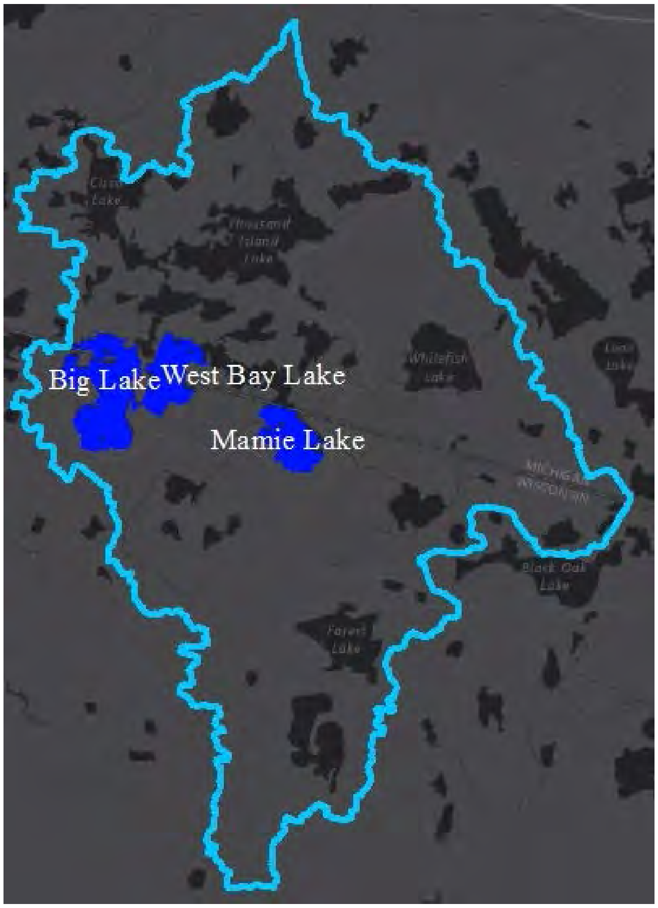
CISCO CHAIN RIPARIAN OWNERS ASSOCIATION

Comprehensive Management Plan for Cisco Chain of Lakes

Wisconsin Department of Natural Resources
Lake Management Planning Program



Plan Approved

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1. Executive Summary

This document describes a plan for the long-term management of the Wisconsin waters within the Cisco Chain of Lakes (Cisco Chain). This plan was developed only for the Wisconsin waters of Big, West Bay and Mamie Lakes in accordance with grant stipulations from the funding agency, the Wisconsin Department of Natural Resources (WDNR). To enhance communication to the broadest range of audiences, this plan is structured such that the level of technical detail increases throughout the document. The Executive Summary is intended as a non-technical summary for all audiences. Sections 2 through 6 provide increased detail and background information to help the reader better understand the social and ecological components of the Cisco Chain ecosystem and rationale for different management recommendations. Appendices A through F are intended for more technical audiences and focus on an exhaustive presentation/discussion of the exiting data sets and management recommendations for different elements of the Cisco Chain ecosystem.

Successful management of the Cisco Chain is dependent on an understanding of the relationship between the desired "use" of the lakes and the physical, chemical, biological and social processes that shape the lake ecosystem. To this end, the plan is comprised of an assessment of 1) the use and value of the Cisco Chain, 2) its current condition and the potential problems affecting it; and 3) the existing policies in place to protect it into the future.

To describe how the Cisco Chain is used and valued by different groups, this plan was developed though collaborative input from the Cisco Chain Riparian Owners Association(CCROA), Wisconsin Department of Natural Resources, Vilas County and informed by a user survey (administered by Northland College). Based on this process, it is obvious that the Cisco Chain is an important ecological and social resource that is used and valued by different groups for different reasons. Across multiple questions in the survey, the majority of respondents highlighted the value of the Cisco Chain as both a site for recreational activity and an important ecological resource that should be protected for the benefit of our natural world and use by future generations. From this process, a series of goals were developed to guide the management of the Cisco Chain into the future.

- Maintain Current Levels of Motorized and Non-motorized Use
- Maintain Scenic Beauty of the Cisco Chain
- Protect and Restore Nearshore and Shoreline Habitat
- Maintain Existing Water Levels and Hydrologic Processes
- Maintain Existing Water Quality Conditions
- Maintain Diverse Native Plant Communities
- Maintain Diverse Native Fish Communities
- Increase Walleye Population Densities
- Maintain Access for Tribal Fish Harvest

To achieve these goals, it was first necessary to assess the current conditions of the Cisco Chain ecosystem. To this end, a two year study was conducted to summarize the existing data describing the health of Big, West Bay and Mamie Lakes and develop new data sets to describe important processes throughout the ecosystem. Elements of the Cisco Chain that were assessed include: Physical and Chemical Processes; Land Use and Runoff; Water Quality Conditions; Organisms and their Habitat; Invasive Species and Ecological Processes. From these studies, a number of important findings emerged.

The Cisco Chain is a relatively healthy lake system and these conditions are created and sustained by a variety of ecological processes. The most significant elements of the Cisco Chain ecosystem that enable its high quality conditions are the 1) diverse native communities of fish and plants that make up the Cisco Chain food web and 2) relatively limited levels of land use change (away from native vegetation) that exist throughout the watershed.

Despite its relatively healthy conditions, a number of potential problems are currently impacting, or have the potential to impact, the Cisco Chain in the future. Water quality in the Cisco Chain, although relatively stable, has likely degraded over the last 100 years, likely in response to increased levels of development along shoreland areas. Given the expected increases in population and changes in land use throughout the area, water quality has the potential to decline in the future—although anticipated changes would likely be small. Additionally, potential changes in land use, particularly in shoreline development have the potential to alter the availability and quality of nearshore habitat, as well as the aesthetics of the shoreline area. Although the biological communities within the Cisco Chain are relatively diverse, changes in the fish community have occurred in recent years and a number of pathways exist that have resulted in invasive species introductions.

A range of federal, tribal, state and local laws, rules and regulations are in place to protect the Cisco Chain and its uses. However, existing policies do not adequately address all current and potential future problems that may affect the Cisco Chain. The elements of the Cisco Chain ecosystem that are best protected by existing regulations are the potential impacts to water quality by any future pollutants discharged from municipal and/or industrial facilities and any artificial changes in water levels (increases or decreases). The elements of the Cisco Chain ecosystem that are least effectively protected are potential changes in shoreline habitat quality and aesthetics and the potential runoff of nutrients to the lakes from future land uses with higher densities of urban/residential development.

The recommendations in this plan are based on a 1) comprehensive inventory and assessment of the existing uses for the Cisco Chain, 2) current conditions of the lake system and 3) existing policies that govern the protection and management of the lakes. However, like all management plans, it is not possible to gather all of the data necessary to fully describe the relationship between human use and ecosystem health, or fully anticipate what future conditions will look like. As a result, the management recommendations are summarized in two forms: things that could (potentially should) be done now and things we should learn more about to make better informed decisions in the future.

Things that could be done now include:

1. Integrate updated climatological data sets into design standards for new development throughout the watershed.
    a. *Why? – Data historically used to size infrastructure (e.g., culverts and bridges) do not reflect current rainfall patterns and more up-to-date data are available.*

2. Continue and expand efforts to monitor, prevent, rapidly detect and respond to invasive species in the Cisco Chain.
    a. *Why? – Current impacts from aquatic invasive species are minimal in the Cisco Chain and preventative efforts are generally more effective than reactive efforts to manage*

invasive species. Hand pulling efforts are most likely to be effective in Big Lake given the observed growth patterns of Eurasian Watermilfoil.

3. Implement efforts to formally designate areas of critical habitat to protect aquatic organisms throughout the lakes.
    a. *Why? – Nearshore and shoreline areas in the Cisco Chain are critical to the lake ecosystem and areas with the highest quality habitat are somewhat disconnected and isolated. Efforts to protect these areas will likely have a disproportionate high benefit to the long-term health of the lakes.*

4. Implement efforts to restore areas of localized shoreline habitat degradation.
    a. *Why? – Shoreland habitat restoration and management represent one of the largest opportunities for short-term improvement in lake condition and long-term protection of lake function. WDNR has a range of grant programs to facilitate shoreline restoration.*

5. Implement recurring monitoring programs that characterize user perceptions and water quality conditions over time.
    a. *Why? – User experiences and water quality conditions are primary drivers of management recommendations. Tracking changes over time will help evaluate the success of management efforts and identify potential future needs.*

Things we should learn more about:

1. Comprehensively evaluate the ability of local land use and zoning policies to effectively manage water quality and aesthetics in the Cisco Chain into the future, with particular attention to the potential impact of anticipated future climate conditions.
    a. *Why? – Current land use and zoning policies are based on existing environmental conditions and may or may not be well suited to anticipated changes in climate and land use development. Recent changes in state law may alter the protection of shoreland habitat.*

2. Investigate the feasibility of seasonal water level drawdowns throughout the Cisco Chain of Lakes.
    a. *Why? – Water level fluctuation is a critical element of healthy lake ecosystems and helps buffer against invasive species establishment. Current outlet regulations at the Bond Falls dam call for nearly consistent water levels year round, which limits much of the natural variability in lake level fluctuation that is common throughout the region.*

3. Locate and map important spawning grounds for different species and important sites for fish harvest by Native American tribal members to facilitate long-term protection.
    a. *Why? – Locations are currently undocumented and may be inadvertently affected by changes in development around the lake shoreline. Identification could help prevent potential impacts to fish spawning and conflict among users into the future.*

2. Introduction

Successful management of the Cisco Chain is dependent on an understanding of the relationship between the desired “use” of the lakes and the physical, chemical, biological and social processes that shape the lake ecosystem. Throughout this document the word “use” will be used to describe all of the potential ways in which people directly use (e.g., fishing and boating), interact with (e.g., wildlife observation) and value (e.g., a site for the conservation of species and native ecosystems) the Cisco Chain. Throughout this document the term Cisco Chain will be used to describe Wisconsin lakes (i.e., Big, West Bay and Mamie Lakes) within the Cisco Chain of Lakes. Wisconsin lakes were targeted in the management plan in accordance with guidance from the funding agency, the Wisconsin Department of Natural Resources (WDNR).

The Cisco Chain is used by different groups for different purposes. For example, some individuals may use the lakes primarily for fishing or boating, while others (or perhaps the same individuals) may use the lakes as a place for natural resource conservation or as a source of peace and relaxation. The Cisco Chain ecosystem supports each of these different uses through a combination of the physical, chemical, biological—and in some cases, social—processes that shape the lake ecosystem and experience of its users. For example, use of a lake as a fishery may be primarily based on its ability to support different species at different sizes and population densities, while use of a lake as a site for relaxation maybe primarily influenced by the number and type of watercraft on the water.

Because different uses of the Cisco Chain are dependent on different ecological and social processes, changes (often referred to as “stressors”) that alter the lake ecosystem or its corresponding social conditions can undermine the ability of different groups to use the lake in the desired way. For example, changes in land use surrounding a lake may lead to decreased water quality, which may limit the utility of the lake for swimming (or other desired uses). Additionally, different uses of the lake may be in direct conflict with each other (often referred to as “incompatible uses”). For example, a desired use of the lake for increased motorized watercraft usage may be incompatible with a desired use of the lake as a site for relaxation and quiet interaction with the natural world.

Thus, to effectively manage the Cisco Chain, it is necessary to:

1. Develop a series of goals that protect and/or restore the most highly valued uses for the lakes by different user groups
2. Describe the conditions of the physical, chemical, biological and social processes that enable and sustain these different uses
3. Identify any potential stressors or use incompatibilities that limit the ability of different groups to use the Cisco Chain in the desired way
4. Identify management options to protect and/or restore the desired use of the lakes and reconcile any potential conflicts among user groups

To promote the health, management and restoration of lakes throughout the state, the WDNR has developed a series of programs and funding sources. Through the WDNR Lake Programs, lake associations, local governments and a variety of other stakeholder groups can access technical resources and grant programs to enhance water quality, prevent and control invasive species introductions, restore shoreland habitat and develop local ordinances. This plan was enabled by funds from a series of WDNR Lake Planning grants (LPL-1511-13, LPL-1531-14) and the Cisco Chain Riparian Owners Association (CCROA) and developed collaboratively through volunteer contributions from the CCROA and technical contributions from Northland College, WDNR and a range of different local, state, federal and tribal agencies.

2.1. Structure of the Plan

This plan is comprised of a series of sections that link the use, conditions and potential management option for the lakes:

1) **Lake Uses and Users -** summarizes who primarily uses the Cisco Chain and how it is used and valued by different groups

2) **Management Goals -** describes specific goals to protect and/or restore the ecological and social conditions necessary to sustain desired uses and values for the Cisco Chain

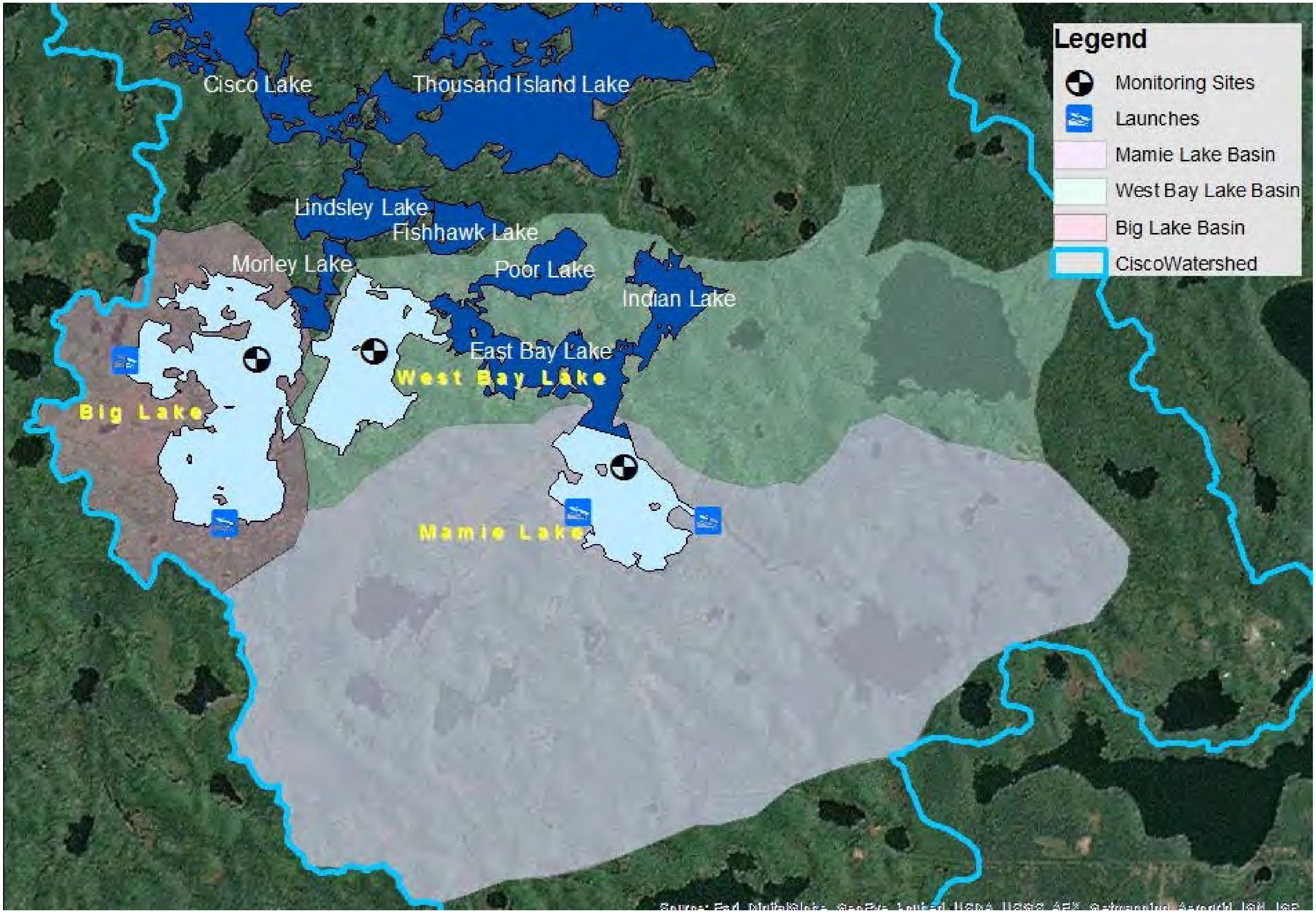
3) **Lake Condition Assessment** - summarizes the historical and newly collected data that describe the conditions of the physical, chemical and biological processes that shape the Cisco Chain ecosystem

4) **Stressor Identification** - describes processes that are likely (now or in the future) to adversely affect the health of the Cisco Chain

5) **Policy Analysis -** summarizes how effective the current rules and regulations are to address the stressors that are affecting (or likely to affect) the Cisco Chain

6) **Management Recommendations -** summarizes potential actions to protect and restore the Cisco Chain

7) **Appendices -** provided detailed assessments and management recommendations related to water quality, shoreland habitat, watershed land use, aquatic plants and invasive species and lake ecosystem dynamics



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP

Figure 2.1. The Cisco Chain and its watershed.

3. Lake Uses, Users and Access

The Cisco Chain (Big Lake, WBIC Code – 2963800; West Bay Lake, WBIC Code – 2964000; Mamie Lake WBIC Code – 2964100) is primarily used as a recreational and fishery resource by local residents, regional outdoor enthusiasts and Native American First Nations. The Cisco Chain (Wisconsin Lakes only) has two public and two undeveloped access points and one public beach (Figure 2.1). Many residents and shoreland owners are actively involved in efforts to understand and protect the health of the lakes. The Cisco Chain has an active association (the CCROA; http://www.ciscochainroa.com/about-us.html) that hosts an annual lake association meeting and distributes quarterly newsletters to lakeshore property owners to increase awareness and understanding of emerging issues and ongoing management initiatives.

The Cisco Chain fishery supports both recreational and Tribal harvest. One creel survey has been conducted on Big Lake to assess recreational usage and harvest (Tobias 2009). Results from this survey suggests that recreational fishing pressure in the Cisco Chain has declined over time. Species-specific harvest rates are described in greater detail in Section 5.5.

3.1. Stakeholder Survey

To further assess the usage patterns and users of the Cisco Chain, a stakeholder survey was conducted. The survey was structured to answer four main questions about the lakes and it users:

1) How is the Cisco Chain currently used?
2) Of these uses, which are most important and/or highly valued?
3) What are the general attitudes among lake users relative to different ecological elements and potential stressors to the lake system?
4) How important is the Cisco Chain in the lives of different user groups?
5) What are the general value sets and beliefs that lake users likely base their actions on?

A census sample (i.e., the entire population) of households within one mile of the lakeshore of Cisco Chain was drawn from Vilas and Gogebic County records. After removing undeliverable surveys, duplicate landowners, or vacant properties, the final sampling size was 640 households or businesses. Surveys were delivered via mail using a modified Dillman method, where respondents were contacted prior to receiving their survey, sent the survey, and then sent a reminder if they did not return the survey within about a two week period. Surveys were sent out and received between October, November and December of 2014 with a 43.9 percent (or 281 surveys) response rate. Survey respondents generally represented the general population in the area. Average age of survey respondents was 65.9 years (ranging from 37 to 96), with an average income of $60,000-$99,000 per year. Of the respondents, ~94% were waterfront owners and 25% were year round residents.

Several trends emerged from the survey responses that highlight the how different individuals and groups use and value the lakes (Figure 3.1). Survey responses are summarized below with respect to the primary survey questions. Complete survey responses can be reviewed in Appendix A.

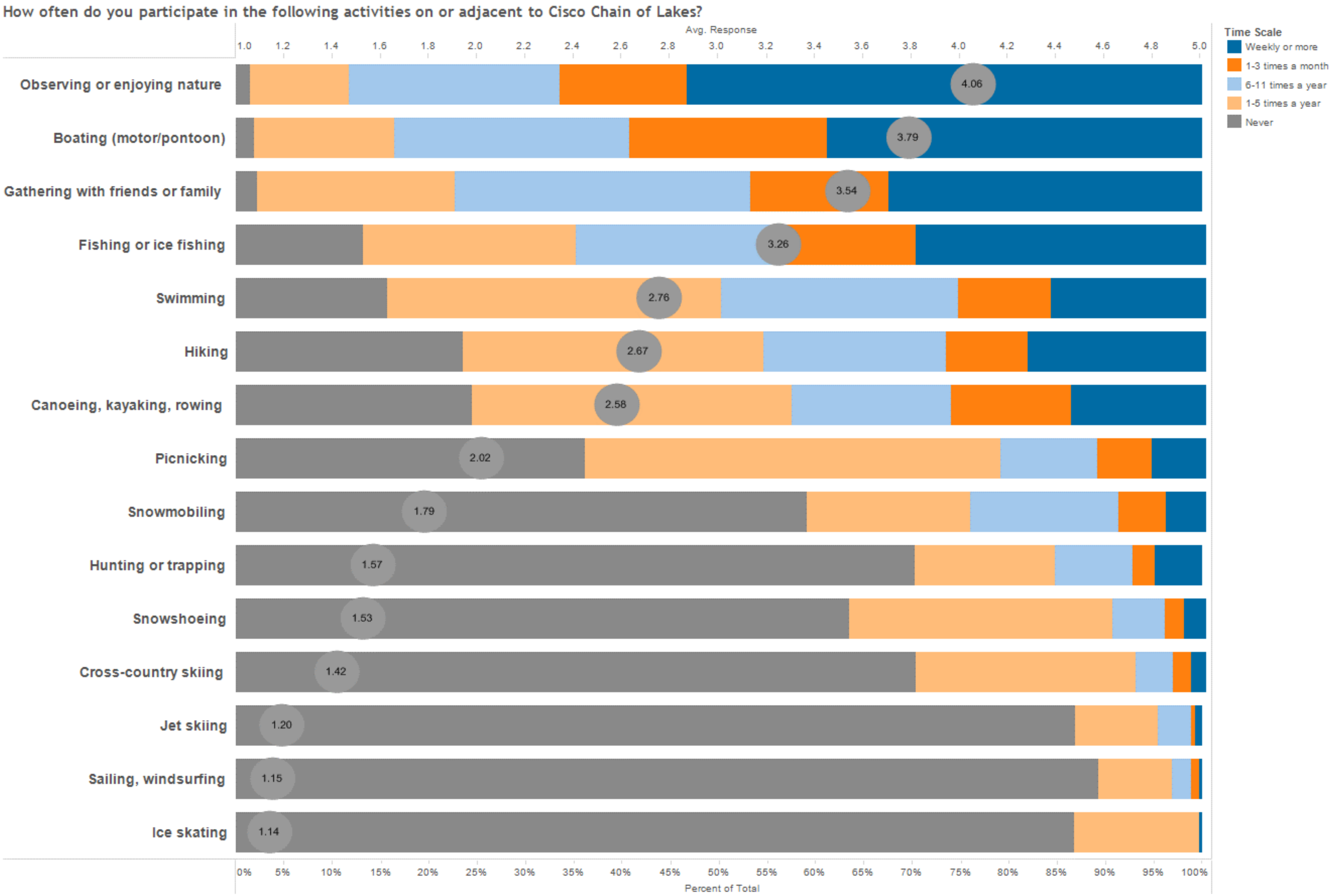


Figure 3.1. Most highly valued uses of the Cisco Chain by survey respondents.

How is the Cisco Chain currently used?
The Cisco Chain is most heavily used as a recreational resource by survey respondents. Among these uses, observing nature, gathering with friends, boating and swimming were the most common activities. Fisherpersons, most typically fished walleye and sunfish, although many indicated an interest in more opportunity to catch walleye.

Which potential uses are most important and/or highly valued by different user groups?
Among the different potential uses of the lakes, those that were most highly valued were: enjoyment of scenic beauty; gathering with family and friends; maintaining a sense of peace and relaxation; and observing and enjoying nature. Fishing and motorized boating were relatively highly valued by many individuals.

What are the general attitudes among lake users relative to different ecological elements and potential stressors to the lake system?
In general, most survey respondents described the Cisco Chain as a relatively quiet, peaceful place that they care for deeply and are concerned that declines in its health would directly impact their wellbeing. Respondents generally preferred lake conditions that most closely reflect natural areas of little observable human disturbance.

How important is the Cisco Chain in the lives of different user groups?
The Cisco Chain is clearly an important part of the lives of those who use and interact with it. The majority of survey respondents indicated significant willingness to alter their behavior and/or financially contribute to enhance/protect the quality of the lakes—in many cases, even if they were not likely to have opportunities to routinely use the lakes.

What are the general value sets and/or beliefs that lake users likely base their actions on?
In general, survey respondents see the Cisco Chain as a place to live and recreate and as an ecosystem that should be protected into the future for the sake of natural resource conservation and use by future generations. Respondents indicated a sense of responsibility for the long-term management/stewardship of the lakes and a recognition that declines in the lakes' health would adversely affect their wellbeing.

3.2. Use and Value Priorities

Based on results of the stakeholder survey and ongoing planning process, a series of priority uses for the Cisco Chain ecosystem were identified. The following values were used to development management goals to protect and/or restore the Cisco Chain ecosystem into the future.

- Aesthetics and scenic beauty
- Observation of the natural world
- Protection of the Cisco Chain ecosystem
- Relaxation and social gathering
- Boating (motor and non-motorized)
- Swimming
- Fishing

4. Management Goals

A series of goals were developed to protect and restore the ecological and social conditions that support the most highly valued uses and natural elements of the lakes. Goals were developed through input from a user survey (described above) as well as a series of public and steering committee meetings. The scope and extent of planning meetings is described below.

4.1. Grant Development Meetings

In the years leading up to initiation of this planning project, a series of meetings were held with representatives from the CCROA and WDNR to develop the scope of work to be conducted. From these initial meetings, concerns were raised about potential changes in water quality and the fishery, as well as the potential for invasive species impacts.

4.2. Public Meetings

In both 2013 and 2014, project summaries were presented to the CCROA membership and Board of Directors. Presentations focused on current results and solicitation of input regarding potential management considerations for the lakes. Additionally, many members were appreciative and supportive of proactive steps to prevent any degradation in the lakes.

4.3. Technical Team Meetings

Following the completion of field work in year one, a technical team meeting was held with representatives from the CCROA, Vilas County and WDNR. Discussions at this meeting were focused on a review of new data and a preliminary conversation regarding potential management goals for the plan.

4.4. Draft Plan Review

Input from the stakeholder survey and planning meetings were integrated to develop a series of management goals for the plan. These goals (and the corresponding draft plan) were submitted for review by the CCROA, WDNR, Vilas County and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC).

The goals that emerged from the stakeholder survey and public meetings are listed below:

- Maintain Current Levels of Motorized and Non-motorized Use
- Maintain Scenic Beauty of the Cisco Chain
- Protect and Restore Nearshore and Shoreline Habitat
- Maintain Existing Water Levels and Hydrologic Processes
- Maintain Existing Water Quality Conditions
- Maintain Diverse Native Plant Communities
- Maintain Diverse Native Fish Communities
- Increase Walleye Population Densities
- Maintain Access to Tribal Fisheries

5. Lake Condition Assessment

The Cisco Chain is located in Northern Vilas County on the Michigan border (Figure 1.1). The lake conditions and processes that are necessary to support the desired uses identified above for the Cisco Chain are influenced by a variety of physical, chemical and biological processes. This section describes the current conditions in and around the Cisco Chain with respect to: Climate and Precipitation; Physical Habitat and Hydrologic Processes; Watershed Conditions; Water Quality Conditions; Biological Communities; and, Ecological Interactions.

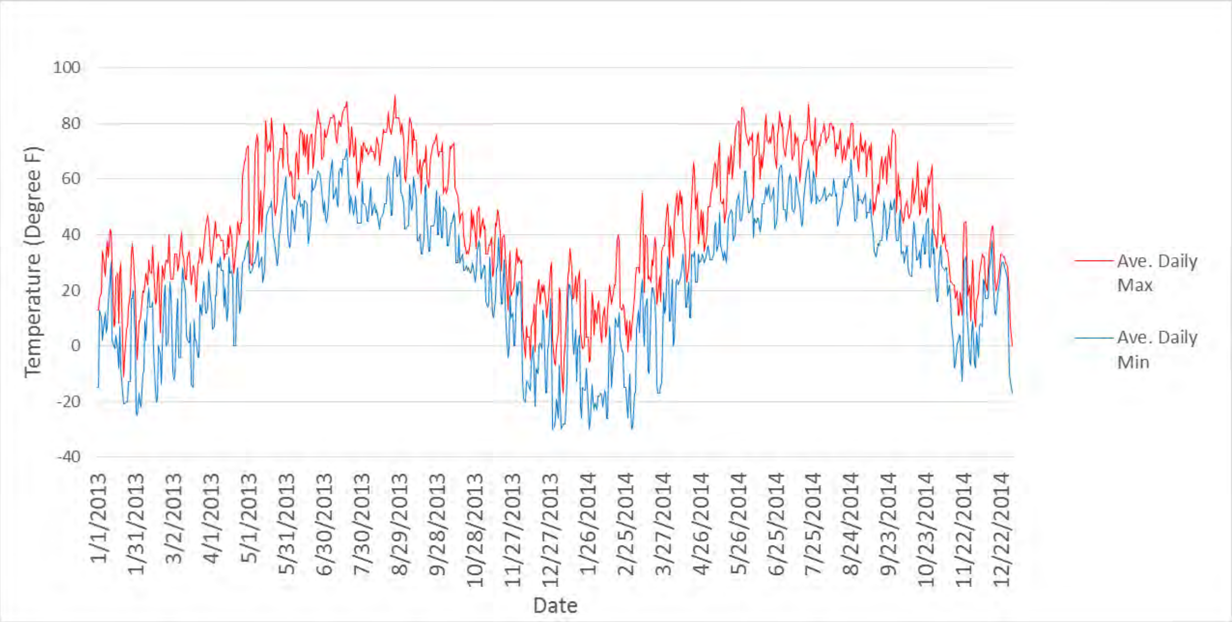


Figure 5.1. Minimum and maximum daily air temperatures through study period.

5.1. Climate and Precipitation

Climate in the Cisco Lakes area is considered continental, but is moderately affected by the Lake Superior climate zone. Summer daily temperatures average 58.6 ^{o}F and winter daily temperatures average 22.6 ^{o}F (Figure 5.1). Annual rainfall precipitation averages 32.2 inches, while average annual snowfall is approximately 92 inches. Historically, the 100-yr, 24-hour precipitation event was expected to yield 4.3 inches and most engineering design throughout the area is based on the TP-40 values (Figure 5.2; Hershfield, 1963). However, precipitation recurrence intervals were recently updated in Atlas 14 (Perica et al. 2013) to account for increased spatial resolution in climatological data and account for any shifts in precipitation patterns over the last ~50 years.

Based on these updates, the 100-year, 24-hr precipitation event in the Cisco Chain area is now expected to yield 6.1 inches (a ~30% increase). However, the Atlas 14 precipitation estimates have only recently become available and have not been incorporated into engineering design and watershed planning work.

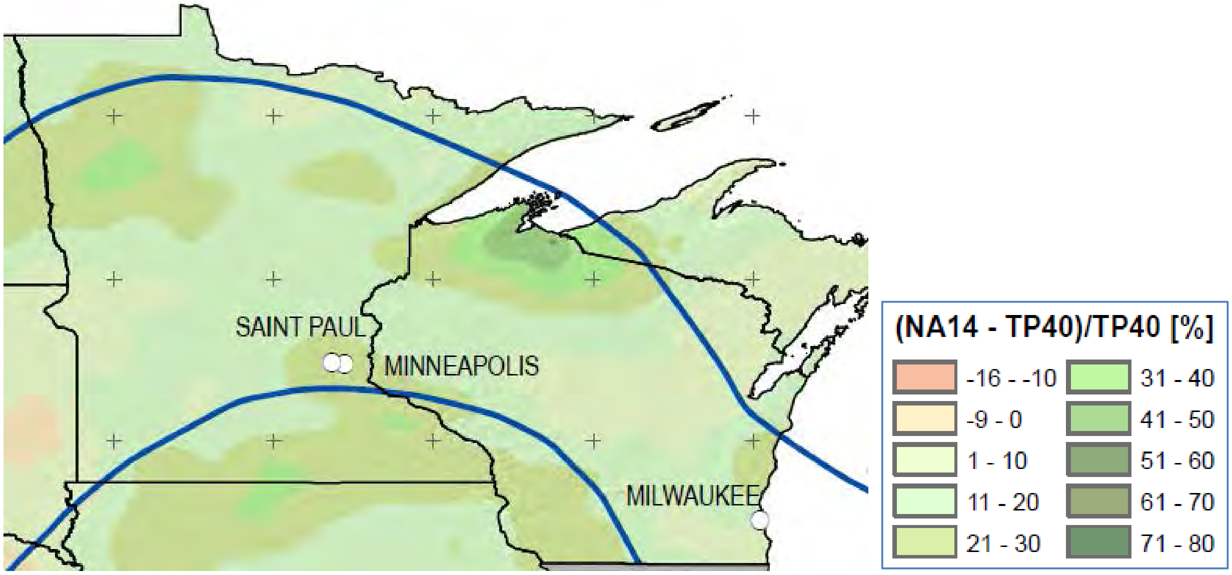


Figure 5.2. A comparison of the percent change in the 100-year, 24-hour precipitation events between the Atlas 14 and TP 40 publications. Adopted from Atlas 14 (Perica et al. 2013).

Additional changes in precipitation and atmospheric temperatures are anticipated throughout the region as a part of global climate change. As part of the Wisconsin Initiative on Climate Change Impacts (WICCI; http://www.wicci.wisc.edu/) as series of studies were conducted across Wisconsin to assess existing, and project future, climatically driven changes in environmental conditions. The major findings of this multi-year assessment (as is related to lake management) are that precipitation patterns are likely to become more intense and less frequent (i.e., increased potential for both drought and flooding) and that annual average temperatures are likely to increase. Evidence suggests that some of these changes may already be occurring, but that the rates of climate change are likely to increase into the future.

5.2. Physical Habitat and Hydrologic Processes

Physical habitat in the Cisco Chain is shaped by a combination of the local geology, topography, landscape position of the lakes and nearshore land use. Different species of plants and animals in lakes require different habitat types and conditions. As a result, lakes that retain the greatest diversity of habitat types often sustain the highest levels of biological diversity and support the widest range of uses. Although many habitat types are most easily viewed as a static “snapshot” of the lake (e.g., how many down trees are in the water), the relative occurrence of different habitat types is highly dependent on many dynamic processes (e.g., range of high and low water levels) that are less easily perceived in a snapshot.

Geology

Geology throughout the Cisco Chain watershed was primarily created by glacial activity ~9,500 to 23,000 ybp. As such, much of the existing geology is dominated by glacial till and outwash (Figure 5.3). Soils are comprised of a range of hydrologic soil groups, with A and B groups dominating upland areas and C and D groups dominating nearshore areas. In general, soils have high infiltration rates which facilitate groundwater flow to the lakes.

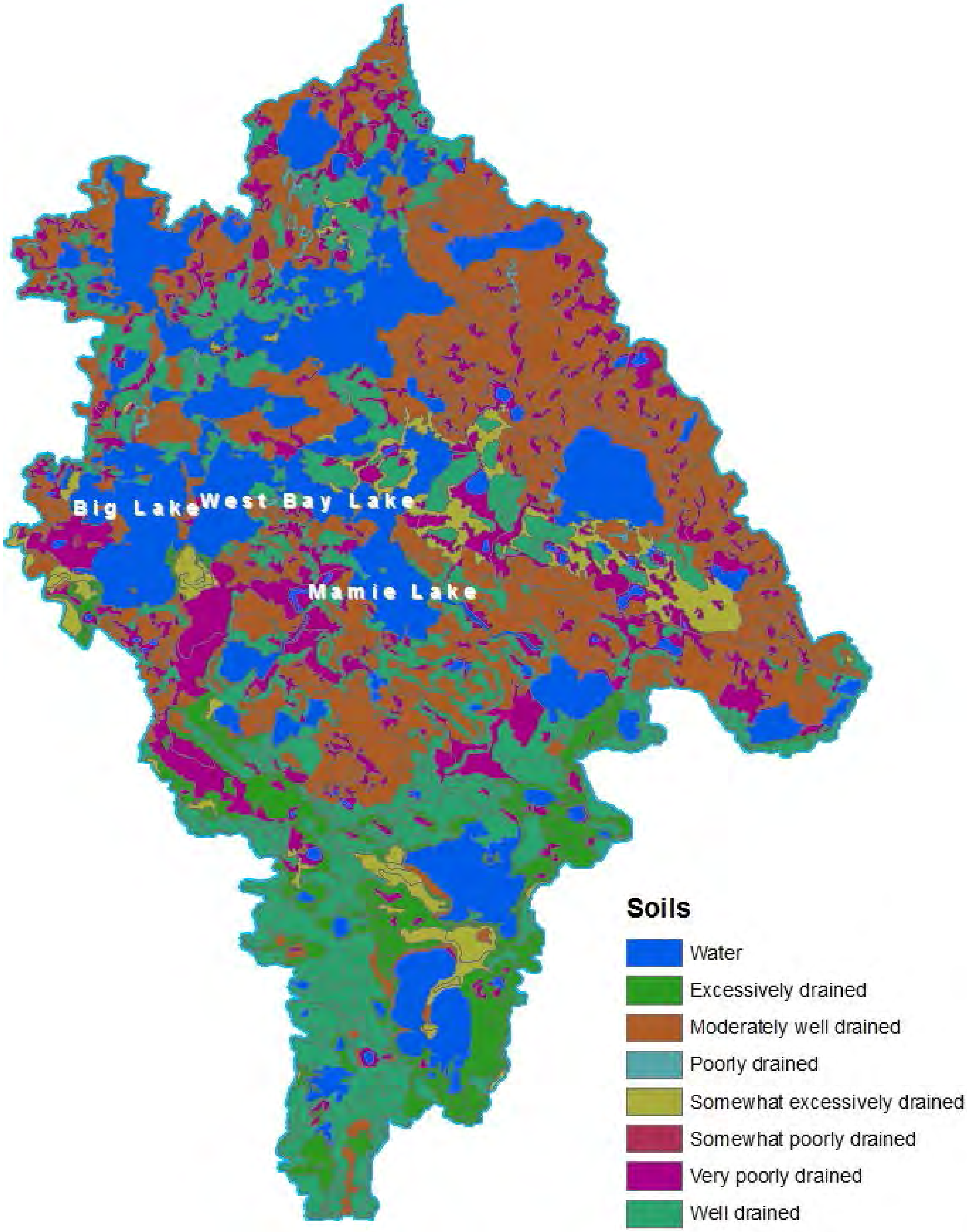


Figure 5.3. Distribution of soil groups throughout the Cisco Chain watershed. Based on Natural Resource Conservation Service (NRCS) SURRGO soil classifications.

Bathymetry
Cisco Chain is a 1487 acre (Wisconsin lakes only), drainage-based system with a maximum depth of 30 feet and an average depth of 20 feet (Figure 5.4). Lakes throughout the Cisco Chain are irregularly shaped with a series of long, narrow bays. Despite the irregular basin shape, the maximum fetch in the lakes is 2.1 miles.

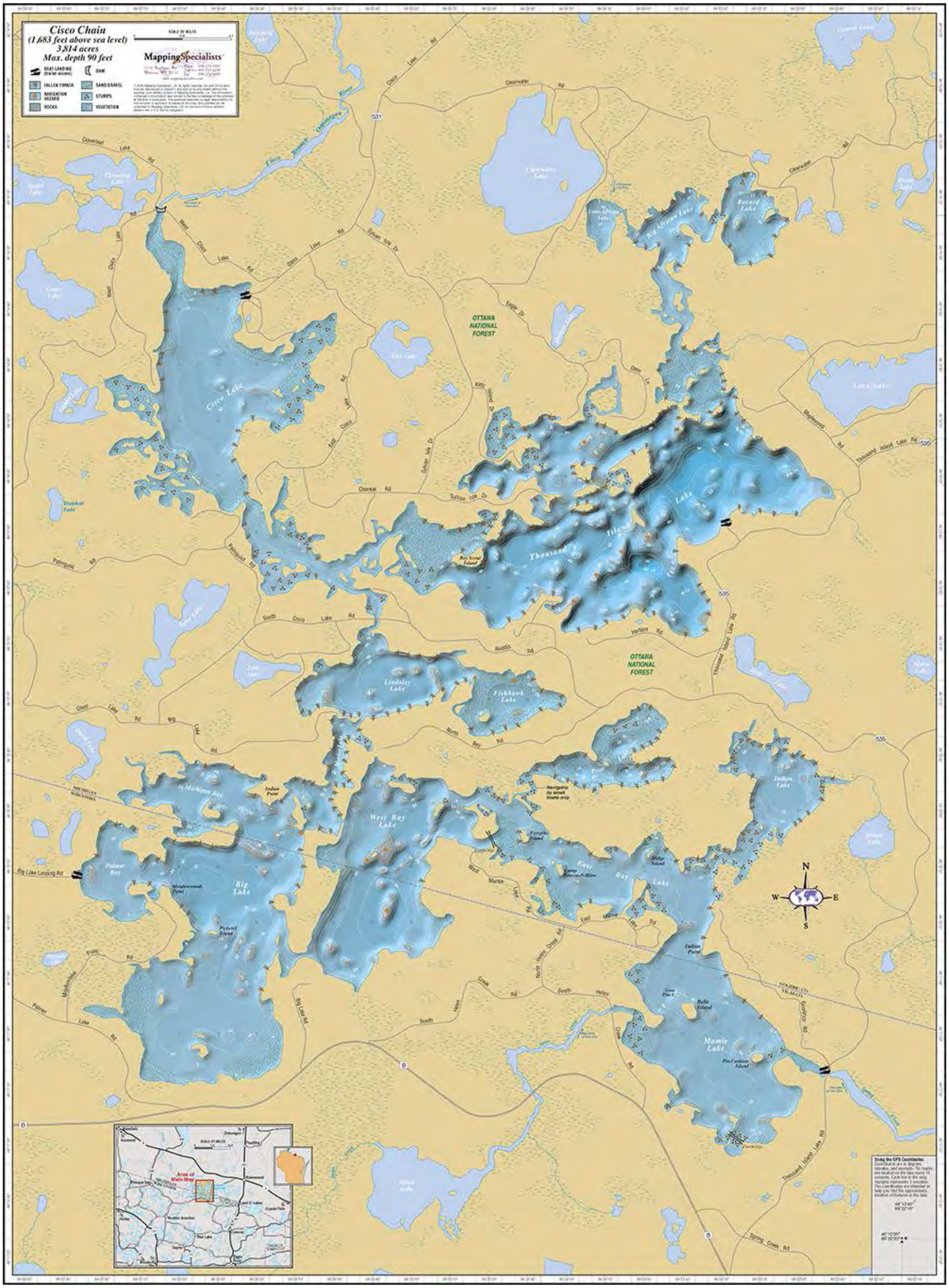


Figure 5.4. Bathymetry of the Cisco Chain of Lakes (Adopted from: www.mapspecialists.com).

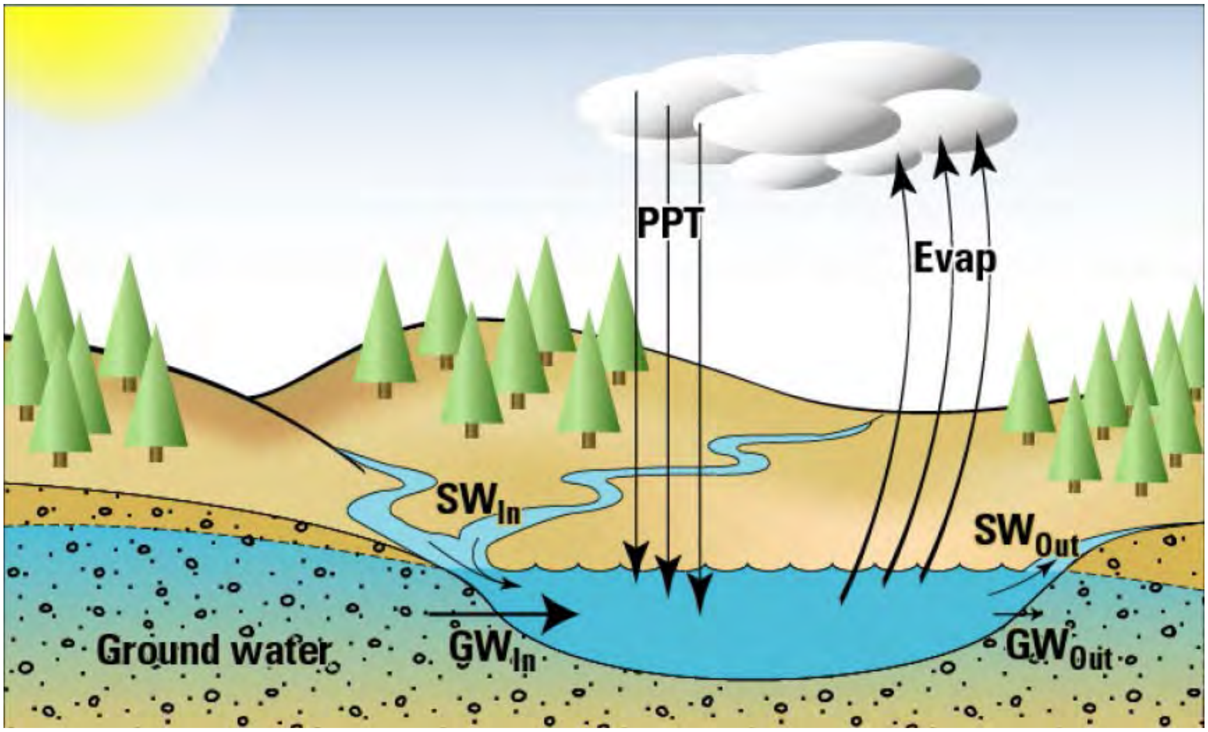


Figure 5.5. Conceptual schematic describing the surface water (SW), groundwater (GW). Precipitation (PPT) and evaporation (Evap) that determine lake levels (adopted from Krohelski, 2003).

Hydrologic Processes
The volume of water in a lake is determined by its bathymetry and the relative inputs and losses (outputs) of water to and from the surrounding atmospheric, groundwater and surface water systems (Figure 5.5). The relative influence of these different systems varies among lakes, and within each specific lake, as the rate and timing of precipitation vary throughout the season. The relationship between the different inflow and loss process in the lake (i.e., its water budget) is heavily influenced by its landscape position (Figure 5.6). In general, groundwater and atmospheric systems are the most important drivers of hydrologic processes in lakes that have a high landscape position (i.e., headwater and/or seepage lakes). As lakes exist further downstream in a watershed system, the more important surface water becomes as an input and loss mechanism. Thus, hydrologic processes in lakes with the lowest landscape position are dominated by the influence of surface water inflow and outflows.

Water Level Fluctuation
Lake levels fluctuate on annual and multi-year time scales. In northern Wisconsin, lake levels are generally highest following spring snow melt and rain and lowest in late summer, fall and winter. Throughout any given year, water levels rise and fall in response to the size and timing of precipitation events. Across years (potentially decades), lake levels maintain different points of equilibrium—in drought years, water levels are generally lower, while in wet years, lake levels are generally higher. Over time, different high water events leave marks on the shoreline that designate the Ordinary High Water (OHW) mark, which has important regulatory and management implications (see Section 7.1 for additional detail).

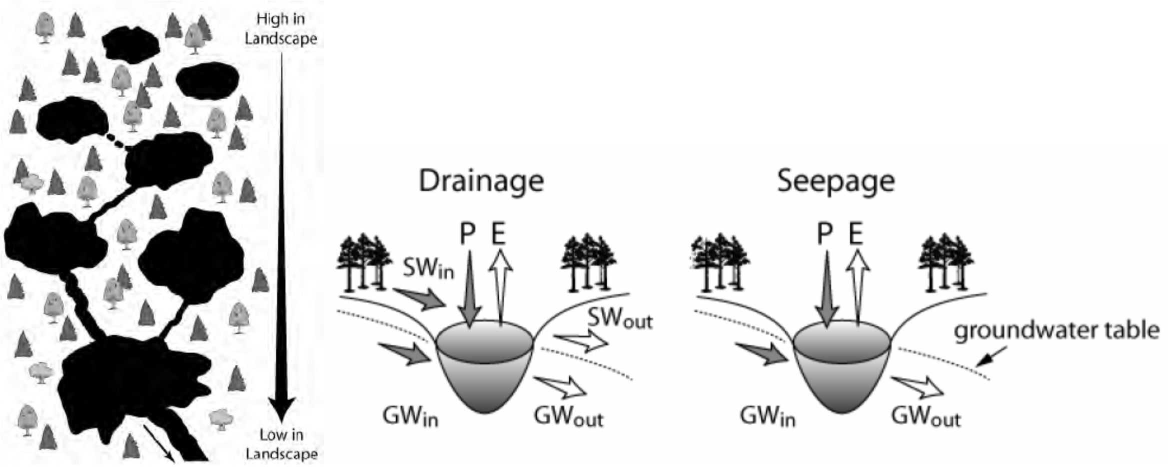


Figure 5.6. Conceptual diagram of "landscape position" and the differences in hydrologic processes between drainage and seepage lakes. Modified from Magnuson et al. 2006.

Water level fluctuation is critical to the health of a lake because it is often a primary process that creates conditions that favor diverse biological communities. Different species (particularly aquatic plants) are better adapted to wetter or dryer conditions—and some are generalists across this range. As water levels fluctuate, no particular species becomes dominant and the biological communities are pushed toward a state of greater diversity that corresponds to different water levels throughout the lake. Similarly, as water (and ice) levels fluctuate, shoreline sediments erode away to an "angle of repose", where erodible soils gradually transition to the water's edge and sediments are anchored by vegetative root structures. When water levels are held constant (particularly at higher levels), the dynamic processes that promote biotic diversity are reduced and rates of shoreline erosion can become increased through wind and wave erosion and "ice-jacking" events (biological diversity in lakes is described in greater detail below).

Stratification and Mixing

Most deep lakes (>15 feet) in northern Wisconsin develop distinct layers throughout the summer (and occasionally winter) months (i.e., stratification; see Figure 5.7). Water is most dense (and heaviest) at a temperature just above freezing. As ice and snow melt in the spring, the "heaviest" water in the lake is at the surface—as this heavy water sinks to the bottom, the lake becomes well mixed (i.e., it "turns over"). In this mixed condition, the temperature and chemistry of the water is essentially uniform from top to bottom. As the lake warms throughout the summer, the surface waters increase in temperature faster than deep water, which often results in the development of three layers that have distinct temperature and chemical profiles. Surface waters (or the epilimnion) are generally warmer and have higher oxygen concentrations. Bottom waters (or the hypolimnion) are generally colder and have lower oxygen concentrations. Middle waters (often referred to as the metalimnion or thermocline) generally represent a transition from surface to bottom conditions.

Stratification and turnover are key drivers of lake ecosystems. Over the course of a year (or millennia) nutrients wash into lakes (often attached to sediment particles) and gradually sink to the bottom. As a result, nutrients tend to accumulate in lake sediments over time. When lakes turn over, nutrients that have settled toward the bottom can be re-suspended and made available to stimulate aquatic plant growth (particularly algae). As a lake stratifies, the metalimnion creates a functional barrier between the surface and bottom waters that tends to trap nutrients at the bottom of the lake and minimize the diffusion of oxygen from the atmosphere down into deeper waters. Thus, over the summer, oxygen concentrations tend to decrease in the deep waters (relative to the surface waters).

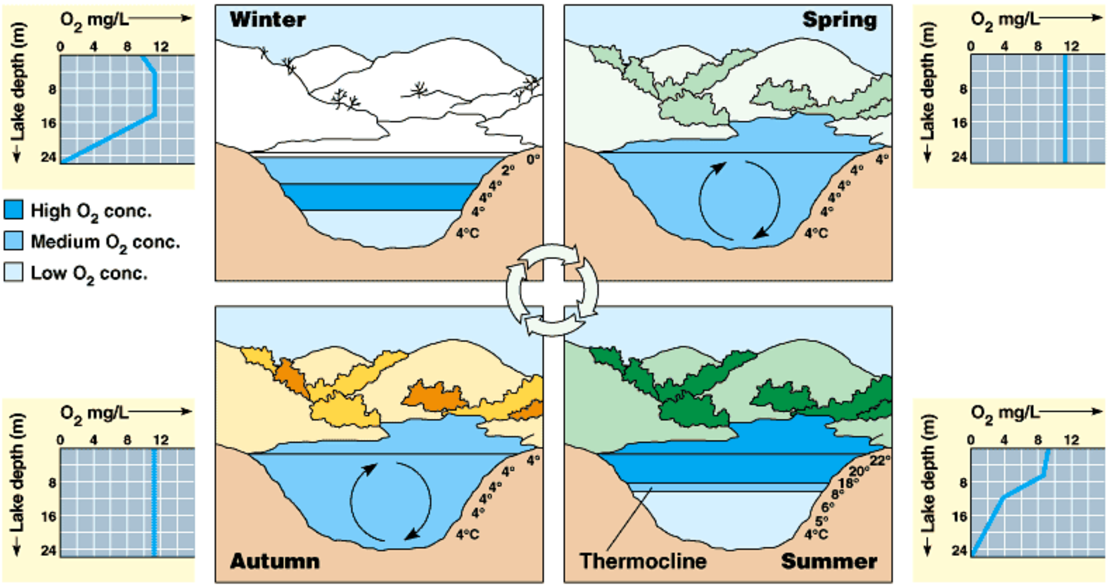


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Figure 5.7. Conceptual schematic of the processes of turnover and stratification and the resulting water quality conditions.

Low oxygen conditions can directly affect a wide range of chemical and biological processes in lake ecosystems. Most directly, low oxygen conditions can result in localized "fish kills" if oxygen levels fall below a critical threshold. Perhaps more importantly, low oxygen conditions along the bottom sediments change the chemical environment from one of oxidizing conditions to one of reducing conditions. This shift in chemical conditions, often facilitates the release of phosphorus (once trapped in the sediments) back into the water column, where it can potentially be used by different organisms (algae in particular). Although low oxygen conditions can have some negative impacts to lake dynamics (e.g., fish kills and nutrient release), there is a significant body of evidence that suggests episodic fish-kills may be an important component of the long-term stability of a lake (particularly in a shallow lake), see Section 5.4 for further discussion.

Shoreland Habitat

The area of transition between the terrestrial and aquatic worlds is often collectively referred to as shoreland habitat. However, shoreland habitat is often broken up into three distinct zones for purposes of lake management (Figure 5.8). The upland zone represents lands that are very rarely, if ever, inundated by water (management of this area is discussed in detail in Section 5.3). The in-lake (or littoral zone) represents the region of the lake where sunlight can penetrate down to the sediments, and rooted plants can grow. The transition zone, or shoreline, is a region of the lake that is rarely (but occasionally) inundated by water, but is linked to the in-lake zone through the processes of erosion, runoff and tree fall.

Coarse woody debris (CWD) is a critical habitat component in the nearshore ecosystems of lakes throughout northern Wisconsin. Shoreline trees fall into lakes as a result of natural die-off and wind and storm events. Once in the lake, this CWD has the potential to remain underwater for decades. In undistributed lake systems, the density of CWD in nearshore areas is often as high as 800 pieces of CWD per kilometer of shoreline. CWD serves as habitat to fish and invertebrates through a variety of processes, and loss of CWD has been shown to dramatically (and rapidly) alter the structure and function of lake ecosystems.

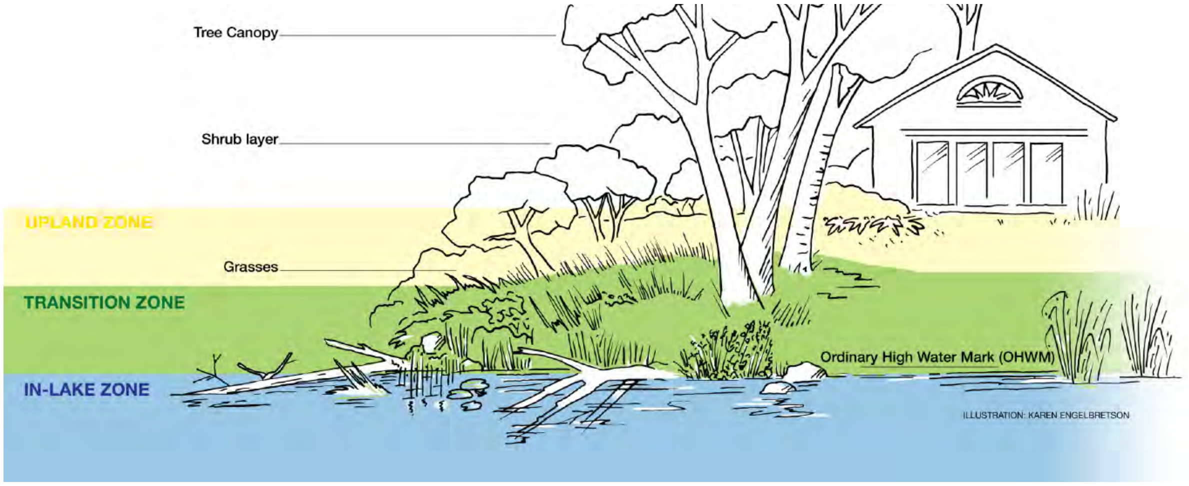

Figure 5.8. Conceptual diagram of the different habitat zones at the land water interface in a lake. Adopted from WDNR Healthy Lakes Implementation Plan, 2014.

Historical Conditions
Historically, relatively little was known about physical habitat and processes in the Cisco Chain. Prior to this study, no data-sets had been developed to describe physical habitat in the Cisco Chain.

New Data Collection
To better characterize shoreland habitat in the Cisco Chain, shoreline and nearshore habitat conditions and the processes of stratification and turnover were characterized over the two year study period. Shoreline and nearshore habitat were quantified using methods described by the Environmental Protection Agency (USEPA, 2007). Following this method, sample transect points were identified at 20 locations around the lakeshore. At each transect, data were collected to describe the habitat conditions and level of disturbance in upland, shoreline and littoral zones of the lake using a series of semi-quantitative ranking criteria. Stratification and turnover processes were assessed following methods outlined by USEPA (2007). Vertical profiles of dissolved oxygen, temperature conductivity and pH were collected at one meter increments every two weeks from one site that represents the deepest hole in each of Big, West Bay and Mamie Lakes. In addition to these internal processes, outflows from the Cisco Chain were tracked over the course of the study period. A more detailed summary of methods, results and management considerations for shoreland habitat and hydrologic processes are provided in Appendices B and C.

Summary Results – Water Budget
Because of their different location throughout the Cisco Chain, each lake has a significantly different watershed area (Figure 1.1). All three lakes are considered to be drainage lakes, but Mamie and West Bay Lakes have considerably larger watershed areas than Big Lake. Results from this assessment confirm the drainage-based classification. Throughout most of the year (except spring) tributary discharge is the dominant source of water to the lakes (Figure 5.9). In the spring, as snow

melts and early season rains are most intense, the majority of water in the Cisco Chain likely comes from watershed runoff. However, as the summer progresses, groundwater likely becomes increasingly important. These results highlight the significance of tributary discharge and outflow regulation as part of the Cisco Chain ecosystem. Because of the connectivity of the Cisco Chain runoff into any lake within the system affects water levels in all lakes.

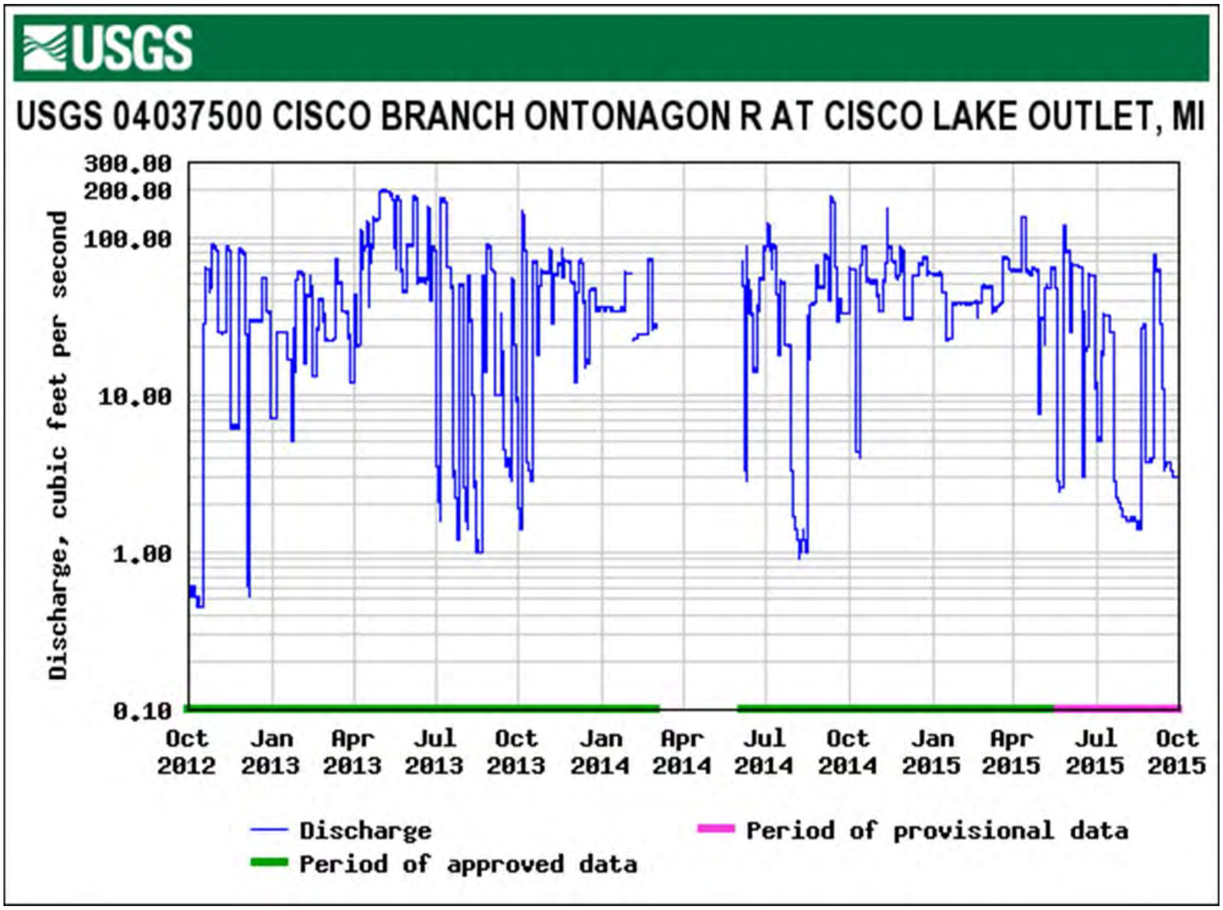

Figure 5.9. Discharge from the Cisco Chain of Lakes from 2012-20115 through the Cisco Lake outlet.

Summary Results – Physical Processes

Like most regional lakes, Big and West Bay Lakes mix twice annually (e.g., Figure 5.10) and develop distinct stratification throughout the summer. However, Mamie Lake is often repeatedly mixed throughout the summer months by wind and wave activity. Because of this stratification in Big and West Bay Lakes, dissolved oxygen concentrations in the bottom waters remained particularly low (often below 1 mg/L) throughout much of the summer. These low oxygen concentrations do not appear to be directly affecting fish and other living organisms throughout the lake (no fish kills were observed over this time period), but they are likely influencing the release of phosphorus from the sediments (discussed further in Section 5.4). Water levels are relatively static within the Cisco Chain as a result of the outlet control regulation by the Bond Falls dam on Cisco Lake.

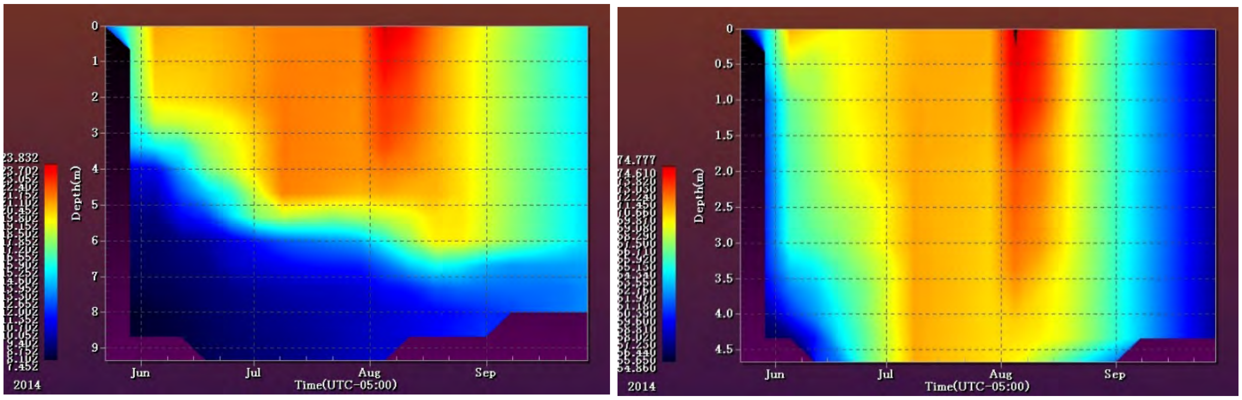

Figure 5.10. Seasonal thermal stratification in West Bay (left) and Mamie (right) Lakes (2014). Red colors indicate the areas of highest temperature.

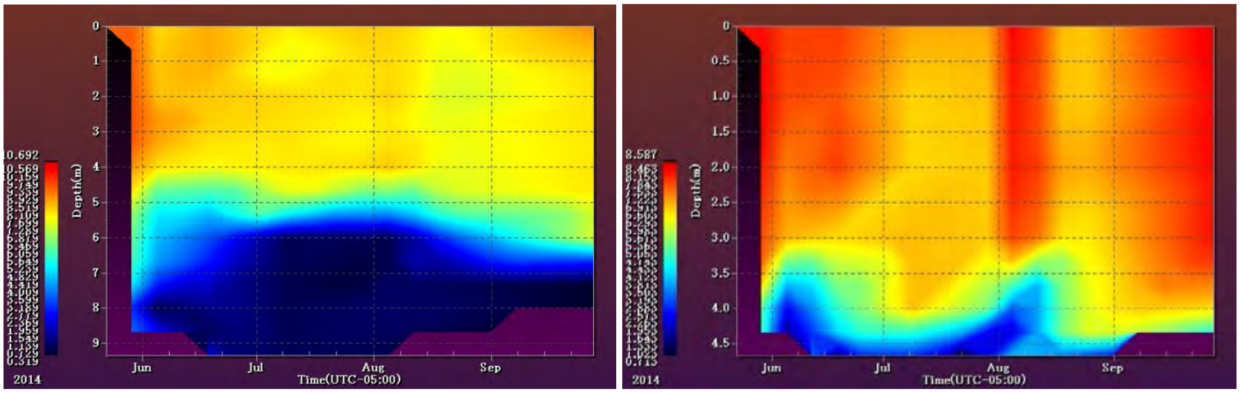

Figure 5.11. Vertical profiles of oxygen concentrations in West Bay (left) and Mamie (right) Lakes (2014). Red colors indicate the areas of highest oxygen concentration.

Summary Results – Shoreland and Critical Habitat

Shoreland habitat is of moderate to high quality in the Cisco Chain (Figure 5.12). In general, the areas of the lakes that contain the highest quality shoreland habitat are located along the north eastern and south western shorelines. Across the lakes, upland, transition and in-lake zones are generally similar in quality, although the in-lake zone has been slightly more impacted by human development. Areas that contain the highest density and diversity of floating and emergent vegetation (and likely serve as the most critical habitat for aquatic organisms) are generally located in protected embayments on the north and south end of the lakes. Not surprisingly, the areas of highest quality in-lake habitat are often adjacent to the areas of highest quality upland/shoreline habitat. Given the mixed condition of shoreline habitat throughout the Cisco Chain opportunities for both restoration and protection exist.

Summary Conclusions – Physical Habitat and Processes

Physical processes in Cisco Chain are consistent with other lakes throughout the region. Much of the condition of the Cisco Chain ecosystem is likely driven by the quality of the shoreline habitat and upstream runoff to Mamie Lake. Long-term management of the Cisco Chain should include strategies for shoreline restoration and watershed land use management. Management strategies should also consider seasonal water level modulation to mimic natural processes of water level fluctuation. Strategies for habitat protection and restoration are described in detail in Appendix C.

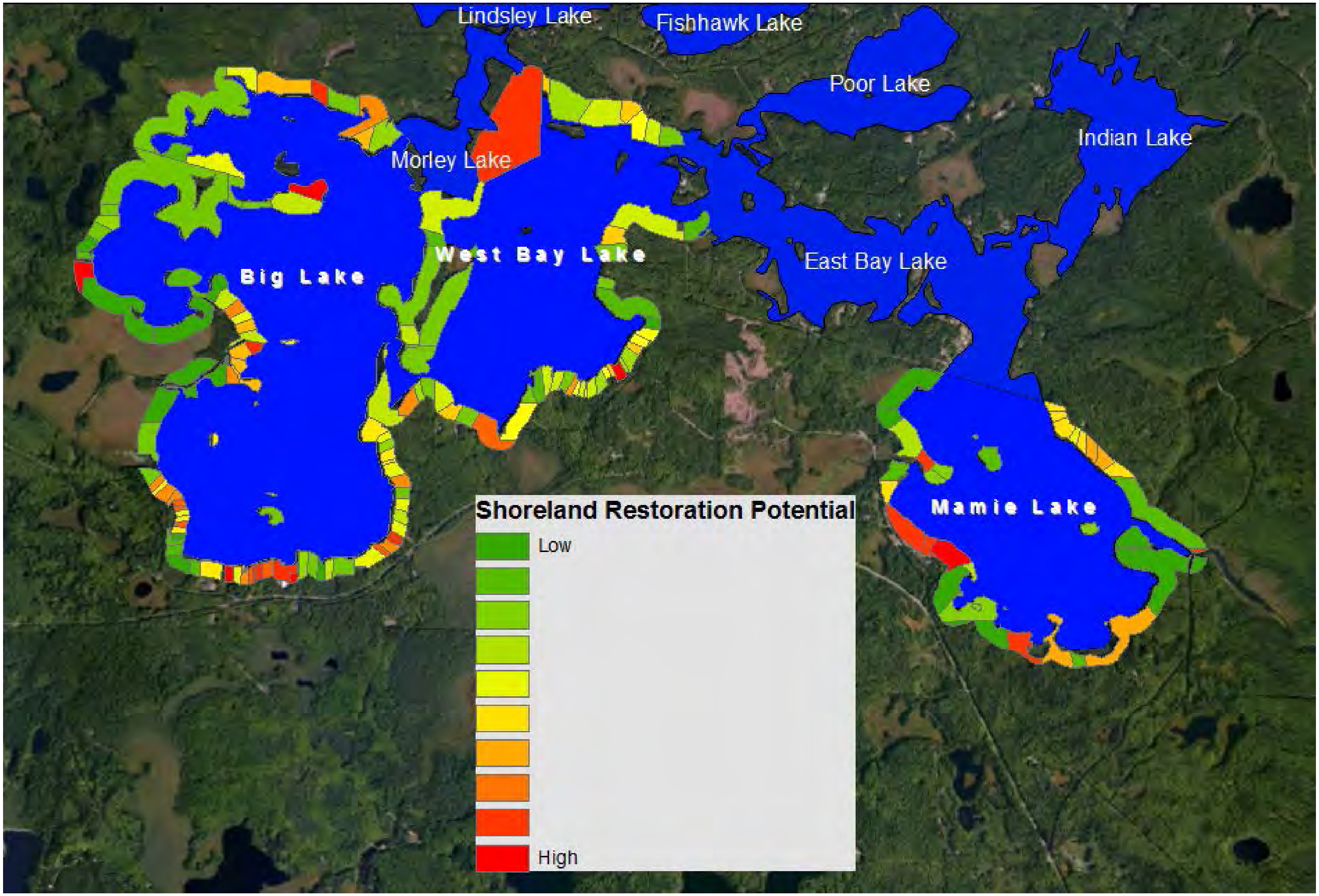

Figure 5.12. Locations of highest quality shoreland habitat, 2013.

5.3.Watershed Conditions and Processes

Lakes are ultimately a product of their watershed (or lakeshed) conditions. In northern Wisconsin, most lakes were formed following the last glacial maxima (~15,000 ybp). Since formation, most all lakes in this region have been accumulating sediments and nutrients that have runoff from their upland watershed following snow-melt and precipitation events (Figure 5.13). As a result, the sediment—and more importantly, nutrient concentrations—in lakes generally increases over time (the chemical and biological effect of nutrient and sediment loading to lakes is described below in Section 5.4).

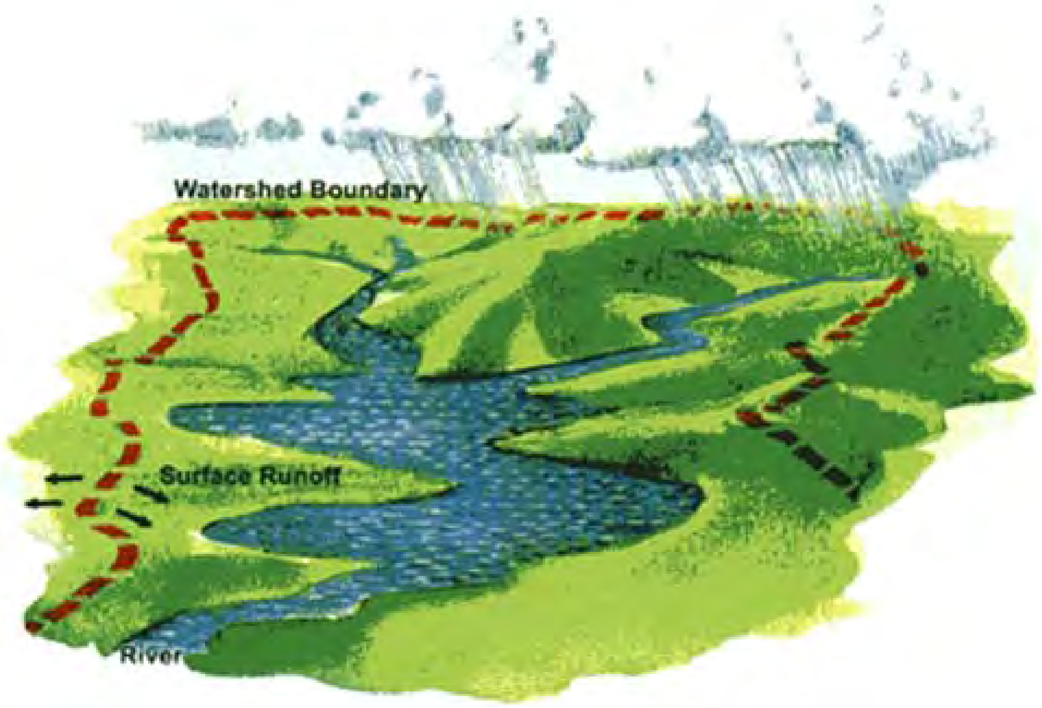

Figure 5.13. Conceptual diagram of the land area that contributes water to a lake—often referred to as the watershed, or lakeshed.

The rate of nutrient (particularly phosphorus) and sediment delivery to a lake is determined by its watershed position, regional precipitation patterns, soil characteristics, topography and the surrounding watershed land use. Of these attributes, land use is typically the only one that can be controlled through management activities and is often a primary consideration in the long-term management of a lake.

In general, as land cover is converted from a native vegetative community to an altered state, the rates of overland water flow and erosion increase. Consequently, rates of groundwater recharge decrease, while rates of phosphorus runoff increase (as well as additional pollutants). Additionally, if the "new" land use increases nutrient and/or sediment application rate (e.g., via fertilizer application or the erosion of exposed sediments), rates of pollutant delivery can be further increased. Changes in rates of nutrient and sediment delivery from different land uses and/or land covers are often described as an annual, unit-area load (i.e., the number of pounds/acre/year of phosphorus that are likely to wash into a lake from different land use types).

To proactively manage lake ecosystems, it is important to understand the relationship between land cover and land use. Land cover describes the current conditions of a particular land area (e.g., a forest vs. a residential development). Land use describes how people are currently and/or plan to use a particular land area in the future. Land use is often driven by local zoning ordinances. For example, a parcel of land can be zoned for low density residential development, but covered primarily by a forest. Because different land covers can have different impacts on a lake (particularly with respect to water quality), it is important to understand the current land cover and how, based on zoning, land cover will likely change in the future.

Historical, Current and Future Land Cover and Use

The transition of land cover types was summarized and projected based on historical, current and anticipated future land uses throughout the watershed. Historical land uses were estimated by examining archived satellite imagery and land cover surveys. Current land uses are based on a combination of the 2011 data from the National Land Cover Dataset (NLCD) and the parcel specific shoreland habitat assessments. Projections of anticipated future land uses were based on zoning conditions specified in the comprehensive plans for local towns of Land O'Lakes and Watersmeet. Details of the land use assessment are described in Appendix D.

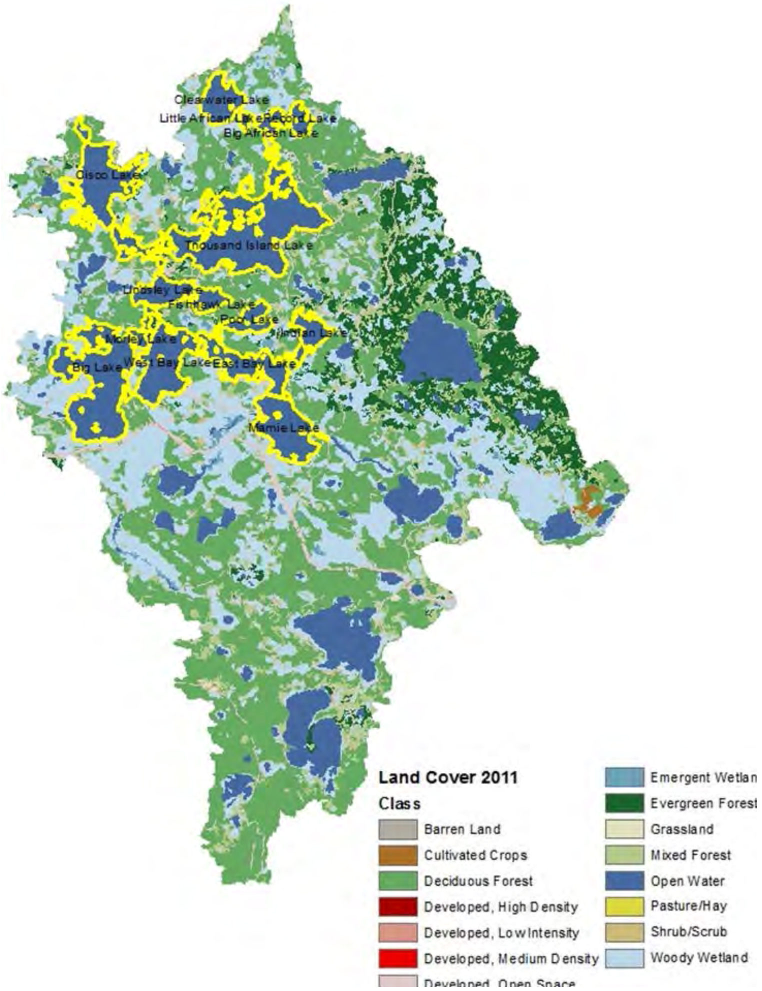

Figure 5.14. Land cover throughout the Cisco Chain watershed and surrounding shoreland areas.

Summary Results – Land Use

Land cover throughout the watershed has shifted significantly since the mid-1800s and is anticipated to continue to change in the coming years (Figures 5.14 and 5.15). Historically, hemlock and sugar maple dominated much of the lakeshore, while sugar maple and yellow birch dominated much of the upper watershed areas. Over time, the relative abundance of coniferous species has declined and has been replaced by mixed forests and small amounts of urban lands. As the permanent and seasonal population in the area continues to grow, land cover throughout the watershed is expected to become more heavily covered by low and medium density urban development.

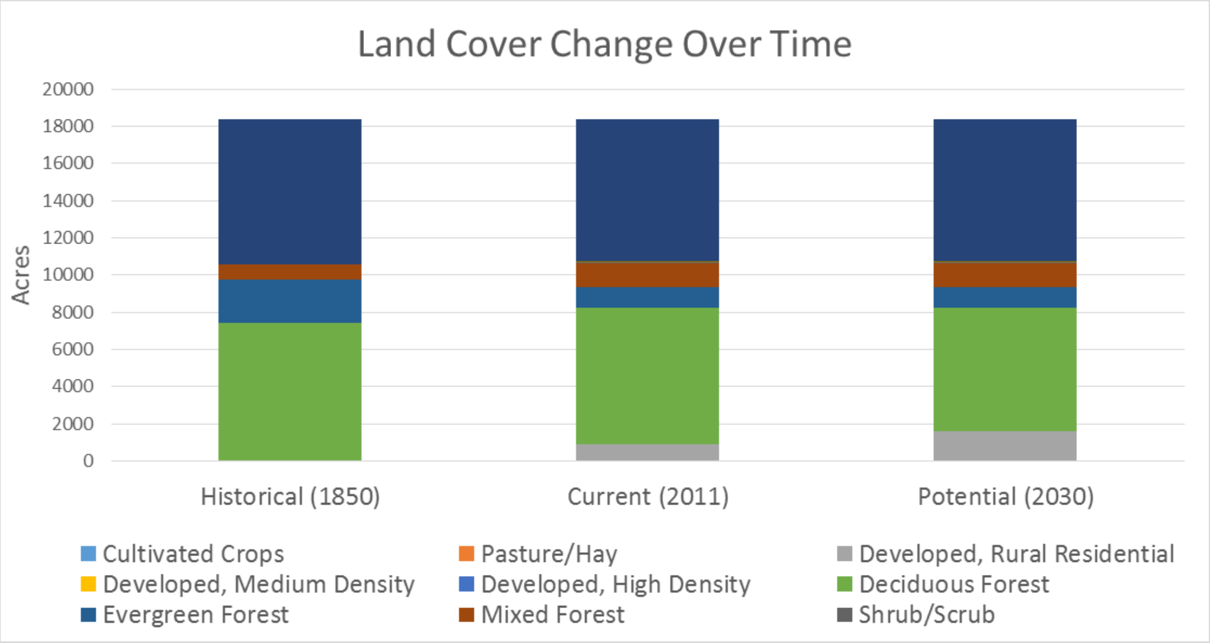

Figure 5.15. Land cover change throughout the Cisco Chain watershed.

Historical, Current and Future Watershed Nutrient Loads

Based on historical, current and anticipated future land use and land cover information, corresponding annual nutrient loads to the Cisco Chain were calculated. Total acreages of different land covers were multiplied by a corresponding expected annual pound/acre/year phosphorus runoff value. Phosphorus runoff to the lakes was then summarized as an annual load from each land use type.

Summary Results – Watershed Nutrient Export

As might be expected, as land throughout the watershed becomes increasingly covered by different types of urban land uses, phosphorus runoff to the lakes is likely to increase (Table 5.1). Based on these changes, annual phosphorus runoff to the lakes has likely increased by approximately 12 percent over pre-development conditions. If the Cisco Chain watershed is fully developed according to existing zoning and land use policies, phosphorus runoff to the lakes has the potential to increase by an additional 30 percent by 2030.

Table 5.1. Potential sources of phosphorus from different land uses in the Cisco Chain watershed.

				Estimated Annual Phosphorus Loads to the Cisco Chain					
	Annual TP Loads			Historical (1856)		Current (2011)		Potential Future	
Potential Phosphorus Source	Minimum	Maximum	Most Likely	Units	TP Load	Units	TP Load	Units	TP Load
Agriculture Lands	(lbs./acre/yr)			Acres	lbs.	Acres	lbs.	Acres	lbs.
Cultivated Crops	0.5	3	1	0	0	0	0	0	0
Pasture/Hay	0.1	3	1	0	0	0	0	0	0
Urban Lands	(lbs./acre/yr)			Acres	lbs.	Acres	lbs.	Acres	lbs.
Developed, Rural Residential	0.05	0.25	0.1	0	0	887	89	1602	160
Developed, Medium Density	0.3	0.8	0.5	0	0	0	0	13	7
Developed, High Density	1	2	1.5	0	0	0	0	3	5
Forest and Grasslands	(lbs./acre/yr)			Acres	lbs.	Acres	lbs.	Acres	lbs.
Deciduous Forest	0.05	0.2	0.09	7407	950	7368	884	6637	818
Evergreen Forest				2342		1106		1106	
Mixed Forest				801		1267		1267	
Shrub/Scrub				0		83		83	
Grassland	0.01	0.25	0.17	0	0	39	7	39	7
Wetland	0.01	0.01	0.01	7852	79	7652	77	7652	77
Permitted Sources	(lbs./source/yr)			Sources	lbs.	Sources	lbs.	Sources	lbs.
None	-	-	-	-	-	-	-	-	-
Non-permitted Sources (lbs./system)	(lbs./systems/yr)			Systems	lbs.	Systems	lbs.	Systems	lbs.
*Septic Systems	1.1	1.8	1.5	0	0	213	114	1149	614
Relative Changes in Phosphorus Load					**Total**	**%**	**Total**	**%**	**Total**
Total Watershed Load					**1028**	**3%**	**1056**	**2%**	**1073**
Permitted/Non-permitted Source Load					**0**	**100%**	**114**	**81%**	**614**
Total Phosphorus Loads					**1028**	**12%**	**1171**	**30%**	**1668**
Per Acre Phosphorus Load					**0.06**	**12%**	**0.06**	**30%**	**0.09**

Shoreland Septic Systems

To calculate phosphorus runoff to the Cisco Chain from septic systems, the total number of septic systems from privately owned shoreline parcels was multiplied by an expected per capita annual phosphorus discharge value and scaled depending on the likely number of users and seasonality of usage. Because no comprehensive inventory of septic system types exists, estimates were based on values observed in similar systems, and as such, results should be interpreted in general terms.

Table 5.2. Potential septic system contributions of phosphorus to the Cisco Chain.

Time Period	Residency	Number of Septic Systems	Number of Users per System	Seasonal Ratio	Soil Retention	Export (lbs/capita years)			Load (lbs/year)		
						Low	High	Average	Low	High	Average
Current Conditions	Full-time	53	2.5	1	0.3	1.1	1.8	1.5	44	72	**60**
	Seasonal	160	2.5	0.3	0.3	1.1	1.8	1.5	40	65	**54**
	Total	**213**	**2.5**	**0.65**	**0.3**	**1.1**	**1.8**	**1.5**	**83**	**137**	**114**
Future Conditions	Full-time	287	2.5	1	0.3	1.1	1.8	1.5	237	388	**323**
	Seasonal	862	2.5	0.3	0.3	1.1	1.8	1.5	213	349	**291**
	Total	**1149**	**2.5**	**0.65**	**0.3**	**1.1**	**1.8**	**1.5**	**450**	**737**	**614**

Summary Results – Septic Systems

Under current conditions, 213 privately owned shoreline parcels draining to the Cisco Chain use septic systems. Of these, most (~75%) are seasonal residences. Based on these parameters, the annual load of phosphorus to the Cisco Chain from septic systems is approximately 114 lbs/year (Table 5.2). If shoreland areas are fully developed according to current zoning regulations, the total number of septic system could increase to 1149 and annual phosphorus load to approximately 614 lbs/yr (see Appendix D).

Summary Conclusions – Watershed Conditions
Watershed delivery of phosphorus to the Cisco Chain has likely increased over time in response to land use/land cover change. Most of this increase in phosphorus is likely as a result of changes in land cover and a smaller percentage is potentially attributable to septic system discharge. If future land use planning/zoning scenarios are realized, it is likely that phosphorus runoff to the Cisco Chain will increase by a relatively moderate amount. Given the limited data available to describe the current condition/use of septic systems and the uncertainty underlying the realization of future land use scenarios, these estimates should only be used to inform general watershed planning.

5.4. Water Quality Conditions

Water quality in the Cisco Chain is influenced by a combination of processes in the lakes and the surrounding watershed. In general, short-term changes in water quality are often attributable to in-lake processes, while long-term trends in lake condition are often attributable to changes in watershed conditions. Although a wide range of biotic and abiotic factors shape water quality conditions in lakes, the primary driver of water quality conditions in lake ecosystems is their nutrient concentration (particularly for phosphorus).

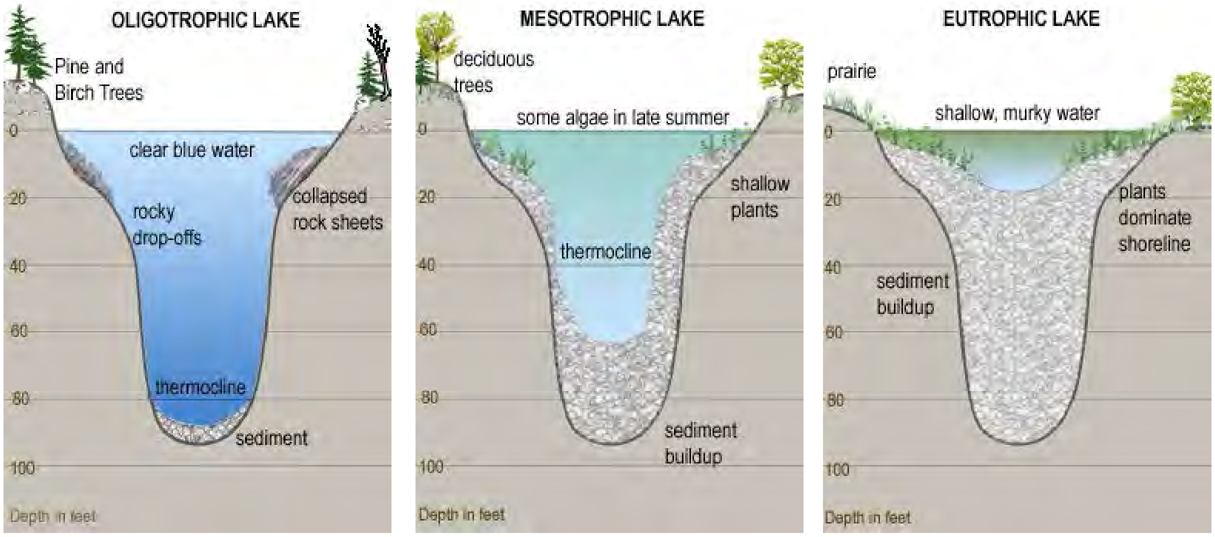

Figure 5.16. Conceptual diagram of the structure of different lake classifications. Adopted from http://rmbel.info/lake-trophic-states-2/.

As described above, as lakes "age" their nutrient concentration generally increases (Figure 5.16 and 5.17). This process of lake aging is generally referred to as eutrophication. Most lakes in northern Wisconsin were created by glaciation and began their existence as low-nutrient, oligotrophic lakes. Oligotrophic lakes are characterized by deep, cold clear water with relatively little plant growth and fish communities that are dominated by trout, cisco and perch. As nutrients and sediments wash into the lake each year and nutrient concentrations increase, the lake becomes more productive (i.e., more plants grow) and the composition of the biological communities shift. Mesotrophic lakes are characterized by increased aquatic plant growth, somewhat warmer, shallower water, with reduced water clarity and fish communities that are dominated by perch, smallmouth bass, walleye and pike. As the lake continues to age and increase in nutrient concentration, the biological communities continue to shift toward more eutrophic conditions. Eutrophic lakes are warmer and shallower and characterized by dense aquatic plant communities and relatively warmer, more turbid waters that are dominated by sunfish, largemouth bass and perch. As lake depth continues to decrease through sedimentation and nutrient concentrations continue to increase, the lake become hypereutrophic and ultimately transitions into a bog and/or wetland ecosystem. Each stage in this nutrient-driven evolution of a lake is often referred to as a trophic state.

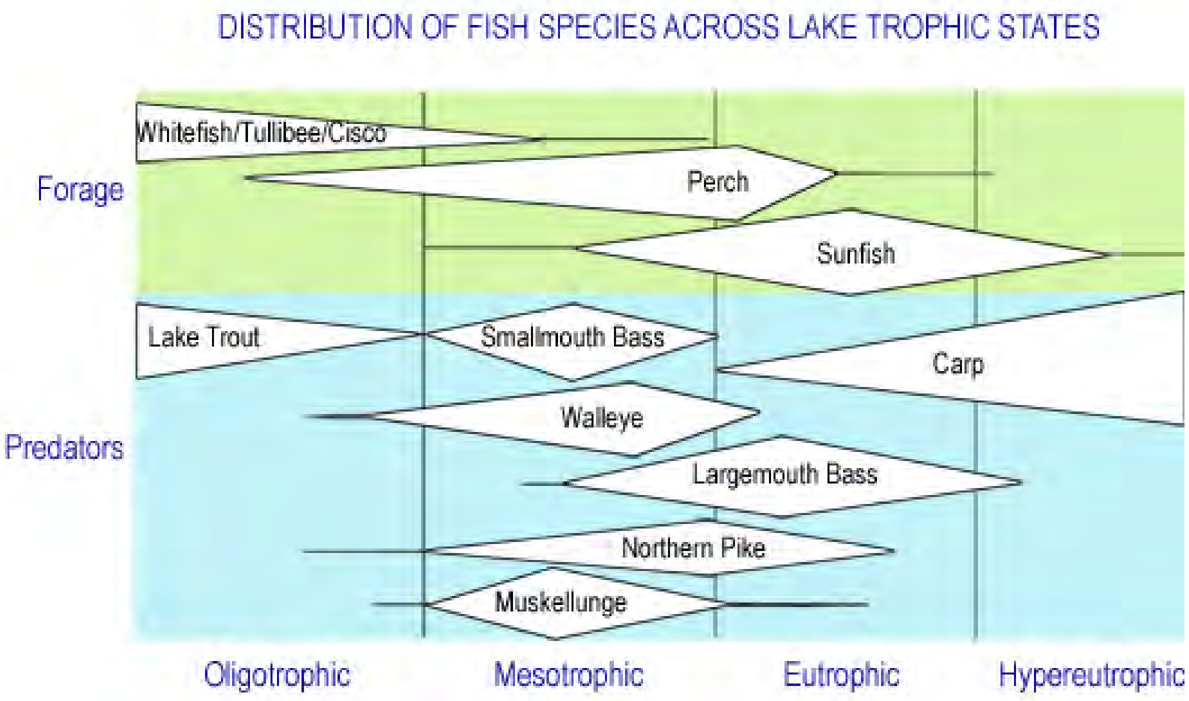

Figure 5.17. Conceptual diagram of the different fish communities that often inhabit lakes of different trophic conditions. Adopted from http://rmbel.info/fish-distribution/.

The process of eutrophication is primarily driven by phosphorus and sediment runoff and deposition from the watershed. However, the transition of lakes between these different tropic states is also influenced by a range of physical and chemical feedback mechanisms. As described above, when lakes stratify, the thermocline (or metalimnion) often creates a barrier that partially isolates surface waters from the bottom waters; and thus, nutrients and sediments that sink to the bottom generally, remain trapped in the deep waters of the lake until they are mixed through the process of turnover.

Because oligotrophic lakes are relatively deep, nutrients and sediments that settle out to the bottom of the lake are generally isolated from biological productivity. As such, water clarity and biological productivity in oligotrophic lakes are primarily influenced by “new” nutrients and sediment that wash in on an annual basis (often referred to as the “external load”). As the lake becomes warmer and shallower, wind mixing and aquatic plant growth and decomposition become more important drivers of water clarity, such that in eutrophic lakes, phosphorus release from sediments and sediment (re)suspension can be the most important drivers of water clarity (often referred to as the “internal load”). Because this stratification also can result in oxygen depletion, nutrients (particularly phosphorus) can be released back to the water column as the chemical processes in the sediments shift to a "reducing" system in the presence of low oxygen conditions. If stratification in the lake is consistently present throughout the year, soluble phosphorus in the deep water remains relatively isolated from the algal communities in the surface water. However, if the depth of stratification is shallow (i.e., sunlight can penetrate through it) or the stratification is periodically broken up wind, wave or current-driven mixing, soluble phosphorus can be released in pulses to the surface waters, resulting in increased algal blooms.

In lakes of all trophic states, water clarity is further influenced by food web interactions. The predominant driver of water clarity in most lakes is phytoplankton (algae) growth (and in lesser instances, suspended sediments). Although phytoplankton growth is predominantly driven by phosphorus concentrations, the density of phytoplankton is further influenced by the rate of phytoplankton consumption (i.e., grazing) by zooplankton. As such, many lakes which have high phosphorus concentrations also have relatively high water clarity, as a result of zooplankton grazing of phytoplankton. Because zooplankton grazing of phytoplankton is such an important driver of water clarity, any processes in the lake that affects the diversity and relative abundance of zooplankton can have an indirect effect on water clarity. In particular, any changes in the fish community that increase the relative abundance of planktivorous fish (e.g., sunfish) can have secondary impacts on water clarity (e.g., as sunfish populations increase, water clarity often decreases in response to reduced zooplankton abundance, particularly in shallow, more eutrophic lakes.) Food web interactions are described in greater detail below (see Section 5.4).

Managing Water Quality Conditions

Because of the importance of water quality process on in-lake conditions and the complexity of these interactions, the management of a lake is often highly dependent on the measurement of different parameters that are taken to characterize the trophic state of a lake. The three most commonly measured water quality parameters in lake management are total phosphorus (TP; a measure of nutrient conditions in the lake), Chlorophyll-a (Chl-a; a measure of algal densities) and Secchi depth (a measure of water clarity). These parameters (individually or combined) are also often used to calculate a Trophic State Index (TSI) that describes the relative trophic state of the lake (e.g., oligotrophic vs. eutrophic).

Because of the particular significance of phosphorus in the determination of lake conditions, it is also important to understand the relative sources and distribution of phosphorus throughout the lake (and watershed) ecosystem. In Wisconsin, the primary water quality parameter used to measure and track the health of a lake ecosystem is the average annual growing season total phosphorus concentration. Expected/allowable total phosphorus concentration is dependent on the lake's trophic state classification (Figure 5.18). In the Cisco Chain, average growing season (June-August) total phosphorus concentrations should not exceed 30 ug/L (for Big and West Bay Lakes) and, perhaps 40 ug/L for Mamie Lake.

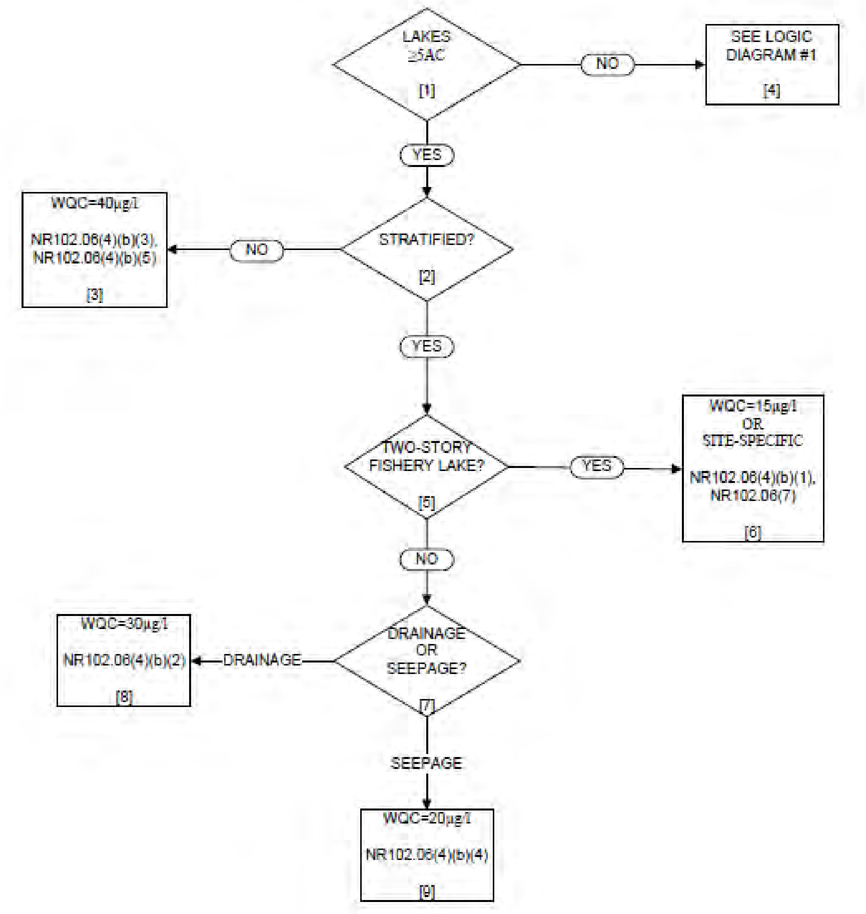

Figure 5.18. Total phosphorus water quality criteria for lakes in Wisconsin.

Historical Water Quality Conditions

Water quality in the Cisco Chain has been monitored over different periods and by different agencies since 1973. All data for this section were accessed through the WDNR Surface Water Information Management System (SWIMS) or the corresponding lake website (http://dnr.wi.gov/lakes/lakepages). The most detailed water quality study for the Cisco Chain has been conducted as part of Citizen monitoring of water clarity that has occurred generally monthly since 1995. Results from this long term data set suggest water clarity has slightly decreased over the last 20 years, but that clarity is highly variable between years, likely in response to environmental conditions.

The combination of the water quality data suggests that the Cisco Chain lakes are mesotrophic with average phosphorus concentrations of between 15 and 35 ug/L, average Secchi depths of 6-10 feet, and a Secchi Trophic State Index (TSI) of 35 to 45 (Figures 5.19 and 5.20). The Cisco Chain lakes are currently classified as mesotrophic, although Mamie Lake may be considered eutrophic (likely as a result of the continual wind mixing of the system). In general, the existing data suggest that water quality has decreased over the last 100 years, but that current water quality conditions are relatively stable.

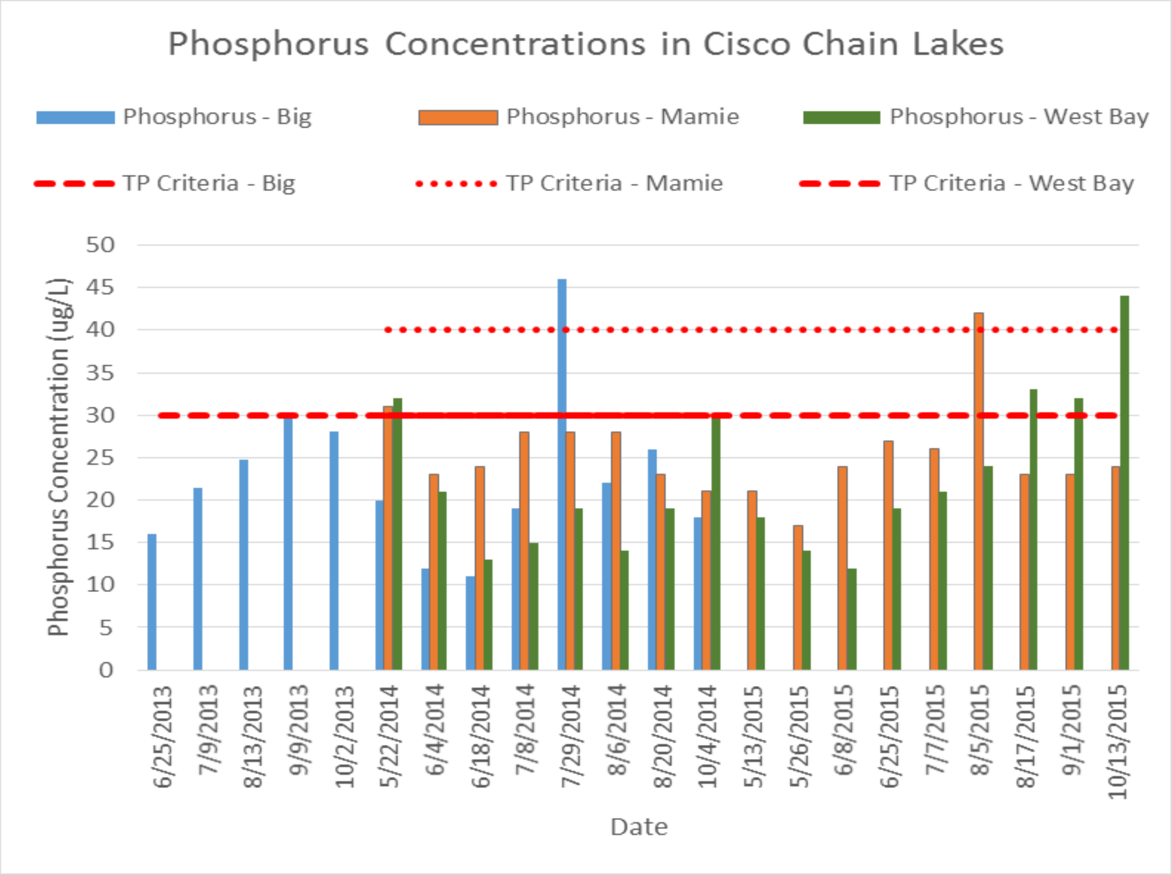

Figure 5.19. Average annual water quality trends in the Cisco Chain (2013-2015).

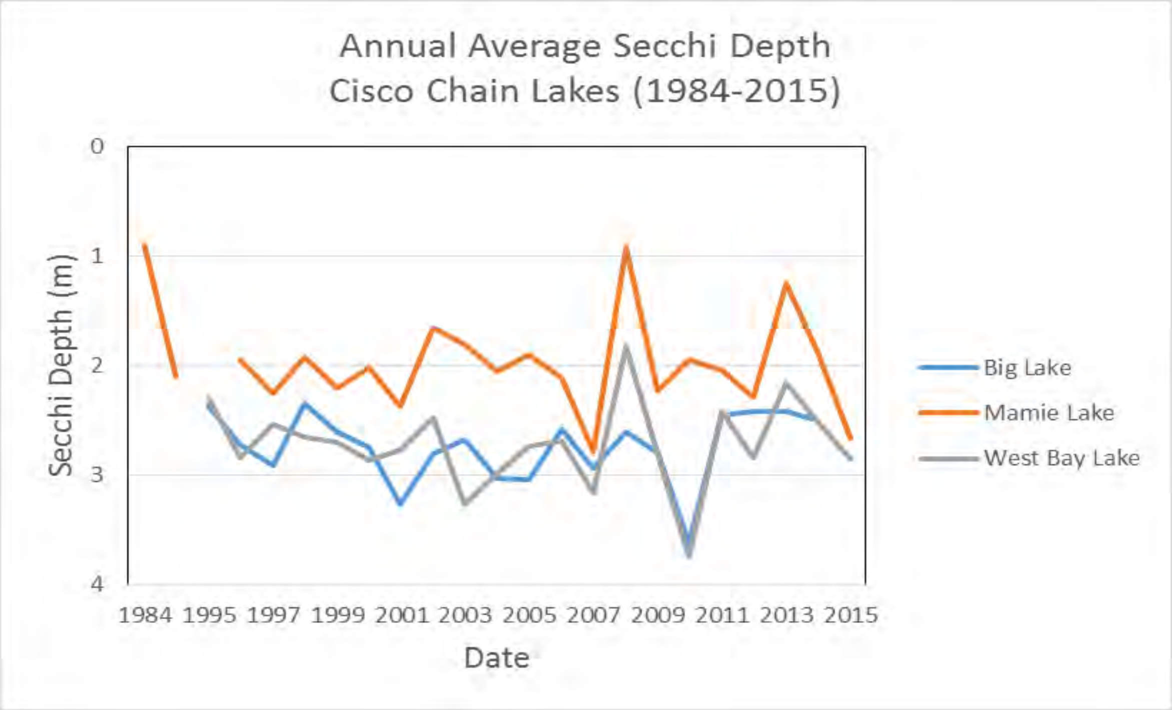

Figure 5.20. Historical trends in Secchi depth throughout the Cisco Chain.

New Data Collection
To supplement the existing water clarity and nutrient data (summarized above), a more intensive water quality assessment was conducted from 2013-2015. As part of this study, samples were collected at sites throughout Big, West Bay and Mamie Lakes every two weeks from May-October. At each site, water quality was described by supplementing Secchi depth measurements with Chlorophyll-a data, as well as profile measurements of temperature, pH, dissolved oxygen, conductivity, total phosphorus, soluble reactive phosphorus and total nitrogen. Details of the intensive water quality sampling are described in Appendix B.

Summary Results – Water Quality
Results from this work suggest that water quality in the Cisco Chain meets state water quality criteria. Total phosphorus, chlorophyll and Secchi depth measurements all indicated that the Cisco Chain lakes are meeting water quality criteria and are accurately classified as mesotrophic/eutrophic lakes.

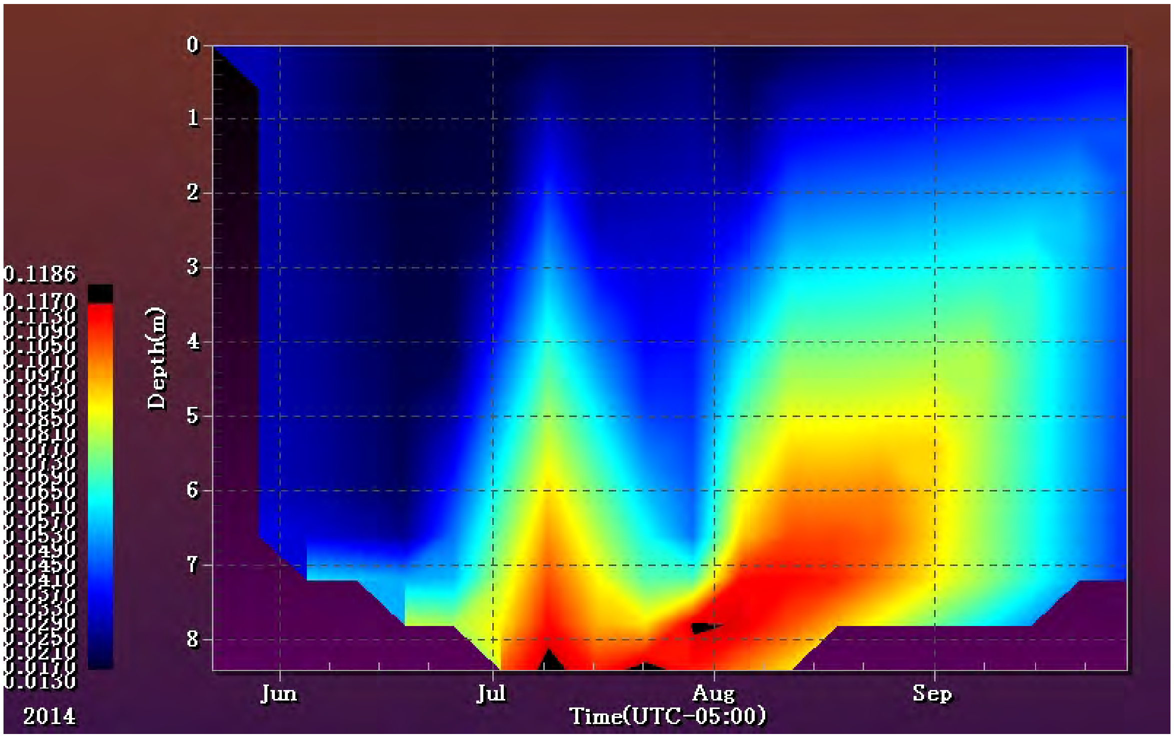

Figure 5.21. Seasonal profiles of total phosphorus concentrations in West Bay Lake (2014). Red colors indicate areas of greater total phosphorus concentration.

Nutrient concentrations throughout the depth profile samples are of interest in West Bay Lake. Although surface water phosphorus concentrations in this lake is relatively low, concentrations of phosphorus in the hypolimnion are often elevated, likely as a result of low oxygen conditions (Figure 5.21).

Summary Results – Lake Nutrient Budget
Within the Cisco Chain, the sources of phosphorus vary considerably depending on the specific characteristics of the individual lakes (Figure 5.22). Most of this watershed loading of phosphorus occurs as part of spring snowmelt and rainfall. Phosphorus budgets in lakes with larger watershed and surface areas are more commonly dominated by “natural sources”, while lakes with smaller

watersheds and higher densities of shoreline houses are more commonly affected by human derived sources of phosphorus. Additional "internal" sources and processes are discussed in Appendix G.

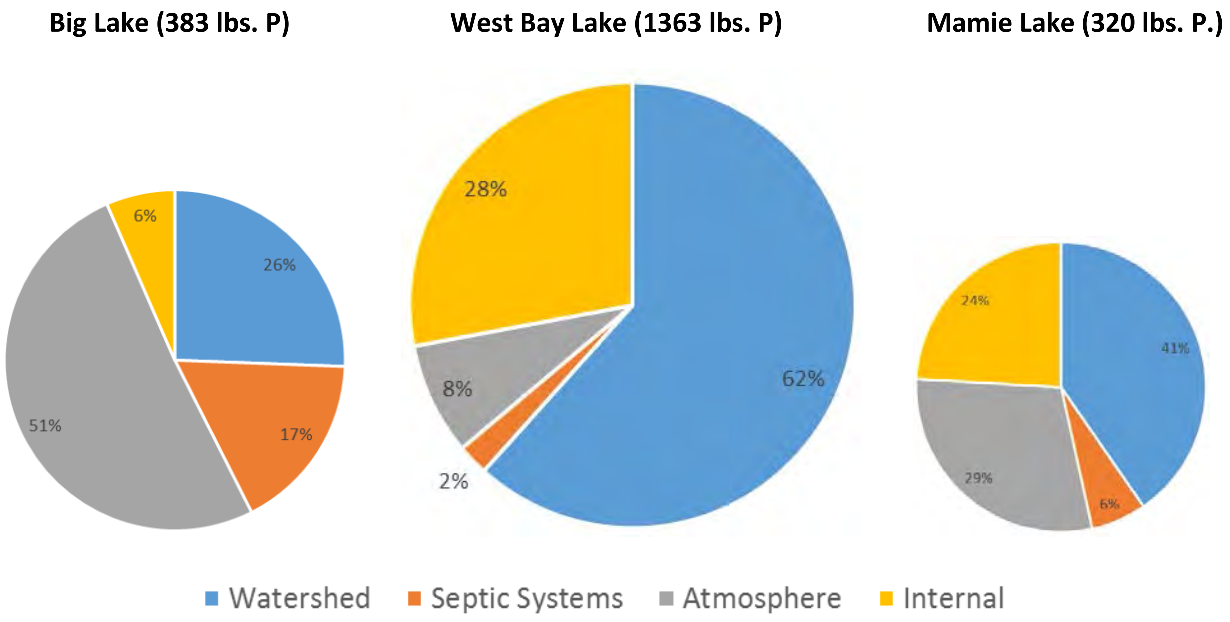

Figure 5.22. Phosphorus sources in Cisco Chain. Percent contributions from different sources and annual loads.

Summary Conclusions – Water Quality Conditions
Water quality conditions in the Cisco Chain are consistent with those expected for mesotrophic lakes. Because a relatively high percentage of annual phosphorus may be retained in the Cisco Chain (particularly Big Lake), it is likely that internal cycling of phosphorus is a key element of the lake ecosystem.

5.5. Biological Communities

Biological communities within a lake ecosystem are structured by a range of physical, chemical and biological processes. Biological communities are fundamentally structured by physical and chemical processes described above. In general, nutrient levels and water temperature define the range of species that can exist within in a lake system and the diversity of the sediment and habitat types and physical processes (e.g., water level fluctuation) determine diversity of species that are likely to coexist within the lake. However, within these physical/chemical ecosystem boundaries, a range of biological interactions (i.e., competition and predation) further shape the structure and function of lake ecosystems. In addition, some biological processes and feedback mechanisms can influence the underlying physical/chemical processes that shape lake conditions.

Species Diversity
The diversity of species in lakes is fundamentally driven by the diversity of habitat types present throughout the lake ecosystem over the course of time. Species within a lake are continually in competition with each other for the limited food and habitat resources throughout the system. Over time, different species have coevolved to utilize different food and habitat resources in such a

way that minimizes the competition among species and maximizes the competition within a particular species. This "evolutionary history" of competition among and within species is a primary mechanism that maintains the diversity of species and genetic variability within species, and these process often lead to the establishment of rare species that are specially adapted to unique local conditions. Species diversity is also generally viewed an important element of the long-term resilience of lake ecosystems (i.e., diverse biological communities are more likely to be resistant to change and recover after large scale disturbances, like drought or flooding).

Species diversity can be influenced through a variety of process. The introduction of species into a lake that does not share an evolutionary history of competition that uniquely exists within each lake can dramatically alter levels of species diversity. Introduced species (i.e., invasive species) often do not have natural predators (natural predator species are often more poorly adapted to feed on species that they have not historically encountered) and are often able to outcompete many native species for local resources (particularly in a lake system that is already being impacted by additional stresses like elevated nutrients). Alternatively, some introduced species (e.g. rusty crayfish or cladphora) affect species diversity by modifying relative habitat abundance or redistribution resources within a lake. Similarly, species diversity and the relative abundance of different species can be altered through a variety of food web processes.

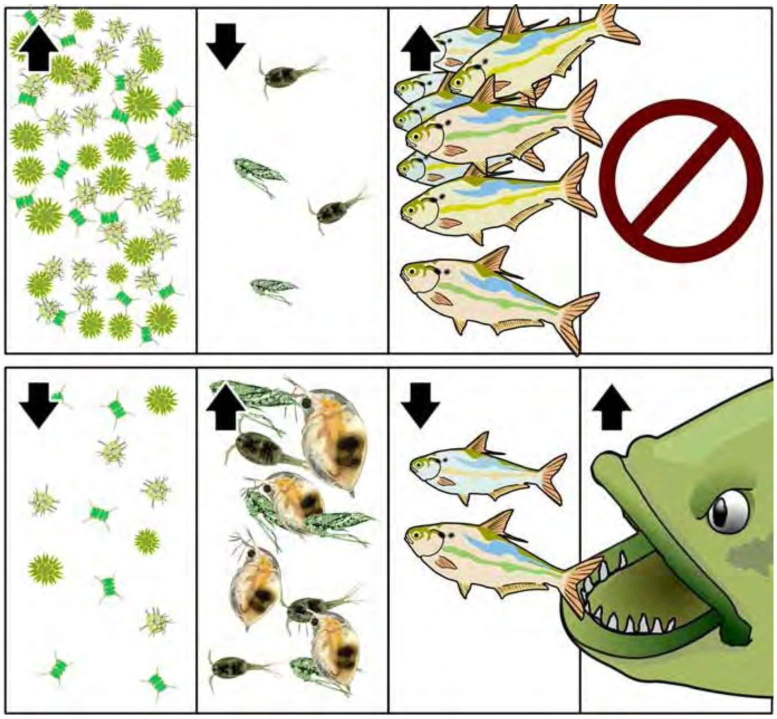

Figure 5.23. Conceptual diagram of the relationship between food web interactions and water clarity. Adopted from http://www.lmvp.org/Waterline/fall2005/topdown.htm.

Food Web Processes

Lake ecosystems are a mosaic of species that are in continuous fluctuation in response to the availability of different food sources. The food web in most lakes throughout northern WI can be viewed as a combination of primary producers (algae and rooted plants), primary consumers (zooplankton and grazing invertebrates), secondary consumers (planktivorous and insectivorous fish), tertiary consumers (picivorous fish) and quaternary consumers (fish eating birds/mammals and people). Changes in the abundance of any species at these different trophic levels often results in a change at all other levels in the food web (often referred to as a "trophic cascade"; Figure 5.23). As such, a change in the abundance of top predators can have a cascading effect that results in shifts benthic invertebrate density and/or water quality conditions, or vice versa.

Food web interactions can also be described with respect to the type of food that is primarily, or preferentially, being consumed by different organisms. For example, a predatory fish may have the ability to feed on many different prey types, but may preferentially feed on one or two species. If the relative abundance of the preferred food-type decreases, this can cause the same predator to shift feeding preferences to different food types—which can result in a cascade effect throughout the food web. Similarly, there may be one or more species that utilize a particular food-type within a lake ecosystem. For example, young bluegills are often the predominant consumers of zooplankton in lake ecosystems. If/when bluegill populations decline (potentially in response to low oxygen conditions, or winter kill), the food web can rapidly restructure, such that zooplankton abundance rapidly increases and algal abundance rapidly decreases. In fact, these shifts can be so rapid and pronounced that lakes that were once considered "impaired" due to poor water quality may now be considered relatively healthy, in a time span of one to two years.

Managing Biological Communities

Because of the importance of species diversity in the long-term resilience of a lake and the ability of changes in species abundance to cascade throughout the food web, lake management often focuses on an assessment of the relative abundance, population trends and trophic interaction among species. To this end, lake managers often rely on measurements of species richness, diversity, and population trends in plankton, aquatic plant and fish populations, as well as the physical and chemical processes that support them.

Historical Data

The majority of the data that exists to describe the biological communities in the Cisco Chain are related to fisheries and invasive species. Fisheries management work in the Cisco Chain has been ongoing since the 1930s and is best described in the most recent Michigan DNR fisheries report (Hanchin et. al., 2008). In general, the fish community has been dominated by walleye (*Sander vitreus)*, northern pike (*Esox Lucius)*, smallmouth bass (*Micropterus dolomieui)*, yellow perch (*Perca flavescens)*, black crappie (*Pomoxis nigromaculatus)* and white sucker (*Catostomus commersoni)*. In the 1930s and 40s walleye were consistently stocked throughout the Cisco Chain. From approximately 1950 to 1980, relatively little fishery management activity took place. In the 1980s, walleye stocking resumed and was supplemented by muskellunge and lake trout stocking. Over its management history, the Cisco Chain has continually experiences stunted northern pike growth. The WDNR has also conducted creel surveys directly on Big Lake (Tobias, 2009).

Beyond the existing fishery data, considerable work has gone into understanding aquatic plant communities. Aquatic plants are the best described biological communities in the Big Lake ecosystem. Aquatic plant surveys have been conducted in Big Lake (and Michigan and Palmers Bays) by WDNR (2008), the Upper Pennisula Power Company (UPPCO, 2010) and Northland College (SOEI, 2010 and 2011). Results from this work have indicated that aquatic plant communities in Big Lake are highly variable, with average Simpson's diversity values ranging between 0.5 and 0.88. Two invasive species have been identified throughout the lake—Curlyleaf Pondweed (*Potamogeton crispus)* in 2011 and Eurasian watermilfoil (*Myriophyllum spicatum*) in 2012. Additional, aquatic invasive species that have been identified are the Chinese mystery snail (*Bellamya chinensis*) and purple loosestrife (*Lythrum salicaria*).

In addition to the work specifically in Big Lake, considerable work has been done by the US Army Corps of Engineers (USACE) and Northland College (on behalf of the CCROA) to understand the occurrence and distribution of aquatic invasive species throughout the Cisco Chain of Lakes (USACE, 2003). This work suggests that there are a range of established populations of aquatic invasive species throughout the Cisco Chain that pose a significant risk of establishment for Big Lake.

New Data Collection

To supplement the existing data, a series of new data sets were developed to characterize aquatic plant communities. Aquatic plant communities in the Cisco Chain were sampled in year one of this project using a point intercept methodology described by Hauxwell, et al. (2010). Aquatic plant data were analyzed to characterize relative species abundance, invasive species distribution, species diversity and Floristic Quality. All aquatic plant survey results were geospatially processed to inform the identification of critical habitat areas throughout the lakes (see Section 5.1 above). Details of collection procedures, data analysis and results are described in Appendix E (aquatic plants). Additionally, the presence of Rare, Threatened and Endangered species in the Cisco Chain area was quantified by working with WDNR staff to conduct a Township Level query of the Natural Heritage Inventory (NHI) database.

Summary Results – Aquatic Plants

The Cisco Chain contains a robust and diverse aquatic plant community (Figure 5.26). Throughout this study, 50 species were identified. The majority of plants were observed growing between 1 and 13 feet, with a maximum depth of 28 feet. The diversity and richness of species also varied among sites within the lakes, with some individual rake pulls not collecting any plants and other collecting up to eleven individual species. In general, the areas of highest species richness were in protected bays at the northern and southern end of the lakes. For details of the aquatic plant community assessment, see Appendix E.

Summary Results – Invasive Species

Eurasian Watermilfoil (*Myriophyllum spicatum*) has been detected in Big Lake and Curlyleaf Pondweed (*Potamogeton crispus*) has been detected in Big and Mamie Lakes. No invasive aquatic plants have been detected in West Bay Lake. Additional non-native species detected in the Cisco Chain are Chinese mystery snail (*Bellamya chinensis*), Banded mystery snail (*viviparous geogianus*), and rusty crayfish (*Orconectes rusticus*).

Summary Results – Rare, Threatened and Endangered Species

Seven rare, threatened and endangered species exist within the townships surrounding the Cisco Chain watershed (Table 5.3). The specific location of each species is kept confidential by the WDNR Endangered Resources staff, but it is unlikely that any of these species/communities are obligate residents within the Cisco Chain (i.e., lake management decisions will likely not affect these species).

Summary Conclusions – Biological Communities

Biological communities throughout the Cisco Chain ecosystem are somewhat variable. Aquatic plant communities are diverse and robust and the only invasive species detected being Eurasian water milfoil and curlyleaf pondweed. Fish communities are generally consistent with those expected in mesotrophic lakes like those throughout the Cisco Chain.

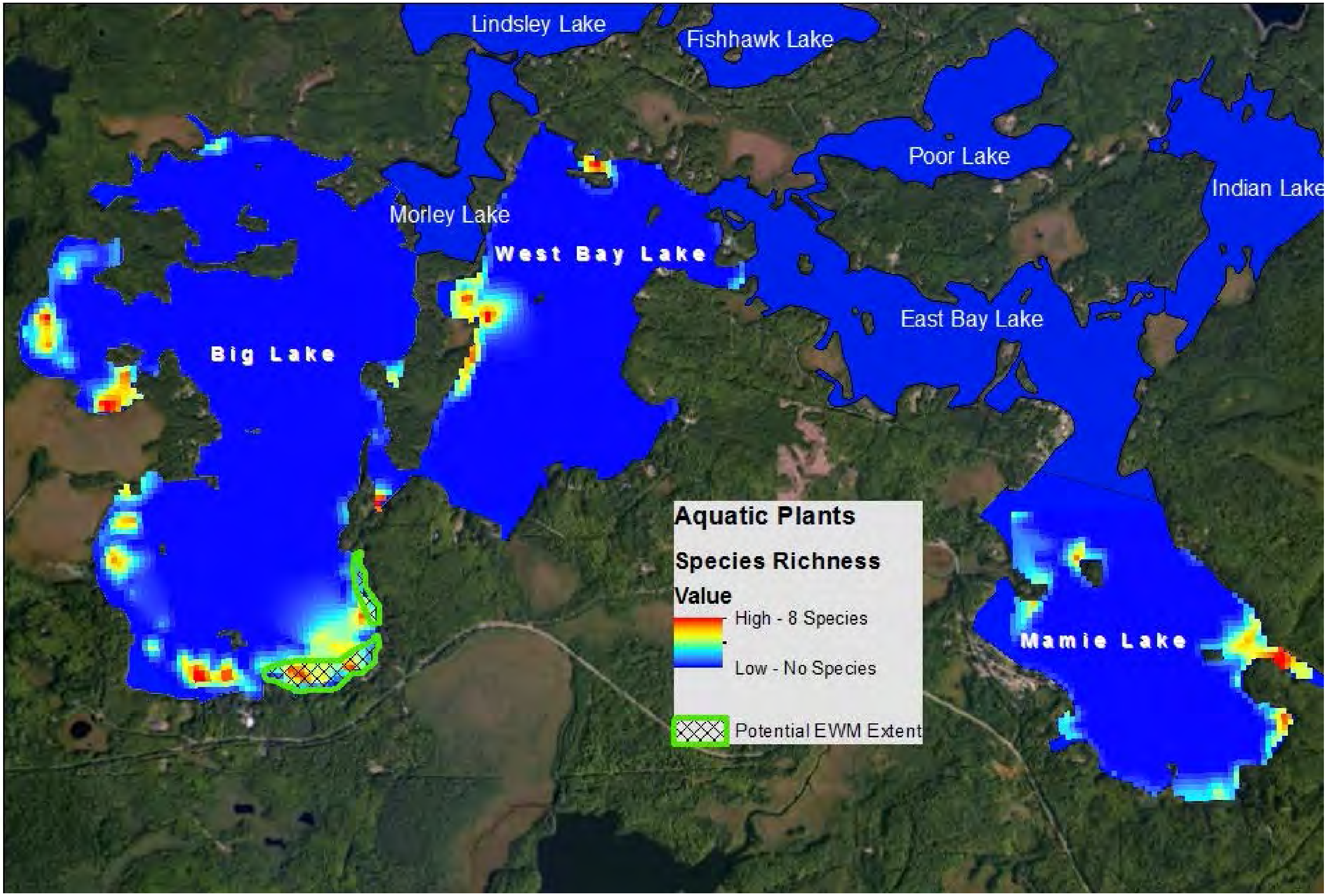

Figure 5.24. Abundance and diversity of native and invasive of aquatic plants throughout the Cisco Chain

Table 5.3. Species of special interest throughout the Cisco Chain watershed

Scientific Name	**Common Name**	**WI Status**	**Group**
Ephemeral pond	Ephemeral Pond	NA	Community~
Helophorus latipenis	A Water Scavenger Beetle	SC/N	Beetle~
Lake--shallow, soft, seepage	Lake--Shallow, Soft, Seepage	NA	Community~
Muskeg	Muskeg	NA	Community~
Northern mesic forest	Northern Mesic Forest	NA	Community
Northern wet forest	Northern Wet Forest	NA	Community~
Open bog	Open Bog	NA	Community~

5.6.Ecological Interactions

To understand the interactions among different components of the Cisco Chain ecosystem, it is necessary to develop a framework that relates physical, chemical and biological processes. To this end, ecological interactions were assessed in the Cisco Chain through the use of the Wisconsin Lake Modeling System (WiLMS) simulation program. WiLMS simulates the relationship between nutrient runoff, water quality and water clarity. Different WiLMS simulations were used to assess the potential impacts of future land use on water quality and the relative importance of internal loading on water quality in each lake.

Summary Results and Conclusions – Ecological Interactions
Model simulations suggest that water quality changes resulting from future land use scenarios are likely to be moderate, but may lead to water quality problems, particularly in Big Lake. However, model simulation of the ecosystem suggest that internal nutrient dynamics are quite complex and that additional data are likely necessary to fully understand water quality dynamics in the Cisco Chain. Given the uncertainty about both the ecosystem processes and the future land use conditions, management of the Cisco Chain should emphasize routine monitoring and assessment to track water quality conditions over time.

Table 5.4. Water quality changes potentially resulting from future land use/nutrient loading scenarios

Land Use Condition (Year)	**Total Phosphorus Load**	**Growing Season Phosphorus Concentration (ug/L)**		
		Big	**West Bay**	**Mamie**
1856	1028	16	16	22
2011	1170	25	25	26
2030	1687	34	29	29

6. Stressor Identification and Analysis

A range of stressors have the potential to impacts lake ecosystems and their use (Table 6.1) by altering the fundamental physical, chemical and biological processes that sustain lake conditions and/or creating social conditions that favor one use over another. For example, increased phosphorus runoff from altered land use can be an ecological stressor to lakes by decreasing water clarity and altering the structure of the food web and fishery. Similarly, increased boat traffic can be a social stressor to lakes by limiting potential use of the lake for quiet, solitude and relaxation. This section describe the current, and potential future, impact of different stressors on the desired uses of the Cisco Chain identified in the goal setting process (see Section 3).

Five categories of stressors were identified to have the theoretical potential to limit the desired uses identified for the Cisco Chain ecosystem: hydrologic alteration, habitat loss, pollutant runoff and deposition, biological community modification and use incompatibility. Within these five general stressor classifications, the potential impact of 17 specific stressor-types were evaluated within the Cisco Chain ecosystem.

Table 6.1. Summary of the sources and impacts of stressors potentially impacting the Cisco Chain ecosystem.

Stressors	Primary Impacts	Potential Sources
Hydrologic Alteration		
Surface Water Alteration	Increases in rates of runoff to a lake can increase shoreline erosion and nutrient runoff. Decreases in runoff and/or water diversion can result in reduced water levels and nearshore habitat alteration.	Impervious surfaces, irrigation and/or drinking water removal
Groundwater Alteration	Increased groundwater withdrawal can result in lower summer water levels, increased water temperatures and loss of shoreline habitat	Increased well usage
Water Level Modification	Artificial water level control in lakes can increase shoreline erosion and minimize water level fluctuations necessary for maintaining diverse aquatic plant communities	Outlet control structures
Habitat Loss		
Nearshore/Shoreline	Loss of nearshore/shoreline habitat can negatively affect fish, invertebrate and aquatic plant communities as well as in crease rates of nutrient runoff and invasive species introduction	Upland vegetation removal, shoreline riprap, increased dock densities
Thermal Restrictions	Changes in temperature profiles and distributions can alter the range and distribution of fish and invertebrates, generally toward communities that are dominated by warm water specialists	Thermal discharges, climate change
Spawning Substrate	Loss of spawning substrate is species dependent (based on preferred spawning substrate) and generally leads to a reduced population density of affected species. Common habitat types include, rocks and cobble, course sand, vegetation, coarse woody debris	Sedimentation, dredging, woody debris removal, thermal restriction
Pollutant Runoff and Deposition		
Agricultural	Increased rates of agricultural runoff can lead to increased nutrient and sediment levels in lakes and an increase in the natural process of eutrophication	Increased erosion, nutrient application
Industrial wastewater	Increased rate of industrial discharge can alter temperature profiles in lakes and increase contaminant and nutrient levels in lakes, depending on the nature of the discharge	New facilities or increase discharge from existing facilities
Municipal wastewater	Increased rates of industrial discharge can lead to increased nutrient (and to a lesser extent, contaminant) levels in lakes and an increase in the natural process of eutrophication	New facilities or increase discharge from existing facilities
Septic Systems	Increased rates of industrial discharge can lead to increased nutrient (and to a lesser extent, contaminant) levels in lakes and an increase in the natural process of eutrophication	New systems or increase discharge from existing systems (i.e., failures)
Urban	Increased rates of industrial discharge can lead to increased nutrient, sediment, and contaminant levels in lakes and an increase in the natural process of eutrophication	Increased impervious surfaces, unmaintained stormwater infrastructure
Contaminant Deposition	Deposition of mercury, lead, pesticides and organic pollutants can negatively impact fish and wildlife reproduction and limit human consumption.	Atmospheric, runoff or direct deposition depending on contaminant
Biological Community Modification		
Non-native Species Introduction	Introduction of non-native species can alter biological communities, often leading to a reduction in species diversity and disproportionately high densities of the introduced species.	Boat transport, stormwater, ornamental gardens, wildlife
Species Incompatibility	Introduction of native species at levels above their natural carrying capacity can alter food web structure and have secondary impacts on ecological processes	Stocking
Overharvest	Harvest at levels above a reproductive replacement rate can lead to localized extinctions of different species and result in tropic cascade alterations in the lake ecosystem	Commercial and/or recreational harvest
Use Incompatibility		
Ecological Incompatibility	Uses that alter fundamental ecological processes may ultimately undermine the characteristics of the lake that are most highly used and valued	Limited monitoring, management and/or regulatory capacity
Use Based Incompatibility	Preferred uses by one group that negatively affect the ability of another group use the resource in a preferred manner may lead to conflict and require mitigation	Limited monitoring, management and/or regulatory capacity
Intergenerational Use	Existing uses that do not currently limit the desired use of the lake but create a trajectory in which the same use (or different use) may not be an option to future generations	Limited monitoring, management and/or regulatory capacity

6.1. Stressor Analysis

To describe the relative impact of different stressors on the Cisco Chain ecosystem, individual stressors (see Table 6.1) were evaluated based on their ability to limit achievement of the identified management goals for the lakes. The impact of each stressor was ranked based on its likely impact on the current conditions of the lakes. Stressors were ranked by Northland College lake assessment staff using a four point scale (Table 6.2).

Table 6.2. Criteria used to rank the relative impact of different potential stressor throughout the Cisco Chain ecosystem

Level of Stressor Impact	Definitions
Low	Unlikely to be affecting use of the lake and attaiment of mangement goals
Medium	Potentially affecting use of the lake and attaiment of mangement goals, now and into the future
High	Likely to be affecting use of the lake and attaiment of mangement goals, now and into the future
Not Applicable (NA)	Management goal not theoretically affect by the specific stressor

Within the Cisco Chain ecosystem, relatively few stressors are negatively impacting its current use (Table 6.3). However, several management goals are partially affected by different stressors and several stressors have the ability to limit the desired use of the lake in the future. The relative impact of these different stressors are summarized below according to each management goal:

Goal 1 – Maintain Current Levels of Motorized and Non-motorized Use
Current levels of motorized and non-motorized use appear consistent with the ecological conditions and user experiences on the Cisco Chain; although some expressed concern over boat traffic and erosion in connecting channels throughout the system. However, given the potential for increased shoreline development, it is possible that watercraft usage may increase in the future. Most survey responses highlighted interest in maintaining or limiting watercraft densities.

Goal 2 – Maintain Scenic Beauty of the Cisco Chain
The scenic beauty of the Cisco Chain is generally consistent with user expectations. Most survey respondents indicated that lake aesthetics did not limit their use and/or enjoyment of the Cisco Chain. It is unclear how much of this aesthetic beauty is driven by shoreline development. But, given the potential changes in shoreline development that are possible under future zoning conditions, it is possible that lake aesthetics will change in the future.

Goal 3 – Maintain Existing Water Levels and Hydrologic Processes
In general, the hydrologic processes in the Cisco Chain are moderately disturbed. Water levels at the outlet are controlled to a consistent depth of four to five feet and the lakes receives runoff from a minimal amount of imperious surface. Given the potential for increased development throughout the watershed, and in the shoreline areas in particular, it is possible that both overland and groundwater flow to the lakes may be altered under future land use conditions. However, the full

extent of these potential changes is unclear. Static water levels may increase the potential for invasion by non-native aquatic plants and potential for shoreline erosion.

Goal 4 – Protect and Restore Nearshore, Shoreline and Critical Habitat

Nearshore and shoreline habitat in Cisco Chain are in moderate to good condition and some localized areas of particularly high quality habitat are present. However, given the potential for changes in shoreline development, it is possible that nearshore, shoreline and critical habitat may continue to be altered in the future.

Goal 5 – Maintain Existing Water Quality Conditions

Water quality conditions in the Cisco Chain are consistent with state standards for mesotrophic/eutrophic lakes. Although water quality has likely declined in the Cisco Chain since the mid-1800s, it is unlikely that existing pollutant sources are currently impacting the Cisco Chain ecosystem in a way that limits the desired uses. However, given the potential for altered land use, shoreline development and climate driven shifts in water temperature and pollutant runoff, it is possible that water quality may decline in the Cisco Chain in the future.

Goal 6 – Maintain Diverse Native Plant Communities

Native aquatic plant communities are diverse and robust despite the presence of localized colonizes of invasive plants, particularly in Big Lake. As such, it is unlikely that existing ecological stressors are negatively impacting this element of the ecosystem. However, given the potential changes in use and shoreline development and difficulty in adequately monitoring all potential pathways for invasive plant species, additional introductions are possible in the future.

Goal 7 – Maintain Diverse Native Fish Communities

Fish communities in the Cisco Chain are generally consistent with those expected in mesotrophic lakes.

Goal 8 – Increase Walleye Population Density

Walleye recruitment has been historically moderate in the Cisco chain. Population enhancement efforts have primarily focused on stocking and habitat enhancement. However, walleye densities (although consistent with other regional lakes) are lower than the state goal of three adults per acre.

Goal 9 – Maintain Access to Tribal Fishing Grounds

Access to tribal spearing grounds for spring harvests appears to currently unimpeded, but has the potential to be impacted by shoreline development in the future.

Table 6.3. Analysis of the potential ability to impair the desired uses for the Cisco Chain.

Management Goals for the Cisco Chain	Potential Stressors and Level of Impairment																		Comments and Analysis
	Hydrologic Alteration			Habitat Loss			Pollutant Runoff and Deposition						Biological Community Modification			Use Incompatibility			
	Surface Water Alteration	Groundwater Alteration	Water Level Modification	Nearshore/Shoreline	Thermal Restrictions	Spawning Substrate	Agricultural	Industrial	Municipal	Septic Systems	Urban	Contaminant Deposition	Non-native Species	Species Incompatibility	Overharvest	Ecological Incompatibility	Use Based Incompatibility	Intergenerational Use	
1 - Maintain Levels of Motorized and Non-motorized Use	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	1	2	Desired recreational usage patterns are currently unimpaired by ecological stressors or incompatible uses.
2 - Maintain Scenic Beauty of the Cisco Chain	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	1	1	2	Scenic beauty of the Cisco Chain is relatively unimpaired through shoreland development, but has the potential to decline in the future in response to shoreline habitat loss and urban runoff.
3 - Maintain Existing Water Levels and Hydrologic Processes	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1	2	2	Hydrologic processes are moderately impaired by the Bond Fall dam outlet control structure and moderate levels of development. Interlake boat access may be in conflict with natural water level fluctuations.
4 - Protect and Restore Shoreline, Nearshore and Critical Habitat	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	1	1	2	Nearshore and shoreline habitat are moderately impacted but have the potential to decline in the future in response to shoreline development and habitat loss.
5 - Maintain Existing Water Quality Conditions	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	1	1	2	Water quality is generally unimpaired, but has the potential to decline in the future in response to urban runoff.
6 - Maintain Diverse Native Aquatic Plant Communities	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	1	1	2	Aquatic plant communities are generally unimpaired, but have the potential to delcine in the future response to existing invasive plants and shoreline habitat loss and urban runoff.
7 - Maintain Diverse Naive Fish Communities	1	1	1	1	2	1	1	1	1	1	2	1	1	2	2	1	2	2	Fish communities are generally unimpaired, but may be beginning to shift in response to thermal restrictions, urban/septic system runoff.
8 - Increase Walleye Population Densities	1	1	1	2	2	2	1	1	1	1	1	1	1	2	1	2	2	2	Native walleye reproduction is limited. Future catches are highly dependent on stocking.
9 - Maintain Access to Tribal Fish Grounds	1	1	1	2	2	2	1	1	1	1	1	1	1	2	1	2	2	2	Access to Tribal fishing grounds appears to be currently unimpeded buy may be depending on levels of future shoreline development.
	8	**8**	**9**	**14**	**11**	**10**	**8**	**8**	**8**	**8**	**14**	**8**	**8**	**11**	**9**	**11**	**13**	**18**	
	Cumulative Stressor Ranks																		

7. Policy Summary and Analysis

To mitigate and prevent the impacts of the different stressors described above, a range of existing rules, regulations and management activities have been developed and implemented by different management units and stakeholder groups surrounding the Cisco Chain. The existing policies are summarized below:

7.1. Existing Policies and Management Activities

Public Access and Recreation

Public use and access to water resources throughout Wisconsin are protected and managed under the Public Trust Doctrine. Under the Public Trust Doctrine, all navigable waterways are commonly owned by all citizen of Wisconsin. As such, the state (generally through the WDNR) is obligated to protect the public's right to use "waters of the state" for transportation, consumptions, recreation and scenic beauty. Wisconsin law affords riparian land owners special privileges adjacent to their private property, but is required under Supreme Court decision to manage water resource primarily for public use and secondarily for private use. Public use of state waters are managed and protected through a variety of mechanisms described below.

Water Quality

Water quality in the Cisco Chain is managed through a series of federal, state and local regulations as well as a range of volunteer efforts. The federal Clean Water Act (CWA) is the primary law that sets regulations for water quality. In Wisconsin, the regulatory authority for the CWA has been delegated to the WDNR, which has in turn delegate some of this responsibility to different local governmental units. The CWA sets the minimum for water quality standards, but different state and local rules and regulations can require more stringent water quality protection measures. Under the CWA, WDNR is required to 1) develop water quality standards, 2) assess the condition of water resources based on these standards, and 3) restore all waterbodies not meeting established water quality standards. Implementation of the CWA is achieved through a series of programs within the WDNR. Details of these programs are described below.

Under the Water Quality Standards program, WDNR reviews and revises water quality standards on a triennial basis. Every two (even) years, existing data sets are compared to water quality standards as part of the Water Condition Assessment and Reporting process at WDNR http://dnr.wi.gov/topic/SurfaceWater/assessments.html. To assess water quality conditions in different waterbodies, the WDNR follows the Wisconsin Consolidated Assessment and Listing Methodology (WisCALM) process, which specifies the criteria for data to be used in an assessment as well as the conditions under which data would be interpreted as evidence of a water quality impairment. When a waterbody has been identified as not meeting standards, or impaired, it is placed on the WDNR impaired waters (or 303d) list. Although routine water quality assessments occur, the ability to conduct a full "condition assessment" for a lake is often limited by the availability of appropriate data sets.

When a waterbody is placed on the impaired waters list, the CWA stipulates that a study must be conducted to identify and reduce the pollutant of concern. The process/study that is required for all impaired waterbodies is called a Total Maximum Daily Load (TMDL). Once a waterbody is listed as impaired, WDNR has 15-years to develop/finalize a TMDL or provide evidence as to why the waterbody should be delisted. Following the development of a TMDL and approval by EPA, local governmental units and potential pollutant sources are responsible for implementing activities to reduce pollutant loads to the impaired waterbody, and this work is generally completed as part of different regulatory/permitting processes.

Runoff and Pollutant Management
The primary program through which pollutant runoff/discharge into lakes (and other waterbodies) is regulated is through the Wisconsin Pollutant Discharge Elimination System (WPDES). All entities that discharge different potential pollutants into a waterbody (e.g., wastewater facilities, industrial plants, municipal stormwater systems, confined animal feeding operations…etc.) are required to obtain WPDES permits. Through the WPDES system, discharges from regulated facilities are required to meet different environmental standards, depending the nature of the discharge and the waterbody being discharged into.

Although the WPDES program is intended to regulate pollutant runoff from all wastewater and industrial discharges, confined animal feeding operations and urban stormwater, different thresholds must be met before a permit is required. Potential point-sources of pollution that are below the WPDES permit thresholds are not regulated unless specific local regulations and/or ordinances exist. Currently, stormwater from urban lands in the surrounding townships is not regulated as part of the WPDES program because the population in these towns is below 5000 (see Comprehensive Planning Law).

All other more diffuse (non-point) potential sources of runoff and pollution (particularly agricultural runoff, http://dnr.wi.gov/topic/Nonpoint/) are regulated through NR 151, and/or local ordinances/zoning requirements. In particular, NR 151 regulates erosion and nutrient runoff through a series of agricultural performance standards and manure management prohibitions. Statewide efforts to manage nonpoint source pollution are described in the 2011-2015 plan. In addition to these agricultural standards, use of fertilizers containing phosphorus in urban areas was banned in 2009 (unless warranted by a soil test).

Comprehensive Planning Law
Wisconsin's comprehensive planning law requires land use plans to be developed (among other items) by local units of government and requires that future land use development be consistent with these stated land uses. Zoning ordinances can then be further used to regulate different aspects of land development (e.g., stormwater and nutrient runoff). Beyond areas zoned for shoreland development, stormwater and nutrient management is not prescribed in existing land use plans for the surrounding towns.

Antidegradation
The CWA also requires that WDNR establish and implement an "antidegradation" policy to prevent the degradation of water resource as a result of future activities and develop special protections for the state's highest quality waters. This antidegradation provision is implemented through Chapter NR 207 of the Wisconsin Administrative Code. Through NR 207 any "new" (initiated after March 1st, 1989) potential pollutant discharges must first demonstrate justification of the new or increased discharge prior to permit issuance. Additionally, WDNR is required to identify Outstanding Resource Waters (ORWs) and Exceptional Resource Water (ERWs). In Wisconsin, ORWs and ERWs are designated by WDNR and listed in Chapter NR 102 of the Wisconsin Administrative Code. Once listed in NR 102, these waterbodies are managed to a higher standard, such that no new discharges are allowed to decrease water quality, except in unusual circumstances. The Cisco Chain is not considered an ORW or ERW.

Chemical Contaminants

Some pollutants are regulated outside the traditional frameworks for point and nonpoint sources described above. The two chemical where this is most applicable to lake management are mercury and lead. Mercury deposition in lakes is primarily regulated by the Clean Air Act, and, in 2015, Mercury and Air Toxics Standards (MATS), both of which are expected to continue to reduce mercury deposition to lakes. However, since much of the mercury deposition in Wisconsin originates from emissions outside of the US, a continuing strategy to reduce mercury exposure is though consumption advisories from the Wisconsin Health Department (http://dnr.wi.gov/topic/fishing/consumption/). Many historical sources of lead have been addressed through different regulations (e.g., gasoline additives, and waterfowl shotgun shell pellets). Currently, the primary source of lead in lakes is fishing tackle (and to a lesser degree ammunition) and most efforts to reduce lead introduction to lakes are based on voluntary tackle buy-back programs (e.g., Get-the-lead-out, http://dnr.wi.gov/topic/fishing/fishhealth/gettheleadout.html). Elevated contaminant concentrations have not been detected in fish throughout the Cisco Chain.

Shoreland Habitat

Shoreland and nearshore habitat is generally regulated through county and/or local zoning ordinances. The WDNR has set minimum standards for shoreline and floodplain zoning (WDNR 2005). However, many counties have adopted local regulations that require more stringent regulations than the WDNR minimum standards. Shoreland zoning regulation only apply to areas above the Ordinary High Water (OHW) mark. In 2015, State shoreline zoning minimums became the maximum allowable regulation for shoreland areas.

Nearshore habitat is additionally regulated through Section 404 of the CWA http://water.epa.gov/lawsregs/guidance/cwa/dredgdis/ . Section 404 is administered by the US Army Corps of Engineers and regulates the dredge and/or fill of material to and from surface water and wetlands. Modification of nearshore areas in which permanent structures are placed and/or lake beds are disturbed require 404 permits. Additionally, docks and piers are regulated in Wisconsin under NR 326—which requires specific standards for all dock, piers and wharfs constructed after 2012.

Pursuant to NR 1.06 areas of Critical Habitat (generally in nearshore areas) can be designated by WDNR if they have Public Right Features and/or Sensitive area. Critical Habitat designation then requires that new developments and/or shoreline modifications me an additional set of more restrictive/protective standards.

Aquatic Plants and Invasive Species

Aquatic plants and invasive species are primarily managed through NR 19, 40, 107 and 109. NR 19 requires the drainage of all water from boats and associated equipment prior transportation. NR 40 makes it illegal to possess and/or transport any aquatic plants on highway systems. NR 107 regulates the control of aquatic nuisance plants using chemical treatment. NR 109 regulates manual and mechanical removal of aquatic plants from nearshore area from areas greater than 30 feet in width.

Wetlands

Modification of wetland habitat is primarily regulated at federal and state levels of government. Wetlands are primarily regulated through Section 404 of the CWA. Section 404 is administered by the US Army Corps of Engineers and is intended to provide a no-net-loss of wetland (function). Under this law, projects potentially impacting wetlands are reviewed and permitted to 1) avoid wetland impacts where possible, 2) minimize the extent of any necessary wetland impacts and 3) mitigate any losses. Federal review only applies to "navigable" wetlands. In addition to these federal regulations, NR 187 establishes minimum standards for shoreland and wetlands zoning and local zoning codes also often require different setback distances from wetlands.

Fisheries

Fisheries in the Cisco Chain are managed through selective stocking and harvest regulations that occur through a number of tribal, state and local programs. Stocking programs are determined by deliberations between tribal and state biologists and related to user demand, ecological need/constraints and available funding. Harvest regulations are determined on a species-by-species basis and through a process that integrates Tribal treaty rights, recreational fishing usage and biological constraints within any given system. For most game species (other than walleye) harvest limits are based on generalized state-wide standards developed by the WDNR. The combined walleye fishery in the Cisco Chain (tribal and recreational angling) is managed through by a "safe harvest" system (http://dnr.wi.gov/topic/fishing/ceded/managing.html).

Safe harvest is based on the total allowable catch (TAC) for a lake. TAC is the total number of adult walleye that can be taken from a lake by tribal and recreational fishermen without endangering the population. Safe harvest is calculated as a percentage of TAC, taking into account the variability in population estimates. Safe harvest is calculated each year for all walleye lakes in the Ceded Territory. If a recent adult walleye population estimate is available for the Cisco Chain, it is used to set safe harvest. If no current population estimate is available, a more conservative approach for estimating the population is used. Safe harvest limits are set so there is less than a 1-in-40 chance that more than 35% of the adult walleye population will be harvested in any given lake by the combined efforts of tribal and recreational fishermen.

However, population estimates cannot be conducted on every lake in the Ceded Territory in a single year and estimates that are more than two years old may no longer accurately reflect the walleye population in a lake. For lakes where there is not a population estimate less than two years old available, a statistical model is used to calculate safe harvest, based on the size of the lake and the primary recruitment source of walleye in the lake (natural reproduction or stocking). The model results in more conservative safe harvest limits than those set using recent population estimates.

The six Chippewa tribes of Wisconsin are legally able to harvest walleyes using a variety of high efficiency methods, but spring spearing is the most frequently used method. In spring each tribe declares how many walleyes and muskellunge they intend to harvest from each lake. Harvest begins shortly after ice-out, with nightly fishing permits issued to individual tribal spearers. Each permit allows a specific number of fish to be harvested, including one walleye between 20 and 24 inches and one additional walleye of any size. All fish that are taken are documented each night with a tribal clerk or warden present at each boat landing used in a given lake. Once the declared harvest is reached in a given lake, no more permits are issued for that lake and spearfishing ceases.

Rare, Threatened and Endangered Species

Rare, threatened and endangered species are primarily regulated though WDNR administration of the Endangered Species Act. Through this process, WDNR develops and updates lists of species considered rare, threatened and/or endangered. As the species are identified throughout the state, they are added to the Natural Heritage Inventory (NHI) Database. Once listed, different species and their associated habitats are afforded a broader range of protections, and different land development activities are required to obtain permits that require review of the NHI database to assess the potential for impacts to protected species. See NR 27 and 29 for additional details.

7.2. Policy Analysis

To characterize the ability of different policies to mitigate and/or prevent potential stressor impacts in the Cisco Chain ecosystem, the scope/implementation capacity of each policies was compared against each individual stressor (Table 7.2). Each stressor-policy combination was assessed based on the ability of the policy to mitigate/prevent stressor impacts to the lake. Policy-based management of different stressors were relatively ranked on a scale of 0 to 4 (Table 7.1). Policy evaluations were based on professional judgement by Northland College staff and faculty and reviewed by stakeholder groups.

The effectiveness of different policies, rules, regulations to prevent and/or mitigate the impacts of different stressors is highly variable. Potential impacts from some stressors are likely to be almost entirely prevented by some policies under current and future conditions, while some stressors are relatively poorly mitigated/prevented by any policies. Stressors that are best regulated through different policies include water level modification, industrial runoff and municipal runoff. Stressors that are least effectively regulated by current policies are spawning habitat loss, polluted runoff from urban and agricultural lands and recreational use incompatibilities.

The primary limitations across all policies is a lack of ability to 1) account for anticipated future conditions and 2) reconcile potential use/ecological incompatibilities. Many policies effectively protect the Cisco Chain ecosystem under current land use and climate scenarios. However, given the potential (arguable likelihood) that both land use and climate will continue to change into the future, it is important to account for these potential changes through educational, planning and regulatory tools.

Table 7.1. Definitions level(s) of stressor mitigation/prevention provided by different policies

Level of Stressor Mitigation/Prevention	Definitions
Excellent	Policy likely to effectively mitigate/prevent stressor impacts under current and potential future conditions
Good	Policy mostly mitigates/prevents stressor impacts but may not under site specific and/or potential future conditions
Fair	Policy partially mitigates/prevents stressor impacts
Poor	Policy unlikely to mitigate/prevent stressor impacts
Policy Not Applicable	Policy not intended to mitigate/prevent stressor impacts

Table 7.2. Summary of policy coverage of current and potential stressors to the Cisco Chain (part I).

Stressors to be Mitigated	Existing Policies																		Cumulative Protection	Comments and Analysis
	USACE	FERC	USEPA	Tribes	WDNR					WDNR			Vilas County		Townships	CCROA		NA		
	Section 404 of Clean Water Act	Bond Falls Dam	Clean Air Act and MATS Rule	Treaties of 1837 and 1842	NR 102 - Water Resource Designation	NR 207 Antidegradation	NR 109 and 107 - Aquatic Plants	WPDES Program	303 Surface Water Program	NR 151 - Ag. Standards	NR 40 - Invasive Species	NR 115 - Shoreland Zoning (State Minimums)	Septic System Permitting	Shoreland Zoning	Comprehensive Plans and Zoning	WDNR, Clean Boats, Clean Waters (Voluntary)	WDNR, Healthy Lakes Initiative (Voluntary)	WDNR, Invasive Species Control (Voluntary)		
Pollutant Runoff and Deposition																				
Agricultural Runoff	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	2	Agricultural runoff is unlikely to affect the Cisco Chain, as current zoning regulations call for less than 1% of future lands to be used for agricultural purposes.
Industrial Runoff	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	4	Industrial runoff is unlikely to impact the Cisco Chain into the future, as current land uses to not allow for industrial development and industrial effluents are well regulated by the WPDES program.
Municipal Wastewater	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	4	Municipal wastewater is unlikely to affect the Cisco Chain, as no effluents currently (or are planned to) discharge to the system and municipal effluents are well regulated by the WPDES program.
Septic Systems	0	0	0	0	0	0	0	0	2	0	0	0	3	0	0	0	0	0	3	Septic systems have a moderate potential to negatively affect the Cisco Chain in the future. Current septic regulations require relatively high standards, but the large potential increase in septic systems that could result from future zoning plans could have a cumulative impact on the lake. Current monitoring efforts are likely poorly suited to detect potential impacts from septic systems.
Urban Runoff	0	0	0	0	0	0	0	2	2	0	0	2	0	3	0	0	2	0	3	Urban runoff has a moderate potential to impact the Cisco Chain in the future. Stormwater management is required for all shoreland parcels, but relatively little stormwater management is required for parcels outside of the shoreland areas. Current stormwater policies do not account for anticipated changes in precipitation from climate change.
Contaminant Deposition	0	0	3	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	3	The primary contaminants to the lake (mercury and lead) are currently (or will be in the near future) well managed through federal regulations and volunteer efforts.
Use Incompatibility																				
Ecological Incompatibility	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Relatively few policies are in place to reconcile the potential ecological incompatibility of the recreational uses for the Cisco Chain.
Use-based Incompatibility	0		0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	No policies/processes are in place to reconcile potential use incompatibilities among different user groups. Recreational use incompatibilities are partially created by static water levels
Intergenerational Incompatibility	0		0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	No policies/processes are in place to reconcile potential use incompatibilities across generations. Recreational use incompatibilities may be partially addressed through local slow-now wake ordinances.
Maximum Policy Benefit	12	6	3	4	15	15	10	13	16	2	2	8	5	9	12	2	8	2		

Table 7.3. Summary of policy coverage of current and potential stressors to the Cisco Chain (part II).

Stressors to be Mitigated	Existing Policies																		Cumulative Protection	Comments and Analysis
	USACE	FERC	USEPA	Tribes	WDNR					WDNR			Vilas County		Townships	CCROA		NA		
	Section 404 of Clean Water Act	Bond Falls Dam	Clean Air Act and MATS Rule	Treaties of 1837 and 1842	NR 102 - Water Resource Designation	NR 207 Antidegradation	NR 109 and 107 - Aquatic Plants	WPDES Program	303 Surface Water Program	NR 151 - Ag. Standards	NR 40 - Invasive Species	NR 115 - Shoreland Zoning (State Minimums)	Septic System Permitting	Shoreland Zoning	Comprehensive Plans and Zoning	WDNR, Clean Boats, Clean Waters (Voluntary)	WDNR, Healthy Lakes Initiative (Voluntary)	WDNR, Invasive Species Control (Voluntary)		
Hydrologic Alteration																				
Surface Water Modification	3	1	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	3	Existing policies are moderately well suited to protect surface water alterations in the Cisco Chain watershed. The primary activity that has the most potential to alter surface water processes is the management of the Bon Fals dam.
Groundwater Modification	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	3	Existing policies are well suited to protect against large scale groundwater withdrawals from the Cisco Chain, but less well suited to protect against the potential cumulative impacts individual well development over time. Groundwater recharge is not protected.
Water Level Modification	3	1	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	3	Water levels in the Cisco Chain are somewhat artificially elevated because of the outlet control structure. This structure may likely have impact on the lake conditions into the future.
Habitat Loss																				
Nearshore/Shoreline	3	2	0	0	2	2	3	0	0	0	0	2	2	3	3	0	2	0	3	Future shoreline habitat loss in the Cisco Chain is moderately protect. Under current policies, the nearshore and shoreline areas have the potential to change significantly in response to shoreland zoning regulations.
Critical Habitat	3	0	0	0	2	2	3	0	0	0	0	2	0	3	3	0	2	0	3	Critical habitat is somewhat protected by existing shoreline zoning and dredge and fill permits. However, Critical Habitat areas have not been formalized throughout the lake for specific protections
Spawning Substrate	0	0	0	0	2	2	2	0	0	0	0	2	0	0	2	0	0	0	2	Spawning substrate is poorly documented throughout the Cisco Chain. It is likely that much of the important spawning habitat will be somewhat protected by existing shoreland zoning and permitting processes. However, without full understanding of the extend of habitat conditions, the effectiveness of current policies is uncertain
Biological Community Modification																				
Non-native Species	0	2	0		0	0	2	0	0	0	2	0	0	0	0	2	2	2	2	Non-native species introduction is relatively poorly prevented through existing polices. Laws exist to prevent invasive species transportation, but complete monitoring and enforcement are limited. Most management of existing invasive species is dependent on volunteer effort.
Species Incompatibility	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	Current policies are moderately well prepared to minimize the potential impacts of native species introductions (e.g., stocking).
Overharvest	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	Current policies are moderately well prepared to prevent overharvest of fish from the Cisco Chain. Current data suggest that harvest of walleyes is beyond a sustainable level.
Maximum Policy Benefit	12	6	3	4	15	15	10	13	16	2	2	8	5	9	12	2	8	2		

8. Management and Monitoring Recommendations

In general, because of the high quality of the Cisco Chain ecosystem, management activities should focus on proactive planning to prevent any future degradation of the lake system and the development of routine monitoring systems to detect any changes in ecosystem condition and/or user experiences early on.

Goal 1 – Maintain Current Levels of Motorized and Non-motorized Use
Maintenance of existing levels of watercraft usage is most likely to be affected by the potential for increased access to the lakes from the higher densities of shoreland properties likely to be encountered under future land use scenarios. There is no particular policy/process in place to manage this potential transition. However, ongoing monitoring of user experience and perception may help to proactively manage any use conflicts that arise in the future. User experience and perception could by monitored by routine administration of the user survey used in the study. Future surveys should expand the use of metrics to more holistically capture and describe the attributes of the Cisco Chain that contribute to positive user experiences.

Goal 2 – Maintain Scenic Beauty of the Cisco Chain
Maintenance of existing aesthetics of the Cisco Chain is most likely to be affected by the potential for increased shoreline development and recreational use of the lakes that could be encountered under future land use scenarios. The primary regulatory process governing shoreland development is NR 115, which (as of 2015) sets a maximum allowable regulation level for shoreland areas. While these zoning rules strive to balance recreational access, environmental quality and lake aesthetics, it is unclear how these development patterns will affect the aesthetic value of the Cisco Chain for current and future users. Ongoing monitoring of user experience and perception may help proactively manage any changes is aesthetic value of the lake that arise in the future. User experience and perception could by monitored by routine administration of the user survey used in the study. Future surveys should expand the use of metrics to more holistically capture and describe the attributes of the Cisco Chain that contribute to the aesthetic elements of the ecosystem.

Goal 3 – Maintain Existing Water Levels and Hydrologic Processes
Maintenance of existing water levels and hydrologic processes is likely to be primarily affected by regulation of the Bond Falls outlet dam and changes in land use surrounding the lakes. Potential water level changes are highly regulated through a variety of mechanisms. However, much depends on the scope of the Federal Energy Regulatory Commission (FERC) permit. Elevated water levels and limited water level fluctuation have the potential to increase shoreline erosion and enhance the establishment of invasive species. Seasonal water level drawdown may be a mechanism to establish water level fluctuation and maintain inter-lake access throughout the Chain.

Additionally, changes in runoff process of surface and groundwater are less fully regulated. Projected changes in land use throughout the watershed are expected to increase levels of impervious surfaces and the potential for increased groundwater extraction. Increased impervious surfaces in shoreland areas are relatively well regulated through shoreland zoning ordinances, but cumulative impacts of shoreland development and groundwater extraction from individual wells are less clearly regulated. Given the likelihood that climate change will lead to increased rainfall intensity, it is important that engineering design standards incorporate (and periodically update) the most current hydrologic model input files to accurately size stormwater management practices and other infrastructure. Maintenance of a dynamic water level within the lake system to mimic natural processes may be an important component of invasive species management.

Goal 4 – Maintain Existing Water Quality Conditions

Water quality in the Cisco chain is regulated and protected through a variety of rules and policies. However, not all relevant/necessary policies apply to the Cisco Chain watershed. The primary mechanism for water quality management in Cisco Chain is through the WDNR implementation of the Clean Water Act 303 program. However, current water quality monitoring efforts (necessary to implement the 303 program) are insufficient to track changes in the condition of the lakes. Using a monthly water quality sampling regime, it will take approximately 10 years of continuous monitoring to detect a change in average phosphorus concentrations of 15% — and 20% for Secchi transparency (summarized in NPS, 2008). Additionally, because the municipal areas potentially contributing runoff to the Cisco Chain are all less than 5000 people, they are exempt from the storm sewer system regulations required in larger communities. In the absence of these regulations, local zoning ordinances are potentially insufficient to fully mitigate increased nutrient loads to the Cisco Chain likely to be encountered under future land use scenarios.

Increased septic system densities potentially developed under future shoreland zoning guidelines will also likely increase phosphorus discharge to the Cisco Chain. Current county zoning ordinances require routine monitoring and maintenance of septic systems. However, current regulations do not consider potential cumulative impacts of relatively dense septic system development along shoreland areas. Future on-site wastewater designs should prioritize use of holding tank systems over conventional and mound systems.

Potential future changes in water quality in the Cisco Chain may be potentially prevented through altered stormwater management and ongoing water quality monitoring. To manage runoff from future development it will be important to develop both water quality and quantify performance standards for land use conversion and regulatory thresholds that are consistent with future development.

Climate change should also be incorporated into future planning. Given the anticipated changes in both water temperature and runoff potential in future climate scenarios, it is critical that all engineering design and land use plans reflect anticipated future hydrologic conditions. This will need to be accomplished through cumulative effect modeling of different land use scenarios, but can also be enhanced through adoptions (and recurring revision of) hydrologic design standards. Current NWS, Atlas 14 rainfall data should be incorporated into design standards as soon as possible.

Goal 5 – Protect and Restore Nearshore, Shoreline and Critical Habitat

The two primary factors may likely to lead to degradation of shoreland and critical habitat around the Cisco Chain are shoreland development and a lack of official critical habitat designation. Nearshore and shoreline habitat are most effectively protected through the 404 permitting process of the USACE and the Vilas County shoreland zoning requirements. While the shoreland zoning requirements provide the most comprehensive levels of protection for shoreland habitats, current zoning requirements do not consider cumulative impacts of multiple individual developments. Given the potential for a more than doubling of shoreland properties around the Cisco Chain and the relatively high quality of current shoreline habitats, cumulative impacts should be considered.

Officially designating areas of Critical Habitat in the Cisco Chain would also enhance protection of in-lake areas. This study identified areas of potential critical habitat around the lakes, but stopped short of delineating these areas and seeking special designation as critical habitat. Critical habitat designation would enhance protection of these areas by requiring additional protection if/when any shoreline development or modification occurs in the future.

Goal 6 – Maintain Diverse Native Plant Communities

Maintenance of diverse native plant communities is likely to be primarily impacted by monitoring/management of existing populations and the potential future introductions of new invasive species. A range of potential invasive species introduction pathways exist for the Cisco Chain. Given the current levels of access and development, the potential introduction pathways do not represent an immediately critical concern. However, if use and access to the Cisco Chain (particularly though increased shoreline development) increase as planned, the probability of additional invasive species introductions increases. Additionally, long-term static water levels and any decreases in water quality increase the likelihood of invasive species introductions.

Invasive species treatment in Big Lake, is of particular challenge given the timing and dispersion of growth. Based on three years of survey work, Eurasian Watermilfoil (EWM) colonies are consistently present in a late season growth pattern. EWM colonies are generally undetectable, sparsely distributed (often in single plant per acre densities) and/or comingled with native plants during early-season herbicide treatment windows. As such, these EWM colonies are poorly suited for herbicide treatment, particularly because herbicide impacts to native plants may accelerate EWM colonization/spread. Alternatively, selective, late-season hand pulling of EWM is likely the most appropriate management technique for Big Lake. Hand pulling can be accomplished though volunteer efforts and/or through contract with local vendors that specialize in hand pulling control. Money from the CCROA Rapid Response grant may be used to contract with vendors.

Prevention of future invasive species can be achieved by both the management of the lakes and education/interaction with its users. Wisconsin laws prohibit transportation of aquatic plants on vehicles and trailers. However, while this law is a deterrent for invasive species introduction, it cannot achieve a level of 100% containment. In fact, most efforts to prevent/respond to invasive species introductions are voluntary. The CCROA currently supports (Clean Boats Clean Waters) CBCW inspections at various landing surrounding the lake system. However, one of the primary invasive species pathways to lakes (riparian introduction) is currently not considered as part of enforcement and/or volunteer efforts. Future invasive species control efforts should focus on increased outreach to riparian landowners and boat launch users.

Beyond prevention, activities to monitor and respond to any potential invasive species introductions could be expanded and formalized. Currently, CCROA hires scientists/volunteers to inspect shoreline areas for potential invasive plant species. These activities could be coupled with the development of an Early Detection, Rapid Response Plan to prepare for any potential future species introductions. Similarly, site-specific monitoring should be combined with routine inventories of the entire aquatic plant community to characterize any changes that may be resulting from related stressors like climate change and/or shoreline development (both of which can increase the probability that introduced species become invasive).

Goals 7-8 – Fish Community and Fishery Management

Goals 7-8 all described desired potential states for fish communities and the Cisco Chain fishery. All management recommendations for these goals are to be provided by the WDNR, MDNR and Tribal fisheries programs.

Goal 9 – Maintain Access to Tribal Fishing Grounds

Current access to the walleye fishery and seasonal spearing grounds is not impeded, but has the potential to be impacted through shoreline development into the future. Identification and protection of important walleye spawning and tribal member spearing grounds is a critical element in the long-term protection of treaty fishing rights.

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10. Appendix A – Use and Value Survey

Introduction

This report summarizes the results from the stakeholder use and value assessment survey. Given the important role that people play in the use and condition of the Cisco Chain ecosystem, it is critical to characterize how different user groups use and value the Cisco Chain. Results from this survey were used to inform the development of management goals for the Cisco Chain.

Methods

Survey construction

One of the primary goals of the Cisco Chain of Lakes grant(s) was to implement a stakeholder survey to describe the values, uses and behaviors that shape the use and management of the Cisco Chain. As a result, a group of faculty and student researchers from Northland College constructed the survey between 2012-2014 as the primary mechanism to capture stakeholder values, attitudes, uses and behaviors. A resource sociologist with the Wisconsin Department of Natural Resources and members of the CCROA vetted the final instrument. The final survey was divided into six parts covering a variety of topics including:

(1) participant demographic information,
(2) property information,
(3) participant uses of the lakes,
(4) importance of these uses,
(5) participant attitudes toward the lakes and their uses, and
(6) general values of the participants.

Sampling strategy and sampling frame

A census sample (i.e., the entire population) of households within one mile of the lakeshore of the Cisco Chain was drawn. The initial sampling frame included 660 households. After removing undeliverable surveys, duplicate landowners, or vacant properties, the final sampling frame was 640. Surveys were delivered via mail using a modified Dillman method where respondents were contacted prior to receiving their survey, sent the survey, and then sent a reminder if they did not return the survey. Researchers from Northland College collected surveys during the months of October, November, and December of 2014 and ended up with a 43.9 percent (n=281) response rate.

Results

Participants

Survey respondents range in age from 37 to 96 years old with the average age being 65.9 years old. Approximately 72.1 percent of respondents were male; the other 27.9 percent were female. Education levels vary from high school diplomas to graduate and professional degrees, of which approximately 60.4 percent have graduate or professional degrees (see Table 10.1). Respondents most commonly identify with the income range of $60,000 to $99,000 (see Table 10.2). When asked what year they first started visiting the Cisco Chain of Lakes, 50 percent of participants first started visiting the area between 1960 and 1990.

Property Description
The average number of years that respondents have owned property in the Cisco Chain of Lakes area is 28.5 years with the range being 1 years to 86 years. Most respondents own property on Thousand Island, Big, Mamie, or Cisco Lakes, with far fewer owning property on West Bay, Clearwater, Lindsley, Fishhawk, East Bay, Poor, Two, Morely, or Spring Lakes (Table 10.3). Approximately 93.8 percent of respondents own waterfront property on Cisco Chain of Lakes, and over 75 percent of the respondents are not full time residents (Table 10.4).

Participation with the Cisco Chain of Lakes Association
Most respondents (81 percent) are current members of the Cisco Chain Riparian Owners Association (Table 10.5), and 36.7 percent of respondents report that they never attend lake association meetings (Table 10.6).

Participant Uses of the Cisco Chain
The second section of the survey asked participants rated "how important it is to you that Cisco Chain of Lakes can be used for the following purposes." The activities identified in this section were similar – and in some cases identical – to the indicators included in the frequency of use activities. These specific items respondents rated included: enjoying scenic beauty, maintaining sense of peace and relaxation, observing or enjoying nature, gathering with family and friends, fishing/ice fishing, motorized watersports, non-motorized watersports, encouraging sense of community among users of the lake, swimming, providing a boost to the local economy, harvesting food, non-motorized snow sports, harvesting food, snowmobiling, hunting or trapping, and using water for irrigation or lawn, (Figure 2). Participants could choose from "not at all important" (gray), "of little importance" (peach), "neutral" (light blue), "somewhat important" (orange), and "very important" (dark blue). The circle on each line indicates the average response for all respondents for each item in the matrix. The matrix is organized in a way that puts the activities with the higher average, or activities found to be more important, at the top and those found to be least important at the bottom.

The activity most important to people was enjoying the scenic beauty of the lake, with almost the entire sample, aside from those choosing to not respond, identifying the activity as very important (95.7 percent) or important (4.3 percent). This conspicuously positive trend continued with almost all respondents (greater than 95%) finding maintaining a sense of peace and relaxation, observing or enjoying nature, and gathering with friends and family as very important or important. Together, these top four indicators predominantly relate to the intrinsic value and enjoyment of Cisco Chain of Lakes. A majority of respondents also identified encouraging a sense of community among users of the lake as very important (50.9 percent) or important (25.8 percent). Like the top four items, this indicator also falls outside of the typical utilitarian uses of Cisco Chain of Lakes, along with supporting the local economy, where 73.7 percent of participants value it as very or somewhat important.

Still identified by a majority of respondents as very important or important, most of the middle cluster of indicators relate to the lake's recreational and utilitarian purposes. Approximately 87 percent identified fishing as very important or important. This is followed by a majority of respondents identifying non-motorized watersports and motorized watersports as very important or important (both about 81 percent). Encouraging a sense of community among users of the lake was somewhat an outlier, wedged between those favoring motorized watersports and swimming at 76.6 percent valued importance. Slightly lower, but still a majority, swimming, snow sports, and harvesting food captured between 53.8 percent and 79.4 percent of respondents' valued importance (very and somewhat). Those viewing snowmobiling of some degree of import fell just below the majority at 49.8%

Less than half of the respondents identified hunting and trapping and using water for irrigation or lawn watering as either very important or important (33.7 percent and 13.1 percent respectively). Between 46.2 percent and 70.4 percent of participants viewed hunting and trapping and using water for irrigation as of little or no importance. The five least favored categories all had a relatively even distribution of response categories, with an increasingly negative skew as respondents valued certain uses less. Most of the indicators are positively skewed otherwise.

Participant Attitudes of The Cisco Chain and Its Uses

In the third section of the survey, respondents were asked: "Please indicate the extent to which you AGREE or DISAGREE with each of the following statements." Respondents were asked to rate a series of twenty-two items related to objects such as: land, plants, water quality, shoreline, boats, other users, and development (Figure 3). Participants could choose from "strong disagree" (gray), "disagree" (peach), "undecided" (light blue), "agree" (orange), and "strongly agree" (dark blue). The circle on each line indicates the average response for all respondents for each item in the matrix. The matrix is organized in a way that puts the attitudes with the higher average, or the items that respondents tended to have a stronger agreement with, at the top and those items participants tended to have a stronger disagreement at the bottom.

Similarly to both use and importance items found in the previous sections, the indicators that deal with the intrinsic value of Cisco Chain of Lakes rise to the top. In fact, the three of the top four items are relate to the intrinsic value of the lake including: enjoying a view of nature from the water, maintaining peace and quiet on the lake, and Cisco Chain of Lakes being a peaceful place to be. The highest rated item, I enjoy having a view of the wilderness from the water, had 95.3 percent of the respondents agree or strongly agree with this statement. The other two indicators – maintaining peace and quiet and Cisco Chain of Lakes being a peaceful place to be – also had a majority of respondents agree or strongly agree with these statements (88.3 percent and 92.5 percent respectively). When taken with the second highest (out of twenty-two) rated item – "I am concerned that if the health of the lake declines, it could decrease my property value" – 88 percent of respondents agree or strongly agree with this statement. Despite intrinsic value being one of the most important parts of Cisco Chain of Lakes, respondents also suggested they have a financial stake in the health of the lake.

The fifth highest rated item (with approximately 87 percent agree or strongly agree) – "Property owners and permanent renters care about water quality" – and the seventh highest rated item (with 68.1 percent agree or strongly agree) – "Property owners and permanent renters are more respectful of the lake than visiting users" – deal with whether respondents agree or disagree with statements of how much other users care and respect the lake. Coupled together, most of the respondents agree that users regardless of relationship to Cisco Chain of Lakes are respectful when utilizing it[1] but definitely have a more favorable opinion of property owners and permanent renters.

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[1] Most respondents felt Cisco Chain of Lakes has either improved (3.6 percent) or stayed about the same (52.7 percent) when asked about whether the quality of the water has "improved," "stayed about the same," or "worsened." Approximately 35.5 percent stated it has worsened. A proportion of respondents (8.2 percent) selected the "I don't know" option.

Rounding out the top rated items, a majority of respondents (72.9 percent) agree or strongly agree with the statement "My individual actions have a significant impact on the lake." This particular item suggests that respondents feel their actions whether good or bad do affect the health and wellbeing of Cisco Chain of Lakes. When asked about their attitude toward motorized boats, respondents were split on concern over the possibility of increased erosion – with a mean score of 3.19 (which is close to the midpoint of the scale, labeled as "undecided", but slightly skewed toward worry about erosion due to boat traffic). Approximately 31.5 percent disagree or strongly disagree, 26.4 percent are undecided, and the remaining 42.5 percent agree or strongly agree. When taken in combination with "I prefer motorized watersports (e.g., boating or jet skiing) to non-motorized sports (e.g., kayaking)," the sample does seem to favor non-motorized sports with approximately 43.7 percent of respondents preferring non-motorized to approximately 31.1 percent who prefer motorized. About 81.3 percent of the respondents disagree or strongly disagree with the idea that "There are too many boating restrictions (e.g. wake, motor size) on Cisco Chain of Lakes" – compared to only 6.5 percent who agree or strongly agree with this statement. Regardless of preference and feeling about possibility of erosion, respondents seemed to feel boating restrictions were not too stringent.

A smaller proportion but still a majority of respondents (approximately 65.7 percent) disagree or strongly disagree with the statement that "Lakes throughout the Cisco Chain are crowded by boat traffic" compared to 18.5 percent who agree or strongly agree. This sentiment is also reflected in another questions related to crowdedness where respondents were asked about to rate the statement "There are too many homes on lakes throughout the Cisco Chain." Approximately 48.9 percent chose either disagree or strongly disagree versus 23.72 percent who agree or strongly disagree. The remaining 27.7 percent of respondents were undecided. Taken together, respondents generally did not see boat traffic nor current number of homes on the lake as contributing to overcrowding.

Respondents did not seem to have either strong positive or negative attitudes toward aquatic vegetation. When asked to rate "Aquatic plans improve the appearance of the lake," 35.1 percent agree or strongly agree, 28.2 percent disagree or strongly disagree, and 36.7 percent are undecided. When asked how aquatic plants influenced their experiences when recreating on the lake, again, respondents did not seem to have either strong positive or negative attitudes. For example, when asked about concerns over density of aquatic plants affecting recreational activity, 56.9 percent of respondents strongly disagree or disagree with the statement: "Aquatic vegetation is too dense for recreational activity (e.g. swimming and boating)." Approximately 24.9 percent of respondents were undecided while only 18.2 percent agree or strongly agree with this statement. Likewise, when asked specifically about algae and swimming, respondents again are distributed somewhat evenly across response categories with a mean score of 3.07 (just above the mid-point of three and slightly skewed toward being concerned with algae). Approximately 39.3 percent of respondents selected that they agree or strongly agree compared to 33.8 percent who disagree or strongly disagree. The remaining 23.9 percent selected undecided.

Respondents were asked to rate their level of agreement on a variety of indicators related to preference of lakeshore practices. On the three items about personal preference – "I prefer the appearance of landscaped shorelines," "Having a grass lawn leading down to the lake's shore is better than natural vegetation," and "Untouched natural vegetation in and around the lake is unattractive" – respondents tended to slightly favor non-landscaped shorelines. For example, approximately 29.9 percent stated a personal preference for landscaped shorelines compared 40.7 percent of respondents who do not. Similarly, 21.7 percent of respondents thought a grass lawn leading down to the waterfront is better than natural vegetation compared to a slight majority at 52.9 percent who did not. Approximately 69.9 percent of respondents disagree or strongly disagree with the statement that untouched natural vegetation in and around the lake is unattractive. Despite having a slight preference for manicured shorelines, a sizable majority did not have a negative attitude toward untouched natural vegetation. Finally, when asked about whether they think other property owners around the lake have a preference for lawns/landscape over natural vegetation, just over 46 percent of respondents said they thought others around the lake prefer lawns, 15.9 percent thought others prefer natural vegetation, and 37.7 percent were undecided.

Finally, a sizable majority of respondents – over 80.1 percent – and the lowest overall mean score (1.96) did not have a problem with the smell of the lake.

Participant Attitudes of the Cisco Chain Management
In this section of the survey, respondents were asked: "Please indicate the extent to which you AGREE or DISAGREE with each of the following statements." Respondents were asked to rate five items related to management of the Cisco Chain of Lakes fishery (Figure 4). Participants could choose from "strong disagree" (gray), "disagree" (peach), "undecided" (light blue), "agree" (orange), and "strongly agree" (dark blue). The circle on each line indicates the average response for all respondents for each item in the matrix. The matrix is organized in a way that puts the attitudes with the higher average, or the items that respondents tended to have a stronger agreement with, at the top and those items participants tended to have a stronger disagreement at the bottom.

Overall, the respondents are mostly undecided but tend to have a negative skew towards the quality of the management of Cisco Chain of Lakes. Just over 45 percent of the respondents are undecided about whether or not the Wisconsin Department of Natural Resources is effectively managing the fishery of Cisco Chain of Lakes while 36.5 percent disagree or strongly disagree and 18.7 percent agree or strongly agree. Respondents seem to have a more negative attitude toward tribal management of the fishery with 58.7 percent of respondents selecting they disagree or strongly disagree with the statement: "Tribal management (e.g., stocking and harvesting) of the Cisco Chain of Lakes fishery enhances its quality". Approximately 24 percent of respondents are undecided (24.9 percent) and the remaining 16.8 percent agree or strongly agree. A little over 32 percent of respondents feel that the fishery in Cisco Chain of Lakes is worse than other lakes in the area (32.7 percent) compared to 23.2 percent of respondents who felt it was better. Most respondents selected that they are undecided (42.9 percent), however. A majority of respondents (64 percent) selected that they disagree or strongly disagree with the statement "Use of the Cisco Chain of Lakes fishery for fishing tournaments enhances its quality". Another sizeable proportion of respondents chose that they were undecided at 27.5 percent. A large proportion of respondents, about 47.6 percent, do not think that there is excessive recreational fishing on Cisco Chain of Lakes compared to 27.6 percent who do.

Angler Attitudes of the Cisco Chain Fishery
Only the respondents who self-identified as anglers (n=228) completed this section. Respondents were asked: "Please indicate the extent to which you AGREE or DISAGREE with each of the following statements" (Figure 5). The matrix above is arranged in the same way as the previous two sections with respondents being asked to rate seven items related to fishing on Cisco Chain of Lakes. Participants could choose from "strong disagree" (gray), "disagree" (peach), "undecided" (light blue), "agree" (orange), and "strongly agree" (dark blue). The circle on each line indicates the average response for all respondents for each item in the matrix. The matrix is organized in a way

that puts the attitudes with the higher average, or the items that respondents tended to have a stronger agreement with, at the top and those items participants tended to have a stronger disagreement at the bottom.

Of the respondents who fish on the Cisco Chain of Lakes the majority (73.1 percent) consider themselves to be experienced anglers. According to about 84.4 percent of the respondents, the most important element of fishing on Cisco Chain of Lakes is interacting with the natural world. Whereas only 33.5 percent of respondents felt social interaction with others while fishing was most important.

Respondents appear to be generally satisfied with the species of fish they are able to catch (50.9 percent), while dissatisfied with the size (53.3 percent) and number (50.2 percent) of fish they are able to catch in the Cisco Chain of Lakes. This is compared to 33.9 percent (size) and 38.8 percent (number) of respondents who identified that they are satisfied with the fish they are able to catch. A slight majority of respondents (51.1 percent) are not concerned with human health advisories for fish in the Cisco Chain of Lakes and another 41.3 percent are undecided. Only 7.6 percent of respondents are concerned.

When respondents were asked what species of fish they typically fish for and which they would most like fish for (Table 10.7 and Table 10.8), 50 percent or more typically fish for Walleyes, Smallmouth Bass, Sunfish/Bluegill, Crappies, and Largemouth Bass. Some anglers typically fish for Northern Pike (49 percent) and Muskie (40.7 percent). Though very few typically fish for Perch, Trout, or Whitefish in Cisco Chain of Lakes. The respondents had similar answers for what they would like to fish. There is an overwhelming majority (80.7 percent) who would like to fish for Walleye. Anglers who want to fish for Smallmouth Bass, Sunfish/Bluegill, Largemouth Bass, Crappies, or Muskie falls between 49 percent and 33.7 percent. The less common fish that anglers would like to fish for include Northern Pike, Perch, Trout, and Whitefish in order from highest percent response to lowest.

Participant Willingness to Protect the Cisco Chain

In this section of the survey, respondents were asked: “The following items are meant to gauge your willingness to participate in certain activities concerning Cisco Chain of Lakes. Your responses are hypothetical and will not indicate any actual commitment to these activities. How willing would you be to…?” (Figure 6). On the six items in the matrix, participants could choose from “extremely unwilling” (gray), “somewhat unwilling” (peach), “somewhat willing” (orange), and “extremely willing” (dark blue). The circle on each line indicates the average response for all respondents for each item in the matrix. The matrix is organized in a way that puts the items respondents are more willing to do at the top and those they are less willing to do toward the bottom.

The majority of respondents would be willing to participate in protecting Cisco Chain of Lakes by attending to an educational event (77 percent), willing to limit their use of the lake in order to protect it (71.7 percent), changing how they manage their personal property (73.9 percent), and volunteer (70.3 percent). Though most respondents are willing to assist in these ways, the majority, about 54.8 percent, are unwilling to offer any financial support through taxes and fees. A higher percentage of respondents (68.2 percent) are unwilling to support the ongoing protection and restoration of the Cisco Chain of Lakes if they moved away and could no longer routinely utilize the lakes.

Participant Values

In the final section of the survey, respondents were asked: "We would like you to tell us your views on various issues. For each statement, please select the circle nearest the statement you most agree with. Selecting the circle furthest left indicates total agreement with the left-hand statement; the circle furthest right indicates total agreement with the right-hand statement. The circles in between indicate varying levels of agreement. The middle circle suggests you have similar levels of agreement with both statements." The matrix asks respondents to evaluate eleven different sentence pairings on a variety of values. The circle on each line indicates the average response (from 1-7) for all respondents for each item in the matrix (Figure 7).

The first item on the matrix asked respondents whether they see their Cisco Chain of Lakes property as primarily a financial investment or a place to live and recreate. The majority of respondents chose values closer to a place to live and recreate. In fact, 86.6 percent of respondents selected numbers 5, 6, or 7 suggesting respondents overwhelmingly saw their Cisco Chain of Lakes property as a place to live and recreate. When taken in combination with whether respondents feel most closely connected to Cisco Chain of Lakes community or another community, as can be seen in from the overall mean score of 3.7, respondents are equally distributed across the scale. Despite the overwhelming majority of respondents stating that their property is primarily a place to live and recreate, this finding is not impacted by more people feeling most closely tied to the area. Only 41 percent identified feeling most closely connected to the community surrounding Cisco Chain of Lakes – as indicated by circling 1, 2, or 3 on the scale – compared to 33.2 percent of respondents who felt most connected with some other community – as indicated by circling 5, 6, or 7 on the scale.

When asked to choose between whether changes in the health of Cisco Chain of Lakes affect the respondents overall well-being, respondents tended to feel changes to the lake would affect their well-being. A majority (70.1 percent) of respondents choose either 1, 2, or 3 while an additional 15.7 percent chose the middle number 4. Although we cannot say for certain, because many respondents tended to identify with the property as a place to live and recreate over a financial investment, one can assume that some of these changes are more than just financial in nature.

Most respondents saw appropriate management of Cisco Chain of Lakes being for the "conservation of the natural ecosystem" over "managed primarily for human uses". Approximately 43 percent of participants chose managing the lake for the conservation of the natural ecosystem versus 17 percent who tended to lean toward management for human uses. This sentiment is not, however, reflected in the percent of participants who tend to agree more with the statement that the natural environment should be protected from human activity with 33.6 percent falling toward protecting from human activity, 29.2 percent in the middle, and 37.3 percent leaning toward utilization for human needs and growth. When asked whether they felt more closely aligned with managing the lake for future generations versus for current users, 43.2 percent of respondents suggested they thought the lake should be managed for the needs of future generations versus 24.7 percent who identified more closely with managing for current users. About a third (32.1 percent) of respondents chose the middle point.

A large majority of respondents felt that it was appropriate for human intervention to help maintain a healthy lake (70.9 percent) rather than not intervene (8.1 percent) and felt that individuals (49.1 percent) – not government (18 percent) – should be primarily responsible for managing the lake. Participants did, however, suggest limitations on what people should be able to do regardless of whether they own property; 21.2 percent tended to lean toward individuals having cart blanche to develop their property versus 66.2 percent who suggested constraint and imposing limitations on an individual's ability to develop their property. Finally, respondents tended to give priority to those who live in and around the lake (67.1 percent) more say in its management over all users of the Cisco Chain (20.4 percent).

Table 10.1. Education

Level of Education	
Less than high school	1.8%
Some high school (no diploma)	1.1%
High school graduate (or equivalency)	13.3%
Some college (no degree)	16.9%
Two year degree	6.5%
Four year degree	32.7%
Graduate or professional degree	27.7%

Table 10.2. Income

Income	
Less than $60,000	20.9%
$60,000-99,999	27.8%
$100,000-149,999	19.6%
$150,000-199,999	8.7%
$200,000-249,000	9.6%
$250,000 or more	13.5%
Income	

Table 10.3. Property Location

On which lake is your property located?	
Thousand Island Lake	22.1%
Big Lake	21.9%
Mamie Lake	11.3%
Cisco Lake	11.3%
West Bay Lake	9.9%
Clearwater Lake	5.1%
Lindsley Lake	5.1%
Fishhawk Lake	4.0%
East Bay Lake	3.3%
Poor Lake	2.6%
Two, Morely, or Spring Lake	2.9%

Table 10.4. Participant Residency

How would you best describe your residency?	
Weekends and/or part time throughout the year	26.1%
Year round	24.3%
Full time in summer	18.4%
Full time in summer and more throughout the year	14.3%
Weekends and/or part time in the summer	9.2%
Irregular	5.9%
Lot only – no home on property	1.8%

Table 10.5. CCROA Membership

What is your affiliation with the Cisco Chain Riparian Owners Association?	
Current member	81.0%
Never been a member	10.0%
Former member	9.0%

Table 10.6. Attendance at Lake Association Meetings

How often do you attend Lake Association meetings?	
Never	36.7%
Every few years	28.8%
Annually	25.9%
More than once a year	8.6%

Table 10.7 Species typically fished for.

What species do you typically fish for in Cisco Chain of Lakes?	
Walleye	90.6%
Smallmouth Bass	69.5%
Sunfish/Bluegill	65.4%
Crappie	52.3%
Largemouth Bass	51.4%
Northern Pike	49.0%
Muskie	40.7%
Perch	23.3%
Trout	4.1%
Whitefish	4.1%

Table 10.8 Species most like to fish for.

What species would you most like to fish for in Cisco Chain of Lakes?	
Walleye	80.7%
Smallmouth Bass	49.0%
Sunfish/Bluegill	42.4%
Largemouth Bass	38.3%
Crappie	35.0%
Muskie	33.7%
Northern Pike	29.2%
Perch	21.8%
Trout	10.3%
Whitefish	7.4%

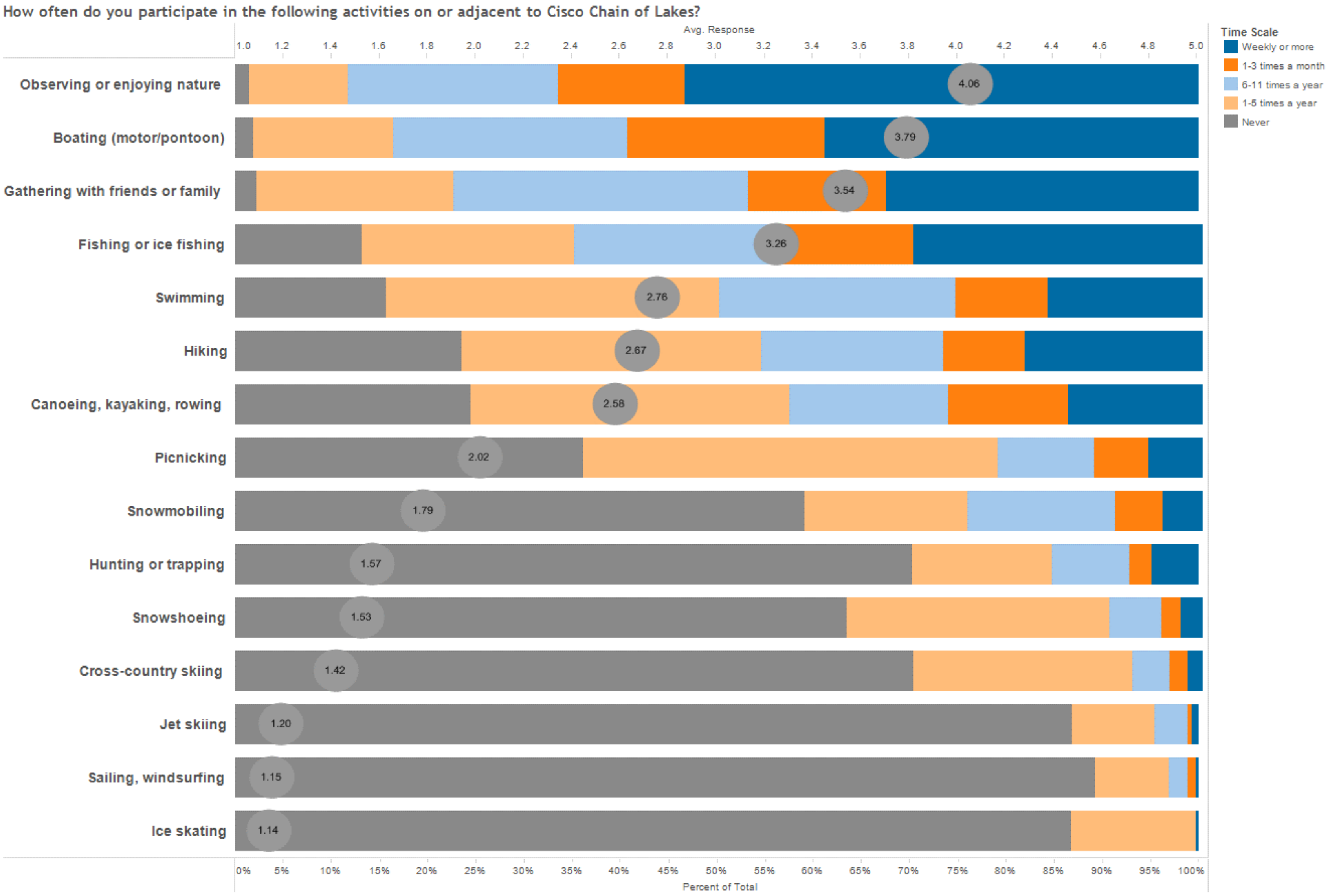

How often do you participate in the following activities on or adjacent to Cisco Chain of Lakes?

Figure 10.1. Participant Uses of the Cisco Chain

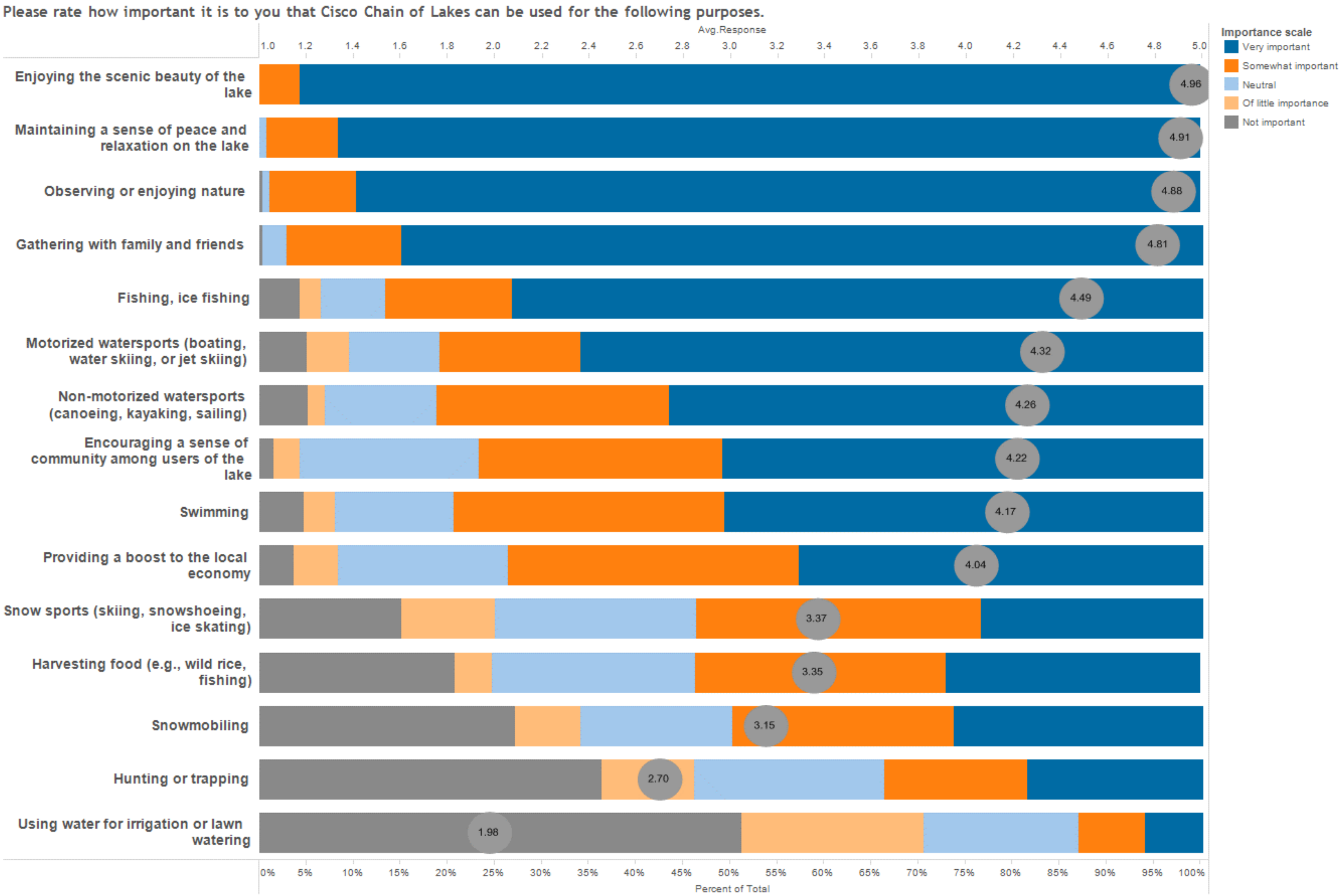


Figure 10.2. Importance of Uses on the Cisco Chain

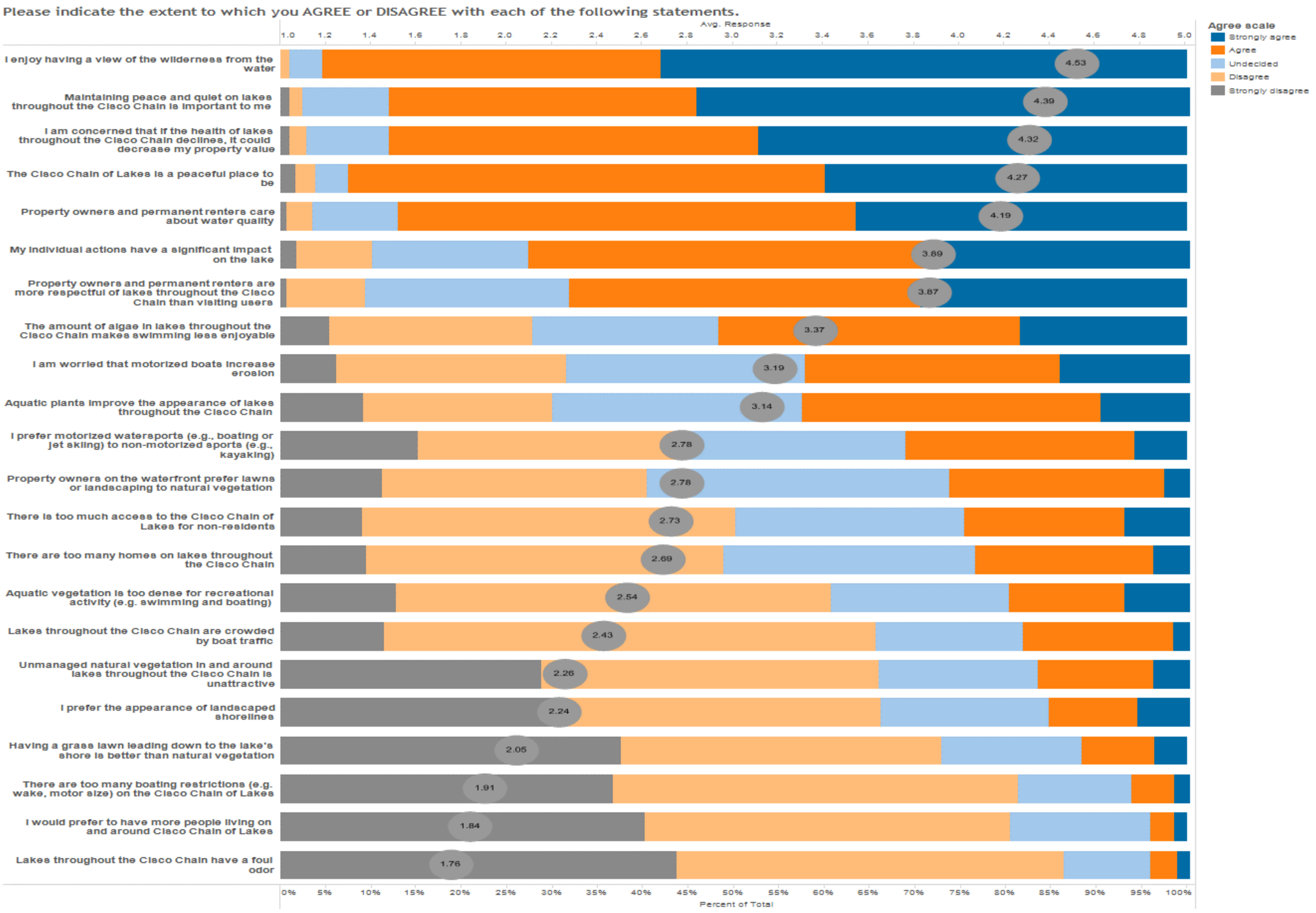


Figure 10.3 Participant Attitudes of the Cisco Chain and Its Uses

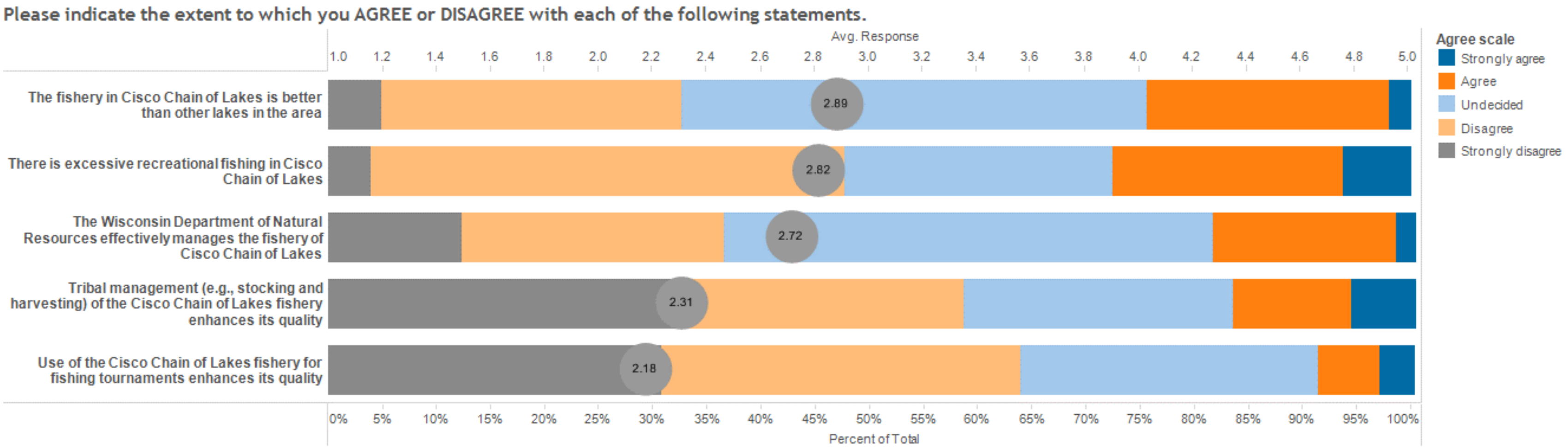


Figure 10.4. Participant Attitudes of Cisco Chain Management

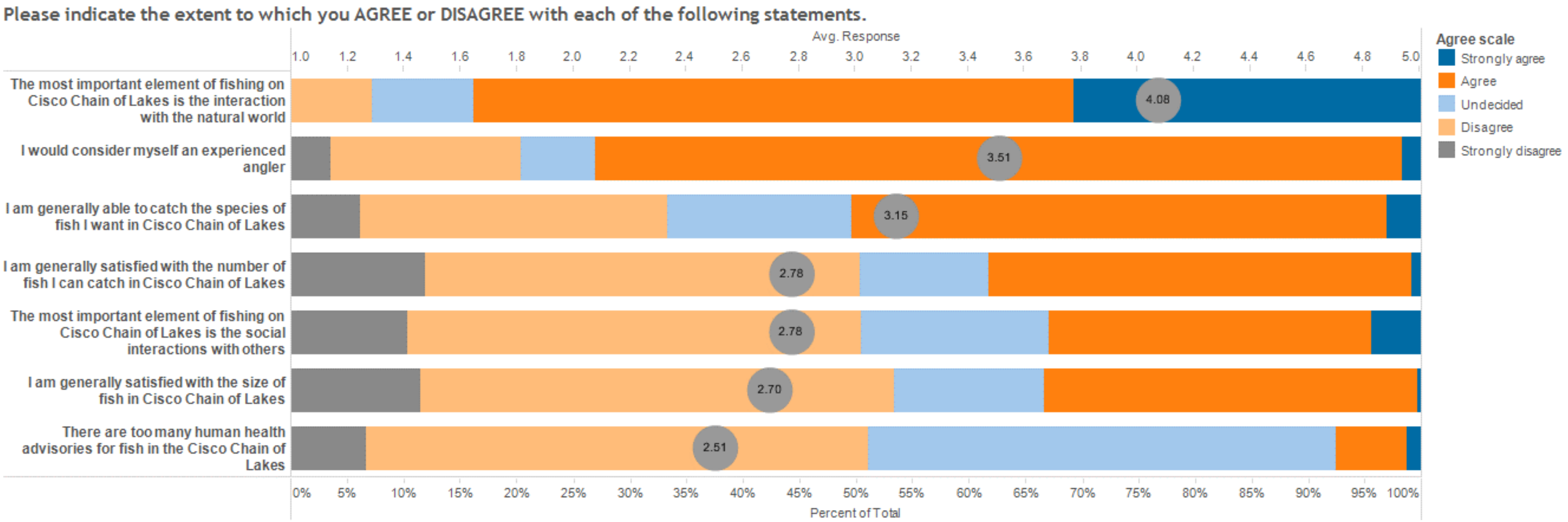


Figure 10.5 Angler Attitudes of Cisco Chain Fishery

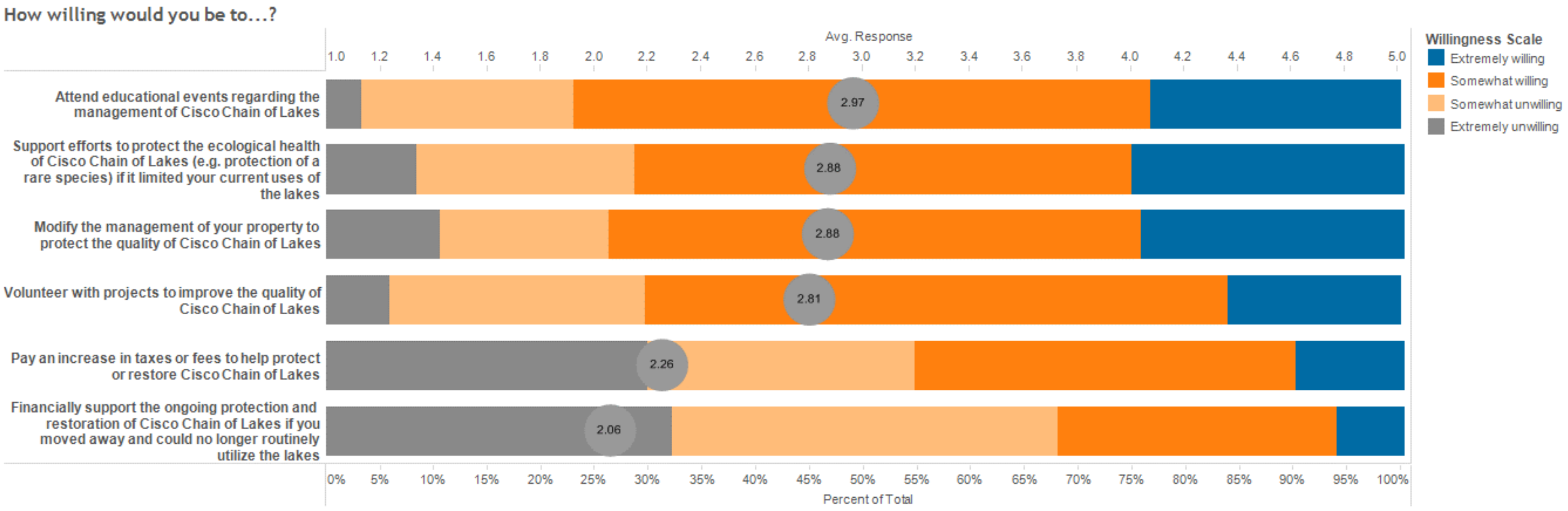


Figure 10.6 Participant Willingness to Protect the Cisco Chain

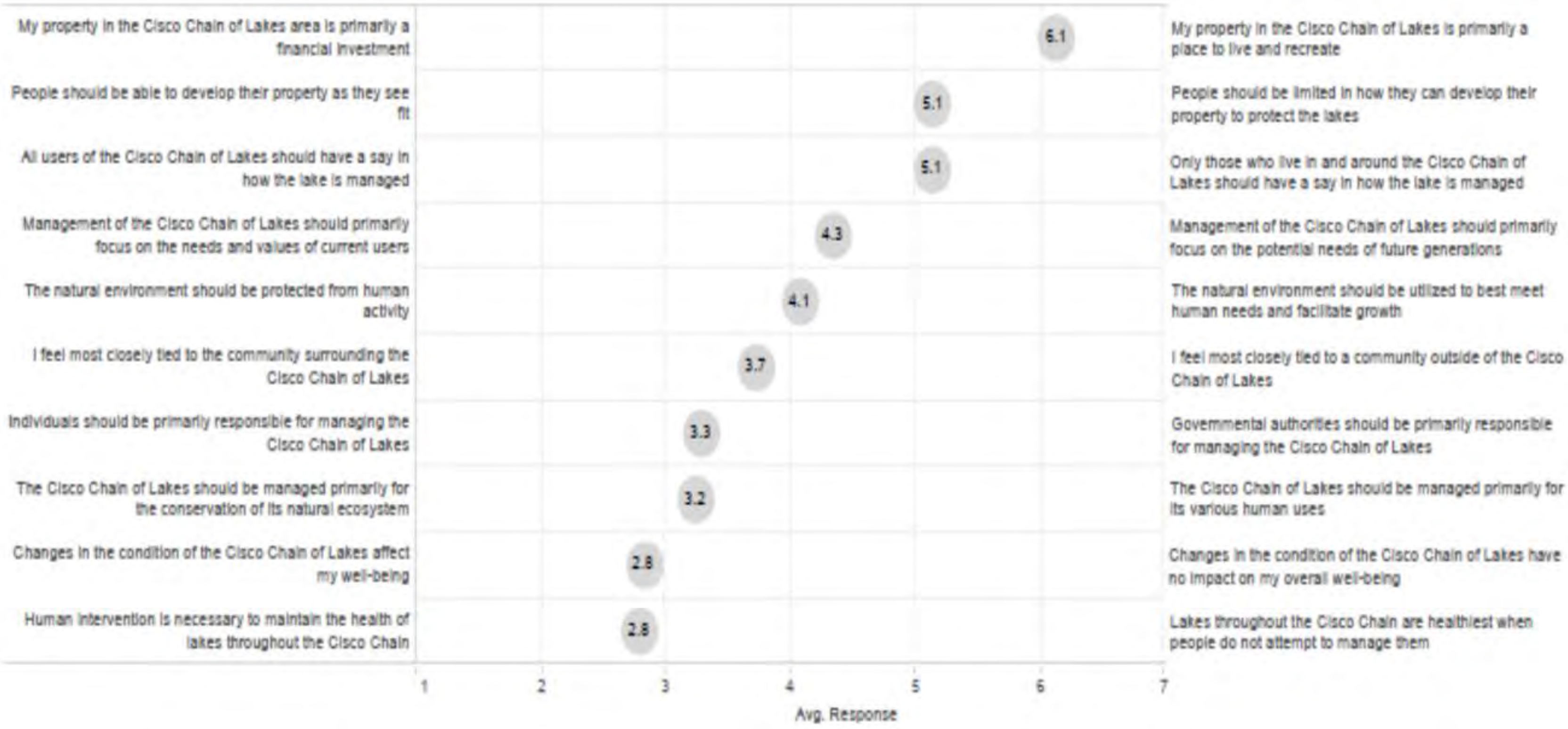


Figure 10.7 Participant Values

11. Appendix B – Summary of Physical-chemical Conditions

Introduction

This report summarizes the status of water quality conditions and physical processes in the Cisco Chain. Given the importance of physical processes and water quality conditions (see Sections 5.1 and 5.4) in lake management, a detailed assessment of these systems was conducted in the Cisco Chain. Results from this assessment were summarized and used to inform the watershed assessment (Appendix D) and ecosystem modeling efforts (Appendix F).

Methods

To assess physical and chemical conditions and processes in the Cisco Chain, water chemistry and lake discharge were sampled throughout the two year study. Chemistry and discharge data were used to assess trophic conditions, describe stratification processes and develop a nutrient budget for the lakes.

All water quality samples were collected and analyzed following methods outlined by USEPA (2007). Samples were collected from epi, meta and hypolimnion layers of the lakes (during stratification) every two week from ice off (generally May) to fall turnover (generally October) throughout the study period. Surface water samples were collected using a two-meter composite method. Samples were collected from the deepest point in the three lakes (Figure 2.1) to represent the range of water quality conditions observed throughout the system. Surface water samples were analyzed for TP, SRP, Chlorophyll-a and Total Nitrogen. Meta and hypolimnion samples were collected using a Van Dorn sampler and analyzed for TP and SRP. Dissolved oxygen, temperature, pH and conductivity data were collected throughout a vertical profile using a YSI multi-probe water quality meter. All water quality samples were analyzed at the Wisconsin State Lab of Hygiene and the Applied Research and Environmental Laboratory (ARELab) at Northland College following Standard Methods for Analysis of Water and Wastewater 21st Ed. (2005). All data were uploaded to the SWIMS system under the Station ID codes 643226 (Big Lake), 643276 (West Bay Lake) and 643247 (Mamie Lake).

Hydrological processes and nutrient budgets were quantified using sequenced approach. Outflows from each lake were calculated using the Wisconsin Lake Modeling Suite (WiLMS). Outflows from the Cisco Chain (via Cisco Lake) were record over the study period, as measured by the USGS gaging station number 04037500. An external nutrient budget (i.e., all sources of phosphorus originating outside of the aquatic system) was developed using the non-point source module in WiLMS (see Appendix D). Septic system inputs were estimated by combining parcel residency data (see Appendix A) with annual per capita export coefficients (see Appendix D). Phosphorus loss via outlet discharge was estimated using the WiLMS outflow module. All phosphorus not discharged via outflow was assumed to be retained within the system (internal phosphorus dynamics are described further in Appendix F)

Results and Discussion

Water Budget

Water budgets vary across lakes within the Cisco Chain (Table 11.1). Much of the water lost from all lakes within the Cisco Chain is via the outlet on Cisco Lake (Figure 11.1). Because the outlet from Cisco Lake is regulated by the Bond Falls dam, natural water level fluctuations are highly modulated and inflows to all lakes throughout the system affect water levels in all waterbodies. Significant flow through some lakes results in the discharge of nutrient and pollutant downstream. For example, West Bay Lake is likely a significant source of nutrients to downstream waters.

Physical Processes

Physical processes throughout the Cisco Chain are consistent with most lakes throughout the region. As described in Section 5.1, most lakes throughout northern WI, mix twice per year and stratify throughout the summer (i.e., are dimictic). Both Big and West Bay Lakes consistently stratified throughout the study period. However, Mamie Lake was often uniformly mixed (Figure 11.2), likely by wind. As a result of continual wind mixing nutrients are likely to be continually re-suspended, making Mamie Lake more susceptible to algal blooms.

Water Clarity

Water clarity in Cisco Chain lakes is consistent with other dimictic, mesotrophic lakes throughout the region. Average Secchi depths range from 2 to 5 meters and this clarity is generally mirrored by the Chl-a concentrations, which range from 3 to 10 ug/L (Figures 11.11 and 11.16). These results suggest that water clarity in the Cisco Chain is primarily driven by algal growth and productivity. Based on the dissolved oxygen concentrations observed in the Cisco Chain, it is likely that maximum algal densities occur in the upper two meters of water, which is consistent with other lakes throughout the region.

Nutrient Concentrations

Nutrient concentrations in the Cisco Chain are consistent with regional mesotrophic lakes (Figures 11.10, 11.14, 11.15 and 11.16). Surface water total phosphorus concentrations averaged 25 ug/L across all lakes during growing season conditions. While hypolimnetic phosphorus concentrations averaged 34 ug/L during the same time period. Surface water TP concentrations are consistent with mesotrophic conditions within the lakes.

These results suggest that sediment release of soluble phosphorus as a result of anoxic conditions in the hypolimnion are common in Cisco Chain lakes. However, because of the concentrations of phosphorus in the hypolimnion are only slightly higher (~2x) than in surface waters it is unlikely that this nutrient release is negatively affecting water quality conditions.

External Nutrient Budget

Within the Cisco Chain ecosystem, the majority of the annual phosphorus load originates from watershed runoff (Table 11.2), except for Big Lake. Most of this watershed loading of phosphorus likely occurs as part of spring snowmelt and rainfall. Approximately 41% of the phosphorus delivered to the lakes from external sources is discharged through the outlet to downstream waters. Additional “internal” sources and loss processes are discussed in Appendix F.

Trophic State and Water Quality Attainment

The combination of nutrient, Secchi depth and chlorophyll-a data suggest that the current conditions in Cisco Chain lakes are consistent with its designation as a mesotrophic lake. Current phosphorus TSI values average 47. Additionally, average annual surface water phosphorus concentrations are below the 30 ug/L level identified as a threshold for water quality impairment in mesotrophic lake types, like Cisco Chain lakes. The water quality conditions observed throughout this study are consistent with the fishery and aquatic plant community data that have been collected for the lakes (see Section 5.4 and Appendix E).

Management and Monitoring Considerations

Because Cisco Chain lakes are currently meeting water quality standards, primary management activities should focus on protection efforts to minimize nutrient runoff to the lakes and alteration of the lakes' hydrologic cycle. The primary regulatory and technological options related to water quality protection in Cisco Chain lakes are related to land use and planning, and thus are described in Section 7.

In addition to these management considerations, a series of ongoing monitoring and assessment studies should be considered. Relatively little is known about the groundwater system surrounding the Cisco Chain. Because of the potential for increased residential development around the lakes, future assessment work should quantify the existing groundwater nutrient concentrations to more accurately characterize any future potential impacts of septic system discharge of phosphorus to the lakes. This assessment characterized the water quality trends and process at sites that reflect general conditions throughout the lakes. However, given the presence of discrete, hydrologically isolated embayments throughout the lakes, future monitoring work should characterize the diversity and connectivity of water quality conditions throughout the lakes to identify areas that may be particularly susceptible to changes in water quality conditions. Using a monthly water quality sampling regime, it will take approximately 10 years of continuous monitoring to detect a change in average phosphorus concentrations of 15% — and 20% for Secchi transparency (summarized in NPS, 2008).

Uncertainty and Data Interpretation

Given that many elements of the water and nutrient budget were derived from literature values, instead of field measurements, a significant level of uncertainty exists within the analyses. Results from these analyses likely represent the general trends in Cisco Chain lakes. For example, some areas of the lakes are likely to be more important sites for groundwater inflow, while others are likely to be sites for groundwater recharge. Similarly, some areas of the lakes likely have higher nutrient concentrations in inflowing ground and surface water and some embayments may be more susceptible to nutrient runoff than others (because of their isolation). Given these uncertainties, these results should be used as general guidance to management planning, but field observations should be collected to support any site-specific management decisions.

Table 11.1. Water budget for Cisco Chain lakes based on WiLMS predictions.

Lake	Runoff Volume (acre-ft)	Evaporation (inches)	Outflow Volume (acre-ft)	Flushing Rate (per year)	Residence Time (year)
Big Lake	1,334	8.5	1,670	0.18	5.71
West Bay Lake	11,688	8.5	11,900	1.42	0.7
Mamie Lake	1,625	8.5	1,780	0.53	1.89

Table 11.2. External Phosphorus Budget for Cisco Chain lakes based on WiLMS predictions.

Lake	Watershed Area (Acres)	Phosphorus Source (lbs/yr)			Total Load (lbs/yr)	Outlfow (lbs/yr)
		Watershed Ruoff	Septic System	Atmostpheric		
Big Lake	1,984	100	65	195	383	108
West Bay Lake	12,438	852	27	110	1,374	774
Mamie Lake	8,210	129	18	89	307	120

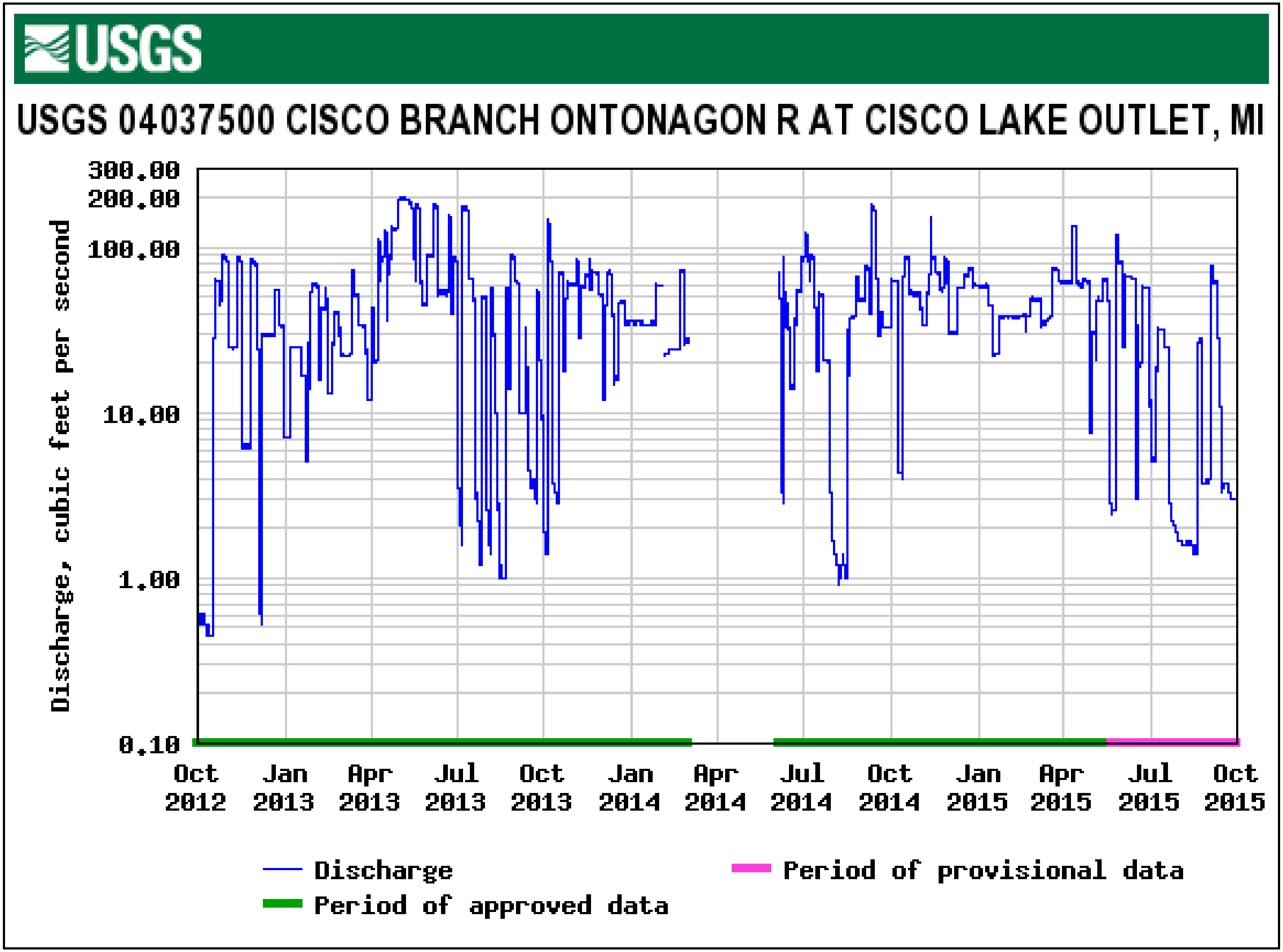
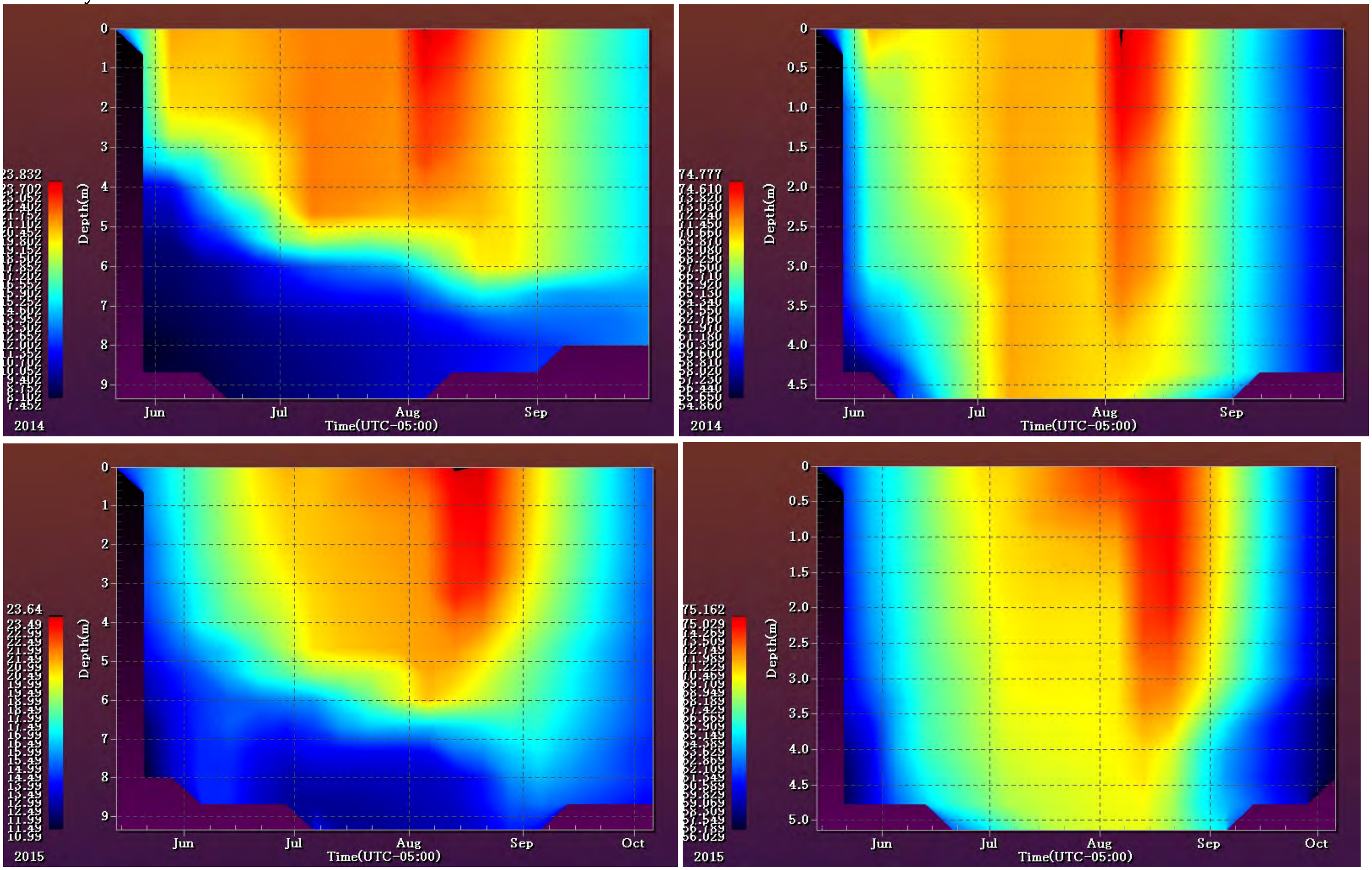


Figure 11.1 Discharge record from the Cisco Chain (at Cisco Lake outlet), 2013 to 2015.

West Bay Lake

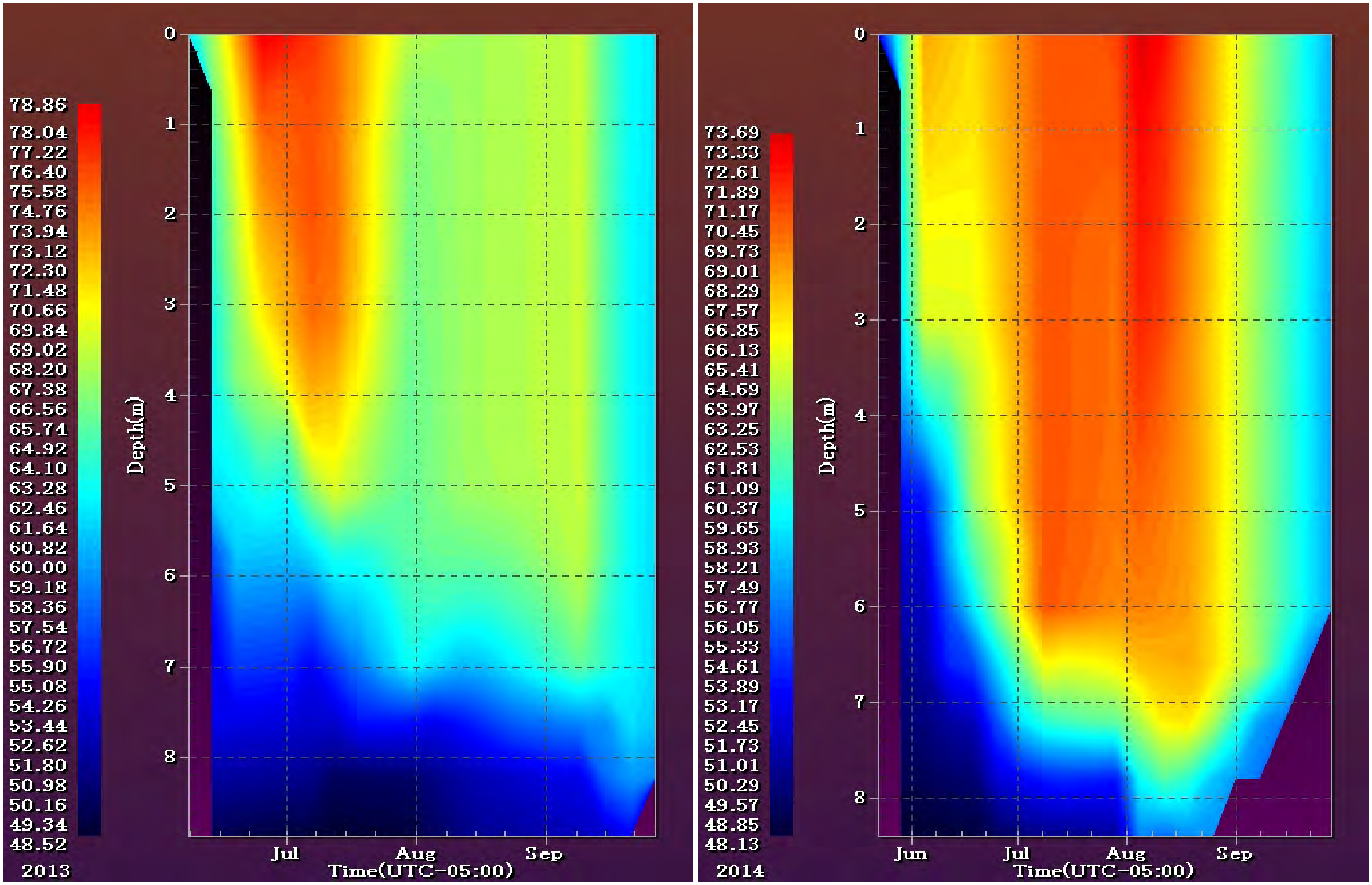
Mamie Lake



2014

2015

Figure 11.2 Thermal stratification in West Bay and Mamie Lakes in 2014 and 2015.


2013

2014

Figure 11.3 Thermal stratification in Big Lake in 2013 and 2014.

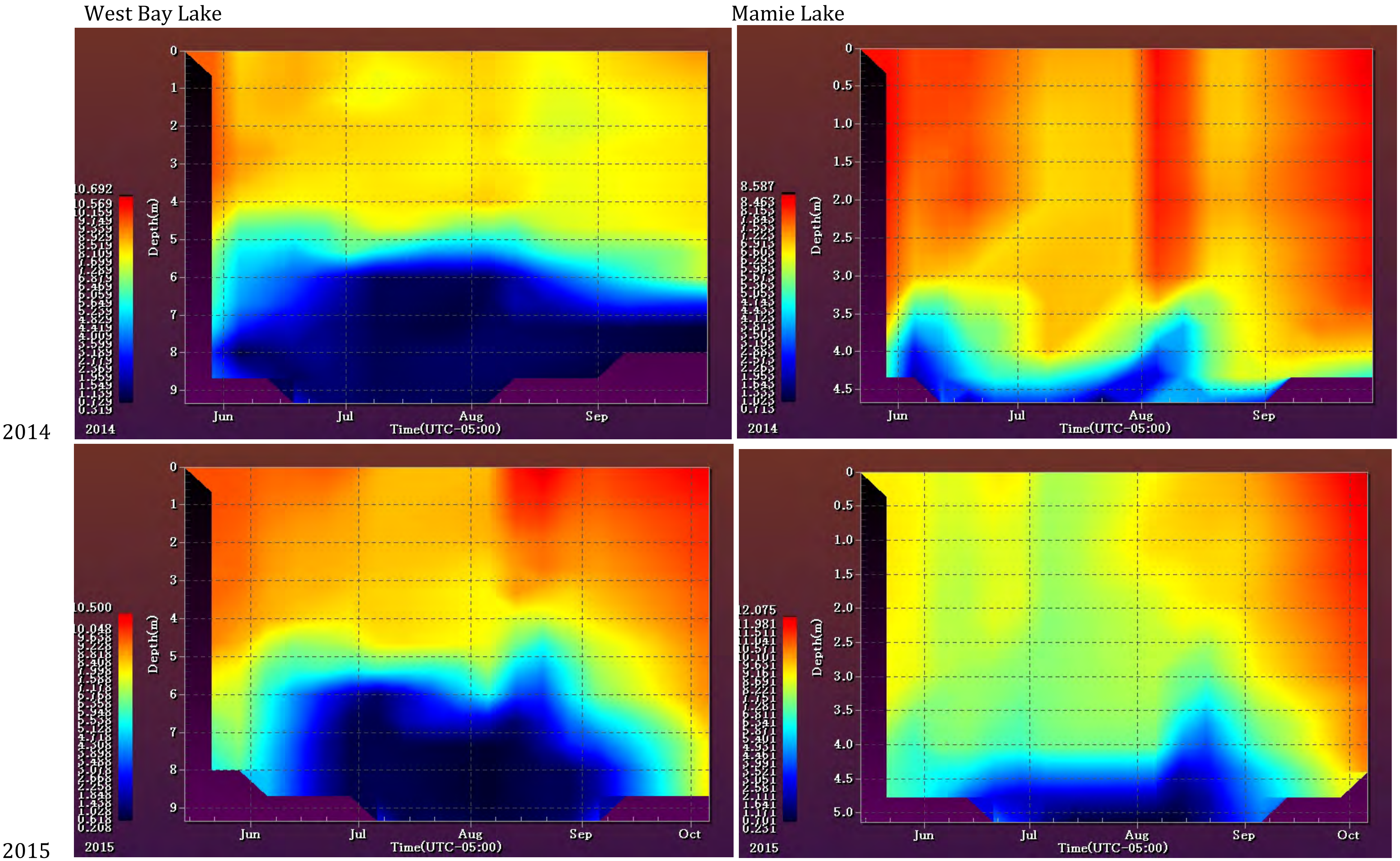
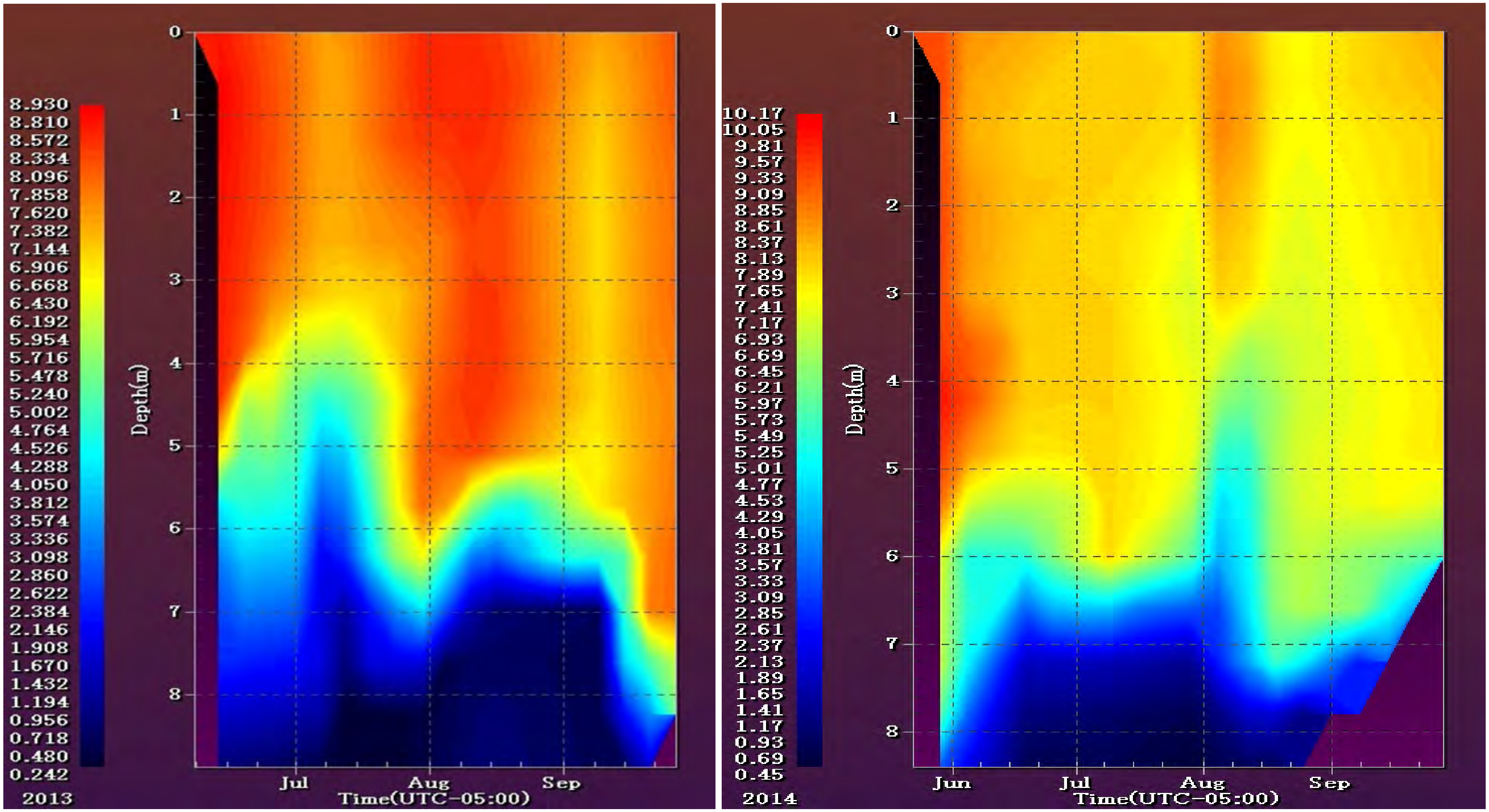


Figure 11.4 Dissolved oxygen stratification in West Bay and Mamie Lakes in 2014 and 2015.


2013

2014

Figure 11.5 Dissolved Oxygen stratification in Big Lake in 2013 and 2014.

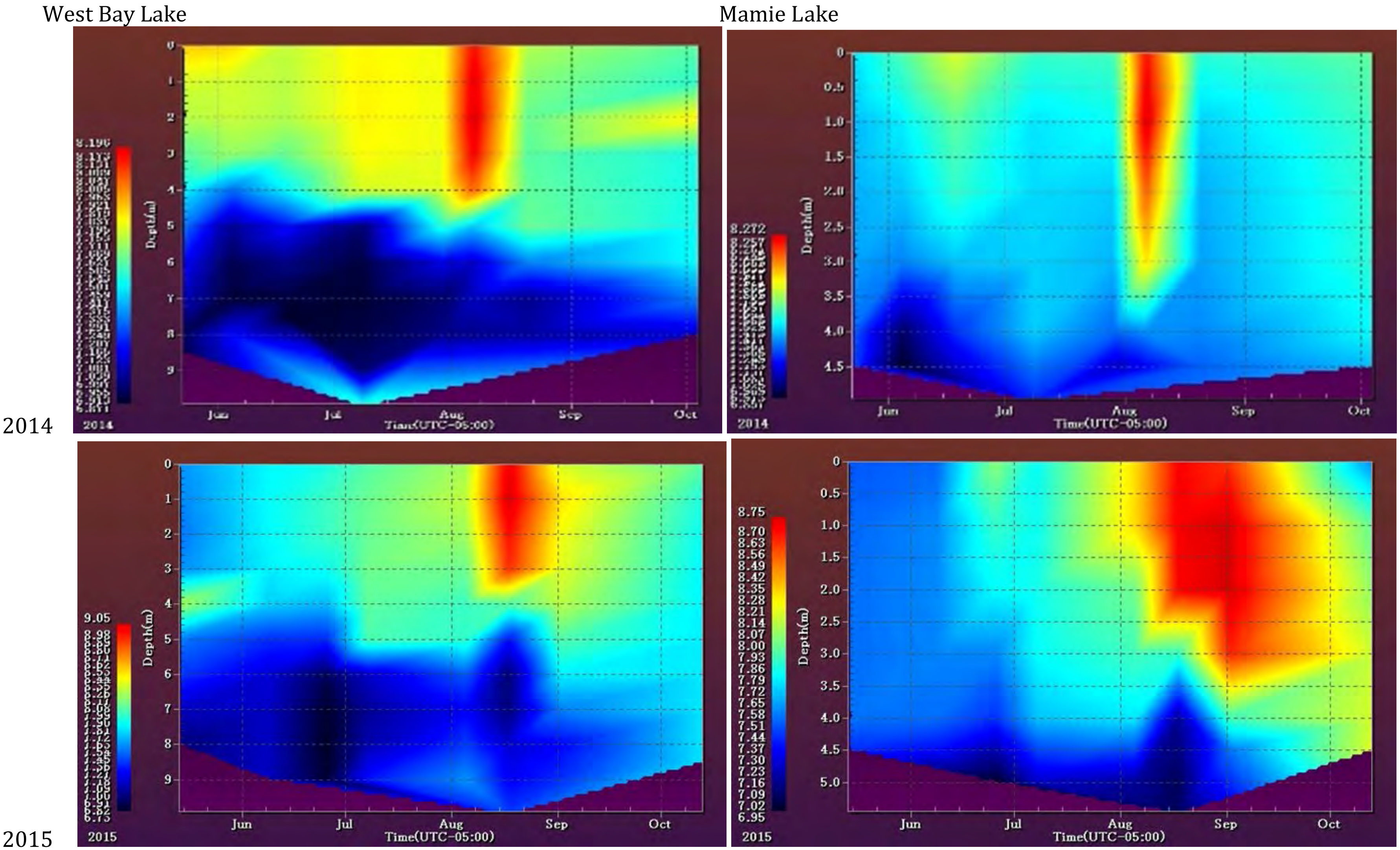


Figure 11.6 pH stratification in West Bay and Mamie Lakes in 2014 and 2015.

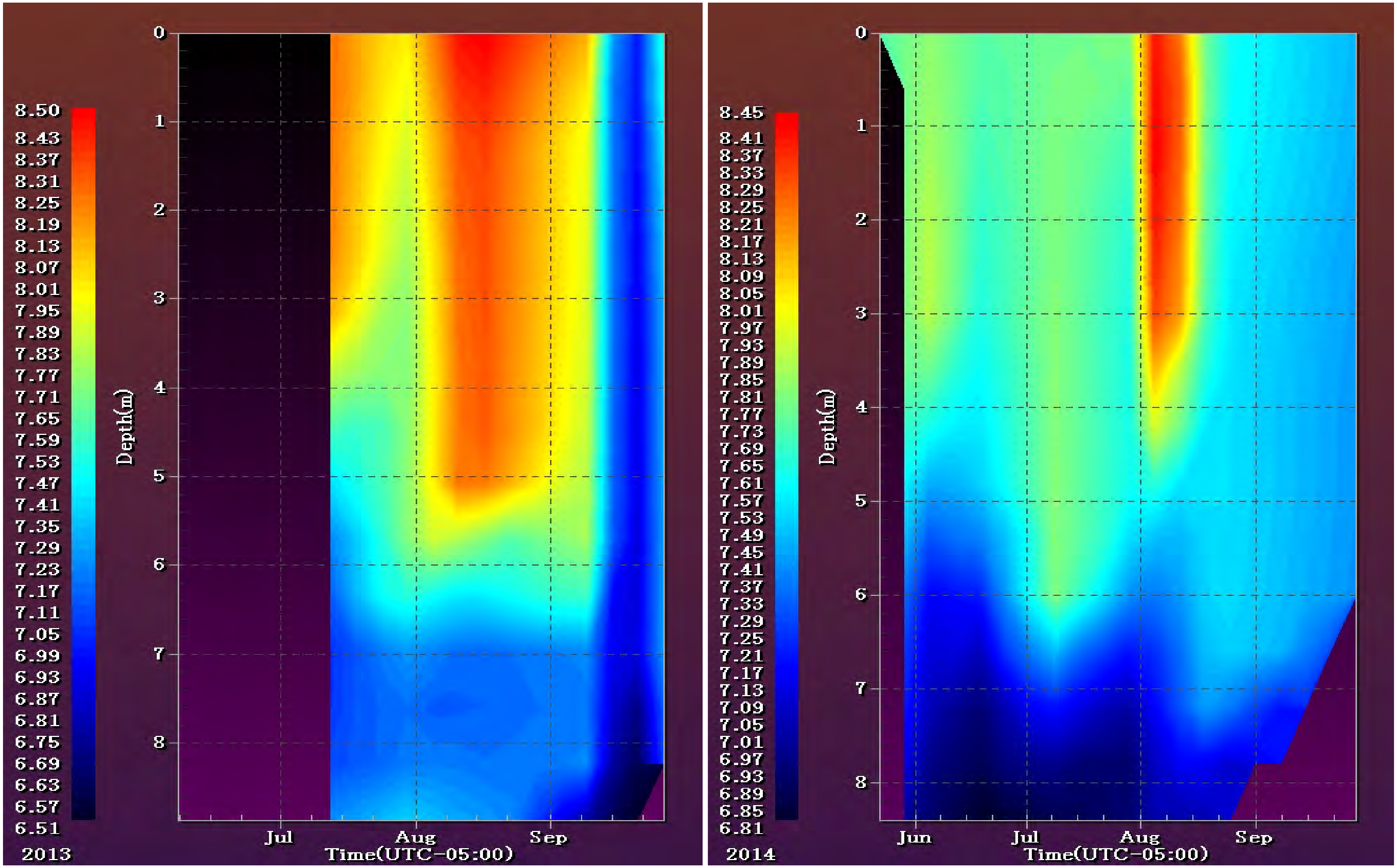


Figure 11.7 pH stratification in Big Lake in 2013 and 2014.

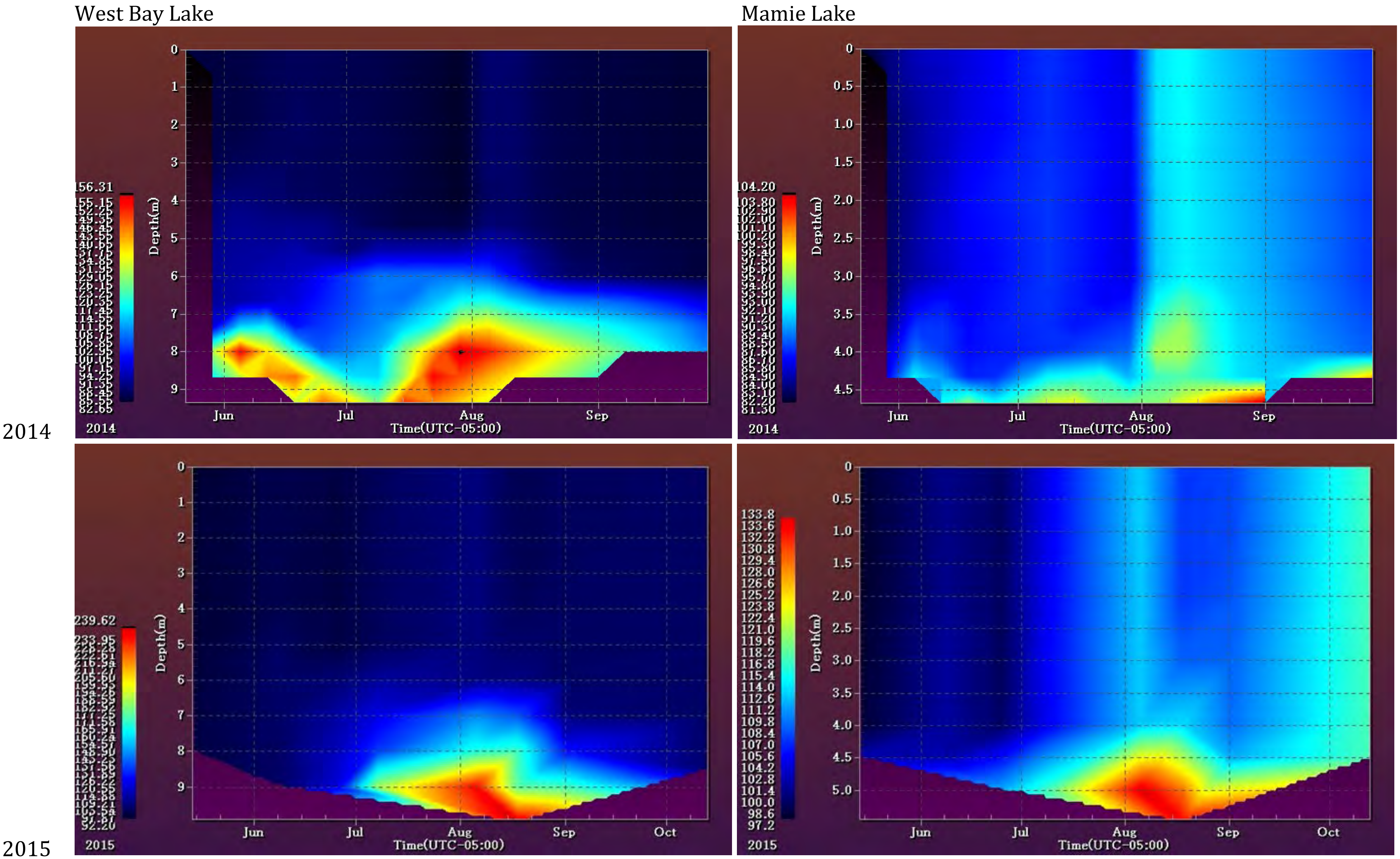
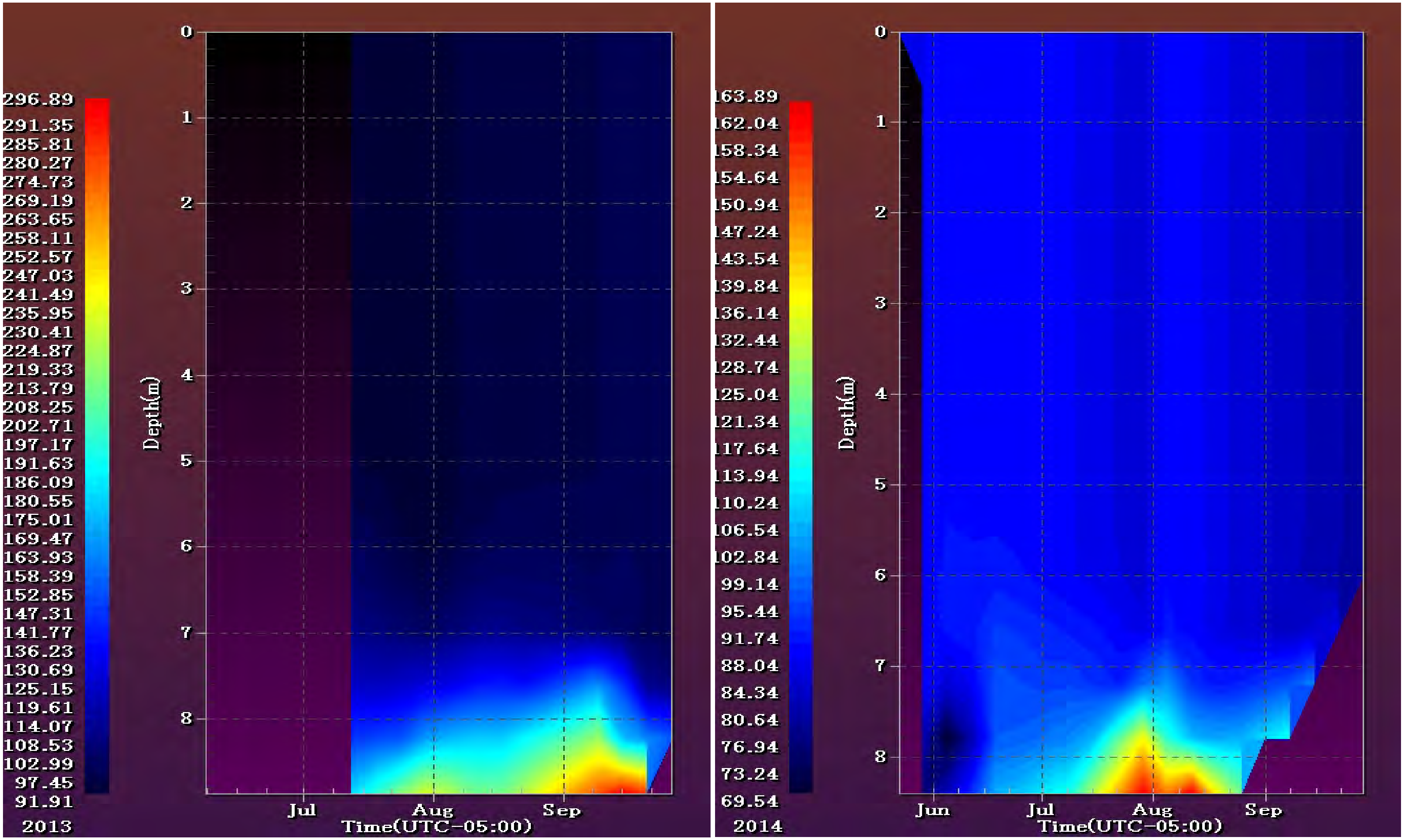


Figure 11.8 Conductivity stratification in West Bay and Mamie Lakes in 2014 and 2015.



2013

2014

Figure 11.9 Conductivity stratification in Big Lake in 2013 and 2014.

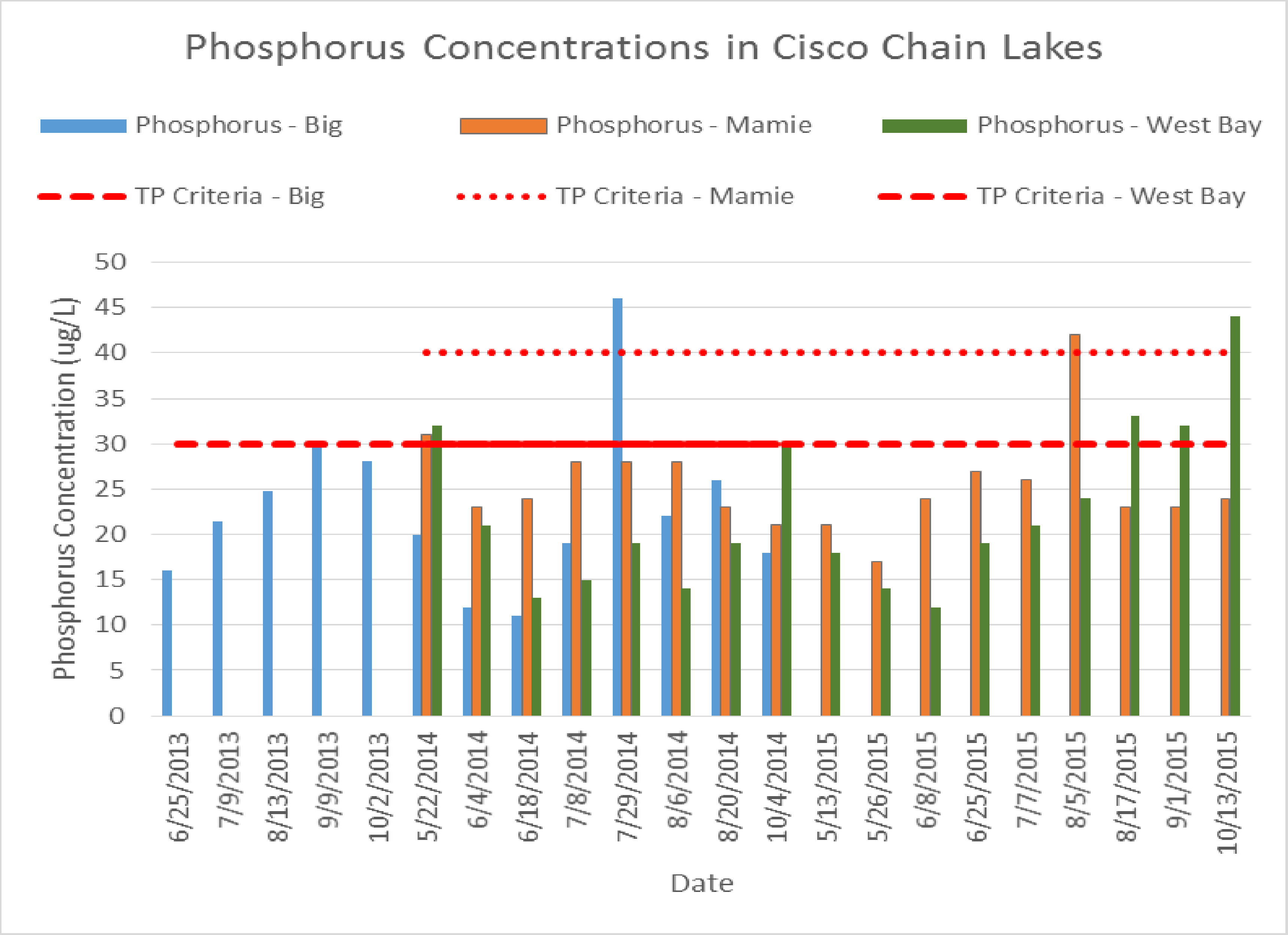


Figure 11.10 Seasonal total phosphorus concentrations compared to Wisconsin's total phosphorus criteria in Big, West Bay and Mamie Lakes (2013-2015).

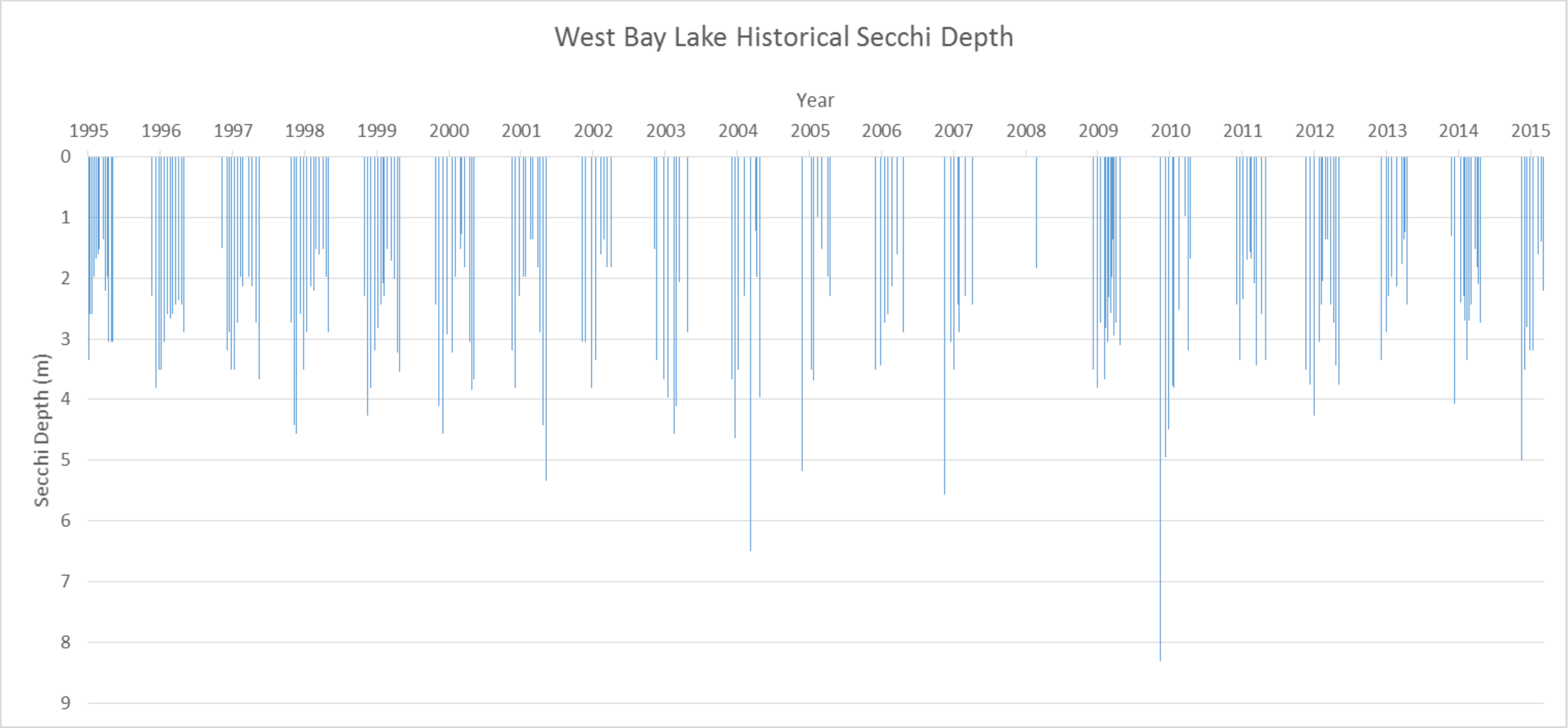


Figure 11.11 Historical trends in water clarity in West Bay Lake.

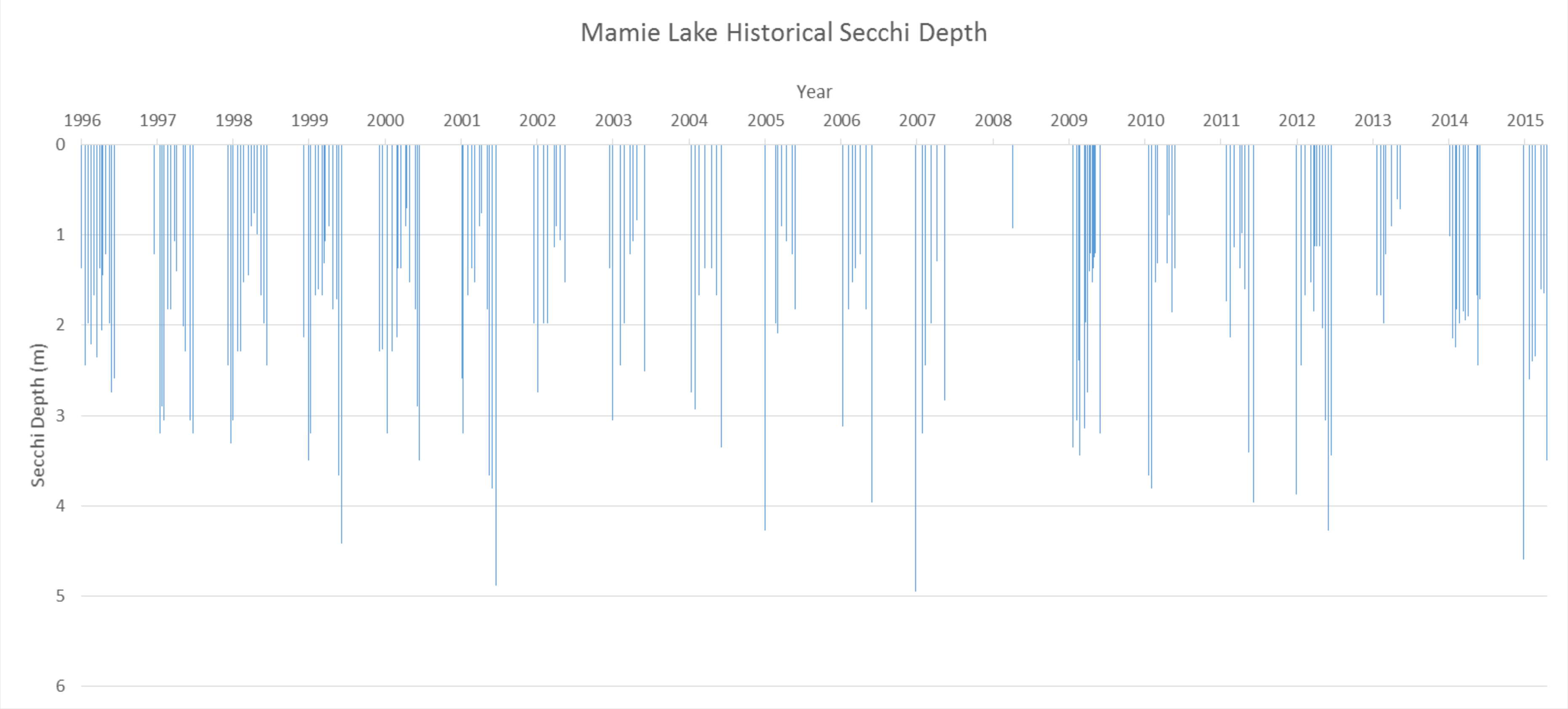


Figure 11.12 Historical trends in water clarity in Mamie Lake.

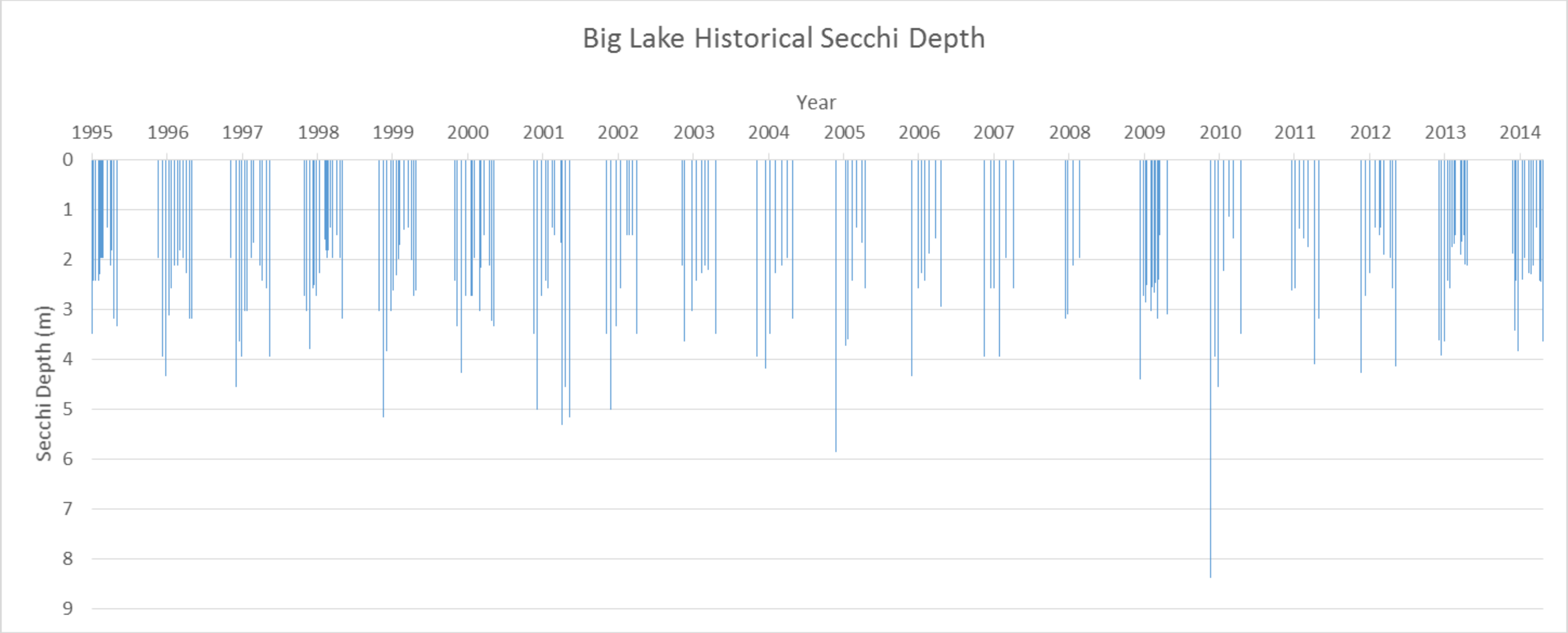


Figure 11.13 Historical trends in water clarity in Big Lake.

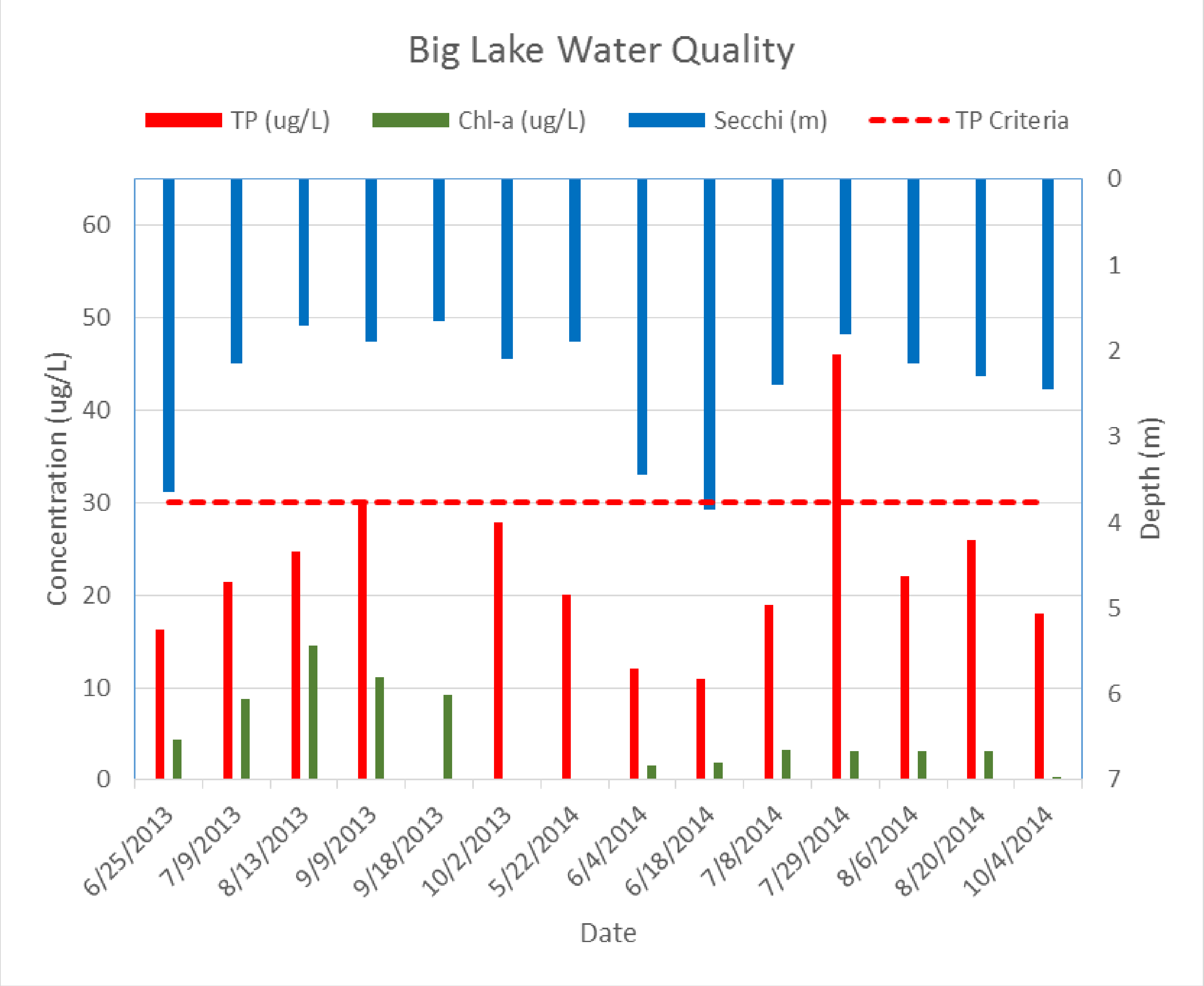


Figure 11.14 Seasonal water quality trends in Big Lake.

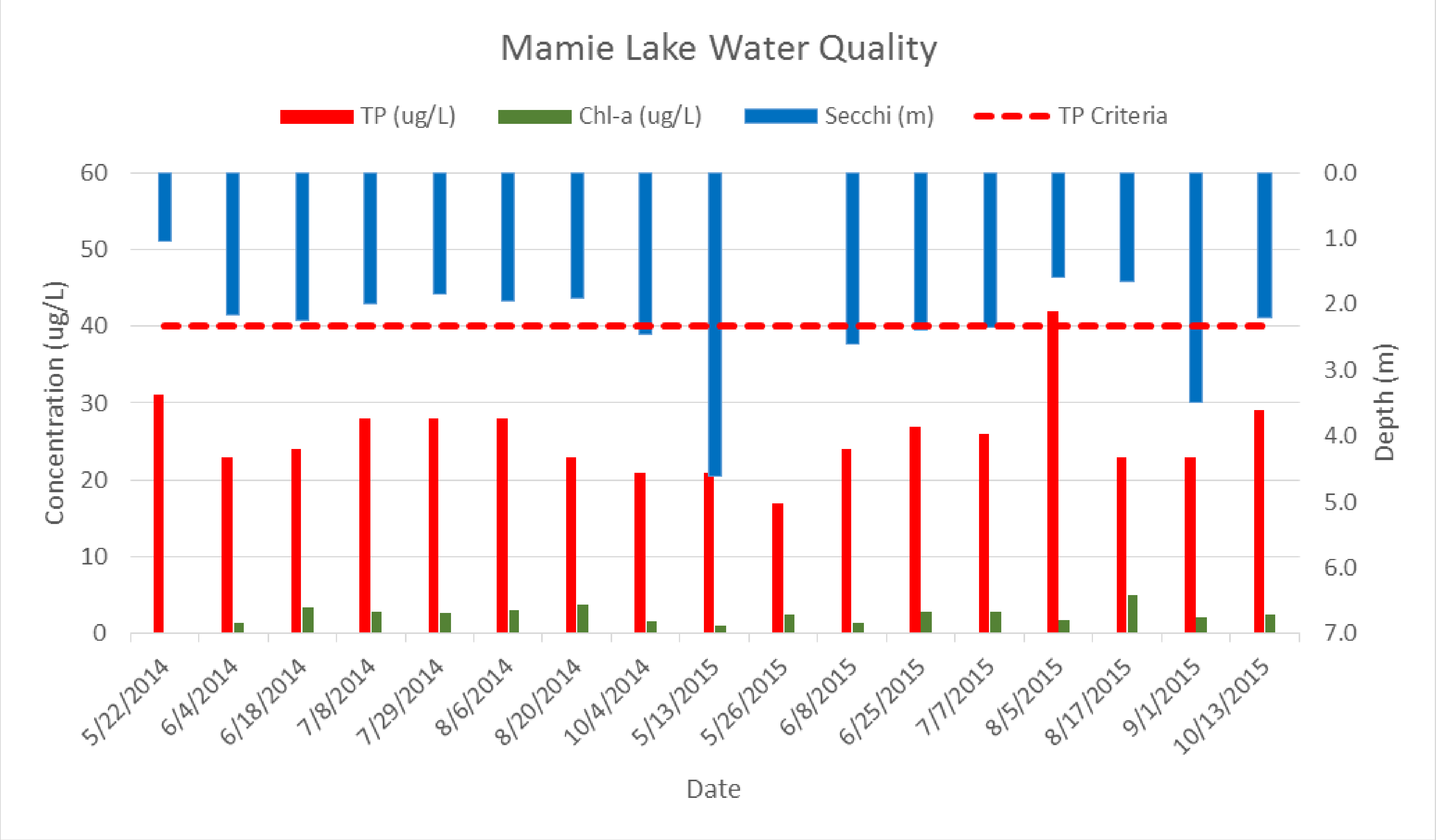


Figure 11.15 Seasonal water quality trends in Mamie Lake.

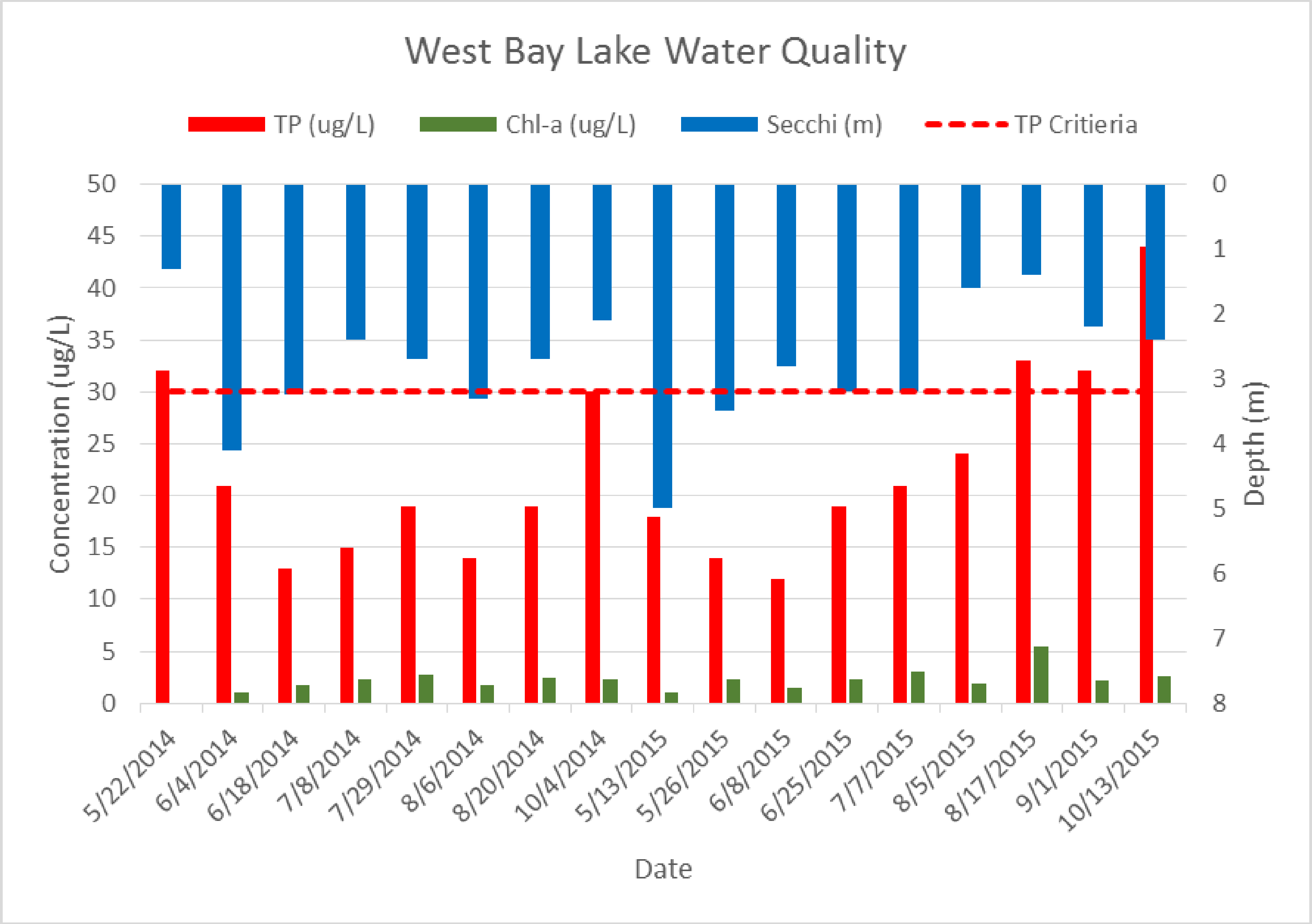
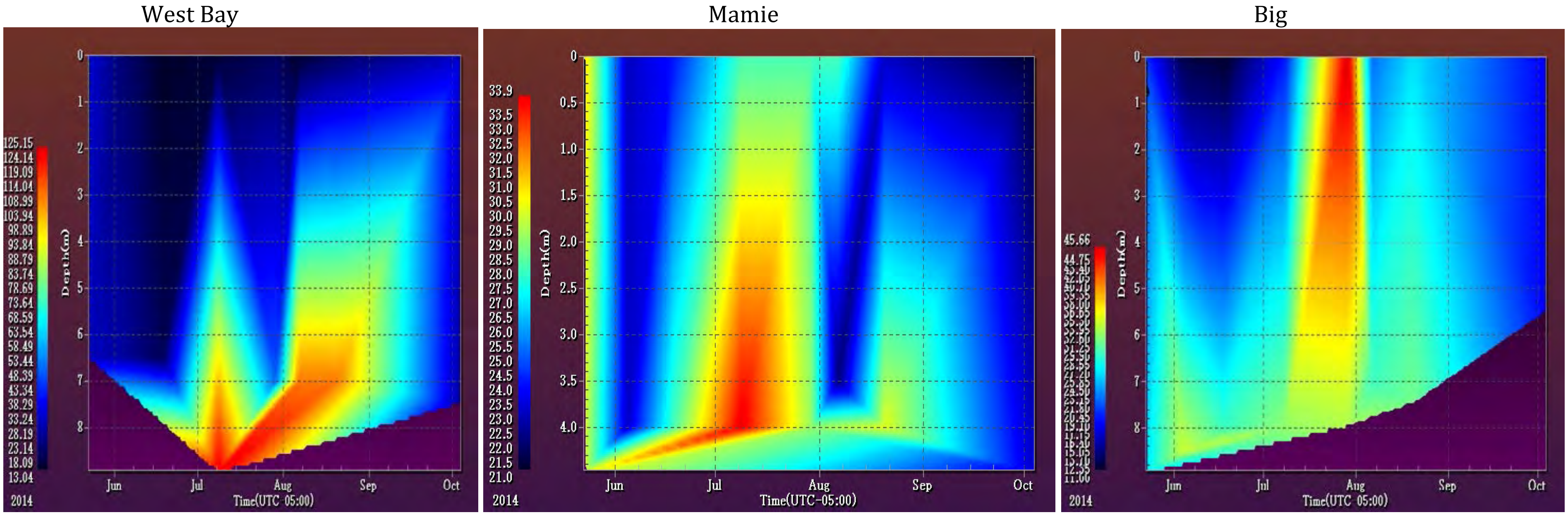


Figure 11.16 Seasonal water quality trends in West Bay Lake.


West Bay

Mamie

Big

Figure 11.17 Total phosphorus stratification in West Bay, Mamie and Big lakes in 2014.

12. Appendix C – Shoreline Habitat Assessment and Management Plan

Introduction

This report summarizes the status of shoreline/nearshore habitat in the Cisco Chain and describes a long-term restoration/management plan for the system. Given the importance of shoreland habitat (see Section 5.1), a detailed assessment of the current conditions in three shoreland habitat zones was conducted in the Cisco Chain. Results from this assessment were combined with data from the point-intercept survey (see Appendix F) to develop recommendations to protect and restore shoreland and critical nearshore habitat.

Methods

Habitat conditions were described for all parcels surrounding the Cisco Chain. Parcel data were separated into public and private ownership and summarized with respect parcel size and shoreline size. Average parcel shoreline length was calculated by extracting the shoreline borders for all privately owned parcels into an aggregate polyline layer. Average length of shoreline parcels was then calculated as the total shoreline length for privately owned parcels divided by the total number of parcels. The potential number of parcels under different land use scenarios was calculated by dividing the total length of privately owned shoreline by the minimum parcel length allowed in current shoreland zoning guidelines. All parcel data were obtained from Vilas and Gogebic County zoning.

To describe shoreland habitat conditions in the Cisco Chain, shoreline and nearshore habitat were quantified using methods described by the Environmental Protection Agency (USEPA, 2007). Following this method, sample transect points were identified at 20 locations around the lakeshore. At each transect, data were collected to describe the habitat condition and level of disturbance in upland, transition (i.e., riparian) and in-lake (i.e., littoral) zones of the lakes using a series of semi-quantitative ranking criteria. Additionally, shoreland habitat conditions and restoration potential were quantified along each parcel using a modified version of the USEPA, 2007 protocol. Data from both the lake-wide and parcel-specific assessments were geospatially processed and represented in a series of maps that describe the relative condition of the upland, transition and in-lake habitat. Shoreland habitat data were used to develop a shoreline habitat restoration/protection plan and combined with sediment and aquatic plant data to highlight areas of critical habitat in and around the Cisco Chain.

Results

The shoreline around the Cisco Chain is approximately 31.3 miles in lengths. Throughout this distance, land is divided into 218 discrete parcels (Figure 12.1). Of these parcels, 5 are publicly owned and 213 are privately owned. Average linear shoreline distance of privately owned parcels is approximately 739 feet.

Based on future land use zoning (see Appendix C), the number of parcels around the Cisco Chain has the potential to increase. Current zoning (based on the 2015 modification of NR 115) requires a minimum of 65 shoreline feet per “sewered” parcels and 100 feet per “unsewered” lot bordering the Cisco Chain. Since the current average shoreline length per parcel is 739, full development of the current zoning regulations could increase the number of shoreline parcels by about seven to eight fold. If this increase in parcel density occurs, it would likely be concentrated in larger parcels located around the north eastern lakeshore.

Critical Habitat and Sediment Types
Results from the point intercept survey and shoreline habitat assessment suggest that there are a range of habitat types and conditions throughout the Cisco Chain ecosystem (Figure 12.2, 12.3, 12.4 and 12.5). Not surprisingly, areas of the highest quality aquatic habitat (as characterized by floating and emergent plant communities) are often adjacent to the areas of highest quality shoreline habitat. Sediment types varied across the lakes, with areas of muck being most common in protected embayments and areas of rock and sand being most common along less protected shorelines and adjacent to steep bathymetric drops (Figures 12.6, 12.7, 12.8 and 12.9).

Shoreland Habitat
Results from the habitat assessment suggest that shoreland habitat is moderately impacted by human disturbance throughout the Cisco Chain. Of the 211 parcels surveyed, the majority were in "idea" or "very good" habitat conditions and that habitat conditions were relatively consistent across the upland, aquatic and shoreline zones—although some within parcel variability does exist (Table 12.1). Areas of the highest quality shoreland habitat are concentrated in the north eastern and south eastern bays (Figures 12.10, 12.11, 12.12 and 12.13).

Discussion and Management Recommendations

Given that most shoreline habitat surrounding the Cisco Chain is in relatively good conditions, the majority of shoreline management activities should focus on protection efforts. As described in Section 7.1, shoreland habitat protection for the Cisco Chain is primarily driven by the statewide shoreland zoning ordinance (NR 115). Although this ordinance provides some protections for water quality and nearshore habitat in the Cisco Chain, full development of the shoreland zoning area has the potential to alter the lake ecosystem. Given the potential for changes in shoreline development, future monitoring efforts should focus on recurring assessment of user perceptions of the lakes as well as general shoreland/critical habitat. Recurring surveys should be conducted every three to five years, depending on the rates of shoreline development. Designation of critical habitat areas within the Cisco Chain has the potential to add additional long-term protections to shoreland habitat.

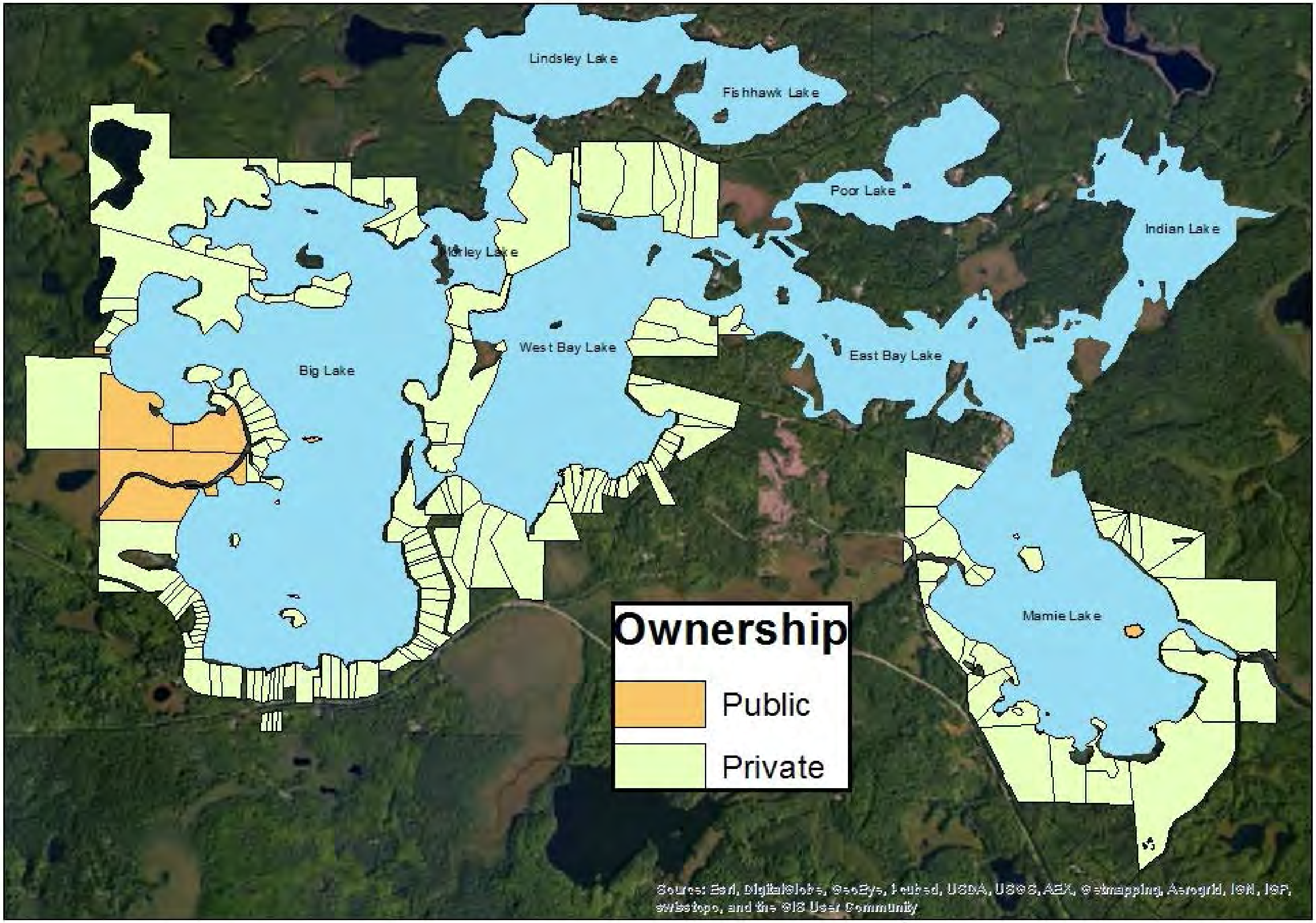
Significant areas for shoreline restoration exist throughout the Cisco Chain system. Areas of greatest opportunity for shoreland habitat restoration are most common on the southern and eastern shorelines of the lakes, however areas adjacent to critical habitat (floating and emergent plant communities) locations should be considered the highest priority for restoration work. The primary restoration tools that should be considered are dependent on the shoreland zone for which restoration is to be targeted. In general, restoration practices that minimize direct runoff to the lakes should be considered in areas with medium to high upland and shoreline restoration potential (Figures 12.5 and 12.6) and practices that maximize habitat complexity should be focused in the in-lake zone (Figure 12.7) in areas with medium to high aquatic restoration potential. Details of appropriate restoration practices are described in the WDNR Healthy Lakes Initiative Implementation Plan (http://www.uwsp.edu/cnr-ap/UWEXLakes/Documents/resources/healthylakes/HealthyLakesPlan.pdf).

Table 12.1. Described the relative condition of the different habitat zones in parcels surrounding the Cisco Chain.

Parcel Condition	West Bay Lake Parcel Data		
	Upland / Terrestrial (OHWM inland 15m)	Shoreline / Riparian Buffer (water's edge inland 1m)	Aquatic / Littoral (waterward 10m from shore)
Ideal	12	14	22
Very Good	23	18	13
Marginal	21	11	20
Poor	2	15	3
Total	**58**		

Parcel Condition	Mamie Lake Parcel Data		
	Upland / Terrestrial (OHWM inland 15m)	Shoreline / Riparian Buffer (water's edge inland 1m)	Aquatic / Littoral (waterward 10m from shore)
Ideal	15	15	19
Very Good	7	9	9
Marginal	6	7	3
Poor	8	5	5
Total	**36**		

Parcel Condition	Big Lake Parcel Data		
	Upland / Terrestrial (OHWM inland 15m)	Shoreline / Riparian Buffer (water's edge inland 1m)	Aquatic / Littoral (waterward 10m from shore)
Ideal	41	40	24
Very Good	25	27	36
Marginal	30	24	29
Poor	21	26	28
Total	**117**		



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 12.1 Shoreline parcel ownership surrounding the Cisco Chain.

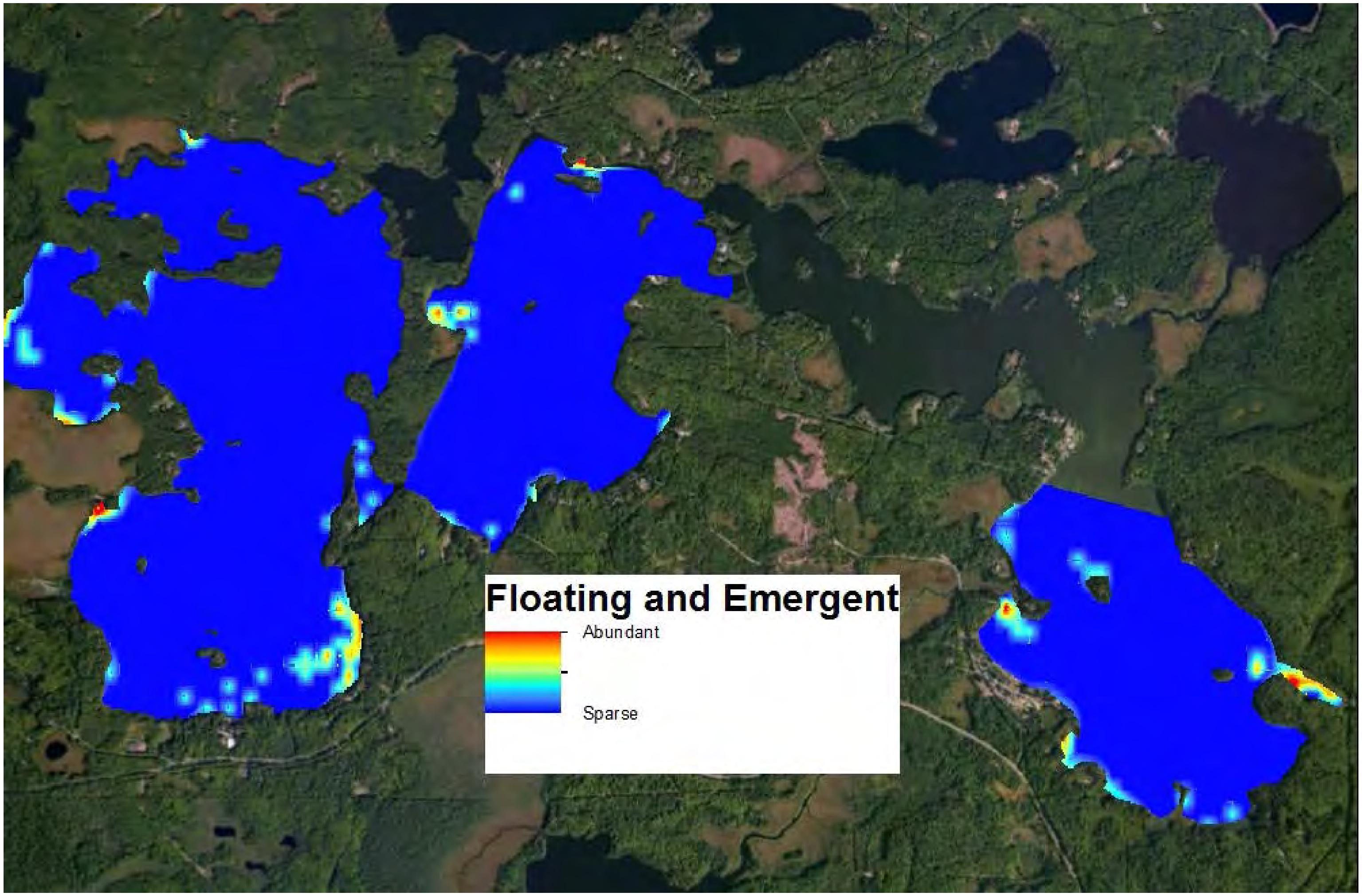


Figure 12.2 Locations of highest quality aquatic habitat (e.g., floating and emergent plant communities) in the Cisco Chain.

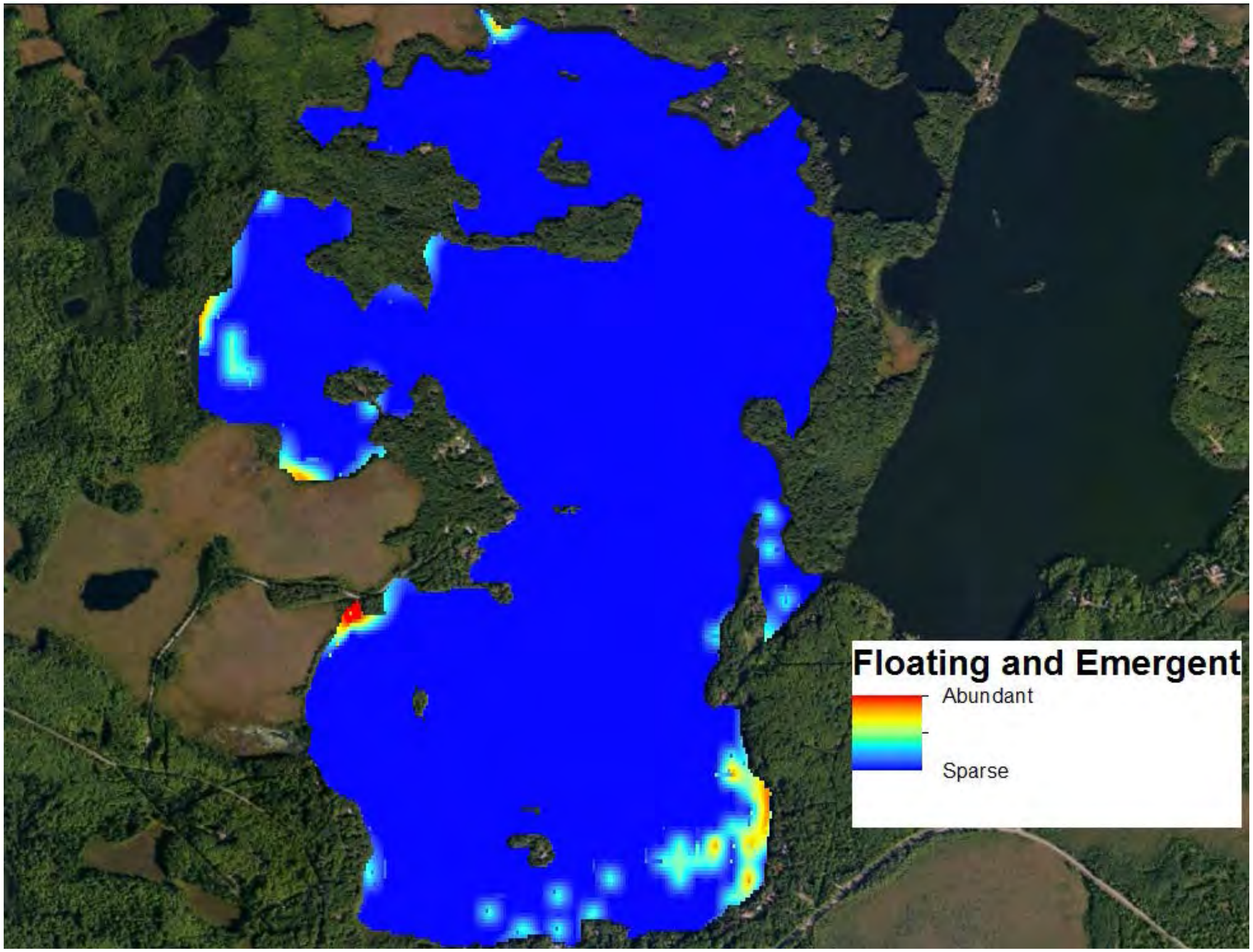


Figure 12.3 Locations of highest quality aquatic habitat (e.g., floating and emergent plant communities) in Big Lake.

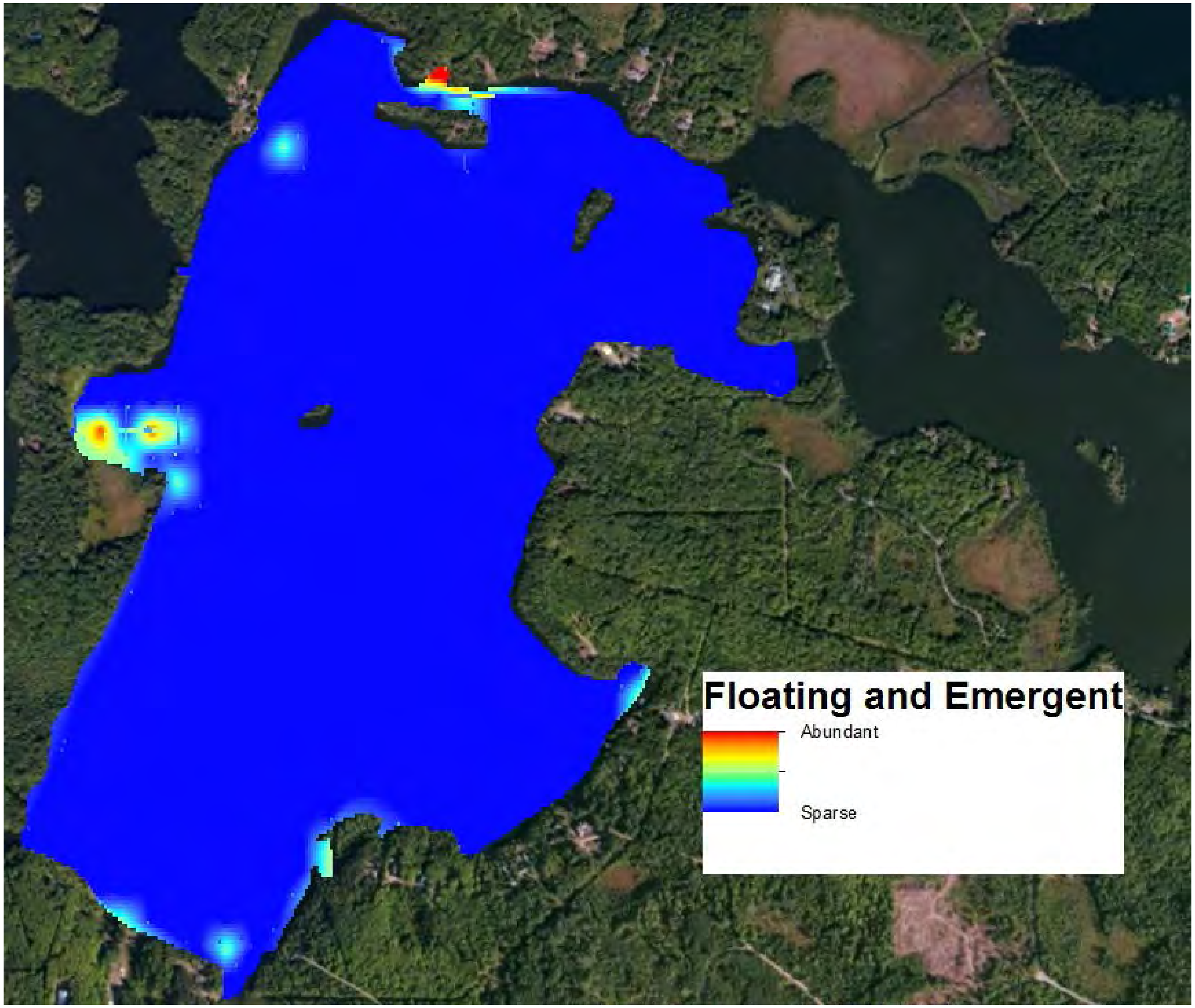


Figure 12.4 Locations of highest quality aquatic habitat (e.g., floating and emergent plant communities) in West Bay Lake.

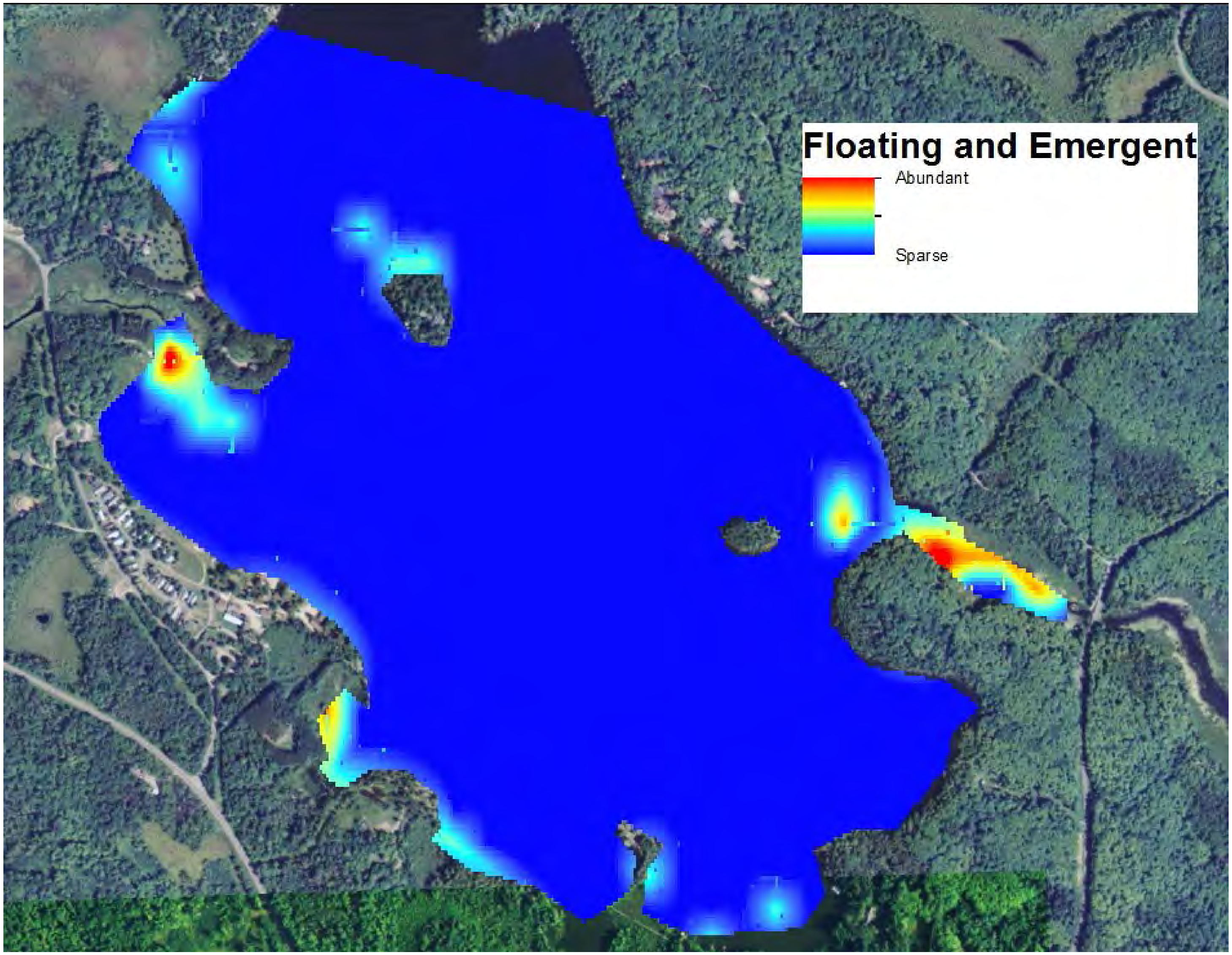


Figure 12.5 Locations of highest quality aquatic habitat (e.g., floating and emergent plant communities) in Mamie Lake.

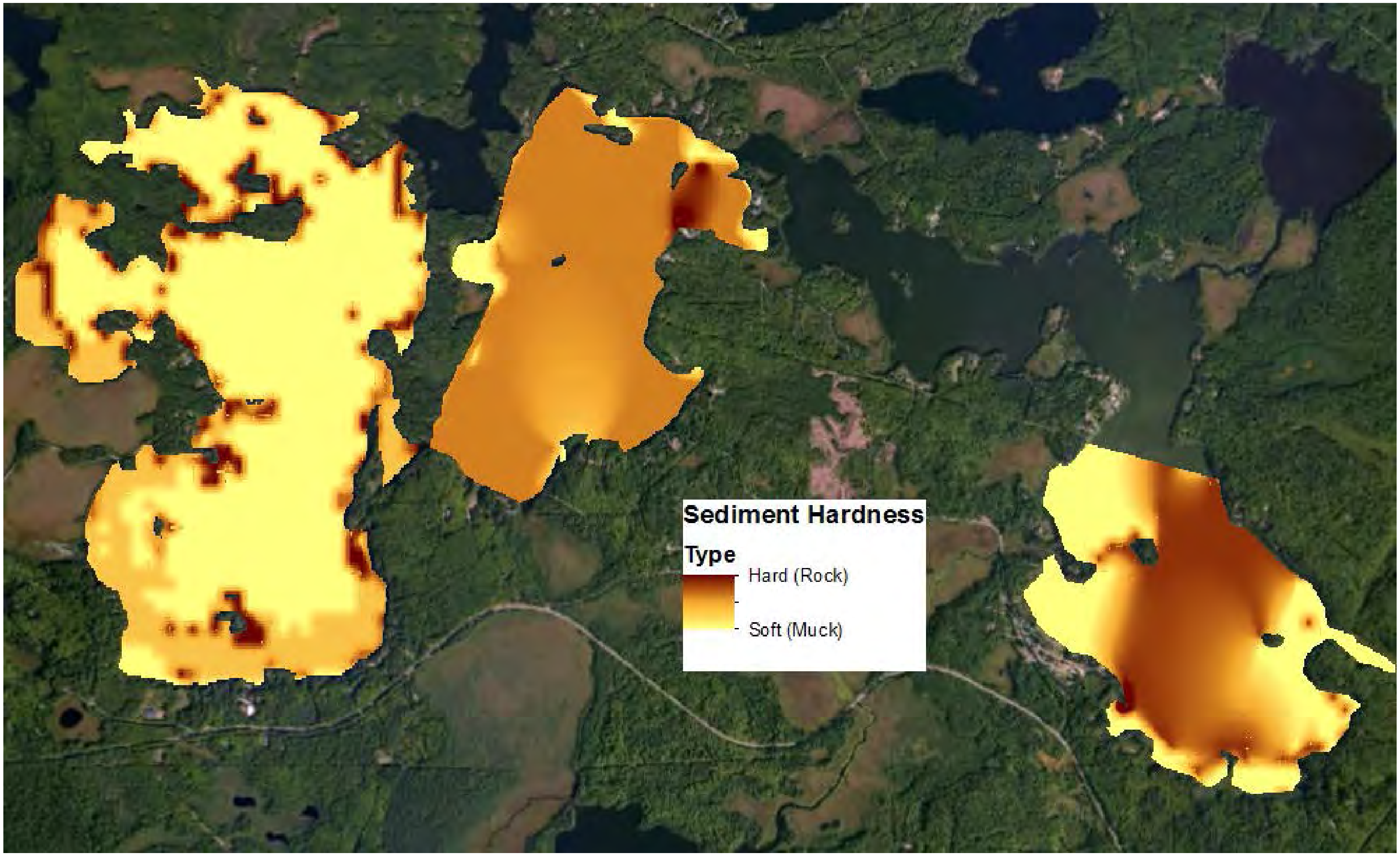


Figure 12.6 Locations of different sediment types in the Cisco Chain.

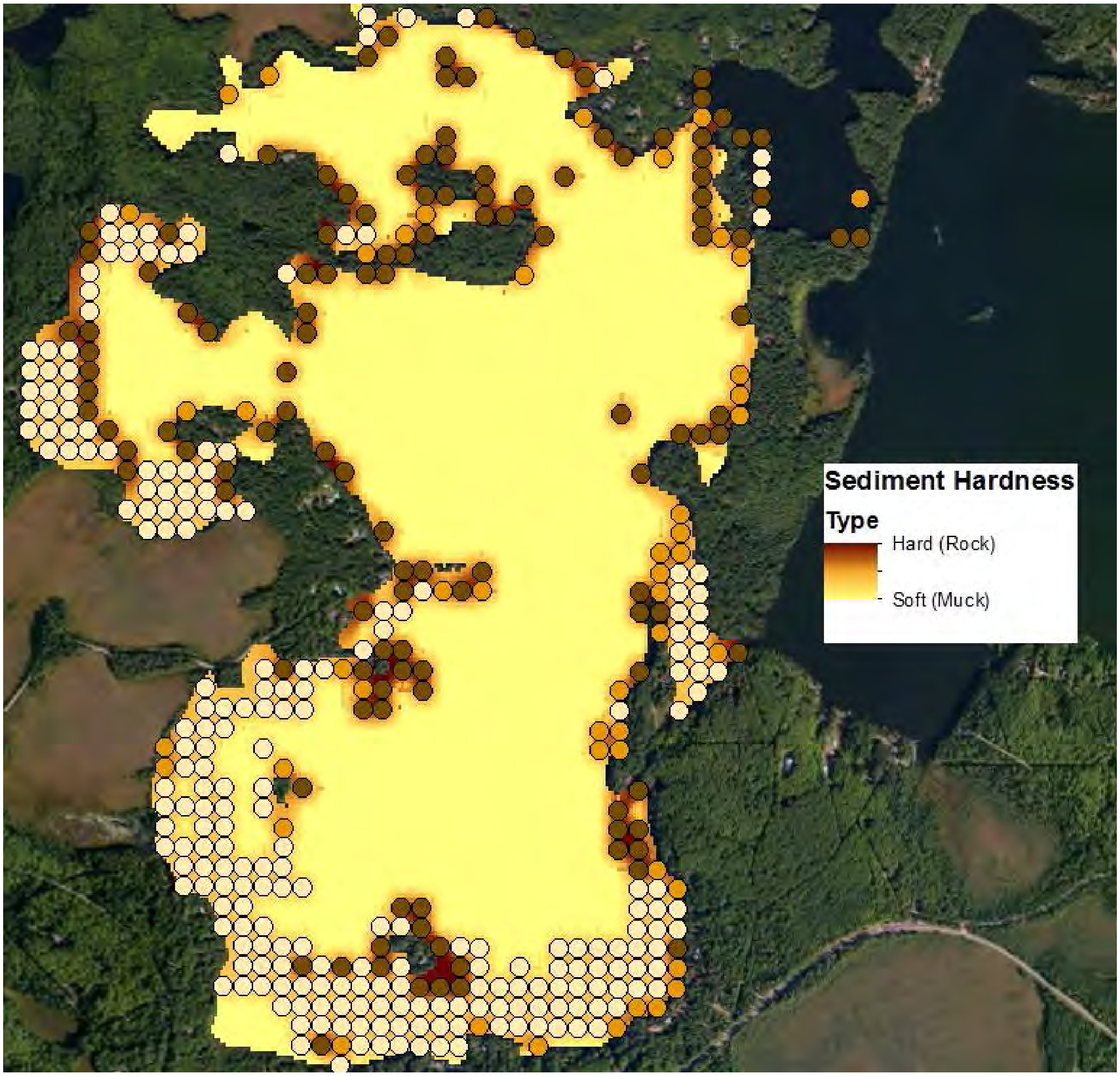
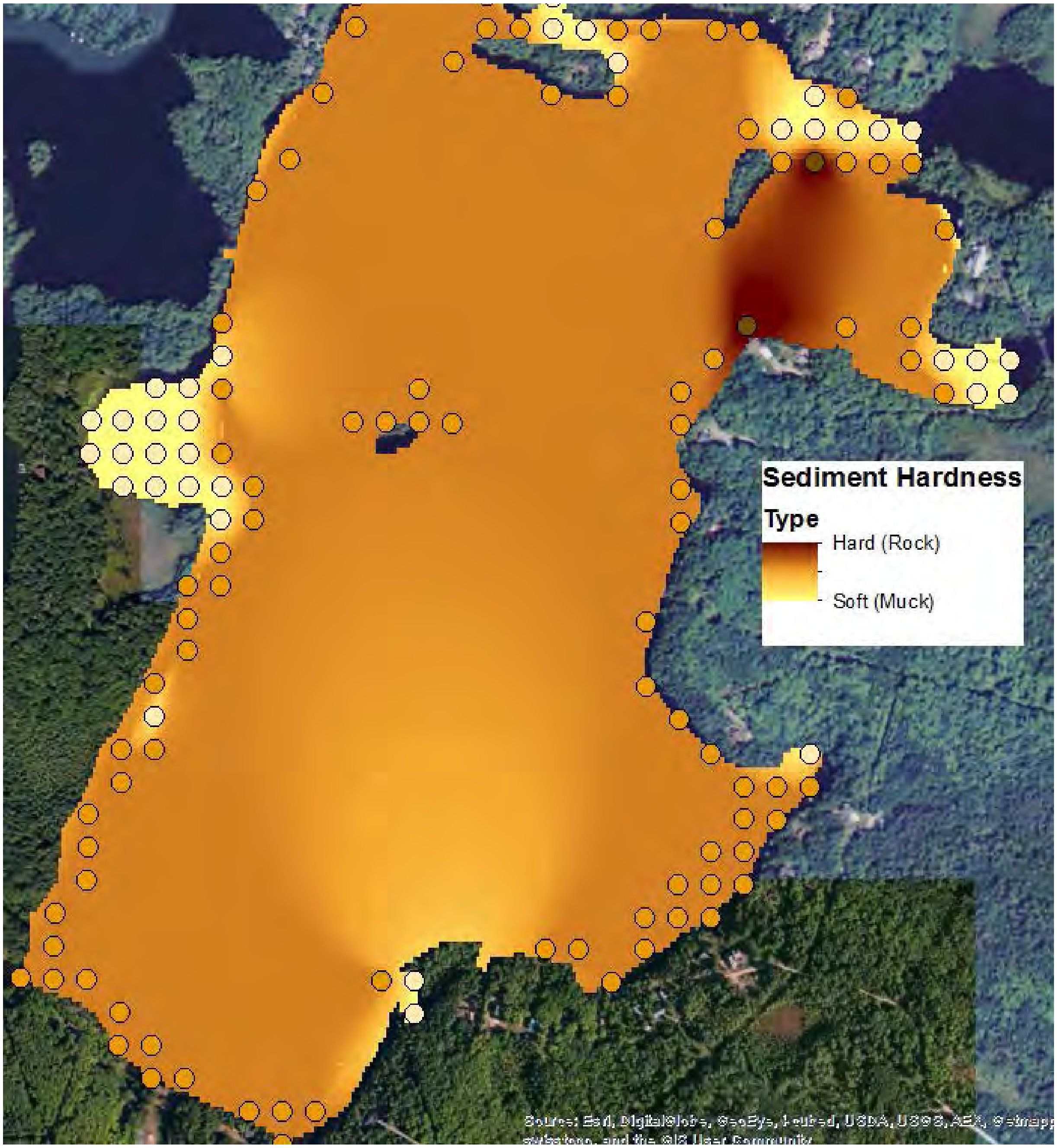


Figure 12.7 Locations of different sediment types in Big Lake.



Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapp
swisstopo, and the GIS User Community

Figure 12.8 Locations of different sediment types in West Bay Lake.

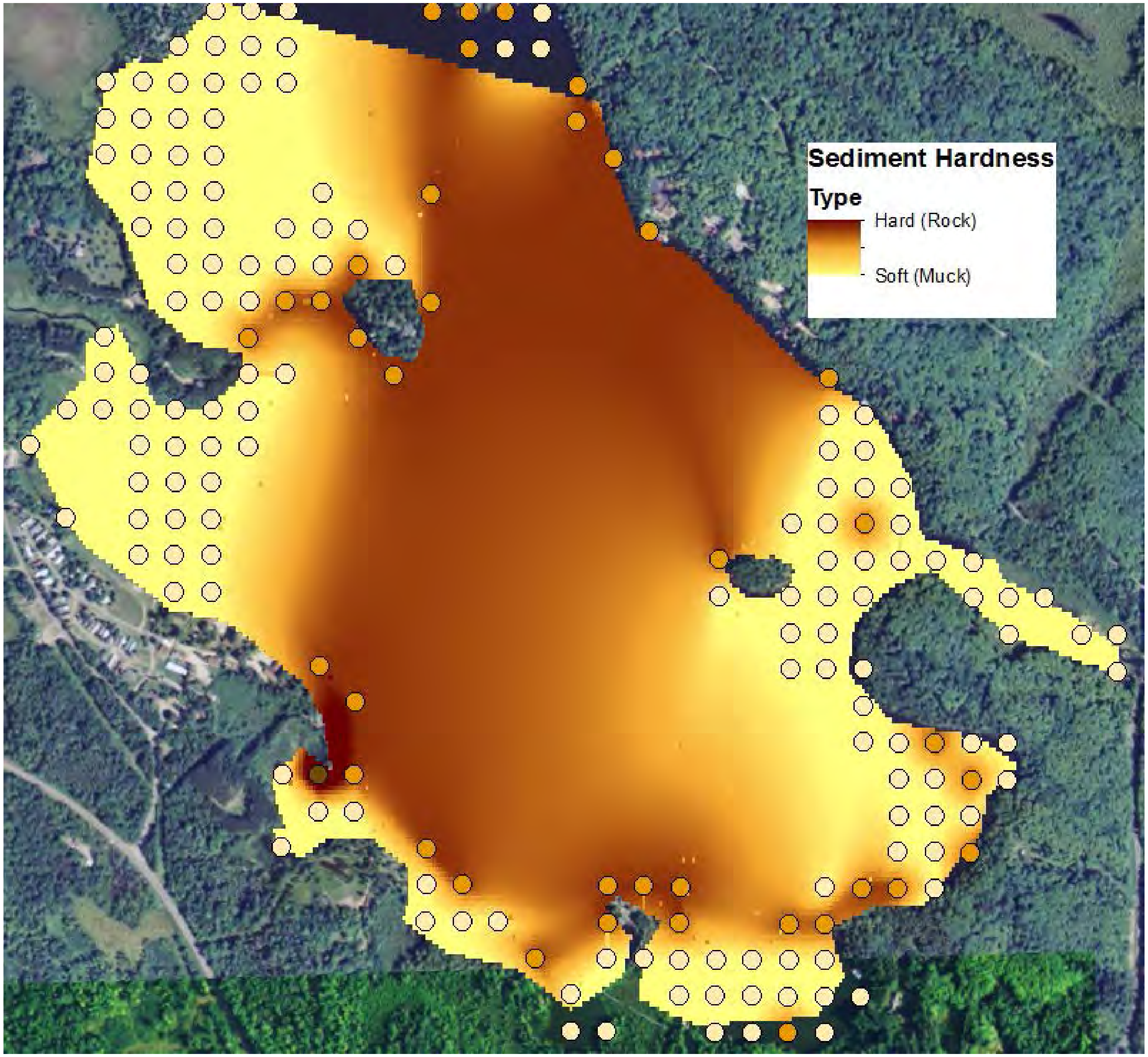


Figure 12.9 Locations of different sediment types in Mamie Lake.

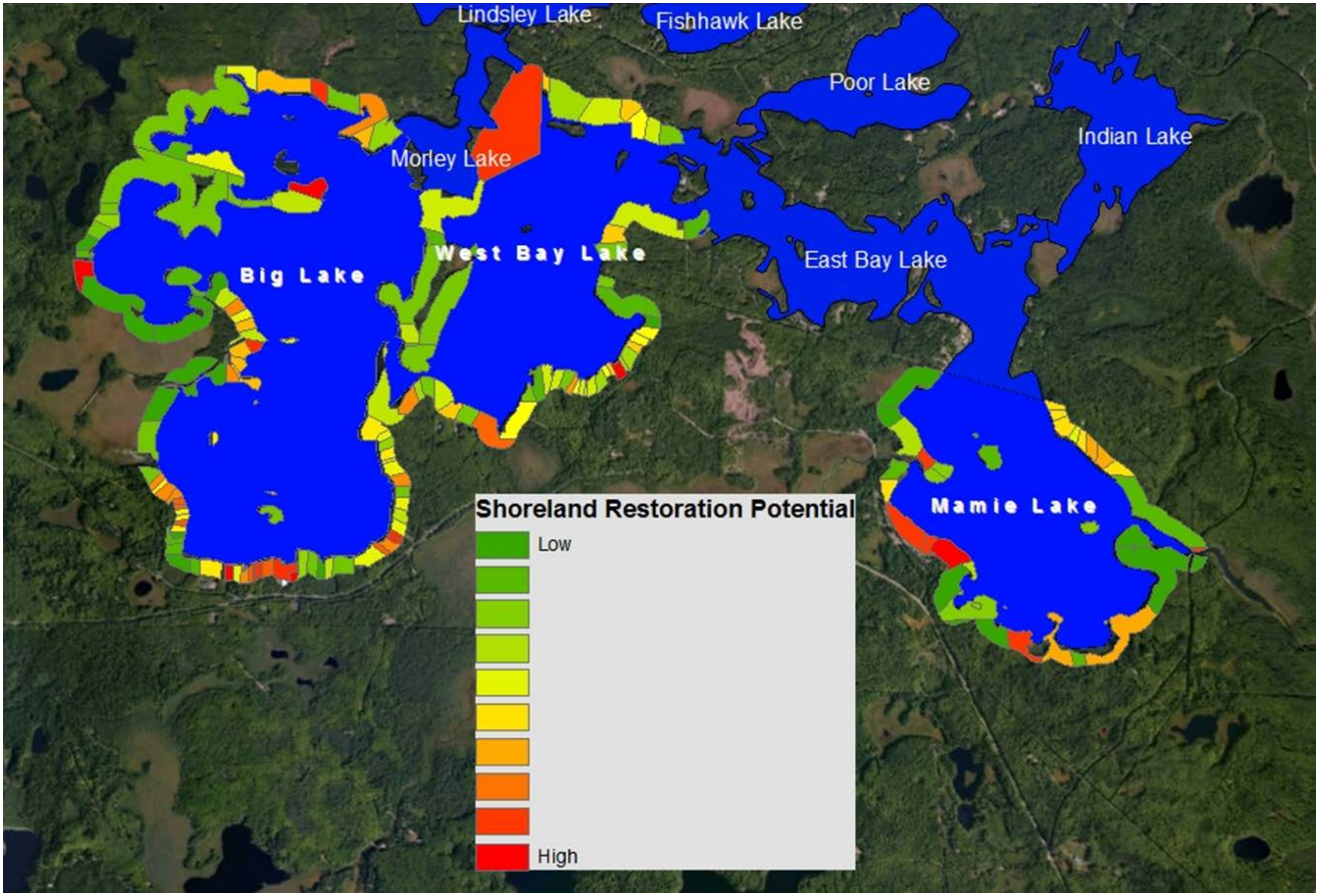


Figure 12.10 Average restoration potential of shoreland areas surrounding the Cisco Chain.

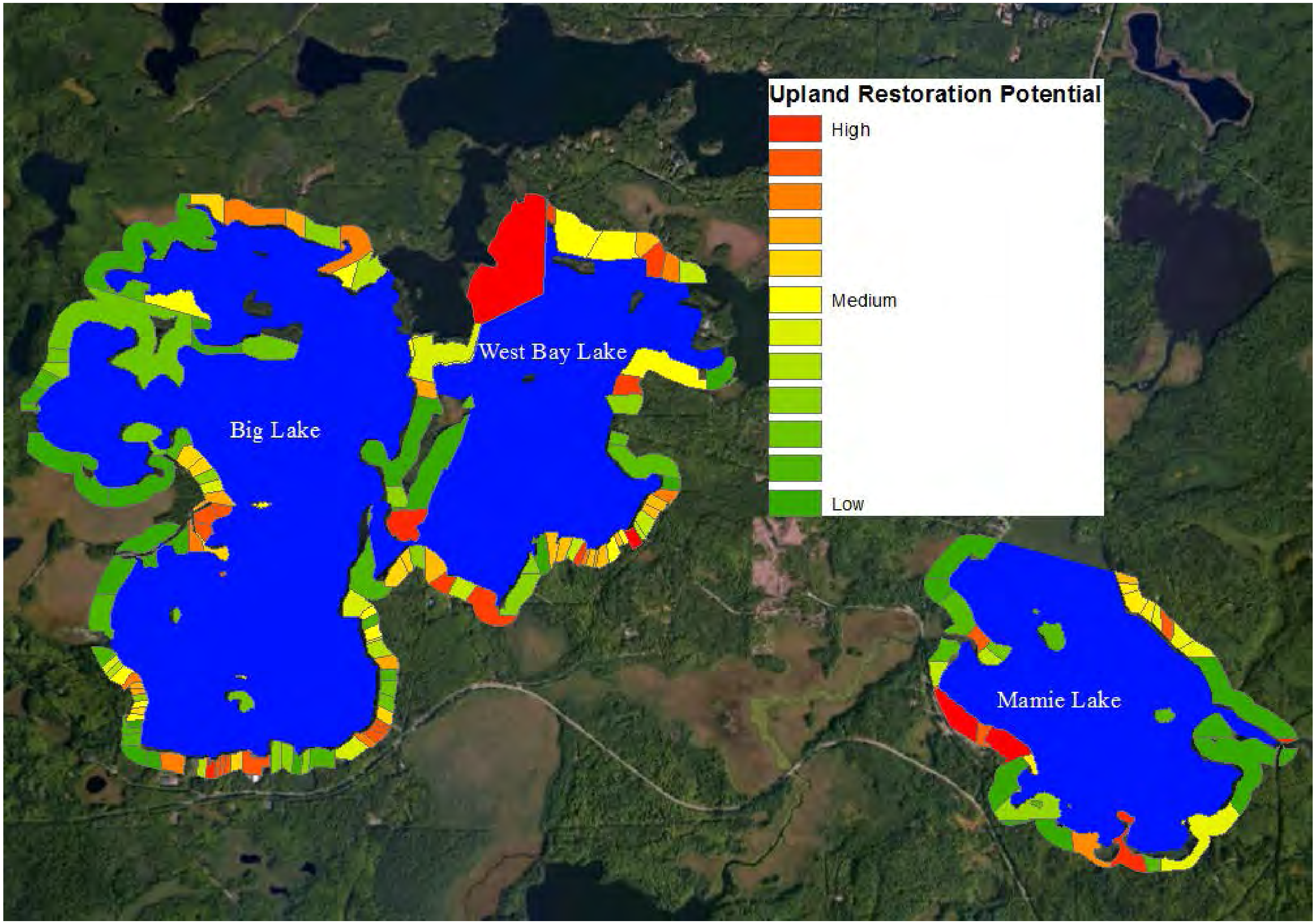


Figure 12.11 Average restoration potential of upland areas surrounding the Cisco Chain.

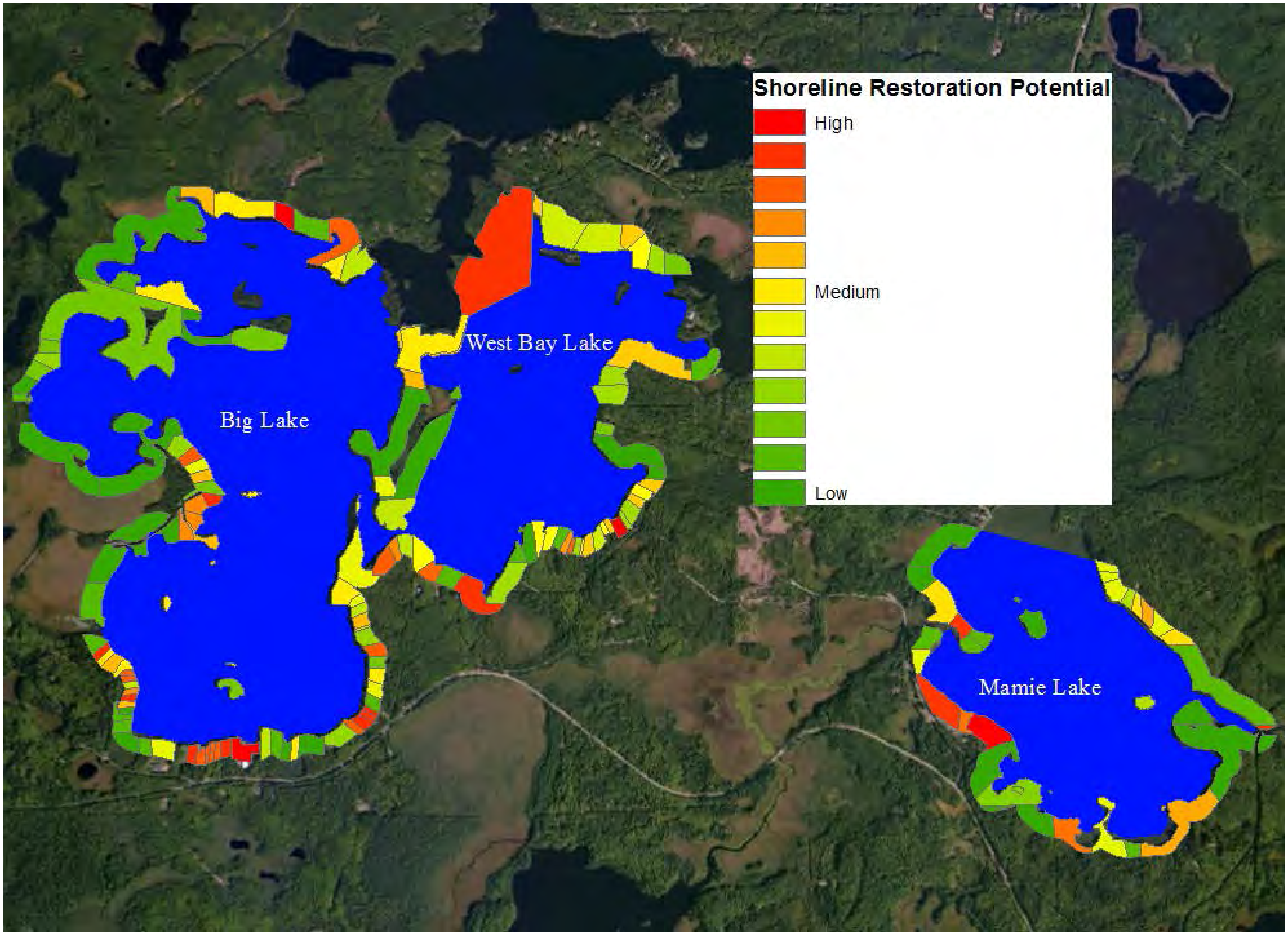


Figure 12.12 Average restoration potential of shoreline areas surrounding the Cisco Chain.

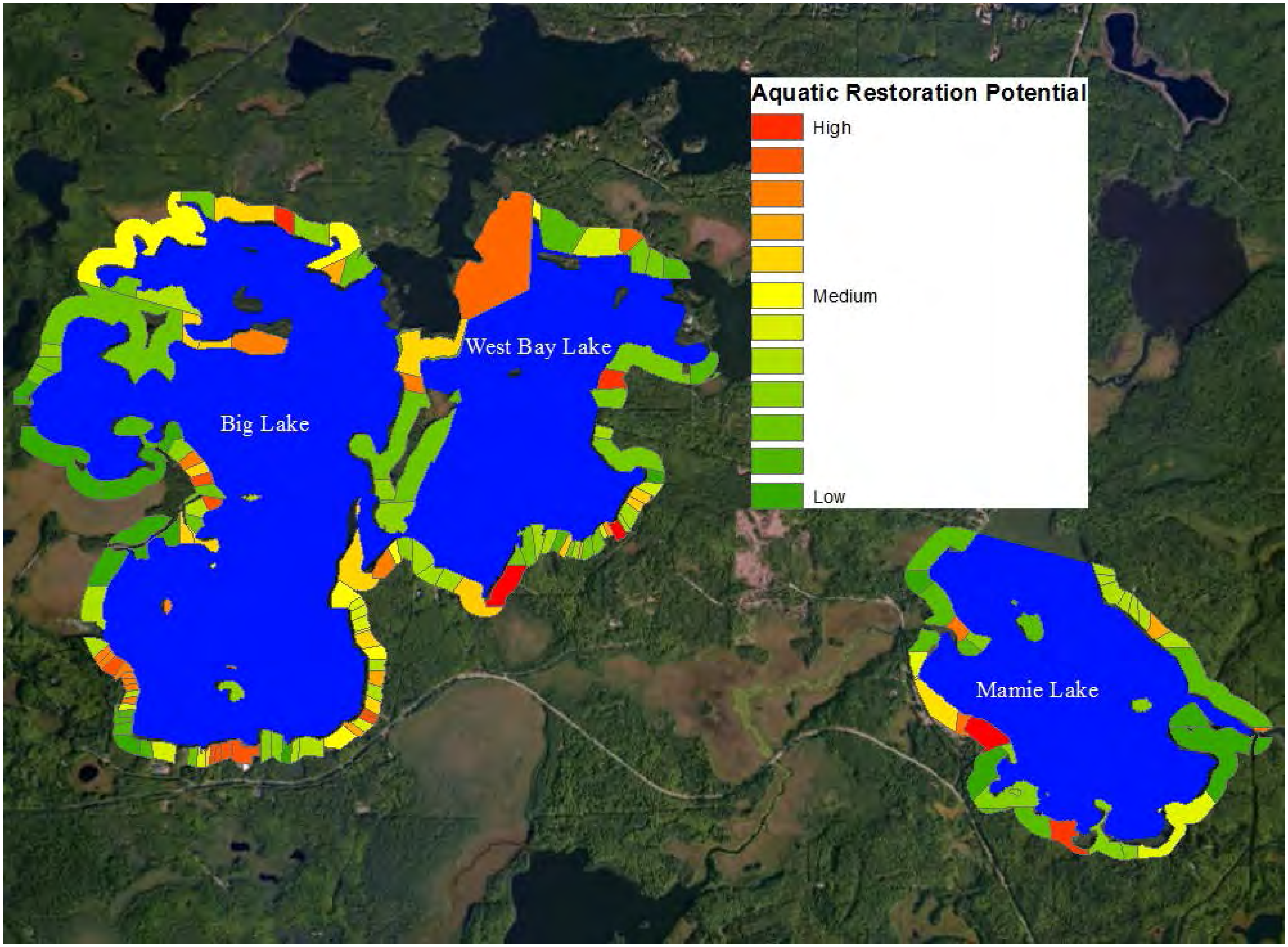


Figure 12.13 Average restoration potential for aquatic/littoral areas surrounding the Cisco Chain.

13. Appendix D – Watershed Assessment and Management Plan

Introduction

This report summarizes the condition of, and potential management options for, the Cisco Chain watershed. Given the importance of watershed nutrient runoff (see Section 5.2), a detailed assessment of the land use types and potential phosphorus sources to the Cisco Chain was conducted. Results from this assessment were compared against the different federal, state and local regulatory/land use policies to develop a watershed nutrient management plan for the Cisco Chain.

Methods

Watershed nutrient loads to the Cisco Chain were developed using land-use specific, annual phosphorus export coefficients. Initially, the Cisco Chain watershed was delineated and spatially characterized use the ArcHydro feature in ArcGIS. The watershed boundary was then used to extract and summarize the relative area of different land cover types using a time series of GIS data layers. Historical land cover was based on the WDNR Original Vegetation data layer. Land cover from 1992 to 2011 was based on the USGS National Land Cover Datasets and data from the shoreline assessment. Future potential land cover was based on the future land use/zoning plans for the local governments. Given that more than 95% of the watershed area occurs in WI, land use analyses did not include MI land areas.

Annual watershed nutrient loads to the Cisco Chain were calculated by multiplying the total area of different land cover types by a corresponding average annual loading estimate (lbs. P/acre/year; based on PRESTO export coefficients). Annual watershed phosphorus loads were calculated for historical (circa 1850), current (2011) and future land use (~2030) scenarios. Annual loads were summarized as total and average, per acre values. Watershed nutrient loads were used to develop an external nutrient budget and integrated into a WiLMS model to describe the relationship between land use and lake condition (see Appendix F).

Septic system phosphorus loads were estimated following methods described by Reckhow et al. (1980). Following this approach, septic system phosphorus load (M) is estimated using a system phosphorus export coefficient (scaled to the number users and time period of use) and soil retention. Phosphorus export coefficients were based on a range of 1.1 to 1.8 lbs/capita/year, with a most likely value of 1.5 lbs/capita/year. Soil retention was assumed to be 0.7, based on soil type (with a corresponding export ratio of 0.3). Numbers of septic system were based on current land use and occupancy was based on the results from the user survey (see Appendix A for more detail). Input parameters were used to estimate a range of septic system phosphorus loads under current and future land use scenarios.

Results and Discussion

The Cisco Chain watershed is approximately 32,016 acres (including waterbodies). Land cover throughout the Cisco Chain watershed is dominated by coniferous forests and wetlands, while developed and agricultural lands make up a relatively small percentage of the land area (Figure 13.3 and Table 13.2). Of the Wisconsin lakes, West Bay (12,438 acres) has the largest watershed area, followed by Mamie (8,210 acers) and Big (1,984 acres) Lakes.

Land cover throughout the watershed has shifted moderately since the mid-1800s and is anticipated to continue to change in the coming years (Figures 13.1, 13.2 and 13.3). Historically, the watershed was dominated by coniferous forests and wetlands with smaller areas of maple and birch. Over time, this land cover has remained relatively constant, but the areas of low density residential have increased. As the permanent and seasonal population in the area continues to grow, land cover throughout the watershed is expected to become more dominated by low and medium density urban development.

Phosphorus loads to the Cisco Chain from septic systems comprise approximately 9 percent of the total watershed load (Table 13.1). Based on future land use plans, phosphorus loads from future land uses have the potential to increase to approximately 36 percent.

In correspondence to the land use changes described above, phosphorus runoff has increased, and has the potential to increase into the future under current land use plans (Table 13.2 and Figures 13.4 and 13.5). Historical phosphorus loads to the lakes were approximately 1028 lbs/yr. Annual phosphorus loads to the lakes increased to approximately 1170 in 2011 and have the potential to increase to 1687 by 2030. However, the increased potential density of shoreline development now possible under the revised statewide shoreland zoning laws (NR 115) have the potential to significantly increase phosphorus runoff to the lakes beyond what would be expected in current land use plans. Historical increases in phosphorus loads to the lakes have likely had a modest impact on water quality (see Section 5.4) and the increased phosphorus loads expected into the future have the potential to have similar impacts on the Cisco Chain ecosystem, depending on the implementation of the revised NR 115 rules (see Appendix F for further discussion on the relative impacts of nutrient loads to the Cisco Chain).

Management and Monitoring Recommendations

Changes in land use throughout the Cisco Chain watershed have likely increased phosphorus runoff to the lakes and phosphorus runoff to the lakes has the potential to increase into the future, depending on land use planning. To prevent any future changes in water quality conditions resulting from watershed nutrient runoff, future management actions should focus on the on-site treatment of stormwater to minimize runoff to the lakes. Current per acre export of phosphorus to the Cisco Chain from the surrounding land use is relatively low, predominantly because of the large areas of undeveloped land throughout the watershed. However, based on current zoning regulations it is likely that a larger percentage of the watershed will be occupied by low and medium density urban/residential lands. Over time, these urban lands have the potential to become the dominant source of phosphorus to the system. As such, future management activities should focus on reducing runoff from existing parcels and minimizing runoff from a new land development.

The capacity of current zoning and stormwater regulations to manage runoff under future land use scenarios is mixed. Current shoreland zoning laws are likely insufficient to mitigate much of the potential impacts to water quality from development in shoreland areas (given recent changes to NR115). However, the potential impact of shoreline development on water quality may be dependent on the on-site wastewater treatment required. Future septic design/requirements should incorporate an assessment of potential cumulative septic impacts to the lake system, preferentially focusing on the use of holding tank systems over traditional or mounded systems. Guidance for on-site wastewater treatment can be seen at http://water.epa.gov/scitech/wastetech/upload/septic_guidelines.pdf.

Runoff from lands outside of the shoreland zone also has the potential to impact water quality in the Cisco Chain. However, potential impacts from upland areas are more likely to occur as a result of stormwater runoff than on-site wastewater management. Because the population density in the surrounding towns is below 5000, state stormwater management standards are not required as part of new development. Although the potential impacts of stormwater runoff are potentially mitigated by large lot size requirements in different rural residential areas, cumulative potential impacts as well as directed runoff from higher density residential areas throughout the watershed should be considered.

To effectively mitigate the potential impacts of watershed runoff to the Cisco Chain, all future development activities should incorporate stormwater management requirements in a similar form to those required in larger urban centers. A range of different practices and technologies are available to mitigate stormwater runoff from different land development types (see http://www.epa.gov/greeningepa/stormwater/best_practices.htm for a complete discussion of potential best management practice options). Additionally, given the likely changes in precipitation patterns that are expected in the future, stormwater design should incorporate up-to-date (e.g., Atlas 14) and potentially future precipitation estimates into engineering model design standards.

Uncertainty and Data Interpretation

Although the existing simulations suggest there is potential for phosphorus levels to increase in the Cisco Chain in the future in response to shoreland and upland development, a range of uncertainty is present that should be considered. Because of the diffuse nature of overland runoff to the Cisco Chain, direct measurements of phosphorus runoff are difficult. As such, phosphorus loads to the lakes are estimated based on literature values from studies in which more precise measurements could be made. Similarly, estimates of phosphorus from septic systems are also based on literature values of phosphorus discharge. The estimates presented within represent the most likely phosphorus runoff, but do not likely provide accurate representation of runoff from all parcels of land throughout the watershed.

Estimates of future land scenarios are also uncertain. Because land is zoned for a particular development type, it does not guarantee that it will undergo the potential land cover transition—as many factors impact this transition (most of which cannot be accurately forecast). Additionally, although zoning laws provide a minimum standard, it is quite possible that voluntary efforts to reduce runoff will be made by landowners, in the absence of regulation. As such, individual variability in land management and on-site waste treatment have the potential to significantly influence future water quality conditions. Additionally, because future land use prescriptions in local comprehensive plans do not encompass the entire watershed, it is difficult to full forecast any potential land changes.

Given these sources of uncertainty, future monitoring efforts and scientific investigations should focus on: tracking land use change over time, tracking the different on-site waste system that are implemented and developing more site specific characterizations of nutrient runoff from the Cisco Chain watershed.

Table 13.1. Estimated annual phosphorus loads from septic systems

Time Period	Residency	Number of Septic Systems	Number of Users per System	Seasonal Ratio	Soil Retention	Export (lbs/capita years)			Load (lbs/year)		
						Low	High	Average	Low	High	Average
Current Conditions	Full-time	53	2.5	1	0.3	1.1	1.8	1.5	44	72	**60**
	Seasonal	160	2.5	0.3	0.3	1.1	18	1.5	40	647	**54**
	Total	**213**	**2.5**	**0.65**	**0.3**	**1.1**	**9.9**	**1.5**	**83**	**719**	**114**
Future Conditions	Full-time	287	2.5	1	0.3	1.1	1.8	1.5	237	388	**323**
	Seasonal	862	2.5	0.3	0.3	1.1	1.8	1.5	213	349	**291**
	Total	**1149**	**2.5**	**0.65**	**0.3**	**1.1**	**1.8**	**1.5**	**450**	**737**	**614**

Table 13.2. Estimated annual total phosphorus loads to the Cisco Chain (all Lakes) from all watershed sources.

Potential Phosphorus Source	Annual TP Loads			Estimated Annual Phosphorus Loads to the Cisco Chain					
				Historical (1856)		Current (2011)		Potential Future	
	Minimum	Maximum	Most Likely	Units	TP Load	Units	TP Load	Units	TP Load
Agriculture Lands	(lbs./acre/yr)			Acres	lbs.	Acres	lbs.	Acres	lbs.
Cultivated Crops	0.5	3	1	0	0	0	0	0	0
Pasture/Hay	0.1	3	1	0	0	0	0	0	0
Urban Lands	(lbs./acre/yr)			Acres	lbs.	Acres	lbs.	Acres	lbs.
Developed, Rural Residential	0.05	0.25	0.1	0	0	887	89	1602	160
Developed, Medium Density	0.3	0.8	0.5	0	0	0	0	13	7
Developed, High Density	1	2	1.5	0	0	0	0	3	5
Forest and Grasslands	(lbs./acre/yr)			Acres	lbs.	Acres	lbs.	Acres	lbs.
Deciduous Forest	0.05	0.2	0.09	7407	950	7368	884	6637	818
Evergreen Forest				2342		1106		1106	
Mixed Forest				801		1267		1267	
Shrub/Scrub				0		83		83	
Grassland	0.01	0.25	0.17	0	0	39	7	39	7
Wetland	0.01	0.01	0.01	7852	79	7652	77	7652	77
Permitted Sources	(lbs./source/yr)			Sources	lbs.	Sources	lbs.	Sources	lbs.
None	-	-	-	-	-	-	-	-	-
Non-permitted Sources (lbs./system)	(lbs./systems/yr)			Systems	lbs.	Systems	lbs.	Systems	lbs.
*Septic Systems	1.1	1.8	1.5	0	0	213	114	1149	614
Relative Changes in Phosphorus Load					**Total**	**%**	**Total**	**%**	**Total**
Total Watershed Load					**1028**	**3%**	**1056**	**2%**	**1073**
Permitted/Non-permitted Source Load					**0**	**100%**	**114**	**81%**	**614**
Total Phosphorus Loads					**1028**	**12%**	**1171**	**30%**	**1668**
Per Acre Phosphorus Load					**0.06**	**12%**	**0.06**	**30%**	**0.09**

*Phosphorus loads from septic systems are scaled to account for seasonal residency. See Table 13.3 for further details.

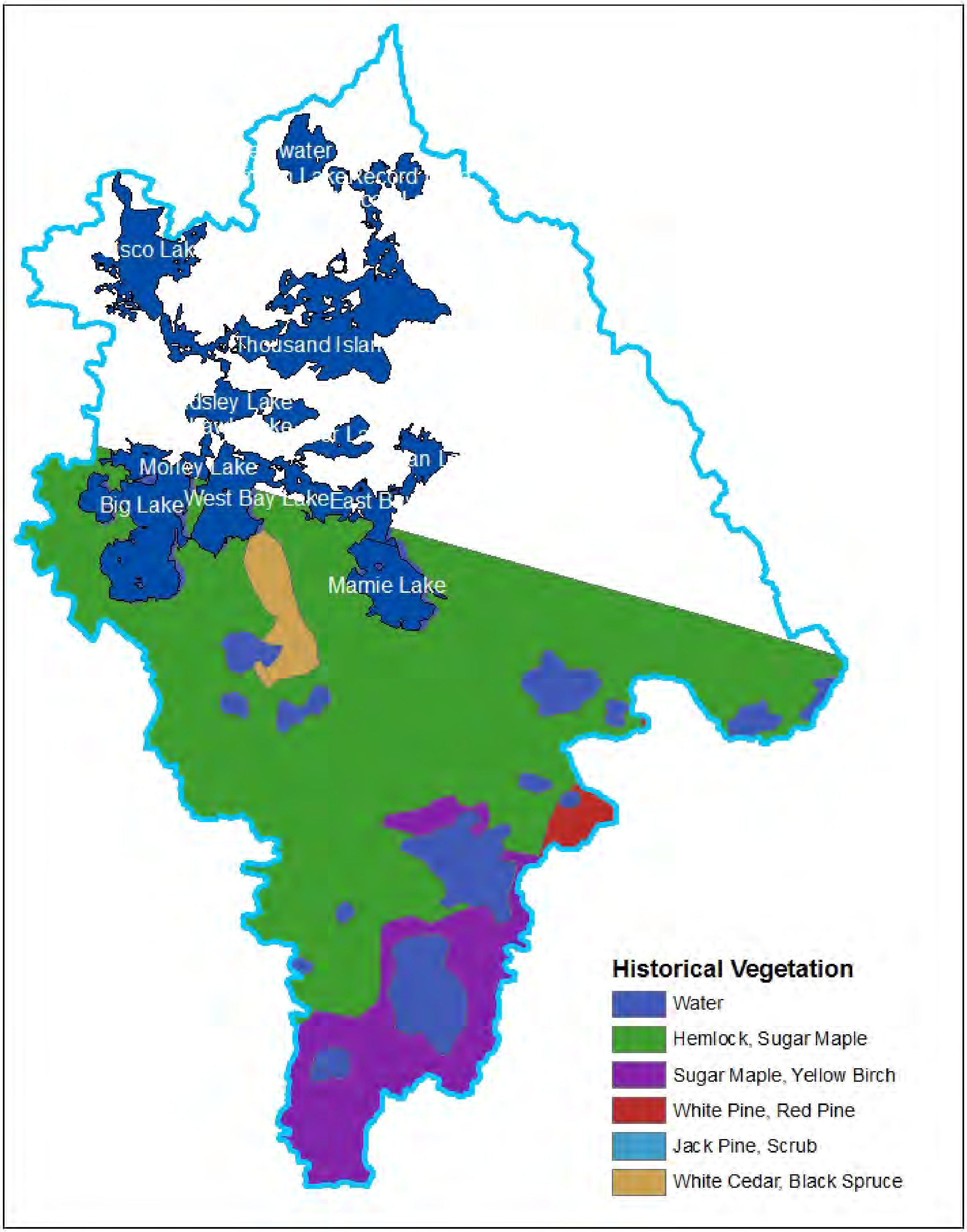


Figure 13.1 Historical vegetative cover in the Cisco Chain watershed. Based on ~1856 vegetative cover assessments.

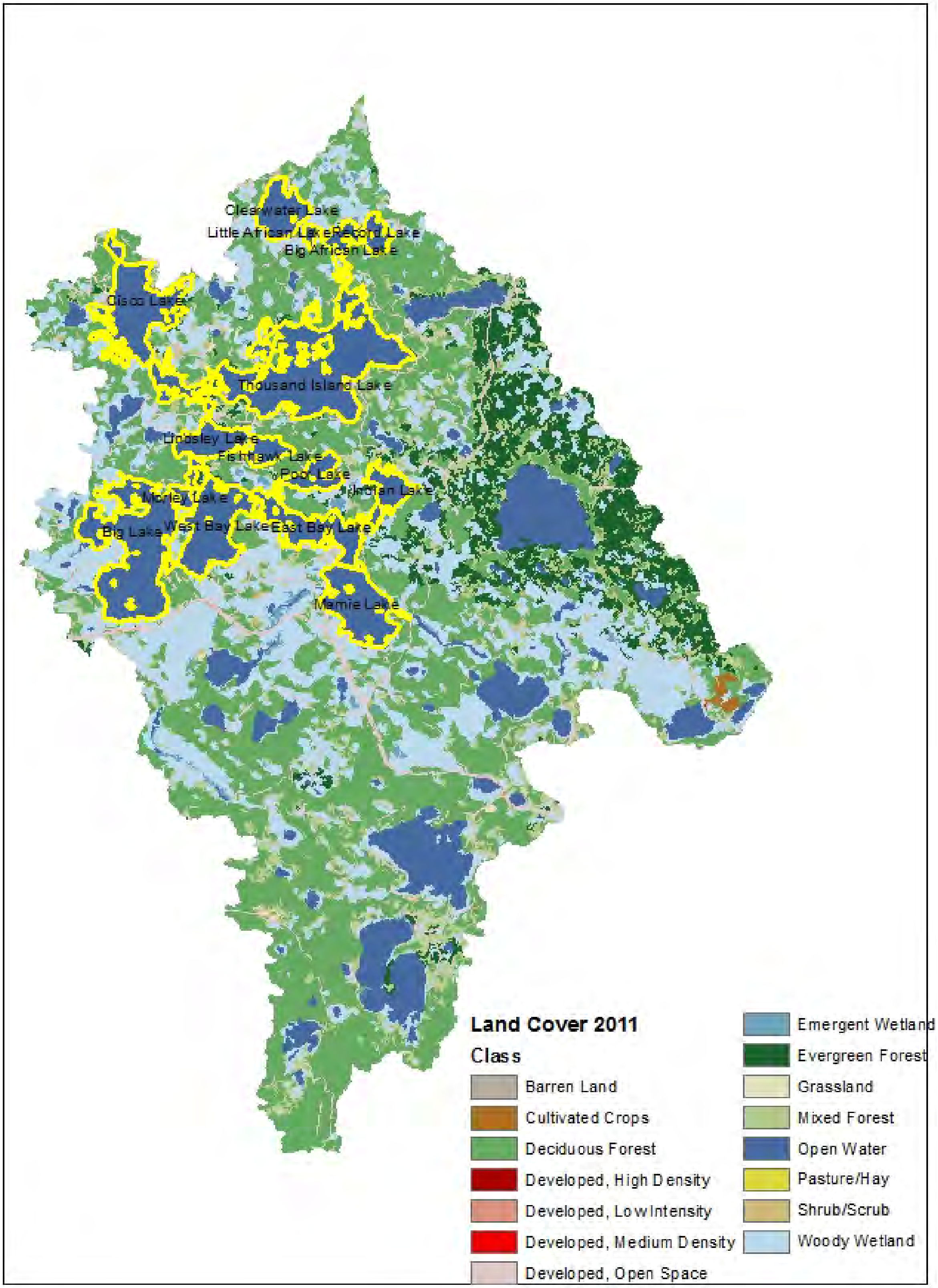


Figure 13.2 Land cover in the Cisco Chain watershed in 2011.

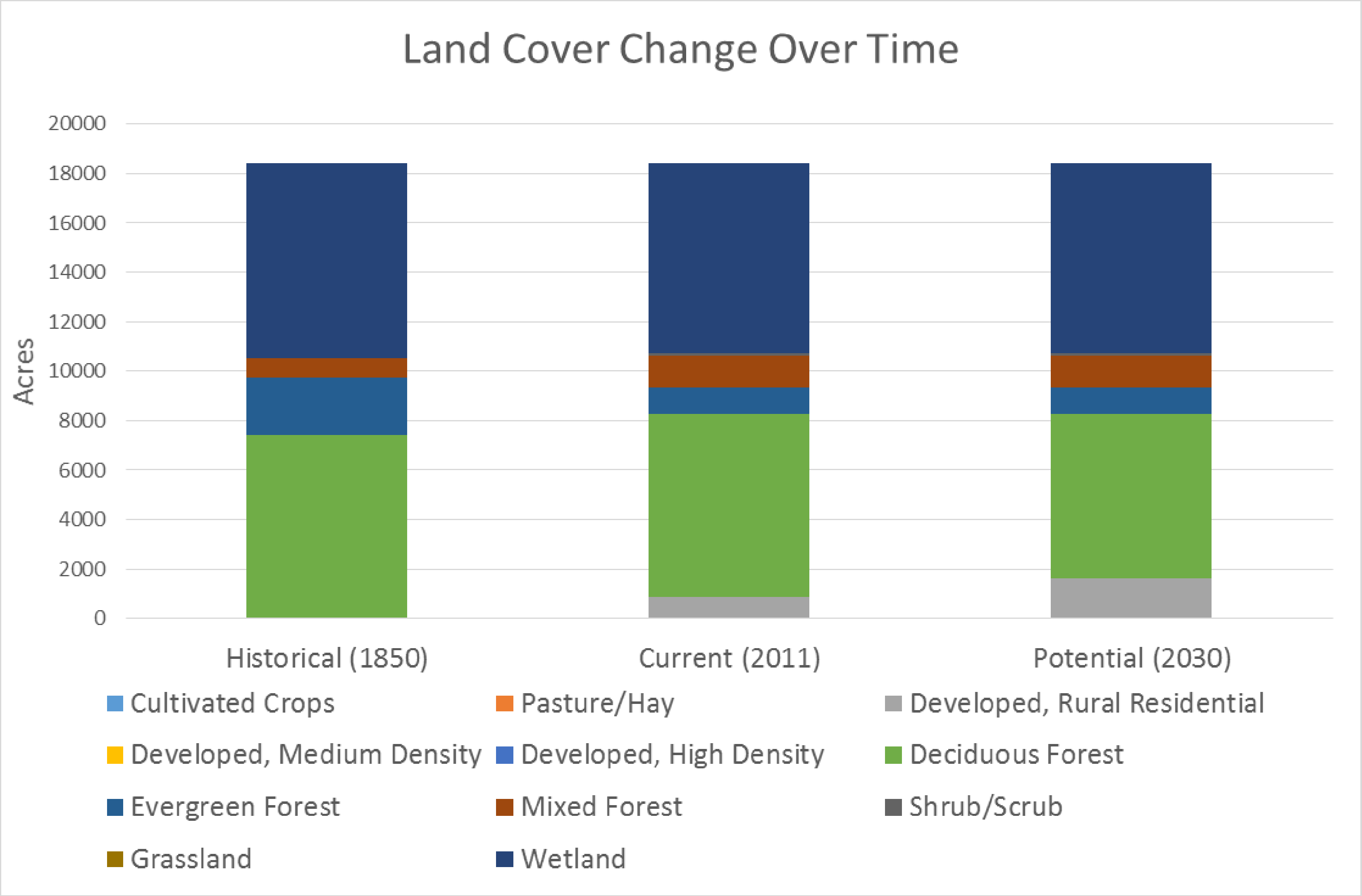


Figure 13.3 Changes in land cover in Cisco Chain (all areas) watershed over time.

Figure 13.4 Existing land use in the Cisco Chain watershed as described in the local comprehensive plan.

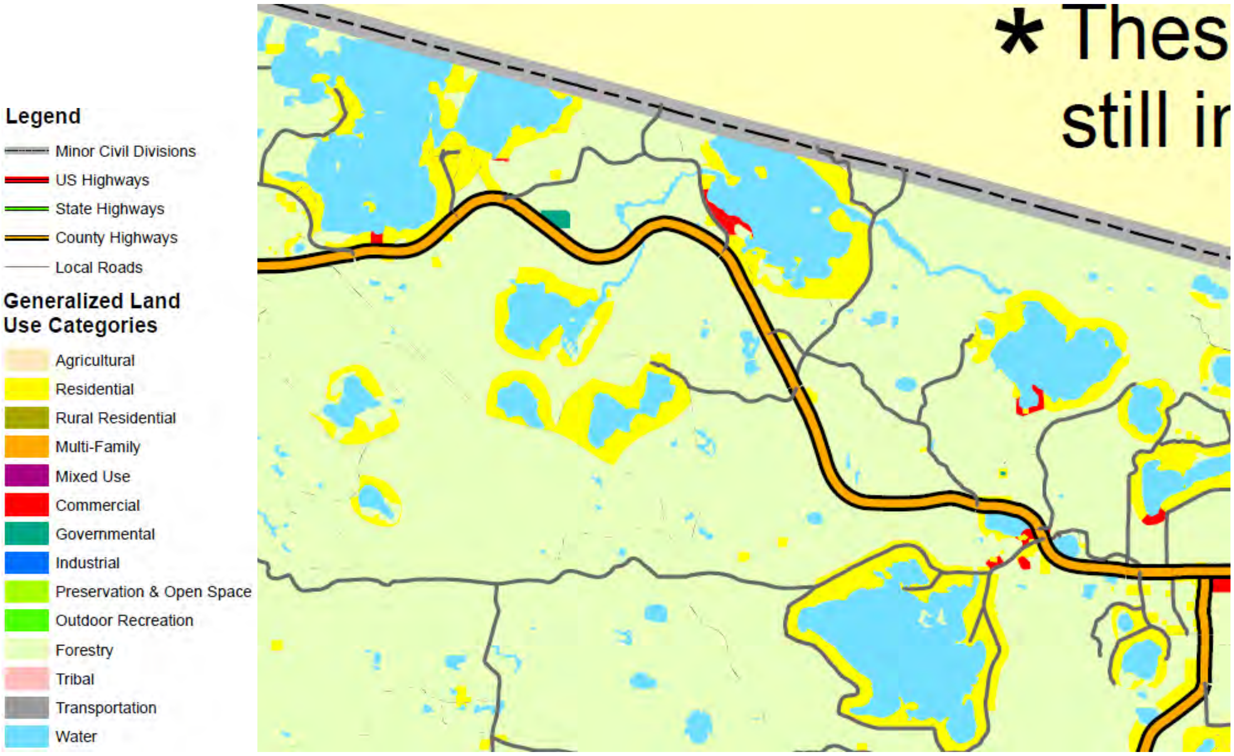


Figure 13.5 Future potential land use in the Cisco Chain watershed as described in the local comprehensive plan (2030).

14. Appendix E – Aquatic Plant Assessment and Management Plan

Introduction

This report summarizes the status of the aquatic plant communities in the Cisco Chain and describes a plan to manage aquatic plants and invasive species throughout the system. Given the importance of healthy native aquatic plant communities and potential negative impacts of invasive species (see Section 5.5), a detailed assessment of the current plant communities and risk of invasive species introduction was conducted for the Cisco Chain. Results from these assessments were combined to develop recommendations to maintain diverse native plant communities, manage existing invasive species populations and prevent future invasive species introductions.

Methodology

Aquatic plant communities were sampled from 965 points in the littoral zone of the Cisco Chain (570 Big Lake; 208 Mamie Lake; 187 West Bay Lake). Surveys were conducted from July to August, 2013 and 2014. All work was implemented by the SOEI at Northland College on behalf of the CCROA. All field staff were trained in the annual WDNR aquatic plant management workshop and overseen by the Lake Program Coordinator at SOEI. Additionally, all lakes throughout the Cisco Chain were sampled by Northland College staff in 2012.

Sampling Procedure

Plant communities were sampled following the WDNR Point Intercept Survey Methodology (Hauxwell, et al. 2010). Following this protocol, plant communities were sampled across a grid of points in shallow waters of the lake—the littoral zone. All sampling grids were generated by WDNR staff (e.g., Figure 15.1).

At each sample point, plant communities were sampled using a double-sided rake sampling device (Figure 15.1). Following the WDNR procedure, the rake is dropped to the bottom, turned three times and pulled to the surface. Once in the boat, the different species are identified and the relative density of the individual species and total plant density are recorded as rake fullness (Figure 15.1). Species composition and relative density data are recorded on the WDNR survey form and voucher specimens are kept for each species. In addition to species data, water depth, sediment type and sample site location are measured and recorded at each point using a handheld sonar and GPS units.

Following completion of the field survey, all data were entered into the WDNR spreadsheet template and analyzed. Raw data were processed to describe the total number and relative abundance of the different plant species encountered throughout the lakes. Data were also used to calculate Floristic Quality Index (FQI).

The FQI describes how well the historical aquatic plant community (i.e., the plant community that likely occupied these lakes before human settlement) has been conserved over time. To calculate FQI, biologists have assigned Coefficients of Conservatism to different species based on their ability to survive across a range of environments. Species that are assigned a value of 0 are species that can survive in most lakes. Species that are assigned a value of 10 are those that represent historical plant communities and are often very sensitive to environmental change. The FQI is calculated by combining the species presence data with the appropriate Coefficient of Conservatism to estimate the historical characteristics of the plant community (methods described in detail in Nichols 1999).

Raw species data for each point were combined with GPS data and used to develop a series of maps to describe the aquatic plant communities. Maps depicting the total number of species detected at each point were developed for all lakes. Point data were then analyzed using a Spline Interpolation technique to estimate the likely species distribution between the individual sample points. The resulting data were used to develop a color-coded intensity map in which areas of high species richness are colored red and areas of low species richness are colored green. Areas of dense floating and emergent vegetation were identified by interpolating between points where these species were identified.

Voucher Specimens

Voucher specimens were retained for all species in all lakes and identified to species using: “Michigan Flora” Part I, by Edward G. Voss (1972); as well as the “Manual of Aquatic Plants” by Norman C. Fassett (1940). Voucher specimens were then pressed, dried and archived at the SOEI and sent to the Freckman Herbarium at the University of Wisconsin – Stevens Point for confirmation and long-term archival (Figure 15.1).

Pathway/Vector Analysis

Five primary pathways (or vectors) exist for invasive species entry into lakes (Table 15.1). Potential pathways were identified and characterized for the Cisco Chain. Risk of introduction for each pathway was assessed and ranked using a five point, qualitative scale. Qualitative rankings are described below:

1. Low – Unlikely to result in species introduction in the short-term
2. Low-Moderate – Somewhat unlikely to result in species introduction in the short-term
3. Moderate – Moderate potential to result in species introduction in the short-term
4. Moderate-High – Somewhat likely to result in species introduction in the short-term
5. High – Likely to result in species introduction in the short-term

Results

Point Intercept Survey

The Cisco Chain contains a robust aquatic plant community. Throughout this study, 50 species were identified (Table 15.2, 15.3, 15.4 and 15.5). The majority of plants were observed growing between 1 and 12 feet, up to a maximum depth of 28 feet (Figure 15.2). The diversity and richness of species also varied among sites within the lakes, with some individual rake pulls not collecting any plants and other collecting up to eleven individual species. In general, the areas of highest species richness were in protected bays at the northern and southern end of the lakes (Figures 15.3, 15.4, 15.5 and 15.6).

Throughout the Cisco Chain, the most common species detected were eloda (*Elodea Canadensis*) and coontail (*Ceratophyllum demersum*). The species that were detected that represent the high level of floristic quality were spiny hornwory (*Ceratophyllum echinatum*), dwarf water-milfoil (*Myriophyllum tenellum*), vasey’s pondweed (*Potamogeton vaseyi*), floating-leaf bur-reed (*Sparganium fluctuans*) and small bladderwort (*Utricularia minor*). In general, the FQI scores for lakes throughout the Cisco Chain had scores that were higher than the regional average of 26, with values for Cisco, Thousand Island, Poor and Clearwater Lakes being well above the state averages—indicating the presence of high quality, diverse aquatic plant communities.

Two invasive species were detected throughout the Cisco Chain—Eurasian watermilfoil (EWM; *Myriophyllum spicatum*) and curly-leaf pondweed (CLP; *Potamogeton crispus*). Eurasian watermilfoil was detected at moderate to high densities in Clearwater and Big Lakes and very low densities in Thousand Island Lake. Curly-leaf pondweed was detected at moderate densities in Fishhawk Lake and at one point in Big Lake.

Pathway/Vector Analysis
Ten potential pathways for invasive species introduction were identified and evaluated (Table 15.6). Of the 10 introduction pathways, five were classified as Low or Low-Moderate risk, three were identified as Moderate risk and one was identified as a high risk. The highest risk pathway for introduction of invasive species is through transportation from connected waterbodies.

Discussion and Management Recommendations

Aquatic plant management efforts in the Cisco Chain should build on the ongoing work of the CCROA and its collaborators to continue to address three primary goals:

1) Monitoring and maintaining the diversity of native aquatic plants;
2) Management of existing invasive species;
3) Prevention of the introduction of new invasive species.

Existing Management Efforts

Existing management efforts are primarily implemented through volunteer the efforts of the CCROA. The primary work of the CCROA is to increase awareness of invasive species and their prevention. To this end, the CCROA hosts an annual meeting and distributes recurring newsletters that highlight ongoing work and needs related to invasive species prevention and management. The CCROA contracts with local partners to implement watercraft inspections at launches throughout the Cisco Chain, as well as the coordination of herbicide treatment projects.

Monitoring and Maintaining the Diversity of Native Aquatic Communities

Diverse native aquatic communities are a key component of healthy lake ecosystems. Native plant communities: 1) support healthy fisheries by providing spawning and rearing habitat for juvenile fish; 2) promote water quality by providing habitat for zooplankton (which control algal blooms) and preventing sediments (and the associated nutrients) from being re-suspended throughout the lakes; and 3) prevent the establishment and spread of invasive species by occupying habitat that invasive species could potentially utilize.

The first step in maintaining diverse native plant communities is to establish/maintain a recurring monitoring program to document any changes in community composition or structure over time. A recurring aquatic plant monitoring program like this would be implemented by conducting a point-intercept survey (the same protocol described above) to characterize the extent and composition of aquatic plant communities in all shallow waters (depth of < 25 feet) of the lakes every three to five years. This work would build on the aquatic plant surveys that were conducted as part of the development of this management plan.

Management of Existing Invasive Species

Proactive control of existing invasive species is necessary to prevent their further establishment and spread and future efforts should build on the ongoing work by the CCROA. Invasive species have detected in three lakes in this past survey (Clearwater Lake, Big Lake, Lindsley and Fishhawk Lake). Management of existing invasive species should continue to be implemented based on lake-by-lake needs, but follow a general structure of preliminary delineation, treatment (potentially using a range of methods; described below) and follow-up monitoring. In general, treatments for Curly-leaf pondweed and Eurasian Water-milfoil should be conducted in the early season (likely in May-June depending on water temperatures) to maximize their efficacy and minimize any impacts on native plant communities.

Methods and/or chemicals that are implemented to control invasive species should be determined on a lake-by-lake basis. In lakes with well-established beds (i.e., areas of dense plant growth that are dominated by invasive species) herbicide application is likely the best option for control of invasive species. The type of herbicide that is applied will vary depending the species of plant, cost of the chemical and potential for secondary or non-target effects of the herbicide.

In lakes with low density invasive species coverage (i.e., noticeable beds do not exist), herbicide application is often less effective and/or has a higher potential for secondary effects. The efficacy of herbicide application is dependent on the concentration and “contact time” (i.e., duration of exposure at a particular concentration) of the chemical. In situations where plants are at a low density, the area that must be treated to maintain an effective herbicide concentration is much larger than the area covered by the invasive plants. As a result, treatments that focus on one plant or a small cluster of plants are often either not effective or have a large area of secondary herbicide exposure. In areas of low density, control methods should consider hand pulling or the use of a containment curtain to maintain effective concentrations in proportionally smaller areas.

Invasive species treatment in Big Lake, is of particular challenge given the timing and dispersion of growth. Based on three years of survey work, EWM colonies consistently presented a late season growth pattern. EWM colonies were generally undetectable, sparsely distributed (often in single plant per acre densities) and/or comingled with native plants during early-season herbicide treatment windows. As such, these EWM colonies are poorly suited for herbicide treatment, particularly because herbicide impacts to native plants may accelerate milfoil colonization/spread. Alternatively, selective, late-season hand pulling of EWM is likely the most appropriate management technique for Big Lake. Hand pulling can be accomplished though volunteer efforts and/or through contract with local vendors that specialize in hand pulling control. Money from the CCROA Rapid Response grant may be used to contract with vendors.

Prevent the Spread and further Introduction of Invasive Species

Given that no invasive aquatic plant species have been detected in many lakes throughout the Cisco Chain, continuing efforts that build on the CCROA’s ongoing work to minimize potential for the introduction of invasive species are critical. To this end, two approaches are recommended: 1) expand educational efforts to include a broader range of potential sources; and 2) develop and implement an early detection, rapid response plan.

Expanded Educational Efforts

Given the potential for invasive species to be introduced to lakes beyond public/private boat launches, targeted educational efforts may help reduce risk of introduction beyond efforts at boat launches. In particular, outreach and educational efforts targeted at 1) local bait dealers to minimize the potential inadvertent distribution of invasive species; 2) lakeshore landowners to minimize inadvertent introduction of invasive ornamental species; 3) individual launch owners to minimize potential impacts of long-range boat transport; 4) upstream lake residents to minimize introduction to the connected system; and 5) beach managers to minimize wildlife attraction to waterfront areas (currently not a high risk activity in the Cisco Chain). See WDNR resources for additional detail http://dnr.wi.gov/lakes/invasives/EducationOutreach.aspx.

Early Detection, Rapid Response Planning

An early detection, rapid response plan combines targeted invasive species monitoring activities with a document that articulates the action steps and decision criteria that will be used to prevent the establishment of new invasive species in a particular lake. Annual monitoring activities are generally comprised of high intensity monitoring efforts in the areas of highest probability for invasive species spread or introduction (e.g., adjacent to boat launches and areas of high traffic—connecting channels). The rapid response planning document is developed collaboratively with the Wisconsin Department of Natural Resources and articulates how (i.e., by what means?), when (i.e., in response to what change?) and by what process (i.e., who needs to be involved when, and in what order) new or expanding invasive species will be managed. Rapid response plans are then implemented in tandem with outreach efforts to increase awareness among lake users of the potential risks of invasive species and the options to prevent future spread or introduction. See ANS Task Force for additional resources http://www.anstaskforce.gov/default.php.

Table 15.1. Description and potential risk for different invasive species introduction pathways

Pathway	Description	Risk of Introduction
Boat Launches	Watercraft movement between lakes is a primary vector for the introduction of invasive species. Invasive species can be transported in bait and ballast water, in and around the motor and on a transportation trailer.	Risk of introduction varies depending on the rates of usage and the levels of invasive species infestation in commonly visited waterbodies
Connected/adjacent Waterbodies	Invasive species are commonly spread between connected and/or adjacent waterbodies by human activities and wildlife movement	Risk of introduction varies depending on the size, level of connectivity and invasive species infestation in connected/adjacent waterbodies
Stormwater Runoff	Invasive species can washed into a lake through storm drain system when introduced to surrounding urban area	Risk of introduction varies depending on the area and usage of lands that directly drain to the lake.
Wildlife	Wildlife (particularly waterfowl) can introduce invasive species from one waterbody to another	Risk of introduction varies depending on the frequency of use and may be increased through human attraction of wildlife to lake systems (e.g., geese at beaches)
Riparian Introduction	Species commonly used in gardens along lakeshore properties can be introduced to lake systems and may become invasive	Risk of introduction varies depending on the density and species composition of gardens around lake systems

Table 15.2. Summary of Results from Aquatic Plant Survey on Big Lake.

Native Species	Common Name	Big	Big - Michigan Bay	Big - Palmer Bay
Bidens beckii	Water marigold	1	0	1
Ceratophyllum demersum	Coontail	1	0	1
Ceratophyllum echinatum	Spiny hornwort	1	0	0
Elodea canadensis	Common waterweed	1	1	1
Lemna trisulca	Forked duckweed	1	0	0
Myriophyllum sibiricum	Northern water-milfoil	1	0	1
Najas flexilis	Slender naiad	1	0	0
Najas gracillima	Northern naiad	1	0	1
Potamogeton alpinus	Alpine pondweed	0	1	0
Potamogeton amplifolius	Large-leaf pondweed	1	1	0
Potamogeton foliosus	Leafy pondweed	1	0	1
Potamogeton friesii	Fries' pondweed	1	0	1
Potamogeton nodosus	Long-leaf pondweed	0	0	1
Potamogeton obtusifolius	Blunt-leaf pondweed	1	0	1
Potamogeton praelongus	White-stem pondweed	1	0	0
Potamogeton richardsonii	Clasping-leaf pondweed	1	0	1
Potamogeton robbinsii	Fern pondweed	1	1	1
Potamogeton vaseyi	Vasey's pondweed	0	0	1
Potamogeton zosteriformis	Flat-stem pondweed	1	0	1
Ranunculus aquatilis	White water crowfoot	1	0	0
Vallisneria americana	Wild celery	1	0	0
Invasive Species				
Potamogeton crispus	Curly-leaf Pondweed	1	0	0
Myriophyllum spicatum	Eurasian Water-milfoil	1	0	0
Species Detected		**18**	**4**	**13**
Floristic Quality Index		**28.28**	**13.50**	**23.85**

Table 15.3. Summary of Results from Aquatic Plant Survey on Mamie Lake.

Species	Common Name
Bidens beckii	Water marigold
Ceratophyllum demersum	Coontail
Ceratophyllum echinatum	Spiny hornwort
Elodea canadensis	Common waterweed
Lemna trisulca	Forked duckweed
Myriophyllum sibiricum	Northern water-milfoil
Myriophyllum verticillatum	Whorled water-milfoil
Nitella	Nitella
Nuphar variegata	Spatterdock
Potamogeton alpinus	Alpine pondweed
Potamogeton amplifolius	Large-leaf pondweed
Potamogeton epihydrus	Ribbon-leaf pondweed
Potamogeton foliosus	Leafy pondweed
Potamogeton friesii	Fries' pondweed
Potamogeton gramineus	Variable pondweed
Potamogeton illinoensis	Illinois pondweed
Potamogeton richardsonii	Clasping-leaf pondweed
Potamogeton zosteriformis	Flat-stem pondweed
Ranunculus aquatilis	White water crowfoot
Stuckenia vaginata	Sheathed pondweed
Utricularia vulgaris	Common bladderwort
Vallisneria americana	Wild celery
Species Detected	**22**
Floristic Quality Index	**31.76**

Table 15.4. Summary of Results from Aquatic Plant Survey on West Bay Lake.

Species	Common Name	West Bay
Bidens beckii	Water marigold	1
Ceratophyllum demersum	Coontail	1
Ceratophyllum echinatum	Spiny hornwort	1
Elodea canadensis	Common waterweed	1
Heteranthera dubia	Water star-grass	1
Lemna trisulca	Forked duckweed	1
Myriophyllum sibiricum	Northern water-milfoil	1
Myriophyllum verticillatum	Whorled water-milfoil	1
Potamogeton amplifolius	Large-leaf pondweed	1
Potamogeton foliosus	Leafy pondweed	1
Potamogeton friesii	Fries' pondweed	1
Potamogeton praelongus	White-stem pondweed	1
Potamogeton richardsonii	Clasping-leaf pondweed	1
Potamogeton robbinsii	Fern pondweed	1
Potamogeton zosteriformis	Flat-stem pondweed	1
Ranunculus aquatilis	White water crowfoot	1
Vallisneria americana	Wild celery	1
Species Detected		**17**
Floristic Quality Index		**27.16**

Table 15.5. Relative occurrence of different aquatic plant species throughout Cisco Chain

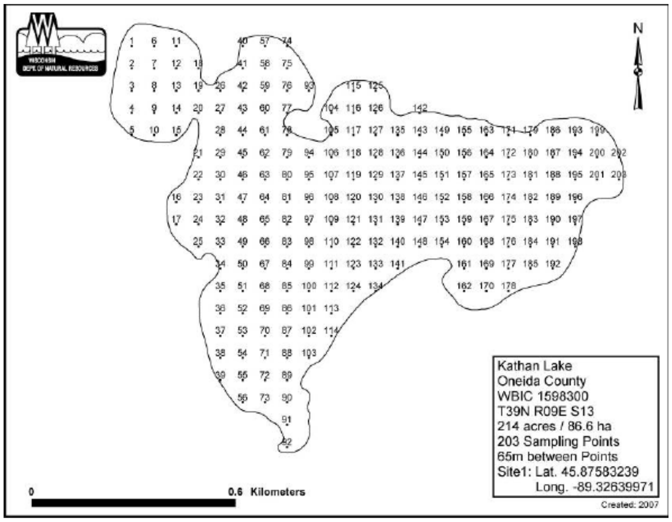
Species	Common Name	Big	Big Africa	Cisco	Clear-water	East Bay	Fish-hawk	Indian	Little Africa	Lindsley	Mamie	Morley	Poor	Record	Thous. Island	West Bay
Alisma triviale	Northern water-plantain	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Bidens beckii	Water marigold	1	1	1	1	0	1	1	0	0	1	0	1	1	1	1
Bolboschoenus fluviatilis	River bulrush	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Brasenia schreberi	Watershield	0	1	1	0	0	0	0	1	0	0	0	1	1	1	0
Callitriche palustris	Common water-starwort	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ceratophyllum demersum	Coontail	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1
Ceratophyllum echinatum	Spiny hornwort	1	0	0	1	0	1	0	0	0	1	0	0	0	0	1
Chara	Muskgrasses	0	0	1	1	1	0	1	0	0	0	1	1	1	1	0
Elodea canadensis	Common waterweed	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
Elodea nuttallii	Slender waterweed	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Eriocaulon aquaticum	Pipewort	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Heteranthera dubia	Water star-grass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Lemna trisulca	Forked duckweed	1	1	1	0	0	0	1	0	0	1	0	0	0	0	1
Myriophyllum sibiricum	Northern water-milfoil	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1
Myriophyllum tenellum	Dwarf water-milfoil	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Myriophyllum verticillatum	Whorled water-milfoil	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1
Najas flexilis	Slender naiad	1	1	0	1	0	1	1	0	0	0	0	1	0	1	0
Najas gracillima	Northern naiad	1	0	0	1	0	0	1	0	1	0	0	1	1	0	0
Najas guadalupensis	Southern naiad	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Nitella	Nitella	0	0	1	1	0	0	1	0	0	1	0	1	1	1	0
Nuphar variegata	Spatterdock	0	1	0	0	0	0	0	0	0	1	0	0	1	1	0
Nymphaea odorata	White water lily	0	1	0	0	1	0	1	1	0	0	0	1	1	1	0
Potamogeton alpinus	Alpine pondweed	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0
Potamogeton amplifolius	Large-leaf pondweed	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1
Potamogeton epihydrus	Ribbon-leaf pondweed	0	0	1	1	0	0	1	0	0	1	0	1	0	1	0
Potamogeton foliosus	Leafy pondweed	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
Potamogeton friesii	Fries' pondweed	1	0	1	0	0	1	1	0	1	1	0	1	1	1	1
Potamogeton gramineus	Variable pondweed	0	1	1	1	0	1	0	0	0	1	0	1	1	0	0
Potamogeton hillii	Hill's pondweed	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0
Potamogeton illinoensis	Illinois pondweed	0	0	0	1	0	0	0	0	0	1	0	1	0	1	0

Native Aquatic Plant Species Detected in the Cisco Chain (Table 1 cont.)

Species	Common Name	Big	Big Africa	Cisco	Clear-water	East Bay	Fish-hawk	Indian	Little Africa	Lindsley	Mamie	Morley	Poor	Record	Thous. Island	West Bay
Potamogeton natans	Floating-leaf pondweed	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0
Potamogeton nodosus	Long-leaf pondweed	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Potamogeton obtusifolius	Blunt-leaf pondweed	1	0	1	1	1	0	0	0	0	0	0	1	1	1	0
Potamogeton praelongus	White-stem pondweed	1	0	1	1	1	1	1	0	1	0	0	1	0	1	1
Potamogeton pusillus	Small pondweed	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Potamogeton richardsonii	Clasping-leaf pondweed	1	0	1	1	1	1	1	0	1	1	0	1	1	1	1
Potamogeton robbinsii	Fern pondweed	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1
Potamogeton strictifolius	Stiff pondweed	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Potamogeton vaseyi	Vasey's pondweed	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Potamogeton zosteriformis	Flat-stem pondweed	1	0	0	1	1	1	1	0	1	1	1	1	1	1	1
Ranunculus aquatilis	White water crowfoot	1	0	0	0	1	1	1	0	1	1	0	0	2	1	1
Sparganium eurycarpum	Common bur-reed	0	1	0	1	0	0	1	0	0	0	0	1	0	1	0
Sparganium fluctuans	Floating-leaf bur-reed	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0
Stuckenia filiformis	Fine-leaved pondweed	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
Stuckenia vaginata	Sheathed pondweed	0	0	1	0	0	0	1	0	1	1	0	0	0	1	0
Utricularia geminiscapa	Twin-stemmed bladderwort	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0
Utricularia gibba	Creeping bladderwort	0	1	0	1	0	0	0	0	0	0	0	1	0	1	0
Utricularia minor	Small bladderwort	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Utricularia vulgaris	Common bladderwort	0	1	0	1	0	0	1	1	0	1	0	0	0	0	0
Vallisneria americana	Wild celery	1	0	1	1	1	0	1	0	0	1	0	1	2	1	1
Total Species Detected throughout the Chain = 50																
Species Detected per Lake		**21**	**17**	**27**	**26**	**15**	**16**	**24**	**4**	**12**	**22**	**9**	**24**	**20**	**35**	**17**
Floristic Quality Index		**28.28**	**26.92**	**35.60**	**34.90**	**25.04**	**26.25**	**29.49**	**14.50**	**21.93**	**31.76**	**18.66**	**33.06**	**26.08**	**41.58**	**27.16**

Table 15.6. Risk of introduction from different invasive species pathways

Pathway	Description	Risk of Introduction
Connected/adjacent Waterbodies	Lakes directly connected to entire Cisco Chain which contains multipule access points and sites of existing invasive species invasions	High; Significant usage by boaters who on connected lakes. Significant increase in access from connected launches. Most connected lakes currently do have existing invasive species
Public Landing, Big Lake	Moderate use access, primarily from regional and extended users	Moderate; Moderate usage by boaters who generally frequent regional lakes, many of which have existing invasive species
Public Landing, Mamie Lake	Moderate use access, primarily from regional and extended users	Moderate; Moderate usage by boaters who generally frequent regional lakes, many of which have existing invasive species
Private Landing, Mamie Lake, Bent's Camp	Moderate use access, primarily from regional and extended users	Moderate; Moderate usage by boaters who generally frequent regional lakes, many of which have existing invasive species
Private Landing, Big Lake Lake, McCormack's	Moderate use access, primarily from regional and extended users	Moderate; Moderate usage by boaters who generally frequent regional lakes, many of which have existing invasive species
Launch from Public Lands	Moderate use access, primarily from local users	Low; Relatively few individial launches surrounding the lake
Individual Boat Launches	Access primarily from adjacent landowner	Low; Relatively few individial launches surrounding the lake
Stormwater Runoff	Primarily from urban areas along the northern shoreline	Low; Runoff from a relatively limited urban area
Wildlife	Migratory and local wildlife	Low; Limited use concentration beyond background levels
Riparian Introduction	Potentially from ornamental gardens in shoreline properties	Low; Relatively few ornamental gardens surrounding the lake



a)

Fullness Rating	Coverage	Description
1		Only few plants. There are not enough plants to entirely cover the length of the rake head in a single layer.
2		There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover the tines.
3		The rake is completely covered and tines are not visible.

b)

c)

Figure 15.1 General description of the a) point intercept sampling grid development; 2) semi quantitative criteria used to describe relative plant abundance; and the archival procedures.

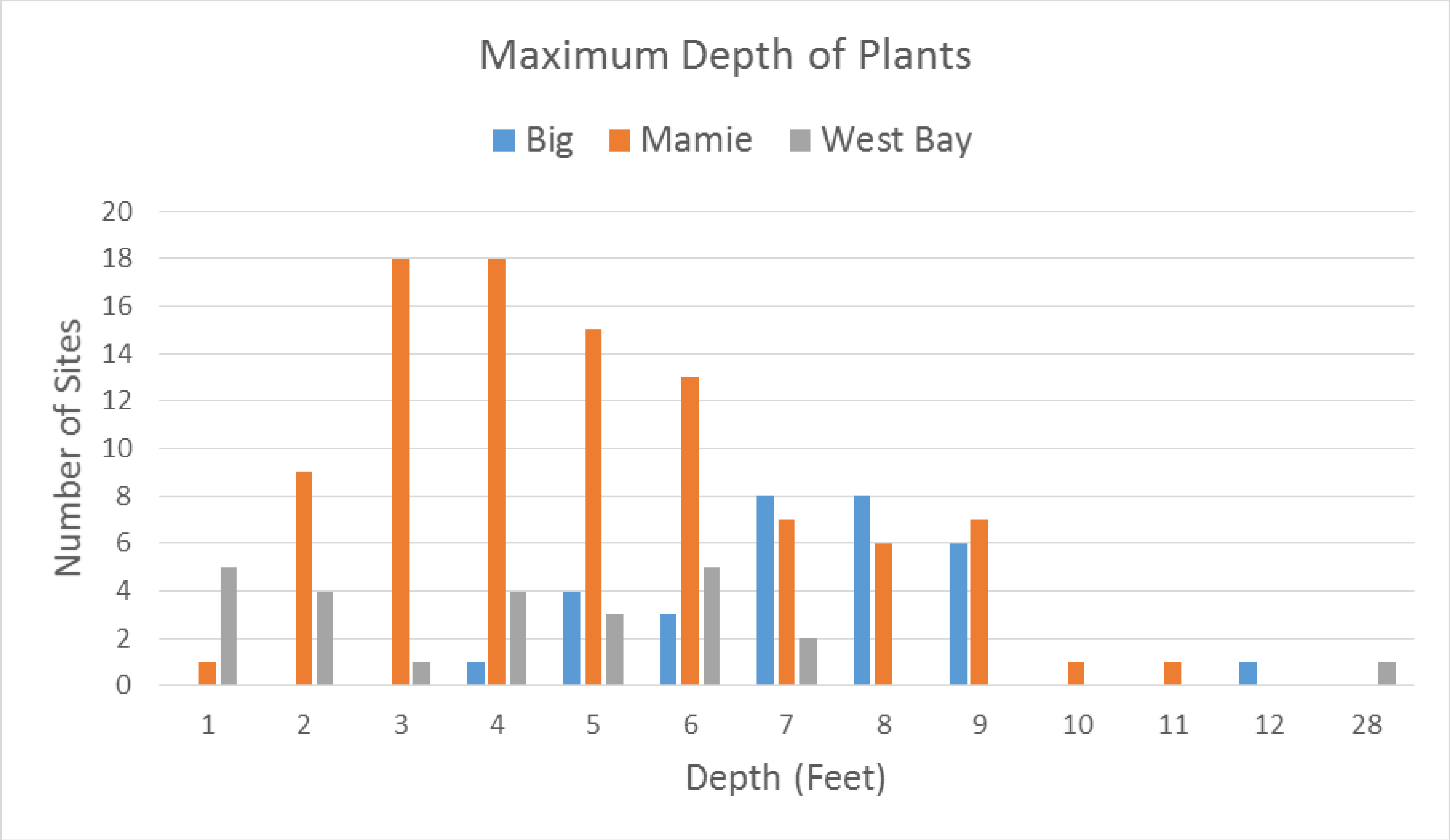


Figure 15.2 Frequency of plant growth at different depths throughout the Cisco Chain.

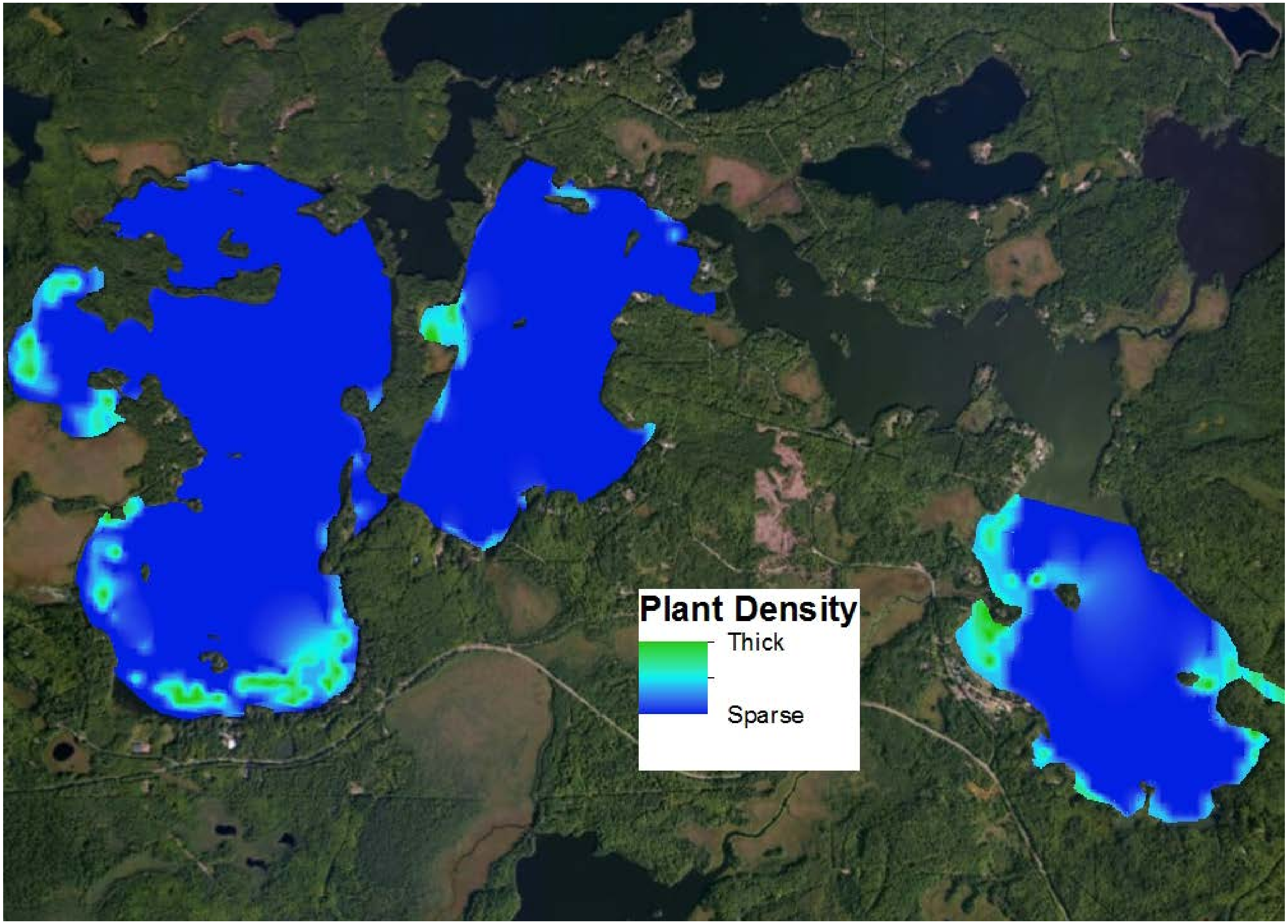


Figure 15.3 Density of aquatic plants throughout the Cisco Chain.

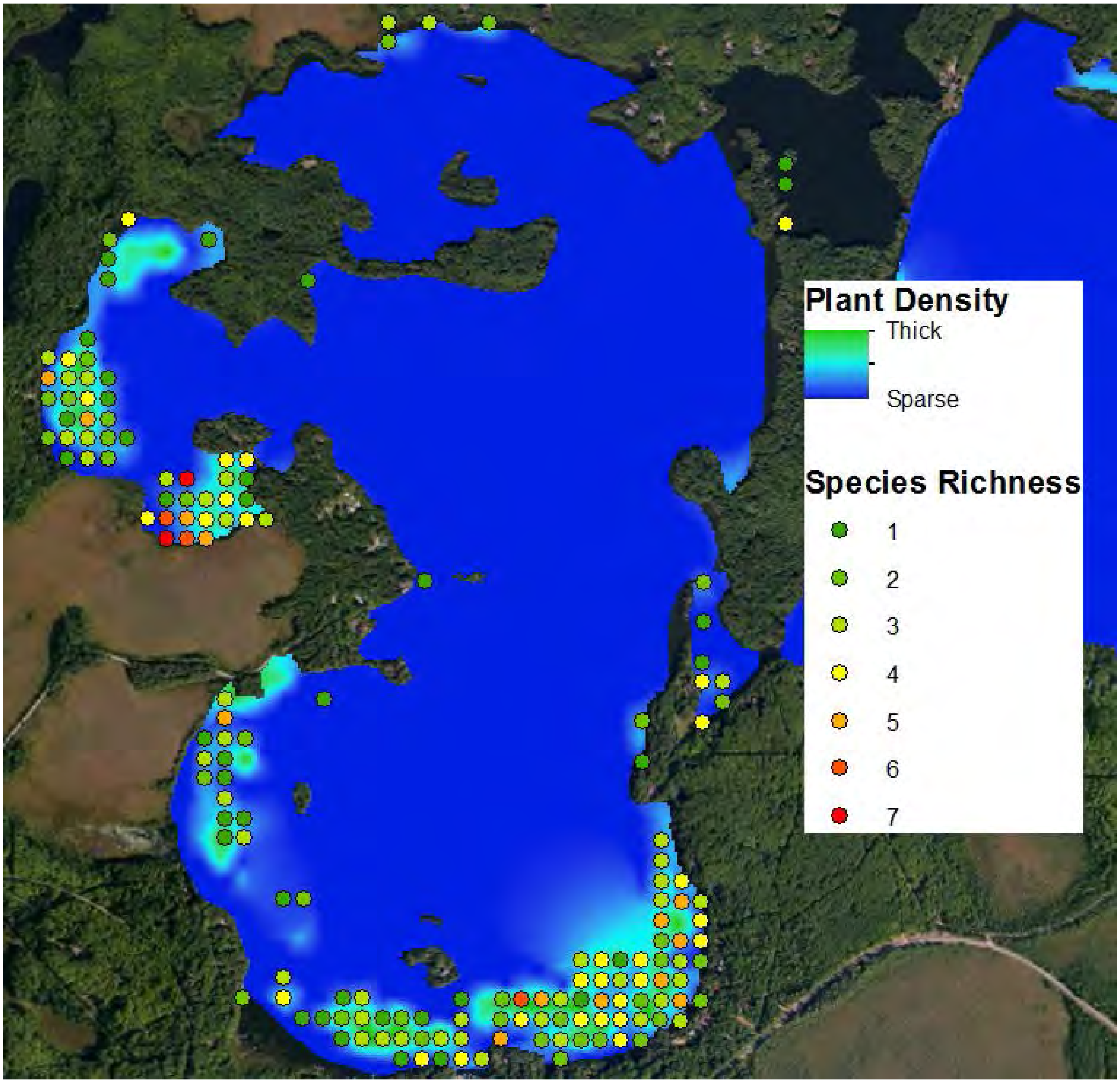


Figure 15.4 Density and richness of aquatic plants in Big Lake.

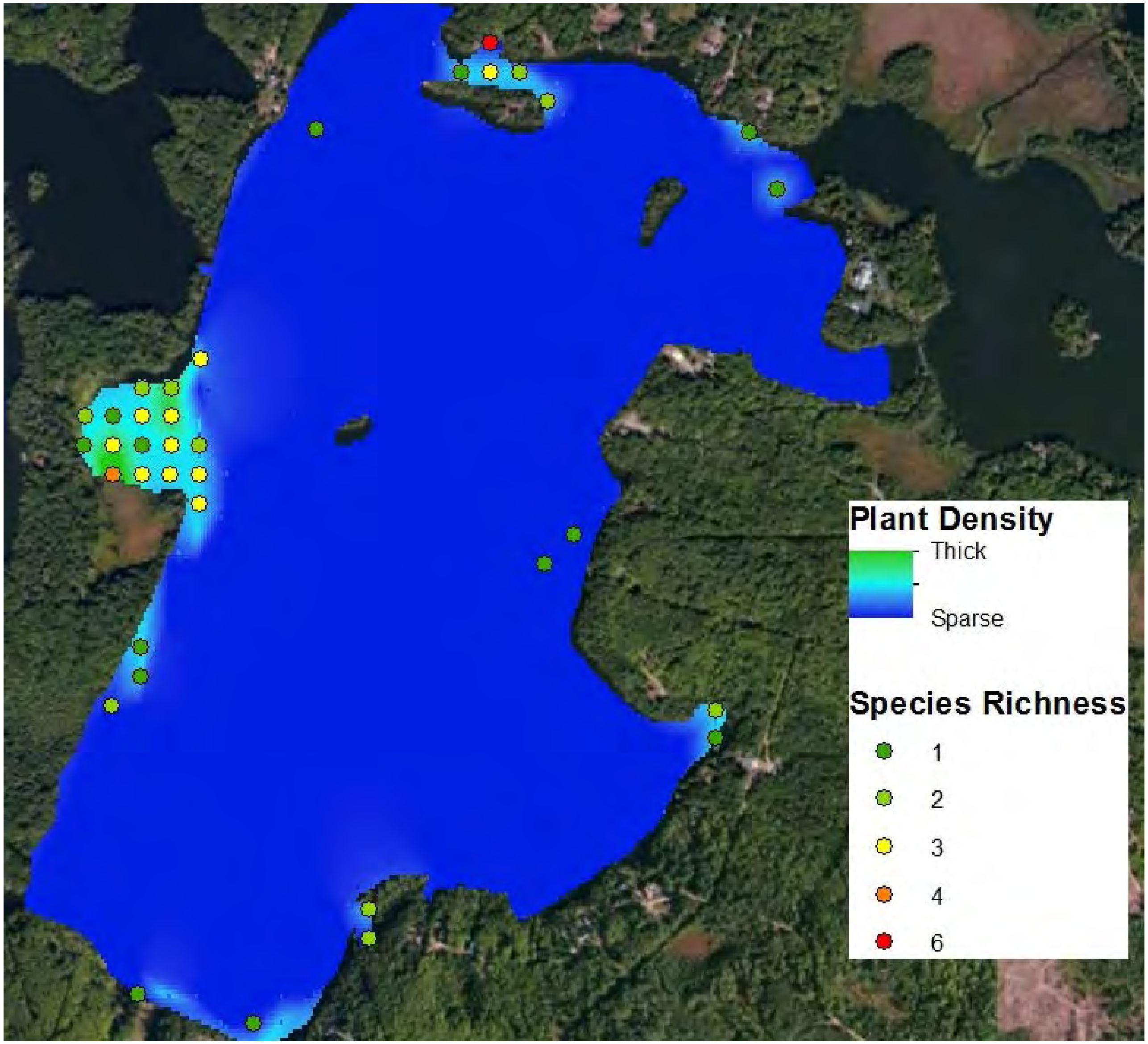


Figure 15.5 Density and richness of aquatic plants in West Bay Lake.

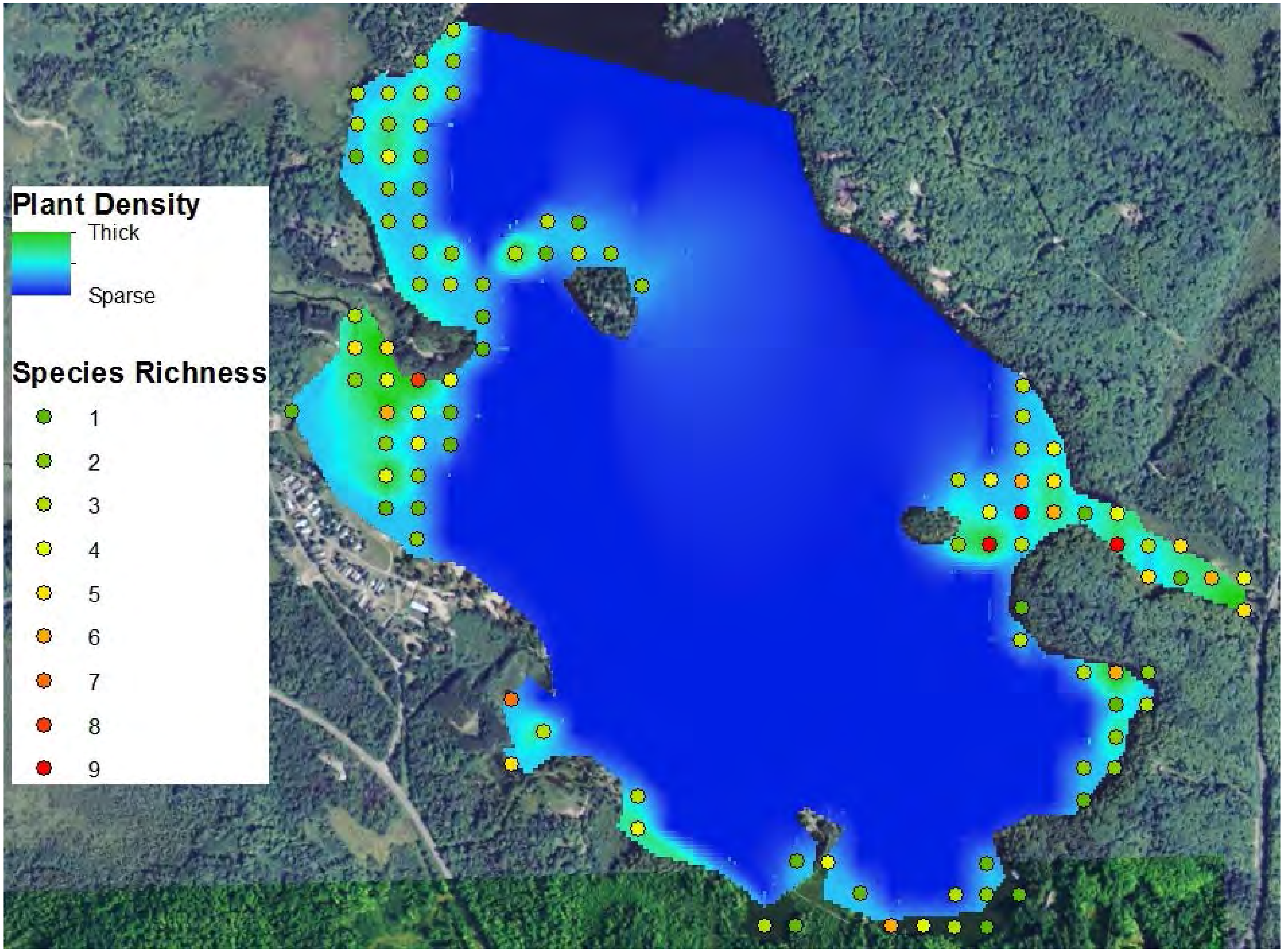


Figure 15.6 Density and richness of aquatic plants in Mamie Lake.

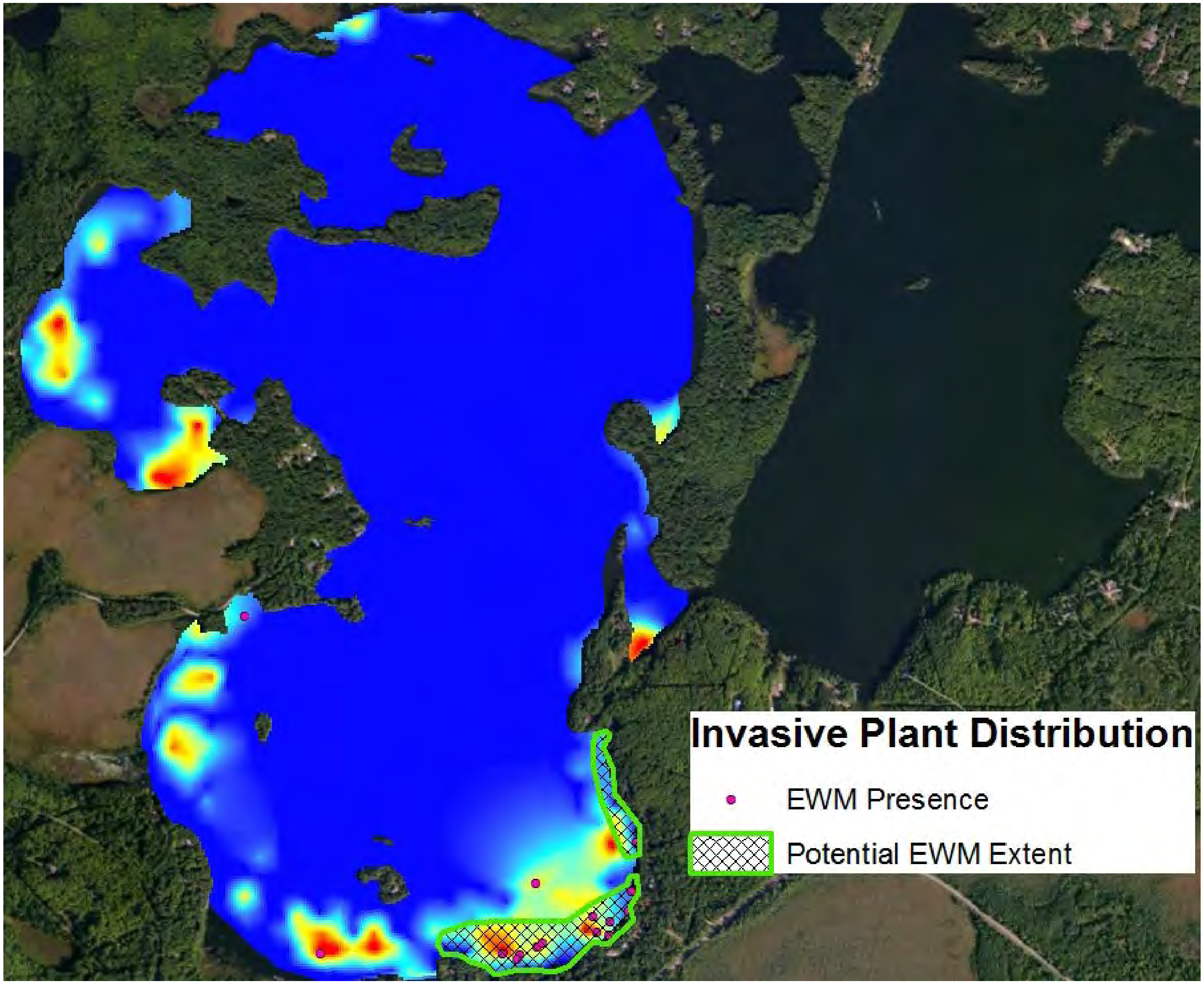


Figure 15.7 Invasive species distribution in Big Lake.

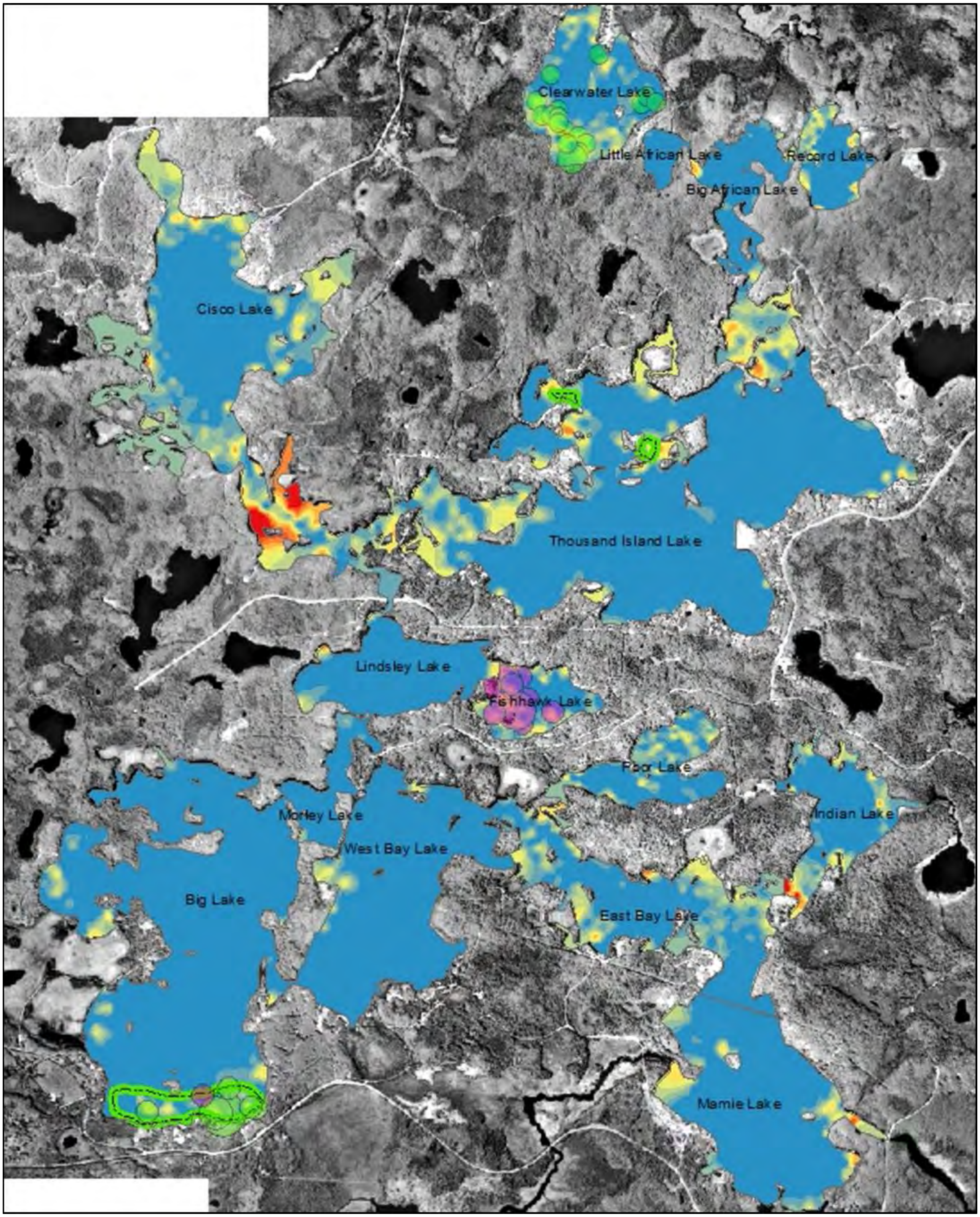


Figure 15.8 Invasive species distribution throughout Cisco Chain. Green dots represent Eurasian Water Milfoil and pink dots represent Curlyleaf Pondweed. Red shaded areas represent region of concentrated species richness.

15. Appendix F – Ecosystem Modeling and Scenario Forecasting

Introduction

To understand the relative role of the different components of the Cisco Chain ecosystem, it is necessary to develop a framework that relates physical, chemical and biological processes. To this end, we developed an in-lake aquatic response model using the Wisconsin Lake Modeling Suite (WiLMS) simulation program. WiLMS simulates in-lake water quality conditions using a mass balance approach that predicts in-lake water quality conditions based off of watershed land use and lake characteristics. WiLMS is widely used for planning purposes and as part of federal water quality restoration projects under the Total Maximum Daily Load program.

Methods

The Cisco Chain was represented using a discrete WiLMS model for each lake. Each lake system was represented using a series of hydrologic and morphometric criteria (Table 16.1). Nutrient inputs to the lakes were based on the nutrient budget describe in Appendix B (Table 16.2). Model simulations were run under current conditions (representing 2011 land cover types) using the Prediction and Uncertainty Analysis function to validate model outputs against observed water quality conditions (Table 16.3). Potential internal loads were estimated using the Mass Balance function (Method 1). Outflow discharge and nutrient outflow loading was calculated using the Water and Nutrient Outflow function. Inflow, outflow and unit area runoff values were used to construct a water and nutrient budget for each lake. Future condition simulations were run for each lake to predict future water quality conditions that could be expected based on full implementation of corresponding land use plans. Historic land cover data were used to hindcast water quality conditions that likely existed in prior to the 1850s.

Results and Discussion

WiLMS model predictions of TP concentrations range from -4% to -20% of observed values, suggesting that model algorithms reasonably predict current water quality conditions. Changes in water quality conditions that are likely to result from future land use change and septic system density, will likely be small to moderate. A transition from historical to current land covers has likely resulted in an approximate 10% to 30% increase in TP concentration and a reduction in water clarity. Based on this relationship, it is likely that future land use conditions (and septic loads) will result in an additional increase in TP concentration of between 11% and 23% (Table 16.4). In all model simulations, the WiLMS algorithms under-predict observed TP concentrations, suggesting that an unaccounted source of TP is likely affecting water quality conditions. Given, the elevated hypolimnetic TP concentrations observed throughout the Cisco Chain lakes, it is likely that internal loading of phosphorus in the lakes is having an impact on water quality conditions.

Management and Monitoring Recommendations

Results suggest that the WiLMS model reasonably predicts water quality conditions throughout the Cisco Chain. However, in all lakes most of the total phosphorus prediction algorithms under-predict in-lake concentrations, suggest that an unaccounted source (likely internal loading) is also influencing water quality conditions. These results suggest that future increases in runoff and nutrient loads to the Cisco Chain may have a moderate impact on water quality conditions, particularly in Big Lake—in which forecasted future conditions are most divergent from current conditions. However, given the uncertainty surrounding future land use scenarios and the potential impacts of climate change on runoff processes, it is important to ensure that best management practices are consistently implemented as part of future land use development and that they are appropriately scaled to existing hydrologic regimes. Additionally, because these simulations represent annual growing season averages, minimum and maximum values may be divergent (i.e., periods of reduced/increased water clarity could occur in any given year).

Uncertainty and Data Interpretation

These model simulations represent statistical descriptions of water quality conditions in the Cisco Chain and are reasonable given the available data. However, the understanding of the Cisco Chain ecosystem is incomplete, and thus, these simulation results should be used for general planning purposes only. Given the uncertainty surrounding future land use and climate scenarios and incomplete understanding of the Cisco Chain ecosystem, future management should include additional data collection to reduce uncertainty.

Table 16.1. WiLMS Model Setup Parameters

Parameter	West Bay	Big	Mamie
Drainage Area (acres, excluding water)	10,018	1,143	1,393
Total Unit Runoff (inches)	14	14	14
Annual Runoff Volume (acre-ft)	11,687	1,335	1,625
Lake Surface Area (acre)	417	733	337
Lake Volume (acre-ft)	6,255	9,529	3,370
Average Depth (ft)	15	13	10
Precipitation-Evaporation (inches)	5.5	5.5	5.5
Hydraulic Loading (acre-ft/year)	11,879	1,670	1,780
Areal Water Load (ft/year)	28.5	2.3	5.3
Observed Spring Overturn (TP, ug/L)	20	20	21
Observed Growing Season Mean (TP, ug/L)	25	25	26

Table 16.2. WiLMS Phosphorus Mass Balance for Cisco Chain Lakes

Lake	Watershed Area (Acres, w/water)	Phosphorus Source (lbs/yr)			Total Load (lbs/yr)	Outflow P Load (lbs/yr)	Internal P Load (lbs/yr)
		Watershed Runoff	Septic System	Atmospheric			
Big Lake	1,984	99	65	195	359	108	24
West Bay Lake	12,438	848	19	112	979	774	384
Mamie Lake	8,210	125	31	90	246	120	74

Table 16.3. WiLMS Model Predictions of Observed TP Concentrations (ug/L)

Predictive Model	Site		
	West Bay	Big	Mamie
Observed Growing Season Mean	25	25	26
Walker, 1987 Reservoir	18	29	25
Canfield Backman, 1981 Natural Lake	19	18	20
Walker, 1977 General	19	24	22
Nuremberg, 1984 Oxic (with Internal Load)	27	25	26
Model Average	21	24	23
Percent Deviation	-20%	-4%	-12%

Table 16.4. Water quality changes potentially resulting from future land use/nutrient loading scenarios

Land Use Condition (Year)	Total Phosphorus Load	Growing Season Phosphorus Concentration (ug/L)		
		Big	West Bay	Mamie
1856	1028	16	16	22
2011	1170	25	25	26
2030	1687	34	29	29