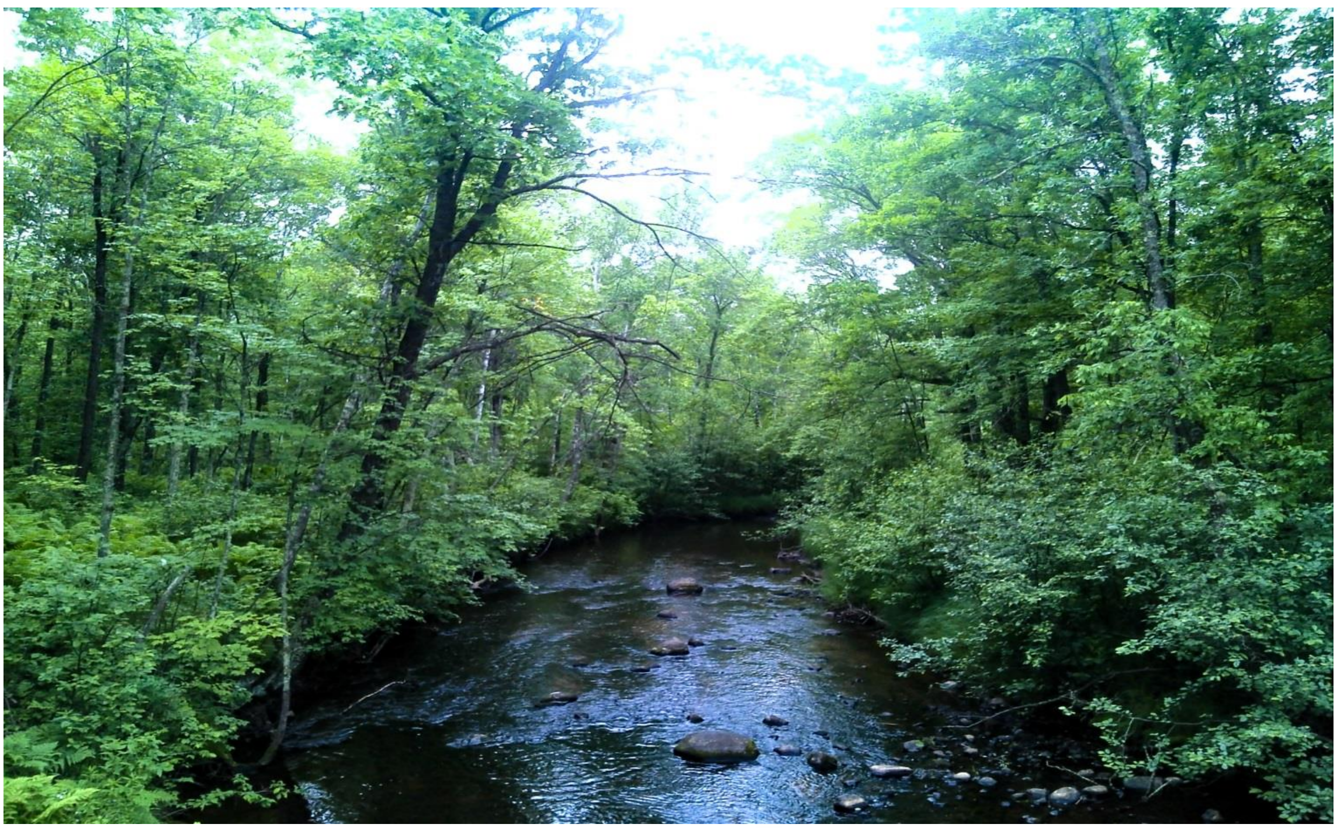
Watershed health

May 2019

Upper St. Croix River Monitoring and Assessment Report



MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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List of acronyms

CI Confidence Interval

CLMP Citizen Lake Monitoring Program

CR County Road

CSAH County State Aid Highway

CSMP Citizen Stream Monitoring Program

CWA Clean Water Act

CWLA Clean Water Legacy Act

DNR Minnesota Department of Natural Resources

DOP Dissolved Orthophosphate

EQuIS Environmental Quality Information System

EX Exceeds Criteria (Bacteria)

EXP Exceeds Criteria, Potential Impairment

EXS Exceeds Criteria, Potential Severe Impairment

FS Full Support

FWMC Flow Weighted Mean Concentration

H Hypereutrophic

HUC Hydrologic Unit Code

IBI Index of Biotic Integrity

IF Insufficient Information

K Potassium

LRVW Limited Resource Value Water

MDA Minnesota Department of Agriculture

MDH Minnesota Department of Health

MINLEAP Minnesota Lake Eutrophication Analysis Procedure

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

NS Not Supporting

OP Orthophosphate

P Phosphorous

PCB Poly Chlorinated Biphenyls

RNR River Nutrient Region

SWAG Surface Water Assessment Grant

SWCD Soil and Water Conservation District

SWUD State Water Use Database

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

WID Waterbody Identification Number

WPLMN Watershed Pollutant Load Monitoring Network

Executive summary

The Upper St. Croix River Watershed drains an area of approximately 2,057 square miles (1,316,404 acres) in eastern Minnesota and northwestern Wisconsin. The Minnesota subwatersheds flow into the St. Croix River and the St. Croix River is the border of Minnesota and Wisconsin. However, the St. Croix River is not within the bounds of this watershed. Approximately 26% of the watershed area lies within Minnesota's Pine County, spanning an area from the Wisconsin Border on the east to the Snake and Kettle River Watersheds to the west and south. The Kettle River Watershed splits Chases Brook-St. Croix River subwatershed off from the other seven subwatersheds in the Upper St. Croix River Watershed.

In 2016, the Minnesota Pollution Control Agency (MPCA) began a two-year, intensive watershed monitoring (IWM) project in Upper St. Croix River Watershed. This project was designed to assess the quality of the lakes and streams in the watershed through both biological and water chemistry monitoring. MPCA biomonitoring staff evaluated fish and macroinvertebrate communities at 34 unique monitoring stations across 28 assessment reaches of stream. Through grant agreements with the MPCA the University of Minnesota's Natural Resources Research Institute (NRRI) completed stream chemistry sampling at eight stream locations at or near the outlets of each major subwatershed. Additionally, they monitored five lakes in the Upper St. Croix Watershed including Razor, Hay Creek Flowage, Rock, Tamarack and Grace Lakes for assessment of aquatic recreation. Four stream sites were monitored for stream clarity by citizen volunteers. Overall, four lakes and 34 stream segments were assessed for aquatic life and/or aquatic recreation (where insufficient data existed, assessments were not made).

The high flow event that occurred prior to the 2016 sampling event had an impact on many streams, but due to excellent water quality, intact riparian zones, and high quality habitats throughout the watershed, all follow-up sampling showed well recovered macroinvertebrate communities. The presence of five stream sections identified as having exceptional aquatic life use for both fish and macroinvertebrate assemblages, with several more stream sections with one exceptional assemblage, shows that the streams of the Upper St. Croix Watershed are amongst the most biologically intact, healthy, and resilient of any watershed in Minnesota. The exceptional designation holds more pristine streams to a higher standard than stream segments in the general or modified use category.

Twenty-nine stream reaches (86% of assessed reaches) were determined to be fully supporting aquatic life for general use waters. Four streams (< 14% of assessed reaches) were determined to be not supporting aquatic life for general use waters.

Fish communities throughout the Upper St. Croix River Watershed were characterized by species that are sensitive to declines in habitat and water quality; species that are not capable of persisting in degraded and sub-marginal habitats. Commonly fish species were collected that are not tolerant of disturbed conditions these fishes include among others: brook trout, brown trout, and longnose dace, and burbot. Fish communities were diverse and balanced in most stream reaches; aquatic life use standards were met at 93% of the streams that were assessed for fish.

A similar pattern was noted among stream macroinvertebrates in the Upper St. Croix River Watershed; 93% of assessed stream reaches had macroinvertebrate communities that were full support for aquatic life. With few exceptions, the condition of the macroinvertebrate community throughout the watershed showed a high level of integrity, with diverse communities and a prevalence of sensitive taxa. Most streams sampled had high quality bed and bank habitat, as well flows adequate to maintain typical lotic aquatic macroinvertebrate communities; when these conditions persist, a healthy and resilient assemblage is the typical result.

Stream water chemistry data indicate overall good water quality in the watershed. Only one reach of Sand Creek was determined to have an impairment for total suspended solids. Elevated levels of bacteria were found on numerous stream reaches, but limited data was available, thus unable to make an assessment.

Tamarack and Razor lakes fully supported aquatic recreation, while Grace and Rock lakes do not. The impairments are for elevated levels of total phosphorus and chlorophyll-a, and low clarity. The impairment on Rock Lake was determined to be due to natural conditions.

Chemical contaminants were examined in fish tissues from two lakes (Rock and Tamarack) and one reach of Crooked Creek within this watershed. Only Tamarack Lake exhibited high levels of mercury and is listed as impaired for aquatic consumption.

Groundwater quality in the Upper St. Croix River Watershed is considered good when compared to other regions with comparable aquifers. There are no exceedances of drinking water standards the primary presence of minerals are from natural sources like iron and manganese. There is data that shows low-level fluctuating chloride concentrations, though it is unclear whether the fluctuations are a result anthropogenic in nature.

The overall condition of wetlands in this watershed is very good. Within the watershed, 84% of wetlands are in good or excellent condition and no wetlands in poor condition. The Upper St. Croix Watershed retains the majority of its historic wetland area, 80% or more of the estimated historic wetlands remain in the watershed.

The very good water quality and biological communities in the Upper St. Croix River Watershed reflect the land use, minimal hydrologic modification, and discharge of pollutants (point and non-point) within this watershed. There has been little change in land use since European settlers moved into the area in the mid-19th century, resulting in a watershed that has very little human disturbance compared to other watersheds in the state. Human disturbance within the Upper St. Croix River Watershed is at a minimum with 86% of the watershed consists of forests and wetlands and there are very few anthropogenic effects within the watershed because of it.

With a continuation of undeveloped land and best land management practices such as an implementation of perennial vegetation buffers along developed stream reaches, improved control of waste runoff at livestock operations, installation of exclusion fencing to limit animal access to streams, and limiting nutrient loading to surface waters from fertilizer application will help to keep the water quality and biological communities throughout the watershed exceptional.

Introduction

Water is one of Minnesota's most abundant and precious resources. The Minnesota Pollution Control Agency (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 water bodies 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 water body 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 (CWLA) 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 Upper St. Croix River Watershed beginning in the summer of 2016. This report provides a summary of all water quality assessment results in the Upper St. Croix 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: Minnesota's Water Quality Monitoring Strategy 2011 to 2021** (https://www.pca.state.mn.us/sites/default/files/p-gen1-10.pdf).

Watershed pollutant load monitoring

The Watershed Pollutant Load Monitoring Network (WPLMN) is a long-term statewide river monitoring network initiated in 2007 and designed to obtain pollutant load information from 199 river monitoring sites throughout Minnesota. Monitoring sites span three ranges of scale:

Basin – major river main stem sites along the Mississippi, Minnesota, Rainy, Red, Des Moines, Cedar and St. Croix rivers

Major Watershed – tributaries draining to major rivers with an average drainage area of 1,350 square miles (8-digit HUC scale)

Subwatershed – major branches or nodes within major watersheds with average drainage areas of approximately 300-500 square miles

The program utilizes state and federal agencies, universities, local partners, and MPCA staff to collect water quality and flow data to calculate nitrogen, phosphorus, and sediment pollutant loads.

Intensive watershed monitoring

The intensive watershed monitoring 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 water bodies 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 dot 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 mi^2. 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.

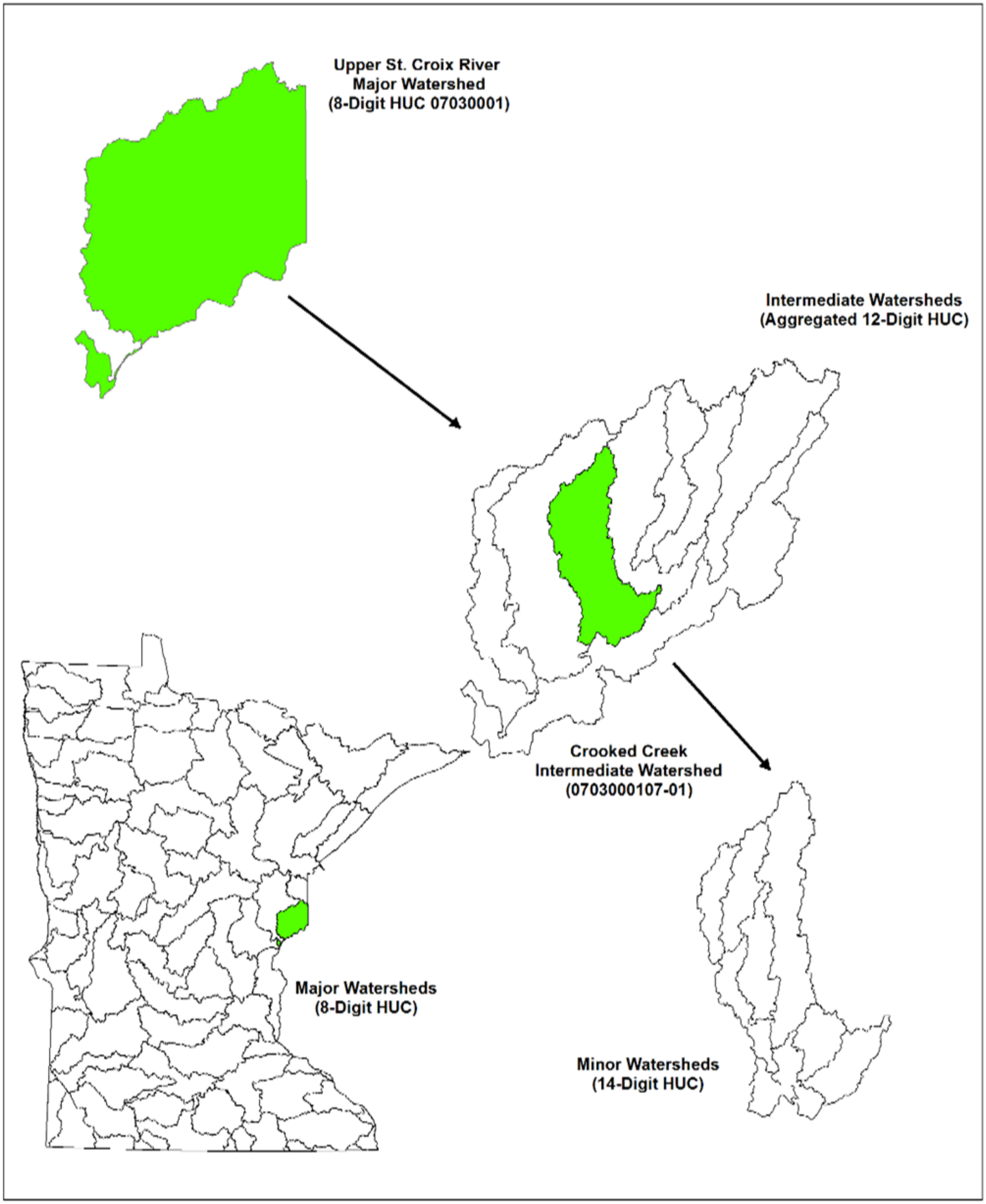
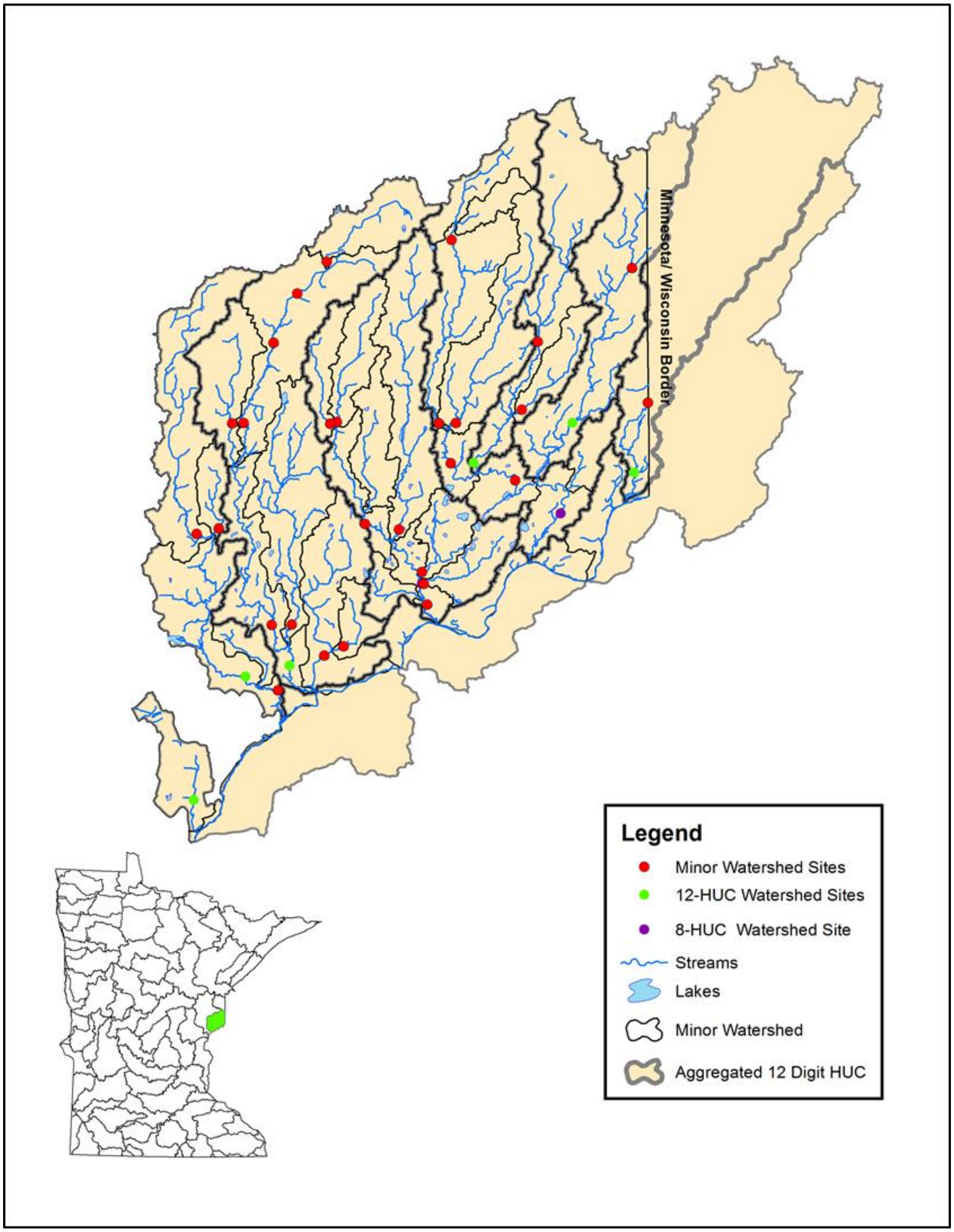


Figure 2. Intensive watershed monitoring sites for streams in the Upper St. Croix River Watershed.



Lake monitoring

Lakes most heavily used for recreation 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 (greater than 100 acres), accessibility (can the public access the lakes), and presence of recreational use.

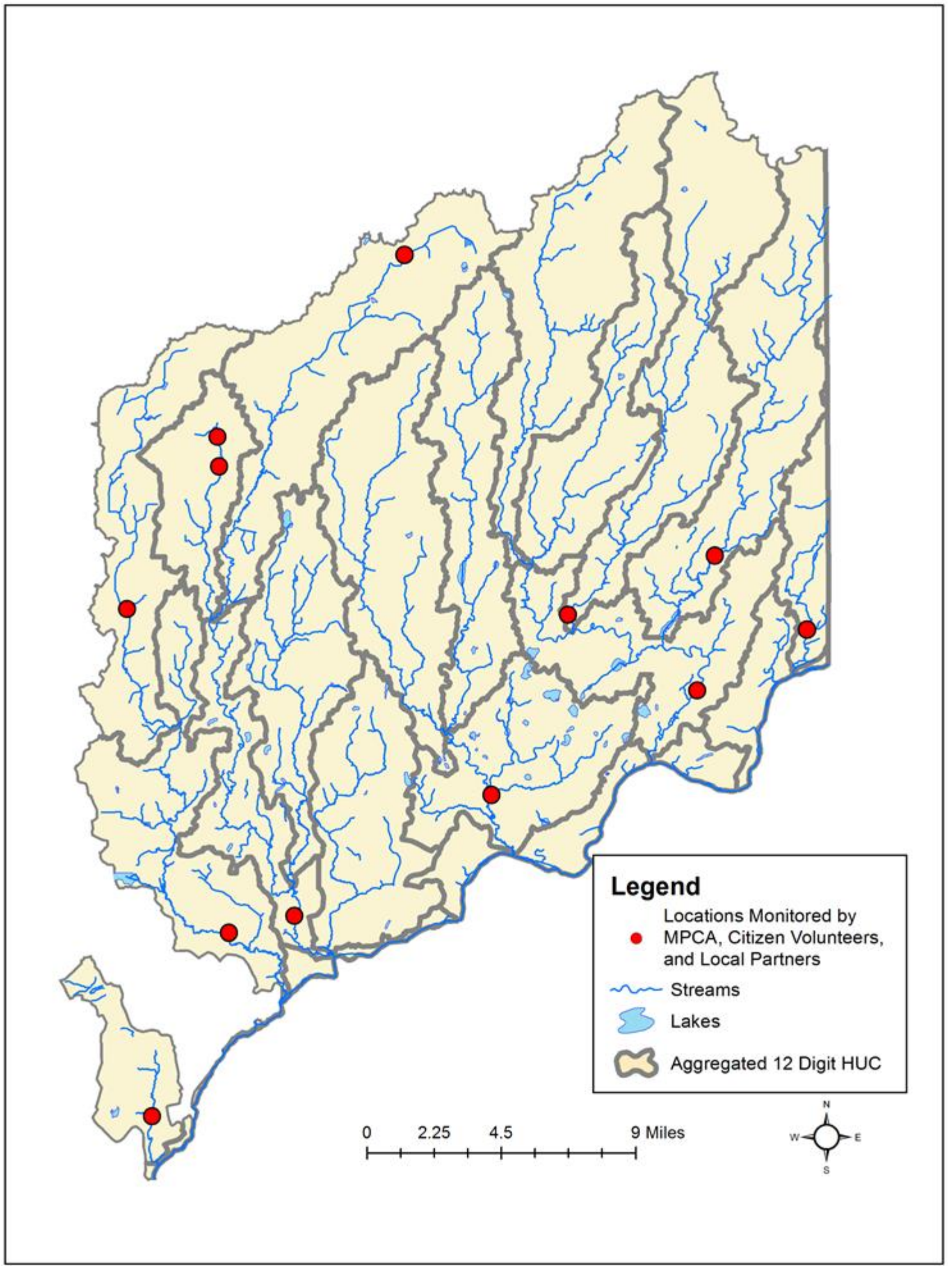
Specific locations for sites sampled as part of the intensive monitoring effort in the Upper St. Croix River Watershed are shown in Figure 2 and are listed in Appendices 2.1 and 2.2.

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 (SWCDs), 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 (CLMP) and the Citizen Stream Monitoring Program (CSMP). 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. Figure 3 provides an illustration of the locations where citizen-monitoring data were used for assessment in the Upper St. Croix River Watershed.

Figure 3. Monitoring locations of local groups, citizens and the MPCA lake monitoring staff in the Upper St. Croix 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, 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 water body 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, macroinvertebrates, 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. The MPCA also uses a lake fish IBI developed by the Minnesota Department of Natural Resources (DNR) to determine if lakes are meeting aquatic life use. Because the lakes, rivers, and streams in Minnesota are physically, chemically, and biologically diverse, IBI's are developed separately for different stream classes and lake class groups 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, total suspended solids, pesticides, and river eutrophication. For lakes, pesticides and chlorides contribute to the overall aquatic life use assessment.

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). These tiered aquatic life uses are determined before assessment based on the attainment of the applicable biological criteria and/or an assessment of the habitat (MPCA 2015). 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. Tiered aquatic life use standards.

Tiered aquatic life use	Acronym	Use class code	Description
Warmwater General	WWg	2Bg	Warmwater 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.
Warmwater Modified	WWm	2Bm	Warmwater 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
Warmwater Exceptional	WWe	2Be	Warmwater 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.
General	CWg	2Ag	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.
Exceptional	CWe	2Ae	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 WID), comprised of the United States Geological Survey (USGS) eight-digit hydrologic unit code (8-HUC) plus a three-character code that is unique within each HUC. Lake and wetland identifiers are assigned by the DNR. The Protected Waters Inventory provides the identification numbers for lake, reservoirs and wetlands. These identification numbers serve as the WID and are composed of an eight-digit number indicating county, lake and bay for each basin.

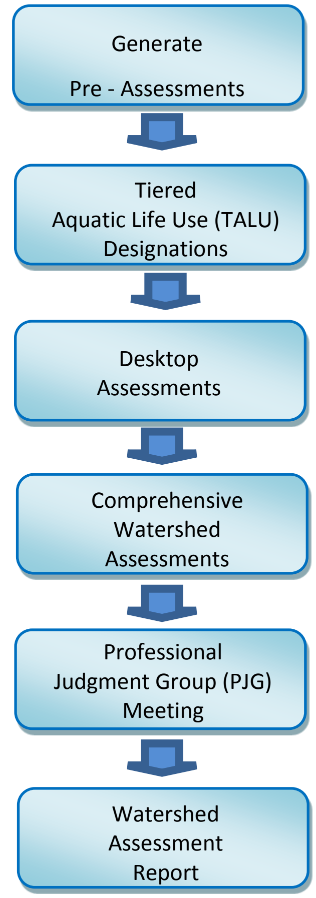
It is for these specific stream reaches or lakes that the data are evaluated for potential use impairment. Therefore, any assessment of use support would be limited to the individual assessment unit. The major exception to this is the listing of rivers for contaminants in fish tissue (aquatic consumption). 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 4.

The first step in the aquatic life 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 insure that data is valid and appropriate for assessment purposes. Tiered aquatic life 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.

Figure 4. Flowchart of aquatic life use assessment process.



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).

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. Iimplementing 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-iw1-04j.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 WID). 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

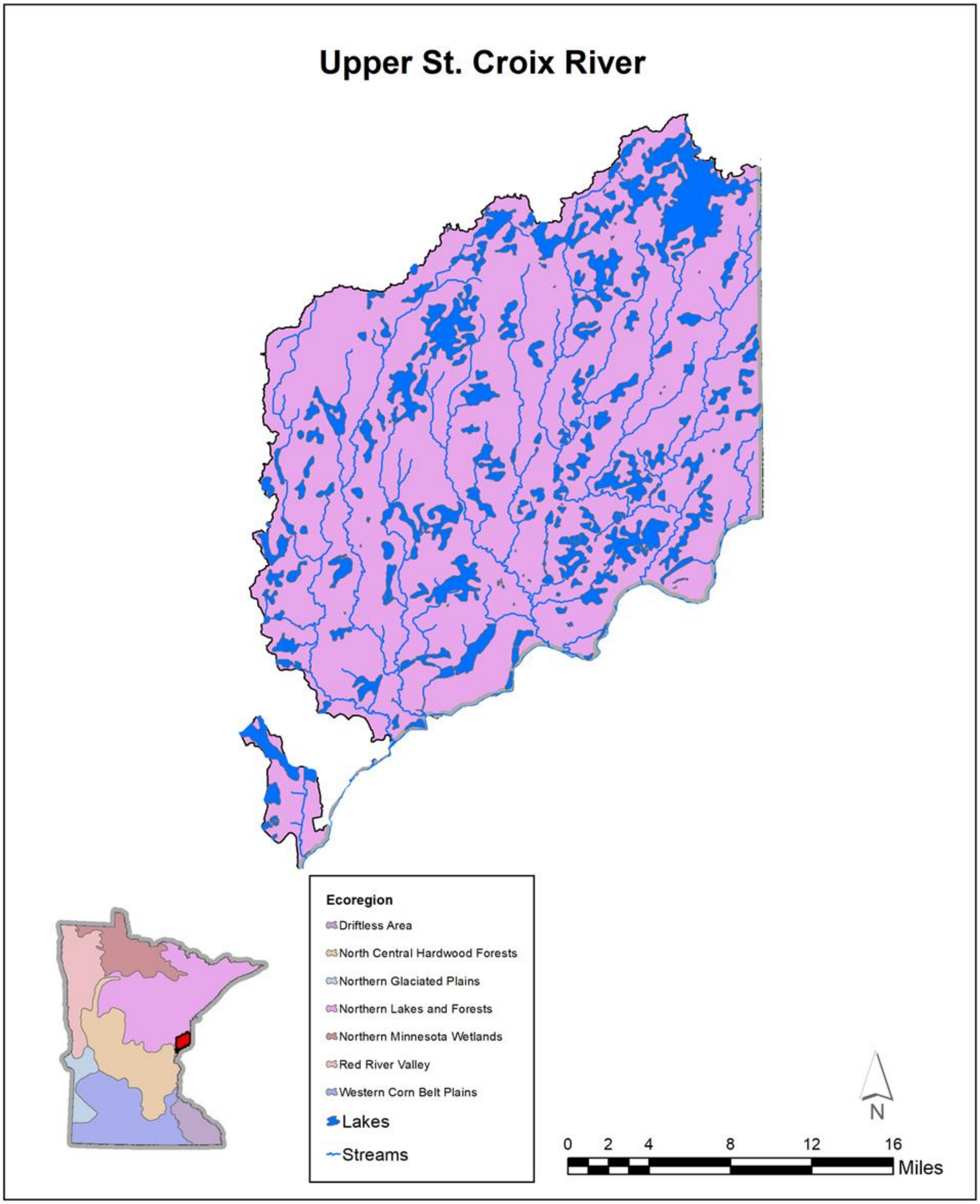
The Upper St. Croix major watershed in east-central Minnesota covers parts of Minnesota and Wisconsin. This watershed is the furthest upstream major watershed in the St. Croix River Basin in Minnesota. Within Minnesota, the most northeast part of the watershed begins near the town of Belden in the Nemadji State Forest. The watershed contains eight subwatersheds that flow south to the St. Croix River. The watershed largely consists of forest and wetlands.

The watershed is bordered to the north by the Nemadji River Watershed, which is in the Lake Superior Basin. The rest of the watershed is surrounded by the Kettle River watershed except for Chases Brook-St. Croix River Subwatershed, which is separated from the rest of the Upper St. Croix River Watershed by the Kettle River Watershed. The Chases Brook-St. Croix River Subwatershed is bordered to the south and west by the Snake River Watershed.

Total watershed area for the entire 8-digit HUC (07030001) is 2,057 square miles (1,316,404 acres), of which Minnesota's portion totals 544 square miles (347,891 acres). The Minnesota portion of the watershed lies completely within Pine County. Towns within the watershed include Belden, Duxbury, Cloverton, Markville, Kingsdale, and Cloverdale.

The entire Upper St. Croix River Watershed lies within the Northern Lake and Forest U. S. Environmental Protection Agency (EPA) Level III ecoregion (Figure 5). The Northern Lakes and Forests is a region of relatively nutrient-poor glacial soils, coniferous and northern hardwood forests, undulating till plains, morainal hills, broad lacustrine basins, and extensive sandy outwash plains. Soils in this ecoregion are thicker than in those to the north and generally lack the arability of soils in adjacent ecoregions to the south. The numerous lakes that dot the landscape are clearer and less productive than those in ecoregions to the south (Omernik and Gallant 1988).

Figure 5. The Upper St. Croix Watershed within the Northern Lake and Forests ecoregion of northeast Minnesota.



Land use summary

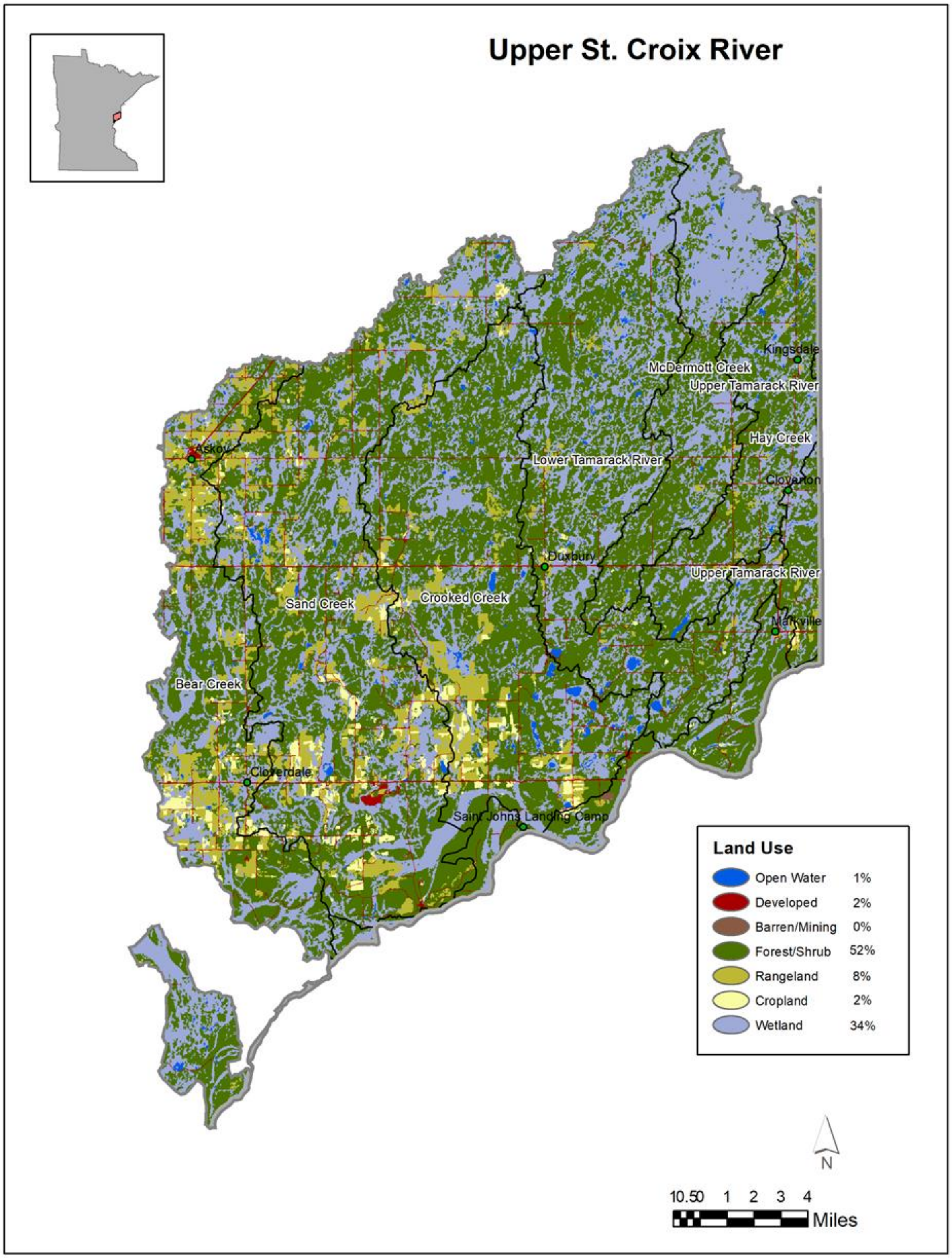
Forest and wetlands are the most significant land uses in the Upper St. Croix River Watershed combining for 86% of the land use (Figure 6). Cropland and rangeland only accounts for 10% of the area in the watershed. There are 1,291 farms located in the watershed including the Wisconsin portion, with an average size farm of 57 acres (NRCS 2007).

Lands within the Upper St. Croix River watershed were first visited by non-indigenous explorers in the mid-17th century and were frequented by French fur traders. Two treaties signed with the Ojibwe in 1837 opened 13 million acres rich in timber to non-indigenous settlements. The population of people of European descent exploded in this area from 11,683 in August 1836, to 155,277 a decade later (https://www.wisconsinhistory.org/turningpoints/). The St. Croix Basin and its rich red and white pine forests were used to build the cities and towns throughout the Mississippi River Valley.

Today, the landscape in this watershed is still dominated by forest and wetlands; only 2% of the Upper St. Croix Watershed in Minnesota is developed.

Much of the watershed is privately owned, but large tracts of land in St. Croix State Forest, St. Croix State Park and Nemadji State Forest are owned by the state and are public.

Figure 6. Land use in the Upper St. Croix River Watershed.



Surface water hydrology

The Upper St. Croix Watershed consists of eight subwatersheds that flow from north to south directly or almost directly into the St. Croix River. The Upper Tamarack, Lower Tamarack, Crooked Creek, Sand Creek, Bear Creek, McDermott Creek, Hay Creek, and Sucker Creek are the main streams within the Minnesota boundaries of the watershed. The majority of the Upper St. Croix River watershed lies in Wisconsin. The start of the watershed is at Lake Namakagon in Wisconsin. Sand Creek is the longest stream in the watershed and is over 42 miles long. The headwaters start 5 miles west of Bruno and flows south to the St. Croix River in St. Croix State Park. The one major anomaly of the watershed is Redhorse Creek. Redhorse Creek is separated to the southwest of the rest of the watershed by the Kettle River Watershed.

A majority of the Upper St. Croix River Watershed consists of natural channels (Figure 7). The natural stream segments make up for 86% of the watershed (Figure 8). The majority of the channelized reaches are in the headwater streams of the watershed. There are a mix of and warmwater stream segments in five of the eight subwatersheds.

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

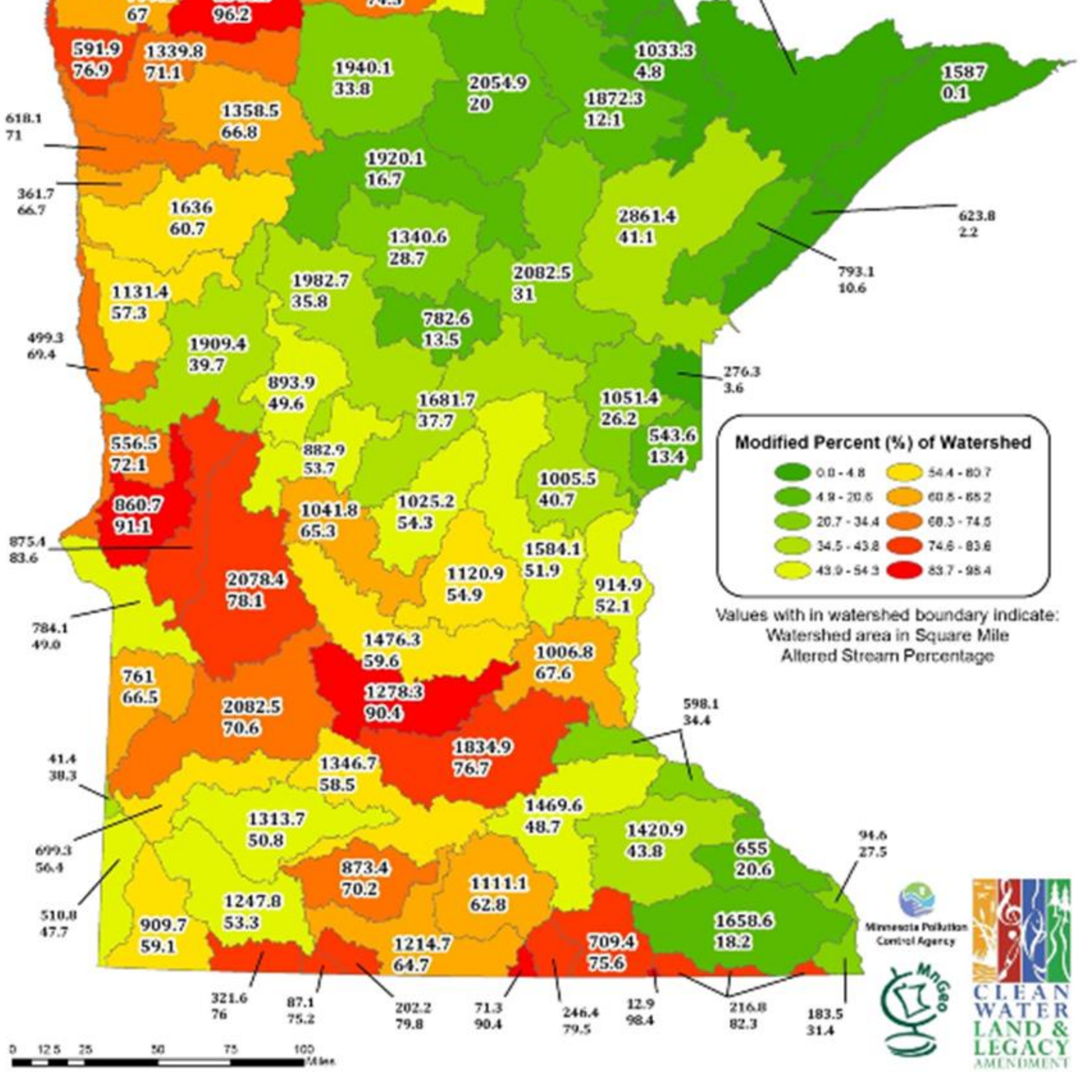
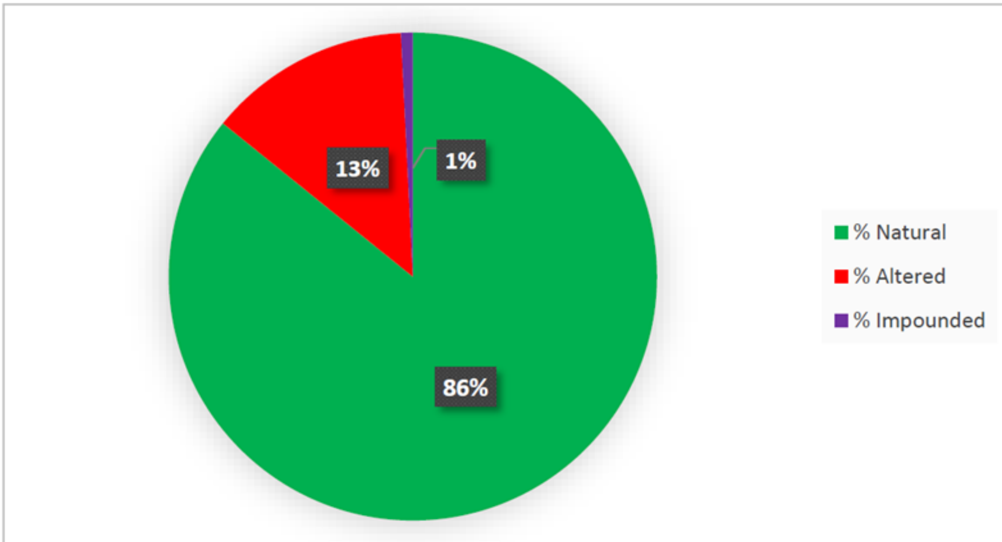


Figure 8. Comparison of natural to altered streams in the Upper St. Croix River Watershed (percentages derived from the Statewide Altered Water Course project).

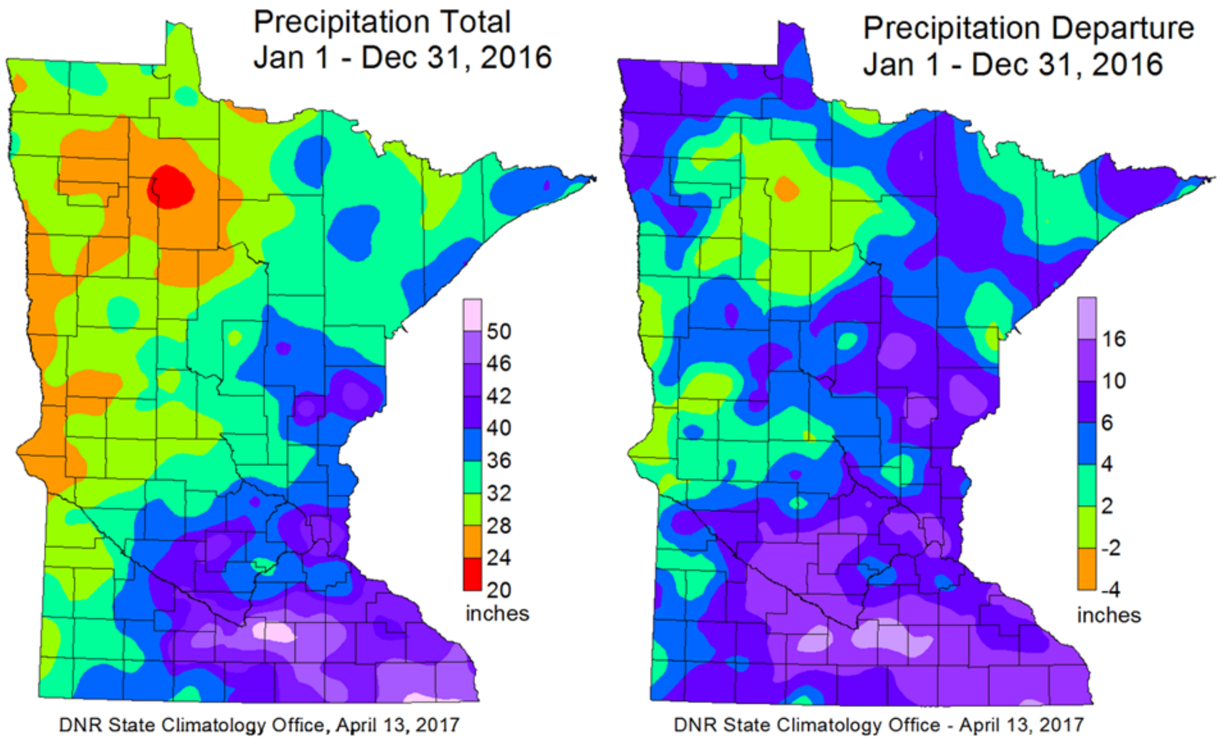


Climate and precipitation

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 Upper St. Croix River Watershed is 18.9˚C and the mean winter (December-February) temperature is -10.3˚ C (DNR: Minnesota State Climatology Office, 2019).

Precipitation is an important source of water input to a watershed. Figure 9 displays two representations of precipitation for calendar year 2016. On the left is total precipitation, showing the typical pattern of increasing precipitation toward the southeastern portion of the state. According to this figure, the Upper St. Croix River Watershed area received 36 to 50 inches of precipitation in 2016. The display on the right shows the amount that precipitation levels departed from normal. The watershed area experienced precipitation that ranged from six to sixteen inches above normal in 2016.

Figure 9. Statewide precipitation total (*left*) and precipitation departure (*right*) during 2016 (Source: DNR State Climatology Office, 2019b).



The Upper St. Croix River Watershed is located within the East-Central precipitation region. Figure 10 and Figure 11 display the areal average representation of precipitation in East-Central 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 East-Central region display no significant trend over the last 20 years. However, precipitation in East-Central 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 East-Central Minnesota (1996-2015) with five-year running average (Source: WRCC, 2017).

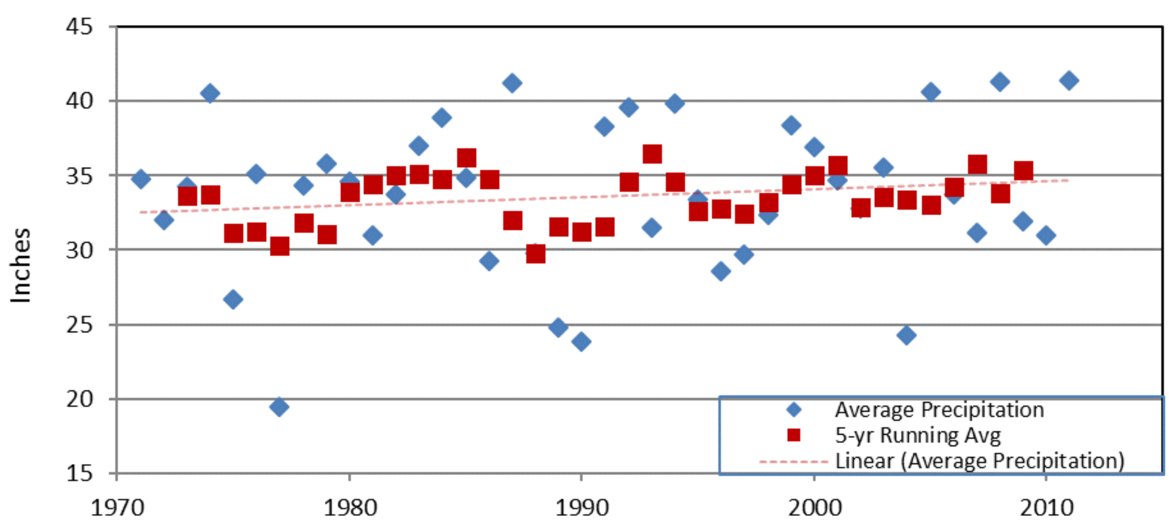
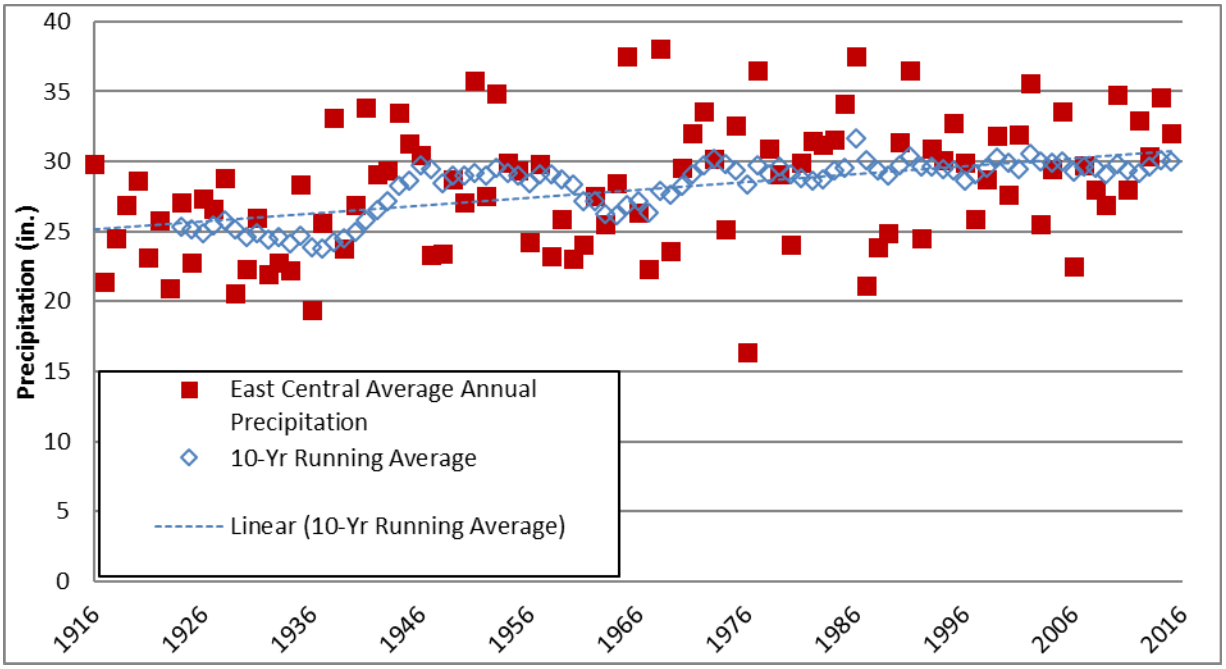


Figure 11. Precipitation trends in East-Central Minnesota (1916-2015) with 10-year running average (Source: WRCC, 2017).



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.

The Upper St. Croix River watershed contains features of three of Minnesota's Groundwater provinces: the Metro, Central and Arrowhead Provinces. The Metro province, present in the extreme west and extreme south of the watershed, is characterized by "sand aquifers in generally thick (greater than 100 feet) sandy and clayey glacial drift overlying Precambrian sandstone and Paleozoic sandstone, limestone, and dolostone aquifers". The bulk of the watershed is characterized by the Central Province, where there are sandy aquifers in sandy and clayey glacial drift. The Arrowhead Province in the watershed is scattered, and is characterized by Precambrian metamorphic rocks exposed at the surface or covered by thin layers of till. Groundwater here is found in fractures and faults. (DNR, 2017a)

Groundwater potential recharge

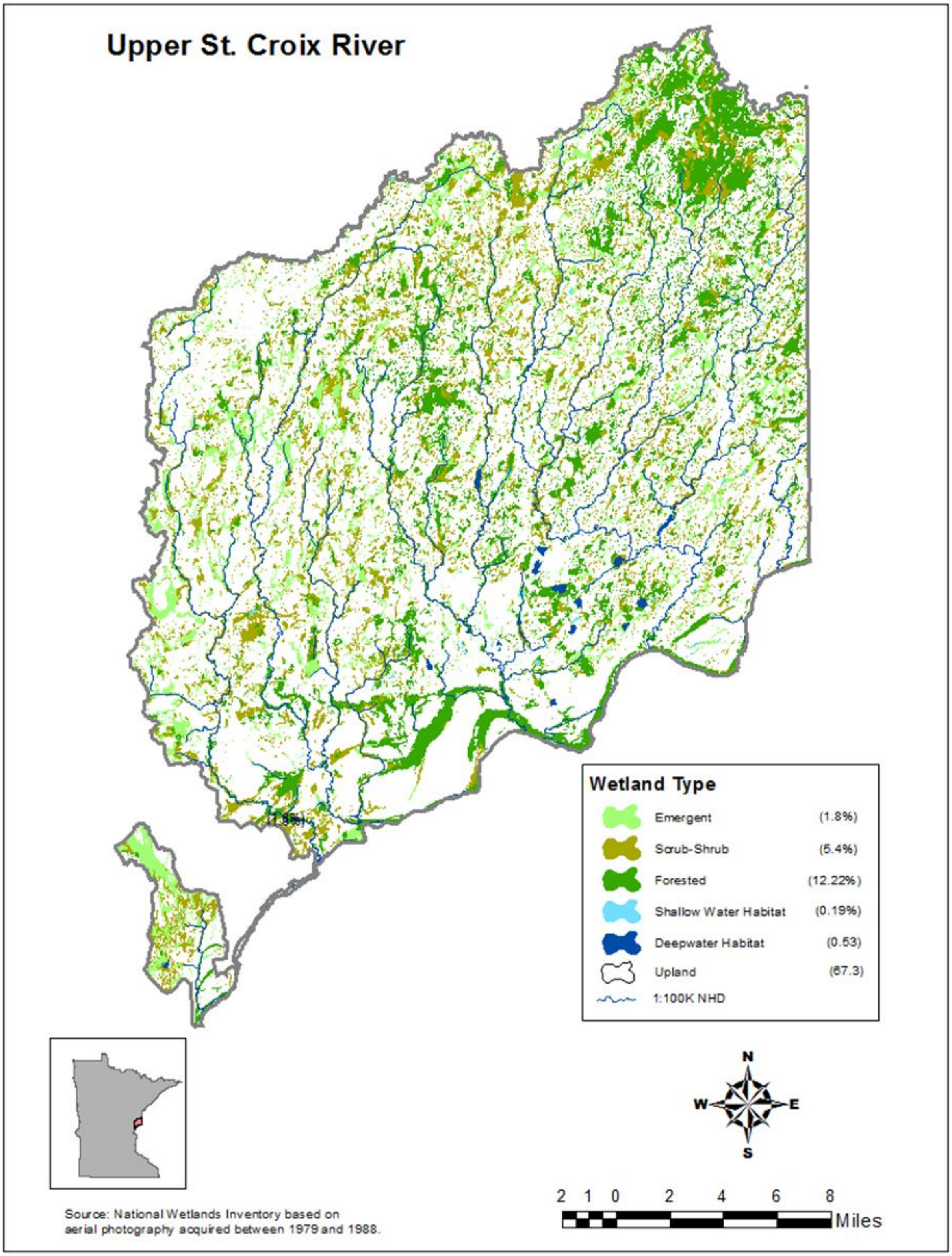
Groundwater recharge is one of the most important parameters in the calculation of water budgets, which are used in general hydrologic assessments, aquifer recharge studies, groundwater models, and water quality protection. Recharge is a highly variable parameter, both spatially and temporally, making accurate estimates at a regional scale difficult to produce. The MPCA contracted the US Geological Survey 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 interface. 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 Upper St. Croix River Watershed, the average annual potential recharge rate to surficial materials ranges from 1.03 to 9.25 inches per year, with a mean of 6.04 inches per year. The statewide average potential recharge is estimated to be four inches per year with 85% of all recharge ranging from three to eight inches per year (USGS, 2015)

Wetlands

Excluding open water portions of lakes and rivers, the Upper St. Croix River Watershed has approximately 111,932 acres of wetlands, which is equivalent to 32.2% of the watershed area (Figure 12). Forested wetlands comprise 12.2% of the watershed area, slightly less than scrub-scrub wetlands at 12.5%, which are the most common wetland class in the watershed. Emergent and shallow water habitat wetlands round out the wetland areas at 7.3% and 0.2% respectively. Peatlands comprise 23% of the wetland extent in the Upper St. Croix River Watershed. Often called "bogs" peatlands are wetlands with thick deposits of partially decomposed plant material that accumulates as peat. Peatlands can occur as forested, shrub dominated or as open herbaceous emergent dominated wetland communities. These estimates of wetland extent and distribution are from the original Minnesota National Wetland Inventory (NWI), based primarily on circa 1982-spring leaf-off imagery. Minnesota's wetland inventory has recently, been updated and is available as preliminary data statewide, though this data is not yet finalized, thus it was not used in these wetland calculations. More information on the NWI update project is available at http://www.dnr.state.mn.us/eco/wetlands/nwi_proj.html.

Figure 12. Wetlands and surface water in the Upper St. Croix Watershed. Wetland data are from the original Minnesota National Wetlands Inventory.



The Upper St. Croix River Watershed surface geology is dominated by ground moraine resulting from the Superior Lobe, during the Wisconsin Glaciation period. Ground moraine is particularly prominent in the central region of the watershed from west to east. Peatland complexes occur along the edge of the ground moraine, especially in the northeast and east-central region of the watershed. Moraine complexes and related glacial features are conducive to formation of wetland or in the case of peatlands, areas are inherently wetland. Across the Upper St. Croix Watershed, wetlands are well distributed, but they are especially prominent in the east-central and northeast regions of the watershed where they comprise an important surface water feature. Many Upper St. Croix River Watershed wetlands are associated with streams.

Wetland loss estimates

The entire extent of the Upper St. Croix Watershed is in the Mixed Wood Shield Ecoregion. Conversion or loss of wetlands has been very limited in this watershed, especially compared to watersheds in the southern and western region of Minnesota. The Upper St. Croix Watershed is entirely within the larger multiple county, north-central region of Minnesota identified as "Greater Than 80% Historic Wetland" used for administration of the Minnesota Wetland Conservation Act (Minn. R. ch. 8420).

Special wetland features

Wetlands in the Upper St. Croix River Watershed are important reserves and habitats of unique plant communities supporting six threatened or special concern; plant and reptile/amphibian species. Of special note are several siting's of Narrow Triangle Moonwort (*Botrychium lance*olatum var. *angustisegmentum*); Down liverwort (*Trichocelea tomen*tella);White Adder's mouth (*Malaxis monophyllos* var. *brachypoda*); Olivaceaous spikerush (*Eleocharis flavescens* var. *olivacea*); Blandings Turtle (*Emydoidea blandingii*) and Four-toed Salamander (*emidactylium scutatum*). No wetland specific Scientific Natural Areas or calcareous fens occur in the Upper St. Croix Watershed.

Watershed-wide data collection methodology

Lake water sampling

Local partners with the University of Minnesota's NRRI monitored five lakes in the Upper St. Croix Watershed through grant agreements with the MPCA in 2016 and 2017. They sampled Razor, Hay Creek Flowage, Rock, Tamarack and Grace Lakes for assessment of aquatic recreation. There are currently no volunteers enrolled in the MPCA's CLMP that are conducting lake monitoring within the watershed. Sampling methods are similar among monitoring groups and are described in the document entitled "*MPCA Standard Operating Procedure for Lake Water Quality*" found at http://www.pca.state.mn.us/publications/wq-s1-16.pdf. The lake recreation use assessment requires eight observations/samples within a 10-year period (June to September) for phosphorus, chlorophyll-a and Secchi depth. No lakes were monitored for fish community health in the Upper St. Croix River Watershed.

Stream water sampling

Eight water chemistry stations were sampled from May through September in 2016, and again June through August of 2017, to provide sufficient water chemistry data to assess all components of the aquatic life and recreation use standards. Following the IWM design, water chemistry stations were placed at the outlet of each aggregated 12 HUC subwatershed that was >40 square miles in area (purple circles and green circles/triangles in (Figure 2). A SWAG was awarded to the University of Minnesota's NRRI to conduct this monitoring. (See Appendix 2.1 for locations of stream water chemistry monitoring sites. See Appendix 1 for definitions of stream chemistry analytes monitored in this study.) The St Croix River was monitored in 2017 and 2018 as part of the Large River Monitoring Program and will be assessed in 2019.

Stream flow methodology

MPCA and the DNR jointly monitor stream water quantity and quality at 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. Information and data on these sites are available at the DNR/MPCA Cooperative Stream Gaging webpage at: http://www.dnr.state.mn.us/waters/csg/index.html.

Stream biological sampling

The biological monitoring component of the intensive watershed monitoring in the Upper St. Croix River Watershed was completed during the summer of 2016. A total of 26 sites were newly established across the watershed and sampled. These sites were located near the outlets of most minor HUC-14 watersheds. In addition, nine existing biological monitoring stations within the watershed were revisited in 2016. These monitoring stations were initially established as part of a random St. Croix River Basin wide survey in 1996, in 2010 as part of a state wide random survey, or in a 1967 and 1968 sampling effort by DNR. While data from the last 10 years contributed to the watershed assessments, the majority of data utilized for the 2018 assessment was collected in 2016. A total of 34 WIDs were sampled in the Upper St. Croix River Watershed. Waterbody assessments to determine aquatic life use support were conducted for 29 WIDs. 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, 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 warmwater classes and two cold water classes, with each class having its own unique Fish IBI and Macroinvertebrate 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

The (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 near the HUC8 pour point, 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 polychlorinated biphenyls (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 poly-and perfluoroalkyl substances (PFAS), whole fish were shipped to AXYS Analytical Laboratory, which analyzed the homogenized fish fillets for 13 PFAS. Of the measured PFAS, 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 EPA. 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 Minnesota Department of Health (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 90th 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.

Pollutant load monitoring

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. Because concentrations typically rise with streamflow for many of the monitored pollutants, and because of the added influence elevated flows have on pollutant load estimates, sampling frequency is greatest during periods of moderate to high flow. All major snowmelt and rainfall events are sampled. Low flow periods are also sampled although sampling frequency is reduced, as pollutant concentrations are generally more stable when compared to periods of elevated flow.

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 total suspended solids (TSS), total phosphorus (TP), dissolved orthophosphate (DOP), nitrate plus nitrite nitrogen (NO3+NO2-N), and total Kjeldahl nitrogen (TKN).

More information can be found at the WPLMN website.

Groundwater monitoring

Groundwater quality

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 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.

Groundwater quantity

Monitoring wells from the DNR Observation Well Network track the elevation of groundwater across the state. The elevation of groundwater is measured as depth to water in feet and reflects the fluctuation of the water table as it rises and falls with seasonal variations and anthropogenic influences. Data from these wells and others are available at:
https://www.dnr.state.mn.us/waters/groundwater_section/index.html

Groundwater/Surface water withdrawals

The DNR permits all high capacity water withdrawals where the pumped volume exceeds 10,000 gallons/day or 1 million gallons/year. Permit holders are required to track water use and report back to the DNR yearly. Information on the program and the program database are found at:
http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html

Stream flow

MPCA and the DNR jointly monitor stream water quantity and quality at 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. Information and data on these sites are available at the DNR/MPCA Cooperative Stream Gaging webpage at: http://www.dnr.state.mn.us/waters/csg/index.html.

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 Indices of Biological Integrity (IBIs) to monitor the macroinvertebrate condition of depressional wetlands with open water and the Floristic Quality Assessment (FQA) 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 https://www.pca.state.mn.us/water/wetland-monitoring.

The MPCA currently does not monitor wetlands systematically by watershed. Rather, the MPCA is using probabilistic monitoring to assess status and trends of wetland quality at a statewide and major ecoregion scale. 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.

Individual aggregated 12-HUC subwatershed results

Aggregated 12-HUC subwatersheds

Assessment results for aquatic life and recreation use are presented for each Aggregated HUC-12 subwatershed within the Upper St. Croix River. 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 HUC-12 subwatersheds contain the assessment results from the 2018 Assessment Cycle as well as any impairment listings from previous assessment cycles. Discussion of assessment results focuses primarily on the 2016 intensive watershed monitoring effort, but also considers available data from the last 10 years.

The proceeding pages provide an account of each aggregated HUC-12 subwatershed. Each account includes a brief description of the aggregated HUC-12 subwatershed, and summary tables of the results for each of the following: a) stream aquatic life and aquatic recreation assessments, and b) lake aquatic life and recreation assessments. Following the tables is a narrative summary of the assessment results and pertinent water quality projects completed or planned for the aggregated HUC-12 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 HUC-12 subwatershed (i.e., where sufficient information was available to make an assessment). Primarily, these tables reflect the results of the 2012 assessment process (2014 U.S. Environmental Protection Agency [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 4). Assessment of aquatic life is derived from the analysis of biological (fish and macroinvertebrate IBIs), dissolved oxygen, total suspended solids, chloride, pH, total phosphorus, chlorophyll-a, biochemical oxygen demand and un-ionized ammonia (NH_3) 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) or cool or warmwater community (2B). 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 HUC-12 subwatershed as well as in the watershed-wide results and discussion section.

Lake assessments

A summary of lake water quality is provided in the aggregated HUC-12 subwatershed sections where available data exists. This includes aquatic recreation (phosphorus, chlorophyll-a, and Secchi) and aquatic life, where available (chloride). Similar to streams, parameter level and over all use decisions are included in the table.

Upper Tamarack River Aggregated 12-HUC HUC 0703000103-01

The Upper Tamarack River subwatershed is located on the east side of the Upper St. Croix Watershed. This 99.1 mi2 watershed lies mostly in Wisconsin. Approximately 20% of the watershed (19 mi2) is within the Minnesota border, and it is completely within Pine County. The Minnesota portion of the Upper Tamarack River flows 8.3 miles south from the Minnesota/Wisconsin border to the St. Croix River 1.5 miles southeast of Markville. Land use is dominated by forest (65.2%), wetland (26.1%), and open water (0.4%) for a total of 91.7% natural land use. Developed land is minimal at 2.5%. In total, there are three stream reaches and no lakes in the watershed. There were two stream reaches with data assessed for aquatic life (Table 2) and no lake were assessable. There are no impairments within the watershed (Figure 13).

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

WID *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	Eutrophication	Aquatic life	Aquatic rec. (Bacteria)
07030001-613, ***Upper Tamarack River,*** *MN/WI State border to Unnamed cr*	96SC037	4.35	WWe	MTS	MTS	IF	IF	IF		IF	IF		FS	
07030001-614, ***Upper Tamarack River,*** *Unnamed cr to St Croix R*	16SC107	3.94	WWg	MTS	MTS	IF	IF	IF	MTS	IF	MTS	IF	FS	IF

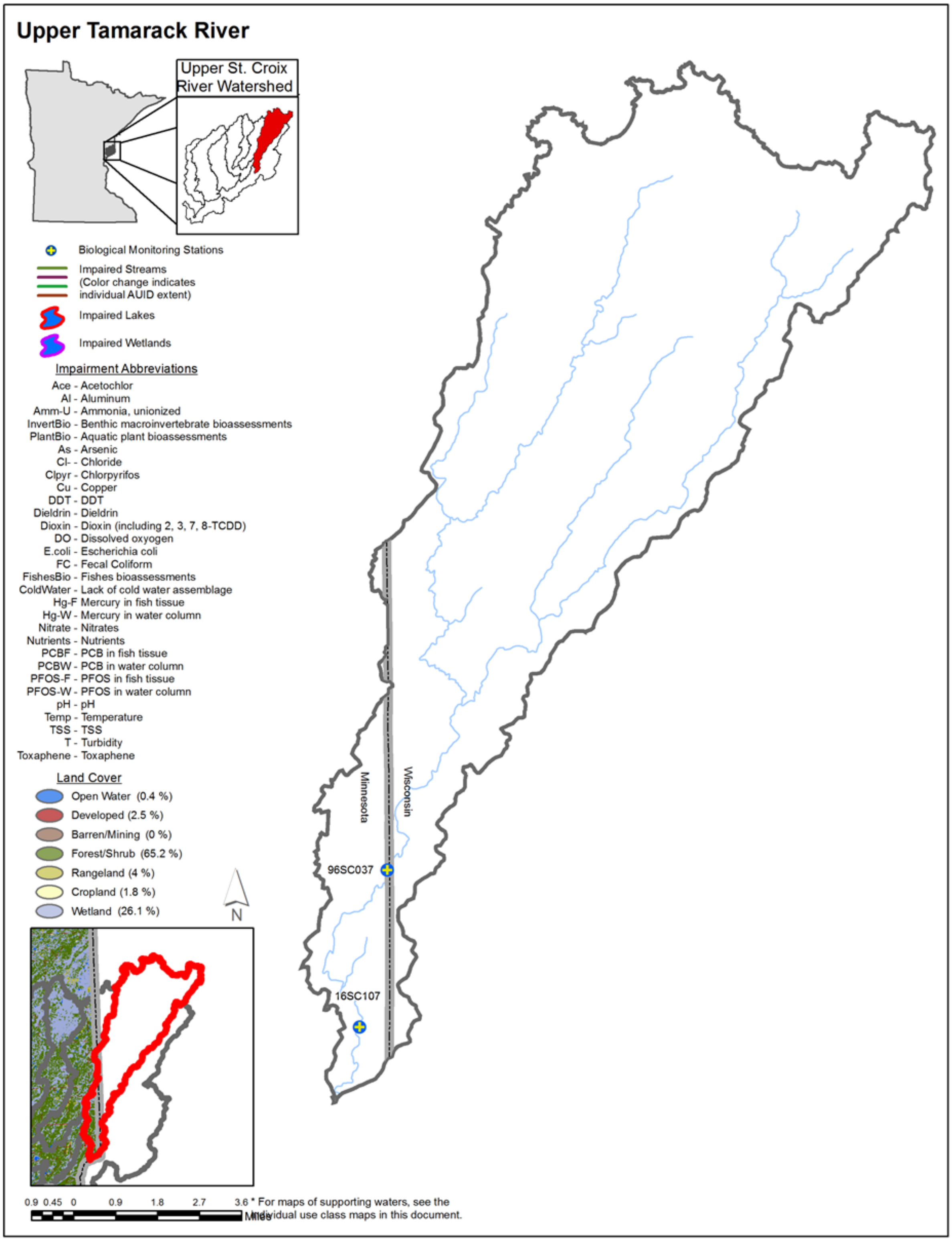
Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: = existing impairment, listed prior to 2016 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** = general, **CWe** = exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Summary

Fish and macroinvertebrates were sampled at two locations within this subwatershed. Both sampling locations are full support for aquatic life and scored well above the general use standard. The upstream reach, site 96SC037, scored well enough to place the associated reach in the exceptional aquatic life use category. The exceptional designation holds more pristine streams to a higher standard than stream segments in the general or modified use category. Most macroinvertebrate samples collected at this location scored near or above the exceptional use standard and all of the fish samples scored above the exceptional use standard. Both stations were sampled for macroinvertebrates after a very high-flow even in 2016 and still maintained very high macroinvertebrate IBI scores, suggesting very stable in-stream habitat and riparian conditions throughout the subwatershed. Very high numbers of intolerant macroinvertebrate taxa have been consistently collected at site 96SC037, since its initial sampling in 1996. Sensitive fish species such as logperch, smallmouth bass, longnose dace, burbot, rock bass, northern hogsucker, slenderhead darter, and hornyhead chub were all present at the 2016 sample. Half of the fish species present at the sample are listed as sensitive species.

Chemistry data was available on the downstream reach of the Upper Tamarack River. Bacteria is a potential concern; elevated concentrations were found, but not enough samples were collected to make an assessment. Based on available data, the water quality in the subwatershed is good, with low nutrients and sediment concentrations, and does not seem to be negatively impacting the biology. Un-ionized ammonia and chloride both meet the standards for aquatic life.

Figure 13. Currently listed impaired waters by parameter and land use characteristics in the Upper Tamarack River Aggregated 12-HUC.



Lower Tamarack River Aggregated 12-HUC HUC 0703000106-01

The lower Tamarack River subwatershed is located on the east central part of the Upper St. Croix Watershed. This 96.4 mi^2 watershed lies completely in Pine County. It flows south out of Nemadji State Forest to the St. Croix River in St. Croix State Park. Land use is dominated by forest (56%), wetland (39.1%), and open water (1.5%) for a total of 96.6% natural land use. Developed land is minimal at 1.5%. In total, there are 14 stream reaches and 2 lakes in the watershed. There were four stream reaches with data assessed for aquatic life and recreation (Table 3) and two lakes were assessable (Table 4). There are no stream impairments within the watershed and two lake impairments (Figure 14).

Table 3. Aquatic life and recreation assessments on stream reaches: Lower Tamarack River Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

WID ***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	Eutrophication	Aquatic life	Aquatic rec. (Bacteria)
07030001-510, ***Lower Tamarack River,*** *Hay Cr to St Croix R*	10EM063	7.85	WWg	MTS	MTS	IF	IF	MTS	MTS	MTS	MTS	IF	FS	IF
07030001-512, ***Lower Tamarack River,*** *McDermott Cr to Hay Cr*	16SC106	5.68	WWg	MTS	MTS	IF	IF	IF		IF	IF		FS	
07030001-514, ***Lower Tamarack River,*** *Headwaters to McDermott Cr*	16SC108, 16SC110, 16SC204	25.48	WWg	MTS	MTS	IF	IF	MTS		IF	IF	IF	FS	
07030001-532, ***Keene Creek,*** *Little Ox Cr to Lower Tamarack R*	16SC112	1.23	WWg	MTS	MTS								FS	

Abbreviations for Indicator Evaluations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment; **EXS** = Exceeds criteria, potential severe impairment; **EX** = Exceeds criteria (Bacteria)

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **NS** = Non-Support, FS = Full Support

Key for Cell Shading: ☐ = existing impairment, listed prior to 2012 reporting cycle; ☐ = new impairment; ☐ = full support of designated use.

Table 4. Lake water aquatic recreation assessments: Lower Tamarack River Aggregated 12-HUC.

Lake name	DNR ID	Area (acres)	Max depth (ft)	Assessment method	Ecoregion	Secchi Trend	Aquatic life indicators: Fish IBI	Chloride	Pesticides ***	Aquatic recreation indicators: Total phosphorus	Chlorophyll-a	Secchi	Aquatic life use	Aquatic recreation use
Rock	58-0007-00	77	11	Shallow lake	NLF	--	--	IF		EXS	EXS	EXS	IF	NS
Grace	58-0029-00	65	10	Shallow lake	NLF	--	--	IF		EXS	EXS	EXS	IF	NS

Abbreviations for Ecoregion: **DA** = Driftless Area, **NCHF** = North Central Hardwood Forest, **NGP** = Northern Glaciated Plains, **NLF** = Northern Lakes and Forests, **NMW** = Northern Minnesota Wetlands, **RRV** = Red River Valley, **WCBP** = Western Corn Belt Plains
Abbreviations for Secchi Trend: **D** = decreasing/declining trend, **I** = increasing/improving trend, **NT** = no detectable trend, **--** = not enough data
Abbreviations for Indicator Evaluations: **--** = No Data, **MTS** = Meets Standard; **EXS** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: ☐ = existing impairment, listed prior to 2016 reporting cycle; ☐ = new impairment; ☐ = full support of designated use; ☐= insufficient information.

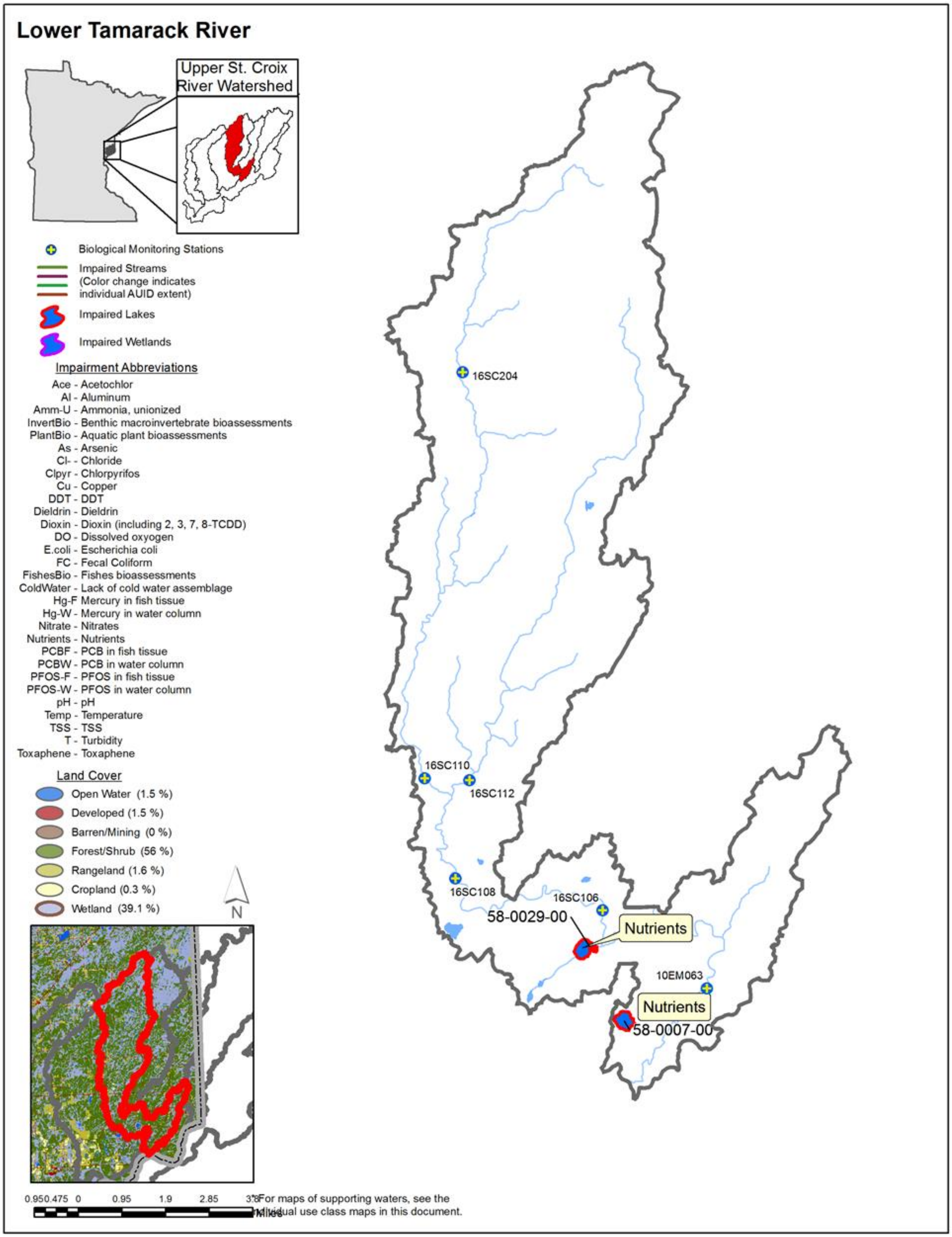
Summary

Fish and macroinvertebrates were sampled at six locations within this subwatershed. All sampling locations are full support for aquatic life and scored above the general use standard. Every fish sample in this subwatershed scored well enough to place the associated reach in the exceptional aquatic life use category. However, to be held to the higher exceptional level both fish and macroinvertebrates must meet this higher standard. Macroinvertebrates scored well above the general use threshold at all of the stations, with the exception of 16SC108, but the macroinvertebrate scores are not in the exceptional range. Macroinvertebrate taxa richness, and the presence of and abundance of intolerant taxa, including the infrequently collected taxa Ectopria, Attenela, and Ueonoidea, contribute to the high MIBI scores throughout this subwatershed.

CSMP volunteers are active on the headwaters portions of the Lower Tamarack River and Keene Creek, both sites have high transparency measurements indicating sediment is not an issue on those reaches. Chemistry data was available on the downstream reach of the Lower Tamarack River. Bacteria is a potential concern; elevated concentrations were found, but not enough samples were collected to make an assessment. TP is elevated in the subwatershed, but other available data, including the robust Secchi tube dataset with high clarity, and low chloride and un-ionized ammonia concentrations, indicate good water quality.

Both lakes in this subwatershed are shallow, and have limited ability to deal with excess nutrients. Shallow lakes will recycle nutrients during the summer months, causing algae blooms to occur throughout the summer. Rock Lake does not support aquatic recreation use due to natural sources of nutrients. There is no shoreline development or catchment disturbance, indicating minimal human impacts to the lakeshed. Grace Lake does not support aquatic recreation use. There is evidence of logging in the lakeshed (circa 2011-12), indicating human influence on the water quality.

Figure 14. Currently listed impaired waters by parameter and land use characteristics in the Lower Tamarack River Aggregated 12-HUC.



Hay Creek Aggregated 12-HUC HUC 0703000106-02

The Hay Creek subwatershed is located on the east side of the Upper St. Croix Watershed. This 51.9 mi^2 watershed lies almost completely in Pine County with a very small sliver in Wisconsin. Hay Creek flows 21.8 miles southwest from the Minnesota/Wisconsin border the Lower Tamarack River in St. Croix State Park. Land use is dominated by forest (61%), wetland (34.7%), and open water (1.5%) for a total of 96.9% natural land use. Developed land is minimal at 1.7%. In total, there are three stream reaches and lake in the watershed. There was one stream reach with data assessed for aquatic life and recreation (Table 5) and no lake were assessable (Table 6). There are no impairments within the watershed (Figure 15).

Table 5. Aquatic life and recreation assessments on stream reaches: Hay Creek Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

WID *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	Eutrophication	Aquatic life	Aquatic rec. (Bacteria)
07030001-511, ***Hay Creek,*** *MN/WI State border to Lower Tamarack R*	10EM127, 16SC113, 96SC067	21.78	WWg	MTS	MTS	IF	IF	MTS	MTS	MTS	MTS	IF	FS	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 2016 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** = general, **CWe** = exceptional, **LRVW** = limited resource value water

*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 6. Lake assessments: Hay Creek Aggregated 12-HUC.

Lake name	DNR ID	Area (acres)	Max depth (ft)	Assessment method	Ecoregion	Secchi trend	Aquatic life indicators:			Aquatic recreation indicators:			Aquatic life use	Aquatic recreation use
							Fish IBI	Chloride	Pesticides ***	Total phosphorus	Chlorophyll-a	Secchi		
Hay Creek Flowage	58-0005-00	88	10	NA	NLF	--	--	--		--	--	--	NA	NA

Abbreviations for Ecoregion: **DA** = Driftless Area, **NCHF** = North Central Hardwood Forest, **NGP** = Northern Glaciated Plains, **NLF** = Northern Lakes and Forests, **NMW** = Northern Minnesota Wetlands, **RRV** = Red River Valley, **WCBP** = Western Corn Belt Plains
Abbreviations for Secchi Trend: **D** = decreasing/declining trend, **I** = increasing/improving trend, **NT** = no detectable trend, **--** = not enough data
Abbreviations for Indicator Evaluations: **--** = No Data, **MTS** = Meets Standard; **EXS** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: ▢ = existing impairment, listed prior to 2016 reporting cycle; ▢ = new impairment; ▢ = full support of designated use; ▢= insufficient information.

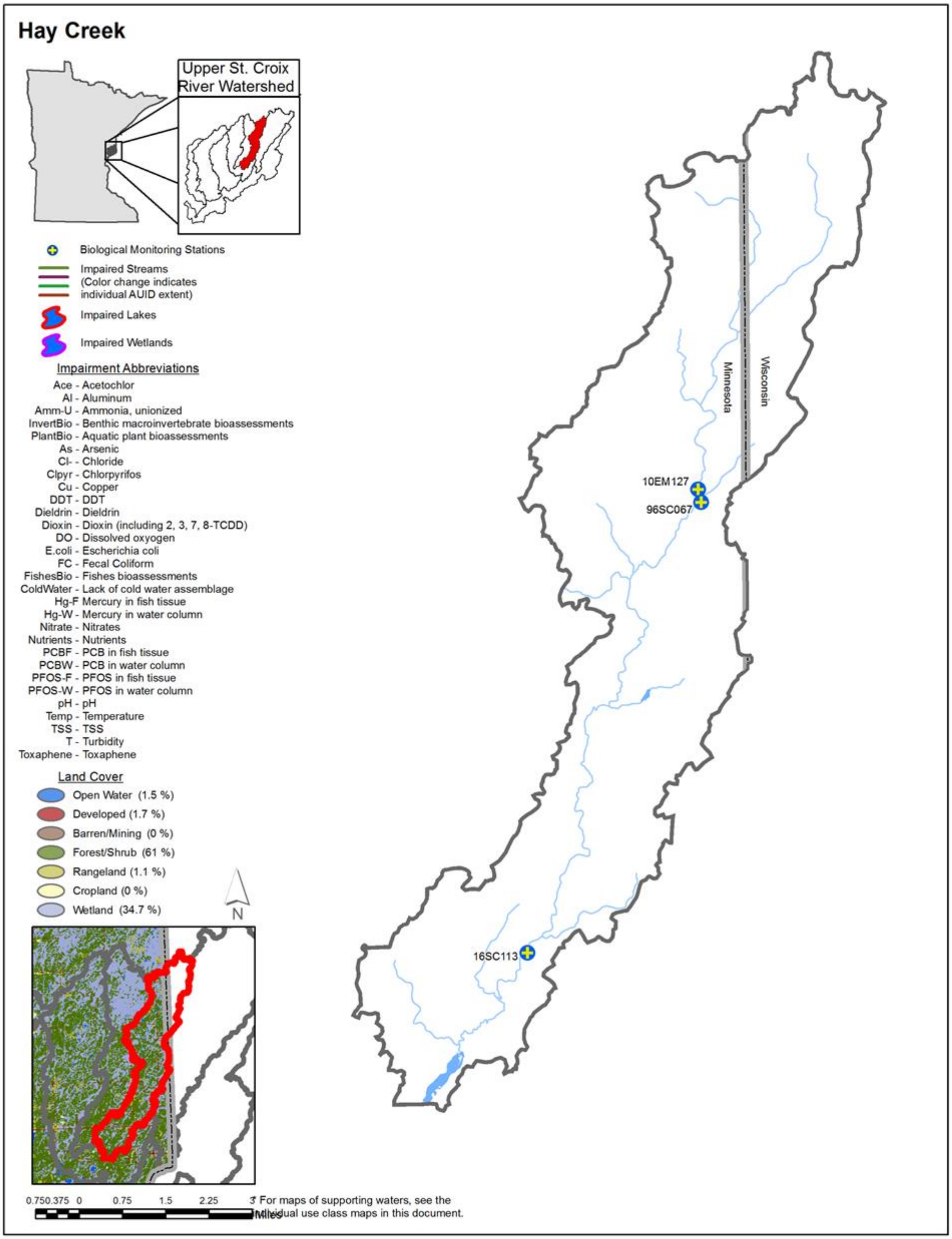
Summary

Fish and macroinvertebrates were sampled at three locations on Hay Creek. All assessable sampling locations are full support for aquatic life and scored above the general use standard. Every fish sample in this subwatershed scored well enough to place the associated reach in the exceptional aquatic life use category. However, to be held to the higher exceptional level both fish and macroinvertebrates must meet this higher standard. Macroinvertebrate data was assessable at two of the three locations samples, and scored well above the general use threshold at both stations, but did not score into the exceptional range. A high percentage of sensitive fish species at the sampling locations propelled the FIBI into the exceptional range. The macroinvertebrate community, while not exceptional, showed an influence of significant groundwater contribution, with several indicator taxa present across all stations. Station 96SC067 showed a very high quality dragonfly community, including Dromogomphus, Hagenius, and Cordulagaster.

Chemistry data was available on the downstream reach of Hay Creek. Data indicate good water quality and meets the standard for aquatic life. Elevated concentrations of bacteria were found, but not enough samples were collected to make an assessment for aquatic recreation use.

Hay Creek Flowage is a lake on the lower reach of Hay Creek. The residence time was calculated to be 4 days. Because the water does not remain in the basin long enough to foster algal growth, it is not assessed as a lake. Available data shows that concentrations of phosphorus are high but chlorophyll-a concentrations are low.

Figure 15. Currently listed impaired waters by parameter and land use characteristics in the Hay Creek Aggregated 12-HUC.



McDermott Creek Aggregated 12-HUC — HUC 0703000106-03

McDermott Creek Watershed is located on the eastern part of the Upper St. Croix Watershed. This 46.6 mi2 watershed lies completely in Pine County. It flows south out of Nemadji State Forest to the Lower Tamarack River in St. Croix State Park. Land use is dominated by forest (46.4%), wetland (51.7%), and open water (0.5%) for a total of 98.6% natural land use. Developed land is minimal at 0.9%. In total, there are three stream reaches and no lakes in the watershed. There were two stream reaches with data assessed for aquatic life and recreation (Table 7). There are no impairments within the watershed (Figure 16).

Table 7. Aquatic life and recreation assessments on stream reaches: McDermott Creek Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

WID *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	Eutrophication		
07030001-513, ***McDermott Creek,*** *Headwaters to Lower Tamarack R*	16SC109, 16SC116	19.07	WWg	MTS	MTS	IF	IF	IF	MTS	MTS	MTS	IF	FS	IF
07030001-528, ***Squib Creek,*** *Headwaters to McDermott Cr*	16SC114	6.20	WWg	MTS	MTS	IF	IF	IF		IF	IF	IF	FS	

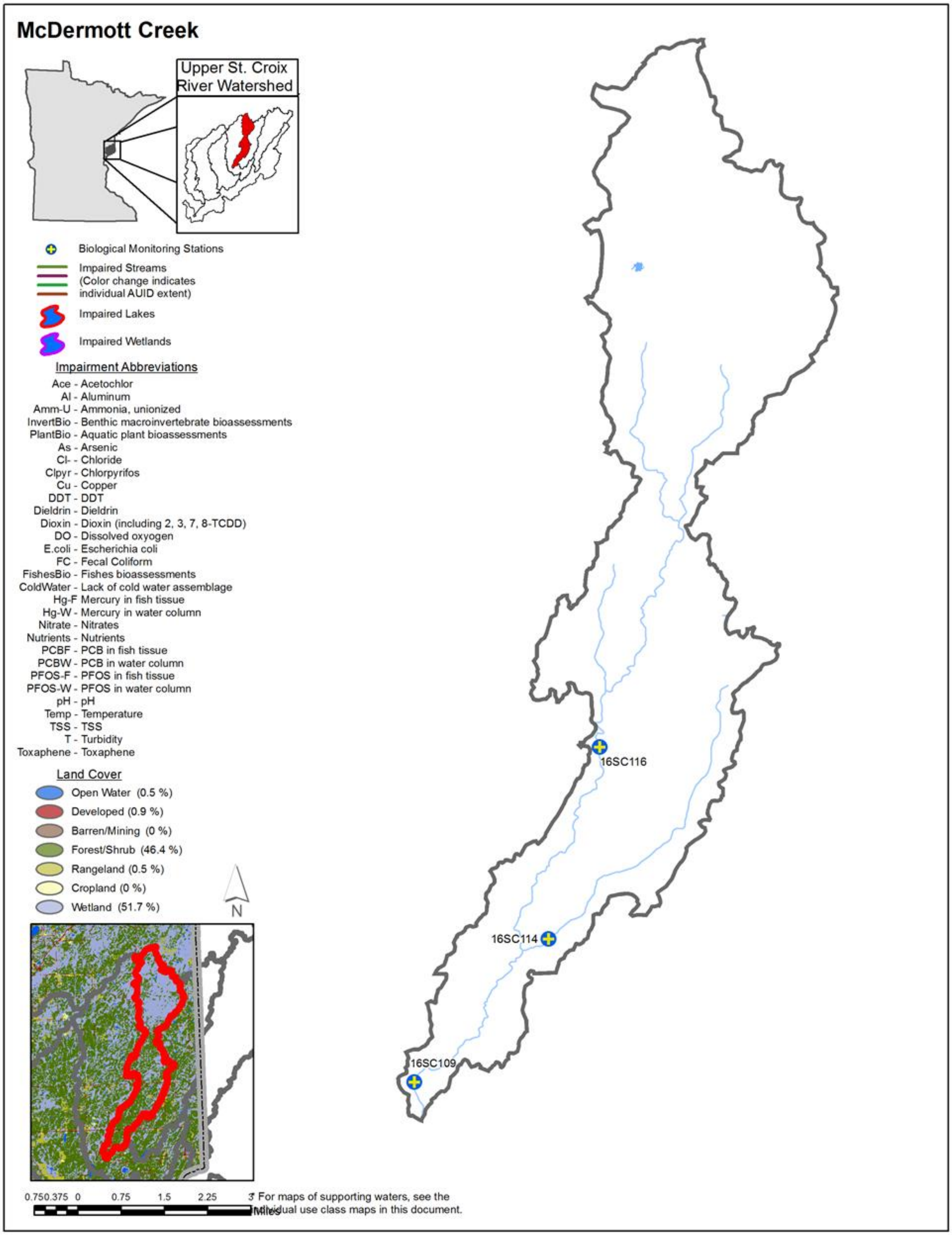
Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)
Key for Cell Shading: ☐ = existing impairment, listed prior to 2016 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** = general, **CWe** = exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Summary

Fish and macroinvertebrates were sampled at three locations within this subwatershed. All assessable sampling locations are full support for aquatic life and scored above the general use standard except for the macroinvertebrate sample at 16SC114 on Squib Creek. This subwatershed is over 50% wetland, which may be the largest contributor to the low dissolved oxygen levels in Squib Creek. Many of the fish present, like black bullhead and central mudminnow, are tolerant of low dissolved oxygen and often found in lower gradient streams. However, sensitive species such as hornyhead chub and smallmouth bass are driving the FIBI score above the general use threshold. The macroinvertebrate community in Squib Creek (16SC114) showed a lower diversity than what is typical in the watershed, but the characteristics of the macroinvertebrates present suggest a higher integrity than the low MIBI score suggests, including three intolerant taxa. Occasionally a MIBI output is determined to be under representative of the associated community, and it is necessary to make a professional judgement to call a station supportive of the standard, which is what was done for Squib Creek. Alternatively, the two assessable macroinvertebrate stations on McDermott Creek showed MIBI scores at or above the exceptional use standard, suggesting an overall healthy watershed.

Chemistry data from the lower reach of McDermott Creek indicate elevated levels of bacteria, but not enough samples were collected to make an aquatic recreation assessment. High precipitation events are likely the driver of the total suspended solid exceedances. All other chemistry data indicate good water quality.

Figure 16. Currently listed impaired waters by parameter and land use characteristics in the McDermott Creek Aggregated 12-HUC.



Crooked Creek Aggregated 12-HUC HUC 0703000107-01

Crooked Creek Watershed is located on the central part of the Upper St. Croix Watershed. This 100.2 mi^2 watershed lies completely in Pine County. East Fork Crooked Creek and West Fork Crooked Creek flow south coming together 2.5 miles north of St. Croix State Park. Crooked Creek then flows south to the St. Croix River in St. Croix State Park. Much of Crooked Creek, the lower portion of East Fork Crooked Creek, and the upper section of West Fork Crooked Creek are designated streams. Land use is dominated by forest (56.1%), wetland (29.2%), and open water (1.7%) for a total of 87% natural land use. Developed land is minimal at 1.8%. In total, there are 32 stream reaches and 3 lakes in the watershed. There were five stream reaches with data assessed for aquatic life and recreation (Table 8) and two lakes were assessable (Table 9). There is one impairments within the watershed (Figure 17).

Table 8. Aquatic life and recreation assessments on stream reaches: Crooked Creek Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

				Aquatic life indicators:										
WID ***Reach name,*** *Reach description*	**Biological Station ID**	**Reach length (miles)**	**Use class***	**Fish IBI**	**Invert IBI**	**Dissolved oxygen**	**TSS**	**Secchi Tube**	**Chloride**	**pH**	**Ammonia -NH_3**	**Eutrophication**	**Aquatic life**	**Aquatic rec. (Bacteria)**
07030001-522, ***Crooked Creek,*** *Confluence of E & W Fk to T41 R17W S29, south line*	67SC015	6.59	CWg	MTS	MTS	IF	IF	MTS	MTS	MTS	MTS	IF	FS	IF
07030001-533, ***Crooked Creek,*** *East Fork, Unnamed cr to Crooked Cr*	16SC104	2.87	CWg	MTS	MTS	IF	IF	IF		IF	IF		FS	
07030001-537, ***Crooked Creek, West Fork,*** *T41 R18W S11, north line to Crooked Cr*	16SC203	2.43	CWg	MTS	MTS	IF	IF	MTS		IF	IF		FS	
07030001-541, ***Crooked Creek,*** *T41 R17W S32, north line to St Croix R*	16SC121	2.32	WWe	MTS	MTS	IF	IF	IF		IF	IF		FS	

07030001-545, ***Bangs Brook,*** *T41 R17W S15, east line to Crooked Cr*	10SC002	4.24	CWe	IF	MTS	IF	IF	IF		IF	IF		FS	
07030001-548, ***Wolf Creek,*** *T43 R18W S32, north line to Crooked Cr*	78SC001	4.14	CWg	MTS	EXS	IF	IF	IF		IF	IF		NS	
07030001-562, ***Kenney Brook,*** *T41 R17W S20, north line to Crooked Cr*	16SC120	1.20	WWg	MTS	MTS	IF	IF	IF		IF	IF		FS	

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** = general, **CWe** = exceptional, **LRVW** = limited resource value water

*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 9. Lake assessments: Crooked Creek Aggregated 12-HUC.

Lake name	DNR ID	Area (acres)	Max depth (ft)	Assessment method	Ecoregion	Secchi Trend	Aquatic life indicators:			Aquatic recreation indicators:			Aquatic life use	Aquatic recreation use
							Fish IBI	Chloride	Pesticides ***	Total phosphorus	Chlorophyll-a	Secchi		
Razor	58-0010-00	94	36	Deep lake	NLF	--	--	IF		MTS	MTS	MTS	IF	FS
Greigs	58-0013-00	52	68	--	NLF	--	--	--		--	--	--	--	--
Tamarack	58-0024-00	73	47	Deep lake	NLF	I	--	IF		MTS	MTS	MTS	IF	FS

Abbreviations for Ecoregion: DA = Driftless Area, NCHF = North Central Hardwood Forest, NGP = Northern Glaciated Plains, NLF = Northern Lakes and Forests, NMW = Northern Minnesota Wetlands, RRV = Red River Valley, WCBP = Western Corn Belt Plains
Abbreviations for Secchi Trend: D = decreasing/declining trend, I = increasing/improving trend, NT = no detectable trend, -- = not enough data
Abbreviations for Indicator Evaluations: -- = No Data, **MTS** = Meets Standard; **EXS** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: -- = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: ☐ = existing impairment, listed prior to 2014 reporting cycle; ☐ = new impairment; ☐ = full support of designated use; ☐= insufficient information.

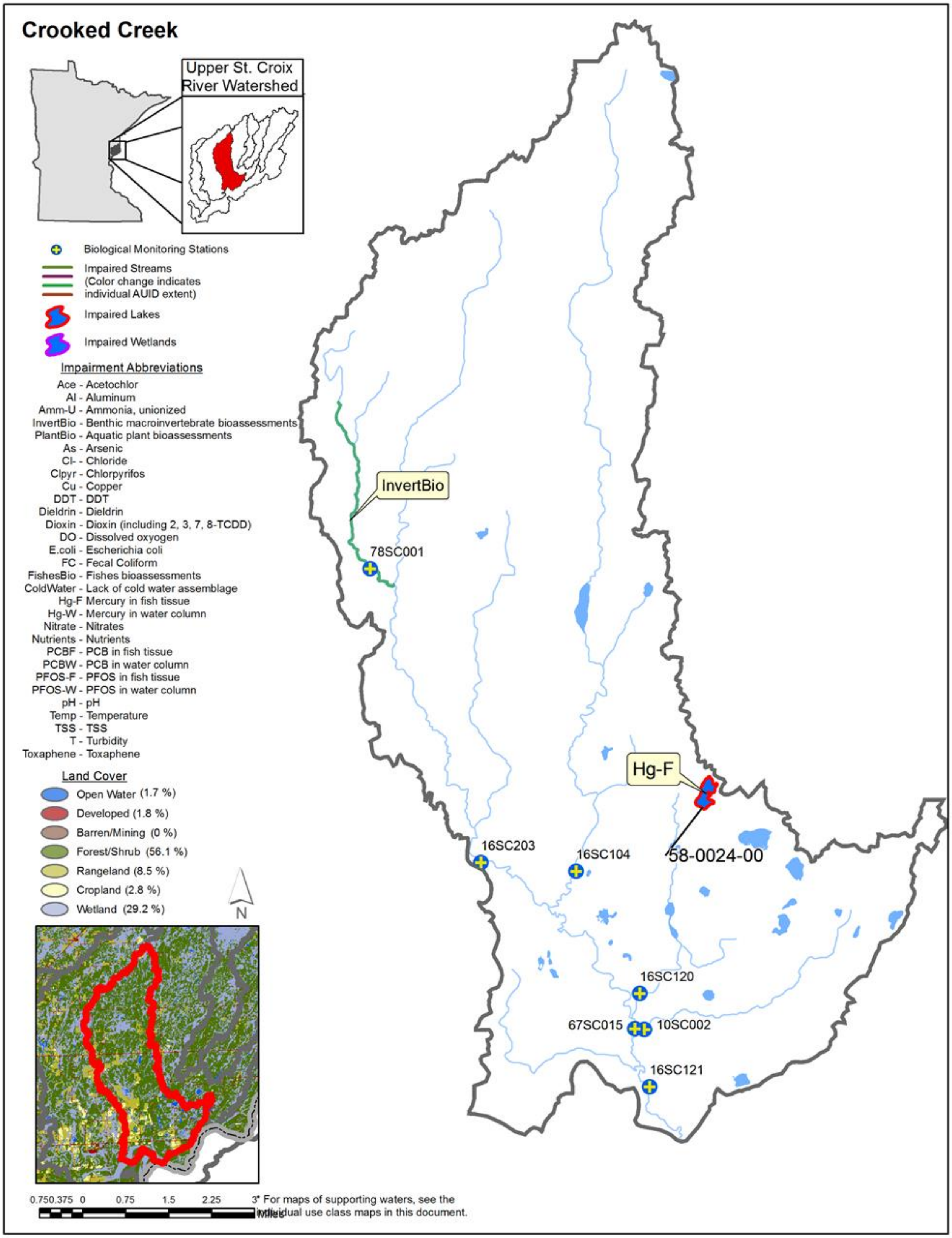
Summary

Fish and macroinvertebrates were sampled at seven locations within this subwatershed. There are five and two warmwater stream segments. Bangs Brook, and the warmwater reach of Crooked Creek are exceptional use and the rest in the subwatershed are general use. Station 16SC121 is located on the warmwater exceptional use stream segment of Crooked Creek. This section of stream is downstream of designated stream segments on Crooked Creek. It was sampled for fish twice in 2016. The first fish sample was in June. Rainbow trout, brown trout, and mottled sculpin, which are species, were present in the sample. There were also three obligate macroinvertebrate taxa present – Eukiefferiella, Lype, and Glossosoma. A historic flood occurred on July 11th dumping up to 10 inches of rain in a 24-hour period. Station 16SC121 was resampled for fish the same year in August and the stream morphology had changed drastically. There were gravel bars in many areas where there was none before. There was also significant bank erosion and many trees that had fallen into the stream. The second sample had a higher FIBI score but, only one mottled sculpin was sampled and no other species were present. The macroinvertebrate sample collected at this station occurred after the flood, and the resulting sample showed one of the most diverse and intact macroinvertebrate communities in the watershed. The resiliency of the macroinvertebrate community suggests a watershed that is well buffered against the impact of extreme flow events, despite the fact that there were temporary habitat impacts. Wolf Creek is a reach that when sampled for invertebrates showed a very small presence of invertebrates, and appeared much more like a high quality, warmwater stream. The presence of a fish community prevents this stream from being reclassified to warmwater. Temperatures taken at the time of fish sampling suggest that higher temperatures may be limiting the invertebrate community. The low gradient nature of this site, and associated low gradient habitats, could also be impacting the composition of the community.

There is extensive amount of data available from the CSMP on the upper reaches of Crooked Creek and Bangers Brook. Both have high transparency measurements indicating that sediment is not an issue in the upper reaches of the subwatershed. Chemistry data was collected on the lower reach of Crooked Creek. Elevated concentrations of bacteria were found, but not enough samples were collected to make an assessment for aquatic recreation use. There is a single dissolved oxygen deployment that captured a 6.5-inch rain event. The DO dropped to 2.04 on the day of the event and recovered to above the standard after 3 days as Crooked Creek water levels dropped.

Two of the three lakes in the watershed have been assessed for aquatic recreation use and are fully supporting (Razor and Tamarack). Tamarack has an extensive Secchi dataset spanning 27 years and has shown improving trend in transparency.

Figure 17. Currently listed impaired waters by parameter and land use characteristics in the Crooked Creek Aggregated 12-HUC.



Sand Creek Aggregated 12-HUC

HUC 0703000110-01

Sand Creek Watershed is located on the west central part of the Upper St. Croix Watershed. This 140.4 mi^2 watershed lies completely in Pine County and is the largest subwatershed in the Upper St. Croix Watershed. Sand Creek starts 5 miles west of Bruno and flows south to the St. Croix River in St. Croix State Park. Much of the headwaters of Sand Creek are designated along with Hay Creek, which is largest tributary to Sand Creek. Land use is dominated by forest (48.8%), wetland (33.5%), and open water (0.8%) for a total of 83.1% natural land use. Developed land is minimal at 2.7%. In total, there are 36 stream reaches and 1 lake in the watershed. There were 10 stream reaches with data assessed for aquatic life and recreation (Table 10) and no lakes were assessable (Table 11). There are three impairments within the watershed (Figure 18).

Table 10. Aquatic life and recreation assessments on stream reaches: Sand Creek Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

				Aquatic life indicators:										
WID ***Reach name,*** *Reach description*	**Biological Station ID**	**Reach length (miles)**	**Use class***	**Fish IBI**	**Invert IBI**	**Dissolved oxygen**	**TSS**	**Secchi Tube**	**Chloride**	**pH**	**Ammonia -NH_3**	**Eutrophication**	**Aquatic life**	**Aquatic rec. (Bacteria)**
07030001-538, ***Sand Creek,*** *Headwaters to T44 R18W S27, south line*		4.96	WWg					EXS					NS	
07030001-546, ***Hay Creek,*** *Headwaters to Lk Clayton*	09SC051, 16SC119	12.72	CWg	EXS	EXS	IF	IF	IF		IF	IF		NS	
07030001-553, ***Partridge Creek,*** *Unnamed cr to Sand Cr*	68SC001	3.97	WWg	MTS	IF	IF	IF	IF		IF	IF		FS	
07030001-554, ***Little Sand Creek,*** *Unnamed cr to Sand Cr*	16SC201	5.58	WWe	MTS	MTS	IF	IF	IF		IF	IF		FS	
07030001-604, ***Sand Creek,*** *T44 R18W S34, north line to Unnamed cr*	67SC008	2.14	CWg	EXS	MTS	IF	IF	IF		IF	IF		NS	
07030001-605, **Sand Creek,** *Unnamed cr to Pickle Cr*	16SC118	4.97	CWg	MTS	MTS	IF	IF	IF		IF	IF		FS	

07030001-606, ***Sand Creek,*** *Pickle Cr to T43 R19W S24, south line*	16SC115	0.80	CWg	MTS	MTS	IF	IF	IF		IF	IF		FS	
07030001-617, ***Sand Creek,*** *T43 R19W S25, north line to Unnamed cr*	16SC111	22.7	WWg	MTS	MTS	IF	IF	IF		IF	IF		FS	
07030001-618, ***Sand Creek,*** *Unnamed cr to St Croix R*	16SC101, 96SC090	7.99	WWe	MTS	MTS	IF	IF	MTS	MTS	MTS	MTS	IF	FS	IF
07030001-902, ***Little Hay Creek,*** *Headwaters to Hay Cr*	16SC100	1.45	CWg	MTS	IF	IF	IF	IF		IF	IF		FS	

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** = general, **CWe** = exceptional,
LRVW = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Table 11. Lake assessments: Sand Creek Aggregated 12-HUC.

Lake name	DNR ID	Area (acres)	Max depth (ft)	Assessment method	Ecoregion	Secchi Trend	Aquatic life indicators:			Aquatic recreation indicators:			Aquatic life use	Aquatic recreation Use
							Fish IBI	Chloride	Pesticides ***	Total Phosphorus	Chlorophyll-a	Secchi		
Wilbur	58-0045-00	43	14	--	NLF	--	--	--		--	--	--	--	--

Abbreviations for Ecoregion: DA = Driftless Area, NCHF = North Central Hardwood Forest, NGP = Northern Glaciated Plains, NLF = Northern Lakes and Forests, NMW = Northern Minnesota Wetlands, RRV = Red River Valley, WCBP = Western Corn Belt Plains
Abbreviations for Secchi Trend: D = decreasing/declining trend, I = increasing/improving trend, NT = no detectable trend, -- = not enough data
Abbreviations for Indicator Evaluations: -- = No Data, **MTS** = Meets Standard; **EXS** = Exceeds Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: -- = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **FS** = Full Support (Meets Criteria); **NS** = Not Support (Impaired, exceeds standard)
Key for Cell Shading: = existing impairment, listed prior to 2014 reporting cycle; = new impairment; = full support of designated use; = insufficient information.

Summary

Fish and macroinvertebrates were sampled on nine stream segments within this subwatershed. Five of the stream segments are and four are warmwater. All of the warmwater sampling locations are full support for aquatic life and scored well above the general use standard. Three of the sampling locations on two stream segments scored well enough to place the associated reach in the exceptional aquatic life use category. The exceptional designation holds more pristine streams to a higher standard than stream segments in the general or modified use category.

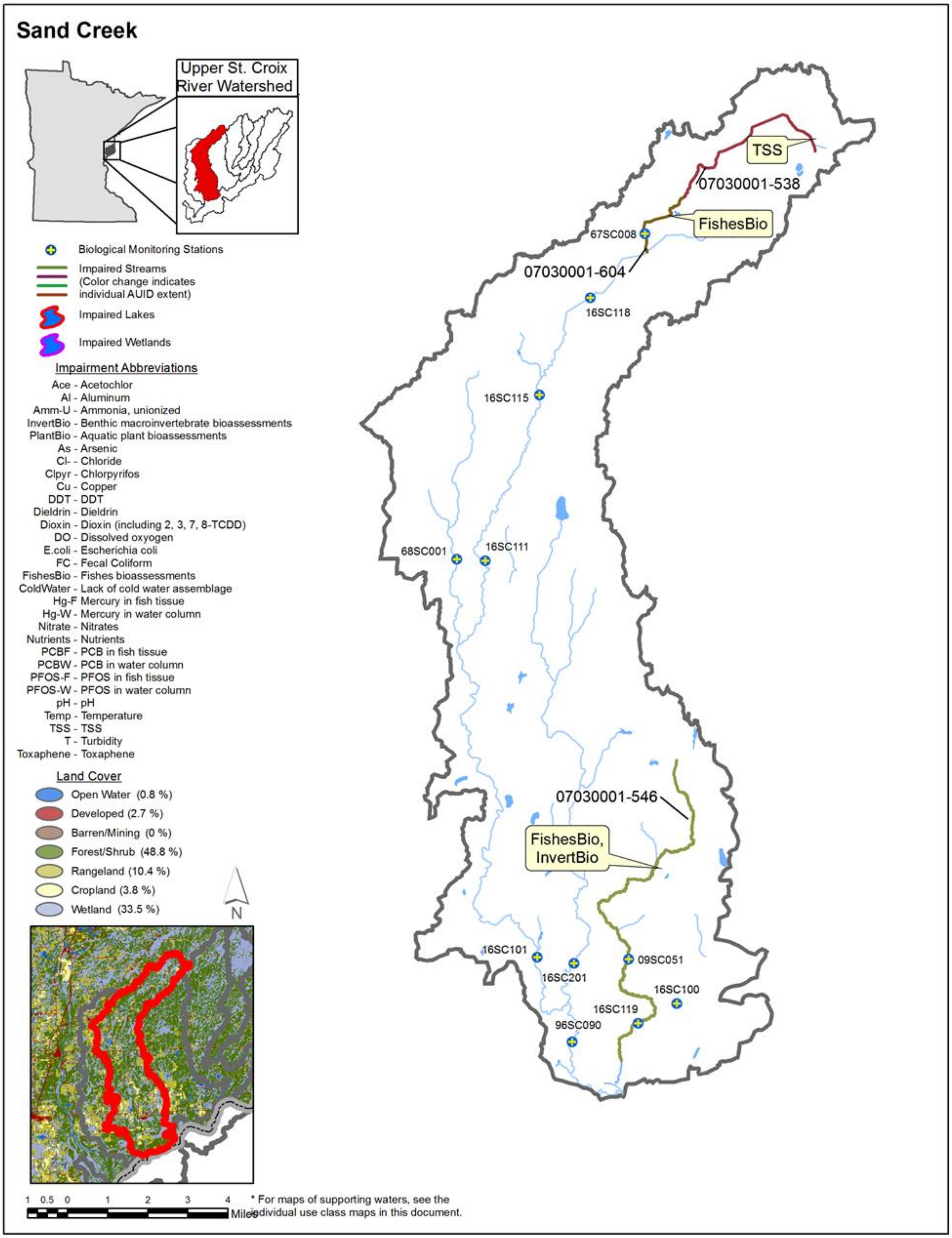
There are two stream segments impaired for aquatic life, one segment on Sand Creek, and one on Hay Creek. Two stations (09SC051 and 16SC119) on Hay Creek were sampled a total of four times for fish, and three time for macroinvertebrates. Three of four fish samples scored below the general use threshold, and all three macroinvertebrate samples scored below the general use threshold for Northern Streams. Macroinvertebrate samples lacked a robust assemblage, while fish species were present at all of the samples, including young of year brook trout. This 2017 data suggest that brook trout inhabit Hay Creek and reproduce. Beaver dams have greatly reduced habitat for trout by increased siltation, widening of the stream channel and increased water temperatures due to ponding of the stream. In 2008, a federal trapper trapped many beavers out of the stream and greatly increased the brook trout population.

Station 67SC008 was sampled twice on Sand Creek in 2016 and 2017. Both FIBI scores were below the Northern Stream threshold, while both MIBI scores scored above the threshold. There were no fish species present at either sample, but numerous obligate macroinvertebrate taxa were present between both samples. In 2009, a DNR survey found brook trout within this stream segment from a wild population. Much like Hay Creek, beaver dams have greatly reduced habitat for trout by increasing siltation, widening the stream channel and increasing water temperatures due to ponding of the stream. There was a beaver dam downstream of the sampling location that could have created a barrier for fish passage.

Extensive Secchi data is available on the upper reach of Sand Creek. This data show impairment for total suspended solids. Chemistry data available on the downstream reach of Sand Creek indicate good water quality for aquatic life use. Elevated concentrations of bacteria were found, but not enough samples were collected to make an assessment for aquatic recreation use. Hay Creek has a small Secchi dataset showing exceedances, which could be impacting the aquatic life community.

Wilber Lake does not have any available data in order to make assessments. It is a small, private lake with estimated clarity of nine feet, which would indicate support of recreation uses.

Figure 18. Currently listed impaired waters by parameter and land use characteristics in the Sand Creek Aggregated 12-HUC.



Bear Creek Aggregated 12-HUC

HUC 0703000111-01

Bear Creek Watershed is located on the western part of the Upper St. Croix Watershed. This 67-mi2 watershed lies completely in Pine County. It start 2 miles south of Askov and flows south to the St. Croix River in St. Croix State Park. Land use is dominated by forest (43.3%), wetland (30.2%), and open water (0.4%) for a total of 73.9% natural land use. Developed land is minimal at 3%. In total, there are 12 stream reaches and no lakes in the watershed. There were two stream reaches with data assessed for aquatic life and recreation (Table 12). There are no impairments within the watershed (Figure 19).

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

WID *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	Eutrophication	Aquatic life	Aquatic rec. (Bacteria)
07030001-518, *Bear Creek,* *Headwaters to St Croix R*	16SC102, 16SC117, 68SC007	39.57	WWg	MTS	MTS	IF	IF	MTS	MTS	MTS	MTS	IF	FS	IF
07030001-581, Little Bear Creek, *Unnamed cr to Bear Cr*	16SC103	1.88	WWg	MTS	MTS	IF	IF	IF		IF	IF		FS	

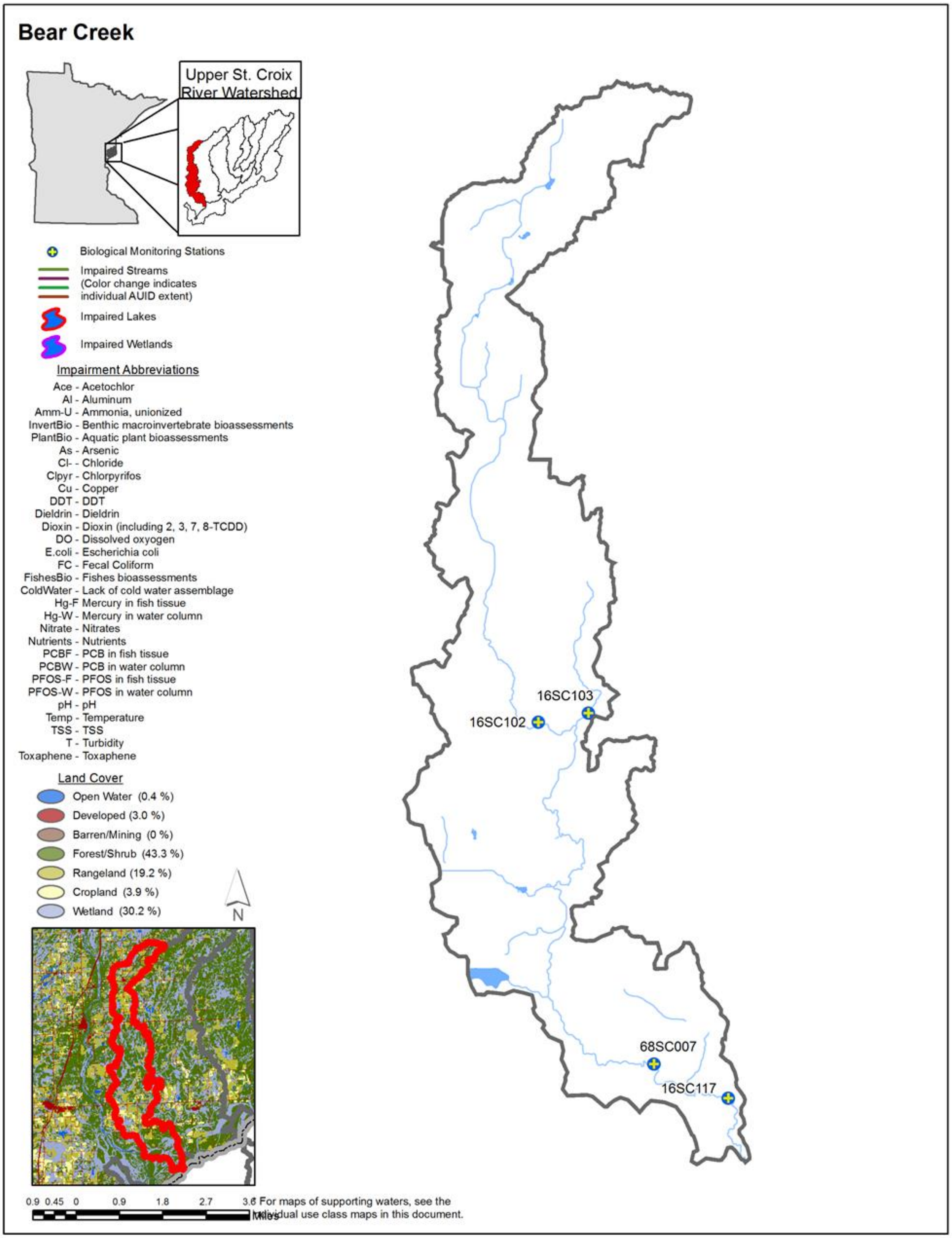
Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (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** = general, **CWe** = exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Summary

Fish and macroinvertebrates were sampled on two stream segments within this subwatershed. All three of the sampling stations on Bear Creek and the one sampling location on Little Bear Creek scored well above the threshold for the FIBI. Two of the three stations on Bear Creek scored above the MIBI threshold, with the upstream most station (16SC102) scoring below the general use threshold. Despite the low score in the upstream station, due to the presence of excellent habitat and lack of disturbance in the watershed, it was determined the outlier score was likely the result of the high-flow event that occurred prior to sampling, and that the watershed was supporting the aquatic life use. Every fish sample in this subwatershed scored well enough to place the associated reach in the exceptional aquatic life use category. However, only one of five macroinvertebrate samples scored above the exceptional use threshold, and to be held to the higher exceptional use standard both fish and macroinvertebrates must meet this higher standard.

CSMP volunteers are active on the headwaters portion of Bear Creek. Data shows high transparency measurements indicating sediment is not an issue on that part of the reach. Chemistry data was available on the downstream reach of the Bear Creek. Bacteria is a potential concern; elevated concentrations were found, but not enough samples were collected to make an assessment for aquatic recreation use. Other available data, including the robust Secchi tube dataset indicate good water quality.

Figure 19. Currently listed impaired waters by parameter and land use characteristics in the Bear Creek Aggregated 12-HUC.



Chases Brook-St. Croix River Aggregated 12-HUC HUC 0703000112-01

Chases Brook- St. Croix River Watershed is located on the western part of the Upper St. Croix Watershed and is separated from the rest of the watershed by the Kettle River. The assessed part of this 177.9 mi^2 watershed lies completely in Pine County. The majority of the watershed is the St. Croix River. Only 13 mi^2 are assessed in this report. Redhorse Creek flows south in Chengwatana State Forest to the St. Croix River. Land use is dominated by forest (55.7%), wetland (37.8%), and open water (3.3%) for a total of 96.8% natural land use. Developed land is minimal at 1.3%. In total, there are five stream reaches and no lakes in the watershed. There was one stream reach with data assessed for aquatic life and recreation (Table 13). There are no impairments within the watershed (Figure 20).

Table 13. Aquatic life and recreation assessments on stream reaches: Chases Brook-St. Croix River Aggregated 12-HUC. Reaches are organized upstream to downstream in the table.

WID ***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	Eutrophication	Aquatic life	Aquatic rec. (Bacteria)
07030001-519, ***Redhorse Creek,*** *Headwaters to St Croix R*	16SC202	4.82	WWg	MTS	MTS	IF	IF	IF	MTS	IF	MTS	IF	FS	IF

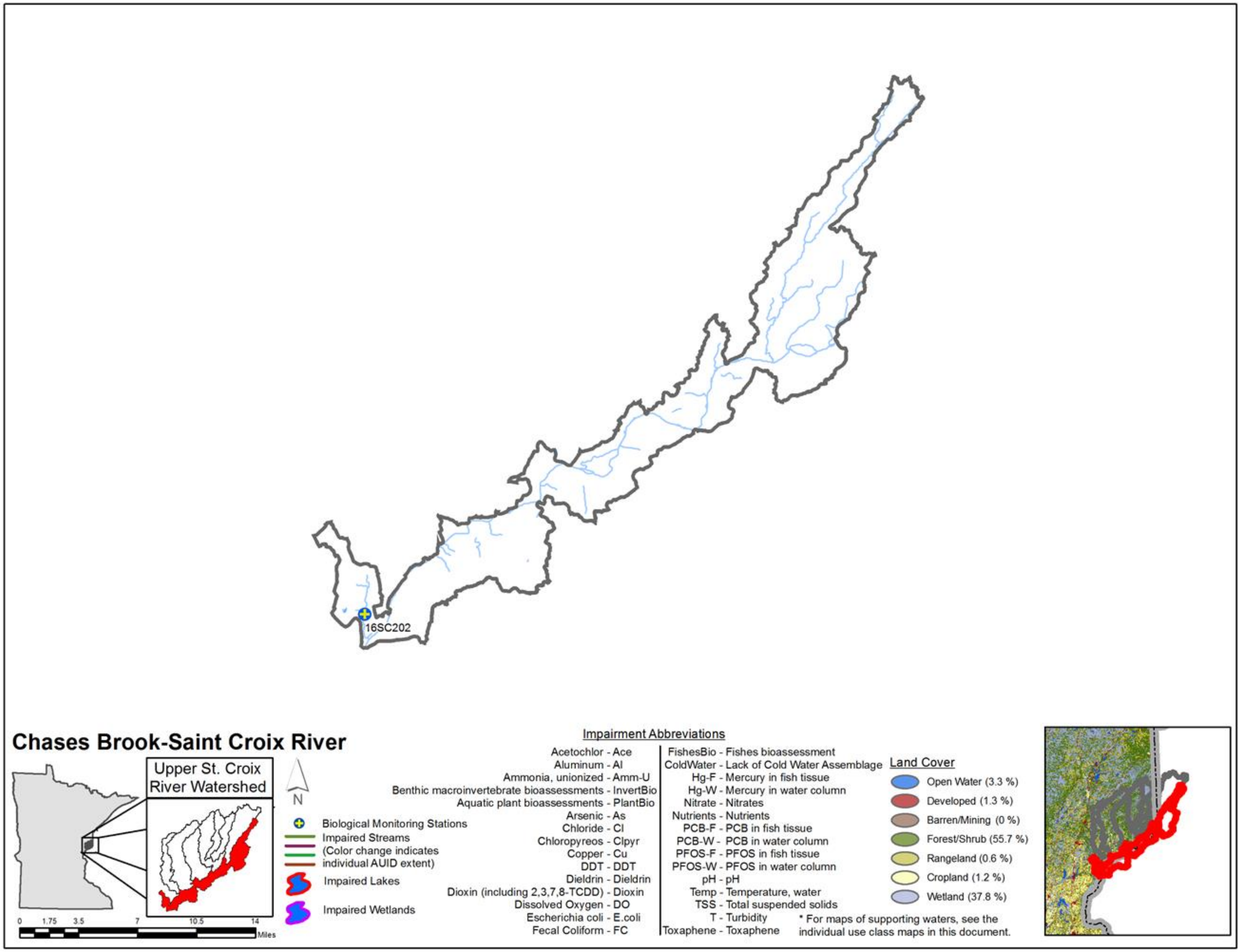
Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information
Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (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** = general, **CWe** = exceptional, **LRVW** = limited resource value water
*Assessments were completed using proposed use classifications changes that have not yet been written into rule.

Summary

Fish and macroinvertebrates were sampled at one station on one stream segment within this subwatershed. Redhorse Creek is not a low gradient stream, but it was observed to have a slower water velocity than other streams of the same drainage area in the watershed. There were beaver dams observed above, below, and within the sampling reach. Despite the lower water velocity, station level habitat was excellent, and both the fish and macroinvertebrates scored above the threshold, within the confidence interval. The fish community may have performed better, as there is likely an impact due to fish passage being limited by beaver dams. The macroinvertebrate community did not appear to be significantly impacted by the relatively reduced water velocities, as it had a very diverse clinger taxa, which are dependent on consistent, moderate flows.

Chemistry data was collected on the lower reach of Redhorse Creek. Based on available data, the water quality in the subwatershed is good, with low nutrients and sediment concentrations. Unionized Ammonia and Chloride both meet the toxic standards for aquatic life.

Figure 20. Currently listed impaired waters by parameter and land use characteristics in the Chases Brook-St. Croix River Aggregated 12-HUC.



Watershed-wide results and discussion

Assessment results and data summaries are included below for the entire HUC-8 watershed unit of the Upper St. Croix River Watershed, grouped by sample type. Summaries are provided for lakes, streams, and rivers in the watershed for the following: aquatic life and recreation uses, aquatic consumption results, load monitoring data results, and transparency trends. Waters identified as priorities for protection or restoration work were also identified. 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 Upper St. Croix River Watershed.

Stream water quality

Thirty-four of the 108 stream WIDs were assessed for aquatic life and/or recreation (Table 14). Of those assessed, 25 streams fully support aquatic life. Throughout the watersheds, four WIDs are non-supporting for aquatic life. One WID is impaired for fish, another for macroinvertebrates, and one for both. Aquatic life water chemistry parameters (total suspended solids, Secchi tube) are not supporting on one stream.

Bacteria concentrations were elevated across the watershed. No impairments were assigned, as data minimums were not met.

Table 14. Assessment summary for stream water quality in the Upper St. Croix River Watershed.

				Supporting		Non-supporting			
Watershed	**Area (acres)**	**# Total WIDs**	**# Assessed WIDs**	**# Aquatic life**	**# Aquatic recreation**	**# Aquatic life**	**# Aquatic recreation**	**Insufficient data**	**# Delistings**
07030001 **HUC 8**	**499320**	**108**	**34**	**25**	**0**	**4**	**0**	**13**	**0**
Upper Tamarack River	63462	3	2	2	0	0	0	1	0
Lower Tamarack River	61751	14	6	4	0	0	0	3	0
Hay Creek	33221	3	1	1	0	0	0	1	0
McDermott Creek	29876	3	2	2	0	0	0	1	0
Crooked Creek	64200	32	9	6	0	1	0	3	0
Sand Creek	89930	36	11	7	0	3	0	2	0
Bear Creek	42922	12	2	2	0	0	0	1	0
Chases Brook-St. Croix River	113959	5	1	1	0	0	0	1	0

Lake water quality

The Upper St. Croix watershed has data on 7 lakes greater than 10 acres (Table 15). Tamarack and Razor both support aquatic recreation use, while Grace does not. Rock also does not support aquatic recreation use but it was determined that natural background conditions are causing the elevated concentrations of nutrients in this lake. The remaining three lakes had insufficient data to make an aquatic recreation assessment. There is no existing data to make aquatic life use support assessments.

Table 15. Assessment summary for lake water chemistry in the Upper St. Croix River Watershed.

			Supporting		Non-supporting			
Watershed	**Area (acres)**	**Lakes >10 acres**	**# Aquatic life**	**# Aquatic recreation**	**# Aquatic life**	**# Aquatic recreation**	**Insufficient data**	**# Delistings**
07030001 **HUC 8**	**499320**	**7**	**0**	**2**	**0**	**2**	**3**	**0**
Upper Tamarack River	63462	0	-	-	-	-	-	-
Lower Tamarack River	61751	2	0	0	0	2	0	0
Hay Creek	33221	1	0	0	0	0	1	0
McDermott Creek	29876	0	-	-	-	-	-	-
Crooked Creek	64200	3	0	2	0	0	1	0
Sand Creek	89930	1	0	0	0	0	1	0
Bear Creek	42922	0	-	-	-	-	-	-
Chases Brook-St. Croix River	113959	0	-	-	-	-	-	-

Fish contaminant results

Mercury and polychlorinated biphenyls (PCBs) have been analyzed in fish tissue samples collected from the Crooked Creek and two lakes in the watershed. Samples were collected by DNR fisheries staff from 1982 to 2007 and MPCA biomonitoring staff collected fish from Crooked Creek in 2016 and 2017.

One of the two tested lakes—Tamarack—is on the 2018 Impaired Waters Inventory (IWI) for mercury in fish tissue (Table 16) and qualified for inclusion in the Minnesota Statewide Mercury TMDL.

PCBs were tested in representative species from Crooked Creek and Northern pike in Tamarack Lake. All PCB concentrations were less than the reporting limits and were, therefore, well below the 0.2-ppm threshold for impairment.

Table 16. Fish contaminants: summary of fish length, mercury and PCBs by waterway-species-year

						Total	Number	Length (in)			Mercury (mg/kg)			PCBs (mg/kg)			
WID	Waterway	Species	Species	Year	Anatomy[1]	Fish	Samples	Mean	Min	Max	Mean	Min	Max	N	Mean	Max	< RL
07030001-541	CROOKED CREEK	BNT	Brown trout	2015	FILSK	8	8	13.5	11.2	17.2	0.054	0.043	0.077	2	0.025	0.025	Y
				2016	FILSK	7	7	12.4	10.9	13.8	0.021	0.014	0.030	2	0.025	0.025	Y
		WTS	White sucker	2015	FILSK	5	5	15.1	13.9	16.6	0.077	0.049	0.110	2	0.025	0.025	Y
				2016	FILSK	5	1	13.1	13.1	13.1	0.121	0.121	0.121	1	0.025	0.025	Y
58-0007-00	ROCK	BLG	Bluegill sunfish	2007	FILSK	10	1	6.6	6.6	6.6	0.148	0.148	0.148				
58-0024-00	TAMARACK*	BLG	Bluegill sunfish	1988	FILSK	15	3	6.8	5.5	8.2	0.260	0.240	0.280				
				1994	FILSK	10	1	6.6	6.6	6.6	0.130	0.130	0.130				
		LMB	Largemouth bass	1982	FILSK	3	1	14.0	14.0	14.0	0.400	0.400	0.400				
				1985	FILSK	1	1	10.2	10.2	10.2	0.310	0.310	0.310				
		NOP	Northern pike	1982	FILSK	7	2	23.2	17.7	28.7	0.470	0.340	0.600				
				1985	FILSK	5	1	19.1	19.1	19.1	0.310	0.310	0.310				
				1988	FILSK	7	7	21.6	18.3	25.2	0.470	0.290	0.750				
				1994	FILSK	23	5	20.9	14.9	26.1	0.248	0.130	0.310	1	0.01	0.01	Y
				1997	FILSK	21	21	21.7	12.6	29.7	0.317	0.150	0.730	3	0.01	0.01	Y

* Impaired for mercury in fish tissue as of 2018 Draft Impaired Waters Inventory; categorized as EPA Category 4a for waters covered by the Statewide Mercury TMDL.

** Impaired for mercury in fish tissue as of 2018 Draft Impaired Waters Inventory; categorized as EPA Category 5 for waters needing a TMDL.

1 Anatomy codes: FILSK – edible fillet, skin-on; FILET—edible fillet, skin-off; WHORG—whole organism.

Pollutant load monitoring

The WPLMN has one monitoring site located within the Upper St. Croix River watershed as shown in Table 17.

Table 17. WPLMN Stream Monitoring Sites for the Upper St. Croix River watershed

Site Type	Stream Name	USGS ID	DNR/MPCA ID	EQuIS ID
Basin	St. Croix River near Danbury, WI*	05333500	W34024002	S000-056

*Water samples are collected at a different location than the USGS flow gaging station. The EQuIS ID and DNR/MPCA ID are the locations where the actual samples are collected. This location is about 13 miles downstream in Minnesota.

Average annual FWMCs of TSS, TP, and NO_3+NO_2-N for major watershed stations statewide are presented in Figure 21, with the Upper St. Croix 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; expressed in inches.

As a general rule, elevated levels of TSS and NO_3+NO_2-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 as well as 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 NO_3+NO_2-N in surface waters impacts fish and other aquatic life, as well as fishing, swimming and other recreational uses. The St. Croix River is recognized as a National Scenic Riverway under the National Wild and Scenic Rivers System. The Upper St. Croix River is classified as scenic and two segments located downstream of the Upper St. Croix River are classified as recreational. Recurring algal blooms have been reported on Lake St. Croix, a naturally occuring lake that lies within one of the two recreational designated segments which the St. Croix River flows through just before its confluence with the Mississippi River.

More information, including results for the additional downstream sites on the St. Croix River, can be found at the WPLMN website.

When compared to the other basin and major watershed sites within the entire St. Croix River Basin, the average annual TP FWMCs for the Upper St. Croix River are less than most. Average annual TSS and NO_3+NO_2-N FWMCs for the Upper St. Croix River are relatively low, as they are throughout the St. Croix River Basin. When compared to other basin and major watershed sites throughout Minnesota, average annual TSS, TP, and NO_3+NO_2-N FWMCs for the Upper St. Croix River are lower than most.

Substantial year-to-year variability in water quality occurs for most rivers and streams, including the Upper St. Croix River. Results for individual years are shown in Figure 22 below. Elevated TSS and TP loads observed in 2016 are due in part to historic flooding that took place throughout the Upper St. Croix River Watershed in July 2016. Increasing TSS and NO_3+NO_2-N loads despite relatively stable FWMCs (Figure 2) indicates that the increasing loads are due to greater amounts of water moving through the Upper St. Croix River.

Annual TSS FWMCs have not exceeded the River Nutrient Region standard of 15 mg/L at the St. Croix River near Danbury, Wisconsin monitoring site during the period of WPLMN monitoring. Of water samples collected, <1% exceed the River Nutrient Region standard. Annual TP FWMCs have not exceeded the River Nutrient Region standard of 0.05 mg/L at the St. Croix River nr Danbury, Wisconsin monitoring site during the period of WPLMN monitoring. Of water samples collected, 6% exceed the

River Nutrient Region standard. Individual samples are not intended to represent standard flow conditions.

Figure 21. 2007-2016 Average annual TSS, TP, and NO_3-NO_2-N flow weighted mean concentrations, and runoff by major watershed.

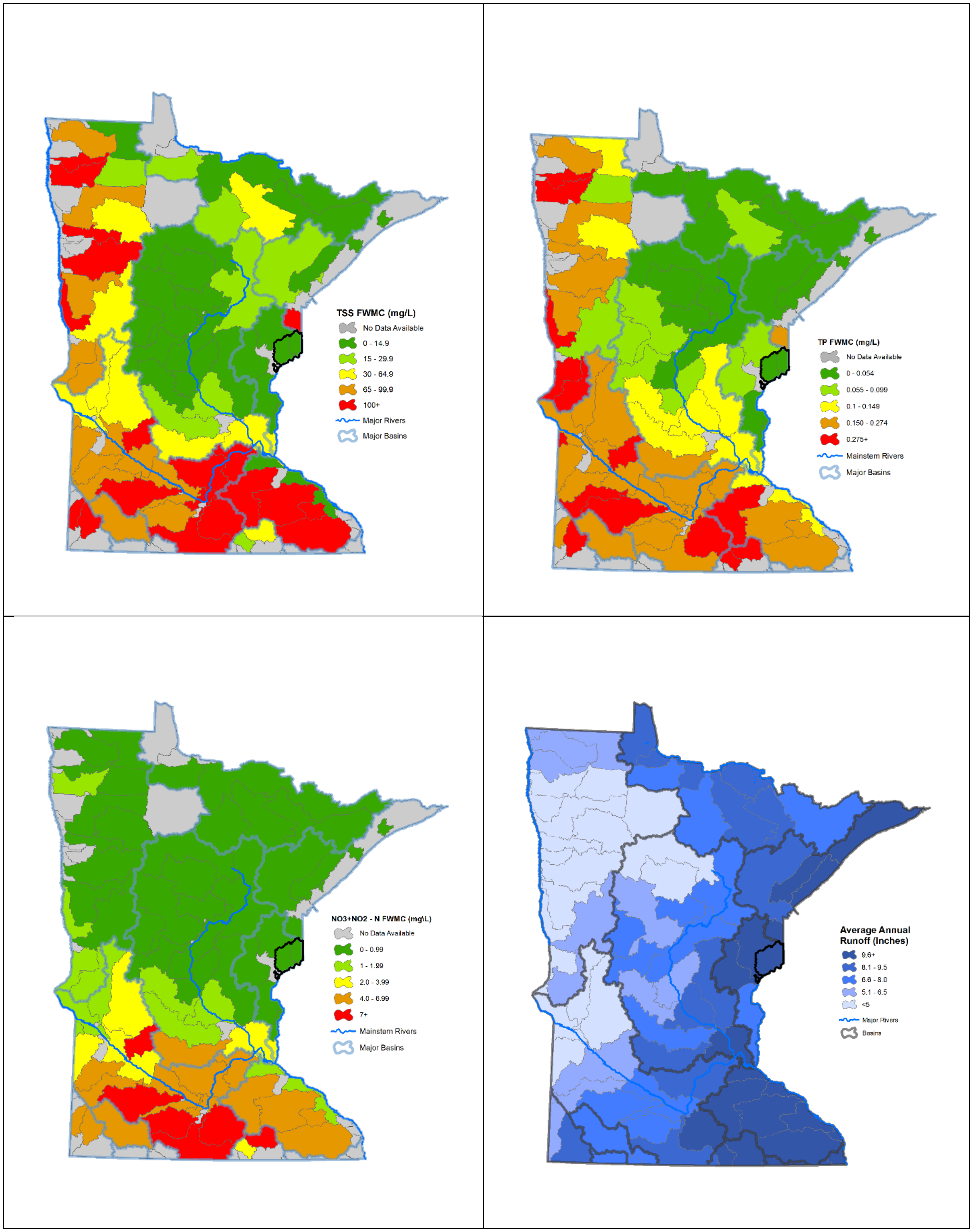
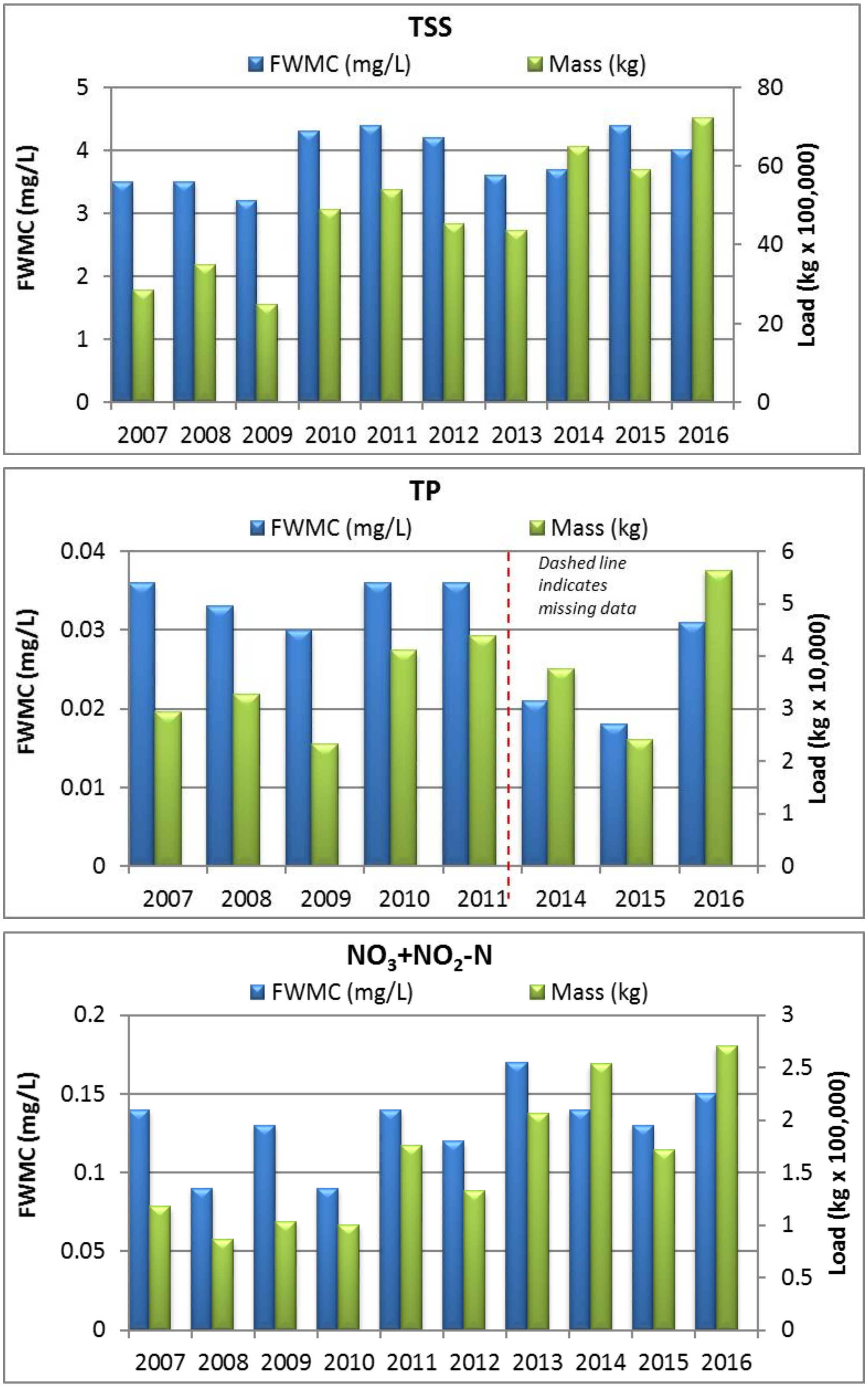


Figure 22. TSS, TP, and NO_3+NO_2-N Flow Weighted Mean Concentrations and Loads for the St. Croix River near Danbury, WI monitoring site.



Groundwater monitoring

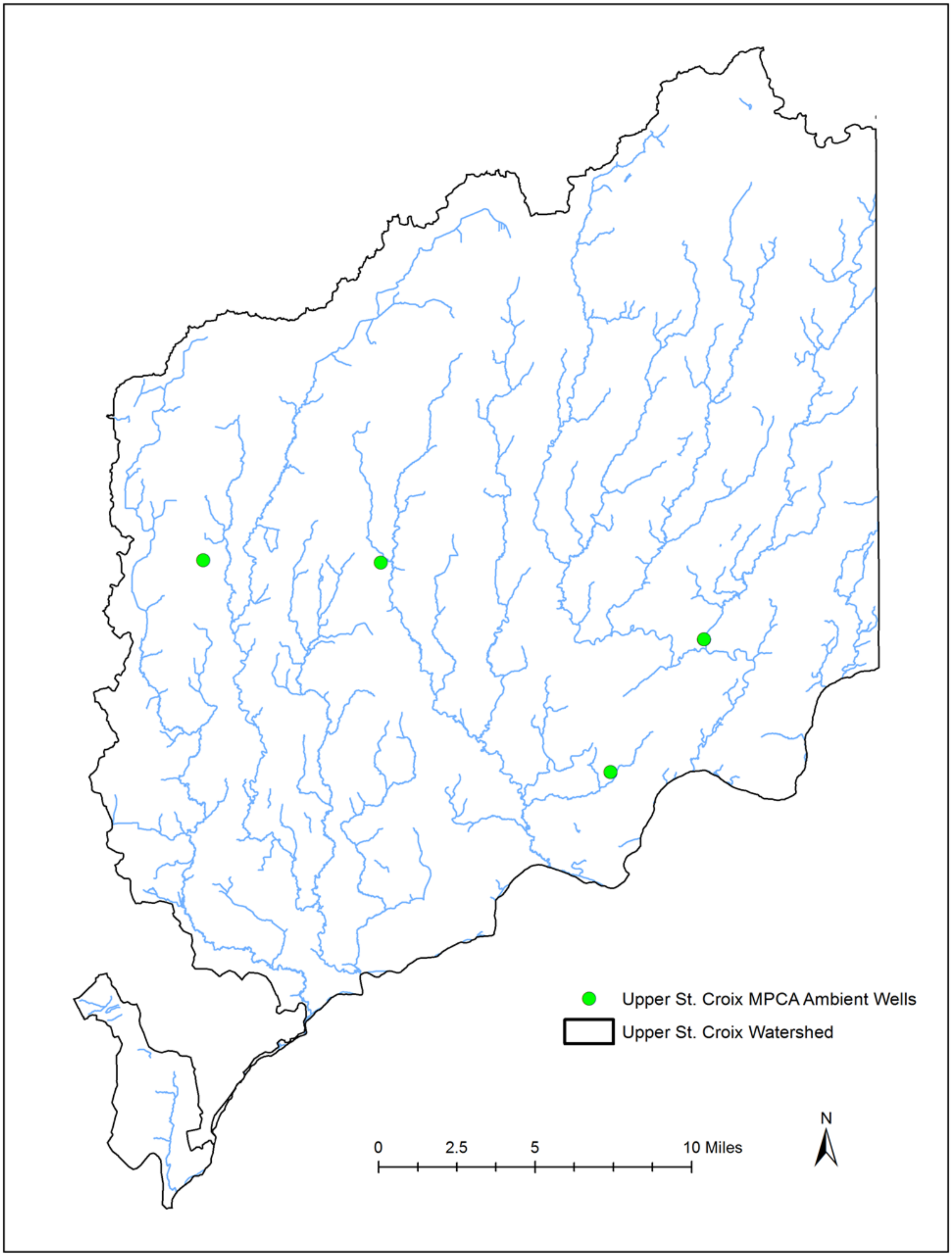
Groundwater quality

Approximately 75% of Minnesota's population receives their drinking water from groundwater, so clean groundwater is essential to the health of its residents. The Minnesota Pollution Control Agency'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 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 four MPCA Ambient Groundwater Monitoring wells within the Upper St. Croix River Watershed (Figure 23). Data from these wells indicate the presence of naturally occurring minerals like iron and manganese. Additionally, the data show low-level fluctuating chloride concentrations, though it is unclear whether the fluctuations are a result of chloride use aboveground.

Another source of information on groundwater quality comes from the MDH. Mandatory testing for arsenic, a naturally occurring but potentially harmful contaminant for humans, of all newly constructed wells has found that an average of 10% of all wells installed from 2008 to 2016 have arsenic levels above the MCL for drinking water of 10 micrograms per liter (MDH, 2019a). The Upper St. Croix River Watershed, in Minnesota, is entirely within Pine County. The frequency of arsenic levels above the MCL in new wells was rare in Pine County at only 2.7%. (MDH 2019b).

Figure 23. MPCA Ambient Groundwater Monitoring wells within the Upper St. Croix River Watershed



Groundwater quantity

The DNR maintains a statewide network of water level wells to assess groundwater resources, evaluate trends and plan. While there are a number of deep wells within the Upper St. Croix River Watershed, a shallower, water table well is more reactive to recharge and withdrawals. Groundwater elevations from wells #244278 and #244276, both near Hinckley, are displayed below on Figure 24 and Figure 25. Fluctuations in water level are common and expected with seasonal change and varied precipitation.

Figure 24. Water table elevations in Well #244278 near Hinckley 1977-2016

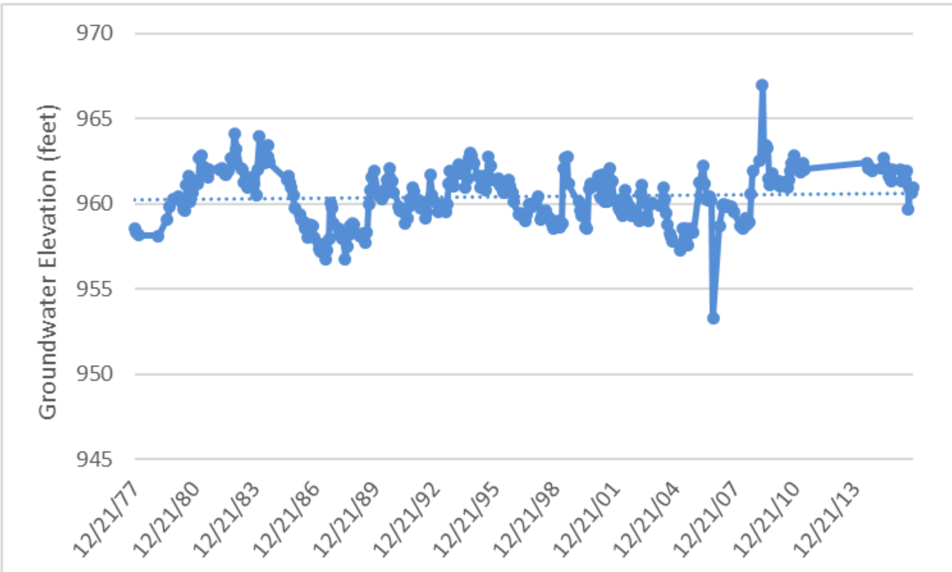
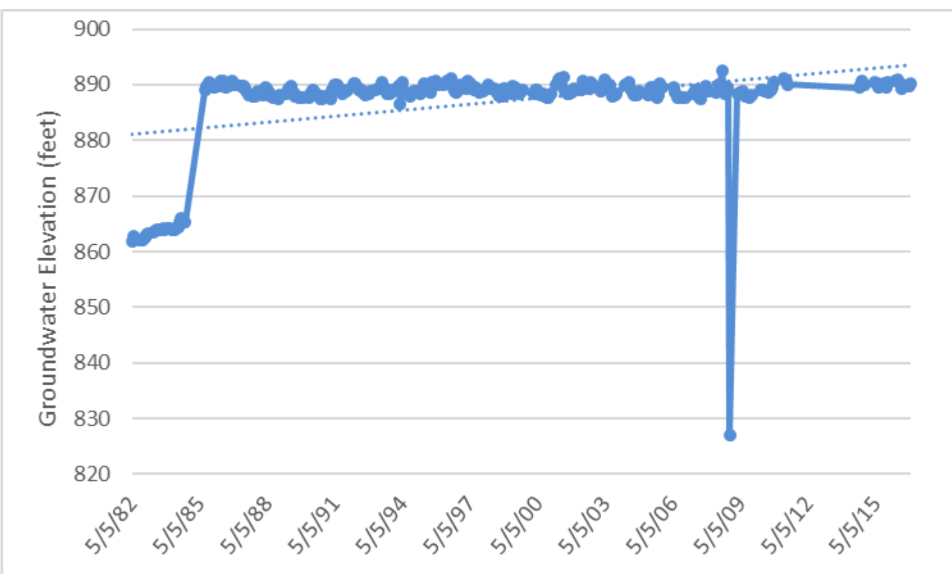


Figure 25. Water table elevations in Well #244280 near Hinckley, 1982-2016



The DNR also permits all high capacity water withdrawals where the pumped volume exceeds 10,000 gallons per day or one million gallons per year. Permit holders are required to track water use and report back to the DNR annually. The changes in withdrawal volume detailed in this groundwater 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.

The three largest permitted consumers of water in the state for 2016 are (in order) power generation, public water supply (municipals), and irrigation (DNR, 2019). According to the most recent DNR Permitting and Reporting System (MPARS), in 2016 the two largest use categories for withdrawals within the Upper St. Croix River Watershed are were water supply (64%) and sand and gravel washing (16%).

Figure 26 displays total high capacity withdrawal locations within the watershed with active permit status in 2016. Permitted groundwater withdrawals are displayed below as blue triangles and surface water withdrawals as red squares. During 1997 to 2016, groundwater withdrawals within the Upper St. Croix River Watershed exhibit no significant trend and surface water withdrawals have increased significantly ($p<0.01$) (Figure 27).

Figure 26. Locations of active status permitted high capacity withdrawals in 2016 within the Upper St. Croix River Watershed (DNR, 2019)

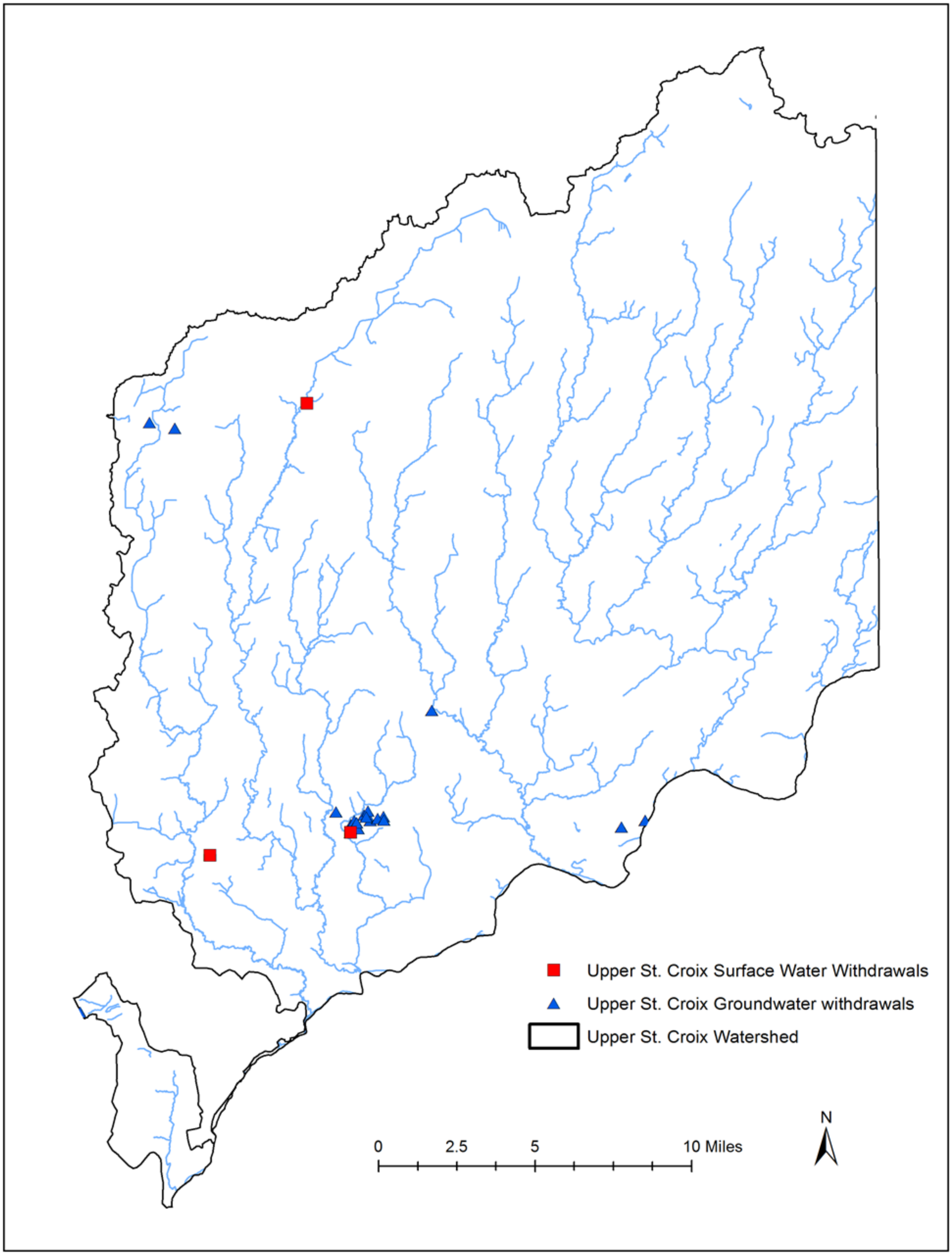
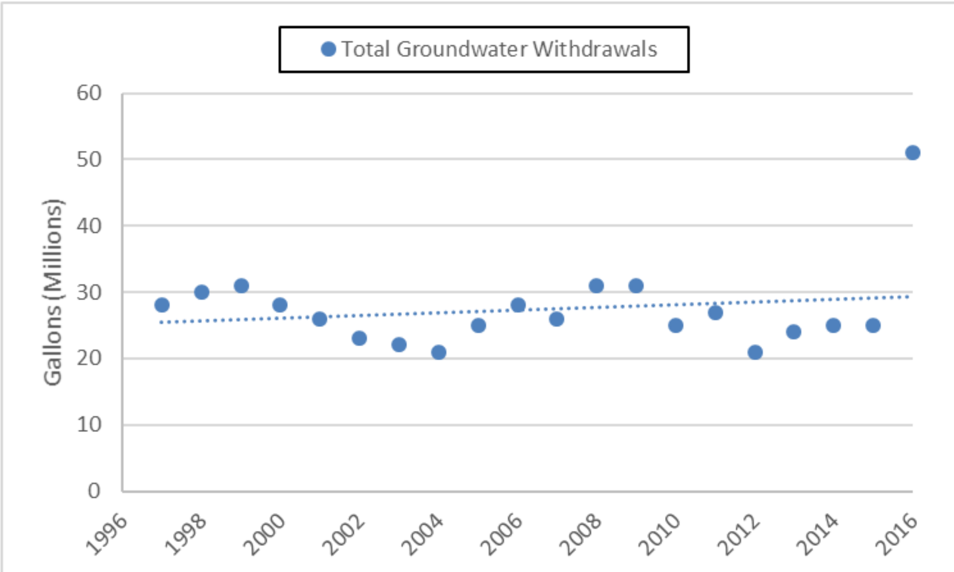
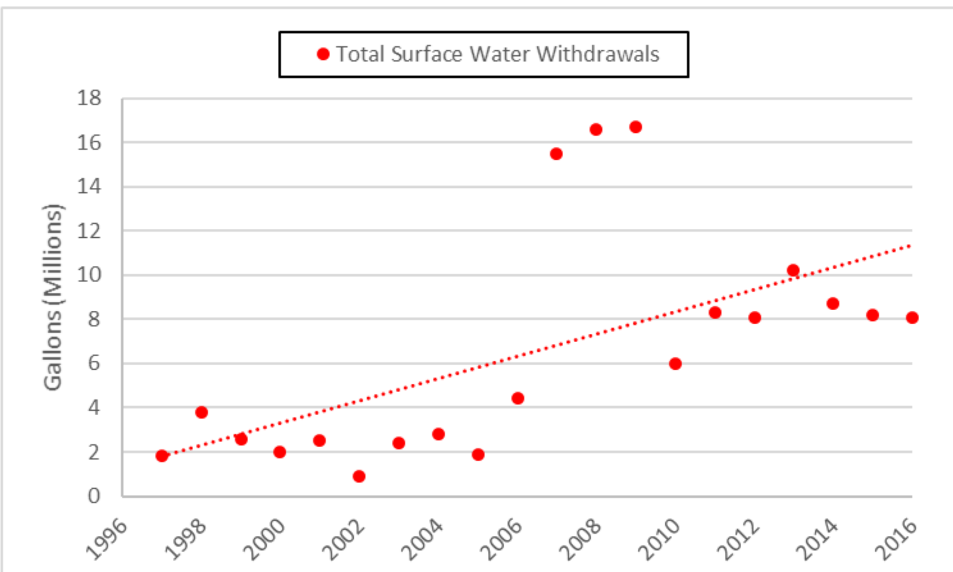


Figure 27. Total annual groundwater (*above*) and surface water (*below*) withdrawals in the Upper St. Croix River Watershed (1997-2016)

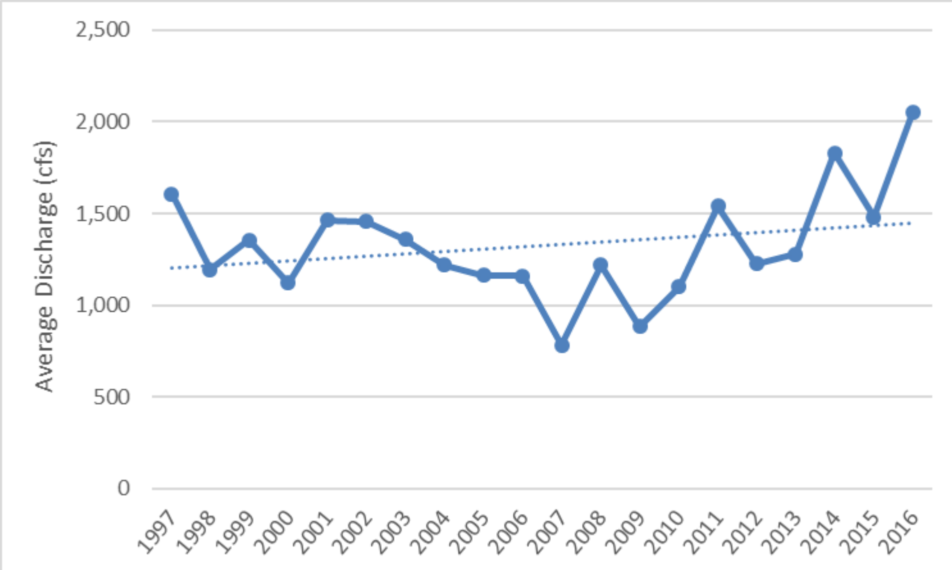


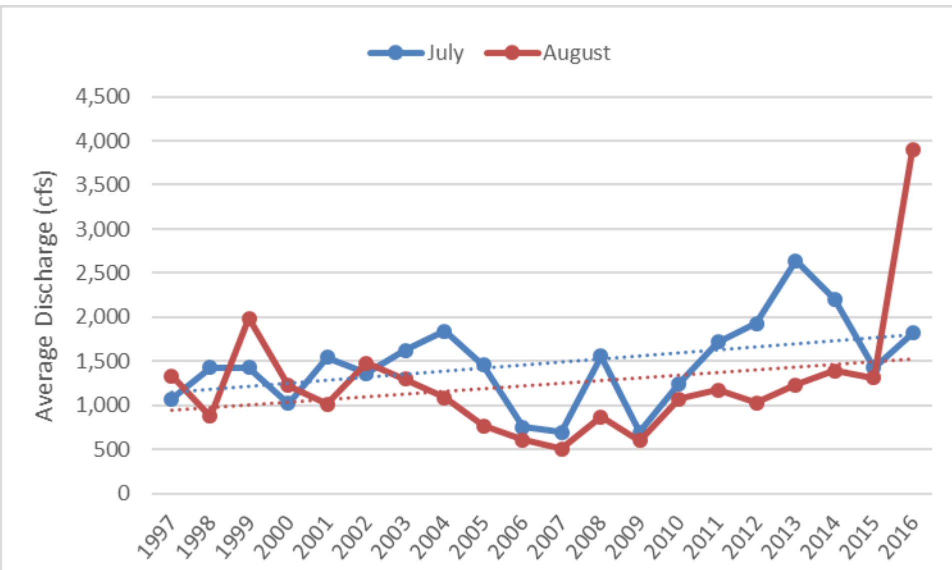


Stream flow

Stream flow data from the United States Geological Survey's real-time streamflow gaging station on the Upper St. Croix River near Sandstone, MN were analyzed for average annual discharge and summer (July and August) monthly average discharge from 1997-2016 (Figure 28). The data fluctuate, but these changes illustrate seasonality of flow and responses to precipitation and are not statistically significant, save the July readings which have increased with slight significance ($p = 0.10$). 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).

Figure 28. Average Annual (above) and Summer (below) mean discharge for the St. Croix River near Danbury, Wisconsin (1997-2016) (Source: USGS 2019)





Wetland condition

The Upper St. Croix River Watershed occurs entirely within the Mixed Wood Shield Ecoregion. Wetland condition, in this ecoregion is very good, compared to other Minnesota ecoregions. Based on plant community floristic quality, 84% of the wetlands in the Mixed Wood Shield Ecoregion are estimated to be in exceptional or good condition, and none are in poor condition (Table 18). In Minnesota's other two ecoregions, wetland condition is essentially opposite. In these locations, over 80% of the existing wetland area is in either fair or poor condition.

Table 18. Wetland biological condition by major ecoregions based on floristic quality. Results are expressed as an extent (i.e., percentage of wetland acres) and include essentially all wetland types (MPCA 2015).

Vegetation Condition in All Wetlands

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

As with stream and lake quality, many stressors can contribute to decreased wetland quality or condition. Altered hydrology, excessive sediment and/or nutrient, and toxic pollutant loading can all affect wetland quality. These stressors often promote establishment and spread of pollution tolerant invasive plants including narrow-leaf cattail (*Typha angustifolia*), hybrid cattail (*Typha* X *glauca*), and reed canary grass (*Phalaris arundinacea*). These invasive plants often outcompete native species due to their tolerance of nutrient enrichment, hydrologic alterations and toxic pollutants such as chlorides (Galatowitsch 2012) and thus strongly influence the composition and structure of affected wetland communities.

In the Upper St. Croix River Watershed, as with other watersheds located in the Mixed Wood Shield Ecoregion, monitoring and management resources allocated to water quality should focus on protecting the existing high quality wetland resource present in the watershed. These efforts should include limiting pollutant discharges and avoiding or minimizing hydrologic alternations that adversely affect wetland condition and facilitate establishment and spread of invasive species known, to rapidly, and dramatically affect wetland quality.

Figure 29. Stream Tiered Aquatic Life Use Designations in the Upper St. Croix River Watershed.

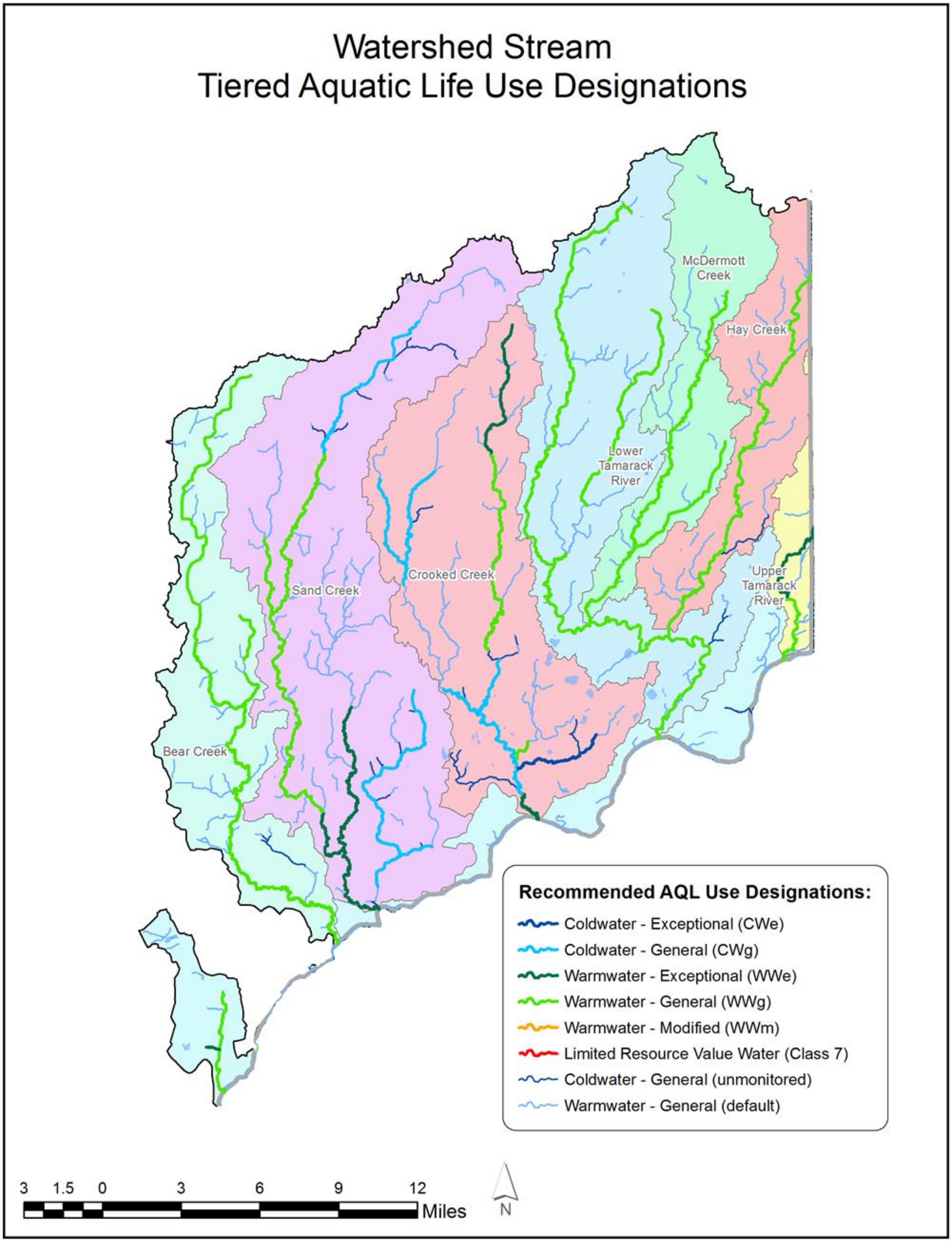


Figure 30. Fully supporting waters by designated use in the Upper St. Croix River Watershed.

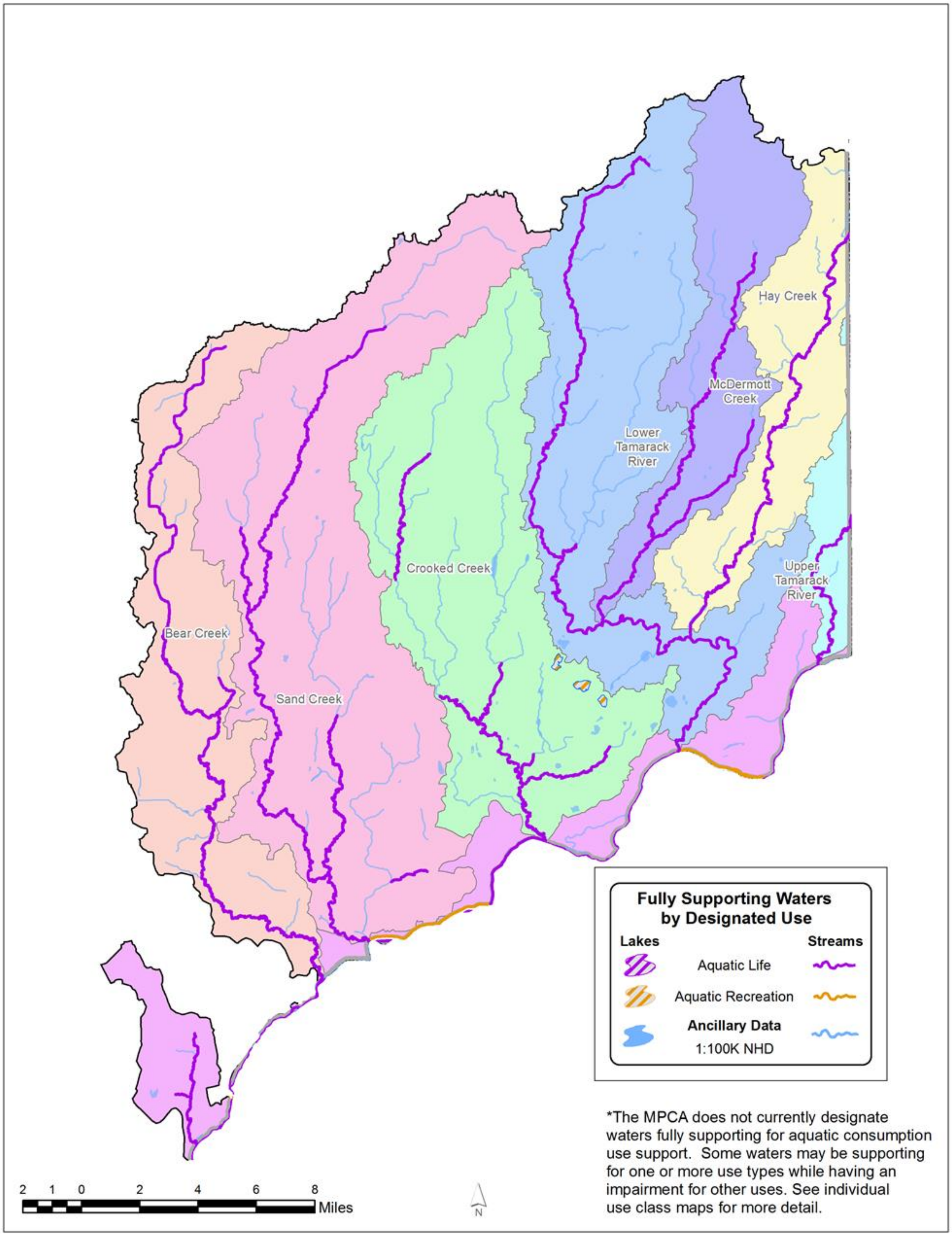


Figure 31. Impaired waters by designated use in the Upper St. Croix River

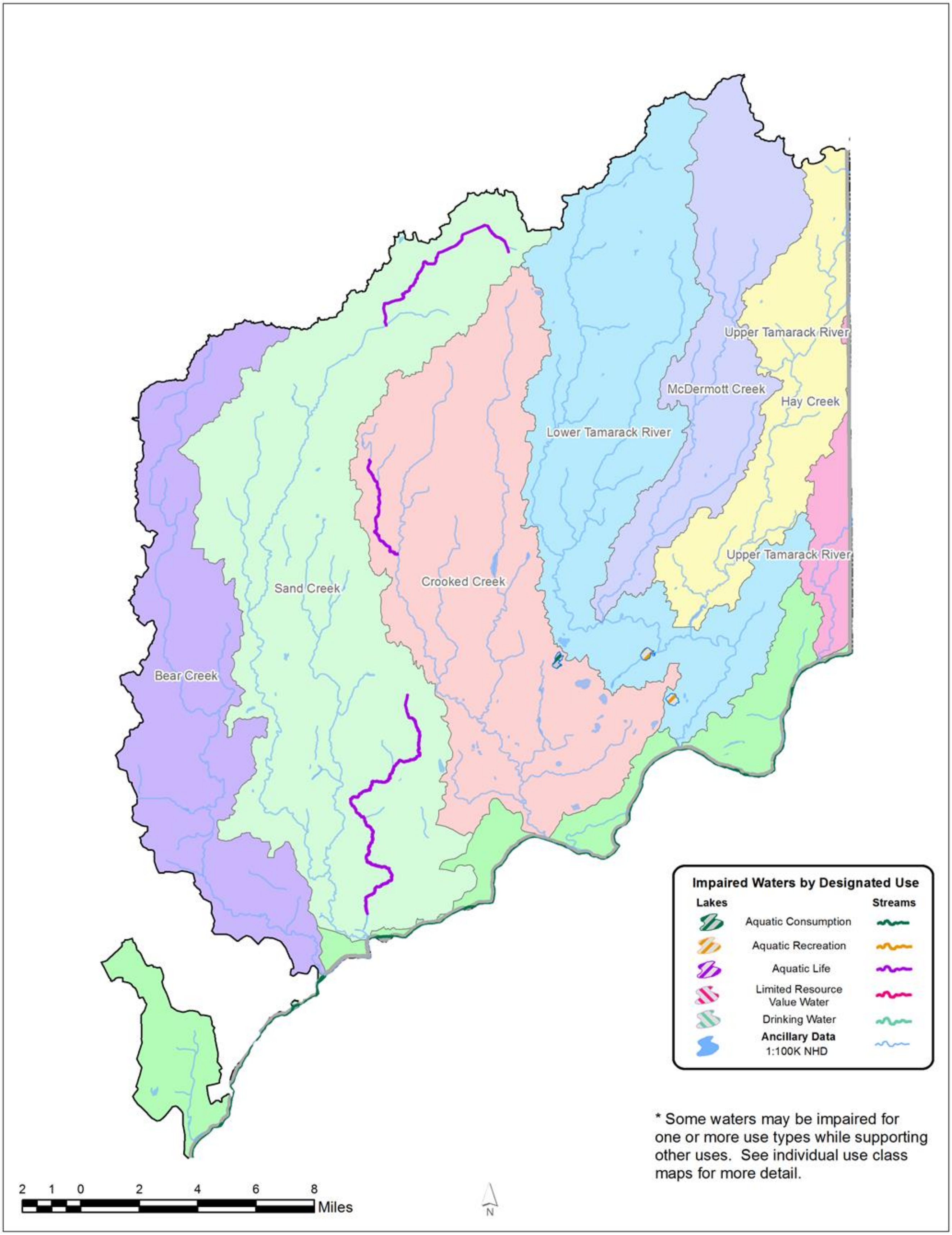


Figure 32. Aquatic consumption use support in the Upper St. Croix River Watershed.

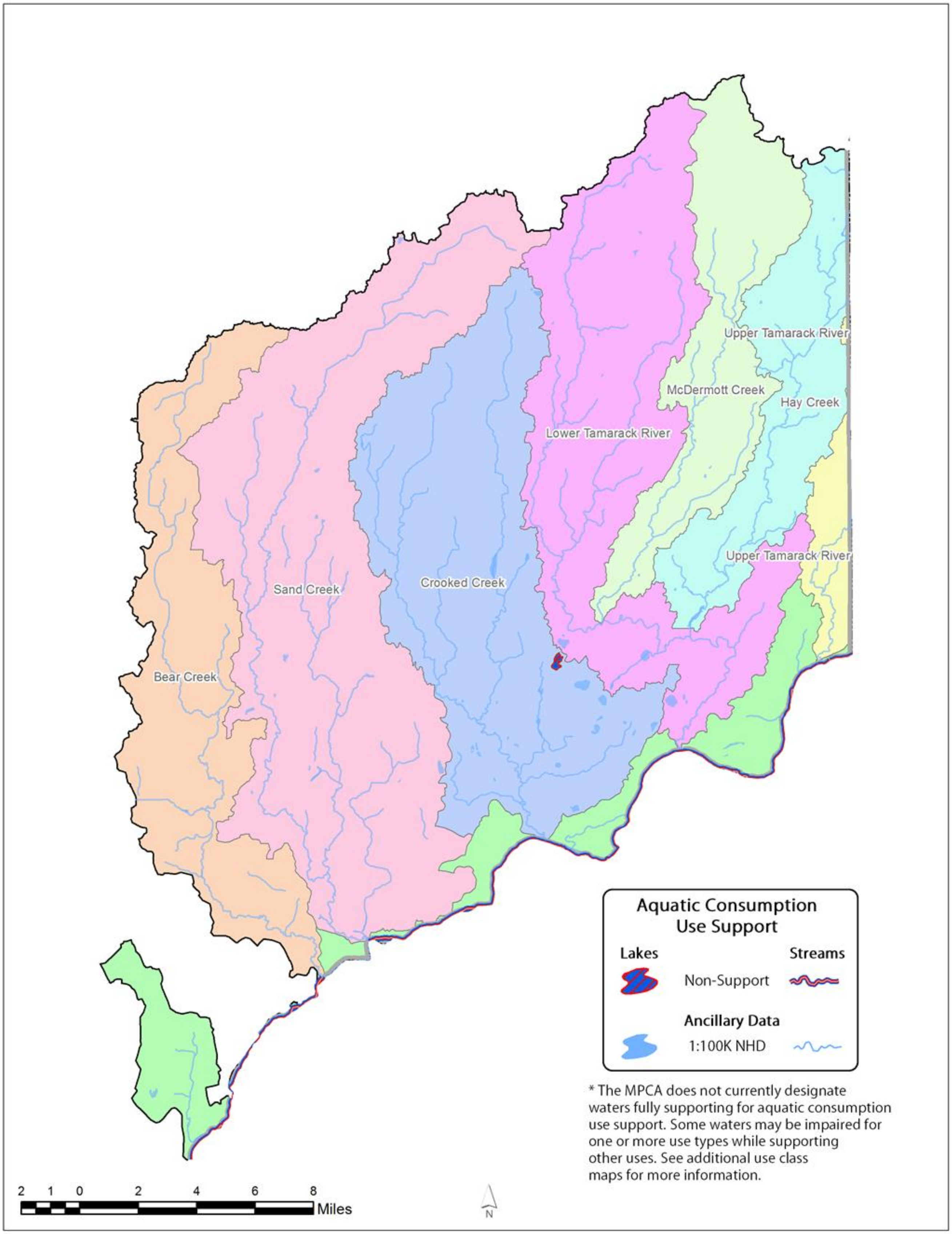


Figure 33. Aquatic life use support in the Upper St. Croix River Watershed

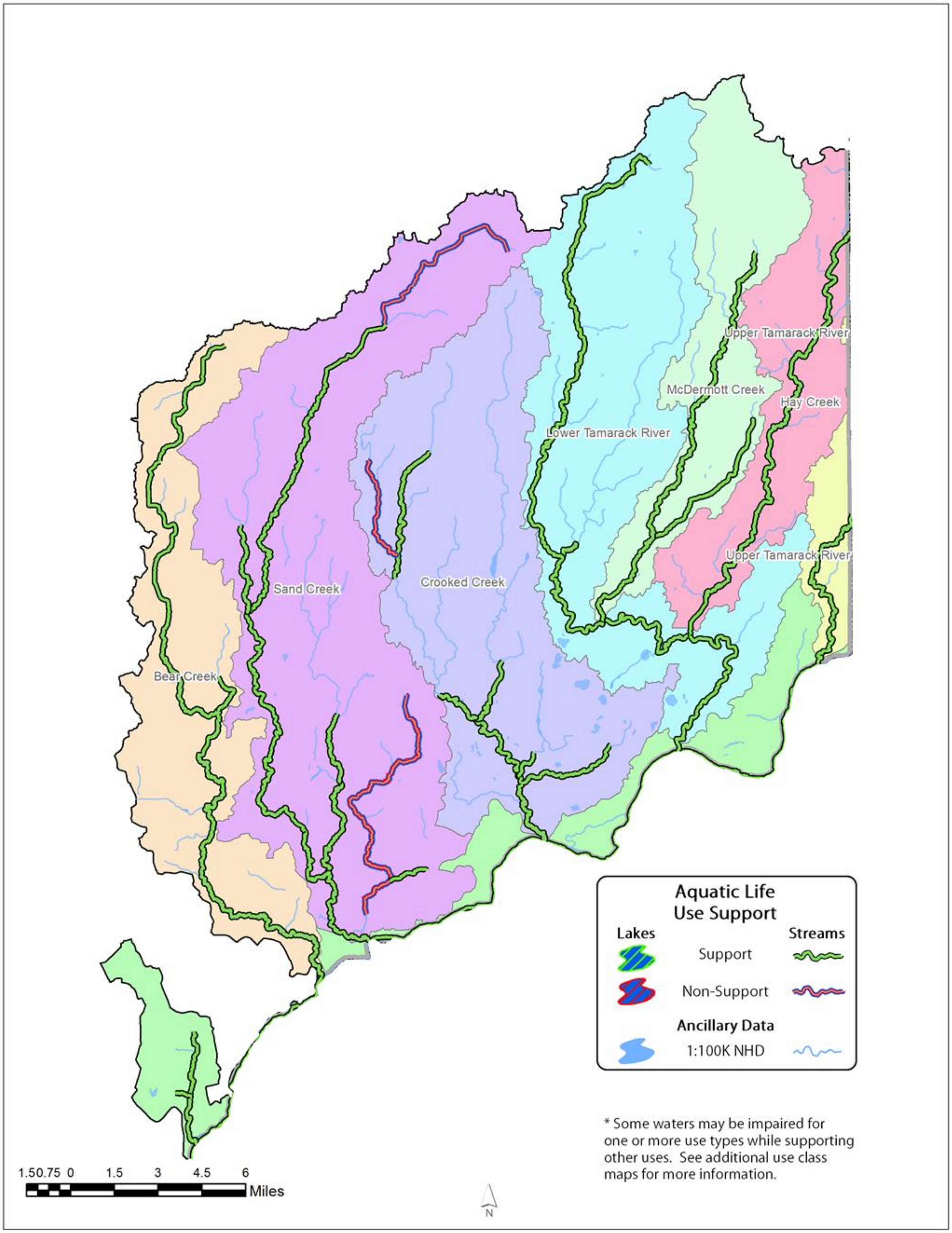
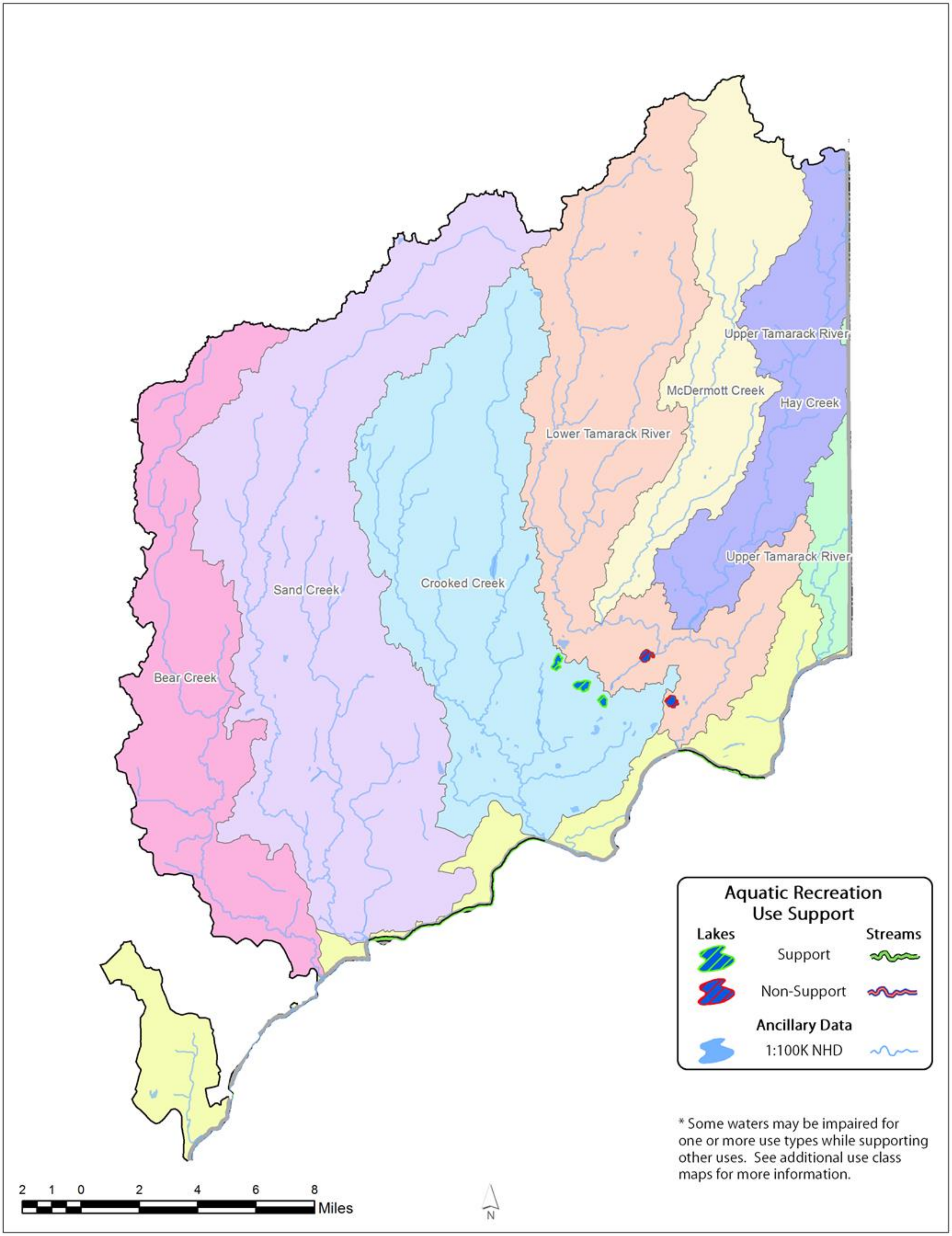


Figure 34. Aquatic recreation use support in the Upper St. Croix River Watershed



Transparency trends for the Upper St. Croix River Watershed

MPCA completes annual trend analysis on lakes and streams across the state based on long-term transparency measurements (Table 19). The data collection for this work relies heavily on volunteers across the state and also incorporates any agency and partner data submitted to EQuIS.

The trends are calculated using a Seasonal Kendall statistical test for waters with a minimum of eight years of transparency data; Secchi disk measurements in lakes and Secchi Tube measurements in streams.

Citizen volunteer monitoring occurs at nine streams in the watershed. Four of these streams show no evidence of a trend; the remaining streams had insufficient data to run trend analysis. Tamarack Lake was monitored in the past by a citizen volunteer (27 years; 1987-2014) with data collected showing strong evidence of improving water clarity on the lake. It would be valuable to grow citizen volunteer monitoring participation in order to increase the number of lakes and streams with trend information in the Upper St. Croix Watershed.

Table 19. Water Clarity Trends.

Upper St Croix HUC 07030001	Streams	Lakes
Number of sites w/increasing trend	0	1
Number of sites w/decreasing trend	0	0
Number of sites w/no trend	4	0

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. Moving forward, the MPCA will be switching to the Pollutant Load Monitoring Network for long-term trend analysis on rivers and streams. Data from the Danbury site will inform long-term river trends for this watershed.

Priority waters for protection and restoration in the Upper St. Croix River Watershed

The MPCA, DNR, and BWSR have developed methods to help identify waters that are high priority for protection and restoration activities. Protecting lakes and streams from degradation requires consideration of how human activities impact the lands draining to the water. In addition, helping to determine the risk for degradation allows for prioritization to occur; so limited resources can be directed to waters that would benefit most from implementation efforts.

The results of the analysis are provided to watershed project teams for use during WRAPS and One Watershed One Plan or other local water plan development. The results of the analysis are considered a preliminary sorting of possible protection priorities and should be followed by a discussion and evaluation with other resource agencies, project partners and stakeholders. Other factors that are typically considered during the protection prioritization process include: whether a water has an active lake or river association, is publically accessible, presence of wild rice, presence of invasive, rare or endangered species, as well as land use information and/or threats from proposed development.

Opportunities to gain or enhance multiple natural resource benefits (“benefit stacking”) is another consideration during the final protection analysis. Waterbodies identified during the assessment process as vulnerable to impairment are also included in the summary below.

The results for selected indicators and the risk priority ranking for each lake are shown in Appendix 6. Protection priority should be given to lakes that are particularly sensitive to an increase in phosphorus with a documented decline in water quality (measured by Secchi transparency), a comparatively high percentage of developed land use in the area, or monitored phosphorus concentrations close to the water quality standard. In the Upper St. Croix Watershed, highest protection priority is suggested Lena Lake. Grace Lake and Hay Creek Flowage were also identified as priorities for protection as fish community health was near the threshold and water quality was in decline.

The results for selected indicators and risk priority ranking for each stream are shown in Appendix 7. Stream protection is driven by how close the stream is to having an impaired biological community, density of roads and disturbed land use in the immediate and larger drainage area, and how much land is protected in the watershed. In the Upper St. Croix Watershed, five Exceptional Use streams were identified as high priority: Little Sand Creek, Bangs Brook, Sand Creek, Crooked Creek and the Upper Tamarack River. In addition, one General Use streams, Kenney Brook, scored as high priority for protection efforts. While these streams currently meet standards, work done to maintain current condition is important to prevent impairment in the future.

Summaries and recommendations

The condition of fish and macroinvertebrate stream communities in the Upper St. Croix River Watershed reflect the land use, hydrologic modification, and discharge of pollutants (point and non-point) upstream of each monitoring location. The habitats, surficial hydrology, and water quality of this watershed have been not been dramatically altered from their natural condition. This has allow the biological communities to thrive and not be influenced by anthropogenic effects.

Beavers are naturally occurring animals within the watershed, but have had an impact on the streams within the Upper St. Croix Watershed. Beaver dams greatly reduce habitat for trout by increased siltation, widening of the stream channel, and increase water temperatures due to ponding of the stream. Habitat improvements in the streams have taken place by the Minnesota Department of Natural Resources (DNR) including beaver trapping, which has greatly increased the brook trout population in many streams.

Overall, scores of biological communities in this watershed were good: 93% are determined to be supporting aquatic life for General Use. The full support stream segments include five steam segments associated reach in the exceptional aquatic life use category. The exceptional designation holds more pristine streams to a higher standard than stream segments in the general or modified use category.

Fish assemblages were assessed in 28 reaches of streams and rivers throughout the Upper St. Croix River Watershed. An overwhelming majority of these reaches, 93% (n=26) exhibited fish communities that meet aquatic life standards. Fish assemblages were assessed in 10 reaches of streams and rivers throughout the Upper St. Croix River Watershed. All of the biological impairments (n=2) occurred on stream segments. One stream segment failed the General Use standard for fish and another failed the General Use standard for fish and macroinvertebrates. There is one stream segment that was assessed using the Exceptional Use standard. All of the warmwater stream segments (n=18) are full support for aquatic life. There is four warmwater stream segments that were assessed using the Exceptional Use standard.

A total of 66 fish species were collected in the Upper St. Croix River Watershed. Of the 66 fish species 38% (n=25) are sensitive. The longnose dace is the fourth most number of fish collected and is a sensitive species.

Macroinvertebrate assemblages were assessed in 28 reaches of streams and rivers throughout the Upper St. Croix River Watershed. An overwhelming majority of these reaches, 93% (n=26) exhibited macroinvertebrate communities that meet aquatic life standards. Macroinvertebrate assemblages were assessed in 10 reaches of streams and rivers throughout the Upper St. Croix River Watershed. All of the biological impairments (n=2) occurred on stream segments. One cold water stream segment failed the General Use Standard for macroinvertebrate and another failed the General Use Standard for fish and macroinvertebrates.

Overall, twenty-two stream reaches support aquatic life and four stream reaches do not. Although there are no aquatic recreation impairments for bacteria due to limited available data, bacteria levels were elevated throughout the watershed. This is a potential concern and should be considered in future watershed planning. Elevated levels of bacteria can indicate conditions that are unsafe for swimming or wading, and secondary body contact such as wading or kayaking.

The majority of lakes and streams in the Upper St. Croix Watershed have good water quality. During this assessment, two lakes were assessed as supporting aquatic recreation; while two lakes are not supporting aquatic recreation.

Groundwater protection should be considered both for quantity and quality. Concerns for quality are possible high levels of naturally occurring elements in drinking water as well as chloride and nitrate from human activities. The concerns for quantity are based on comparing the amount of water withdrawn versus the amount of water being recharged to the aquifer. Groundwater withdrawals in the watershed have not changed significantly and surface water withdrawals have increased significantly, but with only three surface water permits, that significance can change quickly. Groundwater levels do not appear to have changed significantly in monitored locations across the watershed. Continued mindfulness of water users and additional monitoring of groundwater quantity will provide the information needed to conserve the resource in the 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 (OP) 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 Upper St. Croix River Watershed

EQuIS ID	Biological station ID	WID	Waterbody name	Location	Aggregated 12-digit HUC
S008-273	10EM063	07030001-510	Lower Tamarack River	Adjacent to Rock Lake Rd, 5 mi. N of Danbury, WI	0703000106-01
S008-812	96SC090	07030001-618	Sand Creek	Upstream State Park Road 18, In St. Croix State Park	0703000110-01
S008-813	SC112	07030001-513	McDermot Creek	Upstream of CR 25, 4 mi. SE of Duxbury	0703000106-03
S008-814	SC117	07030001-511	Hay Creek	At CR 141, 3.5 mi. NW of Markville	0703000106-02
S008-815	SC108	07030001-614	Upper Tamarack River	At CR 25, 1 mi. E of Markville	0703000103-01
S008-816	67SC014	07030001-522	Crooked Creek	Downstream of Hwy 48, 10 mi. E of Cloverdale	0703000107-01
S008-817	96SC072	07030001-519	Redhorse Creek	Upstream of unnamed FR, 2.5 mi. N of Snake River	0703000112-01
S008-818	68SC007	07030001-518	Bear Creek	At unnamed Road, 11 mi. E of Mission Creek	0703000111-01

Appendix 2.2 – Intensive watershed monitoring biological monitoring stations in the Upper St. Croix River Watershed

WID	Biological station ID	Waterbody name	Biological station location	County	Aggregated 12-digit HUC
07030001-510	10EM063	Lower Tamarack River	Adjacent to Rock Lake Rd, 3.5 mi. SW of Markville	Pine	Lower Tamarack River
07030001-511	16SC113	Hay Creek	Downstream of CR 141, 3.5 mi. NW of Markville	Pine	Hay Creek
07030001-511	96SC067	Hay Creek	At Kingsdale	Pine	Hay Creek
07030001-512	16SC106	Lower Tamarack River	Upstream of CR 25, 2.5 mi. SE of Duxbury	Pine	Lower Tamarack River
07030001-513	16SC109	McDermot Creek	Upstream of CR 25, 4 mi. SE of Duxbury	Pine	McDermott Creek
07030001-513	16SC116	McDermot Creek	Downstream of CR 32, 6 mi. NE of Duxbury	Pine	McDermott Creek
07030001-514	16SC108	Lower Tamarack River	Downstream of CR 25, 2 mi. S of Duxbury	Pine	Lower Tamarack River
07030001-514	16SC110	Lower Tamarack River	Upstream of CR 30, in Duxbury	Pine	Lower Tamarack River
07030001-514	16SC204	Lower Tamarack River	Downstream of CR 153, 8 mi. E of Bruno	Pine	Lower Tamarack River
07030001-518	16SC102	Bear Creek	Downstream of Tenquist Rd, 3 mi. NW of Cloverdale	Pine	Bear Creek
07030001-518	16SC117	Bear Creek	1.5 mi. downstream of State Park Rd 18, in St Croix State Park	Pine	Bear Creek
07030001-518	68SC007	Bear Creek	State Forest Road, 4 mi. S of Cloverdale	Pine	Bear Creek
07030001-519	16SC202	Redhorse Creek	Downstream of unnamed forest road, 2.5 mi. N of Snake River	Pine	Chases Brook-St. Croix River
07030001-522	67SC015	Crooked Creek	Upstream of MN 48, 10 mi. E. of Cloverdale	Pine	Crooked Creek
07030001-528	16SC114	Squib Creek	Downstream of Pete Anderson Rd, 2 mi. E of Duxbury	Pine	McDermott Creek
07030001-532	16SC112	Keene Creek	Upstream of CR 30, 0.5 mi. E of Duxbury	Pine	Lower Tamarack River
07030001-533	16SC104	Crooked Creek, East Fork	Upstream of CR 138, 5 mi. SW of Duxbury	Pine	Crooked Creek
07030001-537	16SC203	Crooked Creek, West Fork	Upstream of CR 172, 6.5 mi. SW of Duxbury	Pine	Crooked Creek

WID	Biological station ID	Waterbody name	Biological station location	County	Aggregated 12-digit HUC
07030001-541	16SC121	Crooked Creek	North of State Park Rd 12, in St Croix State Park	Pine	Crooked Creek
07030001-545	10SC002	Bangs Brook	Upstream of CSAH 24, 24 mi. E of Hinckley	Pine	Crooked Creek
07030001-546	16SC119	Hay Creek	Downstream of CR 91, 14.5 mi. E of Mission Creek	Pine	Sand Creek
07030001-553	68SC001	Partridge Creek	CSAH 30, 6 mi. E of Sandstone	Pine	Sand Creek
07030001-554	16SC201	Little Sand Creek	Downstream of CR 136, 13 mi. E of Mission Creek	Pine	Sand Creek
07030001-562	16SC120	Kenney Brook	Upstream of CSAH 24, 24 mi. E of Hinckley	Pine	Crooked Creek
07030001-581	16SC103	Little Bear Creek	Downstream of CR 142, 3 mi. N of Cloverdale	Pine	Bear Creek
07030001-604	67SC008	Sand Creek	CR 148, 2 mi. S.E. of Bruno	Pine	Sand Creek
07030001-605	16SC118	Sand Creek	Upstream of CSAH 22, 4 mi. S of Bruno	Pine	Sand Creek
07030001-606	16SC115	Sand Creek	Upstream of CR 32, 4.5 mi. E of Askov	Pine	Sand Creek
07030001-613	96SC037	Upper Tamarack River	Downstream of State Line Rd, 2 mi. SE of Cloverton	Pine	Upper Tamarack River
07030001-614	16SC107	Upper Tamarack River	Upstream of CSAH 25, 1 mi. E of Markville	Pine	Upper Tamarack River
07030001-617	16SC111	Sand Creek	Downstream of CR 30, 6.5 mi. E of Sandstone	Pine	Sand Creek
07030001-618	16SC101	Sand Creek	Upstream of CR 136, 12 mi. E of Mission Creek	Pine	Sand Creek
07030001-618	96SC090	Sand Creek	In St Croix State Park	Pine	Sand Creek
07030001-902	16SC100	Trib. to Hay Creek	Downstream of CSAH 22, in St Croix State Park	Pine	Sand Creek
07030001-510	10EM063	Lower Tamarack River	Adjacent to Rock Lake Rd, 3.5 mi. SW of Markville	Pine	Lower Tamarack River

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	71	49	NA	±11
2	Southern Streams	2B	66	50	35	±9
3	Southern Headwaters	2B	74	55	33	±7
10	Southern Cold water	2A	82	50	NA	±9
4	Northern Rivers	2B	67	38	NA	±9
5	Northern Streams	2B	61	47	35	±9
6	Northern Headwaters	2B	68	42	23	±16
7	Low Gradient	2B	70	42	15	±10
11	Northern Cold water	2A	60	35	NA	±10
Macroinvertebrates						
1	Northern Forest Rivers	2B	77	49	NA	±10.8
2	Prairie Forest Rivers	2B	63	31	NA	±10.8
3	Northern Forest Streams RR	2B	82	53	NA	±12.6
4	Northern Forest Streams GP	2B	76	51	37	±13.6
5	Southern Streams RR	2B	62	37	24	±12.6
6	Southern Forest Streams GP	2B	66	43	30	±13.6
7	Prairie Streams GP	2B	69	41	22	±13.6
8	Northern Cold water	2A	52	32	NA	±12.4
9	Southern Cold water	2A	72	43	NA	±13.8

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

National Hydrography Dataset (NHD) Assessment Segment WID	Biological station ID	Stream segment name	Drainage area mi^2	Fish class	Threshold	FIBI	Visit date
HUC 0703000103-01 (Upper Tamarack River)							
07030001-614	16SC107	Upper Tamarack River	96.48	Northern Streams	47	90.74	23-Jun-16
07030001-613	96SC037	Upper Tamarack River	90.39	Northern Streams	61	96.63	15-Aug-16
07030001-613	96SC037	Upper Tamarack River	90.39	Northern Streams	61	96.69	24-Jul-14
HUC 0703000106-01 (Lower Tamarack River)							
07030001-514	16SC110	Lower Tamarack River	39.67	Northern Headwaters	42	83.93	21-Jun-16
07030001-512	16SC106	Lower Tamarack River	122.57	Northern Streams	47	86.79	16-Jun-16
07030001-514	16SC108	Lower Tamarack River	68.50	Northern Streams	47	78.73	09-Aug-16
07030001-514	16SC204	Lower Tamarack River	17.75	Northern Headwaters	42	70.15	10-Aug-16
07030001-510	10EM063	Lower Tamarack River	189.71	Northern Streams	47	86.37	23-Jun-10
07030001-510	10EM063	Lower Tamarack River	189.71	Northern Streams	47	89.85	18-Aug-16
07030001-532	16SC112	Keene Creek	25.31	Low Gradient	42	71.12	15-Jun-16
07030001-510	10EM063	Lower Tamarack River	189.71	Northern Streams	47	84.20	15-Jun-15
HUC 12: 0703000106-02 (Hay Creek)							
07030001-511	96SC067	Hay Creek	20.64	Northern Headwaters	42	74.15	17-Aug-16
07030001-511	10EM127	Hay Creek	18.37	Northern Headwaters	42	74.95	28-Jun-10
07030001-511	16SC113	Hay Creek	41.86	Northern Headwaters	42	71.99	14-Jun-16

National Hydrography Dataset (NHD) Assessment Segment WID	Biological station ID	Stream segment name	Drainage area mi^2	Fish class	Threshold	FIBI	Visit date
HUC 0703000106-03 (McDermott Creek)							
07030001-513	16SC109	McDermot Creek	46.41	Northern Headwaters	42	64.95	21-Jun-16
07030001-513	16SC116	McDermot Creek	30.42	Northern Headwaters	42	60.05	15-Jun-16
07030001-528	16SC114	Squib Creek	8.31	Northern Headwaters	42	51.98	15-Aug-16
HUC 0703000107-01 (Crooked Creek)							
07030001-541	16SC121	Crooked Creek	98.74	Northern Streams	61	81.06	22-Jun-16
07030001-533	16SC104	Crooked Creek, East Fork	29.38	Northern Cold water	35	50.97	28-Jul-16
07030001-533	16SC104	Crooked Creek, East Fork	29.38	Northern Cold water	35	45.02	06-Sep-17
07030001-562	16SC120	Kenney Brook	8.20	Northern Headwaters	42	47.78	22-Jun-16
07030001-541	16SC121	Crooked Creek	98.74	Northern Streams	61	82.38	08-Aug-16
07030001-537	16SC203	Crooked Creek, West Fork	37.04	Northern Cold water	35	60.44	16-Jun-16
07030001-545	10SC002	Bangs Brook	10.52	Northern Cold water	60	72.85	08-Jul-10
07030001-545	10SC002	Bangs Brook	10.52	Northern Cold water	60	34.63	23-Jun-16
07030001-545	10SC002	Bangs Brook	10.52	Northern Cold water	60	64.70	21-Jul-10
07030001-522	67SC015	Crooked Creek	82.52	Northern Cold water	35	49.12	22-Jun-10
07030001-522	67SC015	Crooked Creek	82.52	Northern Cold water	35	53.32	22-Jun-16
07030001-548	78SC001	Wolf Creek	7.42	Northern Cold water	35	47.50	07-Jul-10

National Hydrography Dataset (NHD) Assessment Segment WID	Biological station ID	Stream segment name	Drainage area mi^2	Fish class	Threshold	FIBI	Visit date
HUC 0703000110-01 (Sand Creek)							
07030001-902	16SC100	Trib. to Hay Creek	5.23	Northern Cold water	35	43.10	15-Aug-16
07030001-618	16SC101	Sand Creek	77.58	Northern Streams	61	86.35	10-Aug-16
07030001-546	09SC051	Hay Creek	14.37	Northern Cold water	35	33.00	29-Jun-10
07030001-546	09SC051	Hay Creek	14.37	Northern Cold water	35	46.64	21-Jul-10
07030001-902	16SC100	Trib. to Hay Creek	5.23	Northern Cold water	35	40.06	21-Jun-16
07030001-546	16SC119	Hay Creek	22.98	Northern Cold water	35	37.61	07-Sep-17
07030001-617	16SC111	Sand Creek	42.92	Northern Headwaters	42	86.44	15-Jun-16
07030001-604	67SC008	Sand Creek	14.33	Northern Cold water	35	22.97	07-Sep-17
07030001-606	16SC115	Sand Creek	33.53	Northern Cold water	35	44.50	06-Sep-17
07030001-618	96SC090	Sand Creek	109.98	Northern Streams	61	86.11	14-Jun-16
07030001-604	67SC008	Sand Creek	14.33	Northern Cold water	35	26.65	22-Jun-16
07030001-605	16SC118	Sand Creek	23.31	Northern Cold water	35	47.67	14-Jun-16
07030001-546	16SC119	Hay Creek	22.98	Northern Cold water	35	34.46	21-Jun-16
07030001-554	16SC201	Little Sand Creek	28.54	Northern Headwaters	68	66.45	20-Jun-16
07030001-553	68SC001	Partridge Creek	14.92	Low Gradient	42	57.63	21-Jun-16
07030001-617	16SC111	Sand Creek	42.92	Northern Headwaters	42	78.65	09-Aug-16
07030001-618	96SC090	Sand Creek	109.98	Northern Streams	61	77.32	08-Aug-16
07030001-606	16SC115	Sand Creek	33.53	Northern Cold water	35	33.76	16-Aug-16

National Hydrography Dataset (NHD) Assessment Segment WID	Biological station ID	Stream segment name	Drainage area mi²	Fish class	Threshold	FIBI	Visit date
HUC 0703000111-01 (Bear Creek)							
07030001-518	68SC007	Bear Creek	58.89	Northern Streams	47	71.57	13-Jun-16
07030001-581	16SC103	Little Bear Creek	5.47	Northern Headwaters	42	68.49	22-Jun-16
07030001-518	16SC117	Bear Creek	65.67	Northern Streams	47	73.63	09-Aug-16
07030001-579	06SC076	Little Bear Creek	2.31	Northern Headwaters	42	0.00	11-Jul-07
07030001-518	16SC102	Bear Creek	29.58	Northern Headwaters	42	63.37	21-Jun-16
HUC 0703000112-01 (Chases Brook-St. Croix River)							
07030001-519	16SC202	Redhorse Creek	10.76	Northern Headwaters	42	47.60	20-Jun-16

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

National Hydrography Dataset (NHD) Assessment Segment WID	Biological station ID	Stream segment name	Drainage area Mi²	Invert class	Threshold	MIBI	Visit date
HUC 12: 0703000103-01 (Upper Tamarack River)							
07030001-614	16SC107	Upper Tamarack River	96.48	3	53	62.61	17-Aug-16
07030001-613	96SC037	Upper Tamarack River	90.39	3	82	56.41	17-Sep-14
07030001-613	96SC037	Upper Tamarack River	90.39	3	82	79.52	29-Sep-16
HUC 12: Lower Tamarack River (0703000106-01)							
07030001-514	16SC110	Lower Tamarack River	39.67	3	53	62.61	24-Aug-16
07030001-514	16SC108	Lower Tamarack River	68.50	3	53	55.30	24-Aug-16
07030001-532	16SC112	Keene Creek	25.31	4	51	59.73	24-Aug-16
07030001-510	10EM063	Lower Tamarack River	189.71	3	53	69.59	05-Oct-15
07030001-514	16SC204	Lower Tamarack River	17.75	3	53	59.99	16-Aug-16
07030001-512	16SC106	Lower Tamarack River	122.57	3	53	66.27	17-Aug-16
07030001-510	10EM063	Lower Tamarack River	189.71	3	53	64.13	17-Aug-16
HUC 12: 703000106-02 (Hay Creek)							
07030001-511	16SC113	Hay Creek	41.86	3	53	64.61	16-Aug-16
07030001-511	96SC067	Hay Creek	20.64	3	53	66.96	10-Aug-16
HUC 12: 703000106-03 (McDermott Creek)							
07030001-513	16SC116	McDermot Creek	30.42	3	53	83.27	16-Aug-16
07030001-513	16SC109	McDermot Creek	46.41	3	53	78.99	17-Aug-16
07030001-528	16SC114	Squib Creek	8.31	3	53	33.28	16-Aug-16

National Hydrography Dataset (NHD) Assessment Segment WID	Biological station ID	Stream segment name	Drainage area Mi²	Invert class	Threshold	MIBI	Visit date
HUC 12: 703000107-01 (Crooked Creek)							
07030001-545	10SC002	Bangs Brook	10.52	8	52	52.86	17-Aug-10
07030001-545	10SC002	Bangs Brook	10.52	8	52	58.43	15-Aug-16
07030001-541	16SC121	Crooked Creek	98.74	3	82	76.74	17-Aug-16
07030001-548	78SC001	Wolf Creek	7.42	8	32	23.35	17-Aug-10
07030001-533	16SC104	Crooked Creek, East Fork	29.38	8	32	55.39	12-Sep-17
07030001-562	16SC120	Kenney Brook	8.20	3	53	53.30	15-Aug-16
07030001-522	67SC015	Crooked Creek	82.52	8	32	32.67	25-Aug-09
07030001-522	67SC015	Crooked Creek	82.52	8	32	45.89	02-Sep-10
07030001-522	67SC015	Crooked Creek	82.52	8	32	32.21	15-Aug-16
07030001-537	16SC203	Crooked Creek, West Fork	37.04	8	32	37.45	11-Aug-16
07030001-533	16SC104	Crooked Creek, East Fork	29.38	8	32	25.12	15-Aug-16
07030001-548	78SC001	Wolf Creek	7.42	8	32	15.10	25-Aug-09
HUC 12: 703000110-01 (Sand Creek)							
07030001-617	16SC111	Sand Creek	42.92	3	53	64.56	09-Aug-16
07030001-605	16SC118	Sand Creek	23.31	8	32	41.99	09-Aug-16
07030001-546	09SC051	Hay Creek	14.37	8	32	26.44	25-Aug-09
07030001-618	96SC090	Sand Creek	109.98	3	82	64.44	23-Aug-16
07030001-618	16SC101	Sand Creek	77.58	4	76	84.09	23-Aug-16
07030001-604	67SC008	Sand Creek	14.33	8	32	38.90	12-Sep-17
07030001-554	16SC201	Little Sand Creek	28.54	4	76	88.34	23-Aug-16
07030001-606	16SC115	Sand Creek	33.53	8	32	28.07	09-Aug-16
07030001-606	16SC115	Sand Creek	33.53	8	32	47.31	12-Sep-17
07030001-604	67SC008	Sand Creek	14.33	8	32	40.00	16-Aug-16
07030001-546	16SC119	Hay Creek	22.98	8	32	27.81	13-Sep-17
07030001-546	16SC119	Hay Creek	22.98	8	32	18.13	23-Aug-16

National Hydrography Dataset (NHD) Assessment Segment WID	Biological station ID	Stream segment name	Drainage area Mi²	Invert class	Threshold	MIBI	Visit date
HUC 12: 703000111-01 (Bear Creek)							
07030001-518	16SC102	Bear Creek	29.58	3	53	32.01	18-Aug-16
07030001-518	16SC117	Bear Creek	65.67	3	53	81.41	24-Aug-16
07030001-518	68SC007	Bear Creek	58.89	3	53	72.38	23-Aug-16
07030001-581	16SC103	Little Bear Creek	5.47	4	51	62.64	18-Aug-16
07030001-518	16SC117	Bear Creek	65.67	3	53	77.04	24-Aug-16
HUC 12: 703000112-01 (Chases Brook-St. Croix River)							
07030001-519	16SC202	Redhorse Creek	10.76	3	53	61.43	23-Aug-16

Appendix 4.1 – Fish species found during biological monitoring surveys

Common name	Quantity of stations where present	Quantity of individuals collected
black bullhead	7	15
black crappie	5	18
blacknose dace	28	403
blacknose shiner	5	23
blackside darter	33	874
bluegill	7	54
bowfin	1	1
brassy minnow	16	99
brook silverside	2	4
brook stickleback	24	162
brook trout	8	69
brown trout	2	12
burbot	27	346
central mudminnow	37	453
central stoneroller	3	26
channel catfish	4	13
chestnut lamprey	9	22
common carp	2	8
common shiner	40	2849
creek chub	38	2581
fathead minnow	11	35
finescale dace	4	18
freshwater drum	1	1
Gen: Ichthyomyzon	4	19
Gen: Phoxinus	4	58
Gen: redhorses	5	24
gilt darter	3	14
golden redhorse	17	494
golden shiner	3	4
greater redhorse	5	30
green sunfish	10	19
hornyhead chub	29	367
hybrid sunfish	1	1
Iowa darter	2	7
johnny darter	38	837
lake sturgeon	1	4

Common name	Quantity of stations where present	Quantity of individuals collected
lamprey ammocoete	17	205
largemouth bass	8	34
largescale stoneroller	1	1
logperch	12	223
longnose dace	20	1078
mimic shiner	5	66
mottled sculpin	8	62
muskellunge	11	19
northern brook lamprey	2	2
northern hogsucker	20	231
northern pike	15	54
northern redbelly dace	16	149
pearl dace	18	198
pumpkinseed	1	2
quillback	4	9
rainbow trout	2	14
river redhorse	4	20
rock bass	22	115
sand shiner	1	51
shorthead redhorse	19	324
silver redhorse	9	110
slenderhead darter	8	66
smallmouth bass	21	557
southern brook lamprey	4	6
spotfin shiner	6	258
stonecat	5	9
walleye	6	35
white crappie	1	1
white sucker	38	1732
yellow perch	7	200

Appendix 4.2 – Macroinvertebrate species found during biological monitoring surveys

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Ablabesmyia	28	95
Acari	31	97
Acentrella	5	14
Acentrella parvula	5	7
Acentrella rallatoma	1	1
Acentrella turbida	14	153
Acerpenna	22	93
Acerpenna pygmaea	2	4
Acroneuria	22	184
Acroneuria lycorias	3	13
Aeshna	3	3
Aeshnidae	1	3
Agnetina	1	1
Amphinemura	2	2
Amphipoda	2	10
Anacaena	3	6
Anafroptilum	3	4
Anax junius	1	1
Ablabesmyia	28	95
Acari	31	97
Acentrella	5	14
Acentrella parvula	5	7
Acentrella rallatoma	1	1
Acentrella turbida	14	153
Acerpenna	22	93
Acerpenna pygmaea	2	4
Acroneuria	22	184
Acroneuria lycorias	3	13
Aeshna	3	3
Aeshnidae	1	3
Agnetina	1	1
Amphinemura	2	2
Amphipoda	2	10
Anacaena	3	6
Anafroptilum	3	4
Anax junius	1	1
Ancyronyx variegatus	20	81
Anisoptera	1	1
Anopheles	2	2

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Antocha	7	19
Argia	2	2
Atherix	20	102
Atherix variegata	1	5
Atrichopogon	2	2
Aulodrilus	1	1
Baetidae	13	61
Baetis	18	357
Baetis brunneicolor	9	176
Baetis flavistriga	19	156
Baetis intercalaris	10	27
Baetisca	8	16
Baetisca laurentina	1	2
Basiaeschna janata	3	4
Belostoma flumineum	7	26
Bezzia/Palpomyia	1	1
Bittacomorpha	1	1
Boyeria	2	2
Boyeria vinosa	19	39
Brachycentrus numerosus	9	47
Brachycentrus occidentalis	1	2
Branchiobdellida	2	2
Brillia	19	31
Caecidotea	5	147
Caenis	5	14
Caenis diminuta	21	159
Caenis hilaris	14	77
Caenis tardata	1	5
Calopterygidae	10	25
Calopteryx	20	78
Calopteryx aequabilis	10	27
Calopteryx maculata	4	18
Cambaridae	1	1
Cambarus	2	2
Campeloma	4	5
Capniidae	6	27
Cardiocladius	2	4
Ceraclea	9	19
Ceraclea mentieus	1	3
Ceratopogonidae	2	2
Ceratopogoninae	18	52
Ceratopsyche	19	195

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Ceratopsyche alhedra	6	26
Ceratopsyche bronta	9	30
Ceratopsyche morosa	8	69
Ceratopsyche slossonae	6	18
Ceratopsyche sparna	14	102
Ceratopsyche ventura	1	1
Chaetocladius	1	1
Cheumatopsyche	27	299
Cheumatopsyche lasia	1	36
Chimarra	9	112
Chimarra socia	1	2
Chironomini	8	15
Chironomus	3	22
Chloroperlidae	1	2
Cladotanytarsus	6	8
Coenagrionidae	1	1
Conchapelopia	11	14
Cordulegaster	2	2
Corduliidae	1	1
Corixidae	3	3
Corydalidae	1	2
Corydalus	1	2
Corydalus cornutus	1	1
Corynoneura	9	19
Crangonyx	3	61
Cricotopus	27	209
Cricotopus trifascia	1	7
Cryptochironomus	4	4
Cryptotendipes	1	1
Culicidae	1	1
Cyphon	1	1
Desmopachria convexa	1	1
Diamesa	1	1
Dicranota	9	15
Dicrotendipes	4	44
Diplocladius cultriger	1	1
Dixella	6	25
Dixidae	2	2
Dubiraphia	30	171
Dytiscidae	3	5
Ectopria	1	1
Elmidae	2	5

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Empididae	14	20
Enchytraeidae	1	1
Enchytraeus	8	16
Endochironomus	2	4
Epeorus	4	37
Ephemera	1	1
Ephemerella	8	50
Ephemerella subvaria	1	2
Ephemerellidae	4	11
Ephoron	2	2
Ephydridae	6	11
Epitheca canis	1	2
Eukiefferiella	23	101
Eurylophella	14	147
Eurylophella aestiva	1	1
Ferrissia	30	169
Ferrissia parallelus	1	6
Fridericia	7	10
Gastropoda	1	1
Glossosoma	6	16
Glossosomatidae	8	58
Gomphidae	2	3
Gomphus	2	3
Gyrinidae	1	1
Gyrinus	3	8
Hagenius	1	2
Hagenius brevistylus	6	9
Haliplus	2	2
Helichus	7	15
Helicopsyche	1	2
Helicopsyche borealis	16	50
Helophorus	1	1
Hemerodromia	34	163
Henlea	2	2
Heptagenia pulla	1	2
Heptageniidae	21	249
Heterocloeon	1	1
Heterotrissocladius	2	3
Hexatoma	9	15
Hirudinea	7	11
Hyalella	18	98
Hyalella azteca	1	1

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Hydatophylax	3	4
Hydatophylax argus	9	24
Hydraena	1	2
Hydrobaenus	1	2
Hydrobiidae	4	11
Hydrophilidae	2	2
Hydropsyche	7	35
Hydropsyche betteni	22	202
Hydropsyche dicantha	6	34
Hydropsyche placoda	2	11
Hydropsychidae	31	258
Hydroptila	16	66
Hydroptila xera	1	5
Hydroptilidae	2	3
Hygrotus	1	1
Isonychia	5	7
Isonychia sicca	1	3
Isoperla	4	37
Iswaeon	9	18
Kribiodorum perpulchrum	1	1
Labiobaetis	1	1
Labiobaetis dardanus	1	11
Labiobaetis propinquus	25	128
Labrundinia	20	54
Laccobius	2	2
Laccophilus	1	1
Lampyridae	1	1
Lauterborniella agrayloides	1	1
Lepidostoma	7	65
Leptoceridae	1	1
Leptophlebia	2	2
Leptophlebiidae	28	369
Leucotrichia pictipes	3	4
Leucrocuta	14	122
Libellulidae	1	1
Limnephilidae	17	90
Limnephilus	2	9
Limnophila	3	3
Limnophyes	10	19
Liodessus	6	67
Lopescladius	2	3
Lumbriculidae	6	8

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Lymnaea stagnalis	1	1
Lymnaeidae	1	1
Lype	3	9
Lype diversa	14	69
Maccaffertium	22	249
Maccaffertium exiguum	1	1
Maccaffertium integrum	1	22
Maccaffertium mexicanum	1	3
Maccaffertium modestum	1	3
Maccaffertium terminatum	1	1
Maccaffertium vicarium	18	104
Macromia illinoiensis	1	1
Macromiinae	1	1
Macronychus	3	20
Macronychus glabratus	25	268
Mesenchytraeus	2	3
Metretopodidae	2	2
Metrobates	1	1
Micrasema	2	5
Micrasema rusticum	13	59
Micropsectra	19	76
Microtendipes	27	128
Microvelia	1	1
Mystacides	1	1
Naididae	4	8
Nais	21	55
Nanocladius	8	23
Natarsia	3	3
Nemata	9	11
Nematoda	1	2
Nemouridae	1	1
Neoleptophlebia	2	7
Neoperla	1	3
Neophylax	2	2
Neophylax concinnus	1	1
Neophylax oligius	1	1
Neoplasta	5	16
Neoplea striola	2	2
Neoporus	1	1
Neostempellina reissi	2	17
Neureclipsis	3	8
Neureclipsis valida	1	3

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Nigronia	11	36
Nilotanypus	6	9
Nilothauma	1	2
Nyctiophylax	2	4
Oecetis	4	9
Oecetis avara	2	3
Oecetis persimilis	1	2
Oecetis testacea	15	75
Oligochaeta	4	31
Ophiogomphus	5	9
Ophiogomphus rupinsulensis	4	7
Optioservus	27	522
Orconectes	25	33
Orthocladiinae	15	23
Orthocladius	20	123
Orthocladius (Symposiocladius)	9	13
Orthocladius annectens	1	2
Oxyethira	1	2
Paracapnia	1	7
Paracladopelma	2	2
Paragnetina media	17	131
Parakiefferiella	4	7
Paralauterborniella nigrohalterale	6	7
Paraleptophlebia	3	16
Paramerina	2	19
Parametriocnemus	27	150
Paraphaenocladius	1	1
Paratanytarsus	33	523
Paratendipes	5	10
Pentaneura	2	2
Perlidae	7	34
Perlinella dryma	1	2
Perlodidae	6	22
Phaenopsectra	20	54
Phryganea	2	2
Phryganeidae	2	2
Phylocentropus	3	3
Physa	3	66
Physella	8	36
Physella integra	1	1

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Physidae	1	1
Pisidiidae	28	157
Planorbella	1	3
Plauditus	5	22
Plecoptera	1	2
Polycentropodidae	5	15
Polycentropus	6	26
Polypedilum	36	1269
Potthastia	13	20
Procladius	6	9
Procloeon	11	19
Prostoma	1	6
Protoptila	1	18
Psectrocladius	1	1
Pseudocloeon	1	2
Pseudocloeon propinquum	1	7
Pseudolimnophila	2	18
Pseudorthocladius	1	1
Psychomyia	1	24
Psychomyia flavida	13	57
Psychomyiidae	1	1
Pteronarcys	6	16
Pteronarcys pictetii	1	1
Ptilostomis	10	23
Pycnopsyche	9	12
Quistadrilus	1	1
Ranatra	3	3
Rhagovelia	7	7
Rheocricotopus	24	64
Rheotanytarsus	35	891
Roederiodes	1	2
Scirtidae	1	1
Sialis	5	12
Sigara	1	4
Simuliidae	2	3
Simulium	34	1122
Simulium aureum	1	113
Somatochlora	1	1
Stempellina	8	11
Stempellinella	19	77
Stenacron	5	8
Stenelmis	24	178

Taxonomic name	Quantity of stations where present	Quantity of individuals collected
Stenelmis cheryl	1	2
Stenochironomus	17	38
Stictochironomus	3	3
Stylaria	1	17
Sublettea coffmani	8	17
Tabanidae	7	11
Taeniopteryx	6	71
Tanypodinae	12	16
Tanytarsini	18	46
Tanytarsus	35	452
Thienemanniella	16	41
Thienemannimyia	3	11
Thienemannimyia Gr.	34	276
Tipula	18	80
Tipulidae	4	4
Trepaxonemata	4	4
Triaenodes	12	28
Tribelos	7	30
Trichoptera	5	9
Tricorythodes	10	44
Tricorythodes stygiatus	1	1
Trissopelopia ogemawi	1	1
Tropisternus	4	7
Tubificinae	9	15
Tvetenia	14	59
Uenoidae	9	25
Viviparus	1	1
Xenochironomus xenolabis	5	6
Xylotopus par	9	15
Zavreliella marmorata	1	1
Zavrelimyia	9	35

Appendix 5 – Minnesota Stream Habitat Assessment results

Habitat information documented during each fish sampling visit is provided. This table convey the results of the Minnesota Stream Habitat Assessment (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 HUC-12 subwatershed.

# Visits	Biological station ID	Reach name	Land use (0-5)	Riparian (0-	Substrate (0-27)	Fish cover (0-17)	Channel morph. (0-36)	MSHA score (0-100)	MSHA rating
2	16SC107	Upper Tamarack River	3.75	13.25	25.80	15.50	32.00	90.30	Good
4	96SC037	Upper Tamarack River	5.00	12.63	24.54	13.50	27.50	83.16	Good
Average Habitat Results: *Upper Tamarack River Aggregated 12 HUC*			**4.38**	**12.94**	**25.17**	**14.50**	**29.75**	**86.73**	**Good**
2	16SC110	Lower Tamarack River	3.50	10.75	22.25	13.50	28.50	78.50	Good
1	16SC204	Lower Tamarack River	5.00	14.00	25.00	17.00	32.00	93.00	Good
2	16SC112	Keene Creek	5.00	13.00	9.10	12.50	19.50	59.10	
5	10EM063	Lower Tamarack River	5.00	13.00	25.70	15.20	31.60	90.50	Good
2	16SC106	Lower Tamarack River	5.00	13.75	25.52	14.50	31.50	90.28	Good
2	16SC108	Lower Tamarack River	5.00	12.00	14.07	11.50	15.00	57.58	Fair
Average Habitat Results: *Lower Tamarack River Aggregated 12 HUC*			**4.75**	**12.75**	**20.27**	**14.03**	**26.35**	**78.16**	**Good**
2	16SC109	McDermot	5.00	13.50	16.75	11.50	22.00	68.75	Good
2	16SC114	Squib Creek	5.00	13.75	24.50	12.00	27.50	82.75	Good
2	16SC116	McDermot	5.00	13.75	25.60	14.50	31.50	90.35	Good
Average Habitat Results: *McDermott Creek Aggregated 12 HUC*			**5.00**	**13.67**	**22.28**	**12.67**	**27.00**	**80.62**	Good
1	10EM127	Hay Creek	5.00	13.50	23.00	12.00	33.00	86.50	Good
2	16SC113	Hay Creek	4.25	8.50	17.85	14.50	25.00	70.10	Good
2	96SC067	Hay Creek	5.00	13.00	24.50	14.00	31.00	87.50	Good
Average Habitat Results: *Hay Creek Aggregated*			**4.75**	**11.67**	**21.78**	**13.50**	**29.67**	**81.37**	**Good**

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)

# Visits	Biological station ID	Reach name	Land use (0-5)	Riparian (0-	Substrate (0-27)	Fish cover (0-17)	Channel morph. (0-36)	MSHA score (0-100)	MSHA rating
3	16SC104	Crooked Creek, East Fork	4.50	12.00	26.45	12.33	23.00	78.28	Good
2	16SC203	Crooked Creek, West Fork	3.75	11.75	23.68	15.50	31.50	86.17	Good
1	78SC001	Wolf Creek	2.50	9.50	12.30	8.00	18.00	50.30	Fair
3	10SC002	Bangs Brook	5.00	13.17	22.98	13.67	29.00	83.82	Good
1	16SC120	Kenney Brook	5.00	13.00	22.20	15.00	25.00	80.20	Good
3	16SC121	Crooked Creek	5.00	13.67	17.55	14.00	28.67	78.88	Good
2	67SC015	Crooked Creek	5.00	12.00	20.48	14.50	29.50	81.47	Good
Average Habitat Results: *Crooked Creek Aggregated 12 HUC*			**4.39**	**12.2**	**20.80**	**13.29**	**26.38**	**77.02**	**Good**
3	16SC111	Sand Creek	4.33	11.17	23.33	16.00	28.33	83.17	Good
4	16SC115	Sand Creek	4.75	12.38	10.90	16.00	21.25	65.27	Fair
2	16SC118	Sand Creek	4.75	10.50	18.27	12.50	16.00	62.03	Fair
3	67SC008	Sand Creek	5.00	14.00	12.07	11.00	12.00	54.07	Fair
2	68SC001	Partridge Creek	2.88	11.50	10.55	13.50	15.50	53.92	Fair
2	16SC201	Little Sand Creek	3.75	10.75	14.53	15.00	23.00	67.02	Good
2	09SC051	Hay Creek	5.00	12.50	15.70	10.50	24.00	67.70	Good
3	16SC100	Trib. to Hay Creek	5.00	14.00	2.67	13.00	16.33	51.00	Fair
4	16SC119	Hay Creek	3.13	12.13	12.50	11.00	16.25	55.00	Fair
2	16SC101	Sand Creek	5.00	13.50	14.25	12.50	26.00	71.25	Good
3	96SC090	Sand Creek	4.33	11.33	19.43	15.67	27.00	77.77	Good
Average Habitat Results: *Sand Creek Aggregated 12 HUC*			**4.36**	**12.2**	**14.02**	**13.33**	**20.52**	**64.38**	**Fair**
2	16SC102	Bear Creek	4.75	12.25	19.90	16.00	29.00	81.90	Good
1	06SC076	Little Bear Creek	5.00	15.00	10.00	14.00	14.00	58.00	Fair
2	16SC103	Little Bear Creek	4.75	12.50	11.00	14.00	22.00	64.25	Fair
2	16SC117	Bear Creek	5.00	13.50	20.20	13.50	28.00	80.20	Good
2	68SC007	Bear Creek	5.00	13.50	20.18	16.00	28.00	82.67	Good
Average Habitat Results: *Bear Creek Aggregated 12 HUC*			**4.90**	**13.4**	**16.26**	**14.70**	**24.20**	**73.40**	**Good**
2	16SC202	Redhorse Creek	5.00	12.50	19.60	15.50	28.50	81.10	Good
Average Habitat Results: *Chases Brook-St. Croix River Aggregated 12 HUC Aggregated 12 HUC*			**5.00**	**12.5**	**19.60**	**15.50**	**28.50**	**81.10**	**Good**

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)

Appendix 6 – Lake protection and prioritization results

Lake ID	Lake Name	Mean TP	Trend	% Disturbed Land Use	5% load reduction goal	Priority
58-0010-00	Razor	15	Insufficient data	3	3	C
58-0024-00	Tamarack	20.4	Improving trend	3	2	C
58-0028-00	Little Tamarack	26	Insufficient data	5	4	C
58-0013-00	Greigs	27	Insufficient data	16	2	B
58-0190-00	Unnamed	30.5	Insufficient data	1	5	C
58-0018-00	Lena	32	Insufficient data	15	2	A
58-0054-00	Wallace	32	No data provided	5	4	C
58-0007-00	Rock	35.1	Insufficient data	3	3	B
58-0012-00	McGowan	41	Insufficient data	0	24	C
58-0040-00	Clayton	55	No data provided	3	106	C
58-0009-00	Stevens	63	Insufficient data	7	4	C
58-0029-00	Grace	70.3	Insufficient data	3	31	C
58-0005-00	Hay Creek Flowage	75.3	No data provided	3	340	C

Appendix 7 – Stream protection and prioritization results

WID	Stream Name	TALU	Cold/Warm	Community Nearly Impaired	Riparian Risk	Watershed Risk	Current Protection Level	Protection Priority Class
07030001-554	Little Sand Creek	Exceptional	warm	one	medium	med/low	low	A
07030001-545	Bangs Brook	Exceptional	cold	one	medium	medium	medium	B
07030001-618	Sand Creek	Exceptional	warm	one	medium	medium	medium	B
07030001-613	Upper Tamarack River	Exceptional	warm	one	med/low	low	low	B
07030001-541	Crooked Creek	Exceptional	warm	one	low	med/low	med/high	B
07030001-562	Kenney Brook	General	warm	one	med/high	medium	med/low	A
07030001-522	Crooked Creek	General	cold	one	medium	med/low	medium	B
07030001-581	Little Bear Creek	General	warm	neither	med/high	medium	low	B
07030001-528	Squib Creek	General	warm	one	med/low	med/low	medium	B
07030001-537	Crooked Creek, West Fork	General	cold	neither	med/high	med/low	medium	B
07030001-553	Partridge Creek	General	warm	neither	med/low	medium	med/low	B
07030001-518	Bear Creek	General	warm	neither	med/low	medium	medium	C
07030001-532	Keene Creek	General	warm	neither	med/high	low	medium	C
07030001-533	Crooked Creek, East Fork	General	cold	neither	medium	med/low	medium	C
07030001-617	Sand Creek	General	warm	neither	med/low	medium	medium	C
07030001-605	Sand Creek	General	cold	neither	med/low	med/low	medium	C
07030001-606	Sand Creek	General	cold	neither	medium	med/low	med/high	C
07030001-902	Little Hay Creek	General	cold	neither	med/low	medium	med/high	C
07030001-511	Hay Creek	General	warm	neither	med/low	low	medium	C
07030001-519	Redhorse Creek	General	warm	neither	medium	med/low	high	C
07030001-614	Upper Tamarack River	General	warm	neither	low	low	med/low	C
07030001-510	Lower Tamarack River	General	warm	neither	med/low	low	med/high	C
07030001-514	Lower Tamarack River	General	warm	neither	med/low	low	med/high	C
07030001-512	Lower Tamarack River	General	warm	neither	low	low	high	C
07030001-513	McDermott Creek	General	warm	neither	low	low	high	C