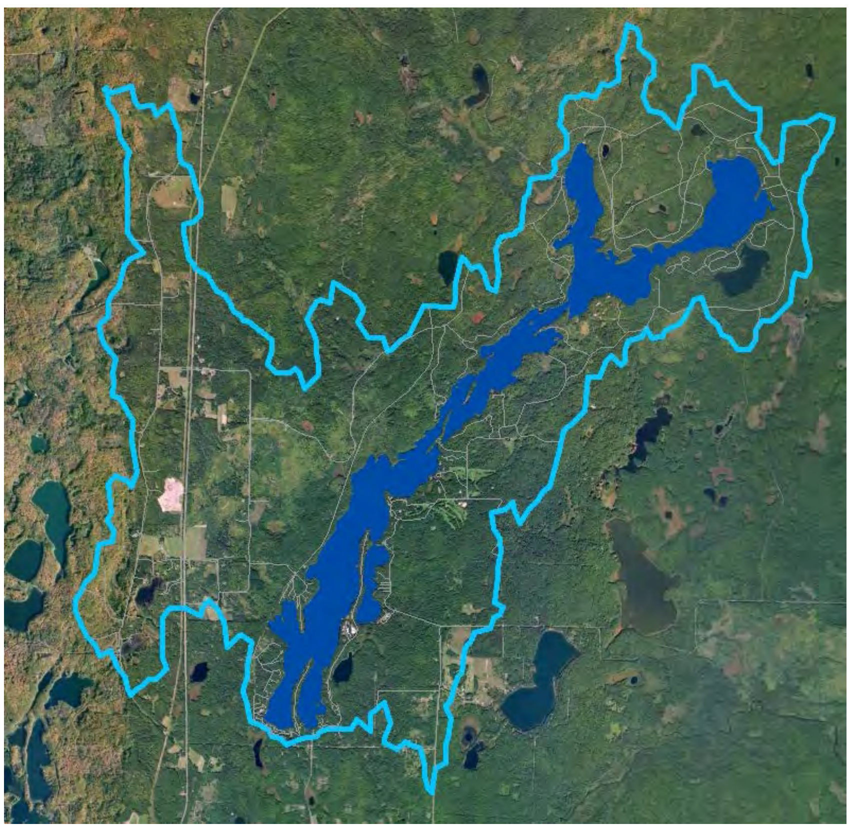
Comprehensive Management Plan for Lake Owen

Wisconsin Department of Natural Resources
Lake Management Planning Program



Plan Approved

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Sigurd Olson Environmental Institute
Northland College
1411 Ellis Ave
Ashland, WI 54806
715-682-1261

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1. Executive Summary

This document describes a plan for the long-term management of Lake Owen. 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 Lake Owen ecosystem and rationale for different management recommendations. Appendices A through G 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 Lake Owen ecosystem.

Successful management of Lake Owen is dependent on an understanding of the relationship between the desired “use” of the lake 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 Lake Owen, 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 Lake Owen is used and valued by different groups, this plan was developed though collaborative input from the Lake Owen Association, Wisconsin Department of Natural Resources, US Forest Service, Bayfield County and informed by a user survey (administered by Northland College). Based on this process, it is obvious that Lake Owen is an important ecological and social resource that is used and valued by different groups for different reasons. Across multiple questions in the survey, the majority of respondents highlighted the value of Lake Owen 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 Lake Owen into the future.

1. Maintain Current Levels of Motorized and Non-motorized Use
2. Maintain Scenic Beauty of Lake Owen
3. Protect and Restore Nearshore and Shoreline Habitat
4. Maintain Existing Water Levels and Hydrologic Processes
5. Maintain Existing Water Quality Conditions
6. Maintain Diverse Native Plant Communities
7. Maintain Diverse Native Oligotrophic Fish Communities
8. Restore Smallmouth Bass Populations to Historical Densities
9. Maintain Current Harvest Levels for Walleye

To achieve these goals, it was first necessary to assess the current conditions of the lake ecosystem. To this end, a two year study was conducted to summarize the existing data describing the health of Lake Owen and develop new data sets to describe important processes throughout the ecosystem. Elements of Lake Owen 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.

Lake Owen is a relatively pristine lake and these conditions are created and sustained by a variety of ecological processes. The most significant elements of the Lake Owen ecosystem that enable its pristine conditions are the 1) depth and relatively minimal mixing that occurs throughout the water column; 2) relatively undeveloped watershed and shoreline areas; and 3) diverse communities of fish, plants and microscopic organisms (i.e., plankton) that make up the Lake Owen food web.

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

A range of federal, tribal, state and local laws, rules and regulations are in place to protect Lake Owen and its uses. However, existing policies do not adequately address all current and potential future problems that may affect the lake. The elements of the Lake Owen 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 Lake Owen 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 Lake Owen, 2) current conditions of the lake and 3) existing policies that govern the protection and management of the lake. 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 used to historically size infrastructure do not reflect current rainfall patterns and more up-to-date data are available.*

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

3. Implement efforts to formally designate areas of critical habitat to protect aquatic organisms throughout the lake.

   a. *Why? – Nearshore and shoreline areas in Lake Owen are critical to the lake ecosystem and in relatively good conditions. Efforts to protect these areas will likely have a disproportionate high benefit to the long-term health of the lake.*

4. Implement efforts to restore areas of localized shoreline habitat degradation.
   a. *Why? – Although shoreline habitat is in relatively good conditions in Lake Owen, some areas of localized degradation do exist. WDNR has a range of grant programs to facilitate shoreline restoration.*

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

Things we should learn more about:

1. Quantitatively assess the current condition of groundwater inflows/outflows to and from Lake Owen as well as identify the most significant areas of groundwater recharge/delivery.
   a. *Why? – Water in Lake Owen primarily comes from groundwater. However, relatively little is known about the groundwater system surrounding Lake Owen.*

2. Comprehensively evaluate the ability of local land use and zoning policies to effectively manage water quality and aesthetics in Lake Owen 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.*

3. Evaluate the relative importance of the food web in controlling water quality conditions throughout the lake.
   a. *Why? – Water clarity in Lake Owen appears to be driven by unique characteristics of the microscopic plants and animals in the lake. However, relatively little is known about these organisms and how they might respond to future conditions.*

4. Evaluate the monetary costs, social benefits and potential for indirect impacts to the Lake Owen ecosystem of walleye stocking.
   a. *Why? – Relatively few stocked walleye survive to adulthood and it is unclear how, if at all, stocked walleye interact with the native fish communities.*

5. Evaluate the structure and abundance of the open water (pelagic) fishery.
   a. *Why? – Given the unique elements of the food web in Lake Owen, it is possible that the open water fishery is more productive and diverse than in many similar lakes. However, recurring fishery assessment work is not structured to sample open water fisheries.*

2. Introduction

Successful management of Lake Owen is dependent on an understanding of the relationship between the desired "use" of the lake and the physical, chemical, biological and social processes that shape the lake ecosystem. Throughout this document the word "use" will be used to describe all of the potential ways in which people directly use (e.g., fishing and boating), interact with (e.g., wildlife observation) and value (e.g., a site for the conservation of species and native ecosystems) Lake Owen.

Lake Owen is used by different groups for different purposes. For example, some individuals may use the lake primarily for fishing or boating, while others (or perhaps the same individuals) may use the lake as a place for natural resource conservation or as a source of peace and relaxation. The Lake Owen 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 the lake as a fishery may be primarily based on the ability of the lake to support different species at different sizes and population densities, while use of the lake as a site for relaxation maybe primarily influenced by the number and type of watercraft on the lake.

Because different uses of Lake Owen 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 Lake Owen, 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 Lake Owen 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 Wisconsin Department of Natural Resources (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 grant (LPL-1483-13) and the Towns of Drummond and Cable and developed collaboratively through volunteer contributions from the Lake Owen Association (LOA) 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 Lake Owen 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 Lake Owen

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 Lake Owen ecosystem

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

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

6) **Management Recommendations -** summarizes potential actions to protect and restore Lake Owen

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

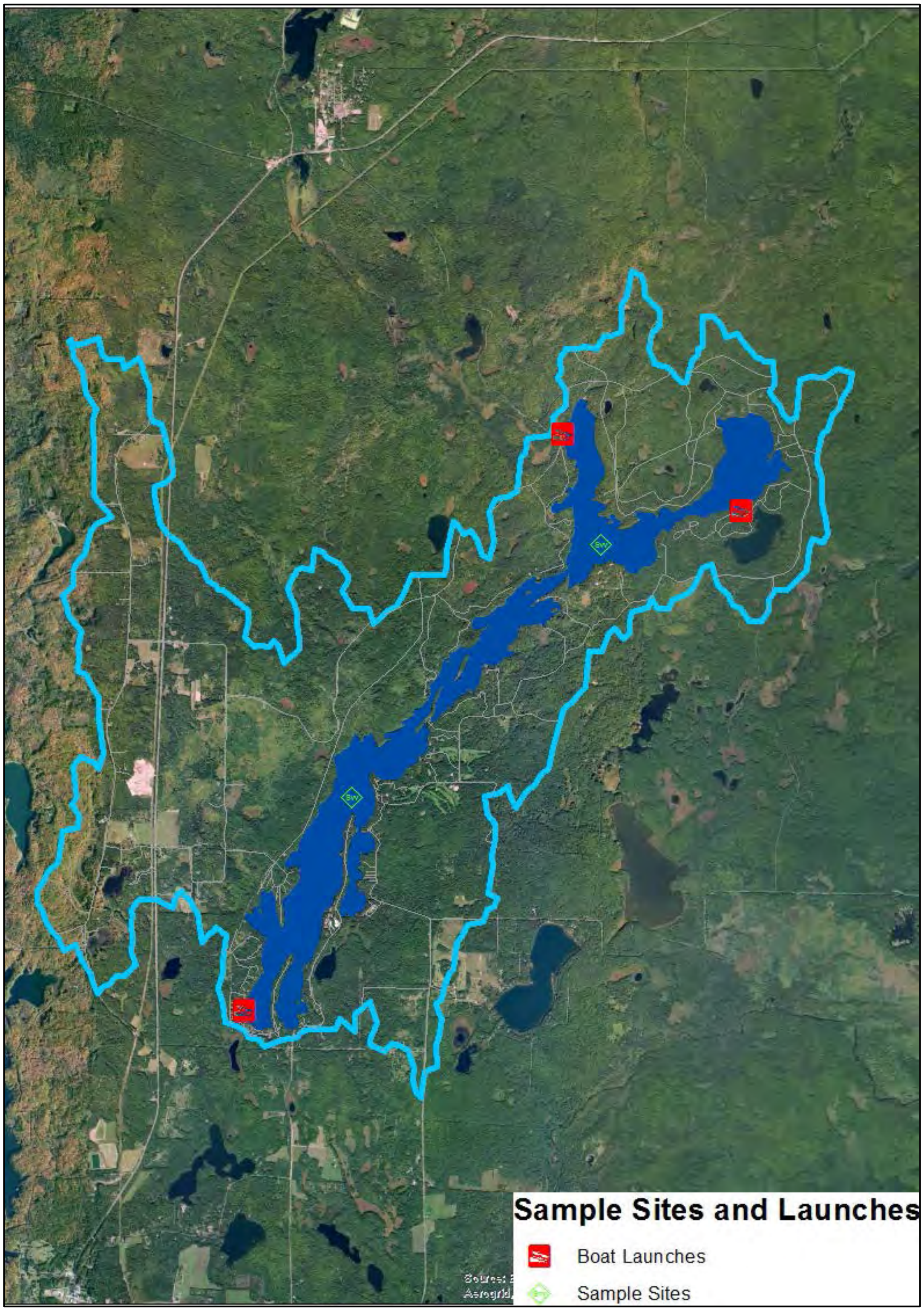

Figure 2.1. Lake Owen and its watershed.

3. Lake Uses, Users and Access

Lake Owen (WBIC Code – 2900200) is primarily used as a recreational and fishery resource by local residents, regional outdoor enthusiasts and Native American First Nations. Lake Owen has two public, one private and two undeveloped access points and two public beaches (Figure 1). Many residents and shoreland owners are actively involved in efforts to understand and protect the health of the lake. Lake Owen has an active association (the Lake Owen Association; http://lakeowenassn.mylaketown.com/) that hosts an annual lake association meeting and distributes quarterly newsletters to lakeshore property owners to increase awareness and understanding of emerging issues and ongoing management initiatives.

The Lake Owen fishery supports both recreational and Tribal harvest. Two creel surveys have been conducted on Lake Owen to assess recreational usage and harvest (Rasmussen et al. 1988 and Toshner 2009). Results from these surveys suggest that recreational fishing pressure in Lake Owen (24.0 hr/acre) is consistent with averages throughout lakes in Bayfield and Douglas County (22.5 hr/acres), but below averages for Northern Wisconsin Region (33.3 hr/acre). Angler usage has remained relatively consistent since 1988 and the most commonly pursued species are smallmouth and largemouth bass and to a lesser extent, walleye. Species specific harvest rates are described in greater detail in Section 5.5. Lake Owen has also been identified as an Outstanding Resource Water (ORW) by the WDNR and its protection and management have been identified in a number of goals in the Bayfield County Land and Water Conservation Plan.

3.1. Stakeholder Survey

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

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

A census sample (i.e., the entire population) of households within one mile of the lakeshore of Lake Owen was drawn from Bayfield County records. After removing undeliverable surveys, duplicate landowners, or vacant properties, the final sampling size was 277 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 August and September of 2014 with a 40.8 percent (or 113 surveys) response rate. Survey respondents generally represented the general population in the area. Average age of survey respondents was 69 years, with an average income of $60,000-$99,000 per year. Of the respondents, ~73% were waterfront owners and 23% were year round residents.

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

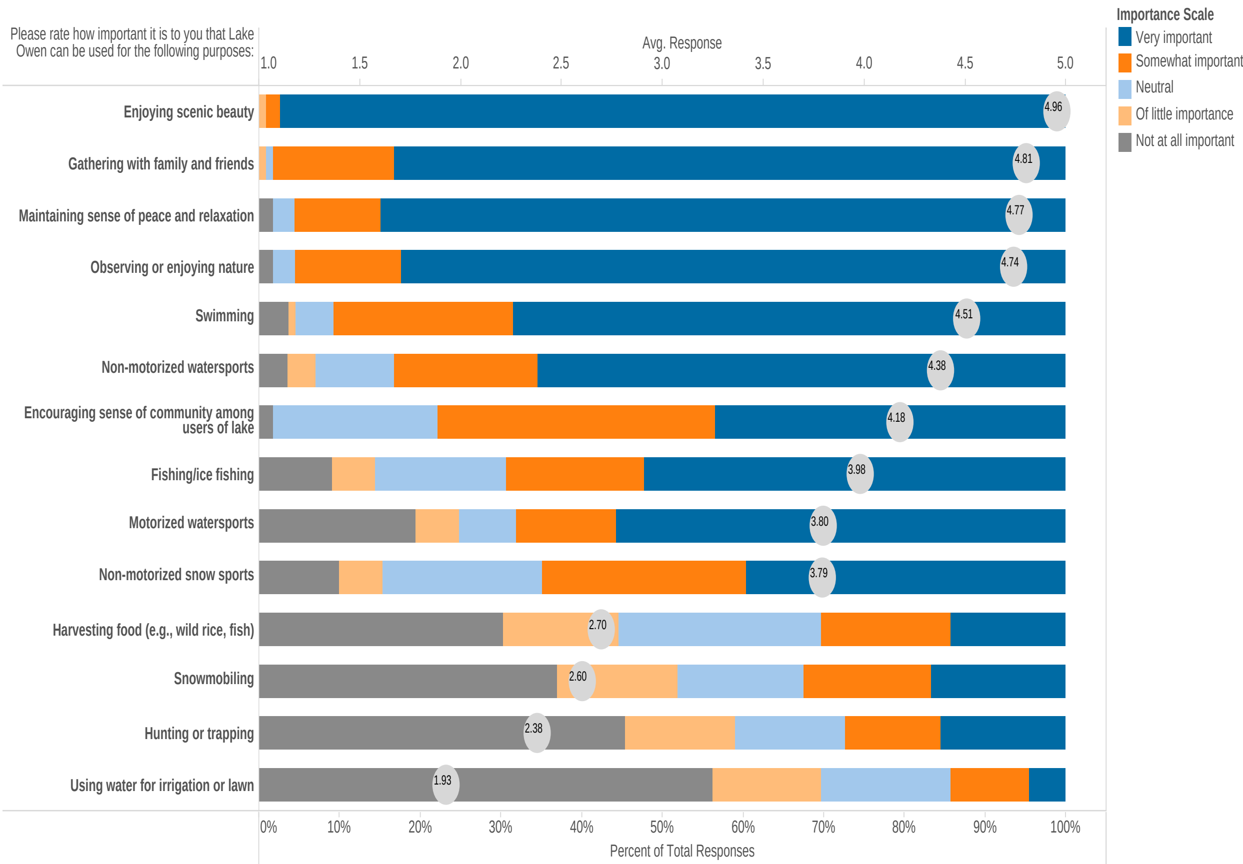

Figure 3.1. Most highly valued uses of Lake Owen by survey respondents.

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

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

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

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

What are the general value sets and/or beliefs that lake users likely base their actions on?
In general, survey respondents see Lake Owen 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.

3.2. Use and Value Priorities

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

- Aesthetics and scenic beauty
- Observation of the natural world
- Protection of the Lake Owen ecosystem
- Relaxation and social gathering
- Boating (motor and non-motorized)
- 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 year leading up to initiation of this planning project, two meetings were held with representatives from the LOA and local government officials to develop the scope of work to be conducted. Drafts of the initial planning grant application were also reviewed by the Bayfield County Land and Water Conservation Department and the Town Boards from Drummond and Cable. From these initial meetings, concerns were raised about potential changes in water quality and the fishery, as well as the potential for invasive species introductions.

4.2. Public Meetings

In both 2013 and 2014, project summaries were presented at the Lake Owen annual meeting. Presentations focused on current results and solicitation of input regarding potential management considerations for the lake. Comments from general lake association members were similar to that of the Lake Owen Association board and local elected officials—changes in the fishery and the potential for invasive species introduction were the primary concerns. 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 LOA and WDNR. Representatives from the US Forest Service and Bayfield County were informally briefed on the status of the project and invited to attend the discussion, but were unavailable. 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 LOA board, WDNR, Bayfield County, US Forest Service, Red Cliff Tribe and made available to the town Boards of Drummond and Cable.

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 Lake Owen
- Protect and Restore Nearshore and Shoreline Habitat
- Maintain Existing Water Levels and Hydrologic Processes
- Maintain Existing Water Quality Conditions

- Maintain Diverse Native Plant Communities
- Maintain Diverse Native Oligotrophic Fish Communities
- Restore Smallmouth Bass Populations to Historical Densities
- Maintain Current Harvest Levels for Walleye

5. Lake Condition Assessment

Lake Owen 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 Lake Owen are influenced by a variety of physical, chemical and biological processes. This section describes the current conditions in and around Lake Owen with respect to: Climate and Precipitation; Physical Habitat and Hydrologic Processes; Watershed Conditions; Water Quality Conditions; Biological Communities; and, Ecological Interactions.

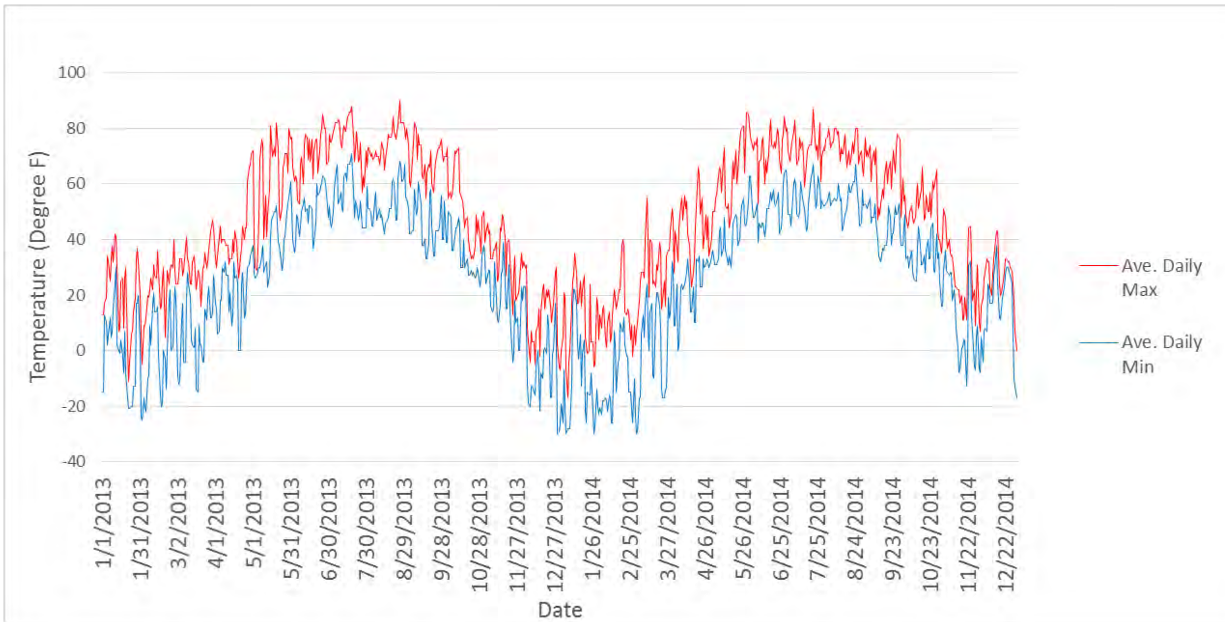

Figure 5.1. Minimum and maximum daily air temperatures through study period.

5.1. Climate and Precipitation

Climate in the Lake Owen area is considered continental, but is moderately affected by the Lake Superior climate zone. Summer daily temperatures average 58.6 ^{o}F and winter daily temperatures average 24.6 ^{o}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 Lake Owen 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.

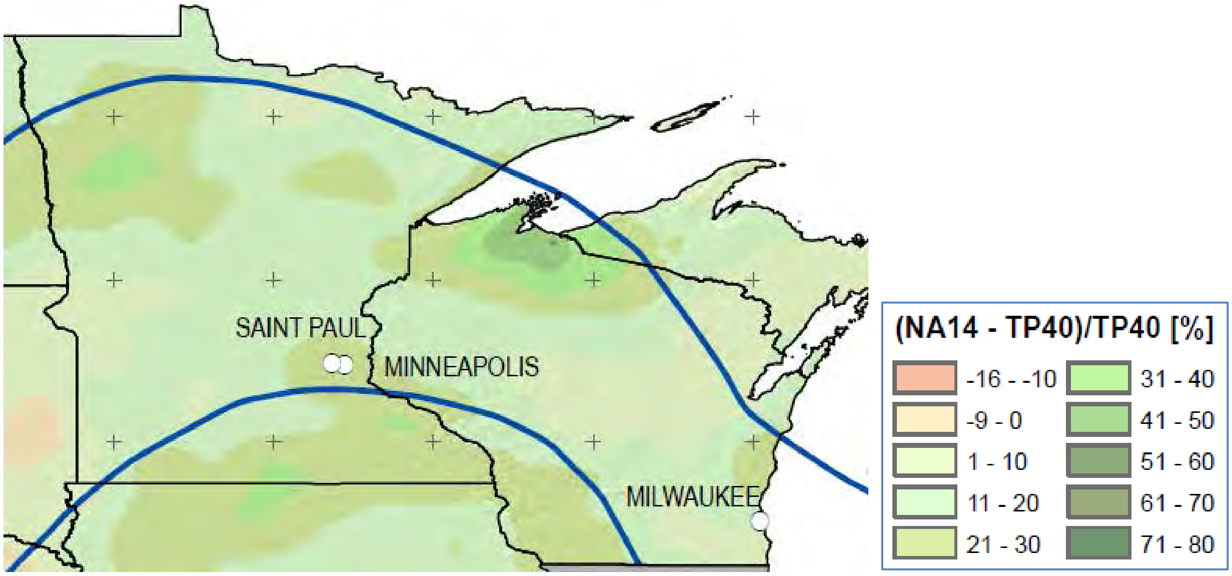

Figure 5.2. A comparison of the percent change in the 100-year, 24-hour precipitation events between the Atlas 14 and TP 40 publications. Adopted from Atlas 14 (Perica et al. 2013).

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 Lake Owen 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 Lake Owen 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.

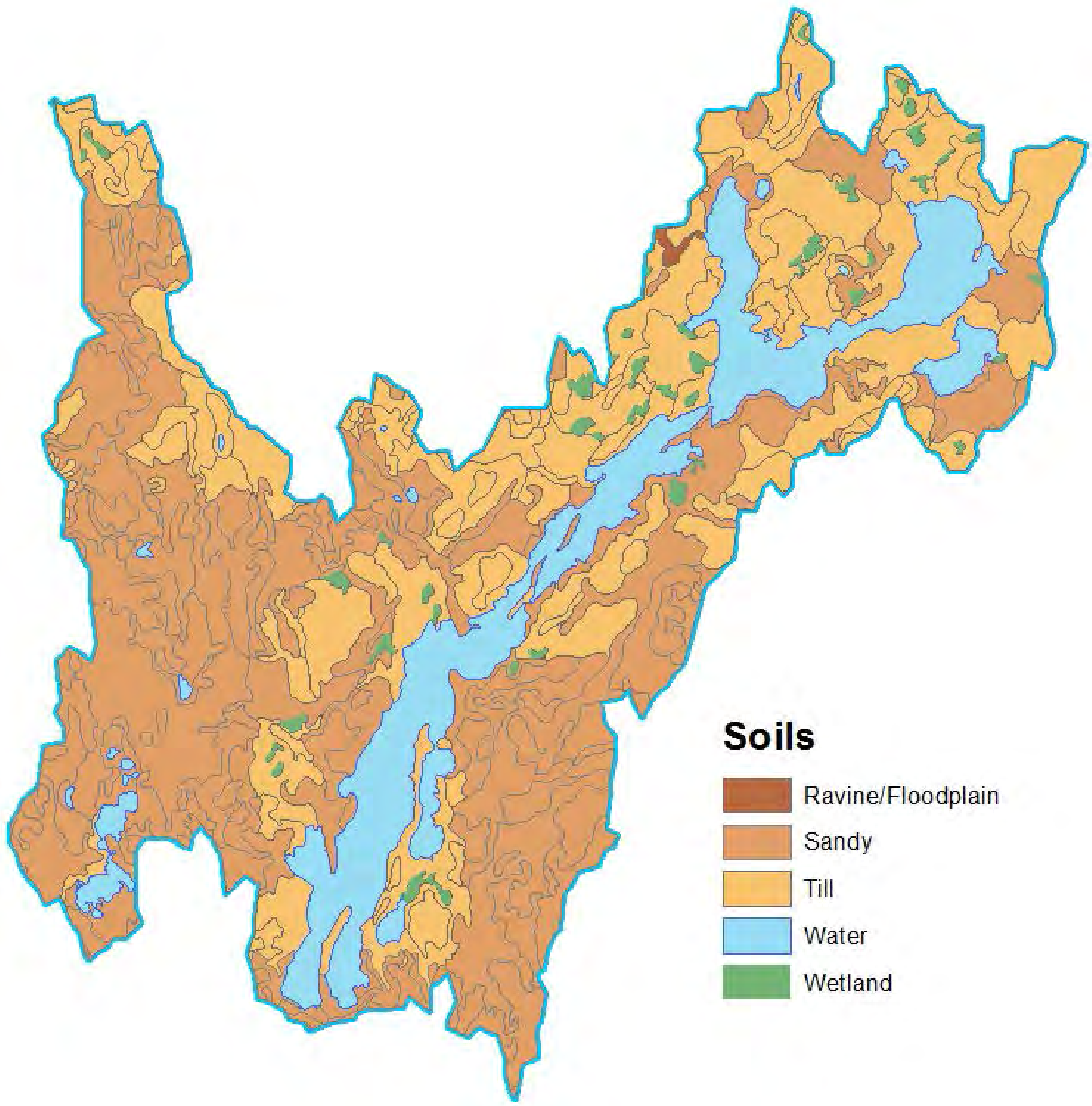

Figure 5.3. Distribution of soil groups throughout Lake Owen watershed. Based on Natural Resource Conservation Service (NRCS) SURRGO soil classifications.

Bathymetry

Lake Owen is a 1,323 acre, drainage-based lake with a maximum depth of 97 feet and an average depth of 23 feet (Figures 5.4 and 5.5). The Lake Owen basin is irregularly shaped with a series of long, narrow islands and bays. Despite its long, narrow basin shape, the maximum fetch in the lake is 2.3 miles (in the southern basin).

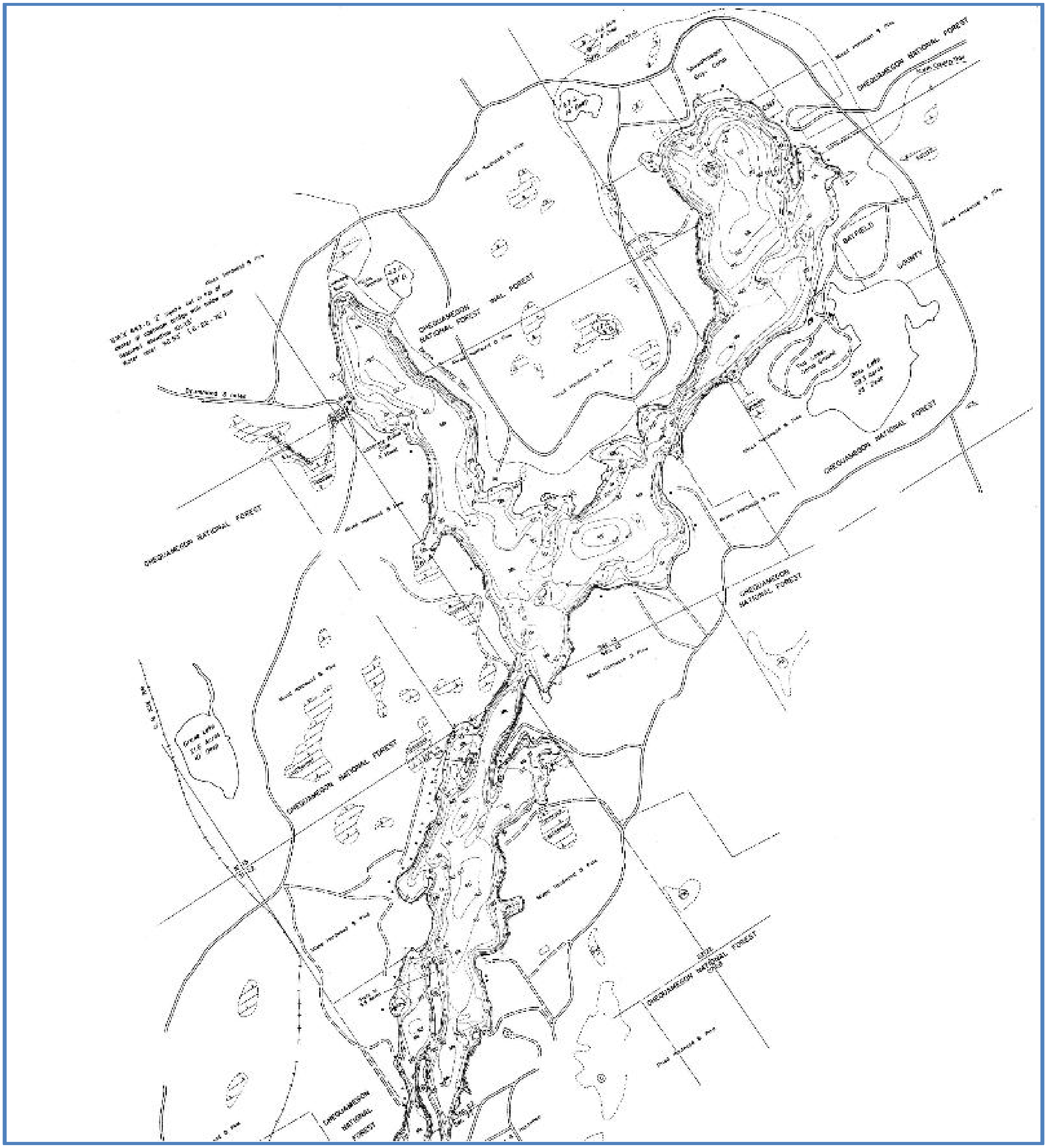

Figure 5.4. Bathymetry of the northern basin of Lake Owen.

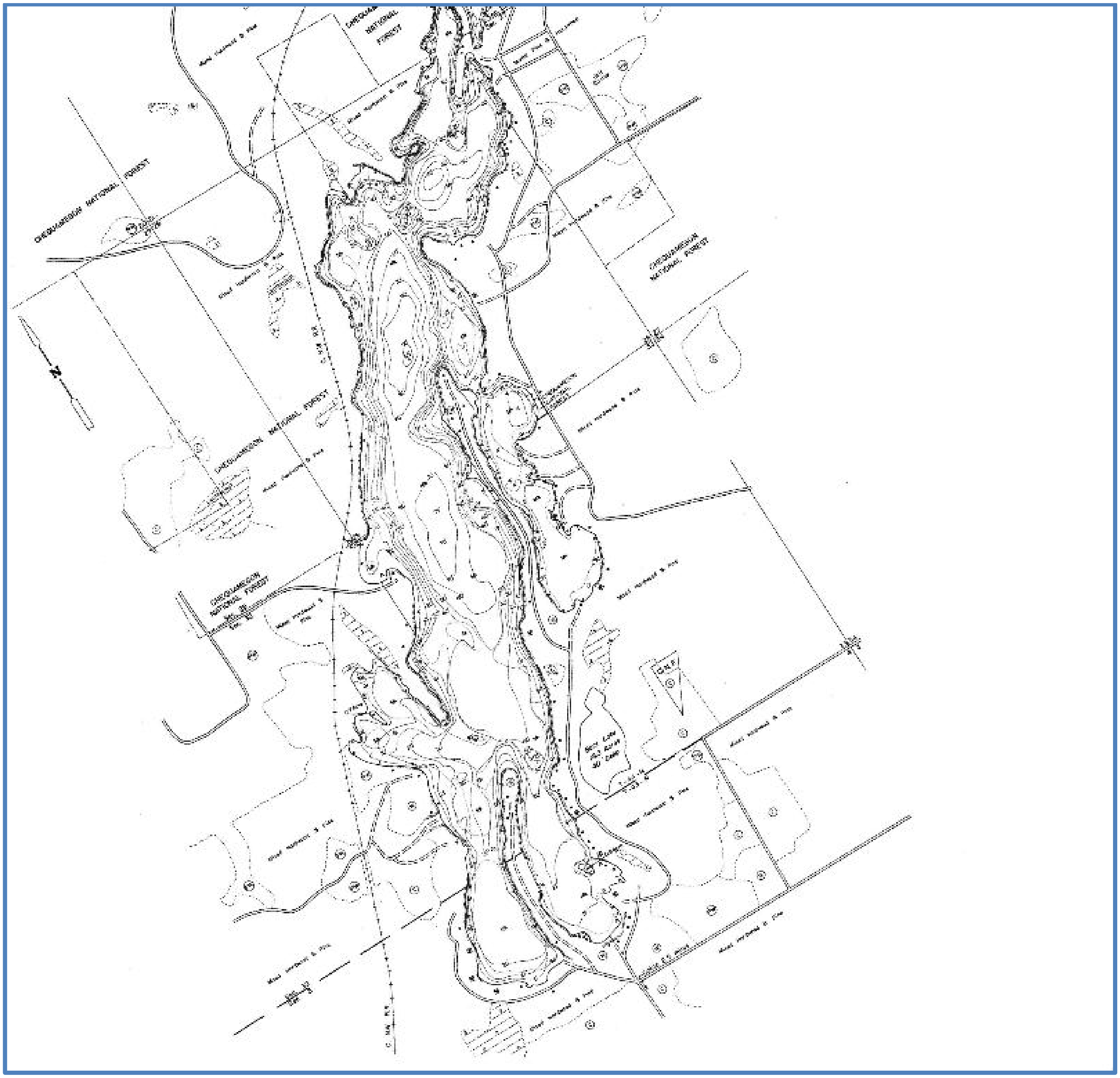

Figure 5.5. Bathymetry of the southern basin of Lake Owen.

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 5.6). 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 5.7). 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.

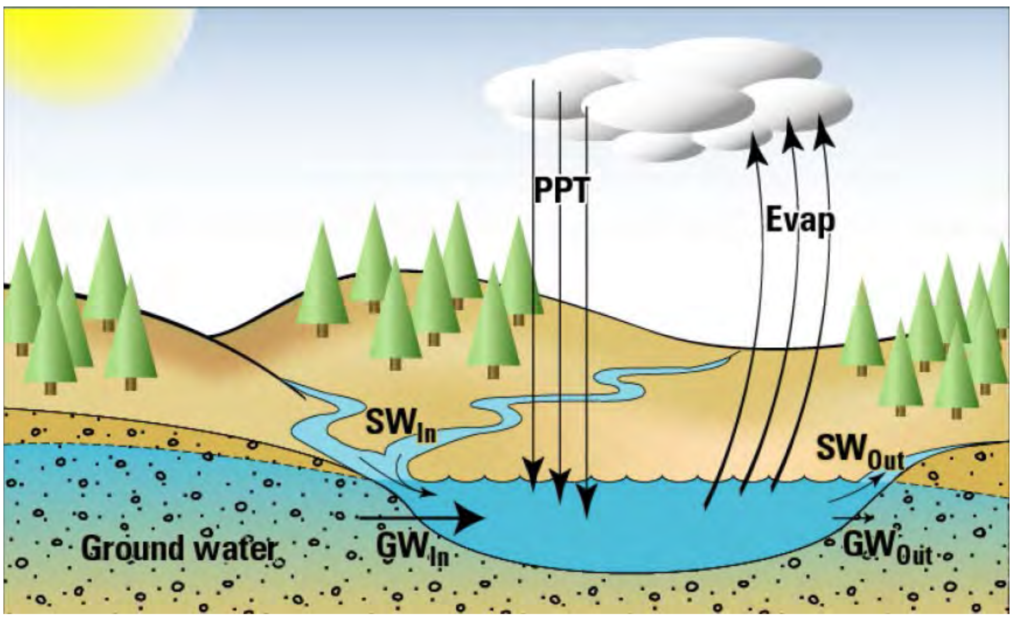

Figure 5.6. Conceptual schematic describing the surface water (SW), groundwater (GW). Precipitation (PPT) and evaporation (Evap) that determine lake levels (adopted from Krohelski, 2003).

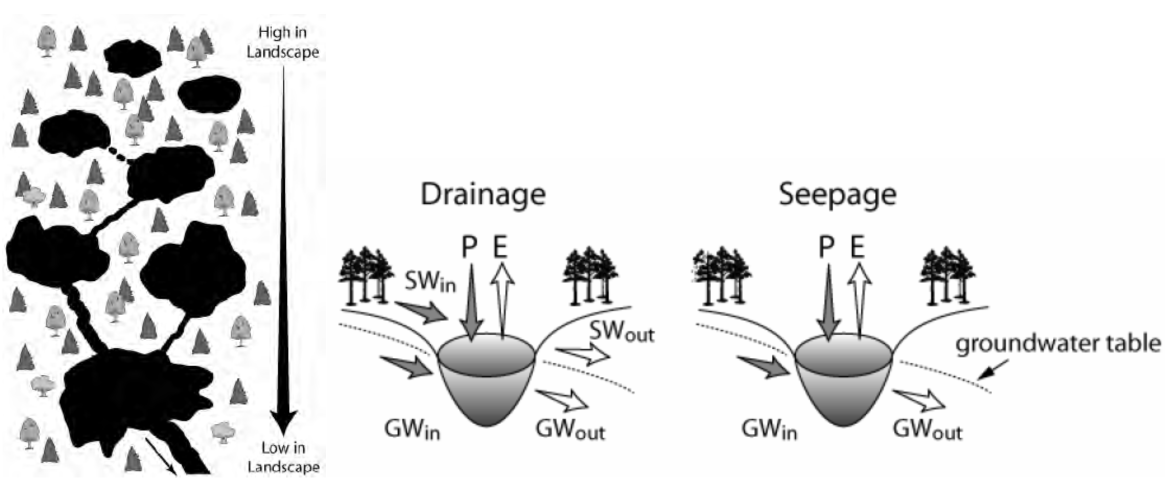

Figure 5.7. Conceptual diagram of "landscape position" and the differences in hydrologic processes between drainage and seepage lakes. Modified from Magnuson et al. 2006.

Water Level Fluctuation
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 implication (see Section 7.1 for additional detail).

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 5.8). 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 overs"). 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 resuspended 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).

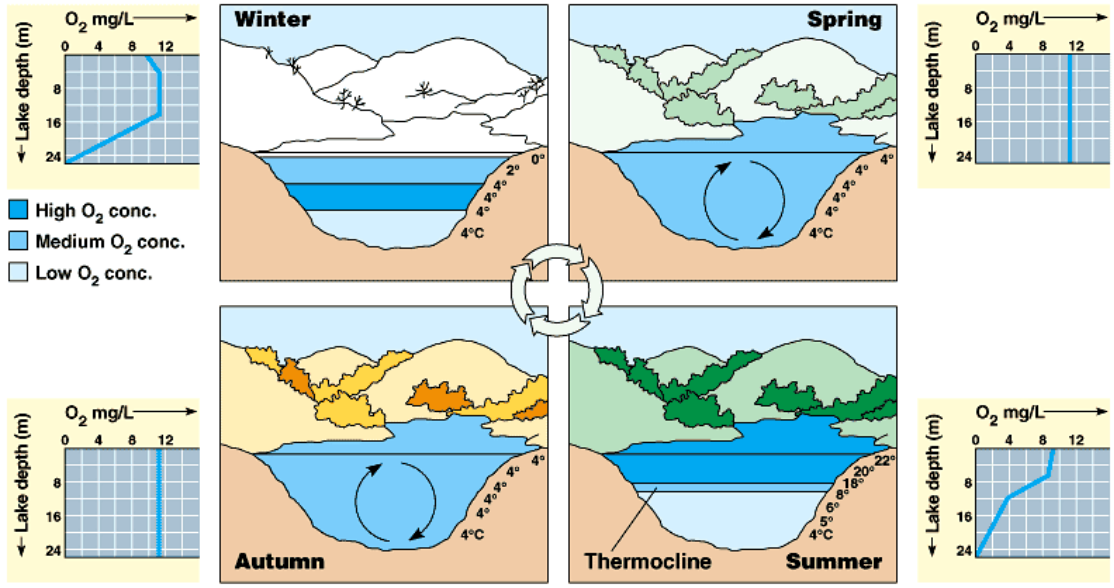

Figure 5.8. Conceptual schematic of the processes of turnover and stratification and the resulting water quality conditions.

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. And, 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 suggest that 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. 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.

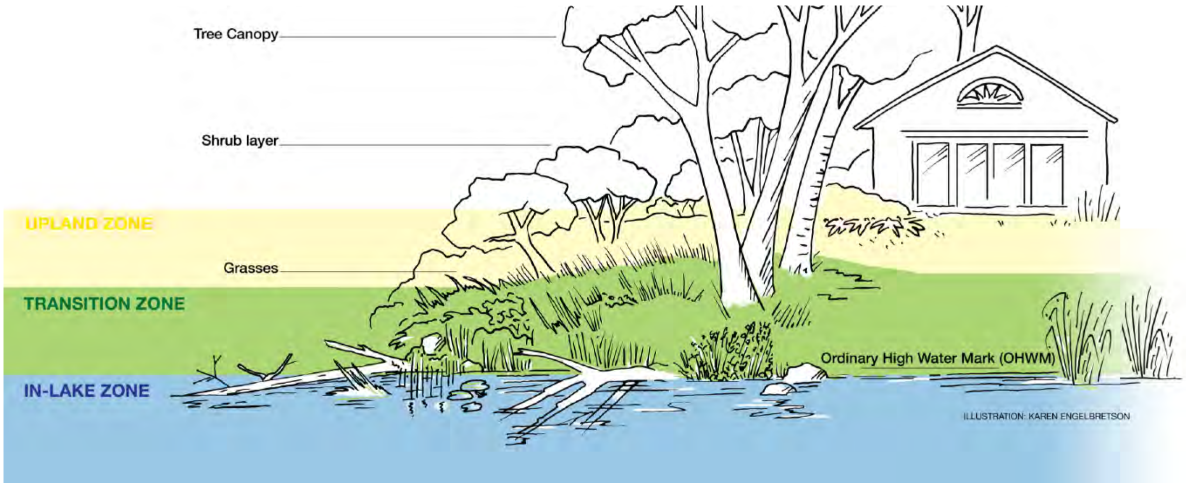

Figure 5.9. Conceptual diagram of the different habitat zones at the land water interface in a lake. Adopted from WDNR Healthy Lakes Implementation Plan, 2014.

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

New Data Collection
To better characterize shoreland habitat in Lake Owen, shoreline and in-lake 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 two sites that represent the deepest hole in the north and south basin of the lake. In addition to these internal processes, outflows from Lake Owen were measured over the two years study, and periods of base flow (and a variety of landscape measurements) were used to develop a water budget for the lake. 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 its location in the watershed relatively little land area drains to Lake Owen (Figure 1.1). As such, Lake Owen is classified as a spring fed lake. Results from this assessment confirm this spring fed classification. Throughout most of the year (except spring) groundwater is the dominant source of water to the lake (Figure 5.10). In the spring, as snow melts and early season rains are most intense, the majority of water in Lake Owen comes from watershed runoff. However, as the summer progresses, groundwater becomes increasingly important. These results highlight the significance of groundwater as part of the Lake Owen ecosystem.

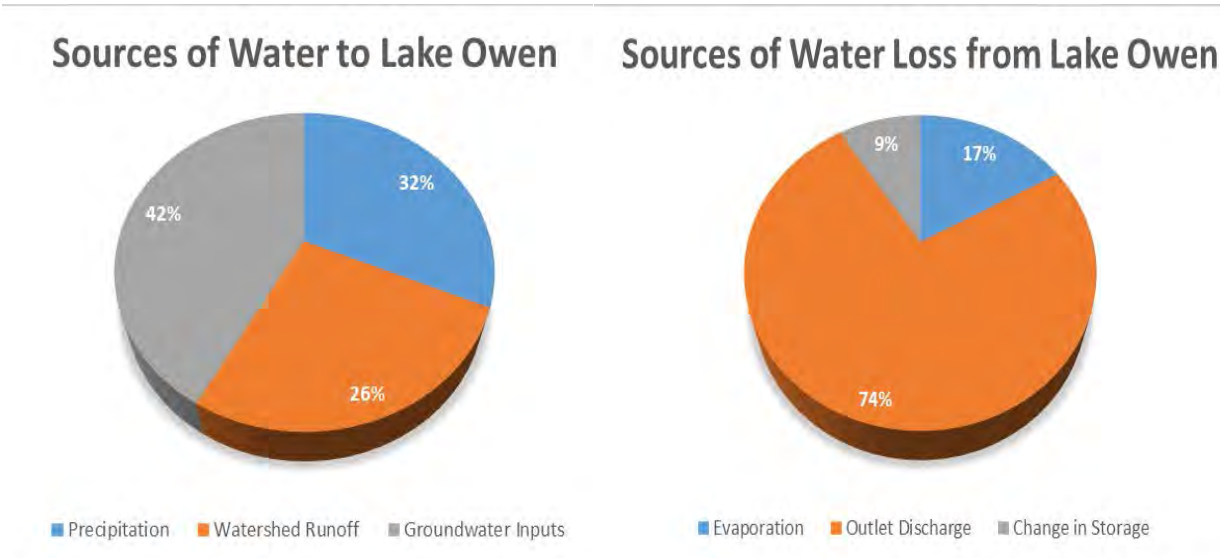

Figure 5.10. Sources of water into and out of Lake Owen.

Summary Results – Physical Processes

Because of its depth and long narrow basin orientation, physical processes in Lake Owen are particularly interesting. Although most regional lakes mix twice throughout the year (i.e., are dimictic), Lake Owen did not fully mix (turn over) throughout the study period (e.g., Figure 5.11). In both the northern and southern basins, temperature profiles never fully destratified at any point throughout this two year study (although the north basin partially mixed in one event). Because of this prolonged stratification, dissolved oxygen concentrations in the bottom water (particularly in the southern basin) remained particularly low (often below 1 mg/L) throughout the year. 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).

This intense and prolonged stratification is likely one factor that contributes to the high levels of water clarity throughout the lake. As nutrients and sediment sink to the bottom, they are rarely reintroduced to the surface waters where they can stimulate algal growth. However, because nutrient concentrations in deep waters are particularly high, plankton growth appears to be concentrated along the metalimnion. The result of this interaction leads to an unusual condition known as a "metalimnetic oxygen maxima". In most lakes oxygen concentrations are highest at the surface (where atmospheric oxygen is readily mixed), but in Lake Owen, rapid algal growth in deeper waters creates a condition where the highest oxygen concentrations are near the middle of the water column (Figure 5.12). Nutrient and biological process are described in further detail in Sections 5.4 and 5.5 below.

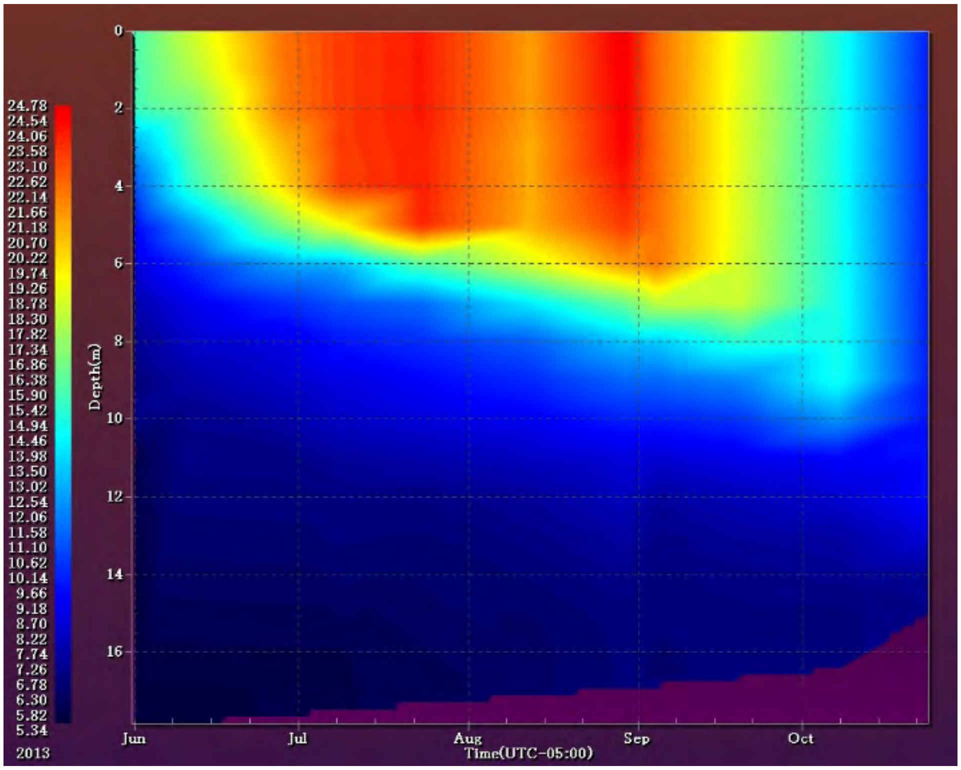

Figure 5.11. Seasonal thermal stratification in Lake Owen in the north (left) and south (right) basins.

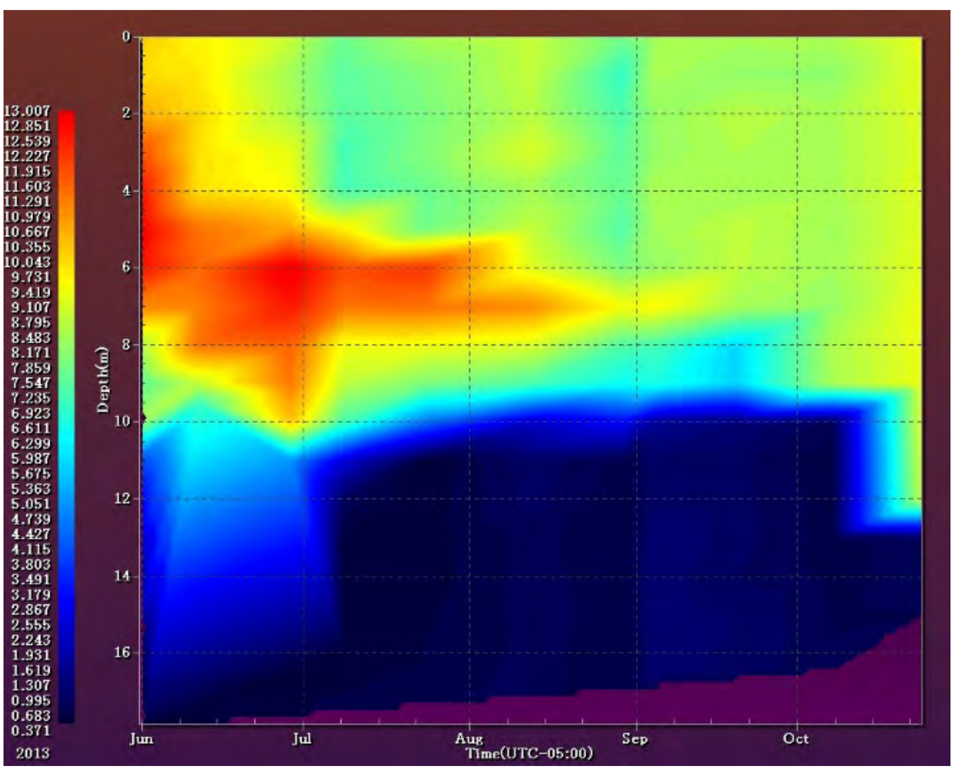

Figure 5.12. Vertical profiles of oxygen concentrations in Lake Owen (north basin). Red colors indicate the areas of highest oxygen concentration.

Summary Results – Shoreland and Critical Habitat
Shoreland habitat is of particularly high quality in Lake Owen (Figure 5.13). Of all of the lakes sampled by Northland College, Lake Owen has (by far) the most intact and highly diverse shoreland habitat. In general, the areas of the lake that contain the highest quality shoreland habitat are located along the northern and eastern 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. Although shoreland habitat surrounding Lake Owen is in relatively good conditions, a range of opportunities exist to restore or enhance habitat conditions. Given its abundance and high quality, it is likely that shoreland habitat is a significant contributor to the long-term health and stability of the Lake Owen ecosystem.

Summary Conclusions – Physical Habitat and Processes
Much of the condition of the Lake Owen ecosystem is likely driven by the quality of physical habitat throughout the system and the unusual stratification patterns observed throughout the lake. Given the likely significance of shoreland habitat to sustaining the Lake Owen ecosystem, management efforts should focus on the long-term protection of this region of the lake and target restoration activities in localized areas that have become degraded over time. Strategies for habitat protection and restoration are described in detail in Appendix C.

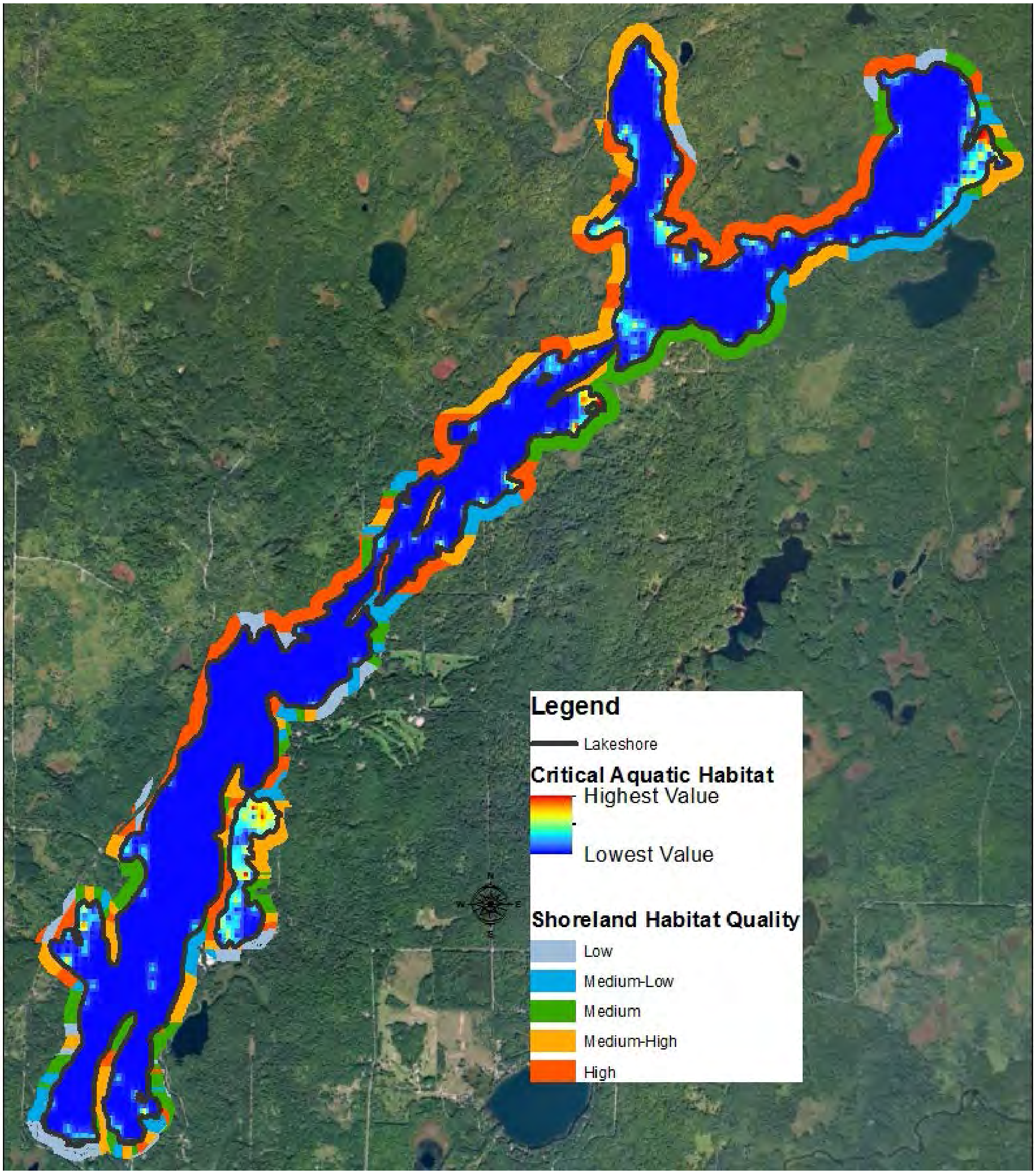

Figure 5.13. Locations of highest quality aquatic and shoreland habitat, 2013.

5.3.Watershed Conditions and Processes

Lakes are ultimately a product of their watershed (or lakeshed) conditions. In northern Wisconsin, most lakes were formed by some glacial event. Following their formation after the last glacial maxima (~15,000 ybp), 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 5.14). 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).

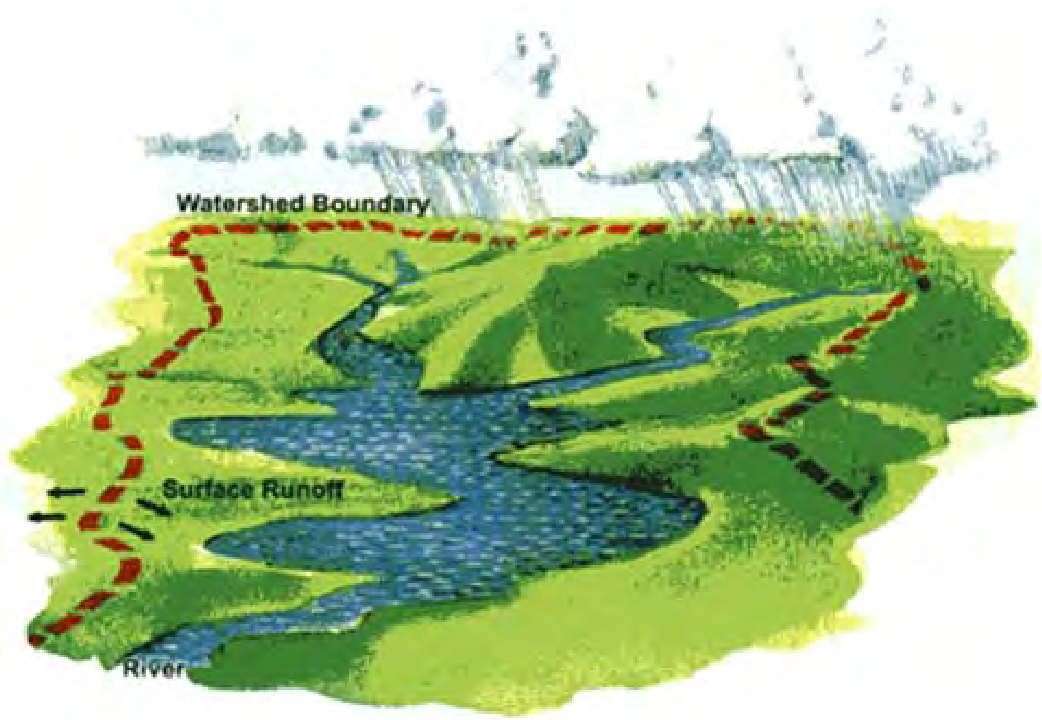

Figure 5.14. Conceptual diagram of the land area that contributes water to a lake—often referred to as the watershed, or lakeshed.

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 deliver 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 developed, 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 and the parcel specific shoreland habitat assessments. Projections of anticipated future land uses were based on zoning conditions specified in the comprehensive plans for the Towns of Drummond and Cable. Details of the land use assessment are described in Appendix D.

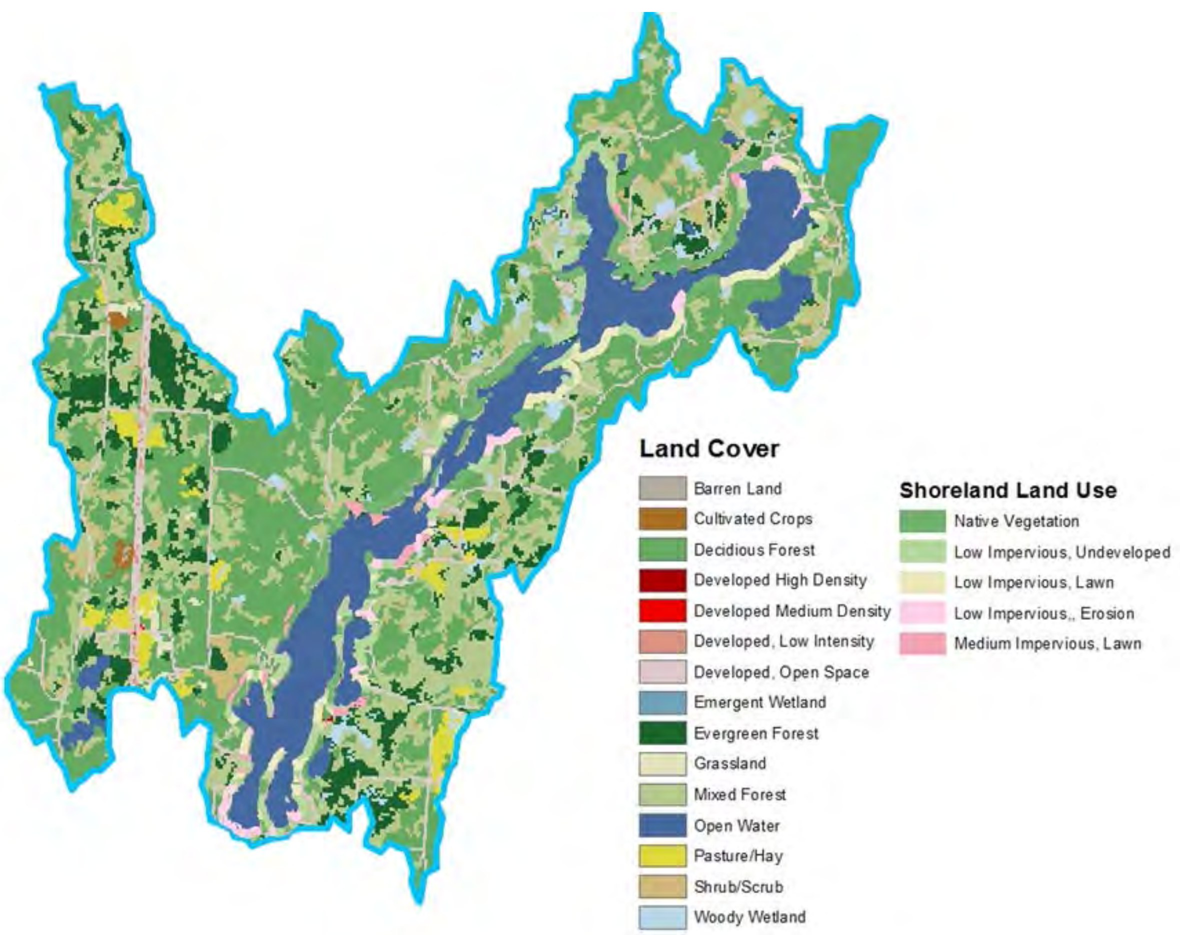

Figure 5.15. Land cover throughout the Lake Owen watershed and surrounding shoreland areas.

Summary Results – Land Use
Land cover throughout the watershed has significantly shifted since the mid-1800s and is anticipated to continue to change in the coming years (Figure 5.15s and 5.16). Historically, sugar maple and yellow birch dominated much of the north and western lake shore, while white, jack and red pine dominated much of the south and eastern lake shore. Over time, the relative abundance of coniferous species has declined and has been replaced by mixed forests and small amounts of urban and agricultural lands. 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.

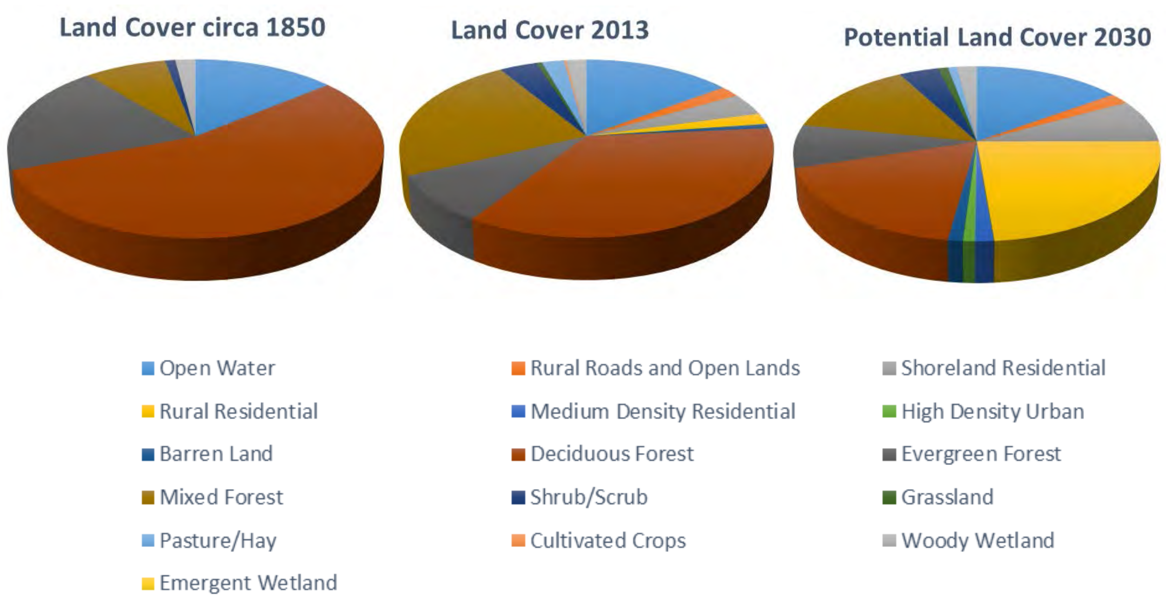

Figure 5.16. Land cover change throughout the Lake Owen watershed.

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 Lake Owen 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 29 percent over pre-development conditions. If the Lake Owen watershed is fully developed according to existing zoning and land use policies, phosphorus runoff to the lake has the potential to increase by an additional 7 percent by 2030.

Table 5.1. Potential sources of phosphorus from different land uses in the Lake Owen watershed.

	Annual TP Loads			Estimated Annual Phosphorus Loads to Lake Owen					
				Historical (1856)		Current (2013)		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	212	212	60	60
Barren Lands	0.1	3	1	0	0	75	75	75	75
Urban Lands	(lbs./acre/yr)			Acres	lbs.	Acres	lbs.	Acres	lbs.
Rural Roads and Open Lands	0.1	0.5	0.3	0	0	191	57	191	57
Shoreland Residential	0.05	0.25	0.2	0	0	383	77	1082	216
Developed, Rural Residential	0.05	0.25	0.1	0	0	191	19	1484	148
Developed, Medium Density	0.3	0.8	0.5	0	0	1	1	95	48
Developed, High Density	1	2	1.5	0	0	0	0	61	92
Forest and Grasslands	(lbs./acre/yr)			Acres	lbs.	Acres	lbs.	Acres	lbs.
Deciduous Forest	0.05	0.2	0.09	5360	732	3411	616	1914	432
Evergreen Forest				2010		844		861	
Mixed Forest				766		2235		1641	
Shrub/Scrub				0		356		383	
Grassland	0.01	0.25	0.17	0	0	53	9	96	16
Wetland	0.01	0.01	0.01	191	2	190	2	192	2
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	169	78	338	156
Relative Changes in Phosphrus Load					**Total**	**%**	**Total**	**%**	**Total**
Total Watershed Load					**734**	**0.31**	**1067**	**0.07**	**1146**
Permitted/Non-permitted Source Load					**0**	**1.00**	**78**	**0.50**	**156**
Total Phosphorus Loads					**734**	**0.36**	**1145**	**0.12**	**1302**
Per Acre Phosphorus Load					**0.08**	**0.31**	**0.11**	**0.07**	**0.12**

Shoreland Septic Systems

To calculate phosphorus runoff to Lake Owen 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, estimate 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 Lake Owen

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	31	2.5	1	0.3	1.1	1.8	1.5	25	42	**35**
	Seasonal	128	2.5	0.3	0.3	1.1	1.8	1.5	32	52	**43**
	Total	**169**	**2.5**	**0.65**	**0.3**	**1.1**	**1.8**	**1.5**	**57**	**94**	**78**
Potential Future Conditions	Full-time	62	2.5	1	0.3	1.1	1.8	1.5	51	83	**69**
	Seasonal	257	2.5	0.3	0.3	1.1	1.8	1.5	64	104	**87**
	Total	**338**	**2.5**	**0.65**	**0.3**	**1.1**	**1.8**	**1.5**	**114**	**187**	**156**

Summary Results – Septic Systems
Under current conditions, all 169 privately owned shoreline parcels draining to Lake Owen use septic systems. Of these, most (~74%) are seasonal residences. Based on these parameters, the annual load of phosphorus to Lake Owen from septic systems is approximately 78 lbs/year (Table 5.2). If shoreland areas are fully developed according to current zoning regulations, the total number of potential septic system could increase to 388 (see Appendix D). Under this potential scenario, assuming the same number of users per residence and proportion of seasonal residences, the phosphorus load to Lake Owen from septic system has the potential to approximately double to 156 lbs./year.

Summary Conclusions – Watershed Conditions
Watershed delivery of phosphorus to Lake Owen 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 Lake Owen will increase by a relatively small amount. Given the land use development guidelines in place, future land uses and potential increases in septic system densities each have the potential to increase phosphorus runoff to the lake by 79 lbs./year. 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 Lake Owen 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).

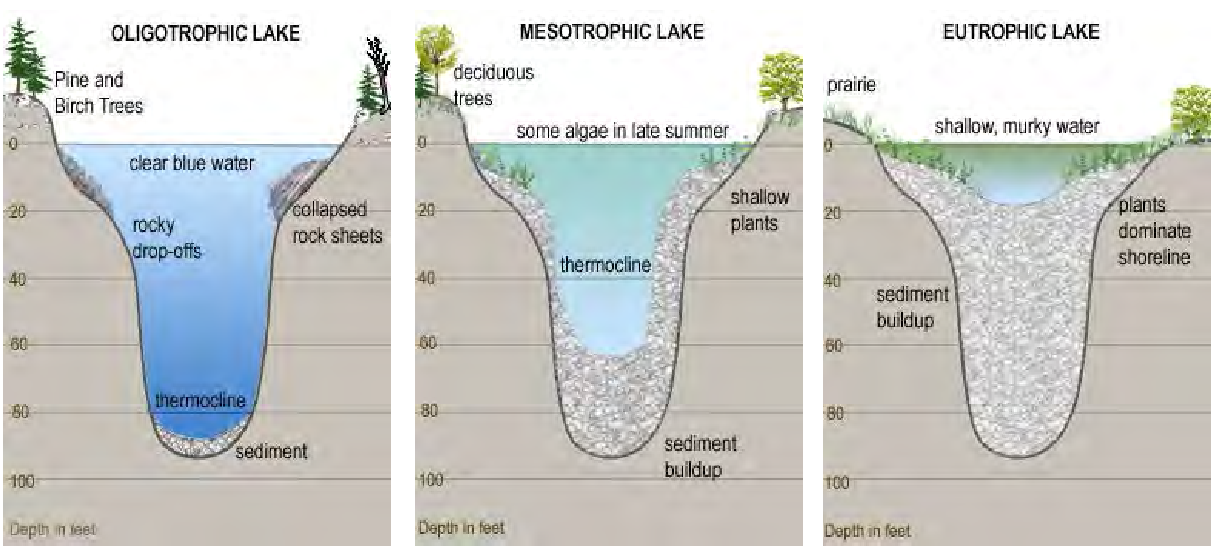

Figure 5.17. Conceptual diagram of the structure of different lake classifications. Adopted from http://rmbel.info/lake-trophic-states-2/.

As described above, as lakes “age” their nutrient concentration generally increases (Figure 5.17 and 5.18). This process of lake aging is generally referred to as eutrophication. Most lakes in northern Wisconsin were created by glaciation and began their existence as low-nutrient, oligotrophic lakes. Oligotrophic lakes are characterized by deep, cold clear water with relatively little plant growth and fish communities that are dominated by trout, cisco and perch. As nutrients and sediments wash into the lake each year and nutrient concentrations increase, the lake becomes more productive (i.e., more plants grow) and the composition of the biological communities shift. Mesotrophic lakes are characterized by increased aquatic plant growth, somewhat warmer, shallower water, with reduced water clarity and fish communities that are dominated by perch, smallmouth bass, walleye and pike. As the lake continues to age and increase in nutrient concentration, the biological communities continue to shift toward more eutrophic conditions. Eutrophic lakes are warmer and shallower and characterized by dense aquatic plant communities and relatively warmer, more turbid waters that are dominated by sunfish, largemouth bass and perch. As lake depth continues to decrease through sedimentation and nutrient concentrations continue to increase, the lake become hypereutrophic and ultimately transitions into a bog and/or wetland ecosystem. Each stage in this nutrient-driven evolution of a lake is often referred to as a trophic state.

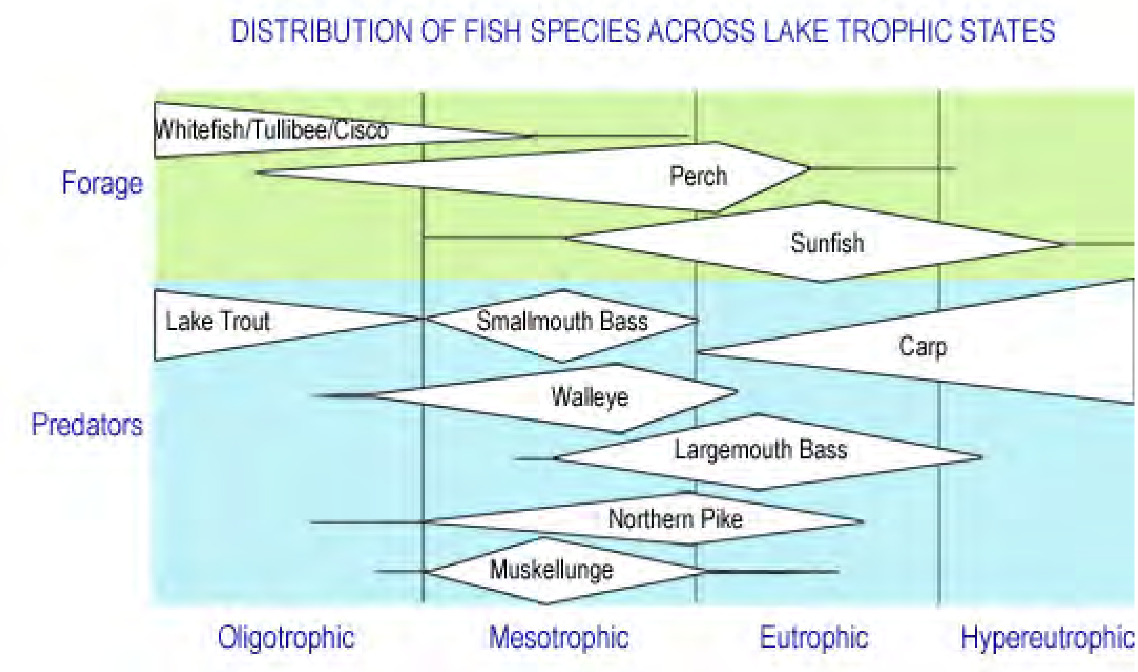

Figure 5.18. Conceptual diagram of the different fish communities that often inhabit lakes of different trophic conditions. Adopted from http://rmbel.info/fish-distribution/.

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 ofs 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).

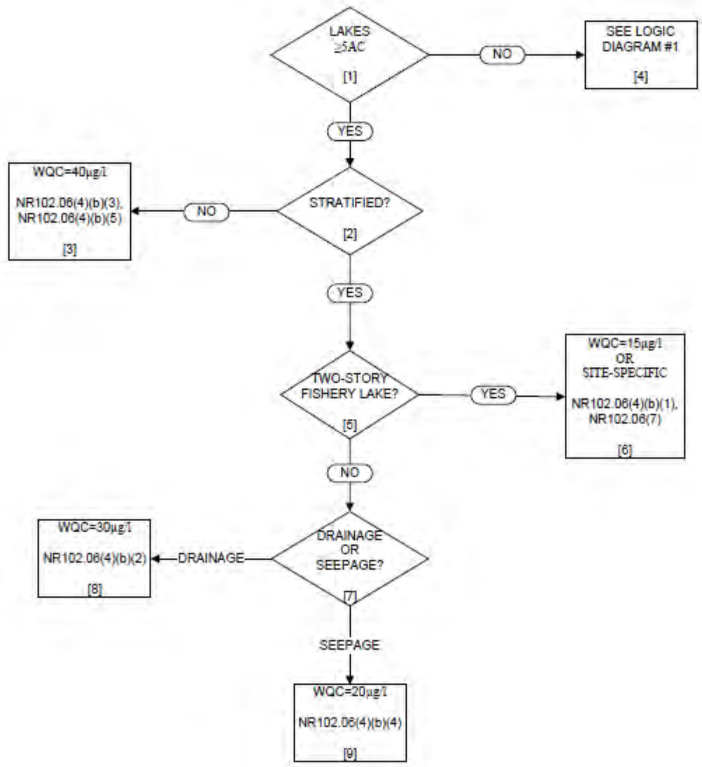

Figure 5.19. Total phosphorus water quality standards for lakes in Wisconsin.

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 seasons total phosphorus concentration. Expected/allowable total phosphorus concentration is dependent on the lake trophic state classification (Figure 5.19). In Lake Owen, average growing season (June-August) total phosphorus concentrations should not exceed 15 ug/L.

Historical Water Quality Conditions

Water quality in Lake Owen has been monitored over different periods and by different agencies since 1992. 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=2900200). The most detailed water quality study for Lake Owen was conducted as part of a WDNR Lake Planning Grant (LPL-964-04) in 2005 (WDNR, 2005). Results from this study suggested that a significant difference in water quality exist between the northern and southern sections of the lake (with southern sections having higher nutrient concentrations) and that water quality had generally degraded over time. Water quality in Lake Owen was also described in 1981 as part of Master Degree thesis (Seiser, 1981).

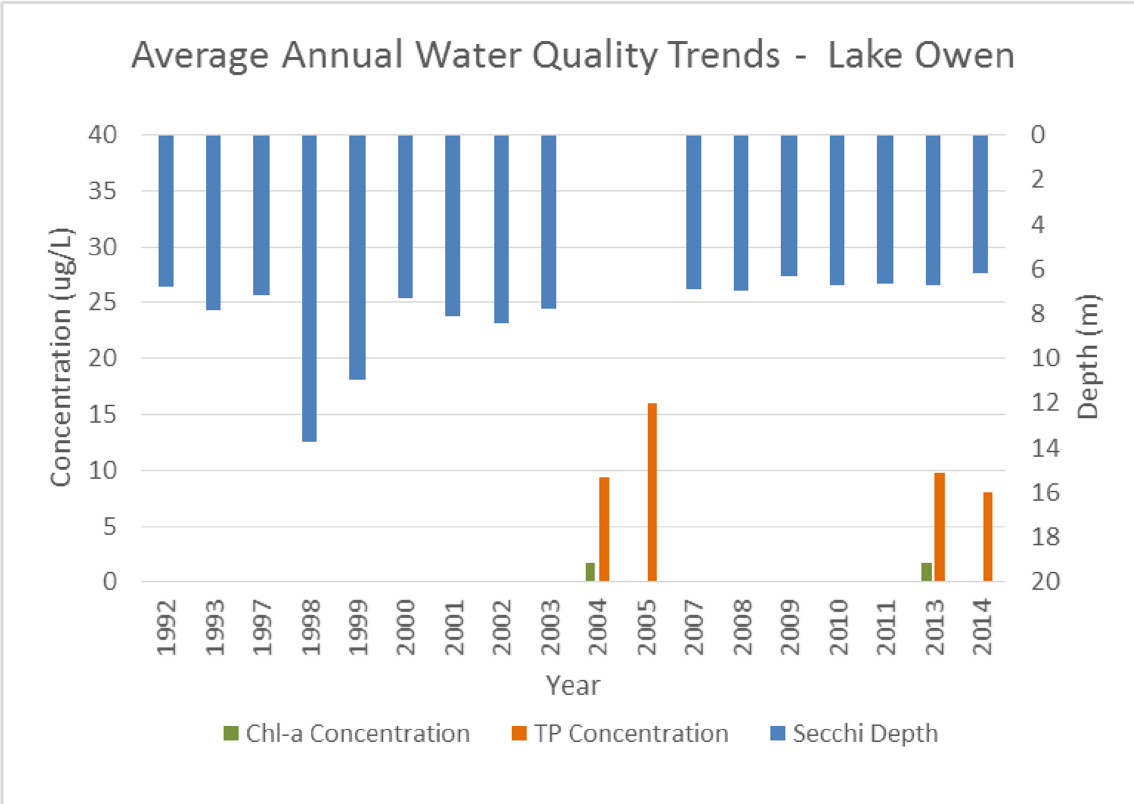

Figure 5.20. Average annual water quality trends in Lake Owen (1992-2014).

The majority of the recent water quality data have been collected through the WDNR Citizen Lakes Monitoring Network (CLMN). Through this program, volunteers have collected data at four primary sites since 1992. Volunteers have generally collected samples once per month from June to September at the deepest points at each of the sampling locations. Water quality measurements have primarily focused on Secchi depth and, to a lesser extent, total phosphorus in surface waters. Interestingly, although the 2005 WDNR study suggested that water quality was poorer in the southern bays of Lake Owen, the ongoing Secchi (and to some degree nutrient) monitoring as part of the CLMN suggests that surface waters in the northern end of the lake have lower clarify and higher nutrient concentrations.

The combination of the water quality data suggests that Lake Owen is a low nutrient lake with average phosphorus concentrations of ~ 11 ug/L, an average Secchi depth of 23 feet, a Secchi Trophic State Index (TSI) of 31.9 and a total phosphorus TSI of 46.5 (Figures 5.20 and 5.21). Lake Owen is currently classified as an oligotrophic lake. 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. Despite these relatively stable conditions, one period in the data record (1998-2000) exhibited a significant increase in water clarity. The cause of this water clarity is unknown, but this event and the difference between the Secchi and total phosphorus TSI scores suggest food-web processes may be an important driver of water clarity in Lake Owen.

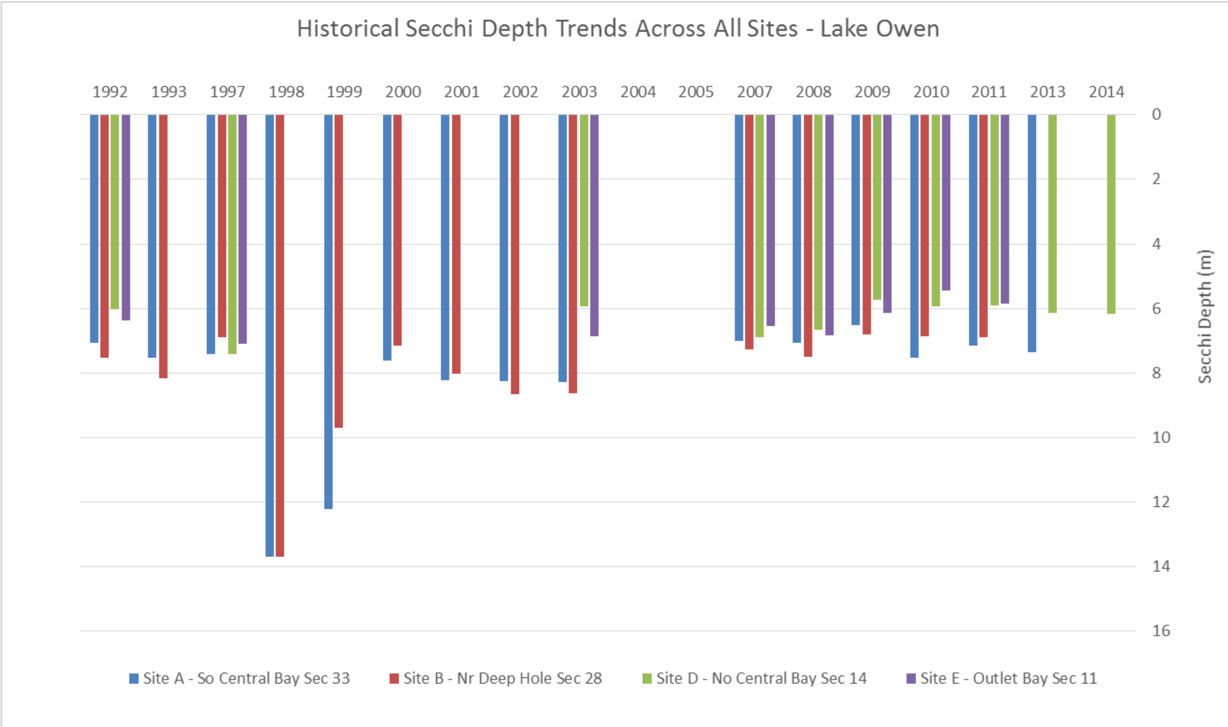

Figure 5.21. Historical trends in Secchi depth across all sites in Lake Owen.

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 two sites (corresponding to Site A and Site D) every two weeks from May-October. At each site, water quality was described by supplementing Secchi depth measurements with Chl-a data, as well as profile measurements of temperature, pH, dissolved oxygen, conductivity, total phosphorus, soluble reactive phosphorus and total nitrogen. Details of the intensive water quality sampling are described in Appendix B.

Summary Results – Water Quality

Results from this work suggest that water quality in Lake Owen meets state water quality standards. Total phosphorus, chlorophyll and Secchi depth measurement all indicated that Lake Owen is meeting water quality standards and is accurately classified as an oligotrophic lake.

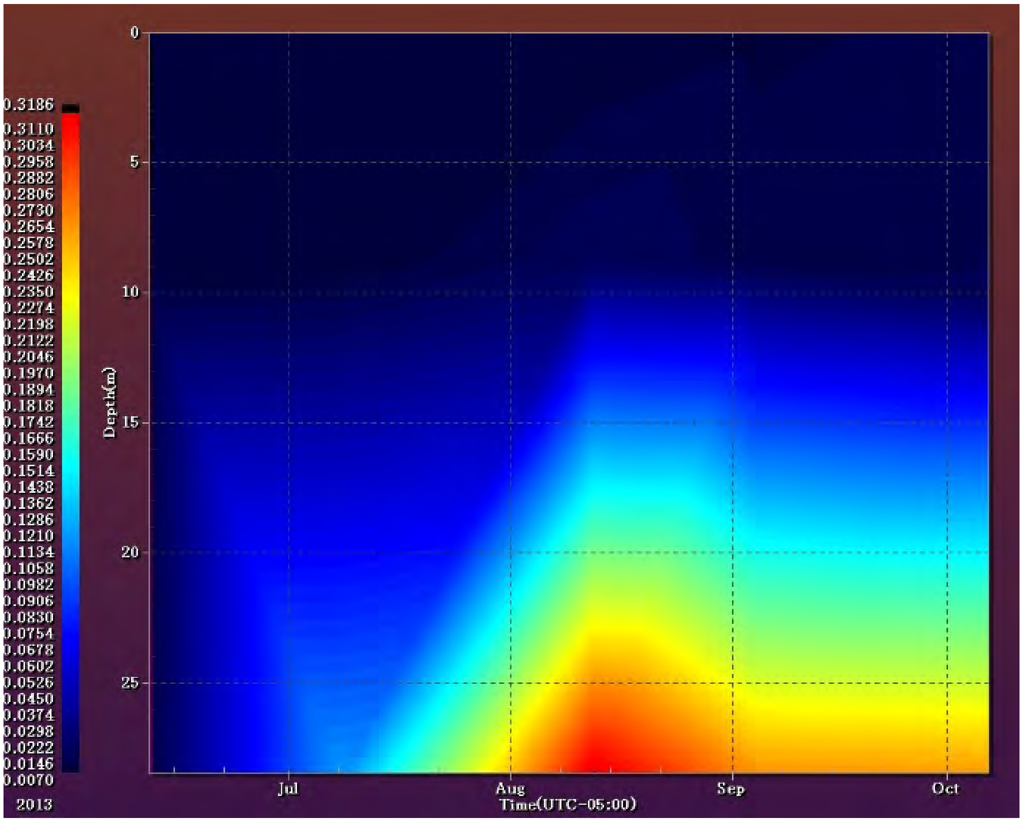

Figure 5.22. Seasonal profiles of total phosphorus concentrations in Lake Owen (south basin).

Nutrient concentrations throughout the depth profile samples are of particular interest in Lake Owen (similar to the physical profile measurements described above). Although surface water phosphorus concentrations in Lake Owen are consistent with an oligotrophic classification, the hypolimnetic phosphorus concentrations are much higher than typically measured in an oligotrophic in lake (Figure 5.22). In fact, hypolimnetic phosphorus concentrations in Lake Owen are more consistent with those observed in eutrophic and hypereutrophic lake systems.

Phosphorus ratios are also of significance in Lake Owen. Throughout most of the year the percentage of total phosphorus in the surface waters that is in soluble form is relatively low, suggesting that most soluble phosphorus is rapidly taken up by algae. Significant algal growth is inconsistent with the clear water consistently observed in Lake Owen, further suggesting that zooplankton grazing is an important control of algal growth. Low soluble phosphorus concentrations in the hypolimnion are somewhat inconsistent with the hypolimnetic dissolved oxygen concentrations. Because hypolimnion oxygen concentrations are consistently below 1 mg/L, sediment release of historically accumulated soluble phosphorus is likely. However, the observed low soluble phosphorus concentrations in the hypolimnion suggest that phosphorus release from the sediments is a relatively small (~15-20%) contributor to the high total phosphorus concentrations observed in the hypolimnion. Interestingly, the percentage of soluble phosphorus in the hypolimnetic waters is relatively consistent in the southern basin and variable in the northern basin. This variability suggests that soluble phosphorus is episodically removed from hypolimnion in the northern basin, potentially as a result of wind-mixing and partial de-stratification. The high percentage of total phosphorus observed in soluble form and low inflow of nutrient and sediment to the lake suggests that the settling of plankton from more productive surface waters is likely an important source of phosphorus to hypolimnion waters.

Summary Results – Lake Nutrient Budget
Within Lake Owen, the majority of the external phosphorus load originates from watershed runoff (Figure 5.23). Most of this watershed loading of phosphorus 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 the Long Lake Branch of the White River. Additional "internal" sources and loss processes are discussed in Appendix G.

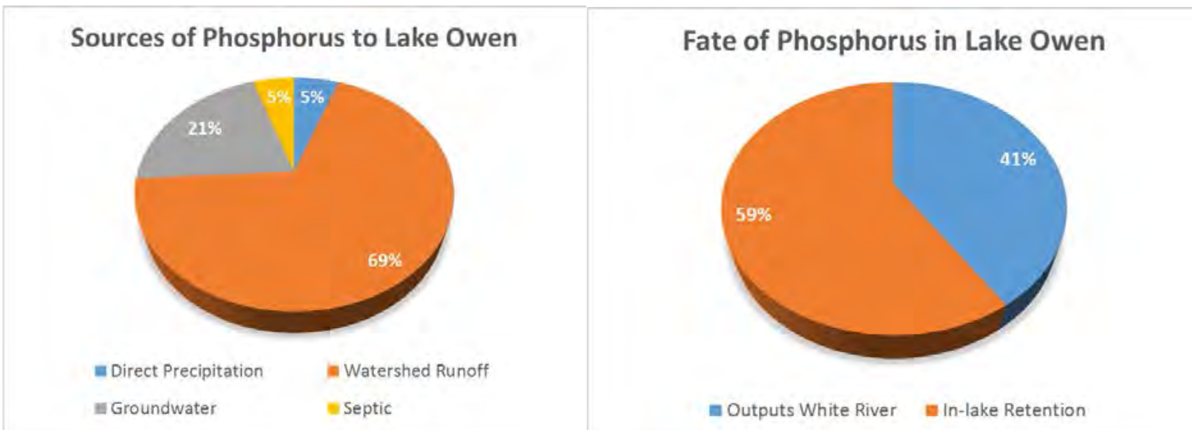

Figure 5.23. External phosphorus budget in Lake Owen.

Summary Conclusions – Water Quality Conditions
Water quality conditions in Lake Owen are consistent with those expected for an oligotrophic lake. The depth and stratification processes in the lake are likely significant contributors to the overall water clarity in the system. Because a relatively high percentage of annual phosphorus is retained in Lake Owen, it is likely that internal cycling of phosphorus is a key element of the lake ecosystem.

5.5. Biological Communities

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

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

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

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

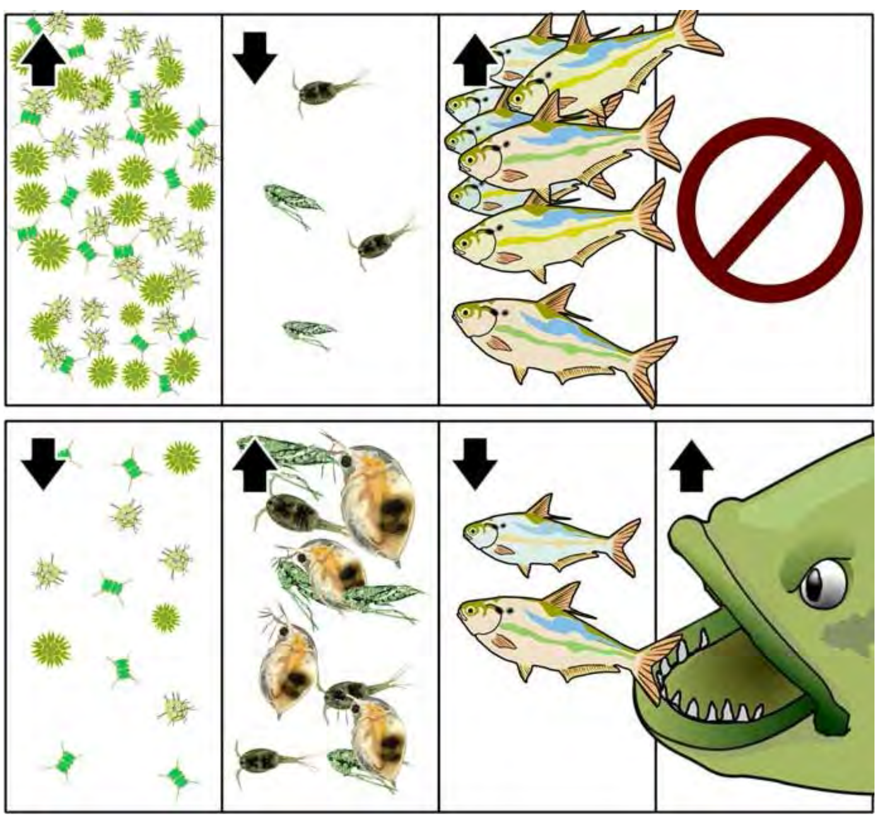

Figure 5.24. Conceptual diagram of the relationship between food web interactions and water clarity. Adopted from http://www.lmvp.org/Waterline/fall2005/topdown.htm.

Food Web Processes
Lake ecosystems are a mosaic of species that are in continuous fluctuation in response to the availability of different food sources. The food web in most lakes throughout northern WI can be viewed as a combination of primary producers (algae and rooted plants), primary consumers (zooplankton and grazing invertebrates), secondary consumers (planktivorous and insectivorous

fish), tertiary consumers (picivorous fish) and quaternary consumers (fish eating birds/mammals and people). Changes in the abundance of any of species at these different trophic levels often results in a change at all other levels in the food web (often referred to as a "trophic cascade"; Figure 5.23). As such, a change in the abundance of top predators can have a cascading effect that results in shifts benthic invertebrate density and/or water quality conditions, or vice versa.

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

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

Historical Data
The majority of the data that exists to describe biological communities in Lake Owen are related to fisheries. Fisheries management work in Lake Owen has been ongoing since the 1930s and is well described in the most recent WDNR fisheries report (Toshner, 2009). All fishery data presented below is based on a summary of Toshner (2009). Based on this report, the fish community is highly diverse, consisting of walleye (*Sander vitreus*), northern pike (*Esox Lucius*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*M. dolomieui*), bluegill (*Lepomis macrochirus*), pumpkinseed (*L. gibbosus*), warmouth (*L. gulosus*), rock bass (*Ambloplites rupestris*), black crappie (*Pomoxis nigromaculatus*), yellow perch (*Perca flavescens*), white sucker (*Catostomus commersoni*), logperch (*Percina caprodes*), Iowa darter (*Etheostoma exile*), bluntnose minnow (*Pimephales notatus*), central mudminnow (*Umbra limi*), cisco (*Coregonus artedii*) and lake whitefish (*Coregonus clupeaformis*).

Lake Owen is a unique, low productivity lake that supports a popular smallmouth bass, largemouth bass and walleye fishery. Since 1988, walleye abundance has declined while largemouth bass abundance has increased. This shift may be the result of overexploitation of walleye, negative interactions between walleye and largemouth bass, or changes in habitat conditions (e.g. temperature, productivity).

Concerns over Lake Owen's shifting gamefish community have resulted in several changes to fisheries management in Lake Owen. Between 2009 and 2011, regulations intended to reduce harvest of walleye were implemented, minimum length limits for smallmouth and largemouth bass were removed, and stocking density of large fingerling walleye was increased. In addition, the model used to assign walleye harvest quotas was changed to more accurately reflect the recruitment status of Lake Owen's walleye population. This resulted in reduced harvest quotas in years when the regression model was used to calculate safe harvest levels (see Section 7.1 for a summary of the process for setting harvest and stocking goals in Lake Owen).

Since these changes have been implemented, modest changes to the gamefish community have occurred. In 2013 and 2014, largemouth bass abundance declined and recruitment of age-1 walleye increased. However, overall walleye density did not increase from 2007. Results from recurring assessments suggest that increased stocking of large fingerling walleye had limited impact on walleye abundance. In 2013, only 9% of the adult population could be attributed to stocking efforts. Additionally, no significant increase in juvenile recruitment has been observed in years when stocking occurred. Lake Owen's oligotrophic nature and abundance of predators may be attributed to the limited success of stocking.

Although changes in harvest quotas and angling regulations potentially influenced exploitation of walleye, smallmouth bass and largemouth bass, it is not possible to assess the impact of these changes because the most recent creel survey occurred in 2007. Similarly, recent changes in the gamefish community to regulation changes could not be attributed without estimates of exploitation or incorporation of a reference lake in the analysis to account for environmental variability. Data are currently being collected that will provide reference lakes for which to compare changes to control lakes. Results from these assessments are expected to be available in 2019.

Beyond the existing fishery data (and a modest amount of historical plankton/diatom data; WDNR 2005), relatively little information exists to describe different elements of the biological communities in Lake Owen.

New Data Collection

To supplement the existing data, a series of new data sets were developed to characterize phytoplankton, zooplankton and aquatic plant communities. Aquatic plant communities in Lake Owen were sampled in year one of this project using a point intercept methodology described by Hauxwell, et al. (2010). Aquatic plant data were analyzed to characterize relative species abundance, invasive species distribution, species diversity and Floristic Quality. All aquatic plant survey results were geospatially processed to inform the identification of critical habitat areas throughout the lake (see Section 5.1 above). Phytoplankton and zooplankton communities were sampled monthly during year two of this project. All plankton data were collected following standard plankton tow methods outlined by the USEPA (2007) and analyzed to characterize the relative abundance of major taxonomic groups and taxa that are known to be key indicators of lake health. Details of collection procedures, data analysis and results are described in Appendix E (aquatic plants) and Appendix F (plankton). Additionally, the presence of Rare, Threatened and Endangered species in the Lake Owen area was quantified by working with WDNR staff to conduct a Township Level query of the Natural Heritage Inventory (NHI) database.

Summary Results – Plankton

Plankton communities in Lake Owen are highly variable, depending on the location within the lake and time of year. Over the course of any given summer, the total density of phytoplankton remains relatively stable, while zooplankton densities are quite variable. Over the course of the summer, the relative abundance of different phytoplankton groups change. In general, diatoms dominate phytoplankton communities early in the summer and blue green algae become increasingly dominant throughout the summer. Zooplankton communities are generally dominated by rotifers throughout the year.

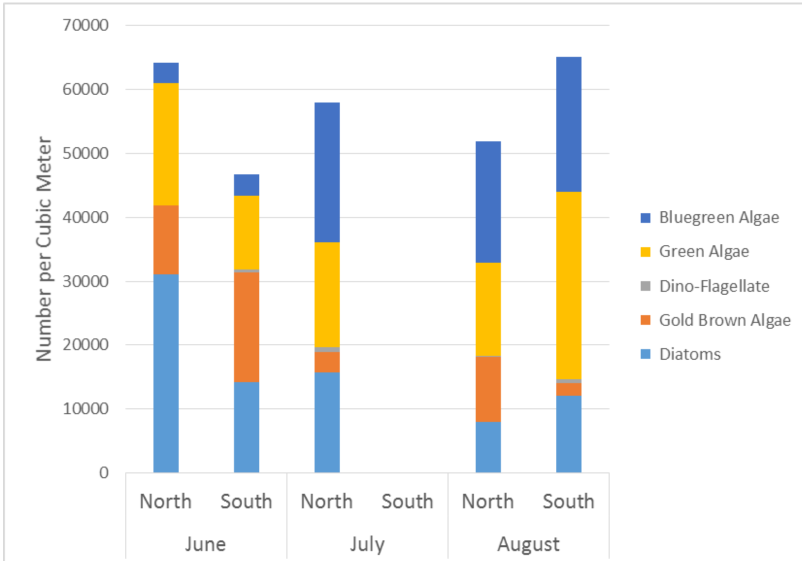

Figure 5.25. Seasonal variation in relative phytoplankton abundance in the north and south basins of Lake Owen in 2014.

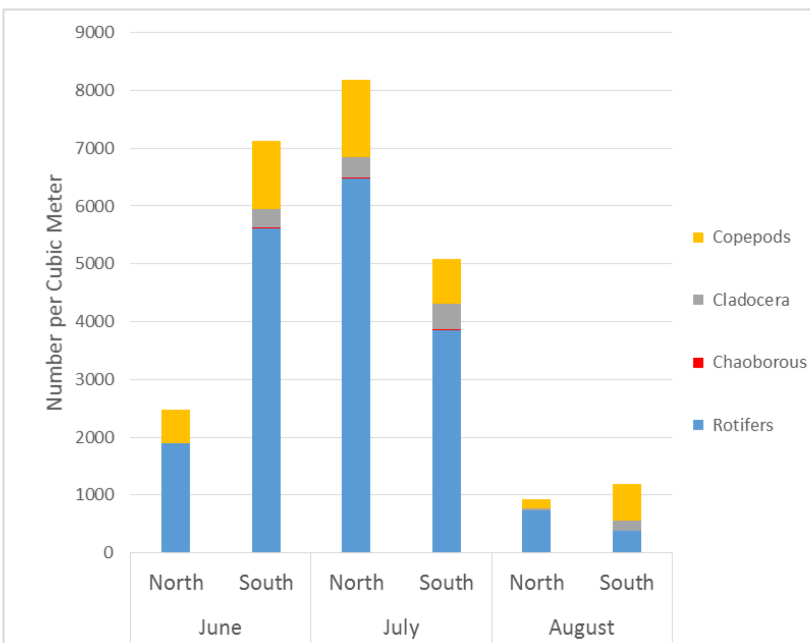

Figure 5.26. Seasonal variation in relative zooplankton abundance in the north and south basins of Lake Owen in 2014.

Summary Results – Aquatic Plants

Lake Owen contains a robust and diverse aquatic plant community (Figure 5.24). Throughout this study, 38 species were identified. The majority of plants were observed growing between 5 and 13 feet, with a maximum depth of 23 feet. The diversity and richness of species also varied among sites within the lakes, with some individual rake pulls not collecting any plants and other collecting up to eleven individual species. In general, the areas of highest species richness were in protected bays at the northern and southern end of the lake. For details of the aquatic plant community assessment, see Appendix F.

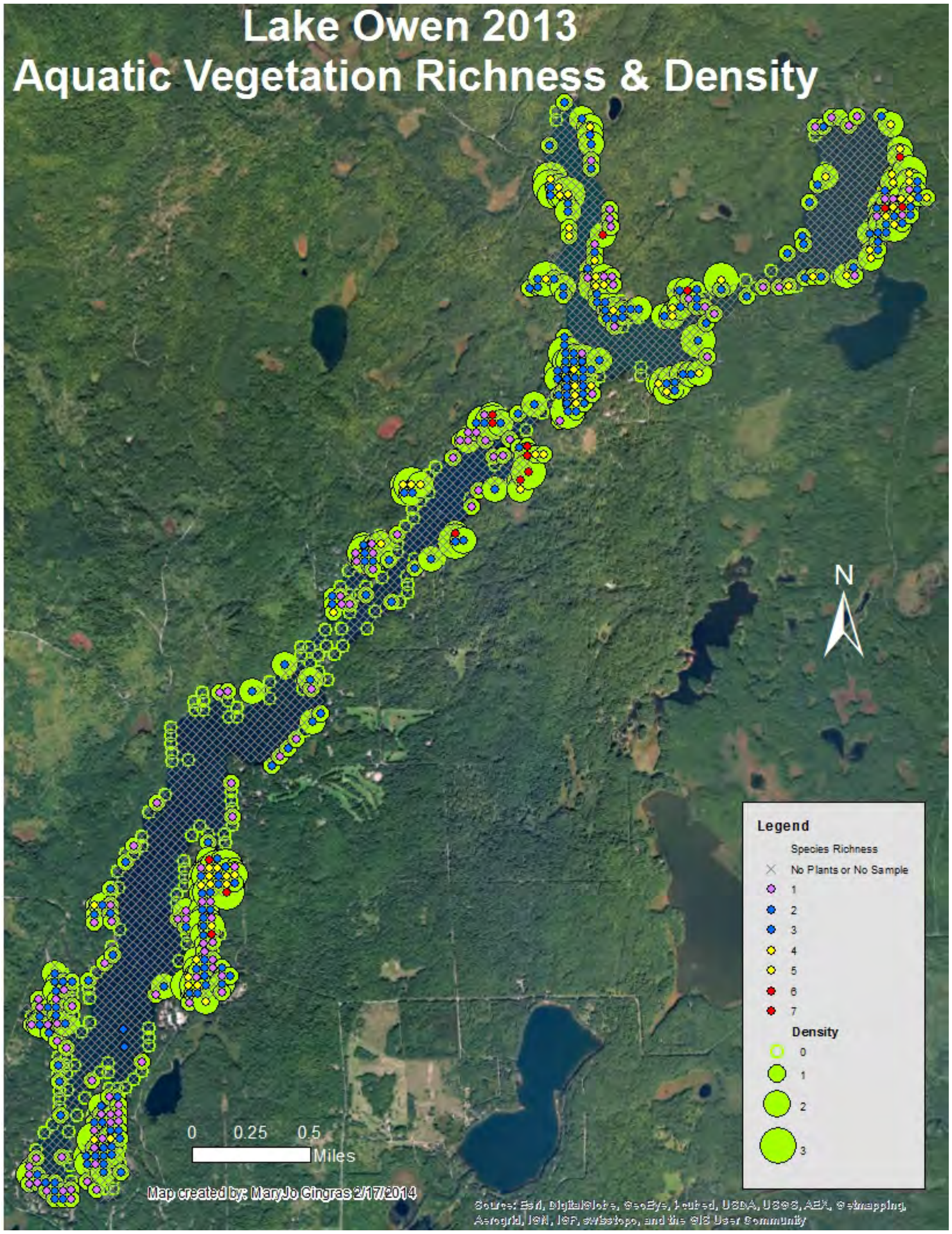

Figure 5.27. Density and species richness of aquatic plants throughout Lake Owen.

Summary Results – Invasive Species

No invasive plant species have been detected throughout the Lake Owen ecosystem. The only non-native species detected in the Lake Owen is the Chinese mystery snail, which has not been documented to have detrimental impacts to lakes ecosystems in Wisconsin.

Summary Results – Rare, Threatened and Endangered Species

Sixteen rare, threatened and endangered species exist within the townships surrounding the Lake Owen 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 is an obligate resident within Lake Owen (i.e., lake management decisions will likely not affect these species).

Table 5.3. Species of special interest throughout the Lake Owen watershed

Scientific Name	Common Name	WI	Group	Scientific Name	Common Name	WI Status	Group
Alasmidonta marginata	Elktoe	SC/P	Mussel~	Northern dry-mesic forest	Northern Dry-mesic Forest	NA	Community
Botrychium minganense	Mingan's Moonwort	SC	Plant	Northern mesic forest	Northern Mesic Forest	NA	Community
Buteo lineatus	Red-shouldered Hawk	THR	Bird~	Pyrola minor	Lesser Wintergreen	END	Plant
Buteo lineatus	Red-shouldered Hawk	THR	Bird~	Rhynchospora fusca	Brown Beak-rush	SC	Plant~
Cygnus buccinator	Trumpeter Swan	SC/M	Bird~	Setophaga cerulea	Cerulean Warbler	THR	Bird
Geum macrophyllum var. macrophyllum	Large-leaved Avens	SC	Plant	Sorex palustris	Water Shrew	SC/N	Mammal~
Napaeozapus insignis	Woodland Jumping Mouse	SC/N	Mammal~	Utricularia resupinata	Northeastern Bladderwort	SC	Plant~
Northern dry-mesic forest	Northern Dry-mesic Forest	NA	Community	Utricularia resupinata	Northeastern Bladderwort	SC	Plant~

Summary Conclusions – Biological Communities

Biological communities throughout the Lake Owen ecosystem are somewhat variable. Aquatic plant and plankton communities are diverse and robust and the only invasive species detected are Chinese Mystery Snails (which appear to have no negative impacts on the lake ecosystem). Fish communities are generally consistent with those expected in oligotrophic lakes like Lake Owen. However, the focus of management for walleye harvest in Lake Owen is likely inconsistent with its low nutrient conditions. Walleye populations are likely constrained by the low nutrient conditions in the lake. As a result, walleye abundance is likely to be dependent on stocking programs into the future. The secondary impacts of walleye stocking (through predation and/or competition) on the oligotrophic food web are unclear. Trends in smallmouth and largemouth bass populations appear to be rebounding toward historical ratios.

5.6. Ecological Interactions

To understand the interactions among different components of the Lake Owen ecosystem, it is necessary to develop a framework that relates physical, chemical and biological processes. To this end, ecological interactions were assessed in Lake Owen through the use of the AQUATOX simulation program. AQUATOX simulates the relationship between nutrient runoff, water quality and food web interactions. Different AQUATOX simulations were used to assess the potential impacts of future land use on water quality and the relative importance of food web processes in the long-term stability of the Lake Owen ecosystem.

Summary Results and Conclusions – Ecological Interactions
Model simulations suggest that water quality changes resulting from future land use scenarios are likely to be relatively small. 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 Lake Owen. Given the uncertainty about both the ecosystem processes and the future land use conditions, management of Lake Owen should emphasis routine monitoring and assessment to track water quality conditions over time and clarify uncertainties surrounding food web dynamics.

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

Land Use Condition	Total Phosphorus Load (Pounds/year)	Growing Season Averages		
		TP Conc.	Secchi (m)	TSI
Historical (~1856)	734	10.77	4.771	38.42
Current (2013)	1145	11.32	4.703	39.14
Future Potential Septic Load (2030)	1224	11.46	4.701	39.32
Future Land Use and Septic Load (2030)	1303	11.6	4.699	39.49

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 Lake Owen 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 Lake Owen 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 Lake Owen ecosystem.

Table 6.1. Summary of the sources and impacts of stressors potential impacting the Lake Owen 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 Lake Owen 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 Lake Owen 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 Lake Owen ecosystem, relatively few stressors are negatively impacting its current use (Table 6.3). However, several management goals are partially affected by different stressors and several stressors have the ability to limit the desired use of the lake in the future. The relative impact of these different stressors are summarized below according to each management goal:

Goal 1 – Maintain Current Levels of Motorized and Non-motorized Use
Current levels of motorized and non-motorized use appear consistent with the ecological conditions and user experiences on Lake Owen. However, given the potential for increased shoreline development, it is possible that watercraft usage may increase in the future. Most survey responses highlighted interest in maintaining or limiting watercraft densities.

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

Goal 3 – Maintain Existing Water Levels and Hydrologic Processes
In general, the hydrologic processes in Lake Owen are relatively undisturbed—even though water levels are maintained artificially high through the use of an outlet control structure. 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.

Goal 4 – Protect and Restore Nearshore, Shoreline and Critical Habitat
Nearshore and shoreline habitat in Lake Owen are in relatively good condition, although some areas of localized degradation are present. However, given the potential for changes in shoreline development, it is possible that nearshore, shoreline and critical habitat may be altered in the future.

Goal 5 – Maintain Existing Water Quality Conditions
Water quality conditions in Lake Owen are consistent with state standards for oligotrophic lakes. Although water quality has likely declined in Lake Owen since the mid-1800s, it is unlikely that existing pollutant sources are currently impacting the Lake Owen 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 Lake Owen in the future.

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.

Goal 7 – Maintain Diverse Native Oligotrophic Fish Communities
Fish communities in Lake Owen are generally consistent with those expected in oligotrophic lakes. However, current shifts in the relative abundance of smallmouth and largemouth bass are inconsistent with fish communities found in unimpaired oligotrophic systems. Stocked walleye do not appear to establish significant resident populations, but their secondary impacts on the lake ecosystem are unclear. Native fish communities may also be disproportionately affected by the interaction of climate change impacts and low hypolimnion dissolved oxygen conditions which may significantly alter habitat availability for cold water adapted species.

Goal 8 – Restore Smallmouth Bass Populations to Historical Densities
Replacement of the smallmouth bass populations by largemouth bass is inconsistent with the oligotrophic structure the Lake Owen ecosystem. The mechanisms leading to this shift are unclear—which potentially limits the sustainable attainment of this goal. Efforts to reduce largemouth bass densities through a modification of harvest size limits have been moderately effective, but long-term efficacy of this management technique is unclear.

Goal 9 – Maintain Current Harvest Levels for Walleye
Maintenance of current walleye harvest levels appears inconsistent with the Lake Owen ecosystem. Harvest levels of walleye in the most recent creel survey (2007) were above the maximum 35% population level identified by the WDNR. Additionally, because of the low nutrient conditions in Lake Owen, high walleye population densities are likely ecologically incompatible and the secondary impacts of walleye stocking is unclear.

Table 6.3. Analysis of the potential ability to impair the desired uses for Lake Owen.

Management Goals for Lake Owen	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	1	2	Desired recreational usage patterns are currently unimpaired by ecological stressors or incompatible uses.
2 - Maintain Scenic Beauty of Lake Owen	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	1	1	2	Scenic beauty of the Lake Owen is generally unimpaired, 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	2	2	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2	Hydrologic processes are generally unimpaired, but have the potential to decline in the future in response to groundwater and surface water alterations.
4 - Protect and Restore Shoreline, Nearshore and Critical Habitat	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2	Nearshore and shoreline habitat are generally unimpaired, 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	1	1	1	1	1	1	1	2	1	1	1	1	1	1	2	Water quality is generally unimpaired, but has the potential to decline in the future in response to urban runoff.
6 - Maintain Diverse Native Aquatic Plant Communities	1	1	2	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 shoreline habitat loss, water level control and urban runoff.
7 - Maintain Diverse Oligotrophic Fish Communities	1	1	1	1	2	1	1	1	1	1	2	1	1	2	2	1	2	2	Fish communities are generally unimpaired, but may be beginning to shift in response to thermal restrictions, urban/septic system runoff, walleye overharvest and incompatible walleye stocking.
8 - Restore Smallmouth Bass Populations to Historical Densities	1	1	1	1	2	1	1	1	1	1	2	1	1	1	2	1	1	1	Smallmouth bass populations have decreased, potentially in response to thermal shifts, habitat loss and species incompatibilities.
9 - Maintain Current Harvest Levels for Walleye	1	1	1	1	2	1	1	1	1	1	1	1	1	2	1	2	2	2	Native walleye reproduction is limited by ecological incompatibilities and overharvest. Future catches are highly dependent on stocking.
Cumulative Stressor Ranks	**9**	**9**	**10**	**10**	**11**	**8**	**8**	**8**	**8**	**8**	**15**	**8**	**8**	**10**	**10**	**10**	**11**	**17**	

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 Lake Owen. 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.

In addition to the management of state waters, local governments also have the ability to manage recreational use through enactment of boating ordinances. The Town of Drummond has enacted a slow-no-wake ordinance (# 20010613) to manage boat traffic and the potential for wave-based erosion in sections of Lake Owen.

Water Quality

Water quality in Lake Owen 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 Towns of Drummond and Cable 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 in the towns Drummond and Cable.

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. Lake Owen is listed as an ORW.

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)

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

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 Owen is identified as a Class 1 lake and thus shoreland zoning requires the following:

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

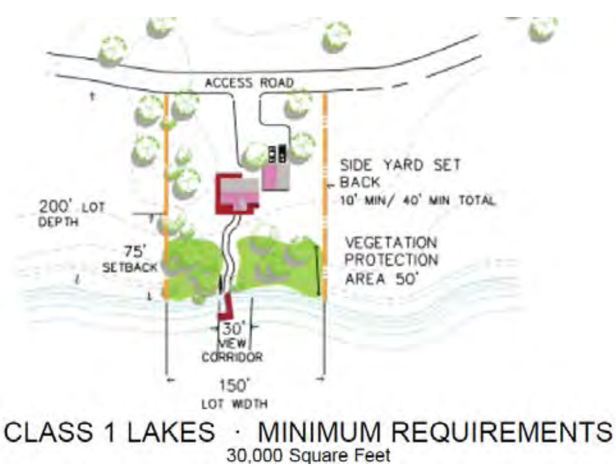

Figure 7.1. Minimum lot requirements for shoreland development along different lake classes. Adopted from Bayfield County.

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. Bayfield County zoning ordinances require that no structure be placed within 25 feet of a mapped wetland 2 acres or greater in area.

Fisheries

Fisheries in Lake Owen 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 Lake Owen (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 Lake Owen, 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 Lake Owen 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 Lake Owen 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 Lake Owen (part I).

Stressors to be Mitigated	Existing Policies																		Cumulative Protection	Comments and Analysis
	USACE	USEPA	Tribes	WDNR					WDNR			Bayfield County		Towns of Drummond and Cable		LOA		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	NR 109 and 107 - Aquatic Plants	WPDES Program	303 Surface Water Program	NR 151 - Ag. Standards	NR 40 - Invasive Species	NR 115 - Shoreland Zoning (State Minimums)	Septic System Permitting	Shoreland Zoning	Comprehensive Plans and Zoning	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	2	Agricultural runoff is unlikely to affect lake Owen, 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	4	Industrial runoff is unlikely to impact Lake Owen 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	4	Municipal wastewater is unlikely to affect Lake Owen, as no effluents currently (or are planned to) discharge to Lake Owen and municipal effluents are well regulated by the WPDES program.
Septic Systems	0	0	0	0	0	0	0	2	0	0	0	3	0	0	0	0	0	0	3	Septic systems have a moderate potential to negatively affect Lake Owen 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	3	0	0	0	2	0	3	Urban runoff has a moderate potential to impact Lake Owen 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	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	2	0	0	0	2	Relatively few policies are in place to reconcile the potential ecological incompatibility of the recreational uses for Lake Owen.
Use-based Incompatibility	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 among different user groups. Recreational use incompatibilities are partially addressed through local slow-now wake ordinances.
Intergenerational Incompatibility	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	14	3	4	15	15		13	16	2	2	8	5	9	12	14	2	8	2		

Table 7.3. Summary of policy coverage of current and potential stressors to Lake Owen (part II).

Stressors to be Mitigated	Existing Policies																		Cumulative Protection	Comments and Analysis
	USACE	USEPA	Tribes	WDNR					WDNR			Bayfield County		Towns of Drummond and Cable		LOA		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	NR 109 and 107 - Aquatic Plants	WPDES Program	303 Surface Water Program	NR 151 - Ag. Standards	NR 40 - Invasive Species	NR 115 - Shoreland Zoning (State Minimums)	Septic System Permitting	Shoreland Zoning	Comprehensive Plans and Zoning	Slow-no-Wake Ordinance	WDNR, Clean Boats, Clean Waters (Voluntary)	WDNR, Healthy Lakes Initiative (Voluntary)	WDNR, Invasive Species Control (Voluntary)		
Hydrologic Alteration																				
Surface Water Modification	4	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	Existing policies are relatively well suited to protect surface water alterations in the Lake Owen watershed. The primary activity that has the most potential to alter surface water processes in Lake Owen 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	3	Existing policies are well suited to protect against large scale groundwater withdrawals from Lake Owen, 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	3	Water levels in Lake Owen are somewhat artificially elevated because of the outlet control structure. This structure likely has minimal 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	2	3	3	2	0	2	0	3	Future shoreline habitat loss in Lake Owen is moderately well 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	3	3	2	0	2	0	3	Critical habitat is somewhat protected by existing shoreline zoning and dredge and fill permits. However, Critical Habitat areas have not been formalized throughout the lake for specific protections
Spawning Substrate	0	0	0	2	2	2	0	0	0	0	2	0	0	2	2	0	0	0	2	Spawning substrate is poorly documented throughout Lake Owen. 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	2	0	0	0	2	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	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	Current policies are moderately well prepared to minimize the potential impacts of native species introductions (e.g., stocking).
Overharvest	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	Current policies are moderately well prepared to prevent overharvest of fish from Lake Owen. Current data suggest that harvest of walleyes is beyond a sustainable level.
Maximum Policy Benefit	14	3	4	15	15		13	16	2	2	8	5	9	12	14	2	8	2		

8. Management and Monitoring Recommendations

In general, because of the relatively undisturbed nature of the Lake Owen 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 Lake Owen that contribute to positive user experiences.

Goal 2 – Maintain Scenic Beauty of Lake Owen
Maintenance of existing aesthetics of Lake Owen 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 around Lake Owen is the Bayfield County Shoreland Zoning Rules (adopted in the Towns of Drummond and Cable). 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 Lake Owen 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 Lake Owen that contribute to the aesthetic elements of the Lake Owen 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 changes in land use surrounding the lake. Potential water level changes are highly regulated through a variety of mechanisms. However, 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 uncertainty in both the current structure of the Lake Owen hydrologic system (relatively little groundwater data have been collected to date) and the timing and extent of land use conversion, long-term monitoring of the hydrologic system is an important management consideration. In particular, it is critical to clarify the relative contribution of groundwater to the lake as well as identify any specific areas of local groundwater recharge, prior to any large-scale land use conversion. Additionally, 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.

Goal 4 – Maintain Existing Water Quality Conditions

Water quality in Lake Owen is regulated and protected through a variety of rules and policies. However, not all relevant/necessary policies apply to the Lake Owen watershed. The primary mechanism for water quality management in Lake Owen 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 Lake Owen 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 Lake Owen 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 Lake Owen. 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 (although this recommendation is potentially in conflict with the Bayfield County permitting).

Potential future changes in water quality in Lake Owen 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. Because of Lake Owen's low nutrient conditions, water quality change is particularly susceptible to small additions of phosphorus. As such, although current shoreland zoning regulations require increased stormwater management, it will be important to characterize future cumulative impacts of shoreline development.

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

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

The two primary factors may likely to lead to degradation of shoreland and critical habitat around Lake Owen are shoreland development and a lack of official critical habitat designation. Nearshore and shoreline habitat are most effectively protected through the 404 permitting process of the USACE and the 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 an approximate doubling of shoreland properties around Lake Owen and the relatively pristine nature of current shoreline habitats, cumulative impacts should be considered.

Potential cumulative impacts could be addressed through a variety of mechanisms. The most straight forward mechanism would be to reclassify Lake Owen as a Class 3 lake which would require 300-foot minimum shoreland lots. Implementation of 300-foot lot minimums could still result in significant increases in shoreland development (current lots average ~330 foot shorelines) but this would provide greater protections than current 150-foot shoreline minimums. Alternatively, different shoreland zoning schemes could be considered that would concentrate development off the shoreline and adjacent to the lowest quality lake shore habitat and/or minimize the deployment of docks and other in-water/shoreline modifications.

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

<u>Goal 6 – Maintain Diverse Native Plant Communities</u>
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 Lake Owen. Given the current levels of access and development, the potential introduction pathways do not represent an immediately critical concern. However, if use and access to Lake Owen (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 LOA currently supports (Clean Boats Clean Waters) CBCW inspections at the primary landing at the north end of the lake, but two other landings are currently unmonitored. Additionally, one of the primary invasive species pathways to lakes (riparian introduction) is currently not considered as part of enforcement and/or volunteer efforts. Future invasive species control efforts should focus on increased outreach to riparian landowners and boat launch users.

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

<u>Fish Community and Fishery Management</u>
Goals 7-9 all described desired potential states for fish communities and the Lake Owen fishery. All management recommendations for these goals are to be provided by the WDNR fisheries program.

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10. Appendix A – Use and Value Survey

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

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

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

Sampling strategy and sampling frame
A census sample (i.e., the entire population) of households within one mile of the lakeshore of Lake Owen was drawn. The initial sampling frame included 301 households. After removing undeliverable surveys, duplicate landowners, or vacant properties, the final sampling frame was 277. 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 August and September of 2014 and ended up with a 40.8 percent (n=113) response rate.

Results

Participants
Survey respondents range in age from 44 to 88 years old with the average age being 68.6 years old. Approximately 71 percent of respondents were male; the other 29 percent were female. Education levels vary from high school diplomas to graduate and professional degrees, of which approximately 43 percent have graduate or professional degrees (Table 10.1). Respondents most commonly identify with the income range of $60,000 to $99,000 (Table 10.2).

Property Description
The average number of years that respondents have owned property in the Lake Owen area is 32.3 years with the range being 5 years to 100 years. Approximately 72 percent of respondents own

waterfront property on Lake Owen (Table 10.3), and over 75 percent of the respondents are not full time residents (Table 10.4).

Participation with the Lake Owen Association

The majority of respondents, 67 percent, are current members of the Owen Lake Association (Table 10.5), although 50.4 percent of respondents report that they never attend lake association meetings (Table 10.6).

Participant Uses of Lake Owen

In the section of the survey on participant uses of Lake Owen, respondents were asked: "how often do you participate in the following activities on or adjacent to Lake Owen?" The activities included observing nature, gathering with friends, boating, swimming, canoeing, hiking, fishing, picnicking, cross country skiing, snowshoeing, hunting, snowmobiling, sailing, jet skiing, and ice skating (Figure 10.1). Participants could choose how often they from never (gray), 1-5 times per year (peach), 5-11 times per year (light blue), 1-3 times per month (orange), and weekly or more (dark blue). The circle on each line indicates the average response for all respondents for each question. The matrix is organized in a way that puts the activities in descending order from the activities done most often at the top the top of the matrix and those done least often at the bottom.

The activities that occur most commonly include observing nature, gathering with friends, boating, and swimming. These four activities all had a mean score above 3 (i.e., more than 6 times per year). The most common activity, observing nature, has not only the highest mean score but also had over 50 percent of the respondents identify that they engage in this activity weekly or more. The next three most common activities – gathering with friends, boating, and swimming – all had over 30 percent of the respondents identify that they do this activity weekly or more.

The activities with the least participation were ice skating, jet skiing, sailing, hunting, and snowmobiling with the majority of people (i.e., over 70 percent on each indicator) never participating. Canoeing, hiking, fishing and picnicking were also favorable activities, with 60 to 80 percent participation, but participation tended to waver to only a couple times of the year rather than several times in a month. The last two activities, cross-country skiing and snowshoeing, only had about 50 percent participation at all but when people did participate, it was only a couple times throughout the year.

Importance of Uses on Lake Owen

The second section of the survey asked participants: "Please rate how important it is to you that Lake Owen can be used for the following purposes." The activities identified in this section were similar – and in some cases identical – to the indicators included in the frequency of use activities. The specific items participants were asked to rate included: enjoying scenic beauty, gathering with family and friends, maintaining sense of peace and relaxation, observing or enjoying nature, swimming, non-motorized watersports, encouraging sense of community among users of the lake, fishing/ice fishing, motorized watersports, non-motorized snow sports, harvesting food, snowmobiling, hunting or trapping, using water for irrigation or lawn (Figure 10.2). Participants could choose from "not at all important" (gray), "of little importance" (peach), "neutral" (light blue), "somewhat important" (orange), and "very important" (dark blue). The circle on each line indicates the average response for all respondents for each item in the matrix. The matrix is organized in a way that puts the activities with the higher average, or activities found to be more important, at the top and those found to be least important at the bottom.

The activity most important to people was enjoying the scenic beauty of the lake, with almost the entire sample, 97 percent, identifying the activity as very important. Gathering with friends and family, maintaining a sense of peace and relaxation, observing or enjoying nature, swimming, engaging in non-motorized water sports, and encouraging a sense of community among users of the lake also had high average scores with 70 percent or more of respondents believing these activities to be very important or somewhat important. Respondents rated the importance of fishing and motorized water sports slightly lower than the most important indicators. However, these two items both have between 60-70 percent of the respondents identifying them as either very or somewhat important.

The other items in this matrix – i.e., harvesting food, snowmobiling, hunting or trapping, and using water for irrigation – had a precipitous drop in average score. Each of these indicators had more than 30 percent of the respondents choose that the activity was "not at all important." Over 50 percent of the respondents identified snowmobiling, hunting or trapping, and using water for irrigation or lawn as "of little importance" or "not at all important."

The activities respondents found important tended to be ones that would not compromise the lake's attractiveness nor take away from the respondent's ability to gather with and enjoy the company of friend and family. While activities may be seen as noisy, polluting, or extractive were rated much lower on average by respondents.

Participant Attitudes of Lake Owen and Its Uses
In the third section of the survey, respondents were asked: "Please indicate the extent to which you AGREE or DISAGREE with each of the following statements." Respondents were asked to rate a series of twenty-two items related to objects such as: land, plants, water quality, shoreline, boats, other users, and development (Figure 10.3). Participants could choose from "strong disagree" (gray), "disagree" (peach), "undecided" (light blue), "agree" (orange), and "strongly agree" (dark blue). The circle on each line indicates the average response for all respondents for each item in the matrix. The matrix is organized in a way that puts the attitudes with the higher average, or the items that respondents tended to have a stronger agreement with, at the top and those items participants tended to have a stronger disagreement at the bottom.

Similarly to both use and importance items found in the previous sections, the items that deal with the intrinsic value of Lake Owen rise to the top. In fact, the top three items are enjoying a view of nature, maintaining peace and quiet on the lake, and Lake Owen being a peaceful place to be. On all three items, between 40 and 50 percent of all respondents strongly agree with these statements. When all respondents who agree or strongly agree with these three items are taken together, the vast majority – over 90 percent – either agree or strongly agree. Not surprisingly, one of the higher rated items – "I am concerned that if the health of the lake declines, it could decrease my property value" – had nearly 75 percent of respondents agreeing or strongly agreeing with this statement. Despite intrinsic value being one of the most important parts of Lake Owen, respondents also suggested they have a financial stake in the health of the lake.

On the bottom part of the matrix, a similarly strong attitude amongst respondents seems to emerge about preference of lawn versus natural vegetation. Respondents overwhelmingly show preference for natural vegetation over manicured or landscaped lawns. On the three items about personal preference – "I prefer the appearance of landscaped shorelines," "Having a grass lawn leading down to the lake's shore is better than natural vegetation," and "Untouched natural vegetation in and around the lake is unattractive" – between 75 and 90 percent of respondents either strongly disagree or disagree with these statements. When asked about whether they think other property owners around the lake have a preference for lawns/landscape over natural vegetation, a majority – just over 55 percent – said they thought others around the lake prefer natural vegetation.

Two of the next four highest rated items in the matrix – "Users of the lake care about the quality of the water" and "Property owners and permanent renters are more respectful of the lake than visiting users"– deal with whether respondents agree or disagree with statements of how much other users care and respect the lake. The majority of respondents, just under 90 percent agree or strongly agree, with the statement that other users care about Lake Owen's water quality. When coupled with the item about property owners and permanent residents versus transient users, respondents tend to agree that the former group is more respectful of Lake Owen than those who do not live or own property on it. However, most of the respondents still agree that users regardless of relationship to Lake Owen are respectful when utilizing it[1].

Rounding out the top rated items, a majority of respondents (over 60 percent) agree or strongly agree with the statement about their individual actions having a significant impact on the lake. This particular item suggests that respondents feel their actions whether good or bad do affect the health and wellbeing of Lake Owen.

When asked about their attitude toward motorized boats, respondents were split on concern over the possibility of increased erosion – with a mean score of 3 (which is not only the midpoint but also the middle item, "undecided"). When taken in combination with "I prefer motorized watersports (e.g., boating or jet skiing) to non-motorized sports (e.g., kayaking)," the sample does seem to favor non-motorized sports with approximately 55 percent of respondents preferring non-motorized to approximately 25 percent who prefer motorized. About 80 percent of the respondents disagree or strongly disagree with the idea that "There are too many boating restrictions (e.g. wake, motor size) on Lake Owen." Regardless of preference and feeling about possibility of erosion, respondents seemed to feel boating restrictions were not too stringent.

Far fewer, but still a majority with approximately 65 percent of respondents, disagree or strongly disagree with the statement that "The lake is crowded by boat traffic." Related to crowdedness, respondents across the board felt strongly about having more people living on and around Lake Owen. Approximately 80 percent – and a mean score of 1.86 – of participants selected that they disagree or strongly disagree with having more people live in and around the lake. A majority of participants (just over 60 percent) disagree or strongly disagree with the statement that "There are too many homes on the lake." Similarly, approximately 60 percent of respondents disagree or strongly disagree with the statement "There is too much access to Lake Owen for non-residents." Despite having overwhelmingly negative attitudes about further increasing the population of people in and around Lake Owen, respondents did not have negative attitudes about increasing access to the lake for other users and felt indifferent or positive about the current number of homes as well as the amount of boat traffic on the lake.

Respondents do not appear to have negative attitudes toward aquatic vegetation related to recreating. When asked about density of aquatic plants for recreational activity, over 80 percent of respondents strongly disagree or disagree with the statement: "Aquatic vegetation is too dense for

[1] Most respondents felt Lake Owen has either improved (1.9%) or stayed about the same (70.4%) when asked about whether the quality of the water has "improved," "stayed about the same," or "worsened." Approximately 18 percent stated it has worsened and a little over 10 percent stated they didn't know.

recreational activity (e.g. swimming and boating)." When asked specifically about algae and swimming, respondents are distributed a bit more evenly with a mean score of 2.47 (just below the mid-point of three and slightly skewed toward not being concerned with algae) and just under 60 percent of them falling into agree or strongly agree categories. When asked about their attitudes toward aesthetic appeal of aquatic plants, respondents are much more spread out with an even distribution of responses across all five categories and an overall mean score of 2.81; again close to the mid-point of 3 on the five-point scale.

Finally, an overwhelming majority of respondents – over 90 percent – and the lowest overall mean score (1.47) did not have a problem with the smell of the lake.

Participant Attitudes of Lake Owen Management

In this section of the survey, respondents were asked: "Please indicate the extent to which you AGREE or DISAGREE with each of the following statements." Respondents were asked to rate five items related to management of the Lake Owen fishery (Figure 10.4). Participants could choose from "strong disagree" (gray), "disagree" (peach), "undecided" (light blue), "agree" (orange), and "strongly agree" (dark blue). The circle on each line indicates the average response for all respondents for each item in the matrix. The matrix is organized in a way that puts the attitudes with the higher average, or the items that respondents tended to have a stronger agreement with, at the top and those items participants tended to have a stronger disagreement at the bottom.

Overall, respondents appeared indifferent with a slight negative skew toward how well Lake Owen is managed. Approximately, 50 percent of the respondents were undecided about whether or not the Wisconsin DNR effectively manages the Lake Owen fishery. A similar pattern can be seen with regard to attitudes toward tribal management of the fishery. When compared to the management of other lakes and their fisheries in the area, a large percentage where undecided but just over 40 percent felt other lake fisheries in the area are managed better than Lake Owen. Nearly 60 percent of respondents do not feel the lake has excessive recreational fishing; this further supports attitudes expressed in the previous section that respondents are generally not concerned with current levels of use of the lake. When taken with the last item in the matrix – use of the Lake Owen fishery for fishing tournaments – respondents did not see this as enhancing the lake.

Angler Attitudes of Lake Owen Fishery

In this section of the survey, only the respondents who self-identified as anglers (n=54) completed this section. Respondents were asked: "Please indicate the extent to which you AGREE or DISAGREE with each of the following statements" (Figure 10.5). The matrix above is arranged in the same way as the previous two sections with respondents being asked to rate seven items related to fishing on Lake Owen. Participants could choose from "strong disagree" (gray), "disagree" (peach), "undecided" (light blue), "agree" (orange), and "strongly agree" (dark blue). The circle on each line indicates the average response for all respondents for each item in the matrix. The matrix is organized in a way that puts the attitudes with the higher average, or the items that respondents tended to have a stronger agreement with, at the top and those items participants tended to have a stronger disagreement at the bottom.

The highest rated item is "the most important element of fishing on Lake Own is the interaction with the natural world" with 83.3 percent of anglers strongly agreeing or agreeing with this statement. When compared with the other items related to importance of fishing on Lake Owen, far fewer anglers – 29.5 percent – stated interacting with others on the lake as the most important element for fishing. Overall, anglers seemed generally satisfied with size of fish (57. 4 percent), species of fish (45.9 percent), and number of fish (40.9 percent) by choosing that they either strongly agree or agree with these statements.

When asked about what species they typically fish for and what species of fish they would most like to fish for on Lake Owen (Table 7), anglers identified smallmouth bass, walleye, sunfish/bluegill, largemouth bass, and northern pike as the most common type of species they fish. Over 50 percent of anglers identified each of these as a "typical" species to fish for on Lake Owen. Just over 39 percent of anglers identified crappie as a typical species to fish for; whereas trout, muskie, and whitefish were much less common. A similar breakdown amongst anglers regarding preference of species of fish in Lake Owen can be seen with walleye, smallmouth bass, crappie, sunfish/bluegill, northern pike and largemouth bass rounding out the species anglers would "most like to fish" (Table 8). Again, trout, muskie and whitefish have the lowest percent of anglers who would like to fish these species.

Participant Willingness to Protect Lake Owen

In this section of the survey, respondents were asked: "The following items are meant to gauge your willingness to participate in certain activities concerning Lake Owen. Your responses are hypothetical and will not indicate any actual commitment to these activities. How willing would you be to…?" (Figure 10.6). On the six items in the matrix, participants could choose from "extremely unwilling" (gray), "somewhat unwilling" (peach), "somewhat willing" (orange), and "extremely willing" (dark blue). The circle on each line indicates the average response for all respondents for each item in the matrix. The matrix is organized in a way that puts the items respondents are more willing to do at the top and those they are less willing to do toward the bottom.

Respondents are most willing to do things that involve their personal property (e.g., modify property), use (e.g., support efforts to protect even if that meant limiting their personal use of the lake), and time (e.g., attending meetings or volunteering with improvement projects). Respondents seemed much less willing to pay money through tax increases or donation even if they were no longer able to use the lake.

Participant Values

In the final section of the survey, respondents were asked: "We would like you to tell us your views on various issues. For each statement, please select the circle nearest the statement you most agree with. Selecting the circle furthest left indicates total agreement with the left-hand statement; the circle furthest right indicates total agreement with the right-hand statement. The circles in between indicate varying levels of agreement. The middle circle suggests you have similar levels of agreement with both statements." The matrix asks respondents to evaluate eleven different sentence pairings on a variety of values. The circle on each line indicates the average response (from 1-7) for all respondents for each item in the matrix (Figure 10.7).

The first item on the matrix asked respondents whether they see their Lake Owen property as primarily a financial investment or a place to live and recreate. The majority of respondents choose values closer to a place to recreate. In fact, 85.3 percent of respondents selected numbers 5, 6, or 7 suggesting respondents overwhelmingly saw their Lake Owen property as a place to live and recreate. When taken in combination with whether respondents feel most closely connected to Lake Owen community or another community, as can be seen in from the overall mean score of 3.9, respondents are equally distributed across the scale. Roughly 42 percent identified feeling connected to another community – as indicated by circling 5, 6, or 7 on the scale – compared to 44 percent of respondents who felt most connected with the surrounding Lake Owen community – as indicated by circling 1, 2, or 3 on the scale.

When asked to choose between whether changes in the health of Lake Owen affect the respondents overall well-being, respondents tended to feel changes to the lake affect their well-being. 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. A majority (63 percent) of respondents choose either 1, 2, or 3 while an additional 17.6 percent chose the middle number 4.

Most respondents saw appropriate management of Lake Owen being for the "conservation of the natural ecosystem" over "managed primarily for human uses". Over 49 percent of participants chose managing the lake for the conservation of the natural ecosystem versus 21.4 percent who tended to lean toward management for human uses. This sentiment is also reflected in the percent of participants who tend to agree more with the statement that the natural environment should be protected from human activity – although the percentages are much more evenly distributed across the scale for this particular item (42.6 percent falling toward protecting from human activity, 25.9 percent in the middle, and 31.4 percent leaning toward utilization for human needs and growth). A similar distribution can be seen in the percent of respondents who suggested they thought the lake should be managed for the needs of future generations (49 percent) versus for current users (29.1 percent). Roughly 22 percent of respondents chose the middle point.

Additionally, respondents felt that it was appropriate for human intervention to help maintain a healthy lake (61.5 percent) rather than not intervene (11.1 percent) and felt that individuals (46.7 percent) – not government (20.6 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; just 17.4 percent tended to lean toward individuals having cart blanche to develop their property versus 68.8 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 (55 percent) more say in its management over all users of Lake Owen (27.5 percent).

Table 10.1. Property Location

How would you best describe your property?	
Waterfront on Lake Owen	72.57%
Non-waterfront	20.35%
Waterfront on a different lake	7.08%

Table 10.2. Participant Residency

How would you best describe your residency?	
Year round	23.42%
Full time in summer and more throughout the year	23.42%
Weekends throughout the year	16.22%
Full time in summer	14.41%
Irregular	9.01%
Weekends only in summer	8.11%
Other	5.41%

Table 10.3. Lake Owen Association Membership

What is your affiliation with the Lake Owen Association?	
Current member	67.0%
Never been a member	26.8%
Former member	6.3%

Table 10.4. Lake Association meeting attendance

How often do you attend Lake Association meetings?	
Never	50.4%
Annually	23.9%
Every few years	17.7%
More than once a year	8.0%

Table 10.5. Species typically fished for.

What species do you typically fish for in Lake Owen?	
Smallmouth Bass	77.0%
Walleye	68.9%
Sunfish/Bluegill	63.9%
Largemouth Bass	57.4%
Northern Pike	52.5%
Crappie	39.3%
Trout	3.3%
Muskie	1.6%
Whitefish	1.6%

Table 10.6. Species most like to fish for.

What species would you most like to fish for in Lake Owen?	
Smallmouth Bass	65.6%
Walleye	90.3%
Sunfish/Bluegill	44.3%
Largemouth Bass	31.1%
Northern Pike	37.7%
Crappie	45.9%
Trout	6.6%
Muskie	4.9%
Whitefish	0.0%

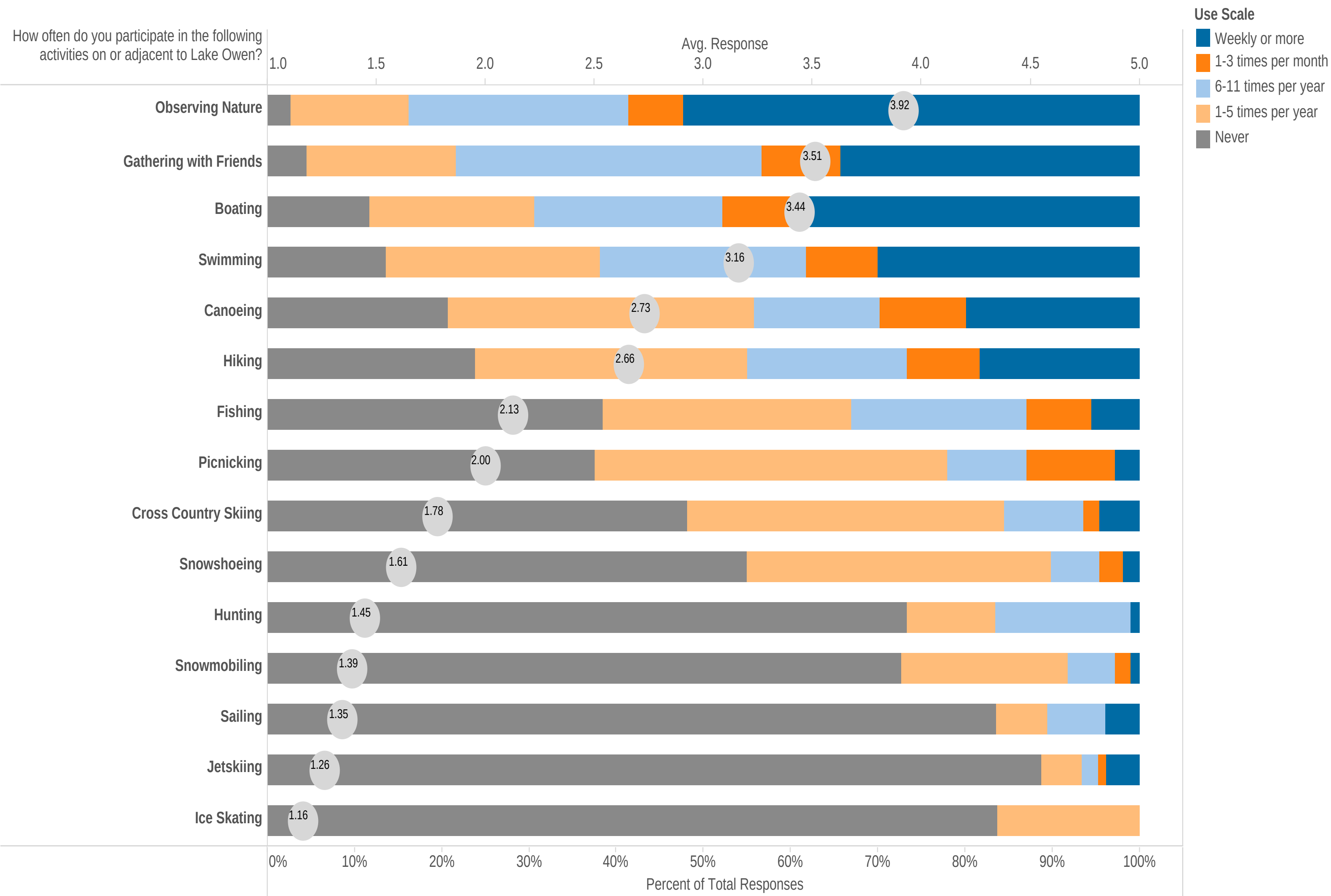


Figure 10.1. Participant Uses of Lake Owen

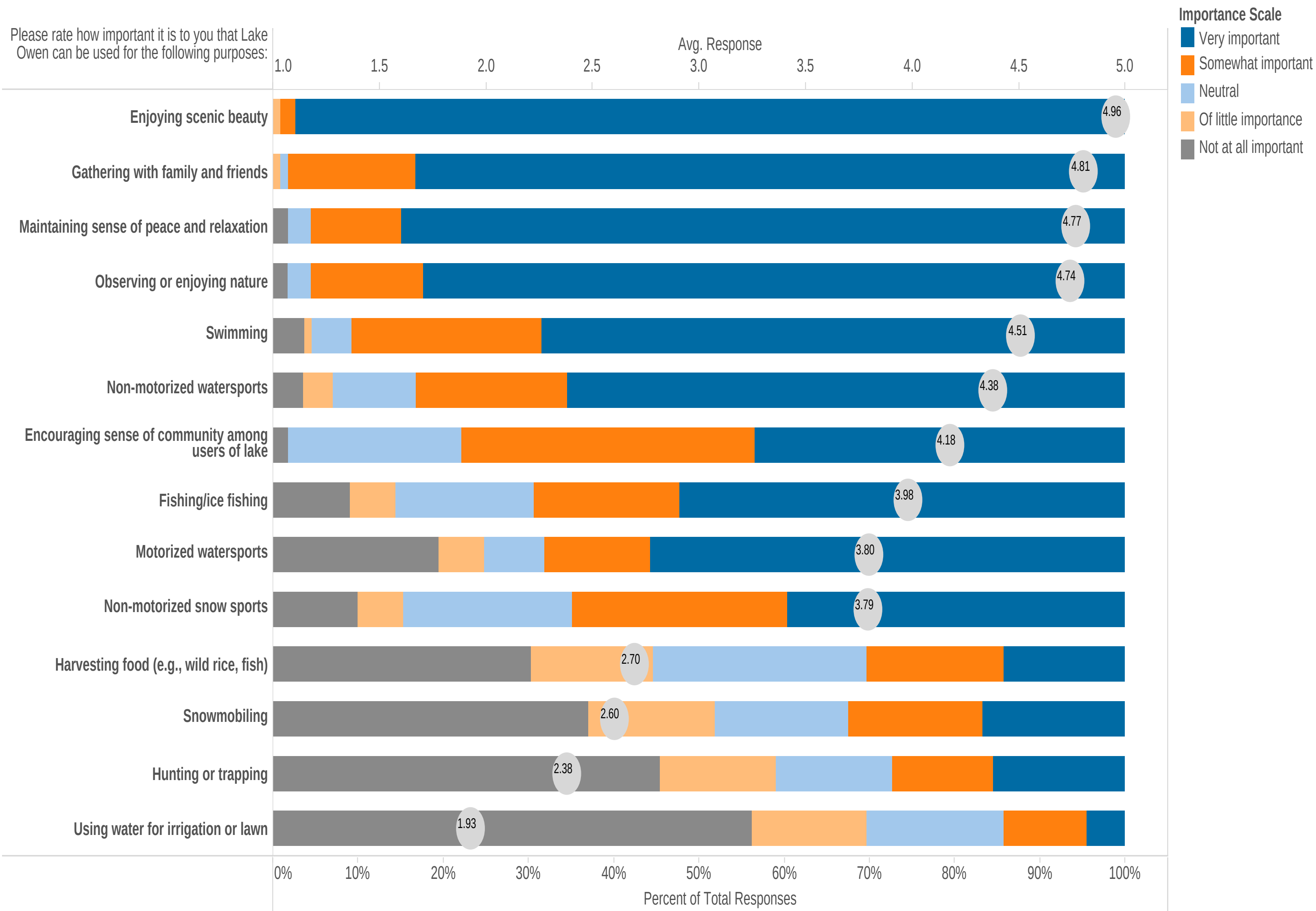


Figure 10.2. Importance of Uses on Lake Owen

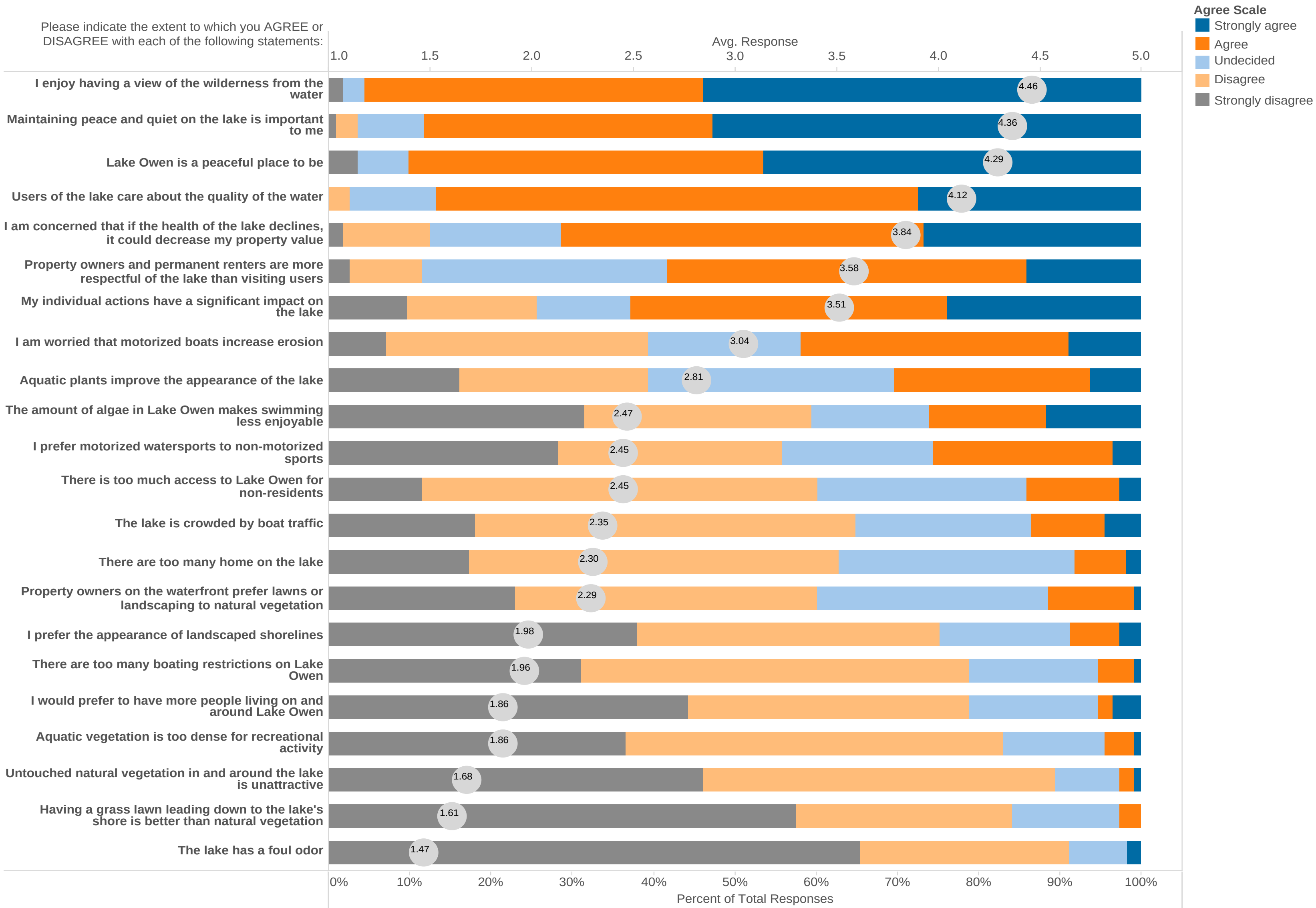


Figure 10.3 Participant Attitudes of Lake Owen and Its Uses

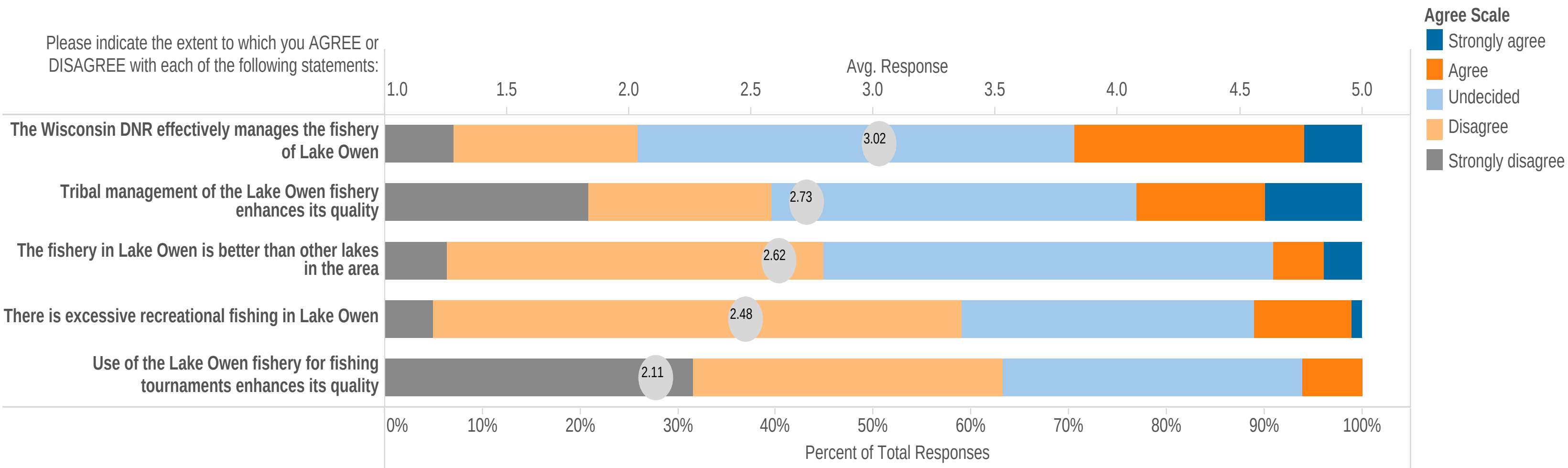


Figure 10.4. Participant Attitudes of Lake Owen Management

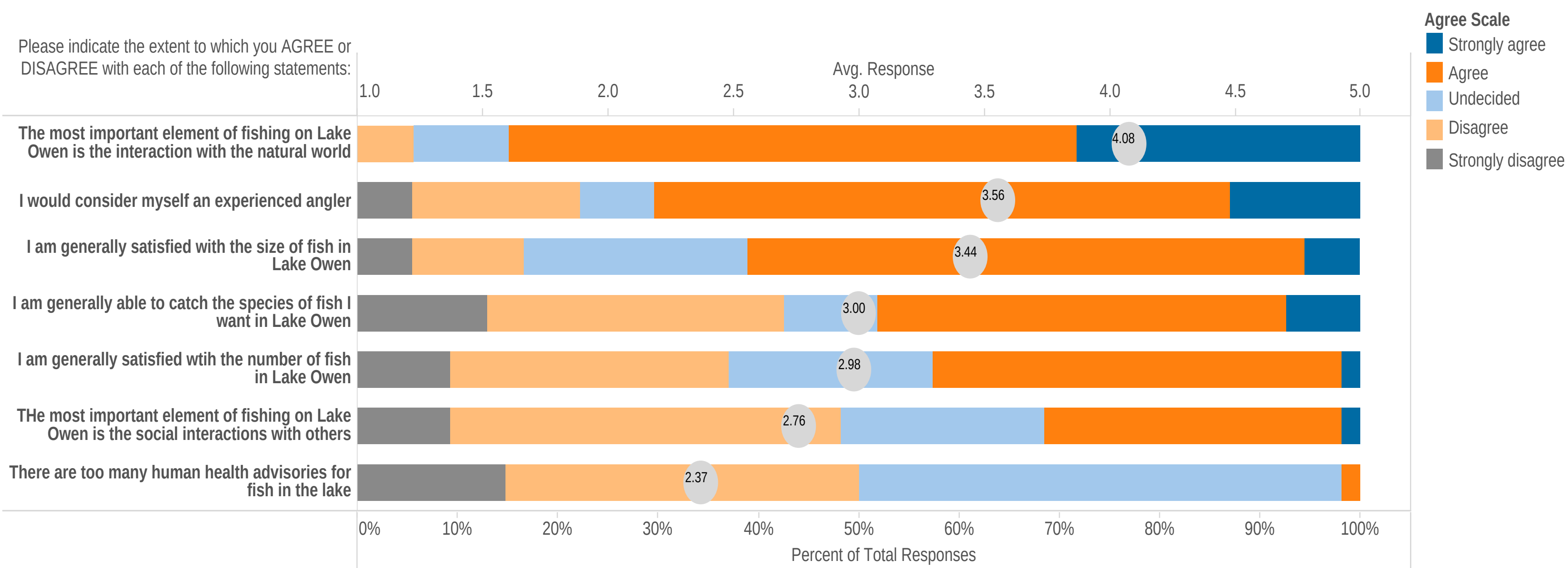


Figure 10.5 Angler Attitudes of Lake Owen Fishery

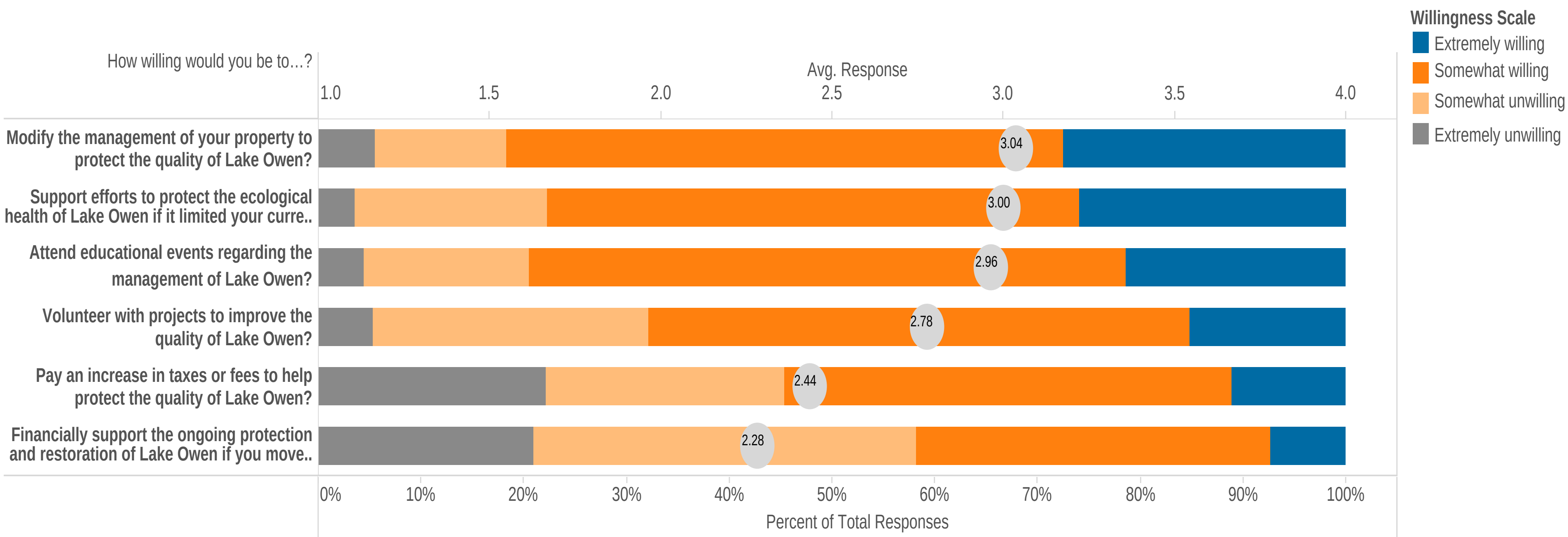


Figure 10.6 Participant Willingness to Protect Lake Owen

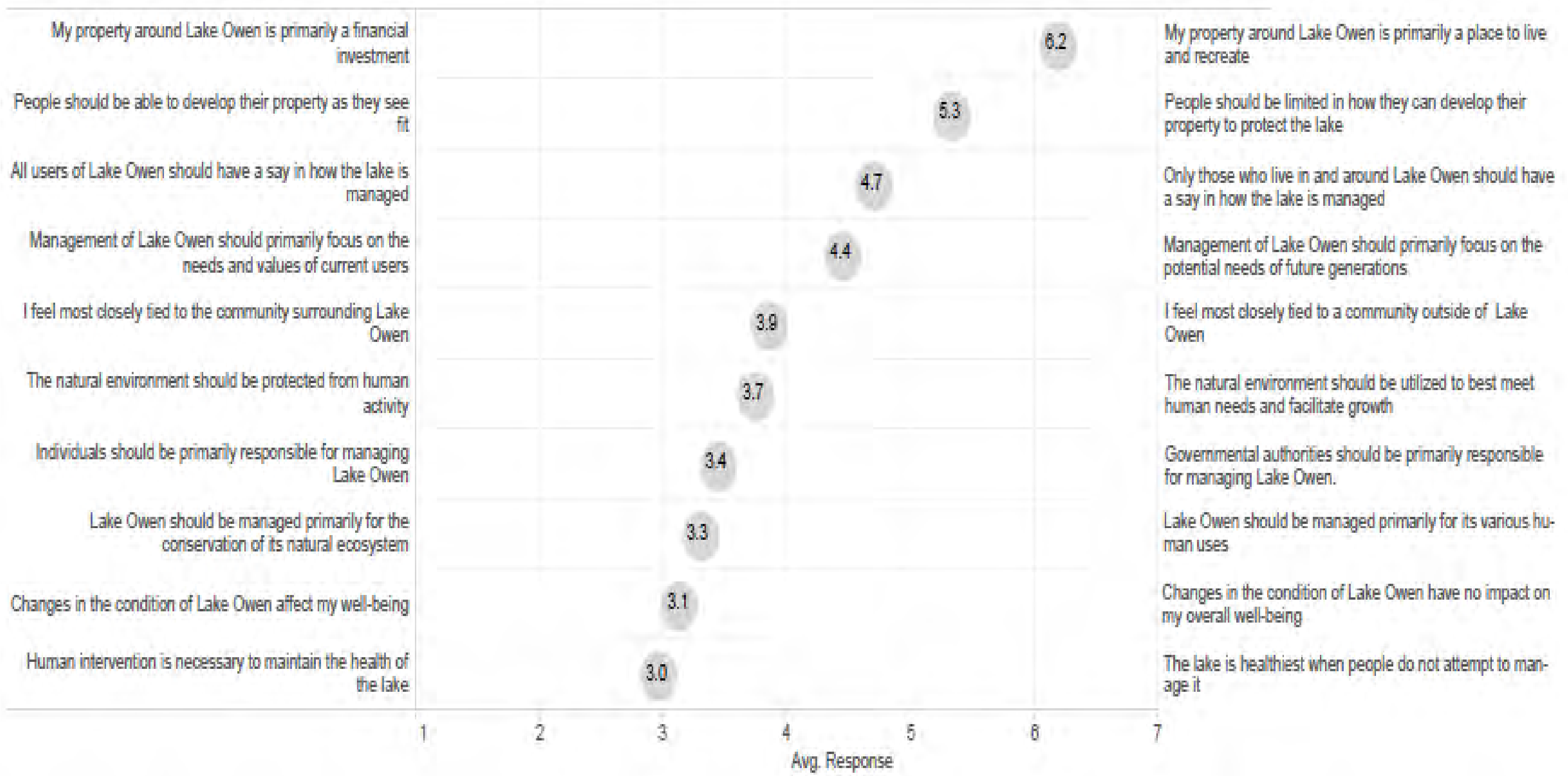


Figure 10.7 Participant Values

11. Appendix B – Summary of Physical-chemical Conditions

Introduction

This report summarizes the status of water quality conditions and physical processes in Lake Owen. 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 Lake Owen. Results from this assessment were summarized and used to inform the watershed assessment (Appendix D) and ecosystem modeling efforts (Appendix G).

Methods

To assess physical and chemical conditions and processes in Lake Owen, water chemistry and lake discharge were sampled throughout the two year study. Chemistry and discharge data were used to assess tropic conditions, describe stratification processes and develop water and nutrient budgets 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 northern and southern sections of the lake (Figure 2.1) to represent the historical 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 43137 (LONBD, north basin) and 43134 (LOSBB, south basin).

A water budget for Lake Owen was developed following a modified version of protocols described by Robertson et al. 2003. Estimation of the water budget for Lake Owen was predominantly based on the continuous measurement of discharge at the Lake Owen outlet. Throughout the study period discharge from Lake Owen was measured following protocols described by Rantz et al. 1982.

Water inputs and output to and from Lake Owen were described with respect to precipitation, evaporation, groundwater inflow and watershed runoff. Within the discharge record, periods of base flow were identified and used as a direct estimate of groundwater discharge to the lake (given the proximity of the gauge site to the outlet, all base flow discharge was assumed to originate from groundwater inflow to the lake). Direct precipitation to the lake was calculated by summing the total inches of rainfall from a corresponding regional weather station (located two miles away in Drummond, WI) across the total area of the lake on a monthly basis. Watershed runoff was estimated by summing the monthly precipitation accumulation across the watershed area and using estimates of soil infiltration capacities and hydrologic connectivity to establish a monthly percentage of precipitation that likely directly runs off to the lake. Given the high infiltration capacity of the soils in the surrounding watershed, ~87% percent of annual precipitation was assumed to infiltrate into the soils.

Water losses from Lake Owen were accounted for evaporation, tributary discharge and changes in storage. Evaporation was estimated using monthly unit area evaporation rates (evaporation during ice cover was assumed to be zero) based on observation from regional evaporation studies (see Robertson et al. 2003). Changes in storage were estimated as the difference between the total inputs to the lake minus the losses from the lake from tributary discharge and evaporation. Changes in storage were then converted to a potential corresponding change in water level to ground-truth the water budget.

An external nutrient budget (i.e., all sources of phosphorus originating outside of the aquatic system) was developed by either assigning annual mass loads of phosphorus to a particular input source or by multiplying likely input concentrations to an associated inflow volume. Phosphorus inputs from precipitation were estimated by assigning an average concentration to annual monthly precipitation measurements. A regional precipitation concentration of 7 ug P /L was assigned to rainfall data. Watershed runoff of phosphorus was estimated by multiplying existing land cover areas by a likely area-based annual phosphorus export coefficients (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). Groundwater inputs were estimated by multiplying estimated groundwater influx values by a corresponding regional average groundwater phosphorus concentration of 20 ug/L. Phosphorus loss via outlet discharge was estimated by multiplying monthly average discharge values by the corresponding surface water concentration. Winter concentrations were estimated by linearly interpolating between fall and spring phosphorus measurements. All phosphorus not discharged via outflow was assumed to be retained within the system (internal phosphorus dynamics are described further in Appendix G)

Results and Discussion

Water Budget

Water levels in Lake Owen are predominantly influenced by groundwater (Table 11.1). Throughout the year, approximately 42% of the total input of water to Lake Owen occurs through groundwater. The majority of water lost from Lake Owen each year occurs though the outlet tributary that forms the Long Branch of the White River (Figure 11.1). As a result, water levels in Lake Owen generally rise each spring in response to snow melt and early season precipitation and then gradually fall over the course of the year reaching minimum flow conditions in early to late fall. Interestingly, the outflow volume from Lake Owen is often episodic and disconnected from rainfall patterns, suggesting that blockages at the outlet structure may have a significant influence on seasonal changes in water level throughout the lake.

Physical Processes

Physical processes in Lake Owen are of particular interest. As described in Section 5.1, most lakes throughout northern WI, mix twice per year and stratify throughout the summer (i.e., are dimictic). Interestingly, Lake Owen never fully de-stratified and/or mixed throughout this two year study period (Figure 11.2). Additionally, dissolved oxygen concentrations in most regional lakes generally decrease with depth. In Lake Owen, the highest oxygen concentrations are found in the metalimnion (particularly during the growing season) and oxygen concentrations in the hypolimnion generally rarely exceed 1 mg/L (Figure 11.3). These phenomena are likely influenced by the depth and orientation of Lake Owen.

pH is also of interest in Lake Owen (Figure 11.4). Throughout most of the year, pH declines with depth at an abrupt transition that coincides with the metalimnion. However in late summer/early fall, pH dramatically shifts, such that pH in both the epi and hypolimnion rapidly decrease. Given the coincidence of this transition with algal production, it is likely that these two processes are linked—potentially through the mortality and decomposition of algal cells.

Water Clarity

Lake Owen is one of, if not the, clearest lake in Wisconsin. Average Secchi depths range from 6 to 13 meters and this clarity is generally mirrored by the Chl-a concentrations, which range from 9 to 12 ug/L (Figures 11.6 and 11.7). These results suggest that water clarity in Lake Owen is primarily driven by algal growth and productivity. Based on the dissolved oxygen concentrations observed in Lake Owen, it is likely that the maximum algal densities are within the metalimnion. This observation is particularly unusual, as algal densities in most regional lakes are greatest in the top two meters of water. This condition likely exists as a result of the water quality nutrient conditions created by the consistent and sustained stratification in Lake Owen.

Nutrient Concentrations

Nutrient concentrations in Lake Owen are also of particular interest (Figure 11.8). Surface water total phosphorus concentrations average 9 ug/L during growing season conditions. While hypolimnetic phosphorus concentrations averaged 245 ug/L during the same time period. Surface water TP concentrations are consistent with oligotrophic/mesotrophic conditions within the lake. However, hypolimnion TP concentration are significantly greater than those commonly observed in other regional lakes.

Hypolimnetic TP concentration are much high than typically observed in oligotrophic-eutrophic lakes. Hypolimnetic TP concentrations are commonly between 20 ug/L and 50 ug/L in regional mesotrophic lakes and often lower in oligotrophic lakes. The hypolimnetic TP concentrations of 245 ug/L are more consistent with results from eutrophic or hyper eutrophic lakes that are often more heavily impacted by nutrient runoff from urban and/or agricultural systems. However, the surface water quality impairments that often correspond with high hypolimnetic TP concentrations are not present in Lake Owen, which is likely as a result of the sustained stratification and increased zooplankton grazing observed throughout the lake.

These results suggest that sediment release of soluble phosphorus as a result of anoxic conditions in the hypolimnion are common in Lake Owen. However, because of the sustained stratification, phosphorus in the hypolimnion (likely released from anoxic conditions in sediment) is never (or rarely) mixed into the surface waters. As a result, the only movement of phosphorus from the hypolimnion to the surface waters occurs through molecular diffusion. In fact, this slow diffusion of phosphorus is likely a primary driver of the elevated oxygen conditions in the metalimnion and potentially a contributor to the high water clarity (as algae may preferentially grow at greater depths in Lake Owen in response to the hypolimnetic phosphorus).

External Nutrient Budget

Within the Lake Owen ecosystem, the majority of the annual phosphorus load originates from watershed runoff (Table 11.2). Most of this watershed loading of phosphorus 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 the White River. Additional “internal” sources and loss processes are discussed in Appendix G.

Trophic State and Water Quality Attainment
The combination of nutrient, Secchi depth and chlorophyll-a data suggest that the current conditions in Lake Owen are consistent with its designation as an oligotrophic-mesotrophic lake. Current phosphorus TSI values average 38.6. Additionally, average annual surface water phosphorus concentrations are below the 15 ug/L level identified as a threshold for water quality impairment in oligotrophic lake types, like Lake Owen. The water quality conditions observed throughout this study are consistent with the fishery, aquatic plant and plankton community data that have been collected for the lake (see Section 5.4 and Appendices E and F).

Management and Monitoring Considerations

Because Lake Owen is currently meeting water quality standards, 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 Lake Owen are related to land use and planning, and thus are described in Section 7.

In addition to these management considerations, a series of ongoing monitoring and assessment studies should be considered. Relatively little is known about the groundwater system surrounding Lake Owen and thus, the existing estimates of the water budget were based on a range of estimated values. Given the significant role that groundwater likely plays in the Lake Owen system, future efforts should focus on quantifying the volume of groundwater inflow to, and loss from, the lake, as well as the primary areas of groundwater recharge that sustain flows to the lake. Additionally, because of the potential for increased residential development around the lake, 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 lake.

This assessment characterized the water quality trends and process at two sites that reflect general conditions throughout the lake. However, given the presence of discrete, hydrologically isolated embayments throughout the lake, future monitoring work should characterize the diversity and connectivity of water quality conditions throughout the lake to identify areas that may be particularly susceptible to changes in water quality conditions. Given the low nutrient conditions throughout Lake Owen, water quality conditions are particularly susceptible to phosphorus additions (small percent changes in nutrient concentrations have been observed to have disproportionately large impacts on trophic conditions in oligotrophic lakes). As such, ongoing monitoring efforts should be structured to capture changes in water chemistry that are consistent with the trophic sensitivity of an oligotrophic 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).

Lastly, future monitoring and assessment work should also consider the relationship between food web processes, stratification and water quality conditions. Given the relatively high phosphorus concentrations that develop in the hypolimnion throughout the summer, the potential for sediment release of nutrients to impact water quality is significant. Because stratification throughout the lake is so pronounced, hypolimnion nutrients are relatively disconnected from the surface waters. However, based on the elevated oxygen concentrations in the metalimnion, it is likely that hypolimnetic phosphorus is driving significant levels of algal productivity. In general, elevated levels of productivity would be mirrored by decreases in water clarity, but water clarity remains high. The maintenance of high levels of water clarity in the presence of high rates of algal production suggests that zooplankton grazing is likely a critical element of water clarity in Lake Owen.

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 Lake Owen quite well, but there is likely to be a significant amount of site specific variability in and around the lake. For example, some areas of the lake 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 lake 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 Lake Owen based on 2013 and 2014 monitoring.

Month	Inputs			Outputs			Maximum Potential Change in Lake Level (ft)
	Precipitation	Watershed Runoff	Groundwater	Evaporation	White River	Change in Storage	
Jan	105	0	307	0	883	-470	-0.36
Feb	151	0	278	0	694	-266	-0.20
Mar	162	165	492	0	764	55	0.04
April	599	734	476	90	924	795	0.60
May	648	2491	615	408	1457	1889	1.43
June	653	81	595	451	1057	-179	-0.14
July	314	39	615	464	1059	-555	-0.42
Aug	580	72	615	399	801	67	0.05
Sept	428	53	595	309	703	64	0.05
Oct	374	47	615	226	636	173	0.13
Nov	244	76	476	52	554	191	0.14
Dec	233	0	307	0	1006	-465	-0.35
Total	4492	3759	5986	2399	10538	1300	0.98
Percent	32%	26%	42%	17%	74%	9%	

Table 11.2. External Phosphorus Budget for Lake Owen based on 2013 and 2014 monitoring.

Month	Phosphorus Mass Load (g)					
	Inputs				Outputs	In-lake Retention
	Direct Precipitation	Watershed Runoff	Groundwater	Septic	White River	
Jan	909	0	7584	1815	10890	-581
Feb	1304	0	6850	1639	8565	1229
Mar	1399	21227	12135	2904	9422	28242
April	5174	94526	11744	2810	78650	35603
May	5593	320728	15169	3629	124038	221081
June	5640	10487	14679	3512	8478	25841
July	2713	5044	15169	3629	8488	18068
Aug	5007	9310	15169	3629	6422	26694
Sept	3694	6868	14679	3512	5638	23115
Oct	3227	6000	15169	3629	7457	20568
Nov	2109	9801	11744	2810	6487	19976
Dec	2013	0	7584	1815	12404	-992
Total	38782	483991	147675	35334	286939	418844
Percent	5%	69%	21%	5%	41%	59%

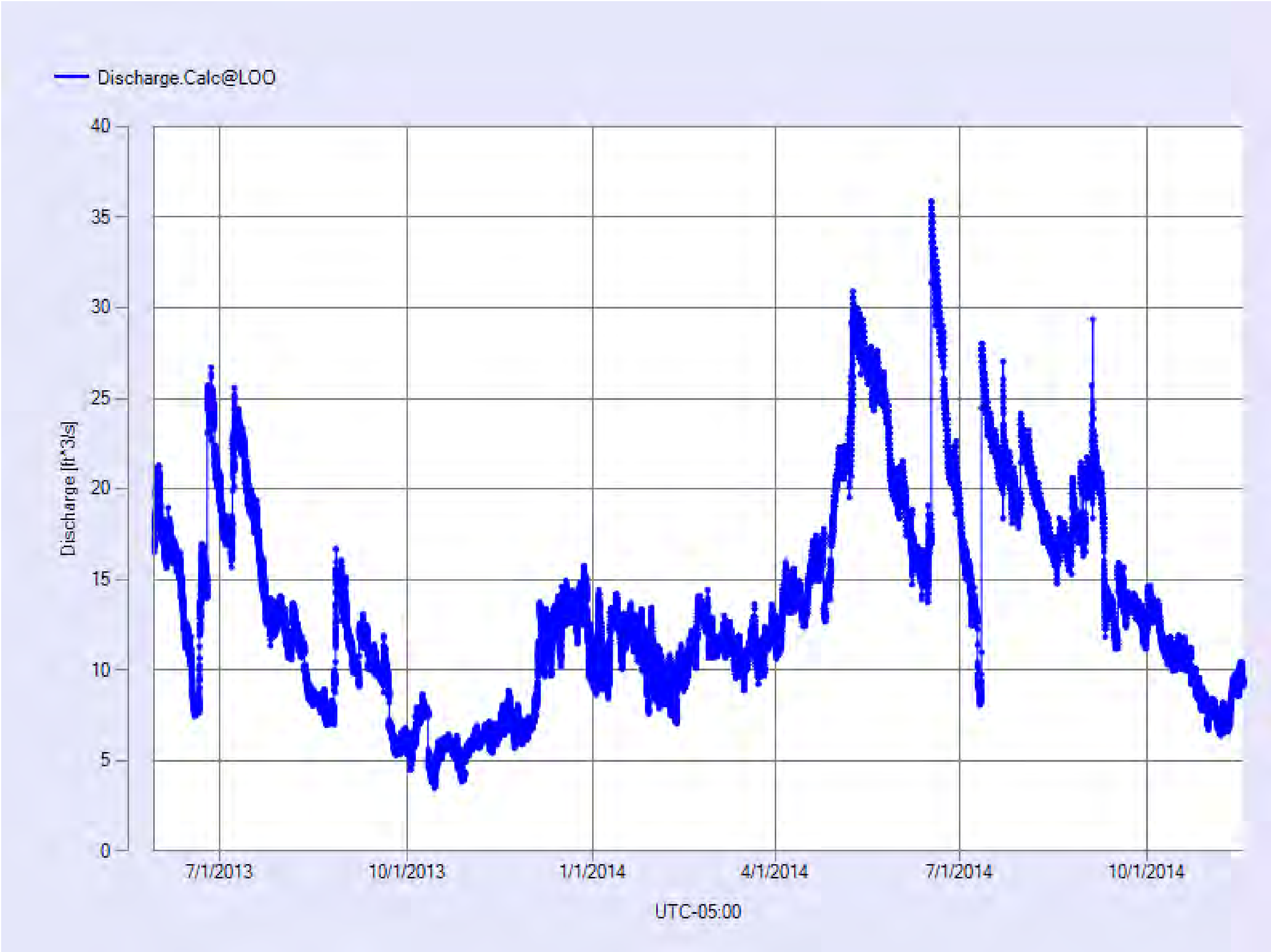


Figure 11.1 Discharge record from Lake Owen, 2013 to 2014.

North Basin South Basin

2013

2014

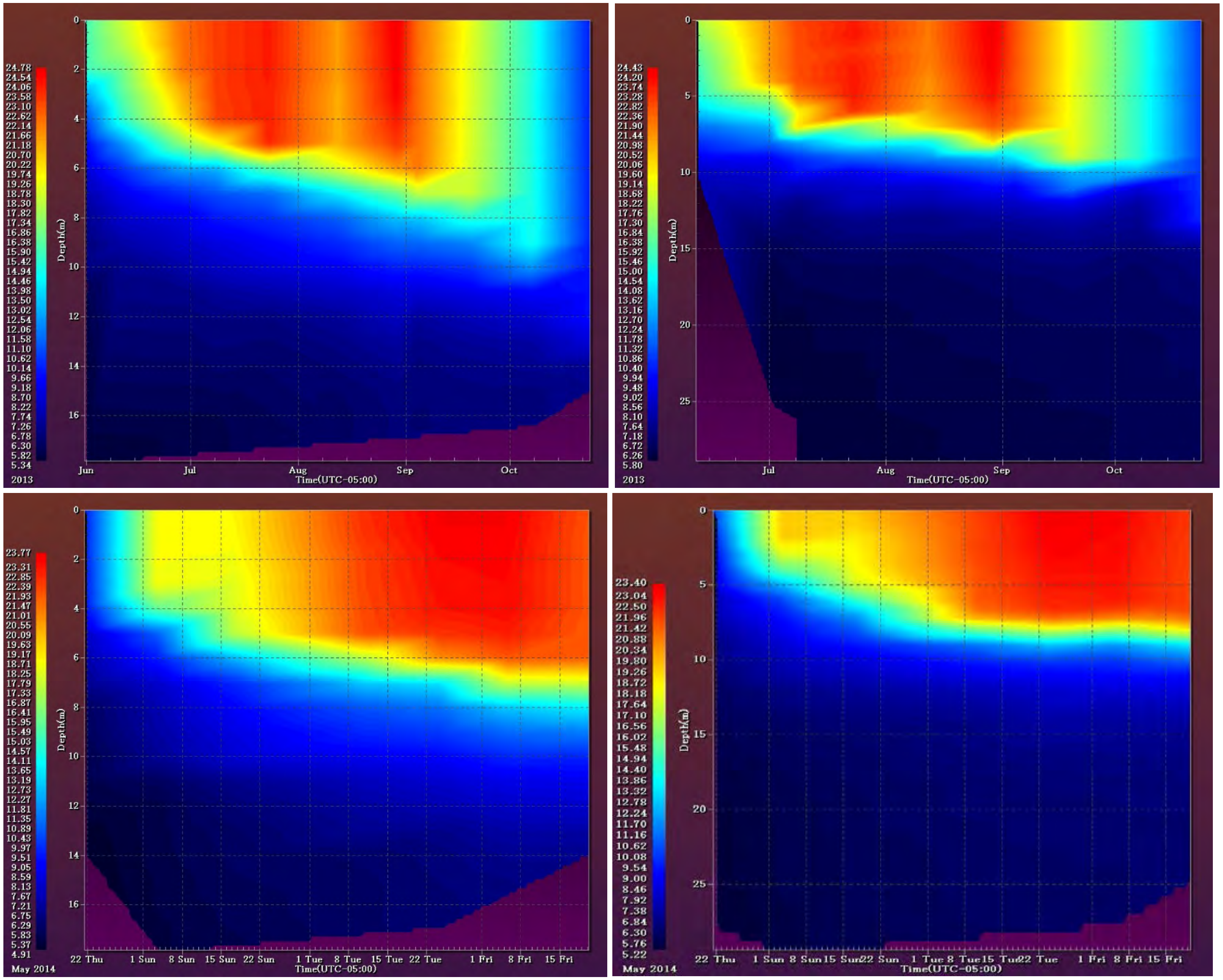


Figure 11.2 Thermal stratification in the north and south basins of Lake Owen in 2013 and 2014.

North Basin South Basin

2013

2014

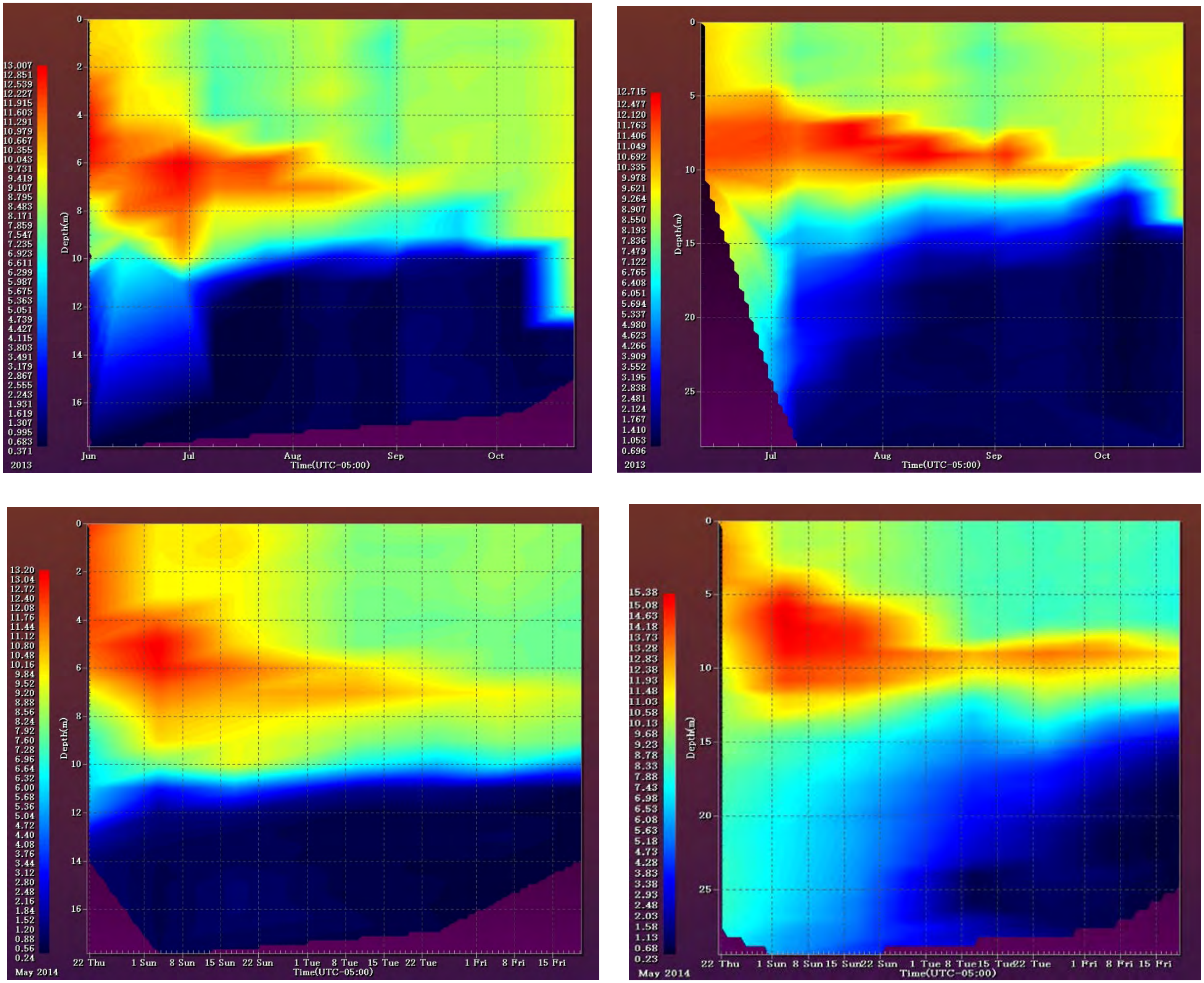


Figure 11.3 Dissolved oxygen stratification in the north and south basins of Lake Owen in 2013 and 2014.

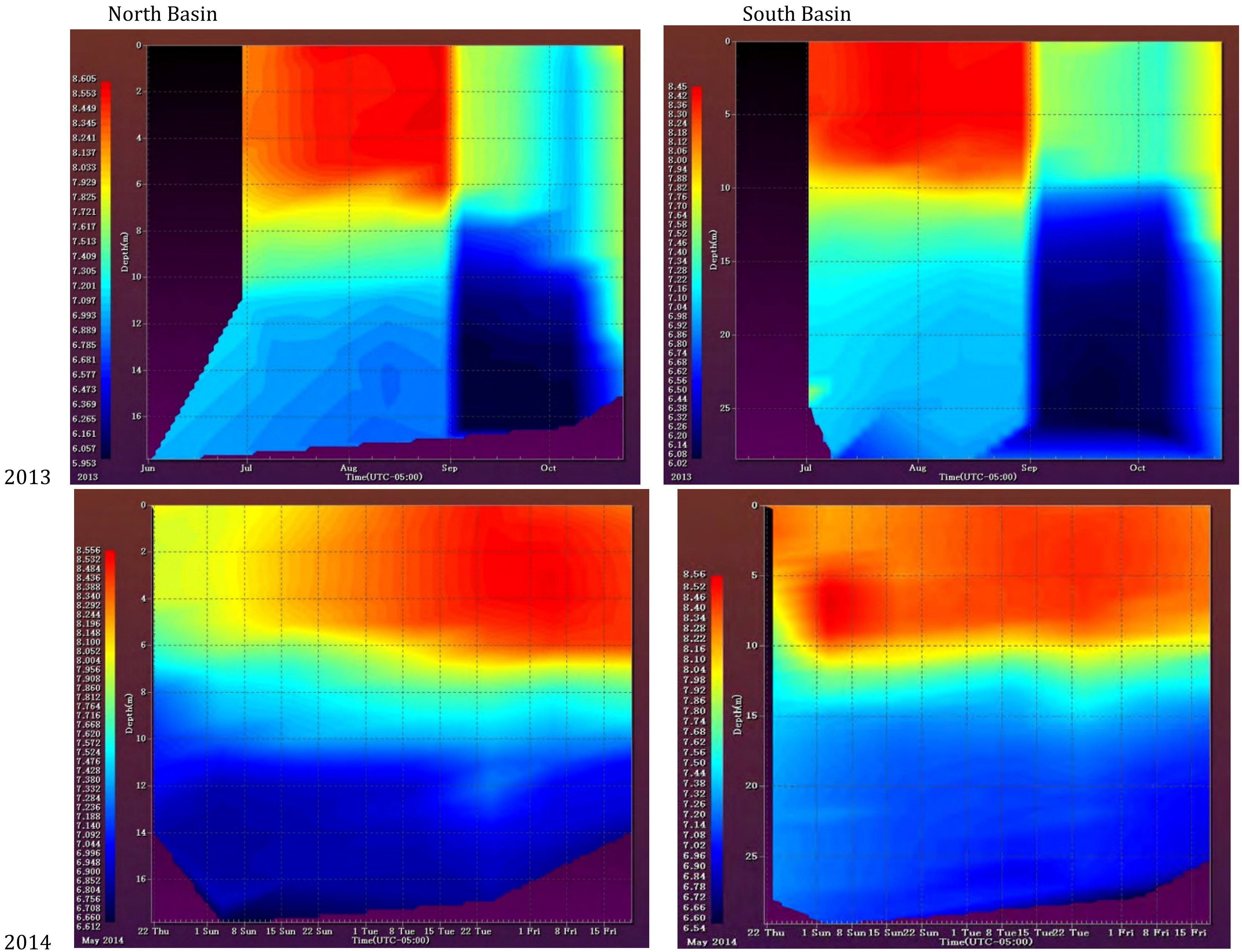


Figure 11.4 pH stratification in the north and south basins of Lake Owen in 2013 and 2014.

North Basin

South Basin

2013

2014

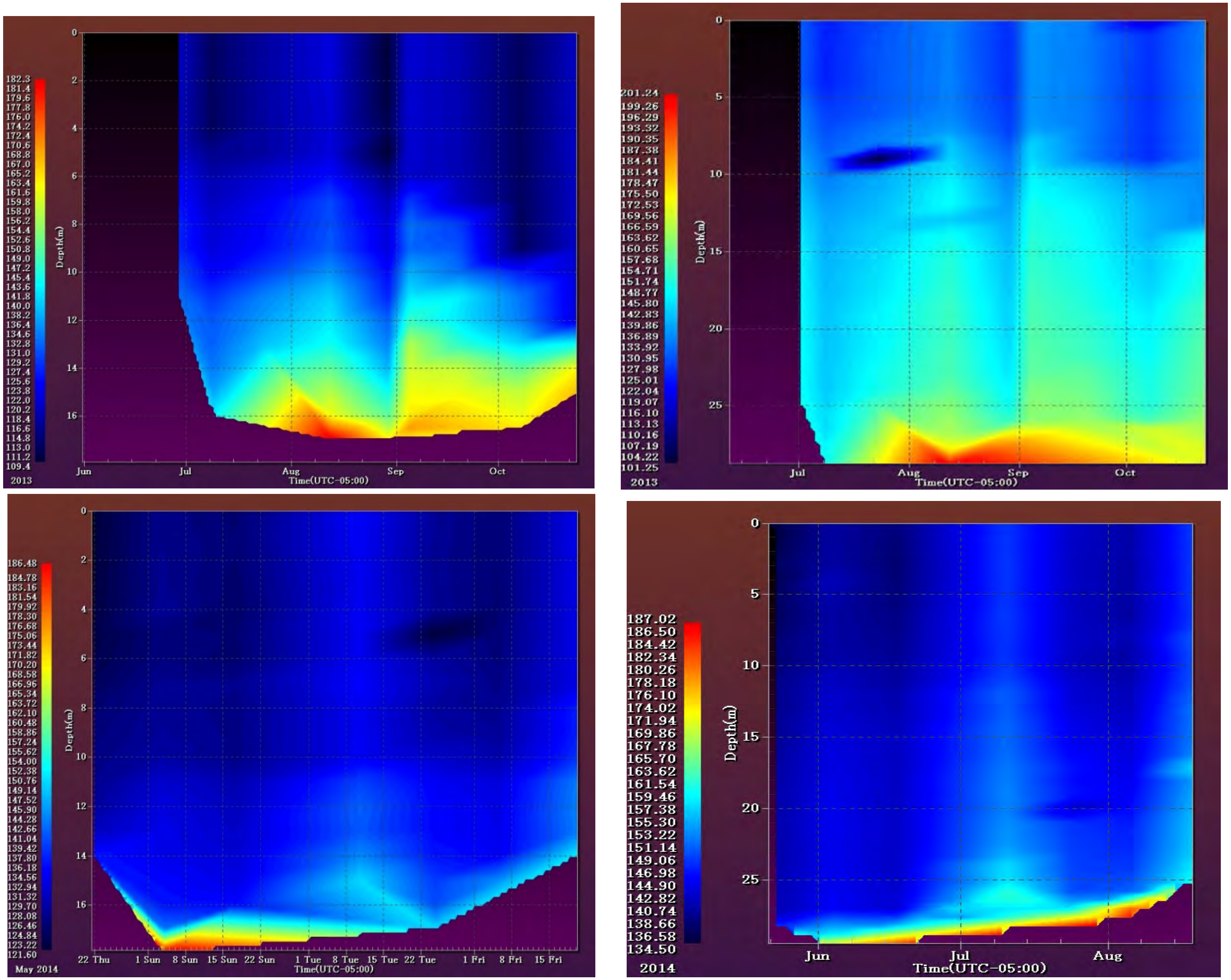


Figure 11.5 Conductivity stratification in the north and south basins of Lake Owen in 2013 and 2014

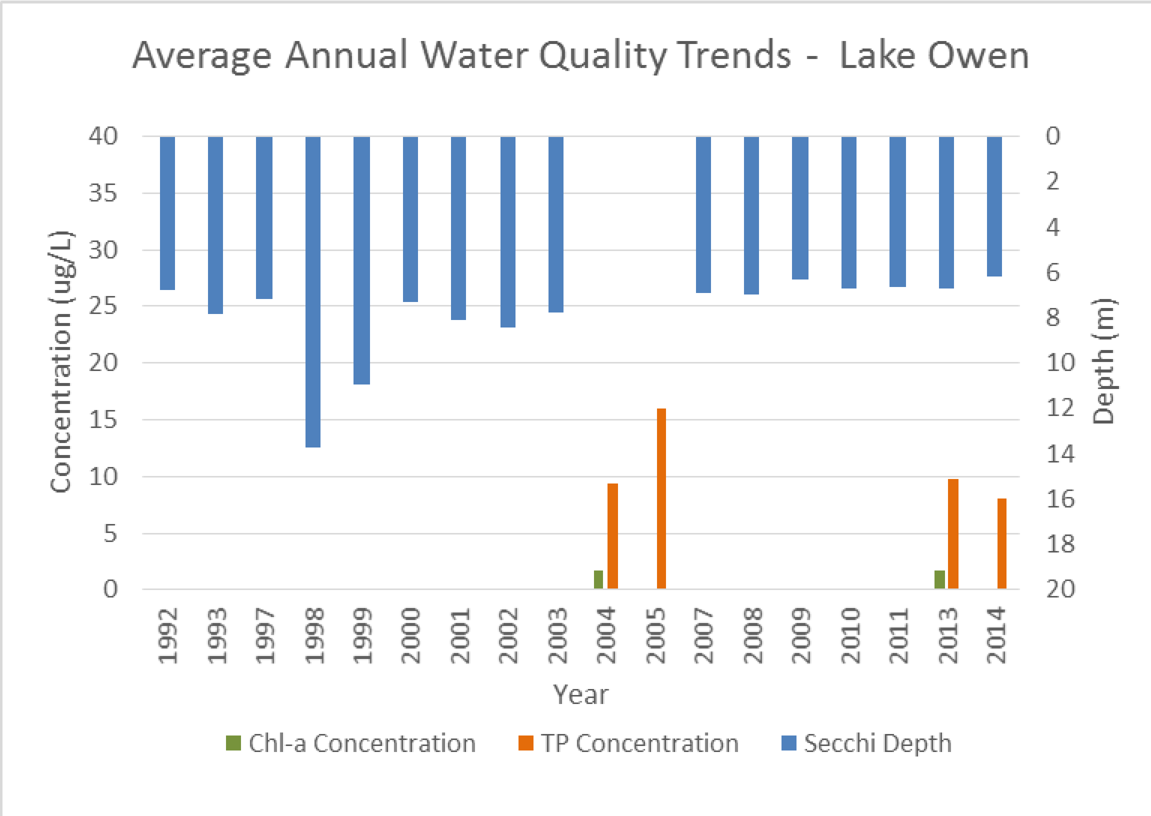


Figure 11.6 Average annual water quality trends in Lake Owen (1992-2014).

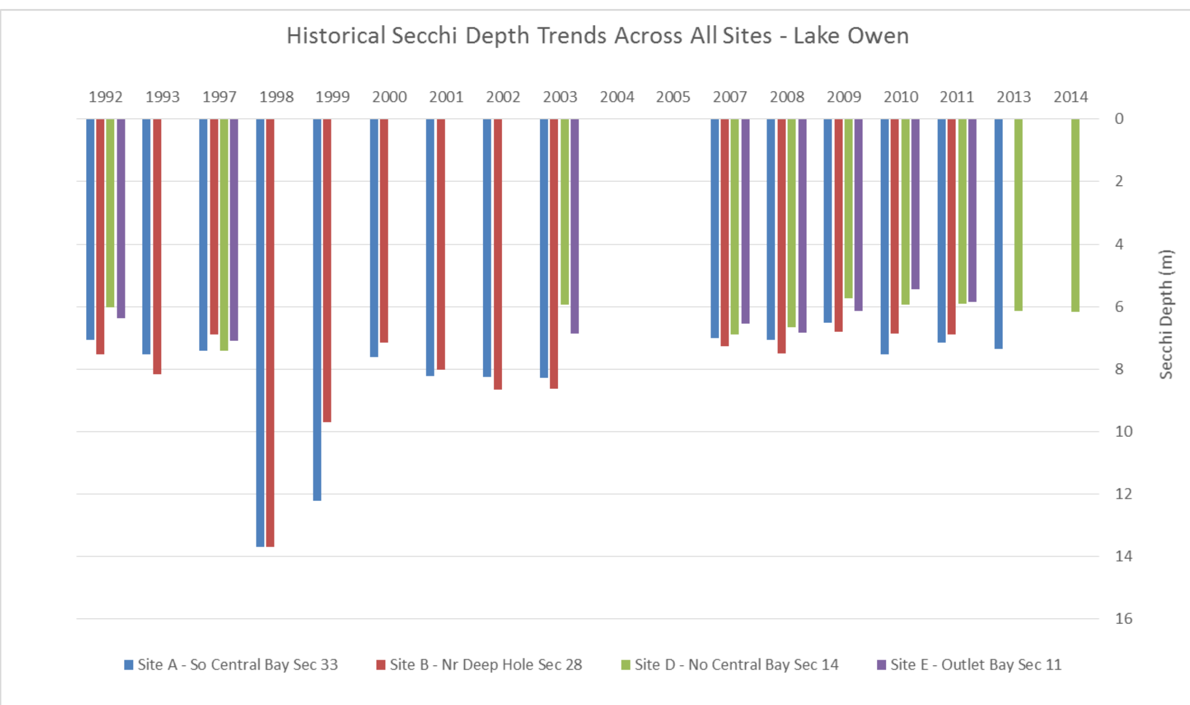


Figure 11.7 Historical trends in Secchi depth across all sites in Lake Owen.

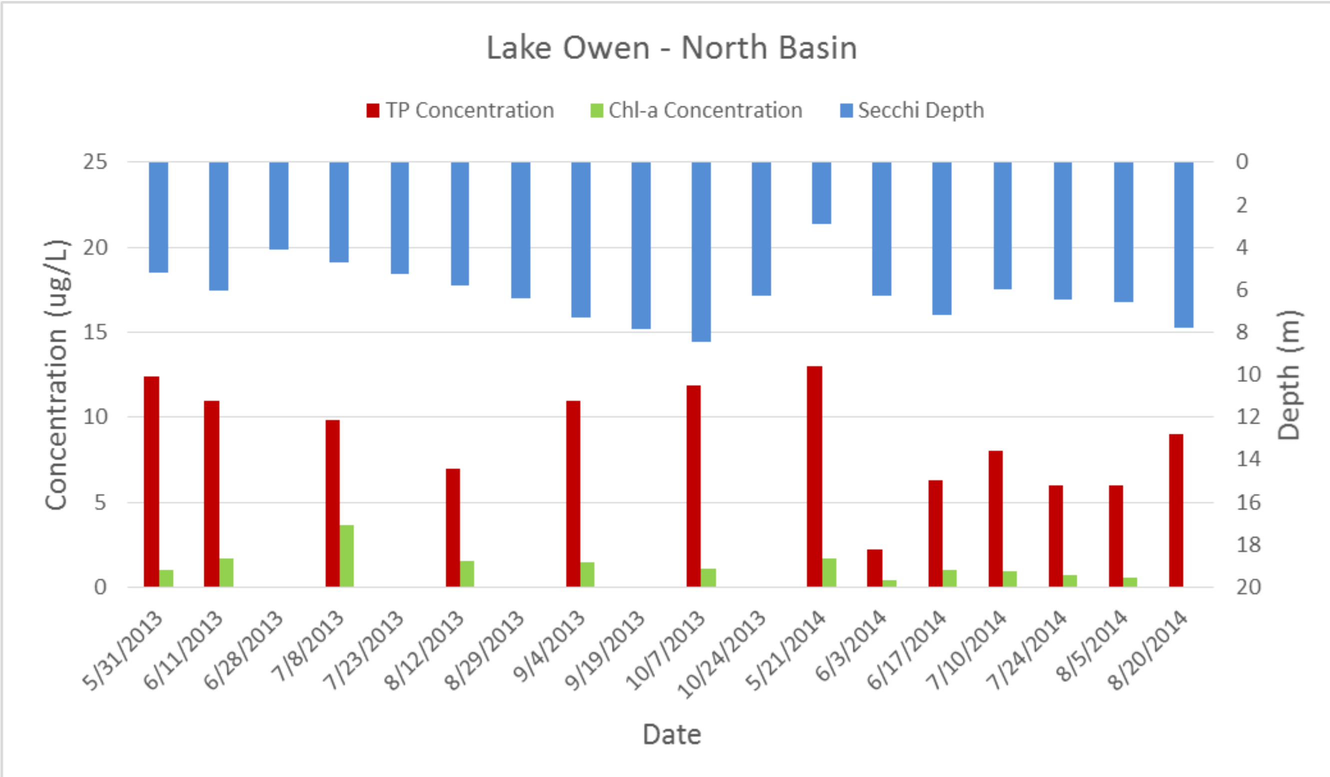


Figure 11.8 Seasonal water quality trends in Lake Owen (north basin).

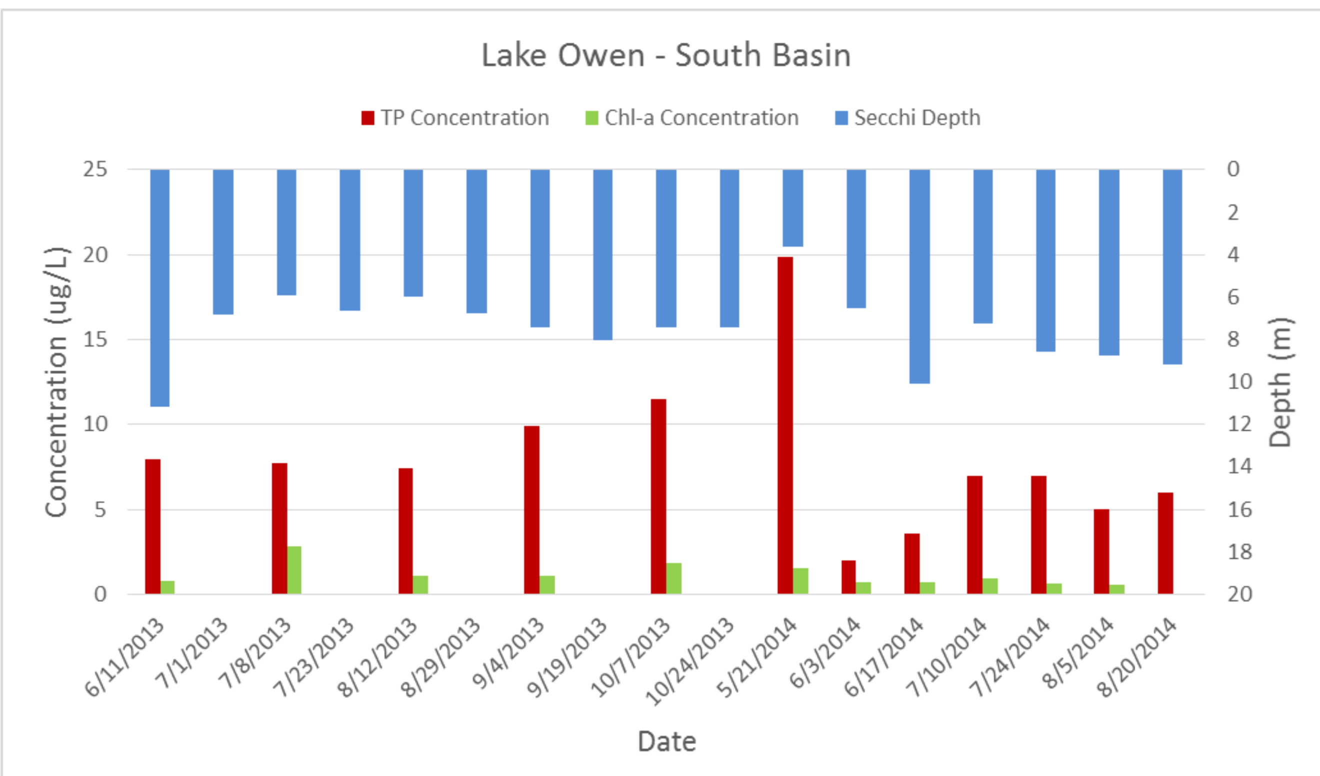


Figure 11.9 Seasonal water quality trends in Lake Owen (south basin).

North Basin South Basin

2013

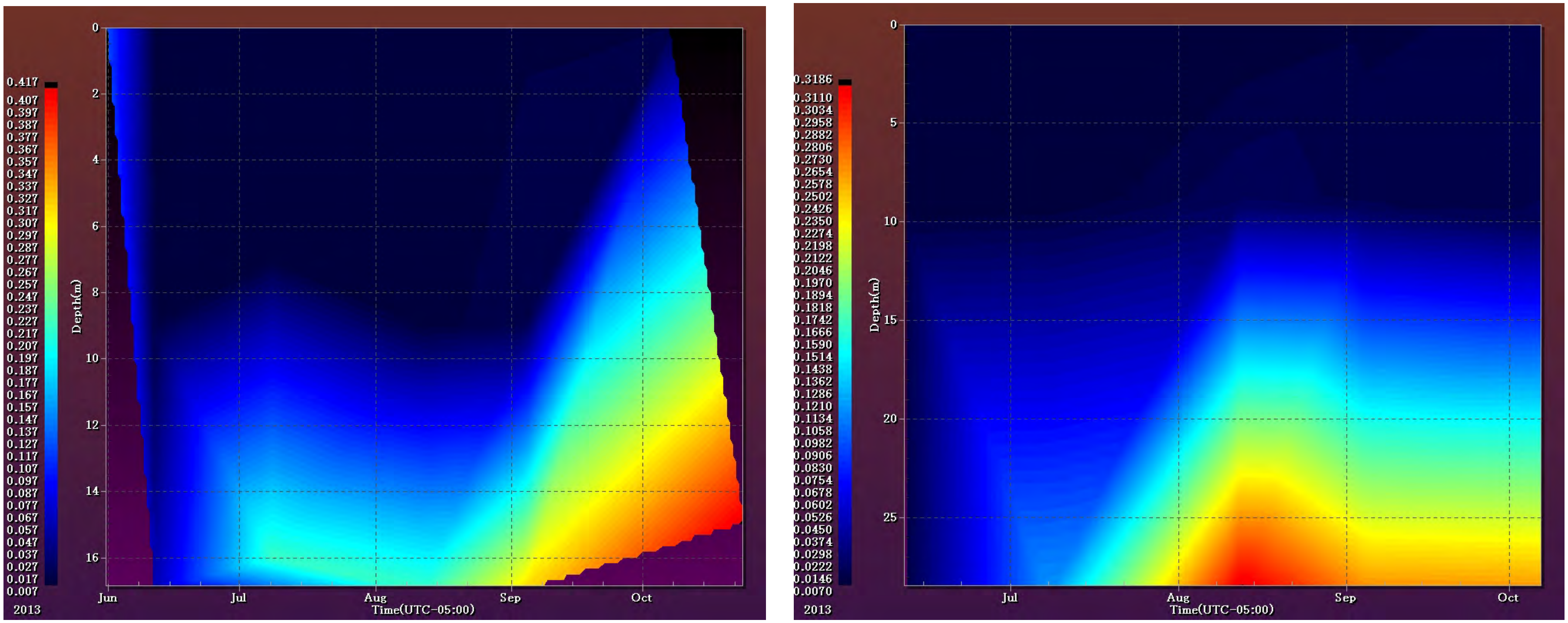


Figure 11.10 Total phosphorus stratification in the north and south basins of Lake Owen in 2013.

12. Appendix C – Shoreline Habitat Assessment and Management Plan

Introduction
This report summarizes the status of shoreline/nearshore habitat in Lake Owen 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 Lake Owen. Results from this assessment were combined with data from the point-intercept survey (see Appendix F) to develop recommendations to protect and restore shoreland and critical nearshore habitat.

Methods
Habitat conditions were described for all parcels surrounding Lake Owen. 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 Lake Owen, 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 and combined with sediment and aquatic plant data to highlight areas of critical habitat in and around Lake Owen.

Results
The shoreline around Lake Owen is approximately 24.5 miles in lengths. Throughout this distance, land is divided into 197 discrete parcels (Figure 12.1). Of these parcels, 29 are publicly owned and 169 are privately owned. Average size of privately owned parcels is 6.7 acres. Average linear shoreline distance of privately owned parcels is approximately 332 feet.

Based on future land use zoning (see Appendix C), the number of parcels around Lake Owen has the potential to increase. Current zoning requires a minimum of 150 shoreline parcels for all lots bordering Lake Owen. Since the current average shoreline length per parcel is 332, full developed of the current zoning regulations could approximately double the number of shoreline parcels. If this increase in parcel density occurs, it would likely be concentrated in the northern sections of the lake, where current parcels are largest in size.

Critical Habitat and Sediment Types

Results from the point intercept survey and shoreline habitat assessment suggest that there are a range of habitat types and conditions throughout the Lake Owen ecosystem (Figure 12.2). Not surprisingly, areas of the highest quality aquatic habitat are often adjacent to the areas of highest quality shoreline habitat. Sediment types varied across the lake, with areas of muck being most common in protected embayments and areas of rock and sand being most common along less protected shorelines and adjacent to steep bathymetric drops (Figures 12.3 and 12.4).

Shoreland Habitat

Results from the habitat assessment suggest that shoreland habitat is relatively unimpaired in Lake Owen. Of the 194 parcels surveyed, the majority were in “very good” or “ideal” 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 along the northern and western shorelines.

Discussion and Management Recommendations

Given that most shoreline habitat surrounding Lake Owen is in relatively good condition, the majority of shoreline management activities should focus on protection efforts. As described in Section 7.1, shoreland habitat protection for Lake Owen is primarily driven by the Bayfield County shoreland zoning ordinance. Although this ordinance provides substantial protections for water quality and nearshore habitat in Lake Owen, 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.

Although most stretches of shoreline are in relatively good condition in Lake Owen, some opportunities for shoreland habitat restoration do exist. 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 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 Lake Owen.

Parcel Condition	Lake Owen Parcel Data		
	Upland / Terrestrial (OHWM inland 15m)	Shoreline / Riparian Buffer (water's edge inland 1m)	Aquatic / Littoral (waterward 10m from shore)
Ideal	79	83	72
Very Good	63	53	65
Marginal	34	42	45
Poor	18	16	12
Total	**194**		

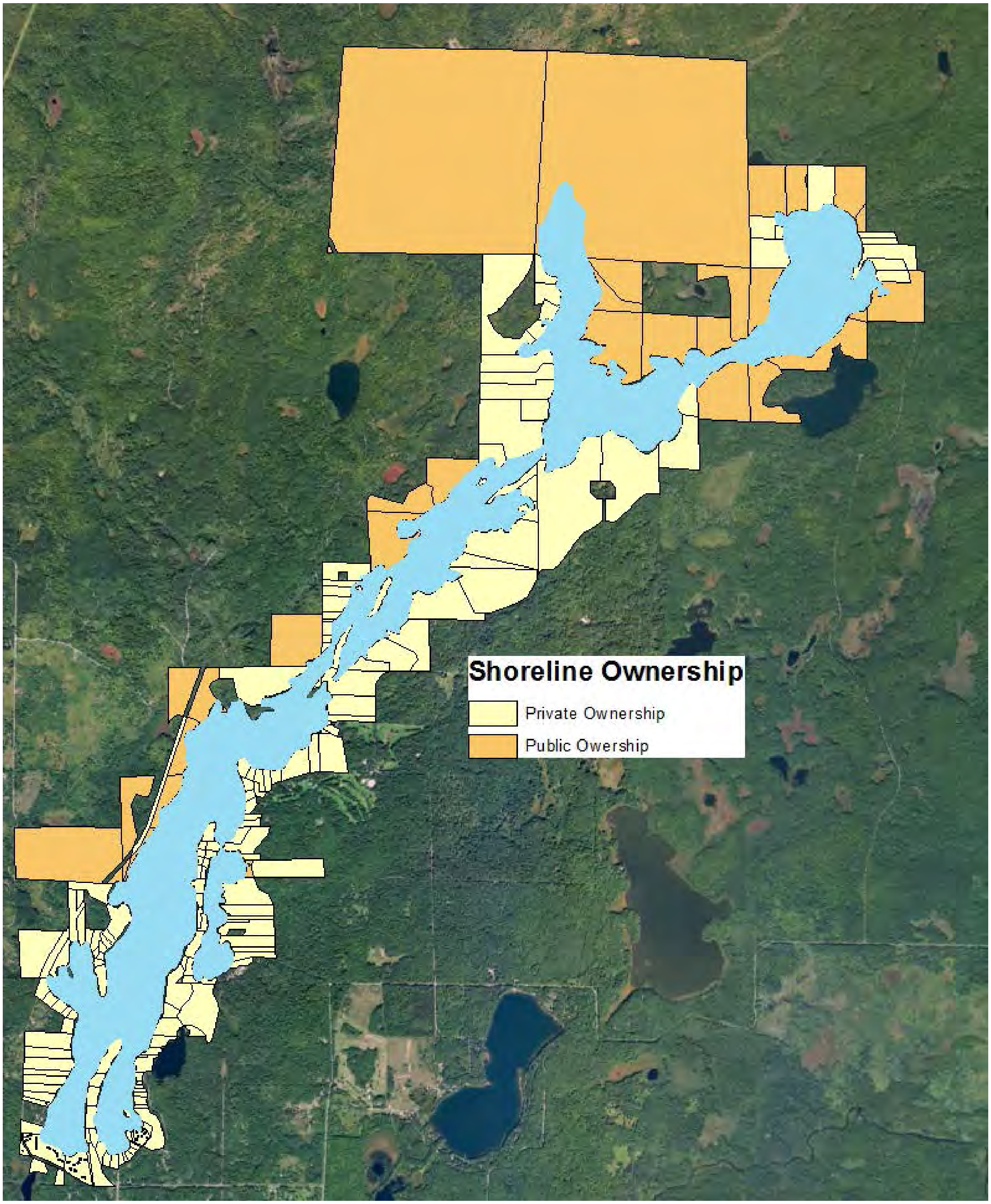


Figure 12.1 Shoreline parcel ownership surrounding Lake Owen.

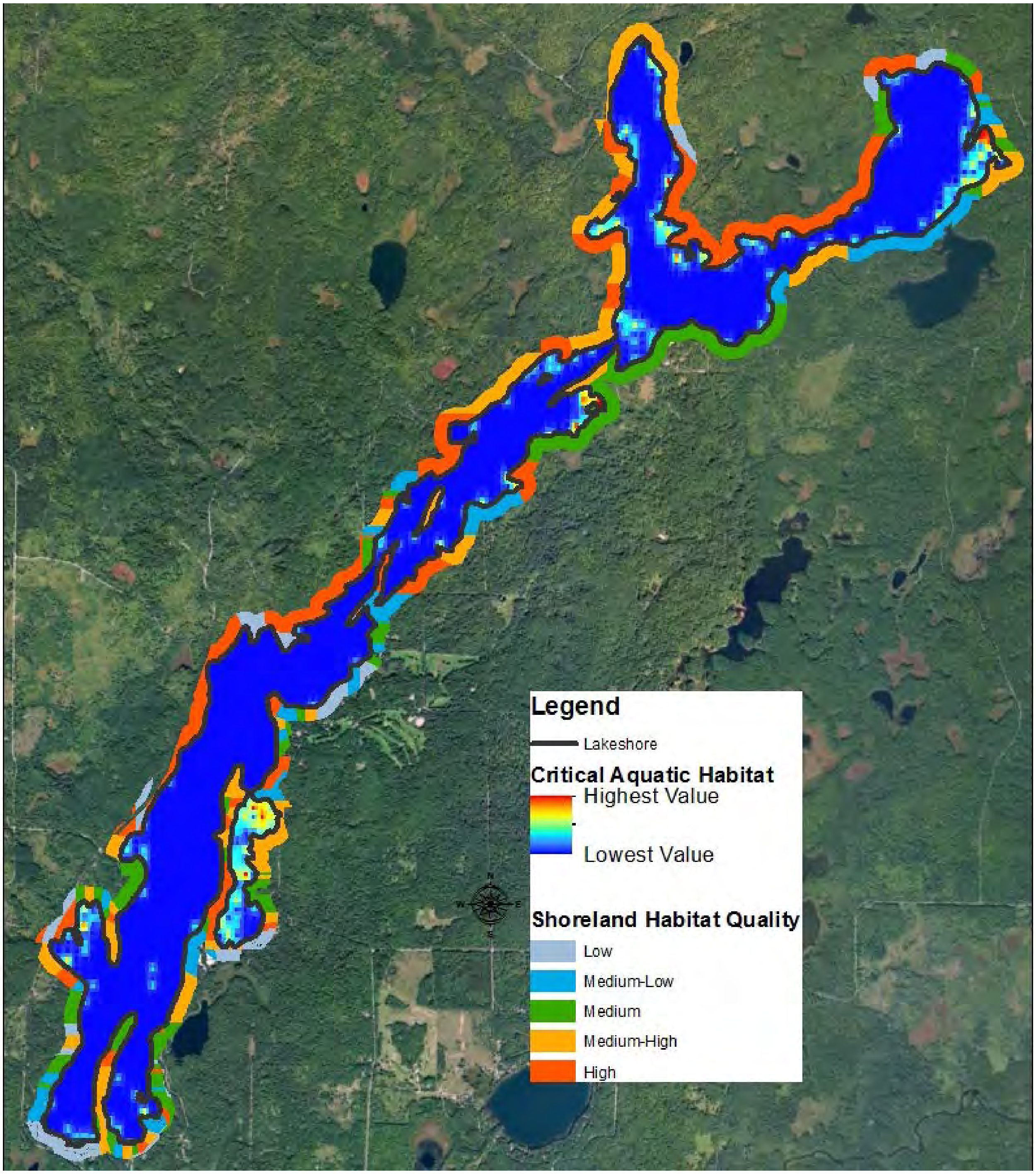


Figure 12.2 Locations of highest quality aquatic and shoreline habitat.

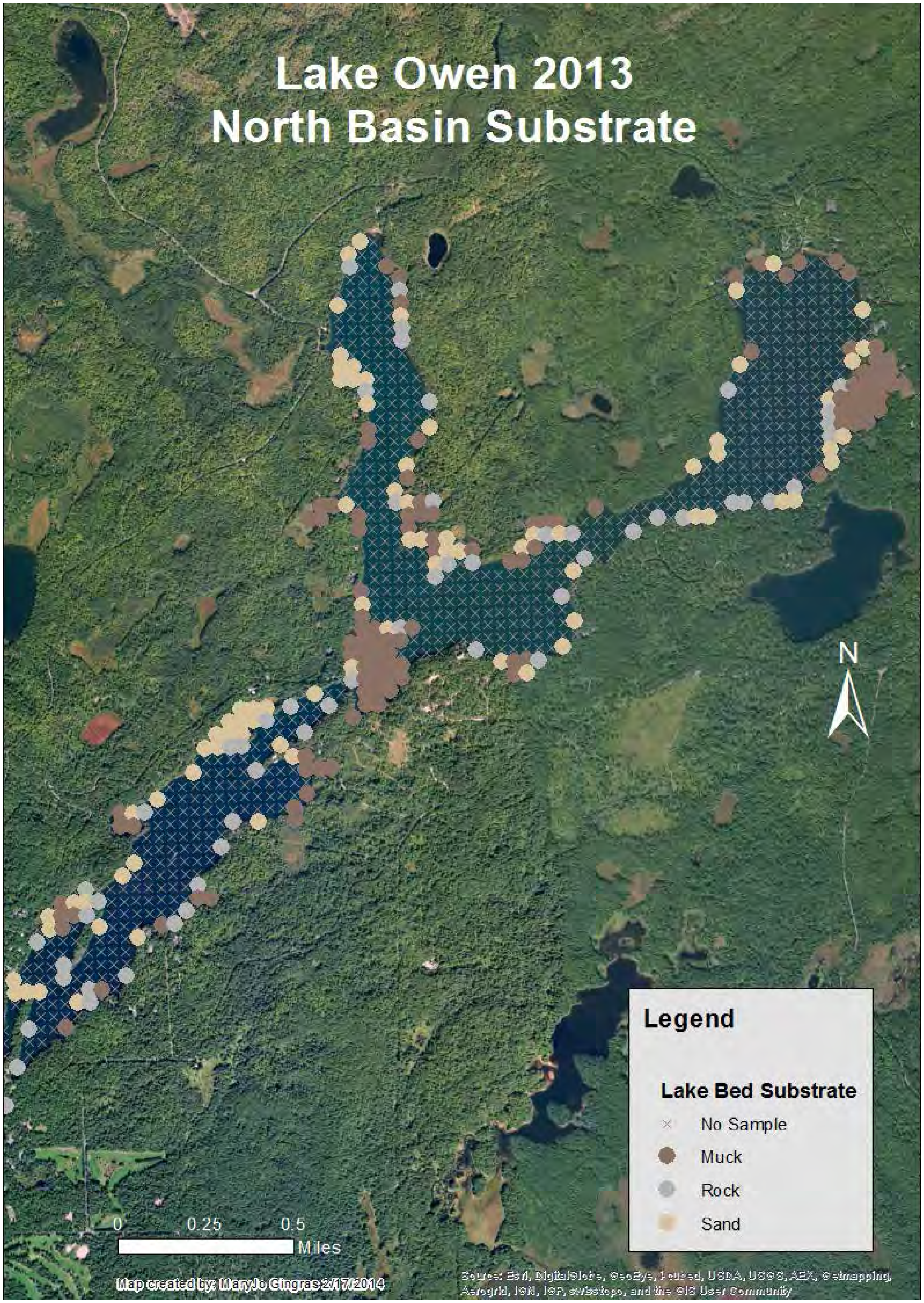


Figure 12.3 Locations of different sediment types in Lake Owen (north basin).

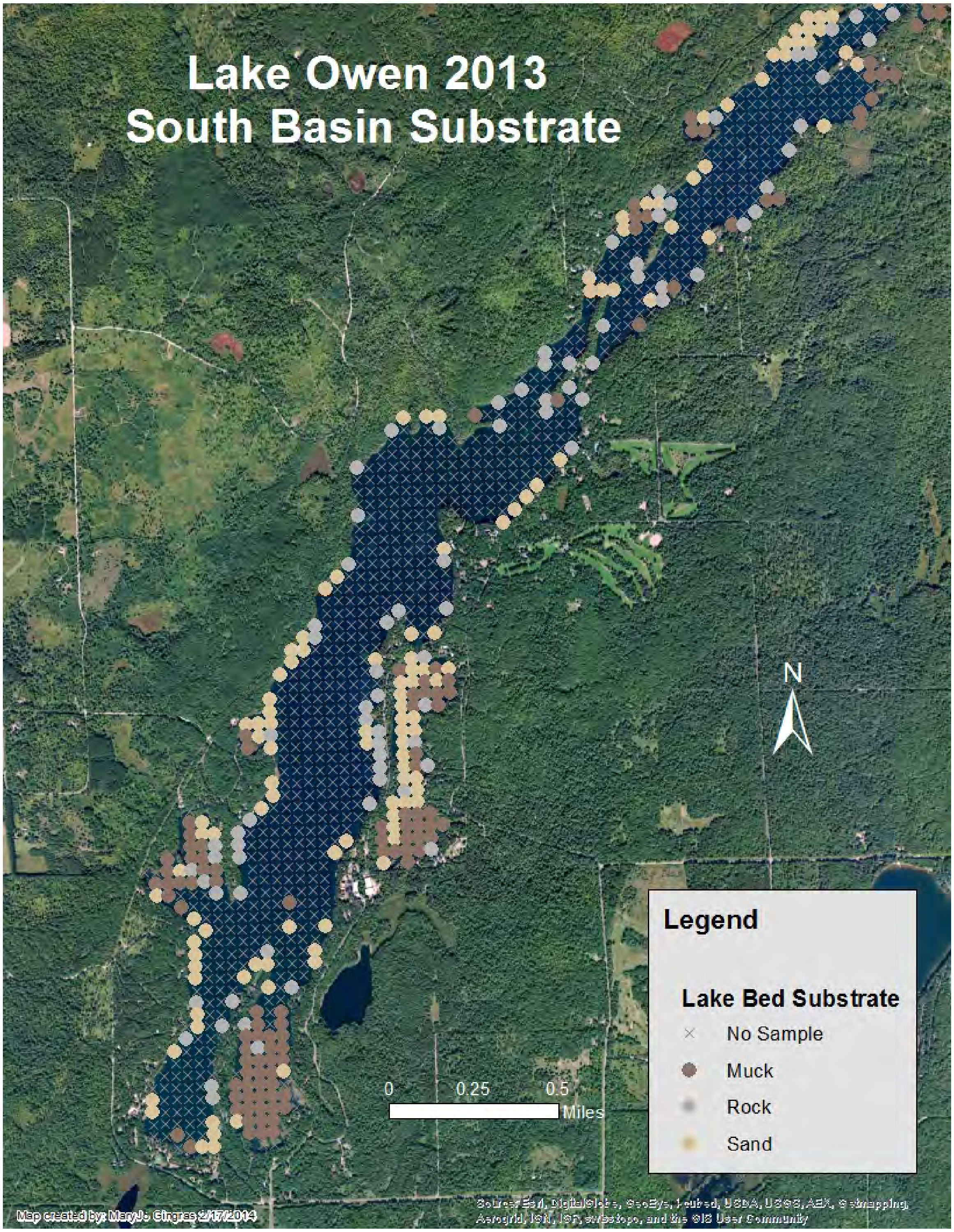


Figure 12.4 Locations of different sediment types in Lake Owen (south basin).

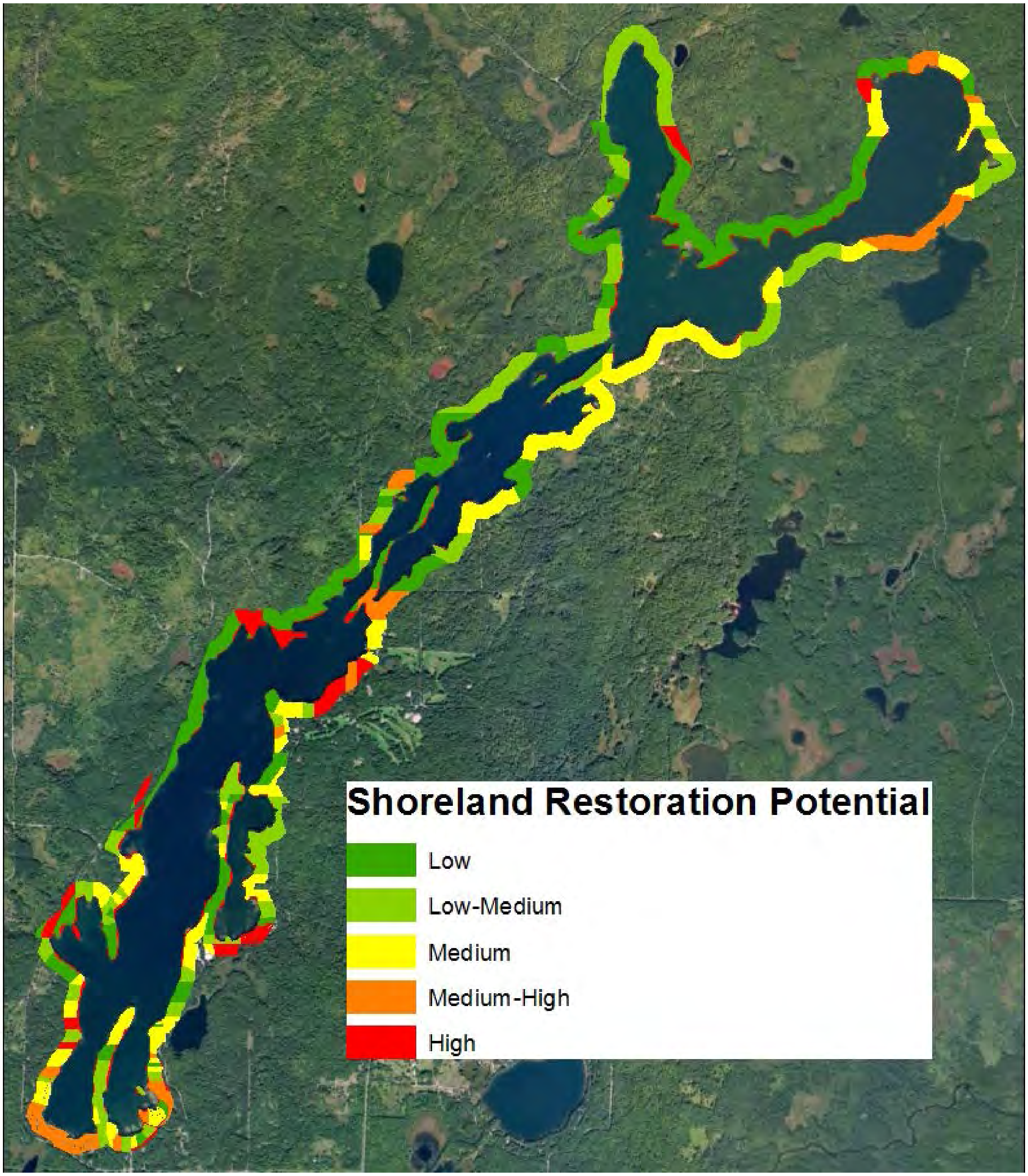


Figure 12.5 Average restoration potential of shoreland areas surrounding Lake Owen

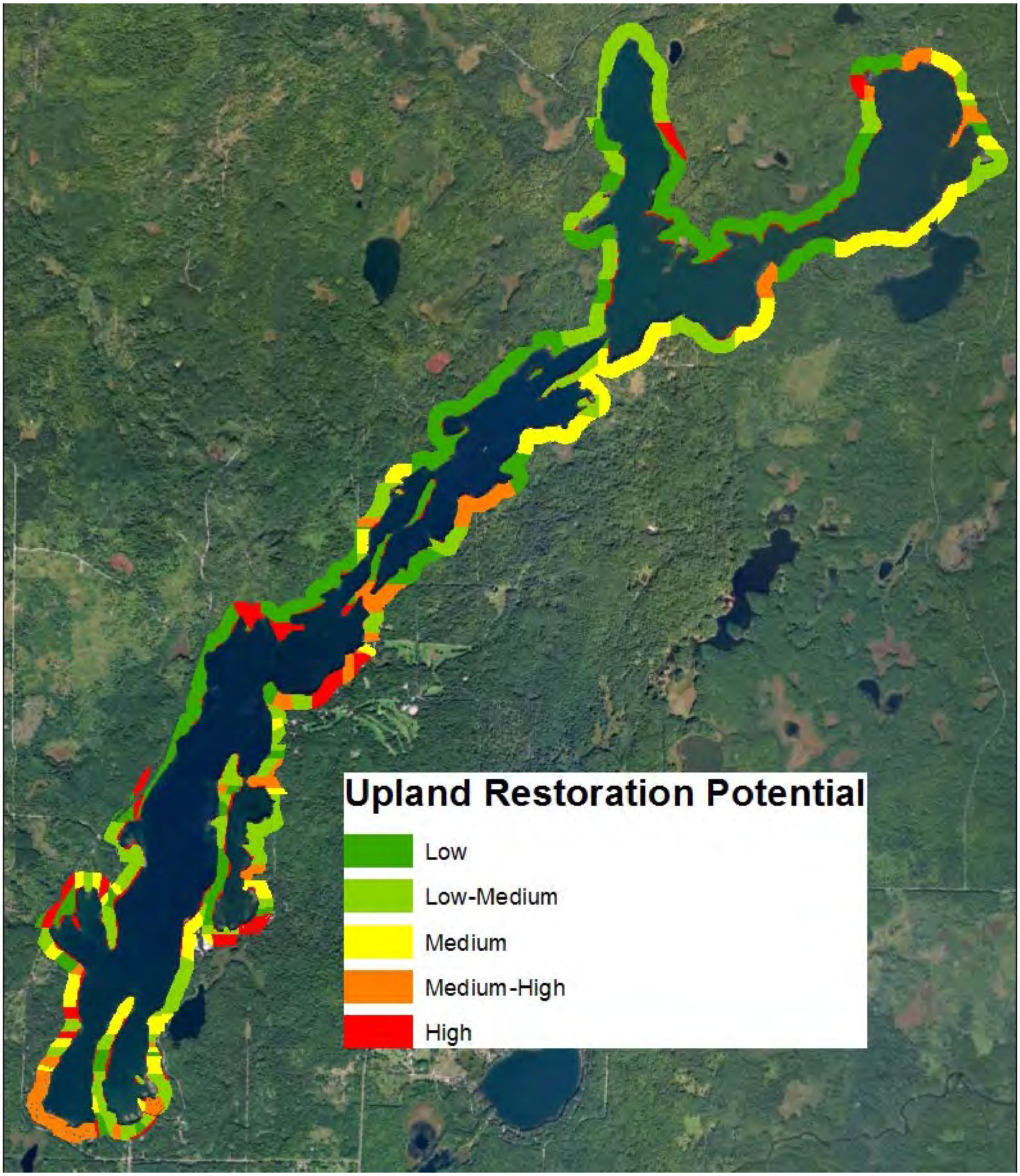


Figure 12.6 Average restoration potential of upland areas surrounding Lake Owen.

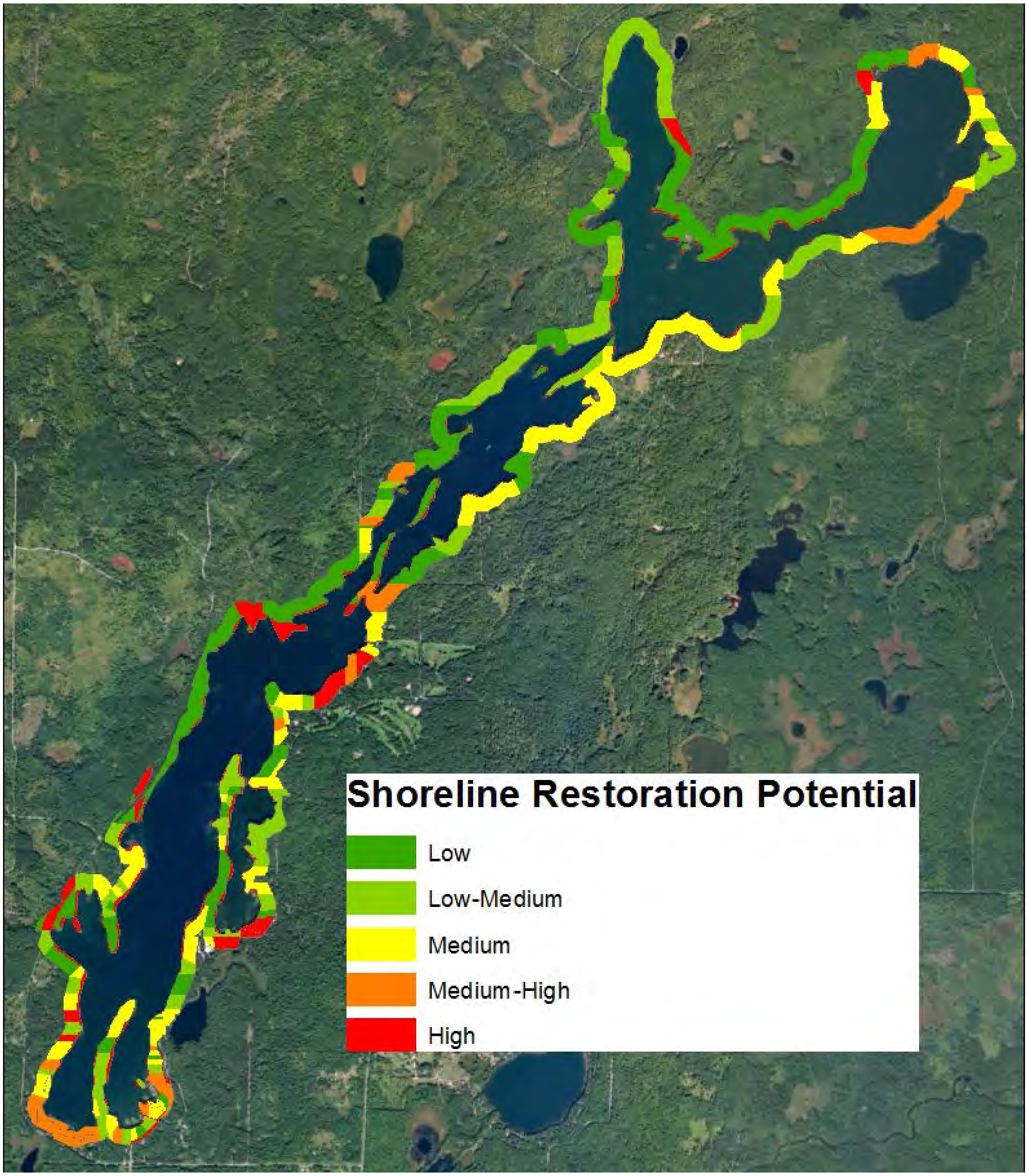


Figure 12.7 Average restoration potential of shoreline areas surrounding Lake Owen.

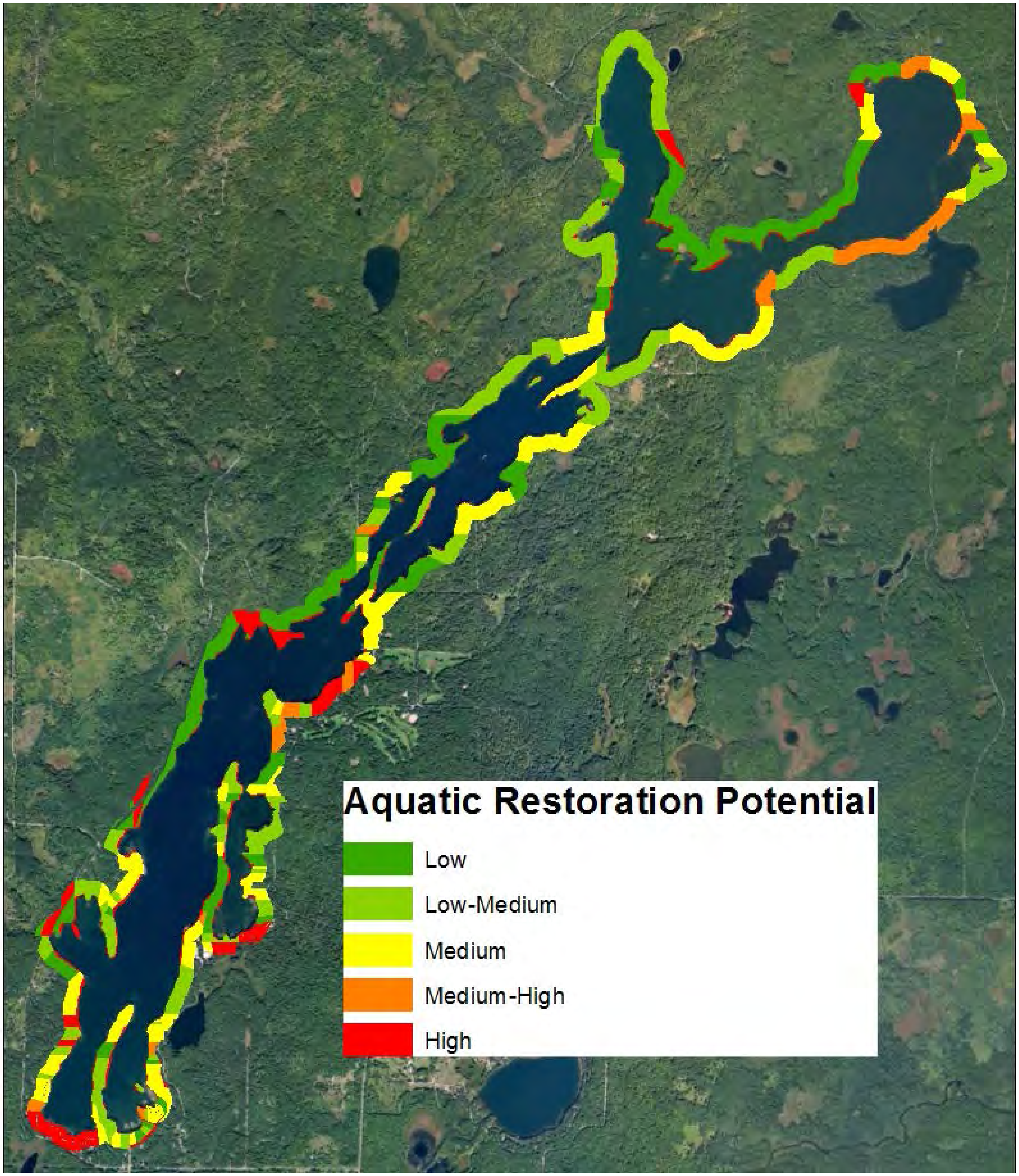


Figure 12.8 Average restoration potential of aquatic/littoral areas surrounding Lake Owen.

13. Appendix D – Watershed Assessment and Management Plan

Introduction
This report summarizes the condition of, and potential management options for, the Lake Owen watershed. Given the importance of watershed nutrient runoff (see Section 5.2), a detailed assessment of the of the land use types and potential phosphorus sources to Lake Owen 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 Lake Owen.

Methods
Watershed nutrient loads to Lake Owen were developed using land-use specific, annual phosphorus export coefficients. Initially, the Lake Owen 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 Towns of Drummond and Cable.

Annual watershed nutrient loads to Lake Owen 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 1856), current (2013) 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 an AQUATOX model to describe the relationship between land use and lake condition (see Appendix G).

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 Lake Owen watershed is approximately 8,165 acres and is the headwaters to the south fork of the White River. Land cover throughout the Lake Owen watershed is dominated by deciduous and mixed forest types, while developed and agricultural lands make up a relatively small percentage of the land area (Figure 13.3 and Table 13.2).

Land cover throughout the watershed has significantly shifted since the mid-1800s and is anticipated to continue to change in the coming years (Figures 13.1, 13.2, 13.3 and 13.4).

Historically, sugar maple and yellow birch dominated much of the northwestern lakeshore, while white, jack and red pine dominated much of the southeastern lake shore. Over time, the relative abundance of coniferous species has declined and this land cover type has been replaced by mixed forests and small amounts of urban and agricultural lands. 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 Lake Owen from septic systems comprise approximately six percent of the total watershed load. Based on future land use plans, phosphorus loads from future land uses have the potential to increase by approximately 12 percent.

In correspondence to the land use changes described above, phosphorus runoff has, and will likely continue to increase into the future. Historical phosphorus loads to the lake were approximately 734 lbs/yr. Annual phosphorus loads to the lake increased to approximately 1067 in 2013 and have the potential to increase to 1146 by 2030. 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 similar impacts on the Lake Owen ecosystem (see Appendix G for further discussion on the relative impacts of nutrient loads to Lake Owen).

Management and Monitoring Recommendations

Changes in land use throughout the Lake Owen watershed have likely increased phosphorus runoff to the lake and phosphorus runoff to the lake has the potential increase by a modest amount into the future. 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 Lake Owen 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.

The capacity of current zoning and stormwater regulations to manage runoff under future land use scenarios is mixed. Current shoreland zoning laws are likely sufficient to mitigate much of the potential impacts to water quality from development in shoreland areas. However, the potential impact of shoreline development on water quality may be dependent on the on-site wastewater treatment required. Given the susceptibility of oligotrophic lakes to nutrient runoff, the cumulative discharge of phosphorus from well-functioning septic systems has the potential to increase phosphorus discharge to the lake by approximately 50%. Future septic design/requirements should incorporate an assessment 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 Lake Owen. However, potential impacts from upland areas is more likely to occur as a result of stormwater runoff than on-site wastewater management. Because the population density in the towns of Drummond and Cable 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/commercial areas throughout the watershed should be considered.

To effectively mitigate the potential impacts of watershed runoff to Lake Owen, all future development activities should incorporate stormwater management requirements in a similar form to those required as part of shoreline zoning. 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 Lake Owen 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 Lake Owen, 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.

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 Lake Owen watershed.

Table 13.1. Percent land cover change over time, based on past present and anticipated future land uses.

Land Cover Classification	Year							
	Historic Vegetation	National Land Cover Database (NLCD)				NLCD + Survey	Local Zoning	
	*1850s	**1992	2001	2006	2011	2013	ǂPotential Current Land Cover	ǂǂPotential Future Land Cover
Open Water	14%	14%	15%	15%	15%	15%	15%	15%
Rural Roads and Open Lands	0.00%	5%	6%	6%	6%	2%	2%	2%
Shoreland Residential	0.00%	0.00%	0.00%	0.00%	0%	4%	6%	8%
Rural Residential	0.00%	0.13%	0.22%	0.22%	0.22%	2%	10%	24%
Medium Density Residential	0.00%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	1.45%
High Density Urban	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.93%
Barren Land	0.00%	0.03%	0.03%	0.03%	0.03%	0.78%	2%	1.14%
Deciduous Forest	55%	44%	39%	39%	38%	36%	27%	18%
Evergreen Forest	20%	12%	9%	9%	9%	9%	9%	8%
Mixed Forest	8%	15%	23%	23%	23%	23%	18%	14%
Shrub/Scrub	1%	2.1%	3.4%	3.3%	4%	4%	4%	4%
Grassland	0.00%	0.12%	0.44%	0.44%	0.55%	0.55%	1%	1%
Pasture/Hay	0.00%	3%	2%	2%	2.2%	2.2%	4%	1%
Cultivated Crops	0.00%	0.29%	0.22%	0.22%	0%	0%	0.22%	0%
Woody Wetland	2.0%	3.6%	2.0%	2.0%	2%	2%	2%	2%
Emergent Wetland	0.00%	0.04%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%

* Estimated from WDNR original vegetation data layer
** Estimated from alternate land cover classification system
ǂ Estimated from current zoning plans
ǂǂ Estimated from future land use (zoning) plans

Table 13.2. Watershed areas covered by different land use types throughout the Lake Owen watershed from historical (~1856), current (2013) and future potential (2030) land use conditions.

	Relative Watershed Land Cover					
	Historic Land Cover ~1856		Current Land Cover 2013		Potential Future Land Cover (2030)	
Land Cover Classification	Percent	Total	Percent	Total	Percent	Total
Open Water	15%	1407	15%	1407	15%	1436
Rural Roads and Open Lands	0.00%	0	2%	191	2%	191
Shoreland Residential	0.00%	0	4%	383	11%	1082
Rural Residential	0.00%	0	2%	191	16%	1484
Medium Density Residential	0.00%	0	0.01%	1	0.99%	95
High Density Urban	0.00%	0	0.00%	0	0.64%	61
Barren Land	0.00%	0	0.78%	75	0.78%	75
Deciduous Forest	54%	5198	36%	3411	20%	1914
Evergreen Forest	20%	1914	9%	844	9%	861
Mixed Forest	8%	766	23%	2235	17%	1641
Shrub/Scrub	1%	96	4%	356	4%	383
Grassland	0.00%	0	0.55%	53	1%	96
Pasture/Hay	0.00%	0	2.2%	212	0.64%	61
Cultivated Crops	0.00%	0	0%	21	0%	0
Woody Wetland	2.0%	191	2%	189	2%	191
Emergent Wetland	0.00%	0	0.01%	1	0.01%	1

Table 13.3. 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	32	2.5	1	0.3	1.1	1.8	1.5	26	43	**36**
	Seasonal	127	2.5	0.3	0.3	1.1	1.8	1.5	31	51	**43**
	Total	**169**	**2.5**	**0.65**	**0.3**	**1.1**	**1.8**	**1.5**	**58**	**94**	**78**
Potential Future Conditions	Full-time	63	2.5	1	0.3	1.1	1.8	1.5	52	86	**71**
	Seasonal	254	2.5	0.3	0.3	1.1	1.8	1.5	63	103	**86**
	Total	**338**	**2.5**	**0.65**	**0.3**	**1.1**	**1.8**	**1.5**	**115**	**188**	**157**

Table 13.4. Estimated annual total phosphorus loads to Lake Owen from all sources.

				Estimated Annual Phosphorus Loads to Lake Owen					
	Annual TP Loads			Historical (1856)		Current (2013)		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	212	212	60	60
Barren Lands	0.1	3	1	0	0	75	75	75	75
Urban Lands	(lbs./acre/yr)			Acres	lbs.	Acres	lbs.	Acres	lbs.
Rural Roads and Open Lands	0.1	0.5	0.3	0	0	191	57	191	57
Shoreland Residential	0.05	0.25	0.2	0	0	383	77	1082	216
Developed, Rural Residential	0.05	0.25	0.1	0	0	191	19	1484	148
Developed, Medium Density	0.3	0.8	0.5	0	0	1	1	95	48
Developed, High Density	1	2	1.5	0	0	0	0	61	92
Forest and Grasslands	(lbs./acre/yr)			Acres	lbs.	Acres	lbs.	Acres	lbs.
Deciduous Forest	0.05	0.2	0.09	5360	732	3411	616	1914	432
Evergreen Forest				2010		844		861	
Mixed Forest				766		2235		1641	
Shrub/Scrub				0		356		383	
Grassland	0.01	0.25	0.17	0	0	53	9	96	16
Wetland	0.01	0.01	0.01	191	2	190	2	192	2
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	169	78	338	157
Relative Changes in Phosphorus Load					**Total**	**%**	**Total**	**%**	**Total**
Total Watershed Load					**734**	**0.31**	**1067**	**0.07**	**1146**
Permitted/Non-permitted Source Load					**0**	**1.00**	**78**	**0.50**	**157**
Total Phosphorus Loads					**734**	**0.36**	**1145**	**0.12**	**1303**
Per Acre Phosphorus Load					**0.08**	**0.31**	**0.11**	**0.07**	**0.12**

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

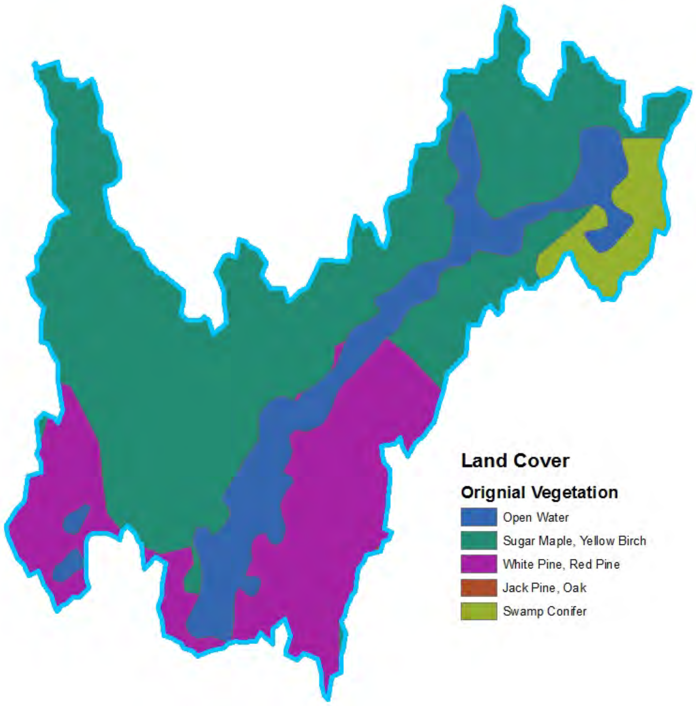


Figure 13.1 Historical vegetative cover in the Lake Owen watershed. Based on ~1856 vegetative cover assessments.

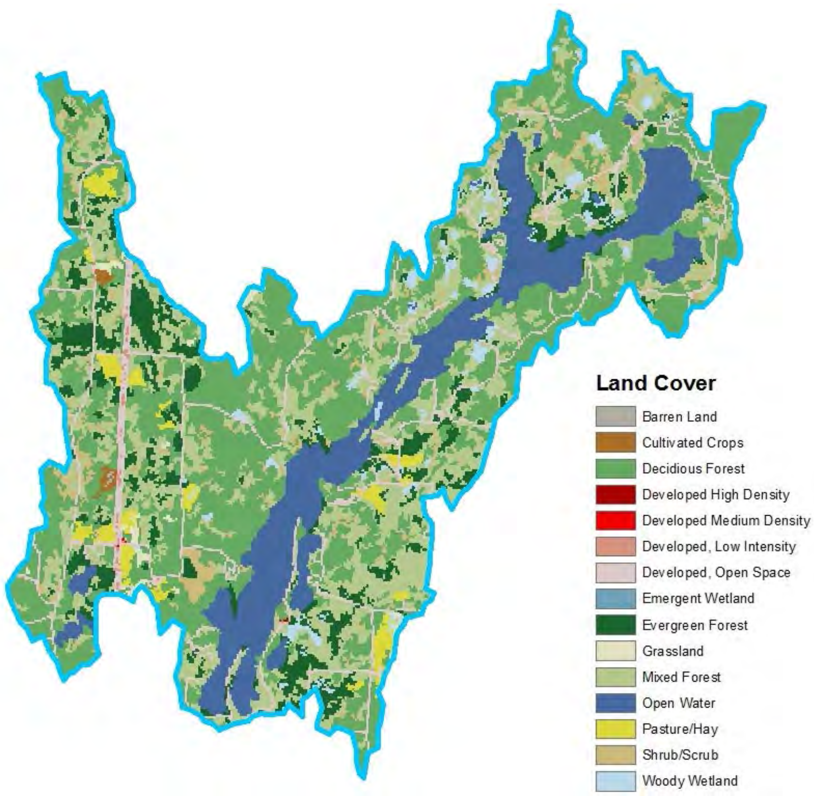


Figure 13.2 Land cover in the Lake Owen watershed in 2011.

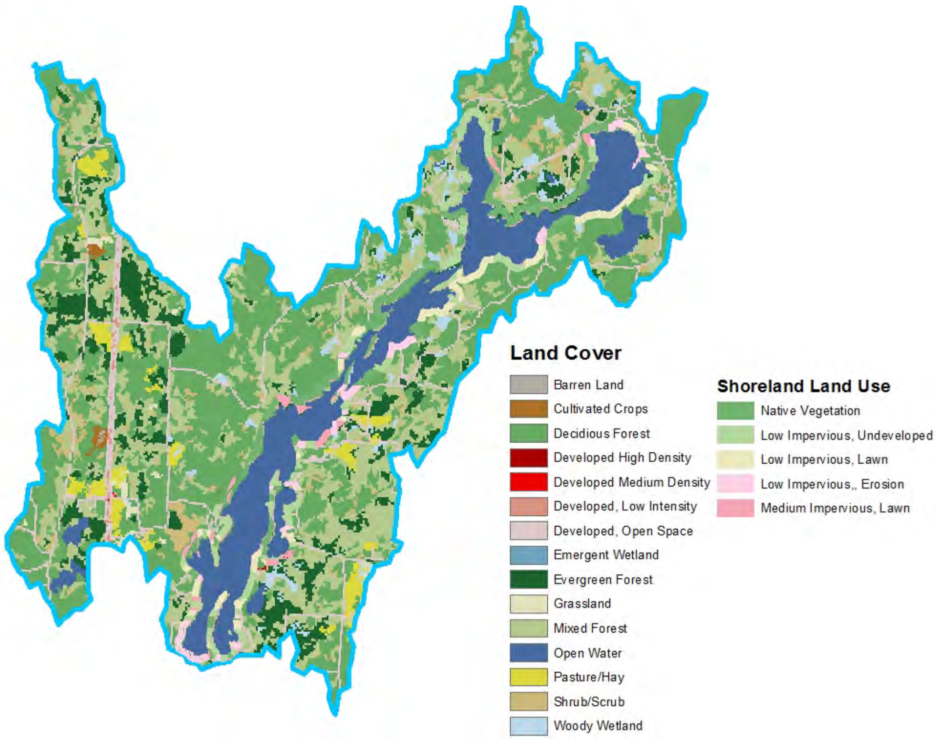


Figure 13.3 Land cover in the Lake Owen watershed including shoreland habitat assessment (2013).

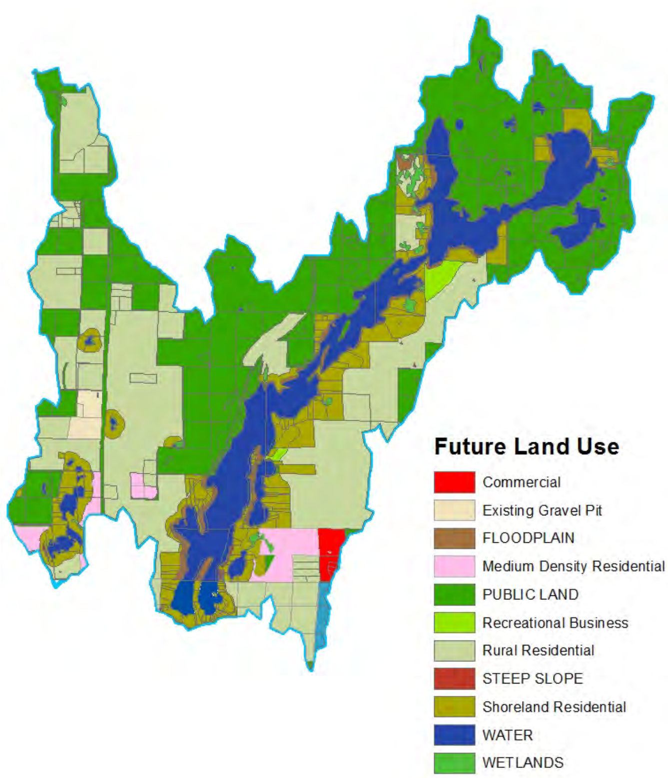


Figure 13.4 Future potential land cover in the Lake Owen watershed (2030).

14. Appendix E – Plankton Community Assessment

Introduction
This report summarizes the status of the plankton communities in Lake Owen. Given the importance of plankton in the food web of lake ecosystems (see Section 5.5), a detailed assessment of the current plankton was conducted for Lake Owen. Results from these assessments were used to characterize variations in the biological communities throughout the lake system and calibrate/validate and AQUATOX model (see Appendix G).

Methodology
All plankton samples were collected and analyzed following methods outlined by USEPA (2007). At each site, samples were collected monthly throughout the growing season in year two of the study. Each sample was collected as a spatially integrated composite from 3-5 sites around the sampling boat. Given the depth of Lake Owen, all samples were collected from a maximum tow depth of 14 meters, which sampled below the thermocline during each sampling visit. Individual tows from each site were combined on-site and preserved for transportation to the laboratory. In the laboratory, samples were condensed and preserved for long-term archival. Triplicate, one milliliter aliquots were analyzed from each sample, and taxa were identified down to the major taxonomic groups. Aliquot abundance was converted into whole-lake abundance and biomass by multiplying the aliquot taxa density by the corresponding water volume sampled throughout the vertical plankton tow. Biomass estimates were based on literature values of length-weight ratios.

Results and Discussion
Plankton communities are spatially and temporally variable throughout the Lake Owen ecosystem (Figures 14.1 and 14.2). The overall densities of phytoplankton remained consistent throughout the summer, but the relative abundance of different taxonomic groups varied. Early season samples were dominated by diatoms and green and blue green algae became increasingly abundant throughout the growing season. Conversely, overall densities of zooplankton varied throughout the summer, while the relative abundance of different taxa remained generally consistent.

Management and Monitoring Recommendations
These results highlight the relative importance of zooplankton and phytoplankton in the structure and function of the Lake Owen ecosystems. The trend where the relative density of zooplankton fluctuates throughout the summer while phytoplankton density remained relatively consistent suggests that phytoplankton productivity must increase in a compensatory manner during times of increased zooplankton abundance/grazing. This trend is consistent with the oxygen-chlorophyll concentration observed throughout the surface waters, where metalimnion oxygen concentrations are super saturated, but water clarity remains relatively high.

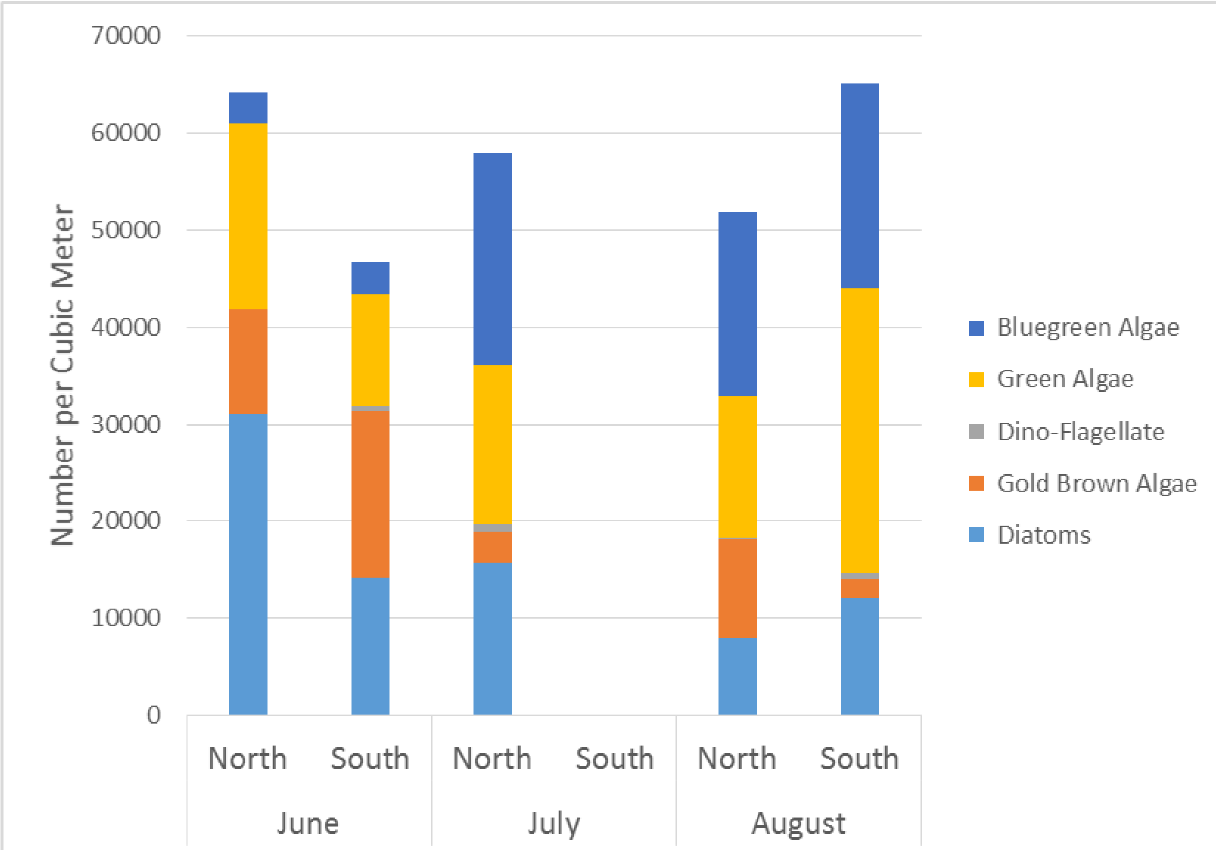


Figure 14.1. Seasonal variation in relative phytoplankton abundance in the north and south basins of Lake Owen in 2014.

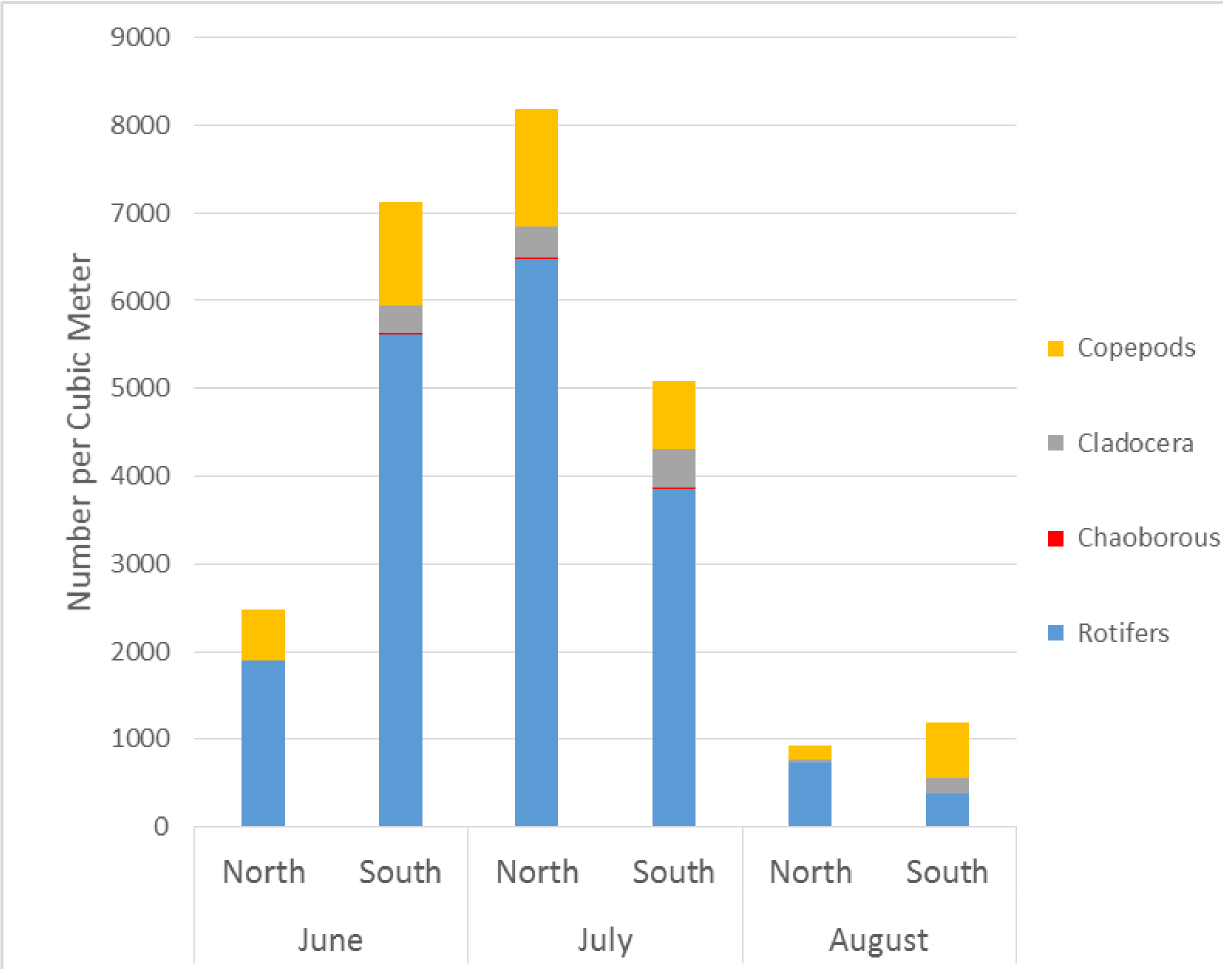


Figure 14.2. Seasonal variation in relative zooplankton abundance in the north and south basins of Lake Owen in 2014.

15. Appendix F – Aquatic Plant Assessment and Management Plan

Introduction

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

Methodology

Aquatic plant communities were sampled from 771 points in the littoral zone of Lake Owen. Surveys were conducted from July to August, 2013. All work was implemented by the SOEI at Northland College on behalf of the LOA. All field staff were trained in the annual WDNR aquatic plant management workshop and overseen by the Lake Program Coordinator at SOEI.

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).

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

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

Pathway/Vector Analysis
Five primary pathways (or vectors) exist for invasive species entry into lakes (Table 15.1). Potential pathways were identified and characterized for Lake Owen. 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
Lake Owen contains a robust aquatic plant community. Throughout this study, 38 species were identified (Table 15.3). The majority of plants were observed growing between 5 and 13 feet, up to a maximum depth of 23 feet (Figure 15.2 and Table 15.2). Average Simpson's diversity score was 0.91. The diversity and richness of species also varied among sites within the lakes, with some individual rake pulls not collecting any plants and other collecting up to eleven individual species. In general, the areas of highest species richness were in protected bays at the northern and southern end of the lake (Figures 15.3, 15.4 and 15.5).

Throughout Lake Owen, the most common species detected were Large-leaf pond weed (*Potamogeton amplifolius*), Northern water-milfoil (*Myriophylum sibiricum*), Fern pondweed (*Potamogeton robbinsii*) and Wild celery (*Vallisneria Americana*) . The species that were detected that represent the high level of floristic quality were spiny hornwory (*Ceratophyllum echinatum*), dwarf water-milfoil (*Myriophyllum tenellum*), vasey's pondweed (*Potamogeton vaseyi*) and small purple bladderwort (*Utricularia resupinata*). In general, the FQI scores for Lake Owen (average of 38) were higher than the regional average of 26. **No invasive aquatic plant species were detected throughout the lake.**

Pathway/Vector Analysis
Six potential pathways for invasive species introduction were identified and evaluated (Table 15.4). Of the six introduction pathways, four were classified as Low or Low-Moderate risk and two were identified as Moderate risk. The two moderate risk pathways identified were watercraft access through the Forest Service boat launch at Twin Lakes Campground and the private launch at the Otter Bay Resort.

Discussion and Management Recommendations

Aquatic plant management efforts in Lake Owen should build on the ongoing work of the LOA and its collaborators to continue to address two primary goals:

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

Existing Management Efforts
Existing management efforts are primarily implemented through volunteer the efforts of the LOA. The primary work of the LOA is to increase awareness of invasive species and their prevention. To this end, the LOA hosts an annual meeting and distributes recurring newsletters that highlight ongoing work and needs related to invasive species prevention and management. The LOA contracts with local partners to implement watercraft inspections at the Forest Service launch from Memorial Day to Labor Day from 8 am to 4 pm five days per week. Additionally, the LOA contracts and/or collaborates with local snorkelers, Northland College and the WDNR to implement lake wide and site-specific monitoring efforts.

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 Lake Owen, continuing efforts that build on the LOA's ongoing work to minimize the potential for the introduction of invasive species are critical. To this end, three approaches are recommended: 1) expand launch inspection effort; 2) expand educational efforts to include a broader range of potential sources; and 3) develop and implement an early detection, rapid response plan.

Launch Inspections

Current launch inspection efforts are primarily focused on the main public boat launch operated by the US Forest Service on the northwest bay of the lake. However, boats launched at the Twin Lakes campground on the northeaster shore, the Otter Bay Resort, Lake Owen Resort and a number of private launches are monitored less intensively. Expanded launch inspections may be potentially funded through grants from the WDNR, Clean Boats, Clean Waters program http://dnr.wi.gov/lakes/cbcw/. Expanded boat inspection effort are also recommended surrounding any fishing tournaments or events that increase traffic from boats that may have been recently moored in other regional water bodies.

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; and 4) beach managers to minimize wildlife attraction to waterfront areas (currently not a high risk activity in Lake Owen).

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. Summary of Results from Aquatic Plant Survey on Lake Owen

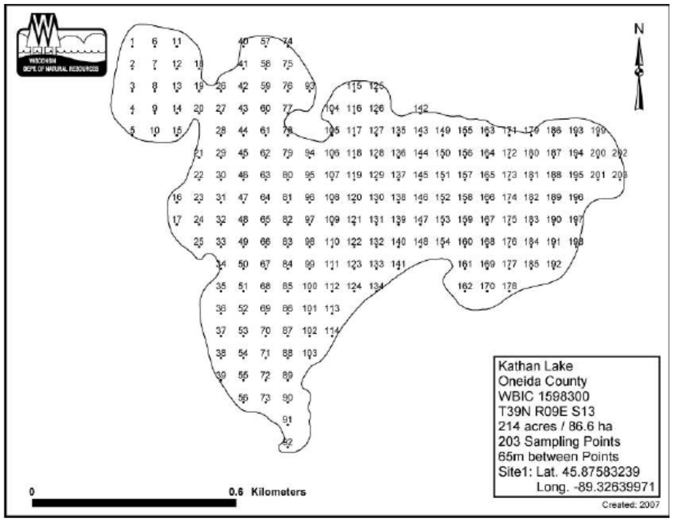
SUMMARY STATS	Results
Total number of sites visited	771
Total number of sites with vegetation	393
Total number of sites shallower than maximum depth of plants	601
Frequency of occurrence at sites shallower than maximum depth of plants	65.39
Simpson Diversity Index	0.91
Maximum depth of plants (ft)**	22.90
Number of sites sampled using rake on Rope (R)	122
Number of sites sampled using rake on Pole (P)	481
Average number of all species per site (shallower than max depth)	1.65
Average number of all species per site (veg. sites only)	2.52
Average number of native species per site (shallower than max depth)	1.65
Average number of native species per site (veg. sites only)	2.52
Species Richness	38
Species Richness (including visuals)	38

Table 15.3. Relative occurrence of different aquatic plant species throughout Lake Owen.

Species	Statistics					
	Frequency of occurrence within vegetated areas (%)	Frequency of occurrence at sites shallower than maximum depth of plants	Relative Frequency (%)	Relative Frequency (squared)	Number of sites where species found	Average Rake Fullness
Brasenia schreberi, Watershield	0.25	0.17	0.10	0.00	1.00	1.00
Ceratophyllum echinatum, Spiny hornwort	0.25	0.17	0.10	0.00	1.00	1.00
Juncus pelocarpus f. submersus, Brown-fruited rush	0.25	0.17	0.10	0.00	1.00	1.00
Najas gracillima, Northern naiad	0.25	0.17	0.10	0.00	1.00	1.00
Nitella sp., Nitella	0.25	0.17	0.10	0.00	1.00	1.00
Potamogeton vaseyi, Vasey's pondweed	0.25	0.17	0.10	0.00	1.00	1.00
Ranunculus flabellaris, Yellow water crowfoot	0.25	0.17	0.10	0.00	1.00	1.00
Sagittaria latifolia, Common arrowhead	0.25	0.17	0.10	0.00	1.00	1.00
Ranunculus spp.	0.25	0.17	0.10	0.00	1.00	1.00
sp4	0.25	0.17	0.10	0.00	1.00	1.00
Elodea nuttallii, Slender waterweed	0.51	0.33	0.20	0.00	2.00	1.00
Isoetes sp., Quillwort	0.51	0.33	0.20	0.00	2.00	1.00
Myriophyllum tenellum, Dwarf water-milfoil	0.51	0.33	0.20	0.00	2.00	1.00
Sparganium sp., Bur-reed	0.51	0.33	0.20	0.00	2.00	1.00
Utricularia resupinata, Small purple bladderwort	0.51	0.33	0.20	0.00	2.00	1.00
Potamogeton sp.	0.51	0.33	0.20	0.00	2.00	1.00
Potamogeton friesii, Fries' pondweed	0.76	0.50	0.30	0.00	3.00	1.00
Potamogeton strictifolius, Stiff pondweed	0.76	0.50	0.30	0.00	3.00	1.00
Potamogeton natans, Floating-leaf pondweed	1.53	1.00	0.60	0.00	6.00	1.17
Stuckenia filiformis, Fine-leaved pondweed	1.78	1.16	0.71	0.00	7.00	1.57
Nymphaea odorata	1.78	1.16	0.71	0.00	7.00	1.00
Potamogeton pusillus, Small pondweed	2.29	1.50	0.91	0.00	9.00	1.11
Potamogeton foliosus, Leafy pondweed	2.54	1.66	1.01	0.00	10.00	1.00
Potamogeton illinoensis, Illinois pondweed	3.82	2.50	1.51	0.00	15.00	1.07
Potamogeton richardsonii, Clasping-leaf pondweed	5.09	3.33	2.02	0.00	20.00	1.20
Sagittaria sp., Arrowhead	5.34	3.49	2.12	0.00	21.00	1.19
Bidens beckii (formerly Megalodonta), Water marigold	5.85	3.83	2.32	0.00	23.00	1.00
Eleocharis acicularis, Needle spikerush	5.85	3.83	2.32	0.00	23.00	1.04
Potamogeton zosteriformis, Flat-stem pondweed	10.18	6.66	4.03	0.00	40.00	1.13
Chara sp., Muskgrasses	10.69	6.99	4.23	0.00	42.00	1.07
Najas flexilis, Slender naiad	10.94	7.15	4.33	0.00	43.00	1.02
Ceratophyllum demersum, Coontail	12.47	8.15	4.94	0.00	49.00	1.33
Potamogeton gramineus, Variable pondweed	13.74	8.99	5.44	0.00	54.00	1.00
Potamogeton amplifolius, Large-leaf pondweed	16.03	10.48	6.35	0.00	63.00	1.13
Myriophyllum sibiricum, Northern water-milfoil	25.95	16.97	10.28	0.01	102.00	1.13
Potamogeton robbinsii, Fern pondweed	31.55	20.63	12.50	0.02	124.00	1.34
Vallisneria americana, Wild celery	37.40	24.46	14.82	0.02	147.00	1.15
Elodea canadensis, Common waterweed	40.46	26.46	16.03	0.03	159.00	1.15
Total vegetation				**0.09**		**0.96**

Table 15.4. Risk of introduction from different invasive species pathways

Pathway	Description	Risk of Introduction
Forest Service Landing - Town of Drummond	Moderate use access, primarily from local users	Low to Moderate; Moderate usage by boaters who generally frequent local lakes, few of which have existing invasive species
Forest Service Landing - Twin Lakes	Moderate use access, primarily from regional and extended users	Moderate; Moderate usage by boaters who generally frequent regional lakes, many of which have existing invasive species
Otter Bay Resort Landing	Moderate use access, primarily from regional and extended users	Moderate; Moderate usage by boaters who generally frequent regional lakes, many of which have existing invasive species
Individual Boat Launches	Access primarily from adjacent landowner	Low; Relatively few individial launches surrounding the lake
Connected/adjacent Waterbodies	Lake not directly to adjacent waterbodies	Low; no directly connected waterbodies and adjacent waterbodies currently do not contain invasive species
Stormwater Runoff	Primarily from urban areas along the southern shoreline	Low; Runoff from a relatively limited urban area
Wildlife	Migratory and local wildlife	Low; Limited use concentration beyond background levels
Riparian Introduction	Potentially from ornamental gardens in shoreline properties	Low; Relatively few ornamental gardens surrounding the lake



a)

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

b)

c)

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

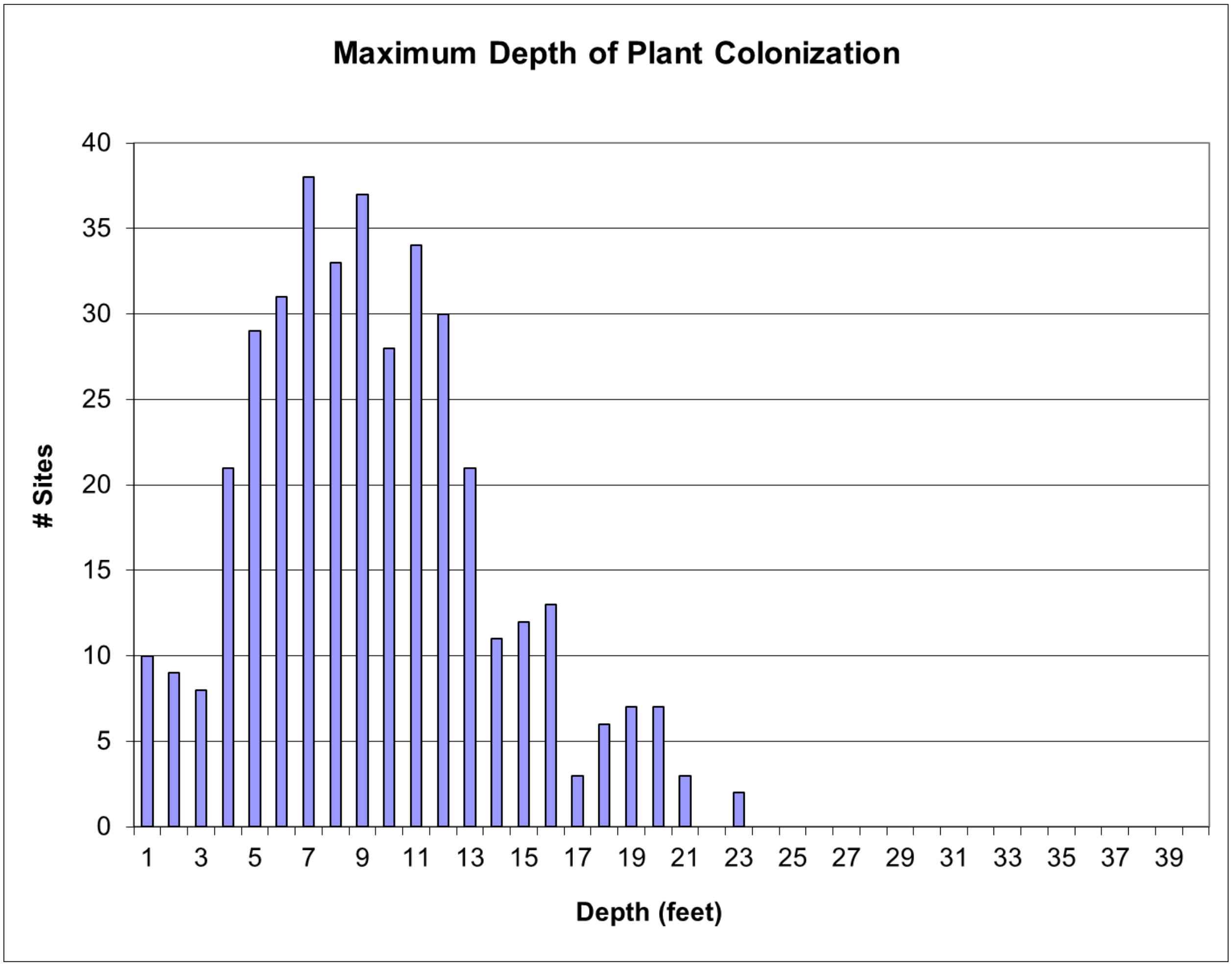


Figure 15.2 Frequency of plant growth at different depths throughout Lake Owen.

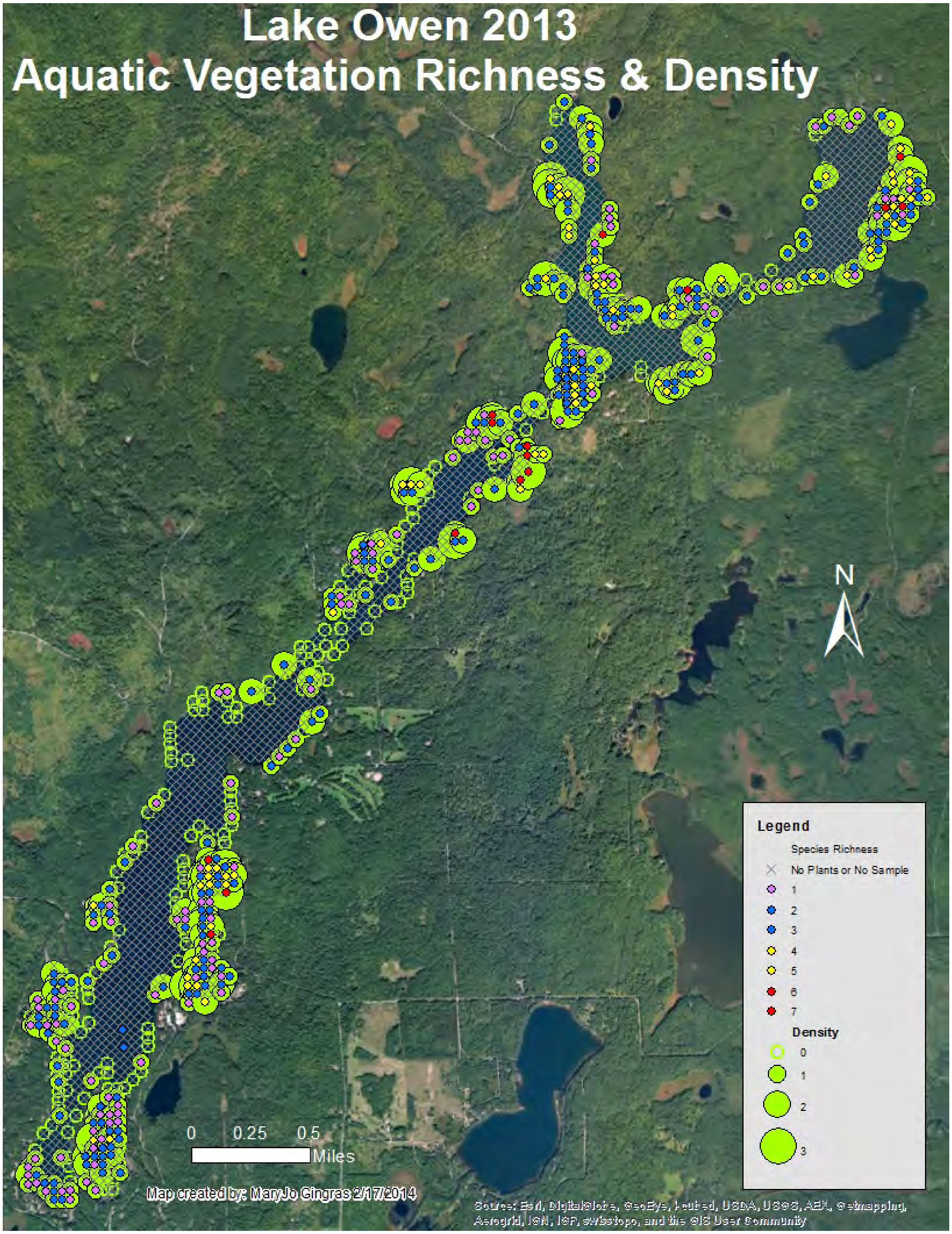


Figure 15.3 Species richness and density of aquatic plants throughout Lake Owen.

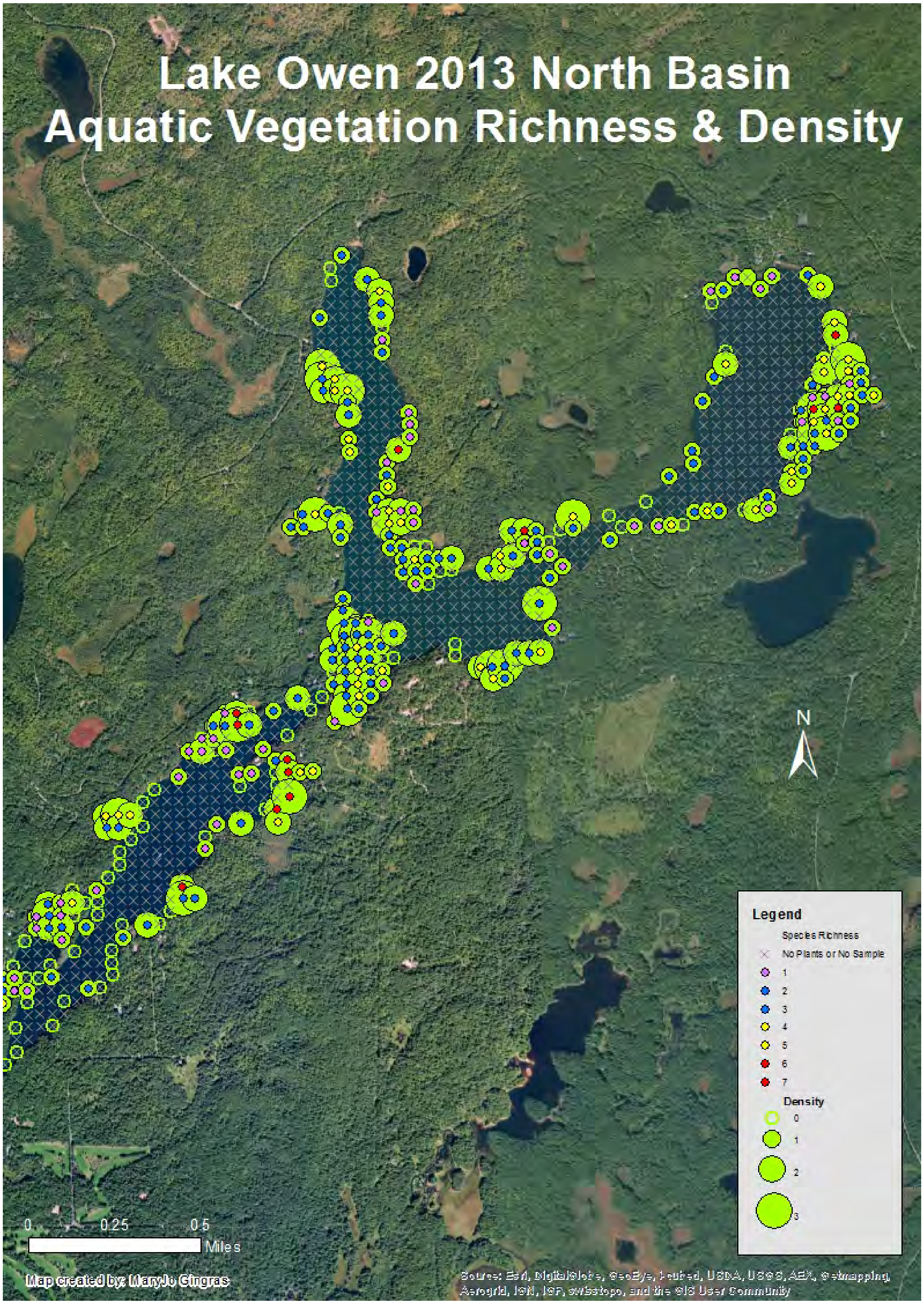


Figure 15.4 Species richness and density of aquatic plants throughout the north basin of Lake Owen.

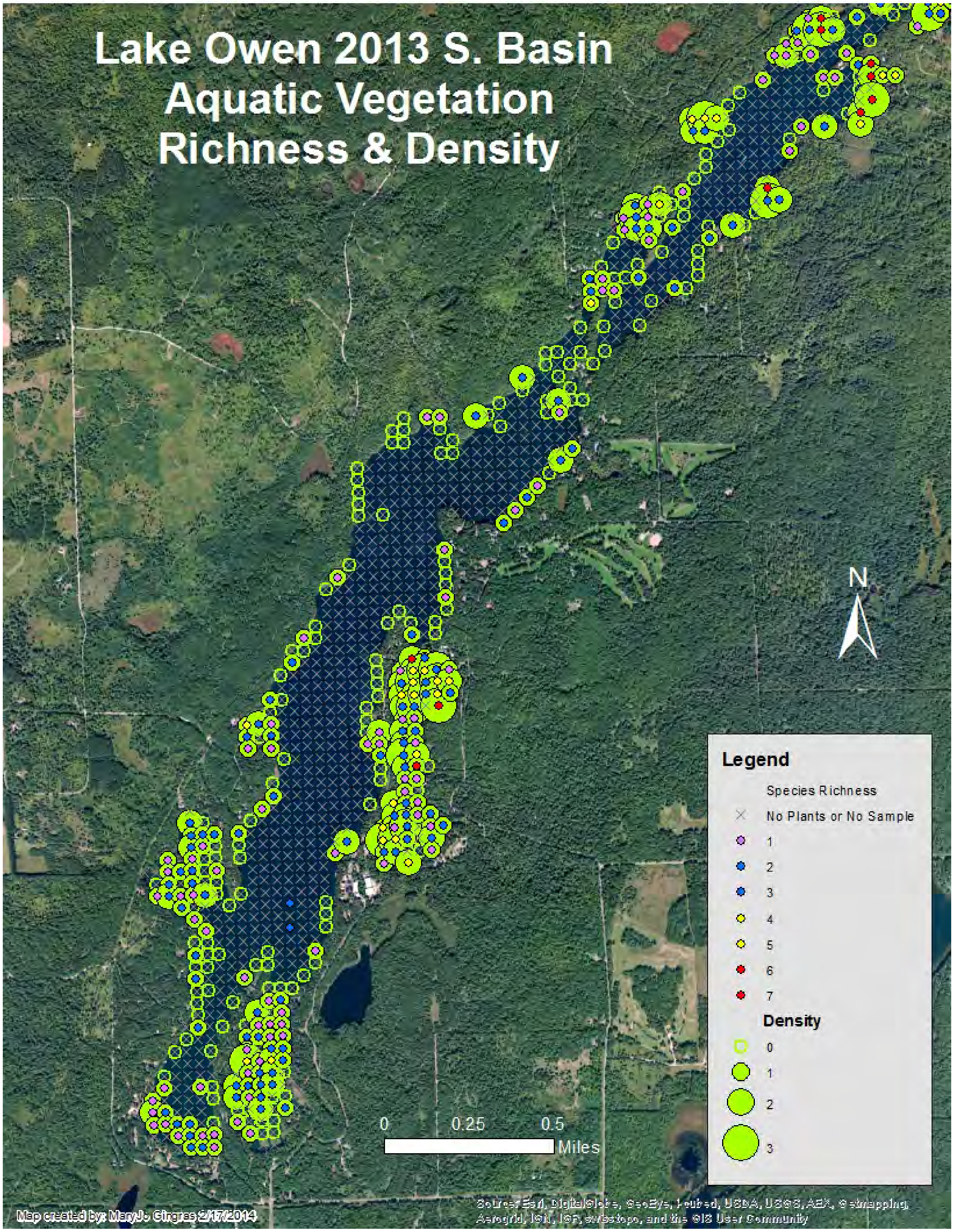


Figure 15.5 Species richness and density of aquatic plants throughout the south basin of Lake Owen.

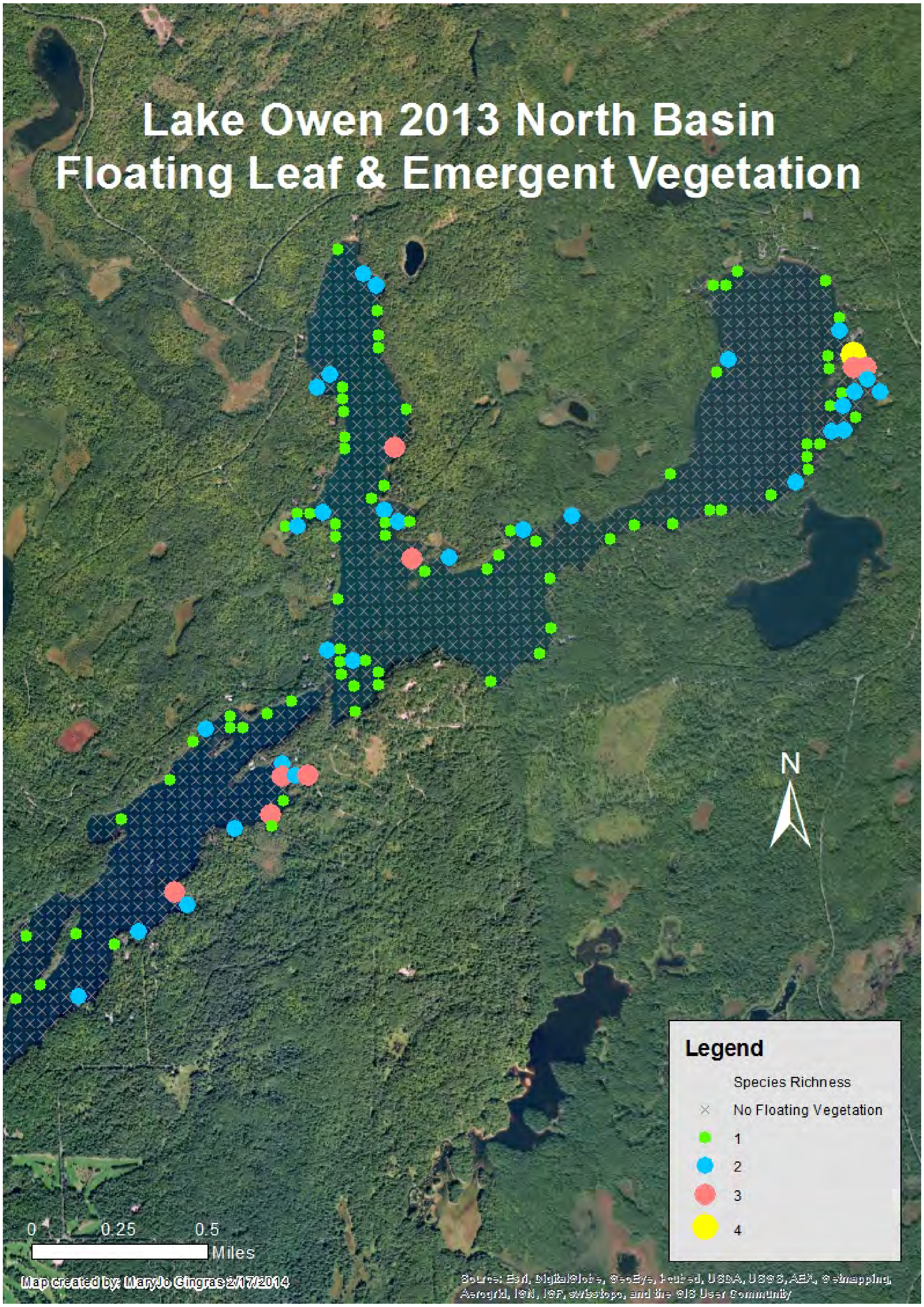


Figure 15.6 Location of floating and emergent leaf aquatic plant communities in the north basin of Lake Owen.

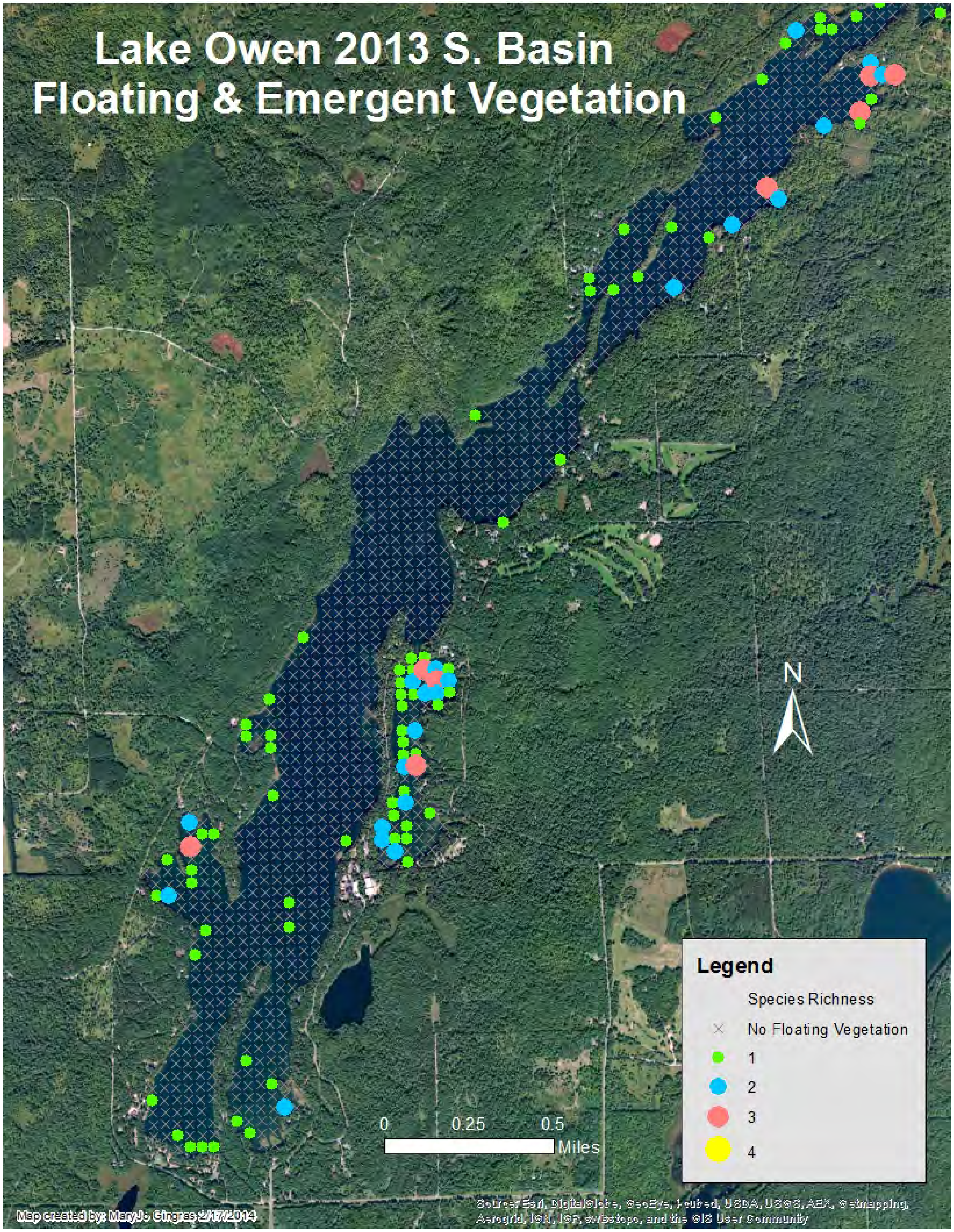


Figure 15.7 Location of floating and emergent leaf aquatic plant communities in the south basin of Lake Owen.

16. Appendix G – Ecosystem Modeling and Scenario Forecasting

Introduction

To understand the relative role of the different components of the Lake Owen 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 AQUATOX simulation program.

> AQUATOX is a PC-based ecosystem model that predicts the fate of nutrients, sediments, and organic chemicals in water bodies, as well as their direct and indirect effects on the resident organisms. AQUATOX simulates the transfer of biomass and chemicals from one compartment of the ecosystem to another. It does this by simultaneously computing important chemical and biological processes over time. AQUATOX simulates multiple environmental stressors (including nutrients, organic loadings, sediments, toxic chemicals, and temperature) and their effects on the algal, macrophyte, invertebrate, and fish communities. AQUATOX can help identify and understand the cause and effect relationships between chemical water quality, the physical environment, and aquatic life. It can represent a variety of aquatic ecosystems, including vertically stratified lakes, reservoirs and ponds, rivers and streams, and estuaries (EPA 2009, http://www.epa.gov/waterscience/models/aquatox/).

Methods

Lake Owen was represented as a single lake site with linked epilimnion and hypolimnion layers. The Lake Owen model was based on the oligotrophic lake model template for Lake George, NY. The model was constructed and initialized using the physical, chemical and biological data described in Appendices B, D and E and the fishery data described by Toshner (2009). In the initial model structure, all model components were consistent with the Lake George template, except for the modification of the food web (which was based on Toshner 2009 and the concurrent plankton assessment). Nutrient inputs to the lake were based on the nutrient budget describe in Appendix B. The lake was allowed to dynamically stratify based on wind speed and direction from the Drummond, WI weather station and discharged based on bathymetry and inflow volumes. Given the complexity and unique internal nutrient dynamics in the lake, a simplified representation of the lake ecosystem was ultimately adopted.

Model calibration followed an interactive approach using 2014 data and validated against measurements from the 2013 field season. Based on these initial conditions, model runs were conducted for one year periods from January 1st to December 31st. Initial model validation was conducted for physical-chemical parameters in the absence of nutrient and biological constituents (Figure 16.1). Results from this validation suggest that physical-chemical process are well represented for temperature and dissolved oxygen and that epilimnion oxygen concentrations are primarily governed by atmospheric diffusion and water temperature. External nutrient loads were added to the model to validate TP, Chl-a and Secchi depth responses. Predicted TP and Secchi depth responses represented average conditions (but not seasonal trends) in observed data sets, suggesting that food web processes are important drivers of water quality conditions in Lake Owen (Figure 16.2). Hypolimnion phosphorus concentrations were disproportionately low, suggesting that there is a significant phosphorus source to Lake Owen, not currently represented in the model.

To simulate trophic dynamics, a simple food web of primary producers (algae), primary consumers (herbivorous zooplankton), secondary consumers (predatory zooplankton) was constructed. Water quality conditions in this more complex system were simulated using the same physical-chemical drivers as in the initial validation run. Temperature dynamics in this model remained well aligned with observed values, but dissolved oxygen conditions diverged from observed values (Figure 16.3), suggesting that phytoplankton productivity is artificially increasing epilimnion DO levels in the model. Model fit to trends in epilimnion TP and Chl-a increased in the complex model, while Secchi depth fit described average conditions, but poorly described seasonal trends (Figure 16.4). Epilimnion SRP was poorly fit under all model scenarios. This lack of temporal fit for Secchi depth and poor fit for SPR suggest that significant particle scavenging and/or primary production is occurring in the epilimnion (which may be related to the high levels of metalimnion productivity observed in depth profiled analyses; Appendix B).

To simulate, hypolimnion phosphorus concentrations, a continuous influx of phosphorus at a concentration 30 mg/L was added as a point source to the hypolimnion. This additional source of phosphorus resulted in an equivalent hypolimnion TP concentration, but did not effectively describe the relative TP:SRP ratios (Figure 16.5). Additionally, these elevated hypolimnion TP levels caused the epilimnion TP concentrations to greatly increase—suggesting that some mechanisms exists to prevent TP diffusion from the hypolimnion to the epilimnion. One potential mechanism that may constrain this diffusion is epilimnetic production and food web processes that may convert phosphorus to biomass and settle it back to the hypolimnion over time.

To simulate the potential containment of phosphorus in the hypolimnion, rates of epilimnion productivity were increased. This increase in phytoplankton and zooplankton productivity in the epilimnion reduced TP concentrations but artificially increased dissolved oxygen concentrations and resulted in a significant reduction in water clarity (Figure 16.6). These results suggest that increased productivity may constrain TP to the hypolimnion, but that productivity is concentrated at the metalimnion, which corresponds to the oxygen maxima observed in the seasonal depth profiles (see Appendix B).

To evaluate the potential impact of different nutrient loads on water quality conditions, three simulations were run based on historical, current and potential future land uses. All future simulations were run using the simple food web model, and thus likely underrepresent the influence of the hypolimnion on the Lake Owen ecosystem. All watershed and septic phosphorus loads are described in Appendix C.

Results and Discussion

Changes in water quality conditions that are likely to result from future land use change and septic system density, will likely be relatively small. A transition from historical to current land covers has likely resulted in an approximate 5 percent increase in TP concentration and a 2 percent 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 of 3 percent and decrease in Secchi depth of 1 percent.

Internal nutrient dynamics in Lake Owen are highly complex and likely influence to a large degree by the sustained stratification and food web dynamics throughout the lake. Hypolimnion TP concentrations cannot be explained by annual runoff processes, which is unexpected because hypolimnion TP concentration are dominated by the particulate phase—suggesting that sediment release of phosphorus as SRP is a relatively small component of the phosphorus budget.

Management and Monitoring Recommendations

These results suggest that future increases in runoff and nutrient loads to Lake Owen may have a relatively small impact on water quality conditions. However, given the uncertainty surrounding future land use scenarios and the potential impacts of climate change on runoff processes, it is important to ensure that best management practices are consistently implemented as part of future land use development and that they are appropriately scaled to existing hydrologic regimes. Additionally, because these simulations represent annual growing season averages, minimum and maximum values may be divergent (i.e., periods of reduced/increased water clarity could occur in any given year).

These model simulation also suggest that the elevated hypolimnion TP concentrations have the potential to have significant impacts on surface water quality conditions, depending on the structure of the food web. As such, it is important to understand this food web-water quality relationship and how it may respond to future climate and use regimes.

Uncertainty and Data Interpretation

These model simulations represent the best-possible mechanistic description of water quality conditions in Lake Owen given the available data. However, the mechanistic understanding of the Lake Owen ecosystem is incomplete, and thus should be used for general planning purposes only. Given the uncertainty surrounding future land use and climate scenarios and incomplete understanding of the Lake Owen ecosystem, future management should include additional data collection to reduce uncertainty.

Table 16.1. Water quality changes potentially resulting from future land use/nutrient loading scenarios

Land Use Condition	Total Phosphorus Load (Pounds/year)	Growing Season Averages		
		TP Conc.	Secchi (m)	TSI
Historical (~1856)	734	10.77	4.771	38.42
Current (2013)	1145	11.32	4.703	39.14
Future Potential Septic Load (2030)	1224	11.46	4.701	39.32
Future Land Use and Septic Load (2030)	1303	11.6	4.699	39.49

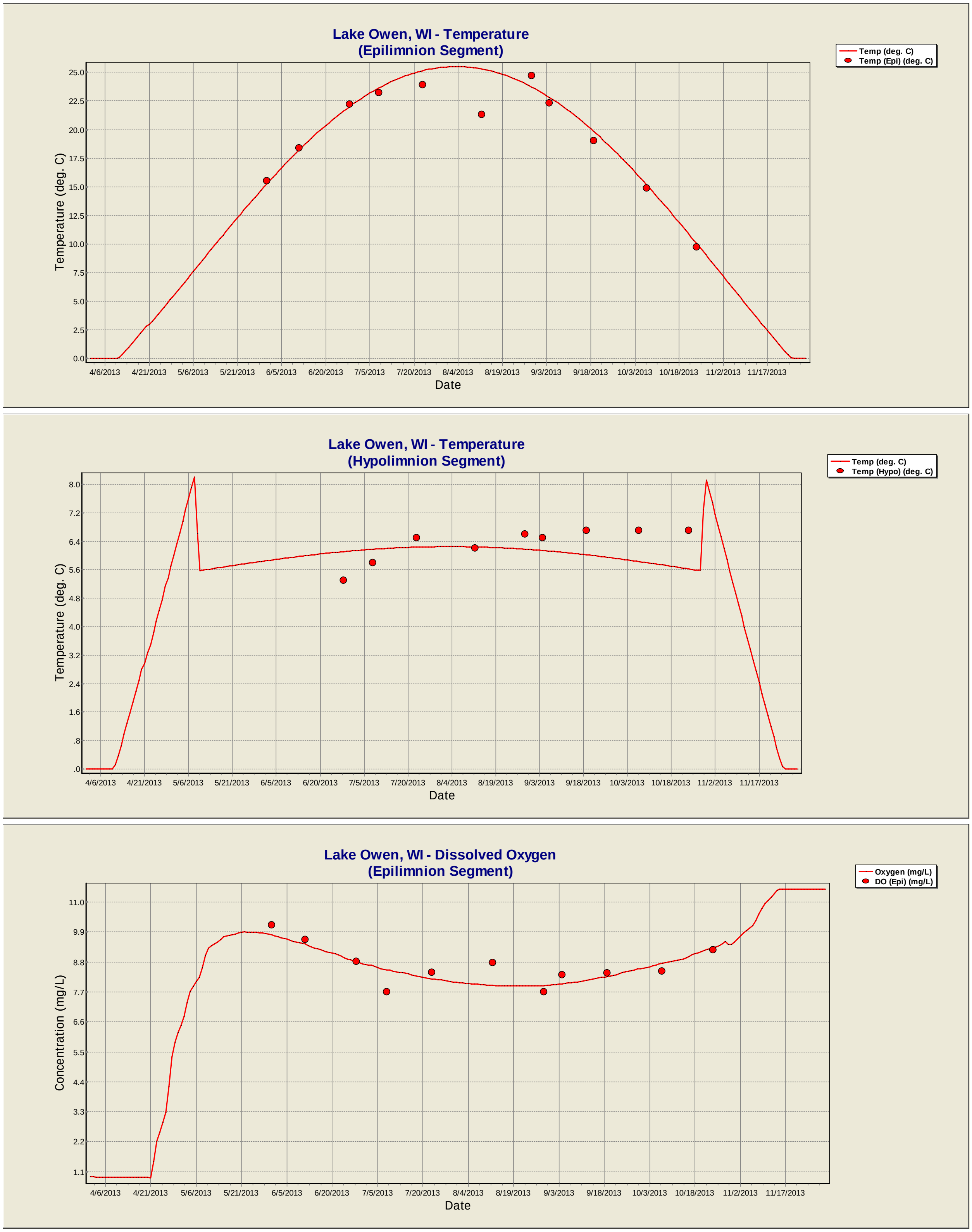


Figure 16.1 Initial calibration of physical-chemical processes in the AQUATOX model.

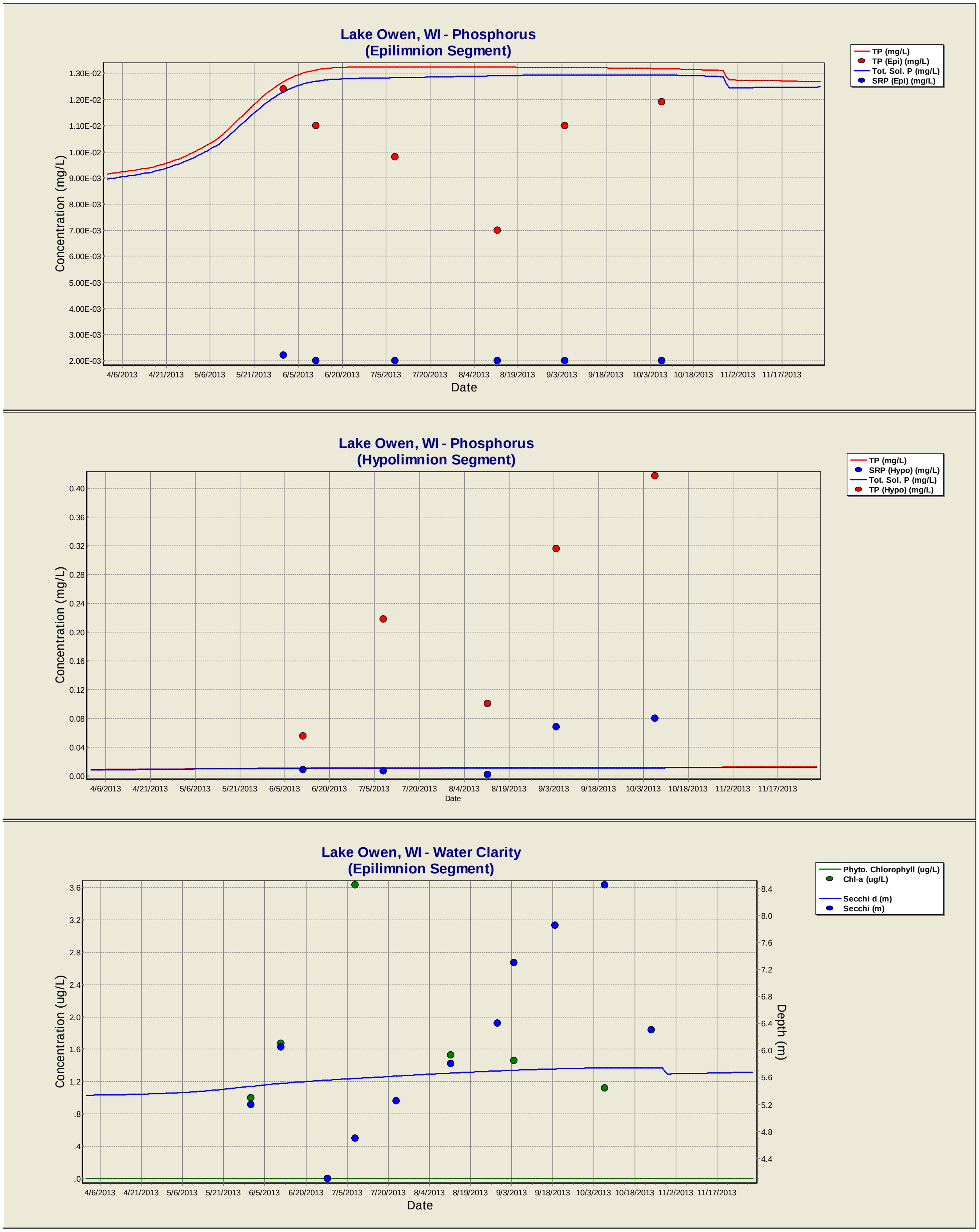


Figure 16.2 Initial calibration of water quality parameters in the AQUATOX model.

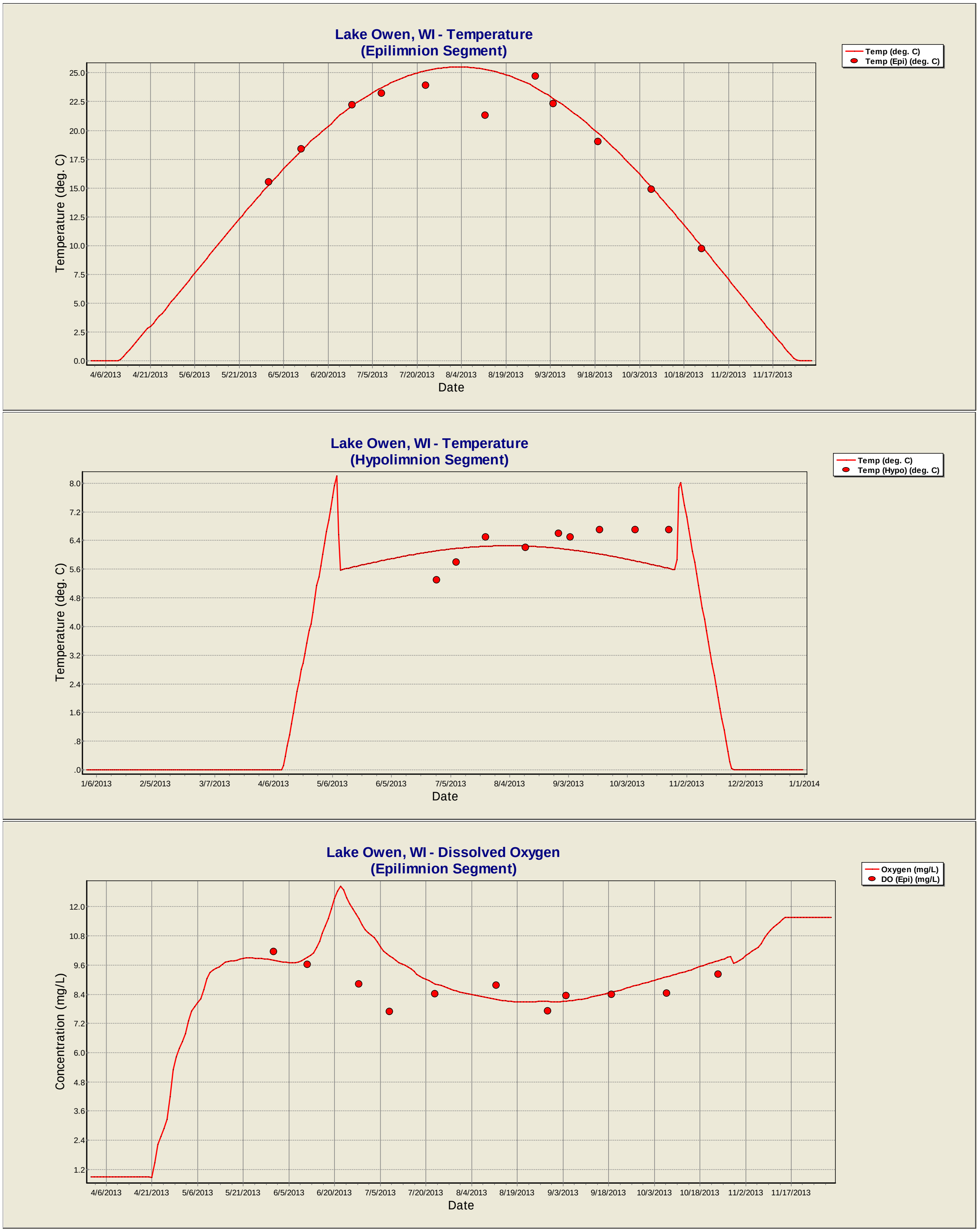


Figure 16.3 Secondary calibration of water quality parameters in the AQUATOX model.

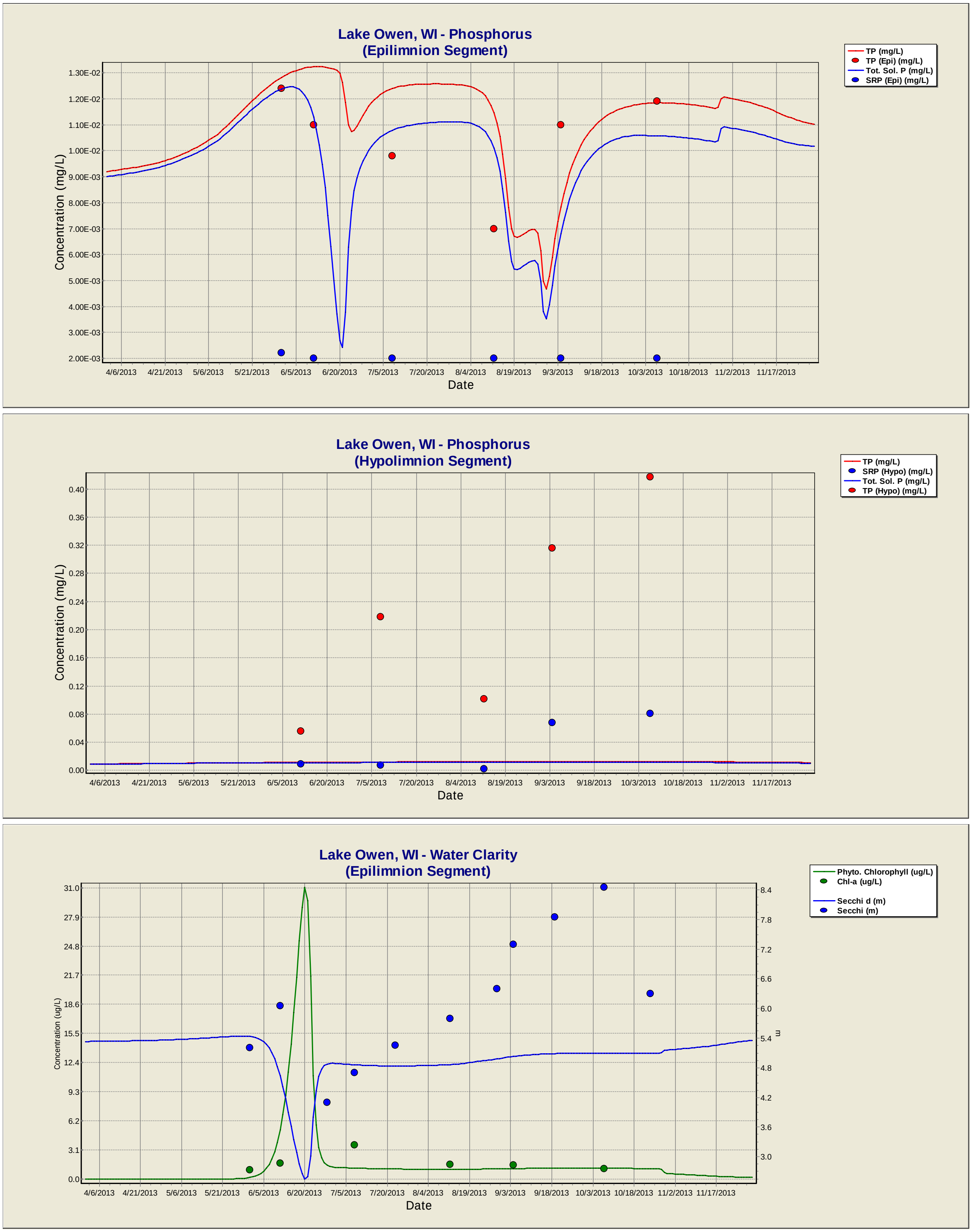
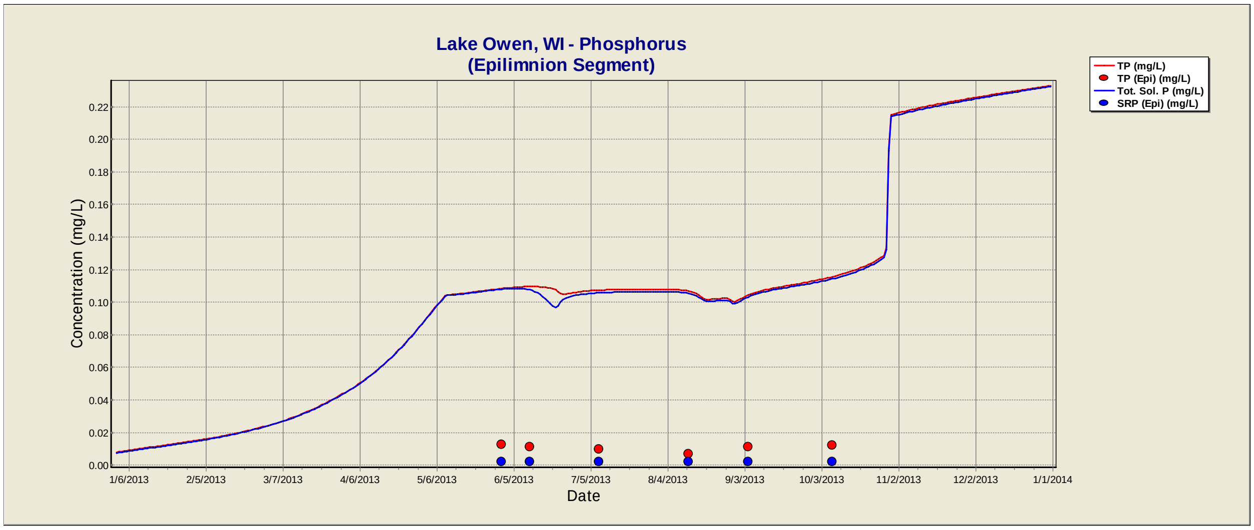


Figure 16.4 Secondary calibration of water quality parameters in the AQUATOX model.



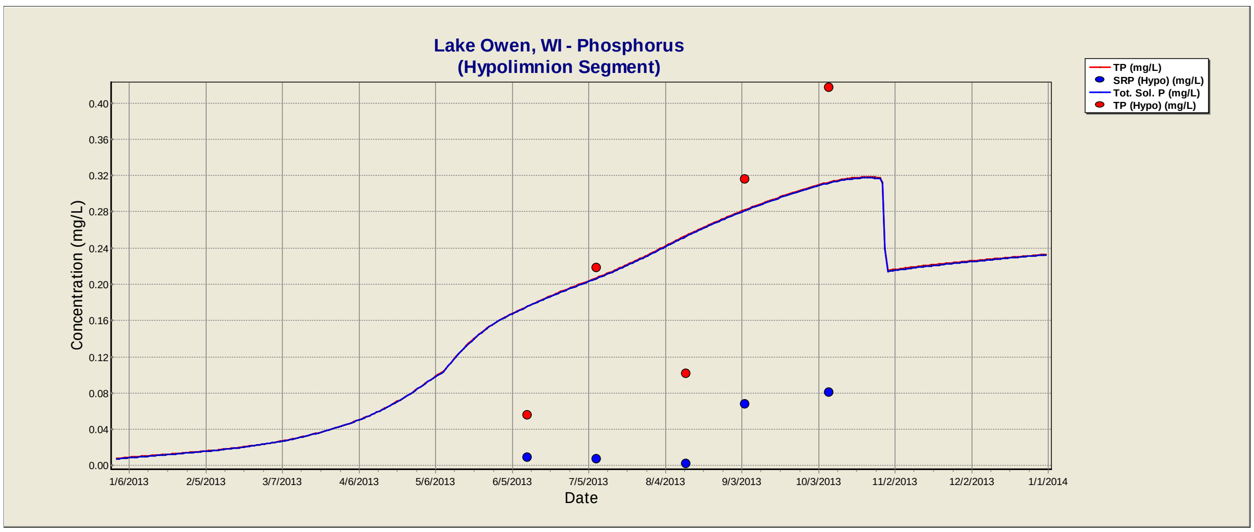


Figure 16.5 Simulation with elevated inputs of hypolimnion TP

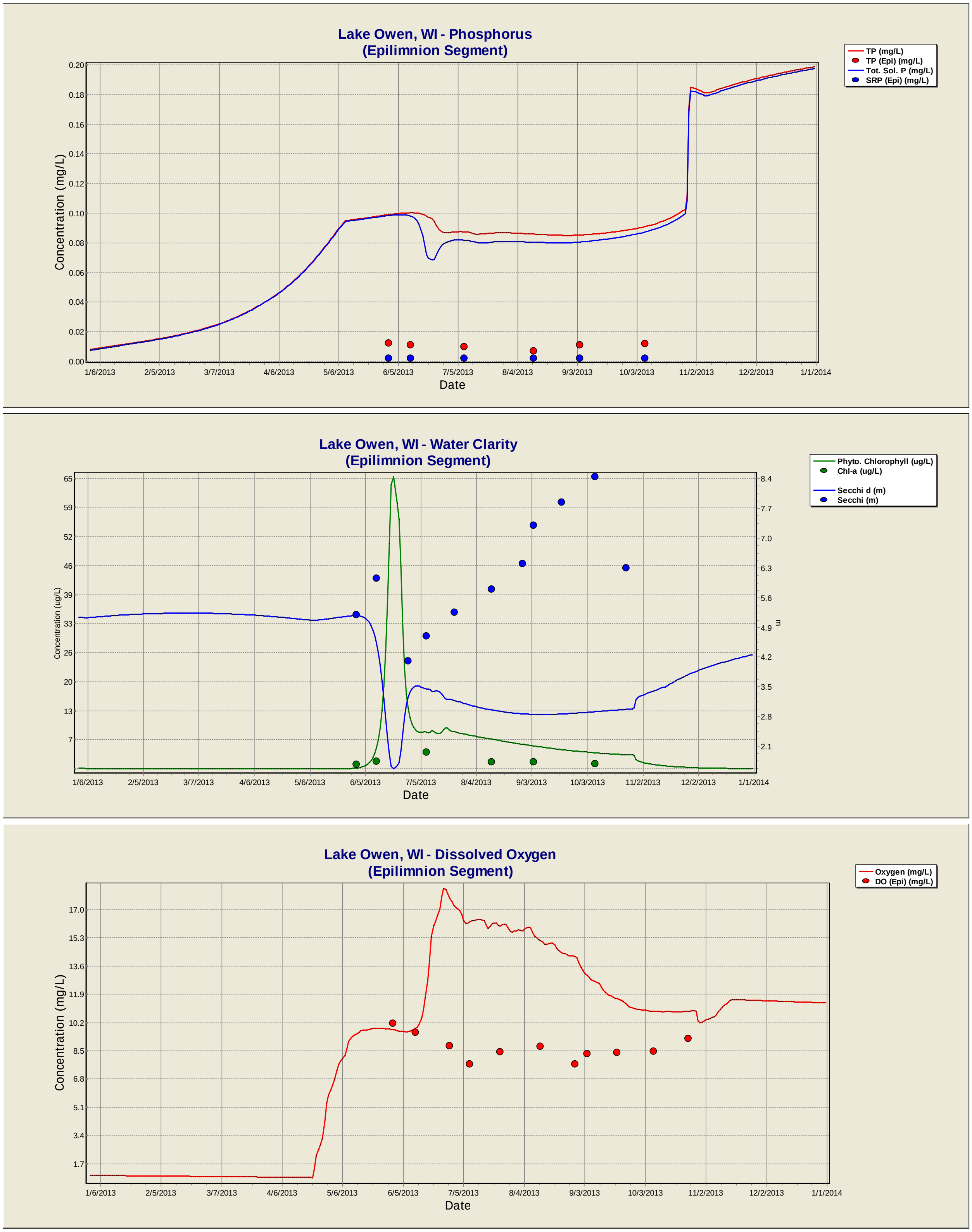


Figure 16.6 Simulation with elevated inputs of hypolimnion TP and increased productivity