DRAFT Church Pine, Round (Wind), and Big Lake Management Plan

Polk County, Wisconsin
June 2013

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Church Pine, Round, and Big Lake Protection and Rehabilitation District

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Table of Contents

Purpose of the Study

Lakes are a product of the landscape they are situated in and of the actions that take place on the land which surrounds them. Due to this fact, lakes situated within feet of others can differ profoundly in the uses they support.

Factors such as lake size, lake depth, water sources to a lake, and geology all cause inherent differences in lake quality.

Additionally, humans, by changing the landscape, can bring about changes in a lake. This arises because rain and melting snow may eventually end up in lakes and streams through surface runoff or groundwater infiltration. Rain and melting snow entering a lake is not inherently problematic. However, water has the ability to carry nutrients, bacteria, sediments, and chemicals into a lake. These inputs can impact aquatic organisms such as insects, fish, and wildlife and—especially in the case of the nutrient phosphorus—fuel problematic algae blooms.

The landscape can be divided into watersheds and subwatersheds, which define the land area that drains into a particular lake, stream, or river. Watersheds that preserve native vegetation and minimize impervious surfaces (cement, concrete, and other materials that water can't permeate) are less likely to cause negative impacts on lakes, rivers, and streams.

Lake studies often examine the underlying factors that impact a lake's health, such as lake size, depth, water sources, and the land use in a lake's watershed. Many forms of data can be collected and analyzed to gauge a lake's health including: physical data (oxygen, temperature, etc.), chemical data (including nutrients such a phosphorus and nitrogen), biological data (algae and zooplankton), and land use within a lake's watershed.

Lakes can be classified based on their nutrient status and clarity levels. Three categories commonly used are: oligotrophic, mesotrophic, and eutrophic.

- ✓ Oligotrophic lakes are generally clear, deep, and free of weeds and large algae blooms.

- ✓ Mesotrophic lakes lie between oligotrophic and eutrophic lakes. They usually have good fisheries and occasional algae blooms.

- ✓ Eutrophic lakes are generally high in nutrients and support a large number of plant and animal populations. They are usually very productive and subject to frequent algae blooms. Lakes can also be hypereutrophic. Hypereutrophic lakes are characterized by dense algae and plant communities and can experience heavy algal blooms throughout the summer.

Lake studies often identify strengths, opportunities, challenges, and threats to a lake's health. These studies can identify practices already being implemented by watershed residents to improve water quality and areas providing benefits to a lake's ecosystem. Additionally, these studies often quantify practices or areas on the landscape that have the potential to negatively impact the health of a lake.

The end product of a lake study is a Lake Management Plan which identifies goals, objectives, and action items to either maintain or improve the health of a lake. These goals should be realistic based on inherent lake characteristics (lake size, depth, etc.) and should align with watershed residents' goals.

Included in this document are the data and conclusions drawn from a 2012 lake study completed by the Polk County Land and Water Resources Department. This study collected and analyzed the following data to aid in the creation of a Lake Management Plan for Church Pine, Round, and Big Lake:

- ✓ Lake resident opinions
- ✓ Lake level and precipitation data
- ✓ In lake physical and chemical data
- ✓ Algae and zooplankton data
- ✓ Shoreline land use results
- ✓ Tributary monitoring results
- ✓ Watershed and subwatershed land use

This study also included a number of educational opportunities for members of the Church Pine, Round, and Big Lake District including:

- ✓ Pontoon classrooms
- ✓ A shoreline restoration workshop
- ✓ A series of five meetings to review the data collected and develop a Lake Management Plan

Whenever possible, past lake studies completed on Church Pine, Round, and Big Lake are used as a baseline comparison for this study. A summary of previous lake studies can be found on page 21.

Executive Summary

1. Church Pine Lake is a 107 acre drainage lake with a mean depth of 23 feet; Round Lake is a 38 acre drainage lake with a maximum depth of 22 feet; and Big Lake is a 259 acre seepage lake with a mean depth of 24 feet.

2. Water flows from Church Pine, to Round, to Big Lake. Big Lake receives water from North Creek and a culvert on County Road K. North Creek is classified as a trout water. The outlet, Forest Creek, is located on Big Lake and is regulated by a dam.

3. The lakes respond greatly to precipitation, with levels dropping nearly a foot during 2012 drought conditions.

4. One hundred sixteen lake residents completed a survey regarding the lakes (52% response rate). The highest concerns for the lakes were property values and/or taxes, invasive species, pollution, and aquatic plants. Data collection, monitoring for new aquatic invasive species, information and education opportunities, and cost-sharing shoreline buffers and rain gardens are practices respondents feel should be continued.

5. Phosphorus levels (the primary nutrient that fuels algae blooms) were lowest on Church Pine Lake, followed by Round Lake, and Big Lake.

6. Church Pine Lake had the greatest water clarity, followed by Round Lake, and Big Lake.

7. Citizen Lake Monitoring Data has been collected since 1986 and indicate that Church Pine lake is oligotrophic/mesotrophic (low nutrient/productivity), Round Lake is mesotrophic/mildly eutrophic (moderate nutrient/productivity), and Big Lake is mildly eutrophic (high nutrient/productivity).

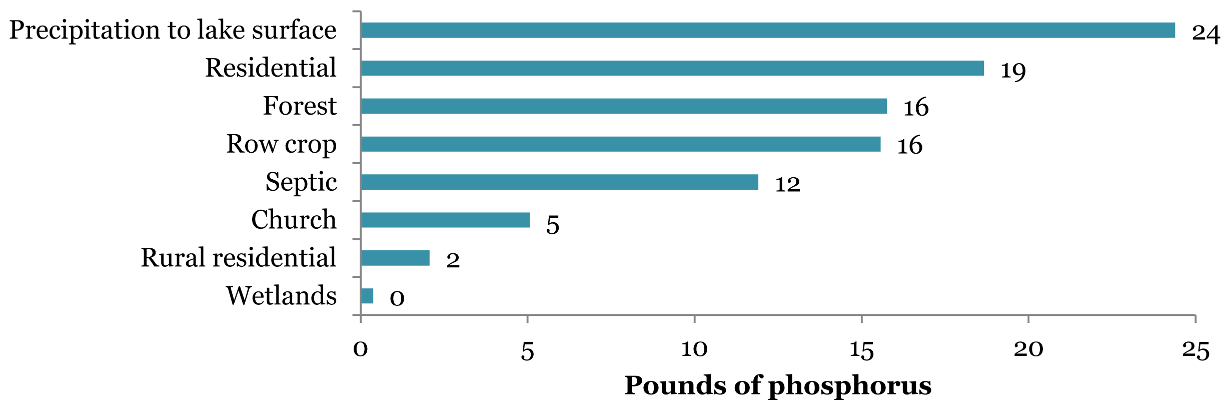
8. The most abundant type of algae on all three lakes was blue green algae. Blue green algae are of specific concern because they produce toxins when their populations are large. Populations in all three lakes in 2012 were associated with a low risk of toxin production.

9. The majority of the shoreline buffer area on all three lakes is in a natural state. However, 31% of the shoreline buffer area on Big Lake is lawn.

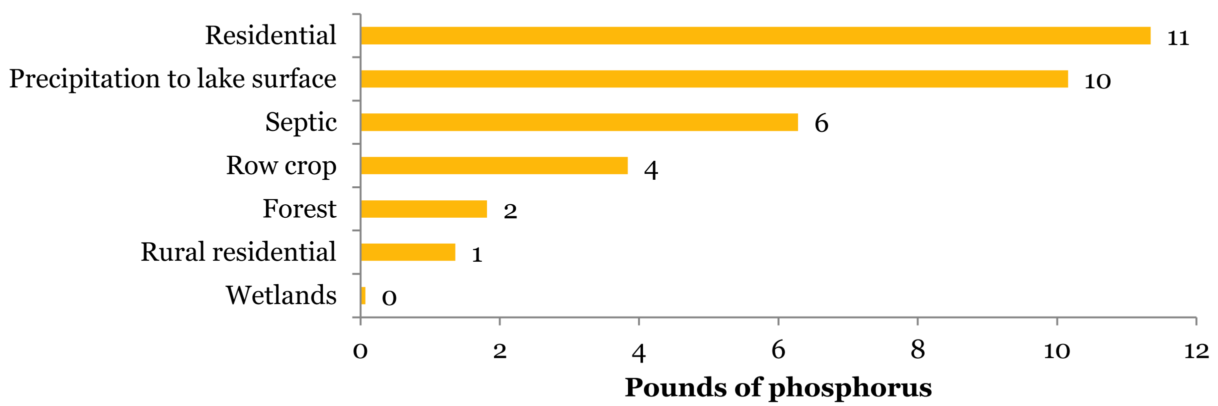
10. A watershed is the area of land that drains to a lake. The Church Pine Lake Watershed is 378 acres, the Round Lake Watershed is 107 acres, and the Big Lake Watershed is 1,766 acres.

11. Modeling was used to estimate how much phosphorus enters Church Pine, Round, and Big Lakes from watershed sources. Shoreline property owners contribute the greatest amount of phosphorus to Church Pine and Round Lakes. North Creek contributes the greatest amount of phosphorous to Big Lake, followed by shoreline property owners.

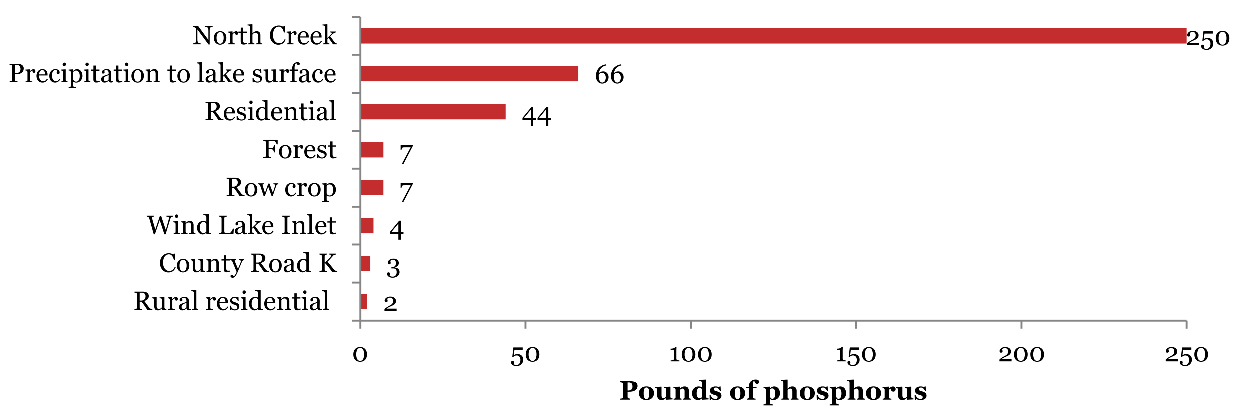
Church Pine Lake phosphorus contributions by source: 94 pounds phosphorus



Round Lake phosphorus contributions by source: 35 pounds phosphorus



Big Lake phosphorus contributions by source: 383 pounds phosphorus



The following goals for Church Pine, Round, and Big Lake were developed through a series of four meetings by the Water Quality Committee. The development of these goals take into account current and past water quality data and a 2012 sociological survey regarding the needs of the Long Lake District.

1. Reduce algae and phosphorus in the three lake system by reducing watershed runoff
2. Evaluate the progress of lake management efforts
3. Protect, maintain, and enhance fish habitat
4. Increase knowledge and participation
5. Support the goals of the Aquatic Plant Management Plan

Introduction to the Lakes

The study area is in southwest Polk County, Wisconsin and includes Church Pine Lake (WBIC 2616100), Round (Wind) Lake (WBIC 2616000), and Big Lake (WBIC 2615900). Church Pine Lake and Round Lake are located entirely in the Town of Alden; whereas, Big Lake is located in the Towns of Alden and Garfield.

Church Pine Lake is the headwaters of this three lake system, with water flowing from Church Pine, to Round, and then to Big Lake. There are two inflows to this three lake system, both of which are located on Big Lake. The main inflow, North Creek, is located on the north side of the lake. Big Lake also receives intermittent flow from a culvert located on County Road K on the east side of the lake.

The outlet for this three lake system, Forest Creek, is located on the west side of Big Lake and drains to Horse Creek. A dam on Forest Creek regulates the water level in Big Lake.

Ramp public access sites are located on Church Pine Lake and Big Lake. Public access on Church Pine Lake is off 45th Avenue on the south side of the lake and public access on Big Lake is off County Road K on the south side of the lake. Round Lake can be accessed from either of the other two lakes.

The soils of all three lake watersheds are loamy to sandy and well to excessively well drained with the exception of the east side of the southern shore of Big Lake which consists of loamy and silty soils ranging from well drained to poorly drained (Lim Tech, October 1987).

Lake Characteristics

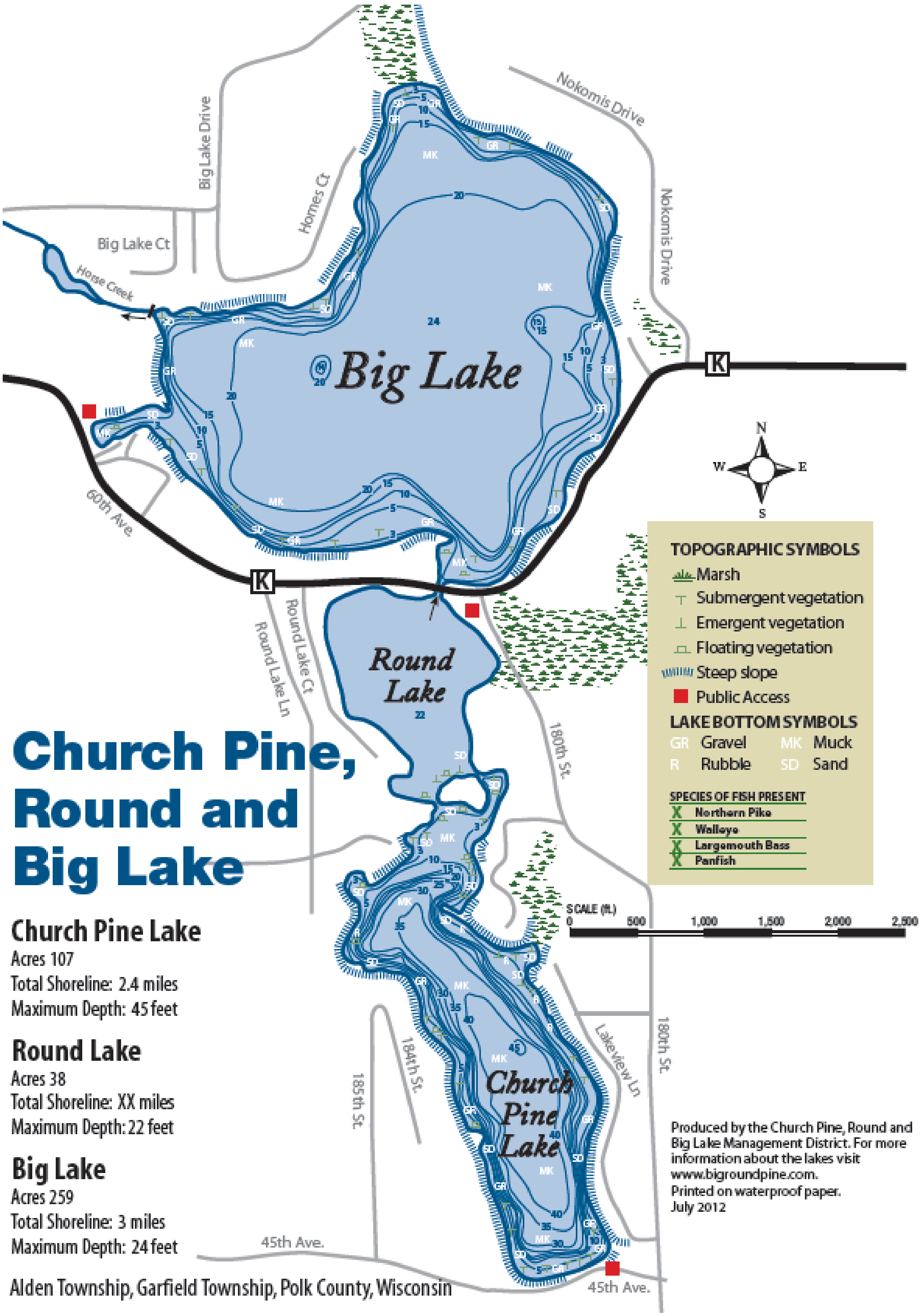
Information from: (Wisconsin Department of Natural Resources).

Church Pine Lake (WBIC: 2616100)
Area: 107 Acres
Maximum depth: 45 feet
Mean depth: 23 feet
Bottom: 80% sand, 5% gravel, 0% rock, and 15% muck
Hydrologic lake type: drainage
Littoral zone depth: 25.7 feet
Total shoreline: 2.4 miles
Invasive species: Chinese mystery snail

Round Lake (WBIC: 2616000)
Area: 38 Acres
Maximum depth: 22 feet
Bottom: 90% sand, 0% gravel, 0% rock, and 10% muck
Hydrologic lake type: drainage
Littoral zone depth: 21.1 feet

Big Lake (WBIC: 2615900)
Area: 259 Acres
Maximum depth: 24 feet
Mean depth: 17 feet
Bottom: 85% sand, 5% gravel, 0% rock, and 10% muck
Hydrologic lake type: seepage
Littoral zone depth: 16 feet
Total shoreline: 3 miles
Invasive species: Chinese mystery snail, curly leaf pondweed, purple loosestrife,

With the exception of 2009, Self Help Monitoring Data has been collected on each lake almost annually since 1986. The Self Help Monitoring Data suggests that Church Pine Lake is hovering on the oligotrophic/mesotrophic line, Round Lake is hovering near the mesotrophic/eutrophic line, and Big Lake is eutrophic.


Big Lake
Round Lake
Church Pine Lake
Church Pine, Round and Big Lake
Church Pine Lake
Acres 107
Total Shoreline: 2.4 miles
Maximum Depth: 45 feet
Round Lake
Acres 38
Total Shoreline: XX miles
Maximum Depth: 22 feet
Big Lake
Acres 259
Total Shoreline: 3 miles
Maximum Depth: 24 feet
Alden Township, Garfield Township, Polk County, Wisconsin
TOPOGRAPHIC SYMBOLS
Marsh
Submergent vegetation
Emergent vegetation
Floating vegetation
Steep slope
Public Access
LAKE BOTTOM SYMBOLS
GR Gravel
MK Muck
R Rubble
SD Sand
SPECIES OF FISH PRESENT
X Northern Pike
X Walleye
X Largemouth Bass
X Panfish
SCALE (ft.)
0
500
1,000
1,500
2,000
2,500
N
S
E
W
Produced by the Church Pine, Round and Big Lake Management District. For more information about the lakes visit www.bigroundpine.com.
Printed on waterproof paper.
July 2012
Big Lake Drive
Big Lake Ct
Horse Creek
Homes Ct
Nokomis Drive
60th Ave
Round Lake Ln
Round Lake Ct
180th St.
184th St.
185th St.
Lakeview Ln
45th Ave.
K

Designated Waters

A designated water is a waterbody with special designations that affect permit requirements. Designations for the three lake system include:

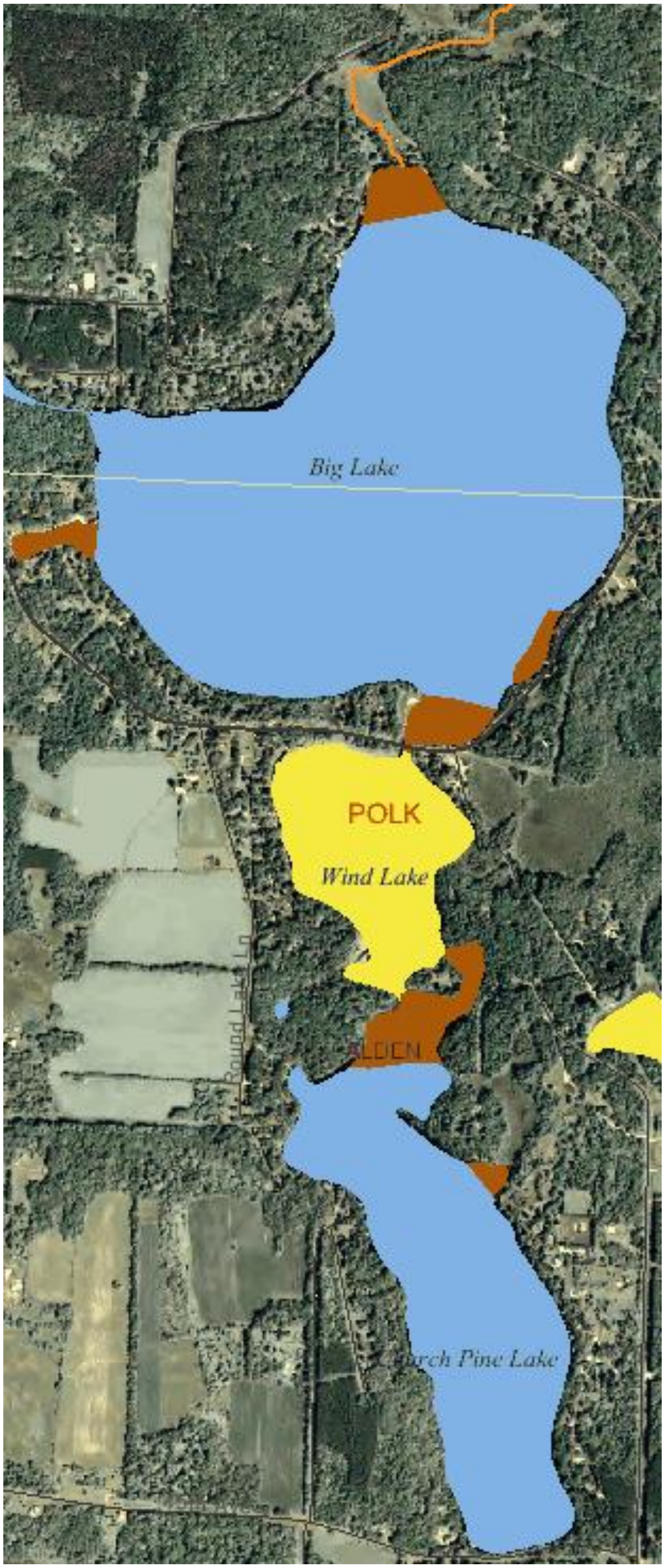
- ✓ **Areas of Special Natural Resource Interest**
  - North Creek due to its classification as a trout water under Chapter NR 1.02(7). Wis. Adm. Code [1]

- ✓ **Public Rights Feature** : identified as areas that merit special protection of aquatic habitat through lake sensitive area survey results
  - 2 locations on Church Pine Lake [2]
  - 4 locations on Big Lake [3]

- ✓ **Priority Navigable Waters**
  - Round Lake due to the size of the waterbody being less than 50 acres under Sections 30.26 and 30.27. Wis. Stats

In 1998 a Sensitive Area Survey Report and Management Guidelines was prepared for both Church Pine and Big Lake. Further information on the Public Rights Features highlighted above can be found in these reports.

[1] "State classified trout streams are considered ASNRI waters due to the narrow window of suitable habitat including substrate and temperatures required by trout species" (Wisconsin DNR).
[2] "The entire littoral zone of Church Pine Lake has a very diverse plant community and should be protected by all means. These designated sensitive areas of aquatic vegetation on Church Pine Lake offer critical or unique fish and wildlife habitat. These habitats provide the necessary seasonal or life stage requirements of the associated fisheries, and the aquatic vegetation offers water quality or erosion control benefits to the body of water" (Wisconsin DNR).
[3] "These areas of aquatic vegetation or rock substrate offer critical or unique fish and wildlife habitat. These habitats provide the necessary seasonal or life stage requirements of the associated fisheries, and the aquatic vegetation offers water quality or erosion control benefits to the body of water" (Wisconsin DNR).



A Designated Water is a waterbody that has special designations that affect permit requirements. Designated Waters include the following:

- Areas of Special Natural Resource Interest (ASNRI)
- Public Rights Features (PRF)
- Priority Navigable Waters (PNW)

PNW ASNRI PRF

Please note that Areas of Special Natural Resource Interest (ASNRI) waters and Public Rights Features (PRF) waters are also considered Priority Navigable Waters (PNW).

Map from: (Wisconsin DNR).

Habitat Areas

Information directly from: (Harmony Environmental and Ecological Integrity Services, September 2010).

Naturally occurring native plants are extremely beneficial to lakes. They provide a diversity of habitats, help maintain water quality, sustain fish populations, and support common lakeshore wildlife such as loons and frogs.

Aquatic plants can improve water quality by absorbing phosphorus, nitrogen, and other nutrients from the water that could otherwise fuel nuisance algal growth. Some plants can even filter and break down pollutants. Plant roots and underground stems help to prevent re-suspension of sediments from the lake bottom. Stands of emergent plants (whose stems protrude above the water surface) and floating plants help to blunt wave action and prevent erosion of the shoreline.

Habitat created by aquatic plants provides food and shelter for both young and adult fish. Invertebrates living on or beneath plants are a primary food source for many species of fish. Other fish such as bluegills graze directly on the plants themselves. Plant beds in shallow water provide important spawning habitat for many fish species. Plants offer food, shelter, and nesting material for waterfowl. Birds eat both the invertebrates that live on plants and the plants themselves.

The Wisconsin Department of Natural Resources (DNR) has completed sensitive area surveys to designate areas within aquatic plant communities that provide important habitat for game fish, forage fish, macroinvertebrates, and wildlife, as well as important shoreline stabilization functions. The DNR has transitioned to designations of *critical habitat areas* that include both *sensitive areas* and *public rights features*.

Sensitive areas offer critical or unique fish and wildlife habitat (including seasonal or life stage requirements) or offer water quality or erosion control benefits to the area (Administrative code 107.05(3)(1)(1)). The Wisconsin Department of Natural Resources is given the authority for the identification and protection of sensitive areas of the lakes.

Public rights features are areas that fulfill the right of the public for navigation, quality and quantity of water, fishing, swimming, or natural scenic beauty. The *critical habitat area* designation provides a holistic approach to ecosystem assessment and protection of those areas within a lake that are most important for preserving the very character and qualities of the lake. Protecting these *critical habitat areas* requires the protection of shoreline and in-lake habitat. The *critical habitat area* designation provides a framework for management decisions that impact the ecosystem of the lake.

The Department of Natural Resources completed Sensitive Areas Designations in September of 1998. Purple loosestrife was identified in Big Lake sensitive areas A, C, and D. Curly leaf pondweed was found in Big Lake sensitive area C.

The general recommendations for the sensitive/critical habitat areas are:

- Preserve/restore shoreline buffers at least 35 feet deep
- Limit aquatic vegetation removal to no more than 25 foot channels – hand pulling is the preferred method for management followed by harvesting and herbicide use
- Leave woody debris in place
- Prevent construction site erosion
- Limit rip rap for shoreline stabilization
- Strictly enforce zoning ordinances
- Control exotic species such as purple loosestrife
- Use conservation easements, deed restrictions or zoning to protect sensitive areas (Church Pine only)

Resource values of each lake sensitive area were each described in the same way: provides bass, panfish, and forage species habitat; northern spawning and nursery areas; and wildlife habitat. All major types of plants: emergent, floating, and submergent were recorded in each sensitive area.

The Natural Heritage Inventory map of Polk County indicates occurrences of aquatic listed special concern species in the sections where project lakes are located. A species list is available to the public only by Town and Range. WDNR and federal regulations regarding special concern species range from full protection to no protection. The current categories and their respective level of protection are as follows: **SC/P** = fully protected, **SC/N** = no laws regulating use, possession, or harvesting.

T32N R18W included the following aquatic species:

Cardamine pratensis	Cuckoo Flowers	Special Concern
Fundulus diaphanous	Banded Killifish	Special Concern/N
Senecio congestus	Marsh Ragwort	Special Concern

T 33N R18W also has the Banded Killifish present.

Fishery

Information directly from: (Harmony Environmental and Ecological Integrity Services, September 2010).

The three lake chain has a naturally reproducing largemouth bass and pan fishery (bluegill, black crappie, pumpkinseed, and yellow perch). In addition, a stocked northern pike and walleye fishery is present. Northern pike are stocked by the WDNR during alternate years to provide a low density top predator to improve the overall angling experience.

Continued stocking will be necessary to maintain viable populations of both northern pike and walleye. Walleye were recently stocked by the Lake District and have survived to provide a fishable population at a low level. The main limiting factor likely affecting walleye is predation by other fishes. Northern pike reproduction is limited because of the lack of spawning habitat. Northern pike prefer to spawn on shallow-flooded emergent vegetation in the spring, and this is limited in the chain. Any efforts to restore potential northern pike spawning habitat would be a valuable management effort.

The Lake District also stocked brown trout in Church Pine in 2009 on an experimental basis.

Lake Classification

Lake classification in Polk County is a relatively simple model that considers:

- ✓ lake surface area
- ✓ maximum depth
- ✓ lake type
- ✓ watershed area
- ✓ shoreline irregularity
- ✓ existing level of shoreline development

These parameters are then used to classify lakes as class one, class two, or class three lakes.

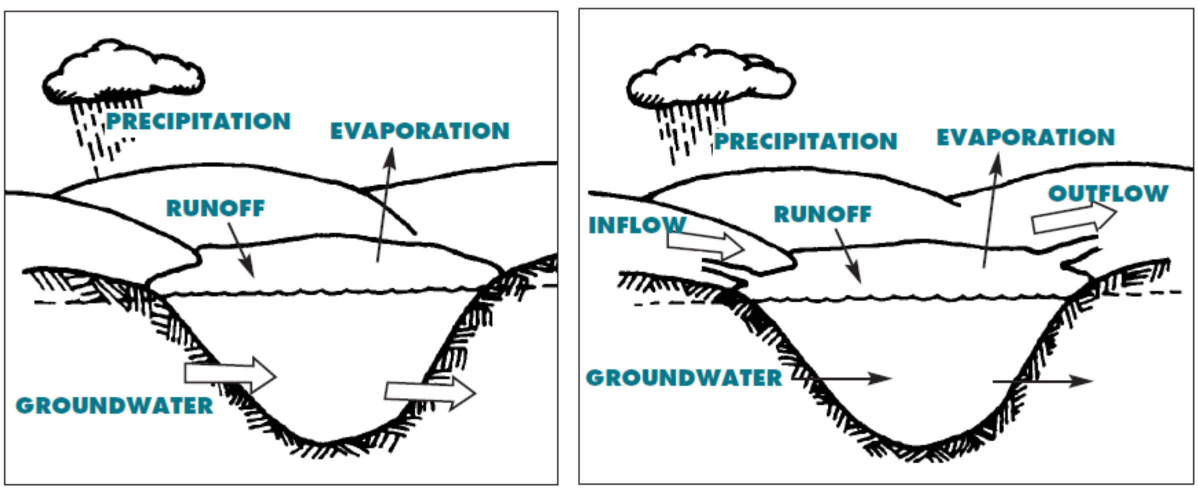
Class one lakes are large and highly developed.
Class two lakes are less developed and more sensitive to development pressure.
Class three lakes are usually small, have little or no development, and are very sensitive to development pressure.

(Polk County Shoreland Protection Zoning Ordinance, Effective April 1, 2010).

Church Pine, Round, and Big Lake are all classified as class one lakes (Polk County, Wisconsin Shoreland Property Owner Handbook A Guide to the Polk County Shoreland Protection Zoning Ordinance in Developing and Caring for Waterfront Property, October 2002).

Lake Types

Lakes are commonly classified into four main types based on water source and type of outflow: seepage lakes, groundwater drainage lakes, drainage lakes, and impoundments. The Wisconsin DNR has classified Church Pine and Round Lake as drainage lakes and Big Lake as a seepage lake. Seepage lakes do not have an outlet and are fed by precipitation, limited runoff, and groundwater; whereas, drainage lakes are drained by a stream and fed by streams, groundwater, precipitation, and runoff (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).



1. SEEPAGE LAKE—a natural lake fed by precipitation, limited runoff and groundwater. It does not have a stream outlet.

3. DRAINAGE LAKE—a lake fed by streams, groundwater, precipitation and runoff and drained by a stream.

Figure from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004)

The drainage basin: lake area ratios (DB: LA) compares the size of a lake's watershed to the size of a lake. If a lake has a relatively large DB: LA then surface water inflow (containing nutrients and sediments) occurs from a large area of land relative to the area of the lake (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

The DB: LA ratio [4] is largest for Big Lake (15.32), followed by Church Pine Lake (3.92) and Round Lake (3.43).

A study by Lillie and Mason (1983) found that in general seepage lakes have better water clarity and are less eutrophic as compared to drainage lakes. In this study, DB: LA for seepage lakes was smaller as compared to drainage lakes. This may explain why seepage lakes tend to have lower levels of nutrients.

[4] DB: LA was calculated using the subwatershed areas from the Nonpoint Source Control Plan for the Horse Creek Priority Watershed Project and lake areas from the Wisconsin Department of Natural Resources website.

Impaired Waters

Every two years, the Wisconsin Department of Natural Resources publishes a list of waters considered impaired under the Federal Clean Water Act, Section 303(d). Impaired waters are not meeting water quality standards and may not support activities such as fishing, swimming, recreating, or public health and welfare.

Monitoring and assessment are used to make decisions regarding surface water quality conditions. Waterbodies are evaluated from their ability to support fish and aquatic life, recreation, and public health and welfare (fish consumption). Waterbodies are given a score based upon current condition and categorized as poor, fair, good, or excellent. Waterbodies classified as excellent or good are considered to be meeting their designated uses. Waterbodies described as fair are considered to be meeting their designated uses but may warrant additional monitoring to assure conditions are not declining. Finally, waterbodies that are listed as poor may be placed on Wisconsin's Impaired Waters List.

Waterbodies can be listed as impaired based on pollutants such as total phosphorus, total suspended solids, mercury, and PCB's.

Total phosphorus criteria for impairment vary depending on the inherent characteristics of a waterbody. For example, the total phosphorus criteria for drainage lakes that stratify (i.e. Church Pine Lake) is 0.030 mg/L; whereas the criteria for drainage lakes that do not stratify (i.e. Round Lake) and seepage lakes that do not stratify (i.e. Big Lake) is 0.040 mg/L. These values for total phosphorus represent the average as measured over the summer index period, which occurs from July 15^{th} through September 15^{th}.

Information summarized from: (Wisconsin Department of Natural Resources, 2013)

The total phosphorus criteria were met in 2012 on all three lakes over the summer index period (Church Pine Lake = 0.0205 mg/L; Round Lake = 0.024 mg/L; Big Lake = 0.033 mg/L).

Previous Lake Studies

Past studies that include Church Pine, Round, and Big Lake are:

- ✓ Lim Tech Consultants Study (1987)
- ✓ Nonpoint Source Control Plan for the Horse Creek Priority Watershed Project (2001)
- ✓ Barr Engineering Aquatic Plant Management (APM) Plan (1997/98)
- ✓ Harmony Environmental and Endangered Resource Services APM Plan (2010)

Lim Tech Consultants Study

The most recent water quality evaluation completed for the three lake system was conducted by Lim Tech Consultants in 1987.

This evaluation included:

- ✓ Watershed delineation
- ✓ Land-use characterization
- ✓ Water quality assessment
- ✓ Hydrological and nutrient-loading patterns
- ✓ Resident survey

Some of the notable conclusions made from the Lim Tech (1987) evaluation include:

1. Groundwater is not a significant source to any of the lakes.
2. The retention time is 7.8 years for Church Pine Lake, 2.9 years for Round Lake, and 1.9 years for Big Lake.
3. Church Pine and Round lake water quality is better than or equal to predicted water quality in the absence of development and Big Lake water quality is lower than predicted.
4. Phosphorus loading to Big Lake is excessive and due in large part to loads from North Creek (84%).
5. No evidence existed for the direct release of sewage waste along the majority of the shorelines of all three lakes with the exception of the west and northwest shores of Round Lake.
6. Algae concentrations were normal on Church Pine and Round Lake and excessive on Big Lake.
7. Aquatic macrophyte densities were normal, although residents were dissatisfied.
8. Dissolved oxygen levels were acceptable.

Nonpoint Source Control Plan for the Horse Creek Priority Watershed Project

Subwatershed descriptions are included in the 2001 Nonpoint Source Control Plan for the Horse Creek Priority Watershed Project prepared by the Polk County Land and Water Resources Department, Wisconsin Department of Natural Resources, and Wisconsin Department of Agriculture, Trade, and Consumer Protection.

	Church Pine Lake	Round Lake	Big Lake
Subwatershed (acres)	416	144	3,737
Direct drainage areas (acres)	376	111	1,775

Adapted from: (Polk County Land and Water Resources Department, June 2001).

Predominant land use in the direct drainage areas was also classified for this report. The predominant land uses in the direct drainage areas were: open space (173.57 acres) and rural residential (42.02 acres) for Church Pine Lake; open space (32.03 acres) and lakeshore residential (12.6 acres) for Round Lake; and open space (878.01 acres) and agriculture (394.01 acres) for Big Lake. [5]

	Church Pine Lake	Round Lake	Big Lake
Cropland (%)	5.2	8.7	20.8
Farmstead (%)	0	0	0.8
Woodland (%)	33.9	22.7	15.3
Lake (%)	24.2	39.1	18.1
Wetland (%)	0.4	6.2	26.9
Grassland (%)	11.9	0	7.2
Pasture (%)	0	0	0.5
Rural residential (%)	12.8	11.9	4.7
Lakeshore residential (%)	11.8	11.4	5.6

Adapted from: (Polk County Land and Water Resources Department, June 2001).

[5] Open space includes wetland, woodland, and grassland and agriculture includes cropland, farmstead, and pasture.

Through 2009 the following projects were completed within the project lake's watershed as part of the priority watershed project:

- ✓ Nutrient/Pest Management: 316 acres
- ✓ High Residue Management: 39 acres
- ✓ Manure Storage Abandonment: 2 facilities
- ✓ Rain Gardens: 5 gardens
- ✓ Critical Area Stabilization: 2 areas
- ✓ Shoreline Habitat Restoration: 3.5 acres

Values from: (Harmony Environmental and Ecological Integrity Services, September 2010).

Barr Engineering Aquatic Plant Management Plan

Aquatic Plant Management Plans were completed by Barr Engineering for Big Lake in 1997 and Church Pine and Round Lake in 1998 (Barr Engineering, April 1997) (Barr Engineering, April 1998).

The goals for Big Lake included:

- ✓ Reduce plant density throughout the littoral region from the existing high density to a moderate plant density
- ✓ Reduce the exotic curly leaf pondweed to the greatest extent possible from Big Lake, while maintaining a healthy native aquatic plant community

The goals developed for Church Pine and Round Lake included:

- ✓ Improve navigation within the lakes through areas containing dense plant beds (two areas within in each lake)
- ✓ Remove or limit current exotic plants (i.e., curly leaf pondweed)
- ✓ Preserve native species and prevent introduction of additional exotic species
- ✓ Preserve and/or improve fish and wildlife habitat
- ✓ Protect and/or improve quality of the resources for all to enjoy (i.e., people, fish, wildlife)
- ✓ Minimize disturbance of sensitive areas (i.e., fish and wildlife)

Harmony Environmental and Endangered Resource Service Aquatic Plant Management Plan

The most recent Aquatic Plant Management Plan for the three lake system was completed in 2010 by Harmony Environmental and Ecological Integrity Services (Harmony Environmental and Ecological Integrity Services, September 2010).

The goals developed for the three lake system include:

- ✓ Prevent introduction of aquatic invasive species and pursue any new introduction aggressively
- ✓ Reduce the population and spread of curly leaf pondweed, purple loosestrife, and other invasive aquatic plants
- ✓ Maintain navigable routes for boating
- ✓ Preserve diverse native aquatic plant community
- ✓ Reduce runoff of nutrients and sediment from the lake's watershed
- ✓ Educate the public regarding aquatic plant management

Lake District Resident Survey

A Wisconsin Department of Natural Resources approved sociological survey was mailed to two hundred twenty four residences of the Church Pine, Round, and Big Lake Protection and Rehabilitation District in early May 2012. Residents were reminded to return their survey at the May 19th Spring Informational Meeting and with an August educational postcard. The survey was designed to gather information from residents concerning property ownership and use, land use, lake use, concerns for the three lake system, water quality, algae, shoreline vegetation, management practices for improvement of the three lake system, and website use.

One hundred sixteen surveys were returned (52% response rate) and data was entered and analyzed. Ninety three percent of respondents own property located on the waterfront of Church Pine, Round, or Big Lake; whereas the remaining 7% do not. Respondents who did not own waterfront property were directed to skip questions to quantify shoreline habitat.

Respondents were also asked which lake their property was located on or located nearest to. If respondents owned property located on more than one lake they were directed to choose the lake they frequented most often. Respondents were directed to use the lake they had chosen to answer questions regarding current water quality, changes in water quality, negative impacts of algae, and current amount of shoreline vegetation.

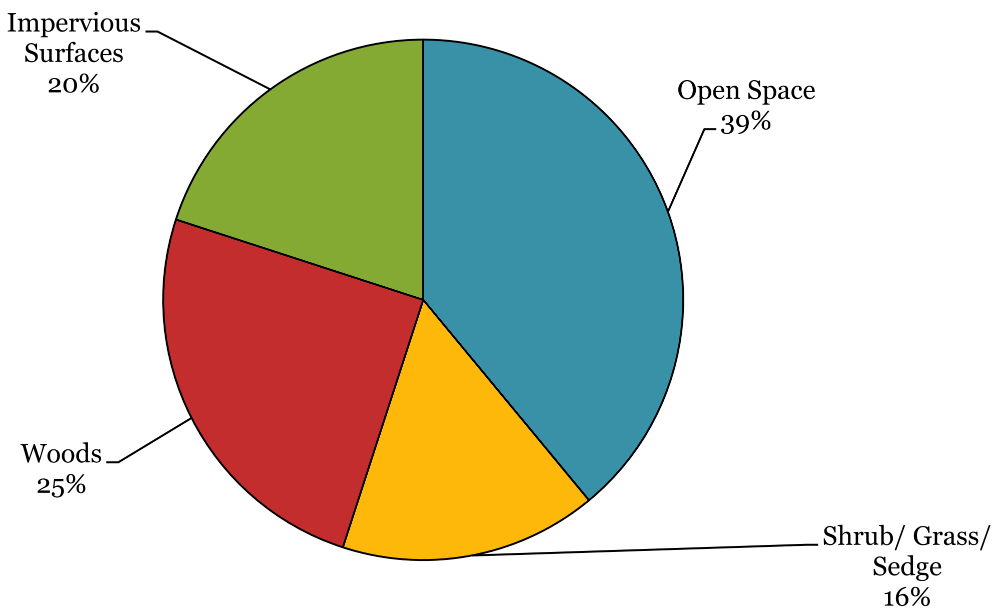
Property Ownership and Use

Respondents have owed property on or near Church Pine, Round, and Big Lake for an average of 22 years. The majority of respondents use their property as a weekend, vacation, and/or holiday residence (46%) or occupy their property on a year round basis (44%). A small percentage of residents (6%) use their property as a seasonal residence (continued occupancy for months at a time). On average, respondents occupy their property for 194 days per year. At any given time, an average of three people occupy each property.

Land Use

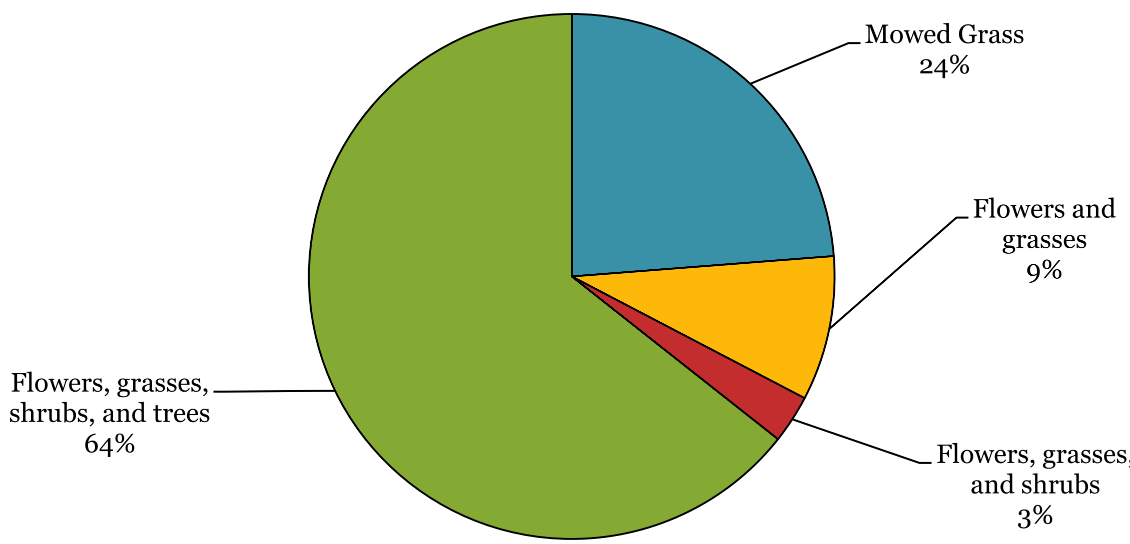
Survey respondents were asked to classify the amount of open space (lawns or mowed areas), shrub/grass/sedge community, woods, and impervious surfaces (buildings, driveways, sidewalks, patios, gravel paths and driveways) on their property to gauge land use in the areas surrounding Church Pine, Round, and Big Lake. According to respondent classification, an average of 39% of properties are occupied by open space, 25% are occupied by woods, 20% are occupied by impervious surfaces, and 16% are occupied by the shrub/grass/sedge community.

Please use estimated percentages to describe the amount of each land use on your property.



Respondents owning waterfront property were also asked to describe the first 35 feet of their shoreline (the area located directly adjacent to the lake). The majority (65%) classified the first 35 feet of their shoreline as a mix of native flowers, grasses, shrubs, and trees. Twenty four percent classified the first 35 feet of their shoreline as mostly mowed grass, 9% as mostly native flowers and grasses, and 3% as a mix of native flowers, grasses, and shrubs.

Which best describes the first 35 feet of your shoreline (the area located directly adjacent to the lake)?



Lake Use

Respondents use Church Pine, Round, and Big Lake for a variety of recreational activities. Eighty eight percent of respondents partake in motorized water activities (PWC, boating, water skiing, tubing, jet skiing); 85% partake in swimming, snorkeling, or scuba diving; 81% partake in fishing (any season); and 65% partake in non-motorized activities (birding, canoeing, hiking, running). Winter specific recreational activities were less frequent on the three lake system, possibly due to the abundance respondents who do not live on the three lake system year round. Thirty nine percent of respondents partake in non-motorized winter activities (skiing, snowshoeing, ice skating) and 16% partake in motorized winter activities (ATV, snowmobile).

Respondents keep a total of 70 paddleboats/rowboats, 89 canoes/kayaks, 3 paddleboards, 8 sailboats, 24 jet skis, 24 motorboats/pontoons (1-20 HP), 64 motorboats/pontoons (21-50HP), and 58 motorboats/pontoons (50+ HP).

Concerns for Church Pine, Round, and Big Lake

Survey respondents were asked to rank their top three concerns for Church Pine, Round, and Big Lake. To analyze this data, each concern that ranked first received 3 points, each concern that ranked 2nd received 2 points, and each concern that ranked third received 1 point. Total points were then added to determine the ranking of concerns for the three lake system. Property values and/or taxes ranked as the 1st concern, followed by invasive species as the 2nd concern, and pollution and aquatic plants which tied as the 3rd concern.

Concerns for Church Pine, Round, and Big Lake	Rank	Points
Property values and/or taxes	1st	119
Invasive species *(Eurasian water milfoil, zebra mussels, curly leaf, purple loosestrife)*	2nd	117
Aquatic plants *(not including algae)*	3rd	80
Pollution *(chemical inputs, septic systems, agriculture, erosion, storm water runoff)*	3rd	80
Water clarity *(visibility)*	4th	64
Algae blooms	5th	39
Quality of life	6th	34
Water levels *(loss of lake volume)*	7th	33
Water recreation safety *(boat traffic, no wake zone)*	8th	31
Quality of fisheries	9th	30
Development *(population density, loss of wildlife habitat)*	10th	29
Other, please describe *(noise/light, preservation of recreational water sports)*	11th	3

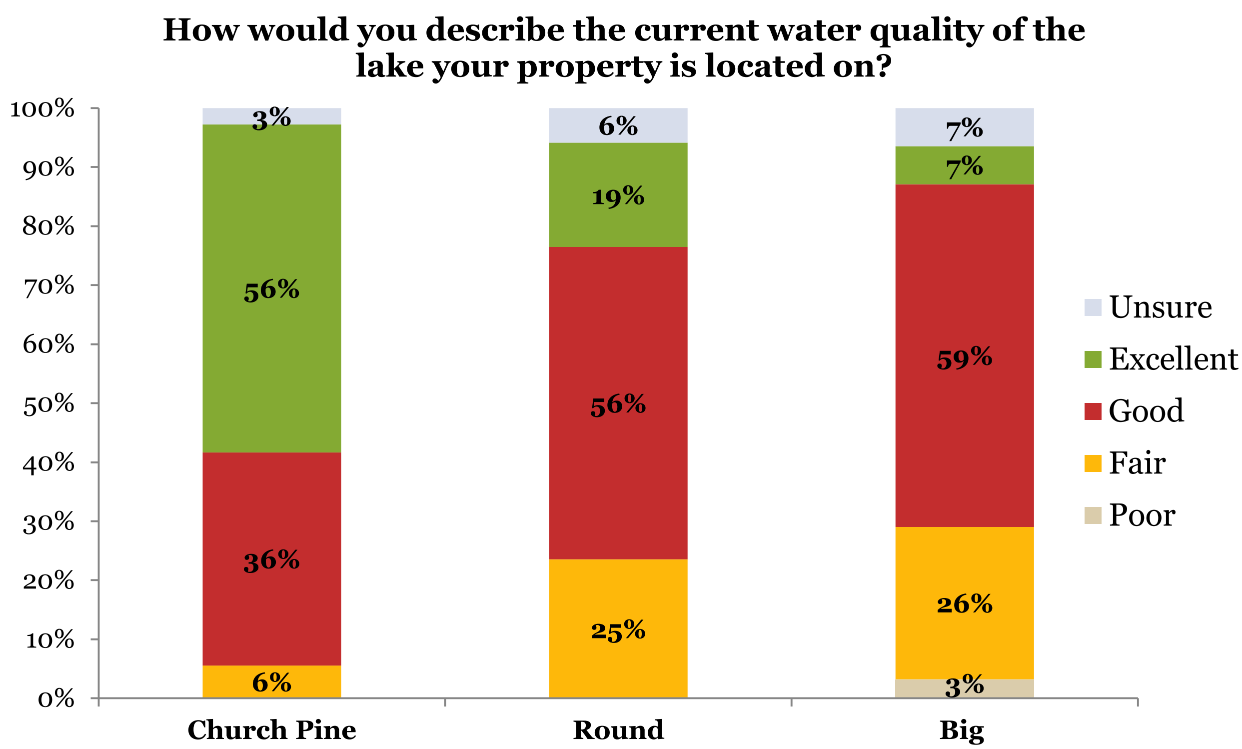
Water Quality

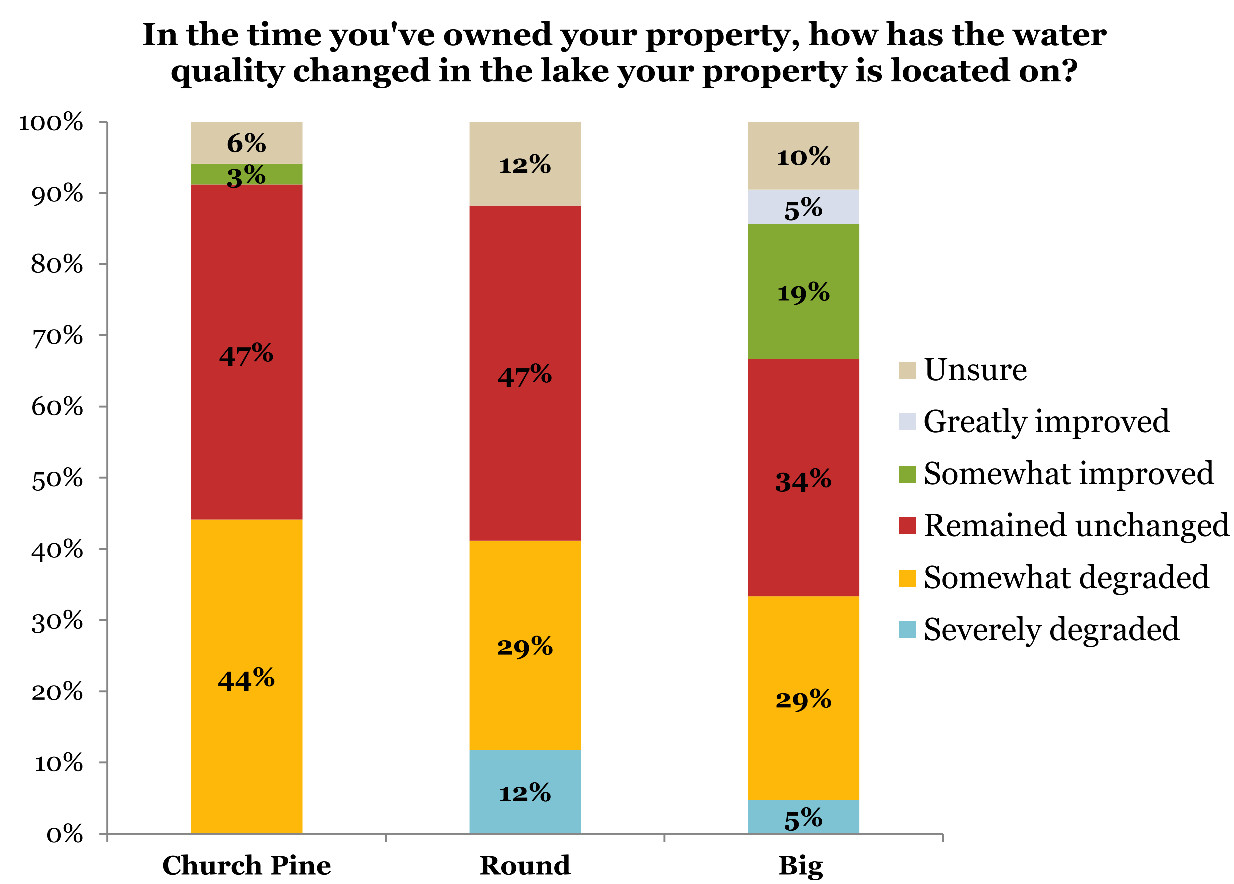
The majority of respondents living on Church Pine Lake described the water quality as excellent (56%) or good (36%). In the time since these respondents have owned their property (average 24 years) the perception has been that water quality has remained unchanged (47%) or somewhat degraded (44%).

The current water quality of Round Lake was perceived as good by the majority of respondents living on Round Lake (56%), fair by a quarter of respondents (25%), and excellent by less than a quarter of respondents (19%). Since these respondents have owned their property (average 16 years) nearly half perceive that water quality has remained unchanged (47%). Twenty-nine percent of respondents perceive that water quality has somewhat degraded, twelve percent perceive that water quality has severely degraded, and twelve percent were unsure how water quality has changed.

Big Lake is perceived as having good water quality by over half of respondents living on Big Lake (59%), and fair by over a quarter of respondents (26%). Only seven percent of respondents perceived the water quality as excellent and another seven percent were unsure (n = 61). In the time since respondents have owned their property (average 22 years), over a third of respondents (34%) felt that the water quality on Big Lake has remained unchanged, less than a third (29%) felt that the water quality has somewhat degraded, and less than a quarter (19%) felt that the water quality has somewhat improved (n = 62).

Overall, the majority of respondents felt that current water quality was good to excellent on the three lake system and that water quality has remained unchanged or somewhat degraded in the time since they have owned property.


How would you describe the current water quality of the lake your property is located on?
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
3%
56%
36%
6%
6%
19%
56%
25%
7%
7%
59%
26%
3%
Church Pine
Round
Big
Unsure
Excellent
Good
Fair
Poor

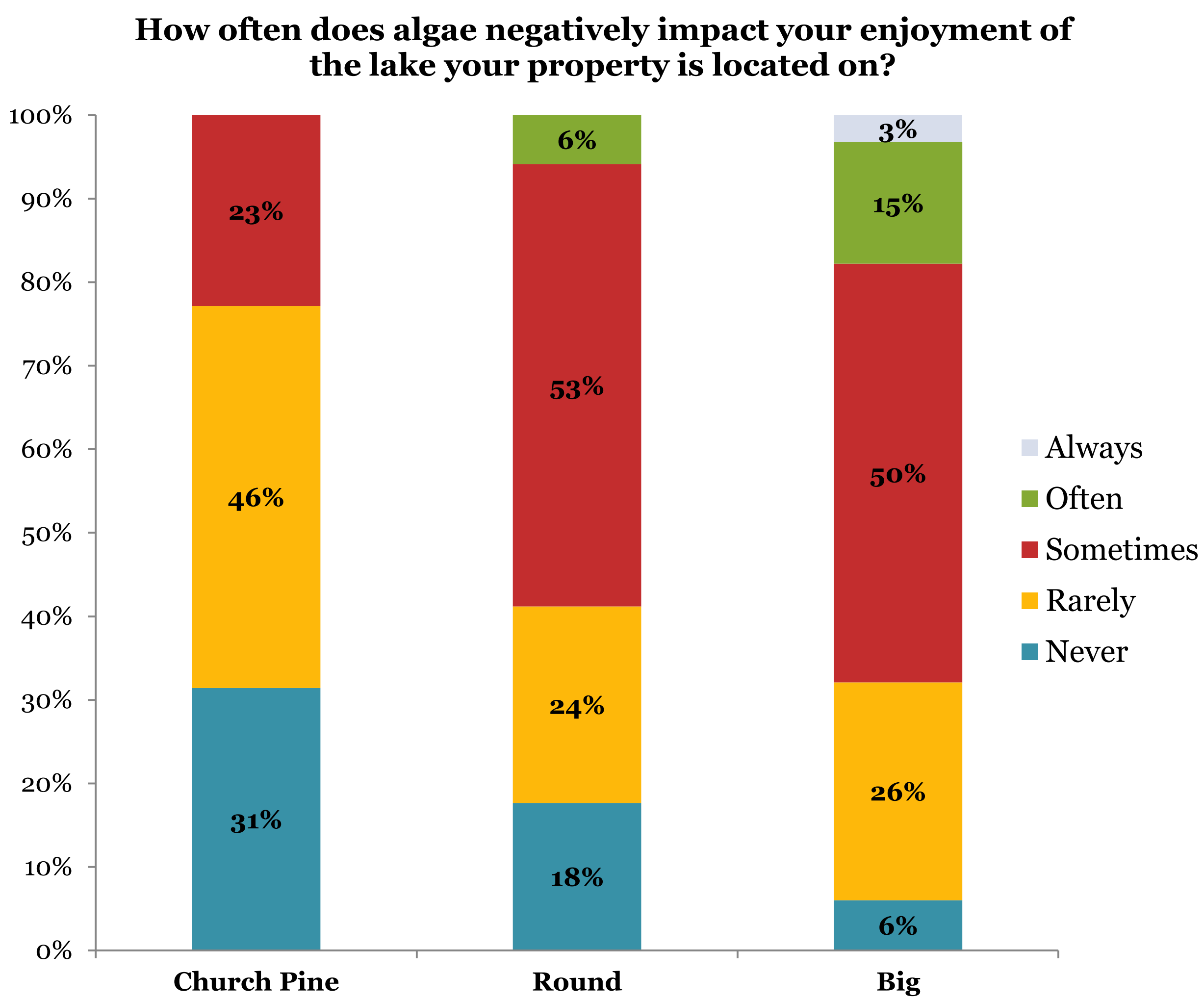

In the time you've owned your property, how has the water quality changed in the lake your property is located on?
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
6%
3%
47%
44%
12%
47%
29%
12%
10%
5%
19%
34%
29%
5%
Church Pine
Round
Big
Unsure
Greatly improved
Somewhat improved
Remained unchanged
Somewhat degraded
Severely degraded

Algae

Algae appear to negatively impact the enjoyment of Big Lake more often as compared to Round Lake and Church Pine Lake. On Church Pine Lake and Round Lake, zero respondents felt that algae always negatively impacts enjoyment of the lakes as compared with 3% of respondents on Big Lake. In contrast, 31% of respondents felt that algae never negatively impacts their enjoyment of Church Pine Lake, 18% felt that algae never negatively impacts their enjoyment of Round Lake, and 6% felt that algae never negatively impacts their enjoyment of Big Lake.

Additionally, most respondents on Big Lake (50%) and Round Lake (53%) felt that algae sometimes negatively impacts their enjoyment of the lakes and most respondents on Church Pine Lake (46%) felt that algae rarely negatively impacts their enjoyment of the lake.

Across all three lakes, very few respondents feel that algae negatively impact lake enjoyment often/always.



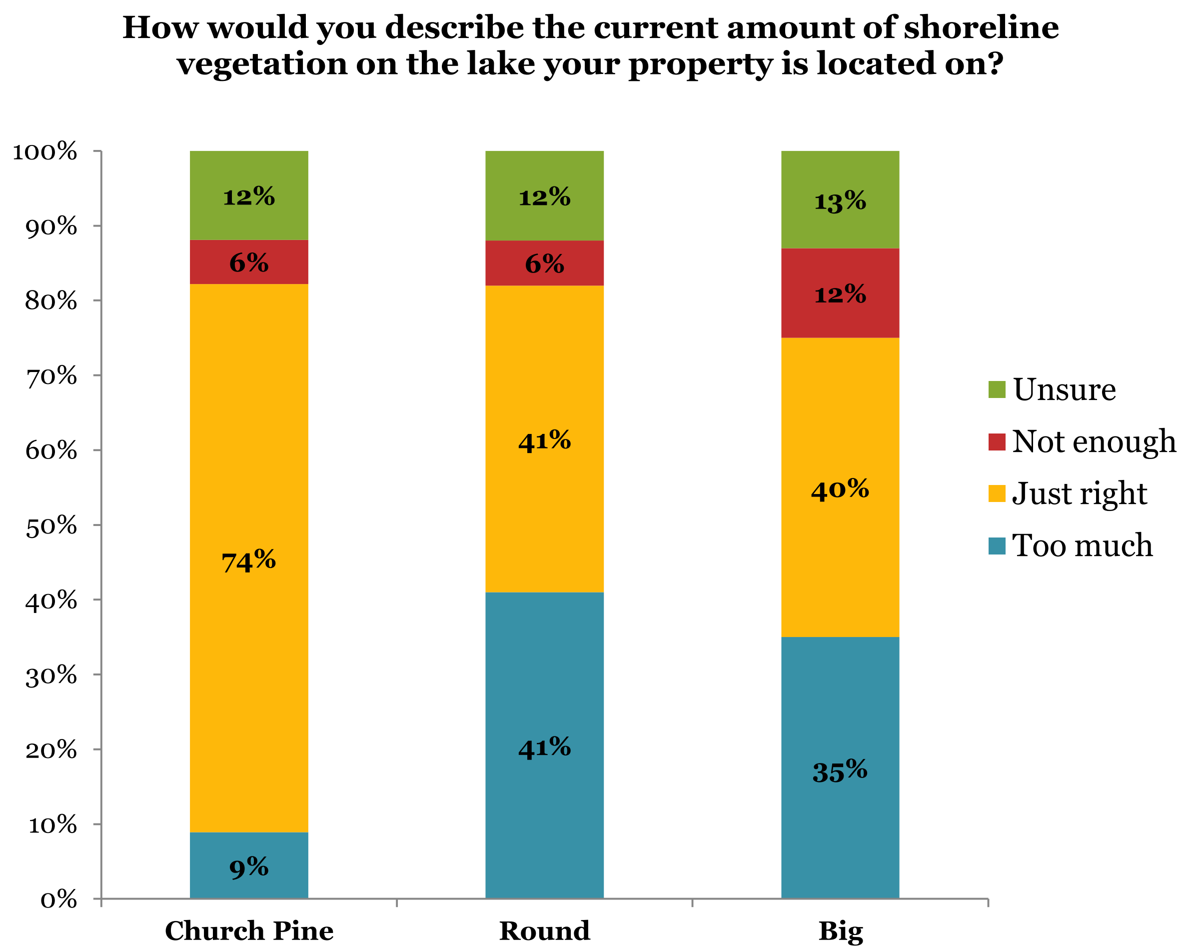
Shoreline Vegetation

Nearly three-fourths of the residents on Church Pine Lake (74%) felt that the amount of shoreline vegetation on the lake was just right. Slightly more respondents felt there was too much shoreline vegetation on Church Pine (9%) as compared to not enough (6%).

On Round Lake an equal amount of respondents felt that the amount of shoreline vegetation was too much or just right (41%) and very few (6%) felt that the amount of shoreline vegetation was not enough.

Most of the respondents on Big Lake felt that the amount of shoreline vegetation was just right (40%) or too much (35%). Fewer respondents (12%) felt there was not enough shoreline vegetation on Big Lake.

Across all three lakes most respondents felt that the amount of shoreline vegetation on the three lake system was just right. Additionally, more respondents felt there was too much shoreline vegetation as compared to not enough.



Overall respondents recognize the importance of shoreline buffers, rain gardens, and native plants to the water quality of the three lake system. Nearly half (46%) of respondents described shoreline buffers, rain gardens, and native plants as very important to water quality and just under a third (32%) described them as somewhat important. In contrast, 8% of respondents felt they were not too important and 2% felt they were not at all important. Additionally, another 12% of respondents were unsure of the importance of shoreline buffers, rain gardens, and native plants to water quality.

The results suggest a possible educational need regarding the importance of shoreline buffers, rain gardens, and native plants to water quality.

Although a combined 78% of respondents felt that shoreline buffers, rain gardens, and native plants are very important or somewhat important to water quality, half (50%) of respondents are not interested in installing a shoreline buffer or rain garden on their property. In contrast 32% of respondents have already installed a shoreline buffer or rain garden and 7% are interested in installing a shoreline buffer or rain garden. The remainder of respondents (14%) were unsure of their interest in installing a shoreline buffer or rain garden.

Overall, respondents are making educated decisions when applying fertilizer to their property. Over half of respondents (58%) do not use fertilizer on their property and over a third (35%) use zero phosphorus fertilizer. Very few respondents use fertilizer but are unsure of its phosphorus content (5%) and an extremely small percentage use fertilizer on their property that contains phosphorus (2%).

Management Practices for Improvement of the Three Lake System

Survey respondents were asked to choose all of the management practices they felt should be used to maintain or improve the water quality of Church Pine, Round, and Big Lake from a list of eight options. Three-fourths of respondents (75%) felt that the in-lake water quality data should continue to be collected and that enhanced efforts to monitor for new populations of aquatic invasive species should be implemented. Other management practices supported by many respondents were information and education opportunities (46%), cost-sharing assistance for the installation of shoreline buffers and rain gardens (44%), and establishment of slow-no-wake zones to protect aquatic plants and fisheries habitat (41%).

Management practices to improve water quality	Percent
Continued collection of in-lake water quality data	75%
Enhanced efforts to monitor for new populations of aquatic invasive species	75%
Information and education opportunities	46%
Cost-sharing assistance for the installation of shoreline buffers and rain gardens	44%
Establishment of slow-no-wake zones to protect aquatic plants and fisheries habitat	41%
Collection of sediment cores to provide information concerning historical lake conditions	33%
Practices to enhance fisheries, such as the introduction of coarse woody habitat	29%
Cost-sharing assistance for the installation of farmland conservation practices (nutrient management plans, contour strips, conservation tillage)	27%

Website Use

The Church Pine, Round, and Big Lake Protection and Rehabilitation District maintains a very extensive website available at www.bigroundpine.com. Less than ten percent of respondents often visit the website (9%), one third of respondents sometimes (34%) or rarely (32%) visit the website, and a quarter of respondents of respondents never visit the website (26%).

Lake Level and Precipitation Monitoring

Lake water-level fluctuations are important to lake managers, lakeshore property owners, developers, and persons using lakes for recreation. Lake level fluctuations can have significant effects on lake water quality and usability. Although lake levels naturally change from year to year, extreme high or low levels can present problems such as restricted water access, flooding, shoreline and structure damage, and changes in riparian (near shore) vegetation.

Records of lake water elevations can be very useful in understanding changes that may occur in lakes. While some lakes respond almost immediately to precipitation, other lakes do not reflect changes in precipitation until months later.

On April 23rd, 2012 Polk County Land and Water Resources Department staff met with volunteers from Church Pine, Round, and Big Lake to provide training on lake level and precipitation data monitoring. Seven residents attended the training and staff and rain gauges were installed on all three lakes. Staff gauges were set at an arbitrary height; therefore, lake levels are not comparable at a specific point in time. However, the relative changes in lake level across all three lakes are comparable.

Lake level and precipitation data were collected daily on all three lakes beginning on April 23rd and ending on September 30th. Staff gauges were removed on October 4th. Beginning on September 1st, the lake level readings on Big Lake were negative due to low water levels. When the staff gauge on Big Lake was removed, the water level was approximately five tenths of a foot below zero.

Seasonal precipitation totaled twenty-three inches on Church Pine Lake, twenty inches on Round Lake, and twenty-four inches on Big Lake. Shortly following precipitation events, the lake levels on Church Pine, Round, and Big Lake increased.

Over the course of the sampling season, lakes levels decreased by nearly a foot on all three lakes[6].

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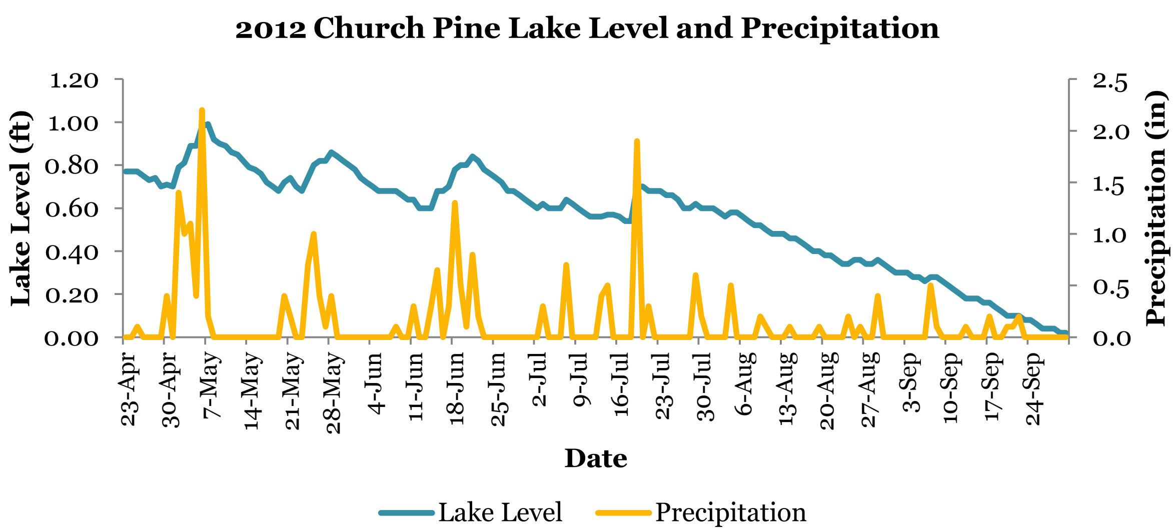
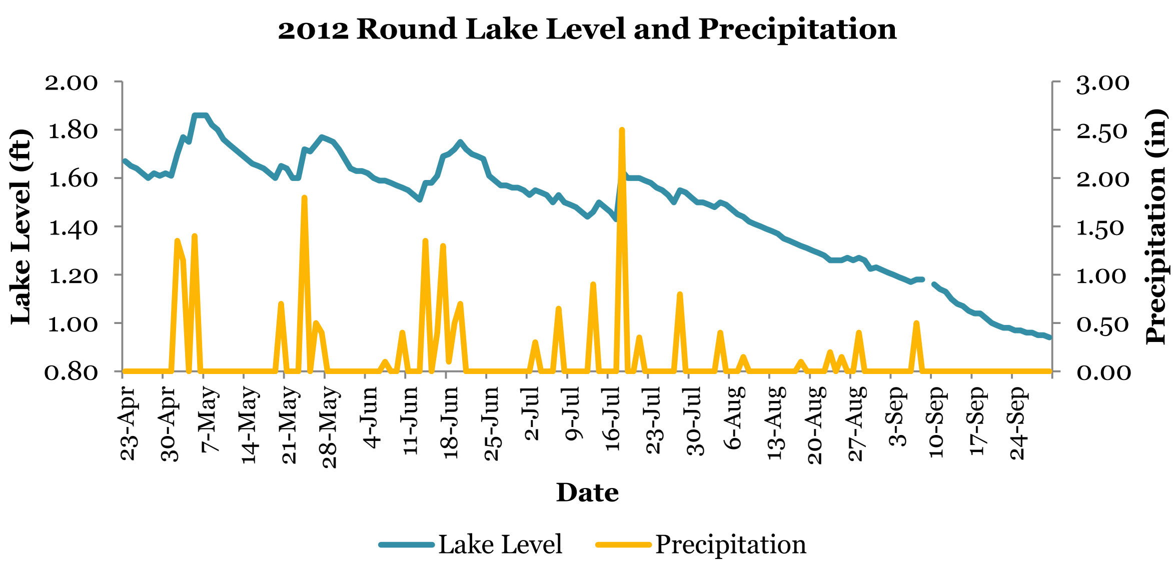
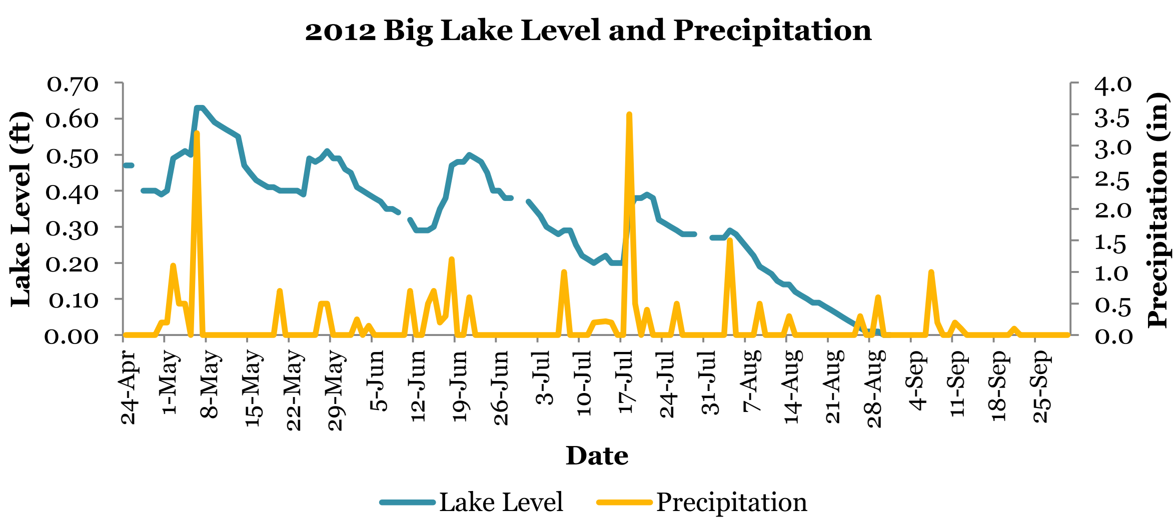
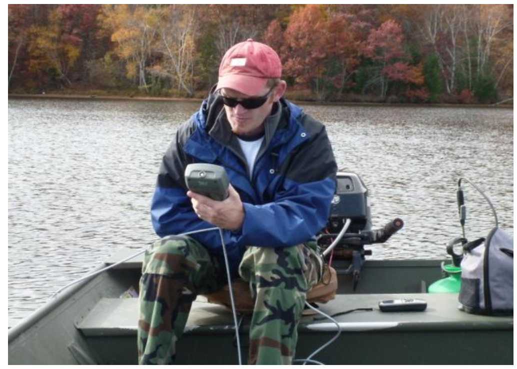
[6] Church Pine Lake 0.97 feet; Round Lake 0.92 feet; and Big Lake 1.13 feet (estimated by adding 0.5 feet to 0.63 feet).


2012 Church Pine Lake Level and Precipitation
Lake Level (ft)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Precipitation (in)
2.5
2.0
1.5
1.0
0.5
0.0
23-Apr
30-Apr
7-May
14-May
21-May
28-May
4-Jun
11-Jun
18-Jun
25-Jun
2-Jul
9-Jul
16-Jul
23-Jul
30-Jul
6-Aug
13-Aug
20-Aug
27-Aug
3-Sep
10-Sep
17-Sep
24-Sep
Date
Lake Level
Precipitation


2012 Round Lake Level and Precipitation
Lake Level (ft)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
Precipitation (in)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
23-Apr
30-Apr
7-May
14-May
21-May
28-May
4-Jun
11-Jun
18-Jun
25-Jun
2-Jul
9-Jul
16-Jul
23-Jul
30-Jul
6-Aug
13-Aug
20-Aug
27-Aug
3-Sep
10-Sep
17-Sep
24-Sep
Date
Lake Level
Precipitation


2012 Big Lake Level and Precipitation
Lake Level (ft)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Precipitation (in)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
24-Apr
1-May
8-May
15-May
22-May
29-May
5-Jun
12-Jun
19-Jun
26-Jun
3-Jul
10-Jul
17-Jul
24-Jul
31-Jul
7-Aug
14-Aug
21-Aug
28-Aug
4-Sep
11-Sep
18-Sep
25-Sep
Date
Lake Level
Precipitation

Chemical and Physical Data Sampling Procedure



Physical and chemical data were collected in lake at the deep hole of Church Pine, Round, and Big Lake from May 7th, 2012 through September 5th, 2012. Spring turnover samples were taken on April 3rd, 2012. However, since ice-out occurred around a month early, the lakes had already begun to stratify by this date. Fall turnover samples were taken on October 15th, 2012.

Two meter integrated samples were collected from the water column once a month during the growing season and at spring and fall turnover. Samples were analyzed at the Water and Environmental Analysis Lab (WEAL) at UW-Stevens Point for two types of phosphorus (total phosphorus and soluble reactive phosphorus), three types of nitrogen (nitrate/nitrite, ammonium, and total Kjeldahl nitrogen), chlorophyll *a*, chloride, and total suspended solids. In addition to these parameters, total hardness, calcium, sulfate, and, sodium were analyzed at both turnover events.

Lake profile monitoring—which included dissolved oxygen, temperature, conductivity, pH, and secchi depth—was conducted bi-monthly during the growing season. Dissolved oxygen, temperature, and conductivity readings were recorded at every meter within the water column using a YSI 85 multi-parameter probe. pH readings were recorded at every meter within the water column using a YSI 60 pH meter. During the second sampling set in July, both YSI meters stopped working. Beginning with the August 6th sample, lake profile monitoring was collected using an HI 9828 multi-parameter probe.

Secchi depth was recorded using a secchi disk, which is an eight inch diameter round disk with alternating black and white quadrants. To record secchi depth, the secchi disk was lowered into the lake on the shady side of a boat until it just disappeared from sight. This depth was measured in feet and recorded as the secchi depth.

In most instances in this report, data is presented as an average over the **growing season**, which refers to data collected from May through September and excludes turnover data, collected in April and October. In some instances, data is averaged over the **summer index period**, which refers to data collected from July 15th through September 15th.

Lake Mixing and Stratification: Background Information

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

Water quality is greatly affected by the degree to which the water in a lake mixes. Within a lake, mixing is most directly impacted by the temperature-density relationship of water. When comparing why certain lakes mix differently than others, lake area, depth, shape, and position in the landscape become important factors to consider.

Water reaches its greatest density at 3.9°C (39°F) and becomes less dense as temperatures increase and decrease. Compared to other liquids, the temperature-density relationship of water is unusual: liquid water is denser than water in its solid form (ice). As a result, ice floats on liquid water.

When ice melts in the early spring, the temperature and density of the water will be constant from the top to the bottom of the lake. This uniformity in density allows a lake to completely mix. As a result, oxygen is brought to the bottom of a lake, and nutrients are re-suspended from the sediments. This event is termed **spring overturn**.

In spring 2012, ice out on Church Pine, Round, and Big Lake occurred approximately a month earlier than what is typical in Polk County. Since the grant start date was April 1st, spring turnover samples were not taken until April 3rd. However, due to early ice out, the spring turnover samples were likely taken after spring turnover occurred.

As the sun's rays warm the surface waters in the spring, the water becomes less dense and remains at the surface. Warmer water is mixed deeper into the water column through wind and wave action. However, these forces can only mix water to a depth of approximately twenty to thirty feet. Generally, in a shallow lake, the water may remain mixed all summer. However, a deeper lake usually experiences layering called **stratification**.

During the summer, lakes have the potential to divide into three distinct zones: the **epilimnion**, **thermocline** or **metalimnion**, and the **hypolimnion**. The epilimnion describes the warmer surface layer of a lake; whereas the hypolimnion describes the cooler bottom area of a lake. The thermocline, or metalimnion, describes the transition area between the warmer surface layer and the cooler bottom layer.

As surface waters cool in the fall, they become denser and sink until the water temperature evens out from top to bottom. This process is called **fall overturn** and allows for a second mixing event to occur. Occasionally, algae blooms can occur at fall overturn when nutrients from the hypolimnion are made available throughout the water column.

The variations in density arising from different water temperatures can prevent warmer water from mixing with cooler water. As a result, nutrients released from the sediments can become trapped in the hypolimnion of a lake that stratifies. Additionally, because mixing is one of the main ways oxygen is distributed throughout a lake, lakes that don't mix have the potential to have very low levels of oxygen in the hypolimnion.

The absence of oxygen in the hypolimnion can have adverse effects on fisheries. Species of cold water fishes, such as trout, require the cooler waters that result from stratification. Cold water holds more oxygen as compared to warm water. As a result, the cooler waters of the hypolimnion can provide a refuge for cold water fisheries in the summer as long as oxygen is present. Respiration by plants, animals, and bacteria is the primary means by which oxygen is removed from the hypolimnion. A large algae bloom can cause oxygen depletion in the hypolimnion as algae die, sink, and decay.

In the winter, stratification remains constant because ice cover prevents mixing by wind action.

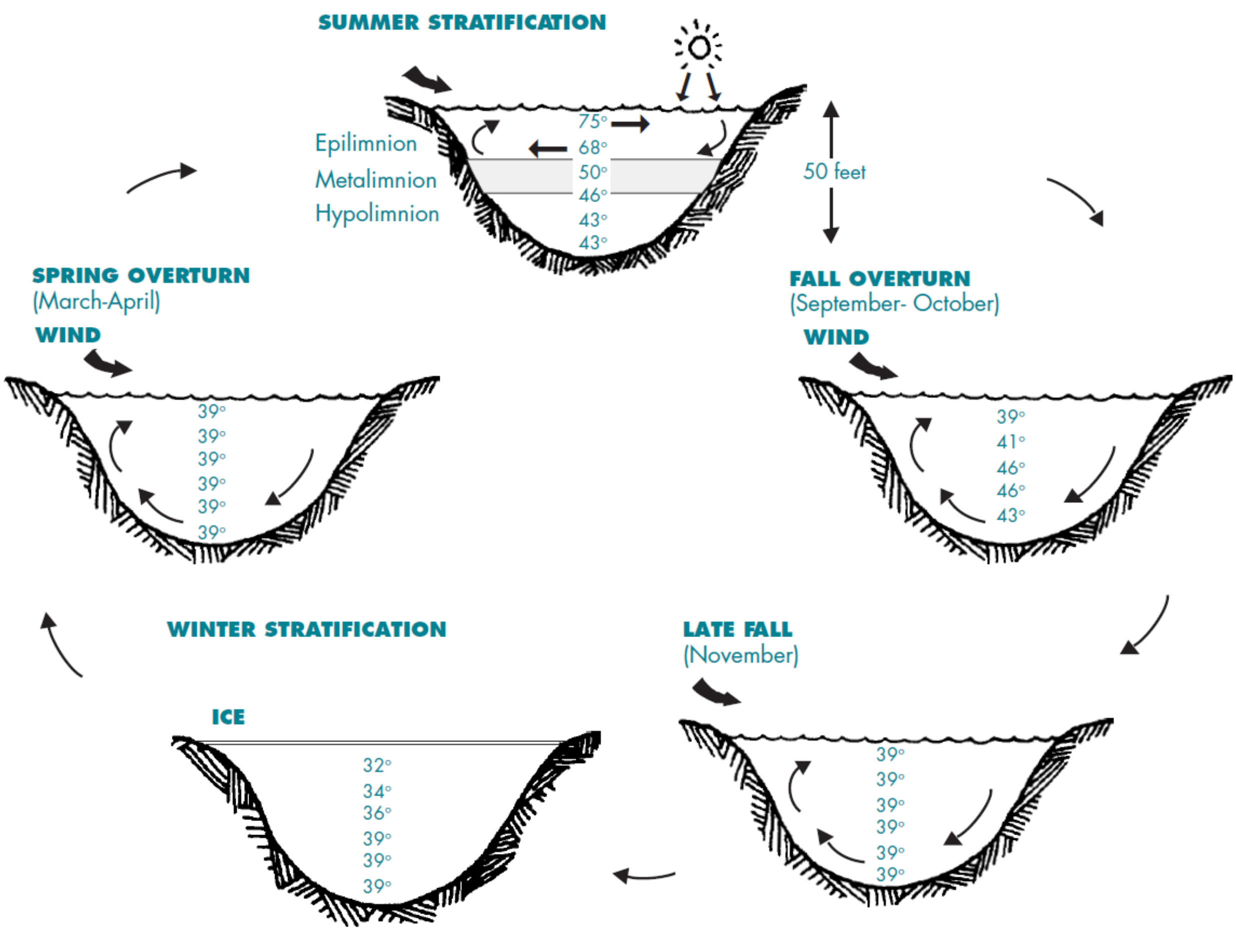
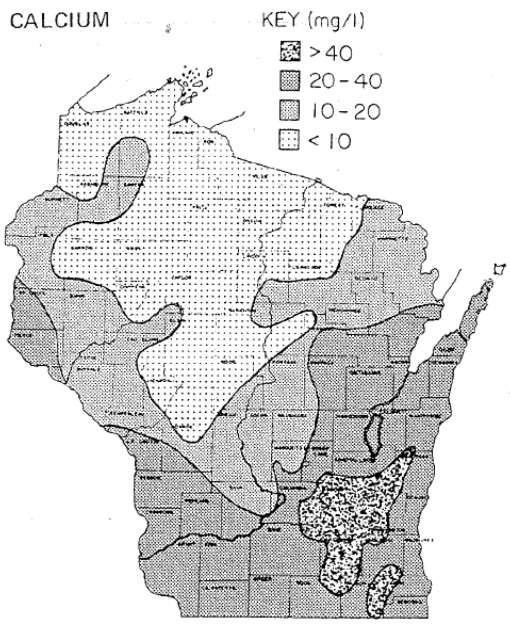


Figure from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

Turnover Data: Calcium, Magnesium, and Sulfate

Data for a number of chemical analyses occurred only at spring and fall turnover. These include calcium, magnesium[7], and sulfate.

Calcium and magnesium concentrations in Wisconsin lakes are closely related to the bedrock geology of the landscape, with highest concentrations found in areas with limestone and dolomite deposits. In Polk County, calcium concentrations typically range from 10-20 mg/L and magnesium concentrations are typically less than 10 mg/L (Lillie, 1983).



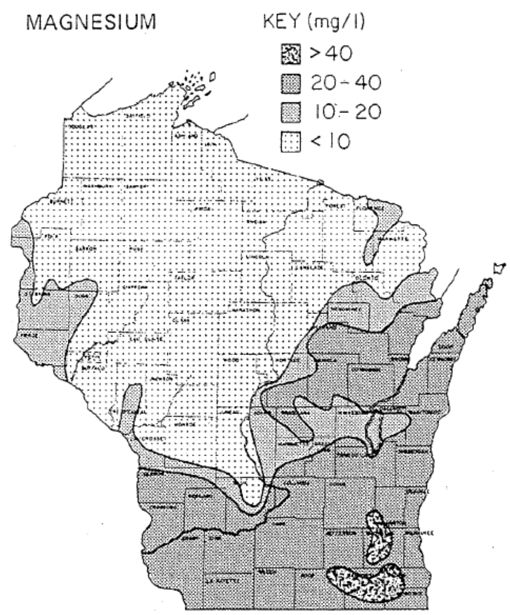


Figure from: (Lillie, 1983).

Average turnover calcium concentrations were elevated as compared to what is typical in Polk County lakes on Round and Big Lake (23.6 mg/L and 26.3 mg/L respectively); whereas concentrations where within the typical range on Church Pine Lake (17.3 mg/L).

Magnesium was only analyzed at fall turnover and was within the typical range for Polk County lakes on Church Pine, Round, and Big Lake.

	Church Pine Lake	Round Lake	Big Lake
Calcium (mg/L) *fall and spring turnover average	17.3	23.6	26.3
Magnesium (mg/L) *fall turnover value	7.5	8.5	8.8

[7] Magnesium was analyzed only at fall turnover.

Sulfate concentrations in lakes are most directly related to the types of minerals found in the watershed and to acid rain. Sulfur compounds released into the atmosphere by coal burning facilities can enter lakes via rainfall. In general, sulfate concentrations are higher in the southeastern portion of the state where mineral sources of sulfate and acid rain are more common.

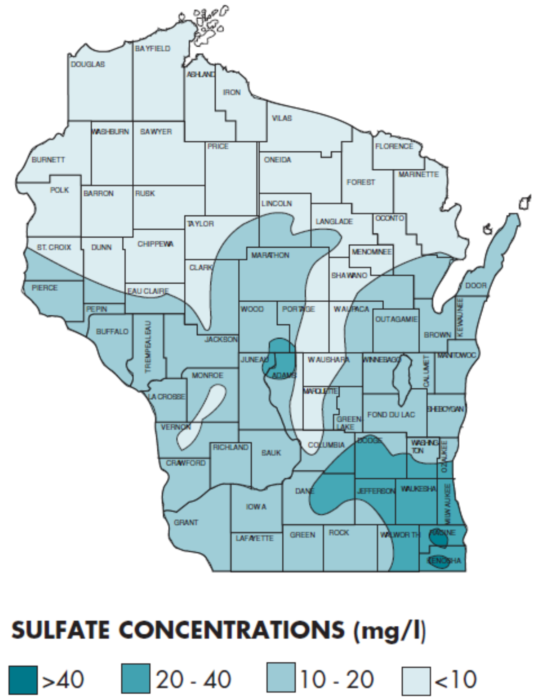


FIGURE 8. Generalized distribution gradients of sulfate in the surface waters of Wisconsin lakes. (*Adapted from Lillie and Mason, 1983.*)

In Polk County, sulfate concentrations are generally less than 10 mg/L (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

In Church Pine and Round Lake, average spring and fall turnover sulfate concentration was well below the typical concentration for Polk County (3.15 mg/L and 4.4 mg/L respectively).

At spring turnover in Big Lake, the sulfate concentration was well above what is typical in Polk County (21.3 mg/L); whereas at fall turnover the concentration was well below the typical concentration (5.2 mg/L).

Phosphorus

Phosphorus is an element present in lakes which is necessary for plant and algae growth. It occurs naturally in soil, rocks, and the atmosphere and can make its way into lakes through groundwater and soil erosion induced from construction site runoff or other human induced disturbances. Additional sources of phosphorus input into a lake can include fertilizer runoff from urban and agricultural settings and manure.

Phosphorus does not readily dissolve in water, instead it forms insoluble precipitates (particles) with calcium, iron, and aluminum. If oxygen is available, iron forms sediment particles that store phosphorus in the sediments. However, when lakes lose oxygen in the winter or when the hypolimnion becomes anoxic in the summer, these particles dissolve in the water. Strong wind action or turnover events can then re-distribute phosphorus throughout the water column.

While phosphorus is necessary for plant and animal growth, excessive amounts lead to an overabundance of growth which can decrease water clarity and lead to nutrient pollution in lakes. Phosphorus is present in lakes in several forms. This study measured two forms of phosphorus: total phosphorus and soluble reactive phosphorus.

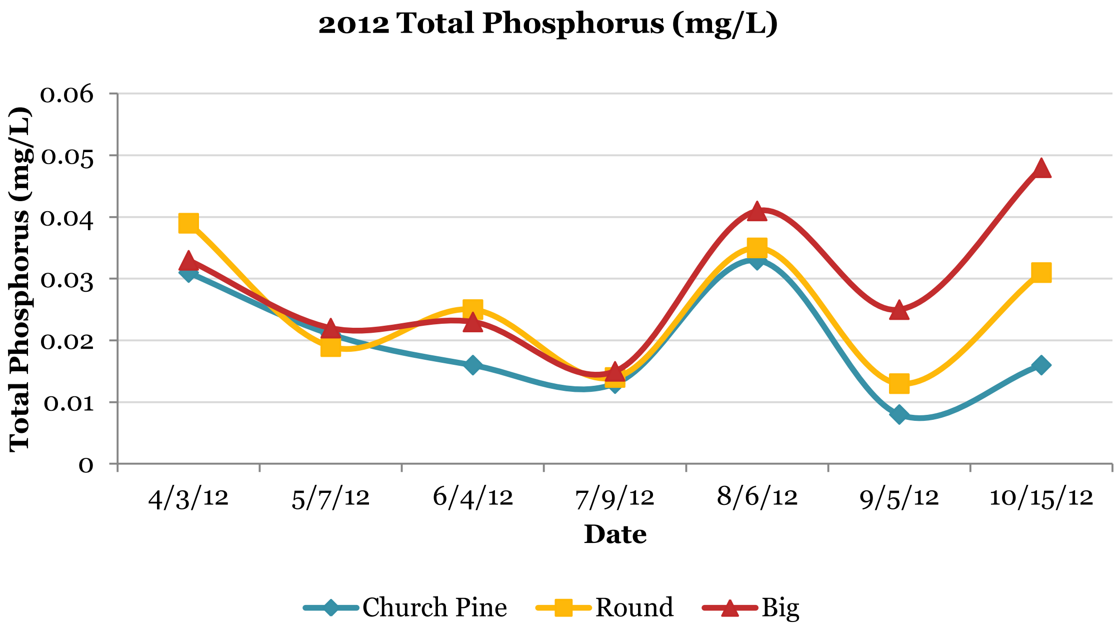
Total phosphorus is a measure of all the phosphorus in a sample of water. In many cases total phosphorus is the preferred indicator of a lake's nutrient status because it remains more stable than other forms over an annual cycle. **Soluble reactive phosphorus** includes forms of phosphorus that are dissolved in the water and are readily available for uptake by algae and aquatic macrophytes (plants).

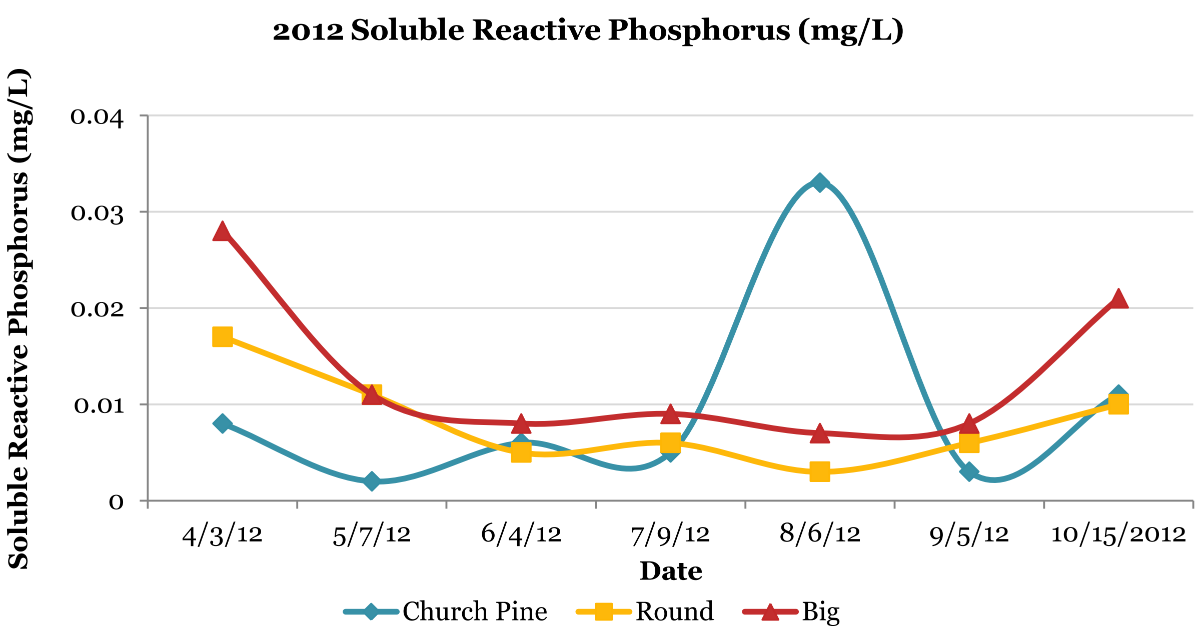
Ideally, soluble reactive phosphorus concentrations should be below 0.01 mg/L at spring turnover to prevent summer algae blooms. Soluble reactive phosphorus was below this threshold on Church Pine Lake (0.008 mg/L), but above this threshold on Round and Big Lake (0.017 mg/L and 0.028 mg/L, respectively).

A concentration of total phosphorus below 0.02 mg/L should be maintained to prevent nuisance algae blooms. Although this threshold was exceeded in all lakes on at least one date, the growing season average was below this threshold on Church Pine Lake (0.0182 mg/L), at this threshold on Round Lake (0.0212 mg/L), and slightly above this threshold on Big Lake (0.0252 mg/L).

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

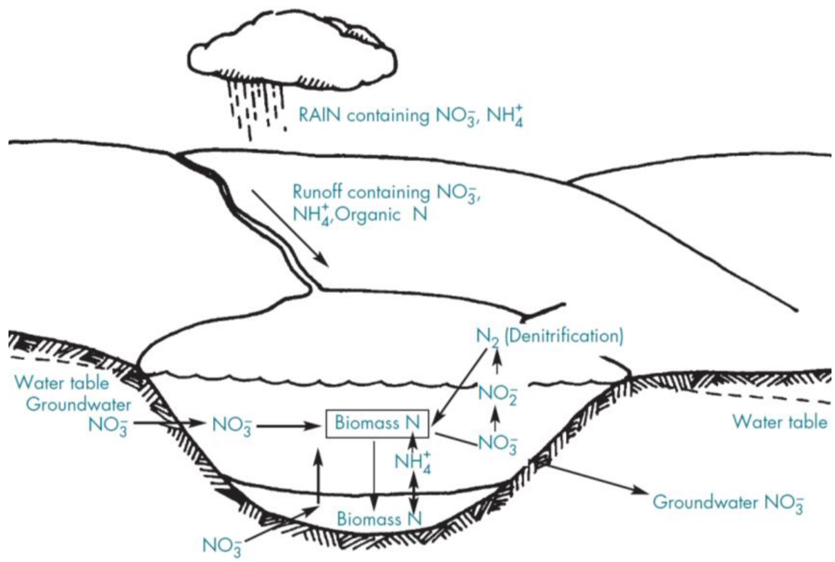
More importantly, the total phosphorus criteria for impairment, as averaged over the summer index period, is 0.030 mg/L for Church Pine Lake and 0.040 mg/L for Round and Big Lake. In 2012, these criteria were met in all three lakes (Church Pine Lake = 0.0205 mg/L; Round Lake = 0.024 mg/L; and Big Lake = 0.024mg/L).





Nitrogen

Nitrogen, like phosphorus, is an element necessary for plant growth. Nitrogen sources in a lake can vary widely. Although nitrogen does not occur naturally in soil minerals, it is a major component of all plant and animal matter. The decomposition of plant and animal matter releases ammonia, which is converted to nitrate in the presence of oxygen. This reaction accelerates when water temperatures increase. Nitrogen can also be introduced to a lake through rainfall, in the form of nitrate and ammonium, and through groundwater in the form of nitrate.



In most instances, the amount of nitrogen in a lake corresponds to land use. Nitrogen can enter a lake from surface runoff or groundwater sources as a result of fertilization of lawns and agricultural fields, animal waste, or human waste from septic systems or sewage treatment plants. During spring and fall turnover events, nitrogen is recycled back into the water column which can cause spikes in ammonia levels. Under low oxygen conditions, nitrogen can be lost from a lake system through a process called denitrification. Under these conditions nitrate is converted to nitrogen gas. Additionally, nitrogen can be lost through permanent sedimentation.

Nitrogen comprises the majority (78%) of the gases in the Earth's atmosphere. As with other gases nitrogen is more soluble in cooler water as compared to warmer water. Nitrogen gas is not readily available to most aquatic plants, with the exception of blue green which are the only algae able to fix nitrogen from the atmosphere.

Similar to phosphorus, nitrogen is divided into many components. In this study nitrate/nitrite, ammonium, and total Kjeldahl nitrogen were analyzed.

Nitrate/nitrite and ammonium are all **inorganic** forms of nitrogen which can be used by aquatic plants and algae. Inorganic nitrogen concentrations above 0.3 mg/L in the spring indicate sufficient nitrogen to support summer algae blooms. Inorganic nitrogen concentrations at spring turnover were below this threshold on Church Pine and Round Lake and above this threshold on Big Lake.

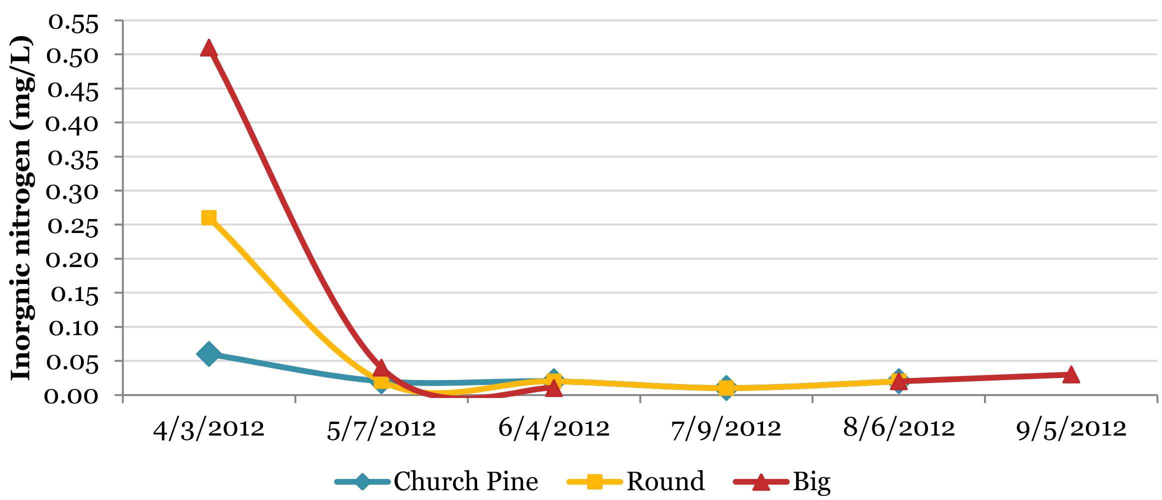
With the exception of Round and Big Lake at spring turnover, nitrate/nitrite levels were below the limit of detection (0.1 mg/L) in all lakes on all sample dates. Additionally, in Big Lake on July 9th, Church Pine Lake on September 5th, and Round Lake on September 5th, inorganic nitrogen levels were below the limit of detection (nitrate/nitrite <0.1 mg/L and ammonium <0.01 mg/L).

Total Kjeldahl nitrogen is a measure of organic nitrogen plus ammonium. By subtracting the ammonium concentration from TKN, the organic nitrogen concentration found in plants and algal material can be found.

Figure and information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

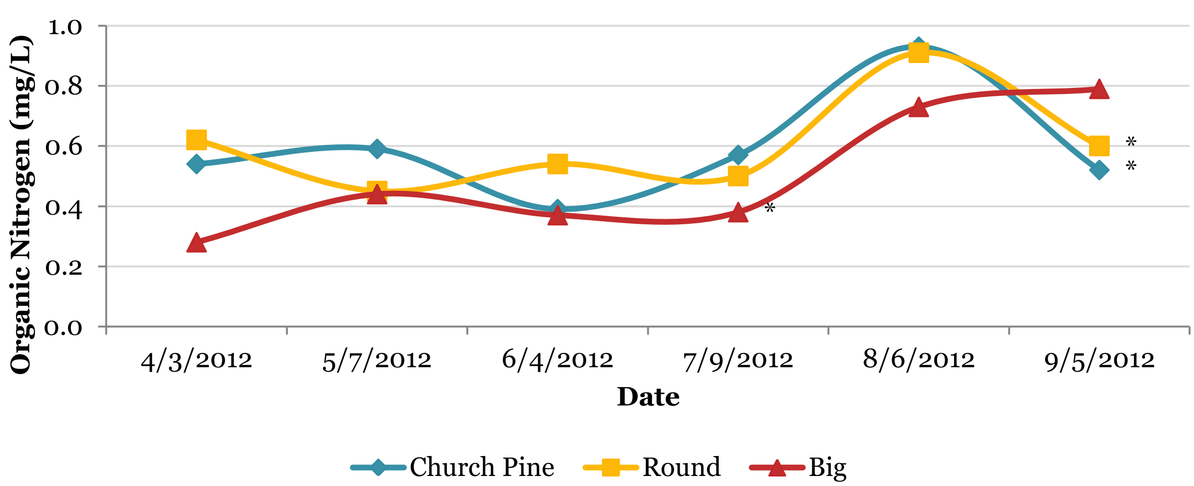
2012 Inorganic Nitrogen (mg/L)

excludes samples where inorganic nitrogen was below the limit of detection



2012 Organic Nitrogen in plants and algae (mg/L)

** indicates samples where ammonia was below the limit of detection*



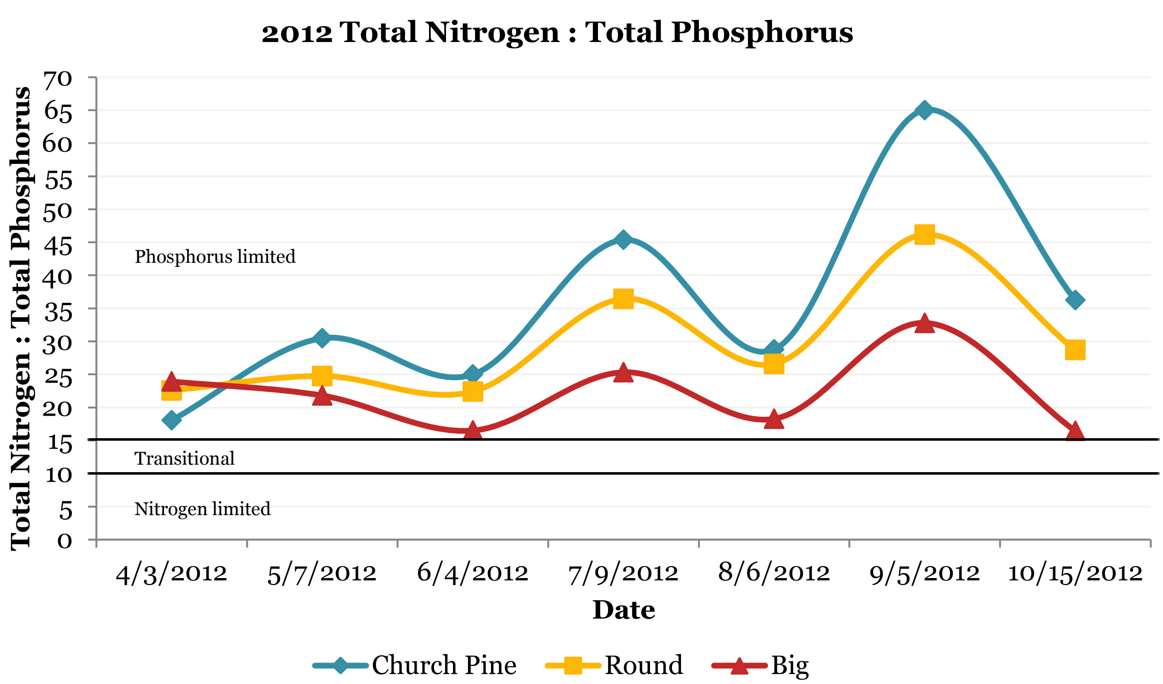
Total Nitrogen to Total Phosphorus Ratio

The total nitrogen to total phosphorus ratio (TN: TP) is a calculation that depicts which nutrient limits algae growth in a lake.

Lakes are considered nitrogen limited, or sensitive to the amount of nitrogen inputs into a lake, when TN: TP ratios are less than 10. Only about 10% of Wisconsin lakes are limited by nitrogen. In contrast, lakes are considered phosphorus limited, or sensitive to the amount of phosphorus inputs into a lake, when the TN: TP ratio is above 15. Lakes with values between 10 and 15 are considered transitional. In transitional lakes it is impossible to determine which nutrient, either nitrogen or phosphorus, is limiting algae growth (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

Total nitrogen is found by adding NO2+NO3+TKN. However, with the exception of spring turnover in Round and Big Lake, NO2+NO3 was <0.1 mg/L in all lakes at all sample dates. The ratios below do not include the addition of NO2+NO3 when the value was <0.1 mg/L. However, even without these values the calculations show that all lakes are phosphorus limited. If a value of 0.1 mg/L was used in place of <0.1 mg/L the ratio would be pushed upwards indicating an even greater phosphorus limitation.

The total nitrogen to total phosphorus ratio for Church Pine, Round, and Big Lake indicates a phosphorus limited state at all sample dates. The ratio indicates that Church Pine Lake experienced the greatest phosphorus limitation, followed by Round, and Big Lake. Generally lakes with high TN: TP ratios have good water quality (Lillie, 1983).



Chloride

Although chloride does not directly negatively impact plants, algae, or aquatic organisms, elevated levels of chloride in a lake can indicate possible water pollution.

With the exception of limestone deposits, chloride is uncommon in Wisconsin soils, rocks, and minerals. Background levels of chloride are generally found in small quantities in nearly every Wisconsin lake and can be introduced to waterways through rainwater.

The watershed for Church Pine, Round, and Big Lakes is located in an area where chloride concentrations can be expected to range from greater than three up to ten mg/L.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

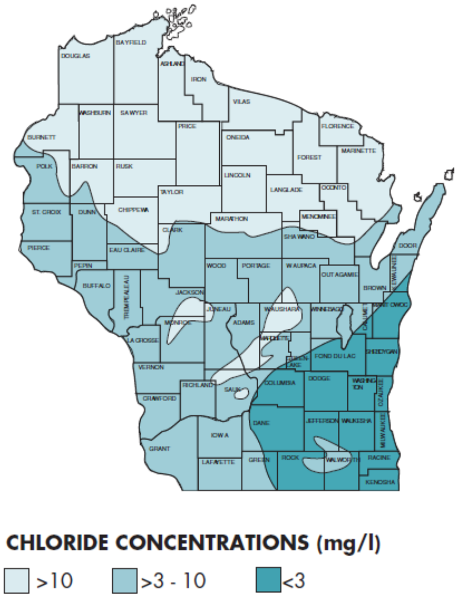
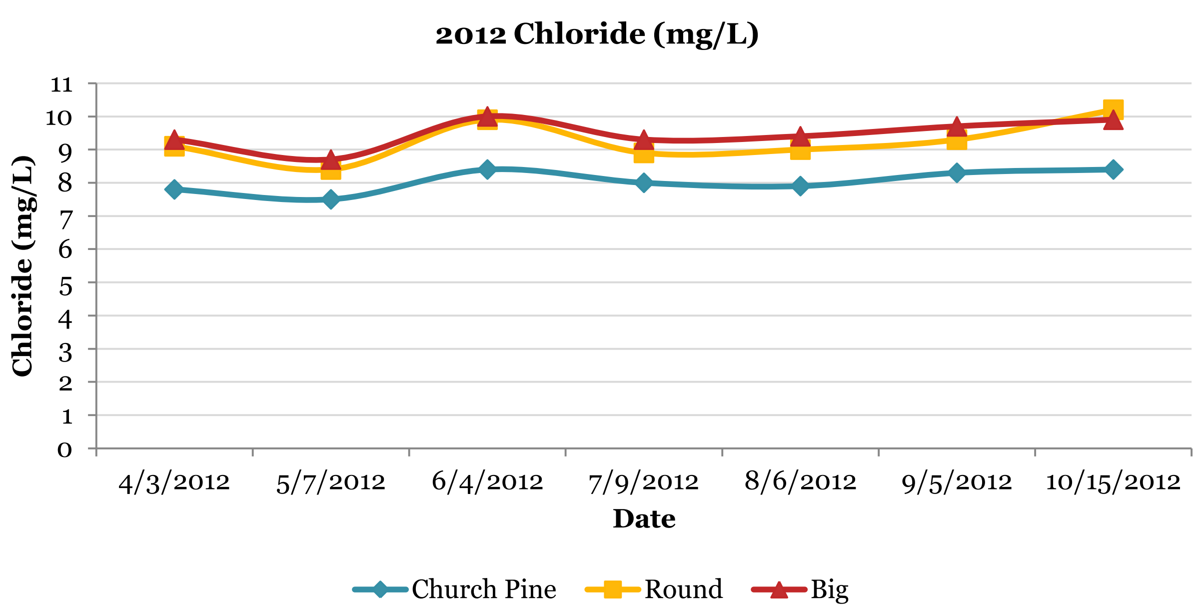


FIGURE 7. Generalized distribution gradients of chloride in the surface waters of Wisconsin lakes. (*Adapted from Lillie and Mason, 1983.*)

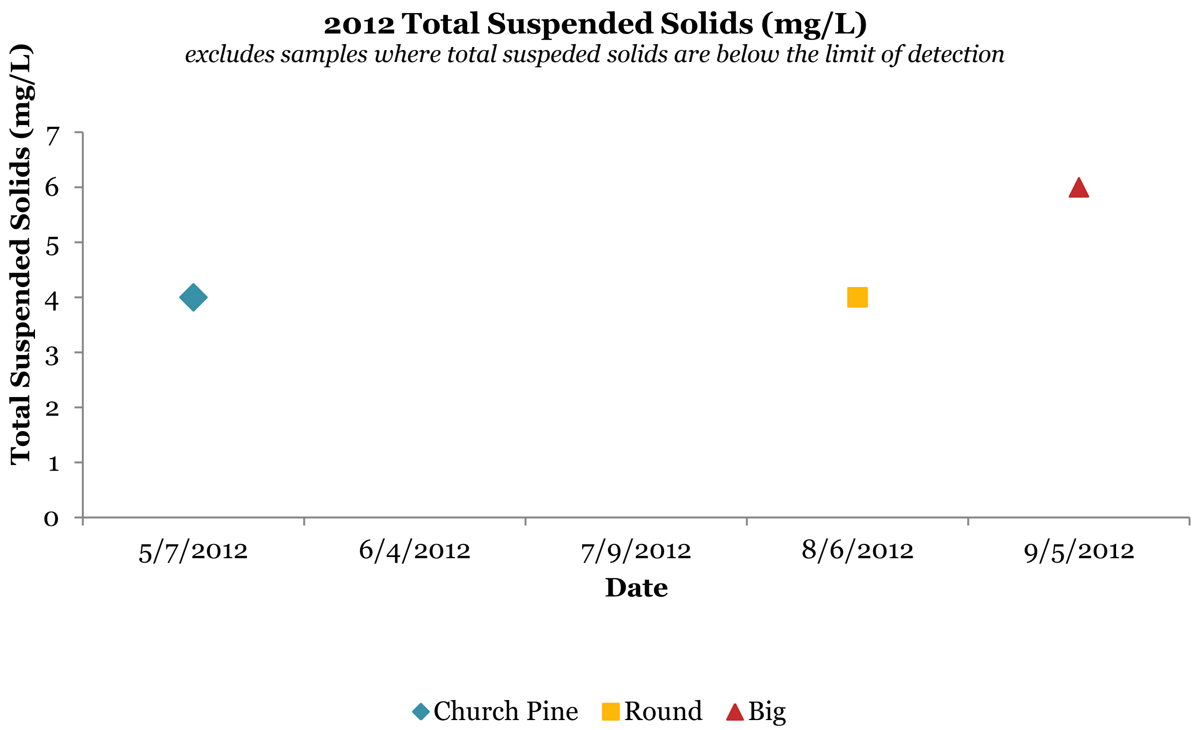
Chloride concentrations in the three lake system range from 7.5 mg/L up to 10 mg/L with values being lowest in Church Pine Lake, followed by Round Lake and Big Lake. Average growing season chloride concentrations were 8 mg/L in Church Pine Lake, 9.1 mg/L in Round Lake, and 9.4 mg/L in Big Lake.



Total Suspended Solids

Total suspended solids (TSS) quantify the amount of inorganic matter that is floating in the water column. Wind, waves, boats, and even some fish species can stir up sediments from the lake bottom re-suspending them in the water column. Fine sediments, especially clay, can remain suspended in the water column for weeks. These particles scatter light and decrease water transparency.

Total suspended solids were below the limit of detection (2 mg/L) in all lakes at all sampling dates with the exception of Church Pine Lake on May 7th, Round Lake on August 6th and Big Lake on September 5th.



Dissolved Oxygen

Oxygen is required by all aquatic organisms for survival. The amount of oxygen dissolved in water depends on water temperature, the amount of wind mixing that brings water into contact with the atmosphere, the biological activity that consumes or produces oxygen within a lake, and the composition of groundwater and surface water entering a lake.

In a process called photosynthesis, plants use carbon dioxide, water, and the sun's energy to produce simple sugars and oxygen. Chlorophyll, the pigment in plants that captures the light energy necessary for photosynthesis, is the site where oxygen is produced. Since photosynthesis requires light, the oxygen producing process only occurs during the daylight hours and only at depths where sunlight can penetrate.

Plants and animals also use oxygen in a process called respiration. During respiration, sugar and oxygen are used by plants and animals to produce carbon dioxide and water.

Temperature °C	Temperature °F	Oxygen solubility (mg/L)
0	32	15
5	41	13
10	50	11
15	59	10
20	68	9
25	77	8

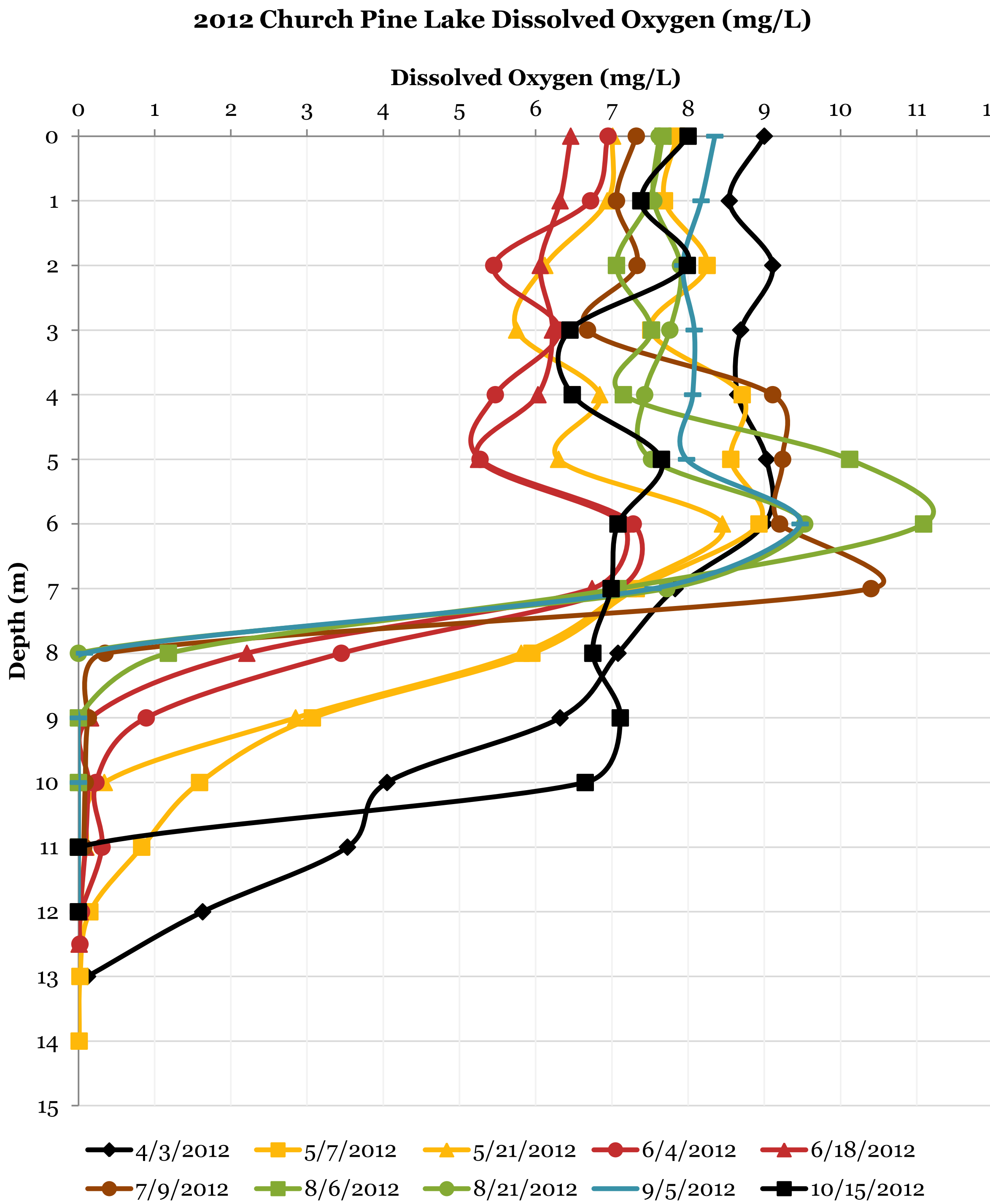
Cold water is able to hold more oxygen as compared to warm water. However, although temperatures are coolest in the deepest part of a lake, these waters often do not contain the most oxygen. This arises because in the deepest parts of lakes, oxygen producing photosynthesis is not occurring, mixing is unable to introduce oxygen, and the only reaction occurring is oxygen consuming respiration. Therefore, it is not uncommon for oxygen depletion to occur in the hypolimnion.

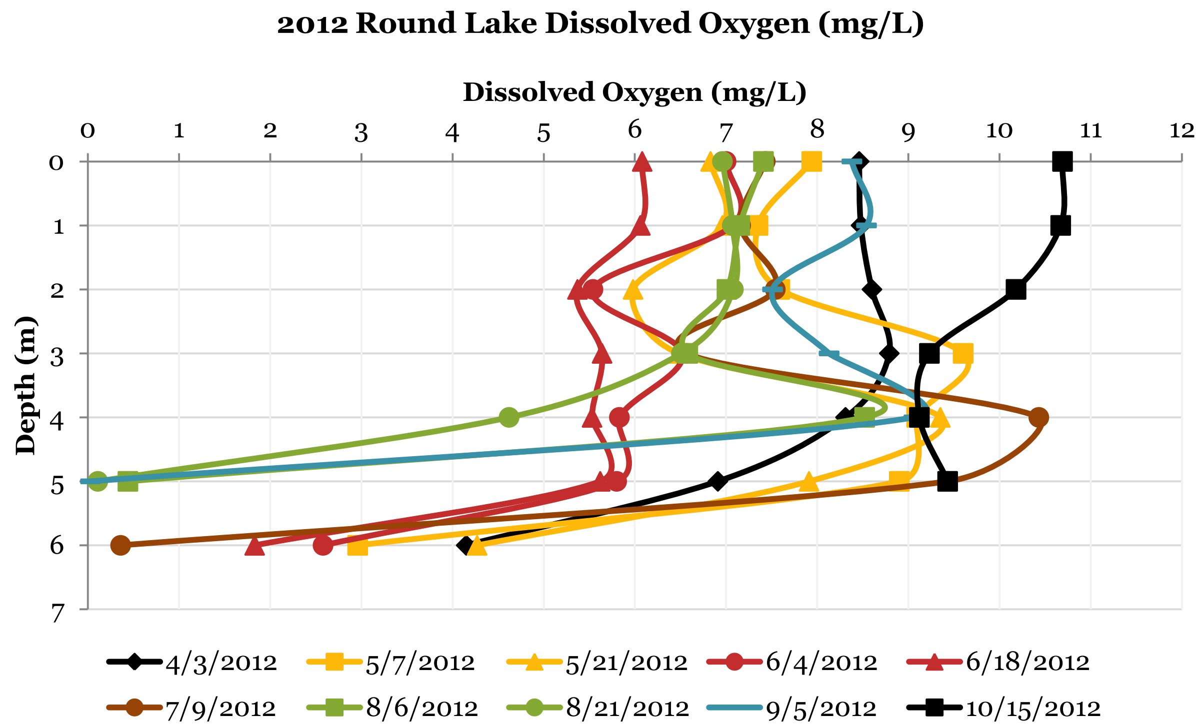
During the sunlight hours, when photosynthesis is occurring, dissolved oxygen levels at a lake's surface may exceed the oxygen solubility values. Conversely, at night or early in the morning (when photosynthesis is not occurring), the dissolved oxygen values can be expected to be lower.

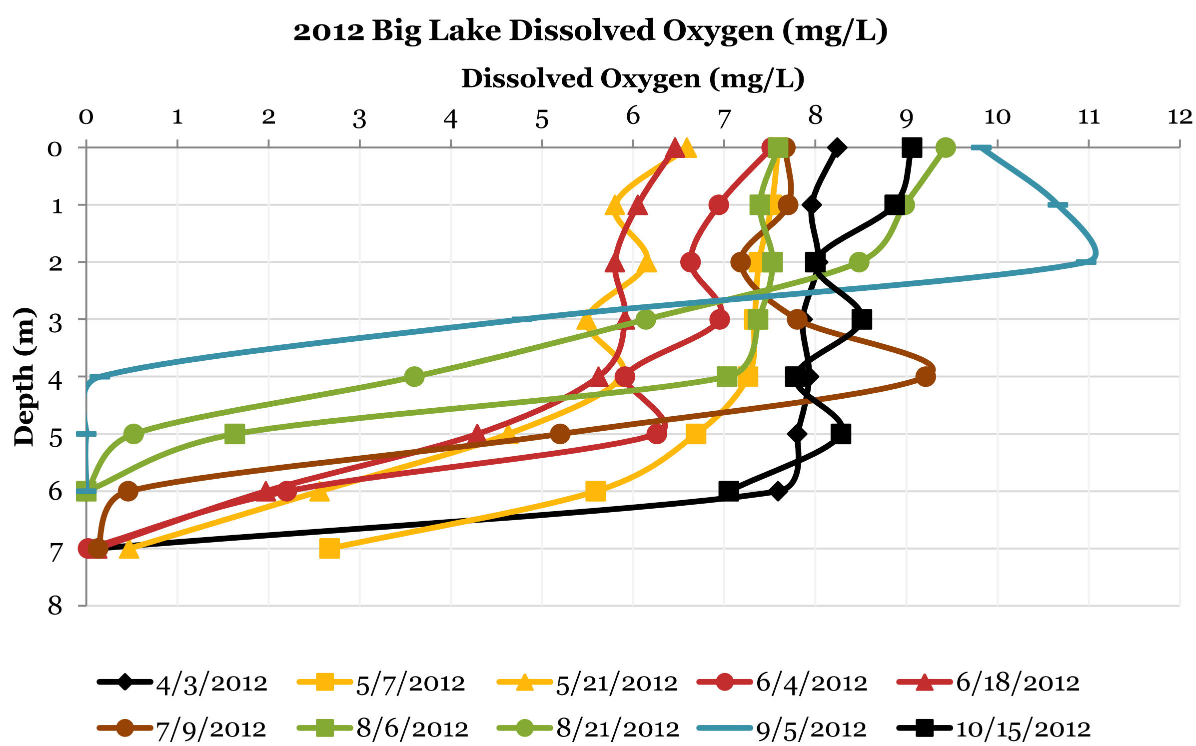
A water quality standard for dissolved oxygen in warm water lakes and streams is set at 5 mg/L. This standard is based on the minimum amount of oxygen required by fish for survival and growth. For cold water lakes supporting trout, the standard is set even higher at 7 mg/L.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

Oxygen levels in all three lakes remained above 5 mg/L near the surface but dropped below this threshold in the bottom waters. In Church Pine and Big Lake bottom waters were anoxic (<1 mg/L) during the majority of the sampling season.


2012 Church Pine Lake Dissolved Oxygen (mg/L)
Dissolved Oxygen (mg/L)
0 1 2 3 4 5 6 7 8 9 10 11 12
Depth (m)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
4/3/2012
5/7/2012
5/21/2012
6/4/2012
6/18/2012
7/9/2012
8/6/2012
8/21/2012
9/5/2012
10/15/2012


2012 Round Lake Dissolved Oxygen (mg/L)
Dissolved Oxygen (mg/L)
0 1 2 3 4 5 6 7 8 9 10 11 12
Depth (m)
0 1 2 3 4 5 6 7
4/3/2012
5/7/2012
5/21/2012
6/4/2012
6/18/2012
7/9/2012
8/6/2012
8/21/2012
9/5/2012
10/15/2012


2012 Big Lake Dissolved Oxygen (mg/L)
Dissolved Oxygen (mg/L)
0 1 2 3 4 5 6 7 8 9 10 11 12
Depth (m)
0 1 2 3 4 5 6 7 8
4/3/2012
5/7/2012
5/21/2012
6/4/2012
6/18/2012
7/9/2012
8/6/2012
8/21/2012
9/5/2012
10/15/2012

Temperature

Church Pine, Round, and Big Lake all reached their warmest surface temperature (~28°C) on July 9th, 2012. By examining the temperature profiles it is clear that in 2012 Church Pine Lake stratified, Round Lake weakly stratified, and Big Lake very weakly stratified. The average growing season differences between surface and bottom temperatures were 14.60°C in Church Pine Lake, 8.33°C in Round Lake, and 4.75°C in Big Lake.

In Church Pine Lake, the lake developed water temperature (thus density) differences that created distinct layers in the water column. As a result, in Church Pine Lake wind and wave action are unable to mix the benthic waters with the surface waters.

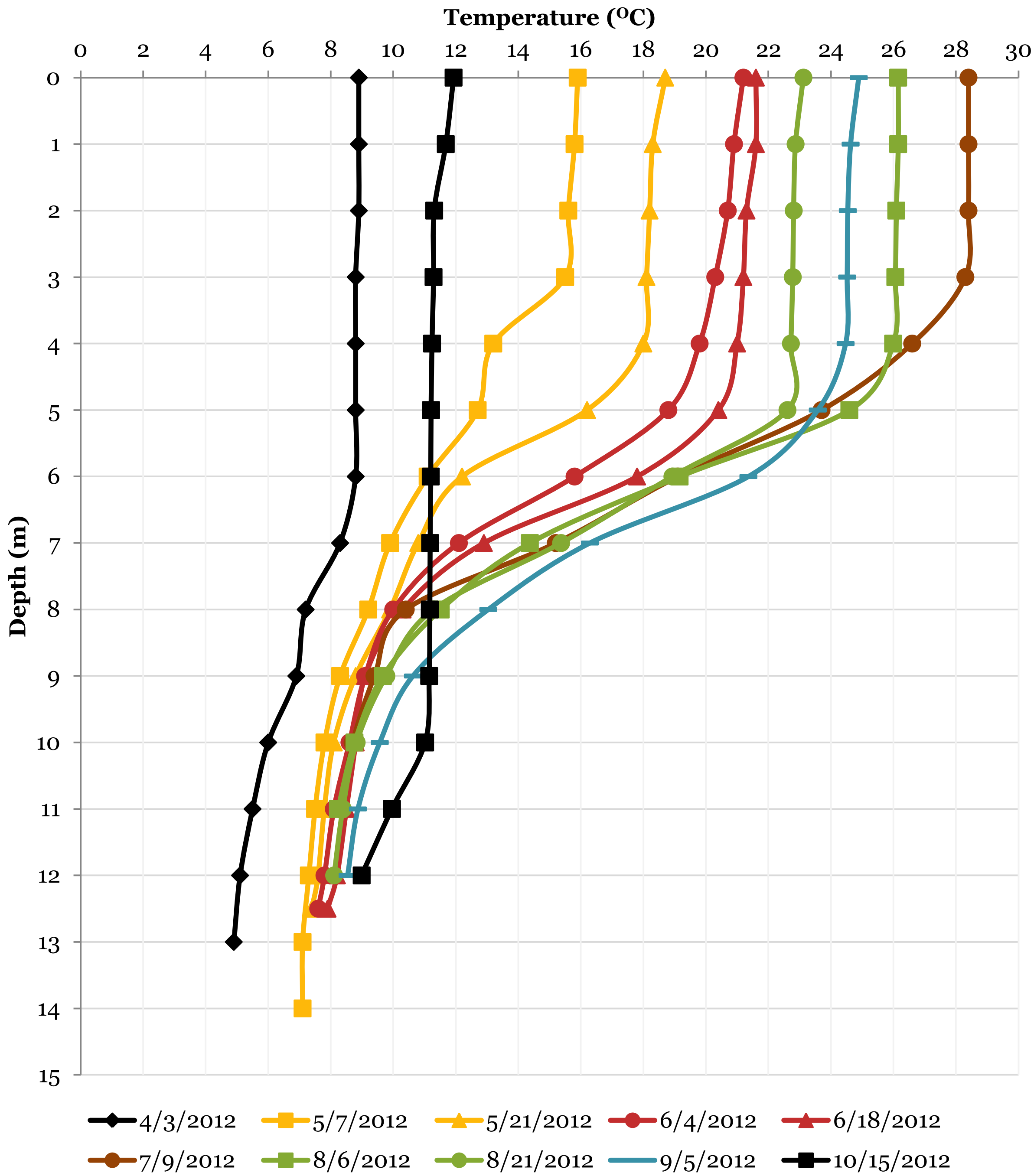
Round Lake experienced weak stratification which intensified as the summer progressed.

During the majority of the 2012 growing season, Big Lake did not stratify. When the Lake reached its maximum temperatures (July and August), slight temperature (density) differences did exist throughout the water column.

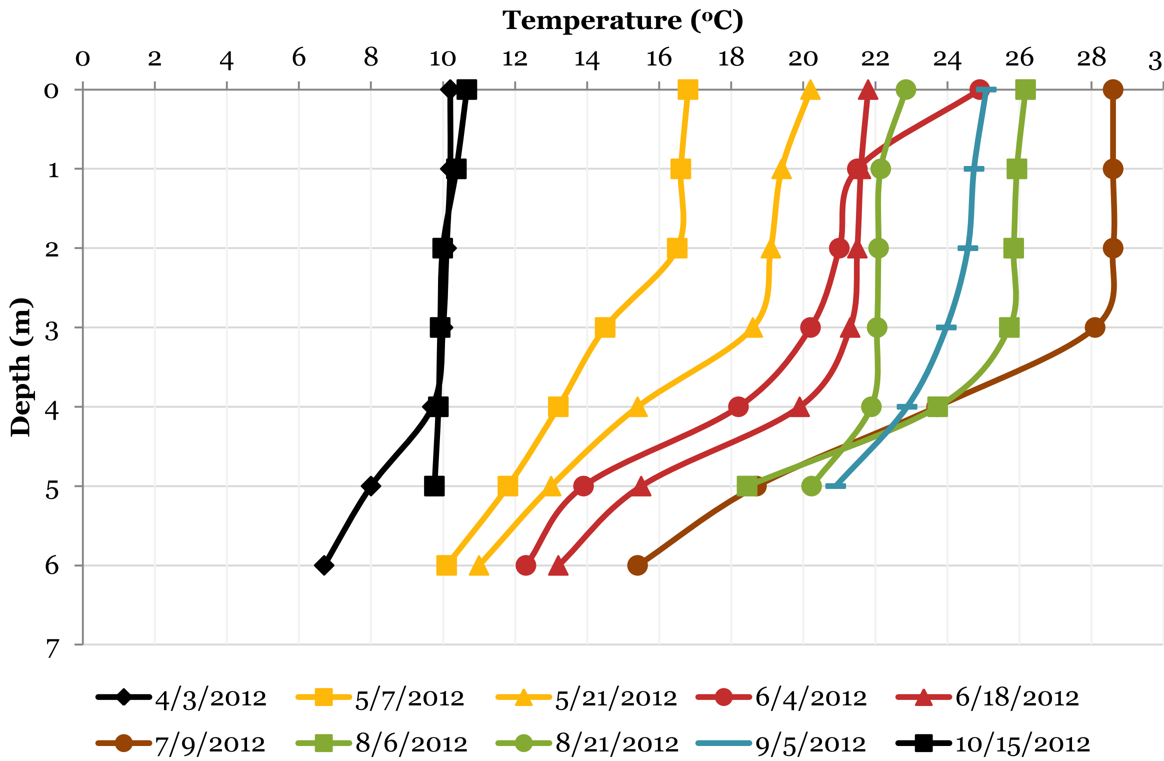
Church Pine Lake is nearly twice the depth of Round and Big Lake. Likely, the depth of Church Pine Lake is the primary explanation for why this lake stratifies. The surface area of Big Lake is over twice the size of Church Pine Lake and the surface area of Church Pine Lake is over twice the size of Round Lake. Likely the difference in surface area between Big and Round Lake is the primary explanation for why these lakes differ in stratification. Big Lake has a greater surface area exposed to wind and wave action as compared to Round Lake.

Additionally, qualitative data during the 2012 sampling season suggests a much greater degree of boat/jet ski traffic on Big Lake as compared to Round Lake. Depending on speed and horsepower, boat/jet ski traffic can have an effect similar to a large storm event in terms of mixing. Additionally, Round Lake may be more sheltered in the landscape as compared to Big Lake. When sampling on windy days, Round Lake was much calmer as compared to Big Lake.

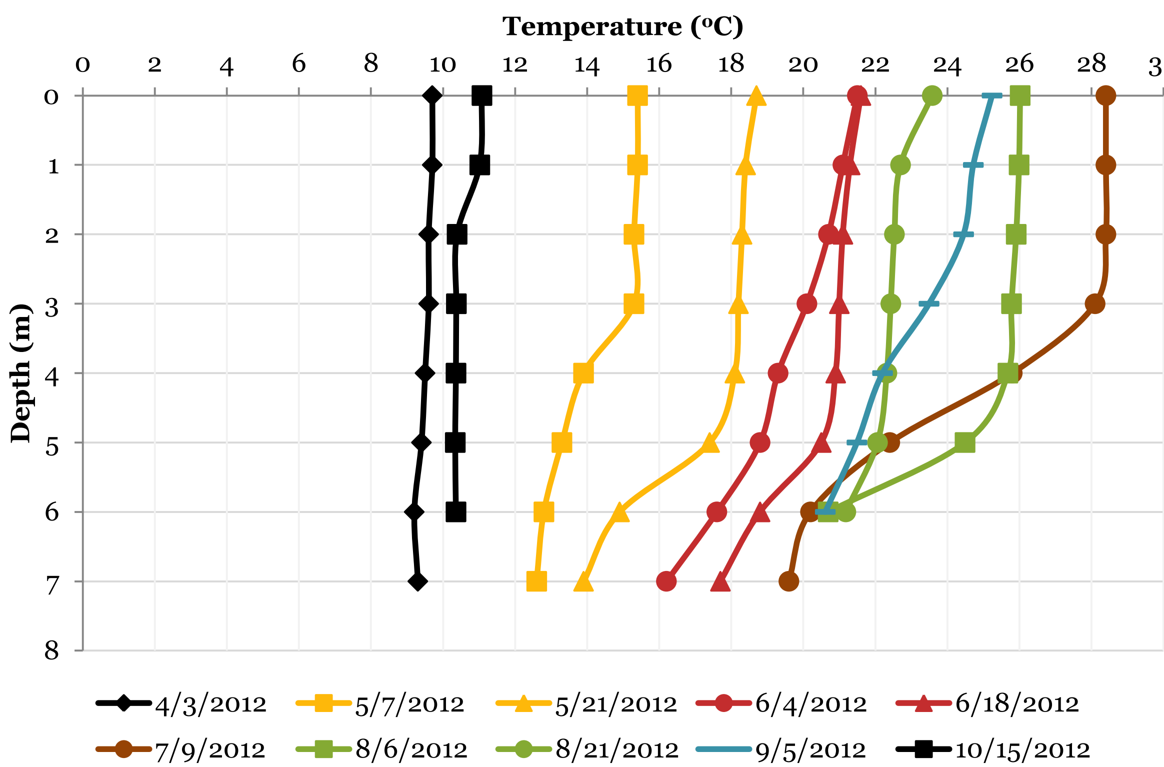
2012 Church Pine Lake Temperature (°C)



2012 Round Lake Temperature (°C)



2012 Big Lake Temperature (°C)



Conductivity (Specific Conductance)

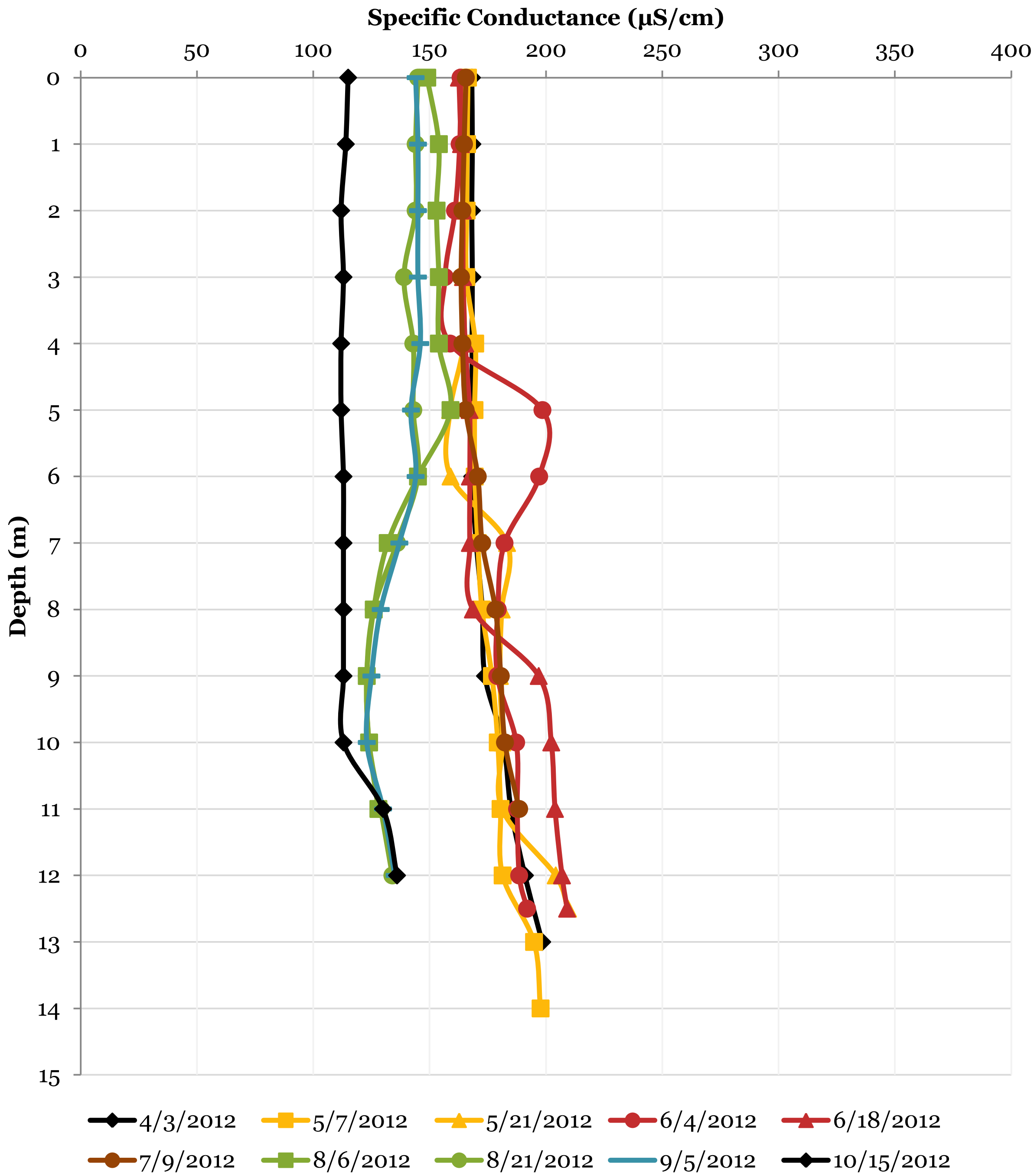
Conductivity is the measure of the ability of water to conduct an electrical current and serves as an indicator of the concentration of total dissolved inorganic chemicals in the water. Since conductivity is temperature related, reported values are normalized at 25°C and termed specific conductance. Specific conductance increases as the concentration of dissolved minerals in a lake increase.

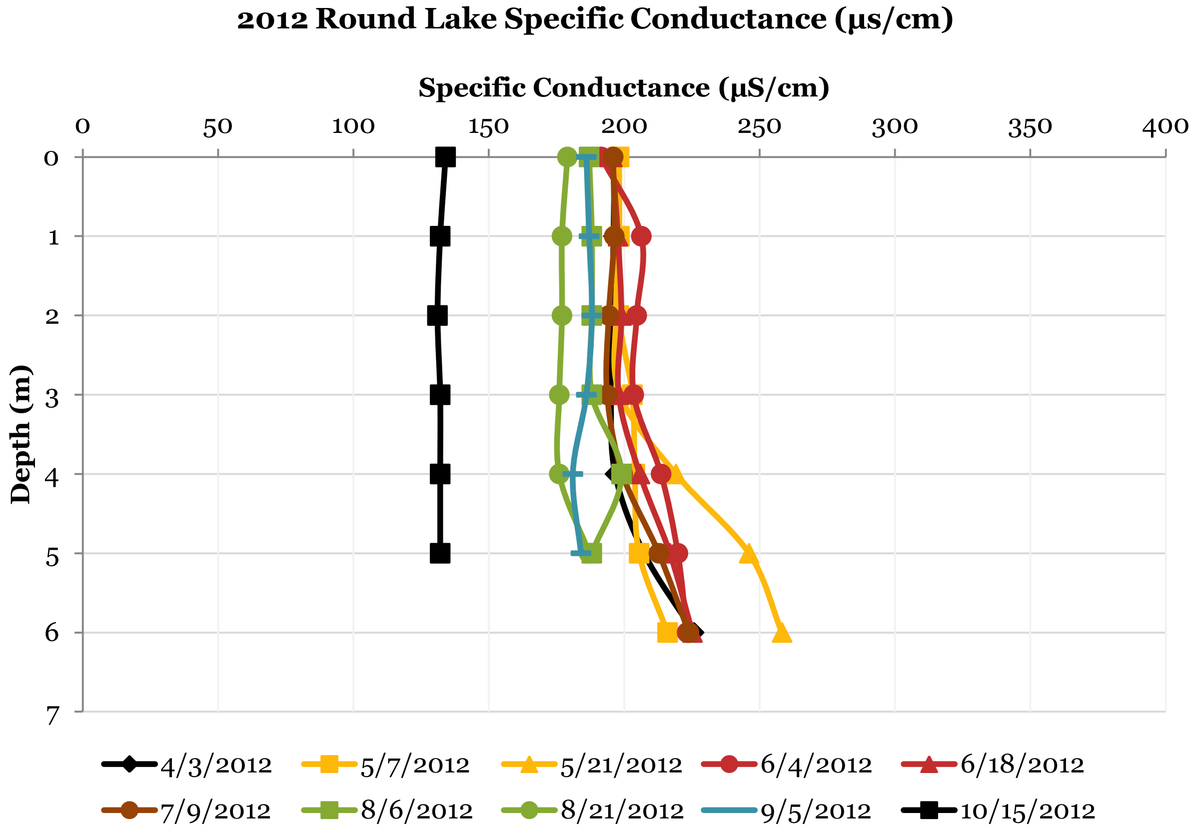
Specific conductance values are typically two times the water hardness. Hardness is the quantity of cations with more than one positive charge, primarily calcium and magnesium. Soluble minerals, especially limestone, in a lakes watershed impact the value for hardness. A categorization of hardness indicates that Church Pine, Round, and Big Lake are all moderately hard (between 61-120 mg/L).

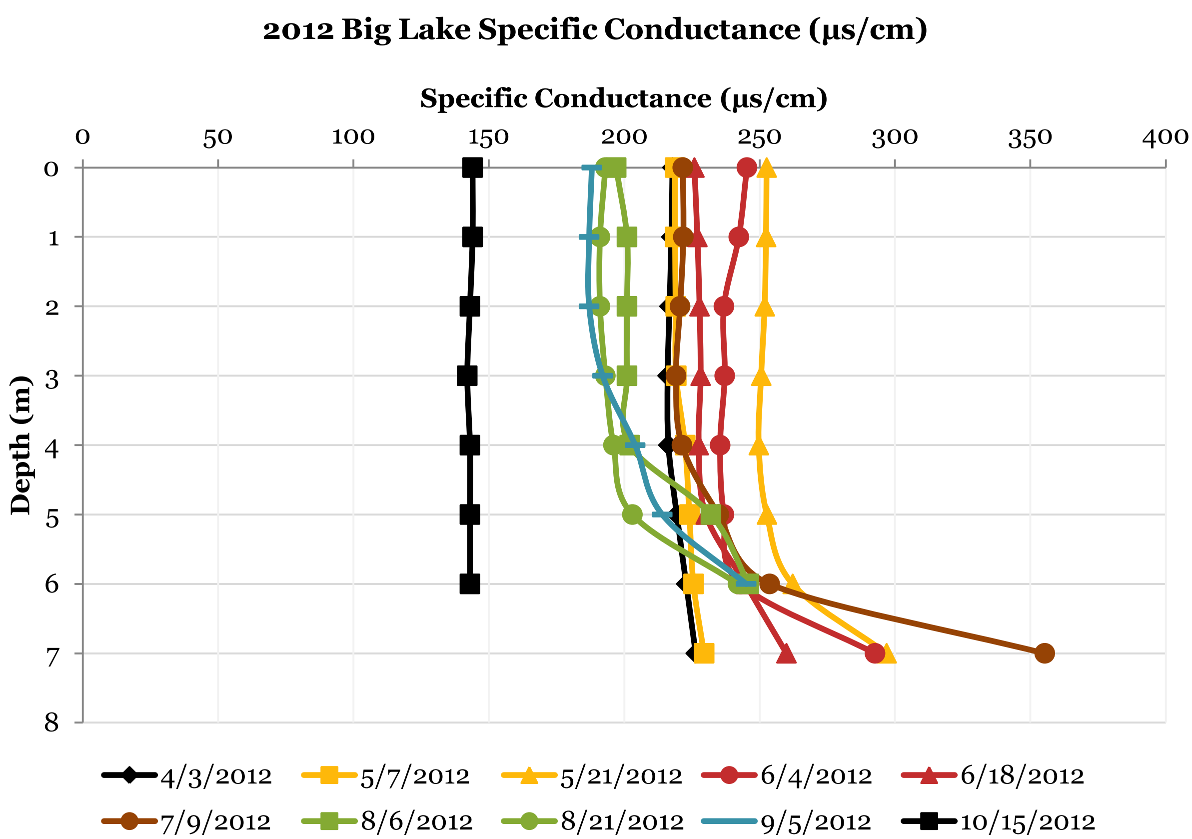
Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

In general, conductivity was lowest on Church Pine Lake and greatest on Big Lake. Conductivity values in Church Pine fell largely between 100-200 µS/cm, values in Round Lake fell between 150-250 µS/cm, and values in Big Lake fell between 150-300 µS/cm.

2012 Church Pine Lake Specific Conductance (µS/cm)




2012 Round Lake Specific Conductance (µs/cm)
Specific Conductance (µS/cm)
0
50
100
150
200
250
300
350
400
Depth (m)
0
1
2
3
4
5
6
7
4/3/2012
5/7/2012
5/21/2012
6/4/2012
6/18/2012
7/9/2012
8/6/2012
8/21/2012
9/5/2012
10/15/2012


2012 Big Lake Specific Conductance (µs/cm)
Specific Conductance (µs/cm)
0
50
100
150
200
250
300
350
400
Depth (m)
0
1
2
3
4
5
6
7
8
4/3/2012
5/7/2012
5/21/2012
6/4/2012
6/18/2012
7/9/2012
8/6/2012
8/21/2012
9/5/2012
10/15/2012

pH

An indicator of acidity, pH is the negative logarithm of the hydrogen ion (H+) concentration. Lower pH waters have more hydrogen ions and are more acidic, and high pH waters have less hydrogen ions and are less acidic.

A pH value of seven is considered neutral. Values less than seven indicate acidic conditions; whereas, values greater than seven indicate alkaline conditions. A single pH unit change represents a tenfold change in the concentration of hydrogen ions. As a result, a lake with a pH value of eight is ten times less acidic than a lake with a pH value of seven.

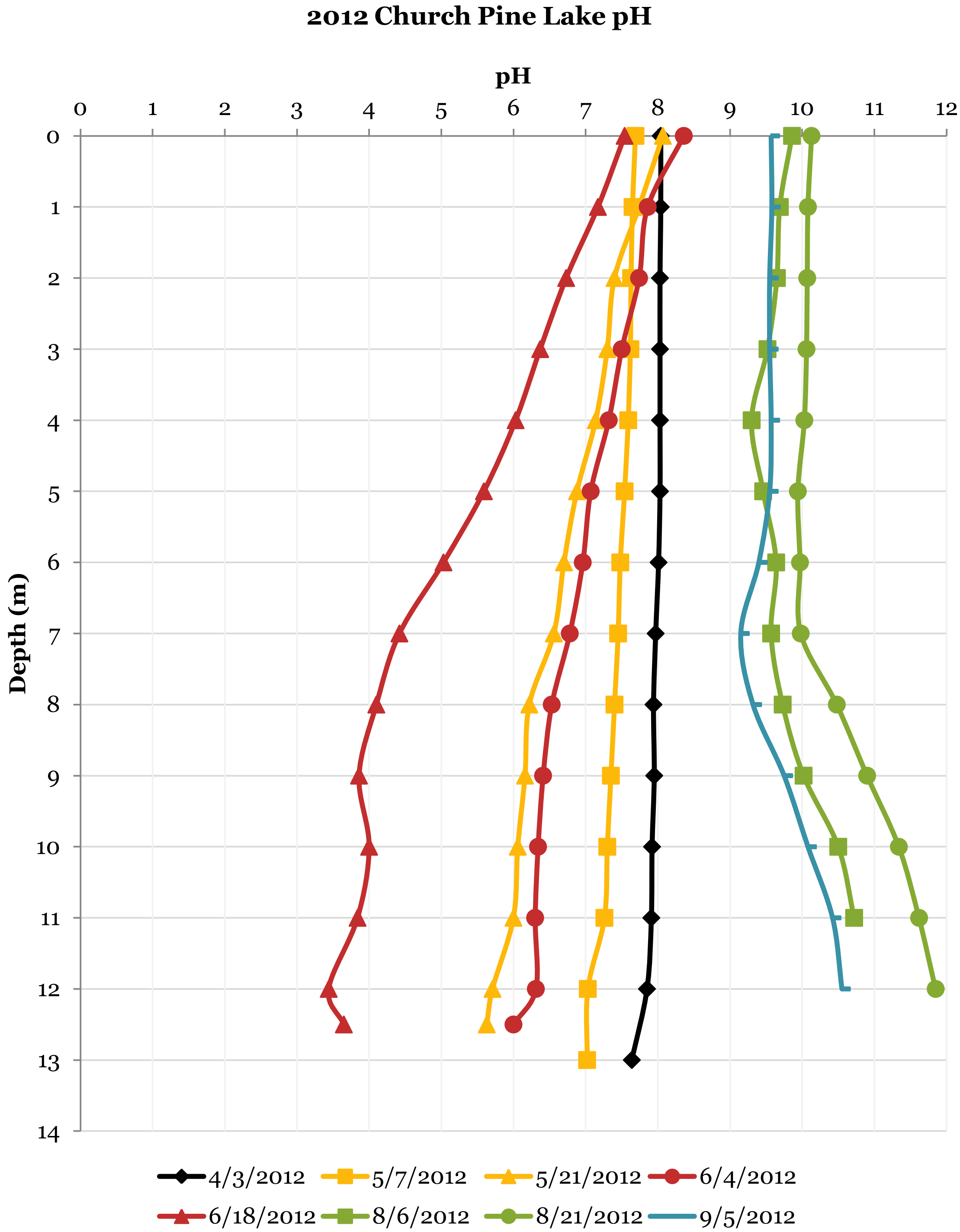
Across Wisconsin lakes, pH values can range from 4.5 (acid bog lakes) to 8.4 (hard water, marl lakes).

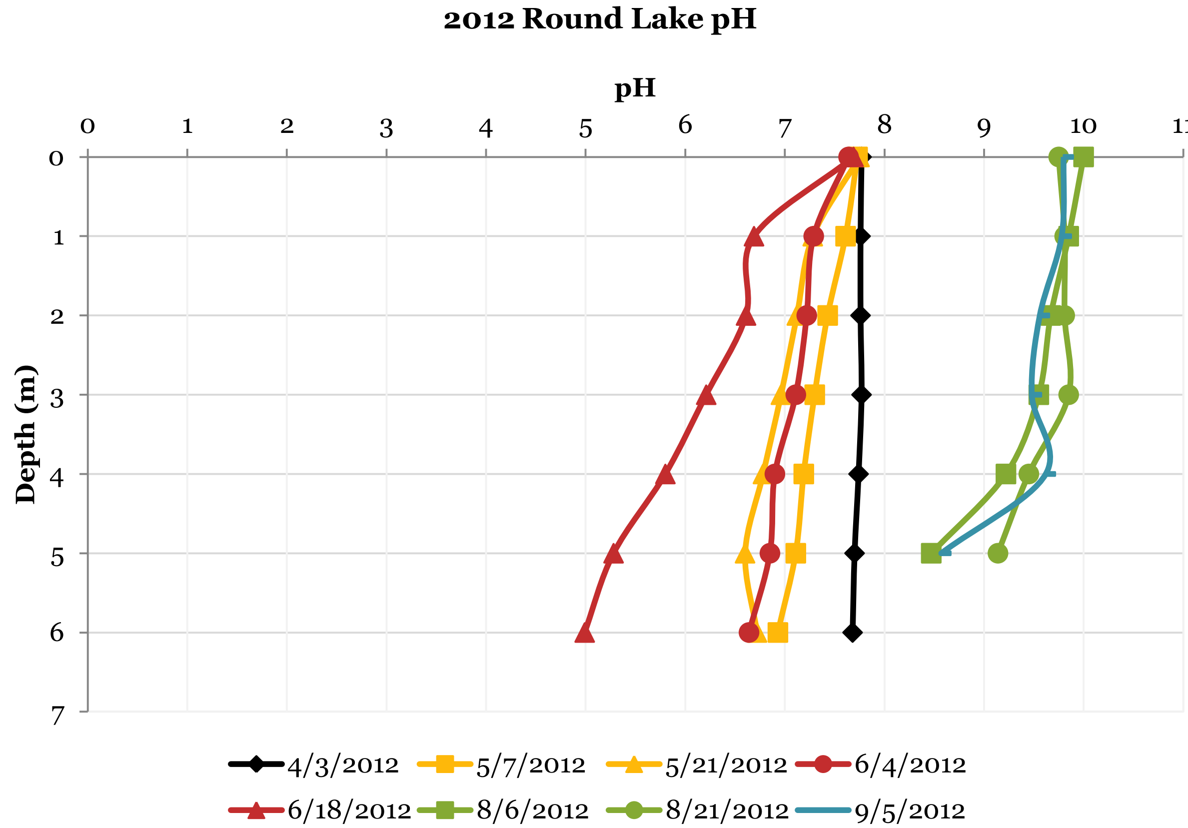
Through the removal of CO_2 from the water column, photosynthesis has the effect of increasing pH. As a result, pH generally increases during the day and decreases at night. Under conditions such as high temperature, high nutrients, and dense algae blooms, pH levels can increase.

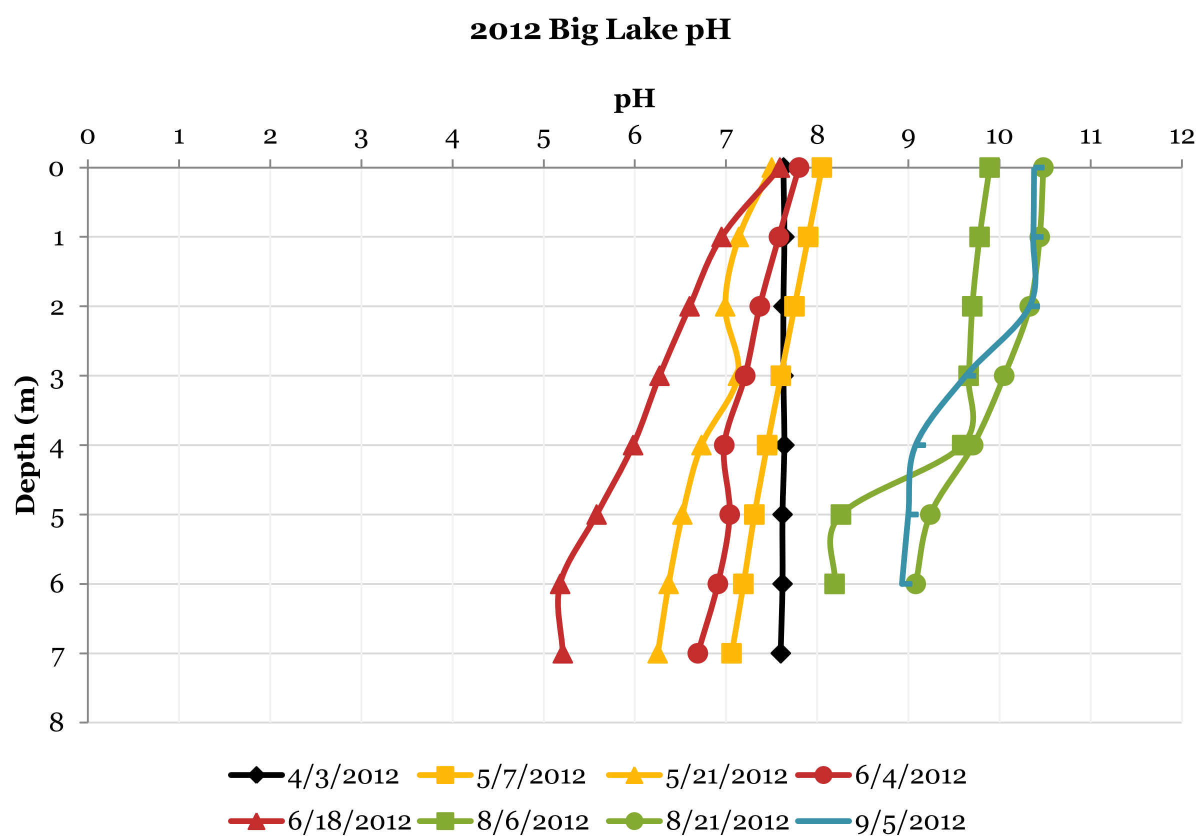
Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

In all three lakes, pH values were two orders of magnitude higher in August and September as compared to April, May, and June. August and September data were collected with a HI 9828 multi-parameter probe; whereas April, May, and June data were collected using a YSI 60 pH meter. Although pH values do typically increase over the course of the summer, it is impossible to tell if the order of magnitude difference in pH is a result of the meters or actual measured differences.

A general trend of decreasing pH was evident in all three lakes as the bottom waters were approached. However, in August and September in Church Pine Lake this trend was reversed, with pH increasing as bottom waters were approached.


2012 Church Pine Lake pH
pH
0 1 2 3 4 5 6 7 8 9 10 11 12
Depth (m)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
4/3/2012
5/7/2012
5/21/2012
6/4/2012
6/18/2012
8/6/2012
8/21/2012
9/5/2012


2012 Round Lake pH
pH
0 1 2 3 4 5 6 7 8 9 10 11
Depth (m)
0 1 2 3 4 5 6 7
4/3/2012
5/7/2012
5/21/2012
6/4/2012
6/18/2012
8/6/2012
8/21/2012
9/5/2012


2012 Big Lake pH
pH
0 1 2 3 4 5 6 7 8 9 10 11 12
Depth (m)
0 1 2 3 4 5 6 7 8
4/3/2012
5/7/2012
5/21/2012
6/4/2012
6/18/2012
8/6/2012
8/21/2012
9/5/2012

Secchi Depth

The depth to which light can penetrate into lakes is affected by suspended particles, dissolved pigments, and absorbance by water. Often, the ability of light to penetrate the water column is determined by the abundance of algae or other photosynthetic organisms in a lake.

One method of measuring light penetration is with a secchi disk. A secchi disk is an eight inch diameter round disk with alternating black and white quadrants that is used to provide a rough estimate of water clarity. The depth at which the secchi disk is just visible is defined as the secchi depth. A greater secchi depth indicates greater water clarity.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

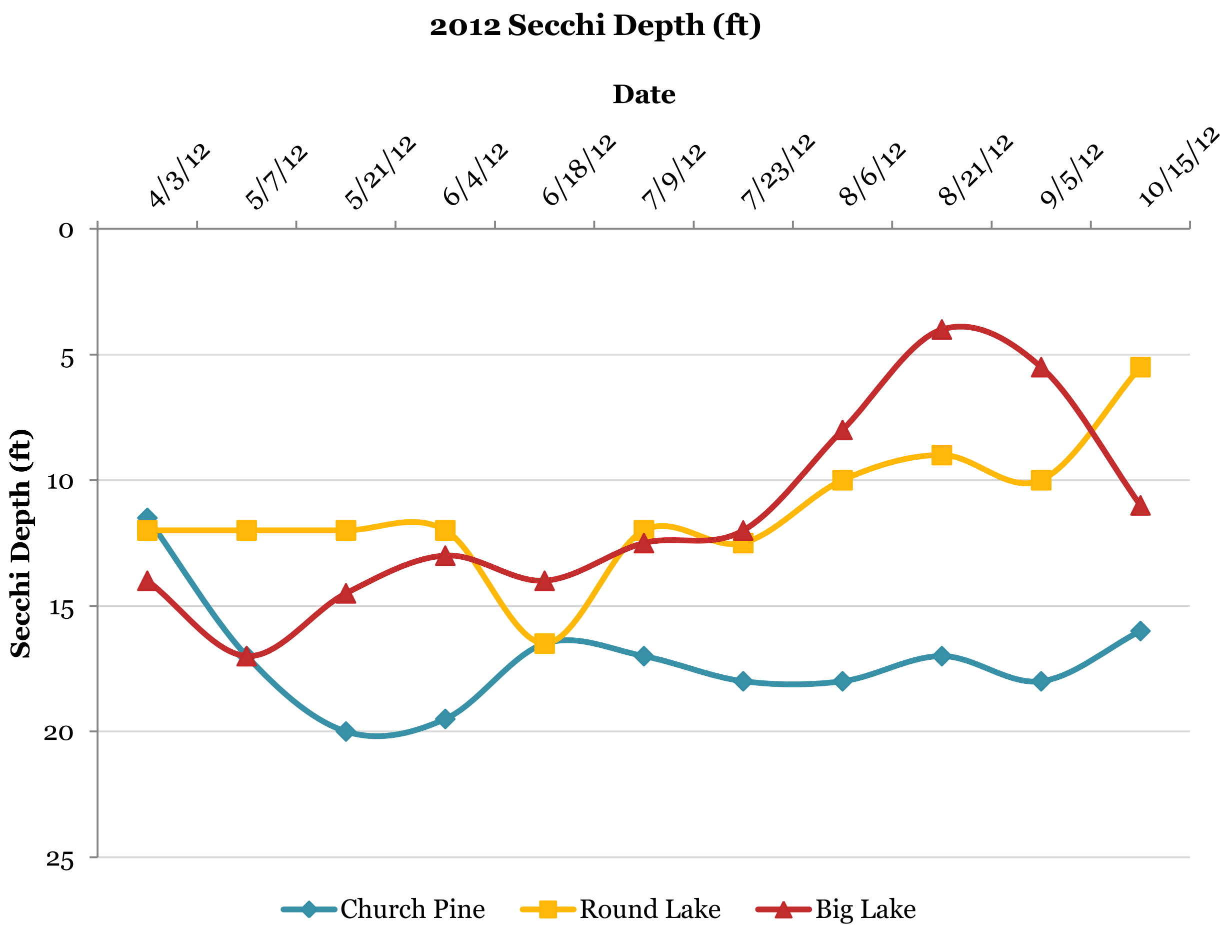
Water Clarity	Secchi Depth (feet)
Very poor	3
Poor	5
Fair	7
Good	10
Very good	20
Excellent	32

Church Pine Lake had the greatest water clarity as compared to Round and Big Lake over the entire sampling season (with the exception of spring turnover). Early in the year, Big Lake had greater water clarity as compared to Round Lake. Around July, this trend reversed with Round Lake exhibiting greater water clarity as compared to Big Lake.

As compared to Big and Church Pine Lake, the water of Round Lake is much more stained (brown in color)[8]. Likely this factor explains why Round Lake had a lower secchi depth as compared to Church Pine and Big Lake early in the year (when algae are less of a determining factor in water clarity).

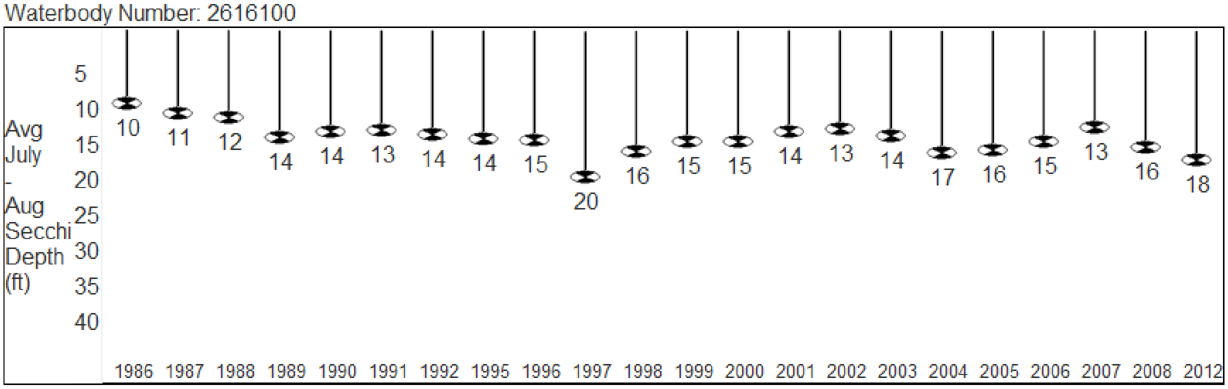
The average growing season secchi depth was greatest for Church Pine Lake (17.9 feet), followed by Round Lake (11.8 ft) and Big Lake (11.2 ft). A similar trend is evident when averaging the secchi depths over the summer index period. Average summer index period secchi depth was greatest for Church Pine Lake (17.8 ft), followed by Round Lake (10.4 ft) and Big Lake (7.4 ft).

[8] Average spring and fall turnover color values are as follows: Church Pine Lake 11.5 units, Round Lake 14.7, and Big Lake 10.6.


2012 Secchi Depth (ft)
Date
4/3/12
5/7/12
5/21/12
6/4/12
6/18/12
7/9/12
7/23/12
8/6/12
8/21/12
9/5/12
10/15/12
Secchi Depth (ft)
0
5
10
15
20
25
Church Pine
Round Lake
Big Lake

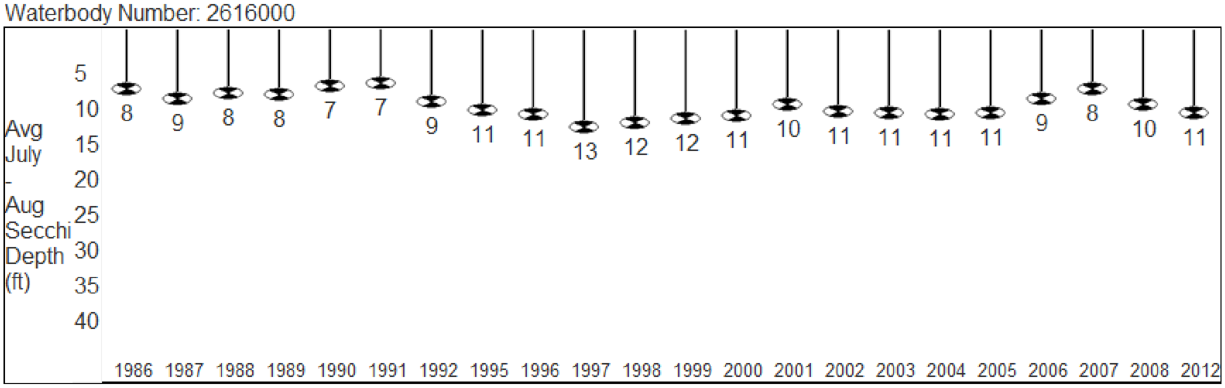
The Wisconsin Department of Natural Resources provides historic secchi depth averages for the months of July and August only. This data exists for Church Pine, Round, and Big Lake from 1986-92, 1995-08, and for 2012.

Church Pine Lake
Polk County
Waterbody Number: 2616100



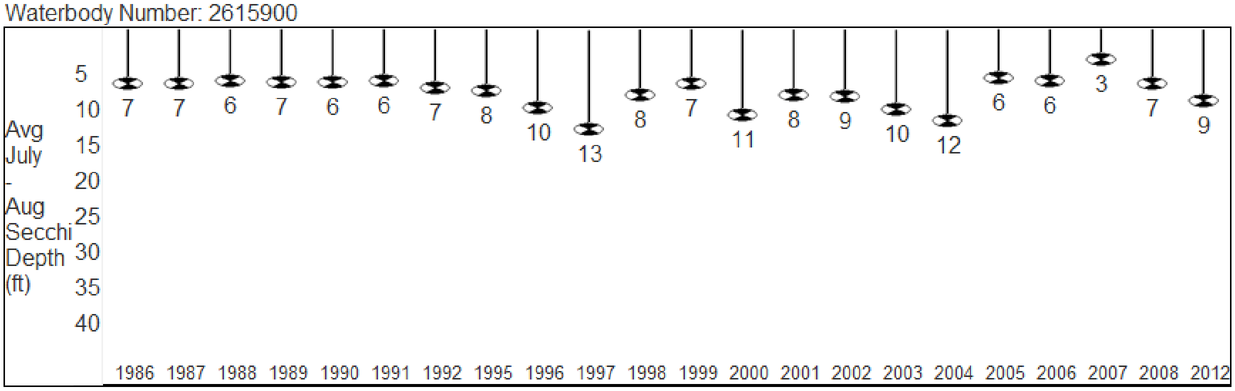
Past secchi averages in feet (July and August only).

Wind Lake
Polk County
Waterbody Number: 2616000



Past secchi averages in feet (July and August only).

Big Lake
Polk County
Waterbody Number: 2615900



Past secchi averages in feet (July and August only).

Chlorophyll *a*

Chlorophyll *a* is a pigment in plants and algae that is necessary for photosynthesis and is an indicator of water quality in a lake. Chlorophyll *a* gives a general indication of the amount of algae growth in a lake, with greater values for chlorophyll *a* indicating greater amounts of algae. However, since chlorophyll *a* is present in sources other than algae— such as decaying plants— it does not serve as a direct indicator of algae biomass.

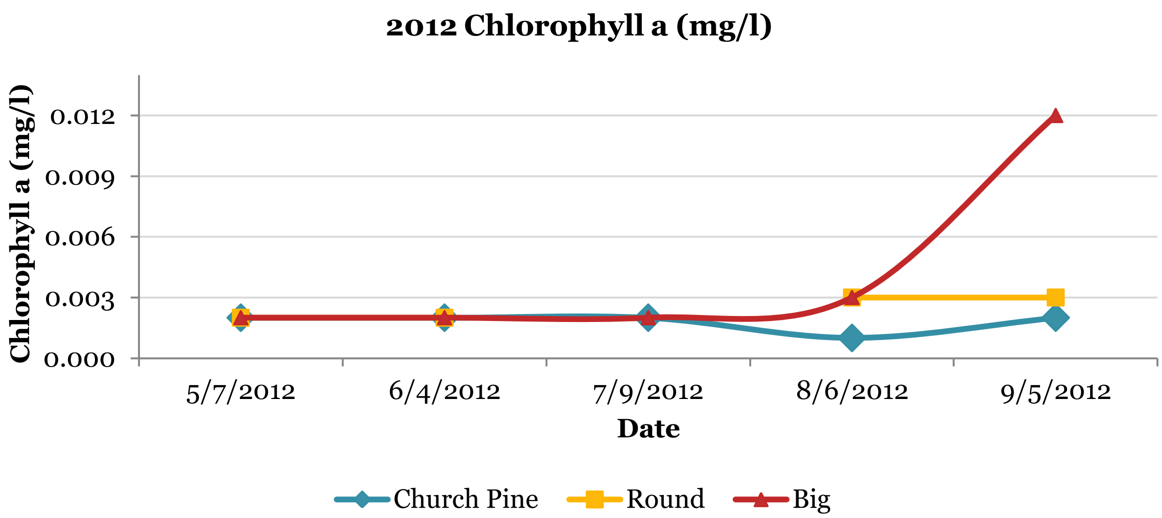
While chlorophyll *a* gives a general indication of the amount of algae growth in the water column, it is not directly correlated with algae biomass. Greater values for chlorophyll *a* do tend to indicate greater amounts of algae.

Chlorophyll *a* seems to have the greatest impact on water clarity when levels exceed 0.03 mg/L. Lakes which appear clear generally have chlorophyll *a* levels less than 0.015 mg/L.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

In Church Pine, Round, and Big Lake chlorophyll *a* levels at all sampling dates were well below 0.03 mg/L and 0.015 mg/L. In Round Lake on July 9th the chlorophyll *a* was below the limit of detection (<0.001 mg/L).

The average growing season chlorophyll *a* concentration was 0.0018 mg/L in Church Pine Lake, 0.0022 mg/L in Round Lake, and 0.0042 mg/L in Big Lake. The average summer index period chlorophyll *a* concentration was 0.0015 mg/L in Church Pine Lake, 0.003 mg/L in Round Lake, and 0.0075 mg/L in Big Lake.



Trophic State Index (TSI)

Lakes are divided into three categories based on their trophic states: oligotrophic, eutrophic, and mesotrophic. These categories reflect a lake's nutrient and clarity level and serve as an indicator of water quality. Each category is designed to serve as an overall interpretation of a lake's primary productivity.

Oligotrophic lakes are generally clear, deep, and free of weeds and large algae blooms. These types of lakes are often poor in nutrients and are therefore unable to support large populations of fish. However, oligotrophic lakes can develop a food chain capable of supporting a desirable population of large game fish.

Eutrophic lakes are generally high in nutrients and support a large number of plant and animal populations. They are usually very productive and subject to frequent algae blooms. Eutrophic lakes often support large fish populations, but are susceptible to oxygen depletion. Mesotrophic lakes lie between oligotrophic and eutrophic lakes. They usually have good fisheries and occasional algae blooms.

All lakes experience a natural aging process which causes a change from an oligotrophic to a eutrophic state. Human influences which introduce nutrients into a lake (agriculture, lawn fertilizers, and septic systems) can accelerate the process by which lakes age and become eutrophic.

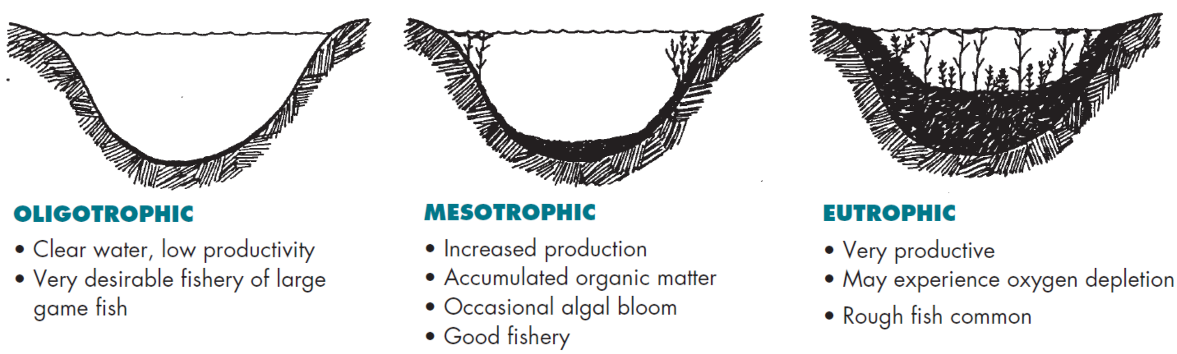


Figure from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

A common method of determining a lake's trophic state is to compare total phosphorus concentration (important for algae growth), chlorophyll *a* concentration (an indicator of the amount of algae present), and secchi disk readings (an indicator of water clarity). Although many factors influence these relationships, the link between phosphorus concentration, chlorophyll *a* concentration, and secchi disk readings is the basis of comparison for the Trophic State Index (TSI).

TSI is determined using a mathematic formula and ranges from 0 to 100. Lakes with the lowest numbers are oligotrophic and lakes with the highest values are eutrophic.

Three equations for summer index period TSI were examined for Church Pine, Round, and Big Lake. Phosphorus and chlorophyll *a* data were averaged from August 6th and September 5th. Secchi depth data were averaged from July 23rd, August 6th, August 21st, and September 5th.

TSI (P) = 14.42 * Ln [TP] + 4.15 (where TP is in µg/L)
TSI (C) = 30.6 + 9.81 Ln [Chlor-a] (where the chlorophyll *a* is in µg/L)
TSI (S) = 60-14.41 * Ln [Secchi] (where the secchi depth is in meters)
Equations from: (Carlson, 1977).

<u>Church Pine Lake</u>
Average summer index period TSI (total phosphorus) = 47.70
Average summer index period TSI (chlorophyll *a*) = 34.58
Average summer index period TSI (secchi depth) = 35.67
Average summer index period TSI = 39.32 = oligotrophic

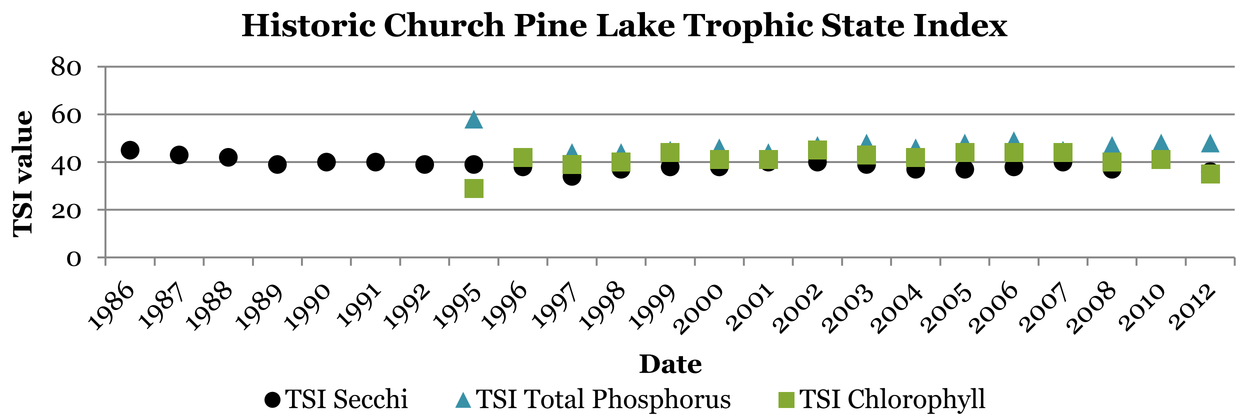
<u>Round Lake</u>
Average summer index period TSI (total phosphorus) = 49.98
Average summer index period TSI (chlorophyll *a*) = 41.38
Average summer index period TSI (secchi depth) = 43.41
Average summer index period TSI = 44.92 = mesotrophic

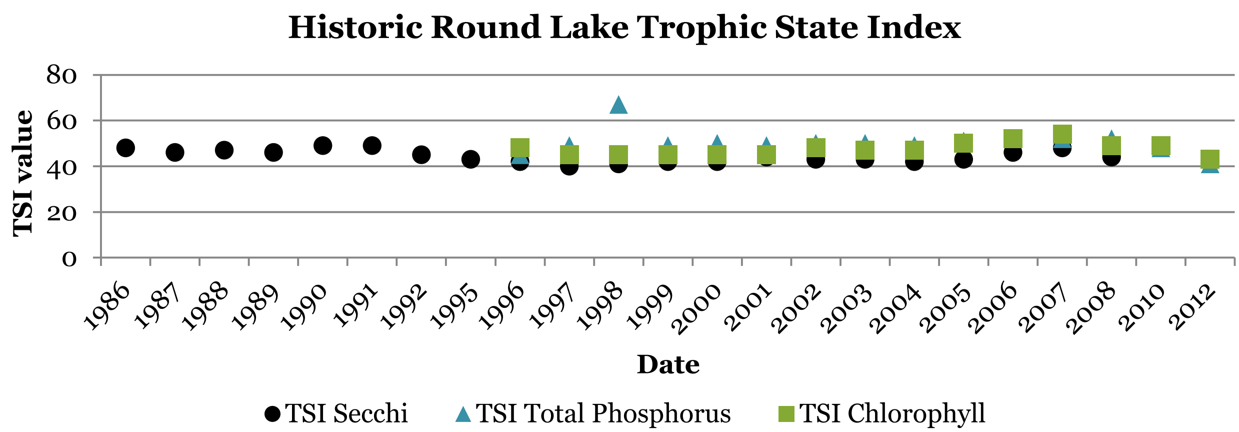
<u>Big Lake</u>
Average summer index period TSI (total phosphorus) = 54.57
Average summer index period TSI (chlorophyll *a*) = 50.37
Average summer index period TSI (secchi depth) = 48.33
Average summer index period TSI = 51.09 = mildly eutrophic

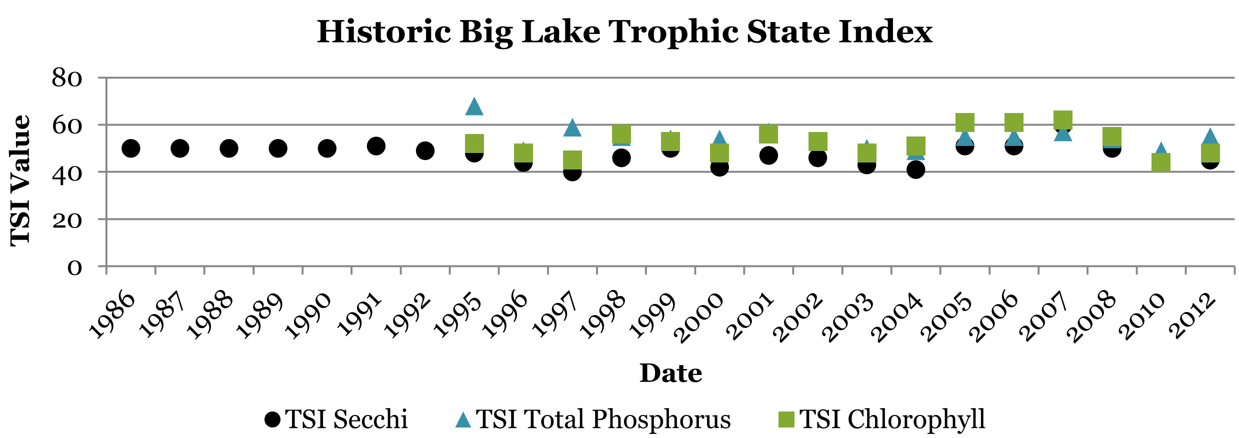
TSI	General Description
<30	Oligotrophic; clear water, high dissolved oxygen throughout the year/lake
30-40	Oligotrophic; clear water, possible periods of oxygen depletion in the lower depths of the lake
40-50	Mesotrophic; moderately clear water, increasing chance of anoxia near the bottom of the lake in summer, fully acceptable for all recreation/aesthetic uses
50-60	Mildly eutrophic; decreased water clarity, anoxic near the bottom, may have macrophyte problem; warm-water fisheries only
60-70	Eutrophic; blue-green algae dominance, scums possible, prolific aquatic plant growth. Full body recreation may be decreased
70-80	Hypereutrophic; heavy algal blooms possible throughout the summer, dense algae and macrophytes
>80	Algal scums, summer fish kills, few aquatic plants due to algal shading, rough fish dominate

Monitoring the TSI of a lake gives stakeholders a method by which to gauge lake productivity over time. Fortunately, complete TSI data exists for all three lakes from 1996-2008 and 2012 (and 1995 for Church Pine). TSI secchi data exists for all three lakes from 1986-1992 and 1996-2008. Additionally, TSI phosphorus and chlorophyll *a* data exists for all three lakes for 2010.

In Church Pine Lake the majority of the historic TSI data falls between 30 and 50, in Round Lake between 40 and 60, and in Big Lake between 40 and 60.







Phytoplankton

Algae, also called phytoplankton, are microscopic plants that convert sunlight and nutrients into biomass. They can live on bottom sediments and substrate, in the water column, and on plants and leaves. Algae are the primary producers in an aquatic ecosystem and can vary in form (filamentous, colonial, unicellular, etc). Zooplankton, are small aquatic organisms that feed on algae. The size and shape of algae determine which types of zooplankton—if any—can consume them.

Algae have short life cycles. As a result, changes in water quality are often reflected by changes in the algal community within a few days or weeks. The number and types of algae in a waterbody can provide useful information for environmental monitoring programs, impairment assessments, and the identification of best management strategies.

The types of algae in a lake will change over the course of a year. Typically, there is less algae in winter and spring because of ice cover and cold temperatures. As a lake warms up and sunlight increases, algae communities begin to increase. Their short life span quickly cycles the nutrients in a lake and affects nutrient dynamics.

The types of algae present in a lake are influenced by environmental factors like climate, phosphorus, nitrogen, silica and other nutrient content, carbon dioxide, grazing, substrate, and other factors in the lake. When high levels of nutrients are available, blue green algae often become predominant.

Chlorophyll *a* is a pigment in plants and algae that is necessary for photosynthesis. Chlorophyll *a* gives a general indication of the amount of algae growth in the water column; however, it is not directly correlated with algae biomass. To obtain accurate algae data, composite samples from a two meter water column were collected monthly, preserved with glutaraldehyde, placed on ice, and sent to the State Lab of Hygiene for identification and enumeration of algae species.

Algae were identified to genus, and a relative concentration and natural unit count was made to describe the algae community throughout the growing season. This method of sampling also allows the identification of any species of concern which might be present.

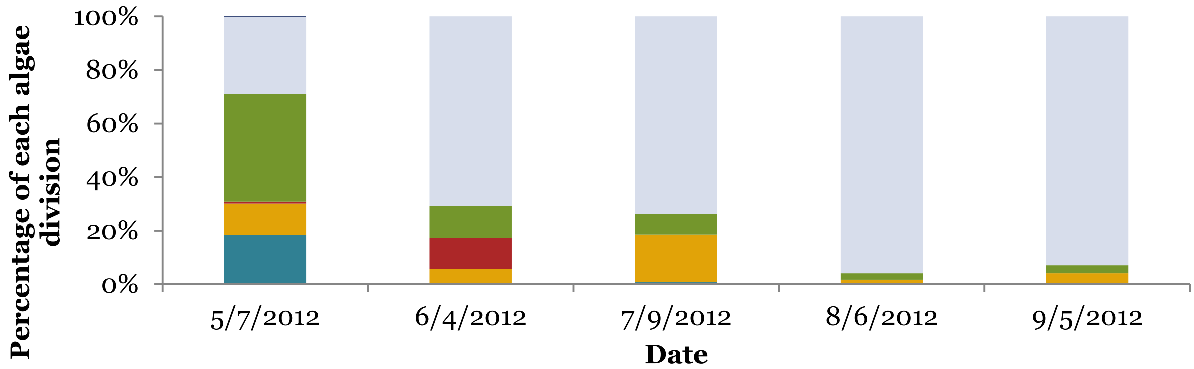
There are 12 divisions of algae typically found in Wisconsin lakes. Seven divisions were found in the three lake system. The class Euglenophyta was present in Big and Round Lakes, but was absent from Church Pine Lake.

Algal Division	Common Name	Season of Peak Population	Characteristics
Bacillariophyta	Diatoms	Spring	Have a siliceous frustule that makes up the external covering. Sensitive to chloride, pH, color, and total phosphorus (TP) in water. As TP increases, see a decrease in diatoms. Generally larger in size. Tend to be highly present in spring and late spring. Can be benthic or planktonic.
Chlorophyta	Green algae	Summer	Have a true starch and provide high nutritional value to consumers. Can be filamentous and intermingle with macrophytes.
Chrysophyta	Golden brown algae	Spring	Organisms which bear two unequal flagella. A genus of single-celled algae in which the cells are ovoid. Contain chlorophyll a, c_1 and c_2, generally masked by abundant accessory pigment, fucoxanthin, imparting distinctive golden color to cells.
Cryptophyta	Cryptomonads	Spring	Have a true starch. Planktonic. Bloom forming, are not known to produce any toxins and are used to feed small zooplankton. Cryptomonads frequently dominate the phytoplankton assemblages of the Great Lakes.
Cyanophyta	Blue green algae	Summer	Prevail in nutrient-rich standing waters. Blooms can be toxic to zooplankton, fish, livestock, and humans. Can be unicellular, colonial, planktonic, or filamentous. Can live on almost any substrate. More prevalent in late to mid-summer.
Euglenophyta	Euglenoids		One of the best-know groups of flagellates, commonly found in freshwater that is rich in organic materials. Most are unicellular.
Pyrrhophyta	Dinoflagellates	Spring	Have starch food reserves and serve as food for grazers.

Across all three lakes the dominant algae division in May was Cryptophyta, or cryptomonads. As the summer progressed, the dominant algae division shifted to Cyanophyta, or blue green algae, in all three lakes. By September, blue green algae made up 93% of the algae community in Church Pine Lake, 81% in Round Lake, and 92% in Big Lake.

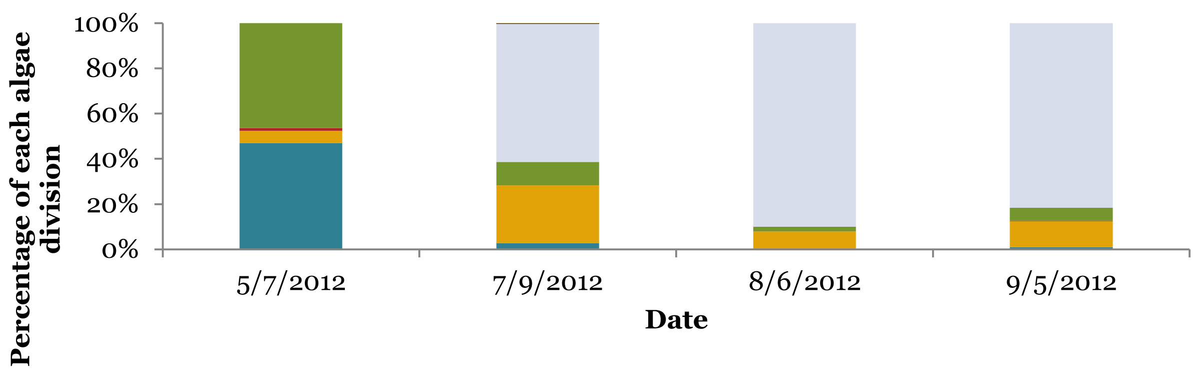
Across the entire sampling season Euglenophyta and Pyrrhophyta made up less than 1% of the algae community in all three lakes (Euglenophyta was not present in Church Pine Lake).

2012 Church Pine Lake Algae Division (% of community)



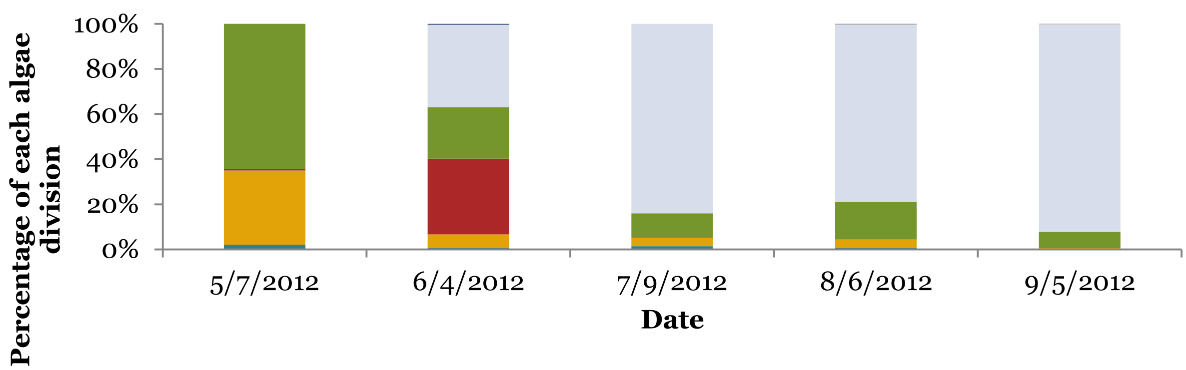
Bacillariophyta Chlorophyta Chrysophyta Cryptophyta Cyanophyta Pyrrhophyta

2012 Round Lake Algae Division (% of community)



Bacillariophyta Chlorophyta Chrysophyta Cryptophyta Cyanophyta Euglenophyta Pyrrhophyta

2012 Big Lake Algae Division (% of community)



Bacillariophyta Chlorophyta Chrysophyta Cryptophyta Cyanophyta Euglenophyta Pyrrhophyta

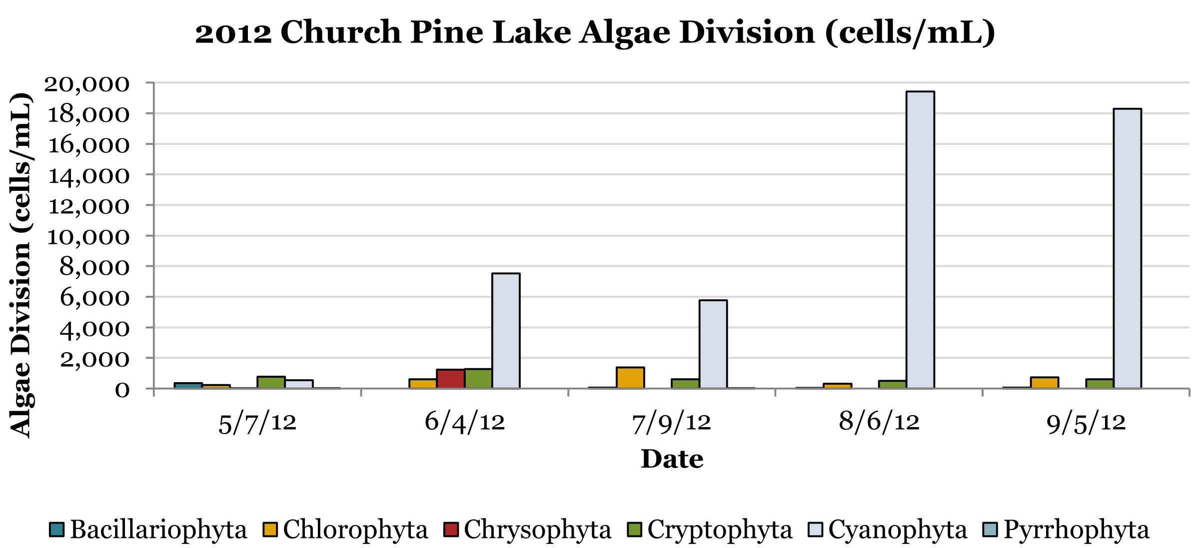
Blue green algae have been around for billions of years and typically bloom during the summer months. However, blue-green algae blooms become more frequent as a result of increased nutrients in the water column.

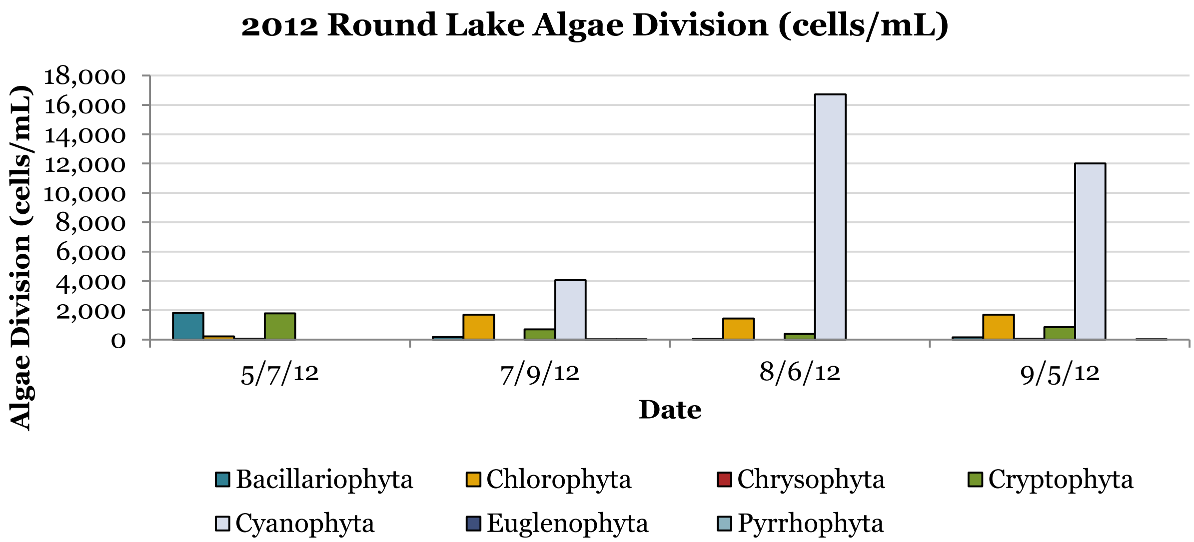
In addition to the negative aesthetics posed by algae, blue green algae are of specific concern because of their ability to produce toxins that can cause short and long term health effects if ingested or inhaled. Effects range from tingling, burning, numbness, drowsiness, and dermatitis to liver or respiratory failure possibly leading to death.

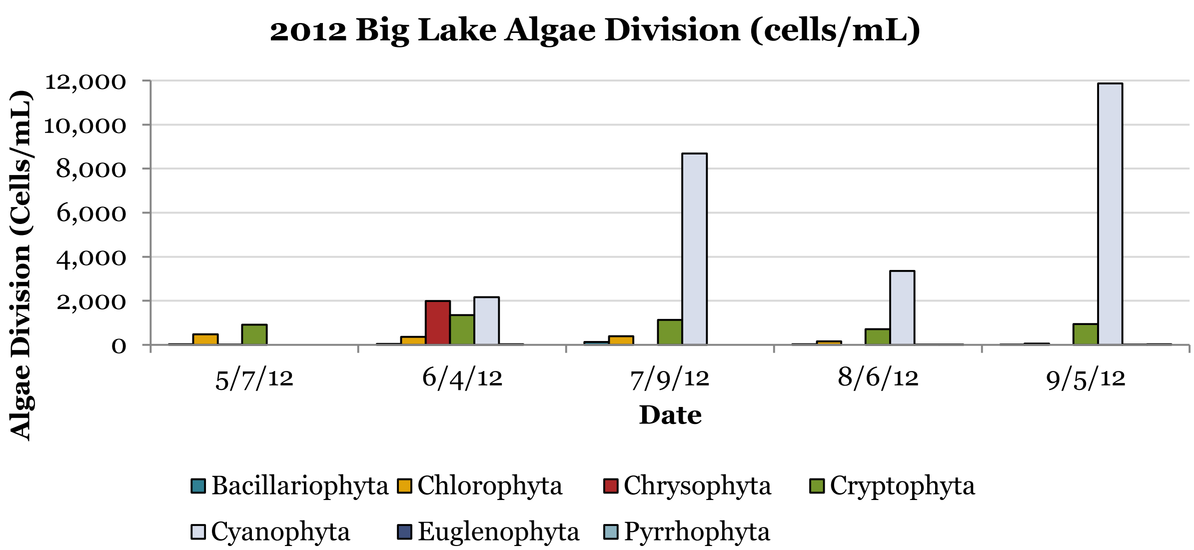
Federal guidelines for cyanobacterial cell densities and chlorophyll *a* concentrations do not exist. The Wisconsin Harmful Algal Bloom (HAB) Surveillance Program uses guidelines of the World Health Organization to determine the risk from cyanobacteria.

Cyanobacterial cell density (cells/mL)	Chlorophyll *a* (mg/L)	Risk from cyanobacteria
Less than 20,000	Less than 0.01	Low
20,000 to 100,000	0.01 to 0.05	Moderate
Greater than 100,000	Greater than 0.05	High

Although blue green algae dominated the algal community in Church Pine, Round, and Big Lakes, their cell densities were relatively low and associated with a low risk. Additionally, chlorophyll a concentrations in Church Pine, Round, and Big Lakes indicate a low risk from cyanobacteria.




2012 Round Lake Algae Division (cells/mL)
Algae Division (cells/mL)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
5/7/12
7/9/12
8/6/12
9/5/12
Date
Bacillariophyta
Chlorophyta
Chrysophyta
Cryptophyta
Cyanophyta
Euglenophyta
Pyrrhophyta


2012 Big Lake Algae Division (cells/mL)
Algae Division (Cells/mL)
12,000
10,000
8,000
6,000
4,000
2,000
0
5/7/12
6/4/12
7/9/12
8/6/12
9/5/12
Date
Bacillariophyta
Chlorophyta
Chrysophyta
Cryptophyta
Cyanophyta
Euglenophyta
Pyrrhophyta

Zooplankton

Zooplankton are small aquatic animals that feed on algae and are eaten by fish. They are divided into three main components: rotifers, copepods, and cladocerans.

Rotifers eat algae, other zooplankton, and sometimes each other. Due to their small size, rotifers are not capable of significantly reducing algal biomass although they are able to shift the algae community to favor larger species.

Copepods feed on algae and other plankton. They are eaten by larger plankton and are preyed heavily upon by pan fish, minnows, and the fry of larger fish.

Cladocerans are filter feeders that play an important part in the food web. Species of cladocerans (particularly Daphnia) are well known for their ability to reduce algal biomass and help maintain clear water in lake ecosystems.

Zooplankton are often overlooked as a component of aquatic systems, but their role in a lake is extremely important. Lake systems are valued primarily for water clarity, fishing, or other recreation, all of which are strongly linked to water quality and ecosystem health. Zooplankton are the primary link between the "bottom up" processes and "top down" processes of the lake ecosystem.

"Bottom up" processes include factors such as increased nutrients, which can cause noxious algal blooms. Zooplankton have the ability to mediate algae blooms by heavy grazing. Conversely, shifts in algal composition, which can be caused by increased nutrients, can change the composition of the zooplankton community. If the composition shifts to favor smaller species of zooplankton, for example, algal blooms can be intensified, planktivorous fish can become stressed, and the development of fry can be negatively impacted.

"Top down" processes include factors such as increased fish predation. Increases in planktivorous fishes (pan fish) can dramatically reduce zooplankton populations and lead to algal blooms. In some lakes, biomanipulation is utilized to manage this effect and improve water clarity. Piscivorous fish (fish that eat other fish) are used to reduce planktivorous fish. This in turn increases zooplankton populations and ultimately reduces algae populations.

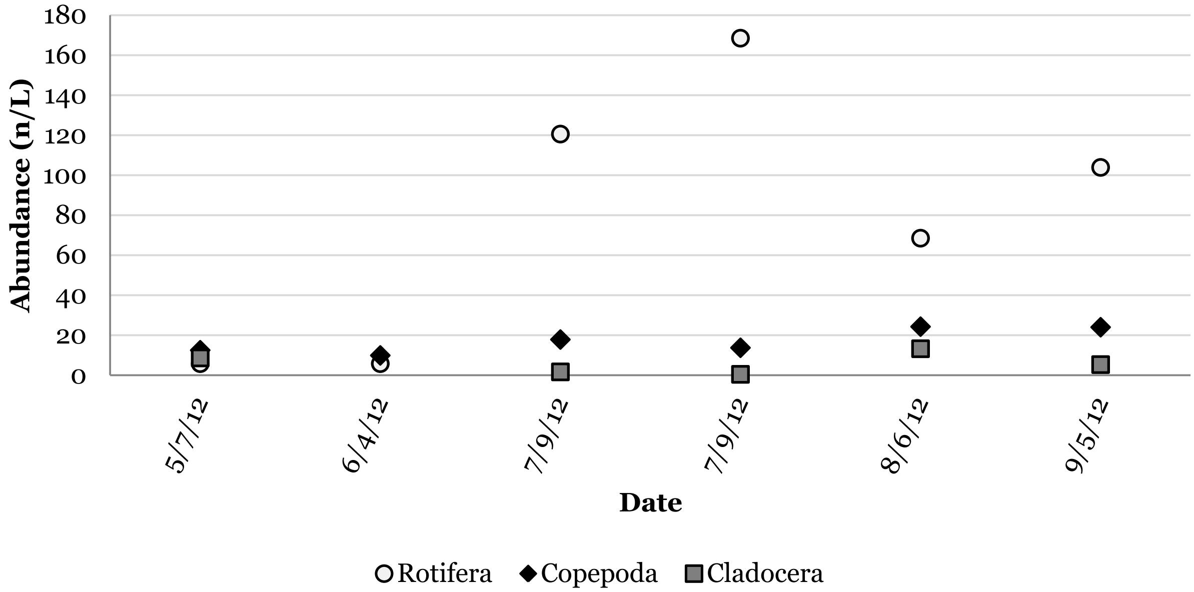
Changes in the aquatic plant community and shoreland habitat can impact zooplankton populations. This occurs especially in shallow lakes where zooplankton are more likely to have the ability to migrate horizontally to avoid predation from fish and other invertebrates. In general, a diverse shoreland habitat (substrate, plant species, and woody debris) will support a diverse zooplankton community.

Composite samples from a two meter water column were collected monthly, preserved with denatured ethanol, placed on ice, and sent to the Northland College for identification and enumeration of zooplankton species. This analysis shows the abundance of the major zooplankton groups: cladocera, copepoda, and rotifer in Church Pine, Round, and Big Lake. Replicate samples were conducted on Big Lake on July 19^{th} and Round lake on August 6^{th} at no extra cost.

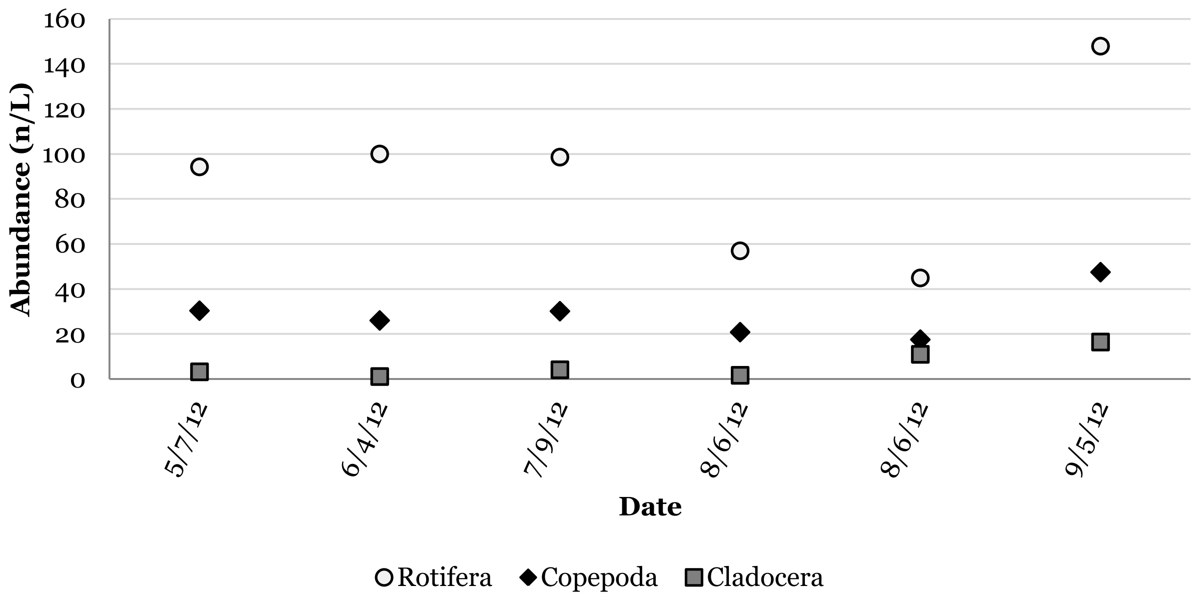
The Big Lake zooplankton community is dominated by rotifers, with an explosion in later summer. Very low numbers of cladocera strongly suggest large populations of planktivorous fishes. The inverse relationship between cladoceran and rotifer populations appearing in the graphical representation are indicative of release from competition and predation on rotifers by elimination of larger crustaceans. Low numbers of crustacean plankton are an index of low algal grazing capacity.

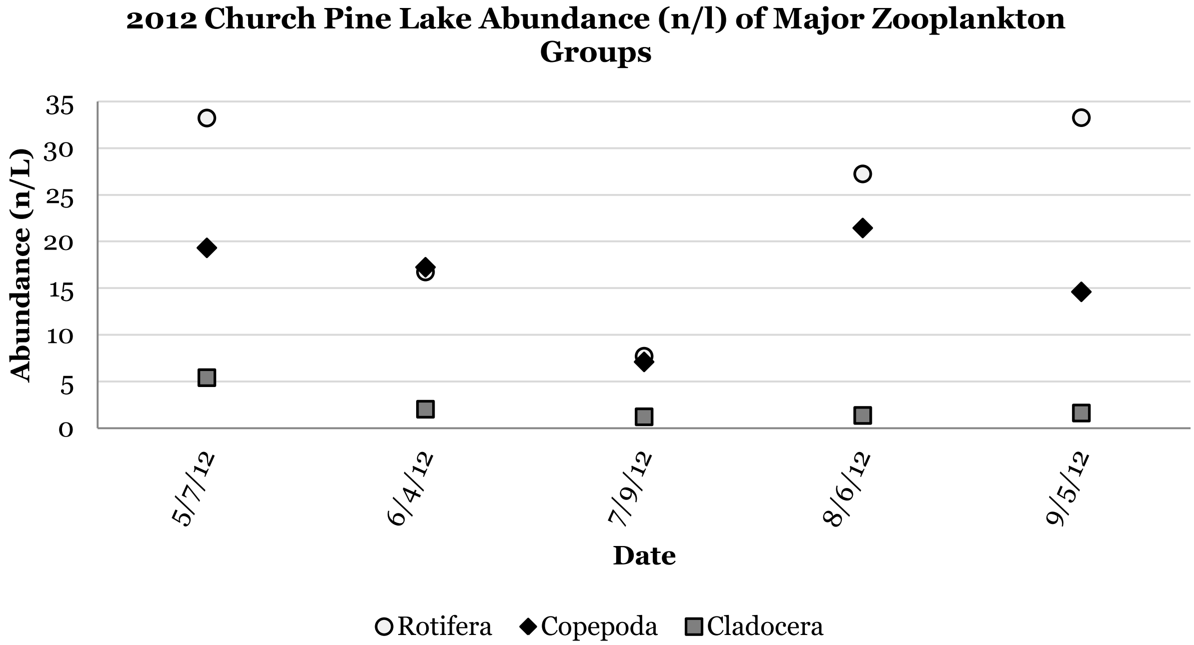
Wind Lake is much like Big Lake in rotifer dominance and fewer crustaceans. In particular, cladoceran numbers are very low relative to similar systems. All groups increase in population in late summer, indicating increased productivity without any competitive interference. Overall patterns show a lake with high planktivorous fish populations and low grazing capacity. The patterns in Church Pine Lake are very similar with a much more dramatic population crash in mid-summer. It is unclear from the zooplankton data alone what may have caused this change (Lafroncois, 2013).

2012 Big Lake Abundance (n/l) of Major Zooplankton Groups



2012 Round Lake Abundance (n/l) of Major Zooplankton Groups

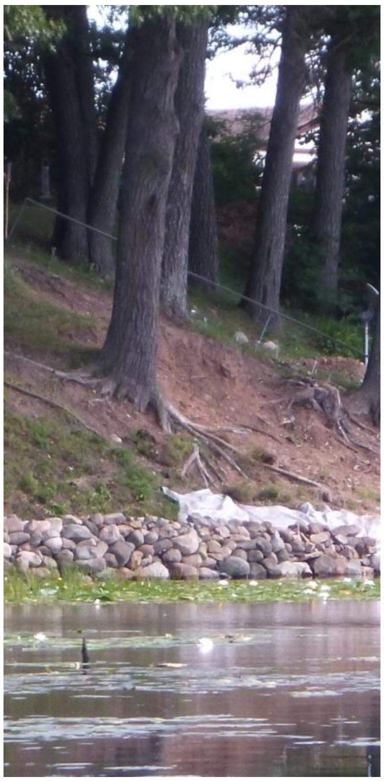



2012 Church Pine Lake Abundance (n/l) of Major Zooplankton Groups
Abundance (n/L)
35
30
25
20
15
10
5
0
5/7/12
6/4/12
7/9/12
8/6/12
9/5/12
Date
Rotifera
Copepoda
Cladocera

Land Use and Water Quality

Information summarized from: (Carrol L. Henderson, Carolyn J. Dindorf, and Fred J. Rozumalski) and (Lynn Markham and Ross Dudzik, 2012).

The health of our water resources depends largely on the decisions that landowners make on their properties. When waterfront lots are developed, a shift from native plants and trees to impervious surfaces and lawn often occurs. Impervious surfaces are defined as hard, man-made surfaces that make it impossible for rain to infiltrate into the ground. Examples of impervious surfaces include rooftops, paved driveways, and concrete patios.



By making it impossible for rainwater to infiltrate into the soil, impervious surfaces increase the amount of rainwater that washes over the soil surface and feeds directly into lakes and streams. This rainwater runoff can carry pollutants such as sediment, lawn fertilizers, and car oils directly into a lake. Native vegetation can slow the speed of rainwater, giving it time to soak into the soil where it is filtered by soil microbes. Median surface runoff estimates from wooded areas are an order of magnitude less than those from lawn areas.

In extreme precipitation events erosion and gullies can result, causing loss of property as soil is carried to the lake. The signs of erosion are unattractive and can cause decreases in property values. Additionally, sediment can have negative impacts on aquatic life. For example, fish eggs will die when covered with sediment, and sediment influxes to a lake can cause decreases in water clarity making it difficult for predator fish species to locate food.

Increases in impervious surfaces can also cause other negative impacts to fisheries. A study of 164 Wisconsin lakes conducted in 2008 found that the amount of impervious surfaces surrounding lakes can cause shifts in fisheries species assemblages. Certain species such as smallmouth and rock bass, blackchin and blacknose shiners, and mottled sculpin become less common with increasing amounts of impervious surfaces. Many of the smaller species affected are an essential food source for common game fish species such as walleye, northern pike, and smallmouth bass.

Increases in impervious surfaces and lawns also cause a loss of habitat for birds and other wildlife. Over ninety percent of all lake life is born, raised, and fed in the area where land and water meet. Overdeveloped shorelines remove critical habitat which species such as loons, frogs, songbirds, ducks, otters, and mink depend on. Impervious surfaces and lawns can be thought of as biological desserts which lack food and shelter for birds and wildlife. Additionally, nuisance species such as Canada geese favor lawns over taller native grasses and flowers. Lawns provide geese with a ready food source (grass) and a sense of security from predators (open views).

Additionally, fish species depend on the area where land and water meet for spawning. The removal of coarse woody habitat, or trees and braches that fall into a lake, causes decreases in fisheries habitat.

Lawns in and of themselves are not particularly harmful and can provide an area for families to recreate. However, problems arise when lawns are not properly maintained, over-fertilized, located in areas important to wildlife habitat, or located on steep slopes. Common lawn species, such as Kentucky bluegrass, are often dependent on chemical fertilizers and require mowing. Excess chemical fertilizers are washed directly into the adjacent water during precipitation events. The phosphorus and other nutrients in fertilizers, which produce lush vegetative growth on land, are the same nutrients which fuel algae blooms and decrease water clarity in a lake. Additionally, since common lawn species have very shallow root systems, when lawns are located on steep slopes, the impacts of erosion can be intensified.

Avoiding establishing lawns on steep slopes and at the water land-interface can provide direct positive impacts on lake water quality. The creation of a buffer zone of native grasses, wildflowers, shrubs, and trees where the land meets the water can provide numerous benefits for water quality and restore valuable bird and wildlife habitat.

In Polk County, all new constructions on lakeshore properties require that a shoreland protection area be in place. A shoreland protection area is required to be 35 feet in depth as measured from the ordinary high water mark, which is defined as the point on the bank or shore up to which the water leaves a distinct mark (erosion, change in vegetation, etc.).

These rules are in place largely to protect water quality and also provide benefits in terms of natural beauty, and bird and wildlife viewing opportunities. Additionally, shoreline protection areas allow for a 30 foot maximum viewing corridor (or 30% of the width of the lot, whichever is less), which can be established as lawn (Polk County, Wisconsin Shoreland Property Owner Handbook A Guide to the Polk County Shoreland Protection Zoning Ordinance in Developing and Caring for Waterfront Property, October 2002) and (Polk County Shoreland Protection Zoning Ordinance, Effective April 1, 2010).

Shoreline Inventory

On Friday, September 7th seven resident volunteers were trained by Polk County Land and Water Resources Department staff to conduct a shoreline inventory for Church Pine, Round, and Big Lake. The shoreline inventory followed the protocol first developed for Bone Lake by Harmony Environmental (Harmony Environmental, Polk County Land and Water Resources Department, and Ecological Integrity Services, 2009).

Prior to the inventory, the linear feet of shoreline and the area of the shoreline buffer at each parcel were estimated using the Polk County Interactive GIS Map available online at: http://polkcowi.wgxtreme.com/.

Land use for each parcel was categorized for the shoreline (linear feet at the ordinary high water mark) and for the shoreline buffer area (area upland thirty-five feet from the ordinary high water mark). Additionally, the presence or absence of coarse woody habitat was determined at each parcel.

The shoreline (linear feet) was categorized as:

- ✓ Rip rap
- ✓ Structure
- ✓ Lawn
- ✓ Sand
- ✓ Natural

The shoreline buffer area (square feet) was categorized as:

- ✓ Hard surface
- ✓ Landscaping
- ✓ Lawn
- ✓ Bare soil
- ✓ Natural

At the training, volunteers conducted the survey on practice parcels to ensure that data collection was consistent across all three lakes.

At the time of the shoreline inventory, lake levels on Church Pine, Round, and Big Lake were close to a foot below the average ordinary high water mark. With decreased water levels, parcel owners may refrain from mowing areas that would otherwise be categorized as lawn because newly exposed soil may be too saturated to support people and/or equipment.

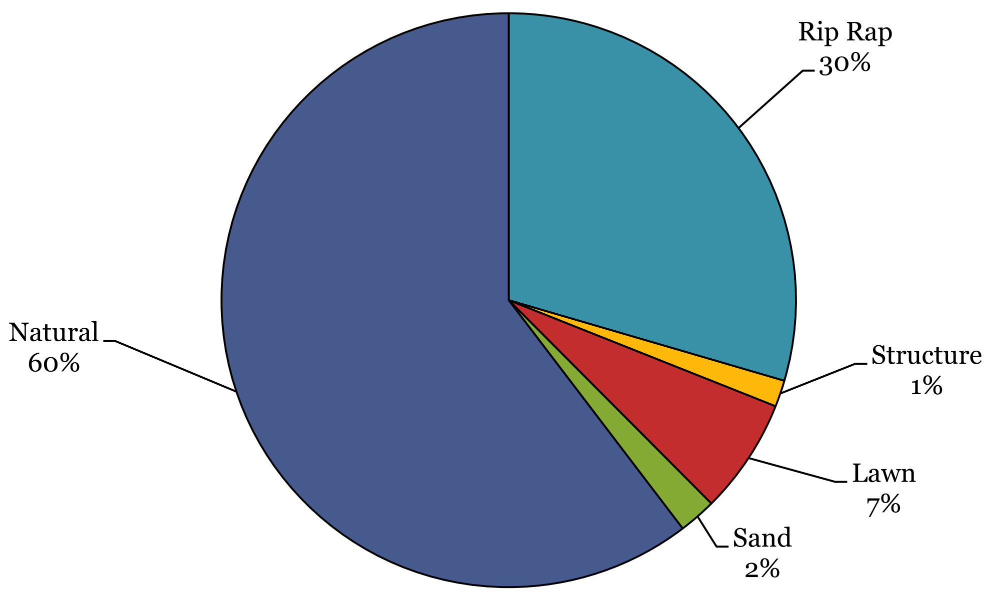
A total of 6.8 linear miles of shoreline and 0.04 square miles of buffer area were categorized by volunteers beginning on September 7th through September 16th.

In total, 2.52 miles of shoreline were inventoried on Church Pine Lake, 1.17 miles of shoreline were inventoried on Round Lake, and 3.08 miles of shoreline were inventoried on Big Lake.

A characterization of the entire three lake system shoreline inventory shows that the greatest land use at the ordinary high water mark is natural (60%), followed by rip rap (30%), lawn (7%), sand (2%), and structure (1%).

Coarse woody habitat was present at twenty-two sites between the three lake system: eleven on Church Pine Lake, six on Round Lake, and five on Big Lake.

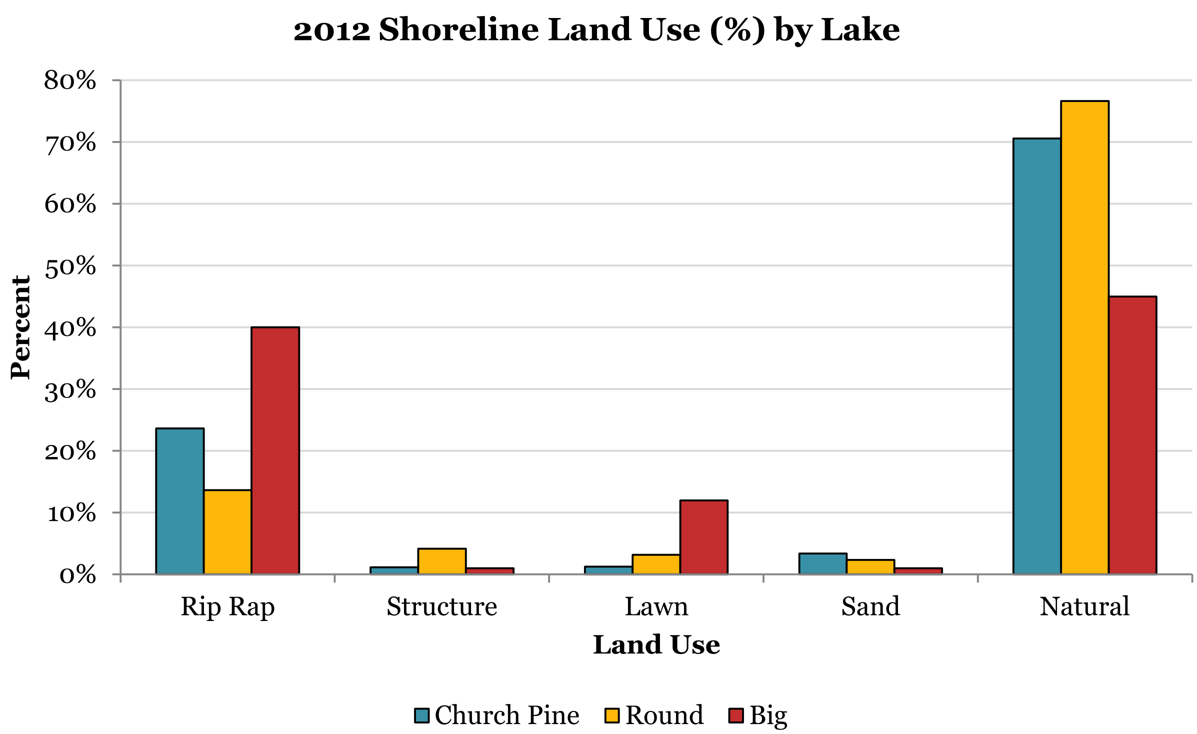
2012 Shoreline Land Use (%) for Three Lake System



The **Church Pine Lake** shoreline inventory shows that the greatest land use at the ordinary high water mark is natural (71%), followed by rip rap (24%), sand (3%), lawn (1%), and structure (1%).

The **Round Lake** shoreline inventory shows that the greatest land use at the ordinary high water mark is natural (77%), followed by rip rap (14%), structure (4%), lawn (3%), and sand (2%).

The **Big Lake** shoreline inventory shows that the greatest land use at the ordinary high water mark is natural (46%), followed by rip rap (40%), lawn (12%), sand (1%), and structure (1%).



Round Lake has the greatest percentage of shoreline in its natural state (77%), followed by Church Pine Lake (71%), and finally Big Lake (46%).

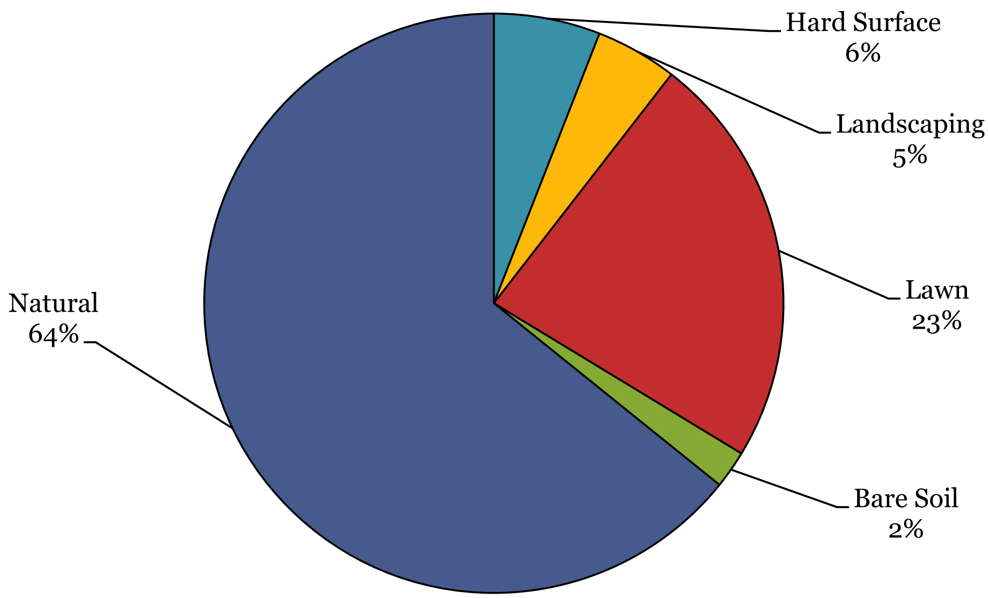
Big Lake has the greatest percentage of shoreline in riprap (40%), followed by Church Pine Lake (24%), and finally Round Lake (14%).

Lawn made up 12% of the shoreline composition of Big Lake. Round Lake and Church Pine Lake both had a lesser degree of lawn (3% and 1% respectively).

A characterization of the entire three lake system shoreline buffer composition inventory shows that the greatest land use is natural (64%), followed by lawn (23%), hard surface (6%), landscaping (5%), and bare soil (2%).

In comparison to the shoreline at the ordinary high water mark, the shoreline buffer area showed a much greater percentage of lawn (23% as compared to 7%, respectively).

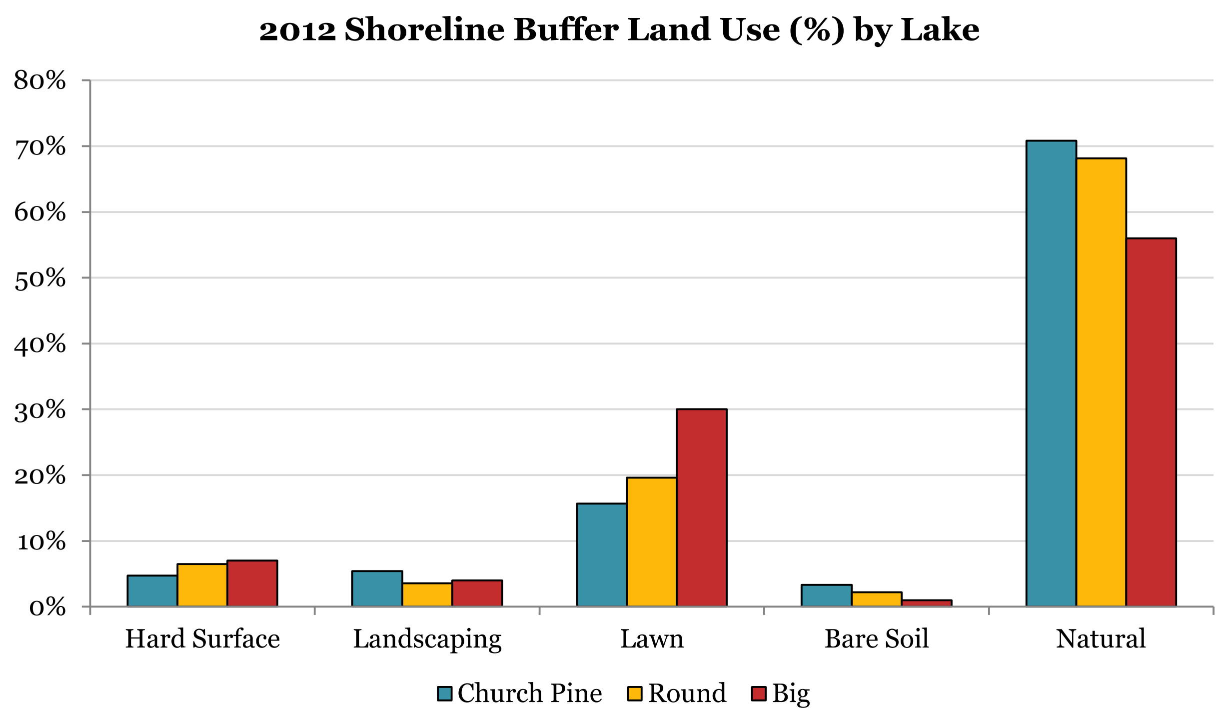
2012 Shoreline Buffer Land Use for Three Lake System



The **Church Pine Lake** shoreline buffer composition inventory shows that the greatest land use is natural (71%), followed by lawn (16%), landscaping (5%), hard surface (5%), and bare soil (3%).

The **Round Lake** shoreline buffer composition inventory shows that the greatest land use is natural (68%), followed by lawn (20%), hard surface (6%), landscaping (4%), and bare soil (2%).

The **Big Lake** shoreline buffer composition inventory shows that the greatest land use is natural (57%), followed by lawn (31%), hard surface (7%), landscaping (4%), and bare soil (1%).



Big Lake had the greatest percentage of lawn in the shoreline buffer area (31%), followed by Round (20%), and Church Pine (16%).

Tributary Monitoring

Data was collected on the tributaries of the three lake system: North Creek (top right), the County Road K culvert (bottom left), and the Big Lake outlet (bottom right).

Flow data was collected bi-weekly at each tributary with a March McBirney Flo-Mate ™ velocity flowmeter. At each foot interval across each of the tributaries, depth (ft) and velocity (m/s) were measured. Grab samples were collected once monthly on each tributary. Samples were analyzed at WEAL for total suspended solids, nitrate/nitrite, ammonium, total Kjeldahl nitrogen, total phosphorus, soluble reactive phosphorus, and chloride.

Samples were not collected when sites were dry or without flow. North Creek exhibited flow at all sample dates. The County Road K culvert had no flow beginning on July 9th through the end of the season and the Big Lake outlet had no flow beginning on August 6th through the end of the season.

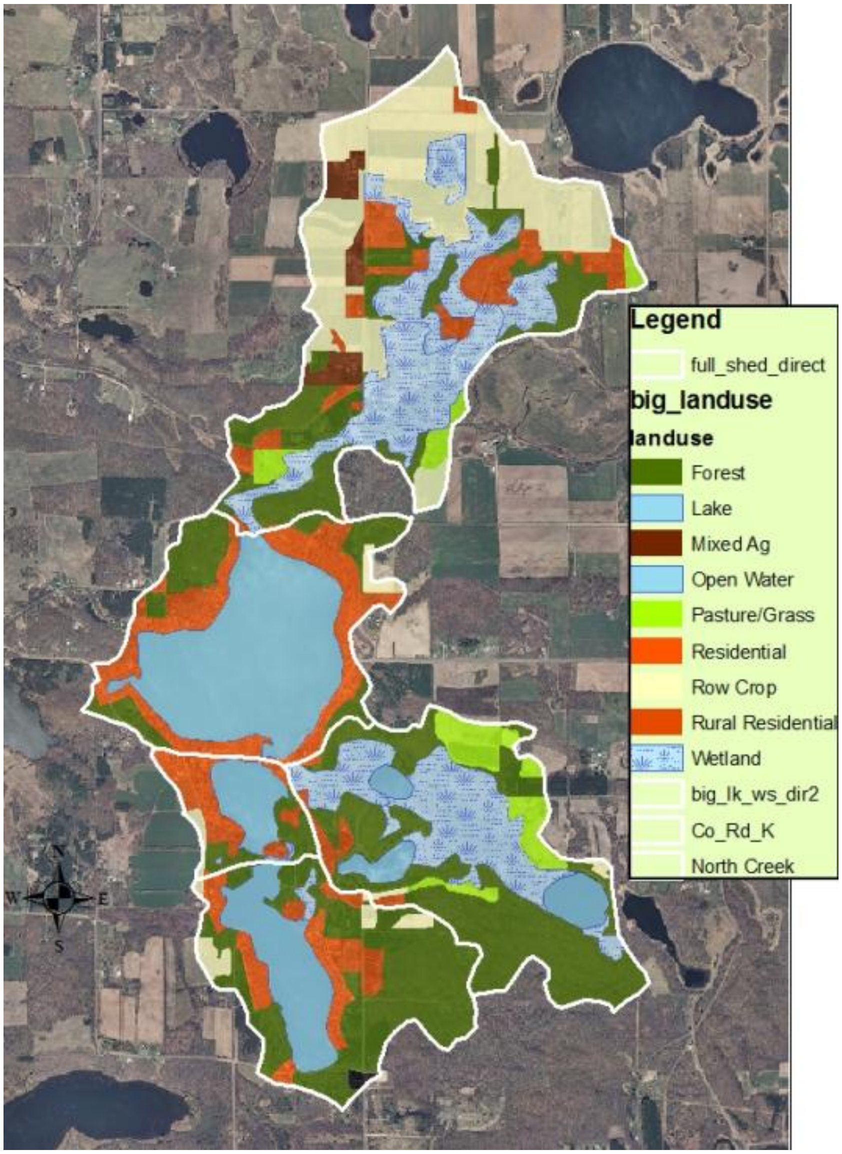
The phosphorus data collected is specific to date and location and can be used to theoretically determine how much phosphorus is entering the lake. Values for phosphorus influxes are established by multiplying the phosphorus concentration at a specific location by the volume of water that moves through a specific location, or the discharge in cubic feet per second. To determine the average instantaneous load of phosphorus (in mg/s), the average phosphorus concentration is multiplied by the average seasonal discharge. Units are then converted and expressed as lb/yr. Since the flow on County Road K and Big Lake Outlet were intermittent, the annual load of phosphorus for these tributaries was calculated over a 2 month and 4 month time period, respectively.

The analysis of this data allows for areas of highest phosphorus loading to be identified. Once areas of highest phosphorus loading are identified, the land use and geology of these areas can be investigated for their total phosphorus contribution and best management recommendations can be made.

The tributary contributing the most phosphorus to Church Pine, Round, and Big Lake is North Creek. The total phosphorus concentration in North Creek is approximately two times greater when compared with County Road K. However, the annual pounds of phosphorus entering Big Lake from North Creek is approximately ninety times greater when compared with County Road K because North Creek is a larger tributary with a consistent flow.

Site	Total Phosphorus (mg/L)	Discharge (L/s)	Instantaneous Load Phosphorus (mg/s)	Annual Load Phosphorus (lb/yr)
County Road K	0.043	5.601	0.241	2.75 (2 mo. flow)
North Creek	0.087	41.409	3.603	250.63 (12 mo. flow)
Big Lake Outlet	0.024	44.884	1.077	24.62 (4 mo. flow)

Land Use and Nutrient Loading in the Three Lake Watershed



The area of land that drains towards a lake is called a watershed.

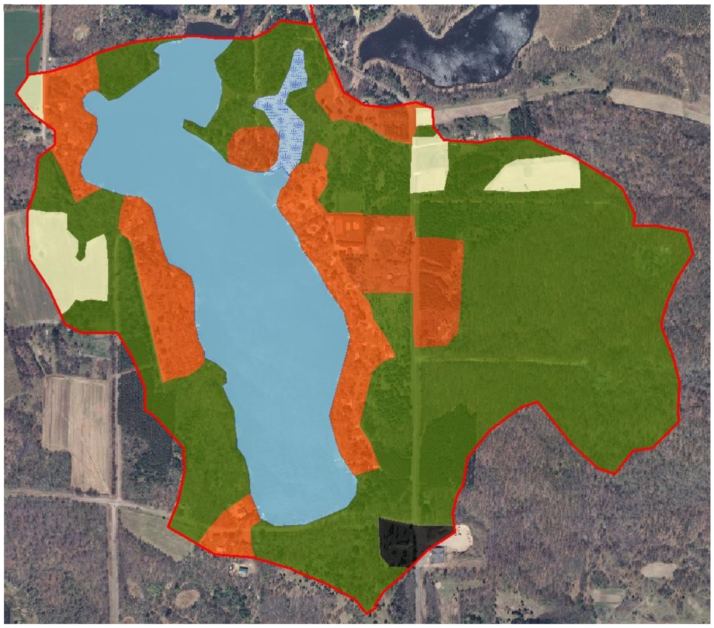
The watershed area of Church Pine Lake, including the lake, is 337.5 acres in size. The lake itself is 91 acres and represents 24% of the total land use in the Church Pine Lake watershed.

The watershed area of Round Lake, including the lake, is 106.6 acres in size. The lake itself is 38 acres and represents 36% of the total land use in the Round Lake watershed.

The watershed area of Big Lake, including the lake, is 1,765.8 acres in size. The lake itself is 243 acres and represents 14% of the total land use in the Big Lake watershed.

The Wisconsin Lakes Modeling Suite (WiLMS) was used to model current conditions for Church Pine, Round, and Big Lakes, verify monitoring, and estimate land use nutrient loading for the watershed. Phosphorus is the key parameter in the modeling scenarios used in WiLMS because it is the limiting nutrient for algal growth in most lakes.

Church Pine Lake Land Use and Nutrient Loading



Forest makes up over half (52%) of the land use in the Church Pine Lake watershed. Other land uses include the lake surface (24%), medium density urban (11%), rural residential (6%), row crop (5%), high density urban (1%), and wetlands (1%).

The largest contributor of phosphorus to Church Pine Lake is the lake surface (26%), followed by medium density urban (20%), forest and row crop (each 17%), high density urban (5%), rural residential (2%), and wetlands (less than 1%).

Additionally, the model predicts that septic systems are contributing 13% of the phosphorus load to Church Pine Lake.

Church Pine Lake				
	Total acres	Percent acres	Total Loading (lb P /year)	Percent loading
Row crop	17.5	5%	15.6	16.6%
High density urban	3.8	1%	5.1	5.4%
Medium density urban	41.9	11%	18.7	19.9%
Rural residential	23.1	6%	2.1	2.2%
Wetlands	4.4	1%	0.4	0.4%
Forest	195.8	52%	15.8	16.8%
Lake surface	91	24%	24.4	26.0%
Septic			11.9	12.70%

Round Lake Land Use and Nutrient Loading

The largest land use in the Round Lake watershed is the lake itself (36%), followed by medium density urban (24%), forest (21%), rural residential (14%), row crop (4%), and wetlands (1%). The largest contributor of phosphorus is medium density urban (33%), the lake surface (29%), row crop (11%), forest (5%), rural residential (4%), and wetlands (less than 1%). Additionally, the model predicts that septic systems are contributing 18% to the phosphorus load to Round Lake.

Round Lake

	Total acres	Percent acres	Total Loading (lb P/year)	Percent loading
Row crop	4.3	4%	3.8	11.0%
Medium density urban	25.4	24%	11.3	32.5%
Rural residential	15.4	14%	1.4	3.9%
Wetlands	0.8	1%	0.1	0.2%
Forest	22.7	21%	1.8	5.2%
Lake surface	38	36%	10.2	29.1%
Septic			6.3	18.0%

Big Lake Land Use and Nutrient Loading

The largest land uses in the Big Lake watershed are forest (26%) and wetlands (24%). Other land uses include row crop (16%), the lake itself (14%), rural residential (8%), medium density urban (6%), pasture/grass (5%), and mixed agriculture (2%). The largest contributor of phosphorus is row crop (50%) followed by the lake surface (13%), medium density urban (9%), wetlands and forest (each 7%), mixed agriculture (5%), pasture/grass (4%), and rural residential (2%). Additionally, the model predicts that septic systems are contributing 3% of the phosphorus load to Big Lake.

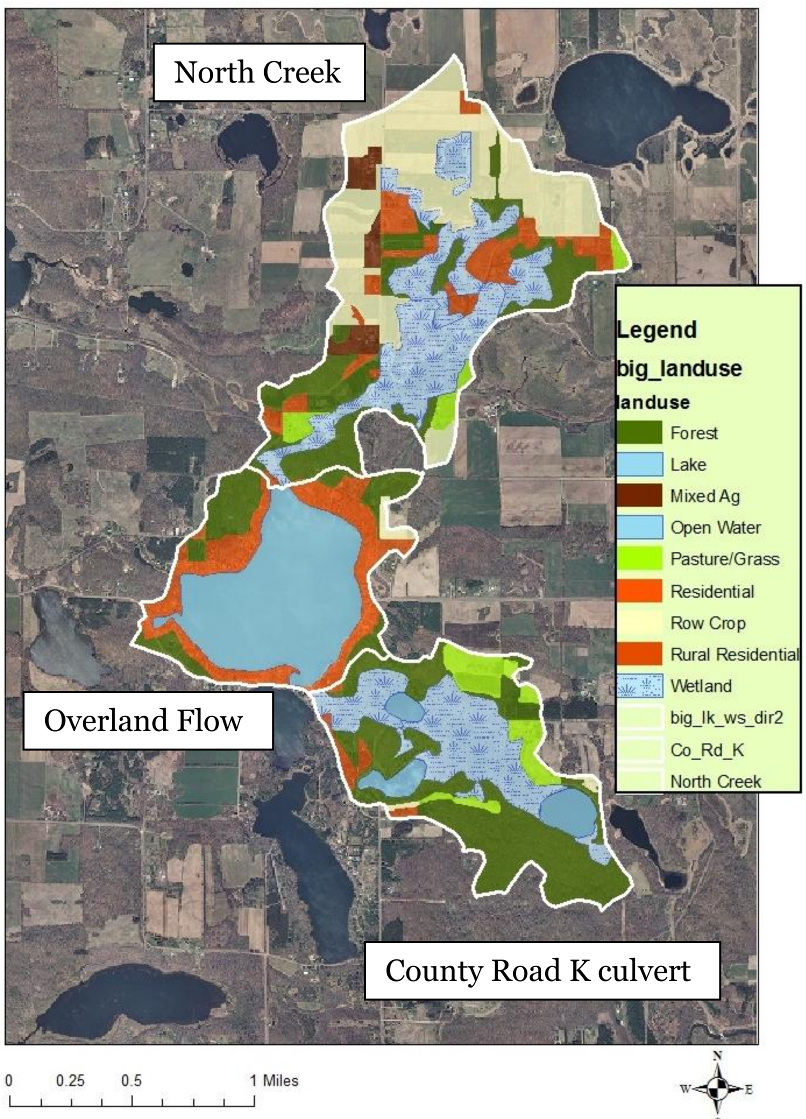
Big Lake

	Total acres	Percent acres	Total Loading (lb P/year)	Percent loading
Row crop	288.6	16%	257.6	49.8%
Mixed agriculture	34	2%	24.3	4.7%
Pasture/grass	80.7	5%	21.7	4.2%
Medium density urban	99.9	6%	44.5	8.6%
Rural residential	134.6	8%	11.9	2.3%
Wetlands	417.513	24%	37.2	7.2%
Forest	467.5	26%	37.8	7.3%
Lake surface	243	14%	65.2	12.6%
Septic			17.6	3.4%

Land Use and Nutrient Loading in the Three Lake Subwatersheds

The total Church Pine watershed is only 246.5 acres in size and the total Round Lake watershed is only 68.6 acres in size. Due to their small size, these watersheds were not further subdivided.

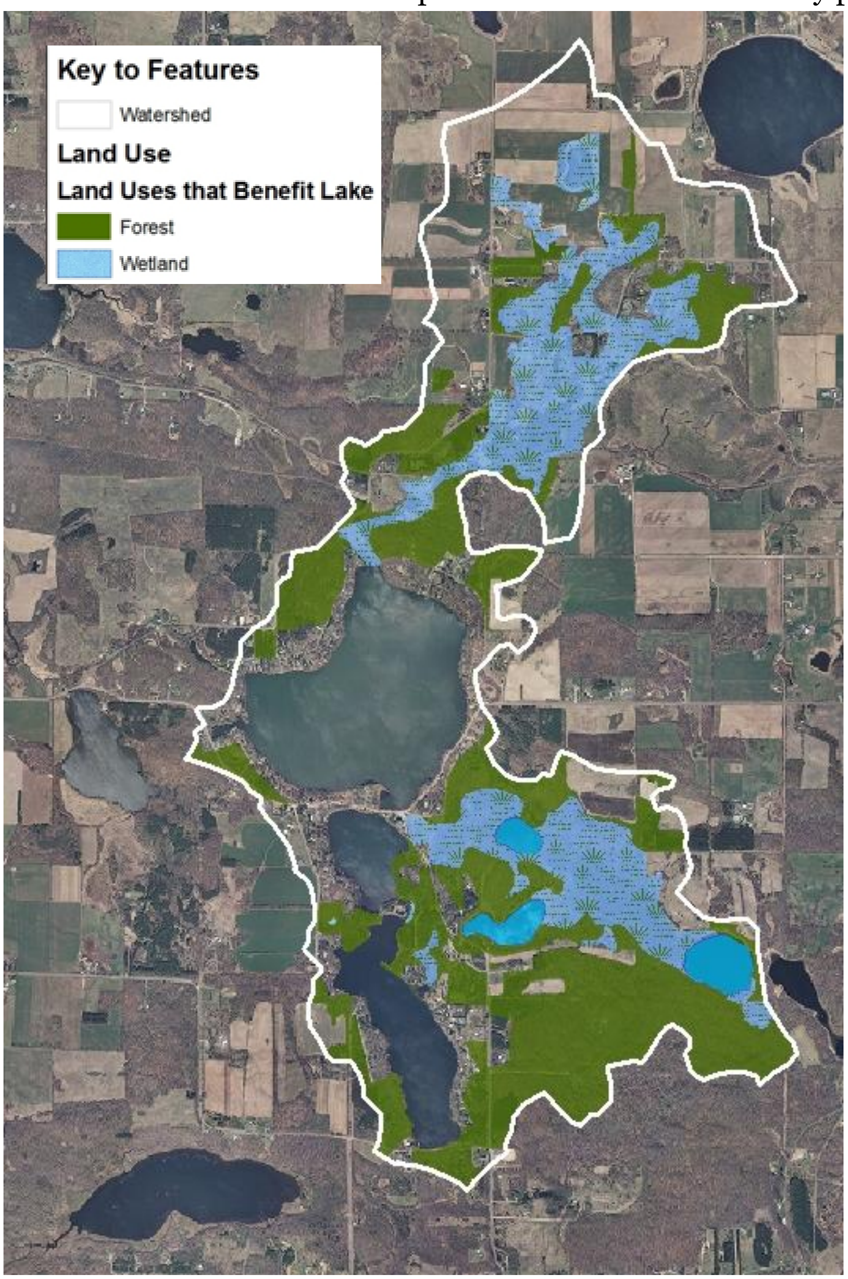
The Big Lake watershed was divided into three subwatersheds to more accurately determine nutrient loading. One of the subwatersheds was determined based off the watershed associated with North Creek and a second was determined based off the watershed associated with the County Road K culvert. Water associated with these subwatersheds enters Big Lake through tributaries. The third subwatershed represents the area of land that drains to Big Lake from overland flow.



Areas Providing Water Quality Benefits to the Three Lake System

Natural areas such as forests and wetlands allow for more infiltration of precipitation when compared with row cropped fields and developed residential sites containing lawns, rooftops, sidewalks, and driveways. This occurs because dense vegetation lessens the impact of raindrops on the soil surface, thereby reducing erosion and allowing for greater infiltration of water. Additionally, wetlands provide extensive benefits through their ability to filter nutrients and allow sediments to settle out before reaching lakes and rivers.

The wetlands and forests of the Church Pine, Round, and Big Lake Watersheds should be considered sensitive areas and preserved for the benefits they provide to the lakes.



Watershed and Lake Modeling

The Wisconsin Lake Modeling Suite (WiLMS) was used to model current conditions and nutrient reductions for Church Pine, Round and Big Lake, verify monitoring, and estimate in-lake nutrient loading. Phosphorous is the key parameter in the modeling scenarios used in WiLMS because it is the limiting nutrient for algal growth in most lakes.

Based on average evaporation, precipitation, and runoff coefficients for Polk County soils and land use, the annual non-point source load was calculated to be 93.8 pounds of phosphorous for Church Pine Lake, 34.9 pounds of phosphorous for Wind Lake and 517.8 pounds of phosphorous for Big Lake.

Sub-watersheds were also modeled to estimate the total loading per acre as was reported in the Church Pine, Round, and Big Lake Land Use and Nutrient Loading section of this report.

Since it was decided not to collect *in situ* chemistry samples near the lake bottom, internal loading needs to be estimated using the lake models selected as the best "fit" for the lakes. WiLMS uses four methods to estimate internal loading. Spring and fall turnover chemistry samples were used as a surrogate for the lack of hypolimnetic samples. This did not prove to be useful and consideration of additional studies quantifying internal loading from hypolimnetic sediment is strongly encouraged.

The first method was a complete total phosphorus mass budget; this method calculates the annual internal load to be -7 pounds of phosphorus in Church Pine Lake, -3 pounds of phosphorous in Round Lake, and -29 pounds of phosphorous in Big Lake.

In the second method the internal load was estimated from the growing season *in situ* phosphorus increases. This method calculated the annual internal load to be 4 pounds of phosphorous in Church Pine Lake, 3 pounds of phosphorous in Round Lake, and 74 pounds of phosphorous in Big Lake. The model calculated that there were 1.2 mg/m^2-day of phosphorus released in Church Pine Lake, 0.5 mg/m^2-day in Round Lake, and 1.2 mg/m^2-day in Big Lake using this method.

The third method estimated the internal load from in situ phosphorus increases in the fall. The annual load was calculated to be 70 pounds of phosphorous with a sediment release rate of 11.6 mg/m^2-day in Church Pine Lake, 19 pounds of phosphorous with a sediment release rate of 6.6 mg/m^2-day in Round Lake, and 499 pounds of phosphorous with a sediment release rate of 27.5 mg/m^2-day in Big Lake.

The fourth method uses the average of the calculated phosphorus release rates and anoxic sediment area. This method calculated the annual internal load to be 44-176 pounds of phosphorus in Church Pine Lake, 10-42 pounds of phosphorus in Round Lake, and 116-465 pounds of phosphorus in Big Lake.

The Nurnberg total phosphorus model takes internal loading into account:

$$\left(P = \frac{L_{Ext}}{q_s}(1 - R) + \frac{L_{Int}}{q_s};\ \text{where} R = \frac{15}{18 + q_s}\right)$$ [9]

This model predicts that the mixed lake total phosphorus concentration would be 88 µg/l in Church Pine Lake, 113 µg/l in Round Lake, and, 137 µg/l in Big Lake. These estimates are quite high compared to the actual measured total phosphorus in all three lakes. There are obvious ecological and biogeochemical processes that affect measurable nutrient levels in lakes (such as sediment REDOX potential) that simply can't be modeled and need to be measured and studied before assumptions can be made about the impact of sediments and internal loading on the nutrient cycle.

The model that was used to more accurately estimate the mixed lake water column total phosphorus concentration was the Reckhow 1977 Oxic Lake Model where $zT_w < 50$ m/yr which is calculated by:

$$\mathrm{P} = \frac{L}{(18z/10+) + 1.05(z/T_w)e^{0.012z/T_w}}.$$ [10]

The model was calibrated with available data for Church Pine, Round, and Big Lakes.

The model estimated the Church Pine Lake water column total phosphorus concentration as 19.71 µg/l, which was exactly the same as the actual annual measured average. A 5% reduction in the external areal load to the lake reduces phosphorus to 19.27 µg/l, which is more than adequate to maintain the water quality of Church Pine Lake.

The model estimated the Round Lake water column total phosphorus concentration as 25.14 µg/l, which was exactly the same as the actual annual measured average. A 10% reduction in the external areal load to the lake reduces phosphorus to 24.24 µg and a 16% reduction reduces phosphorus to 19.87 µg/l which is comparable to Church Pine Lake's concentration.

The model estimated the Big Lake water column total phosphorus concentration as 29.57 µg/l, which was exactly the same as the actual annual measured average. A 10% reduction

[9] P is the predicted mixed lake total phosphorus concentration, L_{ext} is external areal loading, L_{int} is areal internal loading, qs is areal water loading or surface overflow rate, z is the lakes mean depth, and R is the Fraction of inflow total phosphorus retained in the lake.

[10] P is the predicted mixed lake total phosphorus concentration, L is areal loading, z is the lakes mean depth, and T_w is the lake hydraulic retention time.

in the external areal load to the lake reduces phosphorus to 24.24 µg and a 16% reduction reduces phosphorus to 19.87 µg/l which is comparable to Church Pine Lake's concentration.

The Big Lake model was also calibrated to the measured 29.57 µg/l, which was exactly the same as the actual annual measured average. A 16% reduction in the external areal load to the lake reduces phosphorus to 29.02 µg and a 25% reduction reduces phosphorus to 28.71 µg/l

Using the available in situ and modeled data it is possible to predict reductions in chlorophyll a concentrations and total primary productivity within the water column by using the equation

$$\left[\overline{chl.a}\right] = 0.55\{[P]_i/(1+\sqrt{T_w}\}^{0.76}$$

for estimating the annual average chlorophyll a concentrations and

$$\sum C(gm^{-2}yr^{-1}) = \left[\frac{\{[P]_i/(1+\sqrt{T_w}\}^{0.76}}{0.3+0.011\{[P]_i/(1+\sqrt{T_w}\}^{0.76}}\right]$$ [11]

to correlate the relationship of total primary productivity with chlorophyll a. This equation is based on average chlorophyll concentrations and light extinction resulting from turbidity and dissolved organic substances (Wetzel, 2001).

Using these equations it was predicted that Church Pine Lake would have an annual chlorophyll a concentration of 8.01 µg/l under current conditions and 7.82 µg/l with a five percent external load reduction. Both numbers are much higher than the 1.8 µg/l average measured in 2012; however, the model does predict a decline in chlorophyll a even with such a small watershed reduction. Similar results were found in primary productivity with the model predicting 201.24 $\sum C(gm^{-2}yr^{-1})$ under current conditions and 198.00 $\sum C(gm^{-2}yr^{-1})$ with the reduction.

The same equations showed that under current conditions Round Lake would have an annual chlorophyll a concentration of 12.97µg/l with a 10% external load reduction, and 10.25 µg/l with a 16% external load reduction. These values are still higher than the 2.5 µg/l measured in 2012, but still show a 24% reduction in chlorophyll a. Total primary productivity went from 278.87 $\sum C(gm^{-2}yr^{-1})$ under current conditions to 272.51 $\sum C(gm^{-2}yr^{-1})$ with a 10% reduction and to 236.66 $\sum C(gm^{-2}yr^{-1})$ with a 16% reduction.

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[11] $\left[\overline{chl.a}\right]$ is the average annual concentration of chlorophyll a, $[P]_i$ is the average inflow concentration of total phosphorus, T_w is the lake hydraulic retention time, and $\sum C(gm^{-2}yr^{-1})$ is the sum of grams of carbon per meter squared of lake area per year produced during photosynthesis.

In Big Lake the model predicted the average annual chlorophyll *a* concentration to be 15.32 µg/l under current conditions, 15.04 µg/l with a 16% external load reduction, and 14.88 µg/l with a 25% external load reduction. Again these values are above the 4.75 µg/l measured in 2012; however, the chlorophyll *a* concentration on September 5th, 2012 was 12.00 µg/l, closer to what was modeled. The total primary productivity was modeled to be 298.70$\sum C(gm^{-2}yr^{-1})$ at current conditions, 295.79$\sum C(gm^{-2}yr^{-1})$ with a 16% external load reduction, and 294.13 $\sum C(gm^{-2}yr^{-1})$ with a 25% external load reduction.

Models are generally an over simplification of natural phenomenon; however, they can be useful to guide lake management because they can be used to predict many different scenarios. The models employed do show reductions in water column total phosphorus concentrations, chlorophyll *a* concentrations, and total primary productivity. However, to enhance current understanding of these lakes' ecosystems and guide future management decisions a clear understanding of Church Pine, Round and Big Lakes current and past ecosystem functions needs to be achieved.

Current pre and post aquatic macrophyte surveys should be coupled with continuous water column monitoring. Additionally, a detailed study of in situ sediment nutrient release and REDOX conditions should be seriously considered to adequately quantify internal loading and paleolimnological techniques should be employed to understand past water quality and ecosystem change and refine goals as needed.

Nutrient Budget Summary: Church Pine Lake

Modeling was used to estimate an annual phosphorus budget for Church Pine Lake for external (watershed) and internal (in-lake) sources of phosphorus.

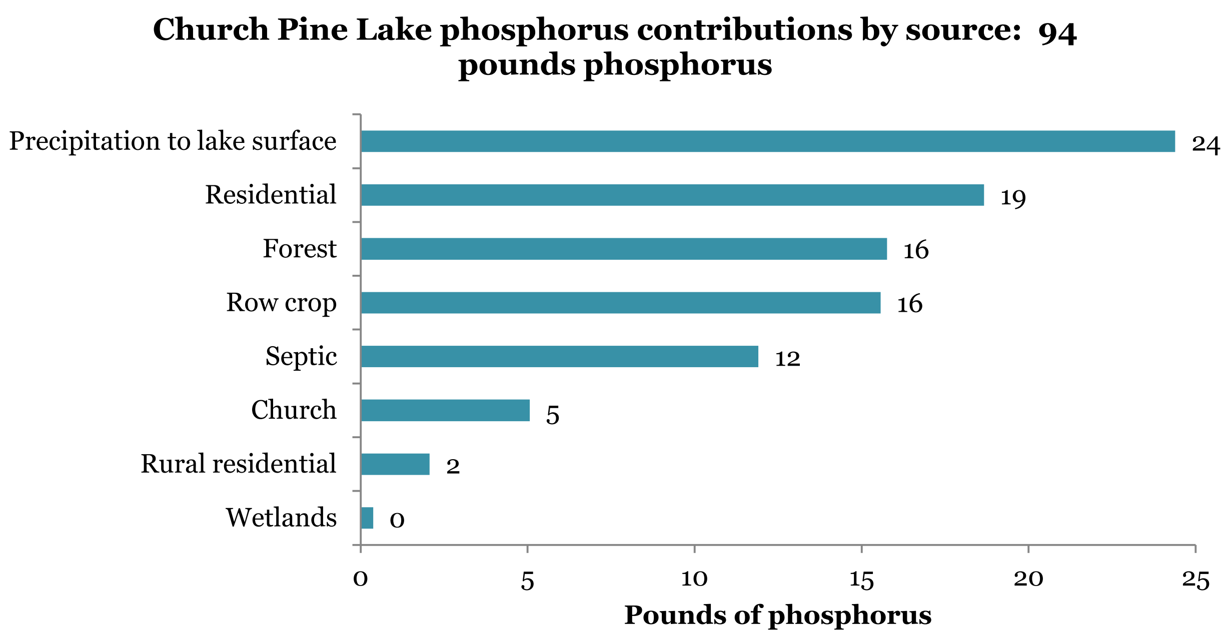
Non-point source load estimated from WiLMS: 93.8 pounds phosphorus/year

Divided by land use:

- ✓ Precipitation to lake surface: 24.4 pounds
- ✓ Residential: 18.7 pounds
- ✓ Forest: 15.8 pounds
- ✓ Row crop: 15.6 pounds
- ✓ Septic: 11.9 pounds
- ✓ High density urban: 5.1 pounds
- ✓ Rural residential: 2.1 pounds
- ✓ Wetlands: 0.4 pounds

Waterfront property load estimated with Virginia Runoff Reduction Method Worksheet: 19.4 pounds phosphorus/year

Internal Load (load from sediments/dead or decaying matter): 70 pounds phosphorus/year



Modeling was used to predict changes in water quality that would result from a 5% reduction in external sources of phosphorus (4.7 pounds of phosphorus) to Church Pine Lake.

Modeling predicts that current water column phosphorus (with no reductions in internal or external loading) would be 0.0197 mg/L with a TSI(phosphorus) value of 47.1. Actual 2012 TSI(phosphorus) was 47.7.

Water column and TSI phosphorus were estimated for a 5% external reduction.

5% external reduction	
Phosphorus (mg/L)	TSI (P)
.0193	46.8

Nutrient Budget Summary: Round Lake

Modeling was used to estimate an annual phosphorus budget for Round Lake for external (watershed) and internal (in-lake) sources of phosphorus.

Non-point source load estimated from WiLMS: 34.9 pounds phosphorus/year

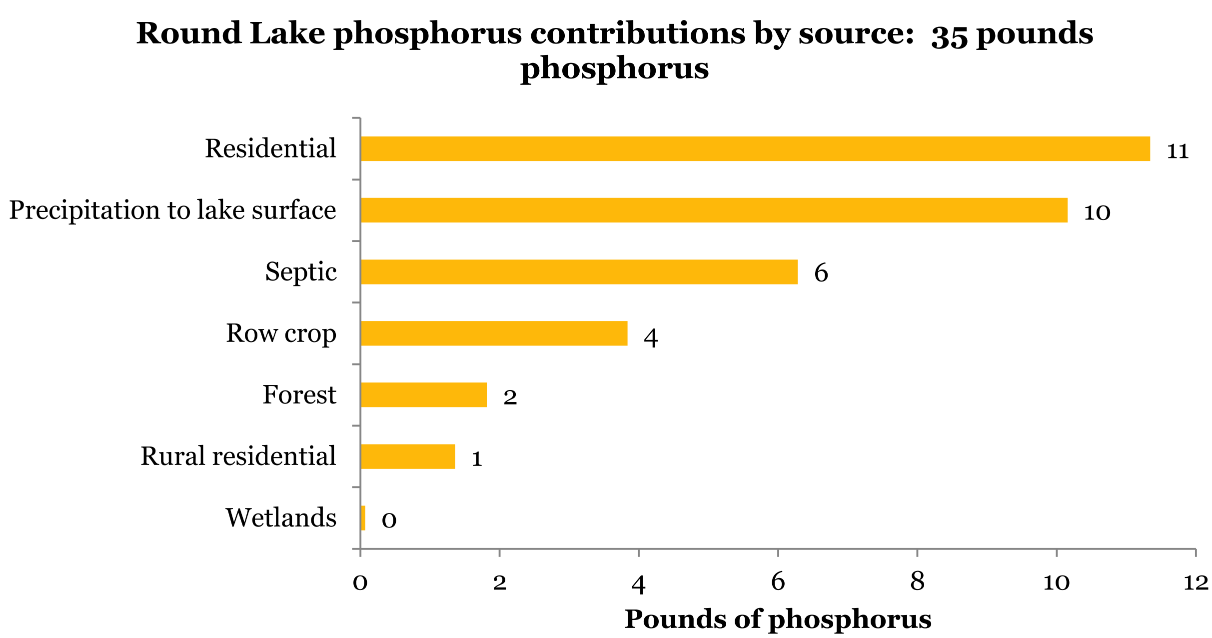
Divided by land use:

- ✓ Residential: 11.3 pounds
- ✓ Precipitation to lake surface: 10.2 pounds
- ✓ Septic: 6.3 pounds
- ✓ Row crop: 3.8 pounds
- ✓ Forest: 1.8 pounds
- ✓ Rural residential: 1.4 pounds
- ✓ Wetlands: 0.1 pounds

Point-source load from Church Pine Lake: 11.0 pounds phosphorus/year

Waterfront property load estimated with Virginia Runoff Reduction Method Worksheet: 10.9 pounds phosphorus/year

Internal Load (load from sediments/dead or decaying matter): 10.70 pounds phosphorus/year



Modeling was used to predict changes in water quality that would result from a 10% and 16% reduction in external sources of phosphorus (3.5 and 5.6 pounds of phosphorus, respectively) to Round Lake.

Modeling predicts that current water column phosphorus (with no reductions in internal or external loading) would be 0.0251 mg/L with a TSI (phosphorus) value of 50.6. Actual 2012 TSI(phosphorus) was 49.4.

Water column and TSI phosphorus were estimated for a 10% and 16% external reduction.

10% external reduction		16% external reduction	
Phosphorus (mg/L)	TSI (P)	Phosphorus (mg/L)	TSI (P)
.0242	50.1	.0199	47.2

Nutrient Budget Summary: Big Lake

Modeling was used to estimate an annual phosphorus budget for Big Lake for external (watershed) and internal (in-lake) sources of phosphorus.

Non-point source load estimated from WiLMS: <u>517.8 pounds phosphorus/year</u>

Divided by land use:

- ✓ Row crop: 257.6 pounds
- ✓ Precipitation to lake surface: 65.2 pounds
- ✓ Residential: 44.5 pounds
- ✓ Forest: 37.8 pounds
- ✓ Wetlands: 37.2 pounds
- ✓ Mixed agriculture: 24.3 pounds
- ✓ Pasture/grass: 21.7 pounds
- ✓ Septic: 17.6 pounds
- ✓ Rural residential: 11.9 pounds

Tributary load calculated using field collected phosphorus data: <u>253.4 pounds phosphorus/year</u>

- ✓ County Road K culvert: 2.8 pounds
- ✓ North Creek: 250.6 pounds

Non point and point source load estimated from WiLMS by subwatershed: <u>312.1 pounds phosphorus/year</u>

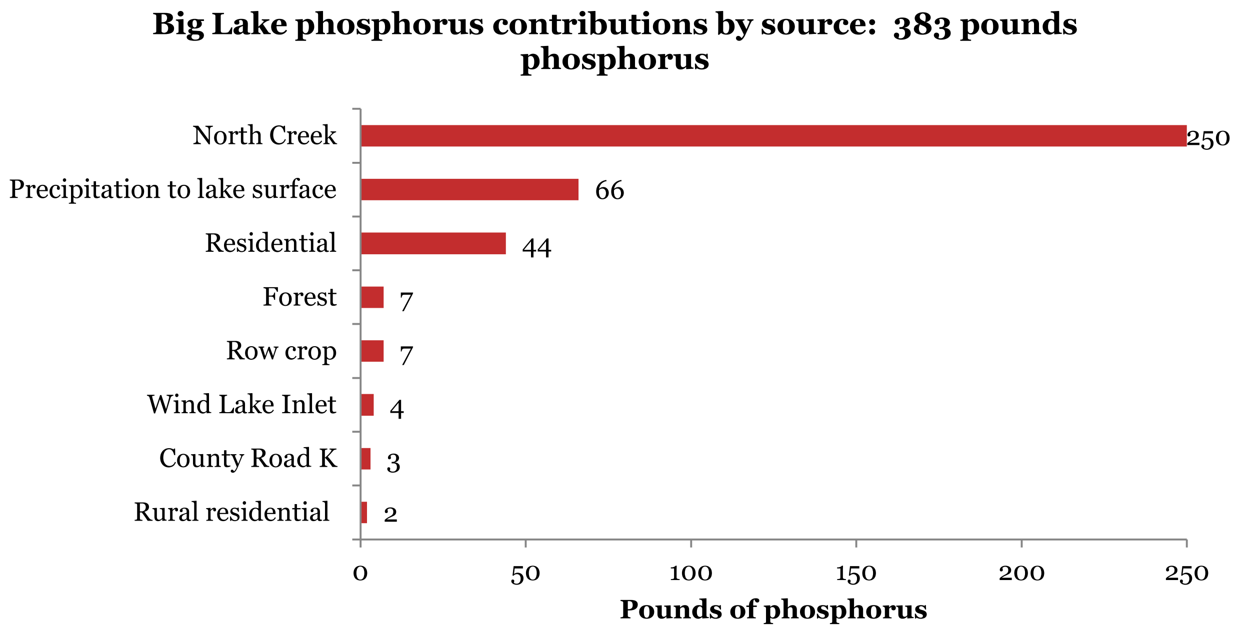
- ✓ County Road K Culvert Subwatershed: 2.75 pounds
- ✓ North Creek Subwatershed: 250 pounds
- ✓ Direct Drainage Subwatershed: 59.3 pounds

Point-source load from Wind Lake: <u>4 pounds phosphorus/year</u>

Tributary load leaving lake through the Big Lake Outlet calculated using field collected phosphorus data: <u>24.6 pounds phosphorus/year</u>

Waterfront property load estimated with Virginia Runoff Reduction Method Worksheet: <u>42.4 pounds phosphorus/year</u>

Internal Load (load from sediments/dead or decaying matter): <u>74 pounds phosphorus/year</u>


Big Lake phosphorus contributions by source: 383 pounds phosphorus
North Creek
Precipitation to lake surface
Residential
Forest
Row crop
Wind Lake Inlet
County Road K
Rural residential
250
66
44
7
7
4
3
2
0
50
100
150
200
250
Pounds of phosphorus

Modeling was used to predict changes in water quality that would result from a 16% and 25% reduction in external sources of phosphorus (82.8 and 129.5 pounds of phosphorus, respectively) to Big Lake.

Modeling predicts that current water column phosphorus (with no reductions in internal or external loading) would be 0.0296 mg/L with a TSI (phosphorus) value of 53. Actual 2012 TSI(phosphorus) was 54.57.

Water column and TSI phosphorus were estimated for a 16% and 25% external reduction.

16% external reduction		25% external reduction	
Phosphorus (mg/L)	TSI (P)	Phosphorus (mg/L)	TSI (P)
.0290	52.7	.0287	52.5

Pontoon Classrooms

On July 20th and August 9th, 2012 pontoon classrooms were held for members of the Church Pine, Round, and Big Lake Protection and Rehabilitation District. The classroom held on July 20th was attended by five adults and the classroom held on August 9th was attended by nine children and one adult.

A third classroom was initially scheduled for August 3rd, rescheduled for August 12th, and eventually cancelled.

The pontoon classrooms were promoted through the District Spring Informational Meeting, the District Annual Meeting, a reminder postcard sent to all residents, and through the District website.

At both pontoon classrooms, participants were given the chance to collect physical and chemical data, zooplankton samples, and algae samples. Data was explained as it was collected and participants had the opportunity to see zooplankton and filter chlorophyll *a* samples. Plants were collected with a rake and shown to participants during a conversation regarding the benefits of aquatic plants and how to identify invasive species. Participants were given the chance to ask any questions they had regarding water quality. Tributary sampling was discussed with the adult group and aquatic macroinvertebrates were collected with the children group.

Shoreline Restoration Workshop

On September 13th, 2012 a shoreline restoration workshop was held for members of the Church Pine, Round, and Big Lake Protection and Rehabilitation District at the Alden Town Hall. The workshop began at 3 pm and lasted over two hours. Eight attendees gained valuable information regarding shoreline restoration and rain gardens and were offered numerous educational handouts including: native plant lists for Polk County, rain garden designs, and grids to design a project of their own.

The workshop was promoted through the District Spring Informational Meeting, the District Annual Meeting, a reminder postcard sent to all residents, and through the District website.

Polk County Ordinances

Comprehensive Land Use Planning

The Polk County Comprehensive Land Use Plan was adopted in 2009. The plan includes an analysis of population, economy, housing, transportation, recreation, and land use trends. It also reports the physical features of Polk County. The purpose of the land use plan is to provide general guidance to achieve the desired future development of the county and direction for development decisions. The lakes classification outlines restriction on development according to lake features. Plan information is available online at http://www.co.polk.wi.us/landinfo/PlanningCompPlan.asp

Town, City and Village Comprehensive Plans are available at: http://www.co.polk.wi.us/landinfo/PlanningCompPlans.asp

Smart growth is a state mandated planning requirement to guide land use decisions and facilitate communication between municipalities. Wisconsin's Comprehensive Planning Law (Statute 66.1001, Wis. Stats.) was passed as part of the 1999 Budget Act. The law requires that if a local government engages in zoning, subdivision regulations, or official mapping, those local land use regulations must be consistent with that unit of local government's comprehensive plan beginning on January 1, 2010. The law defines a comprehensive plan as having at least the following nine elements:

- ✓ Issues and opportunities
- ✓ Housing
- ✓ Transportation
- ✓ Utilities and community facilities
- ✓ Agricultural, natural, and cultural resources
- ✓ Economic development
- ✓ Intergovernmental cooperation
- ✓ Land use
- ✓ Implementation
- ✓ Polk County added "Energy and Sustainability"

Polk County Comprehensive Land Use Ordinance

The Polk County Comprehensive Land Use Ordinance, more commonly known as the Zoning Ordinance, is currently being updated due to the passage of the Comprehensive Plan. 17 of Polk County's 24 Towns have adopted county zoning, including: the Towns of Alden, Apple River, Beaver, Black Brook, Clam Falls, Clayton, Clear Lake, Eureka, Georgetown, Johnstown, Lincoln, Lorain, Luck, McKinley, Milltown, Osceola, and West Sweden. The Towns of Farmington, Garfield, and St Croix Falls have adopted Town Zoning and the Towns of Balsam Lake, Bone Lake, Laketown, and Sterling have no town or county zoning other than the state-mandated shoreland zoning. Land use regulations in the zoning ordinance include building height requirements, lot sizes, permitted uses, and setbacks among other provisions. The current Comprehensive Zoning Ordinance is available at: http://www.co.polk.wi.us/landinfo/pdfs/Ordinances/ComprehensiveLandUse.pdf

Shoreland Protection Zoning Ordinance

The State of Wisconsin's Administrative Rule NR115 dictates that counties must regulate lands within 1,000 feet of a lake, pond or flowage and 300 feet of a river or stream. The Shoreland Protection Zoning Ordinance is also currently being rewritten due to the Comprehensive Plan and the State of Wisconsin passing a new version of NR 115 in 2010. Polk County passed an update of the current Shoreland Ordinance in 2002 and again in 2008. These updates put in place standards for impervious surfaces, a phosphorus fertilizer ban for shoreland property, and lakes classification and setback standards. The current ordinance is available online at:
http://www.co.polk.wi.us/landinfo/pdfs/Ordinances/ShorelandOrdinance.pdf

Updates to the Shoreland Protection Ordinance and the Comprehensive Land Use Ordinance will be completed in 2013. The old and new version of the ordinances will be available at: http://www.co.polk.wi.us/landinfo/ordinances.asp

Subdivision Ordinance

The subdivision ordinance, adopted in 1996 and updated in 2005, requires a recorded certified survey map for any parcel less than 19 acres. The ordinance requires most new plats to incorporate storm water management practices with no net increase in runoff from development. The ordinance is available online at:
http://www.co.polk.wi.us/landinfo/PDFs/Ordinances/Subdivision%20Ordinance%202005-07-01.pdf

Animal Waste

The Polk County Manure and Water Quality Management Ordinance was revised in January 2000. A policy manual established minimum standards and specifications for animal waste storage facilities, feedlots, degraded pastures, and active livestock operations greater than 300 animal units for livestock producers regulated by the ordinances. The Land and Water Resource Department's objective was to have countywide compliance with the ordinance by 2006. The ordinance is available online at:
http://www.co.polk.wi.us/landwater/MANUR21A.htm.

Storm Water and Erosion Control

The ordinance, passed in December 2005, establishes planning and permitting requirements for erosion control on disturbed sites greater than 3,000 square feet, where more than 400 cubic yards of material is cut or filled, or where channels are used for 300 feet more of utility installation (with some exceptions). Storm water plans and implementation of best management practices are required for subdivisions, survey plats, and roads where more than ½ acre of impervious surface will result. The Polk County Land and Water Resources Department administers the ordinance. The ordinance is a local mechanism to implement the Wisconsin Non-agricultural Runoff Performance Standards found in NR 151.

WI Non-Agricultural Performance Standards (NR 151)

Construction Sites >1 acre – must control 80% of sediment load from sites

Storm water management plans (>1 acre)

- Total Suspended Solids
- Peak Discharge Rate
- Infiltration
- Buffers around water

Developed urban areas (>1000 persons/square mile)

- Public education
- Yard waste management
- Nutrient management
- Reduction of suspended solids

Amended Illegal Transport of Aquatic Plants and Invasive Animals

The purpose of this ordinance, passed in June 2011, is to prevent the spread of aquatic invasive species in Polk County and surrounding water bodies by prohibiting the transport of boats, trailer, personal watercraft, and equipment if aquatic invasive plants or invasive animals are attached.

Polk County Land and Water Resources Management Plan

The Polk County Land and Water Resources Management Plan describes the strategy the Land and Water Resources Department (LWRD) will employ from 2010-2018 to address agriculture and non-agriculture runoff management, stormwater discharge, shoreline management, soil conservation, invasive species and other environmental degradation that affects the natural resources of Polk County. The plan specifies how the LWRD will implement NR 151 (Runoff Management). It involves identifying critical sites, offering cost-share and other programs, identifying BMP's monitoring and evaluating projects for compliance, conducting enforcement activities, tracking progress, and providing information and education.

Polk County has local shoreland protection, zoning, subdivision, animal waste, and non-metallic mining ordinances. Enforcing these rules and assisting other agencies with programs are part of LWRD's ongoing activities. Other activities to implement the NR 151 Standards include information and education strategies, write nutrient management plans, provide technical assistance to landowners and lakeshore owners, perform lake studies, collaborate with other agencies, work on a rivers classification system, set up demonstration sites of proper BMP's, control invasive species, and revise ordinances to offer better protection of resources.

WI Agricultural Performance Standards (NR 151)

For farmers who grow agricultural crops

- ✓ Meet "T" on cropped fields
- ✓ Starting in 2005 for high priority areas such as impaired or exceptional waters, and 2008 for all other areas, follow a nutrient management plan designed to limit entry of nutrients into waters of the state

For farmers who raise, feed, or house livestock

- ✓ No direct runoff from feedlots or stored manure into state waters
- ✓ No unlimited livestock access to waters of the state where high concentrations of animals prevent the maintenance of adequate or self sustaining sod cover
- ✓ Starting in 2005 for high priority areas, and 2008 for all other areas, follow a nutrient management plan when applying or contracting to apply manure to limit entry of nutrients into waters of the state

For farmers who have or plan to build a manure storage structure

- ✓ Maintain a structure to prevent overflow, leakage, and structural failure
- ✓ Repair or upgrade a failing or leaking structure that poses an imminent health threat or violates groundwater standards
- ✓ Close a structure according to accepted standards
- ✓ Meet technical standards for a newly constructed or substantially-altered structure

For farmers with land in a water quality management area (defined as 300 feet from a stream, or 1,000 feet from a lake or areas susceptible to groundwater contamination)

- ✓ Do not stack manure in unconfined piles
- ✓ Divert clean water away from feedlots, manure storage areas, and barnyards located within this area

Lake Management Plan

Lake Management Plans help protect natural resource systems by encouraging partnerships between concerned citizens, lakeshore residents, watershed residents, agency staff, and diverse organizations. Lake Management Plans identify concerns of importance and set realistic goals, objectives, and action items to address each concern. Additionally, Lake Management Plans identify roles and responsibilities for meeting each goal and provide a timeline for implementation.

Lake Management Plans are living documents which are under constant review and adjustment depending on the condition of a lake, available funding, level of volunteer commitments, and the needs of lake stakeholders.

The Lake Management Plan goals presented below were created through collaborative efforts using current and past water quality data, a 2012 sociological survey regarding the needs of District members, and a series of four meetings by the Church Pine, Round, and Big Lake Water Quality Committee. Key findings of the study and draft goals were presented at the 2013 Spring Informational Meeting on Saturday, May 18th.

Vision

Church Pine, Round, and Big Lake are clear lakes with ideal nutrient levels which are free of algae blooms and provide a healthy environment that supports a diversity of fish, birds, wildlife, plants, and human uses.

Guiding Principles

- Lake management decisions are driven by what is best for the lakes according to past, present, and future data
- Communication regarding lake management is easy to understand and concise
- Financial decisions are made in cooperation with Lake District members

5-10 Year Implementation Plan Goals

- Reduce algae and phosphorus in the three lake system by reducing watershed runoff
- Evaluate the progress of lake management efforts
- Protect, maintain, and enhance fish habitat
- Increase knowledge and participation
- Support the goals of the Aquatic Plant Management Plan

Goal 1: Reduce algae and phosphorus in the three lake system by reducing watershed runoff [12]

The area of land that drains to a lake is called a watershed. The Church Pine Lake Watershed is 247 acres in size, the Round Lake Watershed is 69 acres in size, and the Big Lake Watershed is 1,523 acres in size.

Church Pine Lake: Reduce watershed runoff by 5% to ensure current water quality is maintained. Reductions on Church Pine Lake will positively impact Round and Big Lakes.

Shoreline property owners contribute the greatest amount of phosphorus to Church Pine Lake

- Identify shoreline landowners willing to install shoreline buffers, rain gardens, and water diversions on their property
- Provide technical assistance and cost sharing for implementation of projects
- Recognize landowners that have taken steps to reduce watershed runoff

Partner with landowners to install rain gardens, water diversions, and erosion control practices at or near the Church Pine Lake boat landing

Round Lake: Reduce watershed runoff by 10-16%. Reductions on Round Lake will positively impact Big Lake.

Shoreline property owners contribute the greatest amount of phosphorus to Round Lake.

- Identify shoreline landowners willing to install shoreline buffers, rain gardens, and water diversions on their property
- Provide technical assistance and cost sharing for implementation of projects
- Recognize landowners that have taken steps to reduce watershed runoff

Big Lake: Reduce watershed runoff by 16-25%.

North Creek contributes the greatest amount of phosphorus to Big Lake (63%) followed by shoreline property owners (31%).

- Support the work of the Horse Creek Watershed Farmer Led Council
- Work with Polk County LWRD/consultant to identify best management practices to reduce the phosphorus load from North Creek
- Examine the economic feasibility and effectiveness of a sediment pond on North Creek
- Identify shoreline landowners willing to install shoreline buffers, rain gardens, and water diversions on their property
- Provide technical assistance and cost sharing for implementation of projects
- Recognize landowners that have taken steps to reduce watershed runoff

Partner with landowners to install rain gardens, water diversions, and erosion control practices at or near the Big Lake boat landing

[12] Impacts of reductions can be found on pages 98 (Church Pine), 100 (Round), and 103 (Big).

<u>Goal 2:</u> Evaluate the progress of lake management efforts

Continue current data collection efforts

Ensure that Citizen Lake Monitoring volunteer is in place for each year

Contact WDNR in Spooner for more information and sampling materials

Expand data collection efforts depending on needs

Monitor tributaries to document reductions in watershed runoff

<u>Goal 3:</u> Protect, maintain, and enhance fish habitat

Balancing fish communities can impact zooplankton populations, which can impact algae populations. Zooplankton are small crustaceans that graze on algae.

Maintain desirable levels of game fish in the lakes

Assess and improve fish habitat i.e. woody habitat

Communicate with WDNR to make informed decisions and encourage assessment and management

Continue monetarily supporting fish stocking based on expert recommendations

<u>Goal 4:</u> Increase knowledge and participation

Watershed residents and lake users are provided information to understand:

- the ever evolving nature of lake management
- the complexity of issues
- the status of projects and activities
- the costs and benefits of actions
- the opportunity and techniques to reduce or prevent any negative consequences of lake use and lakeside living

<u>Methods for communicating information</u>

Website

Annual Meeting

Spring Informational Meeting

Tour to view installed best management practices

Contest for best rain garden, shoreline restoration, etc

<u>Goal 5:</u> Support the goals of the Aquatic Plant Management Plan

- Prevent introduction of aquatic invasive species and pursue any new introduction aggressively
- Reduce the population and spread of curly leaf pondweed, purple loosestrife, and other invasive aquatic plants
- Maintain navigable routes for boating
- Preserve diverse native aquatic plant community
- Reduce runoff of nutrients and sediment from the lake's watershed
- Educate the public regarding aquatic plant management

Further considerations

1. Consider further studies to quantify internal loading, or the nutrients released back into the water column through sediment disturbance or plant die back
2. Consider a sediment core on Church Pine, Round, and Big Lake to gather historical data (i.e. 100-200 years)
3. Consider further studies to quantify groundwater phosphorus inputs within the watershed

<u>Goal 1:</u> Reduce algae and phosphorus in the three lake system by reducing watershed runoff

Action	Timeline	Cost Estimate	Volunteer Hours	Responsible Parties	Funding Sources
Identify shoreline landowners willing to install shoreline buffers, rain gardens, and water diversions on their property	2013, ongoing	$1,000	80	Board Water quality committee	District
Provide technical assistance and cost sharing for implementation of projects	2014, ongoing	$250,000		Board Consultant	District WDNR Lake Protection Grant
Recognize landowners that have taken steps to reduce watershed runoff	Ongoing	$50 annual		Board	District
Partner with landowners to install rain gardens, water diversions, and erosion control practices at or near the Church Pine Lake boat landing	2014, ongoing	TBD		Board Consultant	District WDNR Lake Protection Grant
Support the work of the Horse Creek Watershed Farmer Led Council	2015, ongoing	TBD		Board LWRD	District
Work with Polk County LWRD/consultant to identify best management practices to reduce the phosphorus load from North Creek	2014, ongoing	TBD		Board LWRD Consultant	District WDNR Lake Planning Grant
Examine the economic feasibility and effectiveness of a sediment pond on North Creek	2015	$2,500		Board Consultant	District WDNR Lake Planning Grant
Partner with landowners to install rain gardens, water diversions, and erosion control practices at or near the Big Lake boat landing	2014, ongoing	TBD		Board Consultant	District WDNR Lake Protection Grant

<u>Goal 2:</u> Evaluate the progress of lake management efforts

Action	Timeline	Cost Estimate	Volunteer Hours	Responsible Parties	Funding Sources
Ensure that Citizen Lake Monitoring volunteer is in place for each year	Ongoing	$360 annual stipend	30 annual	Board	WDNR Citizen Lake Monitoring Network
Contact WDNR in Spooner for more information and sampling materials	Ongoing	$0	1	Board	N/A
Monitor tributaries to document reductions in watershed runoff	TBD	$1,200 annual		Board Consultant	District WDNR Lake Protection Grant

<u>Goal 3:</u> Protect, maintain, and enhance fish habitat

Action	Timeline	Cost Estimate	Volunteer Hours	Responsible Parties	Funding Sources
Assess and improve fish habitat i.e. woody habitat	TBD	TBD		Board WDNR LWRD	District WDNR Lake Protection Grant
Communicate with WDNR to make informed decisions and encourage assessment and management	Ongoing	TBD		Board WDNR	NA
Continue monetarily supporting fish stocking based on expert recommendations	Ongoing	$4,000		Board WDNR	District

<u>Goal 4:</u> Increase knowledge and participation

Methods for communicating information	Timeline	Cost Estimate	Volunteer Hours	Responsible Parties	Funding Sources
Website	Ongoing	$100		Board	District
Annual Meeting	Ongoing	$50		Board	District
Spring Informational Meeting	Ongoing	$50		Board	District
Tour to view installed best management practices	2014	$150		Board	District
Contest for best rain garden, shoreline restoration, etc	TBD	$150		Board	District

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