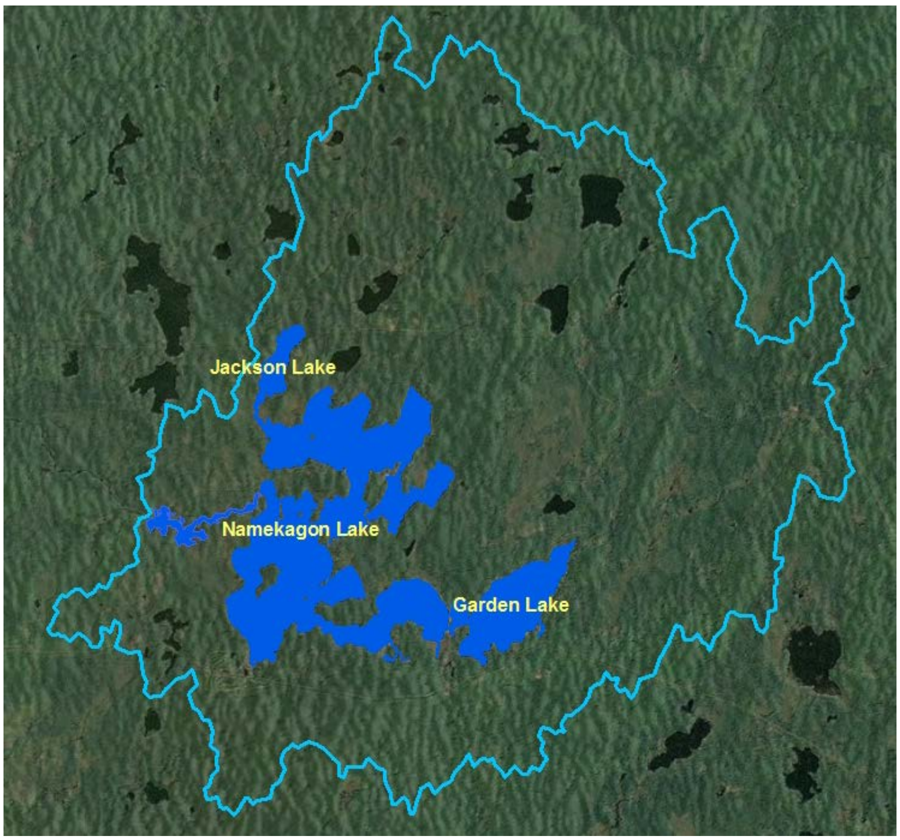
Management Plan - Namakagon Chain of Lakes

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 Namakagon, Garden and Jackson Lakes that comprise the Namakagon Chain of Lakes (Namakagon Chain). 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 Namakagon 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 Namakagon Chain ecosystem.

Successful management of the Namakagon 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 Namakagon 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 Namakagon Chain is used and valued by different groups, this plan was developed though collaborative input from the Namakagon Lake Association (NLA), Wisconsin Department of Natural Resources, Bayfield County and informed by a user survey (administered by Northland College). Based on this process, it is obvious that the Namakagon Chain is an important ecological and social resource that is used and valued by different groups for different reasons. Across multiple questions in the surveys, the majority of respondents highlighted the value of the Namakagon 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 Namakagon Chain into the future.

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

To achieve these goals, it was first necessary to assess the current conditions of the Namakagon Chain ecosystem. To this end, a two year study was conducted to summarize the existing data describing the health of Namakagon, Garden and Jackson Lakes and develop new data sets to describe important processes throughout the ecosystem. Elements of the Namakagon 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 Namakagon 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 Namakagon Chain ecosystem that enable its high quality conditions are the 1) diverse native communities of fish and plants that make up the Namakagon Chain food web and 2) the relatively limited levels of land use change (away from native vegetation) that exists throughout the watershed.

Despite its relatively healthy conditions, a number of potential problems are currently impacting, or have the potential to impact, the Namakagon Chain in the future. Water quality in the Namakagon Chain, although relatively stable over the last 20 years, has likely degraded over the last 100 years in response to increased levels of development along shoreland areas and may be impacting the lake's cisco population (officially documented in 2015). Given the expected increases in population and changes in land use throughout the area, water quality has the potential to decline in the future. 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 Namakagon Chain are relatively diverse, changes in the fish community have occurred and a number of pathways exist that have the potential to introduce invasive species.

A range of federal, tribal, state and local laws, rules and regulations are in place to protect the Namakagon Chain and its uses. However, existing policies do not adequately address all current and potential future problems that may affect the Namakagon Chain. The elements of the Namakagon 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 Namakagon Chain ecosystem that are least effectively protected are potential changes in shoreline habitat quality and aesthetics and the potential runoff of nutrients to the lake 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 Namakagon 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 Namakagon Chain.
    a. *Why? – Current impacts from aquatic invasive species are minimal in the* Namakagon *Chain and preventative efforts are generally more effective than reactive efforts to manage invasive species.*

3. Implement efforts to restore areas of localized shoreline habitat degradation.
    a. *Why? – Shoreland habitat restoration and management represents 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.*

4. 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 Namakagon 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. Determine the relationship between potential changes in water quality conditions and cisco populations in Lake Namakagon
    a. *Why? – Data suggest that current quality conditions are not conducive to for cisco populations that were recently identified in Lake Namakagon in 2015. To determine the most appropriate course of management action to protect cisco populations, it is necessary to determine if changes in water quality led to declines in cisco abundance or if water quality conditions have been stable and Lake Namakagon has historically supported only small isolated population that was recently detected.*

3. Investigate the feasibility of seasonal water level drawdowns throughout the Namakagon Chain of Lakes.
    a. *Why? – Water level fluctuation is a critical element of healthy lakes ecosystems and helps buffer against invasive species establishment.*

4. 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 Namakagon 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 their 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 Namakagon Chain. Throughout this document the term Namakagon Chain will be used to describe the three separate lakes (i.e., Namakagon, Garden and Jackson Lakes) within the Namakagon Chain of Lakes.

The Namakagon 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 Namakagon 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 Namakagon 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 Namakagon Chain, it is necessary to:

1. Develop a series of goals that protect and/or restore the most highly valued uses for the lake 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 Namakagon Chain in the desired way
4. Identify management options to protect and/or restore the desired use of the lake 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 WDNR Lake Planning grants (LPL-1481-13) and the Towns of Grandview and

Namakagon. The project was developed collaboratively through volunteer contributions from the Namakagon Lake Association (NLA) 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 lake:

1) **Lake Uses and Users -** summarizes who primarily uses the Namakagon 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 Namakagon 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 Namakagon Chain ecosystem

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

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

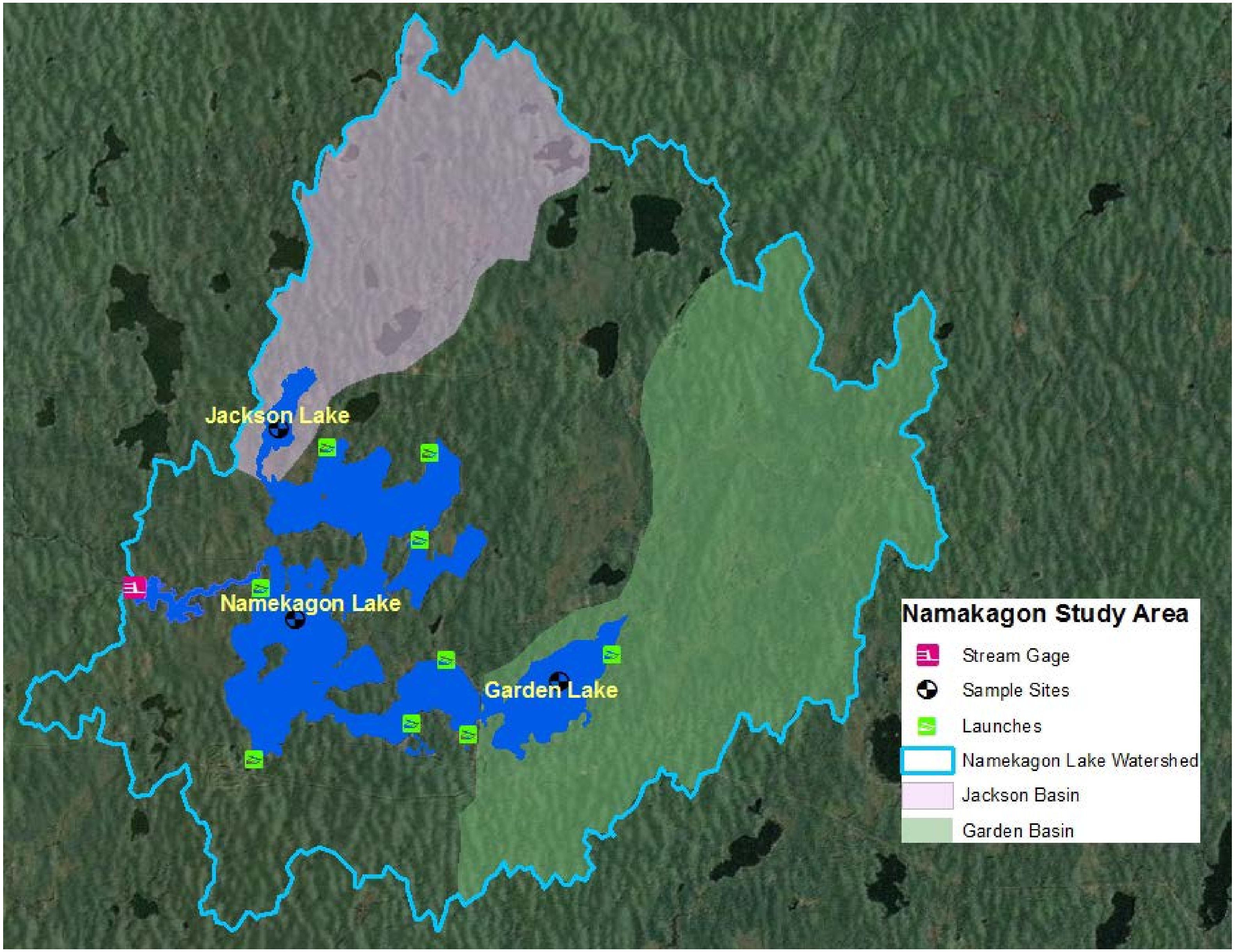

Figure 2.1. The Namakagon Chain and its watershed.

3. Lake Uses, Users and Access

The Namakagon Chain is comprised of Jackson Lake (WBIC Code – 2734200), Garden Lake (WBIC Code – 2735500), and Lake Namakagon (WBIC Code – 2732600) and is primarily used as a recreational and fishery resource by local residents, regional outdoor enthusiasts and Native American First Nations. The Namakagon Chain has three public and 7 private launches, two public swimming beaches and a number of walk/carry-in access points (Figure 2.1). Many residents and shoreland owners are actively involved in efforts to understand and protect the health of the lake. The Namakagon Chain has an active association (the NLA; http://nlaonline.org) 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.

In addition, the NLA and Town of Namakagon have received 17 DNR grants since 1997 to conduct boat launch monitoring for invasive species (SPL-234-10, AEPP-211-10, AEPP-117-08, AEPP-070-07, SPL-094-05, AEPP-012-05, ASPL-009-04, SPL-058-03, SPL-025-02,) assess aquatic plan communities (LPL-1234-08, AEPP-035-06), evaluate septic systems (LPL-1235-08), collect stakeholder information (LPL-520) and collect water quality data (LPL-507). The NLA has had volunteers, collect and report water quality for the Namakagon Chain through the Citizens Lake Monitoring Network (CLM) since 1990.

The Namakagon Chain fishery supports both recreational and Tribal harvest. Four creel surveys have been conducted on the Namakagon Chain to assess recreational usage and harvest (Toshner 2004) since 1989. Results from the most recent survey suggests that recreational fishing pressure is slightly higher on the Namakagon Chain that surrounding lakes and has remained relatively constant since the early 1990s. Open water angling (~91%) is the most common type of fishing on the Namakagon Chain. Species-specific harvest rates are described in greater detail in Section 5.5.

3.1. Stakeholder Surveys

Stakeholder use and perception of the Namakagon Chain have been assessed through a variety of surveys (Shiffered and Judd, 1998 and Foth, 2008). These studies suggest that the most common activities on the Namakagon Chain include motorized boating, entertaining, relaxation, fishing, wildlife observation and swimming. Of these activities motorized boating was most highly valued, followed by relaxation, scenic enjoyment and fishing. In general, survey respondents indicate that the Namakagon Chain is a peaceful site to live and recreate and is generally good health as both a fishery and ecological resource. One key issue that was not addressed in these historical surveys, but has been identified in much of the historical ecosystem data was shoreline restoration.

To better understand the social drivers of shoreland health on the Namakagon Chain and identify opportunities for, and barriers to, shoreland restoration, a shoreland-specific stakeholder survey was conducted. The survey was structured to answer five main questions about the lake and it users:

1) What type of shoreland management activities are most common on the Namakagon Chain?
2) What are the primary goals that drive property management action the Namakagon Chain?
3) Why do, or why don't, people participate in shoreland restoration?
4) What shoreland management activities are perceived as most beneficial to lake health?
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 Namakagon Chain was drawn from Bayfield County records. After removing undeliverable surveys, duplicate landowners, or vacant properties, the final sampling size was 476 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 42.9 percent (or 204 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, approximately 25% were year round residents.

Several trends emerged from the survey responses that highlight the why individuals manage their properties in different ways (Figure 3.1). Survey responses are summarized below with respect to the primary survey questions. Complete survey responses can be reviewed in Appendix A.

What type of shoreland management activities are most common on the Namakagon Chain?
The three most common activities in shoreland areas surrounding the Namakagon Chain are maintenance of seasonal docks, maintenance of a grassed lawn, and maintenance of an undisturbed buffer at the water's edge. Additional common activities include, removal of downed trees from the water, maintenance of rip rap walls use of chemical or physical mechanism to control weeds and pests.

What are the primary goals that influence shoreland/property management around the Namakagon Chain of Lakes?
The primary drivers of property management surrounding the Namakagon Chain, as stated by survey respondents, are improving the ecological health of the lake and the aesthetics and value of individual properties.

Why do, or why don't, people participate in shoreland restoration?
Most respondent indicated shoreland restoration was important because it improved the health of the lake, enhanced property aesthetics and reduced erosion. Barriers to shoreland restoration included a lack of need, awareness and/or empowerment to conduct shoreland restoration. In general, survey respondents indicated a lesser need for shoreline restoration than was observed as part of the shoreline habitat assessment (Appendix C).

What shoreland management activities are perceived as most beneficial to lake health?
In general, most survey respondents indicated that vegetative buffers, rain gardens, sea walls and tree drops had a positive impact on lake health, while polluted runoff and application of chemicals were perceived to have a negative impact on the lake. Activities that were perceived as having a neutral impact on the lake included dock installation and maintenance of ornamental ponds.

What are the general value sets and/or beliefs that lake users likely base their actions on?
In general, survey respondents see the Namakagon 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 lake and a recognition that declines in the lake's health would adversely affect their wellbeing. Respondent indicated that they preferred beach shorelines and enjoy have unobstructed views of the water from their properties. Most respondent indicated that they enjoyed watching birds, but found many water-based, and land animals and insects a nuisance.

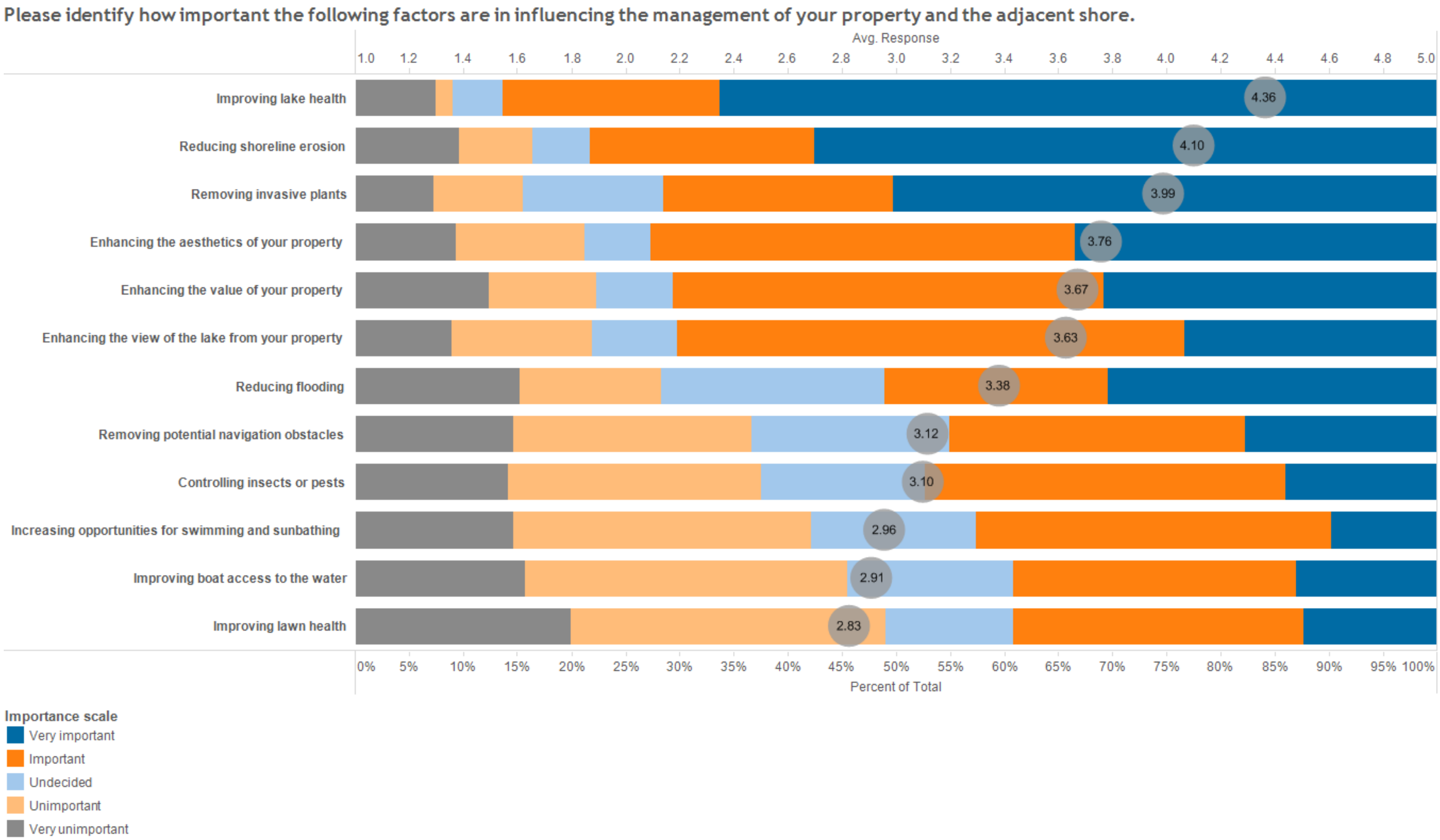

Figure 3.1. Most important elements of property management on Namakagon Chain by survey respondents.

3.2.Use and Value Priorities

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

- Aesthetics and scenic beauty
- Observation of the natural world
- Protection of the Namakagon 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 lake. 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 NLA 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 impact for invasive species impacts.

4.2. Public Meetings

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

4.3. Technical Team Meetings

Following the completion of field work in year one, a technical team meeting was held with representatives from the NLA, Bayfield 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 NLA, WDNR, Bayfield 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 Namakagon Chain
- Protect and Restore Nearshore and Shoreline Habitat
- Maintain Existing Water Levels and Hydrologic Processes
- Maintain or Improve Existing Water Quality Conditions
- Maintain Diverse Native Plant Communities
- Maintain Diverse Native Fish Communities
- Maintain Walleye Population Densities
- Maintain Access to Tribal Fisheries

5. Lake Condition Assessment

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

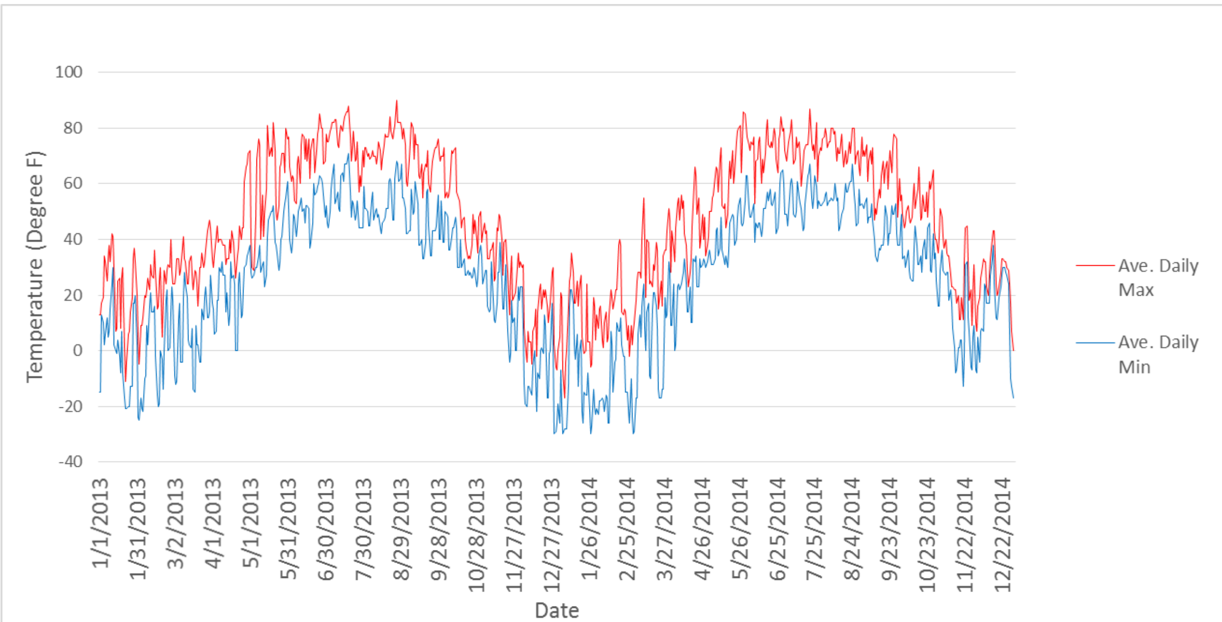

Figure 5.1. Minimum and maximum daily air temperatures through study period.

5.1. Climate and Precipitation

Climate in the Namakagon area is considered continental, but is moderately affected by the Lake Superior climate zone. Summer daily temperatures average 58.6 °F and winter daily temperatures average 24.6 °F. Annual precipitation averages 34.3 inches, most (68%) of which falls between April and September (Figure 5.1). Average seasonal snowfall is 68.1 inches. Historically, the 100-yr, 24-hour precipitation event was expected to yield ~5 inches and most engineering design throughout the area is based on the TP-40 values (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 Namakagon area is now expected to yield 6.75 inches (a ~26% increase). However, the Atlas 14 precipitation estimates have only recently become available and have not been incorporated into engineering design and watershed planning work.

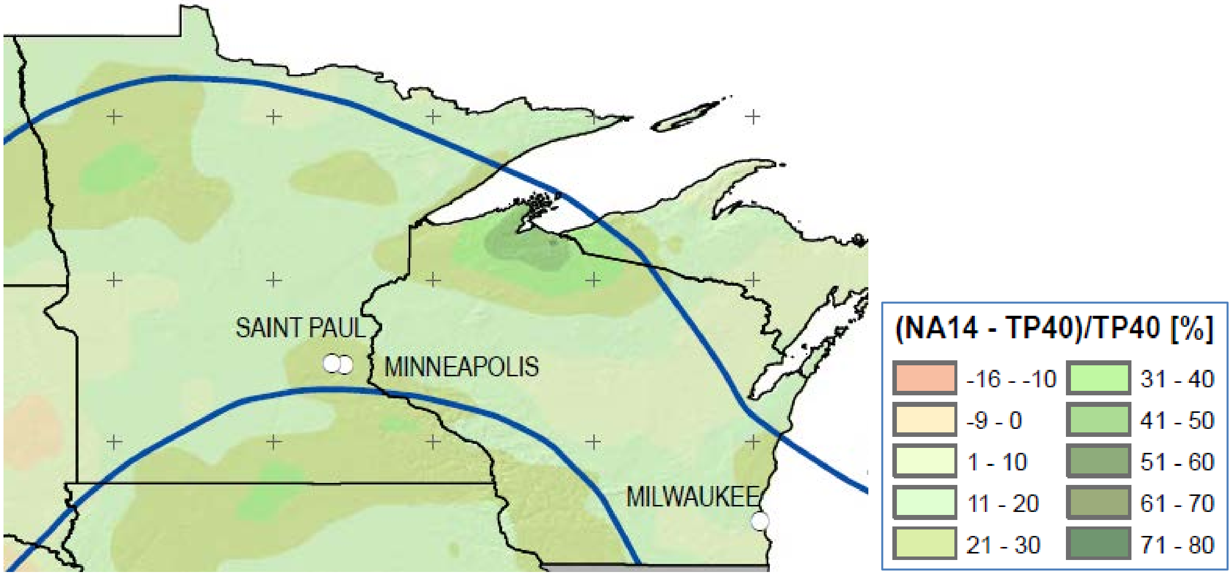

Figure 5.2. A comparison of the percent change in the 100-year, 24-hour precipitation events between the Atlas 14 and TP 40 publications. Adopted from Atlas 14 (Perica et al. 2013).

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 Namakagon Chain is shaped by a combination of the local geology, topography, landscape position of the lake 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 Namakagon 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 lake.

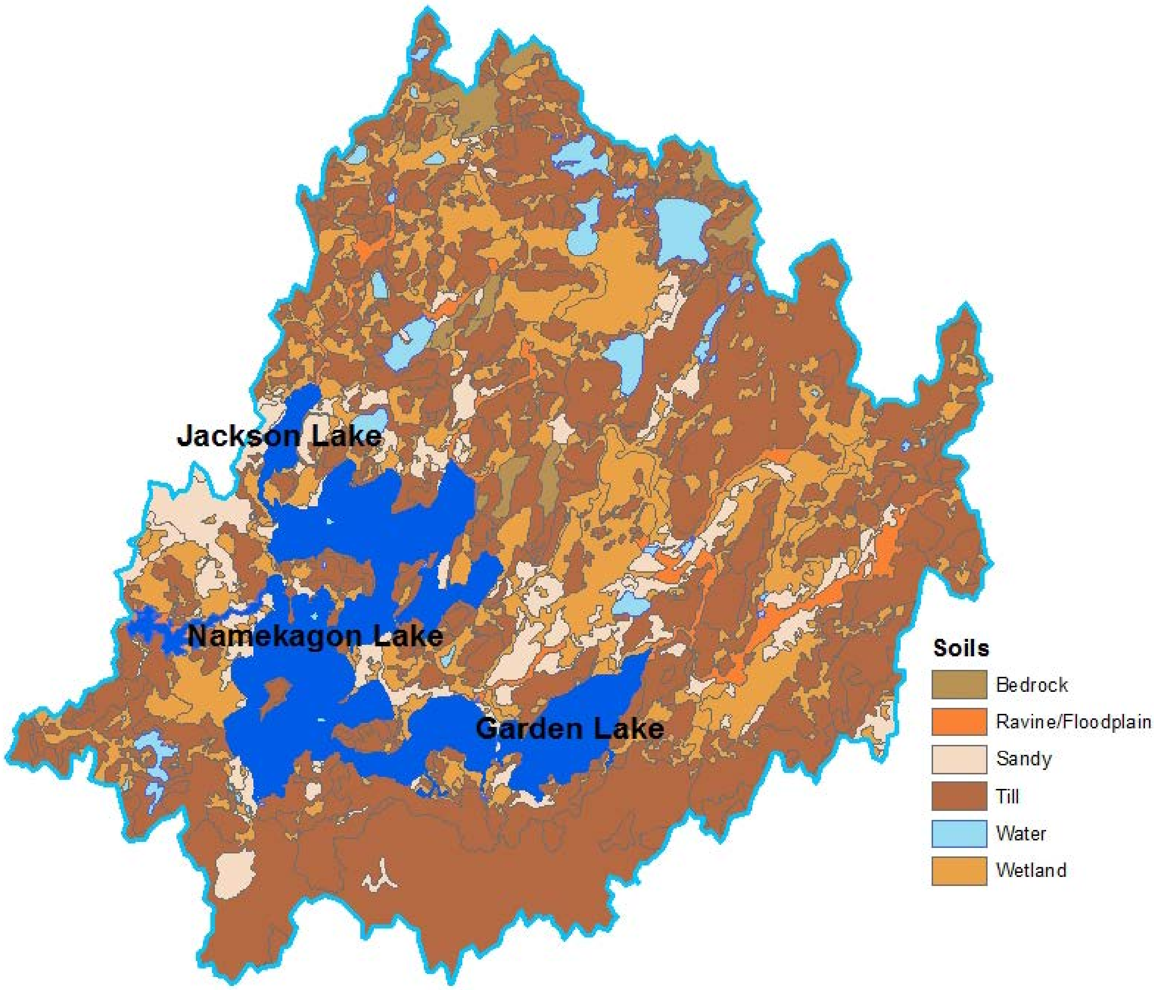

Figure 5.3. Distribution of soil groups throughout the Namakagon Chain watershed. Based on Natural Resource Conservation Service (NRCS) SURRGO soil classifications.

Bathymetry

Namakagon Chain is a 3,314 acre, drainage-based system with a maximum depth of 51 feet and an average depth of 12 feet (Figure 5.4). Lakes throughout the Namakagon Chain are irregularly shaped with a series of long, narrow bays. Despite its elongated bays the maximum fetch in the lake is 1.7 miles (in the southern basin).

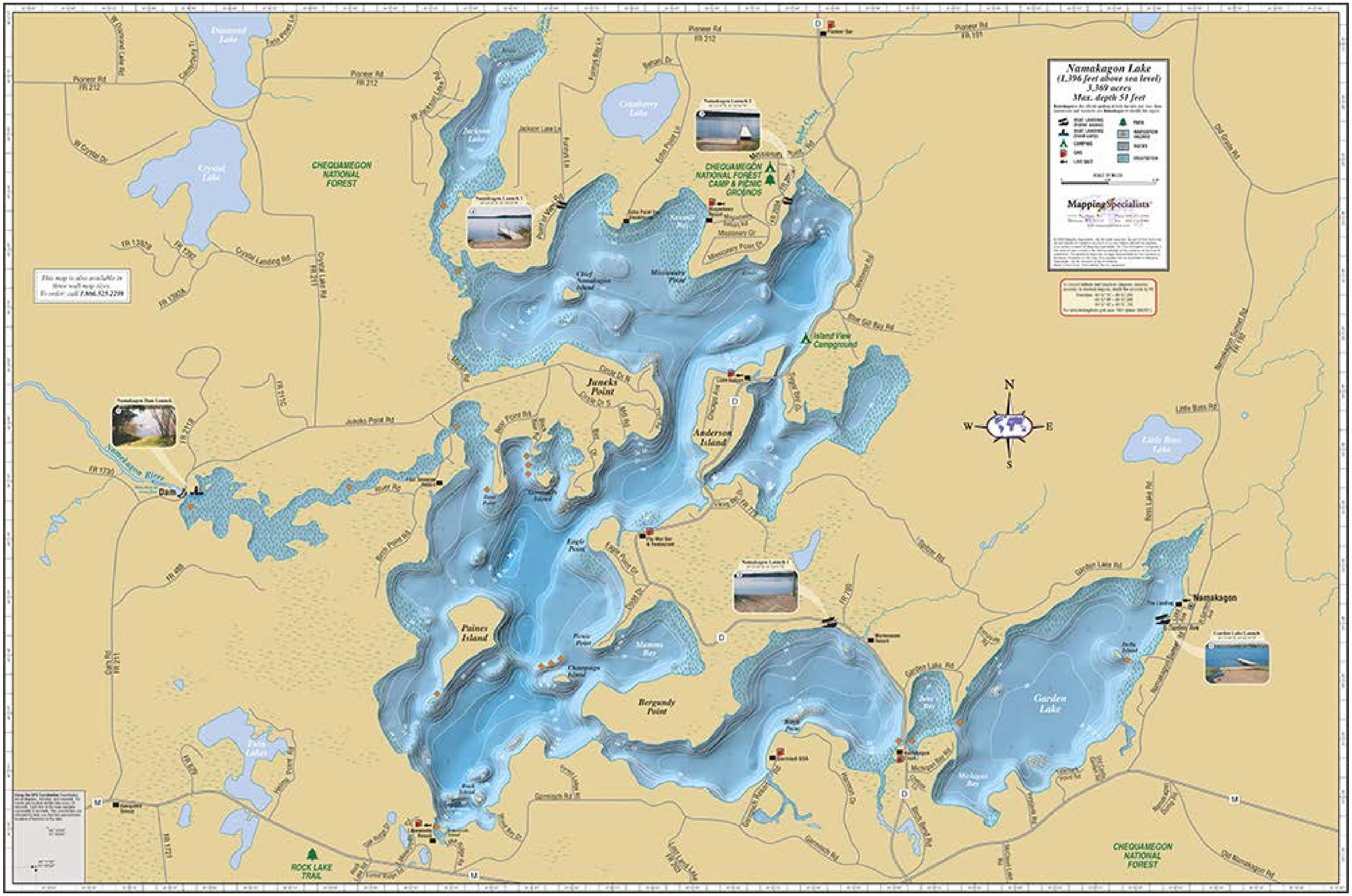

Figure 5.4. Bathymetry of the Namakagon Chain of Lakes (Adopted from: www.mapspecialists.com).

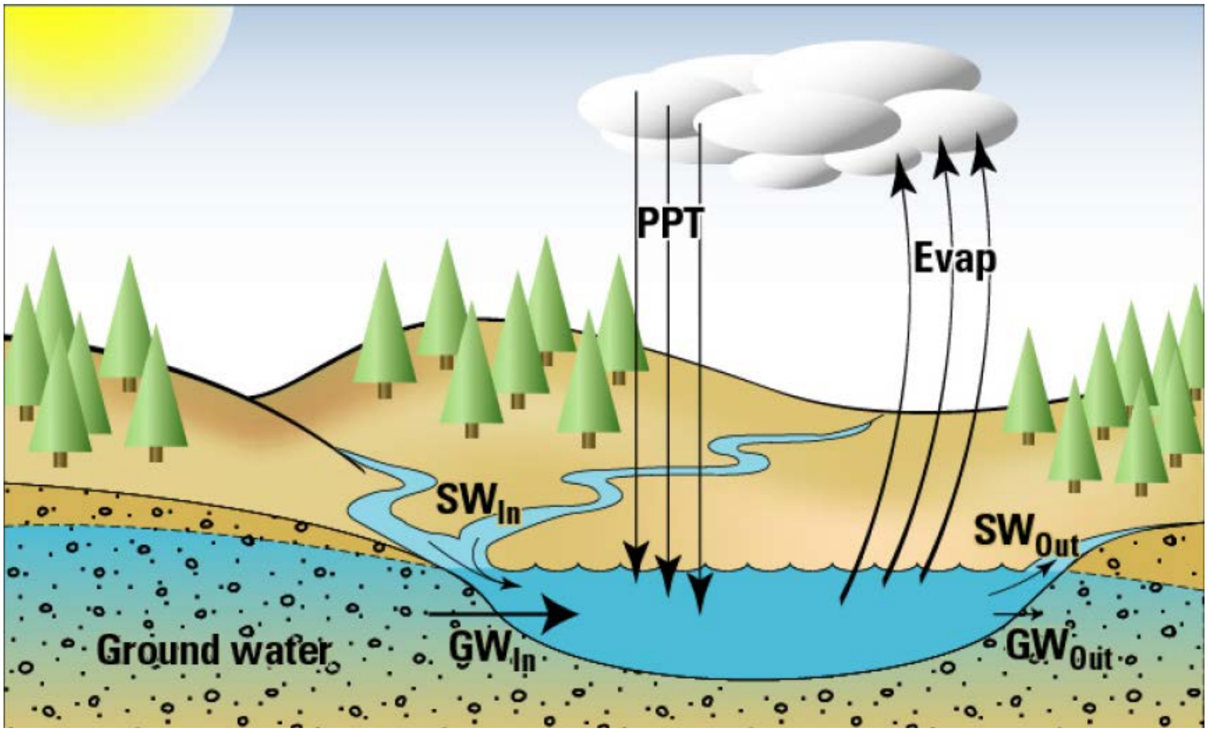

Figure 5.5. Conceptual schematic describing the surface water (SW), groundwater (GW). Precipitation (PPT) and evaporation (Evap) that determine lake levels (adopted from Krohelski, 2003).

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).

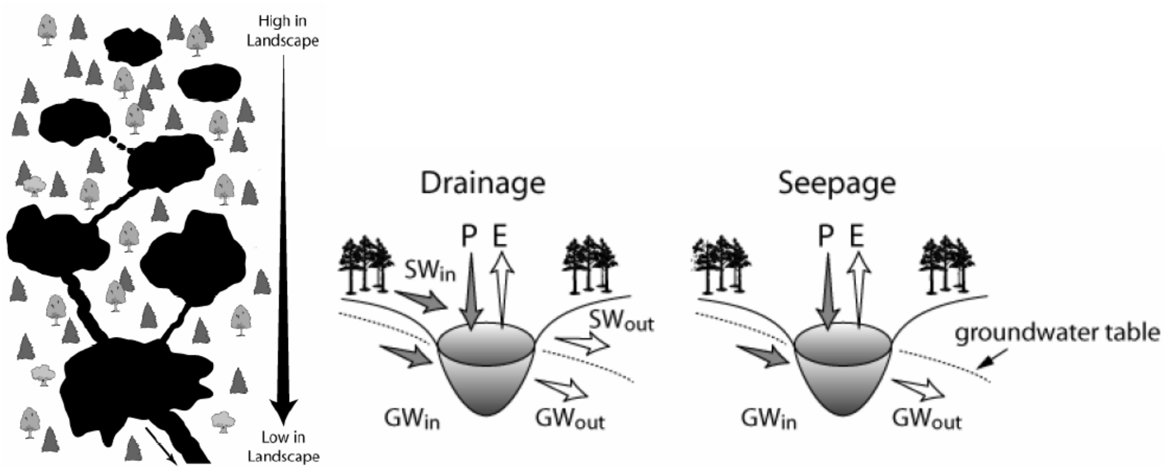

Figure 5.6. Conceptual diagram of "landscape position" and the differences in hydrologic processes between drainage and seepage lakes. Modified from Magnuson et al. 2006.

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).

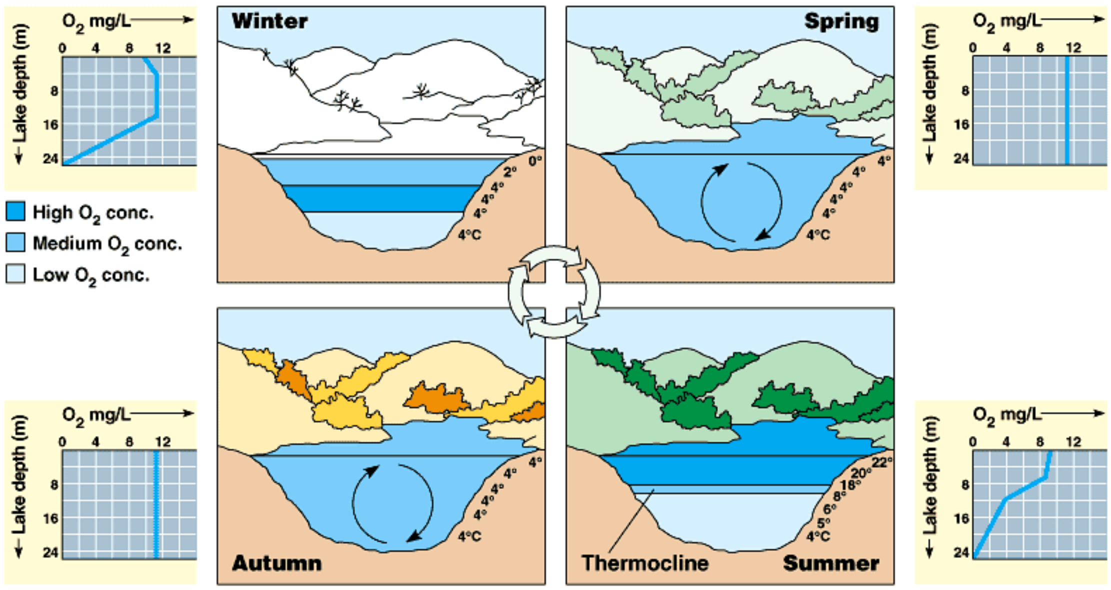

Figure 5.7. Conceptual schematic of the processes of turnover and stratification and the resulting water quality conditions.

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 Namakagon Chain. Prior to this study, no data-sets had been developed to describe physical habitat in the Namakagon Chain.

New Data Collection
To better characterize shoreland habitat in the Namakagon 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 Namakagon, Garden and Jackson Lakes. In addition to these internal processes, outflows from the Namakagon Chain was 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 Namakagon Chain, each lake has a significantly different watershed area (Figure 1.1). All three lakes are considered to be drainage lakes, but Namakagon has considerably larger watershed area than do Garden and Jackson Lakes. 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 lake (Figure 5.9). In the spring, as snow melts and early season rains are most intense, the majority of water in the Namakagon 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 Namakagon Chain ecosystem.

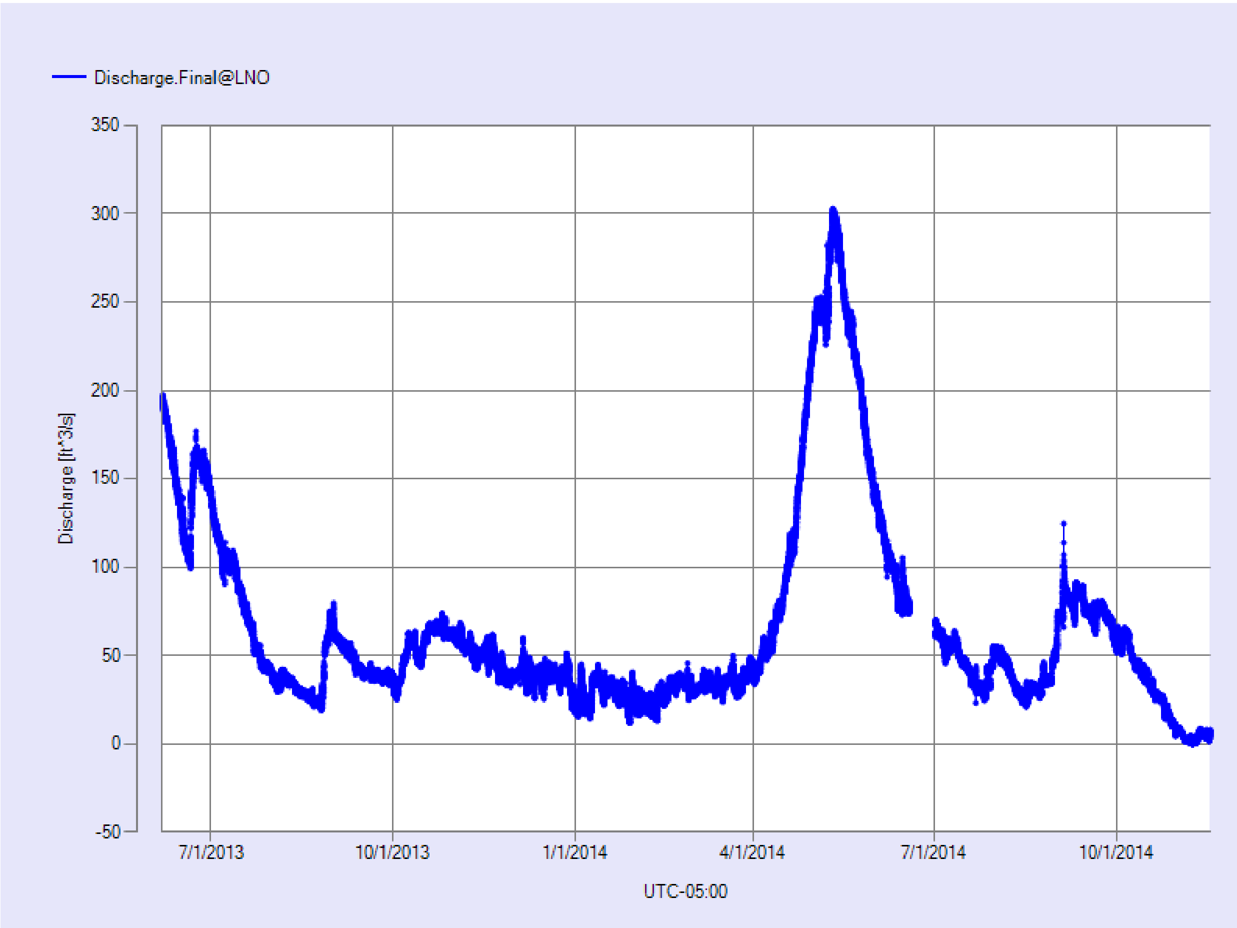

Figure 5.9. Discharge from the Namakagon Chain of Lakes from 2012-20115 through the Namakagon River outlet.

Summary Results – Physical Processes

Like most regional lakes, Namakagon and Garden Lakes mix twice annually (e.g., Figure 5.10) and develop distinct thermal stratification throughout the summer. However, Jackson Lake is generally continually mixed throughout the summer months by wind and wave activity. Because of this stratification in Namakagon and Garden 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 Namakagon Chain as a result of the outlet structure.

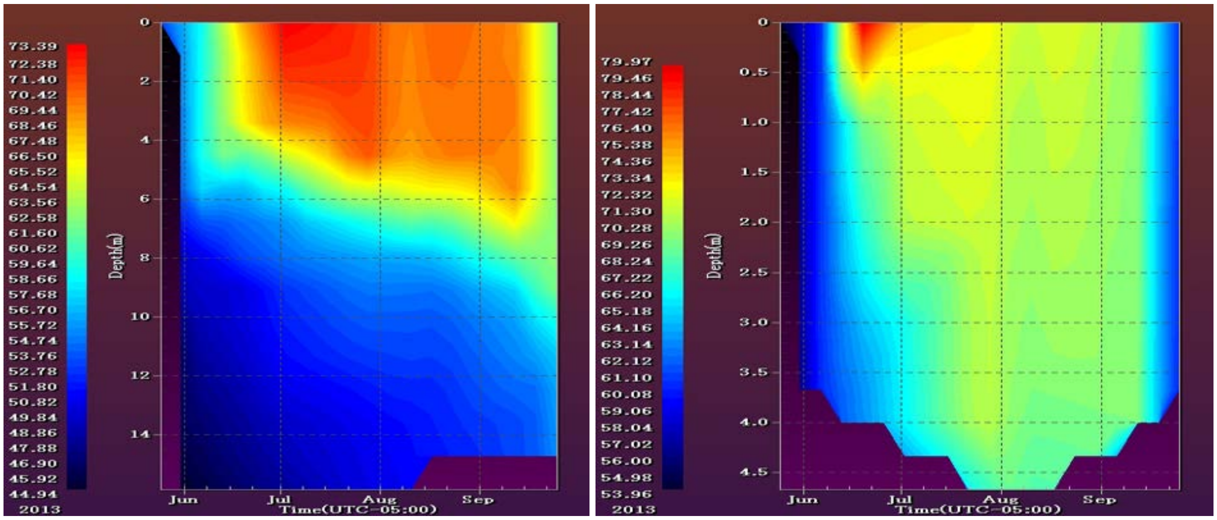

Figure 5.10. Seasonal thermal stratification (degree C) in Namakagon (left) and Jackson (right) Lakes (2013). Red colors indicate the areas of highest temperature.

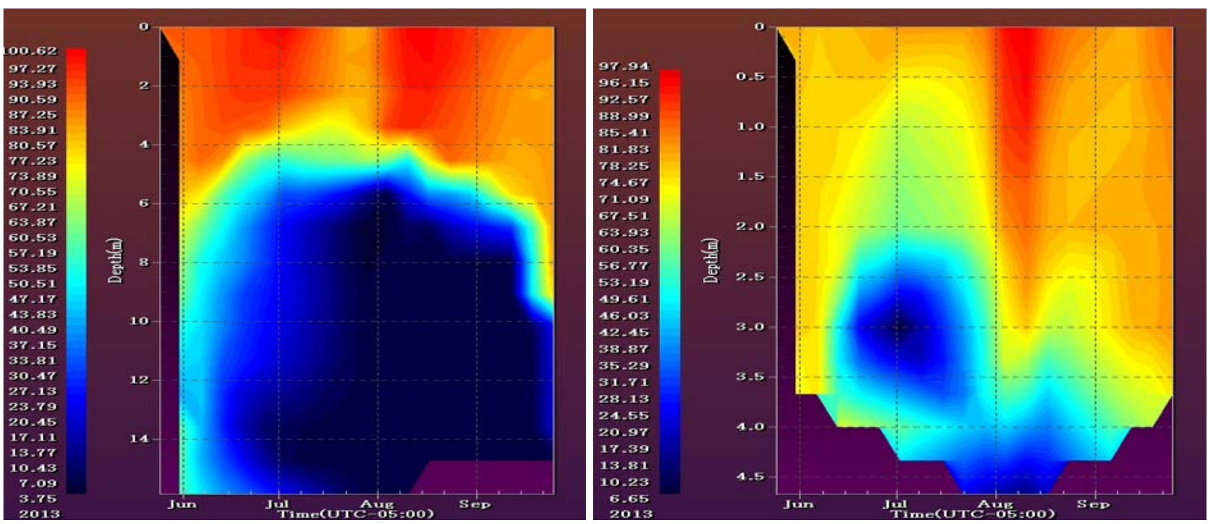

Figure 5.11. Vertical profiles of oxygen concentrations (mg/L) in Namakagon (left) and Jackson (right) Lakes (2013). Red colors indicate the areas of highest oxygen concentration.

Summary Results – Shoreland and Critical Habitat

Shoreland habitat is of moderate quality in the Namakagon Chain (Figure 5.12). In general, the areas of the lake that contain the highest quality shoreland habitat are located along the north eastern and south western shorelines. Across the lake, 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 lake. 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 Namakagon Chain opportunities for both restoration and protection exist. Shoreland restoration throughout the Namakagon Chain is one of the largest opportunities for near-term improvements in fishery productivity and long-term protection of the lake system.

Summary Conclusions – Physical Habitat and Processes
Physical processes in Namakagon and Garden Lakes are consistent with other lakes throughout the region. Much of the condition of the Namakagon Chain ecosystem is likely driven by the quality of the shoreline habitat and differential mixing regimes in different lake systems. Given that Jackson Lake is polymictic (i.e., continually mixed), its water quality criteria should be reclassified to reflect its continually mixed condition. Long-term management of the Namakagon 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.

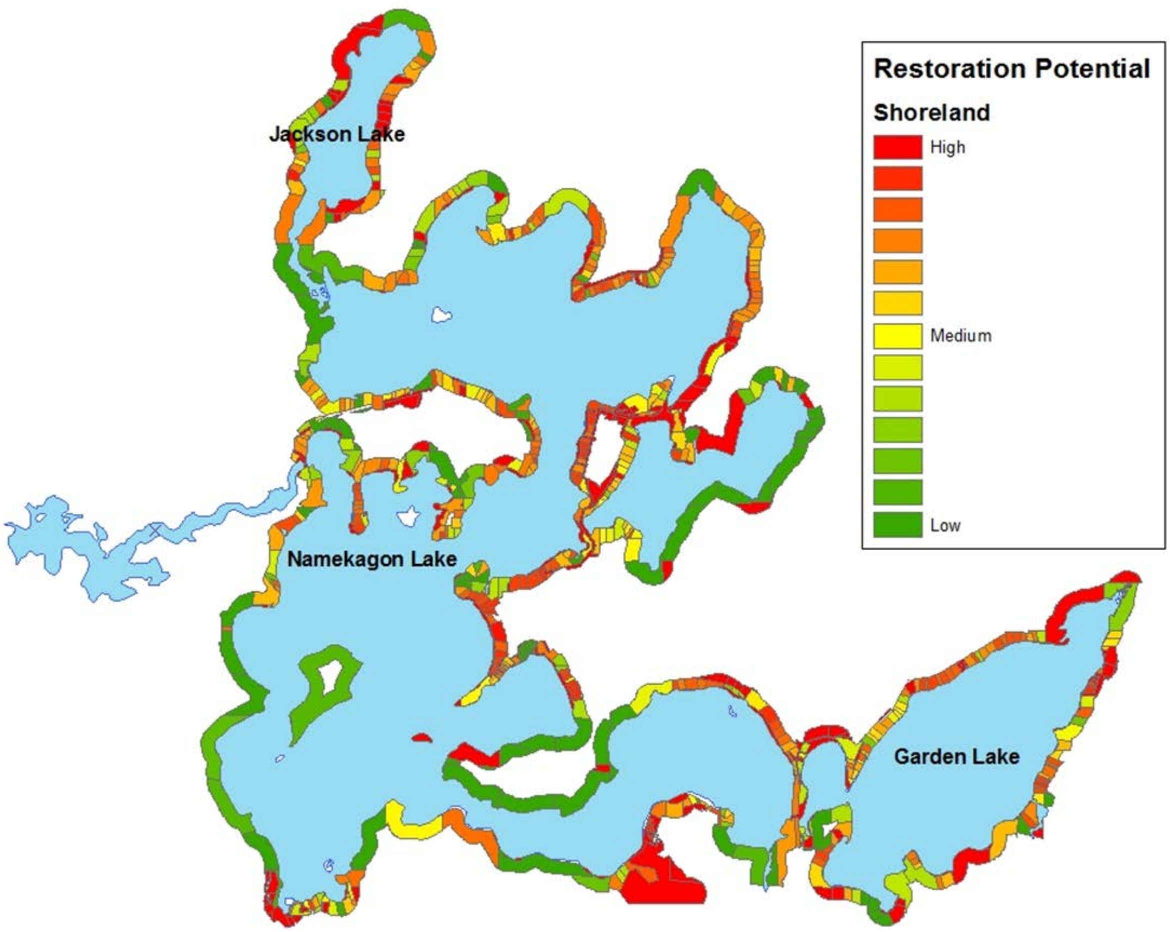

Figure 5.12. Locations of highest quality shoreland habitat, 2013.

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).

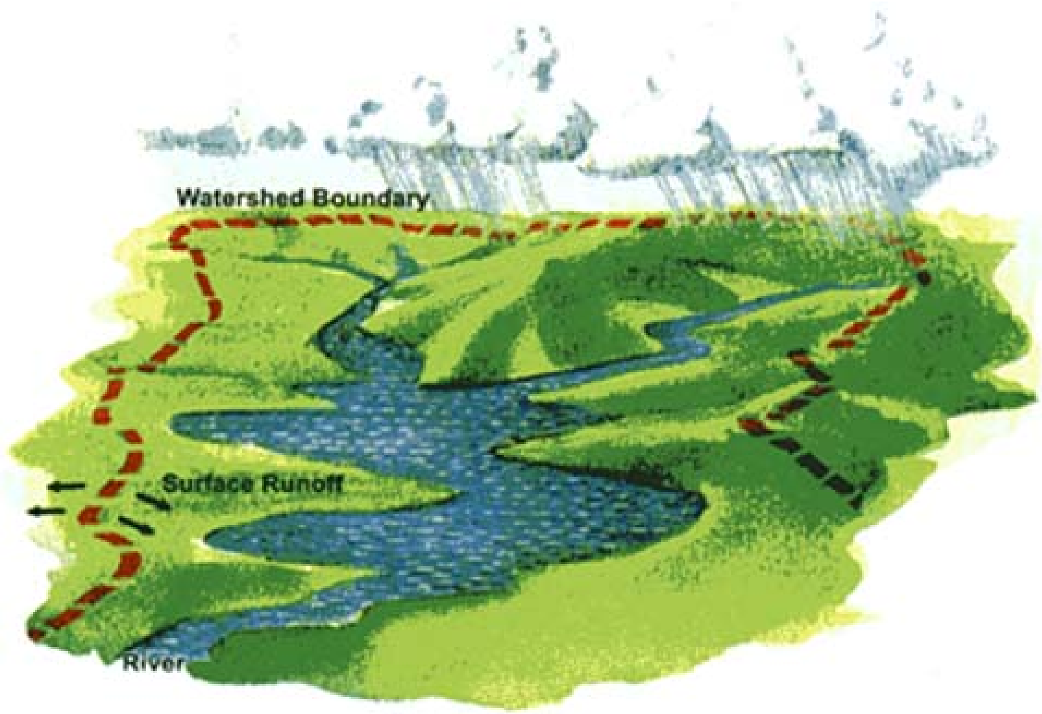

Figure 5.13. Conceptual diagram of the land area that contributes water to a lake—often referred to as the watershed, or lakeshed.

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 Grand View and Namakagon. Details of the land use assessment are described in Appendix D.

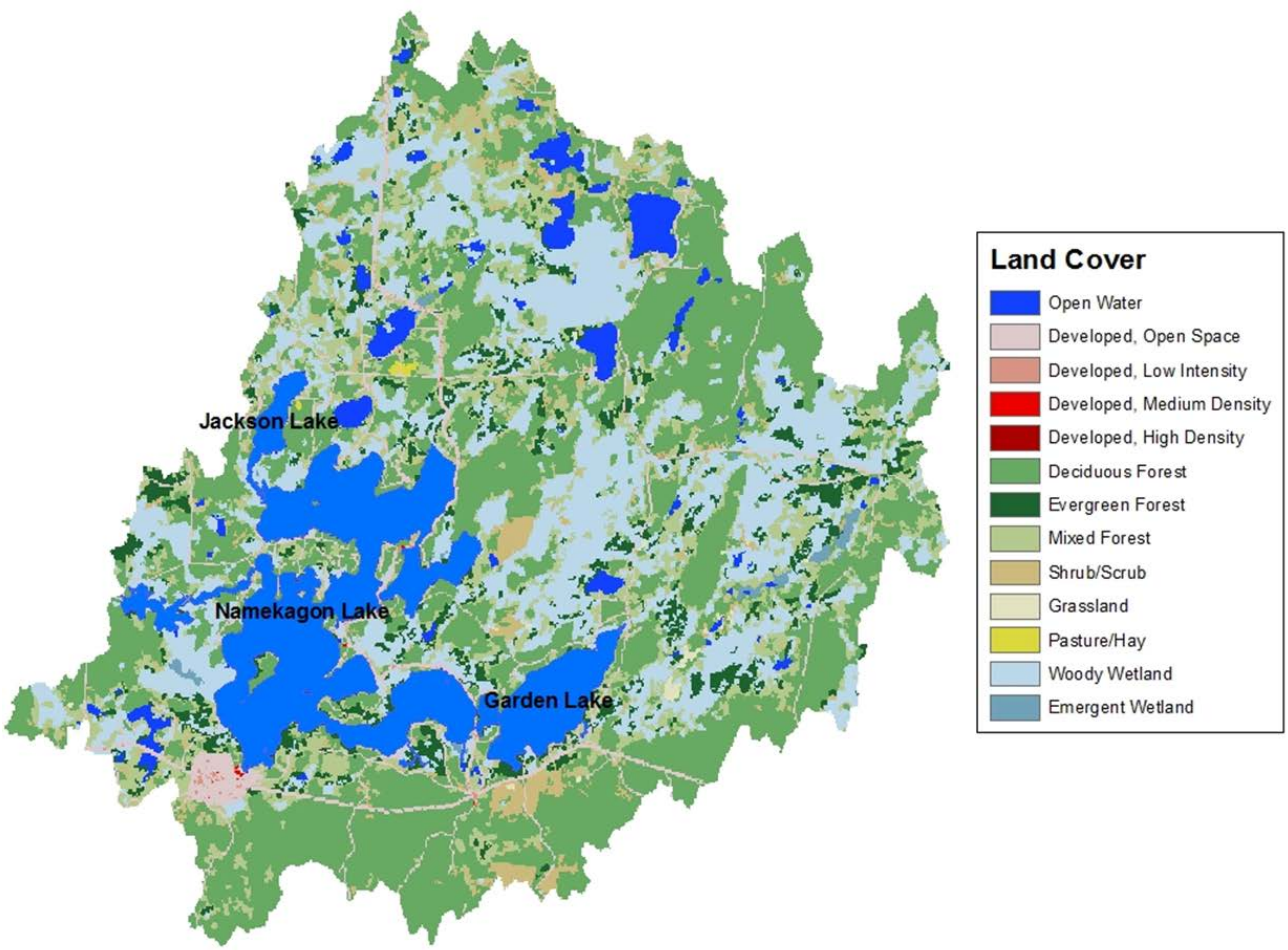

Figure 5.14. Land cover throughout the Namakagon Chain watershed and surrounding shoreland areas.

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 mixed forests has declined and has been replaced by deciduous 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.

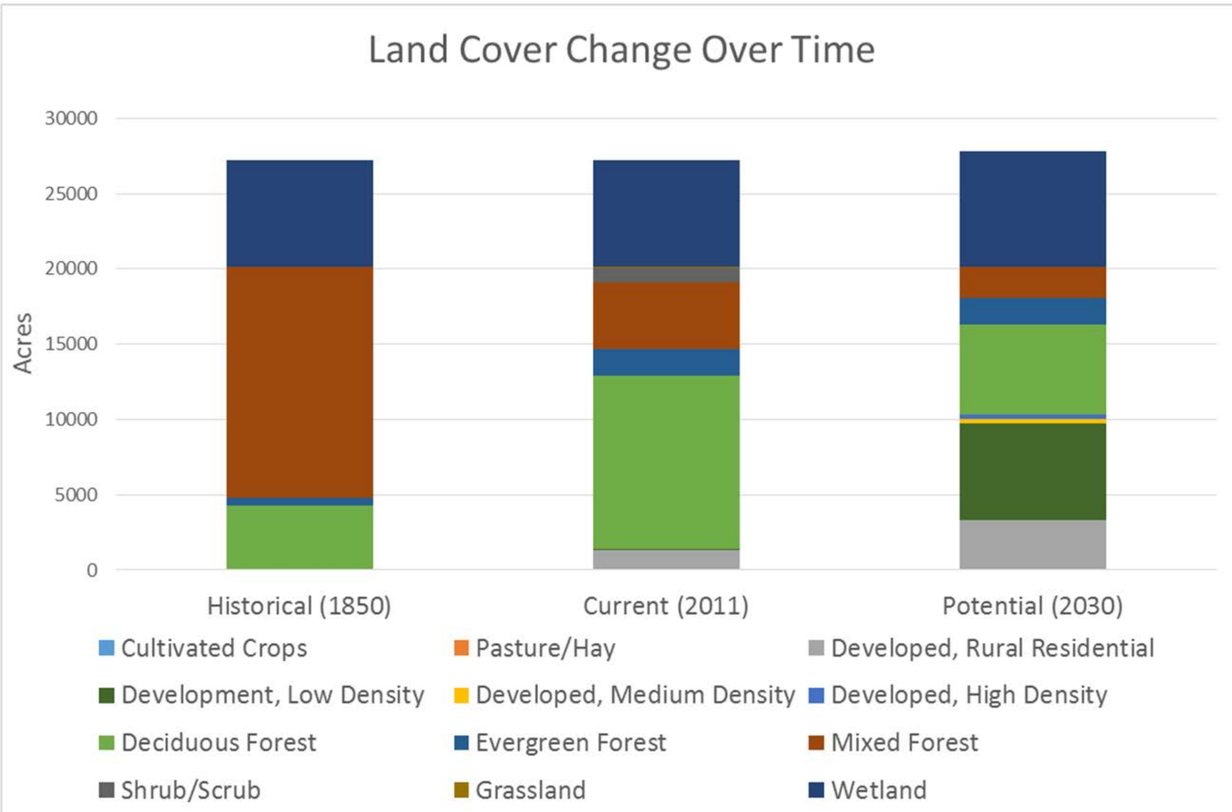

Figure 5.15. Land cover change throughout the Namakagon Chain watershed.

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 Namakagon 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 lake 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 lake is likely to increase (Table 5.1). Based on these changes, annual phosphorus runoff to the lake has likely increased by approximately 15 percent over pre-development conditions. If the Namakagon Chain watershed is fully developed

according to existing zoning and land use policies, phosphorus runoff to the lake has the potential to double over current conditions by 2030.

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

				Estimated Annual Phosphorus Loads to the Namakagon Chain					
	Annual TP Loads			Historical (1856)		Current (2011)		Potential Future (2030)	
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	20	20	0	0
Urban Lands	(lbs./acre/yr)			Acres	lbs.	Acres	lbs.	Acres	lbs.
Developed, Rural Residential	0.05	0.25	0.1	0	0	1321	132	3354	335
Development, Low Density	0.2	0.55	0.3	0	0	50	15	6407	1922
Developed, Medium Density	0.3	0.8	0.5	0	0	5	3	292	146
Developed, High Density	1	2	1.5	0	0	0	0	247	371
Forest and Grasslands	(lbs./acre/yr)			Acres	lbs.	Acres	lbs.	Acres	lbs.
Deciduous Forest	0.05	0.2	0.09	4262	1813	11478	1681	5996	886
Evergreen Forest				511		1770		1770	
Mixed Forest				15371		4489		2078	
Shrub/Scrub				0		946		0	
Grassland	0.01	0.25	0.17	0	0	65	11	0	0
Wetland	0.01	0.01	0.01	7087	71	7087	71	7087	71
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	542	239	1469	739
Relative Changes in Phosphrus Load					**Total**	**%**	**Total**	**%**	**Total**
Total Watershed Load					**1884**	**3%**	**1933**	**93%**	**3731**
Permitted/Non-permitted Source Load					**0**	**239%**	**239**	**209%**	**739**
Total Phosphorus Loads					**1884**	**15%**	**2172**	**106%**	**4470**
Per Acre Phosphorus Load					**0.10**	**15%**	**0.12**	**106%**	**0.24**

Shoreland Septic Systems

To calculate phosphorus runoff to the Namakagon 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 Namakagon Chain.

Time Period	Residency	Number of Septic Systems	Number of Users per System	Seasonal Ratio	Soil Retention	Export (lbs/capita years) Low	High	Average	Load (lbs/year) Low	High	Average
Current Conditions	Full-time	146	2.5	1	0.3	1.1	1.8	1.5	121	198	**165**
	Seasonal	379	2.5	0.3	0.3	1.1	18	1.5	94	1537	**128**
	Total	**542**	**2.5**	**0.65**	**0.3**	**1.1**	**9.9**	**1.5**	**215**	**1734**	**293**
Future Conditions	Full-time	397	2.5	1	0.3	1.1	1.8	1.5	327	535	**446**
	Seasonal	1028	2.5	0.3	0.3	1.1	1.8	1.5	255	416	**347**
	Total	**1469**	**2.5**	**0.65**	**0.3**	**1.1**	**1.8**	**1.5**	**582**	**952**	**793**

Summary Results – Septic Systems
Under current conditions, 542 privately owned shoreline parcels draining to the Namakagon Chain use septic systems. Of these, most (~75%) are seasonal residences. Based on these parameters, the annual load of phosphorus to the Namakagon Chain from septic systems is approximately 293 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 1469 and annual phosphorus load to approximately 739 lbs/yr (see Appendix D). Despite these potential increases in septic systems, nutrients runoff to the Namakagon Chain is currently, and will likely continue to be, dominated by watershed runoff.

Summary Conclusions – Watershed Conditions
Watershed delivery of phosphorus to the Namakagon 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 Namakagon Chain will increase by a significant amount—which has the potential to negatively impact water quality conditions (see section 5.6 for additional discussion). 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 Namakagon Chain is influenced by a combination of processes in the lake and its 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).

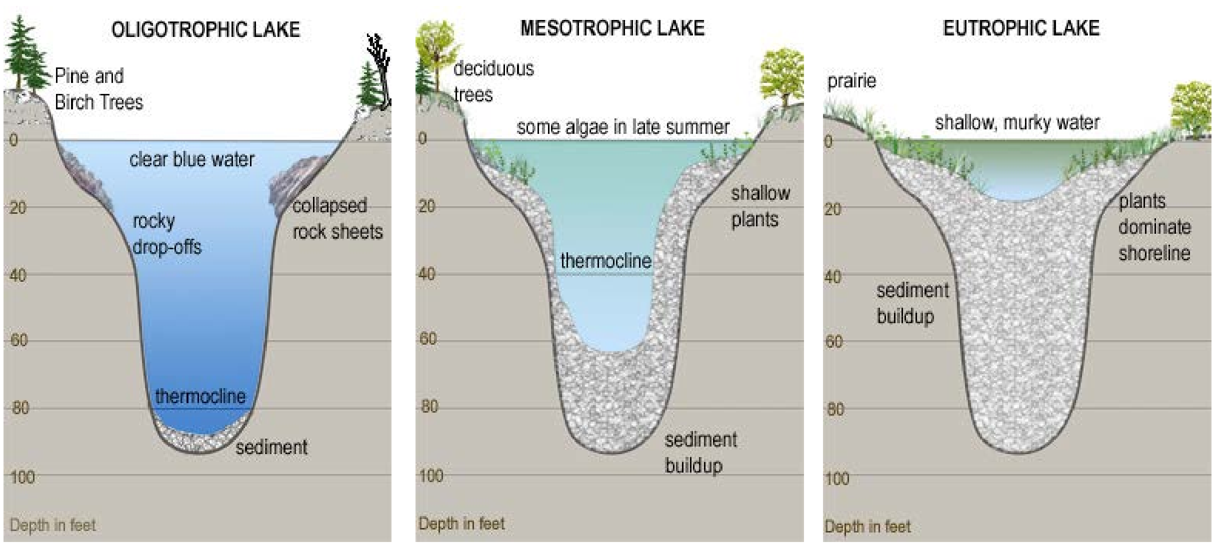

Figure 5.16. Conceptual diagram of the structure of different lake classifications. Adopted from http://rmbel.info/lake-trophic-states-2/.

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 waters, 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.

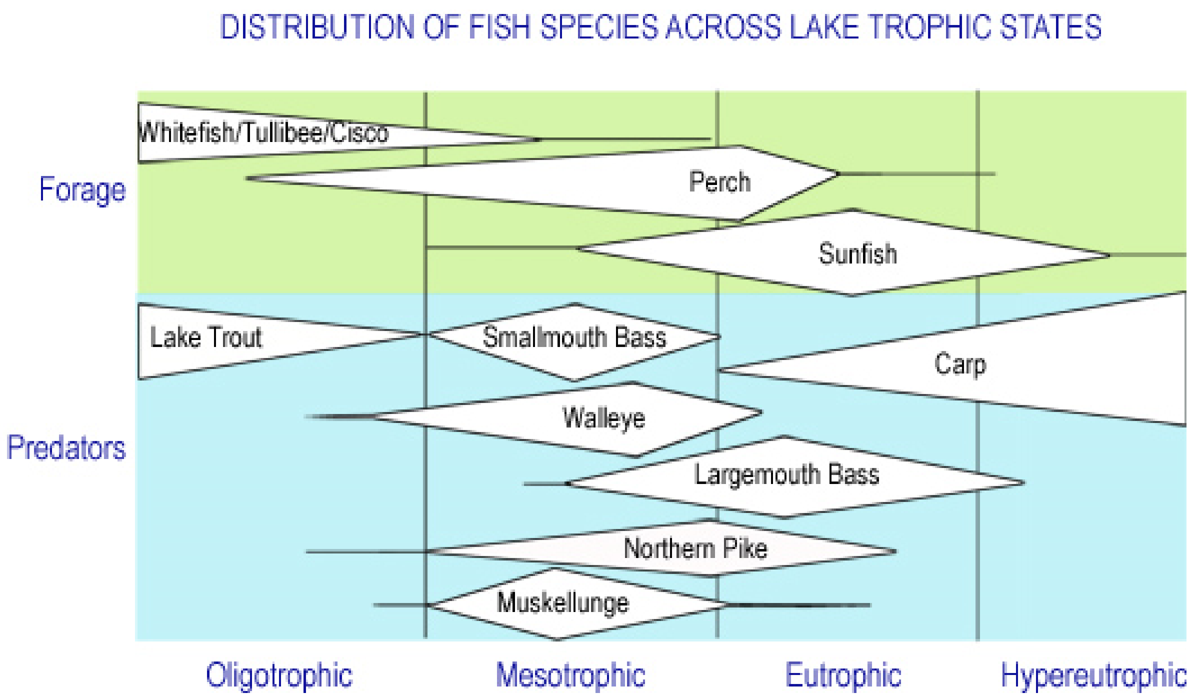

Figure 5.17. Conceptual diagram of the different fish communities that often inhabit lakes of different trophic conditions. Adopted from http://rmbel.info/fish-distribution/.

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 trophic state classification (Figure 5.18). In the Namakagon Chain, average growing season (June-August) total phosphorus concentrations should not exceed 15 ug/L in Lake Namakagon, 30 ug/L in Garden Lake and, 40 ug/L in Jackson Lake. *Note: The water quality criterion for Jackson*

Lake is currently 30 ug/L, but this criterion does not reflect the polymictic structure that was observed throughout 2013 and 214.

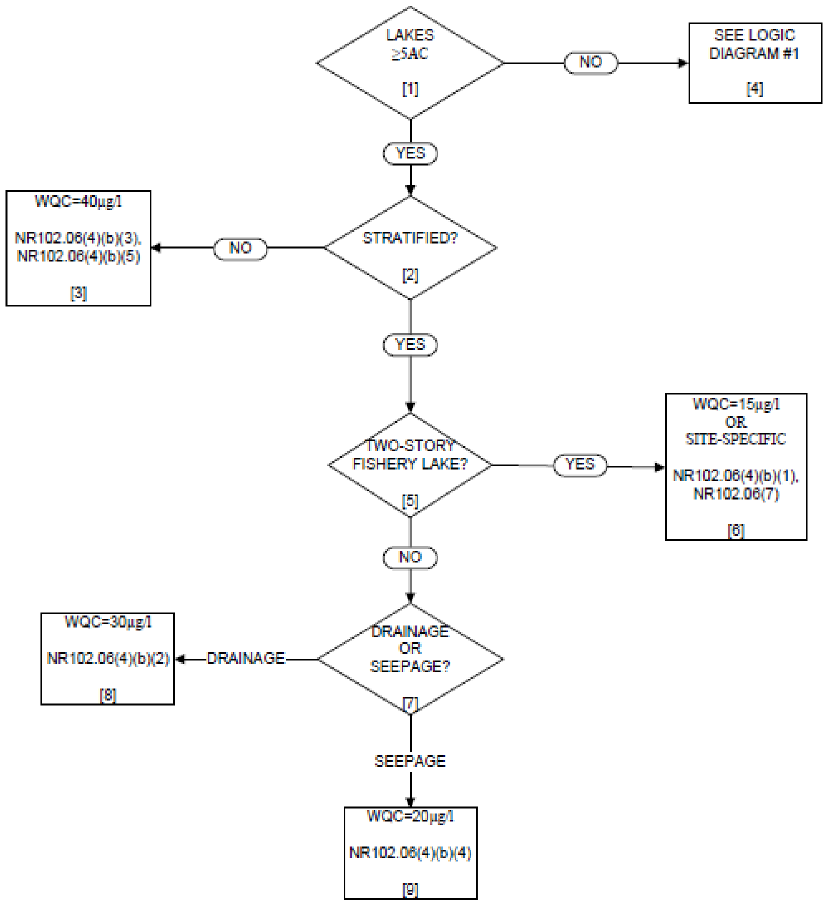

Figure 5.18. Total phosphorus water quality criteria for lakes in Wisconsin.

Historical Water Quality Conditions

Water quality in the Namakagon Chain of Lakes has been monitored over different periods and by different agencies since 1990. 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/LakeDetail.aspx?wbic=2732600). The most detailed water quality study for the Namakagon Chain of Lakes was conducted as part of a WDNR Lake Planning Grant (LPL-507) from 1998-1999 (USGS, 1999). Results from this study suggested that significant difference exist between the water quality and trophic state of Jackson, Garden and Namakagon Lakes. Based on the diversity of water quality conditions, the USGS authors highlighted the need to understand and model the relative nutrient budgets for the respective lakes.

Results from the historic and ongoing water quality monitoring suggest that Jackson Lake is eutrophic, Garden Lake is mesotrophic, and Namakagon is mesotrophic (on the boarder of oligotrophic). Average water quality conditions for the Namakagon Chain of Lakes range from 25 ug/L to 46 ug/L for total phosphorus, 4.4 feet to 9.4 feet for Secchi depth and from 45.7 to 56.5 for average Secchi Trophic State Index. 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, or have slightly improved over the last 20 years.

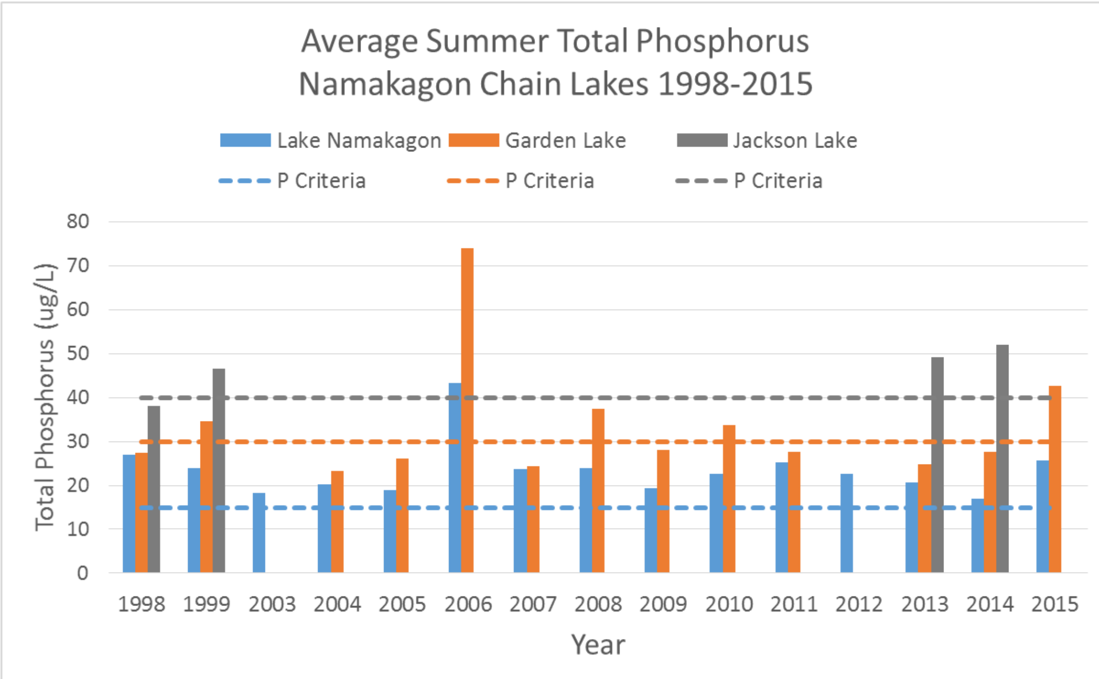

Figure 5.19. Average annual water quality trends in the Namakagon Chain (1998-2015).

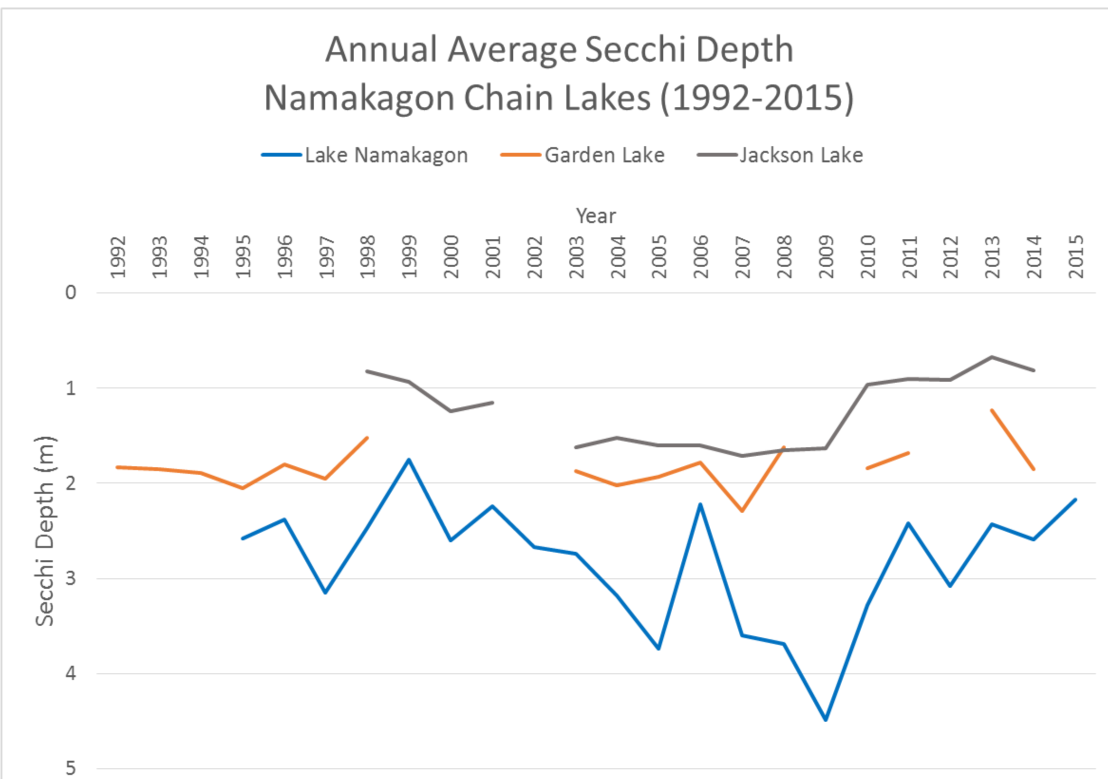

Figure 5.20. Historical trends in Secchi depth throughout the Namakagon Chain.

New Data Collection
To supplement the existing water clarity and nutrient data (summarized above), a more intensive water quality assessment was conducted from 2013-2014. As part of this study, samples were collected at sites throughout all three 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 collecting 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 Garden Lake meets state criteria, but total phosphorus concentrations in Namakagon and Jackson Lakes exceed water quality criteria. Given the limited development in the Jackson Lake watershed, it is likely that the elevated phosphorus concentrations are a result of continual mixing and not a specific pollutant source. Total phosphorus, chlorophyll-a and Secchi depth measurements all indicated that the Namakagon Chain lakes are accurately classified as mesotrophic/eutrophic lakes.

Because total phosphorus concentrations in Lake Namakagon are above the 15 ug/L criterion, this lake was added to the USEPA 303d list (i.e., impaired waters list) in 2015. Prior to 2015, cisco had not been identified in any fishery surveys in the Namakagon Chain of Lakes. This species of fish generally requires lower nutrient conditions to survive. As a result, following the detection of cisco in Lake Namakagon in 2015, the total phosphorus water quality criteria for the lake was adjust from 30 ug/L to 15 ug/L. Water quality conditions in Lake Namakagon, although relatively stable since 1998, exceed the new criteria, which resulted in its addition to the 303d list. Addition to the 303d list requires further study of the Lake Namakagon system to determine the best course of management action to protect the two-tiered cisco fishery.

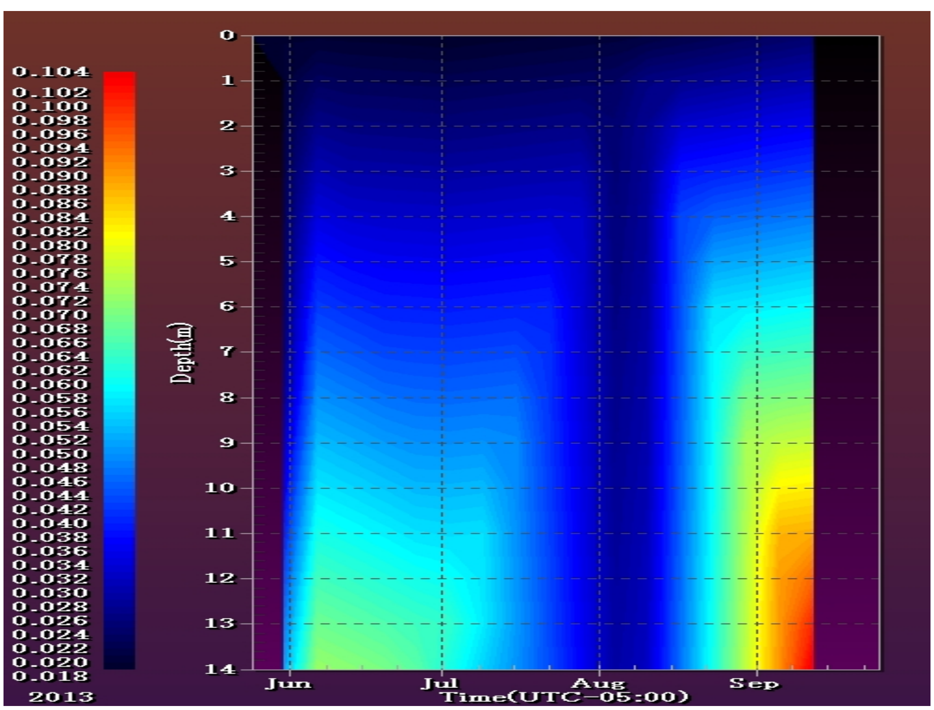

Figure 5.21. Seasonal profiles of total phosphorus concentrations (mg/L) in Namakagon Lake (2014). Red colors indicate areas of greater total phosphorus concentration.

Nutrient concentrations throughout the depth profile samples are of particular interest in Namakagon and Garden Lakes. Although surface water phosphorus concentrations in these lakes are relatively moderate, concentrations of phosphorus in the hypolimnion are often elevated, likely as a result of low oxygen conditions (Figure 5.21). This elevated hypolimnetic phosphorus concentrations are likely important considerations in the long-term management of water quality throughout the Namakagon Chain.

Summary Results – Lake Nutrient Budget
Within the Namakagon 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 likely occurs as part of spring snowmelt and rainfall. Watershed loading is the primary source of phosphorus in Namakagon and Garden Lakes, while internal loading is the dominant source of phosphorus in Jackson Lake. Additional "internal" sources and processes are discussed in Appendix G.

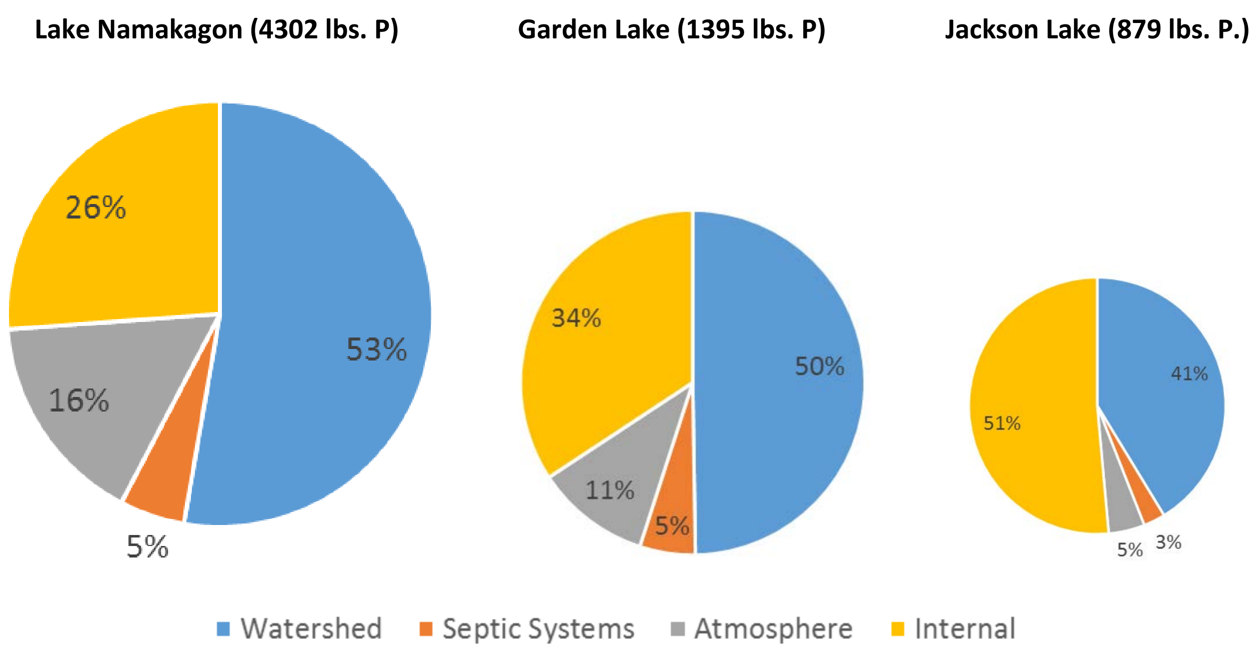

Figure 5.22. Phosphorus sources in Namakagon Chain. Percent contributions from different sources and annual loads.

Summary Conclusions – Water Quality Conditions
Water quality conditions in Garden Lake are consistent with those expected for mesotrophic lakes. However, given the relatively large contribution of internal loading to the overall nutrient budget in this lakes (as well as Lake Namakagon), additional attention should be focused on minimizing future runoff to the lake. Water quality conditions in Jackson Lake are inconsistent with state water quality criteria, likely as a result of continual mixing of sediments/nutrients into the water column. Historically, Jackson Lake has been considered a dimictic lake, but this classification should be changed to reflect its polymictic nature—the corresponding water quality criterion for phosphorus should be change to 40 ug/L.

Similarly, because total phosphorus concentrations are above the 15 ug/L criterion in Lake Namakagon, additional studies should be conducted to determine if changes in water quality have limited the cisco population, or whether the lake system has historically only supported a small isolated population.

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.

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.

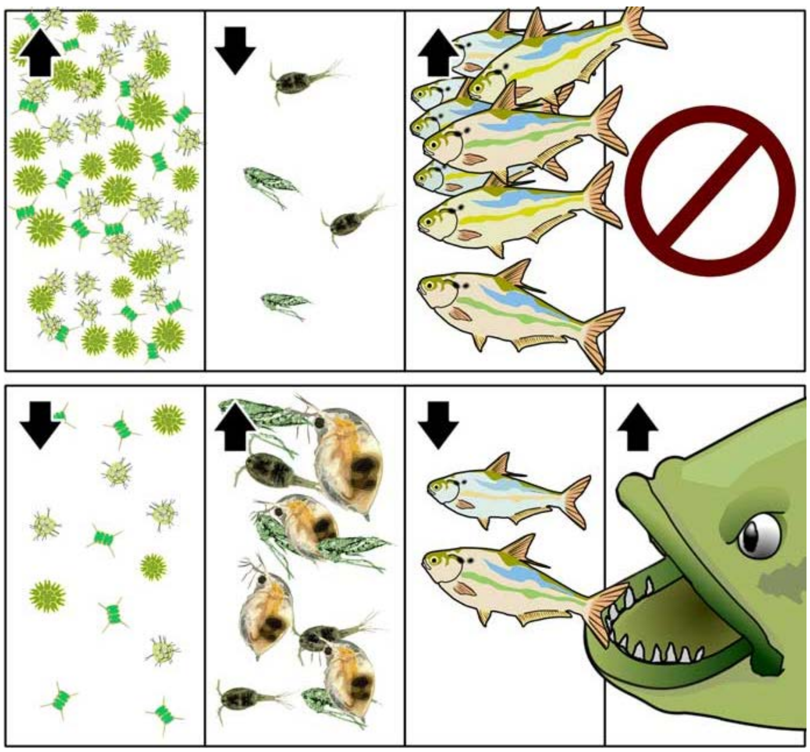

Figure 5.23. Conceptual diagram of the relationship between food web interactions and water clarity. Adopted from http://www.lmvp.org/Waterline/fall2005/topdown.htm.

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 Lake Namakagon are related to fisheries and aquatic plant species. Fisheries management work in Lake Namakagon has been ongoing since 1933 and is well described in the most recent WDNR fisheries report (Toshner, 2004). As described in the WDNR report, the fish community is highly diverse, consisting of walleye (*Sander vitreus)*, muskellunge (*Esox masquinongy)*, northern pike (*E. Lucius)*, largemouth bass (*Micropterus salmoides)*, smallmouth bass (*M. dolomieui)*, bluegill (*Lepomis macrochirus)*, pumpkinseed (*Lepomis gibbosus)*, rock bass (*Ambloplites rupestris)*, black crappie (*Pomoxis nigromaculatus)*, yellow perch (*Perca flavescens)*, white sucker (*Catostomus commersoni)*, yellow bullhead (*Ictalurus natalis)*, black bullhead (*I. melas)*, trout perch (*Percopsis omniscomaycus)*, tadpole madtom (*Noturus gyrinus)*, common shiner (*Notropis cornutlus)*, golden shiner (*Notemigonus crysoleucas)*, and spottail shiner (*N. hudsonius)*. In 2015, cisco (*Coregonus artedi*) were detected in Lake Namakagon at low densities.

Throughout the Namakagon Chain of Lakes, the primary fishery management efforts have been focused on walleye and muskellunge (the lake chain is listed as a Class A Muskellunge Fishery). Both walleye and muskellunge densities have declined in recent years, although walleye densities of 5.2 adults/acre are still above the State objective of 3 adults/acre. Declining muskellunge populations continue to raise concern among anglers and natural resource professionals. Historical stocking rates are summarized in the Aquatic Plant Management Plan (APMP: Foth, 2010). The 2004 DNR fishery report highlighted the need for a comprehensive lake management plan that should, "1) develop management objectives for fisheries including goals for densities and size structures for the various fish species found in the lake, 2) develop strategies for protecting and enhancing sensitive aquatic and shoreline habitats, 3) formally establish exotic species survey and control programs targeting satellite infestations, 4) provide educational and participation forum for environmentally sensitive shoreline living, 5) identify uses and user groups to facilitate all recreational uses on the lake."

In addition to the detailed fishery work described above, significant work has gone into understanding the aquatic plant communities of the Namakagon Chain. The distribution and diversity of aquatic plant communities are well described in the 2007 Lake Namakagon Aquatic Plant Inspection Results (Liesch, 2007) and 2010 APMP (Foth, 2010). In general the diversity of aquatic plants is relatively high, with average Simpson's diversity indices ranging between 0.85 and 0.90. To date, the only aquatic invasive species that has been identified in the Namakagon Chain of Lakes is purple loosestrife (*Lythrum salicaria*). The APMP identified 6 management goals/objectives for the Namakagon Lake Chain that primarily focused on outreach and engagement with lake users and shoreline resident to prevent the introduction of invasive species. Details of the aquatic plant work in the Namakagon Gain are described in Appendix E. Areas of Critical Habitat are depicted in Figure 5.6.

New Data Collection
To supplement the existing aquatic plant data, an invasive species pathway analysis was conducted to characterize and prioritize the primary route for invasive species introduction into the Namakagon Chain. Additionally, the presence of Rare, Threatened and Endangered species in the Namakagon Chain area was quantified by working with WDNR staff to conduct a Township Level query of the Natural Heritage Inventory (NHI) database.

Summary Results – Rare, Threatened and Endangered Species
Seven rare, threatened and endangered species exist within the townships surrounding the Namakagon 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 Namakagon Chain (i.e., lake management decisions will likely not affect these species).

Summary Conclusions – Biological Communities
Biological communities throughout the Namakagon Chain ecosystem are somewhat variable. Aquatic plant communities are diverse and robust and are currently not impacted by invasive species. Fish communities are generally consistent with those expected in mesotrophic lakes like those throughout the Namakagon Chain, although the recent observation of cisco is somewhat inconsistent with the mesotrophic nature of the Namakagon Chain. At present it is unclear of cisco were once abundant and have declined in response to changes in water quality conditions (or some related stressor) or have always survived in the Namakagon Chain at relatively low densities.

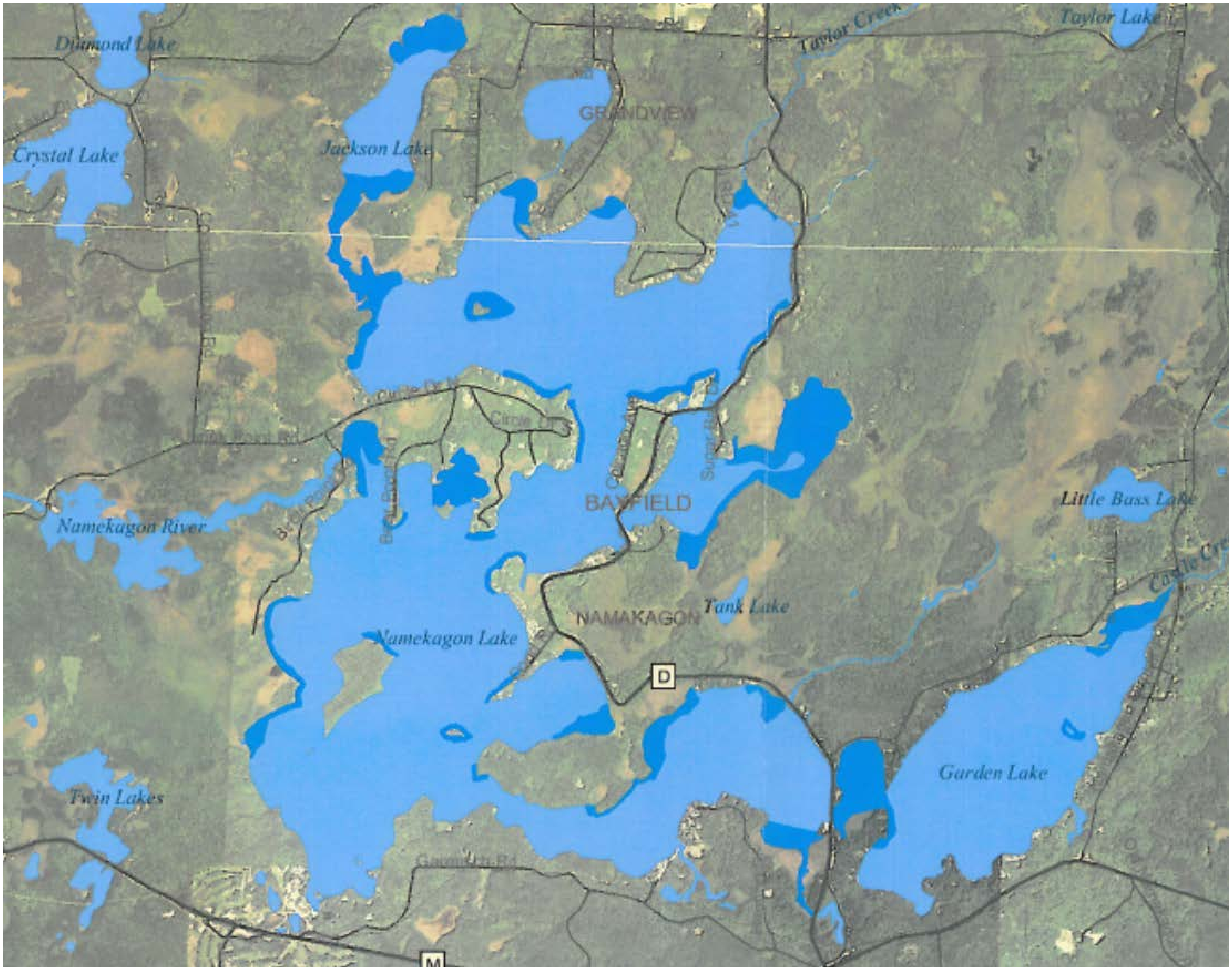

Figure 5.24. Location of Critical and Sensitive Habitat throughout the Namakagon Chain. Areas of dark blue represent critical habitat.

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

Scientific Name	Common Name	WI Status	Group
Alasmidonta marginata	Elktoe	SC/P	Mussel~
Callitriche hermaphroditica	Autumnal Water-starwort	SC	Plant~
Cygnus buccinator	Trumpeter Swan	SC/M	Bird~
Falcipennis canadensis	Spruce Grouse	THR	Bird~
Glaucomys sabrinus	Northern Flying Squirrel	SC/P	Mammal
Lake--deep, soft, seepage	Lake--Deep, Soft, Seepage	NA	Community~
Northern dry-mesic forest	Northern Dry-mesic Forest	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 Namakagon 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 Namakagon 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 have the potential to have a significant impact on water quality conditions throughout the Chain, but particularly in Lake Namakagon (Table 5.4). Based on model simulations, full implementation of the existing land use plans has the potential to elevate phosphorus concentrations, decrease water clarity and increase the occurrence of algal blooms. 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 Namakagon Chain. Given the uncertainty about both the ecosystem processes and the future land use conditions, management of

the Namakagon Chain should emphasize routine monitoring and assessment to track water quality conditions over time.

Simulation also suggest that an approximate 25% and 80% reduction in watershed load would be necessary to meet the 15 ug/L total phosphorus water quality criterion in Lake Namakagon under current conditions. Given that current conditions represent only a 3% to 15% increase in total phosphorus load over pre-development conditions (c. 1865), meeting the 15 ug/L criterion would likely be quite challenging, and potentially unachievable without substantial attenuation of internal loading.

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

Land Use Condition (Year)	Total Phosphorus Watershed Load	Growing Season Phosphorus Concentration (ug/L)		
		Namakagon	Garden	Jackson
1856	1884	9	10	44
2011	2172	23	29	46
2030	4470	46	38	58

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 Namakagon 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 Namakagon 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 Namakagon Chain ecosystem.

Table 6.1. Summary of the sources and impacts of stressors potentially impacting the Namakagon 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 Namakagon Chain ecosystem, individual stressors (see Table 6.1) were evaluated based on their ability to limit achievement of the identified management goals for the lake. The impact of each stressor was ranked based on its likely impact on the current conditions of the lake. 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 Namakagon 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 Namakagon 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:

<u>Goal 1 – Maintain Current Levels of Motorized and Non-motorized Use</u>
Current levels of motorized and non-motorized use appear consistent with the ecological conditions and user experiences on the Namakagon Chain; although some expressed concern over boat traffic and erosion in narrow 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.

<u>Goal 2 – Maintain Scenic Beauty of the Namakagon Chain</u>
The scenic beauty of the Namakagon Chain is generally consistent with user expectations. Most survey respondents indicated that lake aesthetics did not limit their use and/or enjoyment of the Namakagon 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.

<u>Goal 3 – Maintain Existing Water Levels and Hydrologic Processes</u>
In general, the hydrologic processes in the Namakagon Chain are moderately disturbed. Water levels at the outlet are controlled to a consistent depth of four to five feet and the lake receives runoff from a minimal amount of impervious 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 lake 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 Namakagon Chain are in moderate to poor condition, although some localized areas of particularly high quality habitat are present. However, given the potential for changes in shoreline development, it is possible that nearshore and shoreline may continue to be altered in the future. Shoreland restoration is a key management need identified in this study.

Goal 5 – Maintain or Improve Existing Water Quality Conditions
Water quality conditions in the Namakagon Chain are generally consistent with state standards for mesotrophic/eutrophic lakes. Although water quality has likely declined in the Namakagon Chain since the mid-1800s, it is unlikely that existing pollutant sources are currently impacting the Namakagon 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 Namakagon Chain in the future. Potential for water quality change over time is a key finding and management need identified in this study. Water quality degradation may be impacting cisco populations, and the relationship between water quality and cisco health should be investigated further.

Goal 6 – Maintain Diverse Native Plant Communities
Native aquatic plant communities are diverse and robust. 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, introductions are possible in the future. Prevention of future infestations of invasive species is a key management need identified in this study.

Goal 7 – Maintain Diverse Native Fish Communities
Fish communities in the Namakagon Chain are generally consistent with those expected in mesotrophic lakes.

Goal 8 – Increase Walleye Population Density
Walleye recruitment has been above state averages in the Namakagon chain. Population enhancement efforts have primarily focused on stocking and habitat enhancement. Average walleye size has declined over the last 10 years, but it is unclear if this results from sources of stress in the system or a part of a natural cycle.

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 Namakagon Chain.

Management Goals for the Namakagon Chain	Potential Stressors and Level of Impairment: Hydrologic Alteration			Habitat Loss			Pollutant Runoff and Deposition						Biological Community Modification			Use Incompatibility			Comments and Analysis
	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	2	2	Desired recreational usage patterns are currently unimpaired by ecological stressors or incompatible uses. Although some use conflict exists relative to the desired levels of motorized boat traffic.
2 - Maintain Scenic Beauty of the Namakagon Chain	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	1	1	2	Scenic beauty of the Namakagon 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 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	2	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	2	2	1	1	1	1	2	1	2	Water quality is moderately impacted and 1) may not supoort some of the most sensitive fish species, 2) 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	2	2	1	1	2	2	1	2	2	Fish communities are generally unimpaired, but long-term viabitity of muskie stocking/recruitment is unclear as is the status of the cisco fishery.
8 - Maintain 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 relatively strong although size structure has declined over the last 10 years.
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.
Cumulative Stressor Ranks	**8**	**8**	**10**	**14**	**11**	**10**	**8**	**8**	**8**	**10**	**14**	**8**	**8**	**11**	**9**	**12**	**14**	**18**	

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 Namakagon 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 Namakagon 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 Namakagon 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 Namakgon 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; NR 115). 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.

Bayfield County has enacted shoreland management through its shoreland zoning requirements. In Bayfield County the zoning requirements for shoreland areas is dependent on waterbody Class. Lake Namakagon is identified as a Class 1 lake (Table 7.1). However, in 2015, State shoreline zoning minimums became the maximum allowable regulation for shoreland areas and these regulations supersede the County zoning requirements.

Inland Lake Lot Requirements

	Class 1	Class 2	Class 3
Lot Size	30,000 sq ft	60,000 sq ft	120,000 sq ft
Lot Width	150 ft	200 ft	300 ft
Lot Depth	200 ft	300 ft	400 ft
Shoreline Setback	75 ft	75 ft	100 ft
Shoreline Vegetation Protection Area	50 ft	50 ft	75 ft
Side Yard Setback	10 min/ 40 min total	20 min/ 50 min total	30 min/ 60 min total

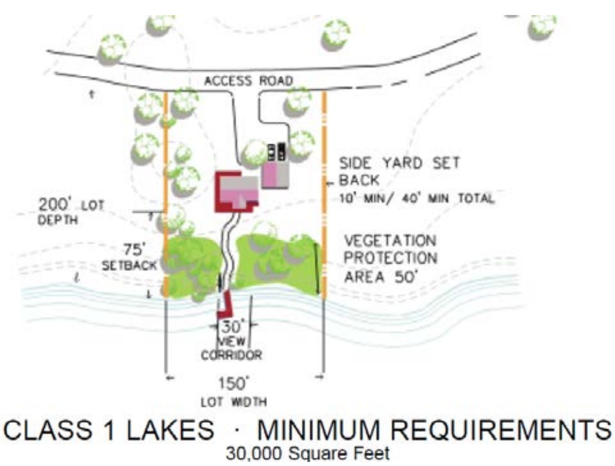

Figure 7.1. Minimum lot requirements for shoreland development along different lake classes. Adopted from Bayfield County.

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 Namakagon 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 Namakagon 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 Namakagon 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 Namakagon 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 Namakagon 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 Namakagon Chain (part I).

Stressors to be Mitigated	Existing Policies: USACE	USEPA	Tribes	WDNR					WDNR				Bayfield County		Towns of Grand View and Namakagon		NLA		NA	Cumulative Protection	Comments and Analysis
	Section 404 of Clean Water Act	Clean Air Act and MATS Rule	Treaties of 1837 and 1842	NR 102 - Water Resource Designation	NR 207 Antidegradation	Aquatic Plant Management	WPDES Program	303 Surface Water Program	NR 151 - Ag. Standards	NR 40 - Invasive Species	NR 115 - Shoreland Zoning (State Minimums)	Treaties of 1837 and 1842	Septic System Permitting	Shoreland Zoning	Comprehensive Plans and Zoning	Slow-no-Wake Ordinance	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	2	2	0	0	0	0	0	0	0	0	0	0	2	Agricultural runoff is unlikely to affect the Namakagon 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	4	4	0	0	0	0	0	0	0	0	0	0	0	4	Industrial runoff is unlikely to impact Namakagon 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	4	4	0	0	0	0	0	0	0	0	0	0	0	4	Municipal wastewater is unlikely to affect the Namakagon Chain, as not effluents currently (or are planned to) discharge to the Namakagon Chain and municipal effluents are well regulated by the WPDES program.
Septic Systems	0	0	0	0	0	0	0	2	0	0	0	0	3	0	2	0	0	0	0	3	Septic systems have a moderate potential to negatively affect the Namakagon 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	2	2	0	0	2	0	1	3	1	0	0	2	0	3	Urban runoff has a moderate potential to impact the Namakagon 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	3	0	0	0	0	3	2	0	0	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	2	0	0	0	2	Relatively few policies exist to describe potential ecological incompatibilities of different recreational uses.
Use-based Incompatibility	0	0	3	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	3	No policies/processes are in place to reconcile potential use incompatibilities among different user groups. Recreational use incompatibilities are partially addressed through local slow-now wake ordinances. Access to Tribal Fishing grounds is moderately well protected.
Intergenerational Incompatibility	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	3	No policies/processes are in place to reconcile potential use incompatibilities across generations. Recreational use incompatibilities are partially addressed through local slow-now wake ordinances.
Maximum Policy Benefit	15	3	3	15	15	10	13	16	2	2	8	4	4	12	17	14	2	8	2		

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

Stressors to be Mitigated	Existing Policies																				Comments and Analysis
	USACE	USEPA	Tribes	WDNR					WDNR				Bayfield County		Towns of Grand View and Namakagon		NLA		NA		
	Section 404 of Clean Water Act	Clean Air Act and MATS Rule	Treaties of 1837 and 1842	NR 102 - Water Resource Designation	NR 207 Antidegradation	Aquatic Plant Management	WPDES Program	303 Surface Water Program	NR 151 - Ag. Standards	NR 40 - Invasive Species	NR 115 - Shoreland Zoning (State Minimums)	Treaties of 1837 and 1842	Septic System Permitting	Shoreland Zoning	Comprehensive Plans and Zoning	Slow-no-Wake Ordinance	WDNR, Clean Boats, Clean Waters (Voluntary)	WDNR, Healthy Lakes Initiative (Voluntary)	WDNR, Invasive Species Control (Voluntary)	Cumulative Protection	
Hydrologic Alteration																					
Surface Water Modification	3	0	0	3	3	0	0	0	0	0	0	0	0	3	2	0	0	0	0	3	Existing policies are relatively well suited to protect surface water alterations in the Namakagon watershed. The primary activity that has the most potential to alter surface water processes in the Namakagon Chain is land use change throughout the watershed.
Groundwater Modification	0	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	Existing policies are well suited to protect against large scale groundwater with drawls from the Namakagon 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	4	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	Water levels in the Namakagon Chain are somewhat artificially elevated because of the outlet control structure. This structure likely has a moderate impact on the lake and future changes in water level are well regulated.
Habitat Loss																					
Nearshore/Shoreline	3	0	0	2	2	3	0	0	0	0	2	0	0	3	3	2	0	2	0	3	Future shoreline habitat loss in the Namakagon Chain is somewhat poorly 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	2	2	3	0	0	0	0	2	0	0	3	3	2	0	2	0	3	Critical habitat is somewhat protected by existing shoreline zoning, dredge and fill permits and Critical Habitat designation.
Spawning Substrate	2	0	0	2	2	2	0	0	0	0	2	0	0	0	2	2	0	0	0	2	Spawning substrate is moderately documented throughout the Namakagon 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	0	0	0	0	2	0	0	0	2	0	0	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	0	0	0	0	0	0	0	0	2	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). Effects of introduced Muskie are unclear.
Overharvest	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	Current policies are relatively well prepared to prevent overharvest of fish from the Namakagon Chain.
Maximum Policy Benefit	15	3	3	15	15	10	13	16	2	2	8	4	4	12	17	14	2	8	2		

8. Management and Monitoring Recommendations

In general, because of the high quality of the Namakagon 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 lake 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 Namakagon Chain that contribute to positive user experiences.

Goal 2 – Maintain Scenic Beauty of the Namakagon Chain
Maintenance of existing aesthetics of the Namakagon Chain is most likely to be affected by the potential for increased shoreline development and recreational use of the lake 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 Namakagon 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 Namakagon 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 outlet dam and changes in land use surrounding the lake. Potential water level changes are highly regulated through a variety of mechanisms. 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 (if possible) 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 area 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 or Improve Existing Water Quality Conditions

Water quality in the Namakagon chain is regulated and protected through a variety of rules and policies. However, not all relevant/necessary policies apply to the Namakagon Chain watershed. The primary mechanism for water quality management in Namakagon 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 lake. 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 Namakagon 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 Namakagon 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 Namakagon 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 Namakagon 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.

Given the 2015 listing of Lake Namakagon on the WDNR impaired waters list, further study is necessary to clarify the relationship between water quality conditions and the cisco populations in the lake system.

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

The primary factor may likely to lead to degradation of shoreland habitat around the Namakagon Chain is shoreland development (particularly under the 2015 update to NR 115). Nearshore and shoreline habitat are most effectively protected through the 404 permitting process of the USACE and the Bayfield 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 tripling of shoreland properties around the Namakagon Chain and the relatively pristine nature of current shoreline habitats, cumulative impacts should be considered.

Goal 6 – Maintain Diverse Native Plant Communities

Maintenance of diverse native plant communities is likely to be primarily impacted by potential future introductions of invasive species. A range of potential invasive species introduction pathways exist for the Namakagon Chain. Given the current levels of access and development, the potential introduction pathways represent moderate to significant concern in the near-term. However, if use and access to the Namakagon Chain (particularly though increased shoreline development) increase as planned, the probability of invasive species introduction increases.

Prevention of future invasive species can be achieved by both the management of the lake 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 NLA currently supports (Clean Boats Clean Waters) CBCW inspections at the three primary landings on 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 and an expansion of boat launch monitoring/education to include private access points.

Beyond prevention, activities to monitor and respond to any potential invasive species introductions could be expanded and formalized. Ongoing prevention 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 Namakagon 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.

9. References

Bayfield County. 2010. Land and Water Resource Management Plan for Bayfield County. Bayfield County Land Conservation and Land and Water Conservation Department.

Dillman, D. A. 1978. Mail and Telephone Surveys: The Total Design Method. John Wiley & Sons, Inc.

Hauxwell, Jennifer, Susan Knight, Kelly Wagne, Alison Mikulyuk, Michelle Nault, Meghan Porzky, and Shaunna Chase. 2010. Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry and Analysis, and Applications. Wisconsin Department of Natural Resources

Hershfield, D.M. 1963. Rainfall frequency atlas of the United States. Technical Paper Number 40. United State Weather Bureau.

Liesch. 2007. Lake Namakagon Aquatic Plant Inspection Results.

Foth. 2010. Lake Namakagon Aquatic Plant Management Plan. Namakagon Lake Association, Bayfield County, Wisconsin. Project ID: 08N015

Foth. 2011. Namakagon Chain of Lakes Sanitary Survey Report. Namakagon Lake Association, Bayfield County, Wisconsin. Project ID: 08N015

National Park Service (NPS). 2008. Water Quality Monitoring Protocol for Inland Lakes. Great Lakes Resource and Monitoring Network. Natural Resources Report NPS/GLKN/NRTR—2008/109

Nürnberg, G.K., 1987. A comparison of internal phosphorus loads in lakes with anoxic hypolimnia: laboratory incubations versus hypolimnetic phosphorus accumulation. Limnological Oceanography. 32: 1160-1164.

Perica, S., Martin, D., Pavlovic, S., Roy, I., St. Laurent, M., Trypaluk, C., Unrun, D., Yekta, M. and Bonnin, G. 2013. Precipitation-Frequency Atlas of the United States. NOAA Atlas 14; Volume 8

Robertson, D.M., W.J. Rose and D.A. Saad. 2003. Water quality and the effects of changes in phosphorus loading to Muskellunge Lake, Vilas County, Wisconsin. Water Resource Investigation s Report 03-4011. US Geological Survey. US Department of Interior

Reckhow, K.H., M.N. Beaulac and J.T. Simpson. 1980. Modeling phosphorus loading in lake response under uncertainty—A manual and compilation of export coefficients: U.S. Environmental Protection Agency, EPA-440/5-80-011

Toshner, Scott. 2008. Fish Survey – Namakagon and Jackson Lakes. Wisconsin Department of Natural Resources

Shifferd, P.A. and Judd, L.A. 1998. Quiet Retreat or Recreation and Venue – Varying Opinions of Lake Property Owners. Lake Namakagon Report

Standard Methods for the Examination of Water and Wastewater. 21st Edition. 2005. American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF). Washington DC.

United States Environmental Protection Agency (USEPA) 2007. Survey of the Nation's Lakes – Field Operations Manual. Washington, DC. EPA841-B-07-004

United State Geological Survey (USGS). 1999. Lake Namakagon – U.S. Geological Survey Lake Monitoring Program in Wisconsin.

Walker, W. W. 1996. "Simplified procedures for eutrophication assessment and prediction: User Manual," Instruction Report W-96-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. (Updated September 1999).

Wisconsin Department of Natural Resources (WIDNR). 2003. Wisconsin Lake Modeling Suite. Program Documentation and User's Manual. PUBL-WR-363-94

10. Appendix A – Shoreland Use 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 Namakagon Chain ecosystem, it is critical to characterize how different user groups use and value the Namakagon Chain. Results from this survey were used to inform the development of management goals for the Namakagon Chain.

Methods
Survey construction
One of the primary goals of the Namakagon Chain of Lakes grant is to understand how different stakeholders interact with, and affect the lake's ecosystem. More specifically, the grant outlines a specific objective of describing the factors that limit the implementation of shoreline restoration efforts and identify potential opportunities for shoreline restoration throughout the Namakagon Chain of Lakes. As a result, a group of faculty and student researchers from Northland College constructed the survey between 2013-2014 as the primary mechanism to capture stakeholder perceptions and behaviors related to lakeshore restoration. A resource sociologist with the Wisconsin Department of Natural Resources and members of the Namakagon Lake Association vetted the final instrument. The final survey is divided into five parts covering a variety of topics including:

(1) participant demographic information,
(2) property information,
(3) participant property management behaviors,
(4) participant attitudes toward lake management practices, and
(5) general values of the participants.

Sampling strategy and sampling frame
A census sample (i.e., the entire population) of households with lakeshore property on one of the Namakagon Chain of Lakes was drawn. The initial sampling frame included 515 households. After removing undeliverable surveys, duplicate landowners, or vacant properties, the final sampling frame was 476. 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 42.9 percent (n=204) response rate.

Results

Participants
Survey respondents range in age from 36 to 90 years old with the average age being 64.7 years old. Approximately 69.4 percent of respondents were male; the other 30.6 percent were female. Education levels vary from some high school (no diploma) to graduate and professional degrees, of which approximately 34.9 percent have graduate or professional degrees (Table 10.1).

Respondents most commonly identify with the income ranges of less than $60,000 and $100,000 to $149,999 (Table 10.2). When asked what year they first started visiting the Namakagon Chain of Lakes, 50 percent of participants first started visiting the area between 1962 and 1992.

Property Description
The average number of years that respondents have owned property in the Namakagon Chain of Lakes area is 24.5 years with the range being 3 years to 100 years. Most respondents (79 percent) own property on Namakagon Lake, with far fewer owning property on Garden Lake (15.4 percent) and Jackson Lake (5.6 percent) – see Table 10.3. Most respondents (42.6 percent) identified that their property has between 101-200 feet of shoreline (Table 10.4). When asked what best describes the space between their home and the shoreline, 42.6 percent of respondents identified lawn (Table 10.5). Respondents were then asked a similar question regarding shoreline (i.e., land about 30 feet away from the water's edge), of which 49 percent of participants selected "undeveloped or natural" and an additional 22.2 percent choose "lawn" (Table 10.6). Finally, respondents were asked what best describes space from the shoreline outward into the water. The majority of respondents selected either minimal aquatic vegetation (50.3 percent) or moderately dense aquatic vegetation (30.8 percent) – see Table 10.7. Over 72 percent of the respondents are not full time residents (Table 10.8).

Participation with the Namakagon Lake Association
Approximately, 55.3 percent of respondents are current members of the Namakagon Lake Association (Table 10.10); however, 65 percent of respondents report that they never attend lake association meetings (Table 10.11).

Participant Property Management Behaviors of Namakagon Chain of Lakes
In the first section of the survey, respondents are asked about their behaviors and practices in the area from their house to the lakeshore. Respondents were asked: "Do you participate in these activities on your property on the Namakagon Chain of Lakes?" The activities included maintaining seasonal dock or pier, mowing or maintaining a grass lawn, maintaining a buffer of undisturbed vegetation between one's home and the lake, removing downed trees or logs from water, maintaining or expanding a sea wall or rocked shoreline, applying fertilizers or herbicides to one's lawn, using chemical control for insects/pests, removing vegetation from shoreline, creating or maintaining a beach, physically and chemically removing underwater plants or weeds, diverting standing water from one's yard, maintaining a rain garden, intentionally placing logs in the lake, maintaining a permanent dock, and establishing or maintaining a rock garden or fish pond (Figure 10.1). Participants either answered yes or no for each property management behavior. The matrix is organized in a way that puts the activities in descending order from the highest percentage of participation in each property management behavior to the lowest percentage.

The management behaviors exhibited most frequently by participants include maintenance of a seasonal dock or pier (89.3 percent), mowing or maintenance of a grass lawn between one's home and the lake (81.0 percent), and maintenance of a buffer of undisturbed vegetation between one's home and the lake (75.1 percent). Aside from these popular activities, respondents did not actively participate in other management behaviors, varying from 1 percent to 27.8 percent depending on the activity. Chemical removal of underwater plants was the most infrequent behavior (1.6 percent), followed by establishing or maintaining a rock garden or fish pond (2.1 percent), establishing or maintaining a permanent dock or pier (3.7 percent), and intentionally placing logs in the lake (4.7 percent).

Importance of Activities to the Management of Property on Namakagon Chain of Lakes
As a continuation of this section of the survey, participants identified "how important the following factors are in influencing the management of your property and the adjacent shore." The factors aligned with property management behaviors, although not directly, and included the following items: enhancing the aesthetics of the property, enhancing the value of the property, reducing shoreline erosion, removing invasive species, improving lake health, reducing flooding, improving lawn health, enhancing view of lake, removing navigation obstacles, improving boat access, increasing opportunities to swim and sunbathe, and controlling insects/pests (Figure 10.2). Participants could choose from "very unimportant" (gray), "somewhat unimportant" (peach), "undecided" (light blue), "somewhat important" (orange), and "very important" (dark blue). The circle on each line indicates the average response for all respondents for each question in the matrix. The matrix organizes the activities with the higher average, or activities found more important, at the top, with those considered least important at the bottom.

The respondents determined improving lake health (86.3 percent), reducing shoreline erosion (78.3 percent), enhancing the aesthetics of their property (72.7 percent), removing invasive species (71.5 percent), enhancing the value of their property (70.6 percent) and enhancing the view of the lake (70.3 percent) as important, by an aggregate measure of very important and somewhat important. Most activities reflected a positive skew, with the top three favored activities possessing a mean value of exactly "somewhat important," or higher. Overall, the participants identified the health and beauty of their property and the lake as important values they harbor.

A minority of respondents deemed the control of insects/pests (47.4 percent), removal of navigation obstacles (45 percent), increasing swimming/sunbathing (43.7 percent), improving lawn health (39.3 percent), and improving boat access (39.3 percent) as somewhat or very important, with similar percentages for finding these activities unimportant. There was a slight negative skew for the three activities with lowest values of importance, with a somewhat even distribution in category responses. These indicators of less import, according to respondents, relate more to leisure-based activities.

Reasons for Engaging in Lakeshore Restoration
For participants who have engaged in lakeshore restoration on their property (n=49), they were asked which of the following items encouraged them to do so. Respondents answered "yes" or "no" for the following statements: "I think lakeshore restoration is important to the health of the lake," "I like the way lake restoration makes my property look," "I wanted to control erosion on my property," "I was required by ordinance or regulation to restore lakefront habitat," "The local government offered me incentives to do lakeshore restoration," "I noticed that my neighbors were doing lakeshore restoration," and "Someone in the community asked me to do lakeshore restoration." (Figure 10.3). The matrix is organized in descending order from the highest percentage of respondents selecting "yes" they have been encouraged to engage in lakeshore restoration for exhibited item.

The items identified as most frequently by participants include deeming lakeshore restoration as important to the health of the lake (91.3 percent), favoring the way lake restoration makes their property look (79.6 percent) and wanting to control erosion on their property (78.3 percent). Aside from these commonly shared values, respondents did not feel encouraged by the remaining options, with responses ranging from 2.2 percent to 28.3 percent depending on the item.

Barriers to Lakeshore Restoration
For participants who have never engaged in lakeshore restoration efforts on their property (n=141), they were asked "…whether or not each of the following is a barrier to you doing lakeshore restoration on your property." The obstacles included "There is no reason to restore the lakeshore on my property," "I am not aware how to do shoreline restoration," "I have been unaware of lakeshore restoration as an option for my property," "I do not think lakeshore restoration would benefit me," "I am not legally required to restore or maintain lakeshore habitat," "I do not have time to lakeshore restoration," "Lakeshore restoration is too expensive," "No one else in my community does lakeshore restoration," "I do not like the way lakeshore restoration would make my property look," and "I do not think lakeshore restoration would benefit the lake" (Figure 10.4). The matrix is organized in descending order from the highest percentage of perceived barriers in partaking in lakeshore restoration to the lowest percentage of chosen barriers (based on respondents answering "yes").

The most notable impediment perceived by participants is that there is no need to restore the lakeshore on their property (80.9 percent). Otherwise, the next most frequent responses are "I am not aware how to do shoreline restoration" (46.7 percent),"I have been unaware of lakeshore restoration as an option for my property" (45.6 percent),"and "I do not think lakeshore restoration would benefit me" (42.9 percent). All of these items indicate some lack of knowledge, skills, or value in lakeshore restoration. The remaining chosen "barriers" varied from 22.4 percent to 35.5 percent. These items in order from most to least commonly selected barriers to lakeshore restoration are: "I am not legally required to restore or maintain lakeshore habitat," "I do not have time to lakeshore restoration," "Lakeshore restoration is too expensive," "No one else in my community does lakeshore restoration," "I do not like the way lakeshore restoration would make my property look," and "I do not think lakeshore restoration would benefit the lake".

Participant Attitudes of Namakagon Chain of Lakes
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" and told to rate a series of eighteen items related to objects such as: landscapes, shoreline, land and aquatic plants, insects, animals, erosion, and development (Figure 10.5). 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 places 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.

The highest rated item is "I prefer sandy beaches to other landscapes along the lakeshore" with 93.9 percent of respondents selecting that they either agree or strongly agree with this statement. Additionally, respondents tended to disagree or strongly disagree (71.4 percent) with the statement "there are too many docks on the Namakagon Chain of Lakes." Combined, respondents demonstrated a preference shorelines that tend to favor recreational purposes. Other items in the matrix that deal with shoreline preferences did not exhibit as strong of an attitude by respondents but still seemed to favor a preference for recreational activities. Approximately 47 percent of respondents disagree or strongly disagree with the statement: "intentionally placing trees in the water ("fish sticks") makes the lakeshore look untidy" – a practice commonly associated with increasing the quality of fish habitat. Finally, most participant (76.3 percent) disagree or strongly disagree with the statement "aquatic vegetation is too dense for recreational activities (e.g., swimming and boating)" suggesting they are not concerned with density of water-based vegetation.

The next highest rated items – "I enjoy watching birds on my property" – had 89.8 percent of respondents agree or strongly agree with this statement. Beyond birds on their property, respondents did not express very positive attitudes towards other animals or insects. In fact, 67.5 percent of participants agree or strongly agree that "water-based animals (e.g., frogs, turtles) are bothersome," 57.1 percent of participants agree or strongly agree that "bugs (e.g., mosquitos, ants) are a nuisance on this lake," and only 17.6 percent of participants agree or strongly agree that they "enjoy having land animals (e.g., deer, squirrels) around the Namakagon Chain of Lakes."

The third highest rated item with 77.5 percent agreeing or strongly agreeing is "I prefer to have a view of the lake form my property that is unobstructed by natural vegetation." Despite preferring to see the water from their property and sandy beaches to other landscapes along the shoreline, most respondents do not see untouched natural vegetation in and around the lake as unattractive with 80 percent choosing they disagree or strongly disagree. Furthermore, respondents seem to be distributed evenly among the various categories when it comes to natural vegetation versus lawn preferences. When asked to rate the item "I think having a grass lawn looks better than leaving natural vegetation," 40.2 percent disagree or strongly disagree, 26.1 percent are undecided, and 33.7 percent agree or strongly agree. An almost identical distribution of responses can be seen among participants on the item "residential development has improved the appearance of the lakeshore" with 40.7 percent disagree or strongly disagree, 26.1 percent are undecided, and 33.1 percent agree or strongly agree. A more negatively skewed distribution of responses can be seen with how respondents rated the statement "I prefer the appearance of landscaped lakeshores" with 61 percent disagree or strongly disagree, 23 percent are undecided, and 16 percent agree or strongly agree.

When asked to rate the item "shoreline erosion is ugly," approximately 48.7 percent of respondents disagree or strongly disagree with statement versus 38.4 percent who agree or strongly agree – approximately 32.0 percent selected "undecided." An overwhelming majority of participants (96 percent) disagree or strongly disagree that they are "concerned that motorized boats increase erosion." Finally, just under 50 percent of participants disagree or strongly disagree with the statement "I think it is important to reduce runoff from people's property into the lake" and another 32.5 percent are undecided.

Finally, 59 percent of respondents disagree or strongly disagree with that "too much concern is made about restoring the lakeshore around the Namakagon Chain of Lakes" while only 15 percent agree (13 percent) or strongly agree (2 percent) suggesting that the majority of respondents believe lakeshore restoration is important.

Participant Knowledge of Impact of Various Property Management Behaviors

In this section of the survey, respondents were asked: "Please indicate the impact you think each of the following points have on the overall health of the lake." The activities and behaviors identified in this section included sixteen items related to the effect of various practices on the lake such as: lawns, natural or undeveloped vegetation, removal of land and aquatic plants, beaches, rain gardens or rain barrels, fertilizers, docks or piers, ornamental ponds, fallen trees, chemical pest control, and runoff (Figure 10.6). Participants could choose from "very negative" (gray), "somewhat negative" (peach), "no impact" (light blue), "somewhat positive" (orange), and "very positive" (dark blue). Respondents also had the choice to select "don't know" as an option (Figure 10.7). The circle on each line in figure 6 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 that respondents identified as having a positive impact on the lake, at the top and those found to have a negative impact toward the bottom.

A majority of respondents saw "undisturbed natural vegetation between residence and the lake" (82.1 percent) and "rain gardens and/or rain barrels" (63.8 percent)[1] as having a positive impact on the overall health of the lake. On the bottom end of the matrix, a large majority of respondents stated "fertilizers and/or insecticides" (92.7 percent), "runoff from residents' yards into the lake" (91.1 percent), "chemical removal of underwater plants and weeds" (89.1 percent), "chemical pest control" (85.4 percent), and "removal of vegetation (i.e., trees, shrubs, grass) from lakeshore" (82.4 percent) negatively impact the overall health of the lake. A slightly lower majority (70.8 percent and 61.1 percent respectively) identified "man-made beaches on the lakeshore" and "grass lawns between residences and the lake" as negatively affecting the overall health of the lake. Finally, just a slight majority of respondents identified "physical removal of underwater plants and weeds" (53.9 percent), "permanent docks or piers" (53.8 percent), and "removal of fallen trees or logs from the water[2]" (52 percent) as negatively affecting the overall health of the lake.

Participants tended to be split on the overall impact the other remaining indicators. There is a slight positive skew on the effect of "seasonal docks or piers," "sea wall or rocked shoreline," and "intentional placement of trees or logs in the water;" whereas, respondents tended to have a more negative skew on rating the impact of "water gardens and ornamental ponds" on the overall health of the lake[3]. For both seasonal docks and water gardens, most respondents (55.4 percent and 40 percent, respectively) selected the "no impact" option on the overall health of the lake.

Participant Values

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 10.8).

The first item on the matrix asked respondents whether they see their Namakagon 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 recreate. In fact, 81.4 percent of respondents selected numbers 5, 6, or 7 suggesting respondents overwhelmingly saw their Namakagon Chain of Lakes property as a place to live and recreate. When taken in combination with whether respondents feel most closely connected to Namakagon Chain of Lakes community or another community, as can be

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[1] Approximately 22.1 percent of respondents selected the "don't know" option when asked about the impact of rain gardens and/or rain barrels" on the overall health of the lake.

[2] Approximately 16.1 percent of respondents chose the "don't know" option for this indicator.

[3] Approximately 26.4 percent of respondents chose the "don't know" option for this indicator.

seen in from the overall mean score of 3.4, respondents are equally distributed across the scale. Roughly 47.2 percent identified feeling connected to the community surrounding Namakagon Chain of Lakes – as indicated by circling 1, 2, or 3 on the scale – compared to 25.7 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 Namakagon Chain of Lakes affect the respondents overall well-being, respondents tended to feel changes to the lake would affect their well-being. A majority (72 percent) of respondents choose either 1, 2, or 3 while an additional 21.8 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 Namakagon Chain of Lakes being for the "conservation of the natural ecosystem" over "managed primarily for human uses". Approximately 46.1 percent of participants chose managing the lake for the conservation of the natural ecosystem versus 20.4 percent who tended to lean toward management for human uses. This sentiment is not reflected, however, in the percent of participants who tend to agree more with the statement that the natural environment should be protected from human activity with 26.7 percent falling toward protecting from human activity, 57.7 percent in the middle, and 42.2 percent leaning toward utilization for human needs and growth. When asked where respondents fell on whether they felt more closely aligned with managing the lake for future generations versus for current users, 50 percent of respondents suggested they thought the lake should be managed for the needs of future generations versus 19.9 percent who identified more closely with managing for current users. Roughly, 30 percent of respondents chose the middle point.

Additionally, a large majority of respondents felt that it was appropriate for human intervention to help maintain a healthy lake (64.4 percent) rather than not intervene (11.9 percent) and felt that individuals (53.1 percent) – not government (21.1 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; 21.1 percent tended to lean toward individuals having cart blanche to develop their property versus 58.8 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 (50 percent) more say in its management over all users of Lake Namakagon (24.7 percent).

Participant Willingness to Protect Namakagon Chain of Lakes

In this section of the survey, respondents were asked: "The following items are meant to gauge your willingness to participate in certain activities concerning Namakagon Chain of Lakes. Your responses are hypothetical and will not indicate any actual commitment to these activities. How willing would you be to…?" (Figure 10.9). 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 Namakagon Chain of Lakes by attending to an educational event (75.3 percent). This is followed by respondents' willingness to support the development of rules and ordinances requiring lakeshore management (65.3 percent), implementing a lakeshore restoration project on their own property if grant funds were available (62.4 percent), and volunteering their time to participate in a lakeshore restoration project (55.6 percent). Though most respondents are willing to assist in these ways, the majority, between 60 and 77 percent, are unwilling to offer any financial support through paying out of pocket, increasing taxes, or paying additional fees.

Table 10.1. Education

Level of Education	
Some high school (no diploma)	2.1%
High school graduate (or equivalency)	11.8%
Some college (no degree)	14.4%
Two year degree	4.6%
Four year degree	32.3%
Graduate or professional degree	34.9%

Table 10.2. Income

Income	
Less than $60,000	21.8%
$60,000-99,999	21.2%
$100,000-149,999	21.8%
$150,000-199,999	10.0%
$200,000-249,000	8.2%
$250,000 or more	17.1%

Table 10.3. Property Location

On which lake is your property located?	
Namakagon	79.0%
Garden	15.4%
Jackson	5.6%

Table 10.4. Feet of Shoreline

How many feet of shoreline does your property have?	
100 feet or less	16.3%
101-200 feet	42.9%
201-300 feet	12.8%
More than 300 feet	28.1%

Table 10.5. Space between Home and Shoreline

Which term best describes the space between you and the shoreline?	
Lawn	41.9%
Undeveloped or natural	29.8%
Other	23.7%
Landscaped (i.e., patio area, garden)	4.5%

Table 10.6. Space 30 Feet Inland from Shoreline

Which term best describes your property 30 feet away from the water's edge?	
Undeveloped or nature	49.0%
Lawn	22.2%
Other	13.1%
Rock or stone embankment	8.6%
Landscaped	3.5%
Groomed sandy beach	3.0%
Retaining wall	0.5%

Table 10.7. Space Outward into the Water

Which term best describes the water immediately outward from your property?	
Minimal aquatic vegetation	50.3%
Moderately dense vegetation	31.8%
No aquatic vegetation	10.8%
Dense aquatic vegetation	7.2%

Table 10.8. Participant Residency

How would you best describe your residency?	
Year round	27.1%
Weekends throughout the year	27.1%
Other	20.6%
Full time in summer and more throughout the year	10.1%
Full time in summer	9.5%
Weekends only in summer	5.5%

Table 10.9. Namakagon Lake Association Membership

What is your affiliation with the Namakagon Chain of Lakes Association?	
Current member	55.3%
Never been a member	30.2%
Former member	14.6%

Table 10.90. Attendance of Lake Association Meetings

How often do you attend Lake Association meetings?	
Never	65.0%
Every few years	18.5%
More than once a year	9.0%
Annually	7.5%

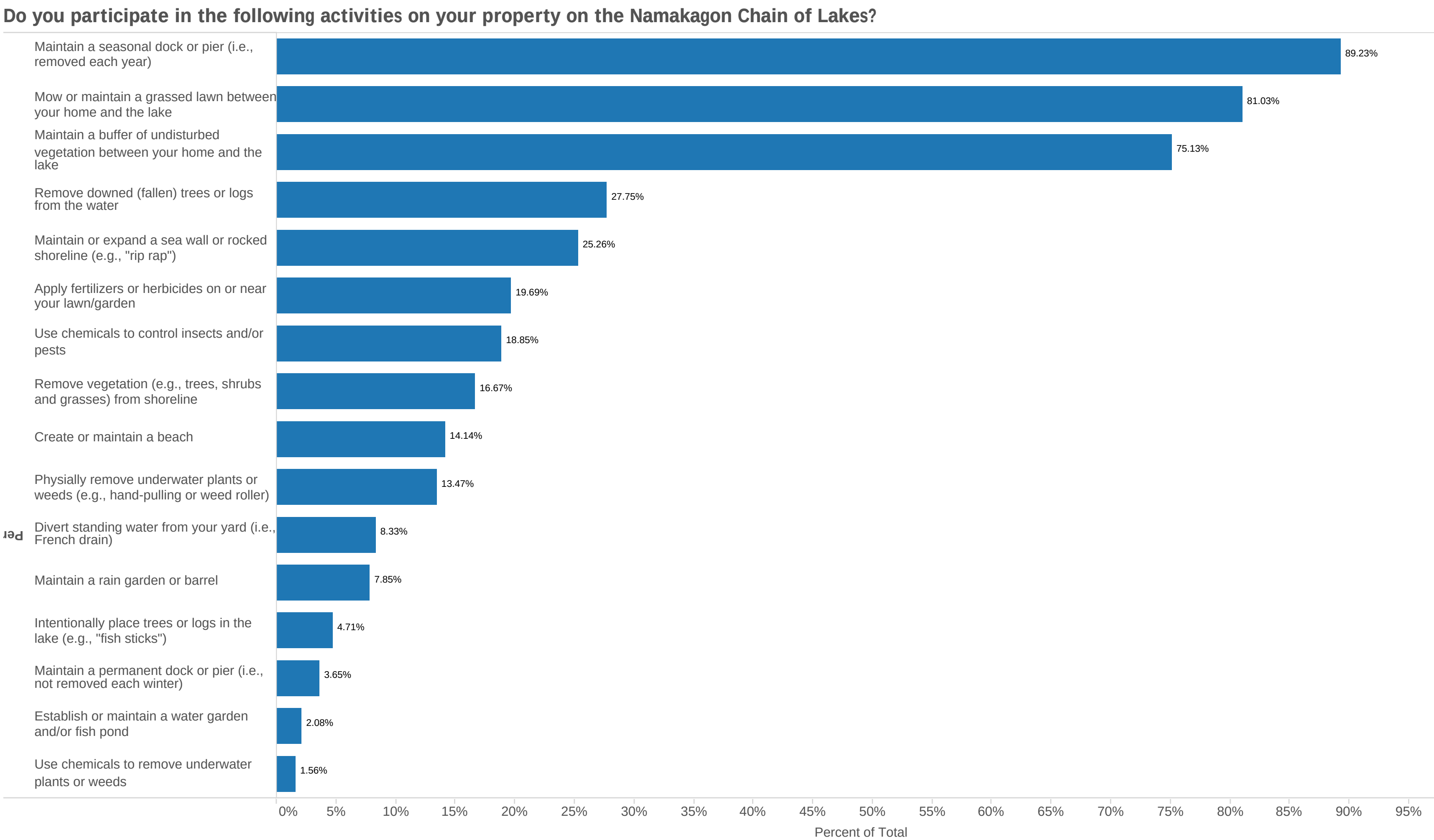


Figure 10.1. Participant Property Management Behaviors

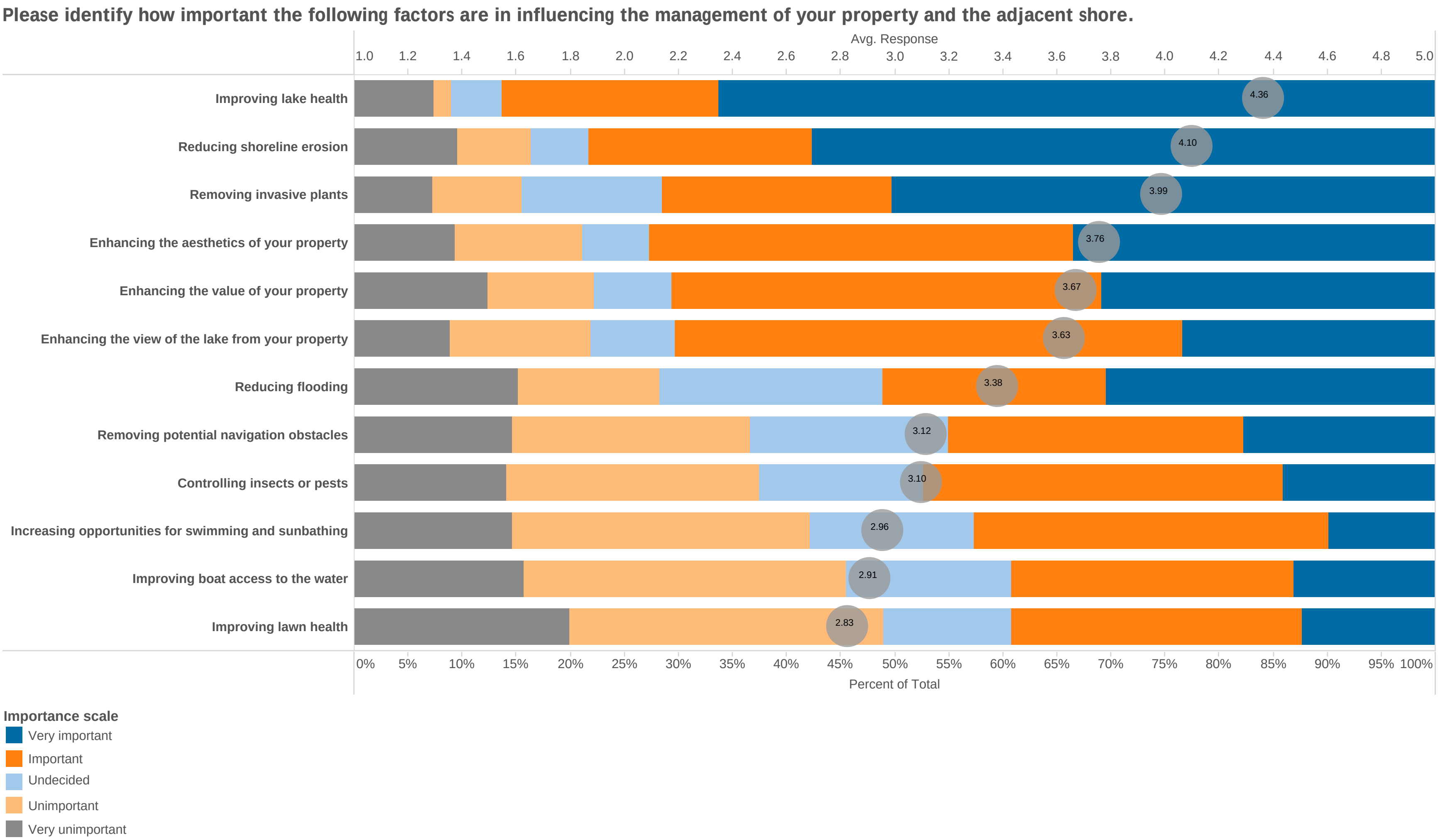


Figure 10.2. Importance of property management behaviors

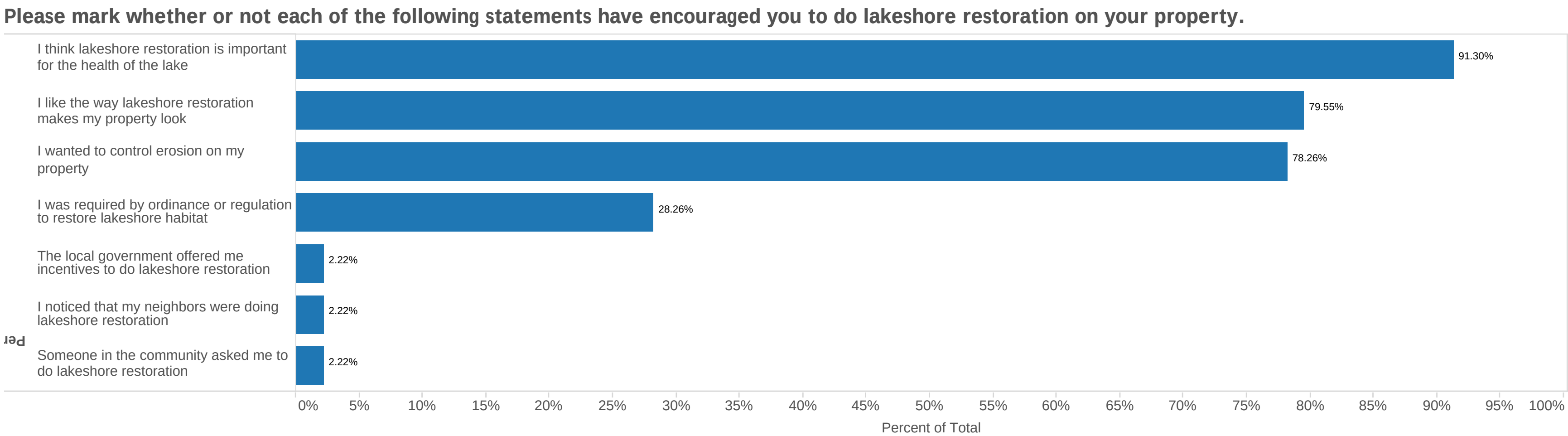


Figure 10.3 Reasons for engaging in lakeshore restoration

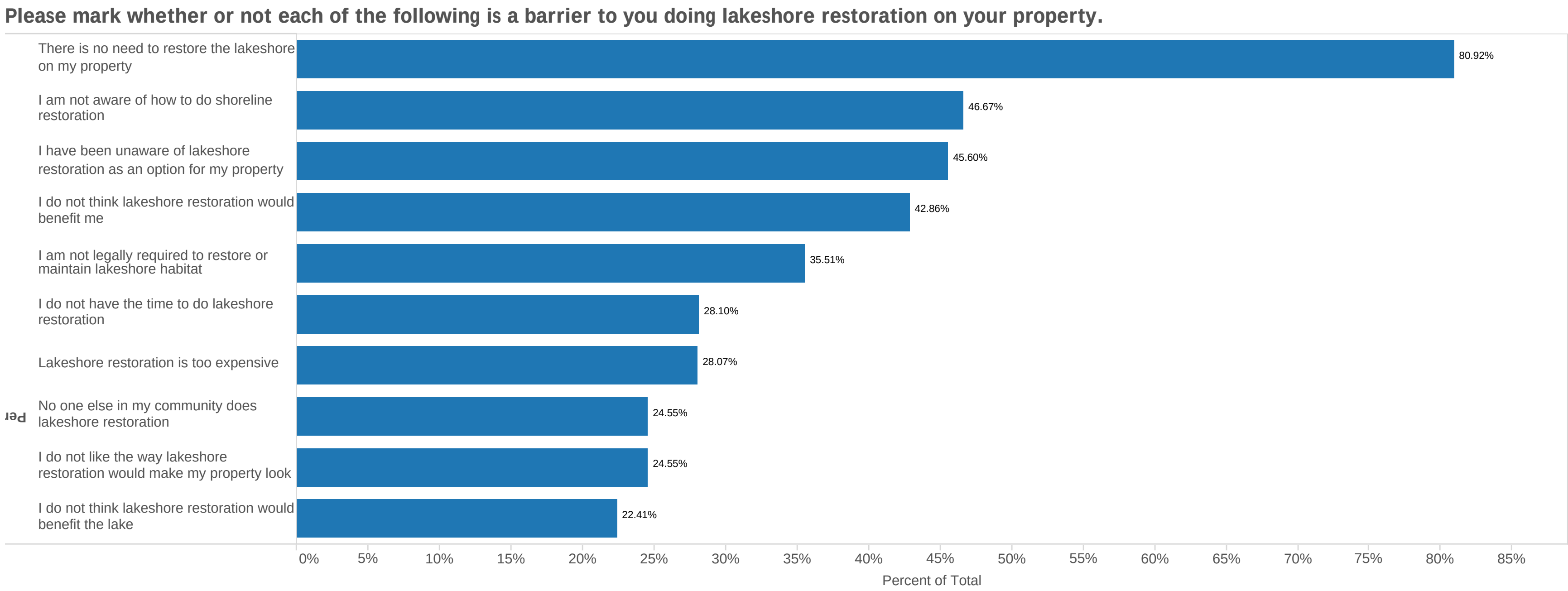


Figure 10.4. Barriers to lakeshore restoration

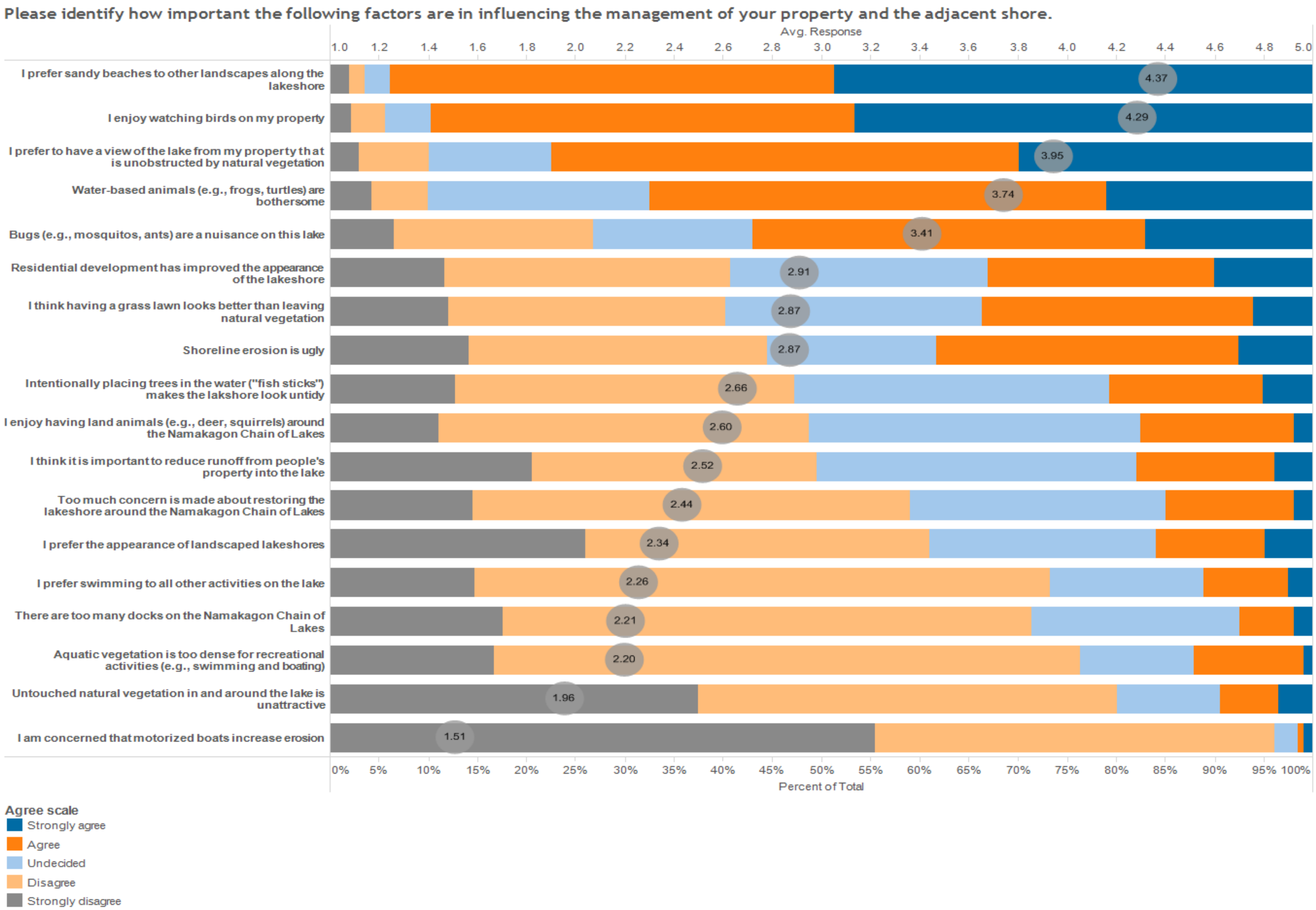


Figure 10.5 Participant attitudes toward the Namakagon Chain of Lakes

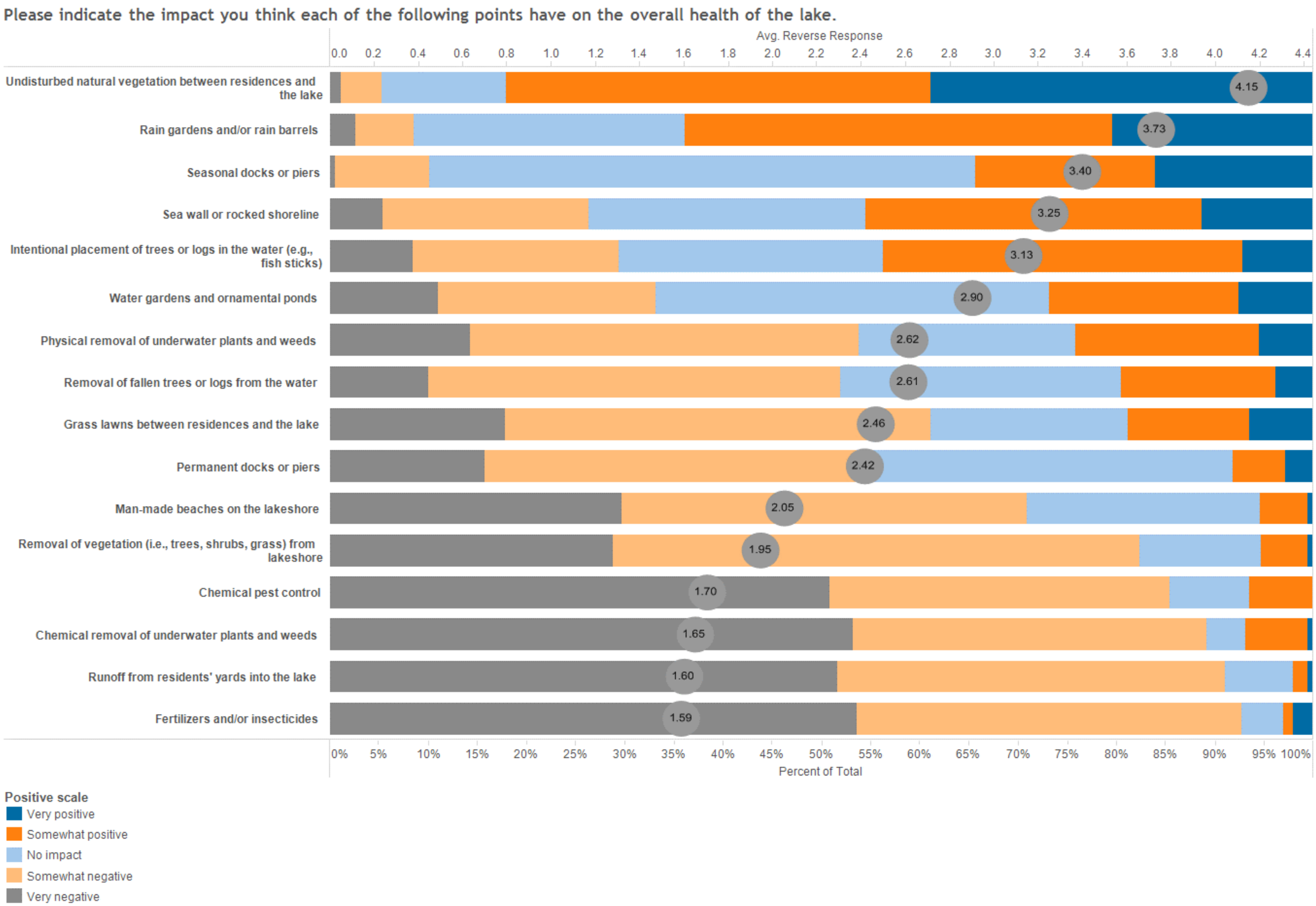


Figure 10.6 Impact of activities on the Namakagon Chain of Lakes

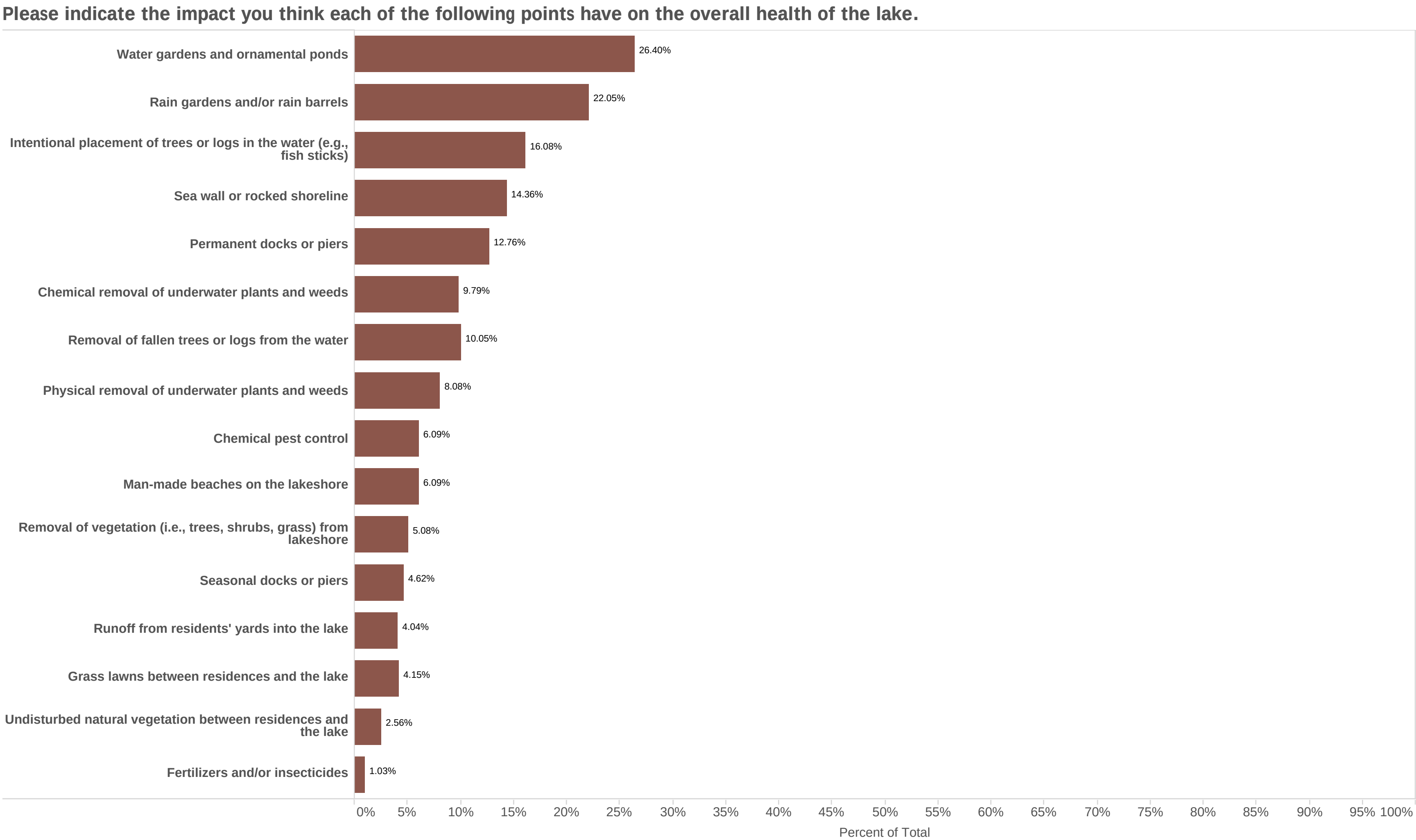


Figure 10.7 Percent of respondent who selected “Don’t Know” regarding impact of activities on lake health.

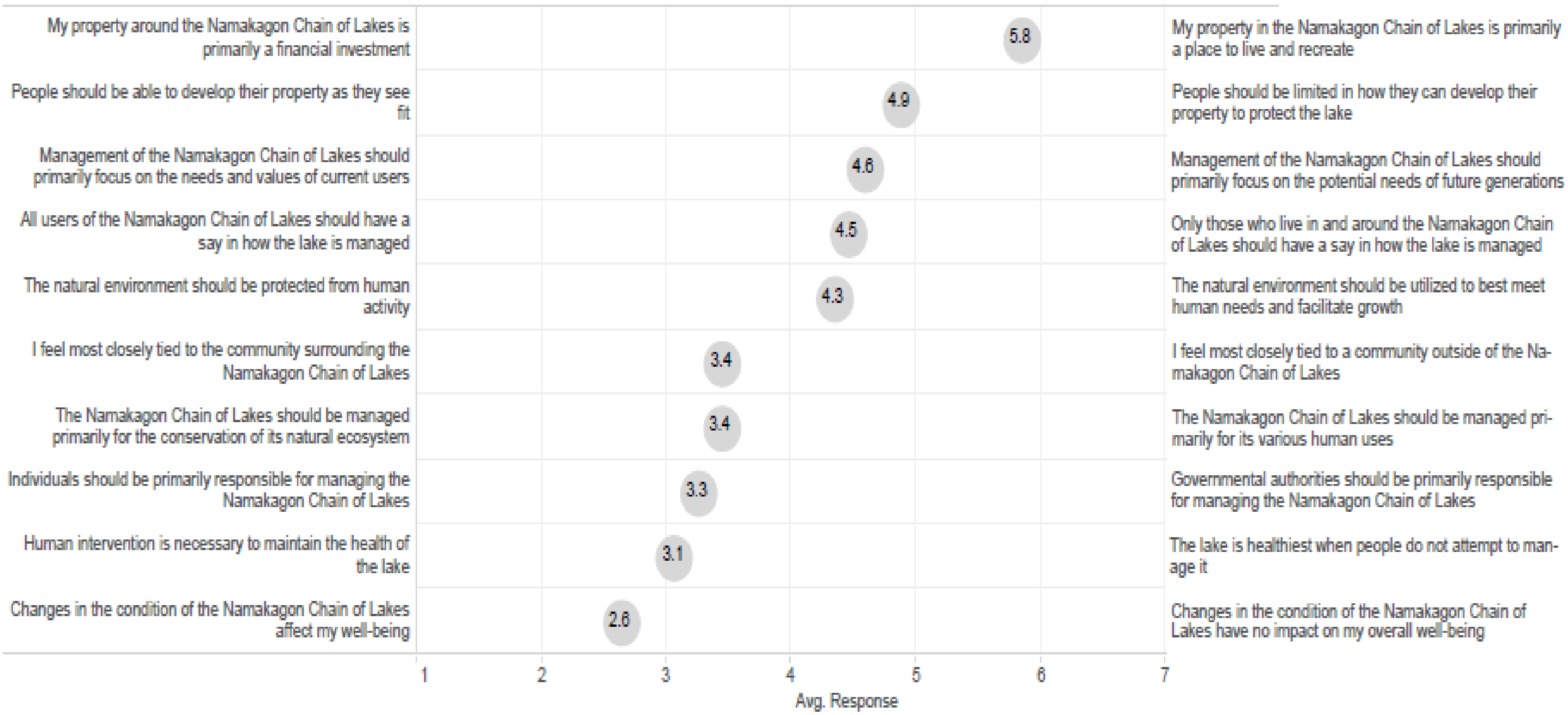


Figure 10.8 Participant Values

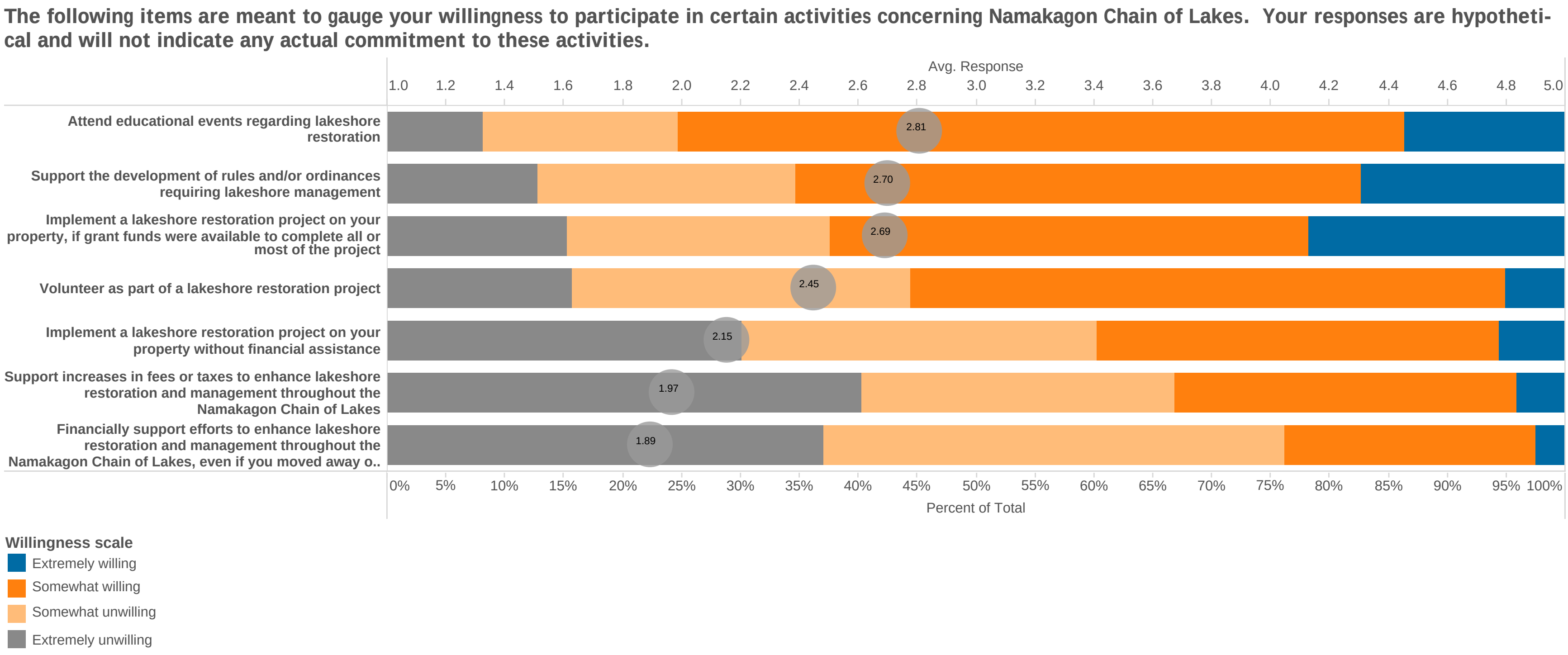


Figure 10.9 Participant willingness to participate in shoreland restoration

11. Appendix B – Summary of Physical-chemical Conditions

Introduction

This report summarizes the status of water quality conditions and physical processes in the Namakagon 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 Namakagon 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 Namakagon 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 lake.

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 lake (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 043115 (Garden Lake), 043111 (Jackson Lake) and 043113 (Lake Namakagon).

Hydrological processes and nutrient budgets were quantified using sequenced approach. Outflows from the Namakagon Chain (via the Namakagon River Outlet) were record over the study period. 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 Namakgon Chain (Table 11.1). Much of the water lost from all lakes within the Namakagon Chain is via the outlet to the Namakagon River (Figure 11.1). Because the outlet to the Namakagon River is regulated by a notched wire-dam system, 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 nutrients and pollutants downstream (Table 11.2). For example, Garden and Jackson Lakes are likely a significant sources of nutrients to Lake Namakagon.

Physical Processes
Physical processes throughout the Namakagon 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 Namakagon and Garden Lakes consistently stratified throughout the study period (Figure 11.2). However, Jackson Lake was often uniformly mixed (Figure 11.3), likely by wind. As a result of continual wind mixing, nutrients are likely to be continually re-suspended, making Jackson Lake more turbid and/or prone to algal blooms.

Water Clarity
Water clarity in the Namakagon Chain lakes is consistent with other similar lakes throughout the region. Average Secchi depths range from 2 to 6 meters and this clarity is generally mirrored by the Chl-a concentrations, which range from 3 to 30 ug/L (Figures 11.11 through 11.16). These results suggest that water clarity in the Namakagon Chain is primarily driven by algal growth and productivity. In general, water clarity appears to go through different phases throughout the Namakagon system, where average clarity will be consistent for several consecutive years, but may abruptly shift to clearer or more turbid conditions (which are then sustained for several years). Based on the dissolved oxygen concentrations (Figures 11.4 and 11.5) observed in the Namakagon 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 Namakagon Chain are consistent with regional mesotrophic/eutrophic lakes, but highly variable among the individual lakes (Figures 11.10, 11.14, 11.15 and 11.16). Surface water total phosphorus concentrations were highest in Jackson (averaging 51 ug/L) and Garden (averaging 29 ug/L) Lakes and lowest in Lake Namakagon (averaging 19 ug/L). While hypolimnetic phosphorus concentrations were double to triple that of surface water concentrations in Namakagon and Garden Lakes (Figure 11.17). Surface water TP concentrations are consistent with mesotrophic conditions within Namakagon and Garden Lakes, while concentrations in Jackson Lake are more consistent with eutrophic conditions.

These results suggest that sediment release of soluble phosphorus as a result of anoxic conditions in the hypolimnion are common in the Namakagon Chain. However, because of the concentrations of phosphorus in the hypolimnion are only moderately higher (two to three times) than in surface waters it is likely that internal loading is moderately affecting water quality conditions, particularly when strong wind events partially mix lake water throughout the growing season. Sediment release of phosphorus has the greatest potential to impact water quality management in Garden Lake, because the existing surface water concentrations of phosphorus are only slightly below the water quality criteria (discussed further below).

External Nutrient Budget
Within the Namakagon Chain ecosystem, the majority of the external phosphorus load originates from watershed runoff (Table 11.2). Most of this watershed loading of phosphorus likely occurs as part of spring snowmelt and rainfall. Approximately 41% of the phosphorus delivered to the lake from external sources is discharged through the outlet to downstream waters. Additional "internal"

sources and loss processes (which are particularly important in Jackson Lake) 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 Namakagon Chain lakes are generally consistent with their designation as a mesotrophic lakes. However, Jackson Lake may be considered eutrophic, given its polymictic dynamics and elevated TP concentrations. Water quality conditions in Garden Lake are consistent with the established water quality criterion of 30 ug/L.

Given the recent detection of cisco in 2015 by the WDNR, Lake Namakagon is now classified as a "two-tiered fishery", which has a corresponding phosphorus criteria of 15 ug/L. Total phosphorus concentrations are above the 15 ug/L criterion in Lake Namakagon. And, as a result, Lake Namakagon has been listed as an impaired waterbody and placed on the USEPA 303d list by the WDNR.

Given the lack of consistent thermal stratification in Jackson Lake, the most appropriate total phosphorus criterion is 40 ug/L. Since average phosphorus concentrations are above the 40 ug/L standard in Jackson Lake, this waterbody could be considered impaired as part of the 303d review process. However, given the limited number of potential phosphorus sources in the Jackson Lake watershed, it is unlikely that the elevated phosphorus concentrations are reflective of a specific pollutant source. Elevated phosphorus concentrations in Jackson Lake are more likely a natural condition that exists because of upstream wetlands and wind mixing of the water column. The water quality conditions observed throughout this study are consistent with the fishery and aquatic plant community data that have been collected for the lake (see Section 5.4 and Appendix E).

Management and Monitoring Considerations

Because the Namakagon Chain is generally unimpacted by pollutant runoff, primary management activities should focus on protection efforts to minimize nutrient runoff to the lake and alteration of the lake's hydrologic cycle. The primary regulatory and technological options related to water quality protection in Namakagon Chain lakes are related to land use and planning, and thus are described in Section 7. Efforts to minimize additional nutrient runoff to the Namakagon Chain are most important in Namakagon and Garden Lakes and their surrounding watershed, since existing water quality conditions are closest to or already exceeding the corresponding water quality criteria. Since Jackson Lake is continually mixed, this waterbody should be reclassified as "un-stratified". Additionally, because existing phosphorus concentrations in Jackson Lake are above state water quality criteria, a more detailed water quality study should be conducted to more specifically identify the source(s) of this phosphorus.

Because total phosphorus concentrations in Lake Namakagon are above the established water quality criterion, additional analyses should be conducted to determine the most appropriate course of management action to protect the two-tiered cisco fishery. Total phosphorus and chlorophyll concentrations have been relatively stable in Lake Namakagon since 1998, suggesting that water quality has not significantly changed or degraded over the last 20 years. Additionally, because the existing fishery survey data suggest that cisco populations were previously unknown in Lake Namakagon and appear to occur are at relatively low densities, it is unclear if changes in water quality have limited the survival of cisco in the system, or if current water quality conditions (although above the 15 ug/L total phosphorus criterion) have historically supported a small, remnant cisco population. Ongoing study should be conducted to determine if water quality degradation has caused a decline is cisco abundance or if Lake Namakagon historically only supported small cisco populations that have only recently been formally documented.

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 Namakagon 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 three sites that reflect general conditions throughout the lake. 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 Namakagon 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 the Namakagon Chain lakes based on WiLMS predictions.

Lake	Runoff Volume (acre-ft)	Evaporation (inches)	Outflow Volume (acre-ft)	Flushing Rate (per year)	Residence Time (year)
Namakagon	31,770	8.6	33,200	0.79	1.26
Garden	9,670	8.6	10,000	1.79	0.56
Jackson	5,083	8.6	5,160	4.33	0.23

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

Lake	Watershed Area (Acres, wo/water)	Phosphorus Source (lbs/yr)			Total Load (lbs/yr)	Outflow P Load (lbs/yr)
		Watershed Runoff	Septic System	Atmospheric		
Namakagon	27,231	2268	213	696	3177	1983
Garden	8,714	694	73	150	917	752
Jackson	4,357	363	24	40	427	618

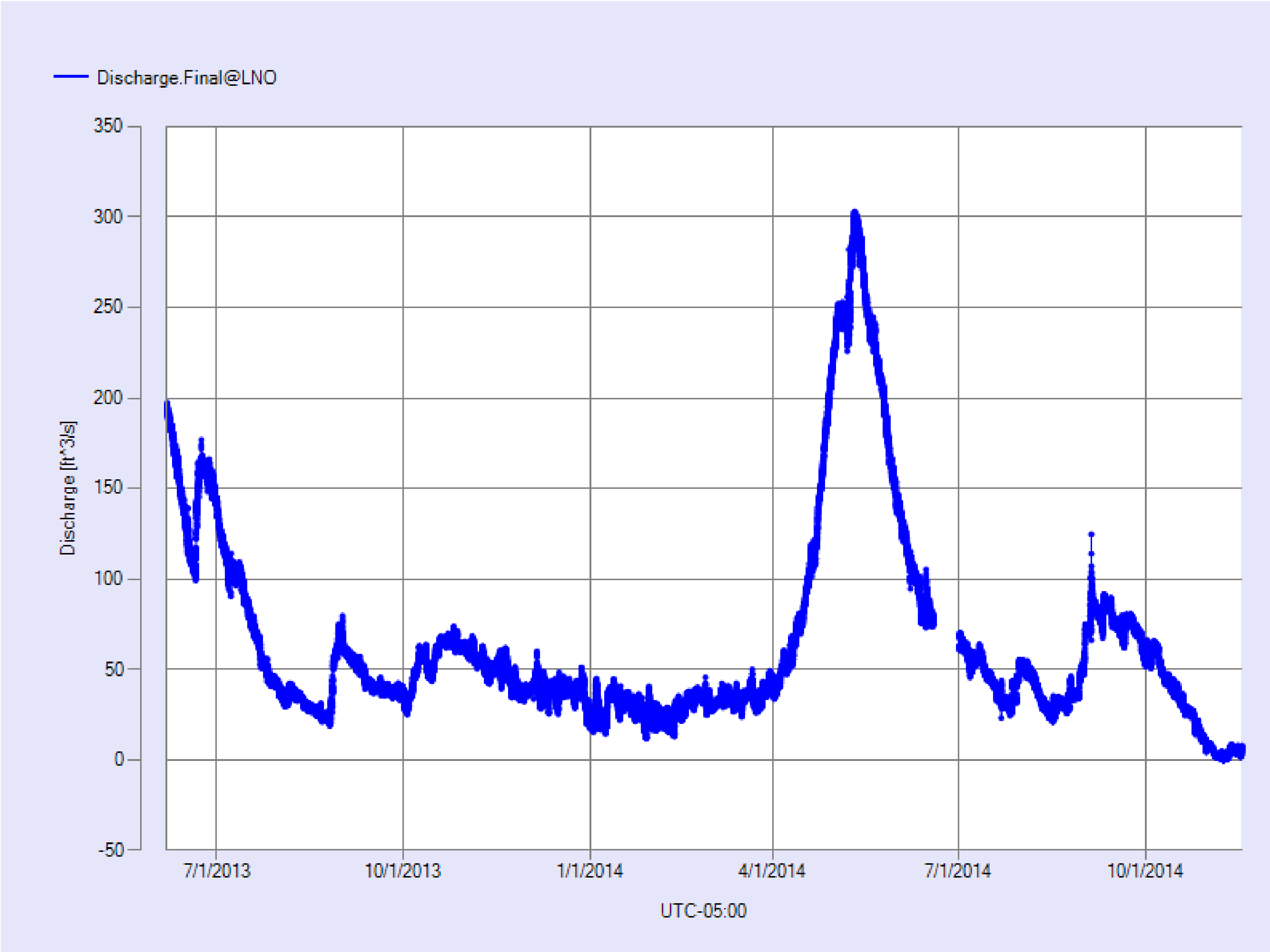
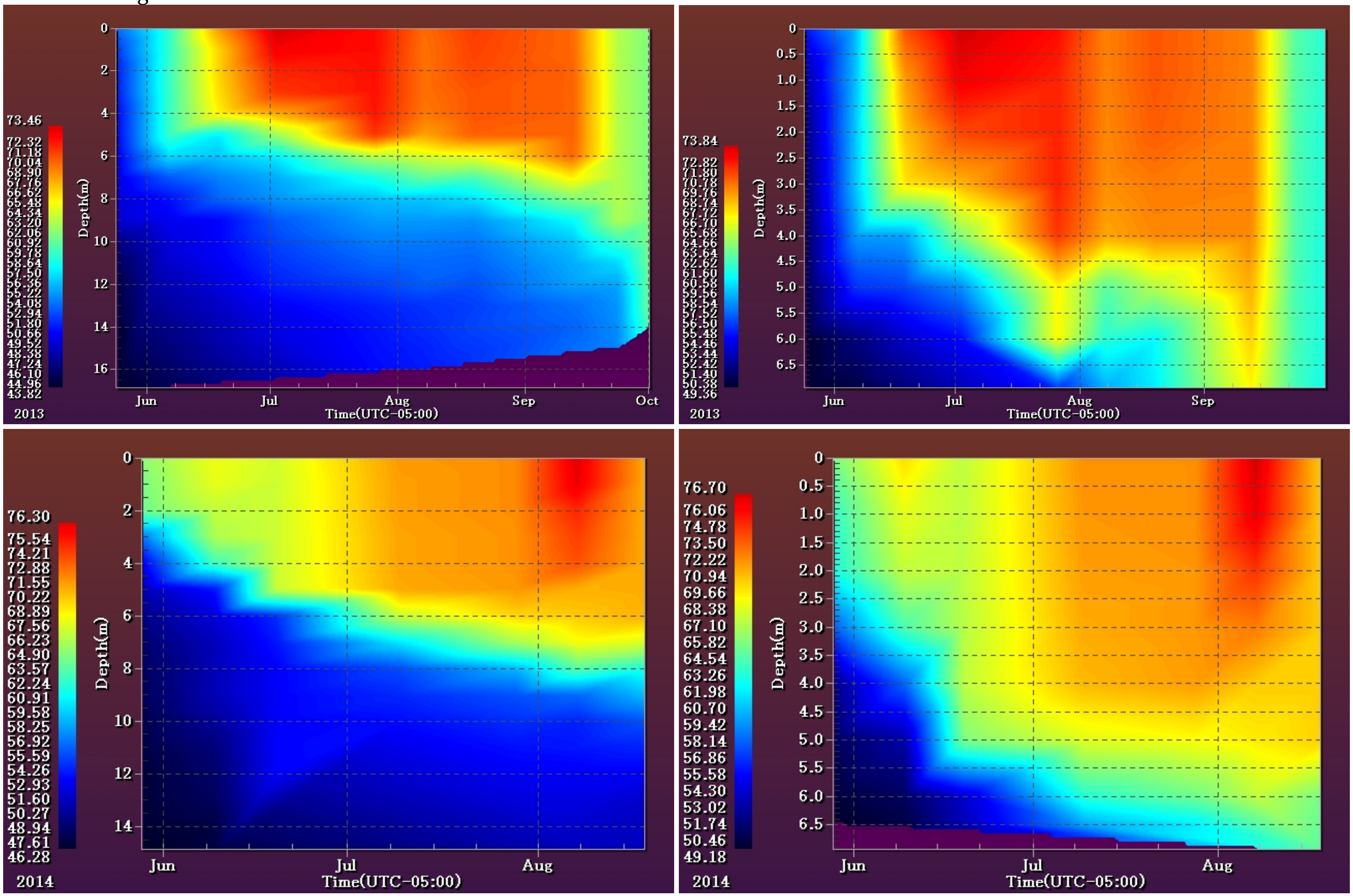


Figure 11.1 Discharge (in cubic feet per second) from the Namakagon River at the Lake Namakagon outlet from June 2013 to November 2014.

Lake Namakagon | Garden Lake



2013

2014

Figure 11.2 Thermal stratification (degrees Fahrenheit) in Namakagon and Garden Lakes in 2013 and 2014.

2013 2014

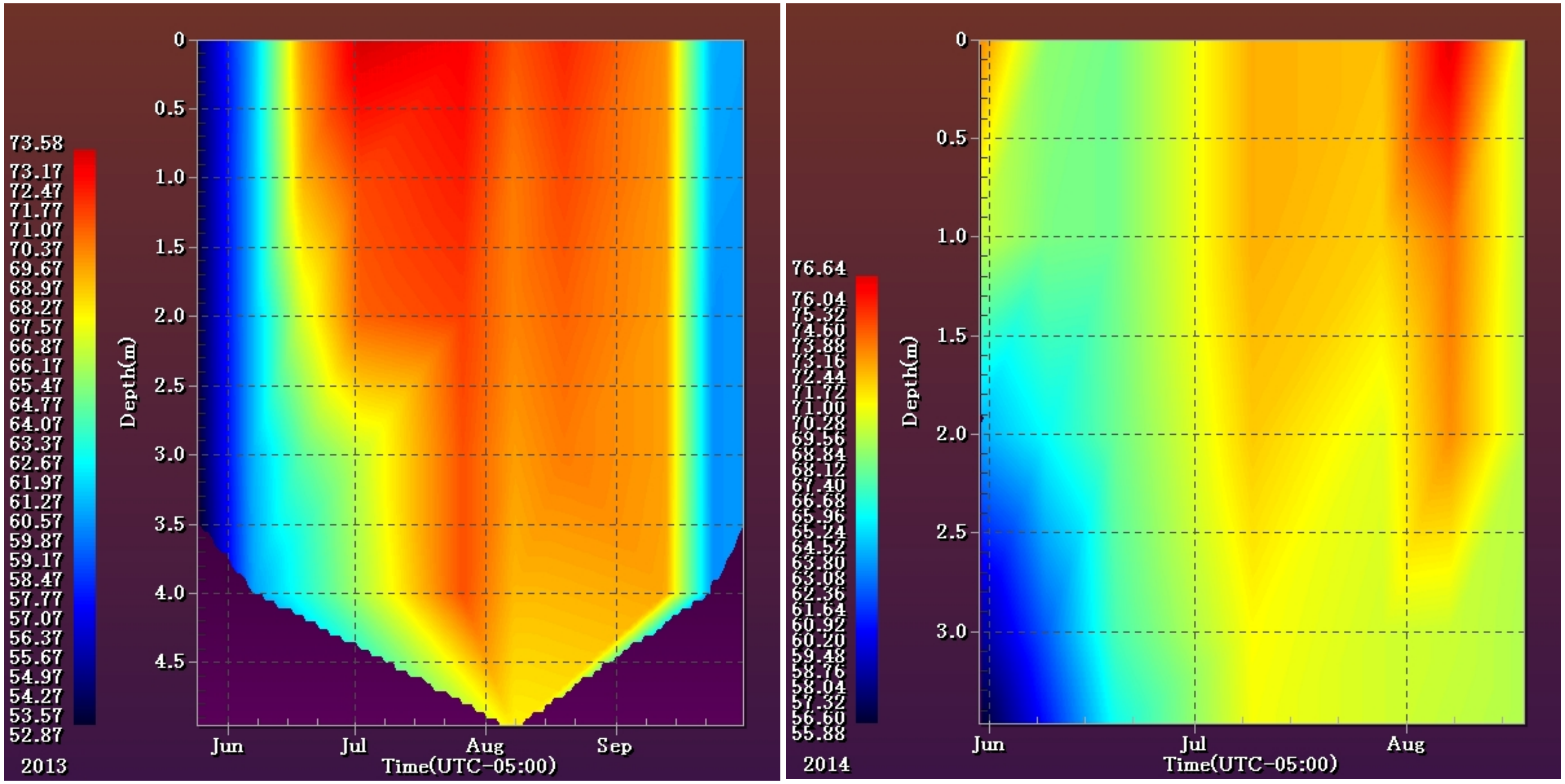
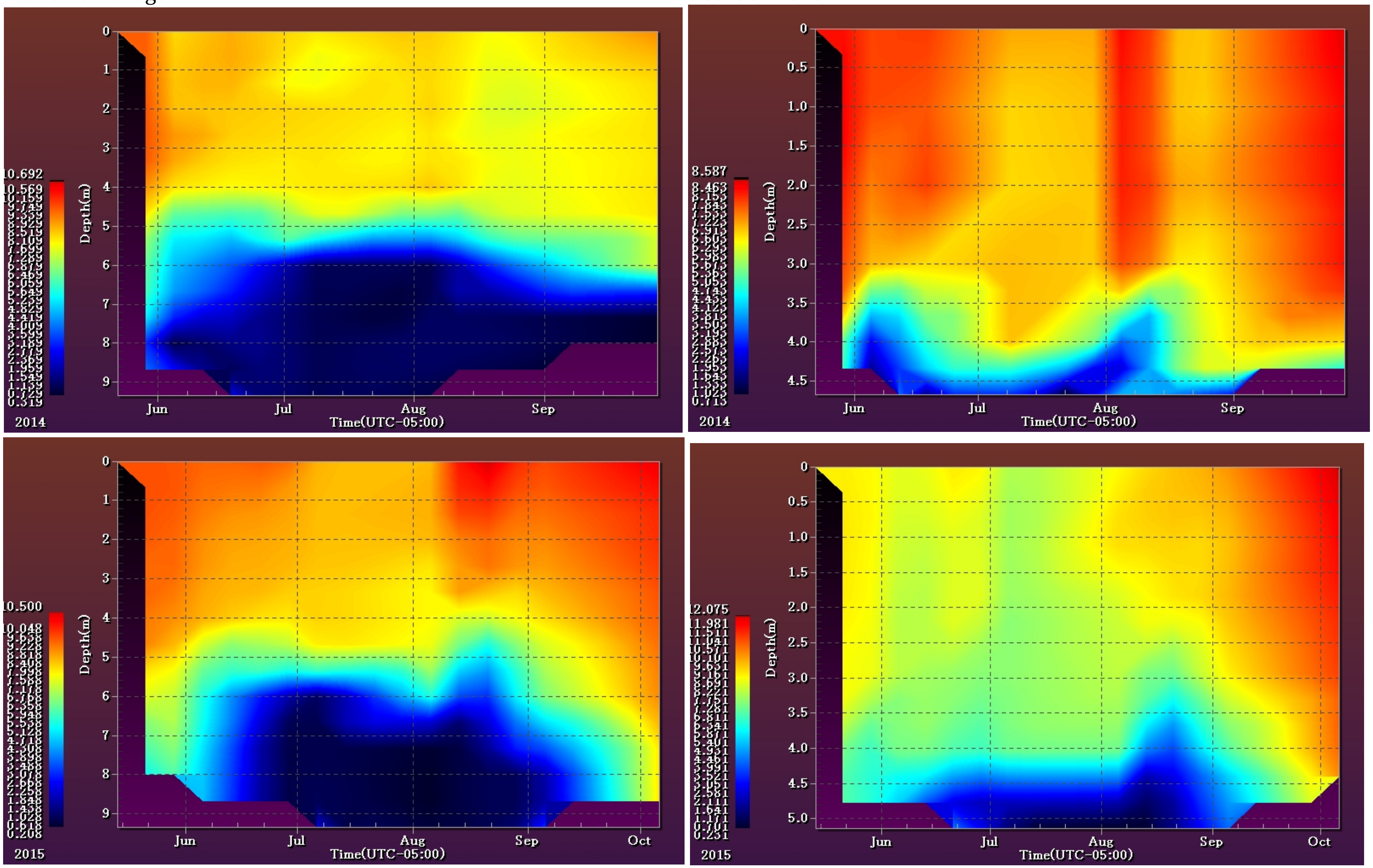


Figure 11.3 Thermal stratification (degrees Fahrenheit) in Jackson Lake in 2013 and 2014.

Lake Namakagon

Garden Lake



2013

2014

Figure 11.4 Dissolved oxygen (mg/L) stratification in Namakagon and Garden Lakes in 2013 and 2014.

2013 2014

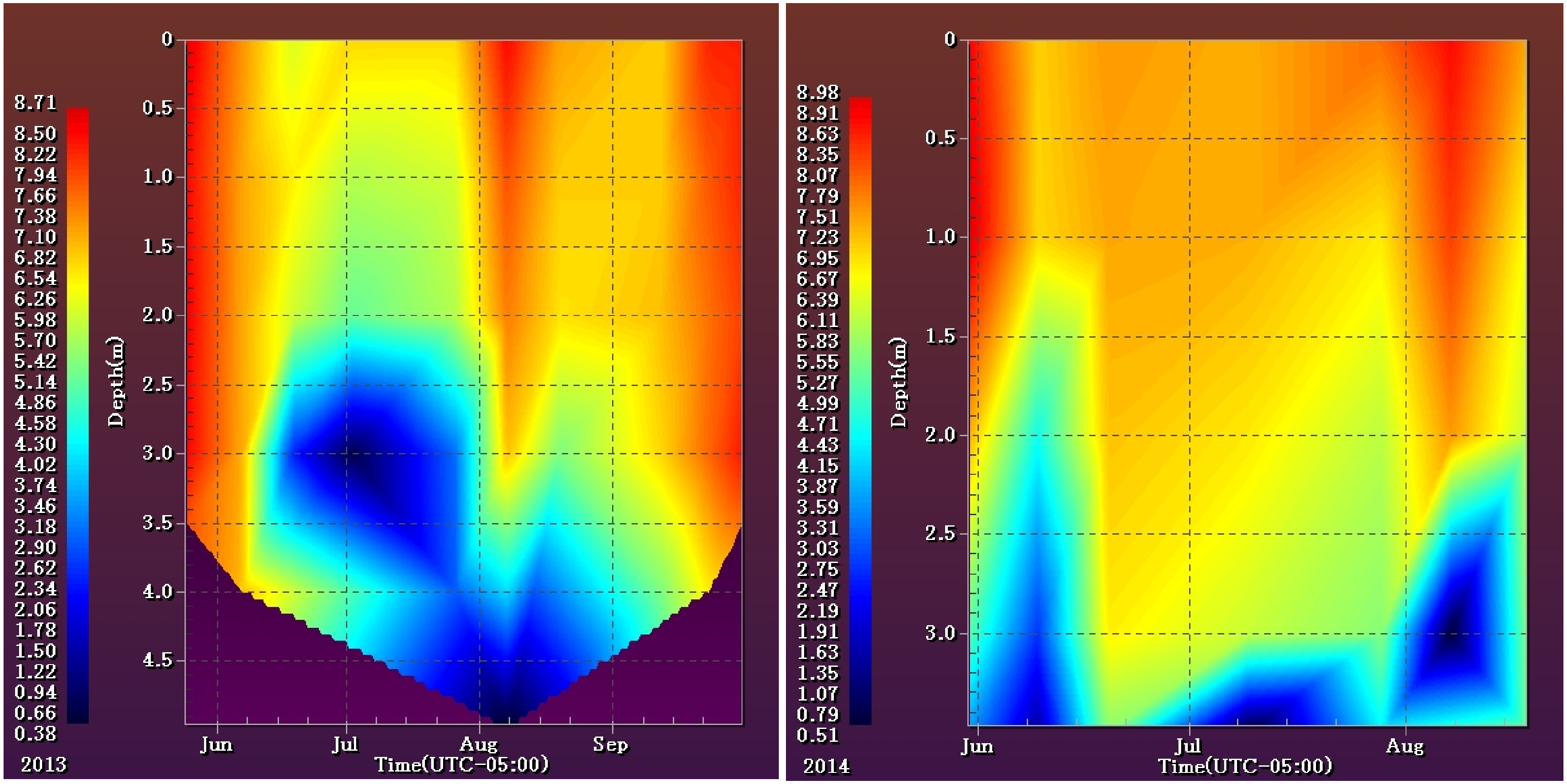


Figure 11.5 Dissolved oxygen (mg/L) stratification in Jackson Lake in 2013 and 2014.

Lake Namakagon Garden Lake

2013

2014

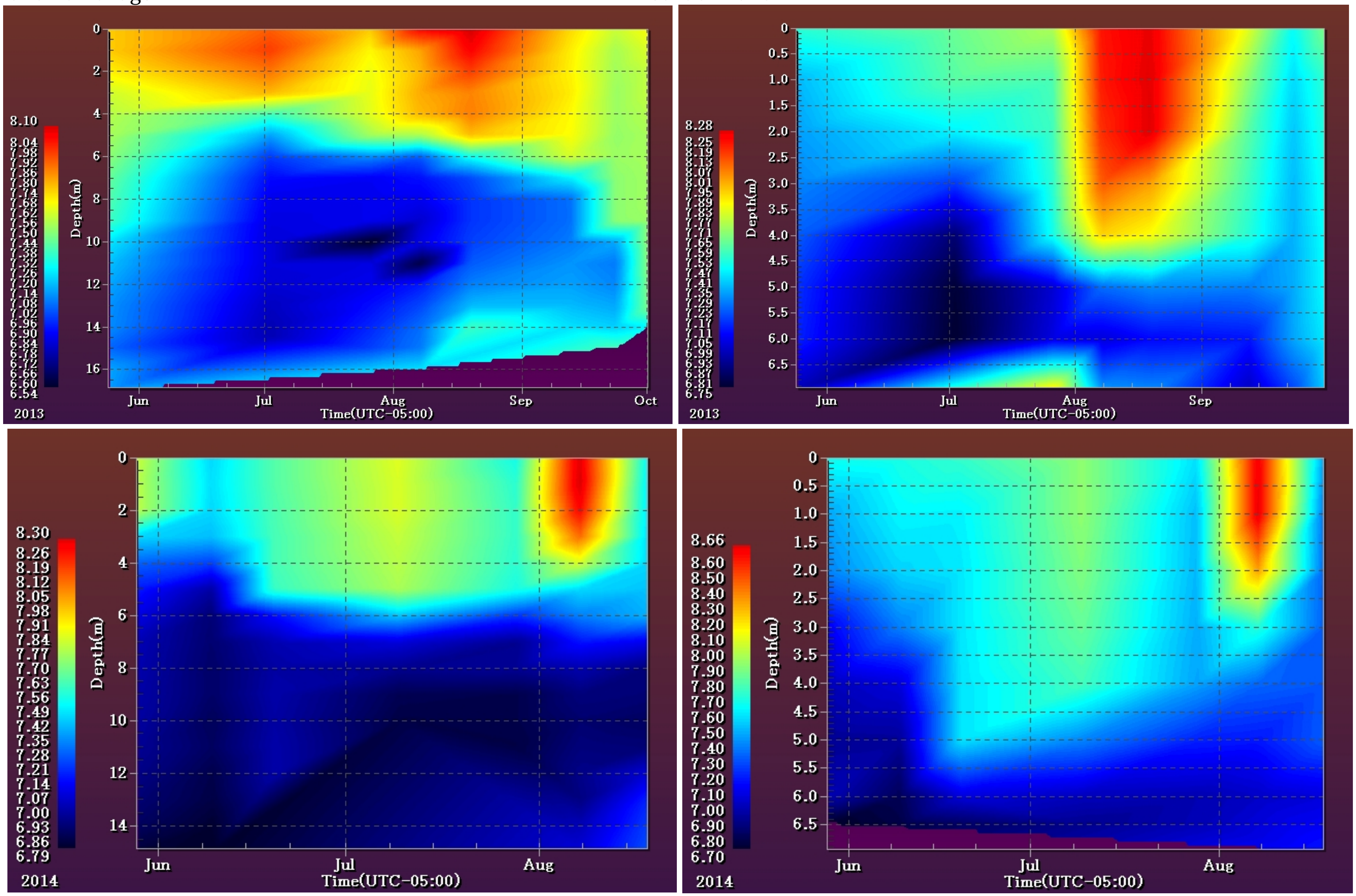


Figure 11.6 pH stratification in Namakagon and Garden Lakes in 2013 and 2014.

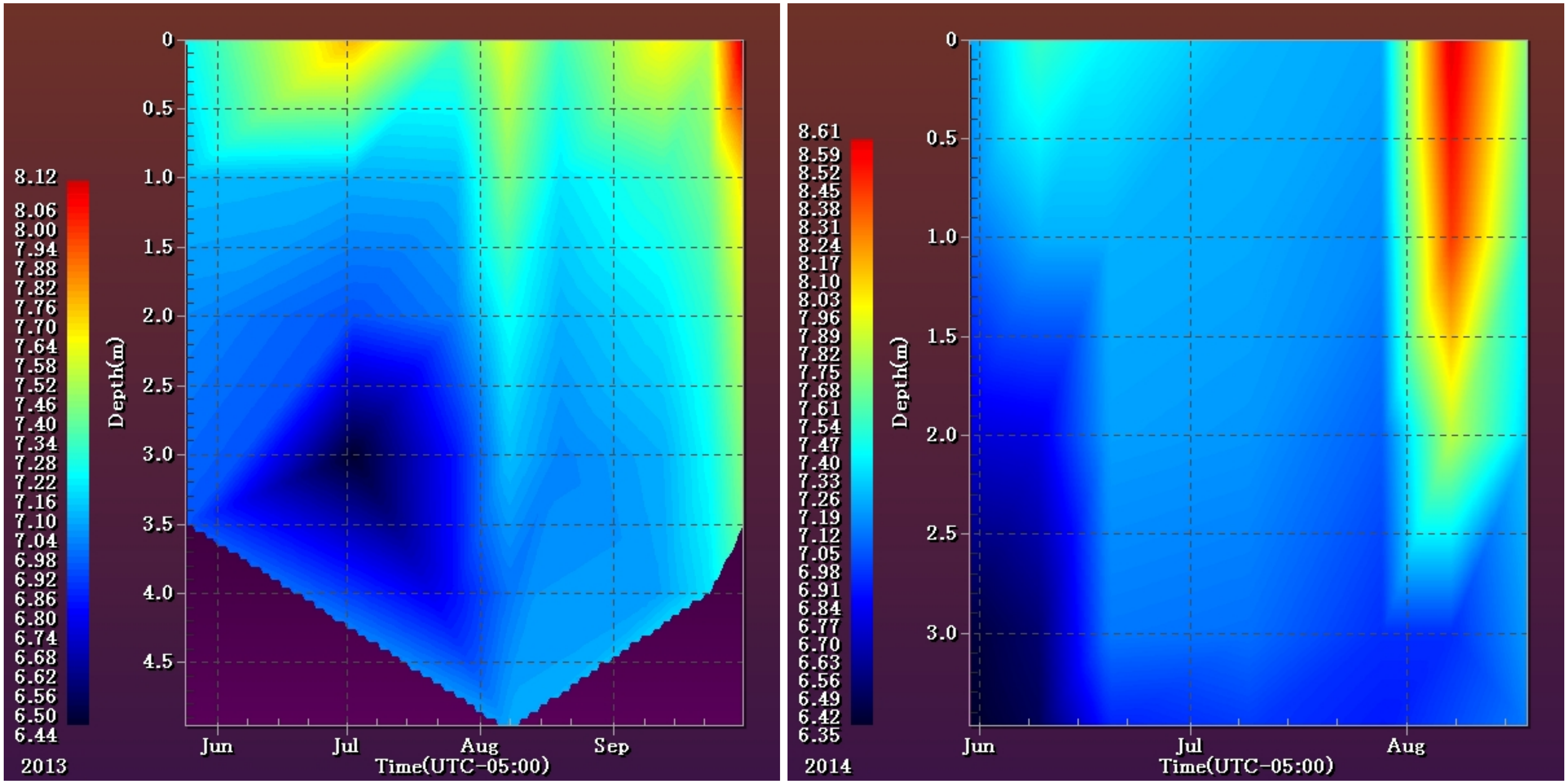
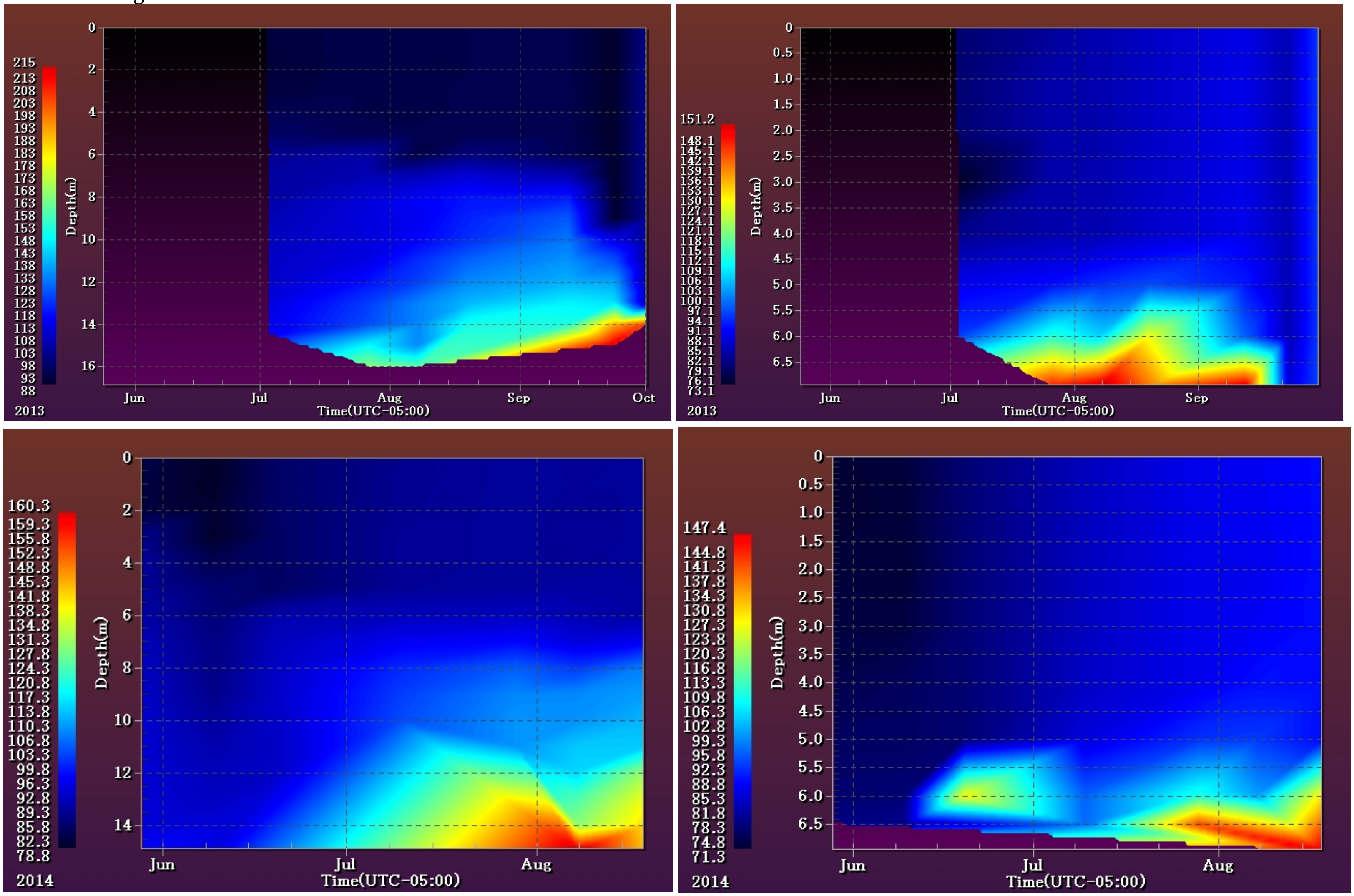


Figure 11.7 pH stratification in Jackson Lake in 2013 and 2014.

Lake Namakagon Garden Lake



2013

2014

Figure 11.8 Specific conductance (uS/cm) stratification in Namakagon and Garden Lakes in 2013 and 2014.

2013 2014

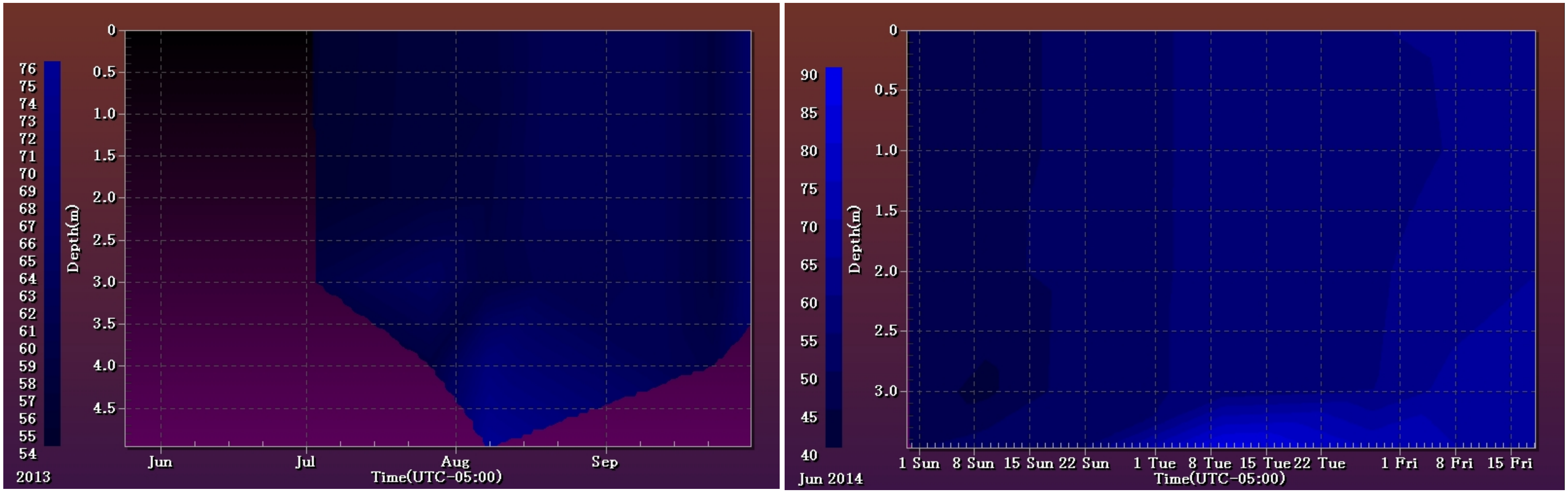


Figure 11.9 Specific conductance (uS/cm) stratification in Jackson Lake in 2013 and 2014.

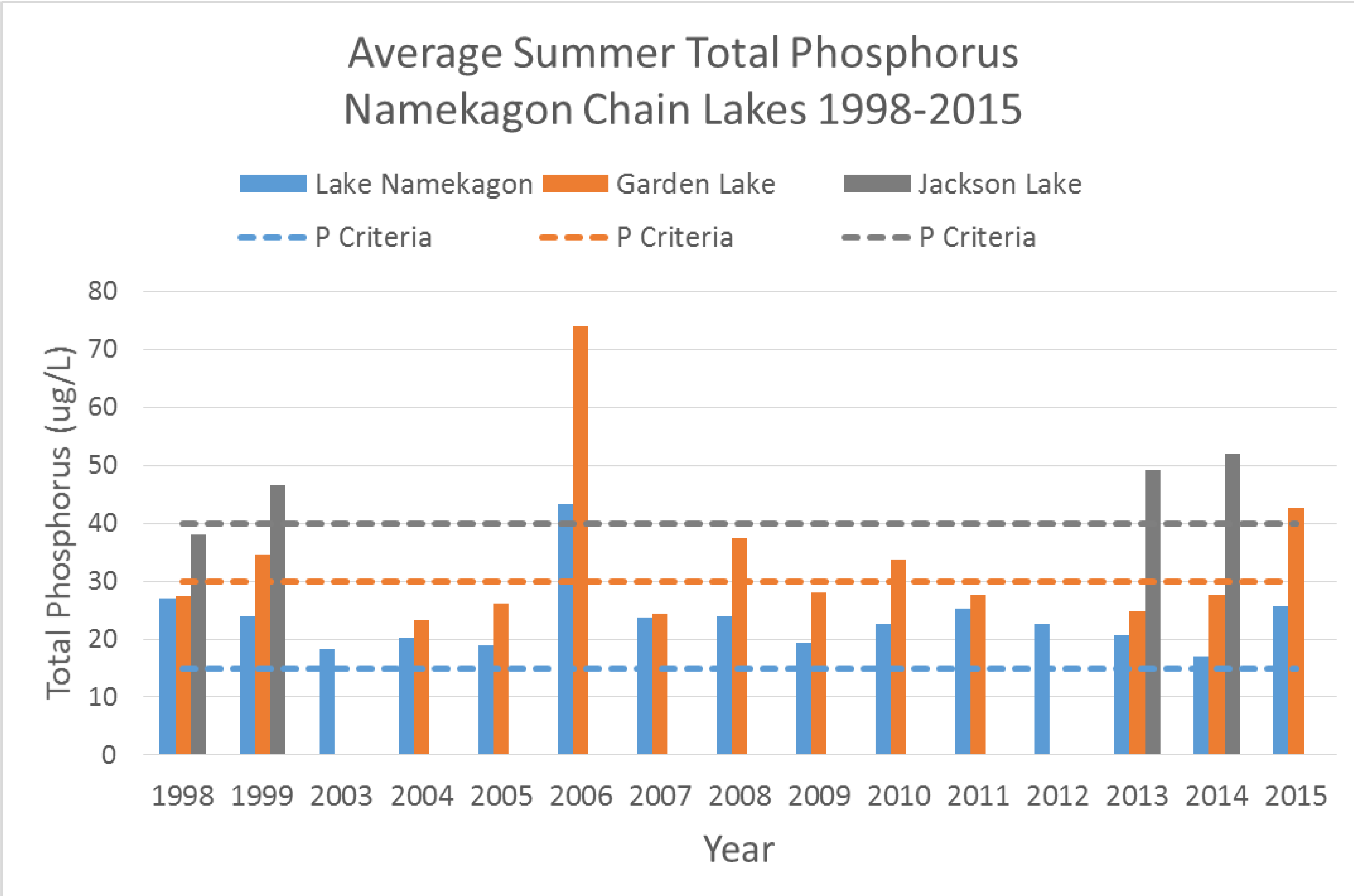


Figure 11.10 Seasonal phosphorus concentrations in Namakagon, Garden and Jackson Lakes (1998-2015).

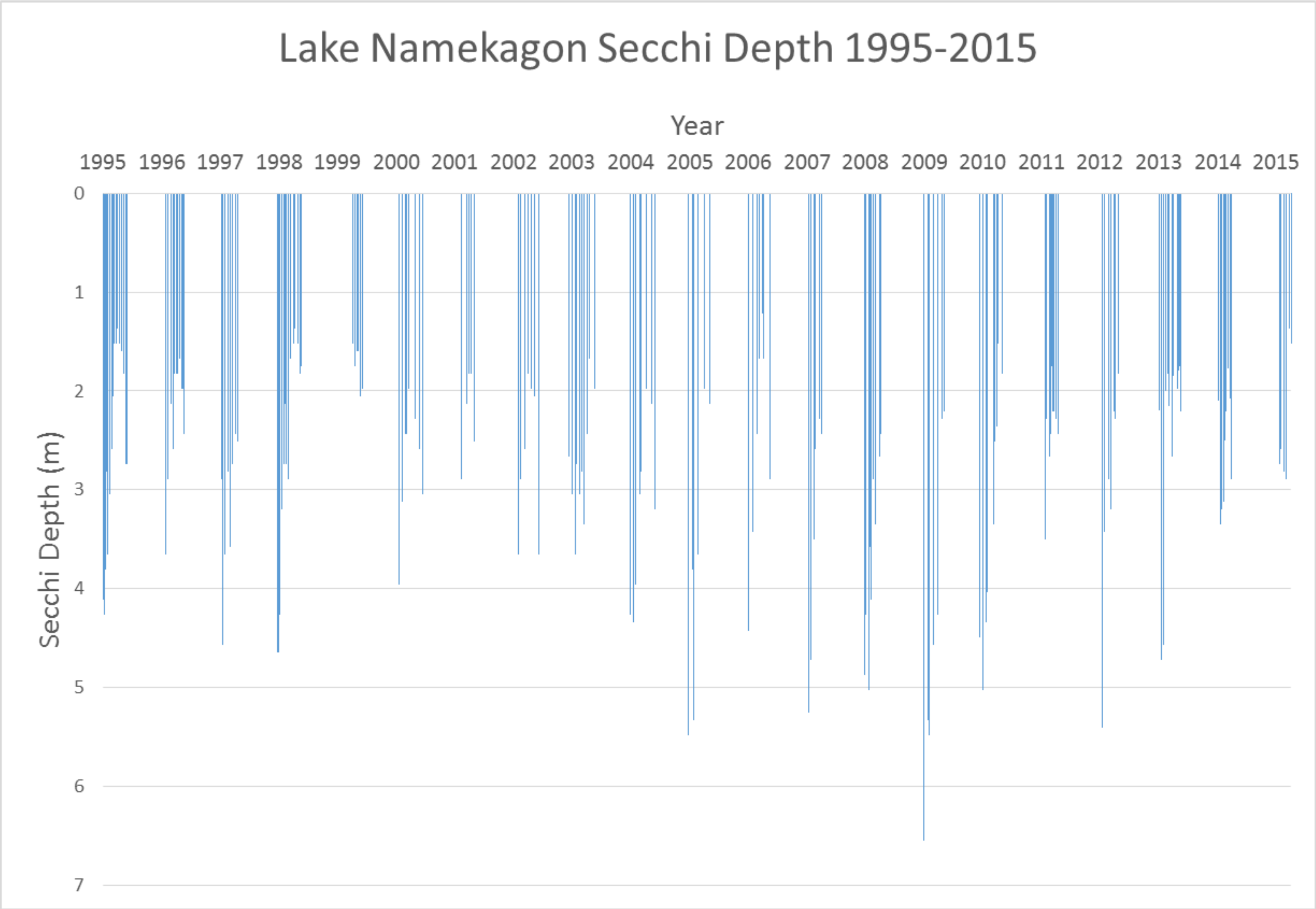


Figure 11.11 Historical trends in water clarity in Lake Namakagon.

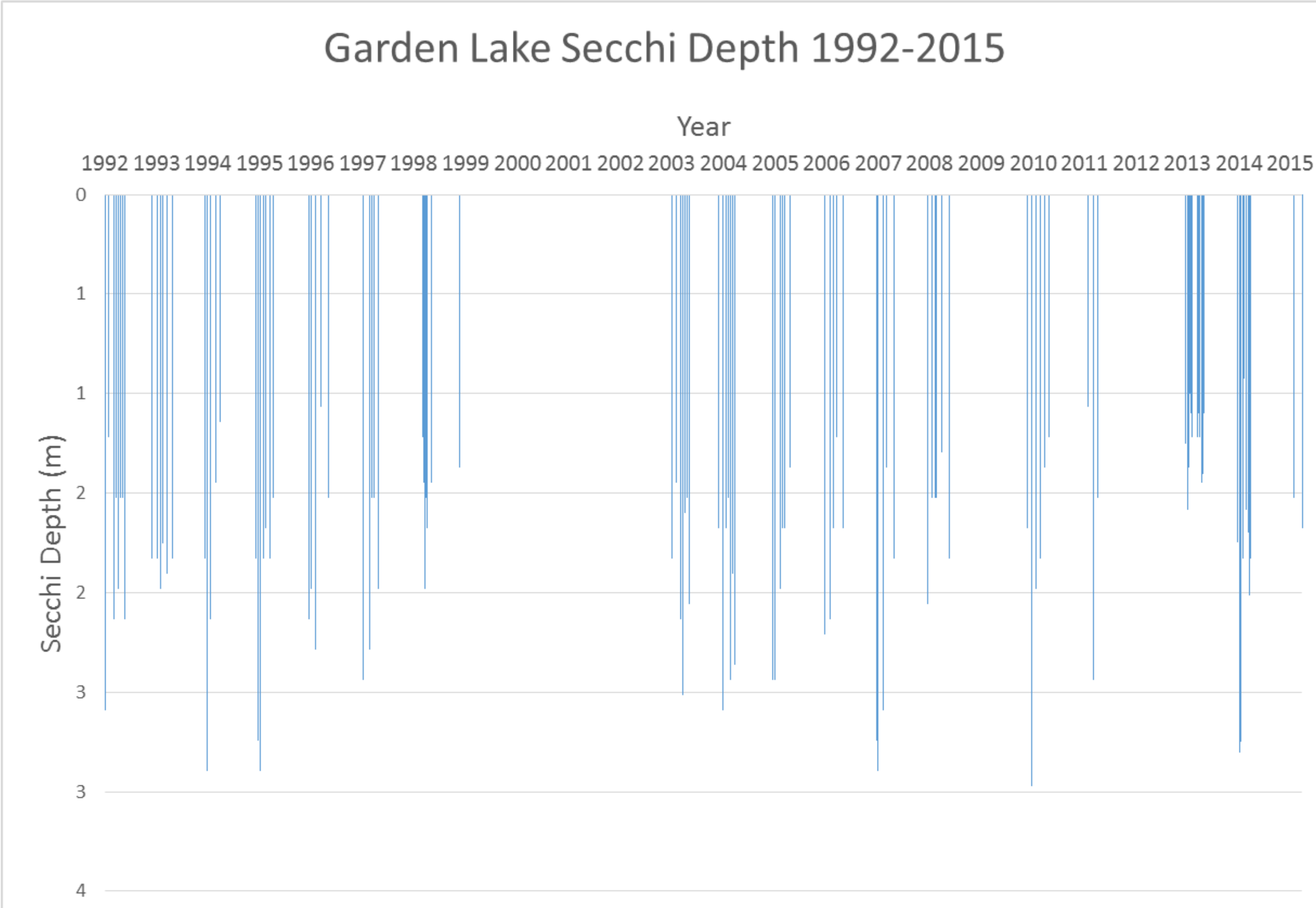


Figure 11.12 Historical trends in water clarity in Garden Lake.

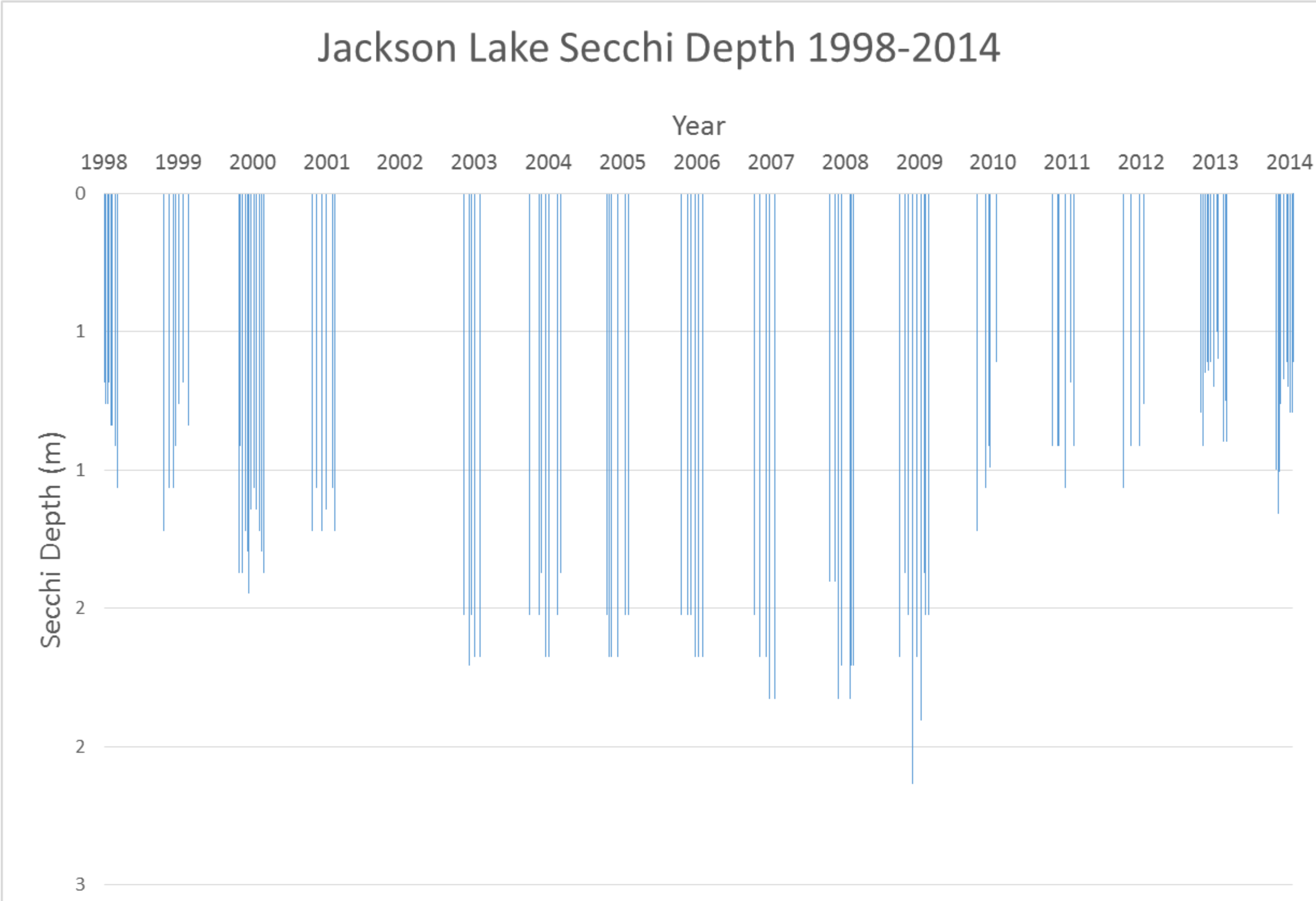


Figure 11.13 Historical trends in water clarity in Jackson Lake.

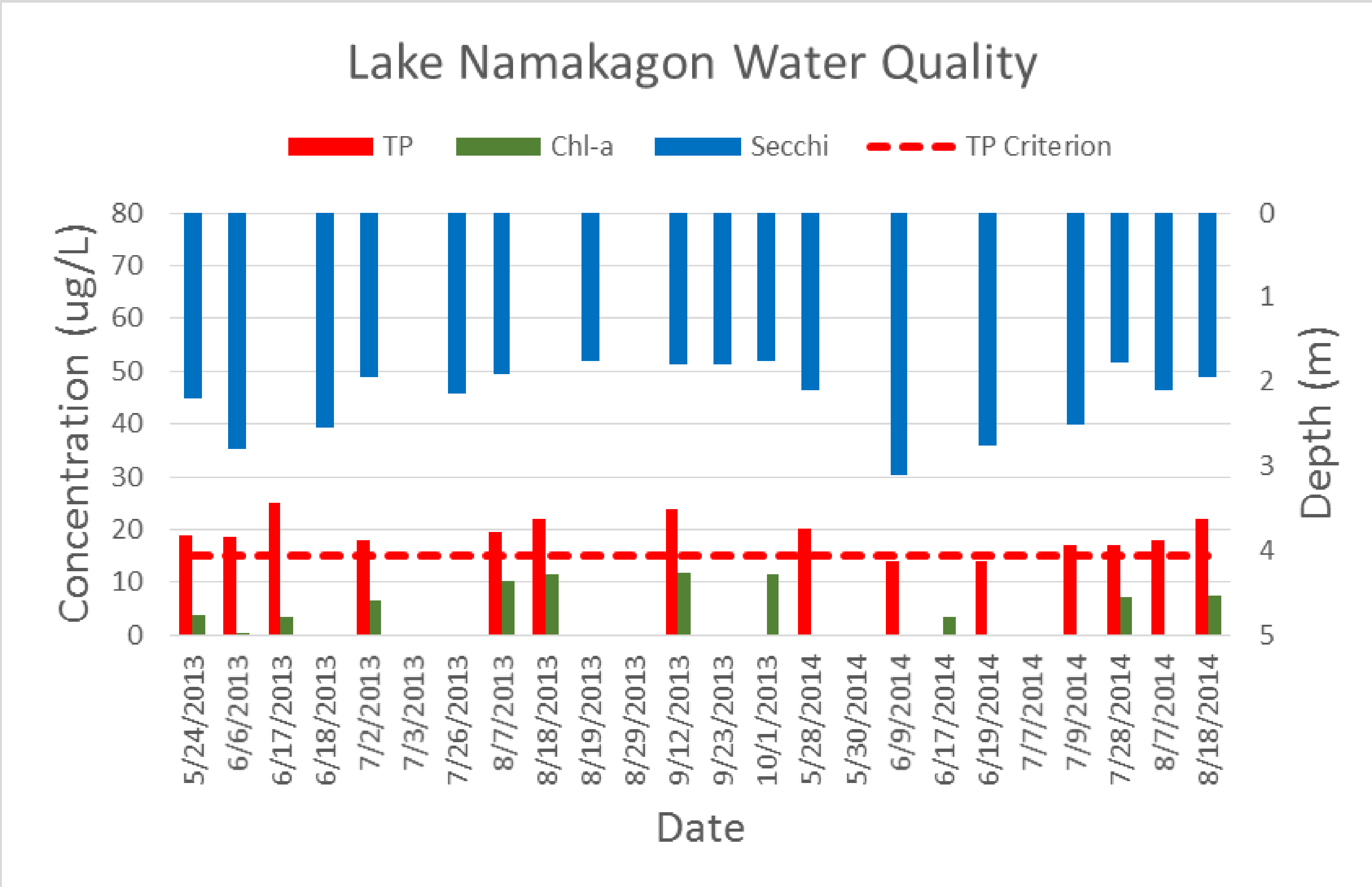


Figure 11.14 Seasonal water quality trends in Lake Namakagon.

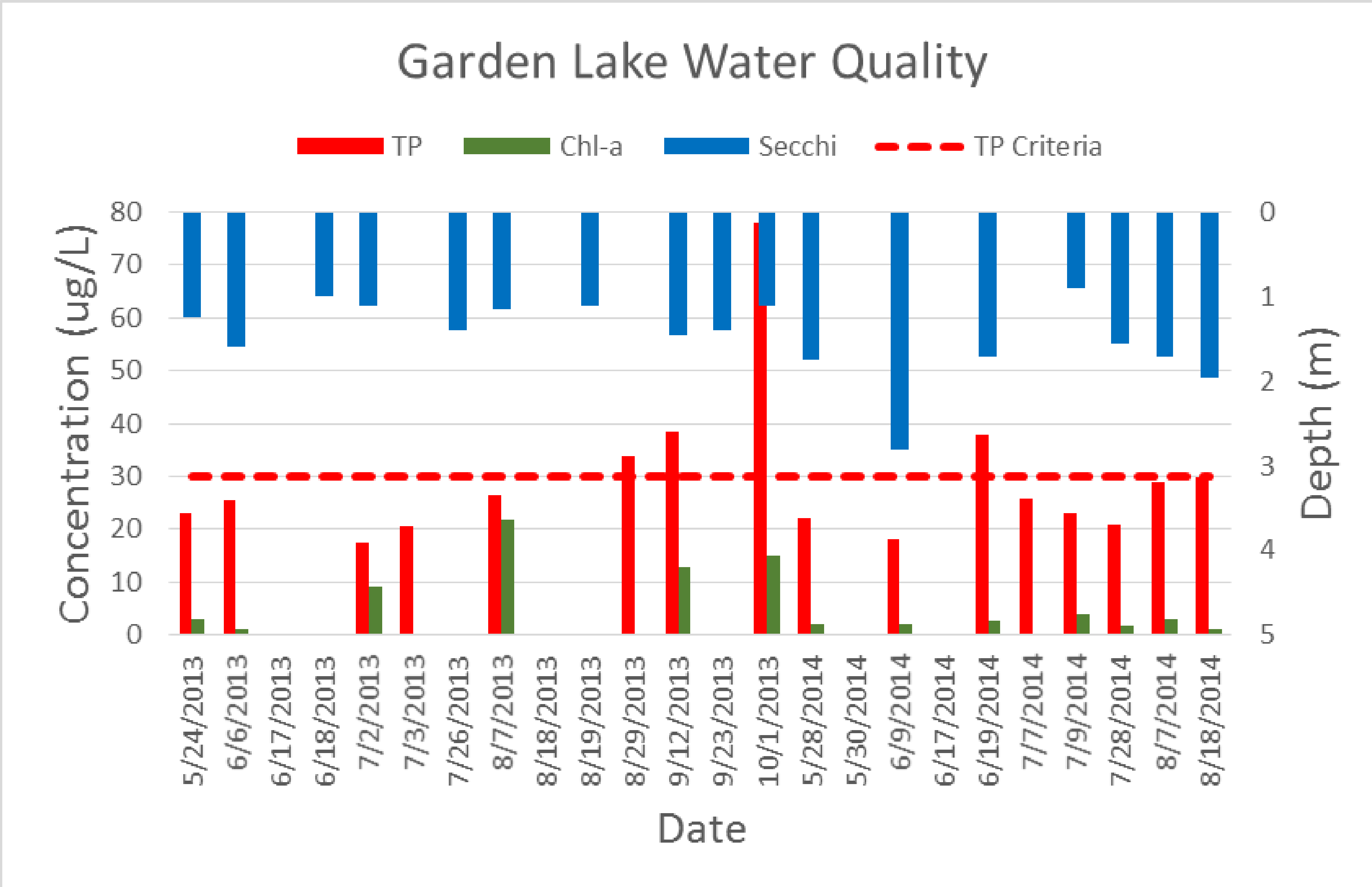


Figure 11.15 Seasonal water quality trends in Garden Lake.

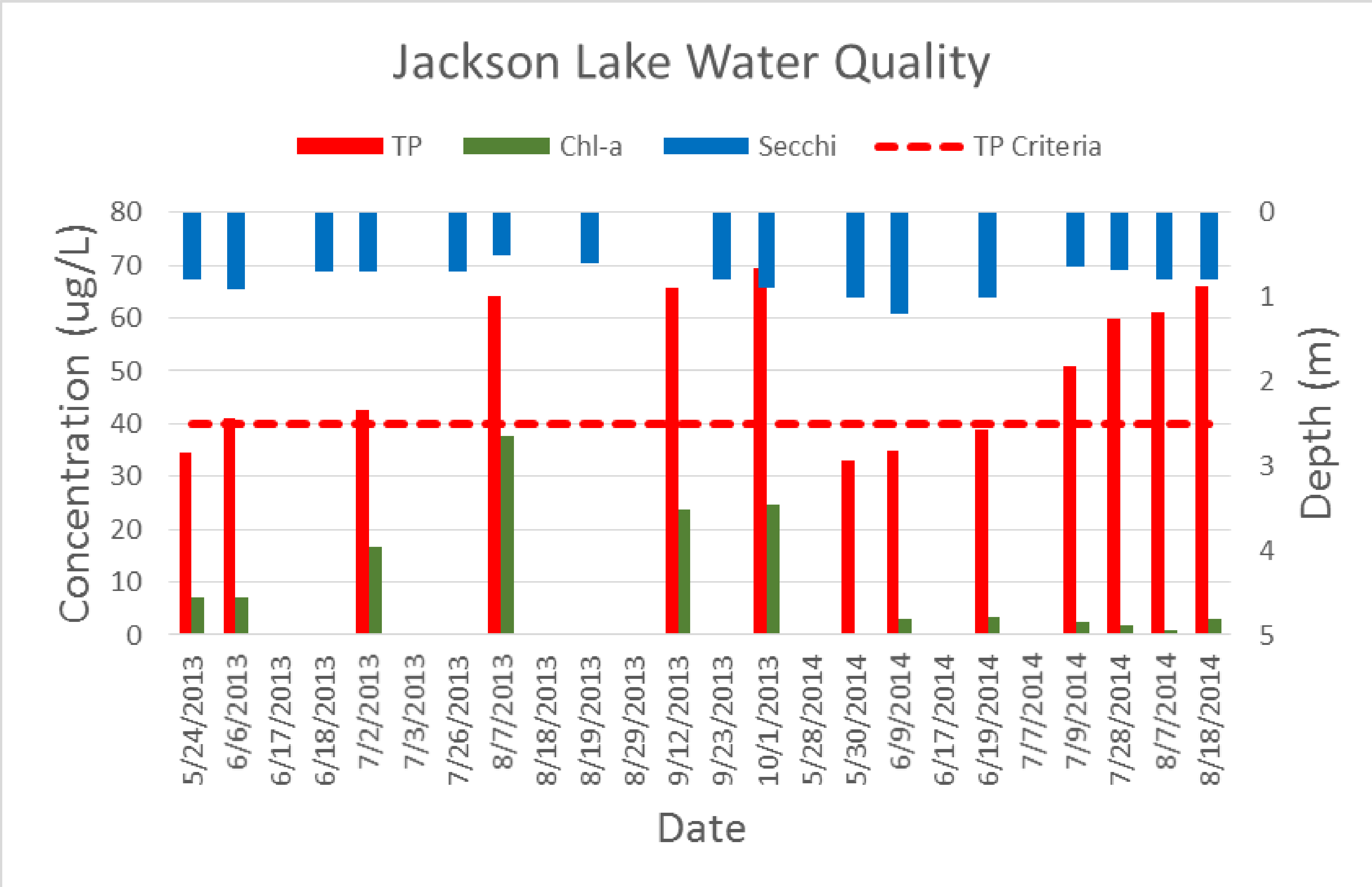


Figure 11.16 Seasonal water quality trends in Jackson Lake.

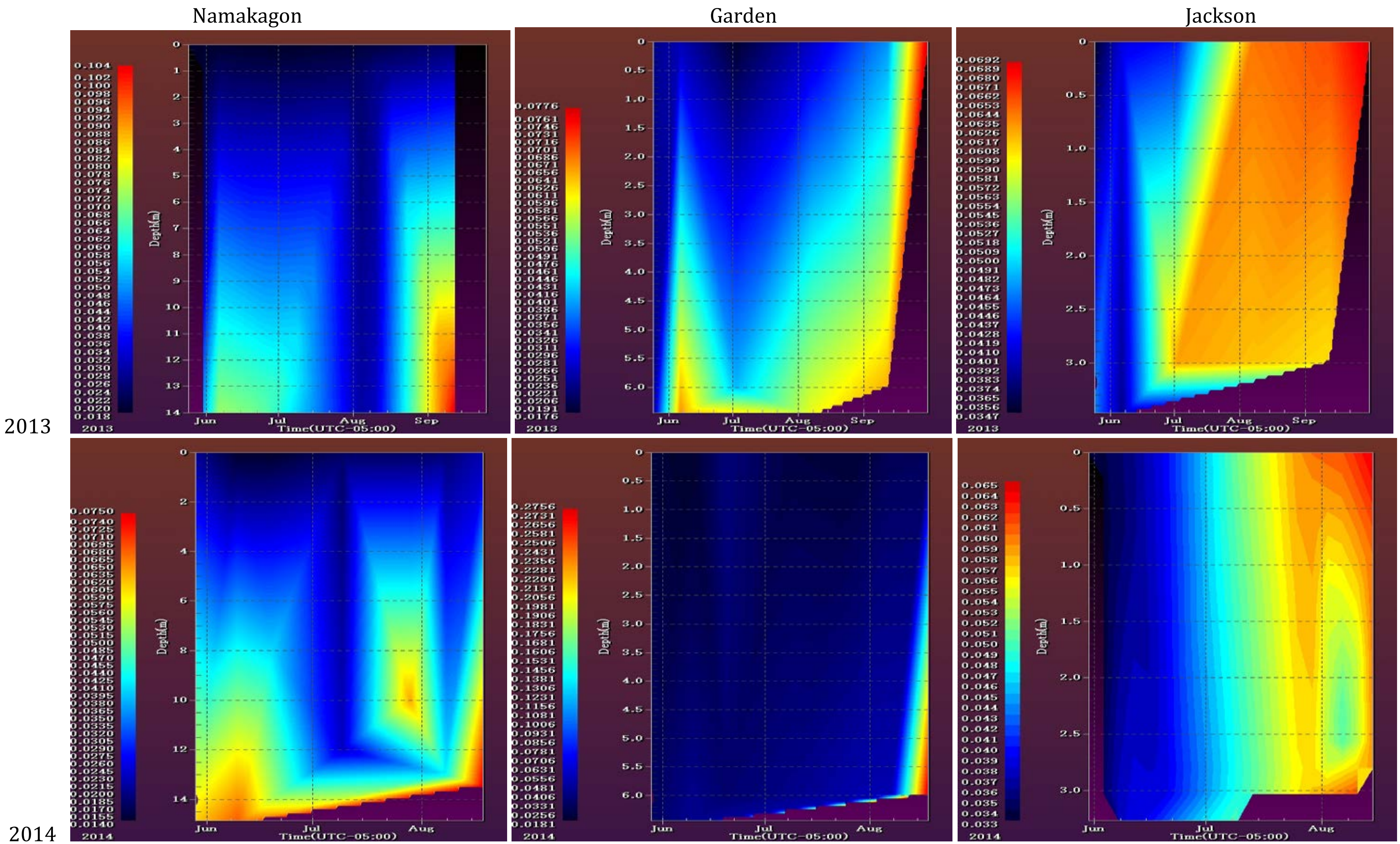


Figure 11.17 Total phosphorus stratification in Namakagon, Garden and Jackson Lakes in 2013 and 2014. *(Note: depth interpolations are based on 2-3 samples collected throughout the water column and may not clearly describe abrupt transitions in phosphorus concentrations that likely exist around the metalimnion)*

12. Appendix C – Shoreline Habitat Assessment and Management Plan

Introduction
This report summarizes the status of shoreline/nearshore habitat in the Namakagon 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 Namakagon Chain. Results from this assessment were combined with results from an aquatic plant 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 Namakagon 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 Bayfield County zoning.

To describe shoreland habitat conditions in the Namakagon 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 lake 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.

Results
The shoreline around the Namakagon Chain is approximately 44 miles in lengths. Throughout this distance, land is divided into 574 discrete parcels (Figure 12.1). Of these parcels, 32 are publicly owned and 542 are privately owned. Average linear shoreline distance of privately owned parcels is approximately 383 feet.

Based on future land use zoning (see Appendix C), the number of parcels around the Namakagon 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 Namakagon Chain. Since the current average shoreline length per parcel is 383, full development of the current zoning regulations could increase the number of shoreline parcels by three to four 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 shoreline habitat assessment and previous aquatic plant and critical habitat surveys suggest that there are a range of habitat types and conditions throughout the Namakagon Chain ecosystem (Figure 12.2). 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.

Shoreland Habitat
Results from the habitat assessment suggest that shoreland habitat is moderately to heavily impacted by human disturbance throughout the Namakagon Chain. Of the 557 parcels surveyed, the majority (~62%) were in “marginal” or “poor” 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 western and southern bays (Figures 12.3, 12.4, 12.5 and 12.6).

Discussion and Management Recommendations

Given that most shoreline habitat surrounding the Namakagon Chain has been significantly modified over time, the majority of shoreline management activities should focus on restoration efforts. As described in Section 7.1, shoreland habitat protection for the Namakagon Chain is primarily driven by the statewide shoreland zoning law (NR 115). Although this law provides some protections for water quality and nearshore habitat in the Namakagon 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 lake as well as general shoreland/critical habitat. Recurring surveys should be conducted every three to five years, depending on the rates of shoreline development.

Significant areas for shoreline restoration exist throughout the Namakagon Chain system. Areas of greatest opportunity for shoreland habitat restoration are most common on the southern and eastern shorelines of the lake, 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 lake 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 Lake 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 Namakagon Chain.

Parcel Condition	Namakagon Chain Parcel Data		
	Upland / Terrestrial (OHWM inland 15m)	Shoreline / Riparian Buffer (water's edge inland 1m)	Aquatic / Littoral (waterward 10m from shore)
Ideal	101	120	134
Very Good	63	95	118
Marginal	119	134	290
Poor	274	208	15
Total	**557**		

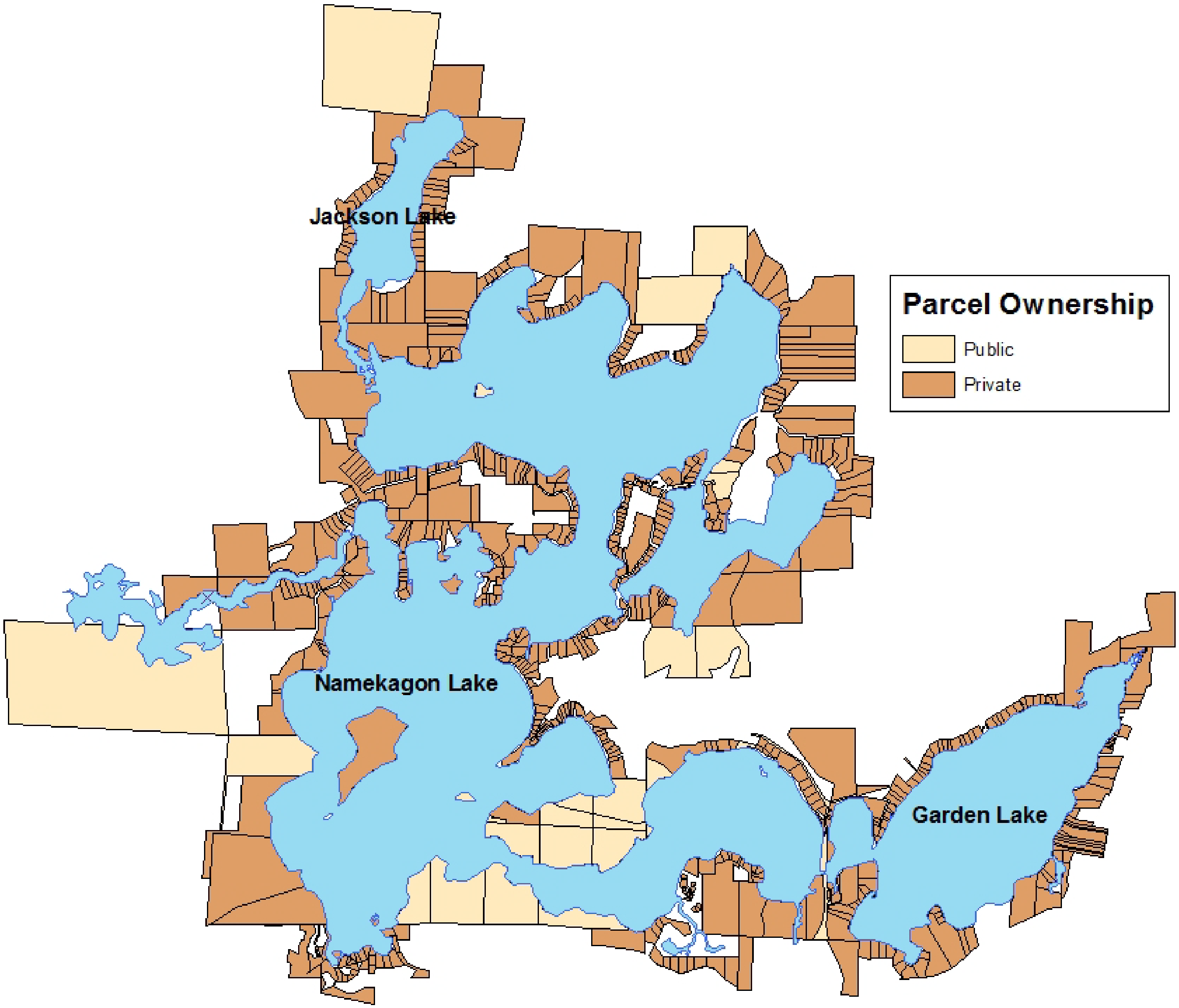


Figure 12.1 Shoreline parcel ownership surrounding the Namakagon Chain.

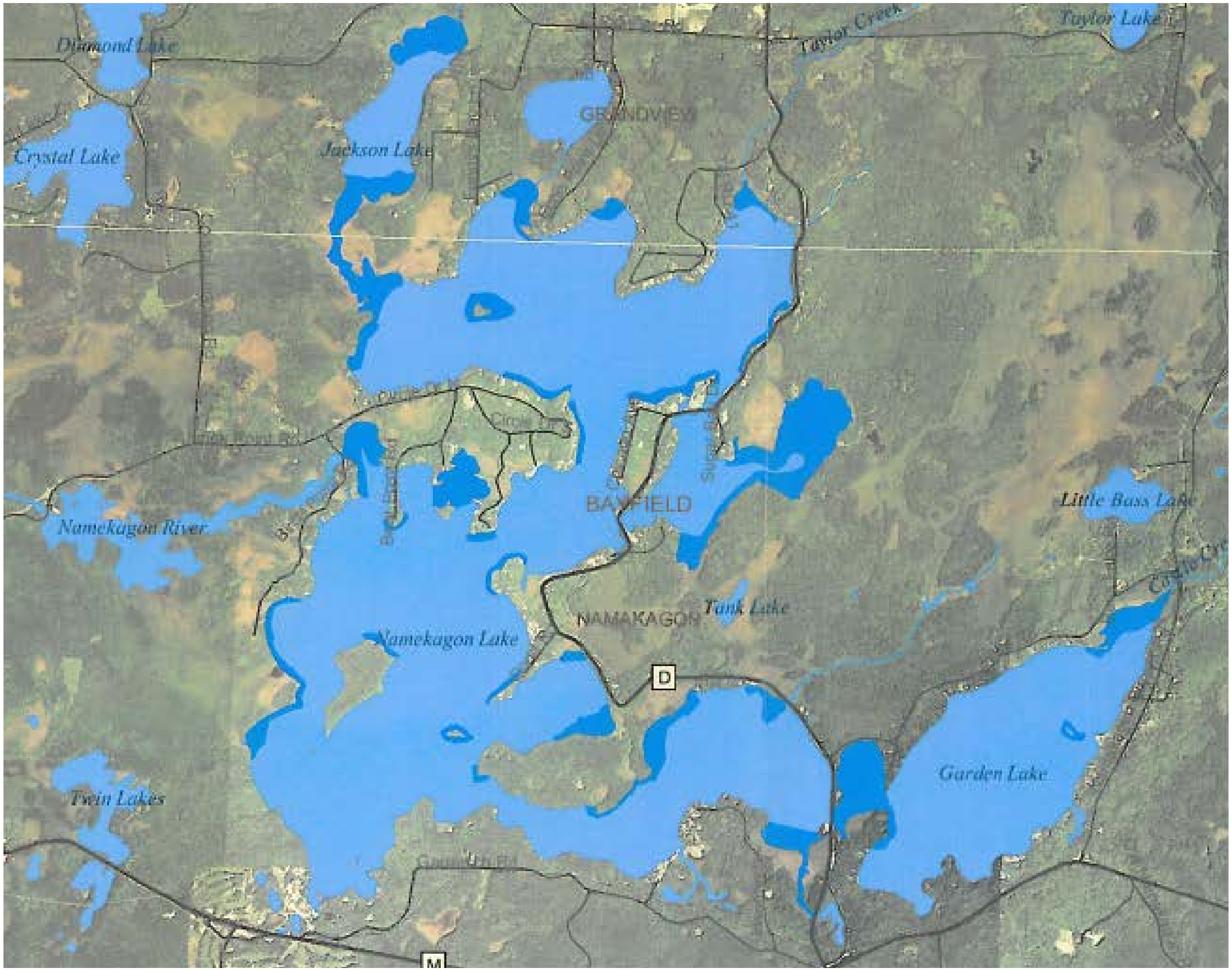


Figure 12.2 Locations of highest quality aquatic habitat (e.g., floating and emergent plant communities) in the Namakagon Chain.

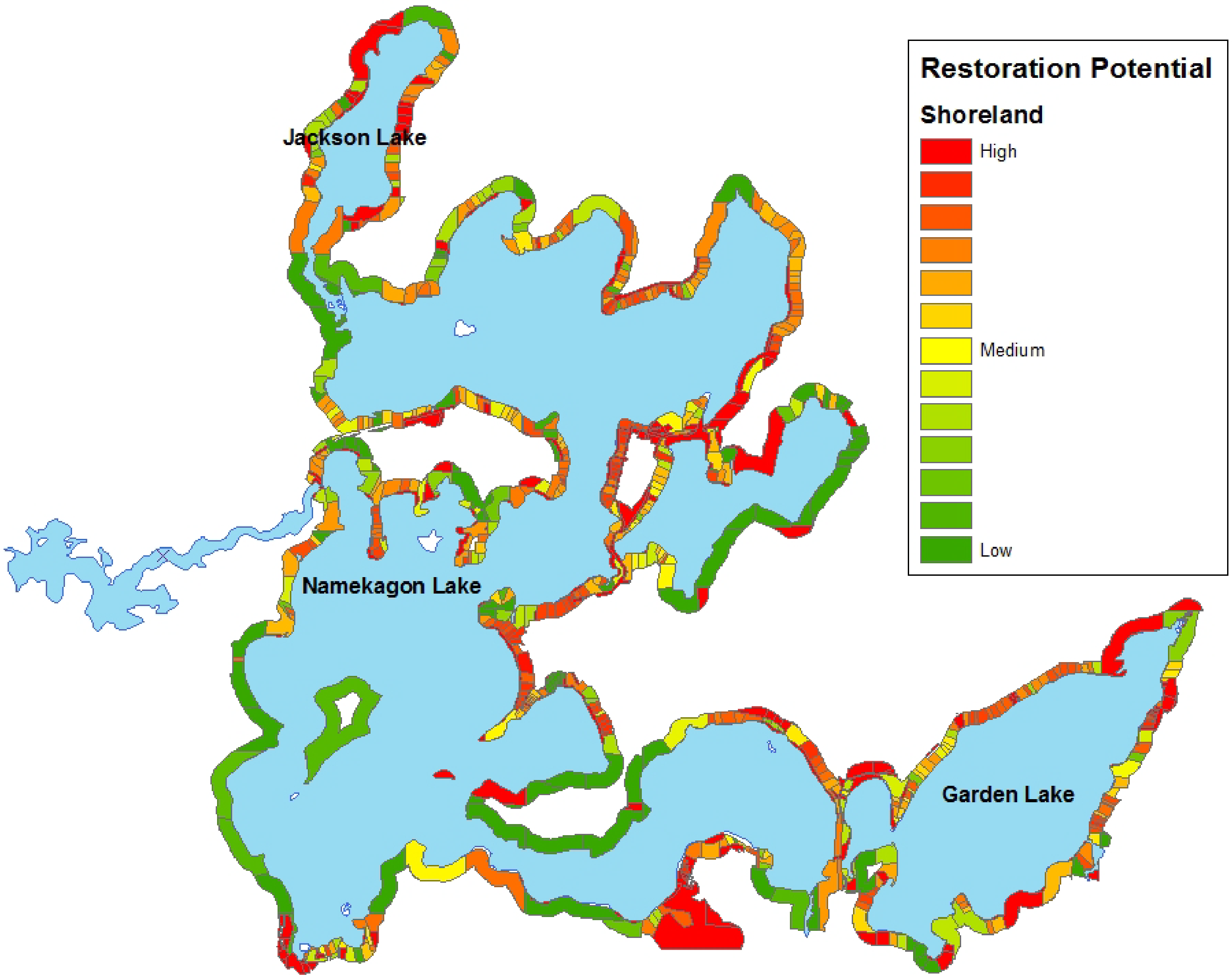


Figure 12.3 Average restoration potential of shoreland areas surrounding the Namakagon Chain.

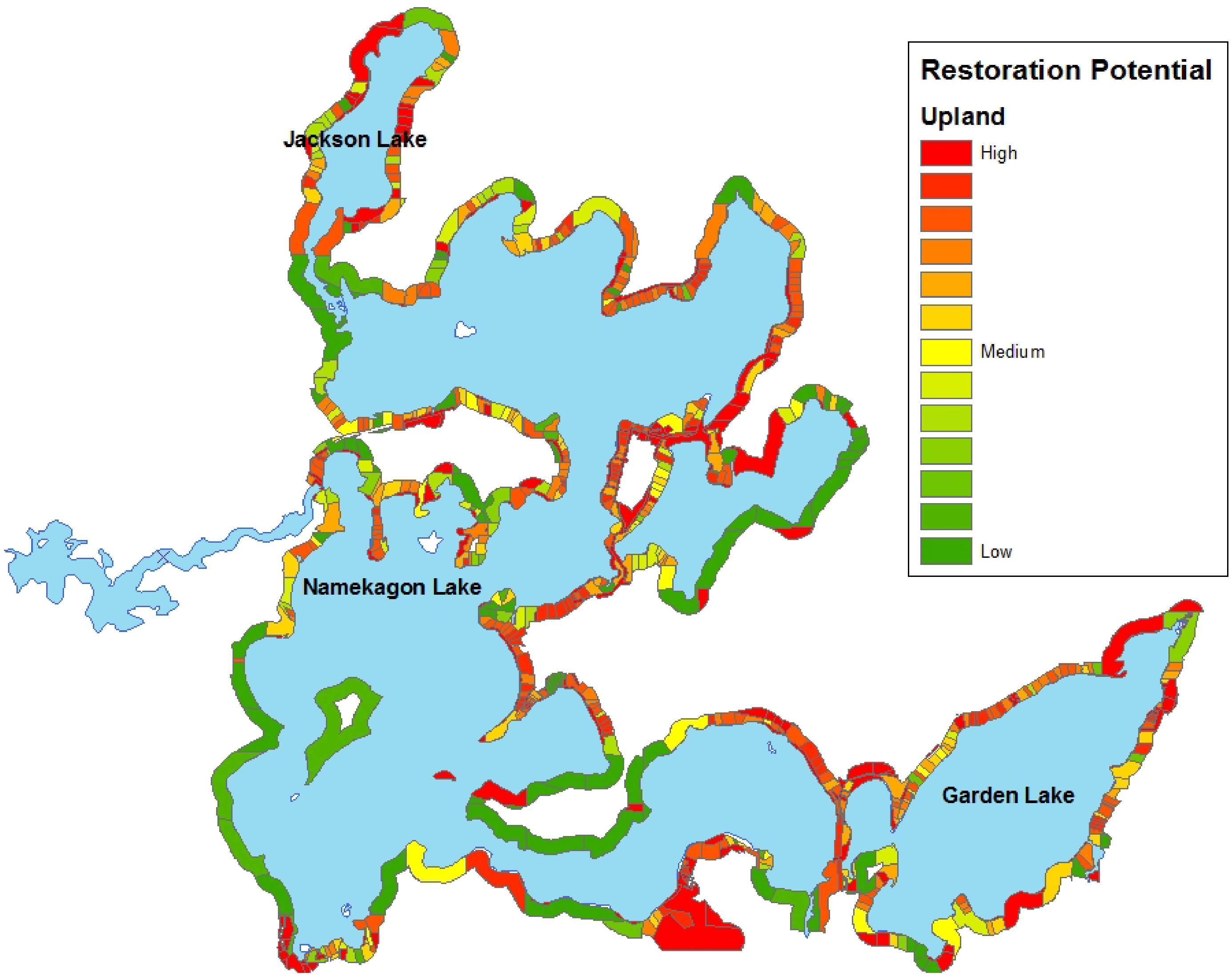


Figure 12.4 Average restoration potential of upland areas surrounding the Namakagon Chain.

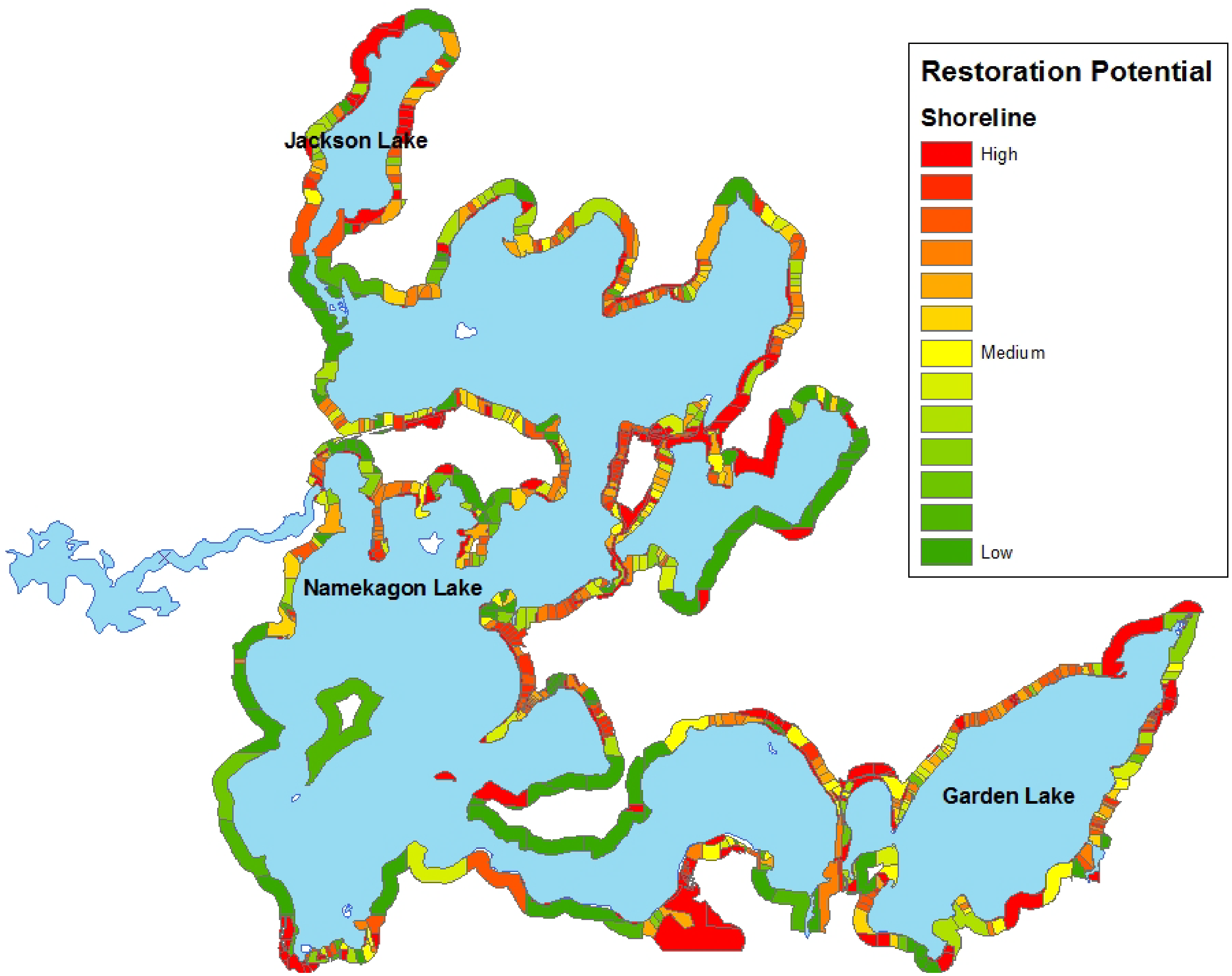


Figure 12.5 Average restoration potential of shoreline areas surrounding the Namakagon Chain.

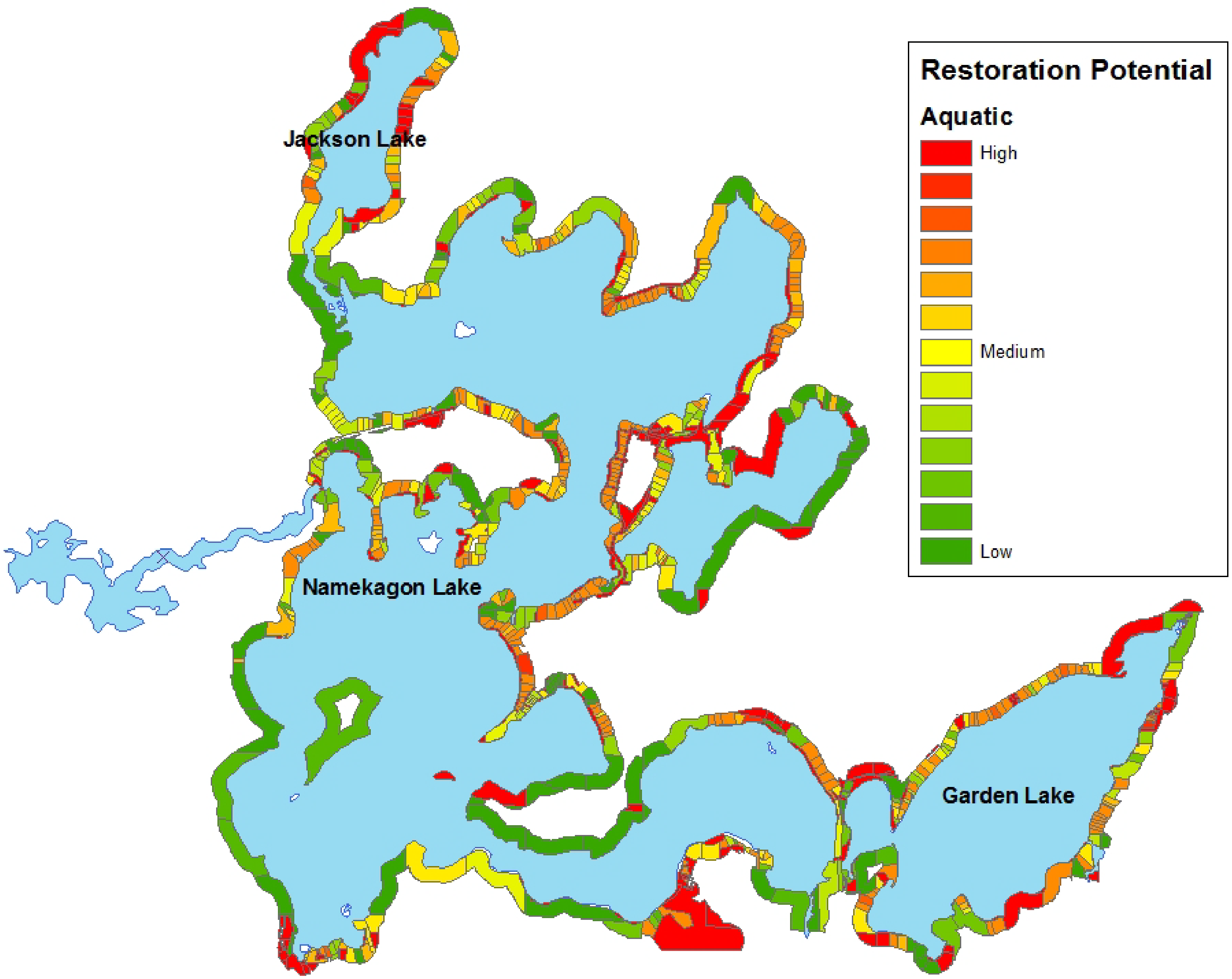


Figure 12.6 Average restoration potential for aquatic/littoral areas surrounding the Namakagon Chain.

13. Appendix D – Watershed Assessment and Management Plan

Introduction
This report summarizes the condition of, and potential management options for, the Namakagon 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 Namakagon 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 Namakagon Chain.

Methods
Watershed nutrient loads to the Namakagon Chain were developed using land-use specific, annual phosphorus export coefficients. Initially, the Namakagon 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.

Annual watershed nutrient loads to the Namakagon 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 Namakagon Chain watershed is approximately 31,614 acres (including waterbodies). Land cover throughout the Namakagon Chain watershed is dominated by coniferous forests and wetlands, while developed and agricultural lands make up a relatively small percentage of the land area (Figures 13.1 and 13.2). Of the Namakagon Chain, Lake Namakagon (31,614 acres) has the largest watershed area, followed by Garden (10,110 acres) and Jackson Lakes (4,954 acres).

Land cover throughout the watershed has shifted moderately since the mid-1800s and is anticipated to continue to change in the coming years (Figure 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 Namakagon Chain from septic systems comprise approximately 13 percent of the total watershed load (Table 13.1). Based on future land use plans, phosphorus loads from septic systems in future land use conditions have the potential to increase to approximately triple.

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 watershed phosphorus loads to the lakes were approximately 1884 lbs/yr. Annual watershed phosphorus loads to the lakes increased to approximately 1993 in 2011 and have the potential to increase to 3731 by 2030. However, the increased potential density of shoreline development now possible under the revised statewide shoreland zoning laws (NR 115) has the potential to significantly increase phosphorus runoff to the lake beyond what would be expected in current land use plans. Historical increases in phosphorus loads to the lake 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 significant impacts on the Namakagon 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 Namakagon Chain).

Management and Monitoring Recommendations

Changes in land use throughout the Namakagon Chain watershed have likely increased phosphorus runoff to the lake and phosphorus runoff to the lake 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 lake. Current per acre export of phosphorus to the Namakagon 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 Namakagon 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 Namakagon 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 Namakagon 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 Namakagon, direct measurements of phosphorus runoff are difficult. As such, phosphorus loads to the lake 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 Namakagon 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	146	2.5	1	0.3	1.1	1.8	1.5	121	198	**165**
	Seasonal	379	2.5	0.3	0.3	1.1	18	1.5	94	1537	**128**
	Total	**542**	**2.5**	**0.65**	**0.3**	**1.1**	**9.9**	**1.5**	**215**	**1734**	**293**
Future Conditions	Full-time	397	2.5	1	0.3	1.1	1.8	1.5	327	535	**446**
	Seasonal	1028	2.5	0.3	0.3	1.1	1.8	1.5	255	416	**347**
	Total	**1469**	**2.5**	**0.65**	**0.3**	**1.1**	**1.8**	**1.5**	**582**	**952**	**793**

Table 13.2. Estimated annual total phosphorus loads to the Namakagon Chain from all watershed sources.

Potential Phosphorus Source	Annual TP Loads			Estimated Annual Phosphorus Loads to the Namakagon Chain					
				Historical (1856)		Current (2011)		Potential Future (2030)	
	Minimum	Maximum	Most Likely	Units	TP Load	Units	TP Load	Units	TP Load
<u>Agriculture Lands</u>	(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	20	20	0	0
<u>Urban Lands</u>	(lbs./acre/yr)			Acres	lbs.	Acres	lbs.	Acres	lbs.
Developed, Rural Residential	0.05	0.25	0.1	0	0	1321	132	3354	335
Development, Low Density	0.2	0.55	0.3	0	0	50	15	6407	1922
Developed, Medium Density	0.3	0.8	0.5	0	0	5	3	292	146
Developed, High Density	1	2	1.5	0	0	0	0	247	371
<u>Forest and Grasslands</u>	(lbs./acre/yr)			Acres	lbs.	Acres	lbs.	Acres	lbs.
Deciduous Forest	0.05	0.2	0.09	4262	1813	11478	1681	5996	886
Evergreen Forest				511		1770		1770	
Mixed Forest				15371		4489		2078	
Shrub/Scrub				0		946		0	
Grassland	0.01	0.25	0.17	0	0	65	11	0	0
Wetland	0.01	0.01	0.01	7087	71	7087	71	7087	71
<u>Permitted Sources</u>	(lbs./source/yr)			Sources	lbs.	Sources	lbs.	Sources	lbs.
None	-	-	-	-	-	-	-	-	-
<u>Non-permitted Sources (lbs./system)</u>	(lbs./systems/yr)			Systems	lbs.	Systems	lbs.	Systems	lbs.
*Septic Systems	1.1	1.8	1.5	0	0	542	239	1469	739
Relative Changes in Phosphorus Load					**Total**	**%**	**Total**	**%**	**Total**
Total Watershed Load					**1884**	**3%**	**1933**	**93%**	**3731**
Permitted/Non-permitted Source Load					**0**	**239%**	**239**	**209%**	**739**
Total Phosphorus Loads					**1884**	**15%**	**2172**	**106%**	**4470**
Per Acre Phosphorus Load					**0.10**	**15%**	**0.12**	**106%**	**0.24**

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

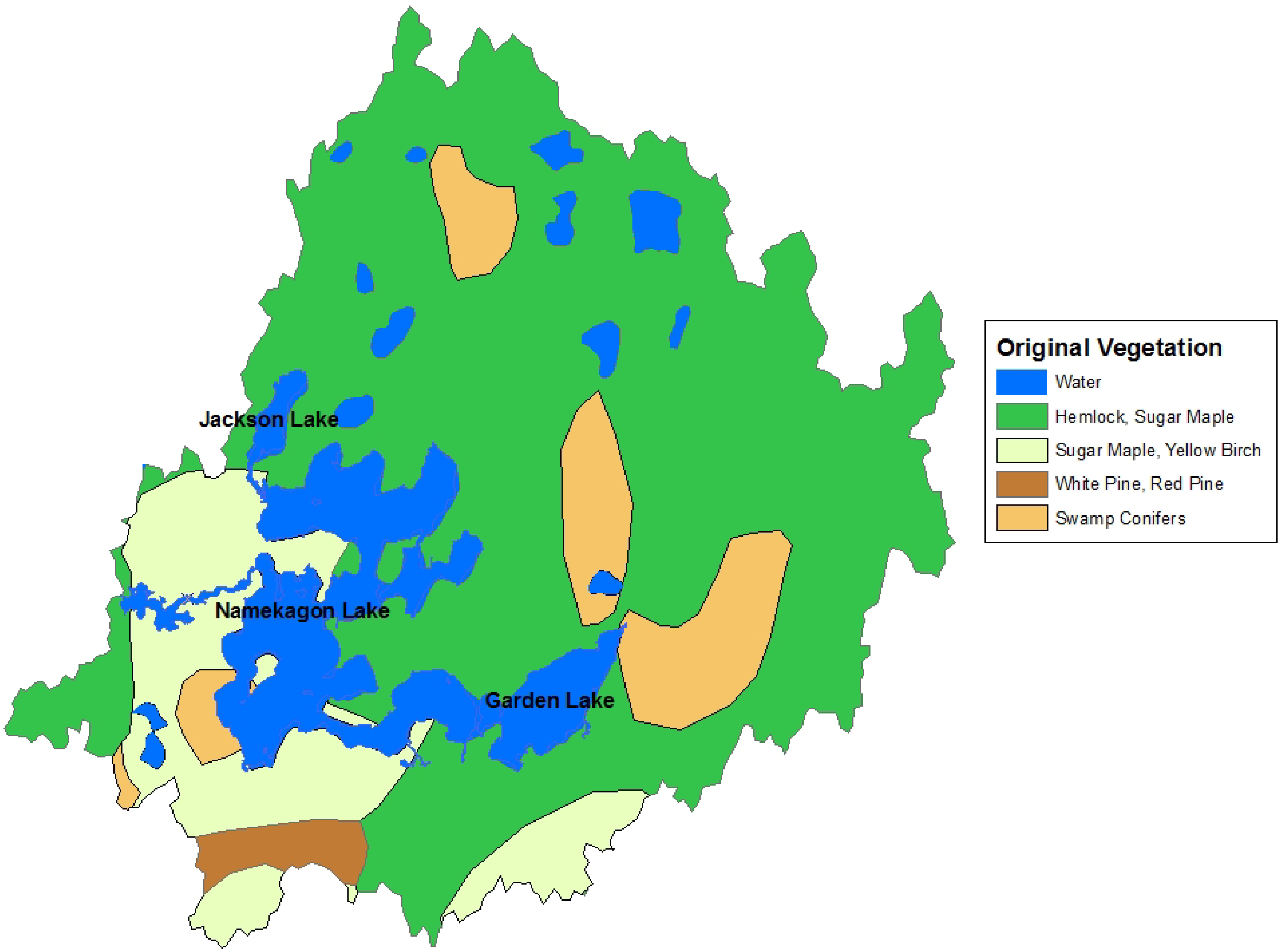


Figure 13.1 Historical vegetative cover in the Namakagon Chain watershed. Based on ~1856 vegetative cover assessments.

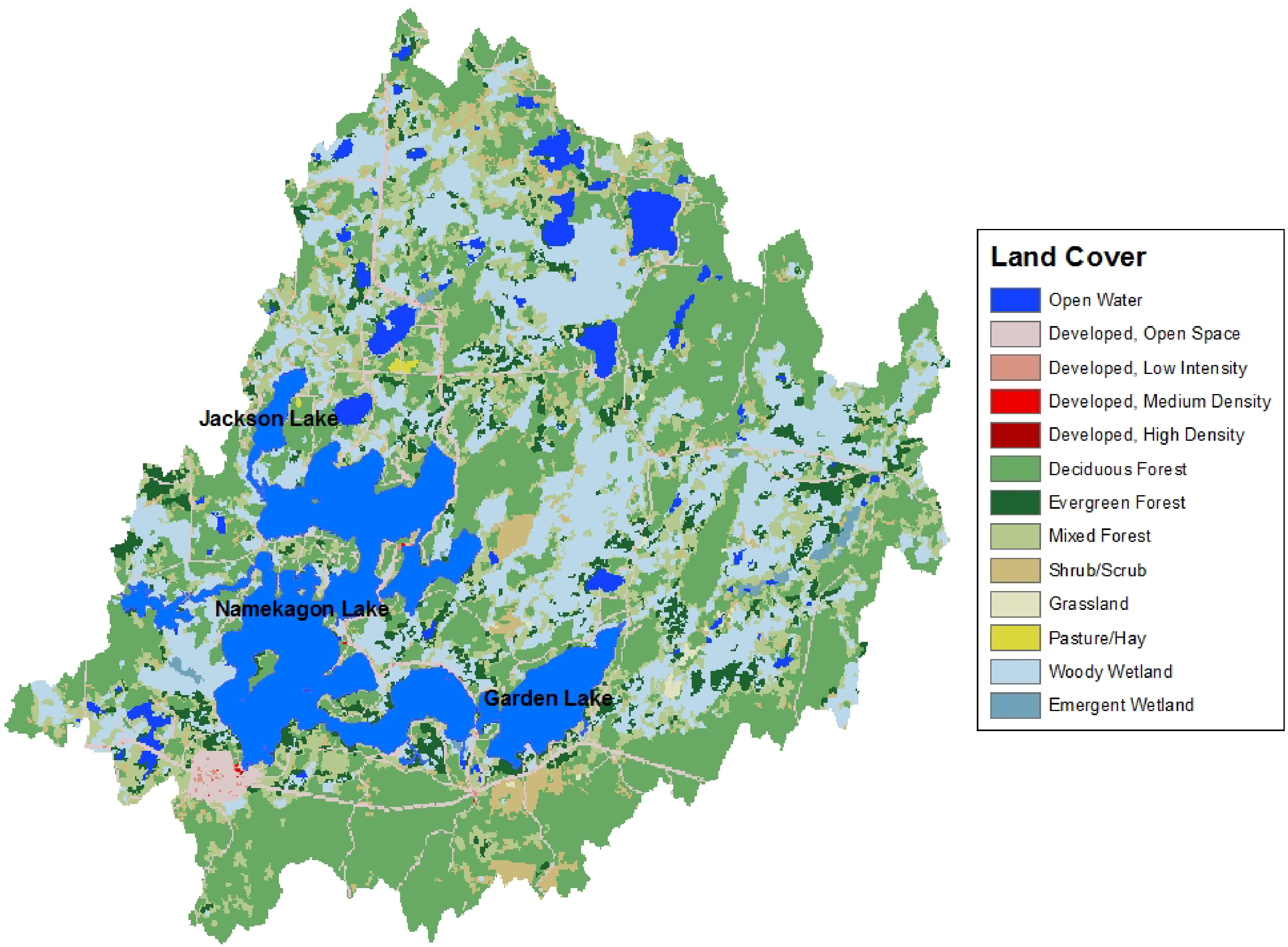


Figure 13.2 Land cover in the Namakagon Chain watershed in 2011.

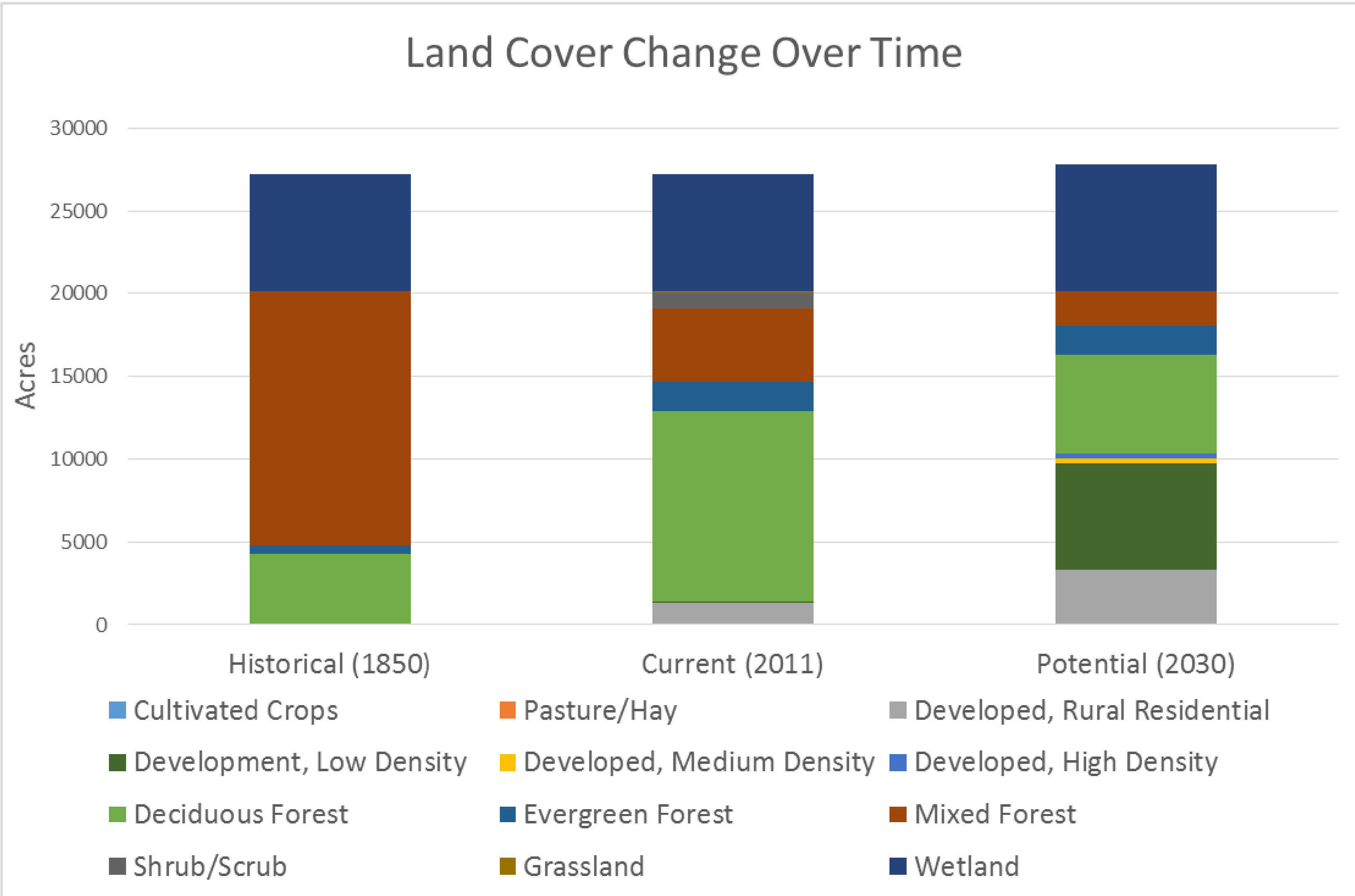


Figure 13.3 Changes in land cover in the Namakagon Chain watershed over time.

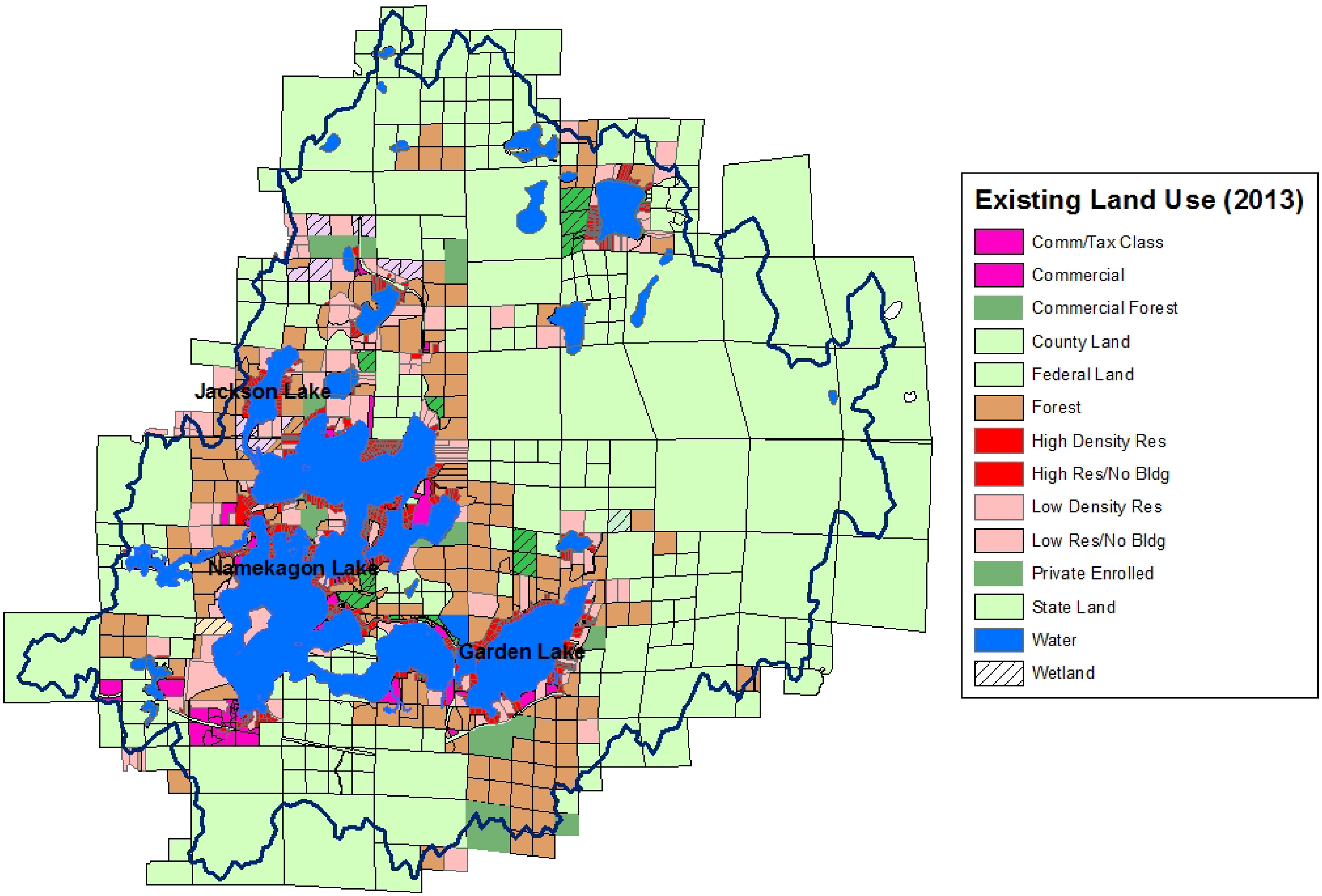


Figure 13.4 Existing land use in the Namakagon Chain watershed as described in the local comprehensive plan.

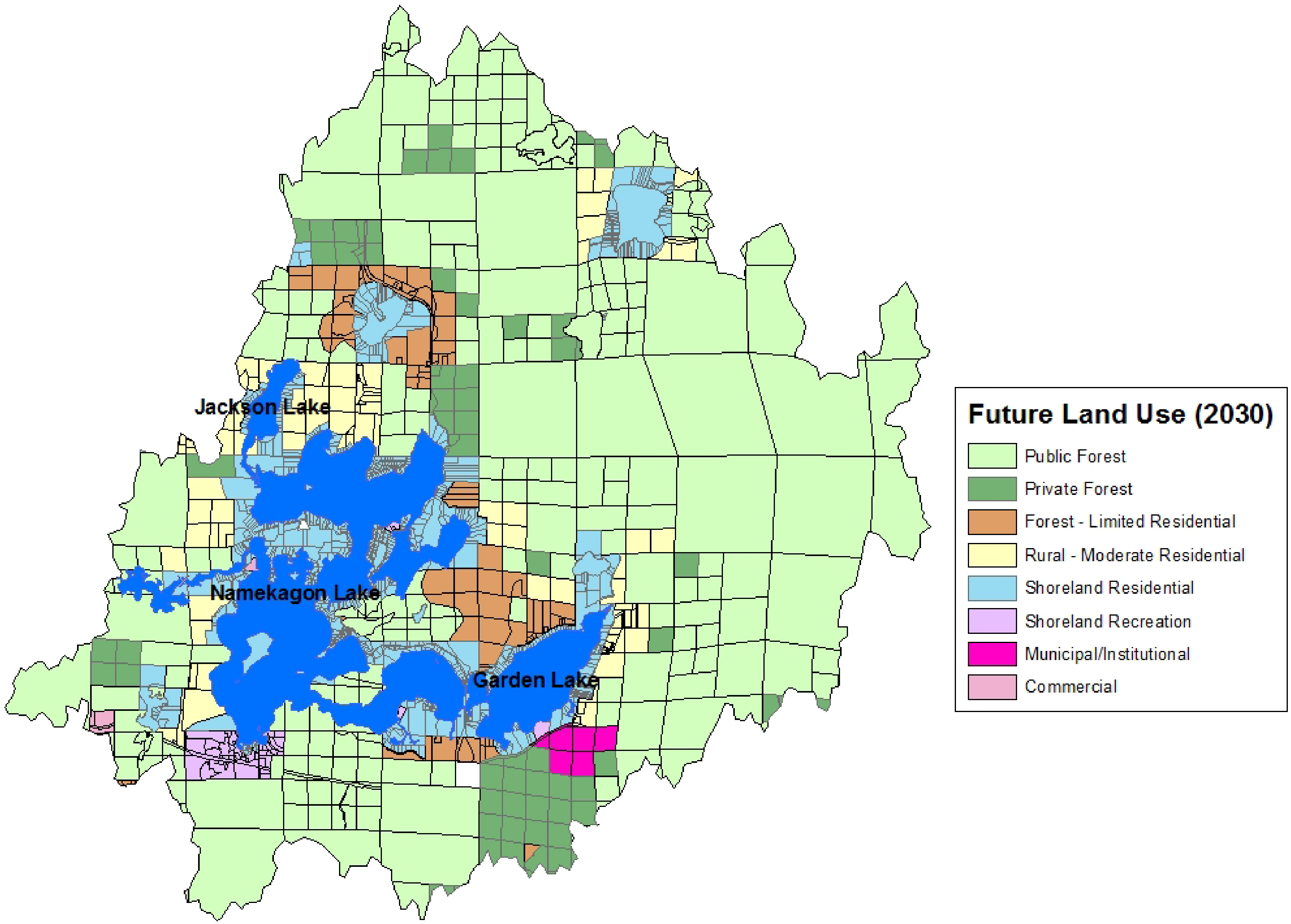


Figure 13.5 Future potential land use in the Namakagon Chain watershed as described in the local comprehensive plan (2030).

14. Appendix E – Aquatic Plant Assessment and Management Plan

Introduction

This report summarizes the status of the aquatic plant communities in the Namakagon 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 (Foth, 2010) and risk of invasive species introduction was conducted for the Namakagon 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 596 points in the littoral zone of the Namakagon Chain in 2009. Full details of this assessment can be reviewed in Lake Namakagon Aquatic Plant Management Plan (APMP, Foth 2010). Sampling procedures used develop the APMP are summarized below.

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 lake. 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).

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 Namakagon 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 Results Summary
The Namakagon Chain contains a robust aquatic plant community. Throughout the APMP assessment, 23 species were identified (Table 15.2, 15.3, 15.4 and 15.5). The majority of plants were observed growing between 1 and 14 feet (Figure 15.2). The diversity and richness of species also varied among sites within the lake, 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 eastern and western ends of the lake system (Figures 15.3, 15.4, 15.5 and 15.6).

Throughout the Namakagon Chain, the most common species detected were eloda (*Elodea Canadensis*) and coontail (*Ceratophyllum demersum*). In general, the FQI scores for lakes throughout the Namakagon Chain had scores that were higher than the regional average of 26. **No aquatic invasive species were detected as part of the 2009 survey.**

Pathway/Vector Analysis
Eight potential pathways for invasive species introduction were identified and evaluated (Table 15.6). Of the 8 introduction pathways, six were classified as Low or Low-Moderate risk, one was identified as Moderate risk and one was identified as Moderate-High. The highest risk pathway for introduction of invasive species is through introduction from unmonitored private launches.

Discussion and Management Recommendations
Aquatic plant management efforts in the Namakagon Chain should build on the ongoing work of the NLA 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 NLA. The primary work of the NLA is to increase awareness of invasive species and their prevention. To this end, the NLA hosts an annual meeting and distributes recurring newsletters that highlight ongoing work and needs related to invasive species prevention and management. The NLA contracts with local partners to implement watercraft inspections at launches throughout the Namakagon Chain.

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 lake; 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 lake 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.

Prevent the Spread and further Introduction of Invasive Species
Given that no invasive aquatic plant species have been detected in the Namakagon Chain, continuing efforts that build on the NLA's ongoing work to minimize the potential for the introduction of invasive species are critical. To this end, three 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 Namakagon Chain).

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.

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. Aquatic plant survey points in the Namakagon Chain.

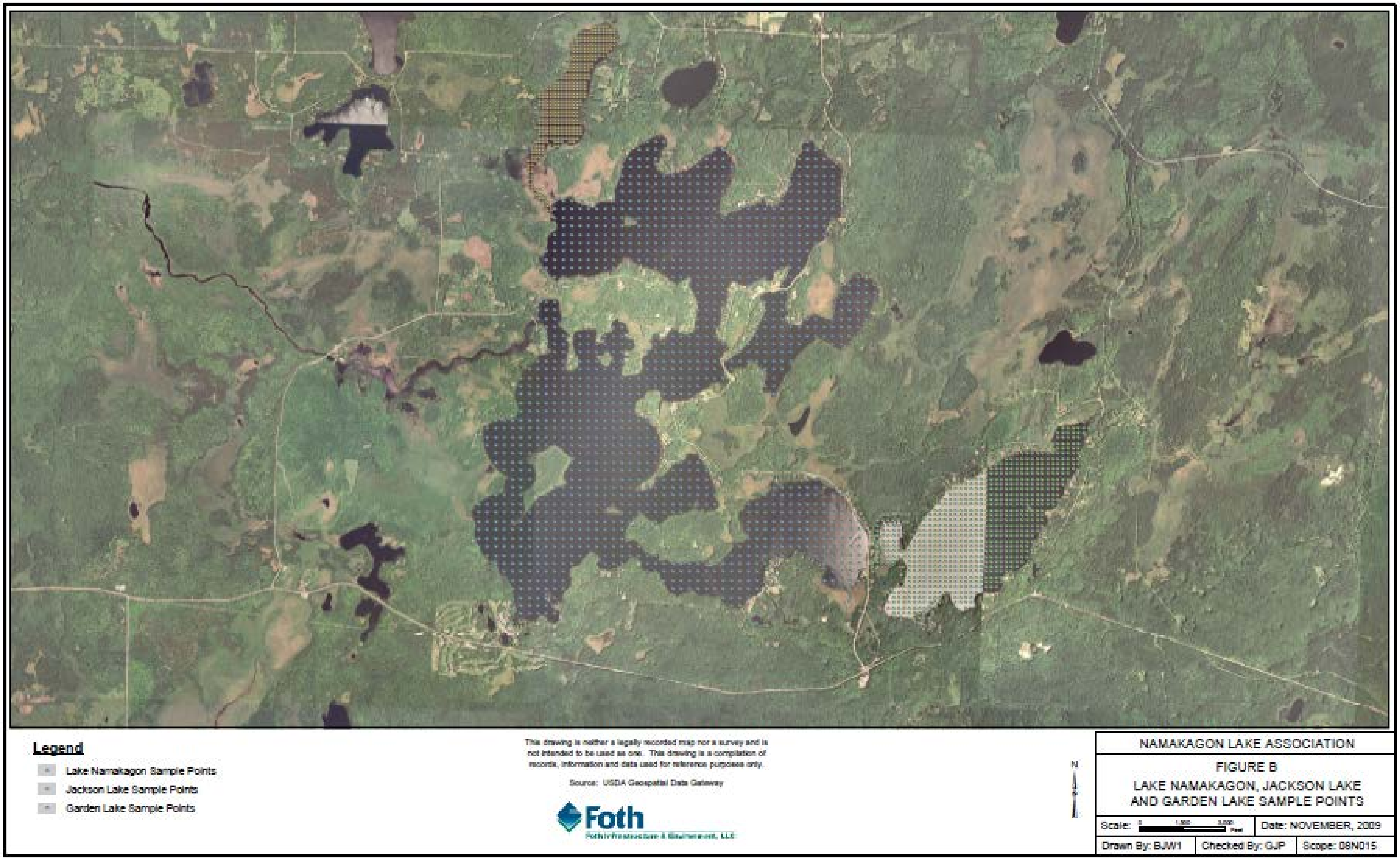


Table 15.3. Summary of Results from Aquatic Plant Surveys across the Namakagon Chain.

Lake Namakagon Floristic Quality Index Worksheet

Species	Common Name	C	Present	Value
Brasenia schreberi	Watershield	7	1	7
Ceratophyllum demersum	Coontail	3	1	3
Chara	Muskgrasses	7	1	7
Elodea canadensis	Common waterweed	3	1	3
Lemna minor	Small duckweed	5	1	5
Littorella americana	Littorella	10	1	10
Myriophyllum sibericum	Northern water-milfoil	7	1	7
Najas flexilis	Bushy pondweed	6	1	6
Nitella	Nitella	7	1	7
Nuphar variegata	Spatterdock	6	1	6
Nymphaea odorata	White water lily	6	1	6
Phragmites australis	Common reed	1	1	1
Pontederia cordata	Pickerelweed	9	1	9
Potamogeton amplifolius	Large-leaf pondweed	7	1	7
Potamogeton epihydrus	Ribbon-leaf pondweed	8	1	8
Potamogeton praelongis	White-stem pondweed	8	1	8
Potamogeton pusillus	Small pondweed	7	1	7
Potamogeton richardsonii	Clasping-leaf pondweed	5	1	5
Potamogeton robbinsii	Robbins pondweed	8	1	8
Potamogeton zosteriformis	Flat-stem pondweed	6	1	6
Schoenoplectus tabernaemontani	Softstem bulrush	4	1	4
Sparganium fluctuans	Floating-leaf-bur-reed	10	1	10
Typha angustifolium	Narrow-leaved cattail	1	1	1
Vallisneria americana	Wild celery	6	1	6
	N		24	
	mean C			6.125
	FQI			30.01

N = number present

Table 15.4. Summary of Results from Aquatic Plant Surveys on individual lakes within the Namakagon Chain.

Vegetation – Garden Lake

Summary Statistics Garden Lake	Percent
Total number of points sampled	233
Total number of sites with vegetation	168
Total number of sites shallower than maximum depth of plants	219
Frequency of occurrence at sites shallower than maximum depth of plants	76.71
Simpson Diversity Index	0.85
Maximum depth of plants (ft)	11.00
Number of sites sampled using rake on Rope (R)	0
Number of sites sampled using rake on Pole (P)	233
Average number of all species per site (shallower than max depth)	1.87
Average number of all species per site (veg. sites only)	2.43
Average number of native species per site (shallower than max depth)	1.80
Average number of native species per site (veg. sites only)	2.43
Species Richness	15
Species Richness (including visuals)	20

Vegetation – Jackson Lake

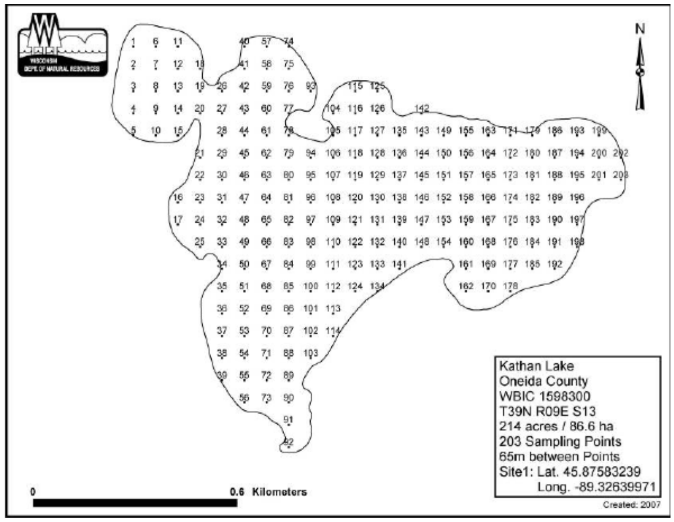
Summary Statistics Jackson Lake	Percent
Total number of points sampled	176
Total number of sites with vegetation	145
Total number of sites shallower than maximum depth of plants	162
Frequency of occurrence at sites shallower than maximum depth of plants	89.51
Simpson Diversity Index	0.85
Maximum depth of plants (ft)	8.80
Number of sites sampled using rake on Rope (R)	0
Number of sites sampled using rake on Pole (P)	229
Average number of all species per site (shallower than max depth)	2.35
Average number of all species per site (veg. sites only)	2.63
Average number of native species per site (shallower than max depth)	2.30
Average number of native species per site (veg. sites only)	2.63
Species Richness	16
Species Richness (including visuals)	19

Vegetation – Lake Namakagon

Summary Statistics Lake Namakagon	Percent
Total number of points sampled	596
Total number of sites with vegetation	486
Total number of sites shallower than maximum depth of plants	574
Frequency of occurrence at sites shallower than maximum depth of plants	84.67
Simpson Diversity Index	0.90
Maximum depth of plants (ft)	14.20
Number of sites sampled using rake on Rope (R)	0
Number of sites sampled using rake on Pole (P)	609
Average number of all species per site (shallower than max depth)	2.31
Average number of all species per site (veg. sites only)	2.72
Average number of native species per site (shallower than max depth)	2.28
Average number of native species per site (veg. sites only)	2.72
Species richness	21
Species richness (including visuals)	23

Table 15.5. Risk of introduction from different invasive species pathways

Pathway	Description	Risk of Introduction
Private Landings	Moderate to heavy use/access, primarily from regional and extended users. Extent of monitoring unclear.	Moderate to High; Moderate usage by boaters who generally frequent regional lakes, many of which have existing invasive species
Public Landings	Moderate to heavy use/access, primarily from regional and extended users. Well monitored.	Moderate; Moderate usage by boaters who generally frequent regional lakes, many of which have existing invasive species
Connected/adjacent Waterbodies	Lakes directly connected to entire the Namakagon Chain	Low; Significant usage by boaters who travel between connected lakes but no invasive colonies exist that can be transported.
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) 

b)

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.

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.

15. Appendix F – Ecosystem Modeling and Scenario Forecasting

Introduction

To understand the relative role of the different components of the Namakagon 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 Namakagon 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 lake 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. Watershed load reductions necessary for Lake Namakagon to meet 15 ug/L water quality criterion with and without the release of internal load (~1125 lbs/year) were estimated using the percent reduction function.

Results and Discussion

WiLMS model predictions of TP concentrations range from 4% to -69% of observed values, suggesting that the ability of model algorithms to predict current water quality conditions is variable across lakes. This differential ability of the model algorithms to predict water quality conditions is likely a result of the internal loading of phosphorus within the systems, as Jackson and Garden Lakes (which have the highest percentages of internal loading) show the greatest divergence between model predictions and observed conditions.

To meet the 15 ug/L total phosphorus water quality criteria a 25% reduction in watershed load was necessary with no assumed internal load and 80% reduction in watershed load was necessary with an assumed internal load of 1125 lbs/yr of internal phosphorus load.

Changes in water quality conditions that are likely to result from future land use change and septic system density have the potential to be significant. A transition from historical to current land covers has likely resulted in an approximate two to three fold 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 26% and 100% (Table 16.4).

Management and Monitoring Recommendations

Results suggest that the WiLMS model reasonably predicts water quality conditions throughout the Namakagon 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 Namakagon Chain may have a significant impact on water quality conditions, particularly in Namakagon and Garden Lakes—in which forecasted future conditions are most divergent from current conditions. Additionally, these results suggest that an approximate 25% and 80% reduction in watershed load would be necessary to meet the 15 ug/L total phosphorus water quality criterion in Lake Namakagon under current conditions. Given that current conditions represent only a 3% to 15% increase in total phosphorus load over pre-development conditions (c. 1865), meeting the 15 ug/L criterion would likely be quite challenging, and potentially unachievable without substantial attenuation of internal loading.

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 Namakagon Chain and are reasonable given the available data. However, the understanding of the Namakagon 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 Namakagon Chain ecosystem, future management should include additional data collection to reduce uncertainty. In particular, substantially more data are necessary to accurately characterize the potential management approach and ultimate attainability of the 15 ug/L total phosphorus criterion.

Table 16.1. WiLMS Model Setup Parameters

Parameter	Namakagon	Garden	Jackson
Drainage Area (acres, excluding water)	27,231	8,714	4,357
Total Unit Runoff (inches)	14	14	14
Annual Runoff Volume (acre-ft)	31,770	9,700	5,083
Lake Surface Area (acre)	2,607	558	149
Lake Volume (acre-ft)	41,712	5,580	1,192
Average Depth (ft)	16	10	8
Precipitation-Evaporation (inches)	5.5	5.5	5.5
Hydraulic Loading (acre-ft/year)	33,160	9,997	5,163
Areal Water Load (ft/year)	12.7	17.9	34.6
Observed Spring Overturn (TP, ug/L)	19	20	21
Observed Growing Season Mean (TP, ug/L)	23	25	26

Table 16.2. WiLMS Phosphorus Mass Balance for the Namakagon Chain Lakes

Lake	Watershed Area (Acres, wo/water)	Phosphorus Source (lbs/yr)			Total Load (lbs/yr)	Outflow P Load (lbs/yr)	Internal P Load (lbs/yr)
		Watershed Runoff	Septic System	Atmospheric			
Namakagon	27,231	2268	213	696	3177	1983	1125
Garden	8,714	694	73	150	917	752	478
Jackson	4,357	363	24	40	427	618	452

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

Predictive Model	Site		
	Namakagon	Garden	Jackson
Observed Growing Season Mean	18	29	46
Walker, 1987 Reservoir	18	20	21
Canfield Backman, 1981 Natural Lake	17	20	22
Walker, 1977 General	17	19	20
Nuremberg, 1984 Oxic (with Internal Load)	23	29	46
Model Average	19	22	27
Percent Deviation	4%	-32%	-69%

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

Land Use Condition (Year)	Total Phosphorus Watershed Load	Growing Season Phosphorus Concentration (ug/L)		
		Namakagon	Garden	Jackson
1856	1884	9	10	44
2011	2172	23	29	46
2030	4470	46	38	58