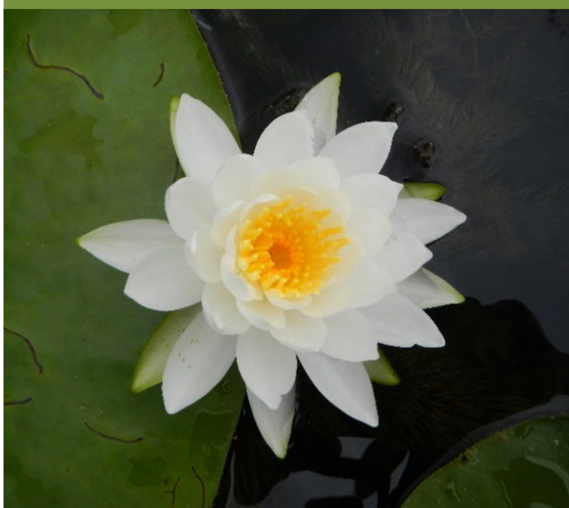
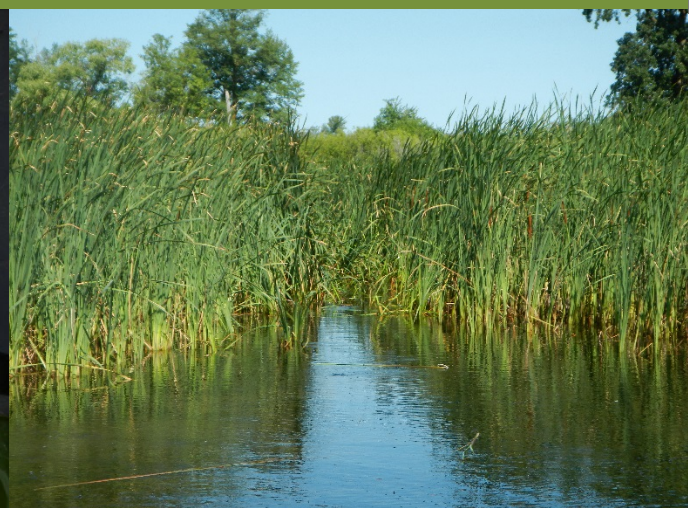
Clearwater River Watershed Fish based Lake IBI Stressor Identification Report

A study of stressors limiting the biotic communities in lakes in the Clearwater River Watershed.





CLEAN WATER LAND & LEGACY AMENDMENT

SPORT FISH & WILDLIFE RESTORATION

DEPARTMENT OF NATURAL RESOURCES

MINNESOTA POLLUTION CONTROL AGENCY

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Acronyms and Abbreviations

APM	Aquatic Plant Management
DOW	Division of Waters
EWR	Ecological and Water Resources
FIBI	Fish-based lake index of biological integrity
IBI	Index of Biological Integrity – a multi-metric index used to score the condition of a biological community
µg/L	Micrograms per Liter; equivalent to parts per billion (ppb)
MDA	Minnesota Department of Agriculture
MNDNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
NLCD	National Land Cover Database, a GIS layer
P	Phosphorus
SID	Stressor Identification – The process of determining the factors (stressors) responsible for causing a reduction in the health of aquatic biological communities.
StS	Score the Shore
TP	Total phosphorus (measurement of all forms of phosphorus combined)

Executive Summary

Over the past couple of years, the Minnesota Pollution Control Agency (MPCA) in coordination with the Minnesota Department of Natural Resources (MNDNR) has substantially increased the use of biological monitoring and assessment to determine and report the condition of Minnesota's lakes. The identification of biological impairments includes the assessment of fish communities of lakes throughout a major watershed. The fish-based lake index of biological integrity (FIBI) utilizes data from trap net and gill net gamefish surveys, as well as nearshore surveys that utilize beach seines and backpack electrofishing to sample nongame fish-communities. From this data, an FIBI score can be calculated for each lake which provides a measure of overall fish community health.

MNDNR developed four FIBI tools to assess different types of lakes throughout the state (Table 1-1). More information on the FIBI tools and assessments based on the FIBI can be found at the MNDNR website Although an FIBI score may indicate that a lake fish community is impaired, that alone is not sufficient to assess a lake as impaired for Aquatic Life Use. A weight of evidence approach is used during the assessment process which factors in considerations such as sampling effort, sampling efficiency, tool applicability, location in the watershed, and any other unique circumstances to validate the FIBI score.

This report summarizes FIBI stressor identification work in the Clearwater River Watershed (Figure 2-1).

The FIBI was used to assess eleven lakes in the Clearwater River Watershed (Figure 2-1; Table 2-1; Table 2-2). Three lakes had repeated nearshore surveys: Whitefish (DOW 04-0300-00), Whitefish (DOW 60-0015-00), and Maple (DOW 60-0305-00).

Nine lakes had FIBI scores at or above the impairment threshold.

Maple Lake (DOW 60-0305-00) had two surveys completed on it with one survey scoring below the threshold (2010) and one scoring above the threshold (2015). The more recent survey takes precedence and resulted in a fully supporting assessment.

Two lakes had FIBI scores above but near to the impairment threshold: Cross Lake (DOW 60-0027-00) and Hill River Lake (DOW 60-0142-00). Because of this and other factors, Cross Lake was listed as "insufficient information" and "vulnerable to impairment." Hill River Lake was assessed as fully supporting but "vulnerable to impairment."

Pine Lake (DOW 15-0149-00) had an FIBI score below the threshold, but sampling effort was low and there was some uncertainty about the extent of winterkill. Therefore there was insufficient information to warrant a not-supporting assessment of aquatic life use.

Badger Lake (DOW 60-0214-00) was sampled but not assessed due to the fish community being heavily influenced by recent winterkills.

This report will examine potential stressors to the fish community in Cross Lake (DOW 60-0027-00) and Hill River Lake (DOW 60-0142-00) and is organized by MNDNR Division of Waters (DOW) lake identification number.

1. Introduction

Stressor Identification (SID) is a formal and rigorous process that identifies stressors causing biological impairment of aquatic ecosystems. The process provides a structure for organizing scientific evidence to support conclusions (Cormier, et al. 2000). In simpler terms, it is the process of identifying the major factors causing harm to aquatic life. Stressor identification is a key component of the major watershed restoration and protection strategy (WRAPS) projects being carried out under Minnesota's Clean Water Legacy Act.

For more detailed information about the Stressor Identification process read the Stressor Identification Technical Guidance document on the MPCA website.

The FIBI utilizes data from trap net and gill net gamefish surveys, as well as nearshore surveys that utilize beach seines and backpack electrofishing to sample nongame fish-communities. From this data, an FIBI score can be calculated for each lake which provides a measure of overall fish community health. The FIBI consists of metrics that measure the fish community structure and function. All metrics are summed then scaled to produce an overall score from 0 to 100.

MNDNR developed four FIBI tools to assess different types of lakes throughout the state (Table 1-1). More information on the FIBI tools and assessments based on the FIBI can be found at the MNDNR website. Although an FIBI score may indicate that a lake fish community is impaired, that alone is not sufficient to assess a lake as impaired for Aquatic Life Use. A weight of evidence approach is used during the assessment process which factors in considerations such as sampling effort, sampling efficiency, tool applicability, location in the watershed, and any other unique circumstances to validate the FIBI score.

It is important to understand the limitations of available data and information that is collected over many years, by many organizations, with a variety of methods, and for different purposes. The availability of confirmable, historic species lists is also limited and makes substantiating claims of loss of species in an individual lake difficult. Protocols for collecting data for FIBI aquatic life use assessments of lakes were adopted in 2012. The recentness of those protocols and a lack of consistency in historic data collection make historic comparisons impossible. The goal of the protocols is to capture a representative sample of the fish community and 90% or more of the warm-water species in a lake. The use of these protocols should allow the data collected for this assessment to be used for future temporal comparisons.

A common misconception regarding assessment decisions based on the FIBI is that if a lake supports a quality gamefish population (e.g. high abundance or desirable size structure of a popular gamefish species), then that lake should be considered a healthy lake. This is not necessarily true because both game- and nongame fish species must be considered when holistically evaluating fish community health. Oftentimes, the smaller nongame fishes serve ecologically important roles in aquatic ecosystems and are generally the most sensitive to human-induced stress. Likewise, high abundance or quality size structure of gamefish populations will not disproportionately affect the FIBI score because multiple metrics are used to evaluate different components of the fish community and each contributes equal weight to the total FIBI score.

Table 1-1: Summary of lake characteristics and metrics for current FIBI tools and their relationship to the FIBI score.

Lake Characteristics	Tool 2	Tool 4	Tool 5	Tool 7
Generally Deep (many areas greater than 15' deep)	X	X		
Generally Shallow (most areas less than 15' deep)			X	X
Generally with Complex Shape (with bays, points, islands)	X		X	
Generally with Simpler Shape (generally round)		X		
Species Richness Metrics	**Tool 2**	**Tool 4**	**Tool 5**	**Tool 7**
Number of native species captured in all gear	+			
Number of intolerant species captured in all gear	+	+	+	
Number of tolerant species captured in all gear	-	-	-	-
Number of insectivore species captured in all gear	+			+
Number of omnivore species captured in all gear	-	-	-	
Number of cyprinid species captured in all gear	+			
Number of small benthic dwelling species captured in all gear	+	+		+
Number of vegetative dwelling species captured in all gear	+	+		+
Community Composition Metrics	**Tool 2**	**Tool 4**	**Tool 5**	**Tool 7**
Relative abundance of intolerant species in nearshore sampling	+		+	
Relative abundance of small benthic dwelling species in nearshore sampling	+	+		
Relative abundance of vegetative dwelling species in nearshore sampling				+
Proportion of biomass in trap nets from insectivore species	+	+	+	+
Proportion of biomass in trap nets from omnivore species	-	-	-	
Proportion of biomass in trap nets from tolerant species	-	-	-	-
Proportion of biomass in gill nets from top carnivore species	+	+	+	+
Presence/Absence of Intolerant species captured in gill nets	+	+		
Total number of metrics used to calculate FIBI	**15**	**11**	**8**	**8**
Number of Lakes Assessed in the Clearwater River Watershed	**1**	**4**	**2**	**3**

2. Overview of Clearwater River Watershed

2.1 Monitoring and assessment of lakes overview

The FIBI was used to assess eleven lakes in the Clearwater River Watershed (Figure 2-1; Table 2-1; Table 2-2). Three lakes had repeated nearshore surveys: Whitefish (DOW 04-0300-00), Whitefish (DOW 60-0015-00), and Maple (DOW 60-0305-00).

Nine lakes had FIBI scores at or above the impairment threshold.

Maple Lake (DOW 60-0305-00) had two surveys completed on it with one survey scoring below the threshold (2010) and one scoring above the threshold (2015). The more recent survey takes precedence and resulted in a fully supporting assessment.

Cross Lake (DOW 60-0027-00) and Hill River Lake (DOW 60-0142-00) both had scores above but near to the impairment threshold. Because of this and other factors, Cross Lake was listed as having "insufficient evidence" and being "vulnerable to impairment." Hill River Lake was assessed as fully supporting but "vulnerable to impairment."

Pine Lake (DOW 15-0149-00) had an FIBI score below the threshold, but sampling effort was low and there was some uncertainty about the extent of winterkill. Therefore there was insufficient information to warrant a not supporting assessment of aquatic life use.

Badger Lake (DOW 60-0214-00) was sampled but not assessed due to the fish community being heavily influenced by recent winterkills.

This report will examine potential stressors to the fish community in Cross Lake (DOW 60-0027-00) and Hill River Lake (DOW 60-0142-00).

Table 2-1: Lake FIBI Tools with respective FIBI thresholds and upper/lower 90% confidence limits (CL) found in the Clearwater River Watershed.

Lake FIBI Tool	FIBI Threshold	Upper CL	Lower CL
Tool 2	45	54	36
Tool 4	38	46	30
Tool 5	24	9	39
Tool 7	36	27	45

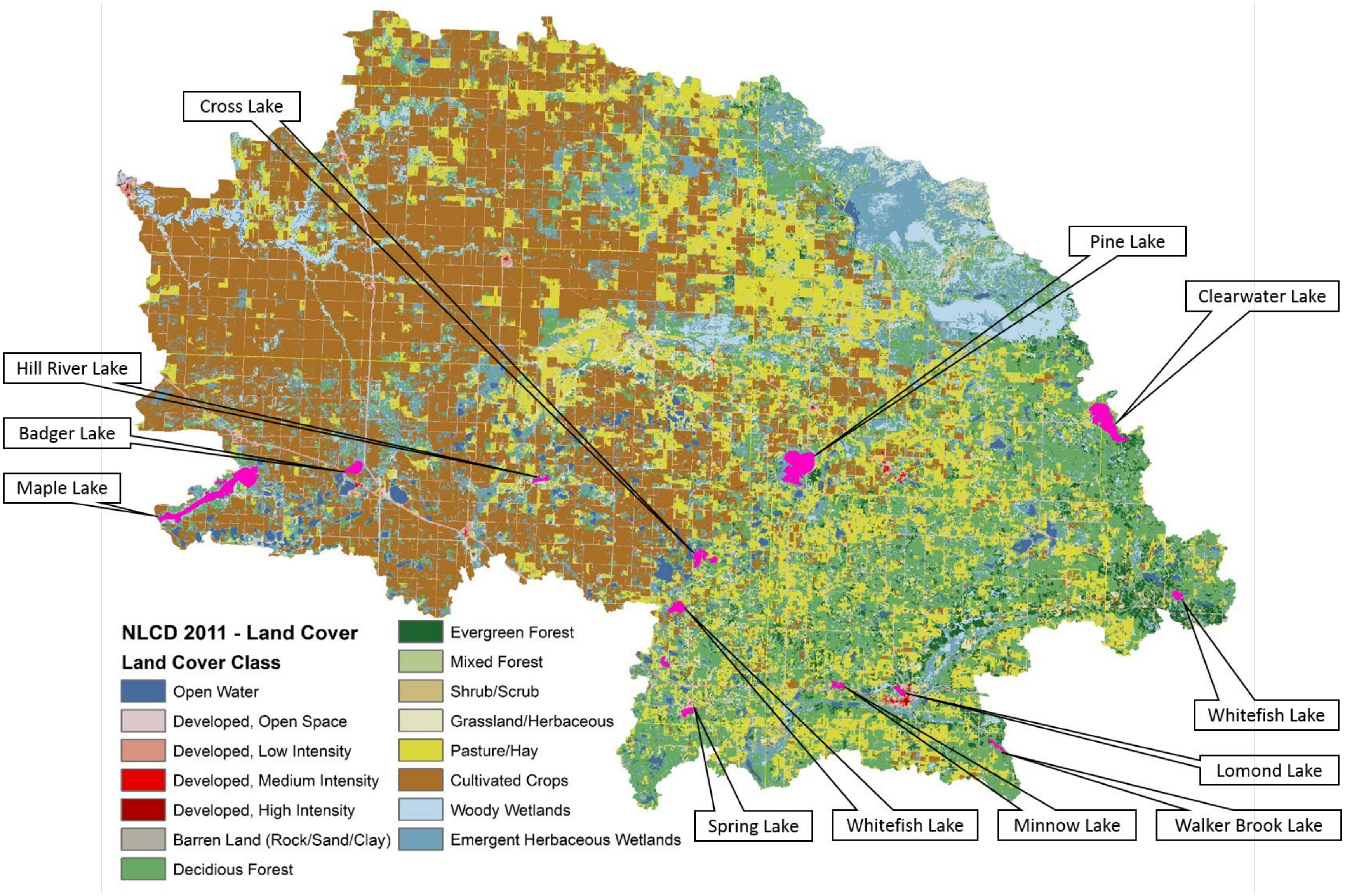

Figure 2-1: Clearwater River Watershed and land cover classes; the lakes that were sampled (with the FIBI protocols) are labelled and colored fuchsia.

Table 2-2: Summary of lakes in the Clearwater River Watershed assessed with FIBI Tools. The shaded rows are the lakes discussed further in this document. The "% littoral" is the percentage of the lake area that is less than 15 feet deep (calculated using the MNDNR GIS data). Color coding is described at the bottom.

DOW	Lake Name	County	Nearshore Survey Year(s)	Notes	MNDNR GIS Acres	FIBI Tool	% Littoral	FIBI Score(s)	Below Impairment Threshold	Within 90% CI of Impairment Threshold
04-0300-00	**Whitefish**	Beltrami	2015	Repeated within year (June and August)	125	4	42	**77, 66**	No, No	No, No
04-0343-00	**Clearwater**	Beltrami	2013		999	2	34	**73**	No	No
15-0060-00	**Walker Brook**	Clearwater	2015	Small; Low effort – 1 of 10 stations seined	95	4	42	**48**	No	No
15-0081-00	**Lomond**	Clearwater	2013	Small; Low effort – 1 of 10 stations seined	95	4	47	**59**	No	No
15-0137-00	**Minnow**	Clearwater	2014	Low effort – 4 of 10 stations seined	110	5	87	**71**	No	No
15-0149-00	**Pine**	Clearwater	2014	Low effort – 7 of 18 stations seined; recent winterkill	1238	5	100	**15**	Yes	Yes
60-0012-00	**Spring**	Polk	2014		130	4	33	**67**	No	No
60-0015-00	**Whitefish**	Polk	2015	Repeated within year (June and August)	243	7	81	**42, 43**	No	Yes
60-0027-00	**Cross**	Polk	2014		166	7	90	**40**	No	Yes
60-0142-00	**Hill River**	Polk	2014		103	5	68	**28**	No	Yes
60-0214-00	**Badger**	Polk	2010	Not assessable – recent winterkill	255	5	100	**6**	Yes	No
60-0305-00	**Maple**	Polk	2010, 2015		1576	7	100	**31, 67**	Yes, No	Yes, No

≤ lower CL	**> lower CL & ≤ Threshold**	**> threshold & ≤ upper CL**	**> upper CL**	**NA = Not available**

2.2 Summary of Biological Impairments of Lakes

The majority of the assessed fish communities in Clearwater River Watershed lakes had FIBI scores above the thresholds during the sampling cycle. Many were near, if not above, the upper bound of the confidence interval.

Table 2-3: Lakes that are vulnerable to future Aquatic Life Use impairment in the Clearwater River Watershed.

Lake name	DOW #	Location description	Impairments
Cross	60-0027-00	Approximately 6.5 miles northeast of the city of Fosston	None
Hill River	60-0142-00	Approximately 4.5 miles northeast of the city of McIntosh	None

3. Possible Stressors to Lake Fish Community

The purpose of SID is to interpret the data collected during the biological monitoring and assessment process. Correlations between FIBI scores and various disturbance gradients can help to identify causal factors for biological impairments. The FIBI scores for Cross Lake and Hill River Lake suggest that the fish communities are vulnerable to future impairment based on FIBI because they met the expected aquatic life scores in the respective FIBI, but are near to the impairment threshold. They are vulnerable to future impairment if stressors are not mitigated.

Several human-induced changes have been shown to impact the community of fish inhabiting a lake. (A comprehensive list of stressors that can potentially cause biological impairment can be found at: Stressors that Can Potentially Cause Biological Impairment).A list of possible stressors was selected for consideration for the Clearwater River Watershed and include:

- Toxic Chemicals
- Watershed Alteration
  - Excess Nutrients
  - Loss of Connectivity
- Non-Native Aquatic Species
- Gamefish Management
- Habitat Alteration
  - Aquatic Plant Control
  - Riparian Lakeshore Development
  - Sedimentation/Change in Substrate
  - Water Level Management

3.1 Eliminated Causes

3.1.1. Toxic Chemicals

A number of toxic chemicals exist which impact aquatic life and can enter the aquatic environment through a variety of pathways. Impacts to fish communities include direct lethal effects on individuals, altered food web from impacts to forage organisms, and reduced fitness from chronic exposure.

Hazardous chemicals such as herbicides, pesticides, fertilizers, and petroleum-based products typically enter the aquatic environment as a result of an unintentional discharge or spillage. A desktop review of Minnesota Department of Agriculture (MDA) incident reports indicated that no agricultural chemical contamination occurred in a quantity and/or proximity that could impact the fish community of any assessed lakes within this watershed (MDA 2016). The MDA also conducts sampling to monitor surface waters for pesticides. A summary of monitoring data from the 2012 National Lakes Assessment concluded that pesticide levels detected in lakes were well below applicable water quality standards and reference values (Tollefson, Ribikawskis and VanRyswyk 2014). A review of publicly accessible Minnesota Pollution Control Agency (MPCA) data did not indicate that hazardous chemicals were significant stressor to the fish community (MPCA 2017). Direct application of chemicals to lakes for management purposes will be discussed in following sections.

Mercury is another naturally-occurring chemical that can be toxic to fish and other aquatic life. Currently, mercury levels in fish tissue are used to assess lakes for the designated use of aquatic consumption. The Clearwater River Watershed has several lakes that have been identified as impaired based on mercury levels in fish tissue. MPCA and local partners have developed a statewide mercury reduction plan approved by EPA to address these impairments (MPCA 2007a). Mercury concentrations that are toxic to fish and other aquatic organisms would need to greatly exceed the current aquatic consumption standards. The current standards and actions intended to address aquatic consumption impairment should provide adequate protection to eliminate mercury as a likely candidate cause for the impaired fish community.

Based on the information presented above, toxic chemicals were eliminated as a candidate cause of FIBI scores near or below threshold.

3.2 Inconclusive Causes

3.2.1. Connectivity

The ability of fish to move upstream and downstream is important to the natural population and community dynamics of some fish species. The impact of connectivity is more widely studied in flowing water systems although there has been increased interest in understanding the importance of connectedness to lake fish diversity. Aquatic connectivity can be an important factor in explaining some of the natural variability of species richness in some gamefish lakes (Tonn and Magnuson 1982), but other geologic and hydrologic variables best explain variation in species richness (Hrabik, et al. 2005). Connectivity influences the number of species available to inhabit lakes and can impact the abundance of certain species (Bouvier, Cottenie and Doka 2009). Connectivity affects the recovery or recolonization of a lake by potentially limiting the species pool.

It is also important to consider how connectivity can influence species diversity differently at short and long-term time frames. Connection to other surface waters may be important to determine the number of species available to inhabit a given lake, but these species should persist after establishment if the lake has enough appropriate habitat. Therefore, the loss of connectivity is not the likely mechanism for loss of species in lakes but may limit the potential for recolonization once a species is lost.

During FIBI development, there was no significant relationships between connectivity and FIBI score. A review of available data (MNDNR 2017) found that 57 fish species were collected from the Clearwater River Watershed, overall, and 41 species were collected from the lakes assessed with the FIBI. Most of the species absent from the assessed lakes were predominantly riverine species. Lake sampling recorded the presence of nine fish species that are commonly found in lakes and are intolerant of disturbance. Eight species have vouchered specimens and one species lacks voucher specimens. Eight of these nine historically reported intolerant species in the Clearwater River Watershed were sampled from lakes during this assessment cycle. The other species is uncommonly found in the types of lakes that were assessed. This indicates there may not have been any loss of species from the lakes in the watershed as a whole, but within any individual lake, species losses cannot be ruled out. This will be discussed further in latter sections.

3.2.2. Gamefish Management

Fisheries management includes a wide range of activities ranging from protecting fish habitat, regulating harvest of species to improve quality, stocking fish to provide additional opportunities, removing fish to restructure the community, and many others. Some of these activities have the potential to be stressors to the fish community in a lake.

In Minnesota, regulating fish harvest is typically pursued to preserve or enhance the quality of predator fish populations such as Largemouth Bass, Northern Pike, or Walleye. It is generally regarded that regulations do not significantly affect biological integrity although no research has been completed in

Minnesota to evaluate the impact of fish regulations on an FIBI score. Predator size may influence the relative abundance of different forage species in a lake, but it is not likely to cause a decrease in species richness. The fish community within a lake has a natural adaptive capacity, or resilience, because it is determined over a long time and by many forces.

Fish stocking is another common technique managers use to preserve or enhance opportunities for anglers. Historically, authorized stocking has focused on the addition of top carnivore species to a fish community that were not naturally present in the lake. There are instances where forage species and non-top carnivore species have been added to the fish community through authorized or unauthorized stocking efforts. Introduced predators can influence the community by replacing an existing predator, adding to total predator density, or providing a predator in a completely new niche for the system (MacRae and Jackson 2001). Therefore, stocking has more potential to influence the fish community (and FIBI score) than the regulation of harvest. Unless the prior fish community was predator-free, however, the fish community structure within a lake is influenced more by its location and the amount/diversity of habitat than by the introduction of a predator species (Trumpikas, Mandrak and Ricciardi 2011).

There are specific case studies that demonstrate the potential for negative consequences of fish stocking in the United States. Some examples include the introduction of Lake Trout to the Greater Yellowstone Ecosystem and the introduction of Northern Pike to river systems in California, which have changed those systems dramatically. In addition, current stocking practices maintain target species above their natural levels through ongoing efforts that stock fish at regular intervals. This higher predator density can affect the composition of the community, but probably not the overall richness of species. Stocking often results in changes to the flow of nutrient and energy through the food web. Stocking affects the food web through direct competition, by indirectly affecting forage fish, or by indirectly affecting zooplankton density and composition (MacRae and Jackson 2001, Eby, et al. 2006).

Predator stocking remains a commonly used tool for fish managers in Minnesota. Limited research in the region has focused on the impact of predator stocking to other gamefish populations (Fayram, Hansen and Ehlinger 2005, Knapp, et al. 2008). Studies have shown a negative relationship between predator stocking and the abundance of Yellow Perch, an important forage fish in many Minnesota lakes (Anderson and Schupp 1986, Pierce, Tomcko and Negus 2006). Strong Yellow Perch year-classes are thought to buffer small bodied fishes like minnows and darters to the impact of Walleye predation (Forney 1974, Lyons and Magnuson 1987). Statewide analysis found a significant negative trend in Yellow Perch catches in Minnesota from 1970 to 2013 (Bethke and Staples 2015) which may indicate a reduced ability of lake fish communities to adapt to stressors.

While some gamefish management activities can result in significant changes to the fish community of a lake, in general, there is an overall lack of conclusive evidence linking these changes to FIBI scores. Therefore, gamefish management activities are not considered further as a potential stressor to the fish community because the effects of gamefish management on the FIBI score are unknown.

3.2.3. Aquatic Plant Alteration

Healthy aquatic plant communities provide important benefits to fish communities by providing spawning habitat for some species, protection or refuge areas for juvenile fish, and foraging opportunities. Because aquatic plants growing in public waters in Minnesota are owned by the state, control activities are regulated by the MNDNR Fisheries, Aquatic Plant Management (APM) permit program.

The APM rules limit the vegetation management on any given lake and are based on the type of plant and method of control. The rules protect fish habitat while also allowing lakeshore owners to have reasonable access. Activities that have the potential to cause damage to fish (herbicide applications) or to important fish habitat (removal of emergent vegetation) require an APM permit. Other activities, such as the removal of some submersed vegetation or a small amount of floating-leaf plants that are not likely to significantly alter fish habitat on a lakewide scale, do not require a permit but are covered under program rules. Current APM rules that limit the total lakewide removal of vegetation are designed to prevent impact to the fish community, but lower amounts of removal still constitute a loss of habitat (Radomski and Goeman 2001, Valley, Cross and Radomski 2004).

In addition to regulated control activities, aquatic plants are sometimes destroyed through illegal activities that can be difficult to identify. The cumulative impact of illegal activities is also difficult to quantify since incremental habitat loss can occur over a long period of time. High quality aquatic plant survey data which would provide a baseline for comparison to quantify the amount of habitat loss is often limited or completely absent. Lack of this type of data is a problem for statewide analysis although some organizations do have quantitative data in various formats.

Aquatic plant alterations are an inconclusive cause for the vulnerable assessment of two lakes because the effects of APM activities on the FIBI score are unknown due to lack of quality data. Although, aquatic plant alterations is not a likely candidate cause because there are no records of permitted aquatic plant destruction and there are very low densities of docks per shoreline length on both of the lakes assessed as "vulnerable to impairment."

3.2.4. Sedimentation

Diverse quality habitats are required to sustain healthy, robust fish communities in lakes. Sedimentation can be caused by a variety of activities. Human development along lakeshores can result in significant changes to the sediment characteristics in a lake (Francis, et al. 2007). Destruction of nearshore aquatic vegetation and removal of woody material, both of which help to stabilize substrates, can lead to resuspension and redistribution of sediments. Non-native Common Carp also contribute to the loss of aquatic vegetation by dislodging plants, which leads to the resuspension of bottom sediments (Bruekelaar, et al. 1994).

The effects of sedimentation could alter a fish community in many ways. The filling of interstitial spaces in spawning substrates can smother entire year classes and reduce the potential for future spawning events. This filling could continue and affect the frequency of winterkill by gradually reducing the depth/volume of water and ultimately filling the entire basin of some lakes. Sedimentation is a transport mechanism where terrestrial phosphorus is deposited into a lake via overland flow (Sharpley, McDowell and Kleinman 2001, Gentry, et al. 2007) and subsurface drainage (Sharpley, McDowell and Kleinman 2001, Gentry, et al. 2007, King, et al. 2015). Additional phosphorus influences eutrophication, which is discussed later in this document.

Minimal quantitative data were collected historically to document the condition of lake substrates in Minnesota, although some MNDNR Fisheries surveys do include a qualitative evaluation. MNDNR Fisheries researchers are currently investigating the spatial relationship between a variety of habitat measurements and their associated fish communities. Completion of this study is pending and may provide a clearer understanding of the importance of different habitats to the overall fish community living within a lake.

Although it is possible that sedimentation may be contributing to lower than expected FIBI scores of some lakes, the lack of high quality quantitative data and scientific research makes it impossible to say conclusively. Therefore, sedimentation is neither considered further as a candidate cause for the vulnerable assessment nor eliminated as factor that could be affecting the FIBI score.

3.2.5. Water Level Management

Historically, managing water levels in lakes has been undertaken in response to perceived problems that humans have with the quantity of water within a lake basin at a given time. Lake water level control structures were often built to allow manipulation of the natural hydrology of a lake. Oftentimes this resulted in maintaining a more consistent water level with elevations set to reduce low water conditions in late summer. Little or no consideration was given to the impact of these water level manipulations on the quantity and quality of the aquatic habitat for fish.

However, research has shown that water level fluctuations are important for maintaining diverse aquatic plant communities and providing complex habitat that benefits several organisms (White, et al. 2008). Most of those studies focused on the impact to aquatic plant communities while few studies directly evaluated the effects on fish communities (Leira and Cantonati 2008). Natural water level fluctuations promote more structurally diverse plant communities than artificially regulated water levels (Wilcox and Meeker 1991). More diverse plant communities provide better fish habitat. Additionally, these plants may perform secondary functions that benefit the fish community such as stabilizing lake sediments or harboring forage organisms for fish. Submersed plant coverage may also be altered due to changes in light penetration that are caused by high water levels. Emergent and shoreline plant coverage could also be affected due to life cycle requirements and optimum conditions not being met.

In addition to direct manipulation using control structures, water levels are impacted by the timing and quantity of water entering the lake basin. These factors are affected by land use in the immediate and contributing watershed and can be caused by human activities such as draining wetlands and increasing impervious surface coverage. These alterations influence the rate at which lake levels rise after a rainfall and the extent of peak lake levels. Sophisticated and time-consuming modeling would be needed to quantify the impact of this change to the quality of the existing aquatic habitat. Also, limited research is available to suggest the appropriate range of lake level fluctuations for optimum fish habitat.

Minimal quantitative data is available describing fish habitat conditions prior to engaging in long-term water level management on lakes within the watershed and the effects of water level management on the FIBI score are unknown. Therefore, hydrologic regime alteration is an inconclusive stressor due to a lack of data to draw conclusions.

3.3 Summary of Candidate Causes in the Clearwater River Watershed

The preliminary list of candidate/potential causes was narrowed down after the initial data evaluation/data analysis to three candidate causes of FIBI scores that suggest Cross and Hill River lakes are vulnerable to future Aquatic Life Use impairment (Table 2-2, Table 2-3). These candidate causes will be discussed further as they pertain to each lake in their respective sections of Chapter 4.

3.3.1. Candidate cause: non-native aquatic species

Fish communities may experience stress caused by direct competition from newly arrived organisms, or non-native species. Smallmouth Bass are an example of a non-native aquatic species that can directly compete with native fishes for resources. When Smallmouth Bass become established in lakes, the cyprinid (minnow) community becomes altered to where some species may even be extirpated (MacRae and Jackson 2001). More often, new species arrivals indirectly alter fish habitat and food web dynamics due to specific life history and behavioral processes.

Some non-native species have multiple mechanisms for impacting the aquatic environment. Common Carp, for example, compete with native fish species for resources and reduce aquatic plant habitat through their feeding behavior. Invertebrate species such as Spiny Waterflea, Zebra Mussels, and Faucet Snails are examples of non-native species that alter lake ecology by changing the food web that structures the fish community. Non-native aquatic plants may compete with native species, which can alter the aquatic plant community and change the character and quality of fish habitat.

Biotic and abiotic characteristics can also impact the extent to which a newly arrived species will ultimately impact each lake. Lake morphology may limit the potential impacts of certain species and favor others based on the amount of available resources in each lake. Regardless of abiotic factors, lakes that maintain high biological diversity are generally more resilient to changes caused by non-native species. Research continues to develop and improve techniques to quantify the impact of non-native species to aquatic ecosystem function.

3.3.2. Candidate cause: riparian lakeshore development

Residential development adjacent to lakes is known to have negative effects upon riparian habitat (Jennings, Emmons, et al. 2003) and result in changes to fish community composition (Jennings, Bozek, et al. 1999, Radomski and Goeman 2001). Among five lakes in northern Wisconsin, several fish species were linked to specific nearshore habitats during spring, summer, and fall, and residential development altered spatial distribution patterns of fishes in Washington lakes (Hatzenbeler, et al. 2000, Scheuerell and Schindler 2004). Human development of lakeshores oftentimes results in clearing of riparian vegetation for lawns and views, addition of sand blankets for swimming beaches, rip-rap for erosion control, destruction of aquatic vegetation, and placement of docks for recreation. An analysis of lakeshore development found that up to half of the shoreline and 14% of the littoral zone habitat in some Minnesota lakes may be lost with full build out on lakes with current shoreland development standards (Radomski, Bergquist, et al. 2010).

These activities affect fish communities through a variety of indirect pathways and to different extents. For example, destruction of aquatic vegetation reduces available fish habitat that influences the reproduction, survival, and abundance of some species. Clearing riparian vegetation can increase sedimentation that affects habitat and nutrient inputs, which influence ecological processes at the base of the food web. About two-thirds of nearshore emergent and floating-leaf vegetation was lost due to development in a subset of Minnesota lakes (Radomski and Goeman 2001). Clearing of dead trees from the shoreline can also reduce habitat complexity, which is important for supporting a biologically diverse and resilient aquatic ecosystem. Density of coarse woody habitat, emergent vegetation, and floating vegetation increased as shoreline development decreased among Wisconsin lakes (Christensen, et al. 1996, Jennings, Emmons, et al. 2003).

Fish communities are influenced by the cumulative effects of modifications to several components of riparian habitat that occur incrementally over many years, making it difficult to separate the impact of individual components (Jennings, Bozek, et al. 1999). In addition, there is a lag time between the loss of habitat and fish community response that occurs over several generations of fish. Therefore, the status of the current fish community reflects the impact of the collective activities that have resulted in the loss of riparian habitat over several decades.

Attempts to assess the extent of riparian habitat loss have ranged from direct measurements of physical conditions to indirect quantification of human structures that are related to decreases in available habitat. Direct measurements of physical habitat are expensive, require large amounts of time, and have lacked professionally accepted standard protocols. To address some of these limitations, MNDNR-EWR developed "Score the Shore" survey protocols (Perleberg, et al. 2016) in 2013 to assess riparian lake habitat. These protocols have subsequently been adopted for use by MNDNR Fisheries beginning with the 2015 field season. A review of Score the Shore (StS) surveys completed on lakes within the Clearwater River Watershed indicate that development of riparian habitat is evident and could be affecting the fish community in some lakes.

Similarly, an inventory of residential docks has been used as a surrogate to measure the impact of human development to riparian areas (Radomski, Bergquist, et al. 2010). MNDNR Fisheries research indicates a dock density greater than 10 docks per kilometer (about 16 docks per mile) of shoreline results in a noticeable change in fish community; at this breakpoint there is a lower likelihood of sampling sensitive nearshore fish species (MNDNR; Bacigalupi J., 2016; personal communication). The assessed lakes in the Clearwater River Watershed had dock densities below the threshold where changes in the fish community are likely detectable.

Although quantifying the status of riparian habitat is difficult, some measures have been developed. Based on available data from the Clearwater River Watershed, the alteration of fish habitat by riparian lakeshore development, as indicated by StS data, may be contributing to low FIBI scores and will be discussed further.

3.3.3. Candidate cause: excess nutrients – eutrophication (phosphorus)

Primary production in lakes is driven by phosphorus (P). In pristine lakes and watersheds, the P comes from resuspension and regeneration in lake sediments. Additional P can enter a lake as runoff from pastures and croplands, or from wastewater treatment facilities (MPCA 2007b) and is associated with increases in algal growth that results in reductions in water clarity, oxygen levels, and submersed vegetation as well as increases in abundance of tolerant fish species such as Common Carp and Black Bullhead (MNDNR-Fisheries 2013).

The addition of excess P is the primary cause of eutrophication in lakes and accounts for about a third of the impairment listings for lakes in Minnesota (Draft 2016 Inventory of All Impaired Waters). Research has shown that elevated P levels significantly affect fish community structure and function in Minnesota lakes (Schupp and Wilson 1993, Heiskary and Wilson 2008). Negative effects of eutrophication include altered plant growth, shifts in phytoplankton and zooplankton composition, and decreases in water transparency that lead to changes in the fish community that are detected by FIBI tools.

There are several mechanisms by which eutrophication contributes to impaired fish communities. Excess nutrients affect plankton communities, which make up the foundation of aquatic food webs. Increased primary production leads to more phytoplankton, reduced light penetration, and fewer rooted aquatic macrophytes. Loss of aquatic plants represents a physical alteration to available habitat which can alter fish community composition over time. Reduced plant cover can impact the success of vegetation dwelling species from a variety of feeding guilds. Decreased light penetration can also reduce the efficiency of sight-feeding piscivores that are not adapted to turbid conditions, like Largemouth Bass and Northern Pike, and result in lower biomass of top carnivores in the community.

Increased phytoplankton can also lead to an unbalanced community with few large-bodied zooplankton that are the preferred food for forage fish and important to the diet of many young game fish. These conditions favor undesirable, plankton-eating fish species over game fish. In turn, some planktivorous/benthivorous fish like Common Carp and Black Bullhead increase the internal loading of nutrients in shallow lakes through feeding behaviors (Matsuzaki, et al. 2007, Chumchal and Drenner 2004).

Eutrophication alters primary production and turbidity of a lake which act jointly with many natural variables to influence the frequency and severity of winterkill (Greenbank 1945, Barica, Gibson and Howard 1983, Webster, et al. 1996, Devito, et al. 2000). Increases in TP are related to greater primary production of macrophytes and phytoplankton; the latter resulting in higher turbidity. The mass of macrophytes and turbidity are both positively related to winter oxygen decay rates (Meding and Jackson 2003) such that shallow, turbid lakes would be expected to have the greatest oxygen decay rates (Barica and Mathias 1979). The faster a lake loses oxygen, the more likely it is to experience anoxic water conditions (Barica and Mathias 1979, Meding and Jackson 2003) and potentially winterkill. Smaller individuals of the cyprinid community are more likely to be reduced when conditions result in a winterkill (Danylchuk and Tonn 2003). This could result in the complete loss of short-lived (2 – 4 years) cyprinid species when there are multiple winterkill events within consecutive winters. Winterkill can be a natural stressor to a fish community but the frequency and severity of winterkill may be affected by anthropogenic forces that result in eutrophication.

Because of the potential impact of eutrophication to aquatic environments MPCA has developed nutrient water quality standards to assess lakes using measurements of total phosphorus (TP), chlorophyll-a, and transparency. Data for TP and either of the other two variables is needed to determine whether a lake meets the standard. Available data will be evaluated later in this report.

4. Evaluation of Candidate Causes

Excess nutrients and riparian lakeshore development have been identified as potential stressors to aquatic life use in Cross Lake (DOW# 60-0027-00) and Hill River Lake (DOW# 60-0142-00) and will be evaluated further. A description of available data and current understanding of levels believed to impact the fish communities will be discussed for each candidate.

4.1 Cross Lake (DOW# 60-0027-00)

The entirety of Cross Lake (2 east basins and west basin) is 320 acres in size. The portion of the lake that is sampled by MN DNR Fisheries personnel, and therefore the only basin discussed and assessed, is the west basin. Occasionally, the west basin is completely separated from the others by dry land. This basin is 166 acres, has a maximum depth of 19 feet, is generally polymictic, and is situated in the North Central Hardwood Forest Ecoregion. The littoral zone in the west basin covers approximately 85% of the total basin surface area. Cross Lake is scored with FIBI Tool 7, which is used to score lakes that are generally shallow and more than 80% littoral area (Table 1-1). Cross Lake is one of the northernmost lakes that is scored with FIBI Tool 7.

4.1.1. Biological community

Cross Lake was assessed as having insufficient information for an assessment at this time, but very near the impairment threshold and vulnerable to future impairment based on data from a nearshore survey in July 2014 and trap net and gill net data from a June 2014 survey. The survey resulted in an FIBI score of 40; above the threshold (36) and within the 90% confidence interval (27-45). Due to having the minimum seine effort, record of a severe winterkill in 1991, and some evidence for partial winterkills during subsequent winters, the data quality is medium: seining was difficult due to abundant emergent vegetation and high water levels. The history of periodic and very severe winterkill events (1948, 1967, 1977, 1988, and 1991) and lighter winterkill events (1981, 1990, 2001, 2004, and 2006) make it difficult to assess with the FIBI. A series of three winterkill events in four years resulted in only Black and Brown Bullheads being captured in test-netting efforts in early 1991. The expectations for Cross Lake may need to be moderated considering how downstream dams may prevent recolonization by some species of fishes after the lake experiences severe winterkill events. In spite of these considerations, many species have been sampled in subsequent years without additional stocking by MNDNR. This could be attributable to the connection between the east basins and the west basin that likely facilitates fish passage (Figure 4-1). Since 1991, Walleye has been the only species stocked into Cross Lake. Supplemental stocking of Walleye fry every other year is ongoing and described in the current Cross Lake management plan (MNDNR-Fisheries 2016a).

The FIBI score (Table 4-1) is negatively influenced by the proportionally low biomass of insectivores (9%) and the proportionally high biomass of tolerant species (29%) in the trap net catch. The four most abundant species by biomass in the trap nets were Northern Pike (26%), Brown Bullhead (26%), Common Carp (16%), and Black Bullhead (13%). Common Carp and Black Bullhead are the two species sampled from Cross Lake that are classified as tolerant of human induced disturbance. The FIBI Tool 7 gill net metric assigns points for vegetation dependent top carnivores only such as Northern Pike and Largemouth Bass (Walleye are excluded and assumed stocked). Northern Pike (48%) and Walleye (24%) were the most abundant species by biomass in the gill nets. Nearshore sampling captured 11 species, including the only intolerant species (Iowa Darter) sampled during the survey. Bluegill (34%) were the most abundant species in the nearshore survey followed by Yellow Perch (21%) and Golden Shiner (19%).

Table 4-1: Summary of lake and fish community characteristics and FIBI metric values comparing Cross Lake (DOW 60-0027-00) to the averages of lakes scored with FIBI Tool 7 and assessed as full support. Averages are derived for lakes 1) in the Clearwater River Watershed, 2) in the Red River Basin, and 3) statewide.

	Cross Lake	Clearwater River Watershed Lakes	Tool 7 lakes assessed as full support	
			Red River Basin	Statewide
Number of lakes		2	6	22
Lake and fish community characteristics				
Score the Shore Score	89	68	73	71
Percent littoral	85	91	87	92
Lake acres	166	909	2518	1298
Watershed acres	10660	38030	82450	52280
Ratio of watershed acres to lake acres	64	79	70	46
Maximum depth (feet)	19	16	30	24
Number of tolerant species	2	2.75	2.6	2.4
Number of insectivore species	6	7	11.2	8.6
Number of small benthic-dwelling species	2	2.75	2.5	1.7
Number of vegetative-dwelling species	3	3.5	6.2	3.9
Fish IBI Score	40	46	60	51
FIBI Metric Values				
Number of tolerant species	0.90	0.74	1.03	0.89
Number of insectivore species	-0.002	-0.18	0.92	0.43
Number of small benthic-dwelling species	1.02	1.34	1.13	0.43
Number of vegetative-dwelling species	0.63	0.61	2.00	0.91
Relative abundance of vegetative dwelling species in nearshore sampling	1.17	1.7	1.92	0.75
Proportion of biomass in trap nets from insectivore species	-1.07	0.31	1.55	1.55
Proportion of biomass in trap nets from tolerant species	-0.25	0.62	1.58	1.40
Proportion of biomass in gill nets from top carnivore species	0.68	-0.05	-0.05	0.72

Table 4-2: Summary of all fish species captured in Cross Lake (DOW 60-0027-00) in 2014 compared with similar fully supporting Tool 7 lakes within the Clearwater River Watershed. The species list includes common fish species (captured in at least half of the lakes assessed as full support) sampled during FIBI sampling of Tool 7 Red River Basin lakes or sampled in Clearwater River Watershed lakes scored with FIBI Tool 7 but not in half of the similar Red River Basin lakes (noted by an asterisk *). Tolerance, feeding, and habitat guilds important for FIBI Tool 7 score calculations are abbreviated as follows: Tol=Tolerant, Insect=Insectivore, TC=Top Carnivore, Veg=Vegetative Dweller, Smb=Small Benthic Dweller. Guild abbreviations colored red contribute negatively to the FIBI score whereas those colored blue contribute positively to the FIBI score.

Species commonly sampled in similar unimpaired Red River Basin lakes	Tolerance, feeding, and/or habitat guild	Clearwater River Watershed	
		Cross Lake	Similar unimpaired Clearwater River Watershed Lakes
Banded Killifish	Insect, Veg		
Black Bullhead	Tol	X	X
Black Crappie	TC	X	X
Blackchin Shiner	Insect, Veg		
Blacknose Shiner	Insect, Veg		
Bluegill	Insect	X	X
Bluntnose Minnow			
Bowfin	TC, Veg		
Brook Stickleback	Insect		X
Brown Bullhead		X	X
Central Mudminnow	Insect, Veg		X
Common Carp	Tol	X	X
Fathead Minnow	Tol		X
Freshwater Drum*	Insect		X
Golden Shiner	Insect	X	
Green Sunfish	Tol, Insect		
Iowa Darter	Insect, Smb, Veg	X	X
Johnny Darter	Insect, Smb		X
Largemouth Bass	TC	X	X
Northern Pike	TC, Veg	X	X
Pumpkinseed	Insect	X	X
Rock Bass	TC		X
Spottail Shiner	Insect		
Tadpole Madtom	Insect, Smb, Veg	X	X
Walleye	TC	X	X
White Sucker		X	X
Yellow Bullhead			X
Yellow Perch	Insect	X	X

There are several historic surveys in which other species of fish were recorded, although no vouchers were taken, so it is not possible to confirm changes in species assemblage. Rock Bass were identified in all three surveys conducted in the 1980's and have not been sampled since. Rock Bass is considered a species that is intolerant of human induced stresses. Two tolerant species, Green Sunfish (1995) and Fathead Minnow (2000), have each been captured during only one survey. The survey data from which the FIBI was calculated had a total of 14 species sampled – the greatest number of species for a survey of Cross Lake to date – although this was the only suite of surveys that involved nearshore sampling efforts (Table 4-2). Throughout the history of surveys on Cross Lake, MNDNR Fisheries personnel have identified a total of 19 different species. Some of these species are represented by only one or two occurrences and identification confirmation cannot occur due to the lack of vouchered specimens. This is the first time that FIBI protocols were utilized to assess this lake, and as such, there are no historical surveys of similar rigor available for comparisons of fish species assemblages through time. The use of these protocols should allow the data collected for this assessment to be used for future temporal comparisons.

4.1.2. Information about select inconclusive causes

Connectivity

Despite inconclusive evidence of the effects that connectivity has had upon the Cross Lake FIBI score, it is still important to investigate how it may affect fish community changes in lakes. Connectivity may play a role in the recovery of a lake by limiting species reestablishment where local extirpation has occurred.

Cross Lake is located on Hill River. The river flows downstream for approximately 47.2 river miles prior to terminating at the confluence with Lost River. Two stream reaches totaling approximately 42 river miles (the reach between Cross Lake and County Ditch 81 was not assessed) between Cross Lake and the confluence with Lost River are assessed as having an impaired fish community based on Aquatic Life Use standards (Johnson and Fitzpatrick 2017). On this circuitous route from Cross Lake to Lost River there are two wetland complexes, 33 road or railroad crossings, six private small bridges, many beaver dams, and a lake – Hill River Lake – as well as the lake outlet dams on Cross Lake (Figure 4-1) and Hill River Lake (Figure 4-3) that could act as seasonal impediments, or complete barriers, to fish migrating upstream and into the lake, these counts were determined utilizing Google Earth aerial imagery from 2015. The Cross Lake outlet dam was inspected in 2008 and found to not have any stop logs in place and the water is free-flowing across the structure. The Hill River Lake outlet dam has been recently reconstructed utilizing a 1997 MNDNR design with a fish passage, although MPCA suggests that this could still be a barrier to fish movement due to steep gradient (6.6%), high flow velocities during high flow, and possibly no flow during low flow periods (Johnson and Fitzpatrick 2017). The multiple beaver dams and the wetland complexes could be a major impediment to fish migration during low flows.

The FIBI is not particularly sensitive to fish species that require access to streams for certain life history processes. The FIBI places importance on the smaller bodied nongame fishes, many of which can sustain populations in lakes with or without inlet streams. Furthermore, the FIBI was developed utilizing a statewide data set and may not be sensitive to nuances of lakes with very unique circumstances.

The ability for smaller bodied fishes to traverse the impediments found along the river to inhabit Cross Lake is not well known. There are about 42 downstream miles of the Hill River that are impaired for aquatic life by not meeting the dissolved oxygen standards.

The portion of Cross Lake that is sampled by MNDNR – Fisheries personnel has one inlet river – Hill River, as reported by MNDNR Fisheries (MNDNR-Fisheries 2016a). No inlet flow measures have been attempted because of the inlet area being densely vegetated with no apparent channel. Hill River upstream of Cross Lake has not been assessed for any use categories. Connectivity is an inconclusive candidate cause of the condition of the fish community of Cross Lake.

Aquatic plant management

The removal of aquatic plants, permitted or not, is still an alteration to the habitat of a lake and could affect the fish community. Aquatic plant control activities are not likely a candidate cause for the vulnerable assessment, but the effects of APM activities on the FIBI score are unknown. Cross Lake has a total of 6 docks along its 2.46 miles of shoreline. Cross Lake has not had any permitted Aquatic Plant Management activities since at least 2010. This lack of permitted aquatic plant destruction and the low density of docks per shoreline length indicate the aquatic plant control is not likely to be affecting the fish community, but the effects it has on the FIBI score are unknown.

4.1.3. Data analysis/evaluation for each candidate cause

Non-native aquatic species

Common Carp, a non-native species, has been sampled from Cross Lake. One Common Carp was sampled in 2007 and four in 2014 via trap nets from Cross Lake. Non-native aquatic species are considered as an inconclusive stressor to the Cross Lake fish community due to these very low numbers of individuals captured.

Riparian disturbance

There is development along the shoreline of Cross Lake. Currently, there are eleven land parcels adjacent to Cross Lake that are not public land. These lots do not have equal shares of shoreline, and some of the longer stretches of undeveloped shoreline are large, single parcels. There are about 6 docks along the shoreline of Cross Lake or approximately 2.4 per mile of shoreline (counted from aerial imagery in Google Earth version 9.0.32.1). The publicly owned parcels contain approximately 0.4 miles of the entire shoreline, or about 17%.

Minnesota DNR Fisheries IBI program staff assessed lakeshore habitat on Cross Lake in June 2015, following StS survey protocols. The assessment consisted of 25 survey sites that were evenly spaced (every 200 meters) around the lake. Assessments were made in three habitat zones: Shoreline Zone (the shore-water interface to the top of the natural bank), Shoreland Zone (landward from shoreline to development structure or 100 feet), and Aquatic Zone (lakeward from the shoreline 50 feet). Table 4-3 depicts the scores calculated from the StS survey efforts. The average lake-wide habitat score was 89.3 (+/- 0.9) out of 100 possible; this is above the average score (73.6) of StS surveyed lakes to date and likely indicative of low shoreline alteration. Twenty percent of the sites were developed with a mean score of 91.3 (± 2.9), while undeveloped sites had a mean score of 88.8 (± 0.9). During the StS survey, 4% of sites had visible woody habitat and 100% of sites had at least 50% of frontage as emergent vegetation in the aquatic zone. The percentage of visible, woody habitat may have been affected by algae growth that hindered efforts to spot fully submersed woody habitat. These results, along with observations during field surveys and review of aerial imagery, indicate the shoreline of Cross Lake is not substantially altered. Research continues to develop and improve techniques to quantify the impact of riparian disturbance to FIBI scores.

The results from this survey are unique in that the developed sites scored higher than the undeveloped sites. This is attributable to a lack of overhanging woody habitat in many undeveloped sites oftentimes due to the wide fringe of emergent vegetation at those locations. The other important thing to note is that development does not have to be detrimental to the lakeshore habitat. Development can occur on a lake and the lakeshore habitat can be high quality.

Table 4-3: Breakdown of how Cross Lake (DOW 60-0027-00) scored utilizing the Score the Shore survey separated out by lakewide, undeveloped and developed land use and each of the three zones (Shoreland, Shoreline, Aquatic).

Category	Survey Sites	Shoreland Score (33)	Shoreline Score (33)	Aquatic Score (33)	Mean Score Std Error	Mean Score (100)
Lakewide	25	32.9	29.5	26.9	0.9	89.3
Undeveloped Total	**20**	**32.8**	**29.3**	**26.7**	**0.9**	**88.8**
Undeveloped Non-wetland	13	32.6	30.8	26.7	1.3	90
Undeveloped Wetland	7	33.3	26.7	26.7	0	86.7
Developed Total	**5**	**33.3**	**30.0**	**28.0**	**2.9**	**91.3**
Public Park	1	33.3	26.7	26.7	0.0	86.7
Roadway	2	33.3	33.3	30.0	3.3	96.7
Single-Family Residential	2	33.3	28.3	26.7	5.0	88.3

The riparian area has not been significantly altered by human activities as indicated by the StS results. The lakewide StS score of 89.3 is above the statewide average for lakes surveyed to date. There is not a strong relationship between FIBI score and riparian disturbance indicators for Cross Lake and other similar lakes scored with FIBI Tool 7. Considering this information, shoreline development practices are not considered a stressor on the fish community of Cross Lake. Local, county, and state shoreland ordinances should be reviewed with a focus on improving water quality and nearshore habitat, specifically focusing on reducing nutrients and sediments from entering the lake.

Excess nutrients

MPCA has developed water quality standards to assess nutrient impairment for lakes using measurements of TP, chlorophyll-a, and transparency. Data for TP and either (or both) of transparency and chlorophyll-a are needed to determine whether a lake meets the standard. Cross Lake was assessed as fully supporting Aquatic Recreation based on the nutrient sampling; the data is presented below. In contrast, Cross Lake was assessed as having insufficient information but vulnerable to future impairment for Aquatic Life Use based on the FIBI score.

Another tool to evaluate the potential impact of excess nutrients to fish communities is to summarize the land use within the immediate watershed. Modeling of Minnesota lakes suggests TP concentrations increase significantly over natural concentrations when land use disturbances occur in greater than 40% of the watershed area and this relationship tends to be stronger in shallow lakes (Cross and Jacobson 2013).

Urban and agricultural land use disturbances affect specific lakes differently due to unique non-stressor variables such as watershed area and lake size and depth that help to modify their impact on aquatic communities. Characterizing land use disturbances at the watershed scale are the best predictors of differences in fish and wetland plant communities although smaller scales may be useful to explain specific responses of particular components of these communities (Brazner, et al. 2007, Drake and Pereira 2002, Drake and Pereira 2002). Data used to develop the FIBI Tools showed a significant relationship between watershed land use and most FIBI metrics and the FIBI score (Drake and Pereira 2002).

The contributing watershed of Cross Lake is 10,659 acres. The ratio of lake size (166 acres) to contributing watershed size is roughly 1:64 (Figure 4-1). There are several wetland complexes within the contributing watershed ranging in size from 6 – 89 acres plus many smaller wetlands and those associated with flowing waters. These have the potential of utilizing and binding excess nutrients before they reach Cross Lake. An overall GIS quantification of land use types based on the National Land Cover Database (NLCD) 2011 (Homer, et al. 2015) showed 42% of the contributing watershed for the MNDNR – Fisheries sampled portion of Cross Lake covered by un-natural land uses (37% cultivated and 4% developed; Figure 4-2). The rest of the contributing watershed is covered by forests (34%), water or wetlands (19% combined), and grasslands (4%; Figure 4-2). Minor changes in land use have occurred since 2001 based on a review of the NLCD coverage. This change is primarily pasture/hay fields being converted into cultivated crops.

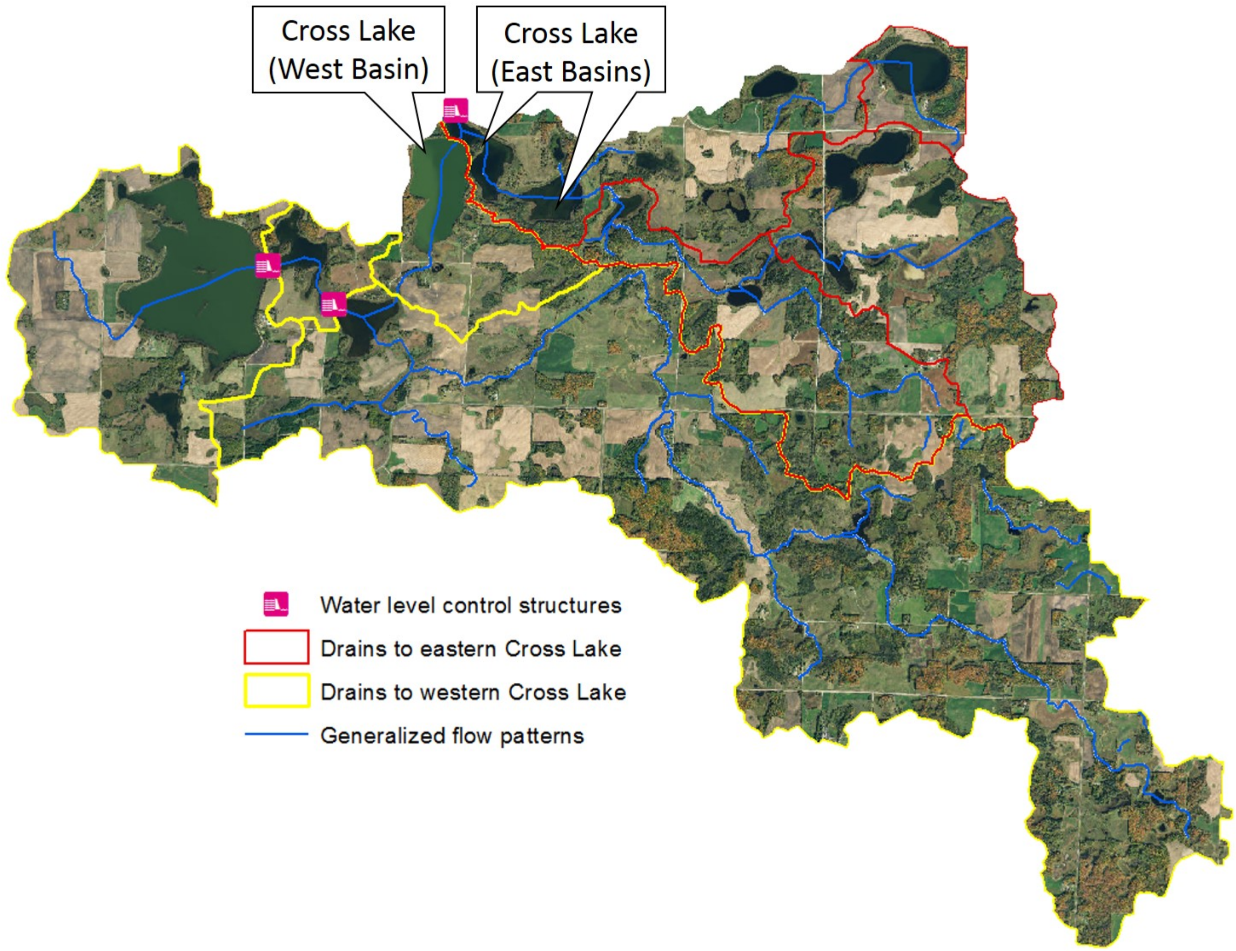

Figure 4-1: Aerial photograph (FSA 2015) of Cross Lake (DOW 60-0027-00) and the contributing watershed. Note the location of the water level control structure on the northern shore of the northern basin. The watersheds highlighted in yellow flow into the portion of Cross Lake that is sampled by MNDNR – Fisheries Personnel.

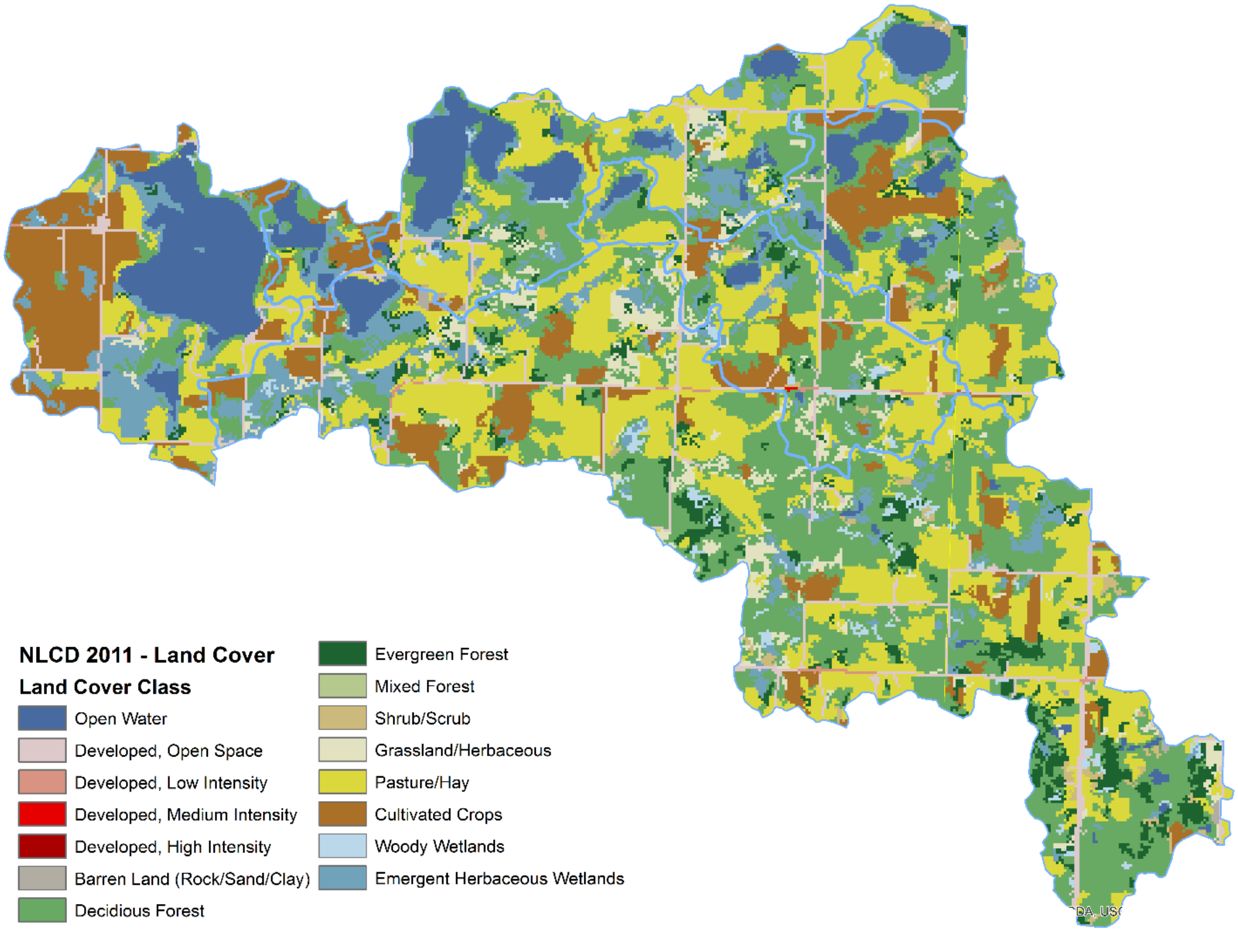

Figure 4-2: Land use (NLCD 2011) in Cross Lake (DOW 60-0027-00) contributing watershed.

Water quality data for Cross Lake has been collected by MPCA and other partners since 1974. Average water quality parameters based on data collected within the last ten years (2006 – 2015) include: TP level of 52 µg/L, chlorophyll-a level of 20 µg/L, and secchi disk reading of 1.3 meters (MPCA, 2015 data, J. Donatell; personal communication). All measurements are meeting the eutrophication standards for Shallow Lakes in the North Central Hardwood Forest Ecoregion (TP not above 60 µg/L, chlorophyll-a not above 20 µg/L, and secchi disk not less than 1.0 meter). From this assessment cycle, Cross Lake was assessed as fully supporting Aquatic Recreation Use standards. This water quality data results in Cross Lake being considered eutrophic.

4.1.4. Conclusions

The FIBI score for Cross Lake was near the impairment threshold developed for similar lakes, which indicates that the fish community may be experiencing elevated levels of human induced stress. Watershed disturbance is slightly greater in the contributing watershed of Cross Lake (42%) than the threshold level of disturbance at which TP concentrations increase significantly (40%). High watershed disturbance and resulting TP levels are shown to negatively affect fish communities in Minnesota lakes. Although current TP levels do not exceed the Aquatic Recreation Use standard for lakes in the region, TP and other measures of eutrophication such as chlorophyll-a and secchi disk transparency are very near their respective threshold limits. In addition to direct effects on the fish community, eutrophication can also alter the frequency and severity of winterkill events, which have historically occurred in Cross Lake. The influence of winterkill events on the Cross Lake fish community cannot be dismissed, but also cannot be disentangled from other stressors, natural or human-caused. Conversely, riparian disturbance has occurred around the lake but at levels below which detectable effects on the FIBI score occur. This information indicates that watershed disturbance – likely resulting in excess TP, eutrophication, and winterkill events – is likely the greatest stressor affecting the fish community of Cross Lake, which has been assessed as vulnerable to future impairment for Aquatic Life Use.

4.2 Hill River Lake (DOW# 60-0142-00)

Hill River Lake is 102 acres in size, has a maximum depth of 60 feet, and is situated in the Red River Valley Ecoregion. The littoral zone covers approximately 66% of the lake surface area. Hill River Lake is scored with FIBI Tool 5. The lakes scored with this tool are generally characterized as having moderate depth, more than 50% littoral area, and simple fish communities (Table 1-1).

4.2.1. Biological community

Hill River Lake was assessed as Full Support for Aquatic Life based on the FIBI, but very near the impairment threshold and vulnerable to future impairment based on data from a nearshore survey conducted in July 2014 and trap net and gill net data from a June 2014 survey. The survey resulted in an FIBI score of 28; above the threshold (24) and within the 90% confidence interval (9-39). Some difficulties were caused by an overabundance of filamentous algae at many of the nearshore stations. These difficulties resulted in questionable efficacy of the seine hauls, reduced visibility for backpack electrofishing, and a reduced (medium) data quality evaluation. There is a history of winterkill events occurring on Hill River Lake. The first period of severe winterkill occurred during the drought of the 1930's. The second period was 1969-1971 and was attributed to runoff from a large poultry farm that was addressed at that time. The third and most recent period was early-to-mid-1990's (MNDNR-Fisheries 2016b). This most recent period has no known direct cause.

The FIBI score was positively influenced (Table 4-4) by proportionally low biomass of tolerant species in the trap nets (2.5%). The score was most negatively influenced (Table 4-4) by the high number of omnivorous species sampled (5), the absence of intolerant species caught in nearshore gears, and the proportionally high biomass of omnivores in the trap nets (37%). Northern Pike (67%), White Sucker (19%), and Yellow Perch (10%) were the most abundant species by biomass in the gill nets. White Sucker (36%), Bluegill (33%), and Northern Pike (14%) were the most abundant species by biomass in the trap nets. Black Bullhead (85%), Largemouth Bass (6%), and Bluegill (2%) were the most abundant species in the nearshore sampling. Supplemental stocking of Walleye fry every other year is ongoing as described in the current Hill River Lake management plan (MNDNR-Fisheries 2016b). Despite the stocking efforts, no Walleye were captured during any of the surveys that were used to calculate the FIBI score.

There are several historic surveys in which other species of fish were recorded. No vouchers were taken during those surveys, so it was not possible to confirm changes in species assemblage. Rock Bass were identified in one survey that was conducted in 1984 and have not been sampled since. Rock Bass is a species that is intolerant of human induced stresses. The survey data from which the FIBI was calculated had a total of 14 species sampled – the greatest number of species for a survey of Hill River Lake to date – although this was the only suite of surveys that involved nearshore sampling efforts (Table 4-5). Throughout the history of surveys on Hill River Lake, MNDNR Fisheries personnel have identified a total of 17 different species. Some of these species are represented by only one or two occurrences and identification confirmation cannot occur due to the lack of vouchered specimens. This is the first time that the FIBI protocols were utilized in the lake assessment process. Therefore, there are no historical surveys of similar rigor available for comparisons of fish species assemblages through time. The use of these protocols should allow the data collected for this assessment to be used for future temporal comparisons.

Table 4-4: Summary of lake and fish community characteristics and FIBI metric values comparing Hill River Lake (DOW 60-0142-00) to the averages of lakes scored with FIBI Tool 5 and assessed as full support. Averages are derived for lakes 1) in the Clearwater River Watershed, 2) in the Red River Basin, and 3) statewide.

	Clearwater River Watershed lakes		Tool 5 lakes assessed as full support	
	Hill River Lake	Minnow Lake	Red River Basin	Statewide
Number of lakes			10	48
Lake and fish community characteristics				
Percent littoral	71	87	80	83
Lake acres	102	110	441	398
Watershed acres	63400	1390	84480	42260
Ratio of watershed acres to lake acres	621	12	185	87
Maximum depth (feet)	60	24	29.4	27.5
Number of intolerant species	0	2	3.0	2.4
Number of tolerant species	2	1	2.1	1.3
Number of omnivore species	5	2	4.5	3.4
Fish IBI Score	28	71	48.7	50.6
FIBI Metric Values				
Number of intolerant species	-0.43	0.67	0.63	0.55
Number of tolerant species	-0.52	0.22	-0.03	0.28
Number of omnivore species	-1.75	0.13	-0.12	0.21
Relative abundance of intolerant species in nearshore sampling	-1.35	2.09	0.88	0.52
Proportion of biomass in trap nets from insectivore species	-0.07	0.37	0.54	0.34
Proportion of biomass in trap nets from omnivore species	-0.94	0.12	0.14	0.33
Proportion of biomass in trap nets from tolerant species	0.74	0.92	0.43	0.56
Proportion of biomass in gill nets from top carnivore species	-0.06	1.62	0.07	0.30

Table 4-5: Summary of all fish species captured in Hill River Lake (DOW 60-0142-00) in 2014 compared with Minnow Lake (the one fully supporting Tool 5 lake within the Clearwater River Watershed). The species list includes common fish species (captured in at least half of the lakes assessed as full support) sampled during FIBI sampling of Tool 5 Red River Basin lakes or sampled in either Hill River Lake or Minnow Lake (noted by an asterisk *). Tolerance, feeding, and habitat guilds important for FIBI Tool 5 score calculations are abbreviated as follows: Intol=Intolerant, Tol=Tolerant, Insect=Insectivore, Omni=Omnivore, TC=Top Carnivore. Guild abbreviations colored red contribute negatively to the FIBI score whereas those colored blue contribute positively to the FIBI score.

Species commonly sampled in similar unimpaired Red River Basin lakes	Tolerance, feeding, and/or habitat guild	Clearwater River Watershed	
		Hill River Lake	Minnow Lake
Banded Killifish	Intol, Insect		
Black Bullhead	Tol, Omni	X	
Black Crappie	TC	X	X
Blackchin Shiner	Intol, Insect		
Blacknose Shiner	Intol, Insect		X
Bluegill	Insect	X	X
Bluntnose Minnow	Omni		
Brown Bullhead	Omni	X	
Central Mudminnow	Insect	X	X
Common Carp*	Tol, Omni	X	
Fathead Minnow*	Tol, Omni		X
Golden Shiner*	Insect		X
Green Sunfish	Tol, Insect		
Iowa Darter	Intol, Insect		X
Johnny Darter*	Insect	X	
Largemouth Bass	TC	X	
Northern Pike	TC	X	X
Pumpkinseed	Insect	X	
Spottail Shiner	Insect		
Tadpole Madtom*	Insect	X	
Walleye	TC		X
White Sucker	Omni	X	
Yellow Bullhead	Omni	X	X
Yellow Perch	Insect	X	X

4.2.2. Information about select inconclusive causes

Connectivity

The evidence of a relationship between connectivity and the Hill River Lake FIBI score is inconclusive. Connectivity was not a significant factor affecting FIBI scores during FIBI tool development, but it is still important to investigate how it may affect fish community changes in lakes. Connectivity may play a role in the recovery of a lake by limiting species reestablishment where local extirpation has occurred, such as by previous winterkill.

Hill River Lake is located on Hill River. This river flows downstream for approximately 34.1 miles prior to terminating at the confluence with Lost River. This segment of the Hill River in its entirety was assessed as having an impaired fish community based on Aquatic Life Use standards (Johnson and Fitzpatrick 2017). On the circuitous route from Hill River Lake to Lost River there are 23 road crossings, one railroad crossing, two private small bridges, many beaver dams, and the lake outlet structure (Figure 4-3) that could act as seasonal impediments, or complete barriers, to fish migrating upstream and into the lake, these counts were determined utilizing Google Earth aerial imagery from 2015. The Hill River Lake outlet dam has been reconstructed utilizing a 1997 MNDNR design with a fish passage, although MPCA suggests that this could still be a barrier to fish movement due to steep gradient (6.6%), high flow velocities during high flow, and possibly no flow during low flow periods (Johnson and Fitzpatrick 2017). The multiple beaver dams and the wetland complexes could be a major impediment to fish migration during low flows.

The FIBI is not particularly sensitive to fish species that require access to streams for certain life history processes. The FIBI places importance on the smaller bodied nongame fishes, many of which can sustain populations in lakes with or without inlet streams. Furthermore, the FIBI was developed by utilizing a statewide data set and may not be sensitive to nuances of lakes with unique circumstances.

The ability for smaller bodied fishes to traverse the impediments found along the river to inhabit Hill River Lake is unknown. There are about 34 downstream miles and 8 upstream miles of the Hill River that are impaired for aquatic life by not meeting the dissolved oxygen standards.

Hill River Lake has one inlet river – Hill River, as reported by MNDNR Fisheries (MNDNR-Fisheries 2016b). No inlet flow measures have been recorded, although in 1989 the outlet had flow of 5.34 cubic feet per second. Hill River upstream of Hill River Lake is assessed as having an impaired fish community based on Aquatic Life Use standards (Johnson and Fitzpatrick 2017). Connectivity is an inconclusive candidate cause of the condition of the fish community of Hill River Lake.

Aquatic plant management

The removal of aquatic plants, permitted or not, is still an alteration to the habitat of a lake and could affect the fish community. Aquatic plant control activities are not likely a candidate cause for the vulnerable assessment, but the effects of APM activities on the FIBI score are unknown. Hill River Lake has a total of 2 docks along its 2.74 miles of shoreline. There have not been any permitted Aquatic Plant Management activities since at least 2010. This lack of permitted aquatic plant destruction and the low density of docks per shoreline length indicate aquatic plant control is not likely to be affecting the fish community, but the effects it has on the FIBI score are unknown.

4.2.3. Data analysis/evaluation for each candidate cause

Non-native aquatic species

Common Carp, a non-native species, has been sampled from Hill River Lake. Trap netting in Hill River Lake has yielded one Common Carp in each of 1989, 2004, and 2014. Non-native aquatic species are considered as an inconclusive stressor to the Hill River Lake fish community due to these very low numbers of individuals captured.

Riparian disturbance

There is minimal development along the shoreline of Hill River Lake. Currently, there are 3 land parcels adjacent to Hill River Lake that are not public land. These lots do not have equal shares of shoreline, and some of the longer stretches of undeveloped shoreline are single larger parcels. There are about 2 docks along the shoreline of Hill River Lake or approximately 1 per mile of shoreline (counted from aerial imagery in Google Earth version 9.0.32.1). The publicly owned parcels contain approximately 0.6 miles of the entire shoreline, or about 23%.

Due to the low development around the lake (3 not public parcels, and 2 docks), additional surveys to assess the extent of development were not conducted. The effects of riparian habitat alteration on the FIBI score are unknown, but currently, there is not a strong relationship between FIBI score and riparian disturbance indicators for Hill River Lake and other similar lakes scored with FIBI Tool 5. Considering this information, shoreline development practices are not considered a stressor on the fish community of Hill River Lake. Local, county and state shoreland ordinances should be reviewed with a focus on improving water quality and nearshore habitat, specifically focusing on reducing nutrients from entering the lake.

Excess nutrients

MPCA has developed water quality standards to assess nutrient impairment for lakes using measurements of TP, chlorophyll-a, and transparency. Data for TP and either (or both) of transparency and chlorophyll-a are needed to determine whether a lake meets the standard. No recent data were available and therefore, Hill River Lake was not assessed for Aquatic Recreation Use during this assessment cycle. Hill River Lake was assessed as fully supporting but vulnerable to future impairment for Aquatic Life Use.

Another tool to evaluate the potential impact of excess nutrients to fish communities is to summarize the land use within the immediate watershed. Modeling of Minnesota lakes suggests TP concentrations increase significantly over natural concentrations when land use disturbances occur in greater than around 40% of the watershed area and this relationship tends to be stronger in shallow lakes (Cross and Jacobson 2013).

Urban and agricultural land use disturbances affect specific lakes differently due to unique non-stressor variables such as watershed area and lake size and depth that help to modify their impact on aquatic communities. Characterizing land use disturbances at the watershed scale are the best predictors of differences in fish and wetland plant communities although smaller scales may be useful to explain specific responses of particular components of these communities (Brazner, et al. 2007, Drake and Pereira 2002, Drake and Pereira 2002). Data used to develop the FIBI Tools showed a significant relationship between watershed land use and most FIBI metrics and the FIBI score (Drake and Pereira 2002).

The contributing watershed of Hill River Lake is very large, 63,470 acres. The ratio of lake size (102.1 acres) to contributing watershed size is roughly 1:621 (Figure 4-3). There are several wetland complexes within the contributing watershed ranging in size from 9 – 89 acres plus many smaller wetlands and those associated with flowing waters as well as many lakes. These all have the potential of utilizing and binding excess nutrients before they reach Hill River Lake. An overall GIS quantification of land use types based on the National Land Cover Database (NLCD) 2011 (Homer, et al. 2015) showed 63% of contributing watershed area covered by un-natural land uses (58% cultivated and 4% developed; Figure 4-4). The rest of the contributing watershed is covered by forests (17%), water or wetlands (10% combined), and grasslands (4%; Figure 4-4). Minor changes in land use have occurred since 2001 based on a review of the NLCD coverage. This change is primarily pasture/hay fields being converted to cultivated crops, but a couple parcels were conversion of grasslands to cultivated crops.

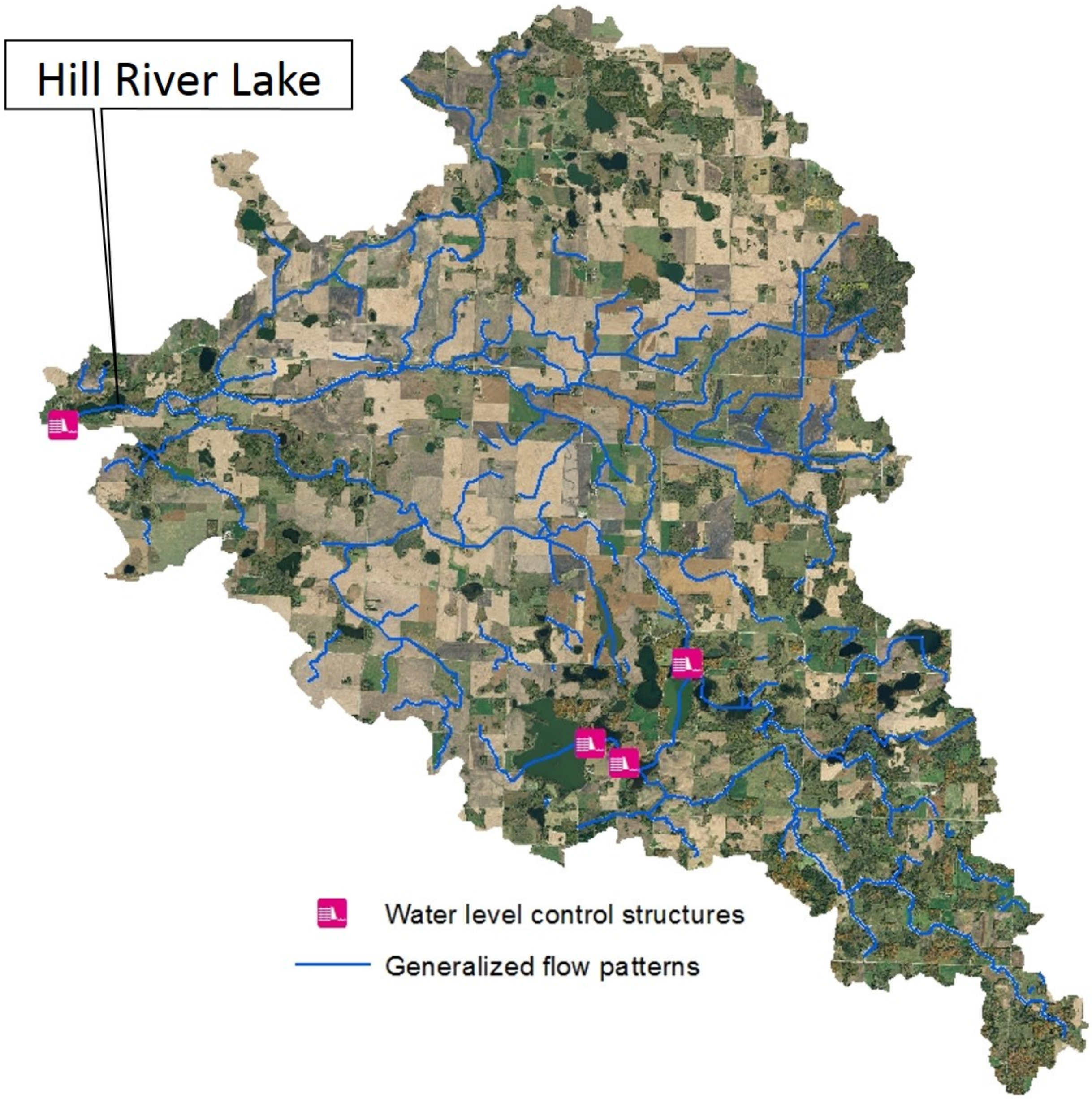

Figure 4-3: Aerial photograph (FSA 2015) of Hill River Lake (DOW 60-0142-00) and the contributing watershed. Note the location of the water level control structure on the southwestern shore; also showing three upstream water level control structures.

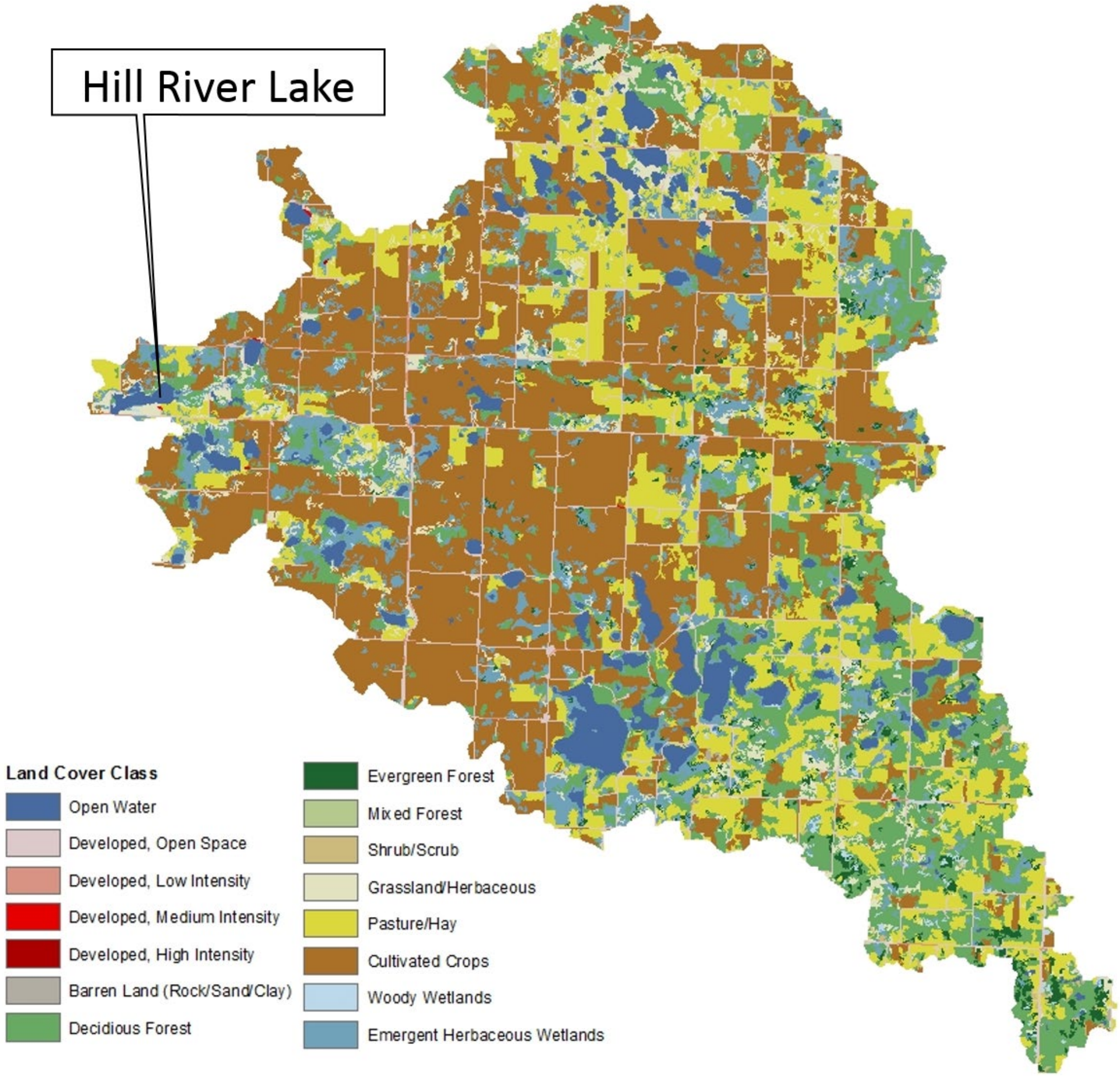

Figure 4-4: Land use (NLCD 2011) in Hill River Lake (DOW 60-0142-00) contributing watershed.

There was no available data for an Aquatic Recreation Use (water quality) assessment during the most recent assessment cycle. Secchi disk is the only water quality data available from the MPCA for Hill River Lake and was collected in 2001 (average of 6 samples from July and August: 0.96 m) and 2004 (average of 6 samples from June through October: 0.88 m), which is too old to utilize for assessment. MNDNR Fisheries has record of one water quality observation from July 1989 (also too old to utilize) where TP was 76 µg/L and chlorophyll-a was 54.8 µg/L, they note in the 2006 lake management plan that nutrient loading is still a significant factor in fish survival. Hill River Lake is in the Red River Valley ecoregion; it is about 7.5 miles from the North Central Hardwoods Forest and 15 miles from the Northern Lakes and Forests ecoregions. The North Central Hardwoods Forest standards are utilized for assessing Hill River Lake because there are not any water quality standards in statute for Red River Valley ecoregion. Both readings, although not a summertime average, and only represented by this one sampling occurrence, are exceeding all current standards for TP and chlorophyll-a that are applicable elsewhere in the state.

4.2.4. Conclusions

Poor water quality, likely from watershed disturbance, is a significant stressor on the fish community. This is concluded because the FIBI score is near the impairment threshold and none of the other possible stressors are at levels where effects on the FIBI score have been observed. Almost 63% of the land cover in the contributing watershed is classified as disturbed, or unnatural. This amount of disturbance is greater than what has been identified to have detectable effects on the FIBI score. Very limited water quality data and large amounts of filamentous algae sampled during the FIBI survey suggest that water quality is likely moderate or poor. The density of docks is below where detectable effects occur on the FIBI score. This information indicates that watershed disturbance, likely resulting in excess TP, is the greatest stressor affecting the fish community of Hill River Lake resulting in an FIBI score indicating a fish community that is vulnerable to future impairment for Aquatic Life Use.

5. Conclusions and Recommendations

5.1 Conclusions

There were two lakes (Cross Lake and Hill River Lake) in the Clearwater River Watershed that have FIBI scores suggestive that the fish communities are vulnerable to future impairment (Table 2-2; Table 5-1). Cross Lake was assessed as having insufficient information to list the lake as impaired for Aquatic Life Use and Hill River Lake was assessed as meeting standards for Aquatic Life Use. These fish communities and the resulting FIBI scores are indicating these lakes are vulnerable to future impairment for Aquatic Life Use. Many potential stressors were considered as affecting the fish communities (Table 5-2). Only one stressor stands out as a likely contributor to the condition of the fish communities of these lakes: watershed disturbance likely resulting in excess nutrients. The percent of the watershed that is classified as disturbed is above levels where effects are frequently detected in the FIBI. The shoreline habitat as described by the StS score (Cross Lake) and dock counts (Cross Lake and Hill River Lake), are not at a level where the effects are typically detectable with the FIBI. The effects of connectivity and water level control on the FIBI are inconclusive. Although inconclusive, the effects of winterkill and connectivity, and the impaired downstream stretches of river, may be limiting the species of these lakes

Table 5-1: Summary, by DOW, of lakes in the Clearwater River Watershed that are vulnerable to future Aquatic Life Use impairment. Score the Shore (StS), a rapid assessment of lakeshore habitat condition with lake-wide scores ranging from 0 – 100. Plant assessment reported as the relation to the threshold determined for plants. Aquatic recreation impairment reported as the lake status as impaired or a candidate for impairment for aquatic recreation. If the lake was not assessed it is denoted with a N/A.

DOW	Lake Name	FIBI Score	% disturbance in contributing watershed	StS Score	# of docks per km of shoreline	Eutrophication Plant Assessment	Aquatic Recreation Impairment?
60-0027-00	Cross	40	42	87.3	1.5	Above threshold	No
60-0142-00	Hill River	28	63	N/A	0.5	Above threshold	N/A

Table 5-2: Summary, by DOW, of stressors causing lakes in the Clearwater River Watershed to be vulnerable to future Aquatic Life Use impairment. The conclusion of excess nutrients being a direct stressor to the fish community of Hill River Lake is based on very limited water quality data.

DOW	Lake Name	FIBI Impairment status	% disturbance in watershed	Shoreline habitat	Excess nutrients - eutrophication	Water levels impacting spawning or other habitat	Other stressor considerations
60-0027-00	Cross	Vulnerable	◊	o*	?	?	History of winterkill events
60-0142-00	Hill River	Vulnerable	..	o*	•	?	History of winterkill events

.. A “root cause” stressor, which causes other consequences that become the direct stressors.

◊ Possible contributing root cause.

• Determined to be a direct stressor.

o* An anthropogenic stressor, but at a level where effects on the FIBI are undetectable

o A stressor, but determined to have very little to no anthropogenic cause. Includes natural background and beaver dams as natural stressors.

? Inconclusive

5.2 Recommendations

Efforts to reduce nutrients entering the lakes and to determine the within lake dynamics of nutrients should be supported. Future projects that mitigate the presence of excess nutrients in the lakes which are vulnerable to future impairment will benefit human (Aquatic Recreation Use) and aquatic ecosystem (Aquatic Life Use) health. Recent research (Schindler, et al. 2008) indicates that controlling P should be the focus of management to reduce eutrophication even in apparently N-limited systems. Furthermore, a full response of lake ecology may take decades after external nutrient loads are reduced (D. W. Schindler 2006). Monitoring of water chemistry in Cross Lake and Hill River Lake should be undertaken during the next assessment cycle to have greater confidence in what may be affecting the lake fish community. Investigations into the historical hydrology changes and the water level control structures of these lakes should be encouraged and could provide valuable information for many other similar waters.

Projects and policies that restore or enhance riparian lakeshore habitat complexity should be promoted. Lakeshore restoration should include trees, shrubs, and natural ground cover in an attempt to reestablish the habitat complexity around the perimeter of the lake. Lakeshore buffers would also have the added benefit of reducing external nutrient loading and sedimentation associated with riparian development. Removal of woody habitat from the lake should be discouraged because natural woody structures add to the nearshore habitat complexity important to a variety of organisms including fish. Trees that provide habitat for wildlife while living can provide habitat in aquatic environments for a much greater period of time because submerged wood decomposes slowly. Removing dead trees from the water has the effect of reducing overall aquatic habitat in a lake for decades or longer. Efforts, projects and ordinances that focus on protecting, enhancing and/or maintaining the emergent aquatic vegetation should be promoted.

The efficacy and longevity of any fish passage structure should be monitored with a focus on the use by smaller bodied and nongame fish species. Projects that investigate this should be supported.

Glossary

Term	Definition
aquatic	In relation to the Score the Shore survey; an area that is defined as 100 feet along the land-water interface and 50 feet lakeward.
contributing watershed	In this report; the upstream catchments that drain or have the potential to drain to a lake.
Division of Waters number (DOW)	In this report; a unique identification number for water basins in Minnesota. They follow the format of XX-YYYY-ZZ where XX is a county code, YYYY is the basin number in that county, and ZZ is the sub-basin identifier.
emergent	In this report; a plant that is rooted in lake substrate and has leaves and stems which extend out of the water. Floating bogs are considered emergent plant stands.
fish-based lake index of biological integrity (FIBI)	An index developed by MNDNR that compares the types and numbers of fish observed in a lake to what is expected for a healthy lake (range from 0 – 100). More information can be found at Lake Index of Biological Integrity website.
floating-leaf	In this report; a plant that is rooted in lake substrate and has its leaves and flowers floating on the water surface.
impervious	A surface that promotes overland flow of precipitation as opposed to allowing it to seep into the ground.
Index of Biological Integrity (IBI)	A tool utilized to measure a biological community's response to human disturbance.
intolerant species	A species whose presence or abundance decreases as human disturbance increases.
littoral acres	In this report; the acres of a lake that are 15 feet deep or less.
National Land Cover Database (NLCD)	A database that utilizes remote sensing at a 30 meter spatial resolution to classify land cover into one of 16 classes.
nearshore survey	In this report; a fisheries survey conducted at evenly spaced, but random sites along the shoreline utilizing 1/8 inch mesh seines and backpack electrofishing to characterize primarily the nongame fish community of a lake.
predator fish	A fish species that derives the majority of its energy and nutrients through the consumption of other vertebrate animals.
riparian	Situated on the bank of a watercourse or lake.
Score the Shore (StS) survey	A survey designed to be able to rapidly assess the quantity and integrity of lakeshore habitat so as to assess differences between lakes and detect changes over time.
shoreland	In relation to the Score the Shore survey; an area that is defined as 100 feet along the top of bank landward for either 100 feet or until the base of a structure such as a cabin, whichever is less.

Term	Definition
shoreline	In relation to the Score the Shore survey; an area that is defined as 100 feet along the land-water interface and landward to the top of bank.
small benthic-dwelling species	A species that is small and predominantly lives in close proximity to the bottom.
species richness	A count of species.
submersed	In this report; a plant that has stems and leaves that grow entirely underwater, although some may have floating leaves or emergent flowers.
tolerant species	A species whose presence or abundance does not decrease, or may even increase, as human disturbance increases.
vegetative-dwelling species	A species that has a life cycle dependent upon vegetated habitats.
weight of evidence approach	A method of using multiple sources or pieces of information to classify a waterbody as impaired

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