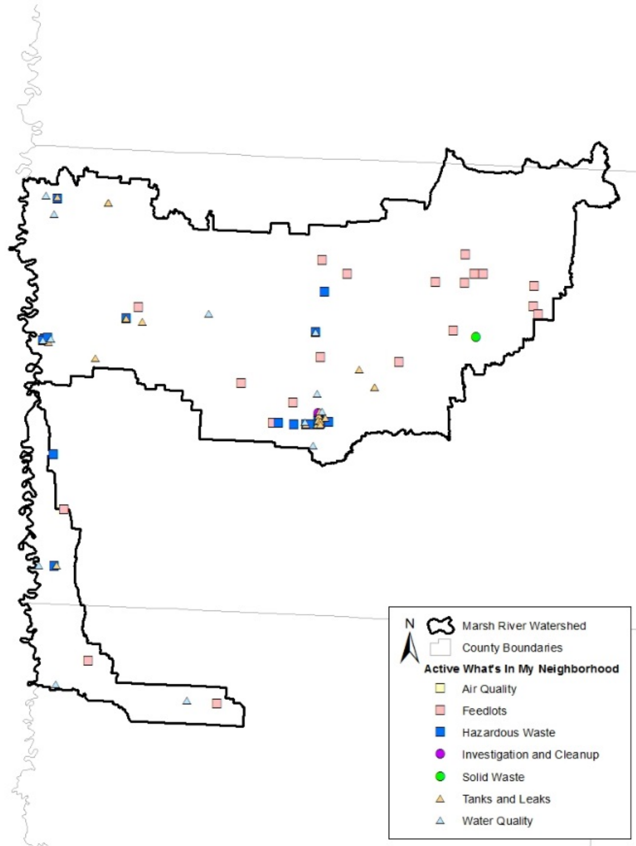

Figure 19. Active "What's In My Neighborhood" site programs and locations for the Marsh River Watershed (Source: MPCA, 2016)

The three largest permitted consumers of water in the state (in order) are power generation, public water supply (municipals), and irrigation (DNR, 2016c). According to the most recent USGS site-specific water-use data system, in 2013, the withdrawals within the Marsh River Watershed are primarily utilized for water supply (public/municipal) and special categories, such as dust control. Other withdrawals that are considered inactive in 2013 include: agricultural irrigation, industrial processing, construction non-dewatering, water level maintenance, and heating and cooling purposes.

Figure 20 displays total high capacity withdrawal locations within the watershed with active permit status in 2013. Permitted groundwater withdrawals are displayed below as blue triangles and surface water withdrawals as red squares. During 1994 to 2013, groundwater withdrawals within the Marsh River Watershed exhibit a significant decreasing withdrawal trend ($p<0.001$) (Figure 21). Surface water withdrawal permittees either did not utilize the permitted amount of water or did not report it, resulting in no surface water withdrawal data to report.

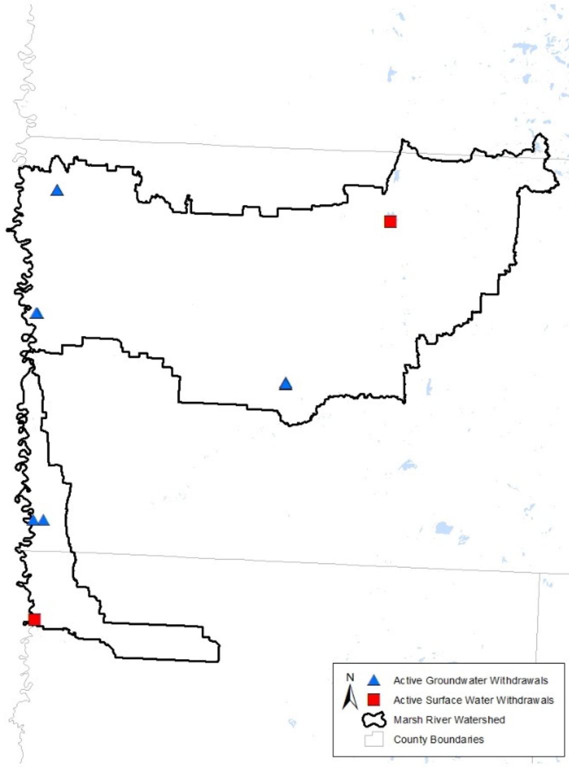

Figure 20. Locations of active status permitted high capacity withdrawals in 2013 within the Marsh River Watershed.

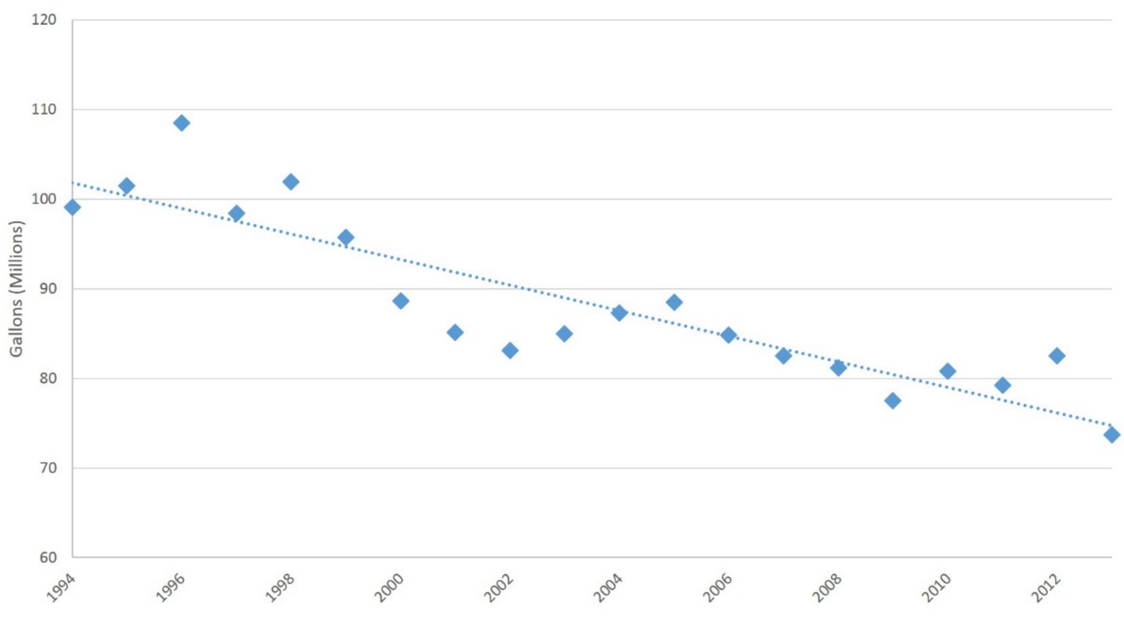

Figure 21. Total annual groundwater withdrawals in the Marsh River Watershed (1994-2013).

Wetlands

Wetlands are uncommon in the Marsh River Watershed. There are an estimated 6,365-wetland acres in the Marsh—or about 3% of the watershed—according to National Wetlands Inventory (NWI) data (Figure 22). This coverage rate is well below the statewide rate of 19% and below the 6% rate for the Temperate Prairies Ecoregion (Kloiber and Norris, 2013, MPCA, 2015). The most prevalent type in the watershed are emergent wetlands that are dominated by grasses, sedges, bulrushes, and/or cattails.

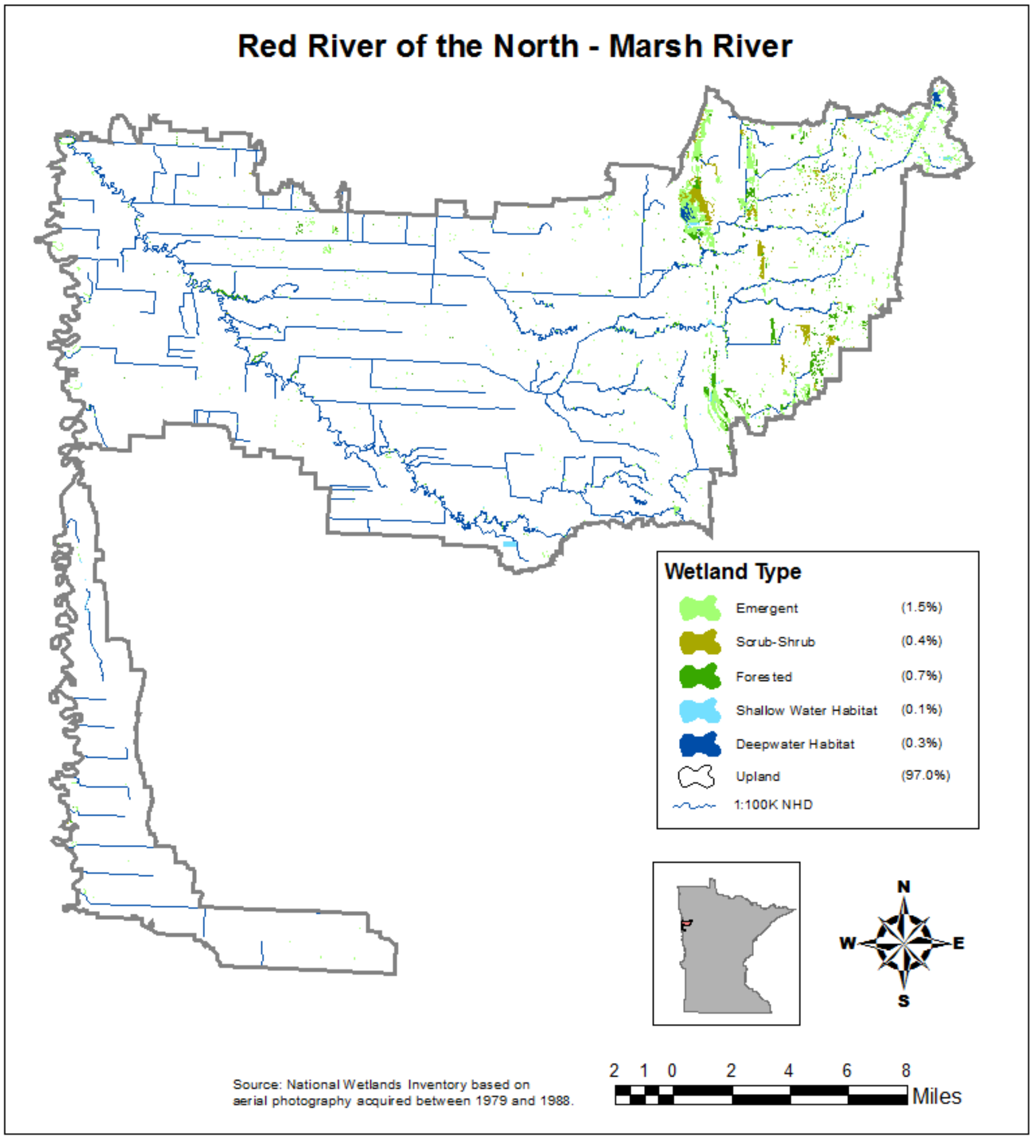

Figure 22. Wetlands and surface water in the Marsh River Watershed. Wetland data are from the National Wetlands Inventory.

Prior to European settlement, wetlands were much more prevalent throughout the watershed. As wetland soil features typically persist after artificial drainage, soil survey data can be used to estimate historical wetland extent. Mapped poorly and very poorly drained soil units (which would typically support wetlands in the absence of drainage) total 119,090 acres—or approximately 51% of the watershed. Comparing that total to the current NWI estimate reveals that approximately 95% of the historical wetland extent has been lost in the watershed, with little variation in wetland loss rates between the five subwatersheds (loss rates range from 84% - 99%).

The predominant glacial lake landform present in the Marsh River Watershed has largely influenced the historical/current extent, distribution, and predominant kinds of hydrogeomorphically (HGM) functioning types of wetlands here. The extremely flat landscape that remained following Glacial Lake Agassiz (MNGS, 1997) had little capacity to drain surface water—promoting saturated soil conditions over expansive areas. The mineral flat HGM type wetlands (Smith et al., 1995) that formed due to these factors have in large part been effectively drained via surface ditching to increase agriculture production. Several narrow bands of glacial lake beach ridges occur within the larger glacial lake plain.

The beach ridges support wetlands where water accumulates behind downstream ridges (depressional HGM type), as well as, where groundwater discharge saturates a sloping soil surface and peat accumulates (slope HGM type; Smith et al. 1995). The majority of the watershed's current wetlands occur amongst the beach ridges—as drainage and agriculture are less practical compared to the glacial lake plain (Figure 22). Calcareous fens—an uncommon wetland type with alkaline (pH > 6.7) peat that support a number of rare plant species—form where the beach ridge groundwater discharge is mineral-rich. They receive additional protections as state Outstanding Resource Value Waters (ORVW; Minn. R. ch. 7050; https://www.revisor.leg.state.mn.us/rules/?id=7050). The DNR has identified five calcareous fens in the watershed, one of which is designated as an ORVW.

Watershed-wide data collection methodology

Stream water sampling

Intensively monitored water chemistry stations were placed at or near the outlet of two aggregated 12-HUC subwatersheds that were >40 square miles in area (purple circles/triangles and green circles in Figure 2). These two chemistry stations were sampled monthly from May through September in 2014, and again in June through August of 2015 by MPCA staff, to provide sufficient water chemistry data to assess all components of the aquatic life and recreational use standards. Occasional periods of no flow prevented some samples from being collected, and resulted in some assessment decisions having insufficient information to confidently determine a use support status (See Appendix 2.1 – Intensive watershed monitoring water chemistry stations in the Marsh River Watershed for locations of stream water chemistry monitoring sites. See Appendix 1 for definitions of stream chemistry analytes monitored in this study).

Stream flow methodology

MPCA and the DNR joint stream water quantity and quality monitoring data for dozens of sites across the state on major rivers, at the mouths of most of the state's major watersheds, and at the mouths of some aggregated 12-HUC subwatersheds are available at the DNR/PCA Cooperative Stream Gaging webpage at: http://www.dnr.state.mn.us/waters/csg/index.html.

Lake biological sampling

No fish or plant IBI surveys within lakes were conducted by the DNR for this watershed assessment process.

Stream biological sampling

The biological monitoring component of the IWM in the Marsh River Watershed was completed during the summer of 2014. A total of five sites were newly established across the watershed and sampled. These sites were located near the outlets of most minor 14-HUC watersheds. In addition, one existing biological monitoring station (05RD055) within the watershed was revisited in 2014. This monitoring station was initially established as part of a random state wide survey in 2006. While data from the last 10 years contributed to the watershed assessments, the majority of data utilized for the 2016 assessment was collected in 2014. A total of six AUIDs were sampled for biology in the Marsh River Watershed. Waterbody assessments to determine aquatic life use support were conducted for all six AUIDs. Biological information that was not used in the assessment process will be crucial to the stressor identification process and will also be used as a basis for long term trend results in subsequent reporting cycles.

To measure the health of aquatic life at each biological monitoring station, indices of biological integrity (IBIs), specifically Fish and macroinvertebrate IBIs (FIBI and MIBI) were calculated based on monitoring data collected for each of these communities. A fish and macroinvertebrate classification framework was developed to account for natural variation in community structure, which is attributed to geographic region, watershed drainage area, water temperature, and stream gradient. As a result, Minnesota's streams and rivers were divided into seven distinct warm water classes and two cold water classes, with each class having its own unique Fish IBI and Invert IBI. Each IBI class uses a unique suite of metrics, scoring functions, impairment thresholds, and confidence intervals (CIs) (For IBI classes, thresholds and CIs, see Appendix 3.1). IBI scores higher than the impairment threshold and upper CI indicate that the stream reach supports aquatic life. Contrarily, scores below the impairment threshold and lower CI indicate that the stream reach does not support aquatic life. When an IBI score falls within the upper and lower confidence limits additional information may be considered when making the impairment decision such as the consideration of potential local and watershed stressors and additional monitoring information (e.g., water chemistry, physical habitat, observations of local land use activities). For IBI results for each individual biological monitoring station, see Appendices 4.1 and 4.2.

Fish contaminants

Minnesota Department of Natural Resource (DNR) fisheries staff collect most of the fish for the Fish Contaminant Monitoring Program. In addition, MPCA's biomonitoring staff collect up to five piscivorous (top predator) fish and five forage fish as part of the intensive watershed monitoring. All fish collected by the MPCA are analyzed for mercury and the two largest individual fish of each species are analyzed for PCBs.

Captured fish were wrapped in aluminum foil and frozen until they were thawed, scaled (or skinned), filleted, and ground to a homogenized tissue sample. Homogenized fillets were placed in 60 mL glass jars with Teflon™ lids and frozen until thawed for lab analysis. The Minnesota Department of Agriculture Laboratory analyzed the samples for mercury and PCBs. If fish were tested for perfluorochemicals (PFCs), whole fish were shipped to AXYS Analytical Laboratory, which analyzed the homogenized fish fillets for 13 PFCs. Of the measured PFCs, only perfluorooctane sulfonate (PFOS) is reported because it bioaccumulates in fish to levels that are potentially toxic and a reference dose has been developed.

From the fish contaminant analyses, MPCA determines which waters exceed impairment thresholds. The Impaired Waters List is prepared by the MPCA and submitted every even year to the U.S. Environmental Protection Agency (EPA). The MPCA has included waters impaired for contaminants in fish on the Impaired Waters List since 1998. Impairment assessment for PCBs (and PFOS when tested) in fish tissue is based on the fish consumption advisories prepared by the MDH. If the consumption advice is to restrict consumption of a particular fish species to less than a meal per week, the MPCA considers the lake or river impaired. The threshold concentration for impairment (consumption advice of one meal per month) is an average fillet concentration of 0.22 mg/kg for PCBs (and 0.200 mg/kg for PFOS).

Monitoring of fish contaminants in the 1970s and 1980s showed high concentrations of PCBs were primarily a concern downstream of large urban areas in large rivers, such as the Mississippi River and in Lake Superior. Therefore, PCBs are now tested where high concentrations in fish were measured in the past and the major watersheds are screened for PCBs in the watershed monitoring collections.

Before 2006, mercury in fish tissue was assessed for water quality impairment based on MDH's fish consumption advisory, the same as PCBs. With the adoption of a water quality standard for mercury in edible fish tissue, a waterbody has been classified as impaired for mercury in fish tissue if 10% of the fish samples (measured as the 90^{th} percentile) exceed 0.2 mg/kg of mercury. At least five fish samples of the same species are required to make this assessment and only the last 10 years of data are used for the assessment. MPCA's Impaired Waters List includes waterways that were assessed as impaired prior to 2006 as well as more recent impairments.

Load monitoring

The Watershed Pollutant Load Monitoring Network (WPLMN) is a long-term program designed to measure and compare regional differences and long-term trends in water quality among Minnesota's major rivers including the Red, Rainy, St. Croix, Mississippi, and Minnesota; at the outlets of the major tributaries (8 digit HUC scale) draining to these rivers; and for subwatersheds of the major watersheds. Intensive water quality sampling occurs at all WPLMN sites. Thirty-five samples per year are allocated for basin and major watershed sites and 25 samples per season (ice out through October 31) for subwatershed sites. Water sample results and daily average flow data are coupled in the FLUX32 pollutant load model to estimate the transport (load) of nutrients and other water quality constituents past a sampling station over a given period of time. Loads and flow weighted mean concentrations (FWMCs) are calculated for TSS, TP, dissolved orthophosphate), nitrate plus nitrite nitrogen (NO_3+NO_2-N), and total Kjeldahl nitrogen (TKN).

More information can be found at the WPLMN website.

Groundwater monitoring

The MPCA maintains an Ambient Groundwater Monitoring Network that monitors the aquifers that are most likely to be polluted with non-agricultural chemicals. This network primarily targets the shallow aquifers that underlie the urban parts of the state, due to the higher tendency of vulnerability to pollution. The MPCA's Ambient Groundwater Monitoring Network as of 2016, when this report was produced, consisted of approximately 250 wells that are primarily located in the sand and gravel and Prairie du Chien- Jordan aquifers.

Some wells in the MPCA's network are used to discern the effect of urban land use on groundwater quality and comprise an early warning network. Most wells in this early warning network contain water that was recently recharged into the groundwater, some even less than one-year-old. The wells in the early warning network are distributed among several different settings to determine the effect land use has on groundwater quality. These assessed land use settings are: 1) sewered residential, 2) residential areas that use subsurface sewage treatment systems for wastewater disposal, and 3) commercial or industrial, and 4) undeveloped. The data collected from the wells in the undeveloped areas provide a baseline to assess the extent of any pollution from all other land use settings.

MPCA staff generally collect water samples from the MPCA's Ambient Groundwater Monitoring Network wells annually. This sampling frequency provides sufficient information to determine trends in groundwater quality. The water samples are analyzed to determine the concentrations of over 100 chemicals, including nitrate, chloride, and volatile organic compounds.

Information on groundwater monitoring methodology is taken from Kroening and Ferrey's report: The Condition of Minnesota's Groundwater, 2007-2011 (2013). To download ambient groundwater monitoring data, please refer to https://www.pca.state.mn.us/data/groundwater-data.

Wetland monitoring

The MPCA is actively developing methods and building capacity to conduct wetland quality monitoring and assessment. Our primary approach is biological monitoring—where changes in biological communities may be indicating a response to human-caused impacts. The MPCA has developed IBIs to monitor the macroinvertebrate condition of depressional wetlands that have open water and the Floristic Quality Assessment to assess vegetation condition in all of Minnesota's wetland types. For more information about the wetland monitoring (including technical background reports and sampling procedures), please visit the MPCA Wetland monitoring and assessment webpage.

The MPCA currently does not monitor wetlands systematically by watershed. Alternatively, the overall status and trends of wetland quality in the state and by major ecoregion is being tracked through probabilistic monitoring. Probabilistic monitoring refers to the process of randomly selecting sites to monitor; from which an unbiased estimate of the resource can be made. Regional probabilistic survey results can provide a reasonable approximation of the current wetland quality in the watershed. As few open water depressional wetlands exist in the watershed, the focus will be on vegetation quality results of all wetland types.

Individual aggregated 12-HUC subwatershed results

Aggregated 12-HUC subwatersheds

Assessment results for aquatic life and recreation use are presented for each Aggregated 12-HUC subwatershed within the Marsh River Watershed. The primary objective is to portray all the full support and impairment listings within an aggregated 12-HUC subwatershed resulting from the complex and multi-step assessment and listing process. This scale provides a robust assessment of water quality condition at a practical size for the development, management, and implementation of effective TMDLs and protection strategies. The graphics presented for each of the aggregated 12-HUC subwatersheds contain the assessment results from the 2016 assessment cycle as well as any impairment listings from previous assessment cycles. Discussion of assessment results focuses primarily on the 2014 IWM effort, but also considers available data from the last 10 years.

The proceeding pages provide an account of each aggregated 12-HUC subwatershed. Each account includes a brief description of the aggregated 12-HUC subwatershed and summary tables of the results for stream aquatic life and aquatic recreation assessments. Following the tables is a narrative summary of the assessment results and pertinent water quality projects completed or planned for the aggregated 12-HUC subwatershed. A brief description of each of the summary tables is provided below.

Stream assessments

A table is provided in each section summarizing aquatic life and aquatic recreation assessments of all assessable stream reaches within the aggregated 12-HUC subwatershed (i.e., where sufficient information was available to make an assessment). Primarily, these tables reflect the results of the 2016 assessment process (2018 EPA reporting cycle); however, impairments from previous assessment cycles are also included and are distinguished from new impairments via cell shading (see footnote section of each table). These tables also denote the results of comparing each individual aquatic life and aquatic recreation indicator to their respective criteria (i.e., standards); determinations made during the desktop phase of the assessment process (see Figure 3). Assessment of aquatic life is derived from the analysis of biological (fish and invert IBIs), dissolved oxygen, TSS, chloride, pH, TP, chlorophyll-a, biochemical oxygen demand and un-ionized ammonia (NH3) data, while the assessment of aquatic recreation in streams is based solely on bacteria (*Escherichia coli*) data. Included in each table is the specific aquatic life use classification for each stream reach: cold water community (2A); cool or warm water community (2B); or indigenous aquatic community (2C). Where applicable and sufficient data exists, assessments of other designated uses (e.g., class 7, drinking water, aquatic consumption) are discussed in the summary section of each aggregated 12-HUC subwatershed as well as in the watershed-wide results and discussion section.

City of Perley-Red River Aggregated 12-HUC HUC 0902010701-01

The city of Perley-Red River Subwatershed is located within Norman and Clay counties, encompassing 121 square miles with the majority of the subwatershed located within Minnesota. This subwatershed contains the city of Perley, and is the most downstream minor subwatershed within the Marsh major Watershed. The Red River of the North flows through this subwatershed along the Minnesota/ North Dakota state line, but was not assessed for this effort. A full report of the findings within the Red River of the North will be released at a later date. The vast majority of the land use within this subwatershed is cropland (87%), but wetlands (4%) and barren land (4%) were also present. All of the tributaries flowing into the Red River of the North in this subwatershed have been historically channelized and are generally ephemeral; this, along with the low gradient nature of these streams, inhibited the ability to capture assessable data within the subwatershed. Therefore, no streams or ditches were assessed.

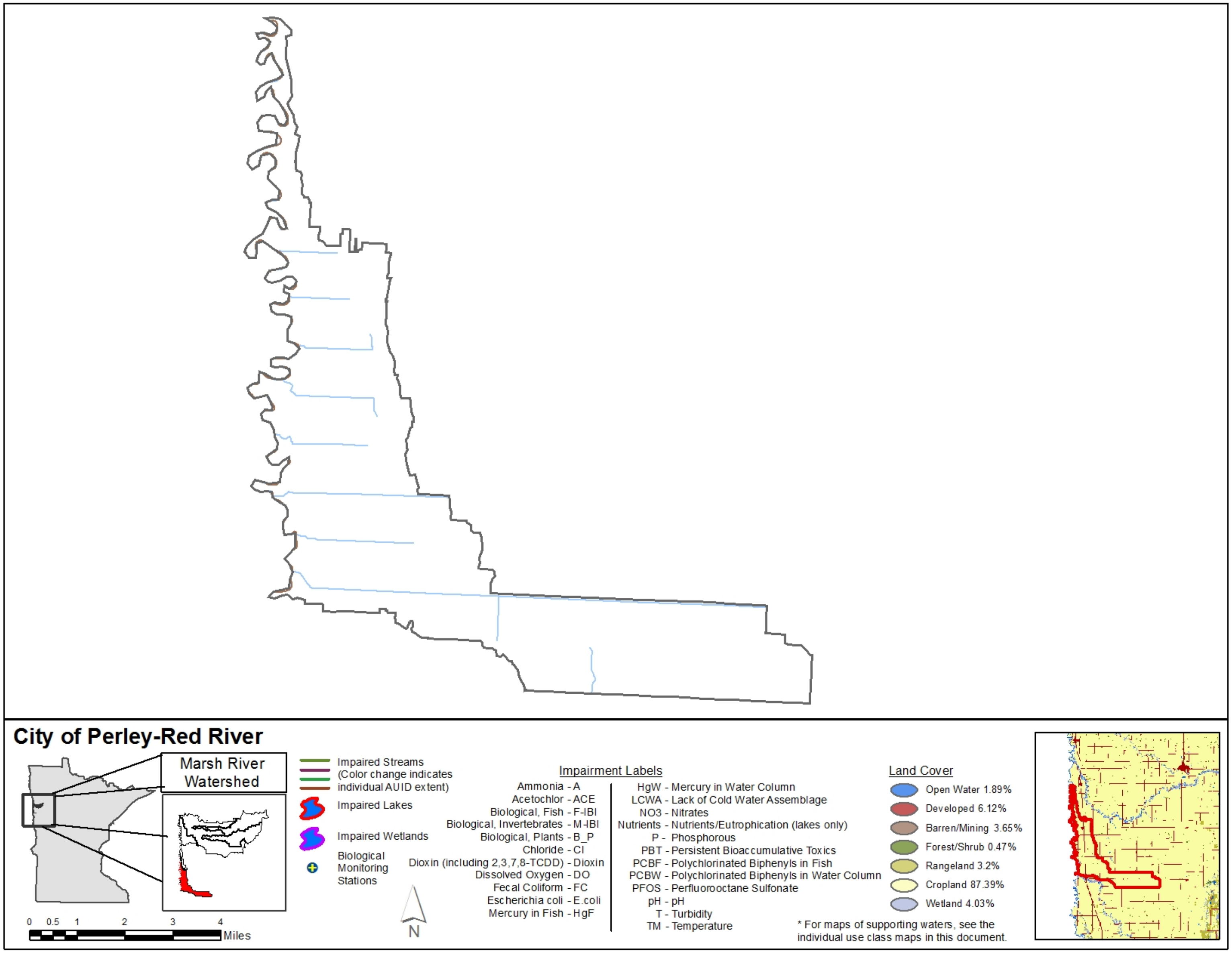

Figure 23. Currently listed impaired waters by parameter and land use characteristics in the city of Perley-Red River Aggregated 12-HUC.

Marsh River Aggregated 12-HUC

HUC 0902010705-01

The Marsh River Subwatershed is located within Norman County and encompasses 146 square miles. This subwatershed contains all 51 miles of the Marsh River from the headwaters, located 2 miles southeast of Ada, to its confluence with the Red River of the North, 2 miles northwest of Shelly. One assessable tributary, Judicial Ditch 51, is also located within this subwatershed. The majority of the Marsh River is not channelized with the exception of the headwaters which was historically altered to connect the Wild Rice River to the Marsh River so that logs could be floated to a sawmill just east of Ada. More recently, this alteration is utilized to aid in flood relief; when the Wild Rice River reaches 95% flow, it flows over the dike, and the extra water flows down the Marsh River. All of the tributaries within the subwatershed have also been channelized to aid drainage. A vast majority of the land use within the subwatershed is cropland (90%), but developed land in Ada (6%), and wetlands (3%) are also present. Two intensive water chemistry stations were established within the subwatershed on the Marsh River (S007-786).

Table 2. Aquatic life and recreation assessments on stream reaches: Marsh River Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

AUID *Reach Name*, *Reach Description*	Biological Station ID	Reach Length (miles)	Use Class	Aquatic Life Indicators:										Aquatic Life	Aquatic Rec. (Bacteria)
				Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH_3	Pesticides	Eutrophication		
09020107-518 ***Judicial Ditch 51,*** *County Ditch 26 to Unnamed Ditch*	05RD055	3.24	WWm	MTS	--	IF	IF	IF	--	IF	IF	--	IF	SUP	--
09020107-503 ***Marsh River,*** *Headwaters to Red River*	14RD072 05RD113 14RD061	51.45	WWg	EXS	EXS	IF	EXS	EXS	MTS	MTS	MTS	--	IF	IMP	IMP

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Summary

The Marsh River Subwatershed contains two stream reaches (09020107-518 and 09020107-503), Judicial Ditch 51 and the Marsh River. The first reach is Judicial Ditch 51 (09020107-518), which had one biological station (05RD055) that was sampled for fish. Macroinvertebrates were not sampled within this stream reach due to the intermittent nature of the stream. This stream section has been channelized, and provides relatively poor habitat indicated by poor channel stability and low channel development within the Minnesota Stream Habitat Assessment (MSHA) score (Appendix 5). Although this reach is lacking quality habitat, the fish community contained sensitive species (Iowa Darter), and had an FIBI score that was above the modified use threshold. Chemistry data collected on Judicial Ditch 51 are limited to one-time grab samples obtained during biological monitoring visits, and are not sufficient for assessment purposes.

This subwatershed also contains the mainstem Marsh River (09020107-503) from the headwaters to the confluence with the Red River of the North. In the early 1900s, the headwaters of the Marsh River were channelized to connect the Wild Rice River, this allowed logs to be floated from the Wild Rice River headwaters to a Wild Rice Lumber Company sawmill located just east of Ada (Figure 24). More recently, this connection with the Wild Rice River was developed into a dike system. These dikes result in flow to the headwaters of the Marsh River during high flow events on the Wild Rice River. The Wild Rice River needs to reach the 95th flow percentile for the water to flow over the dike and into the Marsh River. Due to the additional channel created by the lumber company, the original headwaters to the Marsh River have been drained and plowed under for agriculture. A culvert located upstream of the 190th Avenue crossing of the Wild Rice River (Figure 25) directs flow through a ditch system, before eventually meeting the Marsh River within the Heart of the Valley Golf Club. The Marsh River has a natural channel from just south of Ada to the confluence with the Red River of the North. However, most of the tributaries to the Marsh River have been channelized to accelerate drainage. These hydrologic alterations of the natural waterways within the subwatershed have changed the historic flow patterns of the Marsh River, decreasing late summer base flow. A significant example of this hydrologic alteration is a high gradient culvert at the confluence of County Ditch 11. This culvert drains the entire 72 square miles of the County Ditch 11 subwatershed quickly, contributing sustainable flow until it dries up, usually in late summer. The hydrologic modifications have caused the Marsh River to become an intermittent system that only receives flow under rain events and other wet periods of the year.

The habitat is poor in the upstream portion of this reach, but there is an increasing trend of moderately better habitat from upstream to downstream. Poor quality habitat indicators such as the presence of fine sediments (sand, clay), poor channel morphology, and a lack of channel development were identified at each of three biological stations (14RD061, 05RD113, 14RD072) sampled for fish and macroinvertebrates. The increasing trend in habitat quality is largely due to the flow contribution from the high gradient culvert at the confluence of County Ditch 11; below which, higher flow velocity and coarse gravels were observed during the habitat assessment (Appendix 5). The fish community within this river reach indicated that the Marsh River was marginal as three out of four fish samples had FIBI scores that were just above the threshold. Contrary to the fish community, the macroinvertebrate community was dominated by tolerant taxa (snails and *Hyalella*), and all stations had an MIBI score that was below the threshold. A few sensitive fish species (smallmouth bass) and flow dependent macroinvertebrate taxa were sampled within the reach; however, it is likely that the presence of these sensitive taxa is caused by the higher flow velocity from the County Ditch 11 culvert. This higher flow gives rise to higher DO levels and exposes coarse substrates, providing beneficial habitat attributes for sensitive fish taxa and flow dependent macroinvertebrate taxa. However, due to the intermittent nature of County Ditch 11, the beneficial flow is not available year-round. Lacking the benefit of quality year-round flow, the habitat within the Marsh River cannot sustain sensitive biological communities which results in conditions that are not supportive of aquatic life within the Marsh River.

In 2008, the Marsh River was determined to have an aquatic life use impairment due to excessive turbidity and was placed on the 303(d) Impaired Waters List. New TSS and Secchi transparency data confirm that turbidity (i.e. TSS) concentrations still exceed the regional standard. Each dataset contains nearly 200 observations, and both of them have an individual exceedance rate greater than 10% of all samples. These data suggest that the original turbidity listing is still applicable to this river reach, and the Marsh River (09020107-503) will remain listed for turbidity.

In 2010, the Marsh River was listed for a dissolved oxygen impairment. Review of the 2010 listing data indicate that dissolved oxygen periodically exceeds the water quality standard. Additional observations made before 9:00 a.m. are needed to determine if this reach can be removed from the 303(d) Impaired Waters List.

River eutrophication datasets were inconclusive to determine if nutrients are adversely affecting the aquatic communities. The seasonal mean TP concentration is severely elevated (approaching three-times the concentration allowed under the south nutrient region standard); nearly 100 seasonal samples (collected mostly under the watershed pollutant load monitoring program) over the full 10-year assessment window went into the mean calculation. However, parameters meant to observe an in-system response to elevated nutrients (e.g. chl-a; DO flux; pH) all meet their individual standard.

All other conventional aquatic life use chemistry parameters meet their respective standards.

Bacteria data collected for the Marsh River were collected over five different years show a single exceedance of the individual bacteria standard. Additionally, the monthly geometric mean calculation for the month of June exceeds the monthly standard. These data suggest that bacteria concentrations are chronically (and occasionally, severely) elevated and may pose a risk to human health. As such, this river does not support aquatic recreation, and will be newly listed for E. coli bacteria.

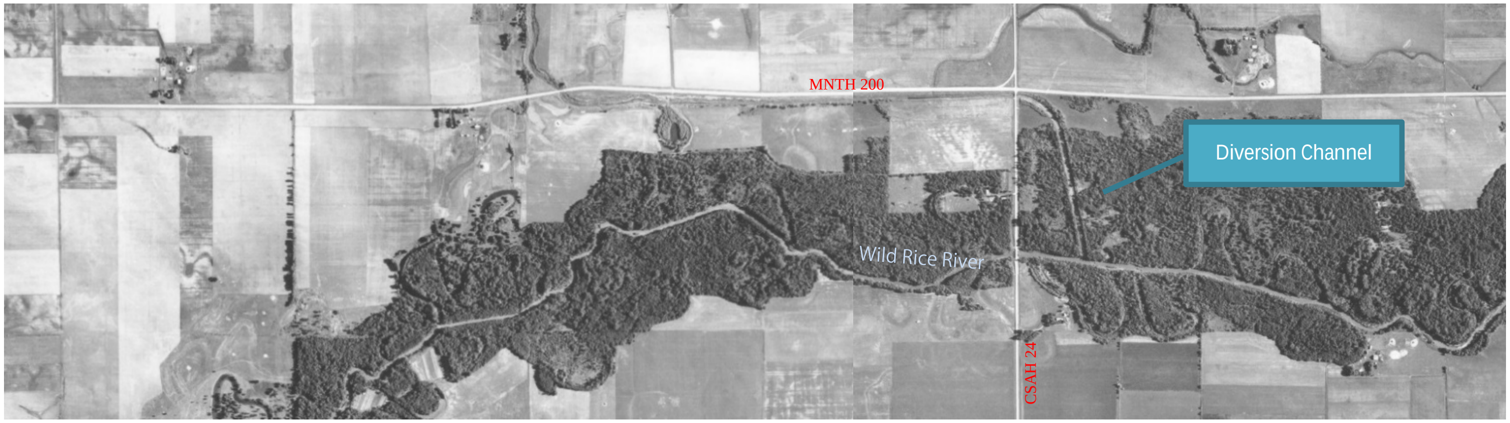

Figure 24. Early 1900s diversion channel created by the Wild Rice Lumber Company on the Marsh River. 1939 photo derived from http://maps.dnr.state.mn.us/landview/historical_airphotos/usda/byb/y1939/byb01030.jpg

Figure 25. Flow diversion culvert in the headwaters of the Marsh River.

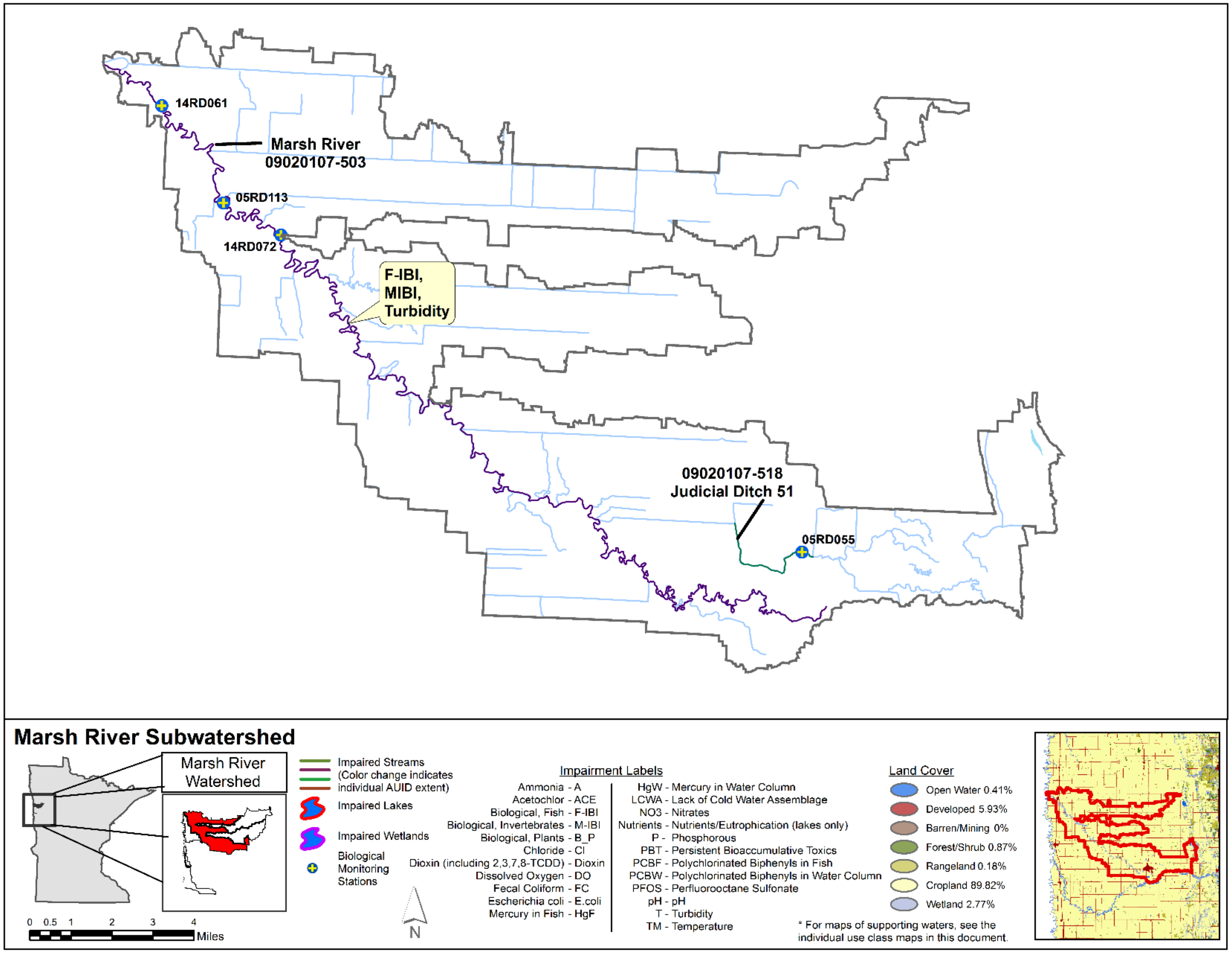

Figure 26. Currently listed impaired waters by parameter and land use characteristics in the Marsh River Aggregated 12-HUC.

County Ditch No. 11 Aggregated 12-HUC HUC 0902010705-02

The County Ditch No. 11 Subwatershed is located within Norman County, encompassing 72 square miles. As the name suggests, this subwatershed contains County Ditch No. 11, but County Ditch 45, Spring Creek, and County Ditch 66 are also within the subwatershed boundaries. This network of streams begins 3 miles southeast of Fertile, and flows for 29 miles before reaching its confluence with the Marsh River, 4 miles southeast of Shelly. Spring Creek, which flows for 10 miles just east of Sundal, is the only natural channel within the subwatershed. A vast majority of the land use within the subwatershed is cropland (83%), but wetlands (6%) and developed land (4%) are also present. The intensive water chemistry station (S007-785) was located off the culvert at the CR 129 crossing.

Table 3. Aquatic life and recreation assessments on stream reaches: County Ditch No. 11 Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

AUID *Reach Name*, *Reach Description*	**Biological Station ID**	**Reach Length (miles)**	**Use Class**	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH_3	Pesticides	Eutrophication	**Aquatic Life**	**Aquatic Rec. (Bacteria)**
09020107-521 ***County Ditch 45,*** -96.3235 47.4726 to County Ditch 5	14RD075	1.75	WWg	MTS	MTS	IF	IF	IF	--	IF	IF	--	IF	SUP	--
09020107-508 ***Spring Creek,*** T146 R45W S24, east line to County Ditch 38	14RD071	9.95	WWg	MTS	MTS	IF	IF	IF	--	IF	IF	--	IF	SUP	--
09020107-516 ***County Ditch 66,*** County Ditch 38 to County Ditch 11	07RD008	5.54	WWg	MTS	MTS	IF	IF	IF	--	IF	IF	--	IF	SUP	--
09020107-517 ***County Ditch 11,*** County Ditch 66 to Marsh River	14RD060	10.37	WWg	EXS	MTS	IF	MTS	MTS	MTS	MTS	MTS	--	IF	IMP	IF

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.
Abbreviations for Use Class: **WWg** = warmwater general, **WWm** = Warmwater modified, **WWe** = Warmwater exceptional, **CWg** = Coldwater general, **CWe** = Coldwater exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Summary

The County Ditch 11 Subwatershed contains four stream reaches (09020107-521, 09020107-508, 09020107-516, and 09020107-517). The biological data were collected from one site within each reach. County Ditch 11 (09020107-517) is the only stream reach in this subwatershed that had water chemistry data to assess against aquatic life use standards.

The most headwater stream, County Ditch 45 (09020107-521), flows for 1.75 miles and contains one biological station (14RD075). The monitoring site had the best habitat in this subwatershed but still had only a fair MSHA score of 54.5 (Appendix 5). Notable habitat characteristics included the presence of riffles, coarse gravel, and moderate flow during both the fish and macroinvertebrate visits. This stream was not designated as modified because the habitat quality as well as the fish and macroinvertebrate IBI scores were sufficient to support the general use. The fish community contained sensitive species (e.g. Pearl Dace) and the macroinvertebrate community contained a mix of tolerant and intolerant taxa.

Spring Creek (09020107-508) is located in the central portion of the subwatershed. The stream had one assessable biological station (14RD071) that was sampled for fish and macroinvertebrates. Spring Creek is a natural stream with habitat that is characterized by a lack of coarse substrates, low channel stability due to shifting bed material, and fair channel development. The FIBI and MIBI scores in Spring Creek were near the impairment threshold suggesting that the stream is vulnerable to becoming impaired. The macroinvertebrate community was dominated by flow dependent, filtering, and disturbance tolerant taxa. Fish were sampled twice because the first sample had an FIBI score that was just below the threshold. The FIBI score from the second sample was just above the impairment threshold and the fish assemblage was very similar to the first sample; the same fish species were collected, only in greater numbers. High levels of nitrates and elevated phosphorus levels in water samples collected during the fish visits suggest that anthropogenic stress is occurring within Spring Creek's Watershed. Though this stream currently supports aquatic life, the stream shows signs of stress that may lead to further degradation unless management strategies are implemented at the local level to improve the water quality and habitat.

County Ditch 66 (09020107-516) was sampled for fish and macroinvertebrates in 2007 (07RD008). It is a channelized stream that was designated as modified (i.e. habitat limited) due to the presence of severely embedded substrates and compromised channel development. The FIBI and MIBI scores were both above the modified use impairment threshold. The fish community consisted of tolerant (Fathead Minnow) and intolerant (Pearl Dace) species while the macroinvertebrate community was dominated by tolerant snails and mayfly taxa.

County Ditch 11 (09020107-517) is the lowest reach prior to the confluence with the Marsh River. Due to the amount of channelization within this subwatershed, the amount of available flow to County Ditch 11 fluctuates dramatically. The flow issue is likely exacerbated by a high gradient culvert (Figure 27, Figure 28) at the downstream portion of County Ditch 11 at its confluence with the Marsh River. County Ditch 11 and a few other tributaries within the subwatershed are the only tributaries that contribute a perceptible amount of flow to the Marsh River within the entire 8-HUC watershed. They have all been highly altered to promote drainage. The alterations to tributary streams likely impact the Marsh River by limiting flow, particularly during dry months. The highly modified nature of this subwatershed has contributed to the Marsh River becoming a highly intermittent system that only receives flow under rain events and other wet periods of the year.

One assessable biological station (14RD060) was sampled for fish and macroinvertebrates on County Ditch 11. This reach had the poorest habitat (MSHA=34.5; Appendix 5 – MSHA results) within the subwatershed. The habitat was characterized by the presence of fine sediments, a low amount of cover, and poor channel development. The reach was designated as modified due to its limited habitat. The fish community was dominated by tolerant species (Fathead Minnow, Central Mudminnow, and Brook Stickleback) and had an FIBI score of 0. Somewhat surprisingly, the MIBI score was above the modified use impairment threshold. The community was dominated by tolerant mayfly nymphs, but the MIBI score was relatively good given the lack of habitat. The high gradient culvert downstream of the biological station could be stressing the fish community. This culvert is too steep for smaller sensitive fishes to swim up into County Ditch 11 from the Marsh River. Thus, the culvert is acting as a barrier, particularly during periods of low flow that may impede fish migration during times of stress (e.g. low dissolved oxygen, low flow, etc.). While fish are susceptible to these types of barriers, many adult macroinvertebrates are not constrained by them which may explain why macroinvertebrate communities appear to be doing better than fish communities upstream of the culvert.

The water quality data indicate that in-stream conditions support aquatic life, and chemistry related stressors to the aquatic communities are not likely occurring. While the phosphorus dataset was small, it did indicate that concentrations are low in this reach.

There was insufficient data to assess for aquatic recreation. However, the results from all individual samples and the geometric means for the months that could be calculated (June and July) suggest that bacteria levels are not impacting aquatic recreation.

Figure 27. County Ditch 11 high gradient culvert, upstream.

Figure 28. County Ditch 11 high gradient culvert, downstream.

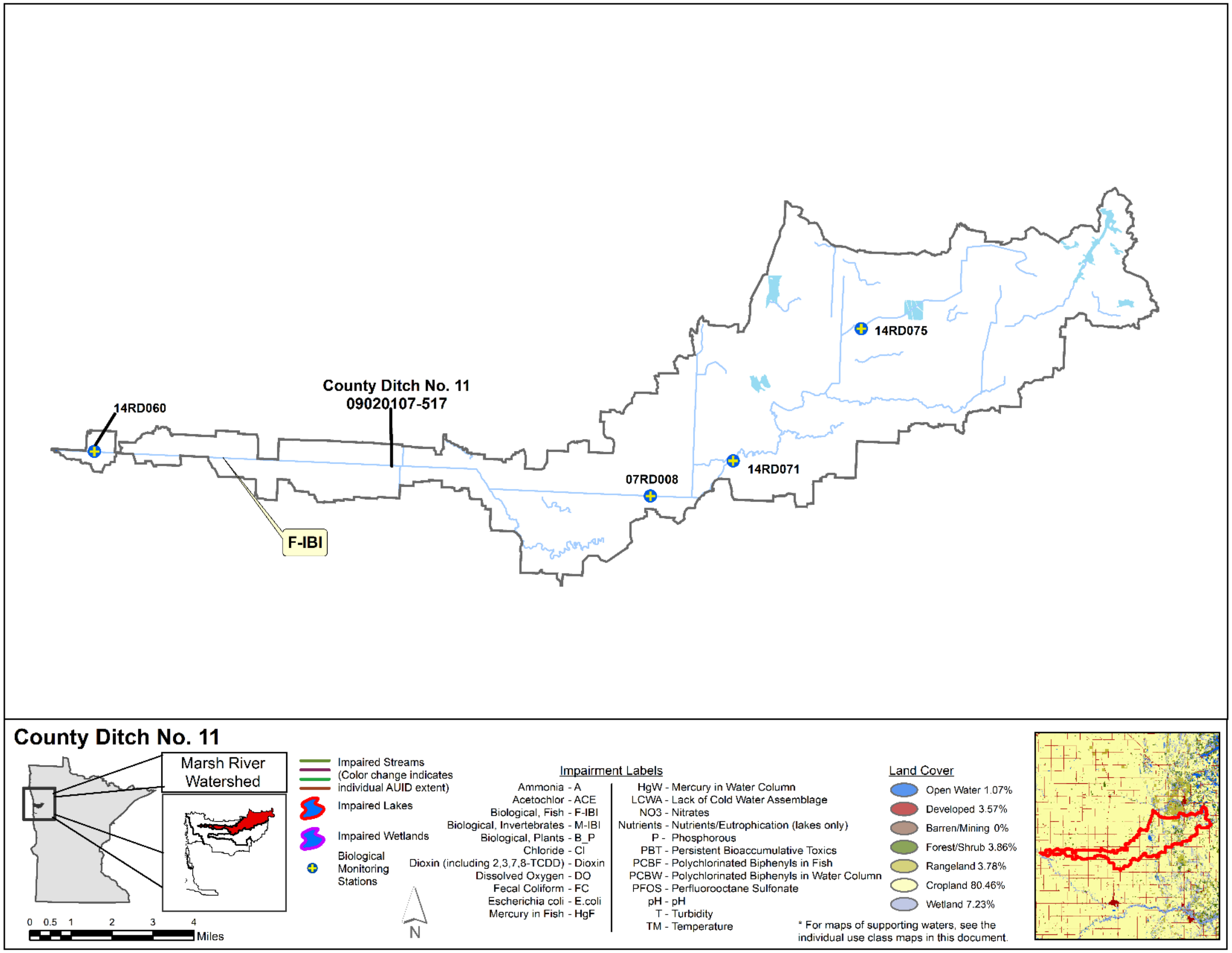

Figure 29. Currently listed impaired waters by parameter and land use characteristics in the County Ditch No. 11 Aggregated 12-HUC.

Spring Creek/ State Ditch 68 Aggregated 12-HUC HUC 0902010705-03

The Spring Creek/ State Ditch 68 Subwatershed is located within Norman County, encompassing 68 square miles. As the name implies, this subwatershed contains Spring Creek/ State Ditch 68 which originates 6 miles northwest of Lockhart, and flows for 15 miles before it reaches its confluence with Marsh River, 5 miles southeast of Halstad. The land use within this subwatershed is dominated by cropland (83%), but wetlands (6%) and developed land (4%) were also present. Throughout history, most of Spring Creek/State Ditch 68 and the tributaries flowing into Spring Creek/State Ditch 68, have been channelized to aid drainage. This channelization, along with the low gradient nature of these streams, inhibited the ability to capture assessable data within the subwatershed, and therefore, no streams or ditches were assessed.

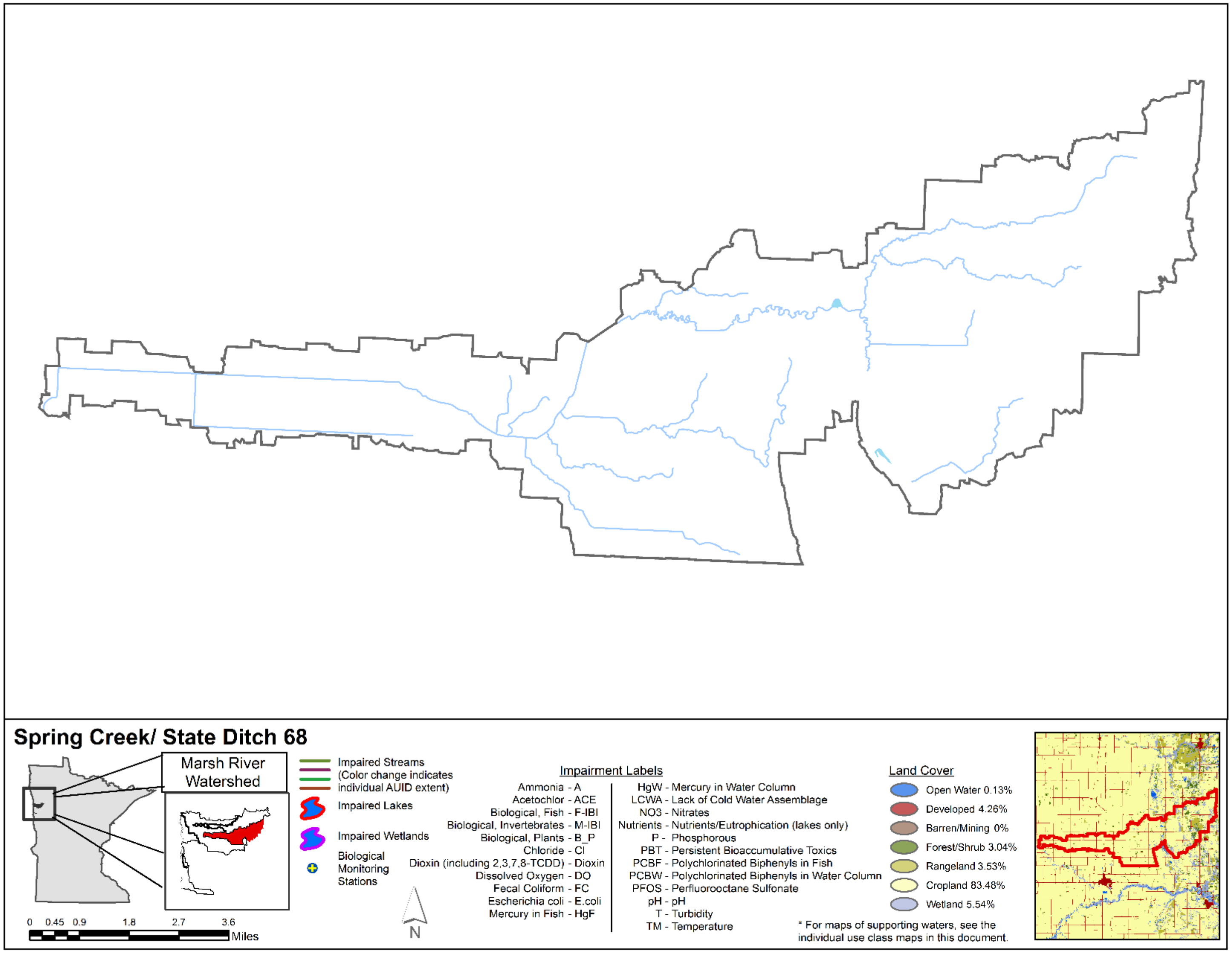

Figure 30. Currently listed impaired waters by parameter and land use characteristics in the Spring Creek/State Ditch 68 Aggregated 12-HUC.

City of Halstad-Red River Aggregated 12-HUC HUC 0902010706-01

The city of Halstad-Red River Subwatershed is located within Norman County, encompassing 114 square miles, with the eastern half of the subwatershed located in Minnesota and the western half in North Dakota. This subwatershed contains the city of Halstad. The Red River of the North flows through this subwatershed along the Minnesota/North Dakota state line, but was not assessed during this monitoring effort. A full report of the findings for the Red River of the North mainstem will be released at a later date. The vast majority of the land use within this subwatershed is cropland (85%), but developed land (7%) and wetlands (3%) are also present. All of the tributaries flowing into the Red River of the North within this subwatershed have been historically channelized to aid drainage, this along with the low gradient nature of these streams, inhibited the ability to capture assessable data within the subwatershed. Therefore, no streams or ditches were assessed.

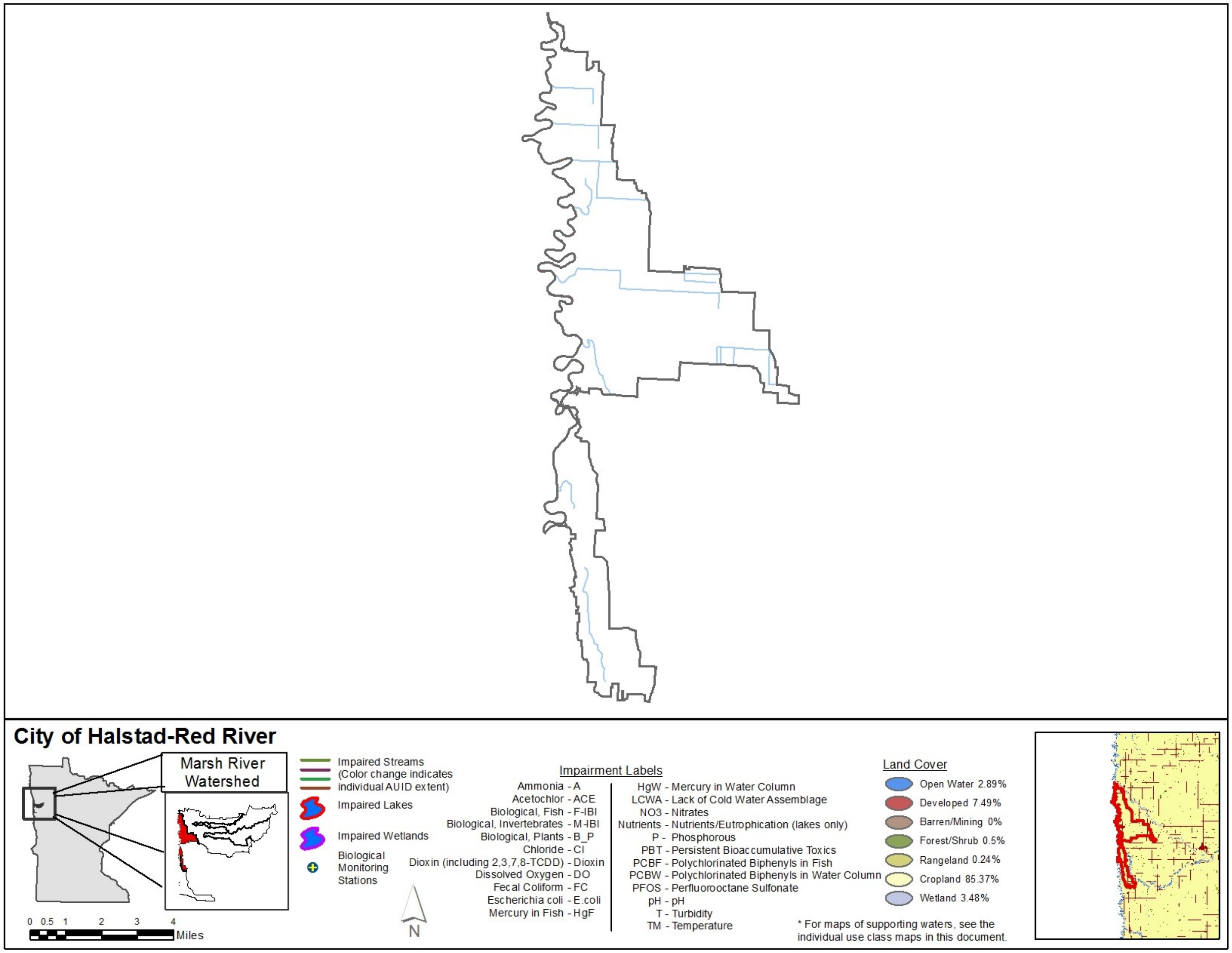

Figure 31. Currently listed impaired waters by parameter and land use characteristics in the city of Halstad-Red River Aggregated 12-HUC.

Watershed-wide results and discussion

Assessment results and data summaries are included below for the entire 8-HUC watershed unit of the Marsh River, grouped by sample type. Summaries are provided for streams and rivers in the watershed for the following: aquatic life and recreation uses, aquatic consumption results, load monitoring data results, and transparency trends. Additionally, groundwater and wetland monitoring results are included where applicable.

Following the results are a series of graphics that provide an overall summary of assessment results by designated use, impaired waters, and fully supporting waters within the entire Marsh River Watershed.

Stream water quality

Six of the 20 uniquely identified stream/river reaches in the Marsh River Watershed were assessed in 2016 (Table 4). Of the assessed streams, only four stream reaches fully support aquatic life and no streams fully support aquatic recreation. None of the assessed reaches are classified as limited resource waters.

Throughout the subwatersheds, two stream reaches do not support aquatic life and/or recreation. Of those two reaches, both do not support aquatic life and one does not support aquatic recreation.

Larger main stem reaches of the Red River of the North were not assessed during this process, and instead will be addressed during the large river assessment for the overall Red River.

Table 4. Assessment summary for stream water quality in the Marsh River Watershed.

				Supporting		Non-supporting			
Watershed	**Area (acres)**	**# Total AUIDs**	**# Assessed AUIDs**	**# Aquatic Life**	**# Aquatic Recreation**	**# Aquatic Life**	**# Aquatic Recreation**	**Insufficient Data**	**# Delistings**
09020107	231,541	20	6	4	- -	2	1	1	0
0902010705-01	93,547	6	2	1	- -	1	1	- -	--
0902010705-02	45,972	7	4	3	- -	1	- -	1	- -

Fish contaminant results

Mercury was analyzed in fish tissue samples collected from the Marsh River in 2014. Three fish species were tested: white sucker, northern pike, and bluegill sunfish. Polychlorinated biphenyls (PCBs) were measured in white sucker and northern pike from the river. A total of 16 fish were collected for contaminant analysis.

Contaminant concentrations are summarized by waterway, fish species, and year (Table 5). “Total Fish” indicates the total number of fish analyzed and “N” indicates the number of samples. The number of fish exceeds the number of samples when fish are combined into a composite sample. This was typically done for panfish, such as bluegill sunfish and yellow perch. “Anatomy” refers to the type of sample; since 1989, most of the samples have been skin-on fillets (FILSK) or for fish without scales (catfish and bullheads), skin-off fillets (FILET).

Marsh River was listed as impaired for mercury in fish tissue in MPCA’s 2016 Draft Impaired Waters List and added to the Statewide Mercury TMDL.

All of the PCB concentrations in fish tissue were below the reporting limit (0.035 mg/kg). Fish consumption advice, developed by the MDH, has meal advice of "unrestricted" for PCBs in fish less than or equal to 0.05 mg/kg.

Overall, mercury and PCB concentrations in fish from Marsh River were low, except for mercury in northern pike. The Fish Contaminant Monitoring Program will continue to retest the fish from impaired waters to assess if mercury levels are changing.

Table 5. Summary of fish length, mercury, and PCBs, by waterway-species-year.

							Length (in)			Mercury (mg/kg)			PCBs (mg/kg)			
AUID	Waterway	Species	Year	Anatomy[1]	Total Fish	No. Samples	Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL
09020107-503*	MARSH R.	White sucker	2014	FILSK	5	5	10.3	9.7	11.3	0.14	0.108	0.159	2	0.035	0.035	Y
		Northern pike	2014	FILSK	6	6	14.4	13.6	16	0.247	0.213	0.287	2	0.035	0.035	Y
		Bluegill sunfish	2014	FILSK	5	1	5.8	5.8	5.8	0.078	0.078	0.078				

* Impaired for mercury in fish tissue as of 2016 Draft Impaired Waters List; categorized as EPA Class 4a for waters covered by the Statewide Mercury TMDL.

1 Anatomy codes: FILSK – edible fillet, skin-on; FILET—edible fillet, skin-off; PLUG—dorsal muscle piece, without skin; WHORG—whole organism

Pollutant load monitoring

The WPLMN has only one seasonal site within the Marsh River Watershed as shown in Table 6.

Table 6. WPLMN stream monitoring sites for the Marsh River Watershed

Site Type	Stream Name	USGS ID	DNR/MPCA ID	EQuIS ID
Subwatershed	Marsh River near Shelly, CR113	05067500	W59007001	S002-127

Average (FWMCs) of TSS, TP, and NO3+NO2-N for major watershed stations statewide are presented below, with the Marsh River Watershed highlighted. Water runoff, a significant factor in pollutant loading, is also shown. Water runoff is the portion of annual precipitation that makes it to a river or stream; this can be expressed in inches.

As a general rule, elevated levels of TSS and NO3+NO2-N are regarded as "non-point" source derived pollutants originating from many small diffuse sources such as urban or agricultural runoff. Excess TP can be attributed to both non-point and point sources such as industrial or wastewater treatment plants. Major "non-point" sources of phosphorus include dissolved phosphorus from fertilizers and phosphorus adsorbed to and transported with sediment during runoff.

Excessive TSS, TP, and NO3+NO2-N in surface waters impacts fish and other aquatic life, as well as fishing, swimming, and other recreational uses. Elevated levels of NO3+NO2-N is a concern for drinking water. Although the Marsh River is not used directly as a drinking water source, the Marsh River is a tributary to the Red River that influences drinking water obtained by surface water intakes for major cities like East Grand Forks, Grand Forks, Drayton, and Grafton.

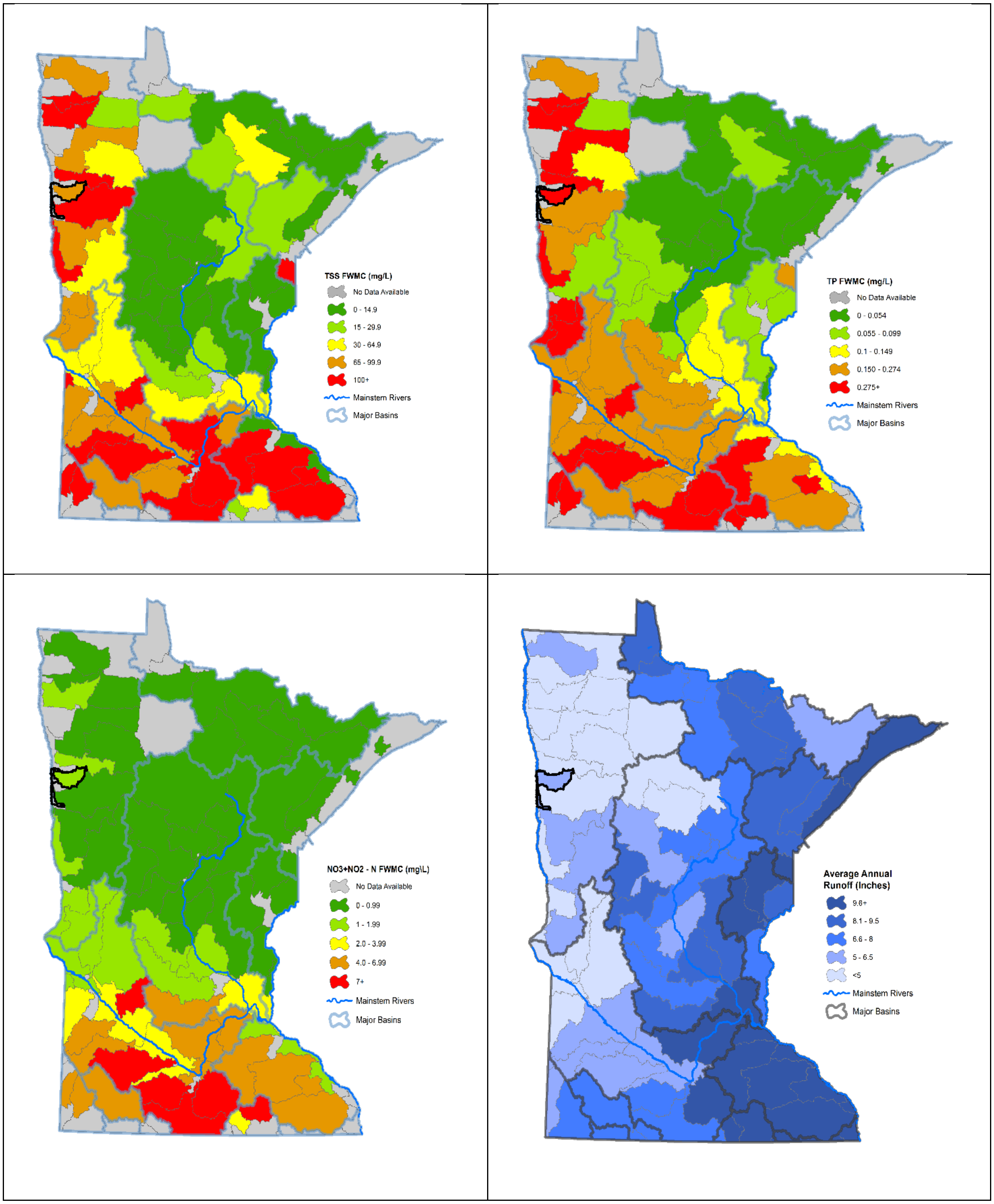

Figure 32. 2007-2014 average annual TSS, TP, and NO3-NO2-N flow weighted mean concentrations, and runoff by major watershed.

When compared with other subwatersheds throughout the state, Figure 32 shows the average annual TSS and TP FWMCs to be several times higher for the Marsh River Watershed than watersheds in north central and northeast Minnesota, but in line with the agriculturally rich watersheds found in the northwest and southern regions of the state. NO_3+NO_2-N FWMCs are more in line with the watersheds in north central and northeast Minnesota but are expected to trend upward as subsurface drainage practices increase.

More information, including results for subwatershed stations, can be found at the [WPLMN website.]

Substantial year-to-year variability in water quality occurs for most rivers and streams, including the Marsh River. Results for individual years are shown in the charts below.

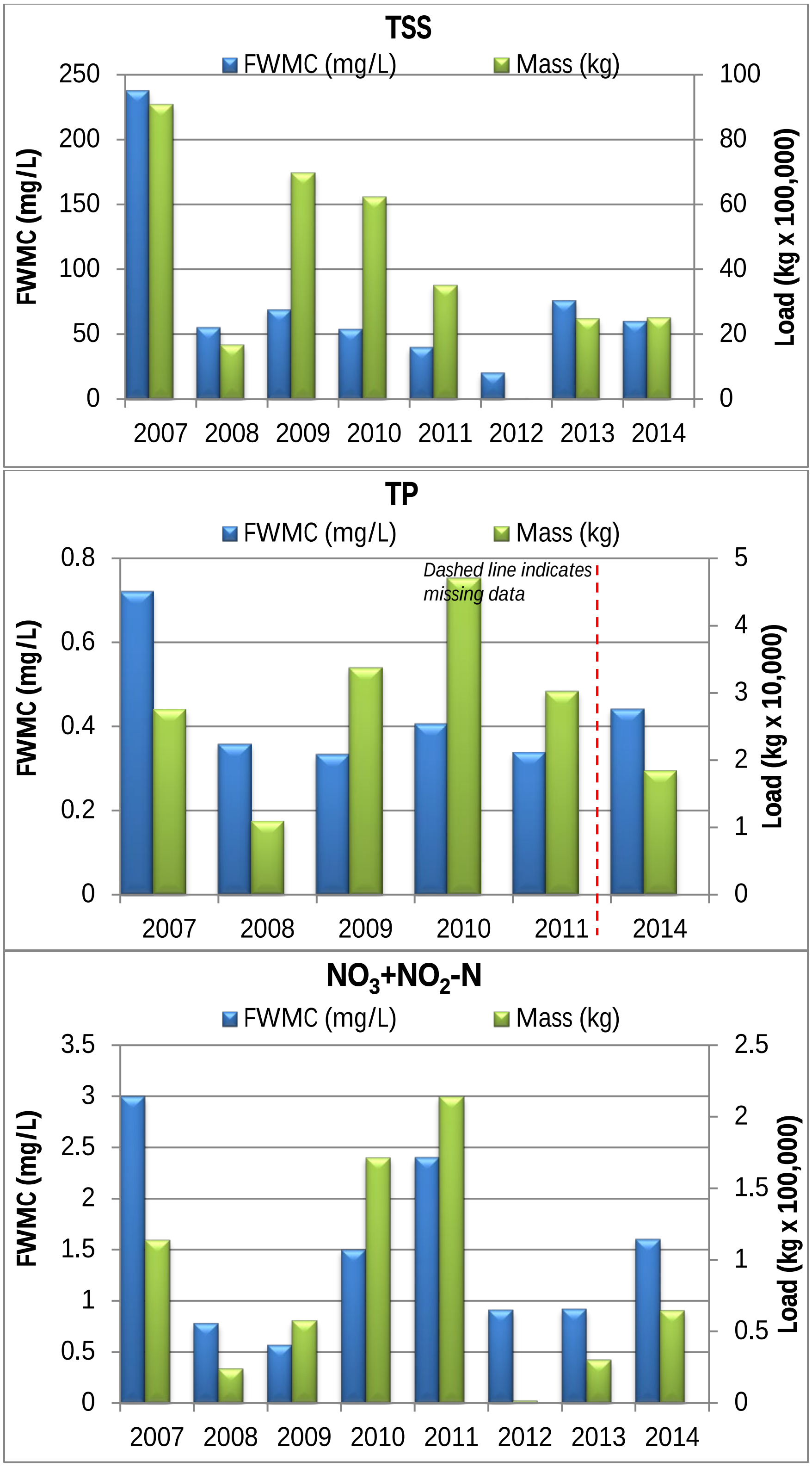

Figure 33. TSS, TP, and NO3+NO2-N flow weighted mean concentrations and loads for the Marsh River near Shelly, MN.

Stream flow

Stream flow data from the USGS's real-time streamflow gaging stations for two rivers within the Marsh River Watershed were analyzed for annual mean and summer monthly mean streamflow (July and August). Figure 34 (top) is a display of the annual mean streamflow for the Marsh River near Shelly, Minnesota from water years 1995 to 2014. The data shows that although streamflow appears to be decreasing, there is no statistically significant trend. Figure 34 (bottom) displays July and August mean flows for the same time frame and for the same waterbody. Graphically, the data appears to be decreasing in July and remaining constant in August, but July's drastic trendline is due to outliers. Figure 35 is the annual (top) and monthly (bottom) mean streamflow for the Red River of the North at Halstad, Minnesota for the same water years. Annual and monthly streamflow for July and August all appear to be increasing slightly, but not at a statistically significant rate. By way of comparison at a state level, summer month flows have declined at a statistically significant rate at a majority of streams selected randomly for a study of statewide trends (Streitz, 2011). For additional streamflow data throughout Minnesota, please visit the USGS website: http://waterdata.usgs.gov/mn/nwis/rt.

Figure 34. Annual mean (top) and monthly mean (bottom) streamflow for Marsh River near Shelly, MN (1995-2014) (Source: USGS, 2016b)

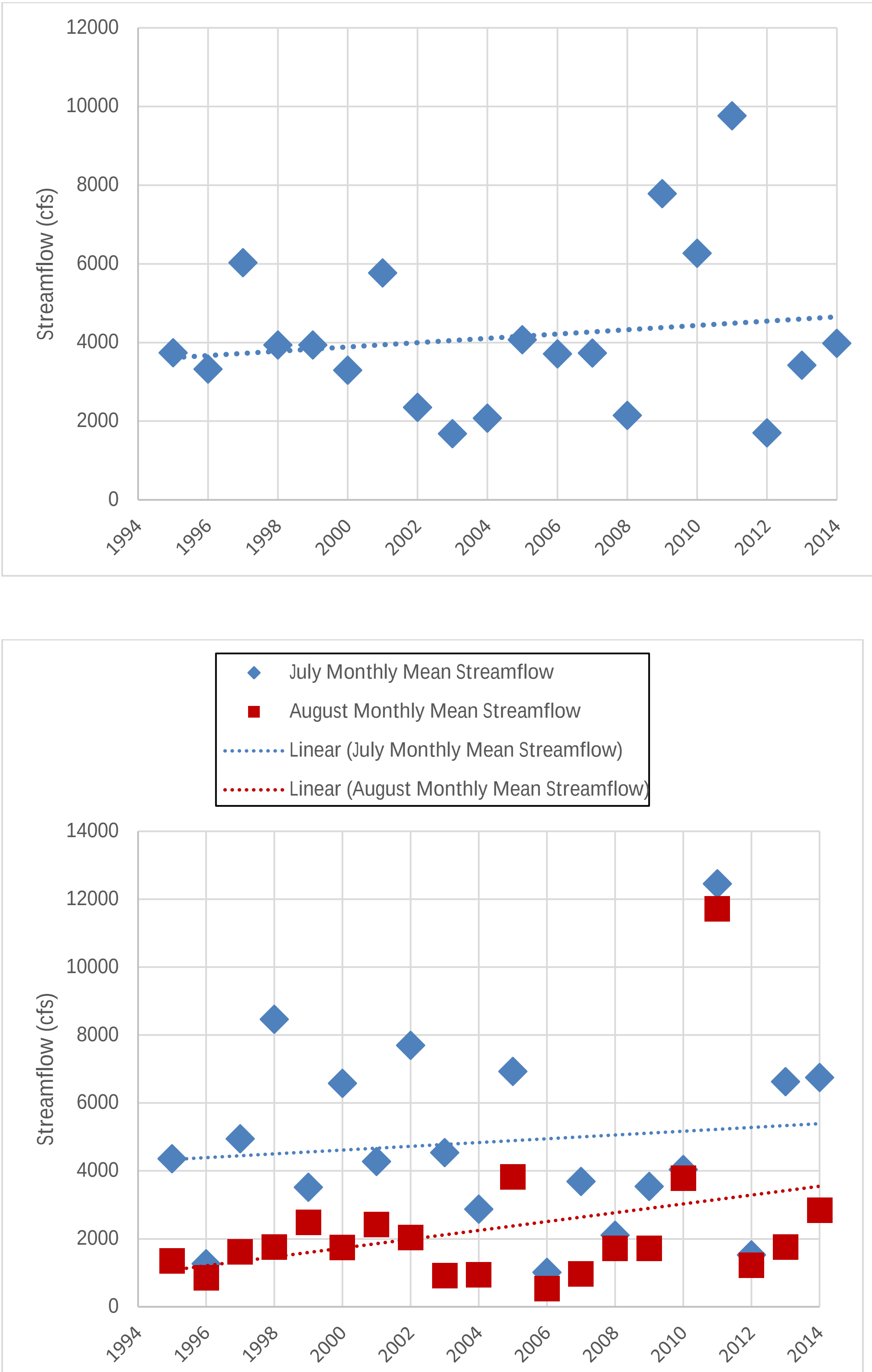

Figure 35. Annual mean (top) and monthly mean (bottom) streamflow for Red River of the North at Halstad, MN (1995-2014) (Source: USGS, 2016c)

Wetland condition

Wetland vegetation quality is generally high in Minnesota (Table 7). This is driven by the large share of wetlands located in Mixed Wood Shield (i.e., northern forest) Ecoregion where development and resulting stressors are much less widespread (and wetland condition is largely intact) compared to the rest of the state. Wetlands in exceptional or good biological condition have few (if any) changes in their expected native species composition or abundance distribution. Wetland vegetation quality is largely degraded in the remainder of the state, where non-native invasive plant species (most notably Reed canary grass and Narrow leaf/Hybrid cattail) have replaced native wetland plant communities over the majority of the remaining wetland extent (MPCA, 2015). High abundance of non-native invasive plant species is associated with a broad spectrum of wetland stressors and may also occur in the absence of stressors.

Table 7. Biological wetland condition statewide and by major ecoregions according to vegetation indicators. Results are expressed by extent (i.e., percentage of wetland acres) and include virtually all wetland types (MPCA 2015).

Condition Category	Statewide	Mixed Wood Shield	Mixed Wood Plains	Temperate Prairies
Exceptional	49%	64%	6%	7%
Good	18%	20%	12%	11%
Fair	23%	16%	42%	40%
Poor	10%		40%	42%

As the Marsh River Watershed is located entirely in the Temperate Prairies Ecoregion, the few remaining wetlands are expected to have fair-poor (or degraded) vegetation quality (Table 7). Plant communities assessed as fair-poor condition have had moderate to extreme changes (e.g., complete replacement of native species by non-native invasives) in their expected species composition and abundance distributions. Intact plant communities will be limited to a few specific locations (e.g., intact calcareous fens in the glacial lake beach ridges).

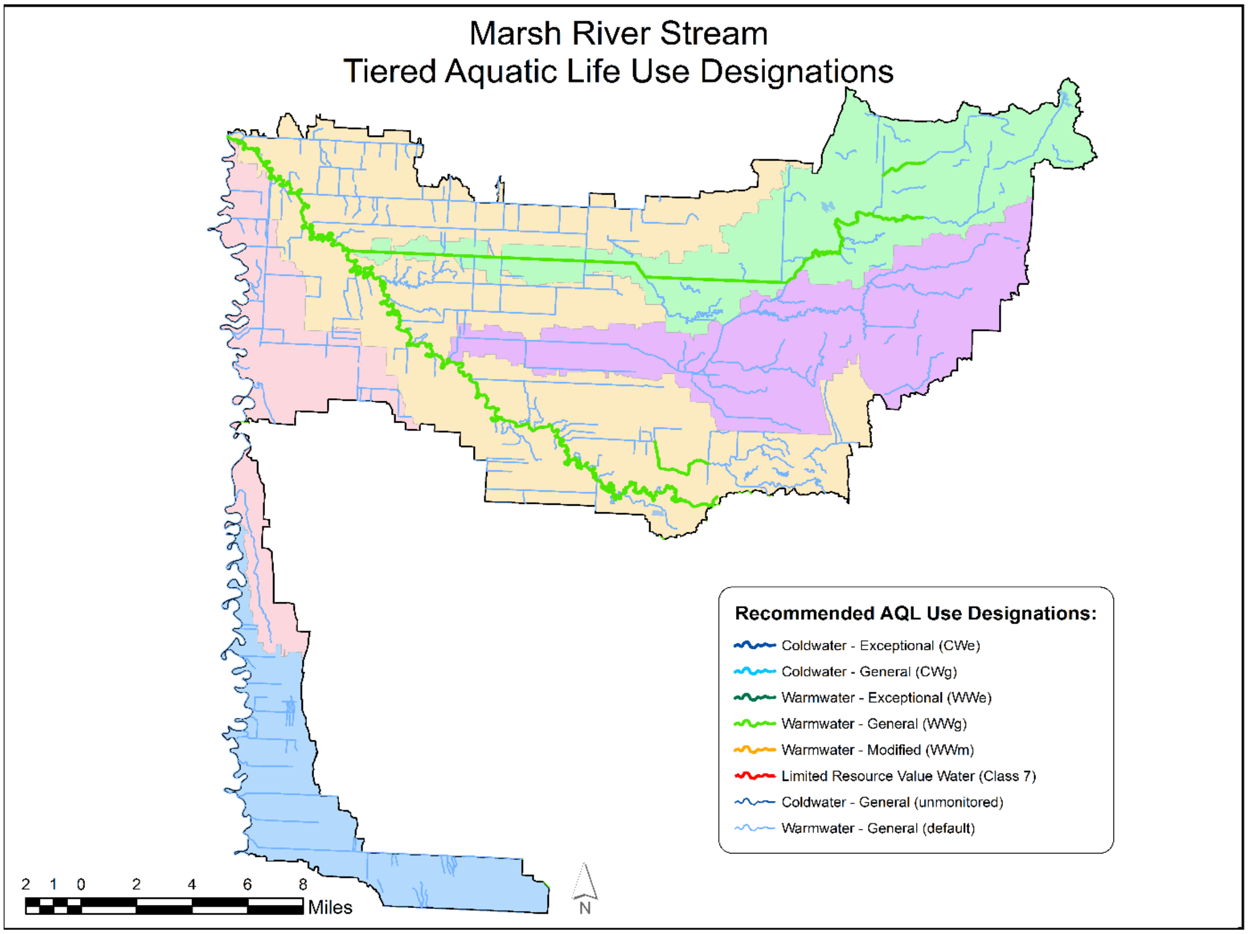

Figure 36. Stream tiered aquatic life use designations in the Marsh River Watershed.

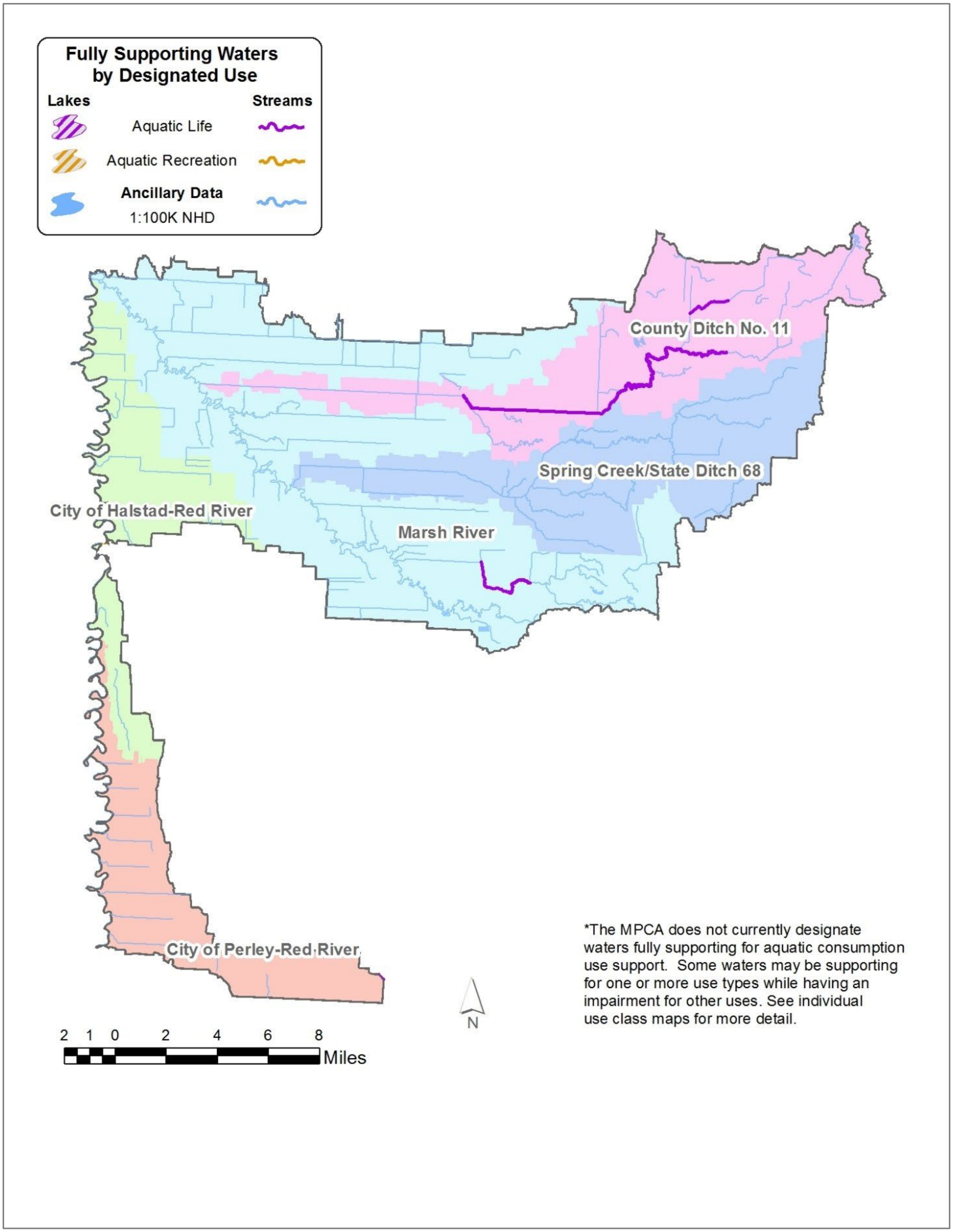

Figure 37. Fully supporting waters by designated use in the Marsh River Watershed.

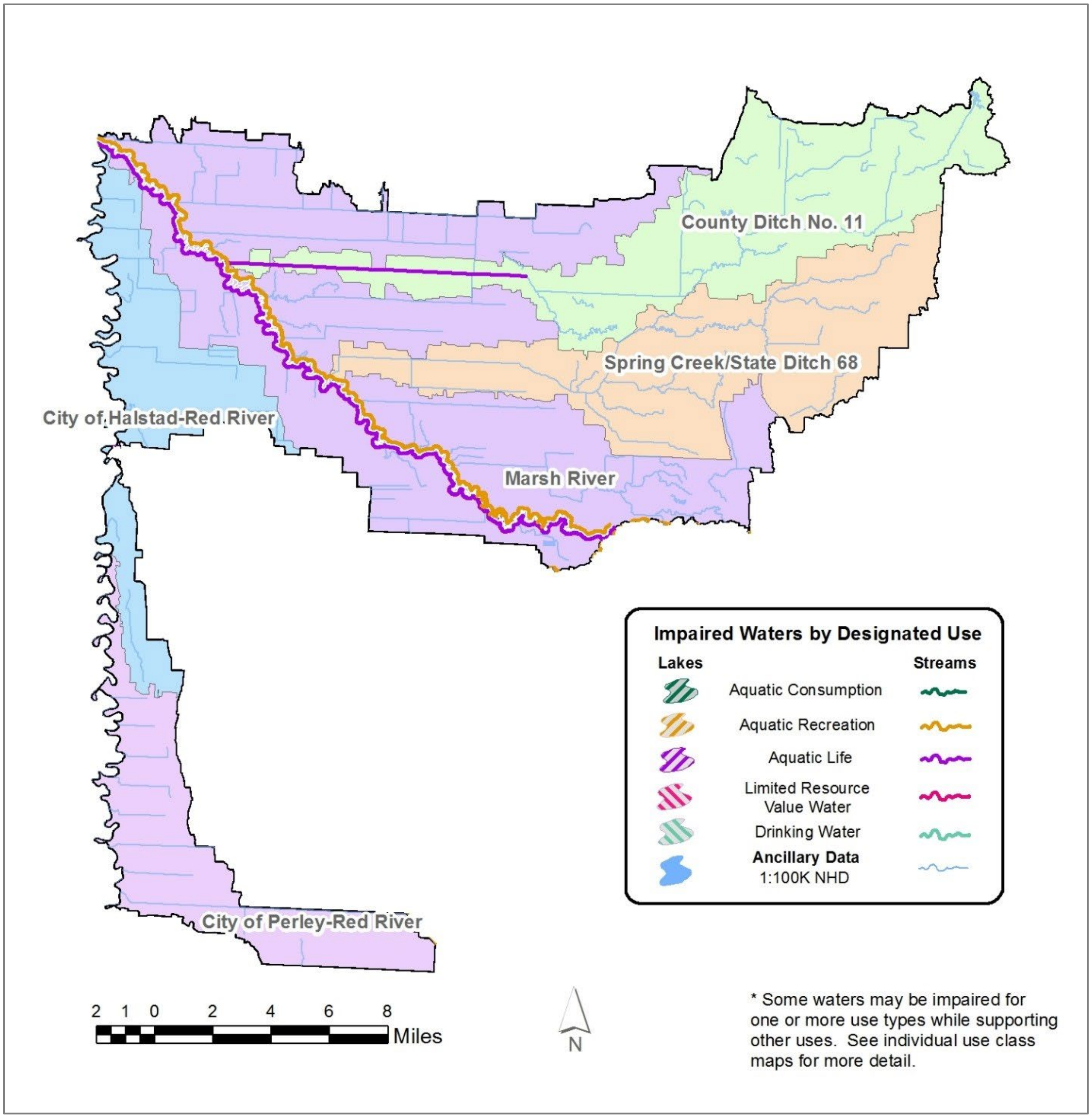

Figure 38. Impaired waters by designated use in the Marsh River Watershed.

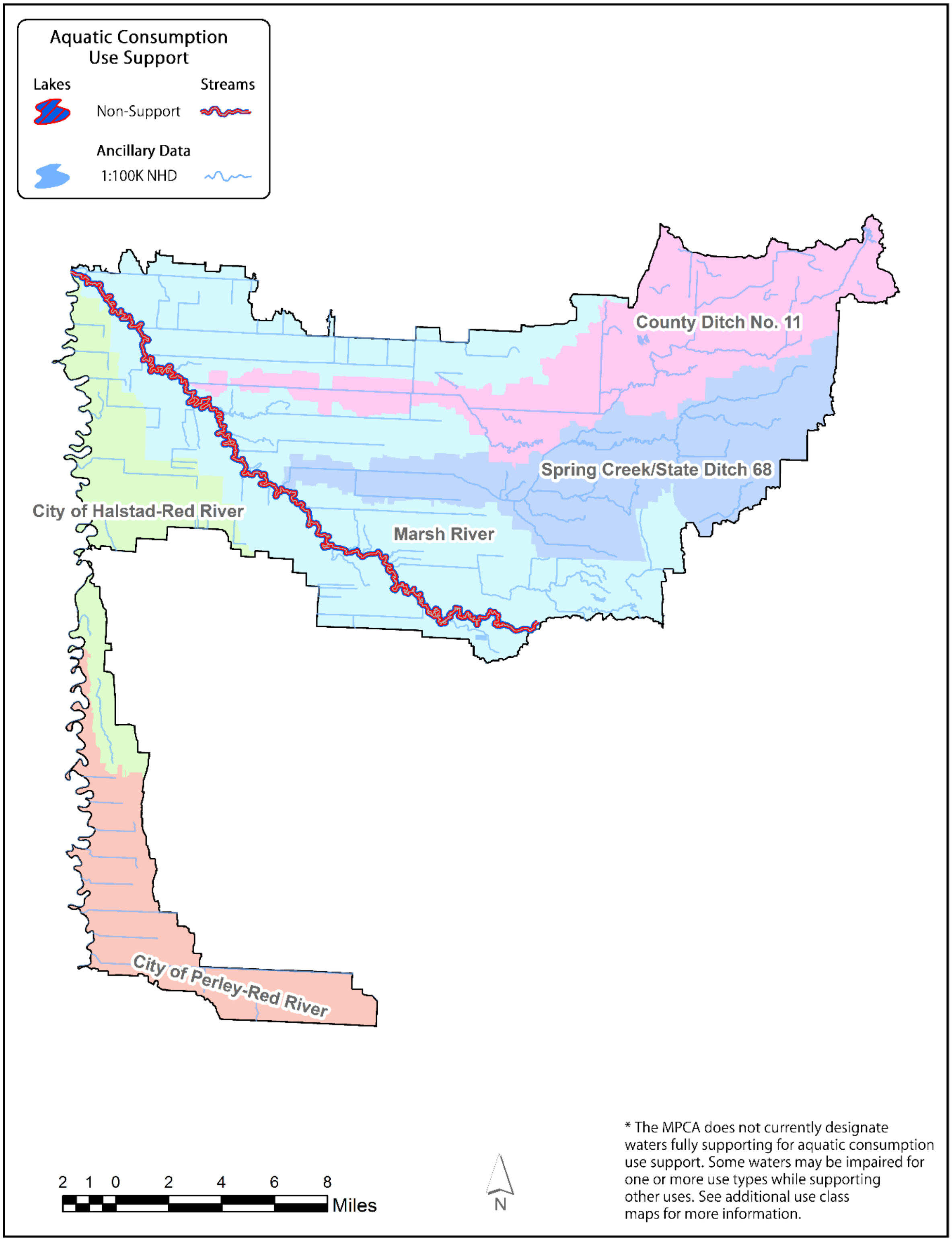

Figure 39. Aquatic consumption use support in the Marsh River Watershed.

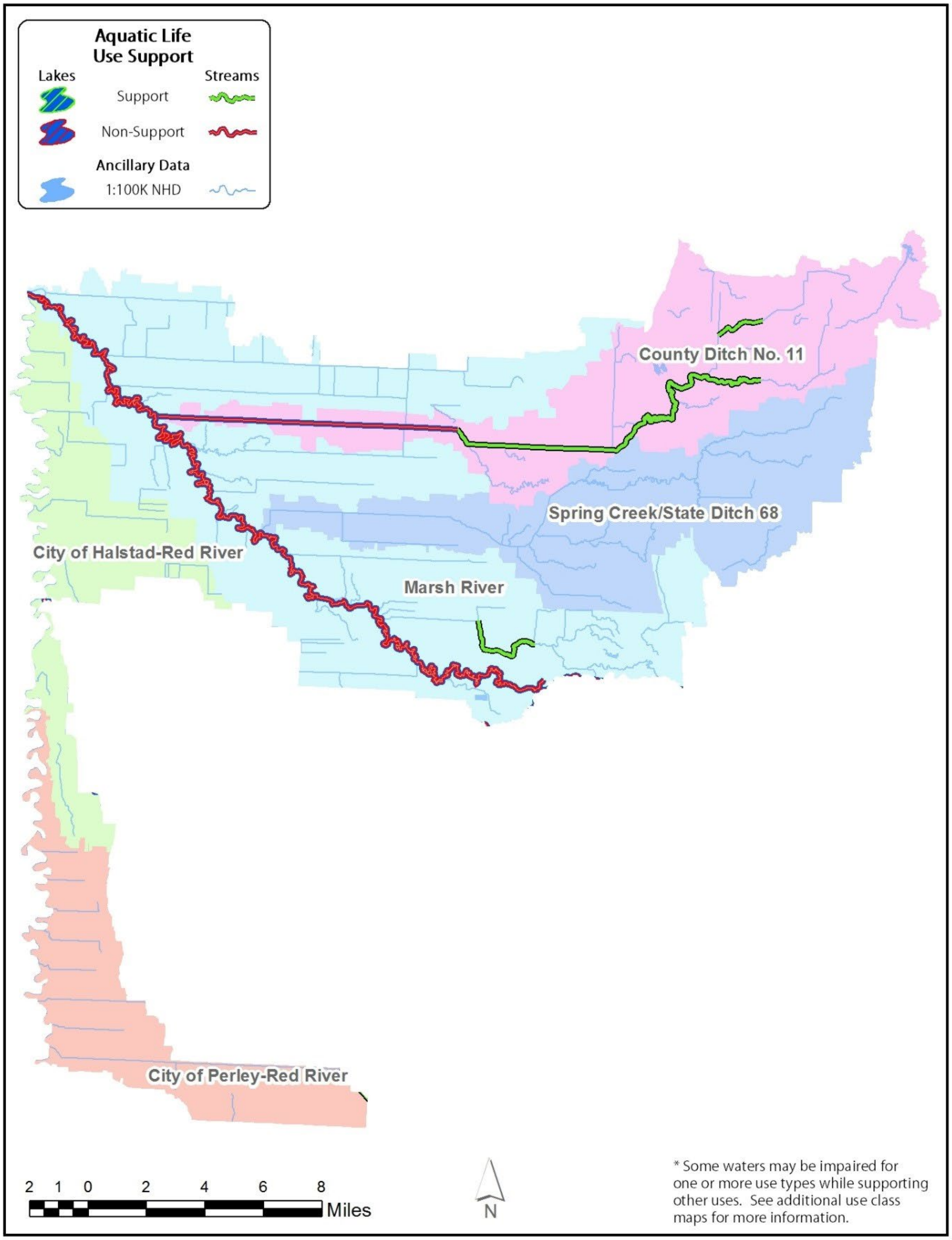

Figure 40. Aquatic life use support in the Marsh River Watershed.

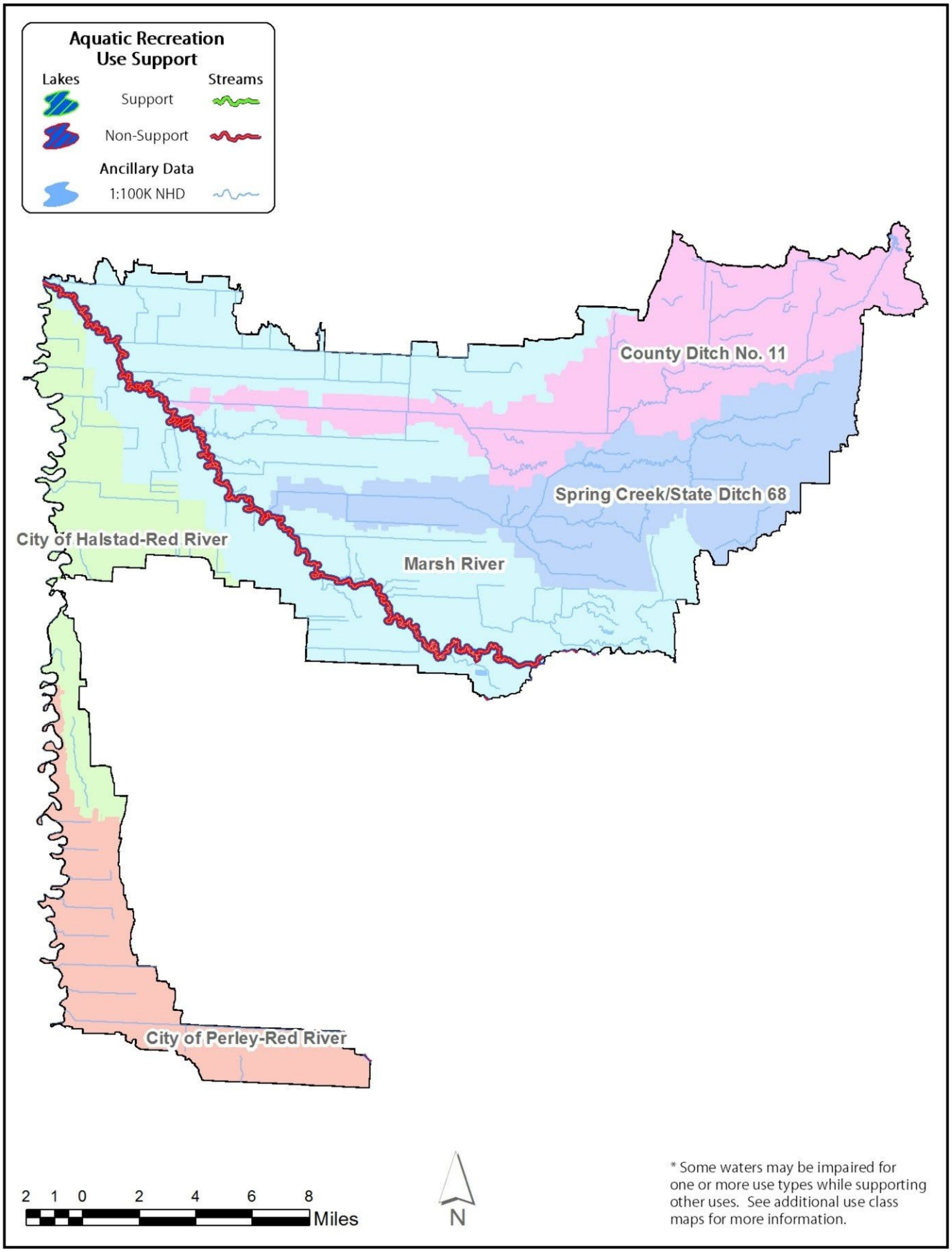

Figure 41. Aquatic recreation use support in the Marsh River Watershed.

Trends for the Marsh River Watershed

In June 2014, the MPCA published its final trend analysis of river monitoring data located statewide based on the historical Milestones Network. The network is a collection of 80 monitoring locations on rivers and streams across the state with good, long-term water quality data. The period of record is generally more than 30 years, through 2010, with monitoring at some sites going back to the 1950s. While the network of sites is not necessarily representative of Minnesota's rivers and streams as a whole, they do provide a valuable and widespread historical record for many of the state's waters. Starting in 2017, the MPCA will be switching to the Pollutant Load Monitoring Network for long term trend analysis on rivers and streams. Data from this program has much more robust sampling and will cover over 100 sites across the state.

Summaries and recommendations

True to its name, vast prairies and numerous shallow wetlands once dominated the landscape of the Marsh River Watershed. These distinctive traits had defined the watershed, formed from the remnants of historic Lake Agassiz. Many changes have occurred throughout the watershed in the last 150 years. Early settlers took advantage of the rich soils left by Lake Agassiz to grow crops and raise livestock. Extensive drainage ditch networks were developed to promote drainage of the many streams and wetlands, optimizing crop growth and aiding in flood relief. Sixty-seven percent of the streams within the watershed have been altered (Figure 8), including all of the tributaries flowing into the Marsh River on the Minnesota side. The Marsh River is the only remaining natural watercourse within the entire watershed.

Although drainage networks can boost crop yields, this practice can have a negative impact on aquatic life. Streams influenced by drainage activities have flow regimes that may not be able to support larger riverine fish species, and sensitive fishes and macroinvertebrates. High gradient culverts and drainage ditch networks within the Marsh River Watershed have altered hydrologic connectivity, creating fish barriers that obstruct migratory fishes from the Red River of the North. Larger riverine fish species such as Redhorses, cannot pass through the high gradient culverts like the one on County Ditch 11. Access to smaller headwater streams is crucial to riverine fishes, as these smaller systems are utilized for spawning. If this connection is broken, spawning success is greatly diminished. Drainage ditch networks can also lead to a lack of flow during portions of the year. The lack of sustained stream flow is a major stressor on fish and macroinvertebrate communities. During periods of low flow, crucial habitat may not be available and dissolved oxygen and stream temperature may undergo severe fluctuations. The loss of flow is specifically detrimental within the mainstem Marsh River. The headwaters of the Marsh River have been eliminated through a series of ditches. The primary ditch (Judicial Ditch 51) to the Marsh River is also connected to the Wild Rice River, and was historically created to move logs from the headwaters of the Wild Rice River to a logging facility just east of Ada. This ditch and another culvert crossing connect the Wild Rice River to a ditch system, creating a scenario where the headwaters to the Marsh River only receives flow during peak flows on the Wild Rice River.

The loss of flow to the Marsh River Watershed has been detrimental to aquatic habitat for fish and macroinvertebrates. Extra siltation and poor channel morphology were noted at each of the biological monitoring stations. The highest habitat values within the watershed on the Marsh River are just below the confluence of the high gradient culvert at the confluence of the Marsh River and County Ditch 11. The habitat is likely better because the additional flow coming through the culvert exposes coarse substrates. Unfortunately, the flow is short lived due to drainage practices that move the water off the landscape and through these stream systems quickly. The data does suggest, however, that the potential for higher quality fish and macroinvertebrate habitat within the Marsh River exists if continuous flow can be restored.

The clay dominated fine sediments left over by Lake Agassiz are easily erodible. The drainage ditch networks increase flow volume during high flow events that result in bank erosion and an increase in sediment load. The resulting excess sediment load fills the interstitial spaces of the coarse substrate that is utilized by sensitive gravel spawning fish and macroinvertebrates. In the Marsh River Watershed, two stream reaches do not support aquatic life based on biological or chemistry impairments. TSS, turbidity, and habitat loss are the leading drivers for the aquatic life impairments. In addition to the aquatic life impairments, the Marsh River will also be listed for E. coli bacteria as concentrations are chronically (and sometimes severely) elevated and may pose a risk to human health.

Although multiple impairments have been identified throughout the watershed, the Marsh River and its tributaries support extensive fish and macroinvertebrate populations. Thirty-six unique fish species (Appendix 4.1) and over 119 unique macroinvertebrate taxa (Appendix 4.2) were sampled during this survey. No Endangered or Species of Special Concern were identified during the sampling. Some actions that can be done to protect and promote a higher species diversity within the Marsh River Watershed include:

- Creating or strengthening buffers along the riparian zone of streams and ditches using native perennial vegetation and trees.
- Utilizing practices that reduce flooding and increase drainage without compromising the hydrologic connectivity.

Additional protections should also be considered for groundwater to aid in both the quantity and quality of the groundwater within the watershed. Quantity is based on the amount of water withdrawn versus the amount of water being recharged to the aquifer. The primary groundwater withdrawal is for municipal/public water supply usage. Groundwater withdrawals decreased by 25% from 1994 to 2013 at a statistically significant rate ($p<0.001$). Since this watershed has a low potential groundwater recharge rate it is important to track development pressure, which currently is considered low to moderate within the basin. In this region, land is occasionally converted from farms to development for business, recreation and country homes (USDA NRCS, 2007). At this time there are no groundwater elevation observation data for this watershed at this time.

There is a limited amount of groundwater quality data available specifically for the Marsh River Watershed. Baseline water quality data indicates that the northwest region has higher concentrations of chemicals in the sand and gravel aquifers; however, this is primarily associated with cretaceous bedrock, which is present in only small portions in the southern tip of the specified watershed. There were high numbers of exceedances to the arsenic MCL for drinking water in private wells for this area. Arsenic is primarily naturally occurring and can be linked to presence of a clay layer and low dissolved oxygen levels, often associated with the Des Moines glacial lobe till, which is abundant in this region. Furthermore, the moderate to high levels of pollution sensitivity of near-surface materials in the eastern portion of the watershed should be considered, especially during development and other land use changes. While it may appear that this watershed is not at risk at this time for significant groundwater changes, it is important to continue to monitor potentially sensitive areas in order to inhibit possible water pollution.

Additional and continued monitoring will increase the understanding of the health of the watershed and its groundwater resources and aid in identifying the extent of the issues present and risk associated. Increased localized monitoring efforts will help accurately define the risks and extent of any issues within the watershed. Adoption of BMPs will benefit both surface and groundwater in the Marsh River Watershed.

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Appendix 1 – Water chemistry definitions

Dissolved oxygen (DO) - Oxygen dissolved in water required by aquatic life for metabolism. Dissolved oxygen enters into water from the atmosphere by diffusion and from algae and aquatic plants when they photosynthesize. Dissolved oxygen is removed from the water when organisms metabolize or breathe. Low DO often occurs when organic matter or nutrient inputs are high, and light inputs are low.

Escherichia coli (E. coli) - A type of fecal coliform bacteria that comes from human and animal waste. E. coli levels aid in the determination of whether or not fresh water is safe for recreation. Disease-causing bacteria, viruses and protozoans may be present in water that has elevated levels of E. coli.

Nitrate plus Nitrite – Nitrogen - Nitrate and nitrite-nitrogen are inorganic forms of nitrogen present within the environment that are formed through the oxidation of ammonia-nitrogen by nitrifying bacteria (nitrification). Ammonia-nitrogen is found in fertilizers, septic systems and animal waste. Once converted from ammonia-nitrogen to nitrate and nitrite-nitrogen, these species can stimulate excessive levels of algae in streams. Because nitrate and nitrite-nitrogen are water soluble, transport to surface waters is enhanced through agricultural drainage. The ability of nitrite-nitrogen to be readily converted to nitrate-nitrogen is the basis for the combined laboratory analysis of nitrate plus nitrite-nitrogen (nitrate-N), with nitrite-nitrogen typically making up a small proportion of the combined total concentration. These and other forms of nitrogen exist naturally in aquatic environments; however, concentrations can vary drastically depending on season, biological activity, and anthropogenic inputs.

Orthophosphate - Orthophosphate is a water soluble form of phosphorus that is readily available to algae (bioavailable). While orthophosphates occur naturally in the environment, river and stream concentrations may become elevated with additional inputs from wastewater treatment plants, noncompliant septic systems and fertilizers in urban and agricultural runoff.

pH - A measure of the level of acidity in water. Rainfall is naturally acidic, but fossil fuel combustion has made rain more acid. The acidity of rainfall is often reduced by other elements in the soil. As such, water running into streams is often neutralized to a level acceptable for most aquatic life. Only when neutralizing elements in soils are depleted, or if rain enters streams directly, does stream acidity increase.

Total Kjeldahl nitrogen (TKN) - The combination of organically bound nitrogen and ammonia in wastewater. TKN is usually much higher in untreated waste samples then in effluent samples.

Total phosphorus (TP) - Nitrogen (N), phosphorus (P) and potassium (K) are essential macronutrients and are required for growth by all animals and plants. Increasing the amount of phosphorus entering the system therefore increases the growth of aquatic plants and other organisms. Excessive levels of Phosphorous over stimulate aquatic growth and resulting in the progressive deterioration of water quality from overstimulation of nutrients, called eutrophication. Elevated levels of phosphorus can result in: increased algae growth, reduced water clarity, reduced oxygen in the water, fish kills, altered fisheries and toxins from cyanobacteria (blue green algae) which can affect human and animal health.

Total suspended Solids (TSS) – TSS and turbidity are highly correlated. Turbidity is a measure of the lack of transparency or "cloudiness" of water due to the presence of suspended and colloidal materials such as clay, silt, finely divided organic and inorganic matter and plankton or other microscopic organisms. The greater the level of TSS, the murkier the water appears and the higher the measured turbidity.

Higher turbidity results in less light penetration, which may harm beneficial aquatic species and may favor undesirable algae species. An overabundance of algae can lead to increases in turbidity, further compounding the problem.

Unionized ammonia (NH3) - Ammonia is present in aquatic systems mainly as the dissociated ion $NH4^{+}$, which is rapidly taken up by phytoplankton and other aquatic plants for growth. Ammonia is an excretory product of aquatic animals. As it comes in contact with water, ammonia dissociates into $NH4^{+}$ ions and ^{-}OH ions (ammonium hydroxide). If pH levels increase, the ammonium hydroxide becomes toxic to both plants and animals.

Appendix 2.1 – Intensive watershed monitoring water chemistry stations in the Marsh River Watershed

EQuIS ID	Biological Station ID	AUID	Waterbody Name	Location	Aggregated 12-digit HUC
S007-785	14RD060	09020107-517	County Ditch 11	Downstream of CSAH 17, 5 mi. SE of Shelly	0902010705-02, County Ditch No. 11
S005-789	14RD072	09020107-503	Marsh River	Upstream of CR 129, 4 mi. NE of Halstad	0902010705-01, Marsh River
S007-786	14RD061	09020107-503	Marsh River	Upstream of CR 3, 0.5 mi. W of Shelly	0902010705-01, Marsh River

Appendix 2.2 – Intensive watershed monitoring biological monitoring stations in the Marsh River Watershed

AUID	Biological Station ID	Waterbody Name	Biological Station Location	County	Aggregated 12-digit HUC
09020107-518	05RD055	Judicial Ditch 51	~0.25 mi. S of CR 163, ~mile NE of Ada	Norman	0902010705-01, Marsh River
09020107-503	05RD113	Marsh River	Downstream of 130th Street, 2.5 miles SE of Shelly	Norman	0902010705-01, Marsh River
09020107-516	07RD008	County Ditch 66	Upstream of CR 46, 7 Mi. NE of Ada	Norman	0902010705-02, County Ditch No. 11
09020107-517	14RD060	County Ditch 11	Downstream of CSAH 17, 5 mi. SE of Shelly	Norman	0902010705-02, County Ditch No. 11
09020107-503	14RD061	Marsh River	Upstream of CR 3, 0.5 mi. W of Shelly	Norman	0902010705-01, Marsh River
09020107-508	14RD071	Spring Creek	Upstream of 310th St, 7.5 mi. NE of Hadler	Norman	0902010705-02, County Ditch No. 11
09020107-503	14RD072	Marsh River	Upstream of CR 129, 4 mi. NE of Halstad	Norman	0902010705-01, Marsh River
09020107-521	14RD075	County Ditch 45	Downstream of 340th St, 3 mi. W/NW of Flaming	Norman	0902010705-02, County Ditch No. 11

Appendix 3.1 – Minnesota statewide IBI thresholds and confidence limits

Class #	Class Name	Use Class	Exceptional Use Threshold	General Use Threshold	Modified Use Threshold	Confidence Limit
Fish						
1	Southern Rivers	2B, 2C	71	49	NA	±11
2	Southern Streams	2B, 2C	66	50	35	±9
3	Southern Headwaters	2B, 2C	74	55	33	±7
10	Southern Coldwater	2A	82	50	NA	±9
4	Northern Rivers	2B, 2C	67	38	NA	±9
5	Northern Streams	2B, 2C	61	47	35	±9
6	Northern Headwaters	2B, 2C	68	42	23	±16
7	Low Gradient	2B, 2C	70	42	15	±10
11	Northern Coldwater	2A	60	35	NA	±10
Invertebrates						
1	Northern Forest Rivers	2B, 2C	77	49	NA	±10.8
2	Prairie Forest Rivers	2B, 2C	63	31	NA	±10.8
3	Northern Forest Streams RR	2B, 2C	82	53	NA	±12.6
4	Northern Forest Streams GP	2B, 2C	76	51	37	±13.6
5	Southern Streams RR	2B, 2C	62	37	24	±12.6
6	Southern Forest Streams GP	2B, 2C	66	43	30	±13.6
7	Prairie Streams GP	2B, 2C	69	41	22	±13.6
8	Northern Coldwater	2A	52	32	NA	±12.4
9	Southern Coldwater	2A	72	43	NA	±13.8

Appendix 3.2 – Biological monitoring results – fish IBI (assessable reaches)

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Fish Class	Threshold	FIBI	Visit Date
HUC 12: 0902010705-01 (Marsh River)							
09020107-503	05RD113	Marsh River	248.13	Southern Streams	50	47.65	23-Aug-05
09020107-503	05RD113	Marsh River	248.13	Southern Streams	50	53.20	07-Jul-14
09020107-503	14RD061	Marsh River	275.44	Southern Streams	50	55.34	30-Jul-14
09020107-503	14RD072	Marsh River	160.06	Southern Streams	50	39.39	07-Jul-14
09020107-518	05RD055	Judicial Ditch 51	16.08	Low Gradient	15	50.39	09-Aug-06
HUC 12: 0902010705-02 (County Ditch No. 11)							
09020107-521	14RD075	County Ditch 45	5.09	Northern Headwaters	42	41.94	10-Jun-14
09020107-508	14RD071	Spring Creek	40.89	Northern Headwaters	42	35.76	11-Jun-14
09020107-508	14RD071	Spring Creek	40.89	Northern Headwaters	42	47.79	17-Jul-14
09020107-516	07RD008	County Ditch 66	48.93	Northern Headwaters	23	41.42	08-Aug-07
09020107-517	14RD060	County Ditch 11	71.50	Southern Streams	35	0.00	11-Jun-14
09020107-517	14RD060	County Ditch 11	71.50	Southern Streams	35	0.00	07-Jul-14

Appendix 3.3 – Biological monitoring results-macroinvertebrate IBI (assessable reaches)

National Hydrography Dataset (NHD) Assessment Segment AUID	Biological Station ID	Stream Segment Name	Drainage Area Mi^2	Invert Class	Threshold	MIBI	Visit Date
HUC 12: 0902010705-01 (Marsh River)							
09020107-503	05RD113	Marsh River	248.13	Prairie Streams GP	41	20.9	02-Sep-2005
09020107-503	05RD113	Marsh River	248.13	Prairie Streams GP	41	17.9	06-Aug-2014
09020107-503	14RD061	Marsh River	275.44	Prairie Streams GP	41	34.9	30-Jul-2014
09020107-503	14RD072	Marsh River	160.06	Prairie Streams GP	41	13.0	30-Jul-2014
HUC 12: 0902010705-02 (County Ditch No. 11)							
09020107-521	14RD075	County Ditch 45	5.09	Southern Streams RR	37	41.2	06-Aug-2014
09020107-508	14RD071	Spring Creek	40.89	Prairie Streams GP	41	45.1	06-Aug-2014
09020107-516	07RD008	County Ditch 66	48.93	Prairie Streams GP	41	36.9	15-Aug-2007
09020107-517	14RD060	County Ditch 11	71.50	Prairie Streams GP	41	34.7	06-Aug-2014

Appendix 4.1 – Fish species found during biological monitoring surveys

Common Name	Quantity of Stations Where Present	Quantity of Individuals Collected
Bigmouth Shiner	3	267
Black Bullhead	3	364
Black Crappie	1	1
Blackside Darter	2	8
Bluegill	2	14
Brook Stickleback	8	433
Carmine Shiner	1	1
Central Mudminnow	7	205
Channel Catfish	2	4
Common Carp	1	8
Common Shiner	2	13
Creek Chub	5	419
Fathead Minnow	6	3161
Freshwater Drum	1	1
Golden Redhorse	1	1
Goldeye	1	1
Green Sunfish	1	3
Hybrid Sunfish	1	1
Iowa Darter	1	16
Johnny Darter	2	41
Northern Pike	3	9
Northern Redbelly Dace	5	548
Orangespotted Sunfish	1	2
Pearl Dace	6	147
Rock Bass	1	1
Sand Shiner	3	29
Sauger	1	1
Shorthead Redhorse	1	2
Smallmouth Bass	2	4
Spotfin Shiner	4	339
Tadpole Madtom	1	1
Trout-perch	1	1
Walleye	2	5
White Bass	1	3
White Sucker	5	280
Yellow Perch	2	12

Appendix 4.2 – Macroinvertebrate species found during biological monitoring surveys

Taxonomic Name	Quantity of Stations Where Present	Quantity of Individuals Collected
Amphipoda		
Hyalella	6	435
Basommatophora		
Ferrissia	1	12
Fossaria	1	1
Gyraulus	1	73
Helisoma	1	1
Lymnaeidae	1	2
Physa	1	88
Physella	6	181
Planorbella	1	1
Planorbidae	1	1
Stagnicola	1	1
Coleoptera		
Dubiraphia	3	38
Dytiscidae	2	2
Gymnochthebius	1	1
Haliplus	2	4
Helichus	1	2
Helophorus	2	2
Hydraena	1	1
Laccobius	1	1
Laccophilus	1	1
Macronychus glabratus	1	1
Ochthebius	2	3
Optioservus	1	10
Peltodytes	1	1
Stenelmis	2	16
Decapoda		
Orconectes	2	9
Diptera		
Ablabesmyia	5	6
Anopheles	1	1
Atherix	1	1

Taxonomic Name	Quantity of Stations Where Present	Quantity of Individuals Collected
Atrichopogon	2	4
Brillia	1	2
Ceratopogonidae	1	1
Ceratopogoninae	1	1
Chironomini	1	1
Cladotanytarsus	1	5
Corynoneura	1	1
Cricotopus	2	12
Cryptochironomus	3	3
Dicrotendipes	5	18
Empididae	2	2
Ephydridae	2	2
Forcipomyiinae	1	2
Glyptotendipes	4	58
Hemerodromia	1	3
Labrundinia	1	1
Limnophyes	1	1
Micropsectra	1	2
Microtendipes	4	8
Nanocladius	1	1
Parachironomus	1	1
Paratanytarsus	4	22
Phaenopsectra	2	6
Polypedilum	6	223
Procladius	2	4
Rheocricotopus	1	1
Rheotanytarsus	6	84
Saetheria	1	1
Simulium	4	48
Stempellina	1	1
Stenochironomus	3	29
Tabanidae	1	1
Tanypodinae	2	5
Tanytarsus	5	22
Thienemanniella	1	1
Thienemannimyia	5	47
Thienemannimyia Gr.	1	1

Taxonomic Name	Quantity of Stations Where Present	Quantity of Individuals Collected
Xenochironomus	1	1
Xenochironomus xenolabis	1	2
Ephemeroptera		
Acerpenna	1	2
Acerpenna pygmaea	1	1
Baetidae	2	3
Baetis	1	10
Baetis brunneicolor	1	12
Baetis flavistriga	2	10
Baetis intercalaris	1	5
Caenis	1	80
Caenis diminuta	4	182
Caenis hilaris	1	15
Heptagenia	1	1
Heptageniidae	2	2
Labiobaetis frondalis	2	10
Leptophlebiidae	1	1
Plauditus	2	2
Procloeon	1	3
Pseudocloeon	1	7
Stenacron	2	10
Haplotaxida		
Oligochaeta	2	4
Hemiptera		
Aquarius	1	1
Corixidae	3	9
Gerridae	1	1
Neoplea striola	3	10
Palmacorixa	1	1
Sigara	1	2
Heterostropha		
Valvata	1	1
Megaloptera		
Sialis	1	1
Neotaenioglossa		
Hydrobiidae	1	5
Odonata		
Aeshna	2	5
Anisoptera	1	2
Boyeria vinosa	1	1
Calopteryx aequabilis	1	1

Taxonomic Name	Quantity of Stations Where Present	Quantity of Individuals Collected
Coenagrionidae	4	25
Enallagma	1	2
Hetaerina	1	1
Trichoptera		
Ceratopsyche slossonae	1	15
Cheumatopsyche	5	69
Hydropsyche	3	10
Hydropsychidae	4	89
Hydroptila	6	24
Hydroptilidae	2	3
Leptoceridae	2	3
Nectopsyche diarina	1	3
Oecetis	1	1
Oecetis testacea	1	2
Polycentropodidae	1	1
Unclassified		
Acari	6	26
Hirudinea	6	10
Nemata	2	2
Veneroida		
Pisidiidae	4	21

Appendix 5 – Minnesota Stream Habitat Assessment results

Habitat information documented during each fish-sampling visit is provided. This table conveys the results of the MSHA survey, which evaluates the section of stream sampled for biology and can provide an indication of potential stressors (e.g., siltation, eutrophication) impacting fish and macroinvertebrate communities. The MSHA score is comprised of five scoring categories including adjacent land use, riparian zone, substrate, fish cover and channel morphology, which are summed for a total possible score of 100 points. Scores for each category, a summation of the total MSHA score, and a narrative habitat condition rating are provided in the tables for each biological monitoring station. Where multiple visits occur at the same station, the scores from each visit have been averaged. The final row in each table displays average MSHA scores and a rating for the aggregated 12-HUC subwatershed.

# Visits	Biological Station ID	Reach Name	Land Use (0-5)	Riparian (0-14)	Substrate (0-28)	Fish Cover (0-18)	Channel Morph. (0-35)	MSHA Score (0-100)	MSHA Rating
1	05RD055	Judicial Ditch 51	0	6.5	8	10	7	31.5	Poor
1	14RD061	Marsh River	3	9	14.6	6	13	45.6	Fair
2	05RD113	Marsh River	1.25	10	12.6	8.5	12.5	44.8	Poor
3	14RD072	Marsh River	2.8	9.5	7	10.6	8.3	38.2	Poor
Average Habitat Results: Marsh River			1.76	8.75	10.55	8.77	10.2	40.03	Poor
2	14RD075	County Ditch 45	0	5	19.5	11.5	18.5	54.5	Fair
3	14RD071	Spring Creek	1.5	8	14.4	10.6	14	48.5	Fair
2	07RD008	County Ditch 66	0	8	11	9	19	47	Fair
3	14RD060	County Ditch 11	0	7.3	10.6	9	7.6	34.5	Poor
Average Habitat Results: County Ditch No. 11 Aggregated 12-HUC			0.38	7.08	13.88	10.03	14.78	46.15	Fair

Qualitative habitat ratings

- = Good: MSHA score above the median of the least-disturbed sites (MSHA>66)
- = Fair: MSHA score between the median of the least-disturbed sites and the median of the most-disturbed sites (45 < MSHA < 66)
- = Poor: MSHA score below the median of the most-disturbed sites (MSHA<45)