

Snake River Watershed Monitoring and Assessment Report



Minnesota Pollution Control Agency

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I. Introduction

Water is one of Minnesota's most abundant and precious resources. The Minnesota Pollution Control Agency (MPCA or agency) is charged under both federal and state law with the responsibility of protecting the water quality of Minnesota's water resources. The MPCA's water management efforts are tied to the 1972 Federal Clean Water Act (CWA) requiring 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 the state's surface waters and to develop a list of waterbodies that do not meet established standards. Such waters are referred to as "impaired waters" and the state must take appropriate actions to restore these waters, including the development of Total Maximum Daily Loads (TMDLs). A TMDL is a comprehensive study identifying all pollution sources causing or contributing to impairment and the reductions needed to restore a waterbody so that it can 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 be successful preventing and addressing problems, decision makers need good information about the status of the resources, potential and actual threats, options for addressing the threats, and data on how effective management actions have been. 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 provided a policy framework and resources to state and local governments to accelerate efforts to monitor, assess, restore, and protect surface waters. In response, the MPCA has developed a watershed monitoring strategy that will promote an effective and efficient integration of water monitoring programs to provide a more comprehensive assessment of water quality and expedite the restoration and protection process. This has permitted the MPCA to establish a strategy and goal to assess the condition of Minnesota's surface waters via a 10-year cycle; provide an opportunity to more fully integrate MPCA water resource management efforts in cooperation with local government and stakeholders; and to allow for coordinated development and implementation of water quality restoration and improvement projects.

The rationale behind the watershed approach is to intensively monitor the 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 efforts. A pilot project of this monitoring strategy was implemented in the Snake River Watershed in the summer of 2006. This report provides a summary of all water quality assessment results at a watershed scale and incorporates all data available for the assessment process, including watershed monitoring, volunteer monitoring, and local government units. Consequently, there is an opportunity to begin to address most, if not all, the impairments through a coordinated TMDL process at a watershed scale, rather than the reach-by-reach and parameter-by-parameter approach historically employed. A watershed approach will more effectively address multiple impairments resulting from the cumulative effects of point and nonpoint sources of pollution and further the CWA goal of protecting, restoring, and preserving the quality of Minnesota's water resources.

II. The Watershed Monitoring Approach

The watershed approach is a 10-year rotation for assessing waters of the state on the level of Minnesota's 81 major watersheds (Figure 1). The primary feature of the watershed approach is that it provides a unifying focus on the water resources within a watershed as the starting point for water quality assessment, planning, and results measures. 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 and protection strategies. The following paragraphs provide details on each of the four principal monitoring components of the watershed approach. For additional information, see: Watershed Approach to Condition Monitoring and Assessment (MPCA 2008a) (<https://www.pca.state.mn.us/water/watershed-approach-restoring-and-protecting-water-quality>).

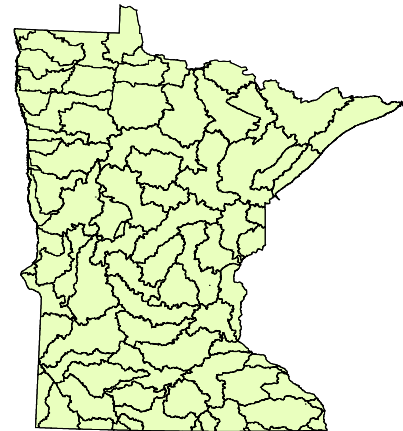


Figure 1. Major watersheds within Minnesota (8-digit HUC)

Load monitoring network

The first component of this effort is the load monitoring network, which involves permanent flow and water chemistry monitoring stations at the outlets (also referred to as "pour points") of each of the state's major watersheds. This partnership effort between the MPCA and the Minnesota Department of Natural Resources (DNR), along with the U.S. Geological Survey (USGS) and the Metropolitan Council, is a cornerstone of the watershed approach in that it involves continuous flow and water quality data collection with the computation of an annual load for each site, each year.

The load defines the amount of a parameter passing through a site per unit time. Loads determined at the outlet of watersheds make it possible to compare watersheds across basin and ecoregion boundaries. Watershed loads can also be used to assess trends in the water quality of a specific watershed over time, and to see how data from a given year compares to the long-term record for a watershed. This will be particularly helpful in putting the intensive watershed monitoring data (see below) into a longer-term context, given that the intensive monitoring will occur once every 10 years. The load monitoring network will also provide critical information for identifying baseline or acceptable loads for maintaining and protecting water resources; and in the case of impaired waters, determining the source(s) and cause(s) of impairment and the reductions needed to attain water quality goals.

Intensive watershed monitoring

The intensive watershed monitoring strategy utilizes a nested watershed design allowing the aggregation of watersheds from a coarse to a fine scale. The foundation of this comprehensive approach is the 81 major watersheds within Minnesota. Sampling occurs in each major watershed once every 10 years. In this approach, intermediate-sized (approximately 11-digit Hydrologic Unit Code [HUC]) and "minor" (14-digit HUC) watersheds are sampled along with the major watershed outlet to provide a

complete assessment of water quality (Figure 2). River/stream sites are selected near the outlet or “pour point” at all watershed scales. This approach provides holistic assessment coverage of rivers and streams without monitoring every single stream reach (see Figure 3 for an illustration of the monitoring site coverage within the Snake River major watershed).

The outlet of the major watershed (purple dot in Figure 3) is sampled for biology, water chemistry, and fish contaminants to allow for the assessment of aquatic life, aquatic recreation, and aquatic consumption use-support. Each 11-digit HUC pour point (green dots in Figure 3) is sampled for biology and water chemistry for the assessment of aquatic life and aquatic recreation use-support. Watersheds at this scale generally consist of major tributary streams with drainage areas ranging from 75 to 150 square miles. Lastly, most minor watersheds (typically 10-20 square miles) are sampled for biology to assess for aquatic life use-support (red dots in Figure 3). Specific locations for sites sampled as part of the intensive monitoring effort in the Snake River Watershed can be found in Appendix 1.

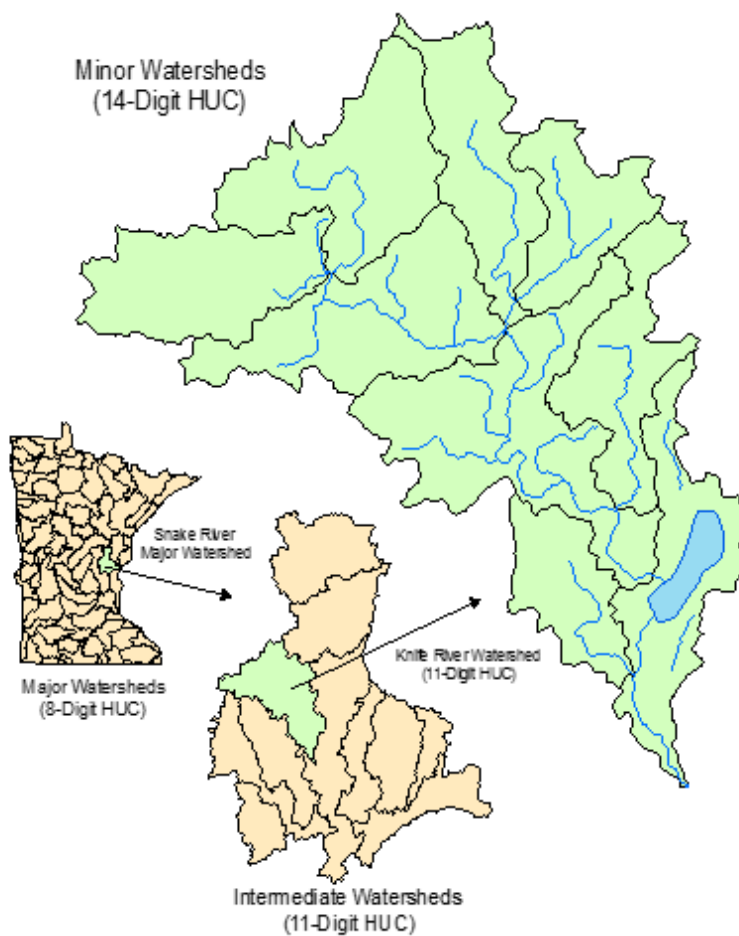


Figure 2. The intensive watershed monitoring design

The second step of the intensive watershed monitoring effort consists of follow-up monitoring at all 11-digit HUC's determined to have impaired waters. This follow-up monitoring is designed to collect the information needed to initiate the stressor identification process in order to identify the source(s) and cause(s) of impairment that is required for TMDL development and implementation.

Lake assessment monitoring

Lake assessment monitoring activities are focused on assessing the recreational use-support of lakes and identifying trends over time. The MPCA also assesses aquatic consumption use-support based on fish-tissue and water-column concentrations of toxic pollutants; the fish-tissue data is provided from monitoring conducted by the DNR and MPCA. Currently the MPCA does not assess aquatic life use-support as methods are not available.

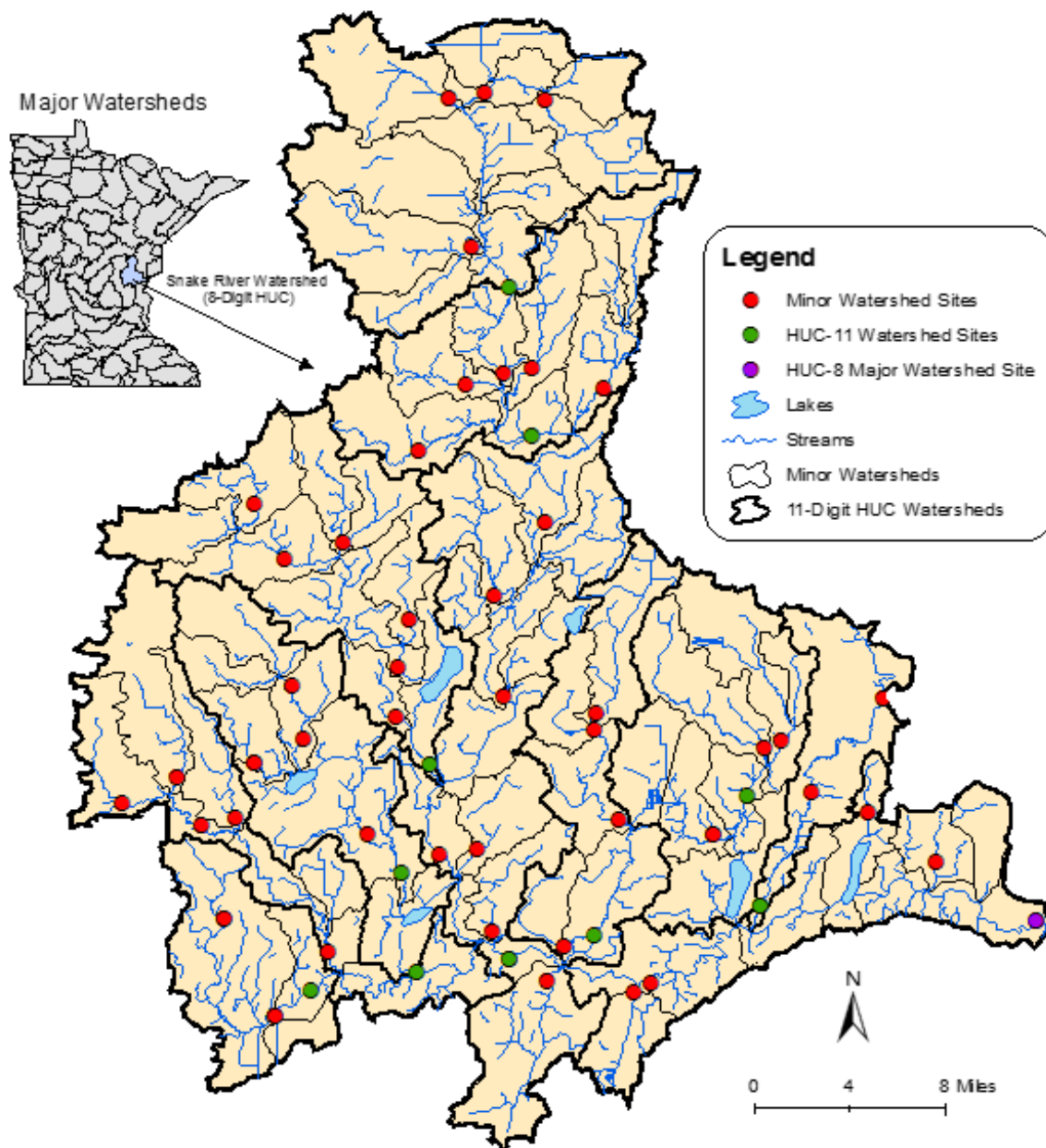


Figure 3. Intensive watershed monitoring stations in the Snake River Watershed

Minnesota has about 12,200 lakes greater than 10 acres in size. Of those, about 2,300 are between 100 and 500 acres, and about 700 are 500 acres or larger. Since it would be prohibitively expensive to monitor and assess all the lakes in Minnesota – just like it would be to sample every stream reach – the state must develop an approach for selecting which lakes to sample, and rely on other indices (such as remote sensing information) to provide a snapshot of the water quality of lakes that are not sampled. The MPCA has a goal of assessing all lakes 500 acres or larger for recreational use support over the next 10 years, and at least 25 of smaller lakes.

The MPCA is in the process of aligning its lake monitoring efforts with the major watershed monitoring schedule. The MPCA intends to schedule its lake monitoring and assessment efforts so that once a major watershed is intensively monitored and assessed for stream water quality, the key lakes within that watershed have also been monitored and assessed. The MPCA will also explore how to target its local

and volunteer monitoring grants to complement the 10-year watershed monitoring cycle. In that way, the lake and stream data can be considered together to provide a comprehensive picture of water quality status, and a determination can be made regarding how best to proceed to develop TMDL(s) and protection strategies, rather than being forced by the monitoring timing to address lakes and streams separately.

For lakes 500 acres and larger, the MPCA will complete its lake monitoring/assessment work in each major watershed by the time the stream monitoring and assessment is complete. For smaller lakes, the MPCA will identify priority sites for monitoring and assessment and seek to engage local governments and volunteers.

Citizen and local monitoring

Citizen and local group monitoring are important components of the watershed monitoring approach. The MPCA coordinates two programs aimed at encouraging citizen surface water monitoring: the Citizen Lake Monitoring Program and the Citizen Stream Monitoring Program. Like the permanent load monitoring network that will be established at watershed pour points, sustained citizen monitoring can provide the long-term picture needed to help evaluate current status and trends. Volunteers also provide weather and lake level data necessary for the proper interpretation of monitoring results and the application of lake and watershed models. The advance identification of lake and stream sites that will be sampled by agency staff provides an opportunity to actively recruit volunteers to monitor those sites too, so that

water quality data are available for the years before and after the intensive monitoring effort. This citizen-collected data will help agency staff interpret the results from the intensive monitoring effort, which only occurs once every 10 years. It will also allow interested parties to track any water quality changes that occur in the years between the intensive monitoring events. Coordinating with volunteers to focus monitoring efforts where it will be most effective for Clean Water Legacy planning and tracking purposes will help local citizens/governments see how their

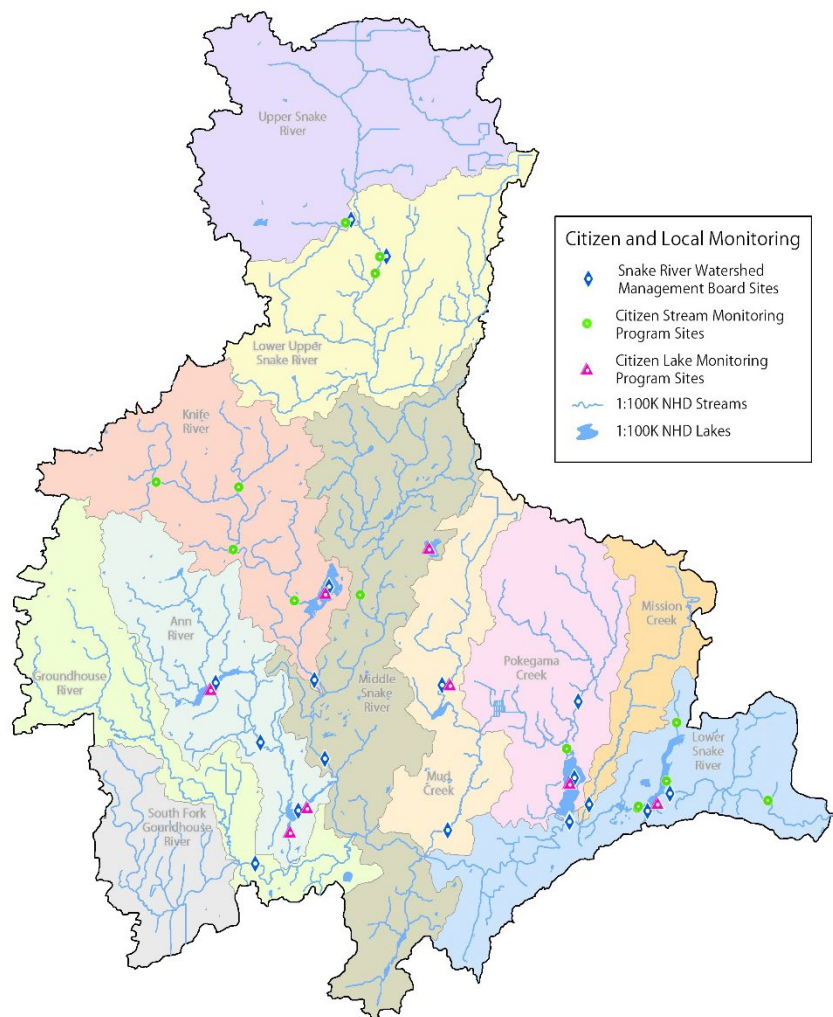


Figure 4. Citizen and local monitoring in the Snake River Watershed

efforts are being used to inform water quality management decisions and affect change. Figure 4 provides an illustration of citizen and local monitoring data used for assessment in the Snake River Watershed.

The watershed approach and schedule provides a communication tool for informing local government and other interested parties about agency monitoring efforts, and for identifying opportunities for partnership - a key benefit of the watershed approach. To encourage this collaboration, the MPCA provides Surface Water Assessment Grants (SWAG) to local governments, educational institutions and nonprofits to carry out condition monitoring on lakes and streams statewide. Our SWAG grantees conduct detailed sampling efforts following established monitoring protocols, providing data that is used directly in assessments. Each year the grant Request for Proposal identifies the major watersheds that are scheduled for upcoming intensive monitoring and some grantees assist the MPCA by sampling water chemistry at sites that are part of the intensive watershed design. Through our grant process, we also identify lakes within the intensive watersheds that the MPCA is unable to monitor. When grantees opt to monitor those lakes, we are able to provide a better picture of the watershed's water quality. As a result, an even more robust dataset will be available for assessment and the watershed planning effort that follows the monitoring (including TMDL development and protection strategies). Many SWAG partners conduct condition monitoring that is outside of the intensive watersheds targeted for a given season; these efforts benefit the assessment of lake and stream conditions statewide.

III. Assessment Methodology

The Clean Water Act requires states to report, every two years, on the condition of the waters of the state. 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. 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 to assess the condition of Minnesota's water resources. For a thorough review of the assessment methodology, see: Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment 305(b) Report and 303(d) List (MPCA 2007a) (<http://www.pca.state.mn.us/publications/wq-iw1-04.pdf>).

Determining use attainment status

Water quality standards are the fundamental benchmarks by which the quality of surface waters are measured. It is the water quality standards that are used to determine impairment. Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by the Minnesota Water Quality Standards (Minn. R. ch. 7050, 2008) (<https://www.revisor.leg.state.mn.us/rules/?id=7050>). 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. Protection of aquatic life means the maintenance of healthy, diverse, and successfully reproducing populations of aquatic organisms, including fish and invertebrates. Protection of recreation means the maintenance of conditions suitable for swimming and other forms of water recreation. Protection of consumption means protecting citizens who eat fish from Minnesota waters or receive their drinking water from waterbodies protected for this use.

Numeric water quality standards represent concentrations of specific pollutants in water that protect a specific designated use. Ideally, if the standard is not exceeded, the use will be protected. However, nature is very complex and variable, and the MPCA may use a variety of tools to fully assess designated uses. Assessment methodologies often differ by parameter and designated use, and consider multiple factors of the pollutants concentration; such as chronic value, maximum value, final acute value, magnitude, duration, and frequency.

Narrative standards are statements of conditions in and on the water, such as biological condition, that protect their designated uses. Interpretations of narrative criteria for aquatic life support in streams are based on multi-metric biological indices including the Fish Index of Biological Integrity (F-IBI), which evaluates the health of the fish community, and the Macroinvertebrate Index of Biological Integrity (M-IBI), which evaluates the health of the aquatic invertebrate community. Biological monitoring is a direct means to assess aquatic life use support, as the aquatic community tends to integrate the effects of pollutants and stressors over time.

Aquatic recreation use support in lakes was previously determined using narrative and numeric translators. With completion of the most recent rulemaking effort in 2008 ecoregion-based numeric eutrophication criteria were adopted into Minnesota's water quality standards. These standards focused on the trophic status and response of a given waterbody to nutrient enrichment. The factors used to assess lake status are divided into two categories: those relating to causal factors (total phosphorus) and those relating to response factors (as measured by chlorophyll-a concentrations and Secchi disk readings).

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 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 to define and index stream, lake, and wetland assessment units. Each river reach is identified by a unique waterbody identifier (known as its AUID), comprised of the USGS eight digit hydrologic unit code plus a three-character code that is unique within each HUC. Lake and wetland identifiers are assigned by the DNR. Bulletin 25 (DNR, 1968) has been the primary basis for identifying lakes and reservoirs and provides unique identification numbers for all lakes greater than 10 acres in size in Minnesota. The six digit Bulletin 25 numbers serve as the AUID and a two-digit suffix may be added as a basis for identifying distinct bays within a lake.

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.

Data management

It is MPCA policy to use all credible and relevant monitoring data to assess surface waters and relies on data it collects along with data from other sources, such as sister agencies, local government, and volunteers. The data must meet rigorous quality-assurance protocols before being used. The MPCA stores surface monitoring data in the U.S. Environmental Protection Agency's Storage and Retrieval Water Data Repository (STORET) system and all monitoring data required or paid for by the MPCA is entered into STORET. Projects funded by the MPCA include 319 projects, Clean Water Partnership projects, SWAG projects, and more recently, TMDL projects. Many local projects not funded by the MPCA choose to submit their data to the MPCA in STORET-ready format so that it may be utilized in the assessment process. Prior to each biennial assessment cycle, the MPCA publishes a "Call for Data" in the *State Register* and contacts partner organizations directly to request their monitoring data.

Period of record

The MPCA uses data collected over the most recent 10-year period for all water quality assessments. Generally, the most recent data from the 10-year assessment period is reviewed first when assessing toxic pollutants, eutrophication, and fish contaminants. Also, the more recent data for all pollutant categories may be given more weight by members of the professional judgment teams. The goal is to use data from the 10-year period that best represents the current water quality conditions. Using data over a 10-year period provides a reasonable assurance that data will have been collected over a range of weather and flow conditions and that all seasons will be adequately represented; however, data for the entire period are not required to make an assessment.

IV. The Snake River Watershed

Located in east-central Minnesota, the Snake River Watershed encompasses most of Kanabec County and parts of Aitkin, Mille Lacs, Pine, and Isanti Counties. The total drainage area of the watershed is 1,008 square miles. The watershed is a relatively flat glacial till plain crossed by several east-west morainal belts (MCD 1959). The undulating hills and depressions of the morainal belts are primarily forested while wetlands are predominant in the flat glacial till plain. Land cover percentages in the watershed are: forest (48.3%), rangeland (24.3%), wetland (14.3%), cropland (8.1%), developed (3.6%), and open water (1.3%) (Figure 5).

The approximately 100-mile long Snake River has its source in the wetland region of Solona State Forest and flows in a southerly direction to Mora where it turns and flows eastward to its junction with the St. Croix River below Pine City. The mean gradient is 4.9 feet/mile, one of the highest in central Minnesota, and the mean discharge is approximately 600 cubic feet per second. Principal tributaries include the Groundhouse, Ann, and Knife Rivers, as well as Mud, Mission, and Pokegama Creeks. The upper watershed is primarily undeveloped with extensive forest and wetland land cover. From Mora to Pine City the Snake River is considerably lower in gradient and the wooded banks give way to a wide farming valley. Downstream of Pine City the river returns to wooded bluffs and flows through a series of rapids and pools to its confluence with the St. Croix River. Principal lakes within the watershed include Ann, Fish, Knife, Pokegama, and Cross. Once important locales for seasonal cabins and recreational opportunities, they have become increasingly developed given their proximity to the two major communities within the watershed, Mora and Pine City. Year round residences are now prevalent on the nearby lakes and development has intensified in these communities due to their proximity and accessibility to the Twin Cities Metropolitan Area.

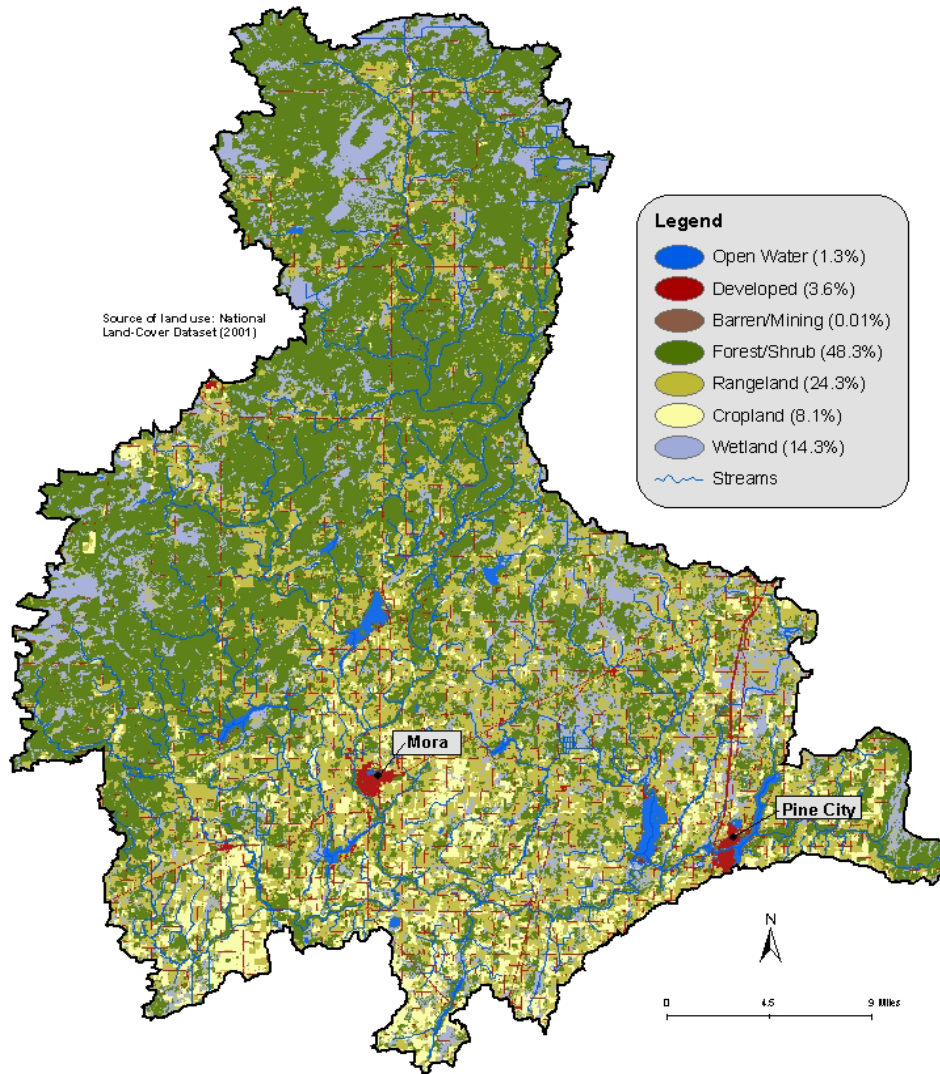


Figure 5. Land use in the Snake River Watershed

The Snake River Watershed was once densely covered with stands of white pine that were extensively logged in the latter half of the 19th century (Waters, 1977). Second growth trees of aspen, birch, and other hardwoods are still harvested for pulpwood and other wood products in the upper half of the watershed. Land use in the lower half of the watershed is primarily agricultural, with pasture and forage production predominating (Figure 5). Recreational opportunities such as fishing, hunting, camping, and canoeing are also numerous due to the amount of public land and river access available in the watershed.

V. Results and Discussion

Load monitoring

The Snake River near Pine City is part of the MPCA's Major Watershed Load Monitoring Program (MWLMP). Designed to assess water quality and trends in Minnesota's major rivers and their tributaries, the program's multi-agency approach couples site-specific stream flow data from the USGS and DNR, with water quality data collected by the MPCA, Metropolitan Council Environmental Services, and local monitoring organizations to compute annual nutrient and sediment pollution loads. The Snake River, tributary to the St. Croix River is monitored at USGS gage #05338500 near Pine City.

Continuous discharge data and water quality samples are modeled using FLUX software to estimate pollutant loads and flow weighted mean concentrations (FWMC). A pollutant load is the mass of a pollutant passing a point on a river over a given time period of time. The flow weighted mean concentration is an estimate of the overall quality of water passing this point and is computed by dividing the seasonal load by seasonal flow volume. Conceptually, a FWMC would be the same as routing all of the flow that passed a monitoring site during a specific time frame into a big, well-mixed pool, and collecting and analyzing one sample to determine the average concentration of the total volume. This makes the FWMC independent of watershed size and total flow volume, thus allowing for between watershed comparisons of water quality.

Pollutant loads for the MWLMP are calculated for total phosphorus (sediment bound plus dissolved phosphorus), orthophosphorus (dissolved phosphorus), total suspended solids (TSS), and nitrate plus nitrite nitrogen. The MWLMP is in the second year of data collection; at this point in time, results are limited. Table 1 lists 2007 pollutant loads and flow weighted mean concentrations for the Snake River near Pine City, Minnesota.

Table 1. 2007 Snake River pollutant loads and flow weighted mean concentrations

Water Quality Parameter	Mass (kg)	Flow Weighted Mean Concentration (mg/L)
Total Suspended Solids	3,186,660	7.54
Total Phosphorus	45,781	0.108
Ortho Phosphorus	13,976	0.0331
Nitrate + Nitrite Nitrogen	84,453	0.2

Nitrate plus nitrite nitrogen, phosphorus, and TSS are generally regarded as "nonpoint" source pollutants or pollutants delivered from many diffuse sources such as urban or agricultural runoff rather than specific sources such as industrial or sewage treatment plants. Currently river nutrient standards are absent for Minnesota streams but are being developed as a part of the current rulemaking effort that is planned for completion in 2011. A water quality standard for nitrate nitrogen is under consideration as a part of this rulemaking effort.

The State of Minnesota does not currently have a TSS standard but does have a standard for turbidity, which is highly correlated with TSS. TSS concentrations above 100 mg/L (milligrams per Liter) for the Snake River and other watersheds within the North Central Hardwood Forest Ecoregion are considered out of compliance with the turbidity standard of 25 nephelometric turbidity units (NTUs). The computed 2007 TSS flow weighted mean concentration as well as all the individual TSS samples collected at the USGS gaging station during the year were well under the 100 mg/L TSS surrogate turbidity value.

Fish contaminants

The watershed monitoring strategy contains a component that requires the collection of fish at the station representing the pour point of the major watershed (8-digit HUC). The objective is to collect fish for the analysis of contaminants to assess whether or not the surface water is meeting the designated use of aquatic consumption. Fish contaminant results are reported separately because the data requirements and protocols used in the assessments are very different. The acceptability of fish for human consumption is considered a designated use separate from aquatic life use support. This is because the two uses are assessed independently (i.e., a waterbody may be impaired for one but not the other). In other words, toxicants may be at levels that have no ill effects on aquatic life (fully supporting), but due to bioaccumulation, the fish are not safe to eat (impaired for aquatic consumption).

Fish collection for contaminant analysis is conducted at the 8-digit HUC level due to the probability of being able to collect the fish necessary at this scale. Collecting top carnivores of edible size becomes less likely as you progress to smaller scale watersheds, as does the prospect of citizens fishing these surface waters for consumption purposes. As indicated in Section III, assessment of aquatic consumption use support is not limited to the individual assessment unit because of the distances fish of edible size have likely traveled. Any impairment listing may encompass multiple assessment units and results from the station representing the pour point of the major eight-digit watershed will in effect characterize the entire watershed for the purposes of aquatic consumption use support.

Of the bioaccumulative pollutants that have been monitored in fish, mercury and polychlorinated biphenyls (PCBs) are the primary contaminants found at levels of concern to human consumers of fish. Top carnivore species are particularly important for mercury analysis and rough fish species for PCB analysis. An adequate size class distribution of smallmouth bass (SMB) and shorthead redhorse (SRD) were collected in 2006 at the station representing the pour point of the Snake River Watershed (06SC007) (Appendix 1) for mercury and PCB analysis of fish tissue. Fish were preserved using appropriate methods, deposited and processed at the DNR fish-processing lab, and analyzed by the Minnesota Department of Health for the contaminants of concern.

Assessment of mercury fish tissue data for water quality impairment is based on the 90th percentile of at least five fish samples of a top predator fish species. The 90th percentile for SMB in the Snake River was 0.388 milligrams/kilograms (mg/kg) (Table 2), which exceeds the water quality standard for total mercury in fish tissue (0.2 mg/kg). Therefore, the Snake River is considered impaired based on MPCA assessment guidelines. Incidentally, the Snake River was first listed as impaired for aquatic consumption use support (mercury in fish tissue) in 1998. If the 90th percentile for SMB is less than 0.572 mg/kg, it qualifies for inclusion in the Minnesota Statewide Mercury TMDL; therefore, the Snake River can be added to the list of waters covered under Minnesota's Statewide Mercury TMDL (MPCA 2007b) (<http://www.pca.state.mn.us/publications/wg-iw4-01b.pdf>). The goal for the statewide mercury TMDL is for the 90th percentile of mercury concentrations in top predator species to be less than 0.2 mg/kg.

Implementation of the mercury TMDL is focused primarily on reducing mercury emissions because, on a statewide basis, wastewater point source discharges are less than 1% of the total mercury load to the state.

As a benchmark for the mercury concentrations, SMB from the Minnesota Fish Contaminant Program database have a mean length of 13.1 inches and a mean mercury concentration of 0.292 mg/kg (n = 405). The mean mercury concentration in SMB from the Snake River in 2006 was 0.231 mg/kg. For SRD, the database mean mercury concentration is 0.191 mg/kg (n = 47) without Snake River data included, and 0.186 mg/kg if the Snake River data is included. Therefore, mercury concentrations for both fish species from the Snake River are less than statewide averages for those species.

Table 2. Summary of results for total mercury concentrations and total fish length

Species	Code	N	Mercury Concentration (mg/kg-ww)				Total Fish Length (inches)	
			90 th Percentile	Minimum	Maximum	Mean	Minimum	Maximum
Smallmouth Bass	SMB	13	0.388	0.092	0.571	0.231	9.9	16.9
Shorthead Redhorse	SRD	8	0.279	0.062	0.285	0.155	11.3	16.2

PCB concentrations were analyzed in the two largest fish from each species. All four individual fish had PCB concentrations less than the reporting limit of 0.01 mg/kg (Table 3). Consequently, there is no impairment of aquatic consumption use support for PCB concentration in fish tissue in the Snake River Watershed. Also, there is no need to analyze smaller fish for PCBs, because the highest concentrations are expected in the larger fish.

Table 3. Summary of results for PCB concentrations and total fish length

Species	Code	N	PCBs Concentration (mg/kg-ww)	Total Fish Length (inches)	
				Minimum	Maximum
Smallmouth Bass	SMB	2	<0.01	14.7	16.9
Shorthead Redhorse	SRD	2	<0.01	15.4	16.2

Hydrologic Unit Code (HUC)-11 watershed units

Assessment results are presented for each of the HUC-11 watershed units within the Snake River Watershed, enabling us to assess all surface waters at one time and begin to develop comprehensive TMDL studies on a watershed basis rather than the reach by reach and parameter by parameter approach historically employed. This scale provides a robust assessment of water quality condition in the watershed unit and is a practical size for the development, management, and implementation of effective TMDLs and protection strategies. The primary objective is to portray all the impairments within a watershed resulting from the complex and multi-step assessment and listing process. The graphics presented for each of the HUC-11 watershed units contain the assessment results from the most recent 2008 Assessment Cycle as well as any impairment listings carried forward from previous assessment cycles. Discussion of assessment results will focus primarily on the 2006 intensive watershed monitoring effort but will consider all available data. The HUC-11 watershed graphics display impairment of aquatic consumption use support (mercury in fish tissue) on the Snake River main-stem but are not discussed further as they were covered in the previous section (fish contaminants). Following the results by HUC-11 watershed 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 Snake River major watershed (HUC-8).

Given all the potential sources of data and differing assessment methodologies for indicators and designated uses it is not currently feasible to provide results or summary tables for every monitoring station by parameter. However, summary tables of water chemistry results for each of the intensive watershed stations representing the pour point of the HUC-11 watersheds are provided in Appendix 2. In the Snake River Watershed, much of this data was provided by the Snake River Watershed Management Board (SRWMB) and its local partners as part of a long term monitoring program. In addition to being used for assessment, the data can provide valuable insight on water quality characteristics and potential parameters of concern in the watershed. Not all water chemistry parameters of interest have developed water quality standards. McCollor and Heiskary (1993)

developed ecoregion expectations for a number of water quality parameters in streams that provide a good basis for evaluating water quality data and estimating attainable water quality for an ecoregion. The expectations were based on the 75th percentile from a long term dataset of least impacted streams.

Biological criteria has not yet been developed for all stream types; therefore, assessment of fish community data (F-IBI) for aquatic life use support was not possible at some sampling sites. Stream types that were not assessed include coldwater streams, large rivers, channelized streams or ditches, and streams characterized by a predominant wetland condition (wetland habitat, naturally low dissolved oxygen, and depauperate fish community).

Invertebrate data collected in 2006 as part of the intensive watershed monitoring effort was not assessed in the 2008 Assessment Cycle because of the drought conditions experienced during the invertebrate sampling index period of August and September. MPCA staff is currently evaluating the effects of drought on invertebrate community structure in an effort to determine the applicability of these samples to characterize water quality condition in future assessment cycles.

Upper Snake River Watershed Unit – HUC 07010004010

The Upper Snake River Watershed Unit, located in southeast Aitkin County, drains an area of 129.3 square miles. The watershed forms the headwaters of the Snake River and consists of several low gradient, bog stained streams that originate in large alder, willow, and black spruce swamps. The upper Snake River flows in a westerly direction to the small community of Pliny, where it turns and flows south to McGrath. The entire watershed is largely undeveloped and consists predominantly of forest, shrub, and wetland land cover (Figure 6). Bear Creek is the only named tributary to the Snake River in this watershed. The pour point of this watershed unit is represented by site 06SC132 on the Snake River and is co-located with an existing SRWMB long-term monitoring station. Although outside the extent of the Upper Snake Watershed Unit as delineated (located in the downstream watershed unit), the monitoring station adequately characterizes the water quality in the watershed and takes advantage of existing data by external partners.

Five biological sampling events were conducted at discrete stations within the Upper Snake River Watershed Unit in 2006. Two sites on the main-stem Snake River (96SC069 and 06SC132) have F-IBI scores of 86 and 69, respectively, and are fully supporting for aquatic life. However, the Snake River reach from the headwaters to Hay Creek (AUID 07030004-508) was listed as impaired for aquatic life (B-F) in a previous assessment cycle (2002). Available data on this AUID suggests that the impairment is likely due to the previous assessment of data from a channelized reach of the Snake River, as all F-IBI scores from stations exhibiting natural stream channels indicate full support. The station on Bear Creek in the town of McGrath (06SC133) has an F-IBI score of 33 and is not supporting for aquatic life. This is significantly below the biological criterion of F-IBI \geq 68 for this stream type and Bear Creek (AUID 07030004-552) was added to the impaired waters list in 2008. Bear Creek was also listed as impaired for aquatic life in 2008, based on potential of hydrogen (pH) data from an existing SRWMB monitoring station. Two sites sampled in 2006 (06SC134, Trib. to Snake River and 06SC135, Snake River) were not assessed due to the channelized condition of the stream channel within the sampling reach.

Water chemistry data was collected by the SRWMB at the station representing the pour point of the Upper Snake River Watershed Unit (06SC132) between 4/9/2001 and 9/28/2006 (Appendix 2). Results indicate that no parameters for which there is data are in potential violation of water quality standards or exceed ecoregion expectations.

With the exception of Bear Creek, water quality conditions within the Upper Snake River Watershed Unit appear to be adequate and meeting their designated uses. Follow-up monitoring in the watershed could be restricted to the Bear Creek Subwatershed in order to identify the source(s) and cause(s) of the impairment.

Upper Snake River Watershed Unit - HUC 07030004010

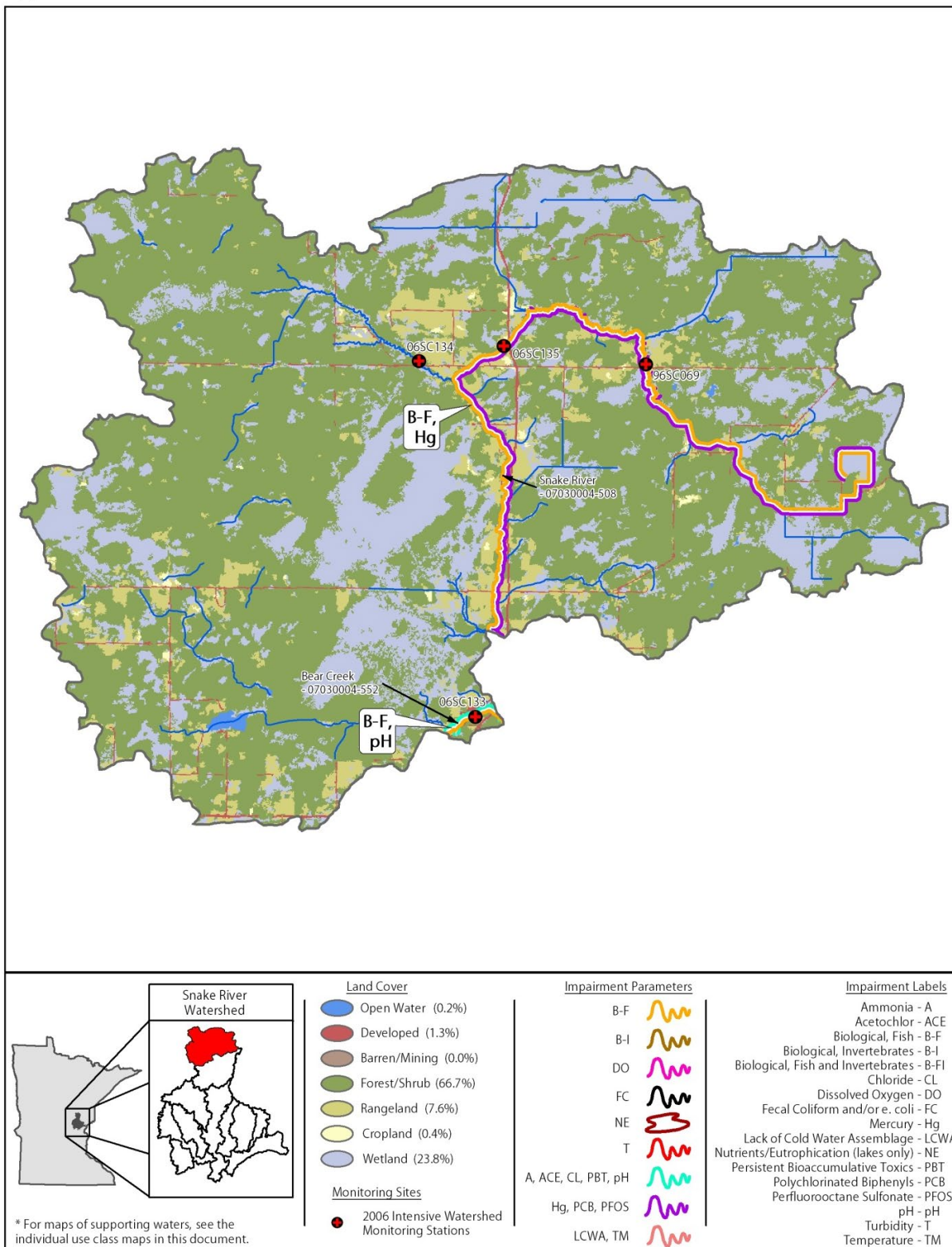


Figure 6. Currently listed impaired waters by parameter and land characteristics in the Upper Snake River Watershed Unit

Lower Upper Snake River Watershed Unit – HUC 07010004020

The Lower Upper Snake River Watershed Unit, located in southeast Aitkin and northern Kanabec Counties, encompasses an area of 113.5 square miles. The watershed unit includes the Snake River main-stem from Highway 18, two miles southeast of McGrath to the confluence of Chelsey Brook. Like the Upper Snake River Watershed, it is largely undeveloped and consists predominantly of forest, shrub, and wetland land cover (Figure 7). Named tributaries within this watershed include Bergman, Cowan's, Chelsey Brooks, and Hay Creek. The pour point of this watershed unit is represented by site 06SC123 on the Snake River.

Six biological sampling events were conducted at discrete stations within the Lower Upper Snake River Watershed Unit in 2006. The two sites on the main-stem Snake River (06SC006 and 06SC123) had F-IBI scores of 74 and 75, respectively, and indicate full support for aquatic life. However, the two sampling stations fall on separate AUIDs (07030004-508 and 07030004-523). The upper station (06SC006) is within the formerly listed reach (B-F) of the Snake River (AUID 07030004-508, headwaters to Hay Creek). As previously mentioned impairment of this reach is not widespread and is limited to a channelized section of the Snake River near the town of Pliny. Biological monitoring stations on Chelsey (06SC022), Cowan's (06SC131), and Bergman (99NF042) Brooks all indicate full support for aquatic life, scoring 66, 68, and 77, respectively, for biological integrity. The 2006 data from Hay Creek (96SC076) was not assessed due to the channelized condition of the stream channel within the sampling reach.

Water chemistry data collected at the station representing the pour point of the Lower Upper Snake River Watershed Unit (06SC123) did not indicate any potential water quality problems within the watershed. Results indicate that no parameters for which there is data are in potential violation of water quality standards or exceed ecoregion expectations, with the exception of pH (Appendix 2). One of 10 pH measurements was slightly below (6.1) the water quality standard range (6.5-9.0). However, the data does not indicate impairment (>10% violations, minimum 20 observations) and could be attributed to the naturally more acidic conditions found in the wetland dominated headwater streams of this region.

Overall, water quality conditions in the Lower Upper Snake River Watershed Unit appear to be adequate and meeting their designated uses. No follow-up monitoring appears necessary at this time.

Lower Upper Snake River Watershed Unit - HUC 07030004020

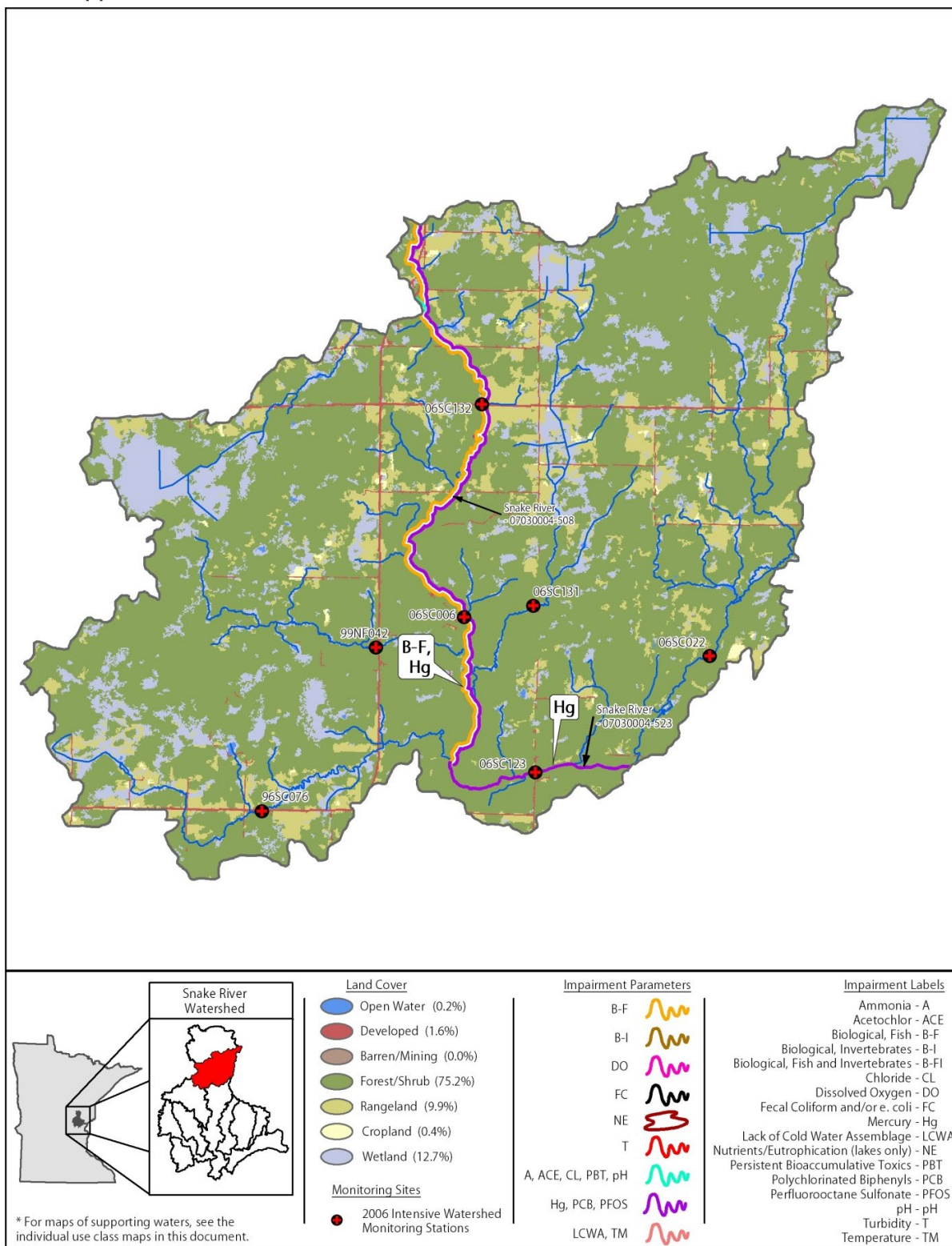


Figure 7. Currently listed impaired waters by parameter and land characteristics in the Lower Upper Snake River Watershed Unit

Middle Snake River Watershed Unit – HUC 07010004030

The Middle Snake River Watershed Unit encompasses an area of 153.5 square miles. The watershed unit includes the Snake River main-stem from the Chelsey Brook to Mud Creek confluences. The river flows in a southerly direction almost the entire length of Kanabec County, before it turns and flows east just south of Mora. The upper half of this watershed remains largely forested while the lower half has been converted primarily to agricultural land uses (Figure 8). Named tributaries within this watershed include Snowshoe and Spring Brooks, and Rice Creek. The pour point of this watershed unit is represented by site 06SC112, on the Snake River near Brunswick.

Nine biological sampling events were conducted at eight discrete stations within the Middle Snake River Watershed Unit in 2006. Four stations in this watershed unit are located on the Snake River main-stem (06SC118, 06SC116, 06SC112, and 06SC115). F-IBI scores range from 71 – 94, all indicating good to excellent biological integrity. Station 06SC112 was sampled twice, scoring 91 and 94, successively. Large river sites (drainage area > 270 square miles) are not currently being assessed for aquatic life using fish community biological criterion in the St. Croix River Basin; therefore, of these main-stem Snake River sites, only station 06SC118 had a drainage < 270 square miles and could be assessed. The F-IBI score of 86 indicates full support of the reach (AUID 07030004-506, Chelsey Brook to Knife River). Snowshoe Brook (06SC117) and an unnamed tributary to the Snake River (06SC113) score 73 and 68, respectively, and are fully supporting for aquatic life. Spring Brook (06SC114) has an F-IBI score of 34 and is not supporting for aquatic life. This concurs with previous biological sampling (1996) conducted at another location that resulted in Spring Brook (AUID 07030004-515) being placed on the impaired waters list (B-F) in 2002. The site on Rice Creek (06SC111) was not assessed due to the channelized condition of the stream channel within the sampling reach.

Water chemistry data collected at the station representing the pour point of the Middle Snake River Watershed Unit (06SC112) did not indicate any potential water quality problems within the watershed with the exception of pH and nitrate-N ($\text{NO}_2 + \text{NO}_3$) (Appendix 2). Two of 10 pH measurements were narrowly outside (6.1 and 9.5) the water quality standard range (6.5-9.0). The mean nitrate-N concentration is 0.21 mg/L and exceeds the ecoregion expectation (0.12 mg/L). A potential source of the elevated concentrations may be the Groundhouse River, which enters the Snake River approximately two miles upstream of this site. In addition, a reach of the Snake River (AUID 07030004-525, Knife River to Fish Lake outlet) was listed as impaired for aquatic recreation in 2008 based on fecal coliform data submitted by the SRWMB's long-term monitoring program.

With the exception of Spring Brook, water quality conditions within the Middle Snake Watershed Unit are supporting for the designated use of aquatic life. Follow-up monitoring in the watershed could be restricted to the Spring Brook Subwatershed in order to identify the source(s) and cause(s) of the biological impairment. Additional monitoring should also be conducted to address the fecal coliform bacteria impairment and to determine if pH and nitrogen are parameters of concern in the watershed and to identify their sources. The existing SRWMB long-term monitoring program in the Snake River Watershed will provide valuable insight into the sources and contributions of pollutants within the watershed.

Middle Snake River Watershed Unit - HUC 07030004030

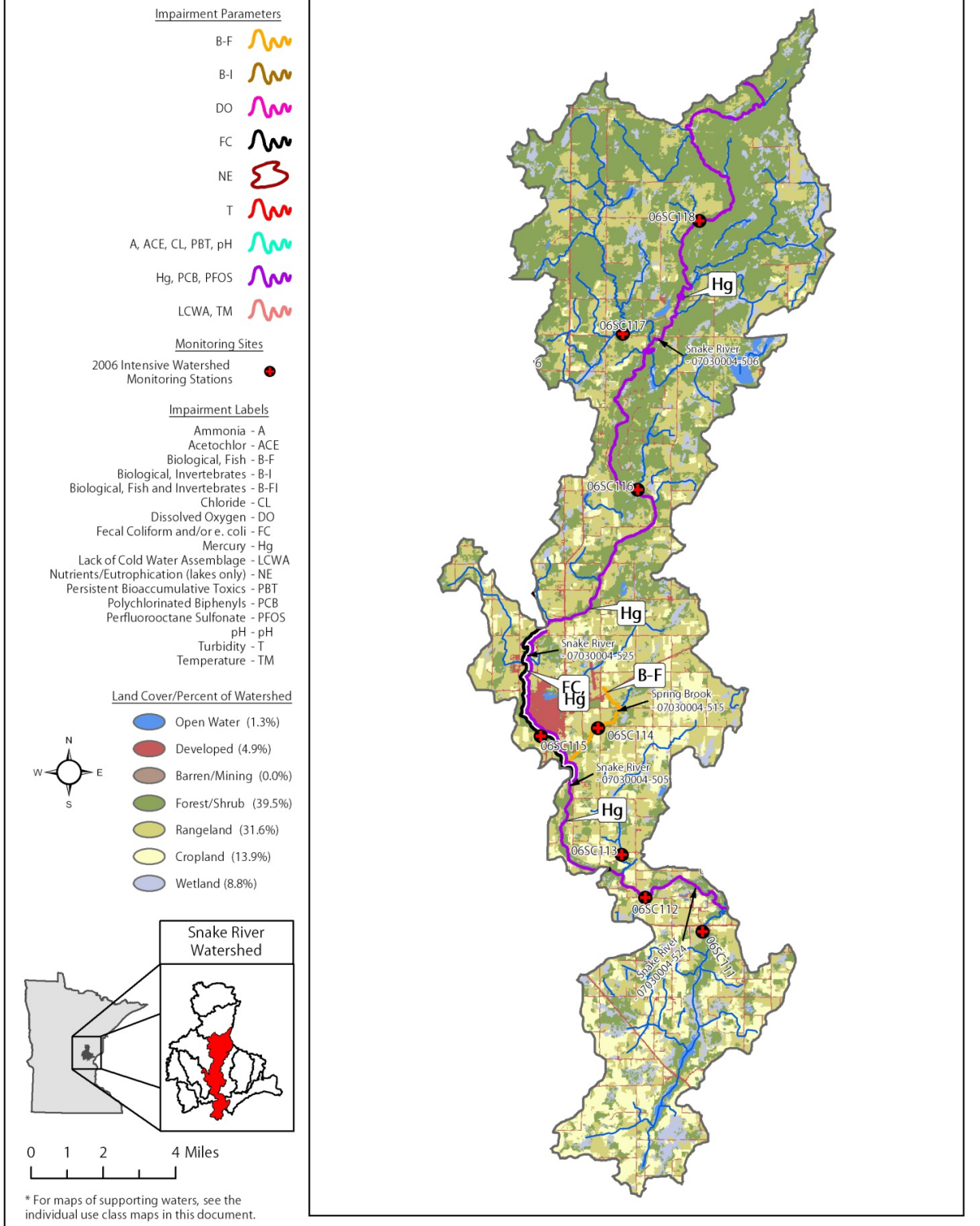


Figure 8. Currently listed impaired waters by parameter and land characteristics in the Middle Snake River Watershed Unit

Knife River Watershed Unit – HUC 07010004040

The Knife River Watershed Unit, located in northeast Mille Lacs and northwest Kanabec Counties, drains an area of 108.0 square miles. The headwaters originate within the Mille Lacs State Wildlife Management Area. The Knife River flows southeast through a matrix of wetland, forest, and rangeland land cover types to Knife Lake (Figure 9). From Knife Lake, the river flows south to its confluence with the Snake River just north of Mora. Agricultural land uses are more predominant in the lower portion of the watershed and the area surrounding Knife Lake is moderately developed. Bean Brook is the only named tributary to the Knife River in this watershed. The pour point of this watershed unit is represented by site 96SC097 and is co-located with an existing SRWMB long-term monitoring station.

Seven biological sampling events were conducted at discrete stations within the Knife River Watershed Unit in 2006. Three stations on the Knife River (06SC128, 06SC125, and 96SC097) have F-IBI scores of 82, 67, and 74, respectively, and indicate full support for aquatic life. The Knife River has been split into two assessment reaches (AUID 07030004-549, Dry Run to Knife Lake and 07030004-551, Knife Lake to Snake River). Previous biological sampling (1996) resulted in the upper Knife River reach (07030004-549) being listed as non-supporting for aquatic life use based on fish and macroinvertebrate assemblage data (B-FI). Bean Brook (06SC126) has an F-IBI score of 77 and is fully supporting for aquatic life. Two unnamed tributaries to the Knife River (06SC127 and 06SC124) also indicate full support, scoring 91 and 68, respectively. The site on Dry Run (06SC129) was not assessed in this watershed due to a predominant wetland condition within the sampling reach; however, previous biological sampling (1996) at another location within this AUID (07030004-537, Dry Run to unnamed creek) indicated it was impaired for aquatic life (B-I).

Water chemistry data was collected by the SRWMB at the station representing the pour point of the Knife River Watershed Unit (96SC097) between 4/7/2004 and 11/22/2005. Results indicate a potential water quality problem with fecal coliform and to a lesser extent nitrate-N ($\text{NO}_2 + \text{NO}_3$) (Appendix 2). Two of 15 fecal coliform samples exceeded the maximum standard of 2,000 organisms per 100 milliliters. Additional bacteria data should be collected in order to calculate a monthly geometric mean to determine aquatic recreation use support. The mean nitrate-N concentration is 0.13 mg/L and marginally exceeds the ecoregion expectation (0.12 mg/L). A single dissolved oxygen (DO) value out of 41 measurements fell below (2.0 mg/L) the water quality standard (5.0 mg/L) and does not indicate a potential DO impairment (>10% violations, minimum 20 observations).

Knife Lake (Lake ID #33-0028-00) is 1,266 acres and has a maximum depth of 15 feet. The lake has a strong secchi record with 60 observations since 1974. Knife Lake exceeds ecoregion based eutrophication standards for total phosphorus, chlorophyll-a, and secchi transparency (Appendix 3). As a result, Knife Lake is impaired for aquatic recreation and was placed on the impaired waters list for excess nutrients in 2004.

Follow-up monitoring should be conducted in the Knife River Watershed Unit in order to assess use support status for all indicators and to determine the source(s) and cause(s) of the impairments in the watershed and to develop a TMDL implementation plan for restoration.

Knife River Watershed Unit - HUC 07030004040

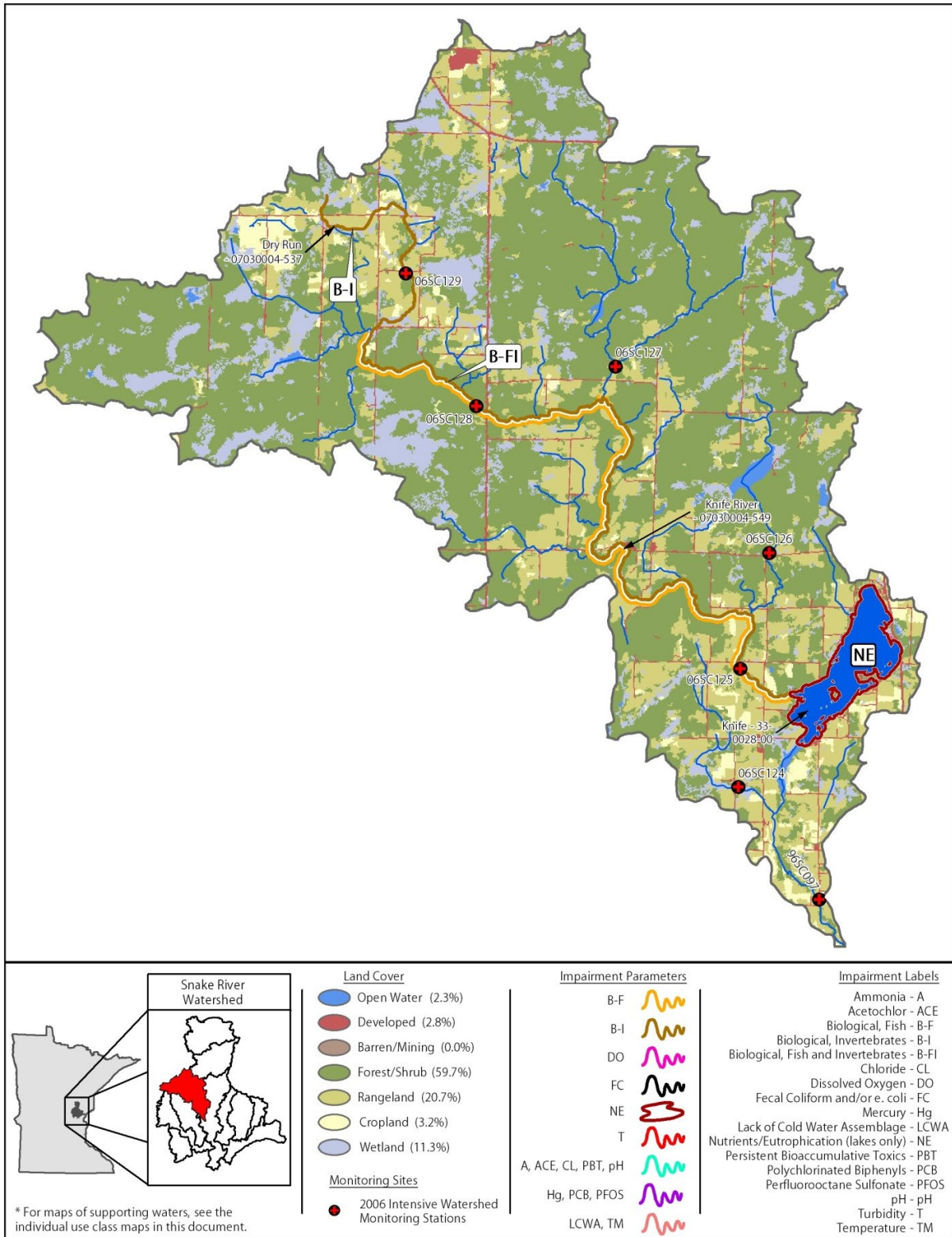


Figure 9. Currently listed impaired waters by parameter and land characteristics in the Knife River Watershed Unit

Ann River Watershed Unit – HUC 07010004050

The Ann River Watershed Unit, located primarily within Kanabec County, drains an area of 84.2 square miles. The headwaters originate within the Mille Lacs State Wildlife Management Area and flows southeast as the Little Ann River through a mostly undeveloped wetland/forest matrix to Ann Lake (Figure 10). From Ann Lake, the Ann River flows southeast approximately 11 miles to Fish Lake through a landscape that has been primarily converted to pasture and other agriculture land uses. The confluence of the Ann and Snake Rivers is located just downstream of the Fish Lake outlet near Mora, Minnesota. The pour point of this watershed unit is represented by site 06SC122.

Six biological sampling events were conducted at five discrete stations within the Ann River Watershed Unit in 2006. Progressing from upstream to downstream in the watershed, the general trend is a decrease in F-IBI score. In the upper half of the watershed, stations on Camp Creek (06SC137) and the Little Ann River (96SC004 and 06SC138) have fish community IBI scores ranging from 76-97, all indicating full support for aquatic life use. The two stations on the Ann River main-stem (06SC136 and 06SC122) have F-IBI scores of 67 and 71, respectively, and narrowly meet their biological expectation for aquatic life use support. This trend seems to correlate with the change in land use from forest/wetland to pasture/agriculture in the southern half of the watershed. However, previous biological sampling in this watershed (1996 and 1998) resulted in the Ann River reach (AUID 07030004-511) being listed as non-supporting for aquatic life use (B-F) and follows the trend of decreasing F-IBI scores progressing downstream. Available macroinvertebrate data also suggests impairment of the Ann River reach and will likely be listed as impaired for this indicator (B-I) in the 2010 assessment cycle.

Water chemistry data collected at the station representing the pour point of the Ann River Watershed Unit (06SC122) indicated a potential water quality problem with e-coli bacteria and, to a lesser extent, DO and pH (Appendix 2). Six of 10 samples taken between May 25, 2006 and August 29, 2006 exceeded the e-coli standard of 126 organisms/100ml. However, the water quality standard is based on a 30-day geometric mean with a minimum of five samples necessary to calculate. The geometric mean of 210 reported in Appendix 2 is a seasonal mean (May – September) and is not sufficient for determination of aquatic recreation use support. This is considered screening level data and suggests a potential problem. Additional data should be collected to calculate a monthly geometric mean in order to determine aquatic recreation use support. Additionally, one of nine DO measurements fell below (4.3 mg/L) the water quality standard (5.0 mg/L) and one of 10 pH values fell outside (6.0) the water quality standard range (6.5-9.0).

Ann Lake (Lake ID #33-040-00) is a 653-acre lake with a maximum depth of 17 feet. The water level is maintained by a sheet piling dam on the north end of the lake. Fish Lake (Lake ID #33-0036-00) is a 407-acre impoundment of the Ann River and has a maximum depth of eight feet. Both lakes exceed ecoregion based eutrophication standards for total phosphorus, chlorophyll-a, and secchi transparency (Appendix 3). As a result, both lakes are considered impaired for aquatic recreation and were placed on the impaired waters list for excess nutrients in 2004. Fish Lake is also impaired for aquatic consumption (mercury in fish tissue).

Additional monitoring should be conducted in the Ann River Watershed Unit in order to identify the source(s) and cause(s) of the impairments in the watershed and to develop a TMDL implementation plan for restoration.

Ann River Watershed Unit - HUC 07030004050

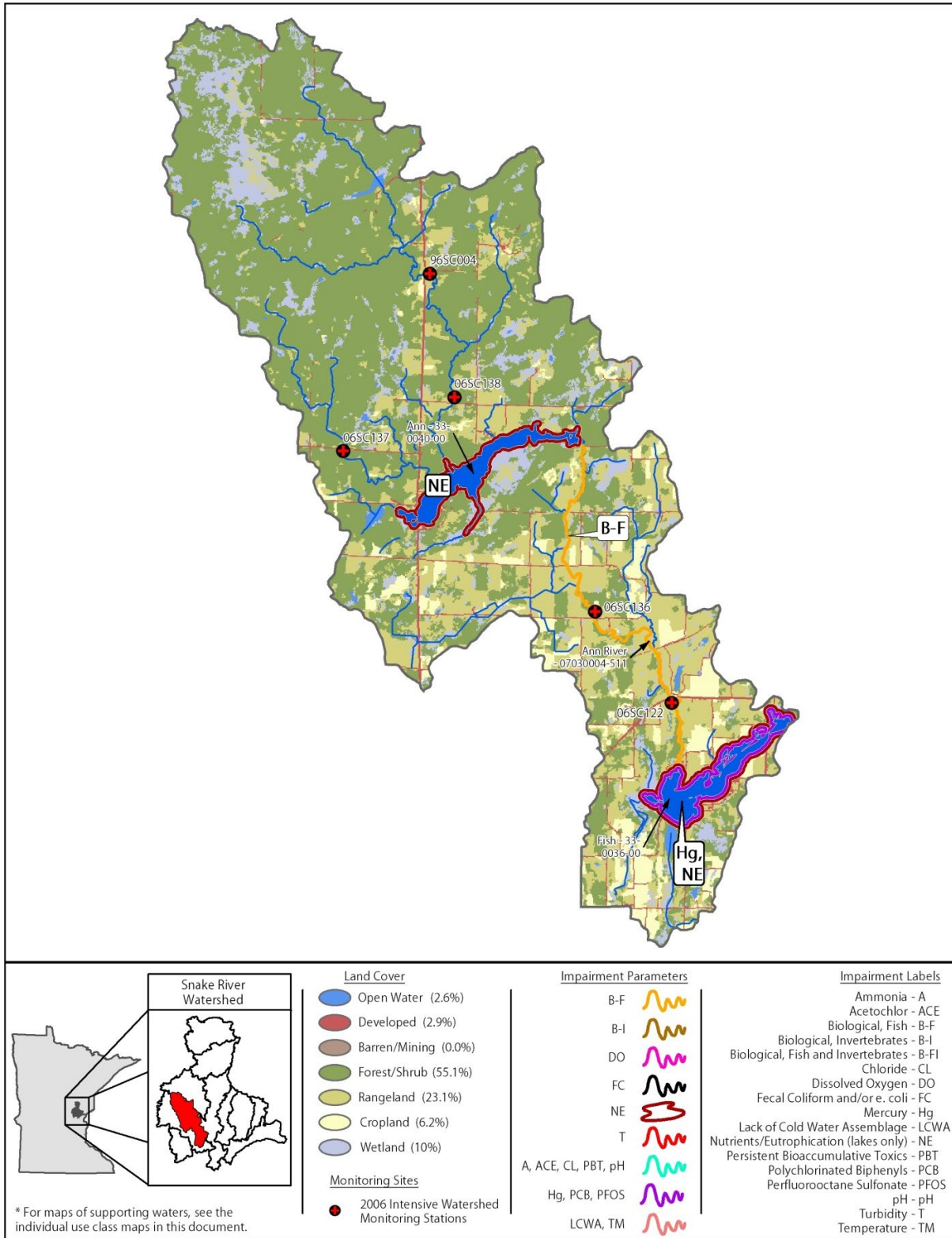


Figure 10. Currently listed impaired waters by parameter and land characteristics in the Ann River Watershed Unit

Groundhouse River Watershed Unit – HUC 07010004060

The Groundhouse River Watershed Unit, located in eastern Mille Lacs and southwest Kanabec Counties, encompasses an area of 87.7 square miles. The headwaters originate in a mostly undeveloped wetland/forest matrix, much of which is located within Rum River State Forest. Agricultural land uses are more predominant in the lower portion of the watershed unit (Figure 11). Significant development is sparse within the watershed unit, with the greatest density in the town of Ogilvie. Several small tributaries drain into the Groundhouse River, most notably the West and South Fork Groundhouse Rivers. The pour point of this watershed unit is represented by site 06SC061 and is located near an existing SRWMB long-term monitoring station.

Six biological sampling events were conducted at discrete stations within the Groundhouse River Watershed Unit in 2006. The Groundhouse River is split into two assessment reaches (AUID 07030004-513, headwaters to S.F. Groundhouse River and 07030004-512, S.F. Groundhouse River to Snake River). Two stations (06SC121 and 96SC070) on the upper reach (07030004-513) have F-IBI scores of 86 and 83, respectively, and are fully supporting for aquatic life. Another station (03SC002) scores below (66) the biological criterion threshold of $F-IBI \geq 69$ for this stream type but is within the 95% confidence limit, therefore, was not determined to be impaired. Previous biological sampling (1996-2003) in this watershed resulted in the upper Groundhouse River reach being listed as non-supporting for aquatic life use based on fish and macroinvertebrate assemblage data (B-FI). Data indicating impairment appears to be restricted to reaches of the Groundhouse River near the town of Ogilvie. The station (06SC061) on the lower Groundhouse River reach (07030004-512) has an F-IBI score of 70, narrowly meeting the biological expectation for aquatic life use support. The West Fork Groundhouse River (06SC029) and an unnamed tributary (06SC120) are fully supporting for aquatic life, scoring 79 and 82, respectively.

Water chemistry data was collected by the SRWMB near the station representing the pour point of the Groundhouse River Watershed Unit (06SC061) between April 7, 2004 and October 25, 2005. Results indicate fecal coliform and nitrate-N (NO_2+NO_3) are parameters of concern in this watershed unit (Appendix 2). Three of 33 fecal coliform samples exceeded the maximum standard of 2,000 organisms per 100 milliliters, including one extremely high observation of 25,000 organisms on October 5, 2005. These results concur with previously available data, as the Groundhouse River was listed as impaired for aquatic recreation in 2002. The mean nitrate-N concentration is 0.44 mg/L and significantly exceeds the ecoregion expectation (0.12 mg/L). A single DO value out of 47 measurements fell below (2.2 mg/L) the water quality standard (5.0 mg/L) and does not indicate a potential DO impairment (>10% violations, minimum 20 observations).

Follow-up monitoring is not necessary as TMDL studies in the Groundhouse River Watershed Unit are currently under way to identify the pollution sources causing and contributing to the impairments and to develop implementation plans for restoration. Lane and Cormier (2004) concluded that excessive fine sediment is the leading cause of the biological impairment. The most significant sources of sediment were found to be erosion from cropland and streambank erosion, and the most significant sources of fecal coliform were found to be animal operations and failing on-site wastewater treatment systems (MPCA, 2008b).

Groundhouse River Watershed Unit - HUC 07030004060

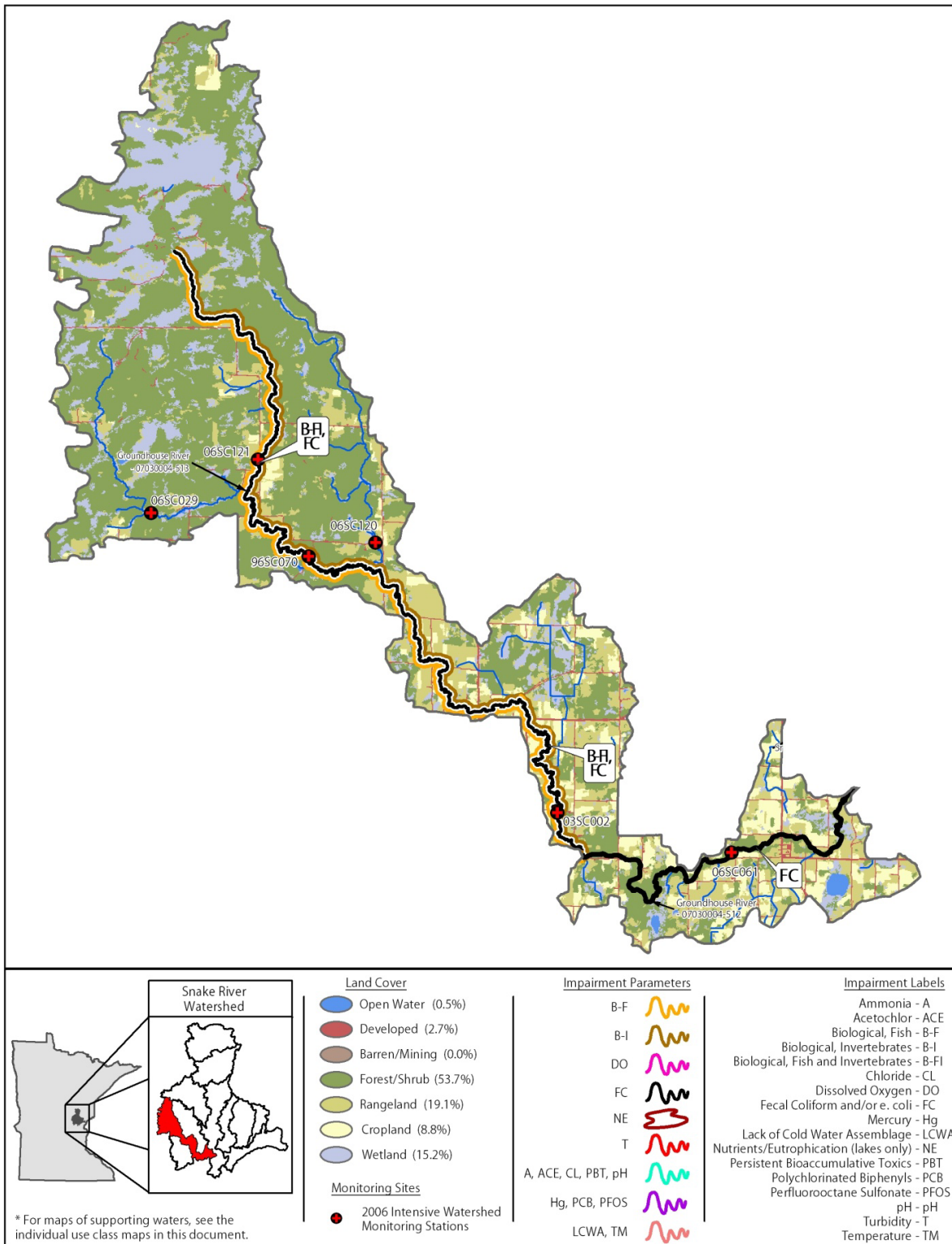


Figure 11. Currently listed impaired waters by parameter and land characteristics in the Groundhouse River Watershed Unit

South Fork Groundhouse River Watershed Unit – HUC 07010004070

The South Fork Groundhouse River Watershed Unit, located primarily within southwest Kanabec County, drains an area of 51.3 square miles. The headwaters originate in a wetland/ forest matrix within the Rum River State Forest. The river flows in a southerly direction for approximately 10 miles before it turns and flows northeast to its confluence with the Groundhouse River 3 miles southeast of Ogilvie. Agricultural land uses (pasture and cultivated cropland) are predominant in the watershed (Figure 12). The only tributaries to the South Fork Groundhouse River are several small channelized streams or ditches. The pour point of this watershed unit is represented by site 03SC003.

Five biological sampling events were conducted at three discrete stations within the South Fork Groundhouse River Watershed Unit in 2006. Station 06SC045 was sampled twice, scoring 19 and 13, successively, and is not supporting for aquatic life. Both results are significantly below the biological criterion of $F\text{-IBI} \geq 46$ for this stream type and the South Fork Groundhouse River (AUID 07030004-573) was added to the impaired waters list in 2008. This AUID was also listed in a previous assessment cycle (2004) as impaired based on macroinvertebrate assemblage data. The 2006 data from stations 06SC065 and 03SC003 on the South Fork Groundhouse River were not assessed for aquatic life due to the channelized condition of the stream channel within the sampling reach.

Water chemistry data collected at the station representing the pour point of the South Fork Groundhouse River Watershed Unit (03SC003) indicated a potential water quality problem with *e-coli* bacteria and nitrate-N ($\text{NO}_2 + \text{NO}_3$) (Appendix 2). Five of 10 samples taken between May 25, 2006, and September 29, 2006, exceeded the *e-coli* standard of 126 organisms/100ml. The water quality standard is based on a 30 day geometric mean with a minimum of five samples necessary to calculate. The geometric mean of 130 reported in Appendix 2 is a seasonal mean (May – September) and is not sufficient for determination of aquatic recreation use support by itself. However, other bacteria data available during the 2008 Assessment Cycle resulted in this AUID being listed as impaired for aquatic recreation.

The mean nitrate-N concentration of 1.3 mg/L significantly exceeds the ecoregion expectation of 0.12 mg/L. Single violations of water quality standards were observed for DO (3.8 mg/L) and pH (6.4). The mean specific conductance (337 $\mu\text{S}/\text{cm}$) slightly exceeds the ecoregion expectation of 310 $\mu\text{S}/\text{cm}$.

The biological and bacteria impairments in the South Fork Groundhouse River are being addressed as part of the Groundhouse River TMDL (MPCA, 2008b). Therefore, more extensive monitoring and diagnostic studies have already been conducted to identify the source(s) and cause(s) of these impairments and to develop a TMDL implementation plan for restoration.

South Fork Goundhouse River Watershed Unit - HUC 07030004070

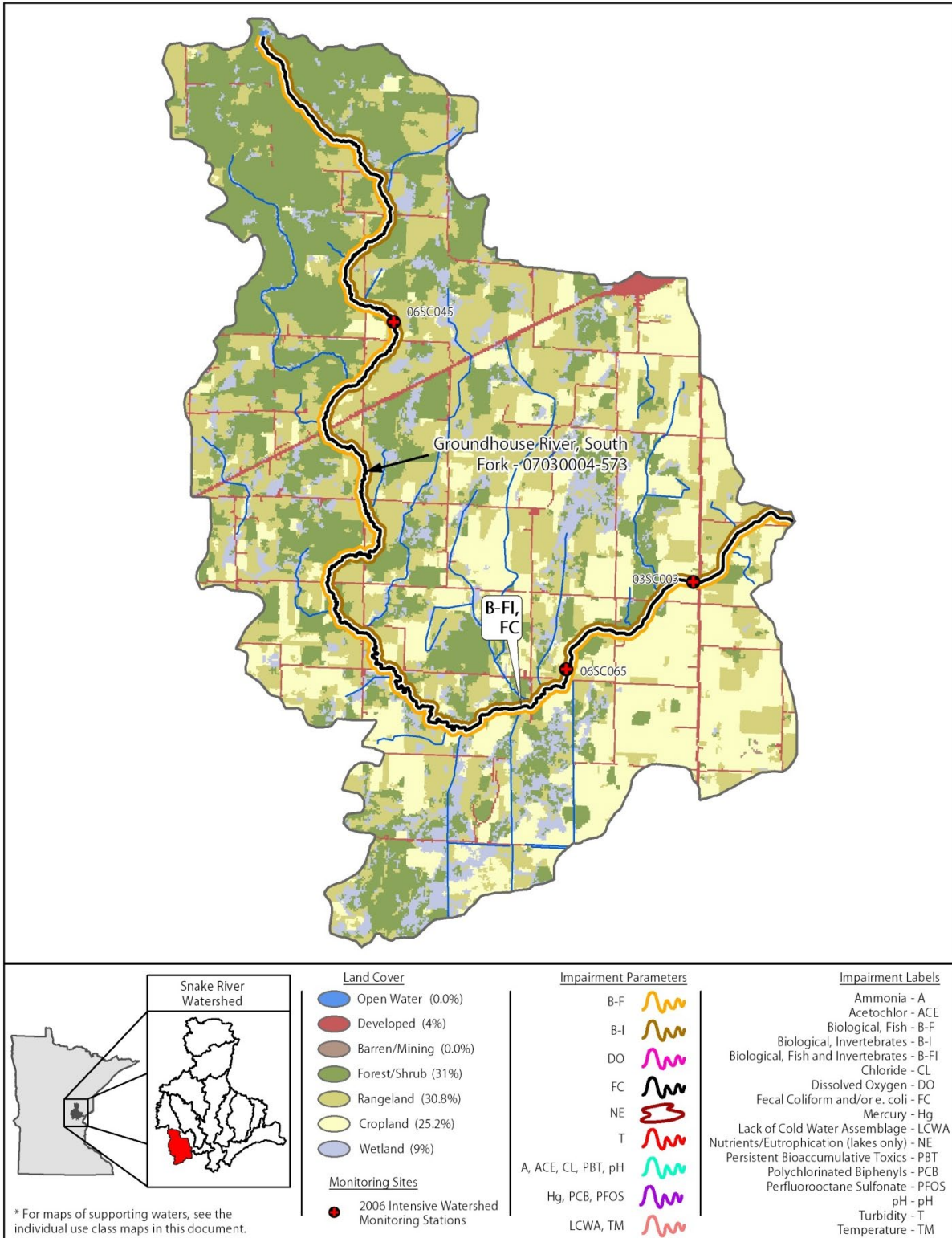


Figure 12. Currently listed impaired waters by parameter and land characteristics in the South Fork Goundhouse Watershed Unit

Mud Creek Watershed Unit – HUC 07010004080

The Mud Creek Watershed Unit, located within southwest Kanabec and southeast Pine Counties, drains an area of 64.9 square miles. Mud Creek is a low gradient stream that flows in a southerly direction over its course for approximately 23 miles to its confluence with the Snake River near Grasston. Land use is predominantly pastured rangeland with scattered areas of forest, shrub, and wetland throughout (Figure 13). Row crop agricultural land uses become more prevalent in the lower portion of the watershed. Tributaries to Mud Creek consist of several small channelized streams or ditches. The pour point of this watershed unit is represented by site 06SC107 and is co-located with an existing SRWMB long term monitoring station.

Five biological sampling events were conducted at discrete stations within the Mud Creek Watershed Unit in 2006. Mud Creek is split into two assessment reaches (AUID 07030004-566, headwaters to Quamba Lake and 07030004-567, Quamba Lake to Snake River). One station (06SC110) on the upper reach has an F-IBI score of 68 and indicates full support. However, previous biological sampling (1998) resulted in the upper Mud Creek reach (07030004-566) being listed as non-supporting for aquatic life use based on fish and macroinvertebrate assemblage data (B-FI). The lower Mud Creek reach (07030004-567) was sampled at two locations (06SC109 and 06SC107) and has F-IBI scores of 86 and 56, respectively. Multiple but discrepant results on an AUID indicate partial support for aquatic life use. This AUID was also listed in a previous assessment cycle (2002) as impaired based on fish assemblage data (B-F). Two sites sampled in 2006 (06SC018, Trib. to Mud Creek and 06SC108, County Ditch #4) were not assessed in this watershed due to the channelized condition of the stream channel within the sampling reach.

Water chemistry data was collected by the SRWMB at the station representing the pour point of the Mud Creek Watershed Unit (06SC107) between April 7, 2004, and April 19, 2006 (Appendix 2). Results indicate Mud Creek (AUID 07030004-567) is impaired for aquatic recreation. More than 10% (7 of 20) individual fecal coliform values exceeded the 200 organisms per 100 ml standard. Two of 20 fecal coliform values exceeded the maximum standard of 2,000 organisms per 100 milliliters, including one extremely high observation of 16,000 organisms on October 5, 2005. The data was sufficient to determine use support status and Mud Creek (AUID 07030004-567) was listed as impaired for aquatic recreation in 2008. Two of 39 pH values were below (6.2) the water quality standard range (6.5-9.0), but does not indicate impairment (>10% violations, minimum 20 observations).

Quamba Lake (Lake ID #33-0015-00) is 214 acres and has a maximum depth of 11 feet. The lake exceeds ecoregion based eutrophication standards for total phosphorus, chlorophyll-a, and secchi transparency (Appendix 3). As a result, Quamba Lake is impaired for aquatic recreation and was placed on the impaired waters list for excess nutrients in 2004.

Additional monitoring should be conducted in the Mud Creek Watershed Unit in order to identify the source(s) and cause(s) of the impairments in the watershed and to develop a TMDL implementation plan for restoration.

Mud Creek Watershed Unit - HUC 07030004080

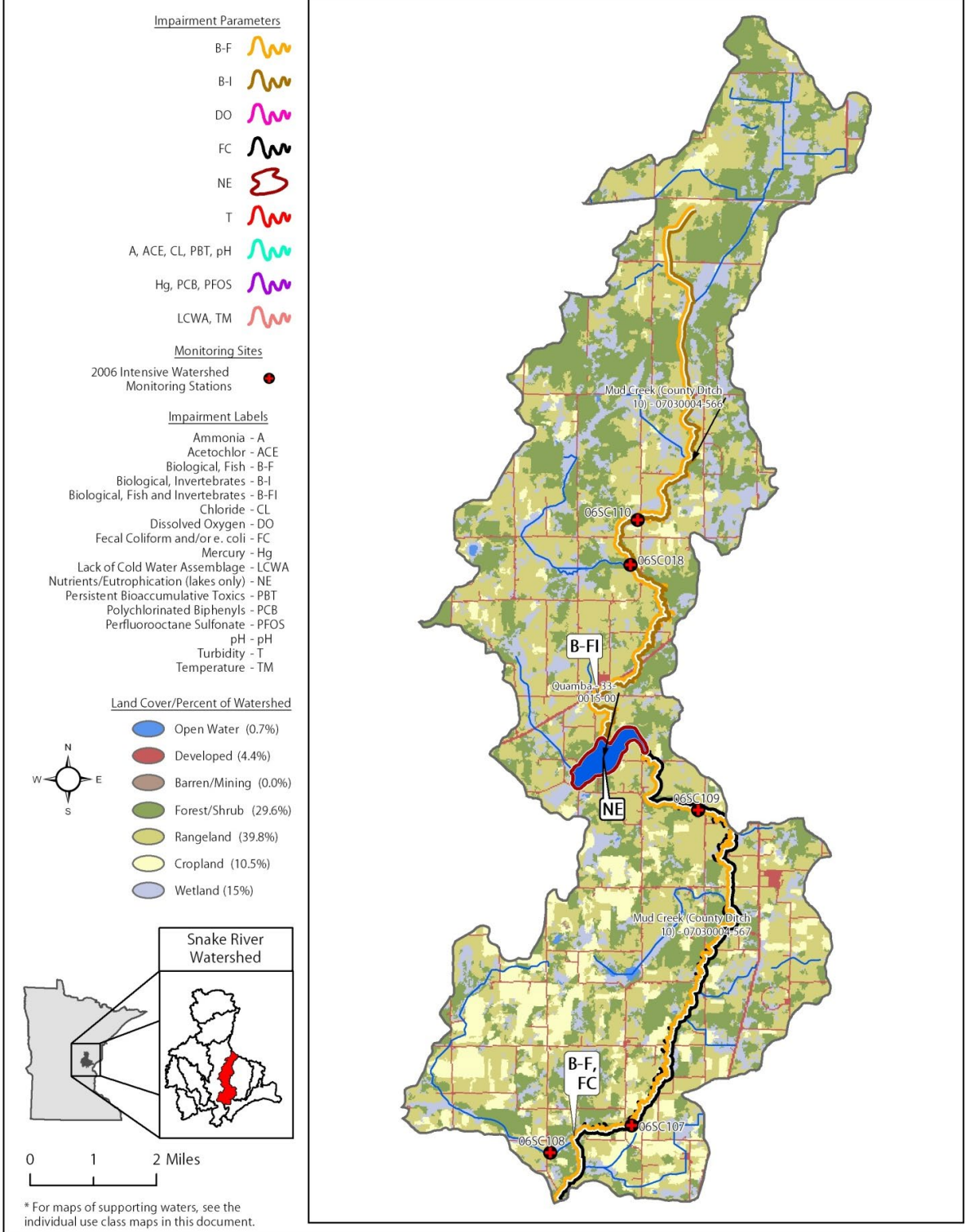


Figure 13. Currently listed impaired waters by parameter and land characteristics in the Mud Creek Watershed Unit

Lower Snake River Watershed Unit – HUC 07010004090

The Lower Snake River Watershed Unit, located in southern Pine County, encompasses an area of 90.0 square miles. The watershed unit includes the Snake River main-stem from Mud Creek to its confluence with the St. Croix River. The river flows in an easterly direction through a wide farming valley to Cross Lake in Pine City. After flowing through Cross Lake and over the dam that maintains the lake level, the river continues east past wooded bluffs to its confluence. Considerable development of homes and cabins exist on this lower section; however, the last three miles of the river is protected within Chengwatana State Forest. Land cover is variable in the watershed unit, with a prevalence of agricultural land uses in the upper portion, areas of significant development in and around Pine City, and predominantly forest/shrub in the lower portion (Figure 14). Named tributaries within this watershed include Bear and Hay Creeks. The pour point of this watershed unit is represented by site 06SC007.

Six biological sampling events were conducted at five discrete stations within the Lower Snake River Watershed Unit in 2006. Two stations in this watershed unit are located on the Snake River main-stem (06SC010 and 06SC007). F-IBI scores range from 73 – 89, all indicating good to excellent biological integrity. Station 06SC007 was sampled twice, scoring 74 and 89, successively. However, large river sites (drainage area > 270 square miles) are not currently being assessed for aquatic life using fish community data in the St. Croix River Basin. Bear Creek (96SC068) has an F-IBI score of 62 and is fully supporting for aquatic life. A tributary to Cross Lake (06SC101) has an F-IBI score of 28 and is not supporting for aquatic life. This is significantly below the biological criterion threshold (F-IBI \geq 46) for this stream type and the reach (AUID 07030004-577) was added to the impaired waters list in 2008. The 2006 data from Hay Creek (98SC068) was not assessed in this watershed due to the channelized condition of the stream channel within the sampling reach.

Water chemistry data collected at the station representing the pour point of the Lower Snake River Watershed Unit (06SC007) did not indicate any potential water quality problems within the watershed. Results indicate that no parameters for which there is data are in potential violation of water quality standards or exceed ecoregion expectations (Appendix 2), with the exception of pH. One of 10 pH measurements was below (5.8) the water quality standard range (6.5-9.0), but is not sufficient data to indicate impairment (>10% violations, minimum 20 observations).

Cross Lake (Lake ID #58-0019-00) is 943 acres and has a maximum depth of 30 feet. The lake exceeds ecoregion based eutrophication standards for total phosphorus, chlorophyll-a, and secchi transparency (Appendix 3). As a result, Cross Lake is impaired for aquatic recreation and was placed on the impaired waters list for excess nutrients in 2004.

Additional monitoring should be conducted in the Lower Snake River Watershed Unit in order to identify the source(s) and cause(s) of the impairments in the watershed and to develop a TMDL implementation plan for restoration. Monitoring should focus on the eutrophication of Cross Lake and the aquatic life impairment in the tributary to Cross Lake (AUID 07030004-577) Subwatershed. Available volunteer monitoring data indicates *E. coli* bacteria may be a parameter of concern.

Lower Snake River Watershed Unit - HUC 07030004090

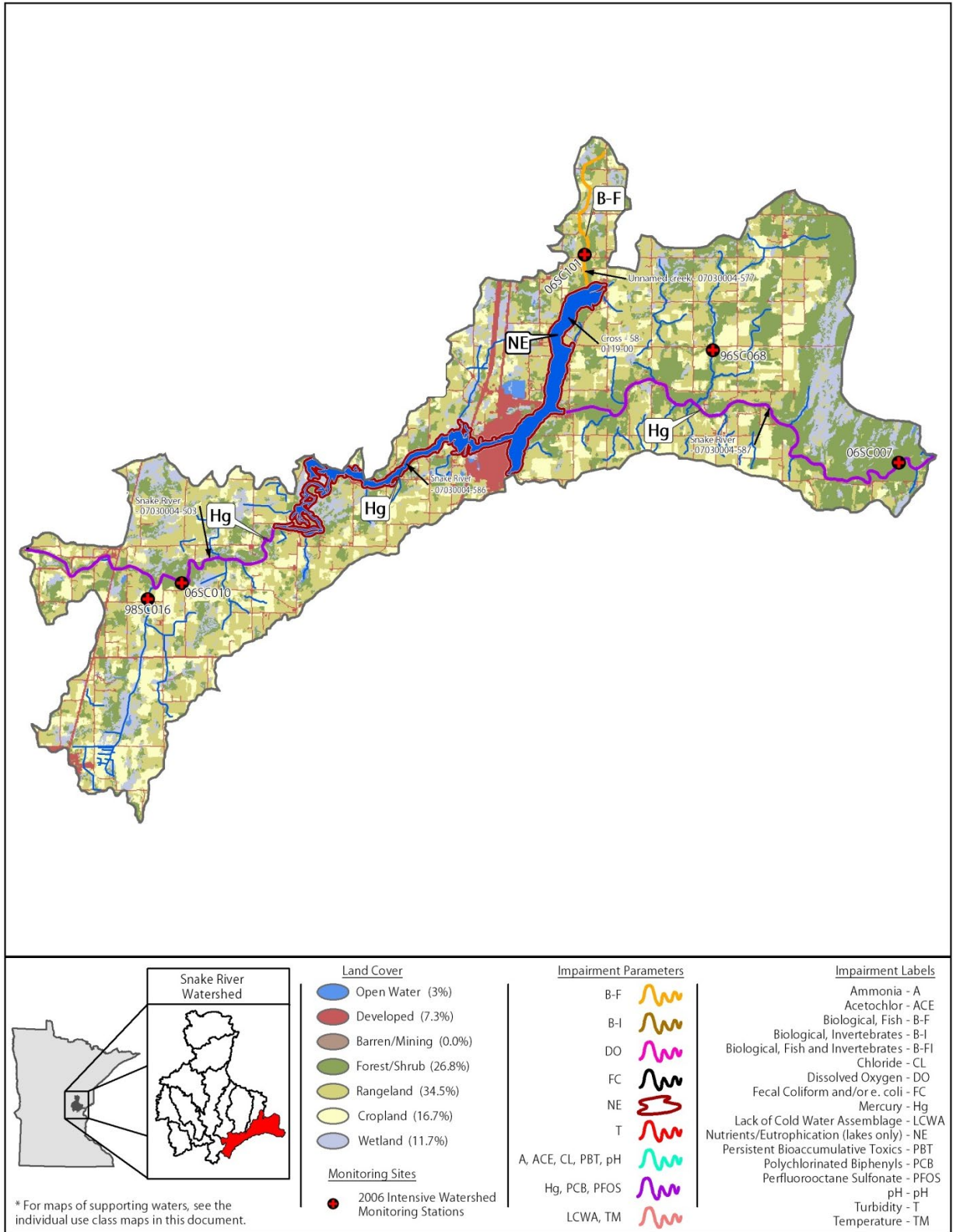


Figure 14. Currently listed impaired waters by parameter and land characteristics in the Lower Snake River Watershed Unit

Pokegama Creek Watershed Unit – HUC 07010004100

The Pokegama Creek Watershed Unit, located in eastern Kanabec and southern Pine Counties, drains an area of 90.4 square miles. Pokegama Creek is a low gradient stream that flows in a southerly direction over its course for approximately 19 miles to Pokegama Lake. Only a very short stream segment exists between the lake and Pokegama Creek's confluence with the Snake River. Land use is predominantly pastured rangeland with scattered areas of forest/shrub (Figure 15). Wetlands are also prevalent throughout the watershed. Significant tributaries include East Pokegama Creek and an unnamed creek. The pour point of this watershed unit is located above the lake in order to characterize the stream condition and is represented by site 06SC042, which is co-located with an existing SRWMB long-term monitoring station.

Five biological sampling events were conducted at four discrete stations within the Pokegama Creek Watershed Unit in 2006. A station (06SC102) on an upper reach of Pokegama Creek (AUID 07030004-530) has an F-IBI score of 74 and indicates full support for aquatic life. The downstream station (06SC042) has an F-IBI score below (64) the biological criterion threshold ($F-IBI \geq 68$) for this stream type but is within the 95% confidence limit. This lower reach (AUID 07030004-532, East Pokegama Creek to unnamed creek) was listed in a previous assessment cycle (2004) as impaired for aquatic life based on macroinvertebrate assemblage data (B-I). The station on East Pokegama Creek (06SC103) has an F-IBI score of 70 and is fully supporting of aquatic life. Station 06SC100 (Trib. to Pokegama Creek) was sampled twice, scoring 51 and 42, successively, and is assessed as fully supporting. The score of 42 is below the biological criterion threshold ($F-IBI \geq 46$) for this stream type, but is within the 95% confidence limit.

Water chemistry data was collected by the SRWMB at the station representing the pour point of the Pokegama Creek Watershed Unit (06SC042) between 4/6/2004 and 4/19/2006. Results indicate that no parameters for which there is data are in potential violation of water quality standards or exceed ecoregion expectations (Appendix 2), with the exception of pH. Two of 40 pH measurements were below (6.32 and 6.35) the water quality standard range (6.5-9.0), but does not indicate impairment (>10% violations, minimum 20 observations).

Pokegama Lake (Lake ID #58-0142-00) has a maximum depth of 25 feet and a basin area of 1,474 acres. Located near Pine City, the lake is highly developed. Nuisance algae blooms have been periodically recorded since 1929. Barr Engineering investigated phosphorus loading into Pokegama Lake in 1991-1992. Sources of phosphorus were identified as internal loading from sediments, Pokegama Creek, Snake River, septic systems along the lake margin, direct precipitation, along with watershed and urban sources. The lake exceeds ecoregion based eutrophication standards for total phosphorus, chlorophyll-a, and secchi transparency (Appendix 3). As a result, Pokegama Lake is impaired for aquatic recreation and was placed on the impaired waters list for excess nutrients in 2004.

Additional monitoring should be conducted in the Pokegama Creek Watershed Unit in order to identify the source(s) and cause(s) of the impairments in the watershed and to develop a TMDL implementation plan for restoration.

Pokegama Creek Watershed Unit - HUC 07030004100

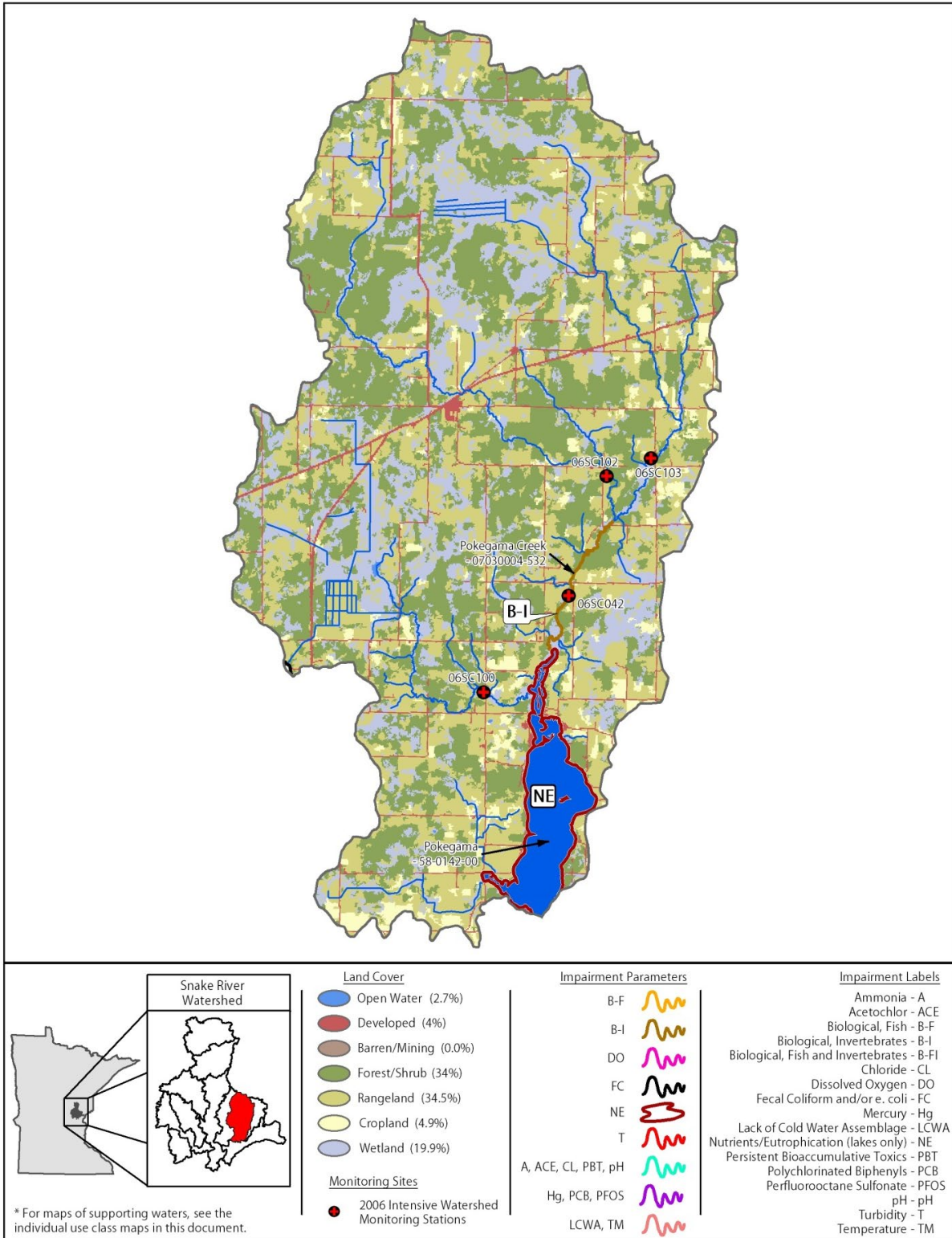


Figure 15. Currently listed impaired waters by parameter and land characteristics in the Pokegama Creek Watershed Unit

Mission Creek Watershed Unit – HUC 07010004110

The Mission Creek Watershed Unit, located in southern Pine County, drains an area of 36.7 square miles. The headwaters of Mission Creek originate just southwest of Hinckley. The creek flows in a mostly southwest direction to its confluence with the Snake River 2.5 miles west of Pine City. Land use is predominantly pastured rangeland with scattered areas of row crop agriculture (Figure 16). Wetlands are also prevalent throughout, particularly in the middle reaches of the watershed. A roughly 2.5-mile reach in the upper section of Mission Creek is currently designated as a trout stream. Mission Creek is a linear watershed and contains no significant tributaries. The pour point of this watershed unit is represented by site 06SC104 and is co-located with an existing SRWMB long-term monitoring station.

Four biological sampling events were conducted at three discrete stations within the Mission Creek Watershed Unit in 2006. The three stations are located on two AUIDs (07030004-547 and 07030004-548). Two stations (06SC106 and 06SC105) on the upper reach (AUID 07030004-547) have F-IBI scores of 49 and 43, respectively, and the reach is considered partial supporting for aquatic life. In addition, this AUID was listed in a previous assessment cycles as impaired based on macroinvertebrate and fish assemblage data (M-IBI and F-IBI). Station 06SC104 was sampled twice on the lower reach (AUID 07030004-548), scoring 13 and 11, successively. These results are significantly below the biological criterion threshold (F-IBI \geq 68) for this stream type and the reach was added to the impaired waters list in 2008.

Water chemistry data was collected by the SRWMB at the station representing the pour point of the Mission Creek Watershed Unit (06SC104) between April 6, 2004 and April 19, 2006. Results indicate DO is a parameter of concern in this watershed, and to a lesser extent fecal coliform (Appendix 2). Twelve of 46 values violated the minimum DO standard (5.0 mg/L). The data set was sufficient (>10% violations, minimum 20 observations) to list Mission Creek (AUID 07030004-548) as non-supporting of aquatic life for this parameter in 2008. One of 20 fecal coliform values exceeded (7,300) the maximum standard of 2,000 organisms per 100 milliliters. However, the results are not sufficient to assess the reach as non-supporting for aquatic recreation. Three of 45 pH measurements were outside (6.05, 6.14 and 9.75) the water quality standard range (6.5-9.0), but does not indicate an impairment (>10% violations, minimum 20 observations).

Water quality conditions within Mission Creek are not meeting the designated use of aquatic life for a number of parameters (B-FI and DO). Additional monitoring should be conducted in the Mission Creek Watershed Unit in order to identify the source(s) and cause(s) of the impairments in the watershed and to develop a TMDL implementation plan for restoration.

Mission Creek Watershed Unit - HUC 07030004110

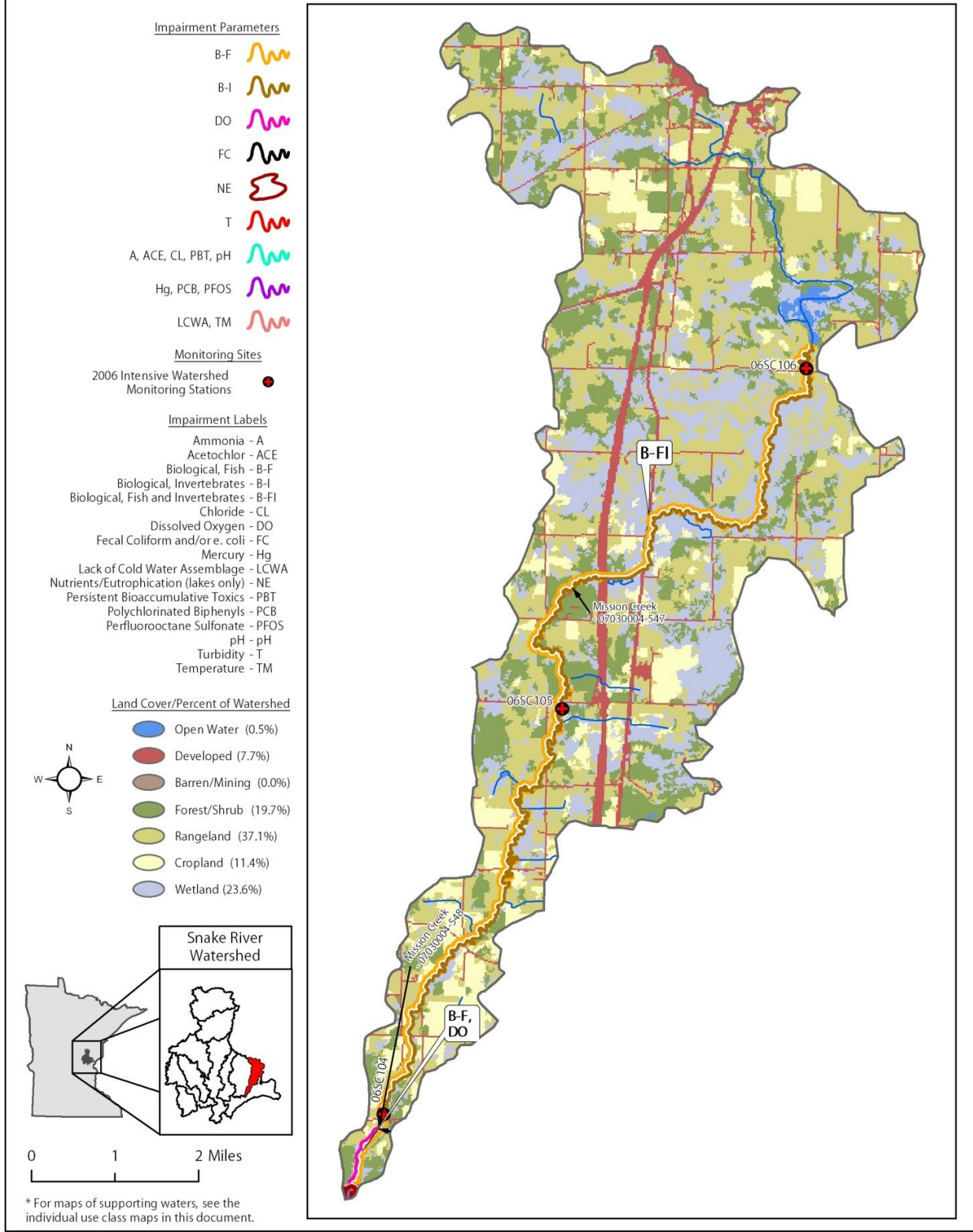


Figure 16. Currently listed impaired waters by parameter and land characteristics in the Mission Creek Watershed Unit

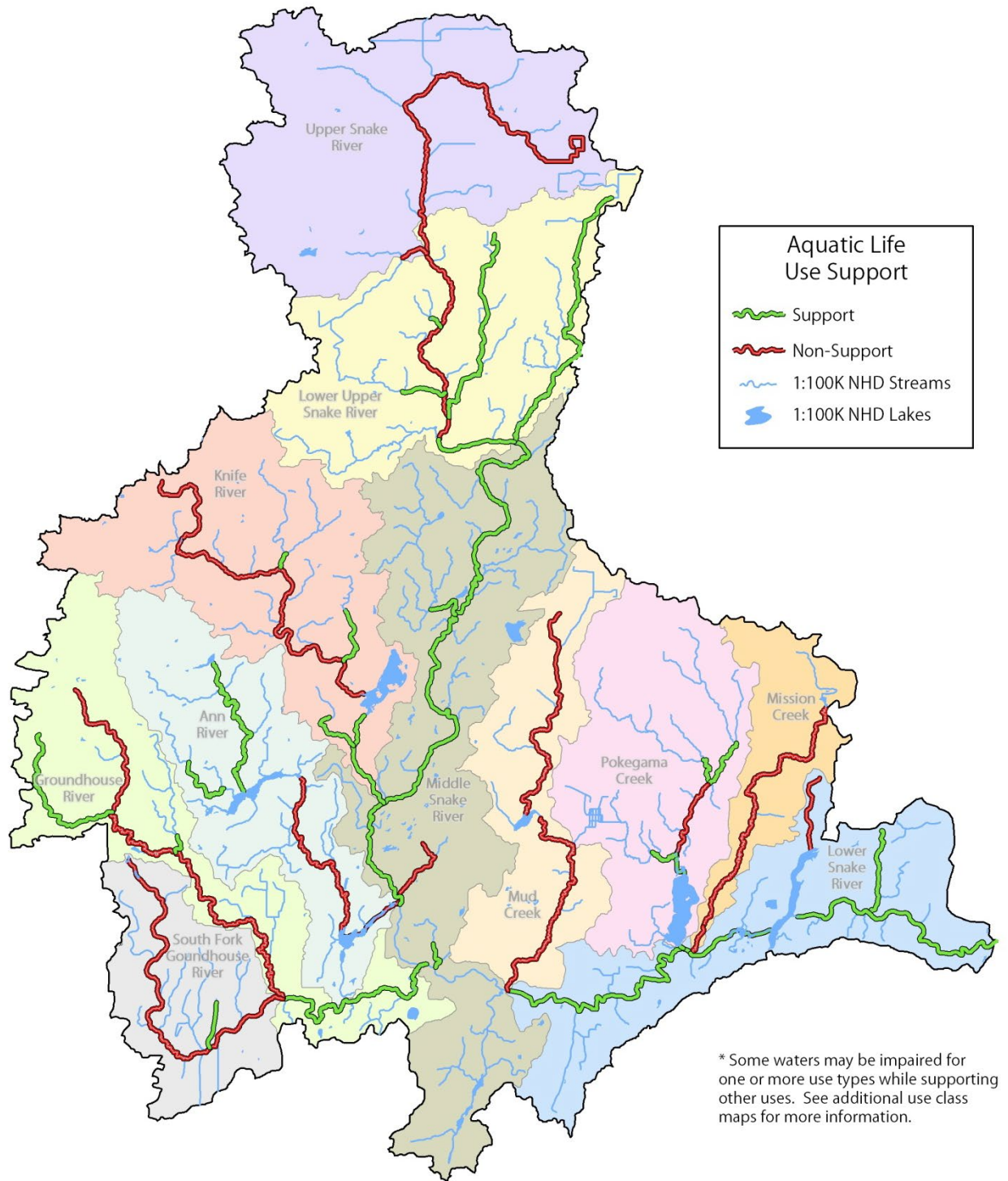


Figure 17. Aquatic life use support in the Snake River Watershed

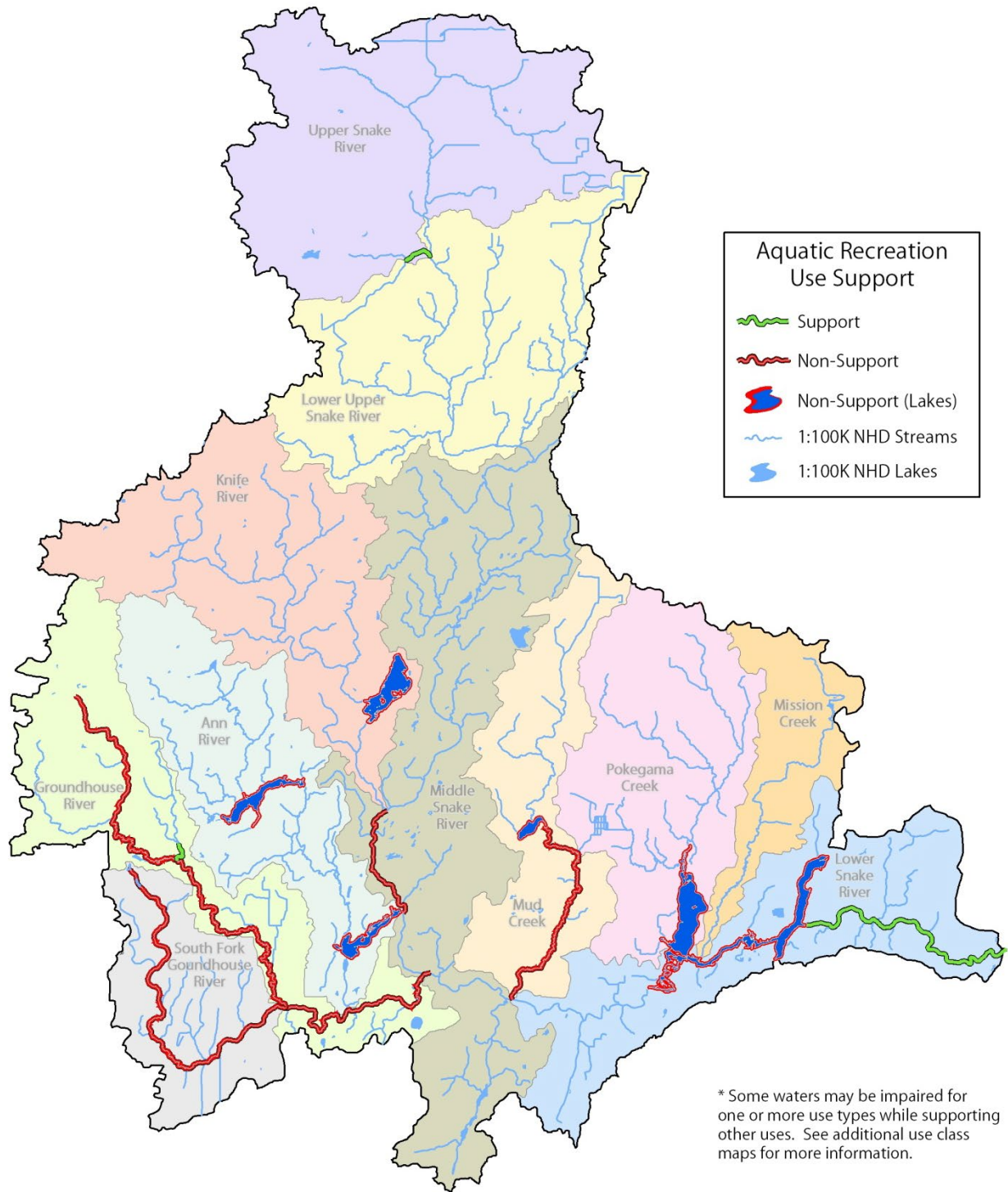


Figure 18. Aquatic recreation use support in the Snake River Watershed

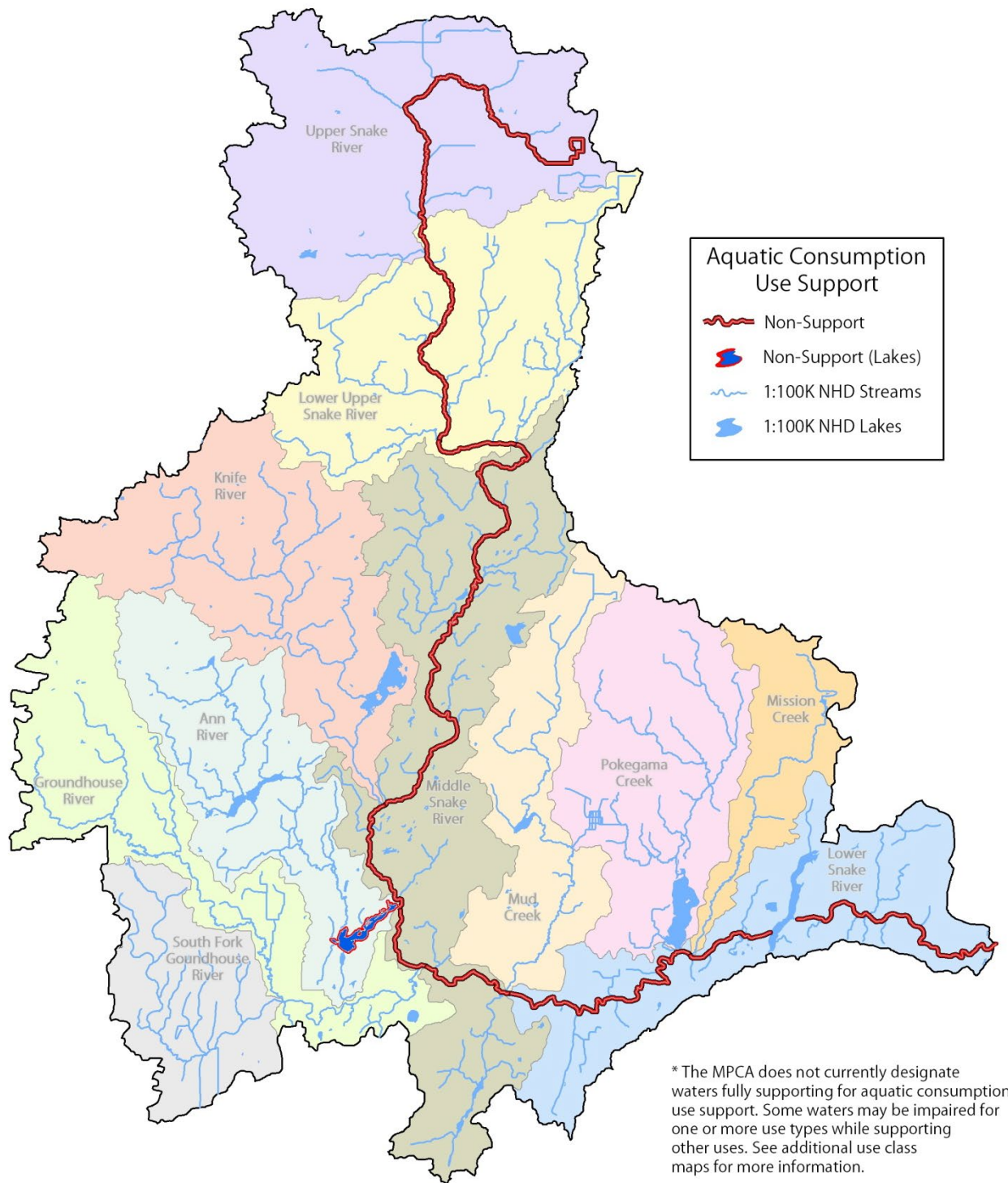


Figure 19. Aquatic consumption use support in the Snake River Watershed

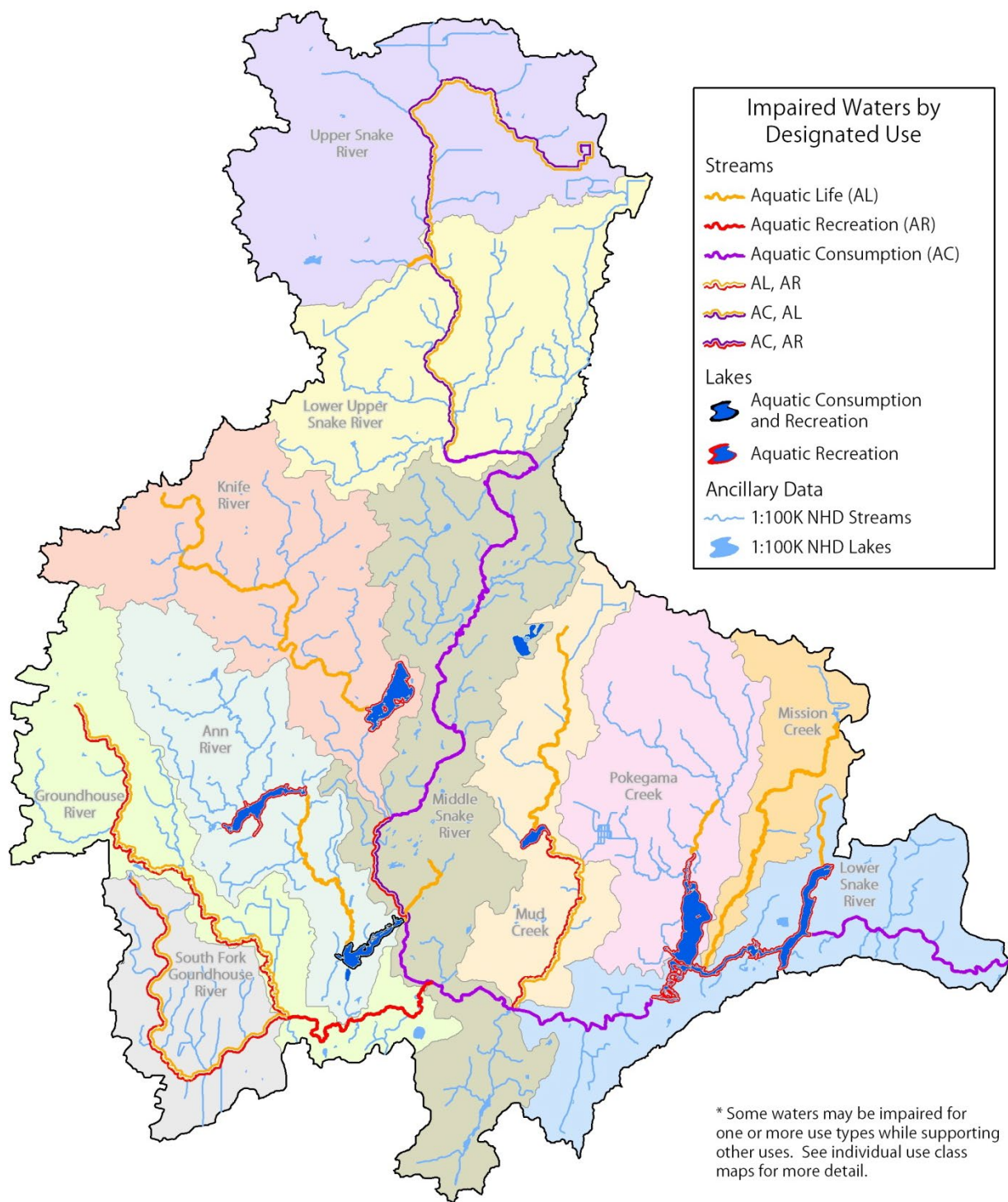


Figure 20. Impaired waters by designated use in the Snake River Watershed

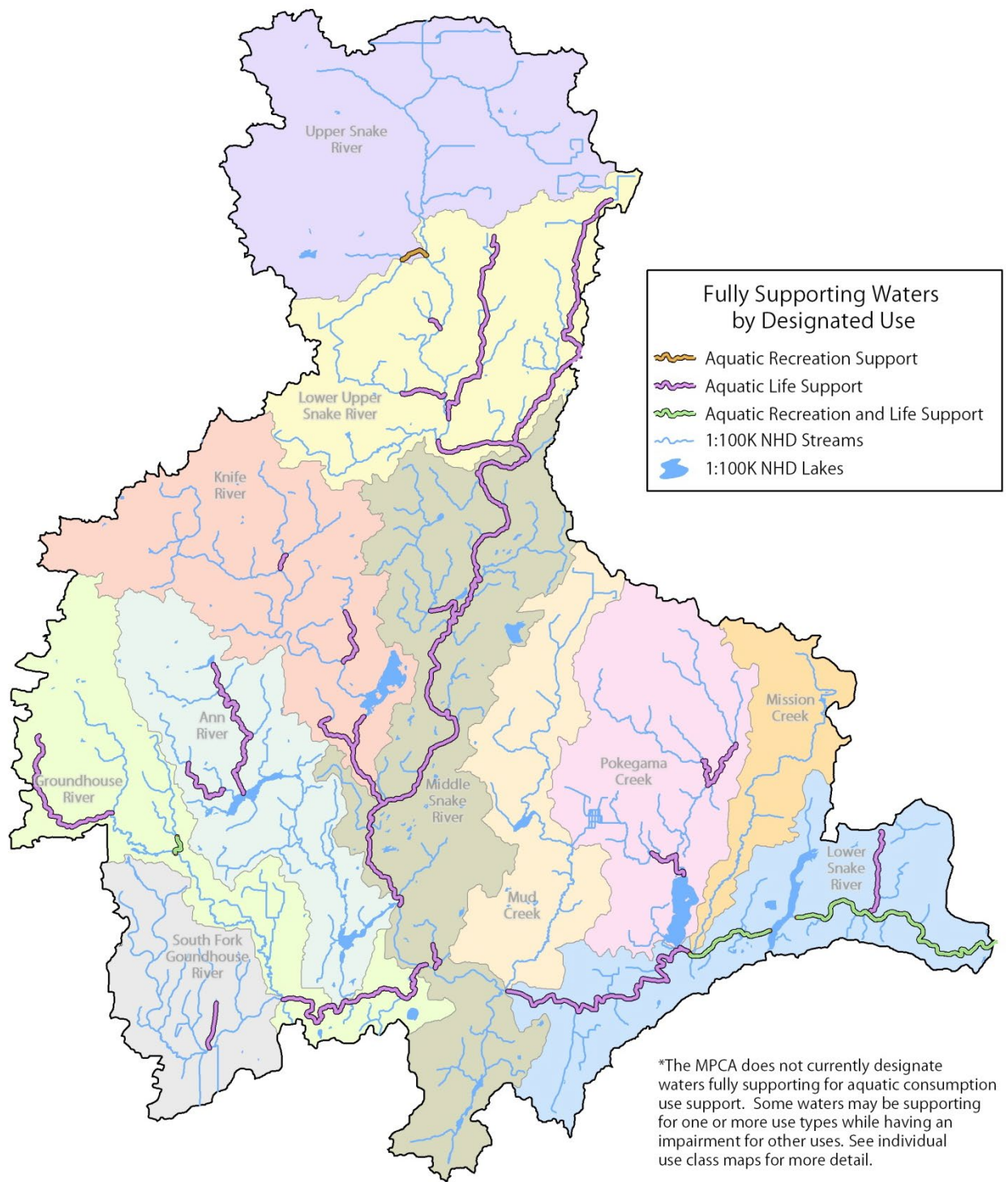


Figure 21. Fully supporting waters by designated use in the Snake River Watershed

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Appendix 1. 2006 Intensive Watershed Monitoring Stations in the Snake River Watershed

HUC-11 Watershed	Watershed Unit Name	Stream Name	Field Number ¹	Sample Type ²	Location	County	Latitude ³	Longitude ³
07030004010	Upper Snake River	Snake River	96SC069	BIO	CR 2, 2.5 mi. E. of Pliny	Aitkin	46.33351178	-93.21024405
		Trib. to Snake River	06SC134	BIO	Upstream of CR 2, 1 mile W. of Pliny	Aitkin	46.33421939	-93.29524226
		Bear Creek	06SC133	BIO	Upstream of CR 9 bridge in McGrath	Aitkin	46.24203748	-93.27374259
		Snake River	06SC135	BIO	Downstream of Hwy 65, just N. of Pliny	Aitkin	46.33821189	-93.26348876
		Snake River	06SC132	WQ	@ Hwy 18, 2 miles SE of McGrath	Aitkin	46.21717723	-93.24076083
07030004020	Lower Upper Snake River	Bergman Brook	99NF042	BIO	~0.15 miles W of Hwy 65, 3 mi. N of Woodland	Kanabec	46.15631843	-93.27859721
		Hay Creek	96SC076	BIO	Upstream of S.H. 27, 2 miles W. of Woodland	Kanabec	46.11534647	-93.31944493
		Cowan's Brook	06SC131	BIO	Downstream of CR 61, 5 miles NE of Woodland	Aitkin	46.16682831	-93.22207628
		Chelsey Brook	06SC022	BIO	Upstream of CR 85, 5 miles SW of Giese	Kanabec	46.15444195	-93.15853863
		Snake River	06SC006	BIO	Snake River County Park, 3 miles NE of Woodland	Aitkin	46.16396925	-93.2469512
		Snake River	06SC123	WQ	Upstream of CR 61, 3 miles NE of Woodland	Kanabec	46.12530824	-93.22106157
07030004030	Middle Snake River	Spring Brook	06SC114	BIO	Downstream of CR 11 @ Jct. with CR 1, 1 mile SE of Mora	Kanabec	45.86737617	-93.26737223
		Trib. to Snake River	06SC113	BIO	Downstream of CR 17, 4 miles SE of Mora	Kanabec	45.81666211	-93.25363909
		Snowshoe Brook	06SC117	BIO	Accessed right off CR 3, 3 miles SE of Warman	Kanabec	46.02539136	-93.25395202
		Rice Creek	06SC111	BIO	Hwy 70, 3 miles W. of Grasston	Kanabec	45.78587023	-93.20706932
		Snake River	06SC118	BIO	South of CR 24, 3 miles E of Warman	Kanabec	46.07085995	-93.20999132
		Snake River	06SC116	BIO	Upstream of CR 19, 6 miles NE of Mora	Kanabec	45.96289896	-93.24498754
		Snake River	06SC115	BIO	Upstream of Hwy 65 in Mora	Kanabec	45.86410366	-93.30030805
		Snake River	06SC112	WQ	Along 150th Ave., 4 miles SE of Mora	Kanabec	45.79950946	-93.23993674
07030004040	Knife River	Trib. to Knife River	06SC124	BIO	Downstream of CR 76, 5 miles NW of Mora	Kanabec	45.9494527	-93.33830279
		Bean Brook	06SC126	BIO	Upstream of CR 3, 4 miles SW of Warman	Kanabec	46.01003957	-93.32720948
		Knife River (Dry Run)	06SC129	BIO	Downstream of CR 115, 4 miles S. of Isle	Mille Lacs	46.08192804	-93.46296674
		Trib. to Knife River	06SC127	BIO	Upstream of CR 15, 5 miles W of Warman	Kanabec	46.05807021	-93.38481885
		Knife River	06SC128	BIO	Upstream of Hwy 47, 7 miles W. of Warman	Mille Lacs	46.04765136	-93.43646229
		Knife River	06SC125	BIO	Downstream of CR 88, 6 miles N. of Mora	Kanabec	45.98005116	-93.33776856
		Knife River	96SC097	WQ	@ C.R. 77, 3 mi. N. of Mora	Kanabec	45.92042601	-93.30815473
07030004050	Ann River	Camp Creek	06SC137	BIO	Downstream of Hwy 26, 2 miles NW of Ann Lake	Kanabec	45.92027102	-93.46227281
		Little Ann River	96SC004	BIO	@ Hwy. 47, 4 mi. N. of Ann Lake	Kanabec	45.9687383	-93.42882213
		Little Ann River	06SC138	BIO	Upstream of CR 26, 3 miles N of Ann Lake	Kanabec	45.93514053	-93.41889173
		Ann River	06SC136	BIO	Upstream of CR 12, 3 miles W. of Mora	Kanabec	45.87688956	-93.36360914
		Ann River	06SC122	WQ	Downstream of Hwy 23, 2 miles SW of Mora	Kanabec	45.85221191	-93.33348075

HUC-11 Watershed	Watershed Unit Name	Stream Name	Field Number1	Sample Type2	Location	County	Latitude3	Longitude3
07030004060	Groundhouse River							
		Trib. to Groundhouse River	06SC120	BIO	Upstream of CR 56, 2 miles SW of Ann Lake	Kanabec	45.88594877	-93.47731033
		West Fork Groundhouse River	06SC029	BIO	1/2 mile N. of CR 116, 9 miles NE of Milaca	Mille Lacs	45.89459805	-93.57687359
		Groundhouse River	06SC121	BIO	Downstream of CR 24, 5 miles W. of Ann Lake	Kanabec	45.91140163	-93.52954107
		Groundhouse River	96SC070	BIO	@ Rum River State Forest	Kanabec	45.88154621	-93.50687055
		Groundhouse River	03SC002	BIO	downstream of 150th Ave., 2 mi. S.E. of Ogilvie	Kanabec	45.80275568	-93.39621925
		Groundhouse River	06SC061	WQ	Upstream of Hwy 65, 1 mile W. of Brunswick	Kanabec	45.79076485	-93.31921389
07030004070	South Fork Groundhouse River							
		South Fork Groundhouse River	06SC045	BIO	Upstream of CR 13, 3 miles W. of Ogilvie	Kanabec	45.82364442	-93.48639625
		South Fork Groundhouse River	06SC065	BIO	Upstream of CR 4, 5 miles S. of Ogilvie	Kanabec	45.76333236	-93.44286949
		South Fork Groundhouse River	03SC003	WQ	upstream of Hwy. 47, 4 mi. S. of Ogilvie	Kanabec	45.77863473	-93.41125281
07030004080	Mud Creek							
		County Ditch #4	06SC108	BIO	Downstream of CR 17, 2 miles NW of Grasston	Kanabec	45.80720867	-93.19286361
		Trib. to Mud Creek	06SC018	BIO	Downstream of CR 73, 1 mile N. of Quamba	Kanabec	45.941911	-93.16702456
		Mud Creek	06SC110	BIO	Downstream of CR 5, 4 miles W. of Brook Park	Kanabec	45.95227843	-93.16465768
		Mud Creek	06SC109	BIO	Upstream of CR 120, 1 mile NW of Henriette	Kanabec	45.885801	-93.14466114
		Mud Creek	06SC107	WQ	Upstream of CR 5, 1 mile NW of Grasston	Kanabec	45.81355093	-93.16625992
07030004090	Lower Snake River							
		Trib. to Cross Lake	06SC101	BIO	Upstream of CR 125, 2 miles SE of Beroun	Pine	45.89059138	-92.92916862
		Bear Creek	96SC068	BIO	CR 10, 4 mi. N.E. of Pine City	Pine	45.85945541	-92.86947265
		Hay Creek	98SC016	BIO	Just downstream of CSAH 5, 9 mi. NW of Rock Creek	Pine	45.77863208	-93.13240963
		Snake River	06SC010	BIO	Downstream of Hwy 107, just E. of Grasston	Pine	45.78387423	-93.11657658
		Snake River	06SC007	FC	Downstream of CR 9, 9 miles E. of Pine City	Pine	45.82285821	-92.78311475
07030004100	Pokegama Creek							
		Trib. to Pokegama Creek	06SC100	BIO	CR 13, 3 miles E. of Henriette	Pine	45.87712199	-93.06333152
		Pokegama Creek	06SC102	BIO	CR 130, 2 miles SE of Brook Park	Pine	45.93101038	-93.01930984
		East Pokegama Creek	06SC103	BIO	Downstream of CR 131, 4 miles SE of Brook Park	Pine	45.93550769	-93.00344095
		Pokegama Creek	06SC042	WQ	Downstream of CR 14, 6 miles NW of Pine City	Pine	45.90124269	-93.03293882
07030004110	Mission Creek							
		Mission Creek	06SC106	BIO	CR 16, 2 miles SE of Mission Creek	Pine	45.96213186	-92.91632063
		Mission Creek	06SC105	BIO	CR 14, 1 mile W. of Beroun	Pine	45.90316224	-92.97708884
		Mission Creek	06SC104	WQ	Upstream of CR 53, 2 miles W. of Pine City	Pine	45.83294022	-93.0214004

¹Field number assigned to each station to designate a unique sampling location.

²Indicates level of sampling effort at each station. BIO=one time biological, physical habitat, and water chemistry; WQ=site represents pour point of HUC-11 watershed, 10x sampling of water chemistry (in addition to BIO); FC=site represents pour point of Snake River Watershed, fish contaminants sampling (in addition to BIO & WQ).

³Latitude and Longitude are formatted in WGS84 decimal degrees.

Appendix 2. Water Chemistry Results at the Intensive Watershed Monitoring Station Representing the Pour Point of Each HUC 11 Watershed Unit

(Bold values indicate potential exceedances of a water quality standard or ecoregion expectation.)

Station representing the pour point of Upper Snake River Watershed Unit (07030004-010)

Station location:	Snake River at HWY 18, 2 mi. SE of McGrath, MN											
Storet ID:	S001-727											
Station #:	06SC132 (water chemistry data collected by SRWMB from 2001 - 2006)											
Parameter	Chloride	DO	Fecal Coliform	NH ₃ + NH ₄	NO ₂ + NO ₃	pH	TP	TSS	Spec. cond.	Sulfate	Temp.	T-tube
Units	mg/L	mg/L	#/100ml	mg/L	mg/L		mg/L	mg/L	µS/cm	mg/L	°C	cm
# Samples		21	16		19	21	39	38			49	67
Minimum		6.6	1		0.005	6.8	0.02	0.5			-6	23
Maximum		13.3	1100		0.08	8.5	0.09	11.0			24.4	60
Mean ¹		9.4	42		0.016	7.3	0.04	2.7			11.6	57.9
Median		8.96	50		0.005	7.2	0.035	2.0			10.6	60
WQ standard	230	5.0	200/ 2000			6.5 - 9.0					30	20
# WQ exceedances ²		0/21	0/16			0/21					0/49	0/67
NLF 75 th percentile ³				0.2	0.03	7.9	0.05	5.6	260		21.7	

Station representing the pour point of Lower Upper Snake River Watershed Unit (07030004-020)

Station location:	Snake River at Olympic St., 3 mi. E of Woodland, MN											
Storet ID:	S004-067											
Station #:	06SC123 (water chemistry data collected by MPCA in 2006)											
Parameter	Chloride	DO	<i>E. coli</i>	NH ₃ + NH ₄	NO ₂ + NO ₃	pH	TP	TSS	Spec. cond.	Sulfate	Temp.	T-tube
Units	mg/L	mg/L	#/100ml	mg/L	mg/L		mg/L	mg/L	µS/cm	mg/L	°C	cm
# Samples	10	9	10	10	10	10	10	10	10	10	10	8
Minimum	1.9	6.5	4	<0.05	<0.05	6.1	0.014	<1.0	60	<5.0	10.0	>100
Maximum	5.1	10.0	64	0.12	<0.05	8.4	0.063	1.6	202	15	25.7	>100
Mean ¹	3.5	8.7	17	0.035	<0.05	7.5	0.031	0.9	156	8.1	20.8	>100
Median	3.3	9.1	18	<0.05	<0.05	7.7	0.029	0.9	172	7.7	22.3	>100
WQ standard	230	5.0	126/ 1260			6.5 9.0					30	20
# WQ exceedances ²	0/10	0/9	0/10			1/10					0/10	0/8
NLF 75 th percentile ³				0.2	0.03	7.9	0.05	5.6	260		21.7	

Appendix 2 (continued)

Station representing the pour point of Middle Snake River Watershed Unit (07030004-030)

Station location:	Snake River along 150th Ave., 3 mi. E of Brunswick, MN											
Storet ID:	S004-070											
Station #:	06SC112 (water chemistry data collected by MPCA in 2006)											
Parameter	Chloride	DO	<i>E. coli</i>	NH ₃ ⁺ NH ₄	NO ₂ ⁺ NO ₃	pH	TP	TSS	Spec. cond.	Sulfate	Temp.	T-tube
Units	mg/L	mg/L	#/100ml	mg/L	mg/L		mg/L	mg/L	uS/cm	mg/L	°C	cm
# Samples	10	9	10	10	10	10	10	10	10	10	10	8
Minimum	4	5.9	8	<0.05	0.09	6.1	0.044	<1.0	142	<5.0	11.2	>100
Maximum	9.2	13.0	84	0.07	0.37	9.2	0.093	3.6	317	11	27.1	>100
Mean ¹	7.3	10.8	30	0.03	0.21	8.1	0.063	2.1	262	5.2	21.8	>100
Median	7.9	11.3	30	<0.05	0.21	8.3	0.059	1.8	279	5.3	22.9	>100
WQ standard	230	5.0	126/ 1260			6.5 9.0		100			30	20
# WQ exceedances ²	0/10	0/9	0/10			2/10		0/10			0/10	0/8
NCHF 75 th percentile ³				0.20	0.12	8.4	0.17	18	310		24	

Station representing the pour point of Knife River Watershed Unit (07030004-040)

Station location:	Knife River at CR 77, 3 mi. N of Mora, MN											
Storet ID:	S003-528											
Station #:	96SC097 (water chemistry data collected by SRWMB from 2004 – 2005)											
Parameter	Chloride	DO	Fecal Coliform	NH ₃ ⁺ NH ₄	NO ₂ ⁺ NO ₃	pH	TP	TSS	Spec. cond.	Sulfate	Temp	T-tube
Units	mg/L	mg/L	#/100 ml	mg/L	mg/L		mg/L	mg/L	uS/cm	mg/L	°C	cm
# Samples		41	15		21	41	41	41			41	
Minimum		2.0	2		0.005	6.87	0.02	0.5			2.1	
Maximum		14.5	6400		0.6	8.66	0.1	27.0			28.9	
Mean ¹		10.4	47		0.13	7.6	0.06	4.5			13.9	
Median		10.23	20		0.07	7.6	0.06	4.0			13.3	
WQ standard	230	5.0	200/ 2000			6.5 9.0		100			30	20
# WQ exceedances ²		1/41	2/15			0/41		0/41			0/41	
NCHF 75 th percentile ³				0.20	0.12	8.4	0.17	18	310		24	

Appendix 2 (continued)

Station representing the pour point of Ann River Watershed Unit (07030004-050)

Station location:	Ann River at HWY 23, 2 mi. SW of Mora, MN											
Storet ID:	S004-066											
Station #:	06SC122 (water chemistry data collected by MPCA in 2006)											
Parameter	Chloride	DO	<i>E. coli</i>	NH ₃ + NH ₄	NO ₂ + NO ₃	pH	TP	TSS	Spec. cond.	Sulfate	Temp.	T-tube
Units	mg/L	mg/L	#/100ml	mg/L	mg/L		mg/L	mg/L	µS/cm	mg/L	°C	cm
# Samples	10	9	10	10	10	10	10	10	10	10	10	8
Minimum	2.8	4.3	23	<0.05	<0.05	6.0	0.039	1.2	131	<5.0	10.1	91
Maximum	4.6	10.5	1100	0.11	0.15	7.9	0.094	3.2	368	8.6	23.3	>100
Mean ¹	3.6	6.8	210	0.034	0.05	7.2	0.064	2.2	266	4.3	18.9	97
Median	3.5	5.9	380	<0.05	<0.05	7.3	0.066	2.4	258	3.8	20.1	>100
WQ standard	230	5.0	126/ 1260			6.5 9.0		100			30	20
# WQ exceedances ²	0/10	1/9	0/10			1/10		0/10			0/10	0/8
NCHF 75 th percentile ³				0.20	0.12	8.4	0.17	18	310		24	

Station representing the pour point of Groundhouse River Watershed Unit (07030004-060)

Station location:	Groundhouse River at HWY 65, 1 mi. W of Brunswick, MN											
Storet ID:	S003-532											
Station #:	06SC061 (water chemistry data collected by SRWMB from 2004 – 2005)											
Parameter	Chloride	DO	Fecal Coliform	NH ₃ + NH ₄	NO ₂ + NO ₃	pH	TP	TSS	Spec. cond.	Sulfate	Temp.	T-tube
Units	mg/L	mg/L	#/100 ml	mg/L	mg/L		mg/L	mg/L	µS/cm	mg/L	°C	cm
# Samples		47	33		11	44	23	36			47	
Minimum		2.2	20		.005	6.6	0.05	1.0			5.5	
Maximum		14.28	25000		1.5	8.6	0.2	38.0			23.9	
Mean ¹		9.5	157		0.44	7.5	0.08	5.9			14.5	
Median		9.5	110		0.3	7.5	0.07	3.5			15.2	
WQ standard	230	5.0	200/ 2000			6.5 9.0		100			30	20
# WQ exceedances ²		1/47	3/33			0/44		0/36			0/47	
NCHF 75 th percentile ³				0.20	0.12	8.4	0.17	18	310		24	

Appendix 2 (continued)

Station representing the pour point of S.F. Groundhouse River Watershed Unit (07030004-070)

Station location:	South Fork Groundhouse River at HWY 47, 3.6 mi. S of Ogilvie, MN											
Storet ID:	S003-638											
Station #:	03SC003 (water chemistry data collected by MPCA in 2006)											
Parameter	Chloride	DO	<i>E. coli</i>	NH ₃ ⁺ NH ₄	NO ₂ ⁺ NO ₃	pH	TP	TSS	Spec. cond.	Sulfate	Temp.	T-tube
Units	mg/L	mg/L	#/100ml	mg/L	mg/L		mg/L	mg/L	µS/cm	mg/L	°C	cm
# Samples	10	9	10	10	10	10	10	10	10	10	10	8
Minimum	5.3	3.8	40	<0.05	0.27	6.4	0.068	<1.0	247	6.1	10.4	54
Maximum	14	15.5	470	0.11	3.2	8.0	0.140	13	404	17	22.8	>100
Mean ¹	9.1	9.9	130	0.047	1.3	7.5	0.101	4.4	337	9.5	19.1	92
Median	9.1	9.5	123	<0.05	1.2	7.5	0.100	2.8	346	9.0	20.1	>100
WQ standard	230	5.0	126/ 1260			6.5 9.0		100			30	20
# WQ exceedances ²	0/10	1/9	0/10			1/10		0/10			0/10	0/8
NCHF 75 th percentile ³				0.20	0.12	8.4	0.17	18	310		24	

Station representing the pour point of Mud Creek Watershed Unit (07030004-080)

Station location:	Mud Creek at CR5, 1 mi. NW of Grasston, MN											
Storet ID:	S003-533											
Station #:	06SC107 (water chemistry data collected by SRWMB from 2004 – 2006)											
Parameter	Chloride	DO	Fecal Coliform	NH ₃ ⁺ NH ₄	NO ₂ ⁺ NO ₃	pH	TP	TSS	Spec. cond.	Sulfate	Temp.	T-tube
Units	mg/L	mg/L	#/100 ml	mg/L	mg/L		mg/L	mg/L	µS/cm	mg/L	°C	cm
# Samples		39	20		22	39	39	39			39	
Minimum		6	18		0.005	6.2	0.05	1.0			1.2	
Maximum		15.9	16000		0.3	8	0.2	17.0			26.6	
Mean ¹		9.2	139		0.05	7.3	0.09	6.6			14.4	
Median		8.7	91		0.04	7.37	0.08	6			14.3	
WQ standard	230	5.0	200/ 2000			6.5 9.0		100			30	20
# WQ exceedances ²		0/39	2/20			2/39		0/39			0/39	
NCHF 75 th percentile ³				0.20	0.12	8.4	0.17	18	310		24	

Appendix 2 (continued)

Station representing the pour point of Lower Snake River Watershed Unit (07030004-090)

Station location:	Snake River near mouth, 9 mi. E of Pine City, MN											
Storet ID:	S000-128											
Station #:	06SC007 (water chemistry data collected by MPCA in 2006)											
Parameter	Chloride	DO	<i>E. coli</i>	NH ₃ ⁺ NH ₄	NO ₂ ⁺ NO ₃	pH	TP	TSS	Spec. cond.	Sulfate	Temp.	T-tube
Units	mg/L	mg/L	#/100ml	mg/L	mg/L		mg/L	mg/L	µS/cm	mg/L	°C	cm
# Samples	10	9	10	10	10	10	10	10	10	10	10	8
Minimum	4.4	6.3	<4	<0.05	<0.05	5.8	0.040	2.0	130	<5.0	11.3	67
Maximum	7.3	13.4	28	<0.05	0.16	9.0	0.098	9.3	263	9.2	25.8	>100
Mean ¹	6.2	8.7	10	<0.05	0.11	7.4	0.063	4.5	216	4.4	20.4	93
Median	6.2	8.2	9	<0.05	0.12	7.6	0.061	4.2	222	3.8	22.6	98
WQ standard	230	5.0	126/ 1260			6.5 9.0		100			30	20
# WQ exceedances ²	0/10	0/9	0/10			1/10		0/10			0/10	0/8
NCHF 75 th percentile ³				0.20	0.12	8.4	0.17	18	310		24	

Station representing the pour point of Pokegama Creek Watershed Unit (07030004-100)

Station location:	Pokegama Creek at CR 14, 6 mi. NW of Pine City, MN											
Storet ID:	S002-542											
Station #:	06SC042 (water chemistry data collected by SRWMB from 2004 – 2006)											
Parameter	Chloride	DO	Fecal Coliform	NH ₃ ⁺ NH ₄	NO ₂ ⁺ NO ₃	pH	TP	TSS	Spec. cond.	Sulfate	Temp.	T-tube
Units	mg/L	mg/L	#/100 ml	mg/L	mg/L		mg/L	mg/L	µS/cm	mg/L	°C	cm
# Samples		45	19		24	40	47	47			44	
Minimum		5.6	20		.005	6.32	.032	1.0			1.5	
Maximum		16.7	800		.13	8.5	.21	25.0			25.85	
Mean ¹		9.2	120		.023	7.3	.076	4.9			13.28	
Median		9.1	140		.01	7.3	.062	3.0			13.04	
WQ standard	230	5.0	200/ 2000			6.5 9.0		100			30	20
# WQ exceedances ²		0/45	0/19			2/40		0/47			0/44	
NCHF 75 th percentile ³				0.20	0.12	8.4	0.17	18	310		24	

Appendix 2 (continued)

Station representing the pour point of Mission Creek Watershed Unit (07030004-110)

Station location:	Mission Creek at CR53, 2 mi. W of Pine City, MN											
Storet ID:	S003-531											
Station #:	06SC104 (water chemistry data collected by SRWMB from 2004 – 2006)											
Parameter	Chloride	DO	Fecal Coliform	NH ₃ + NH ₄	NO ₂ + NO ₃	pH	TP	TSS	Spec. cond.	Sulfate	Temp.	T-tube
Units	mg/L	mg/L	#/100 ml	mg/L	mg/L		mg/L	mg/L	µS/cm	mg/L	°C	cm
# Samples		46	20		22	45	43	39			46	4
Minimum		.05	10		0.005	6.05	0.04	0			0.5	65
Maximum		13.8	7300		.66	9.75	0.5	22.0			26.6	100
Mean ¹		7.4	104		0.07	7.12	0.1	4.4			13.8	81
Median		7.3	60		0.005	7.11	0.08	3.0			13.8	79
WQ standard	230	5.0	200/2000			6.5 - 9.0		100			30	20
# WQ exceedances ²		12/46	1/20			3/45		0/39			0/46	0/4
NCHF 75 th percentile ³				0.20	0.12	8.4	0.17	18	310		24	

¹Geometric mean of all samples is provided for *E. coli* or fecal coliform.

²Represents exceedances of individual maximum standard for *E. coli* (1260/100ml) or fecal coliform (2000/100ml).

³Based on 1970-1992 summer data; see *Selected Water Quality Characteristics of Minimally Impacted Streams from Minnesota's Seven Ecoregions* (McCullor and Heiskary 1993).

Appendix 3. Minnesota's Ecoregion Based Lake Eutrophication Standards and Snake River Watershed Assessed Lakes

Ecoregion	TP	Chl-a	Secchi
	µg/L	µg/L	meters
NCHF – Aquatic Rec. Use (Class 2b)	< 40	< 14	> 1.4
Cross Lake	89	21	0.7
# of observations	67	47	41
Pokegama Lake	121	46	0.5
# of observations	35	28	79
NCHF – Aquatic Rec. Use (Class 2b)	< 60	< 20	> 1.0
Shallow lakes			
Fish Lake	162	64	0.3
# of observations	21	20	44
Knife Lake	164	41	0.5
# of observations	58	57	60
Ann Lake	90	42	0.7
# of observations	19	19	13
Quamba Lake	135	39	0.8
# of observations	29	29	22