Pipe and North Pipe Lakes Lake Management Plan, 2018-2023

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Pipe and North Pipe Lakes Protection and Rehabilitation District

We would like to thank the following for their contributions to this project. Asterisks indicate members of the Lake Planning Committee.

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Purpose of the Study

In December 2014, the Pipe and North Pipe Lakes Protection and Rehabilitation District applied for a Wisconsin Department of Natural Resources Lake Planning Grant in partnership with the Polk County Land and Water Resources Department. The grant was awarded and data collection occurred in 2015 and 2016.

Although the impetus for this planning project arose from the proposed listing of North Pipe Lake for Wisconsin's Impaired Waters List, the timing of the grant proposal correlated exactly with the timeframe during which a comprehensive lake management plan should be updated for Pipe and North Pipe Lakes.

Methods and activities completed through this grant award include:

- ✓ In-lake physical data
- ✓ Top nitrogen and bottom iron to augment Citizen Lake Monitoring Network data
- ✓ Phytoplankton
- ✓ Lake resident survey
- ✓ Lake level and precipitation monitoring data
- ✓ Watershed delineation and boundaries
- ✓ Phosphorus loads
- ✓ Shoreline inventory
- ✓ Pontoon classroom
- ✓ Sediment core collection on North Pipe Lake

The following report details the methods and activities completed through this grant award. The full sediment core write up can be found in Appendix I.

Executive Summary

- If a waterbody does not meet water quality standards, it is placed on Wisconsin's Impaired Waters List under the Federal Clean Water Act, Section 303(d). North Pipe Lake is listed for recreation based on the impairment excess algal growth (pollutant unknown) and Pipe Lake is listed for fish consumption for the pollutant mercury and the impairment contaminated fish tissue.

- The average summer secchi depth (July and August) for the Northwest geo-region was 8.4 feet in 2015 and 2016. In both years, secchi depth for Pipe Lake was well above the Northwest geo-region average (15.08 feet and 13.75 feet, respectively) and secchi depth for North Pipe Lake was below the geo-region average (3.88 feet and 5.15 feet, respectively).

- On all sampling dates, surface phosphorus was below the healthy limit of 20 µg/L on Pipe Lake and above the heathy limit on North Pipe Lake. Phosphorus concentrations were elevated on the bottom of both lakes, but especially in North Pipe Lake.

- Chlorophyll a seems to have the greatest impact on water clarity when levels exceed 30 µg/L. Lakes which appear clear generally have chlorophyll levels less than 15 µg/L. Chlorophyll a levels on Pipe Lake were well below 15 µg/L on all sample dates. Chlorophyll a levels on North Pipe Lake were below 15 µg/L in June and also in July of 2016, between 15 and 30 µg/L in July of 2015 and August of 2016, and over 30 µg/L in August of 2015.

- Monitoring the trophic state index (TSI) of a lake gives stakeholders a method by which to gauge lake productivity over time. Historic TSI data indicates an oligotrophic to mesotrophic state on Pipe Lake and a mesotrophic to eutrophic state on North Pipe Lake. Data from 2015 and 2016 indicate an oligotrophic/mesotrophic state in Pipe Lake and a mildly eutrophic state in North Pipe Lake.

- On most of the sampling dates in 2015 and 2016, blue green algae were the most abundance division of algae in both lakes, but less so on Pipe Lake.

- In Pipe Lake, toxin risk from blue green algae was low on all sampling dates based on blue green algae cell density and chlorophyll a. In North Pipe Lake, toxin risk was low in June of both years and moderate in July and August of both years based on chlorophyll a. Based on cyanophyta, toxin risk was low on 50% of the sampling dates, moderate on 40% of the sampling dates, and high on 10% of the sampling dates on North Pipe Lake.

- The shoreline of North Pipe Lake is primarily undisturbed (92%) as compared to disturbed (8%). In contrast, more than half of the shoreline of Pipe Lake is disturbed (59%) as compared to undisturbed (41%). Pipe Lake had much more shoreline alterations than North Pipe Lake.

- There were twenty-two areas along the shoreline of Pipe Lake and two areas along the shoreline of North Pipe Lake that included coarse woody structure. These areas provide important benefits for fish and wildlife.

- The largest contributor of phosphorus to Pipe Lake based on land use is row crop (28%), followed by forest (12%), residential (5%), pasture/grass (2%), and wetlands (2%). Modeling predicts that atmospheric deposition (precipitation to the lake's surface) contributes 22% of the phosphorus load, septic contributes 15%, and North Pipe Lake contributes 14%. The largest contributors of phosphorus to North Pipe Lake based on land use were forest (37%) and row crop (32%), followed by residential (6%), pasture/grass (6%), and wetlands (5%). Modeling predicts that atmospheric deposition (precipitation to the lake's surface) contributes 10% of the phosphorus load and septic contributes 4% of the load.

- WiLMS determined the annual external source load of phosphorus to Pipe Lake as 344.4 pounds per year. WiLMS determined the annual external source load of phosphorus to North Pipe Lake as 176.7 pounds per year.

- Overall, the internal load is predicted to be significant and is likely a controlling factor in both the nutrient and phytoplankton dynamics of North Pipe Lake. While controlling the internal load can be a difficult endeavor and cost prohibitive, it could be a useful way to improve the water quality of North Pipe Lake. Pipe Lake stratifies so strongly that it is likely not a major component of the nutrient budget during the growing season.

- Since Pipe Lake has very low nutrient levels and a low watershed to lake ratio, shoreline practices such as restoration could make a significant impact on water quality and habitat. An enhanced understanding of North Pipe Lake's internal load would make management decisions easier and help the Protection and Rehabilitation District better manage funds for management activities. It is recommended that an internal load assessment be done for the lake in shallow areas.

Executive Summary of the Paleolimnology Study of North Pipe Lake[1]

- A piston core was collected from North Pipe Lake on August 7, 2015 in 10.96 m of water. The coring location represented a flat and deep area of the basin, to provide a highly integrated sample of diatom community structure from the lake as a whole. The piston core was collected using a drive-rod piston corer equipped with a 6.5 cm diameter polycarbonate barrel.

- Seventeen core sections were analyzed for lead-210 activity to determine age and sediment accumulation rate for the past 150 years and calibrated with cesium-137.
    - Sedimentation rates nearly doubled around 1860, probably due to logging, and then fell again. In 1936 the sedimentation rate was almost three times as high as the early 1800s, probably due to conversion of land to agriculture, and then slowly fell again. Sedimentation rates are low compared to other lakes in the region.

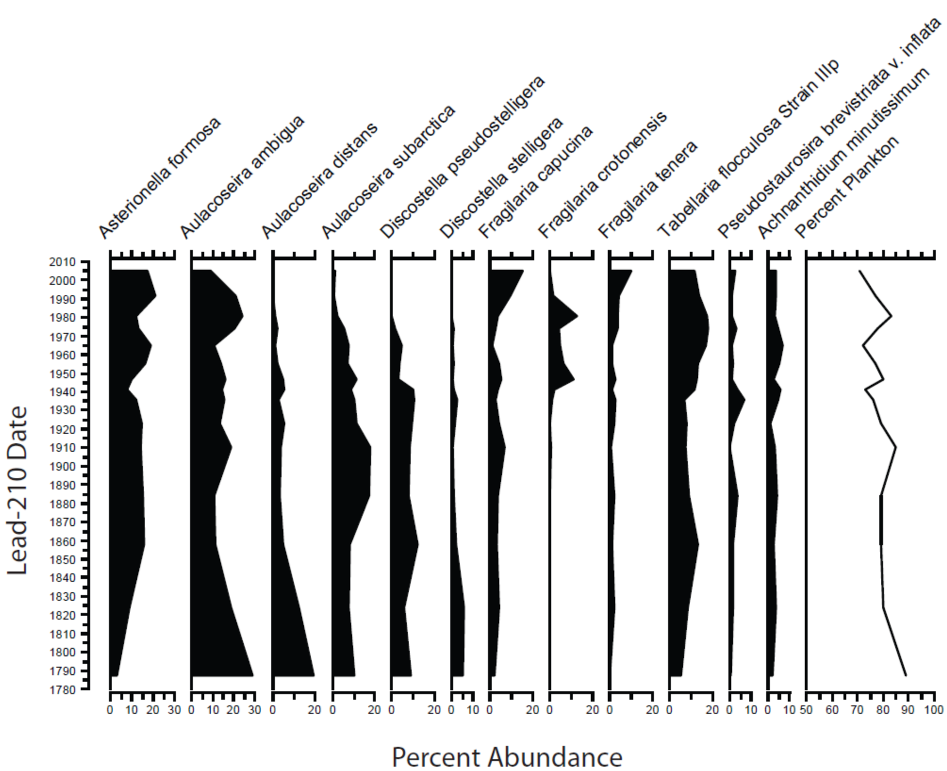
- Weighed subsamples were taken from regular intervals throughout the core for loss-on-ignition analysis to determine bulk and dry density and dry weight percent of organic carbonate and inorganic matter.
    - The composition of the sediment showed little variation over time. The sediment flux is calculated by multiplying each part of the sediment (organic, carbonate, and inorganic) by the sedimentation rate. This shows that the two spikes in the sedimentation rate are primarily inorganic, likely from erosion.

- Twenty-two core increments were analyzed for total phosphorus and extracts were analyzed colorimetrically on a Lachat QuikChem 8000 flow injection autoanalyzer.
    - Phosphorus in the sediments showed peaks in the 1860s and near the top of the core. The peak at the top is likely due to chemical changes in phosphorus and what it is bound to (Fe, Mn, and organic matter). This indicates great potential for internal loading and any additional inputs of phosphorus could change the state of the lake.

[1] Photo credit: Larry Bresina

- Biogenic silica, a proxy for historical diatom and chrysophyte algal productivity, was measured using weighed subsamples from the cores. Dissolved silica was measured colorimetrically on a Unity Scientific SmartChem 170 discrete analyzer as molybdate reactive silica.
    - Biogenic silica showed very little variation in the core. The percent by weight ranged from 12 to 18 percent. Most lakes studied range between two and four percent, so the abundance of silica could help explain the diatom results.

- Fifteen down core samples were analyzed for diatoms and a minimum of 400 valves were counted in each sample. Identification of diatoms used regional floras and primary literature to achieve consistent taxonomy.
    - Statistical analysis clustered samples together based on the similarity of diatom taxa found. There were changes in the diatom communities from the late 1700s to the early 1800s, the mid-1800s to the 1940s, the 1940s through the 1970s, and the three most recent samples.
    - The diatom community was dominated by mesotrophic, planktonic species. This is likely due, in part, to the high concentration of biogenic silica in the water. *Aulacoseira ambigua* is present throughout the core. This species is indicative of mesotrophic waters. The increase in *Fragilaria crotonensis* and *Fragilaria capucina* near the top of the core are indicative of nutrient increases in the water body, likely phosphorus.



    - Diatoms were used to reconstruct total phosphorus in the lake's water column. The reconstruction shows that North Pipe Lake has been mesotrophic through most of its recent history. Since the 1970s the diatom-inferred total phosphorus is higher than the rest of the core. This timing suggests that shoreline development may be responsible for these increases.
    - Statistical analysis shows that total phosphorus explains about 55% of the variation in the diatom community, but there are other factors at play as well. The high biogenic silica may also skew this.

- Carotenoids, chlorophylls, and derivatives were extracted from freeze-dried sediments in twelve core sections, measured on a Hewlett-Packard model 1050 high performance liquid chromatography system, and are reported relative to total organic carbon.
    - Total algae production showed that there was more production in the 1700s and 1800s than the early 1900s, with a rise in production occurring in the 1990s. Myxoxanthophyll, which is an indicator of colonial blue-green algae, increases throughout the core.

- North Pipe Lake has changed likely due to incremental increases in phosphorus over time. The high biogenic silica content may be skewing the samples for phosphorus reconstruction.

- The high proportion of phosphorus in the upper sediments, along with data collected near the bottom of the lake the last two summers, shows that North Pipe Lake has enormous potential for internal phosphorus loading. There is enough phosphorus within the system itself that any additional phosphorus has the potential to severely alter the algal community and the trophic state of the lake.

Background Information on Lakes, Studies, and Management Plans

Lakes are a product of the landscape they are situated in and of the actions that take place on the land which surrounds them. Factors such as lake size, lake depth, water sources, and geology all cause inherent differences in lake quality. As a result, lakes situated within feet of others can differ profoundly in the uses they support.

A landscape can be divided into watersheds and subwatersheds. These areas define the land that drains to a particular lake, flowage, 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. This arises because rain and melting snow eventually end up in lakes and streams through surface runoff or groundwater infiltration. Rain and melting snow entering a waterbody is not inherently problematic. However, water has the ability to carry nutrients, bacteria, sediments, and chemicals into a waterbody. 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.

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, zooplankton, and aquatic plants), geological data (soils, glacial till, and sediment chemistry) and land use within a lake's watershed. Additionally, sediment cores can be used to determine how a lake has changed over the course of hundreds of years

Lake studies identify challenges and threats to a lake's health along with opportunities for improvement. These studies identify practices already being implemented by watershed residents to improve water quality and areas providing benefits to a lake's ecosystem. Additionally, these studies quantify practices or areas on the landscape, or within the lake, which have the potential to negatively impact the health of a lake and identify best management practices for improvement.

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 and watershed characteristics (lake size, depth, land use etc.) and should align with the goals of watershed residents.

Lake management plans are designed to be working documents that are used to guide the actions which take place to manage a specific lake.

Introduction to Pipe and North Pipe Lakes

Pipe and North Pipe Lakes[2] are located in the Town of Johnstown in Polk County Wisconsin, approximately 80 miles northeast of the Twin Cities metropolitan area. The lakes are connected, with water flowing from North Pipe Lake into Pipe Lake. Pipe Lake is 294 acres in size with a maximum depth of 68 feet; whereas, North Pipe Lake is 66 acres in size with a maximum depth of 37 feet. The area of land that drains to a lake is called a watershed. Pipe and North Pipe Lakes are situated within the Upper Apple River Watershed.

On a smaller scale, the area of land that drains to each lake, or the Pipe Lake watershed and North Pipe Lake watershed, are also defined. Pipe Lake's watershed is 1,267 acres in size and North Pipe Lake's watershed of 1,272 acres. The drainage basin: lake area ratio (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. The DB:LA for Pipe Lake is 4:1 and the DB:LA for North Pipe Lake is 20:1.

The shoreline of Pipe Lake varies from undisturbed forest to urban-type lawns with bare soil banks. In the summer, the near-shore area of North Pipe Lake has an aesthetic of being within a forest because building structures are mostly set back 75 feet and native plant removal has been limited to only a few parcels.

Lakes are classified according to their primary source of water and how that water enters and leaves the system. Pipe Lake is classified as a seepage lake and North Pipe Lake is classified as a drainage lake. Seepage lakes receive their water from precipitation, limited runoff, and groundwater and do not have an outlet. Drainage lakes receive their water from streams, groundwater, precipitation, and runoff and are drained by a stream.

A public boat landing and swimming beach are located on the north side of Pipe Lake. Pipe Lake also has four State owned islands on the south end of the lake.

The only invasive species documented on Pipe and North Pipe Lakes are snails. Both lakes have populations of Chinese mystery snails and North Pipe Lake also has banded mystery snails.

The trophic state is a measure of a lakes health which relates to the amount of algae in the water. The average summer trophic state for the last five years based on chlorophyll data indicated that Pipe Lake was mesotrophic and that North Pipe Lake was eutrophic. Pipe Lake is categorized as a deep seepage lake[3] and with a trophic state value of 43, water quality is

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[2] Pipe Lake WBIC: 2490500 and North Pipe Lake WBIC: 2485700

[3] Deep Seepage lakes stratify (form separate layers of water) during the summer and have no inlet or outlet

considered good. North Pipe Lake is categorized as a deep headwater lake[4] and with a trophic state value of 60, water quality is considered fair.

Pipe Lake has been monitored by volunteers since 1994 and North Pipe has been monitored since 1998.

[4] Deep Headwater lakes stratify (form separate layers of water) during the summer and have a watershed area less than 4 square miles

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 used to classify lakes as class one, class two, or class three lakes. Pipe Lake is classified as a class one lake; whereas North Pipe Lake is classified as a class two lake.

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.

Pipe and North Pipe Lake Characteristics

Pipe Lake [5]

Area: 293 Acres
Maximum depth: 68 feet
Mean depth: 27 feet
Bottom: 80% sand, 0% gravel, 0% rock, and 20% muck
Hydrologic lake type: Seepage
Invasive species: Chinese mystery snail
Fish: Panfish, largemouth bass, smallmouth bass, northern pike, and walleye
Trophic Status: Mesotrophic

North Pipe Lake [6]

Area: 64 Acres
Maximum depth: 37 feet
Bottom: 75% sand, 5% gravel, 0% rock, and 20% muck
Hydrologic lake type: Drainage
Invasive species: Chinese mystery snail, banded mystery snail
Fish: Panfish, largemouth bass, smallmouth bass, northern pike, and walleye
Trophic Status: Eutrophic

Oligotrophic lakes are generally clear, deep, and free of plants and large algae blooms.

Mesotrophic lakes lie between oligotrophic and eutrophic lakes. They usually have productive fisheries, healthy plant life, 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.

Hypereutrophic lakes are characterized by dense algae communities and can experience heavy blooms throughout the summer.

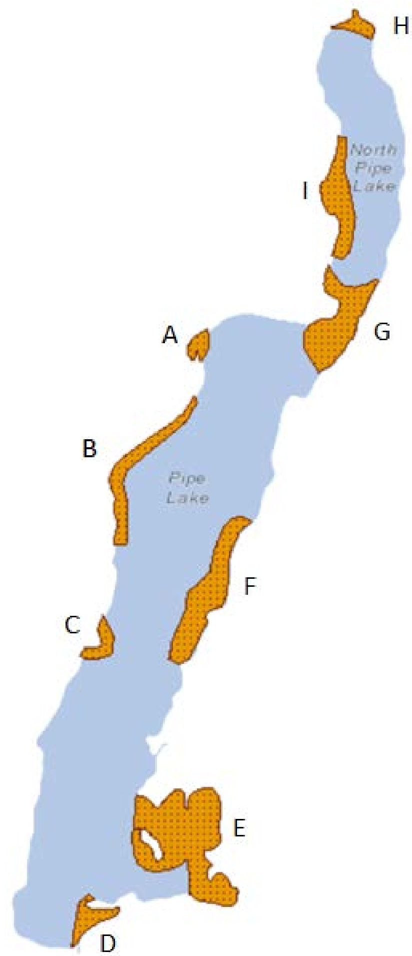
[5] http://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2490500&page=facts
[6] http://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2485700&page=waterquality

Designated Waters and Sensitive Areas

A designated water is a waterbody with special designations that affect permit requirements.

Pipe Lake is listed as a Priority Navigable Waterways Areas of Special Natural Resources Interest Outstanding Resource Water. Waters designated as Outstanding Resource Waters provide outstanding recreational opportunities, support valuable fisheries and wildlife habitat, have good water quality, and are not significantly impacted by human activities. The state of Wisconsin has determined that these waters warrant additional protection from pollution and that their water quality should not be lowered under the Clean Water Act obligations. Less than 1% of Wisconsin lakes and impoundments are designated as Outstanding Resource Waters.

Both Pipe and North Pipe Lakes are listed as Priority Navigable Waterways Walleye Areas.



Nine areas in Pipe and North Pipe Lakes are designated as Priority Navigable Waterways Areas of Special Natural Resources Interest Sensitive Areas. Six areas are located in Pipe Lake, two areas are located in North Pipe Lake, and the remaining area encompasses the area surrounding the channel between the two lakes.

Sensitive areas A, D, E, G, H, and I contain aquatic plant communities that provide important fish and wildlife habitat and provide shoreline stabilization. These areas provide important habitat for spawning and nursery habitat for fish and wildlife. Chemical treatments and mechanical removal efforts should be limited to navigation channels only in these areas.

Sensitive areas B, C, and F provide the habitat necessary for successful walleye spawning (gravel and cobble with little or no fine sediment). To protect this habitat, alternations of the gravel and rock substrate should not occur at these sites, unless it is done specifically to improve walleye habitat. Permanent shoreline vegetative buffers will decrease runoff and fine sediment to these areas. These areas are not considered aquatic plant sensitive areas in accordance with NR 107 Wisconsin Administrative Code; however, dredging, structures, and deposits should not occur in these areas.

Impaired Waters

Wisconsin lakes, rivers, and streams are managed to determine if their conditions are meeting state and federal water quality standards. Water samples are collected through monitoring studies and results are compared to guidelines designed to evaluate conditions as compared to state standards. General assessments place waters in four different categories: poor, fair, good, and excellent. The results of assessments can be used to determine which actions will ensure that water quality standards are being met (anti-degradation, maintenance, or restoration).

If a waterbody does not meet water quality standards, it is placed on Wisconsin's Impaired Waters List under the Federal Clean Water Act, Section 303(d). Every two years the State of Wisconsin is required to submit list updates to the United States Environmental Protection Agency for approval.

Waterbodies can be listed as impaired based on pollutants such as total phosphorus, total suspended solids, and metals. Wisconsin waters are each assigned four uses (fish and aquatic life, recreation, public health and welfare, and wildlife) that carry with them a set of goals.

Impairment thresholds vary for each use and vary based on lake characteristics such as whether a waterbody is shallow or deep and whether a waterbody is a drainage or seepage lake. North Pipe Lake is classified as a deep headwater lake that does stratify. [7]

North Pipe Lake was assessed during the 2014 and 2016 listing cycle. In both years chlorophyll data exceeded the listing thresholds for recreation but total phosphorus data met the listing thresholds for recreation.[8] Additionally, in both years, the listing thresholds were not exceeded for fish and aquatic life[9]. North Pipe Lake was listed in April 2014 for recreation based on the impairment excess algal growth (pollutant unknown).

In April 2014, Pipe Lake was listed for fish consumption based on electrofishing and netting data and fish tissue samples for the pollutant mercury and the impairment contaminated fish tissue. Current use restricts fish consumption.

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[7] Listing thresholds can be found in Wisconsin 2014 Consolidated Assessment and Listing Methodology (WisCALM) Clean Water Act Section 305(b), 314, and 303(d) Integrated Reporting, Wisconsin Department of Natural Resources, September 2013

[8] Recreation impairment threshold: total phosphorus ≥ 30 µg/L and > 5% of days in sampling season have nuisance algal blooms (> 20 µg/L)

[9] Fish and aquatic life impairment threshold: total phosphorus ≥ 60 µg/L and chlorophyll ≥ 27 µg/L

Previous Lake Studies

Past studies and grant awards on Pipe and North Pipe Lake include:

Pipe Lake and Watershed Study, Lake Management Plan initiated in 2000

This study included in-lake, tributary, and outlet water quality monitoring, a sociological survey, watershed evaluation, lake modeling, monitoring and mapping groundwater, lake level and precipitation monitoring, a shoreline inventory, and the development of a comprehensive lake management plan. The final report was prepared by the Polk County Land and Water Resources Department.

Land use mapping determined that the watershed of both lakes is primarily forested. Average secchi depth for July from 1999-2002 was over 14 feet on Pipe Lake and 6.5 feet on North Pipe Lake. Data indicated an oligotrophic state in Pipe Lake and a eutrophic state in North Pipe Lake. However, dissolved reactive phosphorus was low in both lakes which likely contributed to high productivity without the presence of nuisance algae blooms in North Pipe Lake. Three stream/inlet sampling locations were identified as having high phosphorus readings. Modeling indicated that a 45% reduction in phosphorus loading would be necessary to significantly affect clarity in North Pipe Lake and that reductions would be unlikely to impact Pipe Lake. A sociological survey indicated that respondents generally felt that water quality in the lakes was average or above average. However, over half of respondents felt that water quality had degraded since they've owned property on the lakes.

Pipe Lake Comprehensive Management Plan initiated in 2003

This grant developed a comprehensive lake management plan for Pipe and North Pipe Lakes and included water quality monitoring, an aquatic plant survey, a watershed runoff survey, a shoreland habitat conditions survey, a wildlife observation study, the development of a nutrient budget, and phosphorus reduction scenarios. The final report for this grant was prepared by Blue Water Science.

The shoreland habitat survey indicated that 64% of the parcels on Pipe Lake and 99% of the parcels on North Pipe Lake met the survey's criteria for natural conditions.[10] Volunteers documented a wide variety of wildlife present around Pipe and North Pipe Lakes. Water quality data from 1998 through 2003 indicated that Pipe Lake was in excellent shape and that North Pipe Lake was in fair shape. Phosphorus in the bottom water was greater than in the surface water, indicated phosphorus release from the bottom. Alkalinity was low in both lakes, indicating a lack of acid buffering capacity. North Pipe Lake also had a higher color reading, exhibiting a brownish-red color most likely from wetland discharges. Plants were found to be growing in up to 8 feet of water depth with ten species found in Pipe Lake and 13 species found

[10] Presence of 50% native vegetation in the understory (ground cover) and at least 50% natural vegetation along the shoreline in a strip at least 15 feet deep

in North Pipe Lake. Trophic state index data for Pipe Lake indicated that the lake is oligotrophic based on secchi depth and mesotrophic based on chlorophyll and phosphorus. Trophic state index data for North Pipe Lake indicated that the lake is mesotrophic to eutrophic.

As a result of notable declines in water clarity noticed by lake residents, the Water Quality Committee proposed clarity goals for Pipe and North Pipe Lakes. The goal was to improve clarity by four feet for a summer average of 19.1 feet for Pipe Lake and to improve clarity by two feet for a summer average of 8.6 feet in North Pipe Lake. It was modeled that for North Pipe Lake a 40% reduction in watershed nutrients would be necessary to meet this goal. It was also determined that the goal for Pipe Lake would not be feasible and that factors other than watershed runoff are contributing to decreased water clarity.

Pipe and North Pipe Lakes Lakeshore and Subwatershed Analysis #1 and #2 initiated in 2007
The purpose of this grant project was to determine where and what lake protection activities are necessary to improve the lakes. The first phase of the project included mapping of tributary, wetland, and erosion areas, ground-truthing of watershed delineation and refinement of water quality modeling, watershed best management plan analysis with prioritized recommendations, communications with landowners for best management plan

implementation, and stakeholder meetings. The second phase of this project involved a shoreline assessment, point intercept aquatic plant surveys, a curly leaf pondweed study, and stakeholder meetings and updates. The plant surveys were completed by Endangered Resource Services and the remaining deliverables were completed by Cedar Corp.

The results of the plant surveys indicated an above average plant community for both lakes. An unusually high number of species were found on each lake (44 species on Pipe and 47 species on North Pipe) and the Floristic Quality Index was above average for where the lakes are located in the landscape. Additionally, five species listed as special concern were found in the lakes.

The report by Cedar Corp focused on improving runoff water quality in four critical sub-watersheds. Goals for improvement included repairing existing/ongoing surface runoff degradation, protecting critical land features currently protecting surface runoff water quality, and modifying the current hydrology to better treat surface runoff. Modifying hydrology was not recommended unless the remaining goals do not reach desired benefits. The report provided an in-depth review of the four sub-watersheds and provided maps documenting numerous areas for improvement around the lakes.

Five Year AIS Inspection/Control and CBCW Program initiated in 2008
This grant included Clean Boats, Clean Waters boat inspections and monthly aquatic plant monitoring at the boat landings. No aquatic invasive species were detected through plant monitoring.

Pipe Lakes Action Plan Implementation initiated in 2009
The primary goal of this project is to implement the recommendations of the Pipe Lakes Action Plan. Grant activities included repairing and replacing problem culverts and remediating erosion on intermittent tributaries, designing/building detention basins in high pollution sub-watersheds, restoring shorelines and integrating woody habitat, implementing residential diversion/infiltration best management practices, completing point intercept surveys, monitoring tributaries and lake water quality and quantity, and information and education.

Four Year AIS Inspection/Control and Clean Boats, Clean Waters Program initiated in 2013
This project funded watercraft inspections, AIS monitoring, participation in the Landing Blitz, installation of AIS signs, and establishing a partnership with the Polk County Sheriff's Department.

Fisheries[11]

The most recent fisheries survey conducted on Pipe and North Pipe Lakes was in 2015. Fyke netting and shocking were used to sample the fisheries population.

April fyke netting resulted in the following number of fish caught per net night: 0.0 largemouth bass (only 1 fish caught total), 0.80 northern pike, and 2.6 walleye on Pipe Lake and 1.4 northern pike, 0.10 smallmouth bass, and 3.10 walleye on North Pipe Lake.

Spring shocking for walleye resulted in a catch of 3.53 fish per mile on Pipe Lake and 10.56 fish per mile on North Pipe Lake.

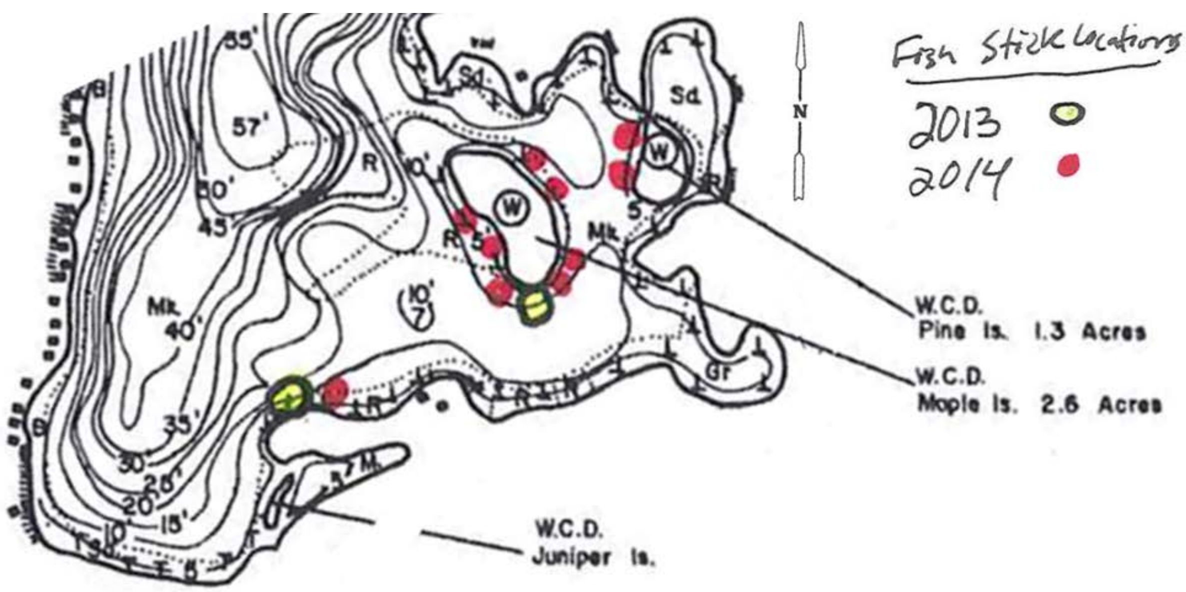
Spring shocking resulted in the following number of fish caught per mile on Pipe Lake: 186 bluegill, 7 green sunfish, 29.44 largemouth bass, 0.30 northern pike, 10 rock bass, 1.39 smallmouth bass, 0.74 walleye, and 2 yellow perch. Spring shocking resulted in the following number of fish caught per mile on North Pipe Lake: 10 black crappie, 147 bluegill, 66.04 largemouth bass, 1.13 northern pike, 2 rock bass, 1.51 smallmouth bass, 1.32 walleye, and 12 yellow perch.

Fall shocking resulted in the following number of fish caught per mile on Pipe Lake: 4.9 largemouth bass, 1.96 northern pike, 1.57 smallmouth bass, and 2.94 walleye. Fall shocking resulted in the following number of fish caught per mile on North Pipe Lake: 8.33 largemouth bass, 3.89 northern pike, 0.56 smallmouth bass, and 2.22 walleye.

[11] Information provided by Aaron Cole, Fisheries Biologist, Wisconsin DNR

In 2005, half log structures were installed around the state owned islands on the south end of Pipe Lake.

In 2013 and 2014, fish sticks were installed around the state owned islands on the south end of Pipe Lake.



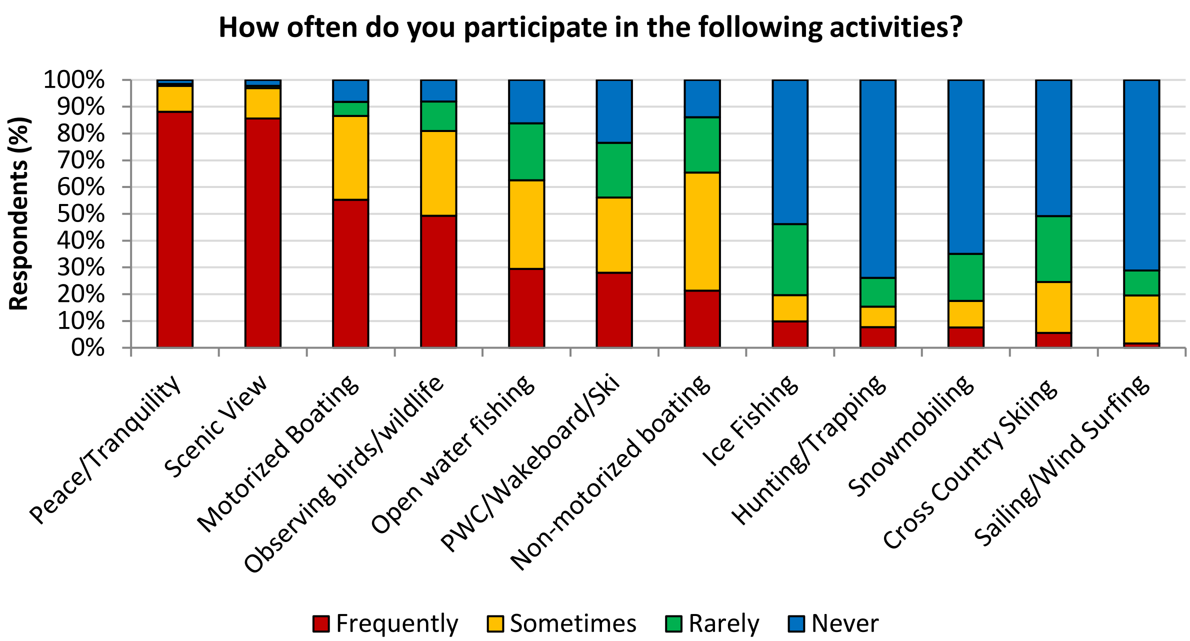
Lake Resident Survey

A Wisconsin Department of Natural Resources approved survey was mailed to two hundred thirty-four property owners on Pipe and North Pipe Lake on February 16th, 2016. Seven surveys were returned due to address issues and one survey was returned because the property was being sold. One hundred and forty eight surveys were completed and returned for a 65% response rate. [12]

Nearly three quarters of respondents own property on Pipe Lake (73%) and nearly one quarter own property on North Pipe Lake (22%). A small minority of respondents own property near the lakes (5%).

Survey respondents have owned their property on Pipe and North Pipe Lakes for an average of 22 years. A majority of survey respondents use their property part time, either as a weekend, vacation, or holiday residence (62%) or as a seasonal residence (17%). A minority of respondents own their property as a year round residence (14%). On average, properties on Pipe and North Pipe Lakes are used 111 days per year and occupied by 3.4 people.

The survey asked respondents which activities they enjoy on Pipe and North Pipe Lakes. Activities enjoyed frequently or sometimes by over 75% of respondents included: enjoying peace and tranquility, scenic viewing, motorized boating, and observing birds and wildlife. Activities enjoyed only rarely or never by over 75% of respondents included: ice fishing, hunting/trapping, snowmobiling, cross country skiing, and sailing/wind surfing.



[12] Survey sample size reduced to 226 to account for returned surveys

Nearly two thirds of respondents keep canoes and kayaks on their property (64%) and half keep motorboats/pontoons that are 21-50 HP (50%). Around a third of respondents keep paddleboats/rowboats (39%), motorboats/pontoons greater than 50 HP (35%), and fishing boats with motors (30%). Approximately a quarter of respondents keep personal watercraft (22%). Fewer respondents keep motorboats/pontoons between 1-20 HP (19%) and sailboats (15%). Eleven percent of respondents don't keep watercrafts at their property. The majority of boats that are kept on the lakes are not used on other bodies of water (90%).

Survey respondents reported that they were very familiar (57%) or somewhat familiar (40%) with how aquatic invasive species can be introduced into Pipe and North Pipe Lakes. Additionally, nearly all survey respondents felt that it was very important (97%) that efforts to prohibit the introduction of aquatic invasive species should continue. The remaining 3% of respondents felt that it was fairly important that efforts should continue.

The survey also asked respondents how important it is that efforts to improve water quality of Pipe and North Pipe Lakes continue. Nearly all survey respondents felt that these efforts were very important (93%) and most of the remaining respondents felt that these efforts were fairly important (6%).

Additionally, the survey asked respondents which actions should be considered by the District to manage Pipe and North Pipe Lakes. Actions supported by over three-fourths of respondents included: practices to enhance fisheries (82%), offering incentives to upgrade non-conforming septic systems (79%), and offering incentives for installation of farmland conservation practices (75%). Around two-thirds of respondents supported offering incentives for installation of shoreline buffers and rain gardens (67%) and around half of respondents supported lake fairs and workshops to share information (55%) and enforcement of excessive boat or personal watercraft speeds within 200 feet of the shoreline or rafts (51%).

Which of the following practices should be considered by the District to manage Pipe and North Pipe Lakes?	**Yes**	**No**	**Unsure**
Practices to enhance fisheries	82%	4%	14%
Offering incentives to upgrade non-conforming septic systems	79%	6%	15%
Offering Incentives for installation of farmland conservation practices	75%	6%	20%
Offering incentives for installation of shoreline buffers and rain gardens	67%	8%	25%
Lake Fairs and workshops to share Information	55%	10%	34%
Enforcement of excessive boat or personal watercraft speeds within 200 feet of the shoreline or rafts	51%	27%	21%

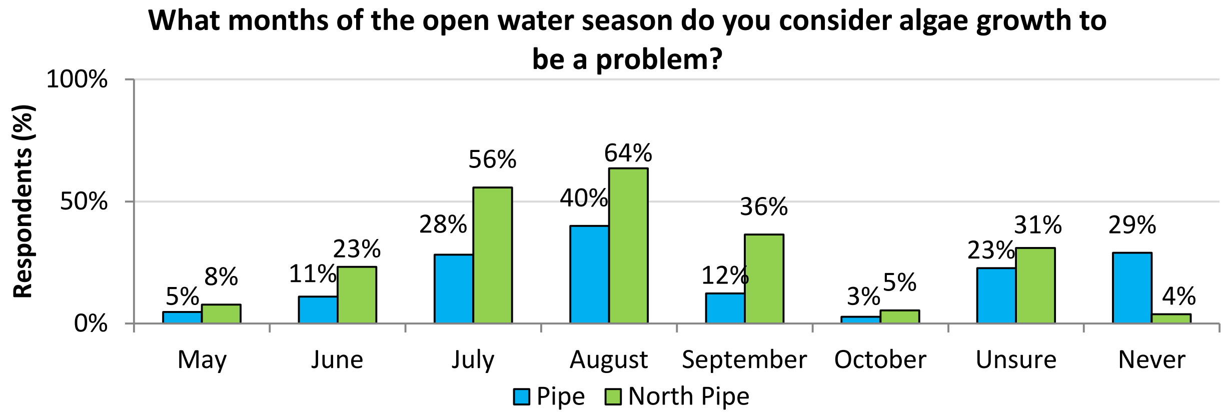
A similar question asked respondents which activities should be considered to manage aquatic invasive species. Actions supports by over three-fourths of respondents included: training for boaters and others to learn to identify and manage aquatic invasive species (85%) and educational programs to provide information on invasive species (78%). Almost two-thirds of respondents supported boat landing cameras to monitor and track use (61%) and approximately half of respondents supported a boat wash station at the landing (52%).

Which of the following practices should be considered by the District to manage aquatic invasive species?	**Yes**	**No**	**Unsure**
Training for boaters and others to learn to identify and manage aquatic invasive species	85%	2%	12%
Educational programs to provide information on invasive species	78%	5%	16%
Boat landing cameras to monitor and track use	61%	7%	31%
Boat wash station at landing	52%	11%	37%

The survey also asked a variety of questions regarding algae and aquatic plants. Respondents were asked to describe the amount of aquatic plants in the lakes, what months algae and aquatic plants are a problem, and what uses are impaired as a result of algae and aquatic plants.

Over one quarter of respondents didn't perceive algae growth to ever be a problem on Pipe Lake (29%). Less than half of respondents considered algae a problem in August (40%) and about one-quarter of respondents considered algae to be a problem in July (28%). On North Pipe Lake, very few respondents felt that algae growth was never a problem (4%). Almost two-thirds of respondents considered algae problematic in August (64%) and over half considered algae problematic in July (56%). Very few respondents indicated that activities were impaired by algae on Pipe Lake. Activities indicated as being impairment by approximately a quarter of respondents included swimming (25%) and overall enjoyment of the lake (22%). On North Pipe Lake these same activities were impaired by close to half of respondents (swimming 54% and overall enjoyment of the lake 46%). Close to one quarter of respondents indicated that dogs/animals using the water was a use impaired by algae on North Pipe Lake (23%).

Please indicate whether you believe each of the following activities are impaired by algae. *Values for Pipe Lake, North Pipe Lake*	**Yes**	**No**	**Unsure**
Swimming	25%, 54%	60%, 12%	15%, 34%
Fishing	12%, 19%	63%, 44%	25%, 37%
Boating	12%, 18%	69%, 47%	19%, 35%
Navigation	11%, 13%	70%, 50%	19%, 37%
Dogs/animals using the water	12%, 23%	59%, 28%	29%, 50%
Overall enjoyment of the lake	22%, 46%	55%, 19%	23%, 34%



Prior to the survey, the Pipe and North Pipe Lakes District offered site visits to evaluate runoff and offer suggestions for ways to mitigate runoff. These shoreline protection assessments were provided by Harmony Environmental. The survey asked respondents if they participated in the assessment. Over one-third of respondents indicated that they had participated in the program (35%). About a quarter had not participated in the program (24%) and the remaining respondents weren't aware of the program (41%). The survey also asked respondents which initiative they implemented as a result of the assessment. Practices installed included seventeen shoreline buffer plantings, nine rain gardens, eleven infiltration pits/trenches, four rain barrels, two plantings in the water, and five tree falls.

The survey also asked respondents which activities they might be interested in participating to improve Pipe and North Pipe Lakes. Over half of respondents were interested in learning to identify aquatic invasive species (62%) and learning how to monitor for aquatic invasive species (56%). Around half of respondents were interested in learning how to monitor water quality (48%), around a third were interested in installing a shoreline buffer on their property (31%), and around a quarter were interested in installing a rain garden on their property (26%). Fewer respondents were interested in serving on a committee to develop an action plan for improving Pipe and North Pipe Lakes (17%). Less than a quarter of respondents weren't interested in any of the above activities (19%).

Education is an important component of responsible lake management. Topics approximately two-thirds of respondents would like to learn more about include: information about District activities (66%) and general education related to lake ecosystems (62%). Around half of respondents would like to learn more about Wisconsin legislative activities that affect water quality (46%). Less than a quarter of respondents didn't want to learn more about any of the above topics (18%).

The survey also asked respondents about current and past volunteer activities. The majority of households are not currently performing volunteer activities for the District (82%); however, close to half have volunteered in the past (41%).

Lake Level and Precipitation Monitoring

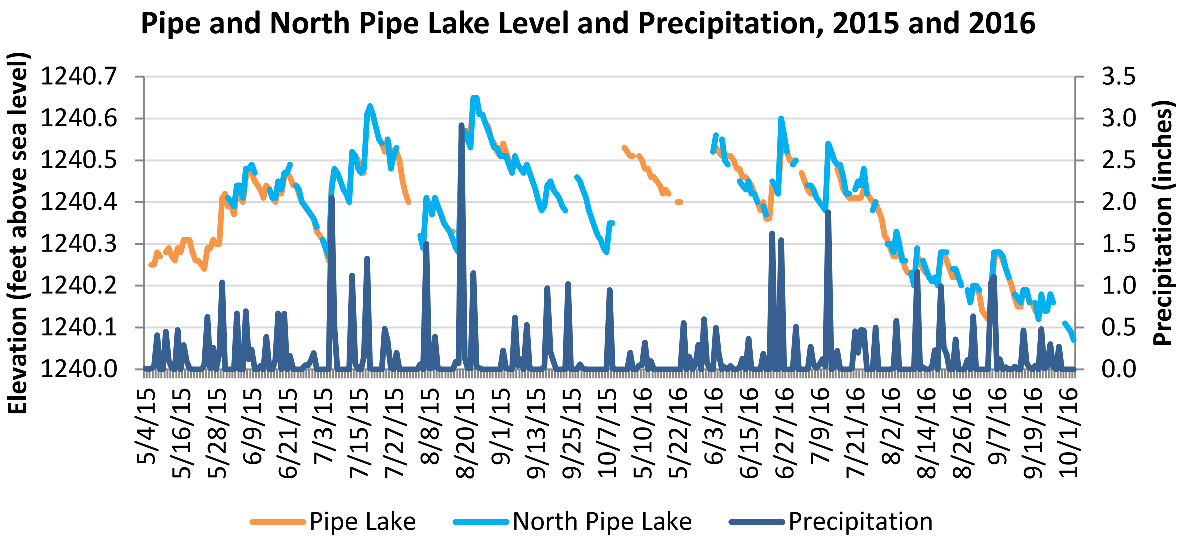
Lake water-level fluctuations are important to lake managers, lakeshore property owners, developers, and recreational users because they can have significant impacts on lake water quality and usability. Although lake levels naturally change from year to year, extreme high or low levels can present problems such as restricted water access, flooding, shoreline and structure damage, and changes in 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.

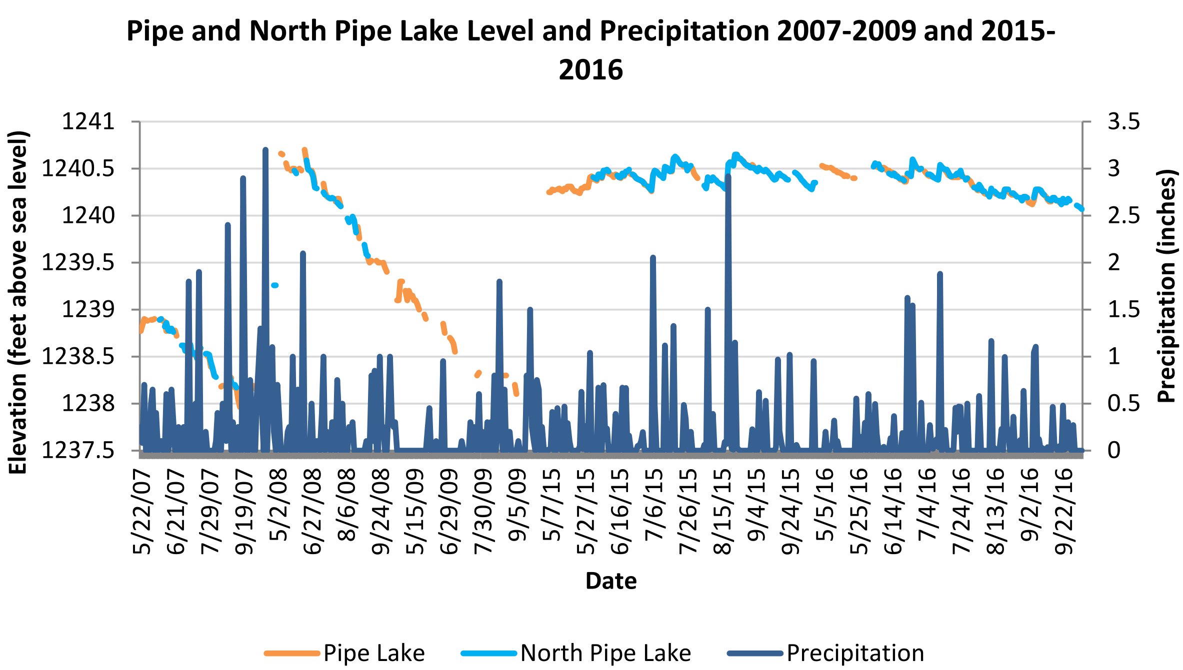
Volunteers monitored lake level and precipitation on Pipe and North Pipe Lakes in 2015 and 2016. Polk County Land and Water Resources Department provided training on data collection methods and installed staff and rain gauges. The Polk County Land Information Department calibrated the staff gage by referencing the numbered height on the gage to the surveyed elevation of the water when the gage was installed in the spring and prior to removal in the fall in 2015 and 2016. As a result, the 2015 and 2016 data can be tied back to actual elevation. Monitoring began in May and continued through September/October. Lake level has been monitoring on Pipe and North Pipe Lakes since 2000. However, in addition to 2015 and 2016, elevation data is only available in 2007, 2008, and 2009 (Pipe Lake only).

Seasonal precipitation on Pipe and North Pipe Lakes totaled 24.3 inches in 2015, and 21.4 inches in 2016. Lake level did respond to precipitation events, with levels increasing following rainfall events. [13] Lake level was similar on Pipe and North Pipe Lakes. Over the course of this study, lake level was the lowest from July through September 2016.

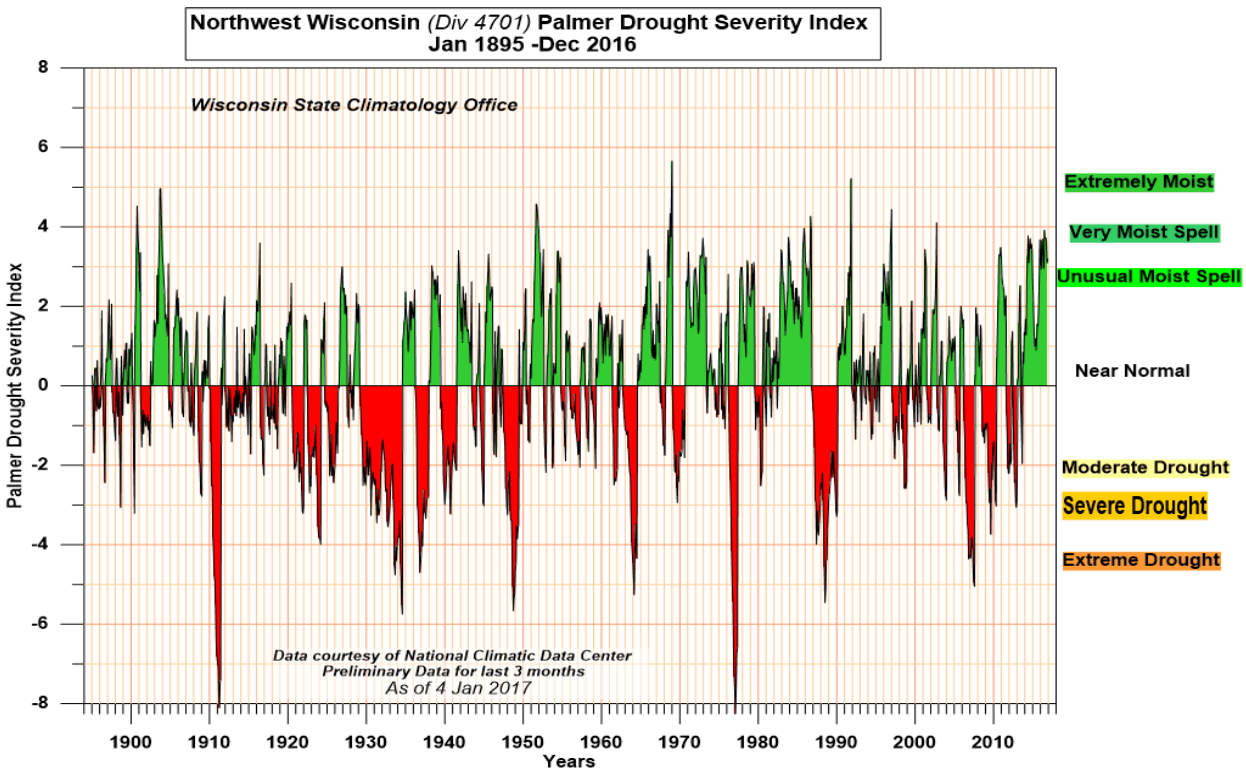
[13] Values for rainfall are an average of the gauges on Pipe and North Pipe Lakes



In 2015 and 2016 lake level in Pipe and North Pipe Lakes only varied by approximately 0.5 feet. However in 2007 and 2009, lake level was approximately 1-2 feet less than in the majority of 2008 and in all of 2015 and 2016.



Wisconsin State Climatology Office data indicate that 2007 was a year of extreme drought, 2008 began as a year of above normal moisture and ended as a year of below normal moisture, 2009 was a year of severe drought, and 2015 and 2016 were years of unusual moisture.



Lake Mixing and Stratification: Background Information

Water quality is 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^{o}C (39^{o}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 more dense 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 turnover**.

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 based on temperature differences, called **stratification**.

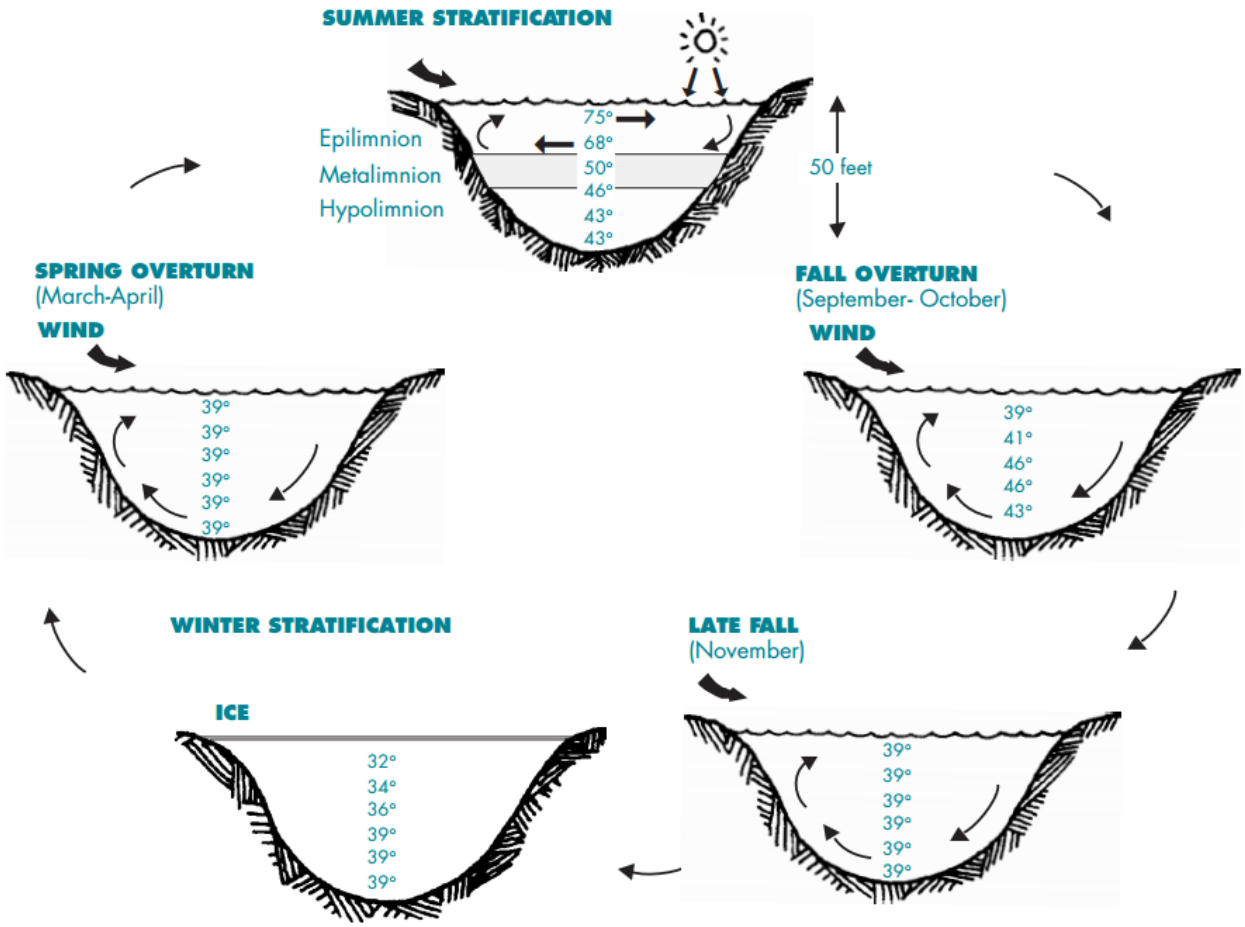
During the summer, lakes have the potential to divide into three distinct zones: the **epilimnion**, **thermocline** or **metalimnion**, and the **hypolimnion**. The epilimnion describes the warmer surface layer of a lake and the hypolimnion describes the cooler bottom area of a lake. The thermocline,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

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

Variations in density arising from differences in 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, since 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 fish 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 especially bacteria is the primary way 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.



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14 Figure from Understanding Lake Data (G3582), UW-Extension, Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004

Deep Hole Sampling Procedure

In-lake data were collected by the Polk County Land and Water Resources Department and volunteers of the Pipe and North Pipe Lakes District at the deep hole of Pipe and North Pipe Lakes during the 2015 and 2016 growing season.

Lake profile monitoring

Dissolved oxygen, temperature, conductivity, specific conductance, and pH were recorded at meter increments with a Hanna Instruments 9828 multi-parameter probe biweekly by the Land and Water Resources Department.

Secchi depth

Secchi depth was recorded with an eight inch diameter round disk with alternating black and white quadrants called a secchi disk. To record secchi depth, the disk was lowered into the lake on the shady side of a boat until just before it disappeared from sight. This depth was measured in feet and recorded as the secchi depth. Data were collected biweekly to correspond with lake profile monitoring readings. Additional readings were collected by District volunteers.

Chemistry and chlorophyll a

Total phosphorus and chlorophyll a samples were collected as part of the WDNR Citizen Lake Monitoring Network Program in 2015 and 2016. Volunteers collected additional samples for surface nitrogen and bottom iron.

Dissolved Oxygen

Oxygen is required by all aquatic organisms for survival. The amount of oxygen dissolved in water depends on 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, 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.

Cold water has a higher capacity for oxygen than warm water. 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.

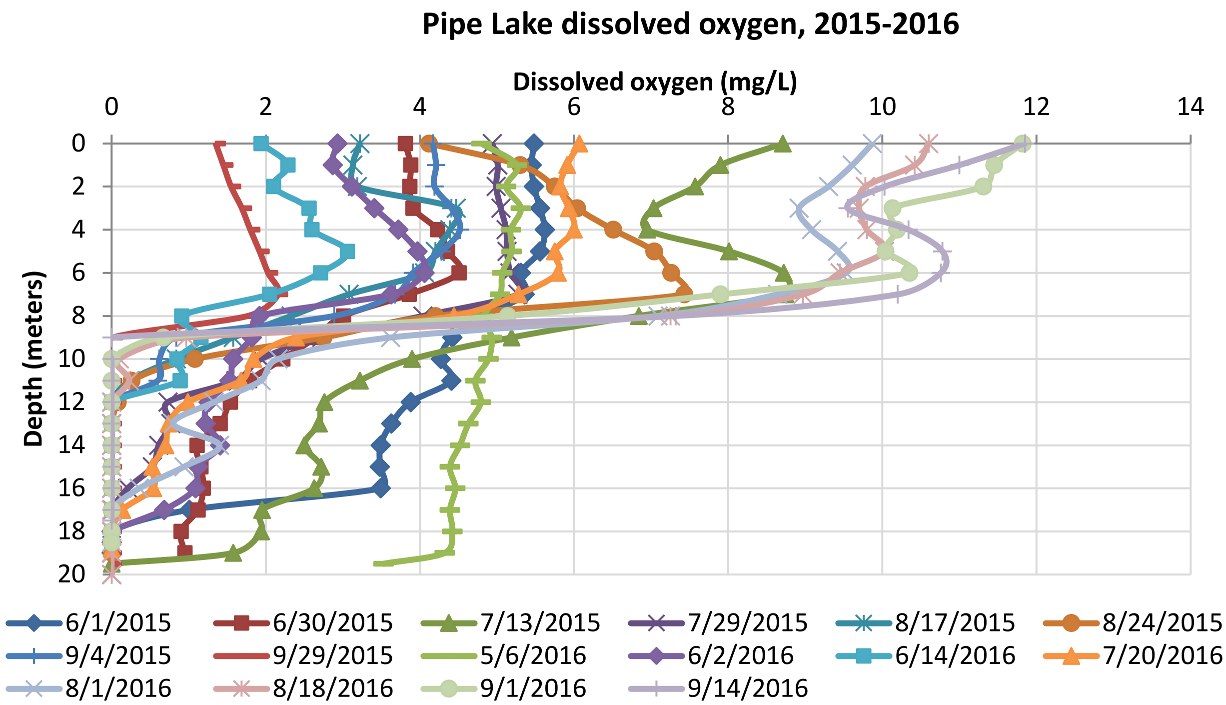
During the sunlight hours, when photosynthesis is occurring, dissolved oxygen levels at a lake's surface may be quite high. Conversely, at night or early in the morning (when photosynthesis is not occurring), the dissolved oxygen values can be expected to be lower.

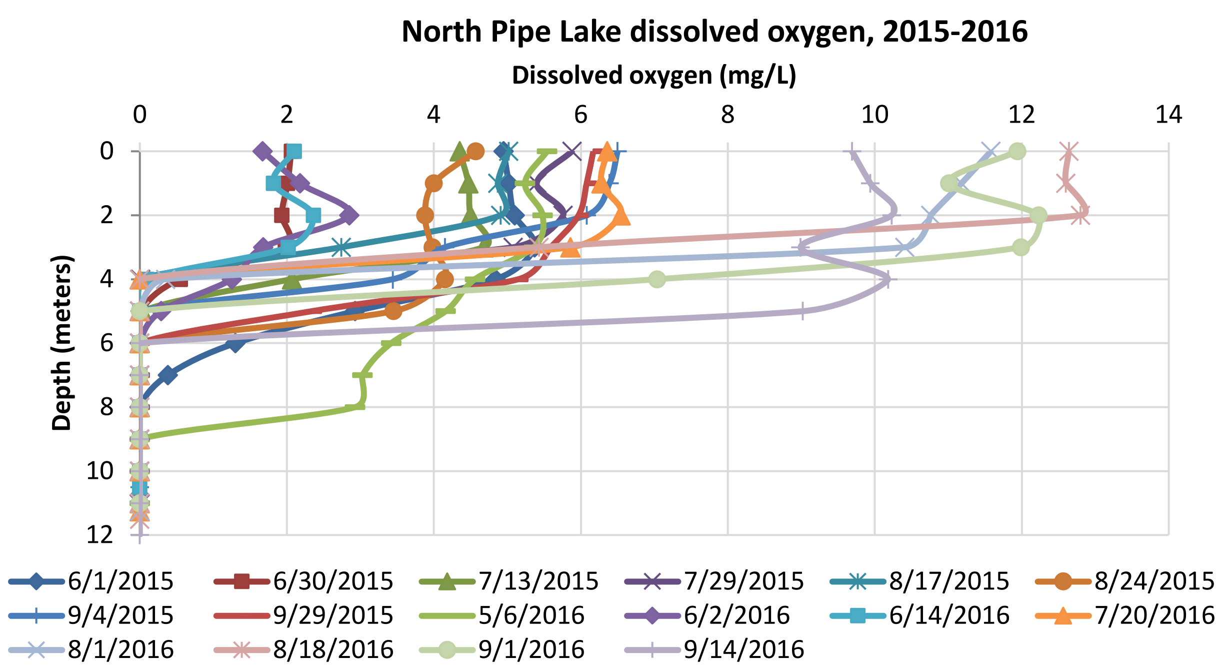
A water quality standard for dissolved oxygen in warm water lakes and streams is set at 5 mg/L. This standard is based on the minimum amount of oxygen required by fish for survival and growth. For cold water lakes supporting trout, the standard is set even higher at 7 mg/L.

The Land and Water Resources Department probe used for this study was sent off for repair of a faulty dissolved oxygen sensor in July 2016. As a result, data collected prior to June 2016, maybe be inaccurate. Readings collected following the probe repair were greater in Pipe and North Pipe Lakes.

In Pipe Lake, dissolved oxygen levels remained above zero throughout the water column in the spring. Early in the growing season, the majority of the water column remained oxygenated, but by August of both years dissolved oxygen dropped to zero approximately halfway through the water column. In North Pipe Lake, dissolved oxygen levels dropped to zero at a depth of four and six meters with the exception of the first sample date of each year. These trends were consistent across 2015 and 2016.

In about half of the sample dates, dissolved oxygen levels at the surface were below 5 mg/L in both lakes. This could be a result of the faulty sensor on the probe. However, after reviewing data from lakes that were sampled with the same probe over the same time period it was concluded that values for 2015 were likely accurate.



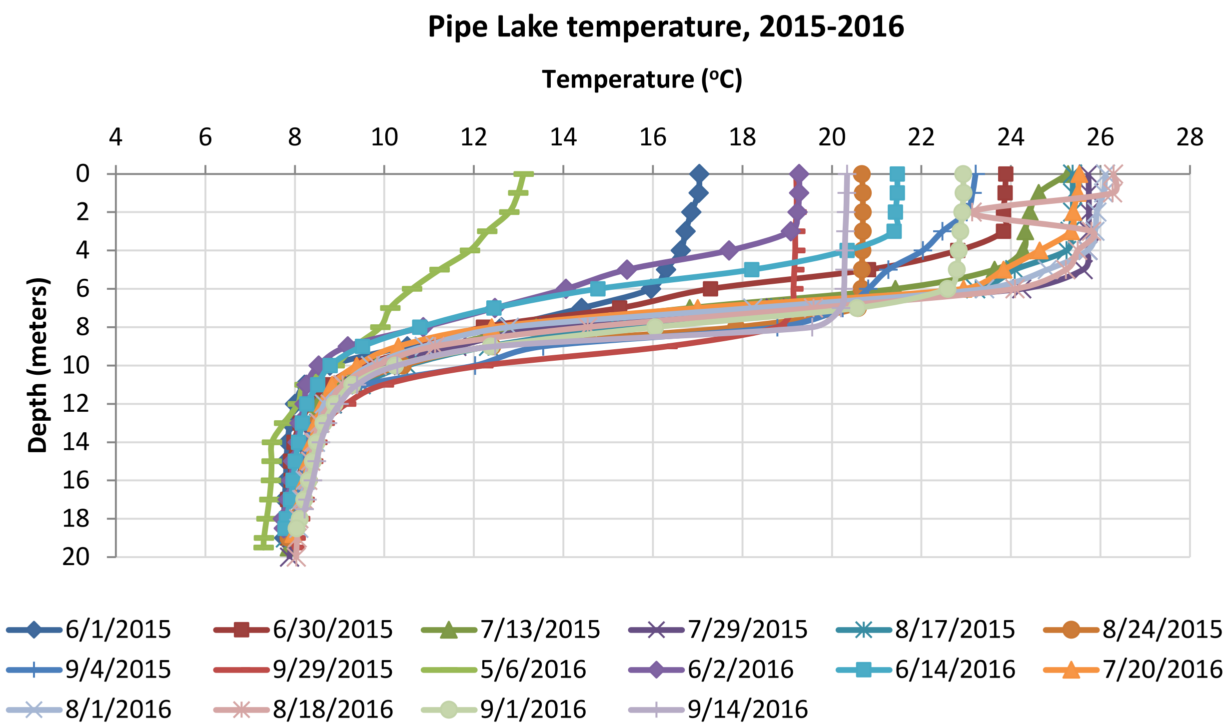


Temperature

Pipe and North Pipe Lakes stratified, or set up density dependent layers, during both years of the study. The upper level of the lake, or the epilimnion, reaches to depth of four to six meters on Pipe Lake and two to four meters on North Pipe Lake. The water in this area of the lake is warmer and is well mixed by wind and wave action. The cooler bottom area of the lake, or the hypolimnion, begins between ten and twelve meters on Pipe Lake and between seven and nine meters on North Pipe Lake. These waters are cooler and do not mix with the waters of the epilimnion. The transition zone between these two layers is called the metalimnion.

The surface temperature on both lakes was greatest in July and August. Both Lakes reached their warmest surface temperature on August 18th, 2016.

Surface temperature on Pipe and North Pipe Lakes		
	Pipe Lake	North Pipe Lake
6/1/2015	17.04	17.79
6/30/2015	23.88	24.32
7/13/2015	25.28	23.76
7/29/2015	25.73	25.70
8/17/2015	25.38	25.19
8/24/2015	20.67	19.63
9/4/2015	23.21	24.16
9/29/2015	19.20	18.99
5/6/2015	13.11	15.61
6/2/2016	19.27	19.66
6/14/2016	21.46	21.91
7/7/2016	25.13	25.98
7/20/2016	25.53	25.88
8/1/2016	26.11	26.09
8/18/2016	26.29	26.57
9/1/2016	22.93	22.71
9/14/2016	20.34	19.87


Pipe Lake temperature, 2015-2016
Temperature (°C)
4 6 8 10 12 14 16 18 20 22 24 26 28
Depth (meters)
0 2 4 6 8 10 12 14 16 18 20
6/1/2015
6/30/2015
7/13/2015
7/29/2015
8/17/2015
8/24/2015
9/4/2015
9/29/2015
5/6/2016
6/2/2016
6/14/2016
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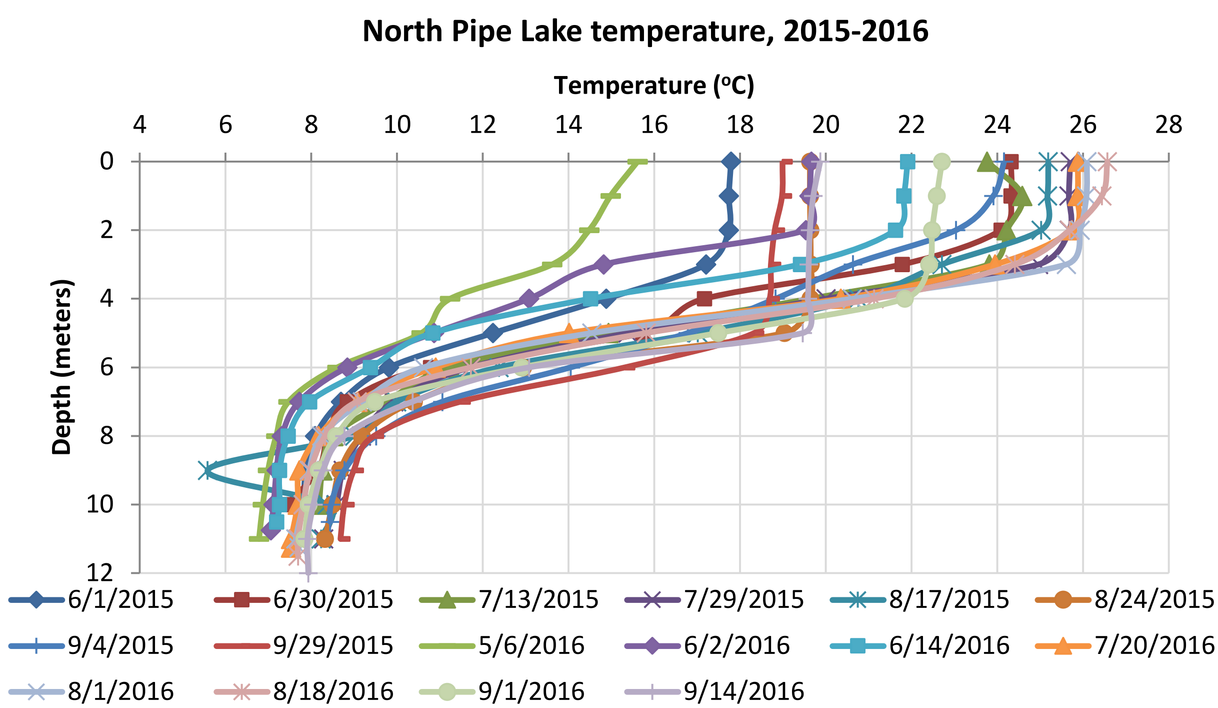
8/1/2016
8/18/2016
9/1/2016
9/14/2016

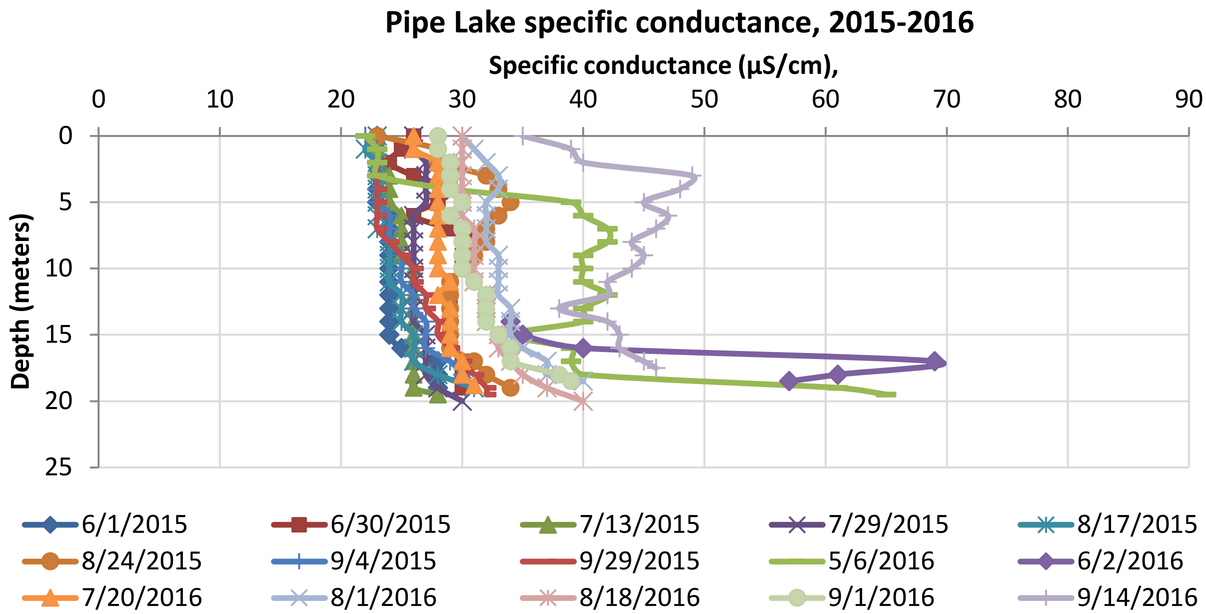

North Pipe Lake temperature, 2015-2016
Temperature (°C)
4 6 8 10 12 14 16 18 20 22 24 26 28
Depth (meters)
0 2 4 6 8 10 12
6/1/2015
6/30/2015
7/13/2015
7/29/2015
8/17/2015
8/24/2015
9/4/2015
9/29/2015
5/6/2016
6/2/2016
6/14/2016
7/20/2016
8/1/2016
8/18/2016
9/1/2016
9/14/2016

Specific Conductance (Conductivity)

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^{o}C and termed specific conductance. Specific conductance increases as the concentration of dissolved minerals in a lake increase.

In general, specific conductance values at the surface were between 20 and 30 µS/cm in Pipe Lake and between 25 and 35 µS/cm in North Pipe Lake. In both lakes, but most notably in North Pipe Lake, specific conductance values were elevated in 2016 as compared to 2015. In both lakes, specific conductance increased towards the bottom of the lake, with the increase being more pronounced in North Pipe Lake.

While not atypical, specific conductance values in Pipe and North Pipe Lakes are low compared to many Wisconsin lakes. Based on specific conductance values, Pipe and North Pipe Lakes are considered soft water lakes. When watersheds contain easily dissolved carbonate rocks, lakes are more likely to have higher conductivity. In contrast, watersheds that contain slow-to-dissolve rocks, such as granite, are more likely to have lower conductivity. Lakes with especially low conductivity are also more likely to be precipitation dominated (rather than groundwater or runoff dominated), because precipitation contains very little dissolved minerals.


Pipe Lake specific conductance, 2015-2016
Specific conductance (µS/cm),
0
10
20
30
40
50
60
70
80
90
Depth (meters)
0
5
10
15
20
25
6/1/2015
6/30/2015
7/13/2015
7/29/2015
8/17/2015
8/24/2015
9/4/2015
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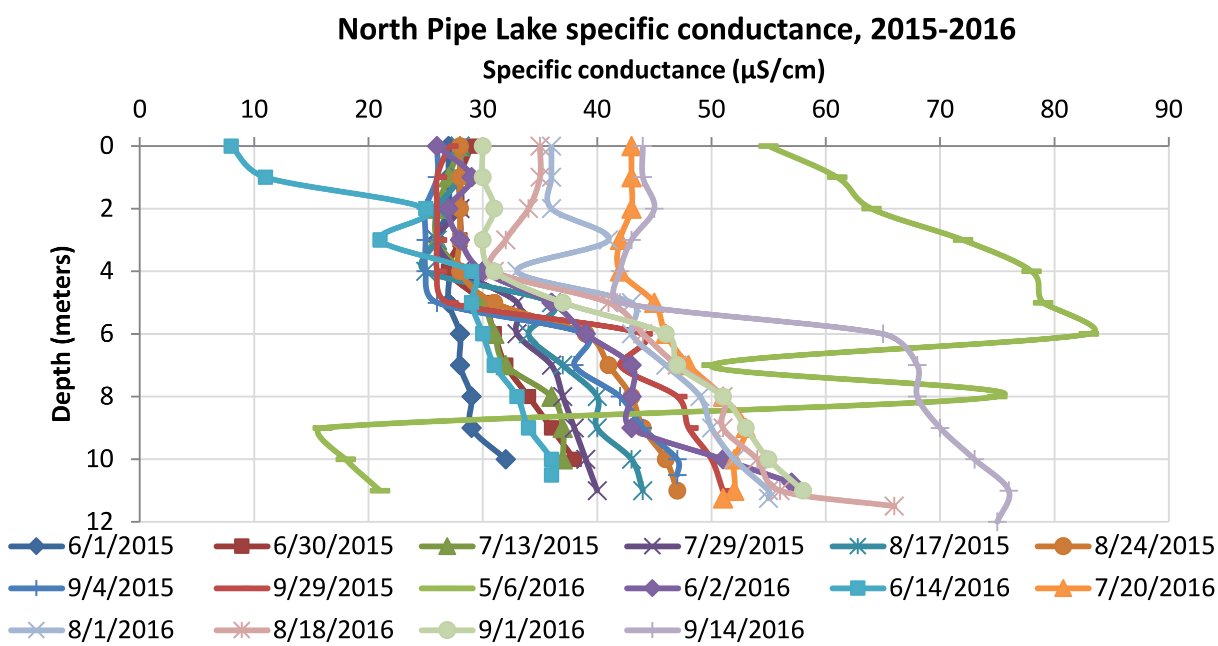
8/1/2016
8/18/2016
9/1/2016
9/14/2016


North Pipe Lake specific conductance, 2015-2016
Specific conductance (µS/cm)
0
10
20
30
40
50
60
70
80
90
Depth (meters)
0
2
4
6
8
10
12
6/1/2015
6/30/2015
7/13/2015
7/29/2015
8/17/2015
8/24/2015
9/4/2015
9/29/2015
5/6/2016
6/2/2016
6/14/2016
7/20/2016
8/1/2016
8/18/2016
9/1/2016
9/14/2016

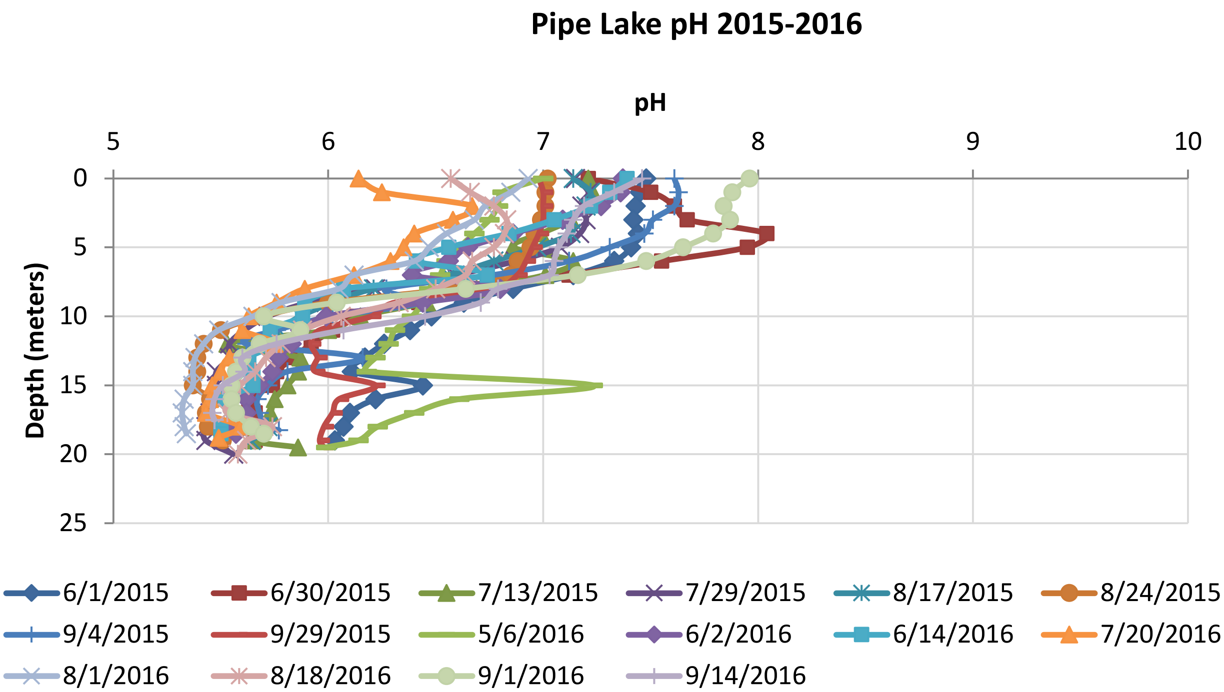
pH

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 higher 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.

In general, pH levels were greater on North Pipe Lake as compared to Pipe Lake. In both 2015 and 2016 pH levels on North Pipe Lake increased to between eight and ten in July and August. In both lakes, pH was greater in the epilimnion and deceased in the hypolimnion.


Pipe Lake pH 2015-2016
pH
5
6
7
8
9
10
0
5
10
15
20
25
Depth (meters)
6/1/2015
6/30/2015
7/13/2015
7/29/2015
8/17/2015
8/24/2015
9/4/2015
9/29/2015
5/6/2016
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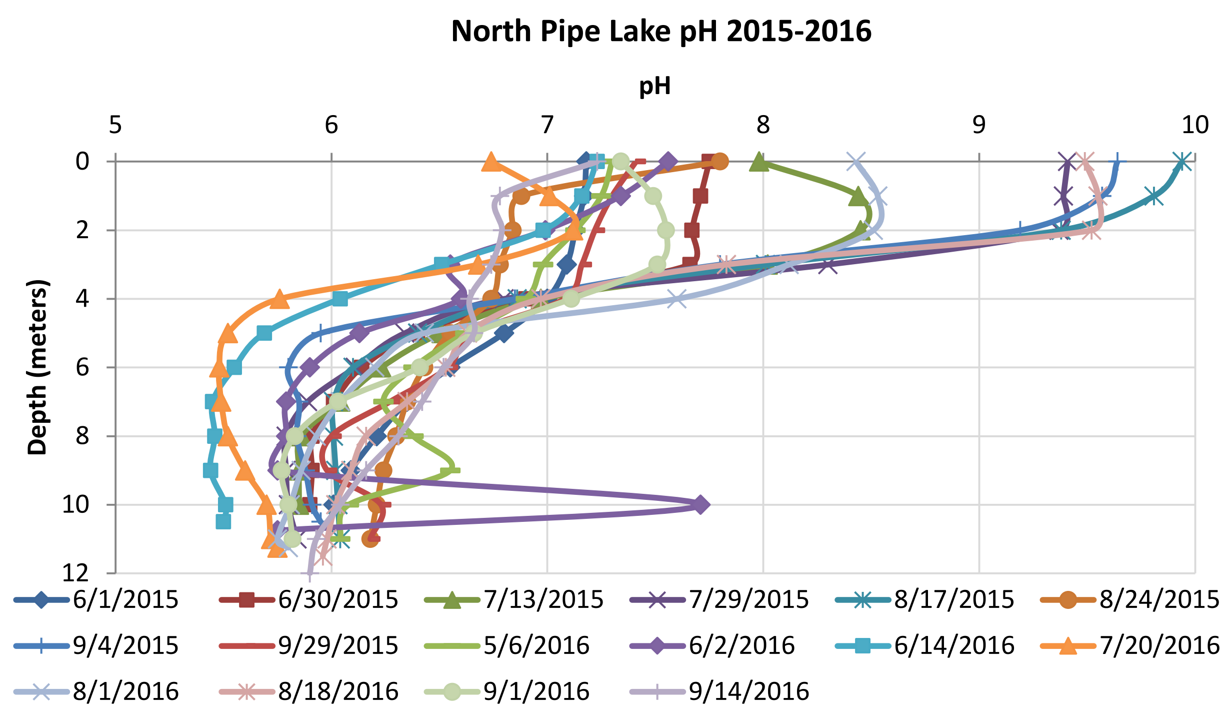
8/18/2016
9/1/2016
9/14/2016


North Pipe Lake pH 2015-2016
pH
5
6
7
8
9
10
0
2
4
6
8
10
12
Depth (meters)
6/1/2015
6/30/2015
7/13/2015
7/29/2015
8/17/2015
8/24/2015
9/4/2015
9/29/2015
5/6/2016
6/2/2016
6/14/2016
7/20/2016
8/1/2016
8/18/2016
9/1/2016
9/14/2016

Secchi Depth

The depth 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.

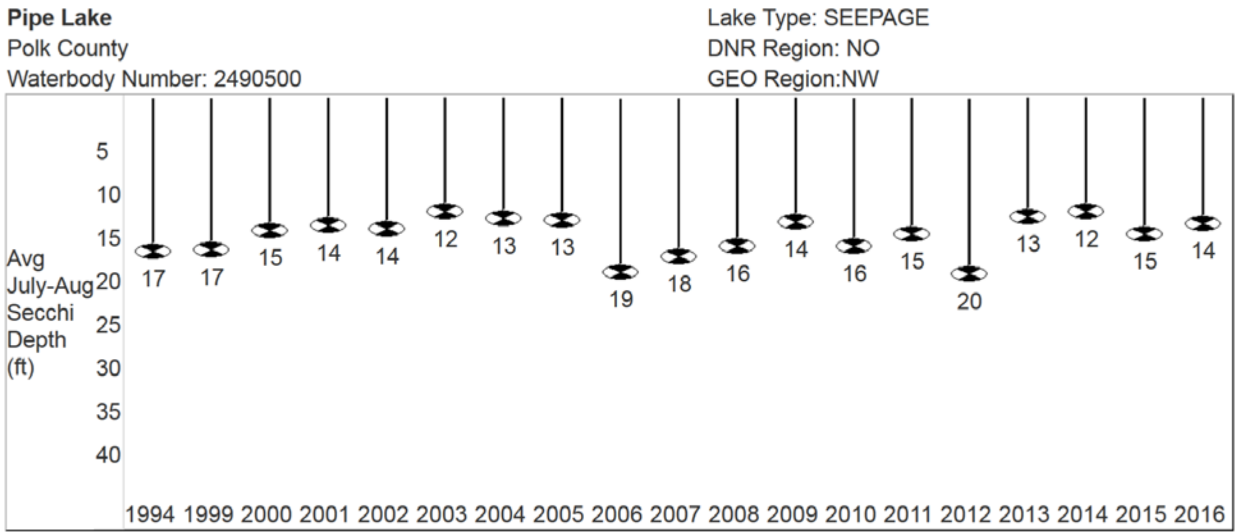
Secchi depth values vary greatly on Pipe and North Pipe Lakes. On Pipe Lake, secchi values ranged from a low of 13 feet to a high of 18 feet. In comparison, on North Pipe Lake, values ranged from a low of 2.5 feet to a high of 8 feet.

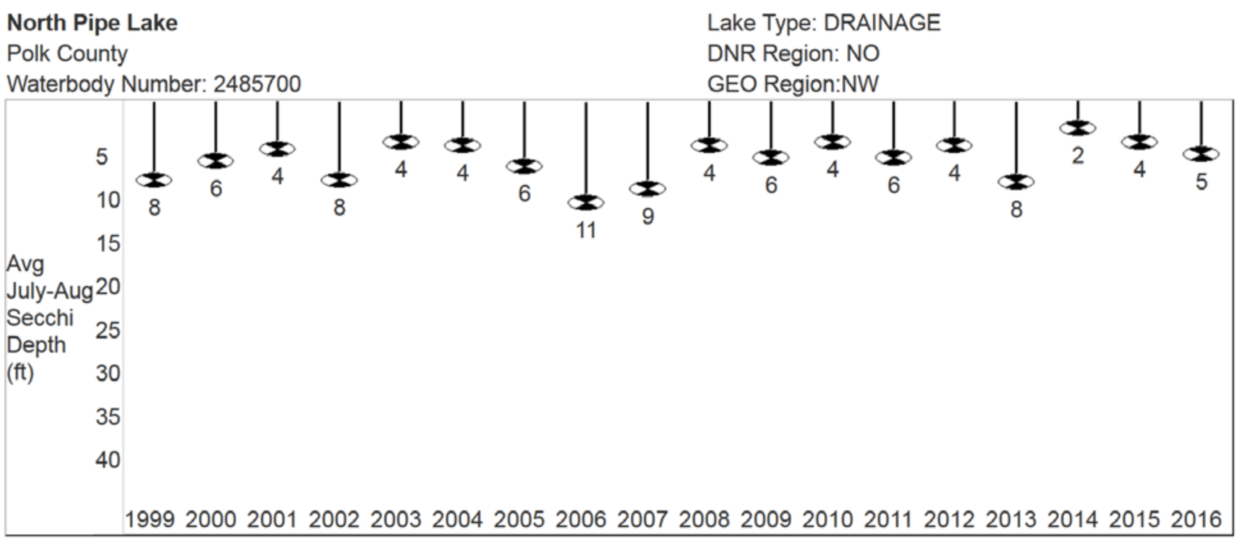
Growing season average secchi depth (May-September) on Pipe Lake was 15 feet in 2015 and 14 feet in 2016. Growing season average secchi depth (May-September) on North Pipe Lake was 4.6 feet in 2015 and 5.7 feet in 2016.

Summer index period average secchi depth (July 15-September 15) on Pipe Lake was 15 feet in 2015 and 14 feet in 2016. Summer index period average secchi depth (July 15-September 15) on North Pipe Lake was 3.4 feet in 2015 and 4.9 feet in 2016.

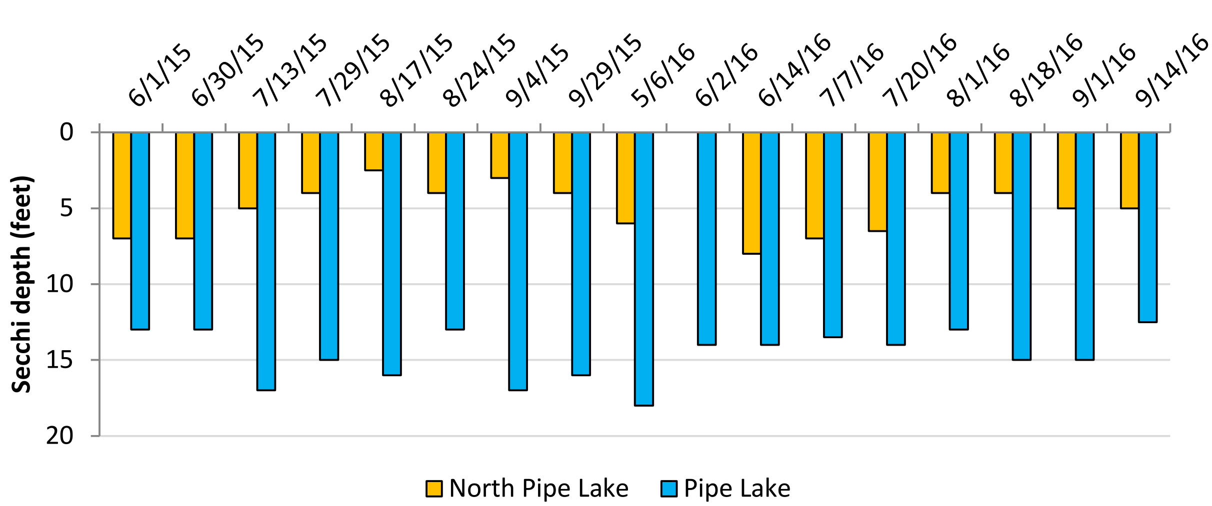
The Wisconsin Department of Natural Resources website provides historic secchi depth averages for the months of July and August. This data exists for both lakes from 1999-2016 (1994 data also exists for Pipe Lake). Over this timeframe, secchi depth has ranged from 12-20 feet on Pipe Lake and from 2-11 feet on North Pipe Lake.

The average summer secchi depth (July and August) for the Northwest geo-region was 8.4 feet in 2015 and 2016. In both years, secchi depth for Pipe Lake was well above the Northwest geo-region average and secchi depth for North Pipe Lake was below the geo-region average.





Pipe and North Pipe Lake secchi depth, 2015-2016



Phosphorus

Phosphorus is an element present in lakes which is necessary for plant and algae growth. It occurs naturally in soil and rocks and in the atmosphere in the form of dust. Phosphorus can make its way into lakes through groundwater and human induced disturbances such as soil erosion. Additional sources of phosphorus inputs into a lake can include external sources such as fertilizer runoff from urban and agricultural settings and internal sources such as release from lake bottom sediments.

Phosphorus does not readily dissolve in water, instead it forms insoluble precipitates with calcium, iron, manganese, sulfur, and aluminum. If oxygen is available in the hypolimnion, 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 and phosphorus is redistributed throughout the water column with strong wind action or turnover events.

Phosphorus is necessary for plant and animal growth. Excessive amounts can lead to an overabundance of growth which can decrease water clarity and lead to nutrient pollution in lakes.

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.

In lakes, a healthy limit of total phosphorus is set at 20 µg/L. If a value is above the healthy limit it is more likely that a lake could support nuisance algae blooms. On all sampling dates, surface phosphorus was below the healthy limit on Pipe Lake and above the heathy limit on North Pipe Lake.

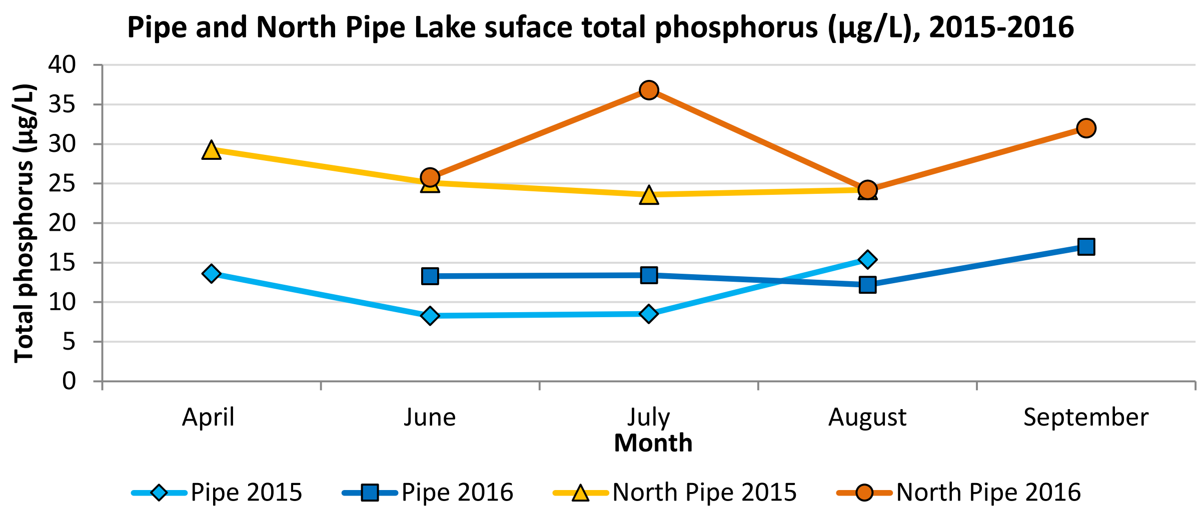
Growing season average surface phosphorus on Pipe Lake was 11.4 µg/L in 2015 and 14.0 µg/L in 2016. Growing season average surface phosphorus on North Pipe Lake was 25.6 µg/L in 2015 and 29.7 µg/L in 2016.

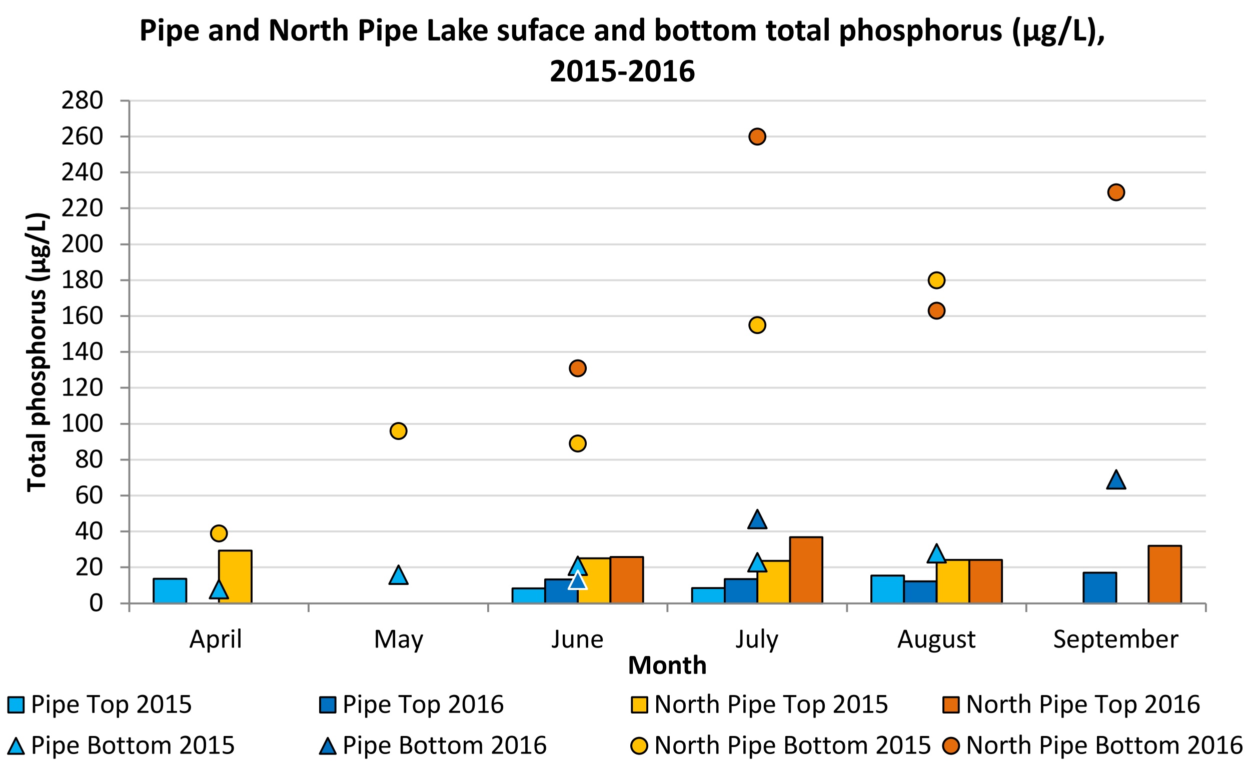
Summer index period (July 15-September 15) average surface phosphorus on Pipe Lake was 12 µg/L in 2015 and 14.2 µg/L in 2016. Growing season average surface phosphorus on North Pipe Lake was 23.9 µg/L in 2015 and 31.0 µg/L in 2016.

Phosphorus concentrations were elevated on the bottom of both lakes, but especially in North Pipe Lake.

Growing season average bottom phosphorus on Pipe Lake was 19.2 µg/L in 2015 and 43.0 µg/L in 2016. Growing season average bottom phosphorus on North Pipe Lake was 111.8 µg/L in 2015 and 195.8 µg/L in 2016.

Summer index period (July 15-September 15) average bottom phosphorus on Pipe Lake was 25.5 µg/L in 2015 and 58 µg/L in 2016. Growing season average bottom phosphorus on North Pipe Lake was 167.5 µg/L in 2015 and 217.3 µg/L in 2016.





Nitrogen

Nitrogen, like phosphorus, is an element necessary for plant growth. Nitrogen sources in a lake can vary widely. Nitrogen does not occur naturally in soil minerals; however, 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 circumstances, 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 algae.

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 300 µg/L can support summer algae blooms.

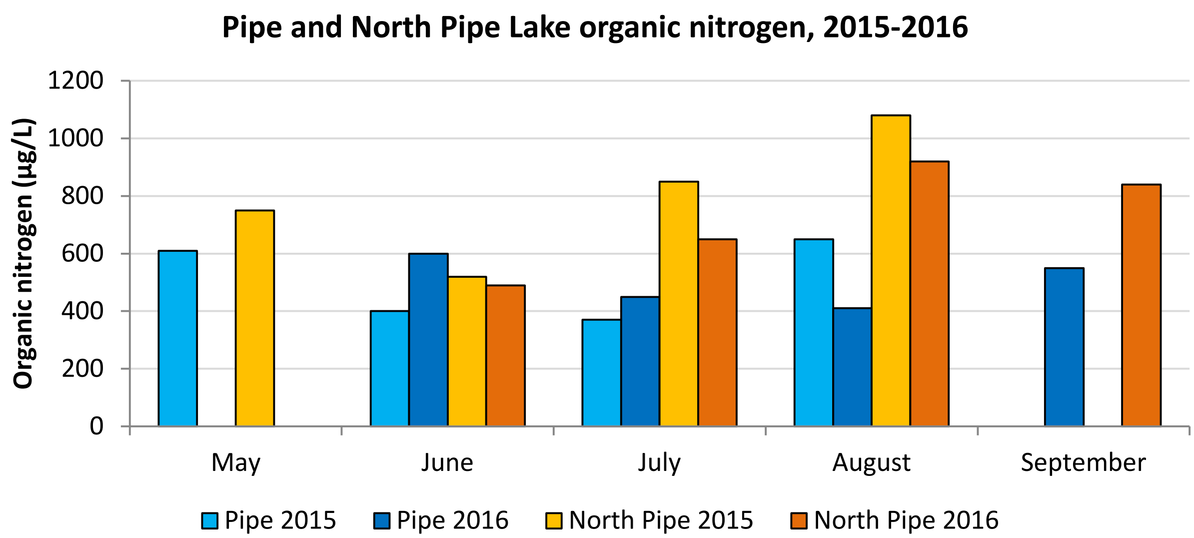
Nitrate/nitrite was below the limit of detection or less than 100 µg/L on all sample dates in 2015 and 2016 in both Pipe and North Pipe Lakes. Inorganic nitrogen was well below 300 µg/L in both lakes over the course of the 2015 and 2016 growing season.

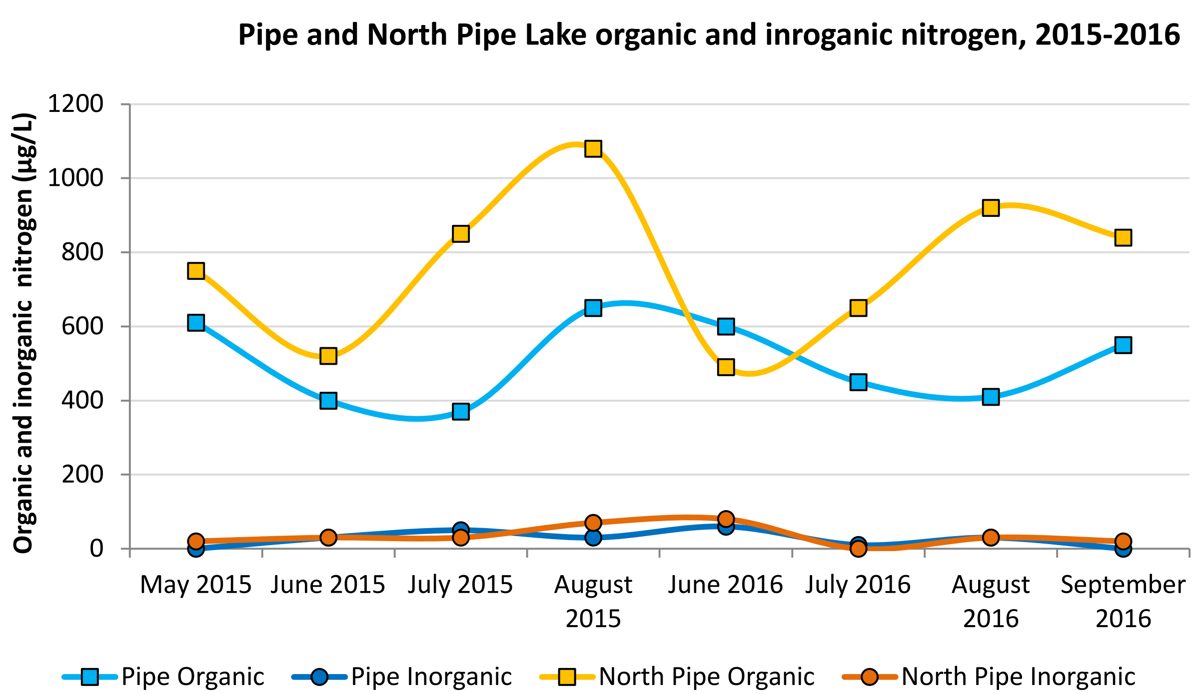
Total Kjeldahl Nitrogen is a measure of organic nitrogen plus ammonium. By subtracting the ammonium concentration from total Kjeldahl nitrogen, the organic nitrogen concentration found in plants and algae can be found.

Growing season average organic nitrogen was 508 µg/L in 2015 and 503 µg/L in 2016 in Pipe Lake and 800 µg/L in 2015 and 725 µg/L in 2016 in North Pipe Lake.

Summer index period average organic nitrogen was 510 µg/L in 2015 and 470 µg/L in 2016 in Pipe Lake and 965 µg/L in 2015 and 803 µg/L in 2016 in North Pipe Lake.

Organic nitrogen was greater in North Pipe Lake as compared to Pipe Lake. In 2015, organic nitrogen in Pipe Lake decreased from May through July and increased in August. In North Pipe Lake, organic nitrogen decreased from May to June, and increased over the remainder of the growing season. In 2016, organic nitrogen in Pipe Lake decreased from June to August, and increased in September. In North Pipe Lake, organic nitrogen increased through August and decreased slightly in September.





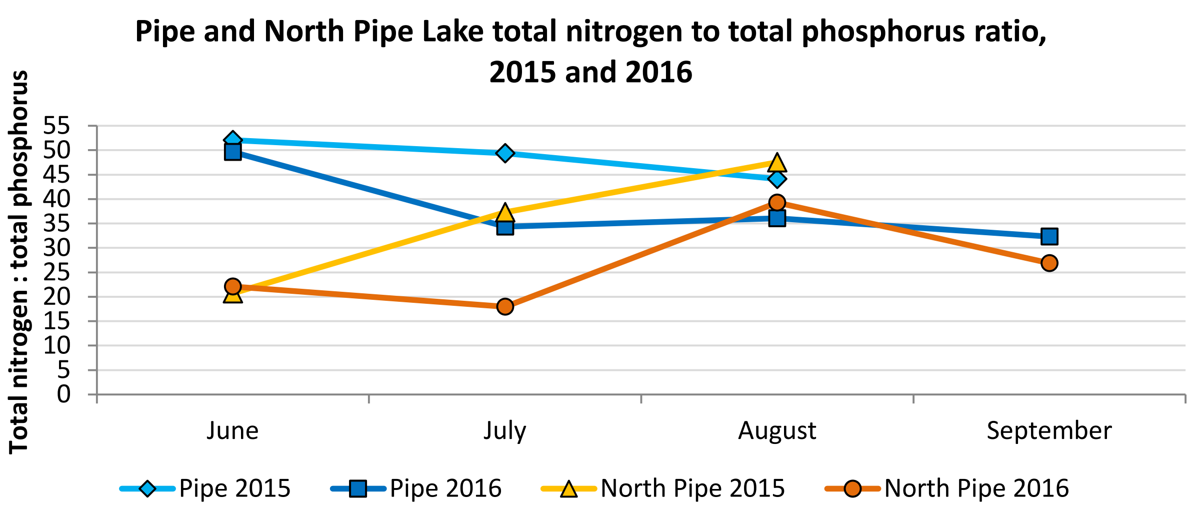
Total Nitrogen to Total Phosphorus Ratio

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, 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.

Total nitrogen is found by adding nitrate/nitrite to total Kjeldahl nitrogen. As previously mentioned, nitrate/nitrite concentrations were below the limit of detection or less than 100 µg/L on all sampling dates. As a result, total nitrogen is reflected by TKN.

Pipe and North Pipe Lakes are both phosphorus limited. Over the course of the growing season, Pipe Lake becomes less sensitive to phosphorus inputs, whereas North Pipe Lake becomes more sensitive to phosphorus inputs.

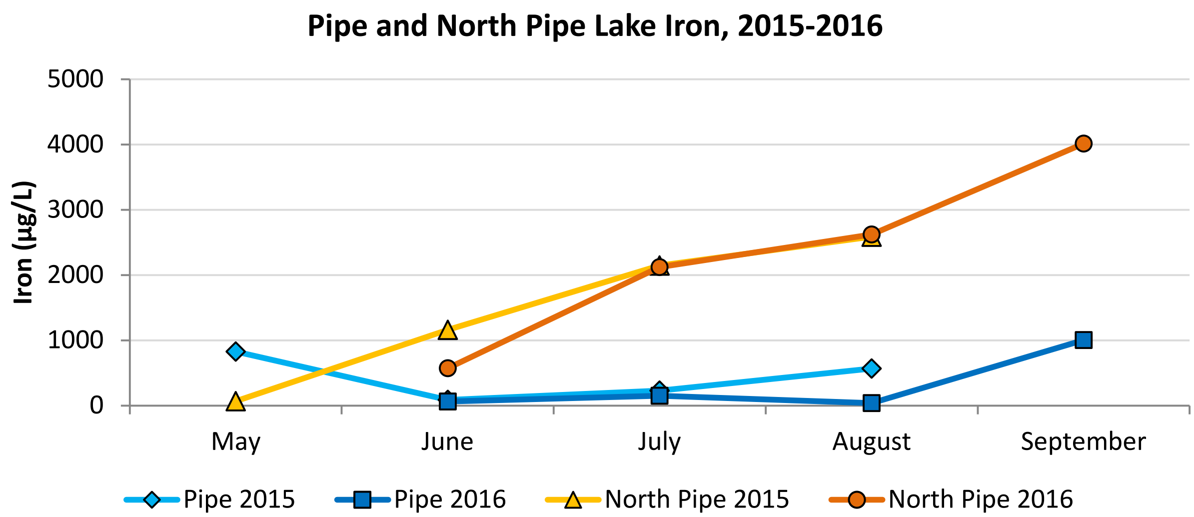


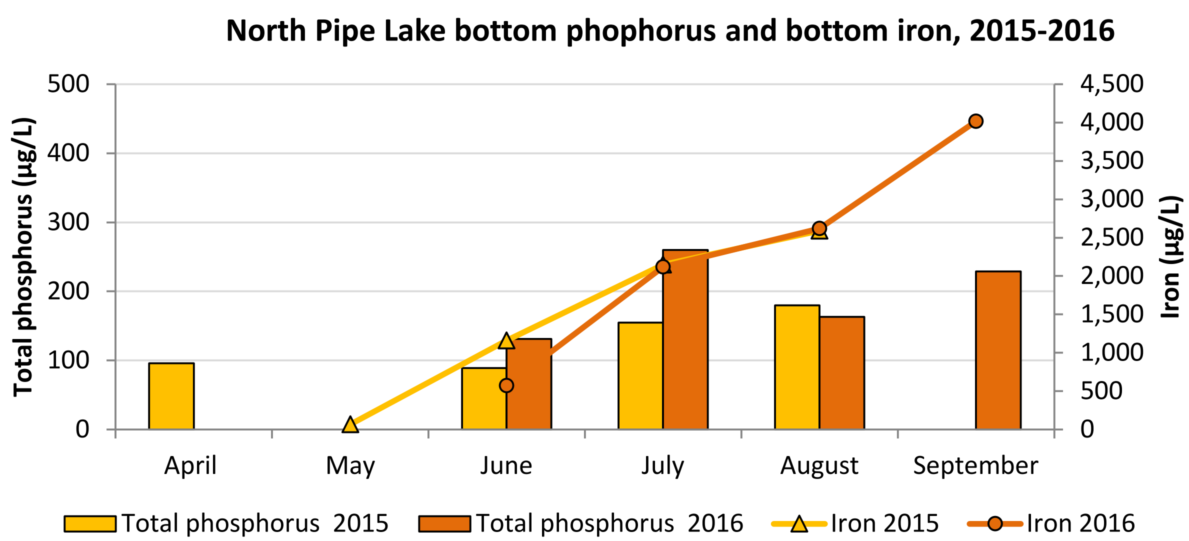
Iron

Iron is a micronutrient required by living organisms in lakes. It is an abundant metal in the Earth's crust although its concentration in lakes is typically low due to low solubility.

In the presence of oxygen, iron and phosphorus bind to one another in lake sediments. Under low oxygen conditions, iron and phosphorus are released into the water column from the bottom sediments.

Iron levels in Pipe Lake remained relatively low over the course of the growing season. In North Pipe Lake, iron levels increased quite dramatically over the course of the growing season. Dissolved oxygen levels were at zero in the hypolimnion of both Pipe and North Pipe Lake. In North Pipe Lake, bottom iron and phosphorus increased over the course of the growing season in both sample years.





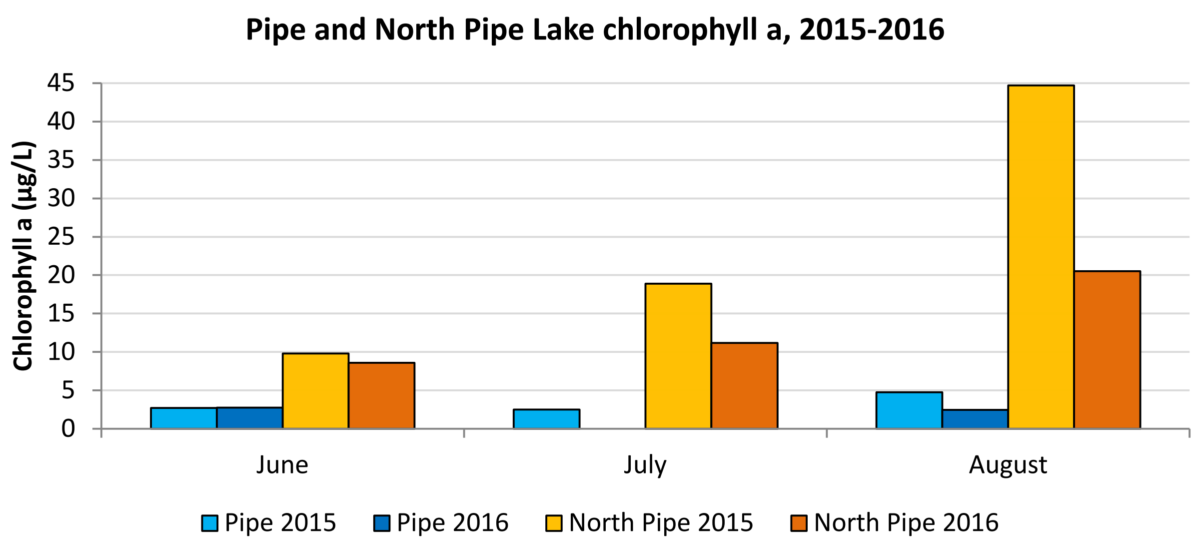
Chlorophyll a

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.

Chlorophyll a seems to have the greatest impact on water clarity when levels exceed 30 µg/L. Lakes which appear clear generally have chlorophyll a levels less than 15 µg/L.

Growing season average (excludes turnover) surface chlorophyll a on Pipe Lake was 3.3 µg/L in 2015 and 2.6 µg/L in 2016. Summer index period (excludes turnover) surface chlorophyll a on Pipe Lake was 3.6 µg/L in 2015 and 2.5 µg/L in 2016. Chlorophyll a levels on Pipe Lake were well below 15 µg/L on all sample dates.

Growing season average surface chlorophyll a on North Pipe Lake was 24.5 µg/L in 2015 and 13.4 µg/L in 2016. Summer index period average surface chlorophyll a on North Pipe Lake was 31.8 µg/L in 2015 and 15.9 µg/L in 2016. Chlorophyll a levels on North Pipe Lake were below 15 µg/L in June and July of 2016, between 15 and 30 µg/L in July of 2015 and August of 2016, and over 30 µg/L in August of 2015.



Trophic State Index

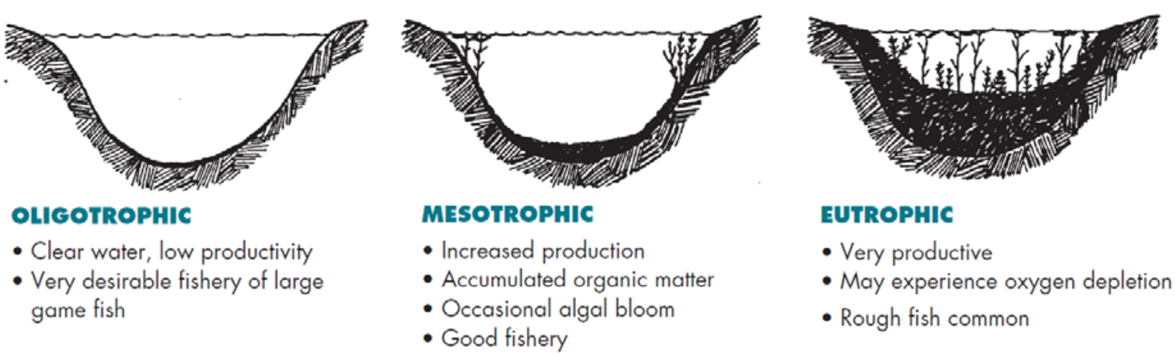
Lakes are divided into three categories based on their trophic states: oligotrophic, eutrophic, and mesotrophic. These categories reflect a lake's nutrient and clarity level and serve as an indicator of water quality. Each category is designed to serve as an overall interpretation of a lake's primary 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 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 plants and animals. 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 that introduce nutrients into a lake (agriculture, lawn fertilizers, and septic systems) can accelerate the process by which lakes age and become eutrophic.



[15]

A common method of determining a lake's trophic state is to compare total phosphorus (important for algae growth), chlorophyll a (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 total phosphorus, chlorophyll a, and secchi disk readings is the basis of comparison for the trophic state index (TSI).

[15] Figure from Understanding Lake Data (G3582), UW-Extension, Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004

TSI is determined using a mathematic formula and ranges from 0 to 110. 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 Pipe and North Pipe Lakes.

TSI (P) = 14.42 * Ln [TP] + 4.15 (where total phosphorus 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)

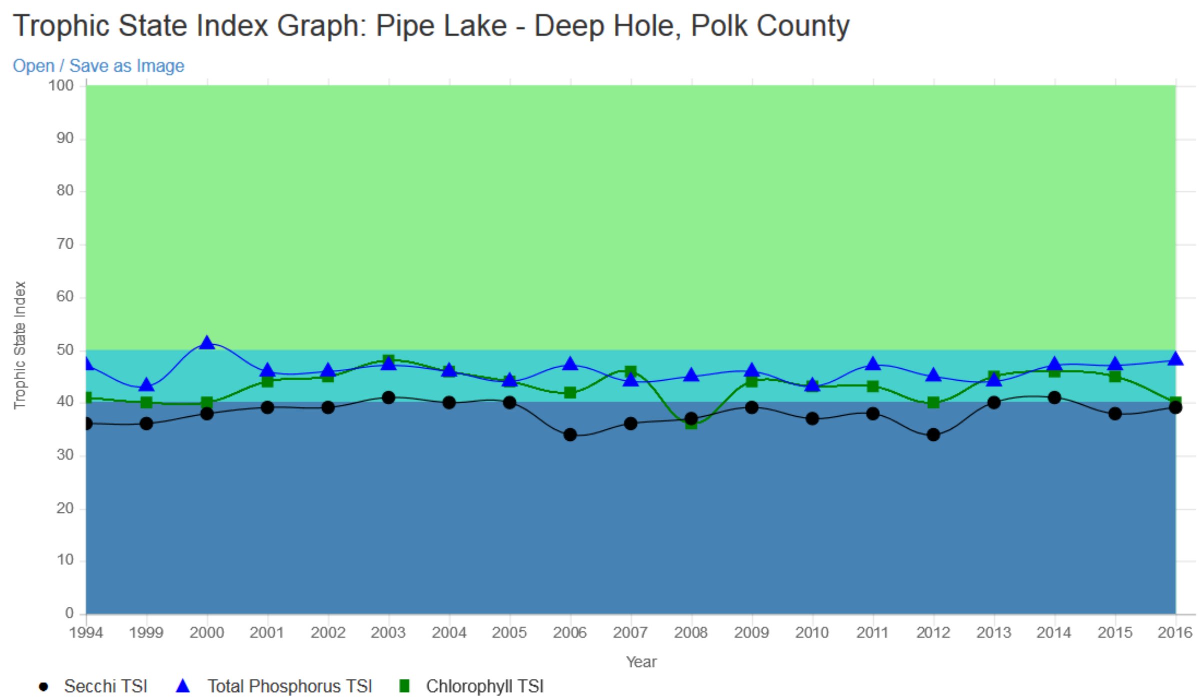
<u>Pipe Lake 2015 and 2016, respectively</u>
Average summer index period TSI (total phosphorus) = 40 and 42
Average summer index period TSI (chlorophyll a) = 43 and 40
Average summer index period TSI (secchi depth) = 38 and 39
Average summer index period TSI = 40 = oligotrophic/mesotrophic (2015 and 2016)

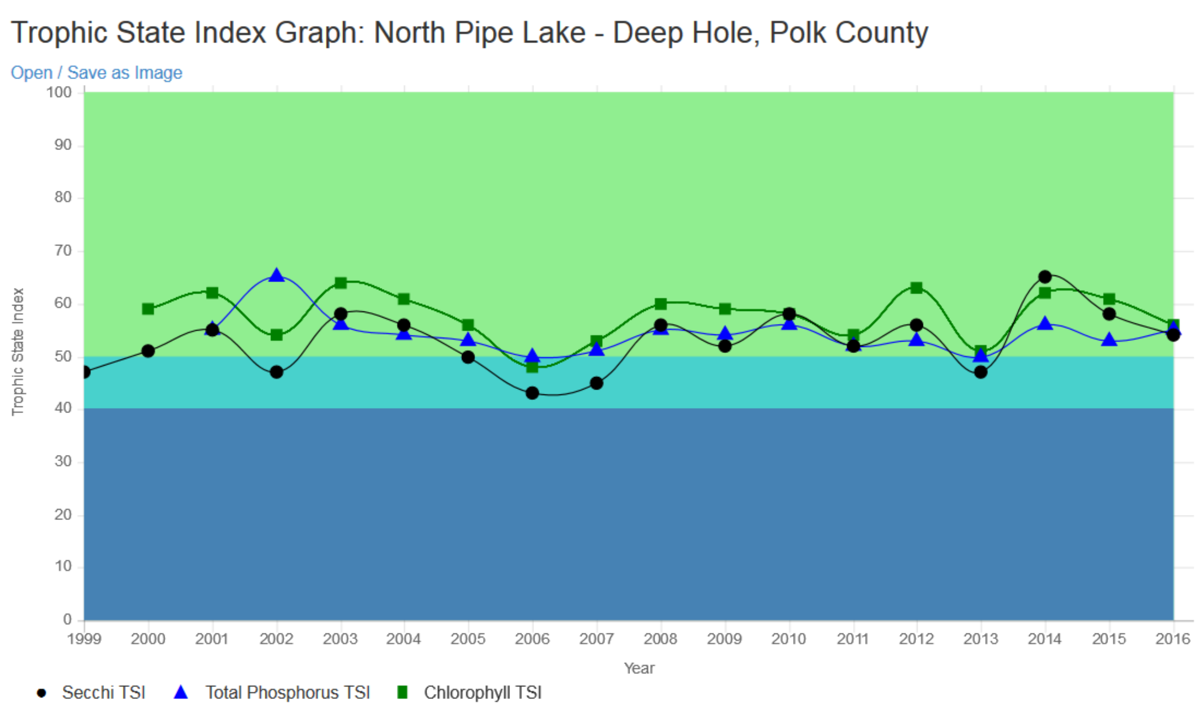
<u>North Pipe Lake 2015 and 2016, respectively</u>
Average summer index period TSI (total phosphorus) =50 and 54
Average summer index period TSI (chlorophyll a) = 65 and 58
Average summer index period TSI (secchi depth) = 59 and 54
Average summer index period TSI = 58 and 55 = mildly eutrophic

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 trophic state index of a lake gives stakeholders a method by which to gauge lake productivity over time. TSI data exists for both lakes from 1999-2016. Additionally, 1994 data exists for Pipe Lake.

Historic TSI data indicates an oligotrophic to mesotrophic state on Pipe Lake and a mesotrophic to eutrophic state on North Pipe Lake.





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. 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 and create light limited conditions for other groups of algae. Additionally, under nitrogen limited conditions, blue green algae have a competitive advantage over other algae because of their unique ability to fix nitrogen from the atmosphere.

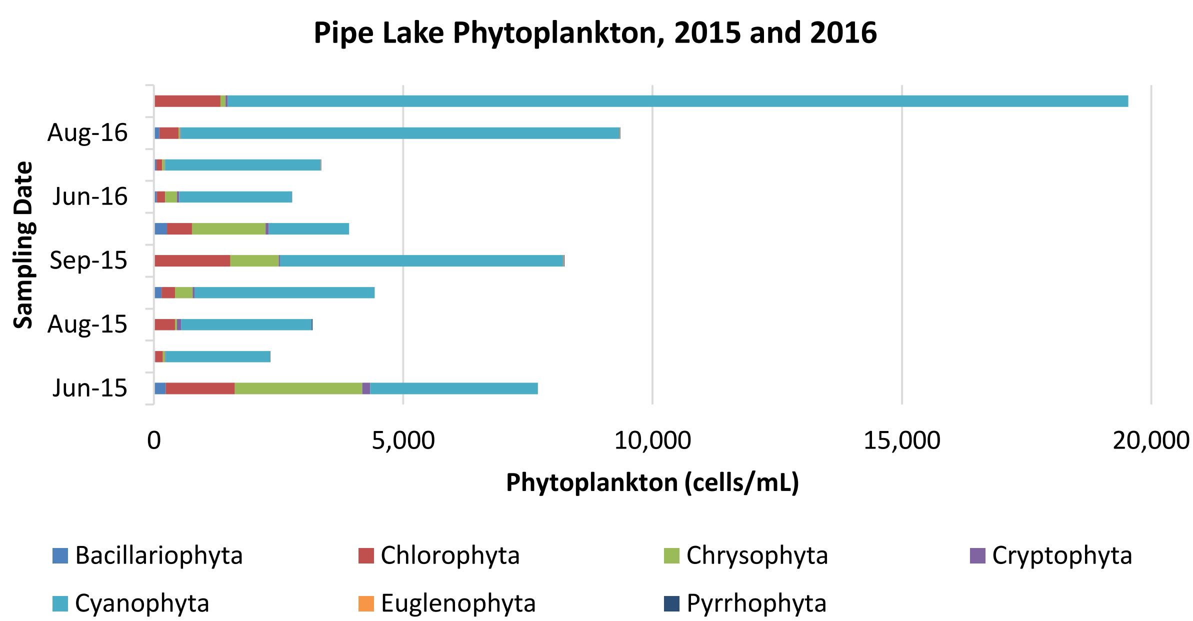
Chlorophyll a is a pigment in plants and algae that is necessary for photosynthesis. Chlorophyll a gives a general indication of the amount of algae growth in the water column; however, it is not directly correlated with algae biomass. To obtain accurate algae data, composite samples from a two meter water column were collected monthly, preserved with glutaraldehyde, placed on ice, and sent to the UW-Oshkosh for identification and enumeration of algae species. Sampling was conducted in 2015 and 2016.

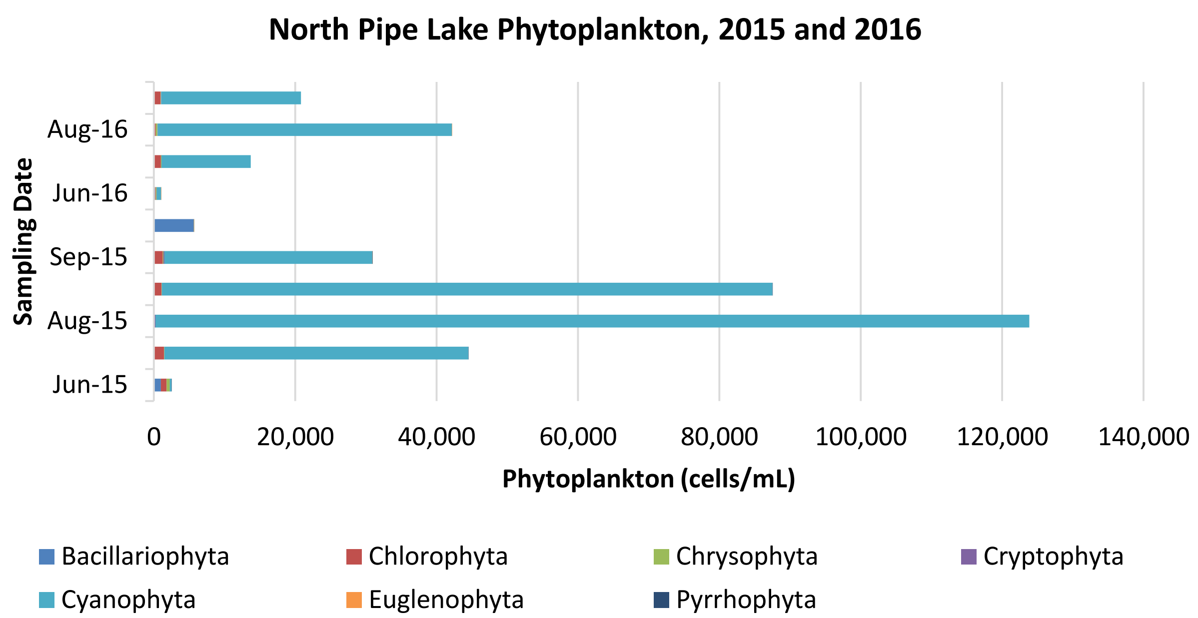
Algae were identified to the lowest taxonomic level, and a relative concentration and cell count was made to describe the algae community throughout the growing season. This method of sampling also allows the identification of any species of concern which might be present.

There are 12 divisions of algae found in typical lakes of Wisconsin. Seven divisions were found in Pipe and North Pipe Lakes. The divisions Pyrrhophyta and Euglenophyta were found in very low numbers.

Algal Class	Common Name	Characteristics
Bacillariophyta	Diatoms	Sensitive to chloride, pH, color, and total phosphorus in water. As total phosphorus increases, diatoms decrease. Generally larger in size. Tend to be highly present in spring and late fall.
Chlorophyta	Green algae	Provide high nutritional value to consumers. Can be filamentous and intermingle with macrophytes.
Chrysophyta	Golden brown algae	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	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	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	Commonly found in freshwater that is rich in organic materials. Most are unicellular.
Pyrrhophyta	Dinoflagellates	Have starch food reserves and serve as food for grazers.

On most of the sampling dates, blue green algae were the most abundance division of algae in both lakes, but less so on Pipe Lake.

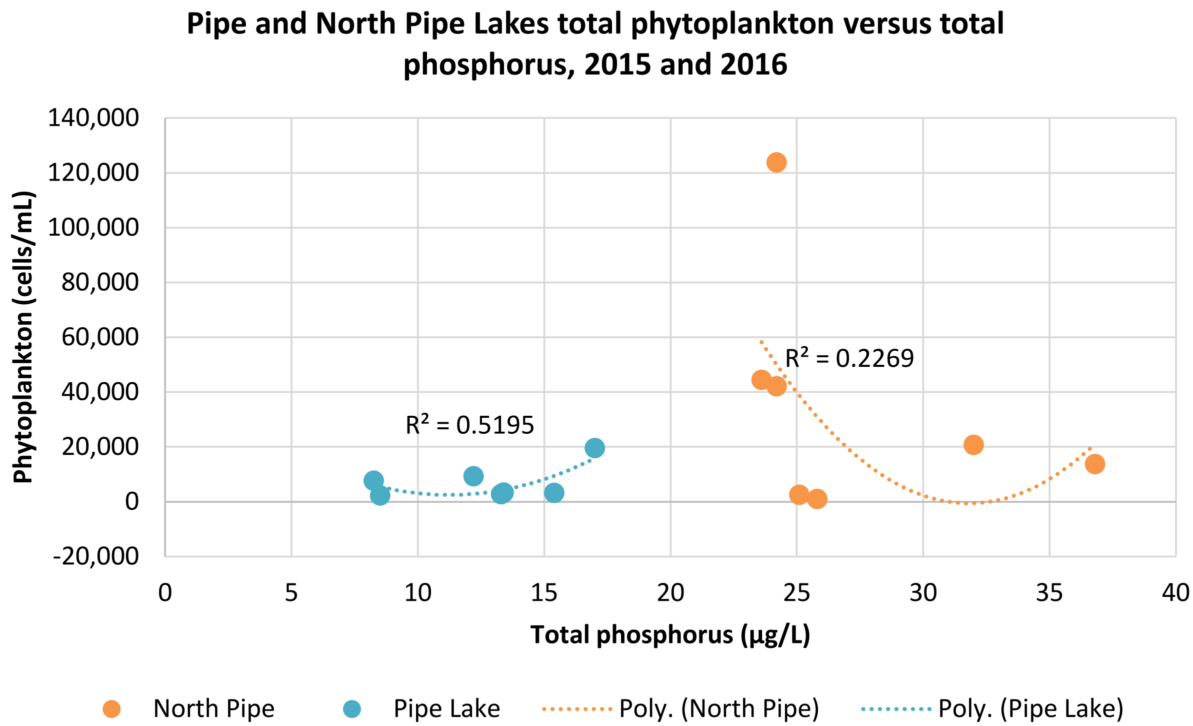


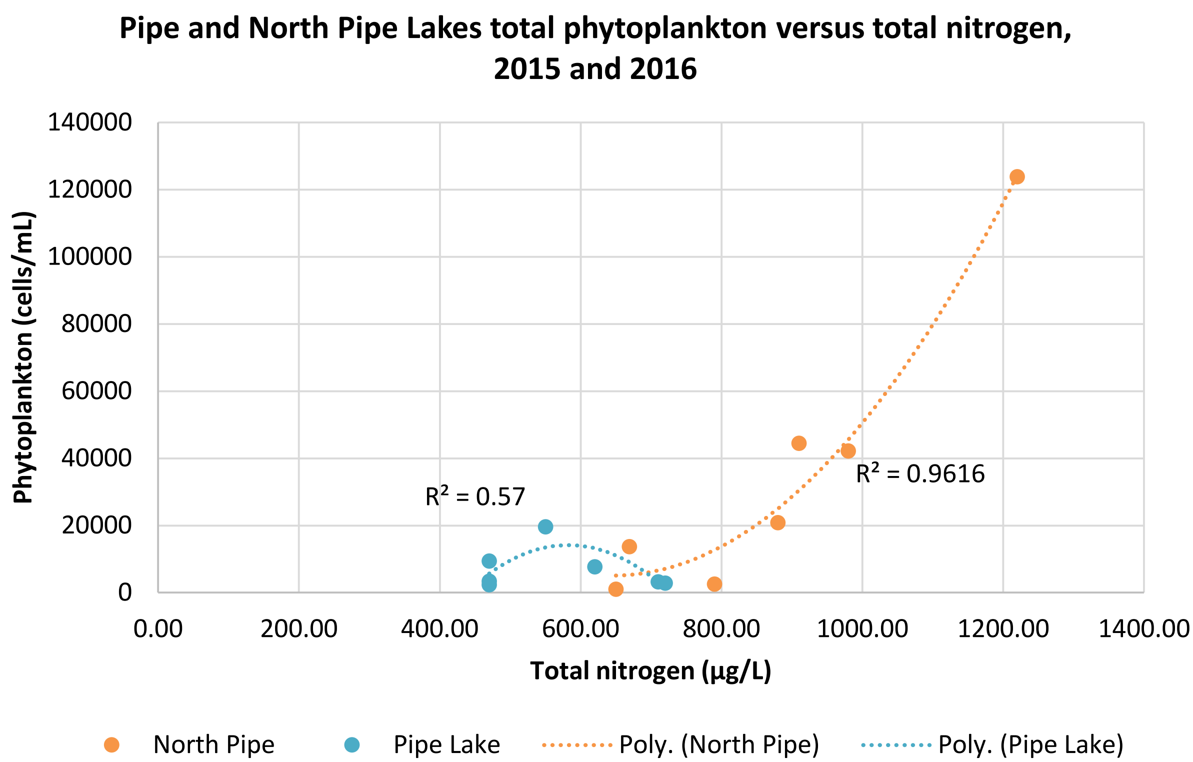


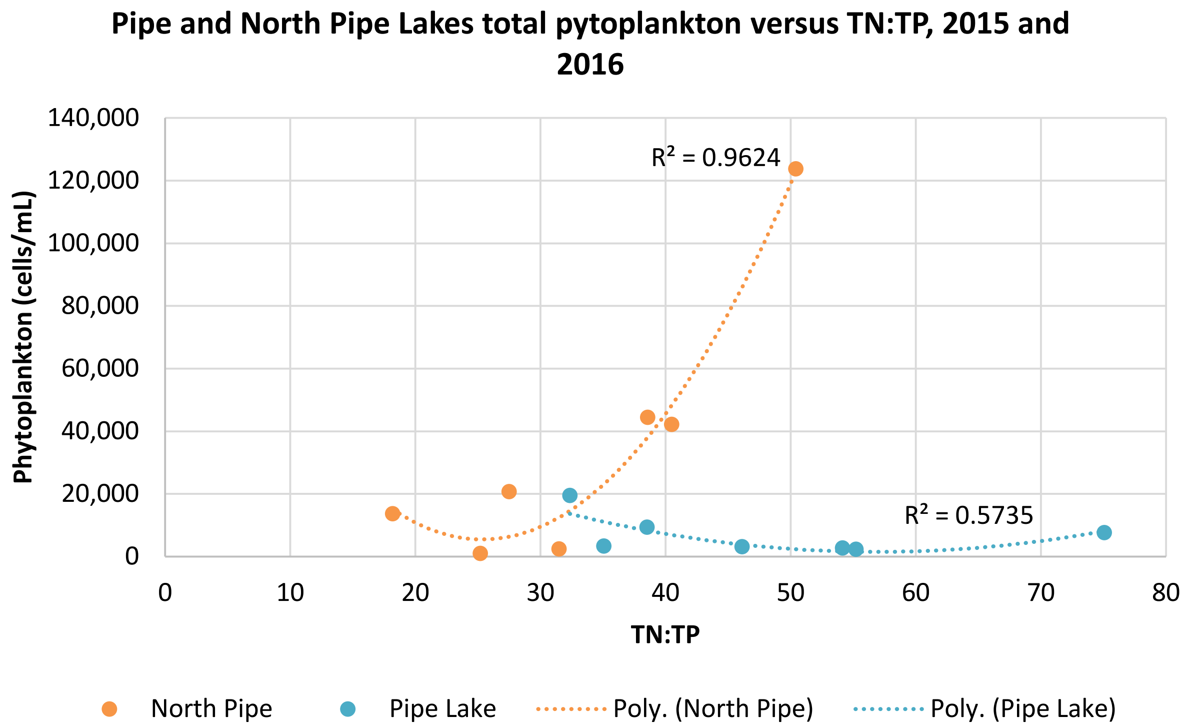
Blue green algae or cyanobacteria have been around for billions of years and typically bloom during the summer months. However, blue green algae blooms become more frequent as a result of increased nutrient concentrations. In North Pipe Lake, blue green algae seem to have a competitive advantage over other algae because of their unique ability to fix nitrogen from the atmosphere.

In addition to the negative aesthetics posed by algae, blue green algae are of specific concern because of some have the ability to produce toxins. Toxin producing groups such as *Anabaena sp.*, *Aphanizomenon flos-aquae*, *Microcystis aeruginosa*, and *Planktolyngbya spp.* were common during the sampling season.

When the total phytoplankton production is analyzed against common nutrients typically monitored in limnological studies, it is clear to see that either nitrogen is influencing the phytoplankton community on North Pipe Lake or nitrogen fixing cyanobacteria is influencing the lake's chemistry. On Pipe Lake it appears that both phosphorus and nitrogen influence the algal community. Additional nutrient monitoring may be necessary in order to fully understand the phytoplankton community on the lakes, specifically nitrogen and possibly iron in addition to typical limnological parameters.


Pipe and North Pipe Lakes total phytoplankton versus total phosphorus, 2015 and 2016
Phytoplankton (cells/mL)
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
-20,000
0
5
10
15
20
25
30
35
40
Total phosphorus (µg/L)
$R^2 = 0.2269$
$R^2 = 0.5195$
North Pipe
Pipe Lake
Poly. (North Pipe)
Poly. (Pipe Lake)


Pipe and North Pipe Lakes total phytoplankton versus total nitrogen, 2015 and 2016
Phytoplankton (cells/mL)
140000
120000
100000
80000
60000
40000
20000
0
0.00
200.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
Total nitrogen (µg/L)
$R^2 = 0.9616$
$R^2 = 0.57$
North Pipe
Pipe Lake
Poly. (North Pipe)
Poly. (Pipe Lake)


Pipe and North Pipe Lakes total pytoplankton versus TN:TP, 2015 and 2016
Phytoplankton (cells/mL)
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
0
10
20
30
40
50
60
70
80
TN:TP
R² = 0.9624
R² = 0.5735
North Pipe
Pipe Lake
Poly. (North Pipe)
Poly. (Pipe Lake)

Blue Green Algae Toxin Risk

Blue green algae, or cyanobacteria, 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 nutrient concentrations.

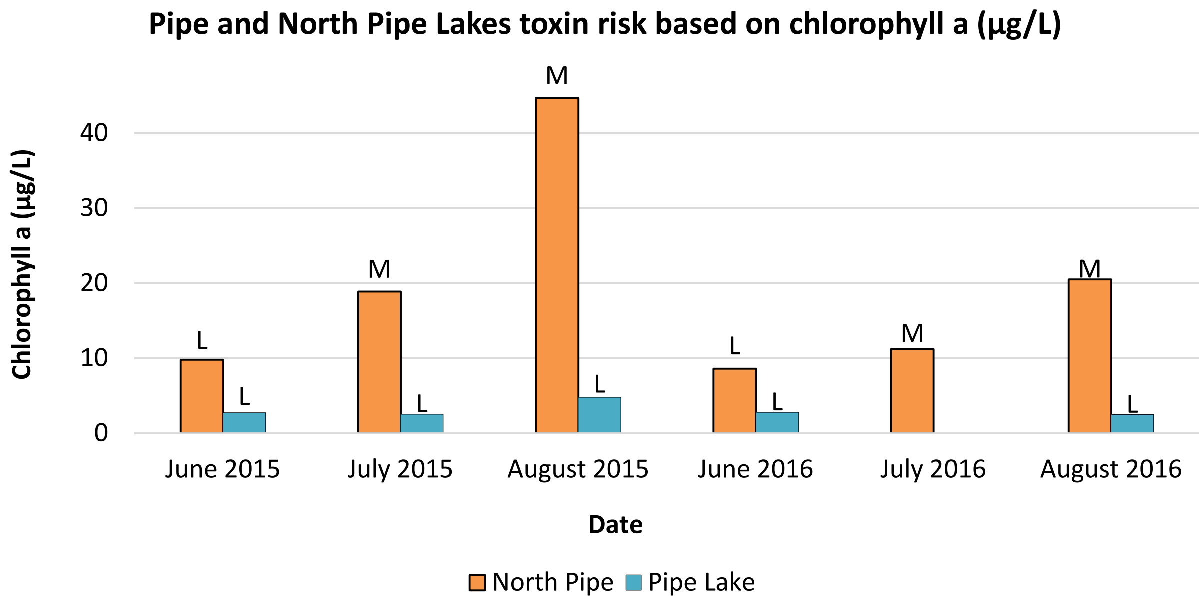
Blue green algae are of specific concern because of their ability to produce toxins, that when ingested or inhaled, can cause short and long term health effects. Effects range from tingling, burning, numbness, drowsiness, and dermatitis to liver or respiratory failure possibly leading to death.

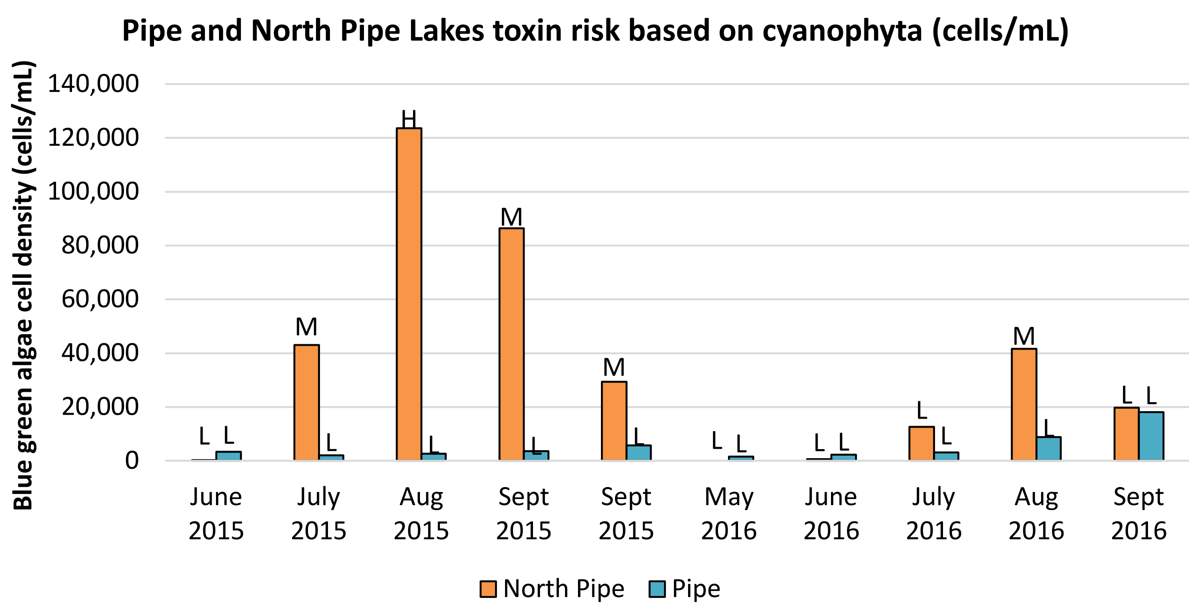
It is not known which environmental conditions cause the production of cyanotoxins, but scientists have found that when blue green algae is present at concentrations over 100,000 cells/mL toxin production is more likely to occur.

Federal guidelines for blue green algae cell densities and chlorophyll concentrations do not exist. The Wisconsin Harmful Algal Bloom (HAB) Surveillance Program uses guidelines of the World Health Organization to determine risks from blue green algae.

Blue green algae cell density (cells/mL)	Chlorophyll a (µg/L)	Risk
Less than 20,000	Less than 10	**Low**
20,000 to 100,000	10 to 50	**Moderate**
Greater than 100,000	Greater than 50	**High**

In Pipe Lake, toxin risk was low on all sampling dates based on blue green algae cell density and chlorophyll a. In North Pipe Lake, toxin risk was low in June of both years and moderate in July and August of both years based on chlorophyll a. Based on blue green algae cell density, toxin risk was low on 50% of the sampling dates, moderate on 40% of the sampling dates, and high on 10% of the sampling dates on North Pipe Lake.


Pipe and North Pipe Lakes toxin risk based on chlorophyll a (µg/L)
Chlorophyll a (µg/L)
0
10
20
30
40
L
L
M
L
M
L
L
L
M
M
L
June 2015
July 2015
August 2015
June 2016
July 2016
August 2016
Date
North Pipe
Pipe Lake


Pipe and North Pipe Lakes toxin risk based on cyanophyta (cells/mL)
Blue green algae cell density (cells/mL)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
June 2015
July 2015
Aug 2015
Sept 2015
Sept 2015
May 2016
June 2016
July 2016
Aug 2016
Sept 2016
North Pipe
Pipe

Land Use and Water Quality

The health of 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 hard, man-made surfaces such as rooftops, paved driveways, and concrete patios that make it impossible for rainwater to infiltrate into the ground.

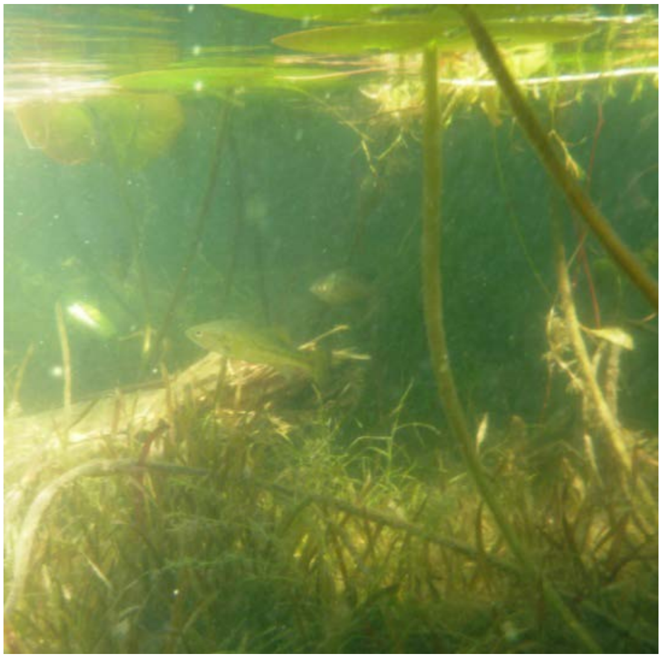
By making it impossible for rainwater to infiltrate into the soil, impervious surfaces increase the volume of rainwater that washes over the soil surface and runs off directly into lakes and streams. Rainwater runoff can carry pollutants such as sediment, lawn fertilizers, and car oils directly into 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.

In extreme precipitation events, erosion and gullies can result. The signs of erosion are unattractive and can cause decreases in property values. Sediment can also have negative impacts on aquatic life. Fish eggs will die when covered with sediment and sediment influxes to a lake can decrease water clarity making it difficult for predator fish species to locate food.

Increases in impervious surfaces and lawns 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. 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, cause decreases in fisheries habitat.

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, soil capacity is reduced and the impacts of erosion can be intensified.

Avoiding establishing lawns 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 35 feet per 100 feet of shoreline viewing corridor which can be established as lawn.

Shoreline Inventory

A shoreline inventory was completed using methodology developed by the University of Wisconsin Stevens Point Center for Watershed Science and Education. Land and Water Resources Department, with assistance from five Pipe and North Pipe Lakes Protection and Rehabilitation District volunteers, completed the Shoreland Vegetation Survey and Shoreland Disturbance Survey Above and Below the Ordinary High Water Mark on September 14th, 16th, and 29th, 2016.

In the Shoreland Vegetation Survey, the general shoreline condition is characterized as disturbed or undisturbed, the dominant short vegetation ground condition is determined[16], the presence or absence of each short shoreland vegetation ground condition is characterized, and it is established if tall shoreland vegetation is present or absent.

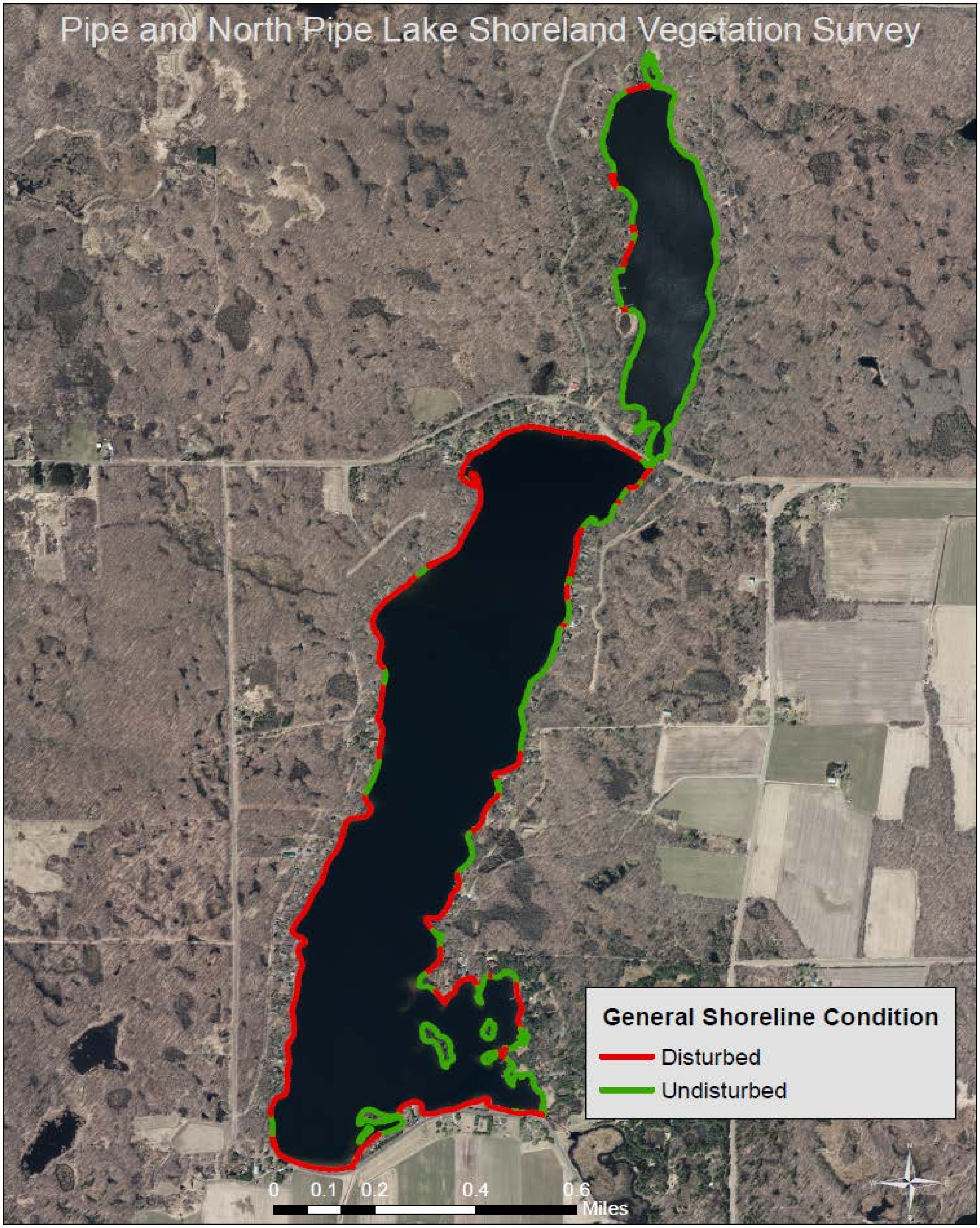
Using the Shoreland Vegetation Survey and Shoreland Disturbance Survey Above and Below the Ordinary High Water Mark, the survey established the presence of shoreland alterations[17], determined presence of erosion (undercut banks/slumping and furrows/gullies), characterized the areas below the ordinary high water mark[18], and documented culvert size, shape, and material.

[16] Short shoreland vegetation ground conditions include: organic-leaf pack/needles, barren/bare dirt (erosion), new shoreland restoration, mowed vegetation, short un-mowed vegetation < 3 feet tall, and impervious surface

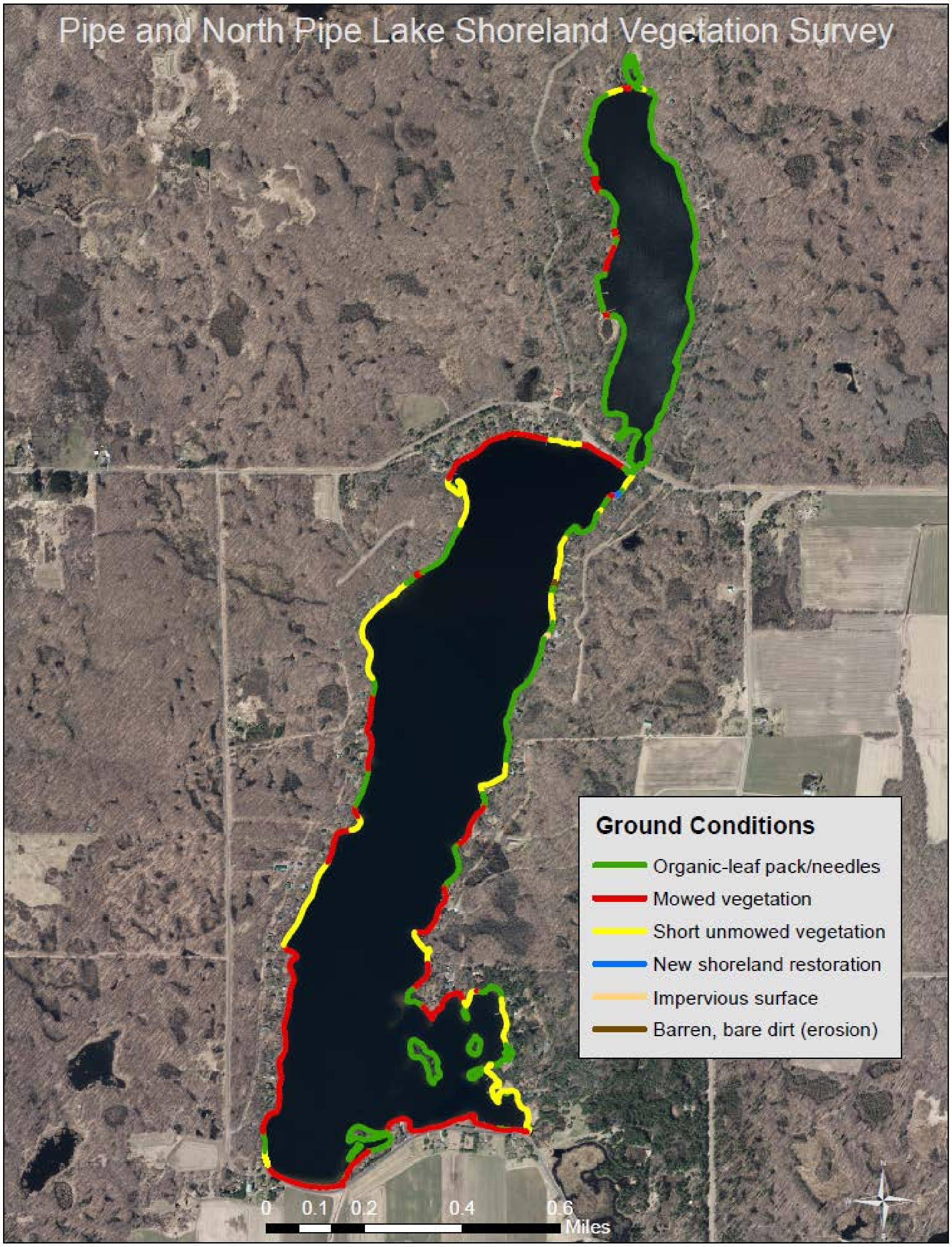
[17] Shoreland alterations include: dock/pier, seawall, rip-rap, artificial beach, boat landing, and dam/spillway

[18] The presence of the following were characterized for the area below the ordinary high water mark: cut/mowed area >30 feet wide, tilled/erosion, motor vehicle tire imprints, and woody structure

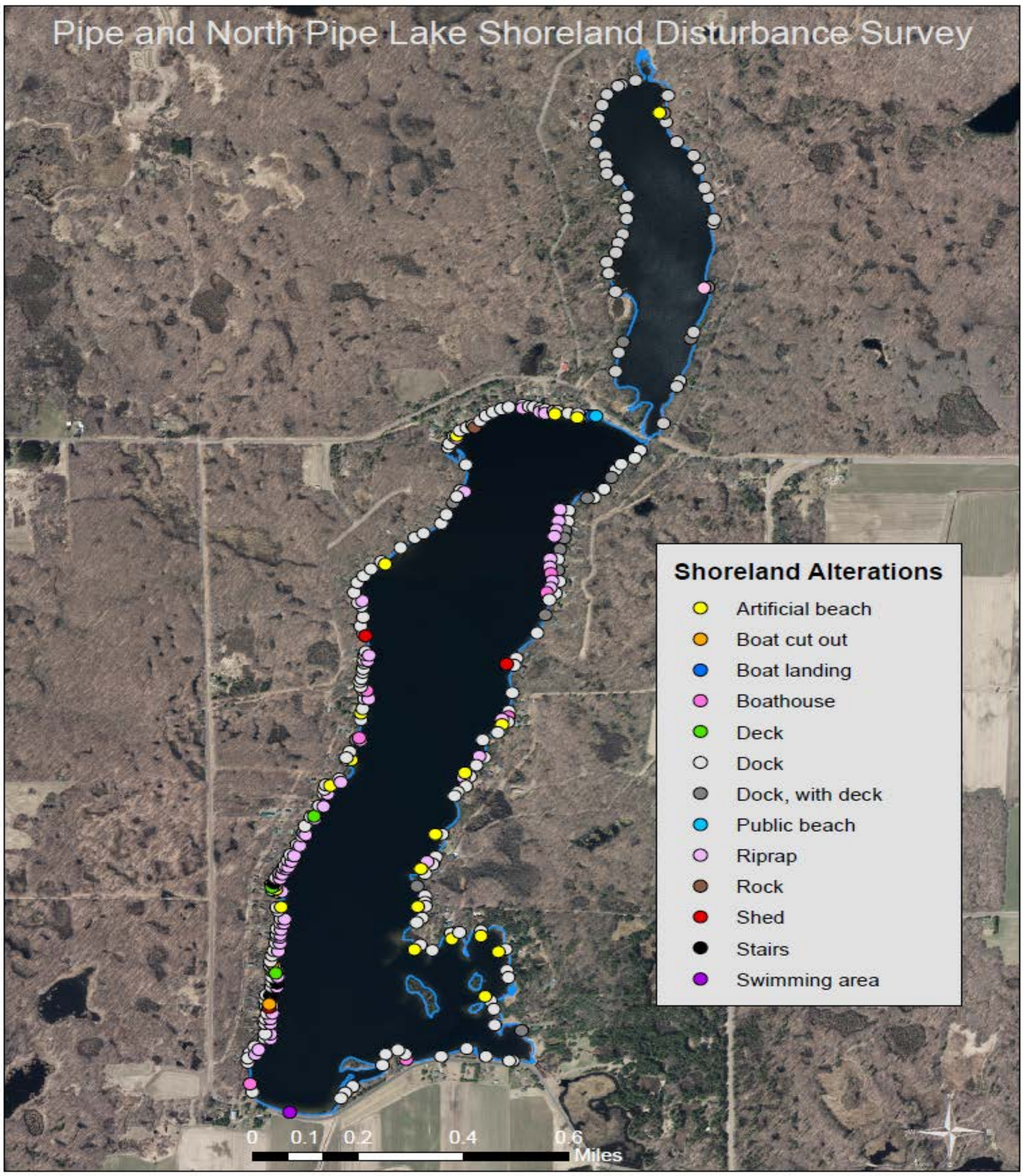
The shoreline of North Pipe Lake is primarily undisturbed (92%) as compared to disturbed (8%). In contrast, more than half of the shoreline of Pipe Lake is disturbed (59%) as compared to undisturbed (41%).



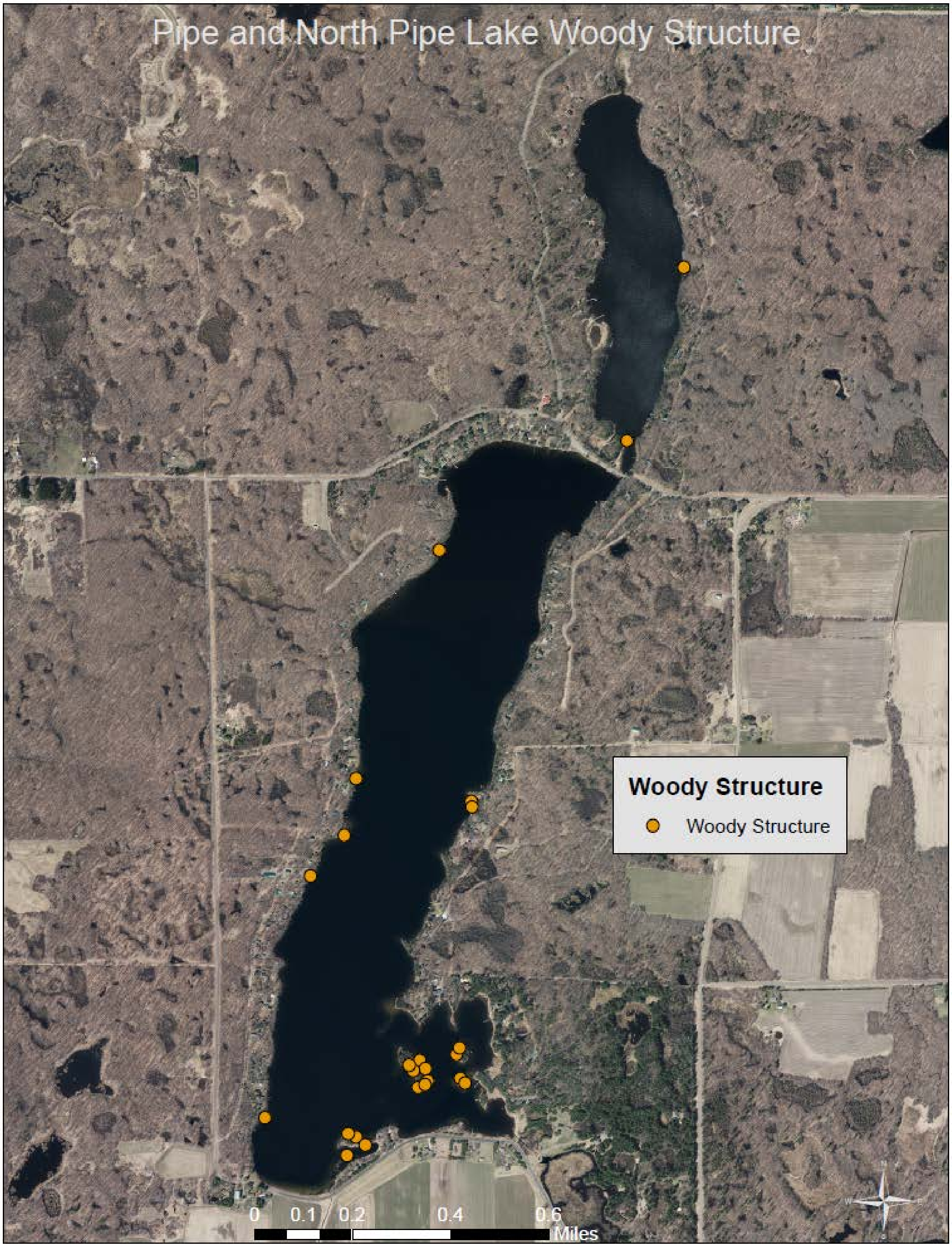
The dominant shoreland vegetation and ground cover on Pipe Lake was organic-leaf pack/needles (37%) and mowed vegetation (36%), followed by short un-mowed vegetation (26%). On North Pipe Lake, the dominant shoreland vegetation and ground cover was organic-leaf pack/needles (92%). Less of the shoreline was mowed vegetation (6%) and short un-mowed vegetation (2%).



The shoreline inventory also characterized disturbances around Pipe and North Pipe Lake. Pipe Lake had much more shoreline alterations than North Pipe Lake. On Pipe Lake there were a total of one hundred and sixty docks, thirteen docks with decks, seven boat houses, four sheds, three decks, three stairs, two boat cut outs, and one boat landing. Additionally, there were fifty seven segments of riprap totaling 4,245 feet, nineteen artificial beaches totaling 932 feet, one segment of rock totaling 20 feet, and two swimming areas totaling 215 feet. These disturbed segments make up 17% of the total shoreline on Pipe Lake. On North Pipe Lake there were a total of thirty-six docks, four docks with decks, and one artificial beach. Additionally, there was one fifty foot segment containing riprap.

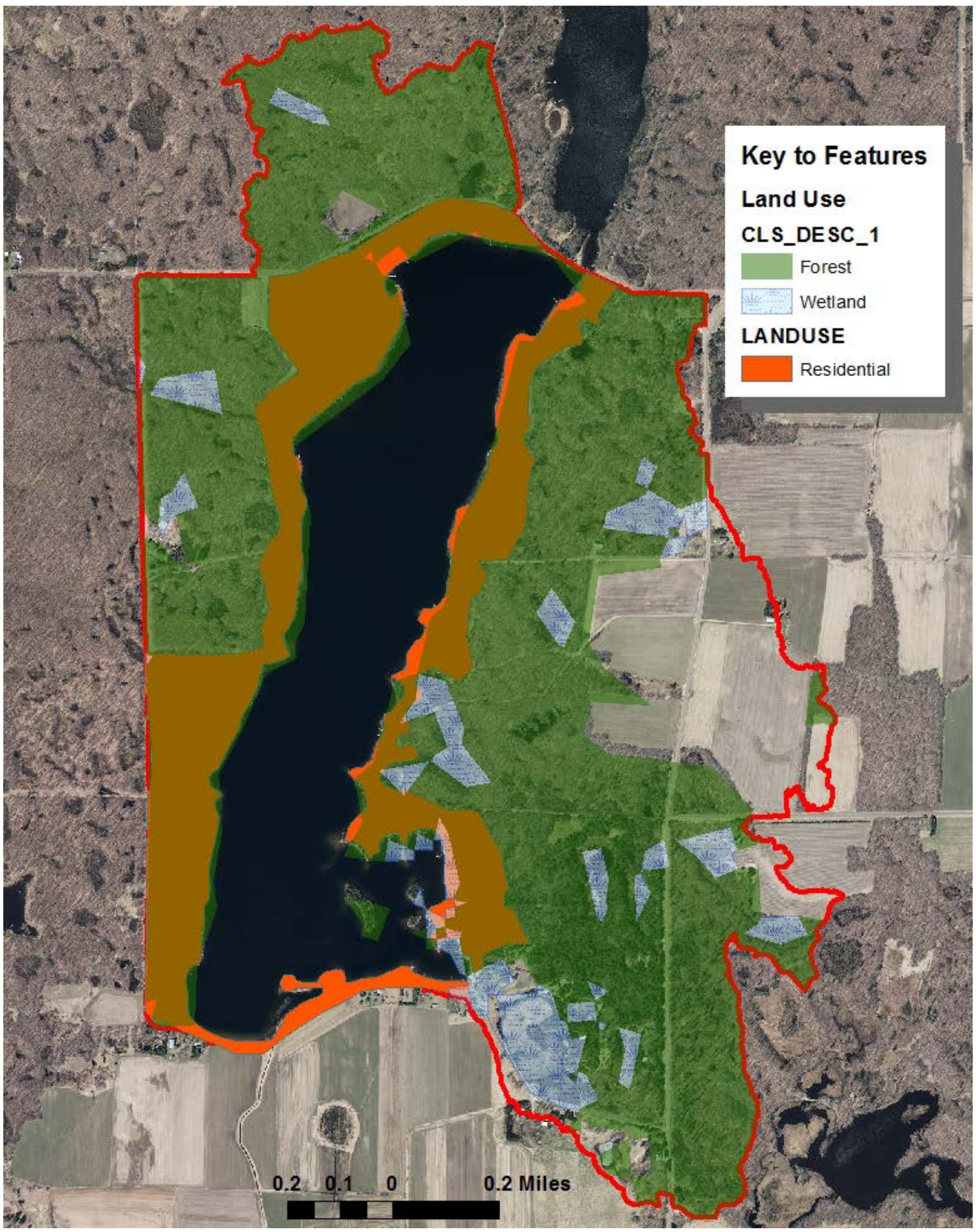


There were twenty-two areas along the shoreline of Pipe Lake and two areas along the shoreline of North Pipe Lake that include coarse woody structure. These areas provide important benefits for fish and wildlife.



Areas Providing Water Quality Benefits to Pipe and North Pipe Lake

Natural areas such as forests, grasslands, 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. In the Pipe Lake watershed 41% of the land use is forest and 6% is wetland. In the North Pipe Lake watershed, 68% of the land use is forest and 8% is wetland.



Land Use in the Pipe and North Pipe Lakes Watershed

The area of land that drains to a lake is called a watershed. Land use in the Pipe and North Pipe Lake watershed was delineated using WISLAND 2 satellite derived data and aerial photos from 2014. The Wisconsin Lakes Modeling Suite (WiLMS) was used to model historic and current conditions for Pipe and North Pipe Lake, 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.

The most common land use in the Pipe Lake watershed is forest (41%), followed by residential (16%), row crop (8%), wetland (6%), and pasture/grass (2%). The largest contributor of phosphorus to Pipe Lake based on land use is row crop (28%), followed by forest (12%), residential (5%), pasture/grass (2%), and wetlands (2%). Modeling predicts that atmospheric deposition (precipitation to the lake's surface) contributes 22% of the phosphorus load, septic contributes 15% of the load, and North Pipe Lake contributes 14% of the load.

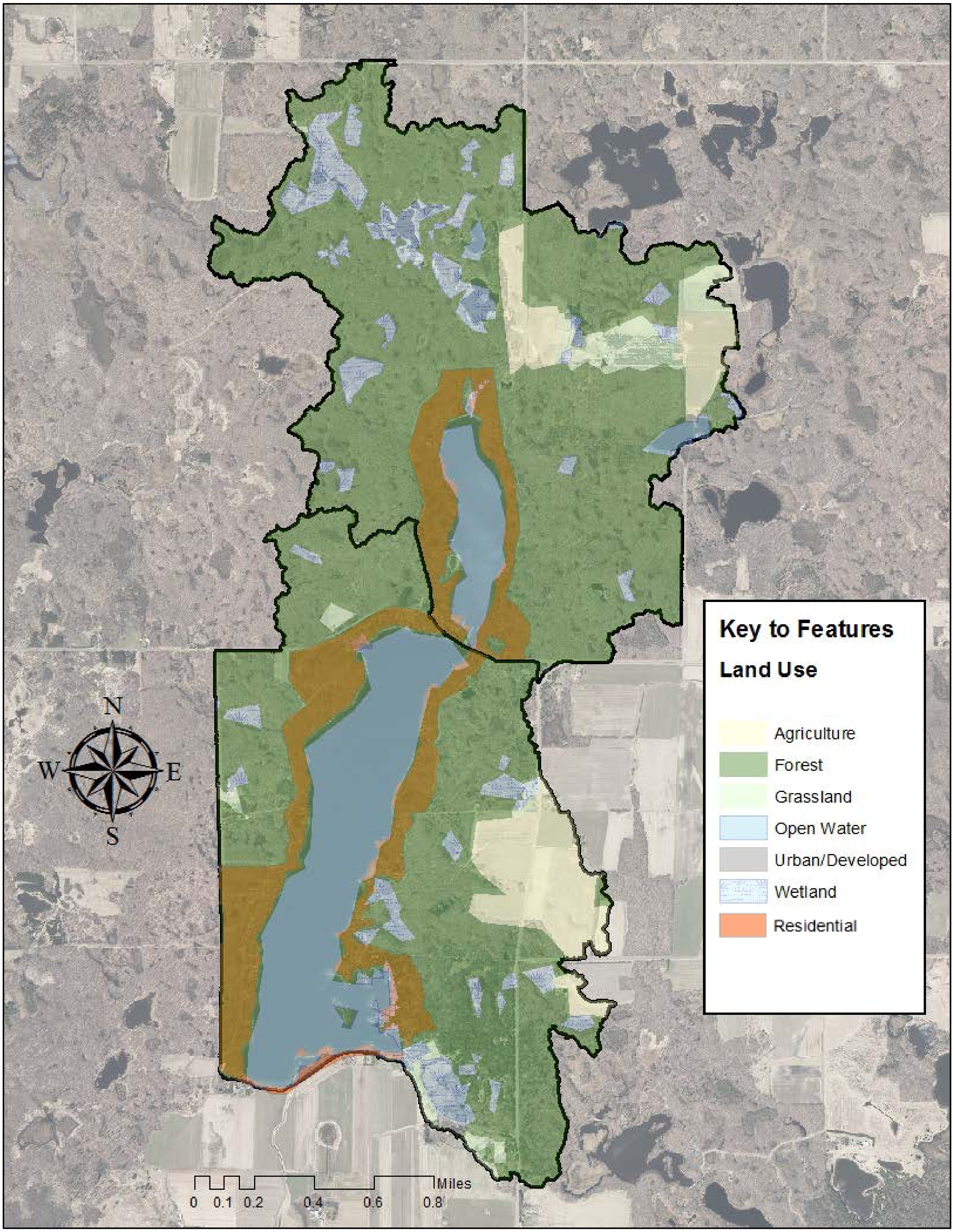
Pipe Lake Land Use and Nutrient Loading

Source	Acres	% Land Use	Loading (lbs/year)	% Load
Row Crop	112	8	99	28
Pasture/Grass	21	2	7	2
Residential	216	16	20	5
Wetland	76	6	7	2
Forest	549	41	44	12
Atmospheric Deposition (lake surface)	293	22	79	22
North Pipe Lake	64	5	50	14
Septic		NA	53	15

The most common land use in the North Pipe Lake watershed is forest (68%), followed by residential (10%), wetland (8%), row crop (5%), and pasture/grass (4%). The largest contributors of phosphorus to North Pipe Lake based on land use were forest (37%) and row crop (32%), followed by residential (6%), pasture/grass (6%), and wetlands (5%). Modeling predicts that atmospheric deposition (precipitation to the lake's surface) contributes 10% of the phosphorus load and septic contributes 4% of the load.

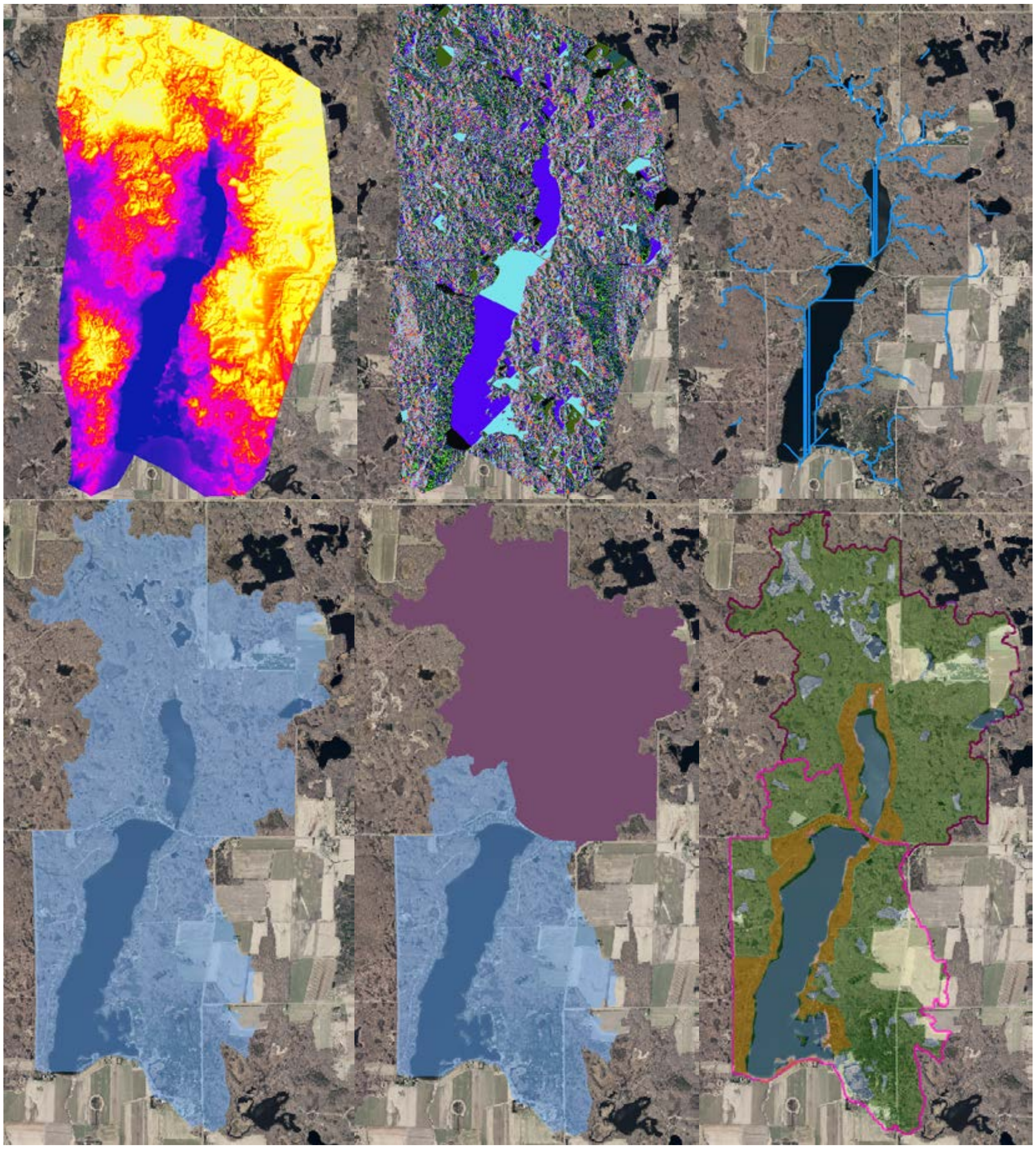
North Pipe Lake Land Use and Nutrient Loading

Source	Acres	% Land Use	Loading (lbs/year)	% Load
Row Crop	67	5	60	32
Pasture/Grass	45	4	11	6
Residential	131	10	11	6
Wetland	105	8	9	5
Forest	860	68	68	37
Atmospheric Deposition (lake surface)	64	5	18	10
Septic	NA	NA	7	4


Key to Features
Land Use
Agriculture
Forest
Grassland
Open Water
Urban/Developed
Wetland
Residential
N
S
W
E
0 0.1 0.2 0.4 0.6 0.8
Miles

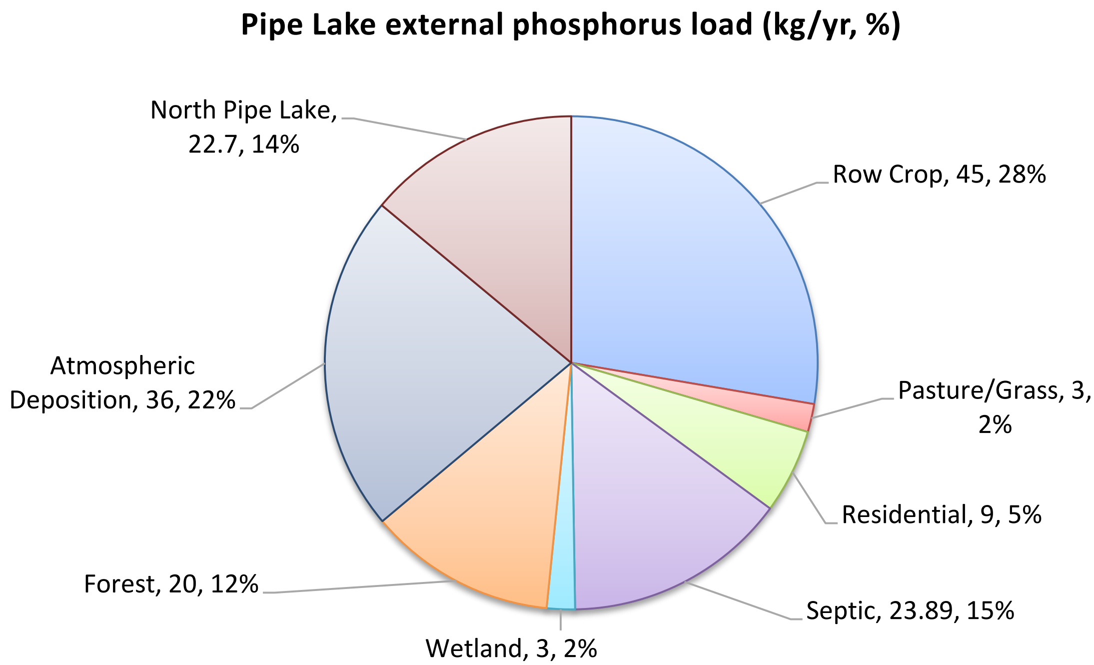
Watershed and In-Lake Modeling

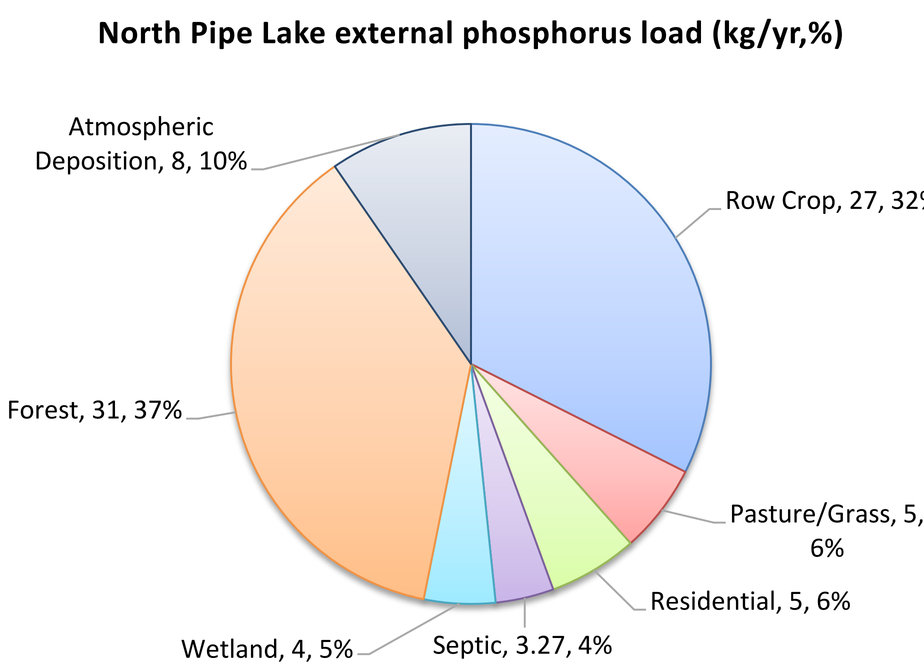
In order to delineate the watersheds for Pipe and North Pipe Lakes, the ArcGIS Spatial Analyst Toolbox was used to manipulate LiDAR data and satellite derived land cover to model the hydrological conditions and flow patterns entering Pipe and North Pipe Lakes. The Wisconsin Lake Modeling Suite (WiLMS) was then used to model current conditions for Pipe and North Pipe Lakes, verify monitoring, and estimate land use nutrient loading for the watersheds. Phosphorus is the key parameter in the modeling scenarios used in WiLMS because it is the limiting nutrient for algal growth in most lakes.



Watershed modeling can be used to estimate the external (or land based) inputs of phosphorus to a lake and the internal (or lake based) sediment inputs of phosphorus to a lake. However, because models can only make estimates, the outputs from modeling scenarios need to be compared with actual in-lake water quality data.

Based on average evaporation, precipitation, and runoff coefficients for Polk County soils and land use, WiLMS determined the annual nonpoint source load of phosphorus to Pipe and North Pipe Lakes under several scenarios for each year of the study and the combined data for both years. WiLMS determined the annual external source load of phosphorus to North Pipe Lake as 83.3 kilograms per year. WiLMS determined the annual external source load of phosphorus to Pipe Lake as 162.59 kilograms per year. Additional scenarios can be read in Appendix G.





Pipe Lake external phosphorus	
Source	**Load kg/yr**
Row Crop	45
Pasture/Grass	3
Residential	9
Septic	23.89
Wetland	3
Forest	20
Atmospheric Deposition	36
North Pipe Lake	22.7

North Pipe Lake external phosphorus	
Source	**Load kg/yr**
Row Crop	27
Pasture/Grass	5
Residential	5
Septic	3.27
Wetland	4
Forest	31
Atmospheric Deposition	8

The internal load for Pipe and North Pipe Lakes was estimated using *in-situ* data. Four methods were used to estimate internal loading under different scenarios over the study period.

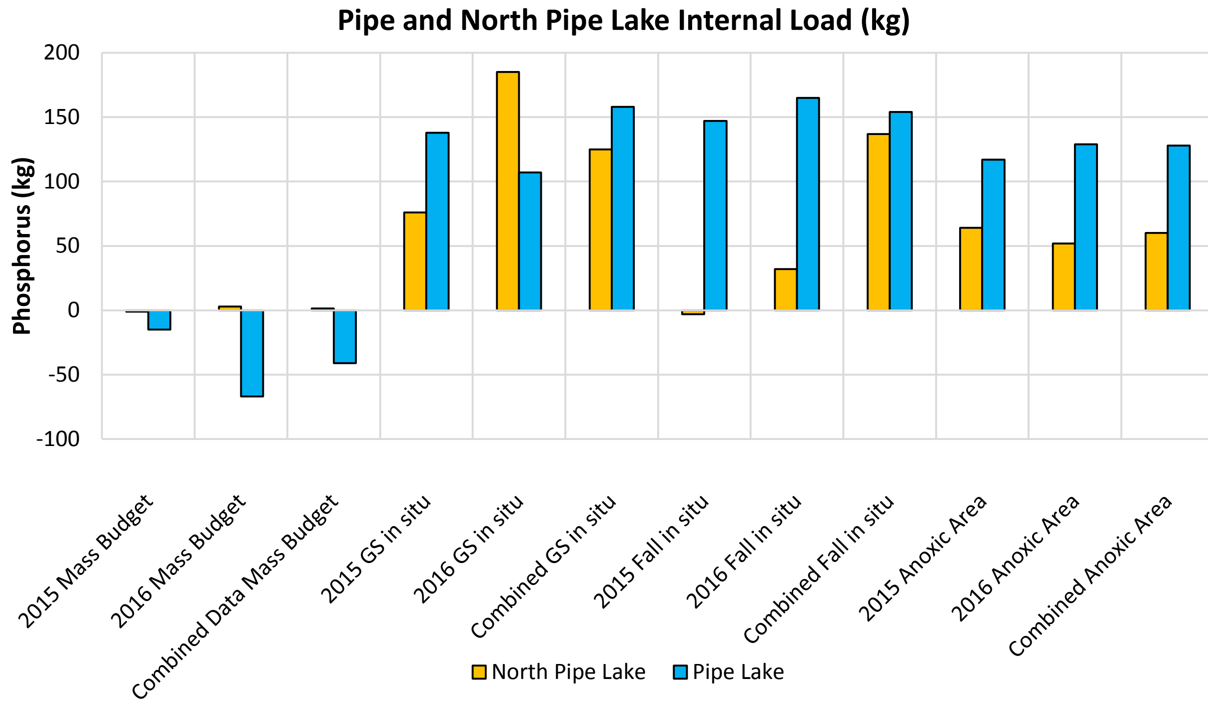
The first method was a complete total phosphorus mass budget. Using this method, the internal load in North Pipe Lake varied from -1 kg phosphorus per year to 3 kg phosphorus per year. In Pipe Lake it estimated to be between -15 kg phosphorus per year to -67 kg phosphorus per year. This modeling method estimated that Pipe Lake is burying phosphorus in the sediment.

In the second method the internal load was estimated from growing season *in situ* phosphorus increases. This method predicted the internal load to be between 76 kg phosphorus per year to 185 kg phosphorus per year in North Pipe Lake. In Pipe Lake it was modeled to be between 107 kg phosphorus per year to 158 kg phosphorus per year.

The third method estimated the internal load from *in situ* phosphorus increases in the fall. Utilizing this method, the internal load for North Pipe Lake was estimated to be between -3 kg phosphorus per year to 137 kg phosphorus per year. The scenarios on Pipe Lake were between 147 kg phosphorus per year to 165 kg phosphorus per year.

The fourth method used the average of the calculated phosphorus release rates (1.7-51.6 mg/m^2-day in North Pipe Lake, 10.7-14.8 mg/m^2-day in Pipe Lake) and anoxic sediment area. Employing this method, the internal load was predicted to be between 52 kg phosphorus per year to 64 kg phosphorus per year in North Pipe Lake and 117 kg phosphorus per year to 129 kg phosphorus per year in Pipe Lake.

Overall, the internal load is predicted to be significant and is likely a controlling factor in both the nutrient and phytoplankton dynamics of North Pipe Lake. While controlling the internal load can be a difficult endeavor and cost prohibitive it could be a useful way to improve the water quality of North Pipe Lake. Pipe Lake stratifies so strongly that it is likely not a major component of the nutrient budget during the growing season.



Since the internal load of phosphorus is calculated to be a significant portion of the total phosphorus entering North Pipe Lake, nutrient budgets need to be recalculated. This was done using several different internal loading scenarios. A modified version of the Nürnberg total phosphorus model is in agreement with this conclusion. The Nürnberg model is as follows:

$P = \frac{L_{Ext}}{q_s}(1 - R) + \frac{L_{Int}}{q_s}$; where

$R = \frac{15}{18+q_s}$,

P = the predicted mixed lake total phosphorus concentration;

L_{ext} = external loading;

L_{int} = internal loading;

qs = areal water loading or surface overflow rate; and

z = the lakes mean depth.

The Osgood Lake Mixing Index was used to predict how often the lake mixes. The Osgood Lake Mixing Index is as follows:

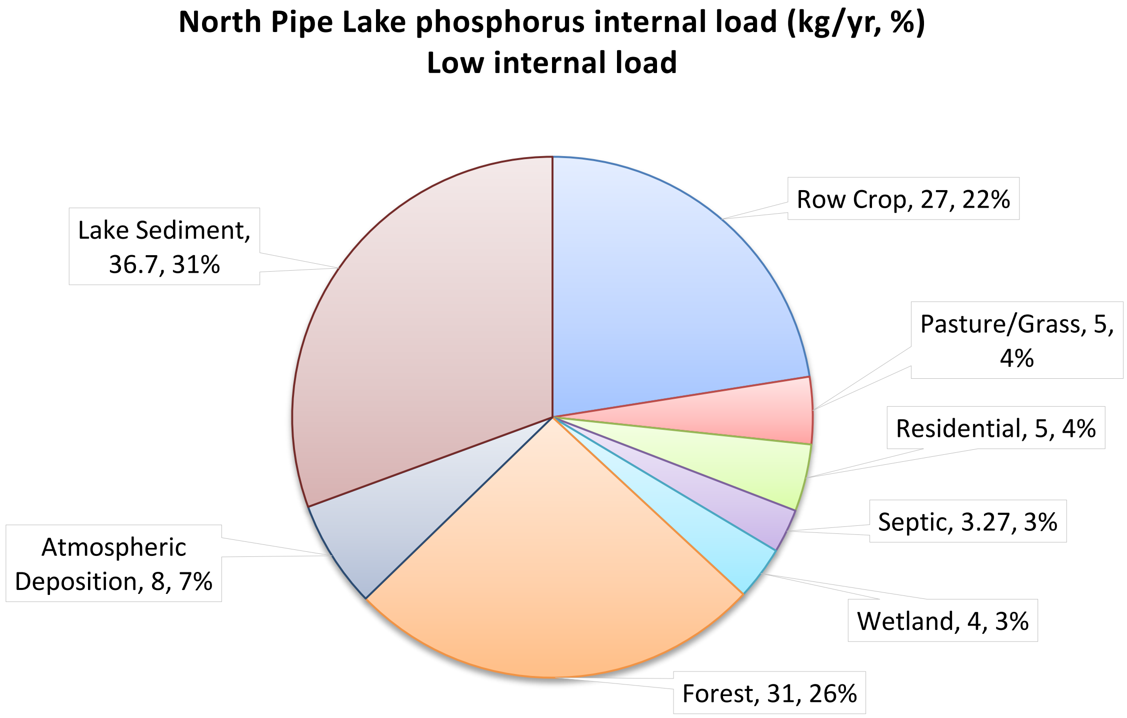
$(OI = z/\sqrt{km^2})$; where

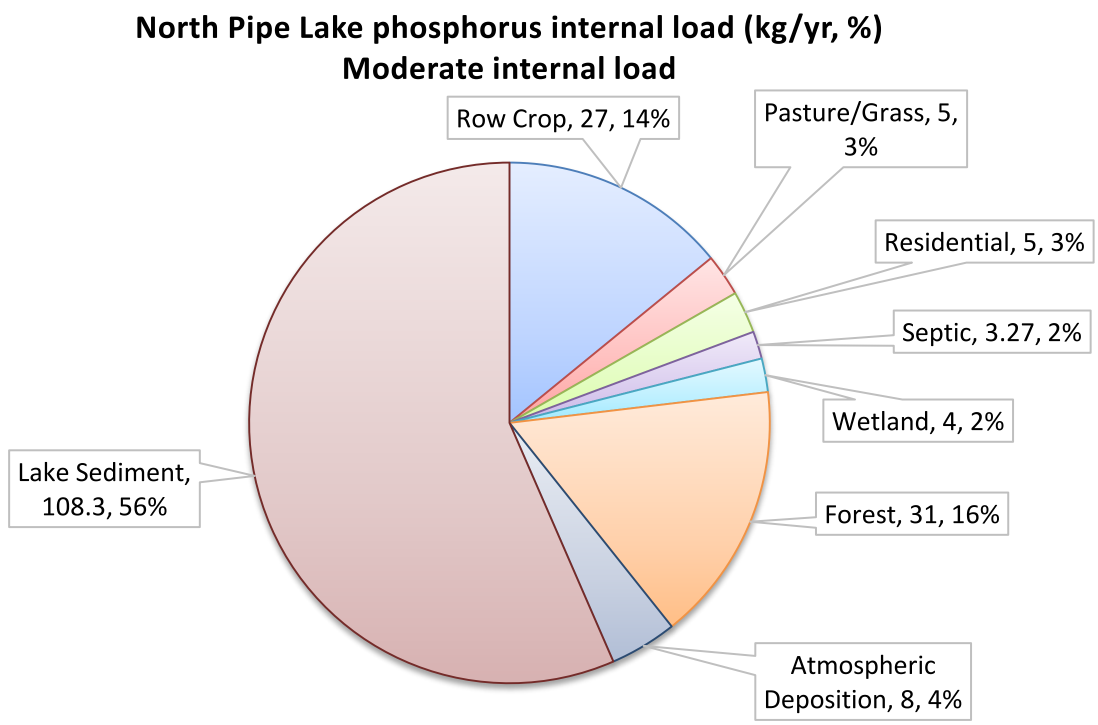
z = the lake mean depth; and

km = kilometers of lake surface area.

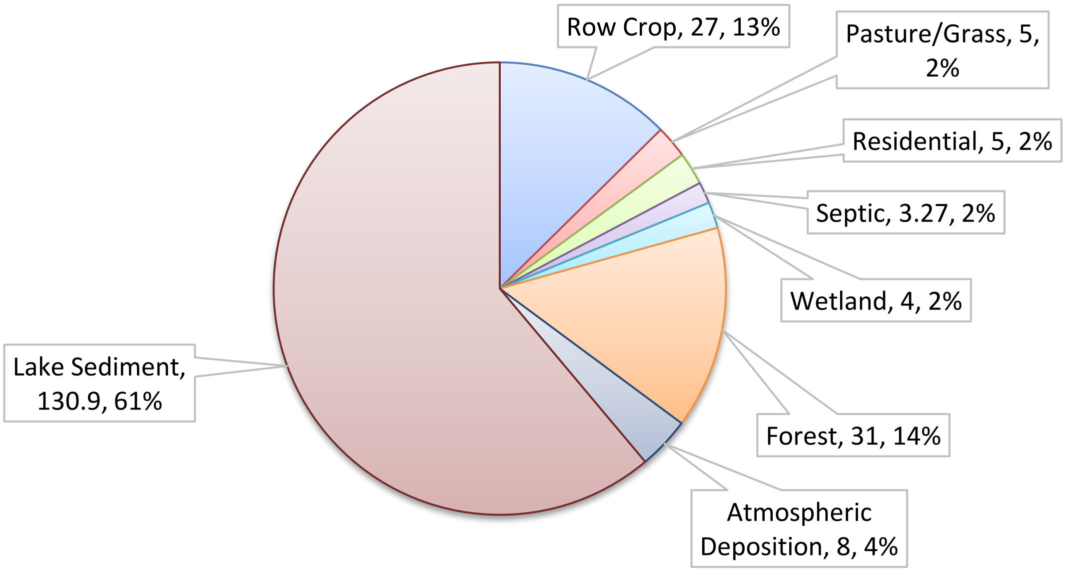
This index predicts that North Pipe Lake has moderate sediment/water interactions.

The nutrient budget for North Pipe Lake was recalculated using a low, moderate, elevated and high internal loading scenario. Even with a low estimated internal load, the sediment contributes a significant amount of phosphorus to the water column.





North Pipe Lake phosphorus internal load (kg/yr, %)
High Internal Loading



The data generated from the different scenarios can be used to model the likely phosphorus content of a lake's water column using a phosphorus back calculation:

$$P_{inflow} = P_{in-lake} \div \frac{FR}{6+FR}$$

where the sedimentation rates are calculated as:
P = predicted mixed lake total phosphorus concentration;
FR $=$ the reciprocal of the retention time; and
6 = sedimentation rate (calculated as $6 = \sqrt{FR}$ in case 1 and cacluated as $6 = 10 \div z$ in case 2)

The data was used to select the 1977 Reckhow Oxic Lake Model:

$$P = \frac{L}{(18z/10+z)+1.05(z/T_w)e^{0.012z/T_w}}$$; where

z < 50 m/yr for both lakes;
L = areal load;
Tw = lake hydraulic retention time; and
z = lake mean depth

These calculations were used to estimate the total phosphorus content of the water column under many different scenarios.

The first North Pipe Lake modeling scenario used land use phosphorus coefficients and did not take into account the calculated internal load. In this scenario, the 1977 Reckhow Oxic Lake Model (where z < 50 m/yr) calculated the total phosphorus concentration as 29.8 µg/L for North Pipe Lake. This is reasonable as the lake average phosphorus value was 27.6 µg/L over this study period and 31.1 µg/L since 2000. However, there can be intense interaction at the sediment water interface, especially in lakes with a mean depth under 11 meters, so other scenarios were computed.

In the second scenario, an internal load of 47.22 mg/m^2 of lake surface area internal loading rate was applied in addition to land use phosphorus coefficients. In this scenario the model predicted the mixed lake water column phosphorus concentration to be 34.39 µg/L phosphorus. North Pipe Lake experiences concentrations this high often in August. Although this is not as high a rate as the internal load estimates in WiLMS, it does provide some evidence that internal loading could be important during certain times of the year and more frequent mixing events occur as the thermocline erodes.

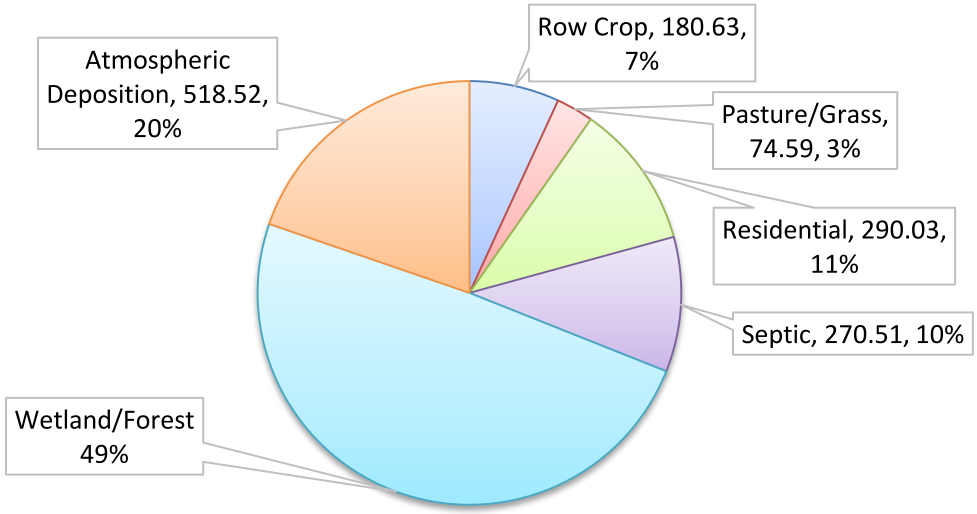
For Pipe Lake, the model calculated the water column phosphorus concentration to be 13.52 µg/L with no internal loading. This is very close to the mean of 12.7 µg/L phosphorus in sampling years 2015 and 2016. Modeling additional scenarios with internal loading as a component was not completed for Pipe Lake. Pipe Lake is a heavily stratified lake and research has shown that lakes such as Pipe Lake can actually lose water column phosphorus due to precipitation of organic matter through the thermocline.

Lakes are generally considered to be phosphorus limited, while nitrogen is considered a secondary limiting nutrient. However, large amounts of data seem to contradict this and instead indicate that most lakes are co-limited.[19] Recent analysis of nitrogen in lakes can argue for increased attention for control of nitrogen sources along with further reductions in phosphorus sources to counteract the negative impacts on human health, biodiversity, and water quality. [20] In the case of North Pipe Lake, nitrogen seems to explain lake productivity better than phosphorus while Pipe Lake appears to be co-limited, which is further explained in the algae section of the report.

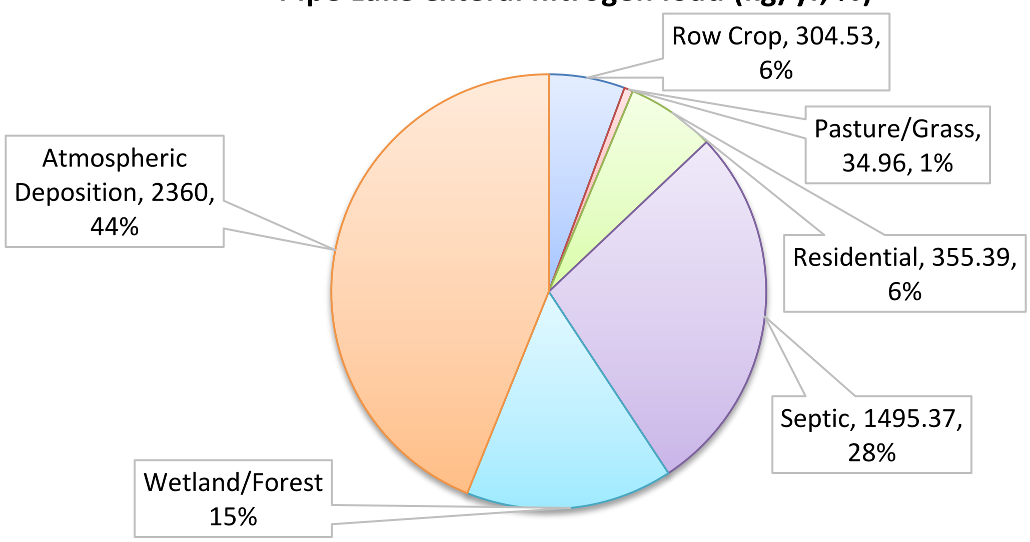
The data recovered from the GIS database used to model water and phosphorus loading was also used to model nitrogen loading using mean total nitrogen export coefficients [21] and statistical algorithms for nitrogen leeching losses. [22] Estimates of atmospheric deposition of nitrogen were obtained from the National Atmospheric Deposition Program (NADP, wet nitrate deposition) and the Clean Air Status and Trends Network (CASTNET, dry nitrate deposition).

[19] Sterner, R. W. 2008. On the Phosphorus Limitation Paradigm for Lakes. Internat. Rev. Hydrobiol. 93:433-445
[20] Finlay, J.C. et al. 2013. Human influences on nitrogen removal in lakes. Science 342:247
[21] Clesceri, N.L et al. 1986. Nutrient loads to Wisconsin lakes: Part I. Nitrogen and phosphorus export coefficients. Water Resources Bulletin 22:983-989
[22] Mulla, D.J. et al. 2013. D4. Nonpoint Source Nitrogen Loading, Sources, and Pathways for Minnesota Surface Waters. Minnesota Pollution Control Agency. 65pp

North Pipe Lake exteral nitrogen load (kg/yr, %)



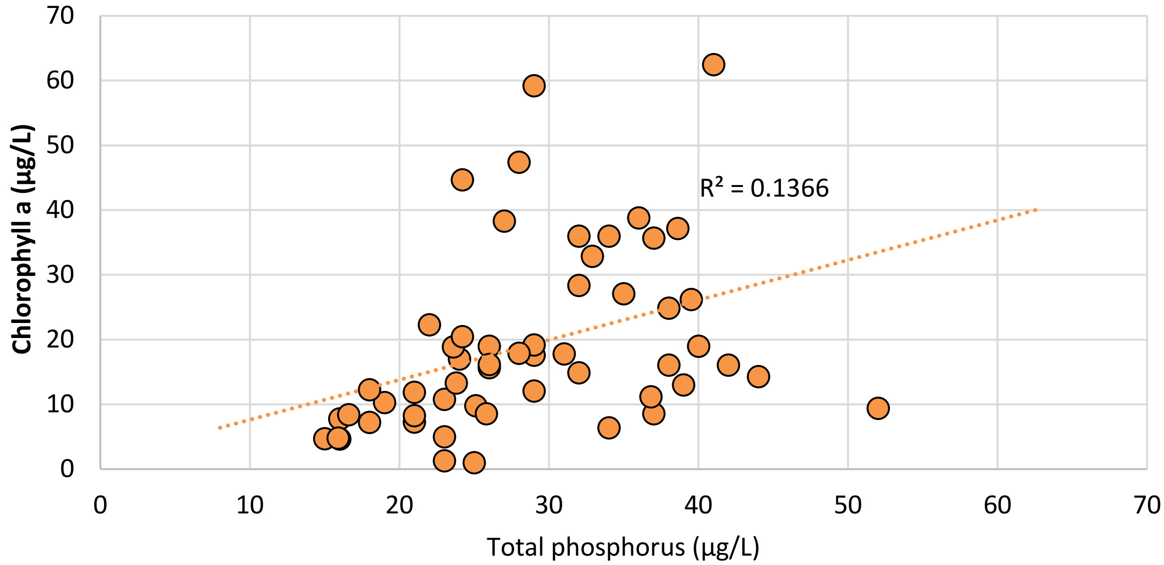
Pipe Lake exteral nitrogen load (kg/yr, %)



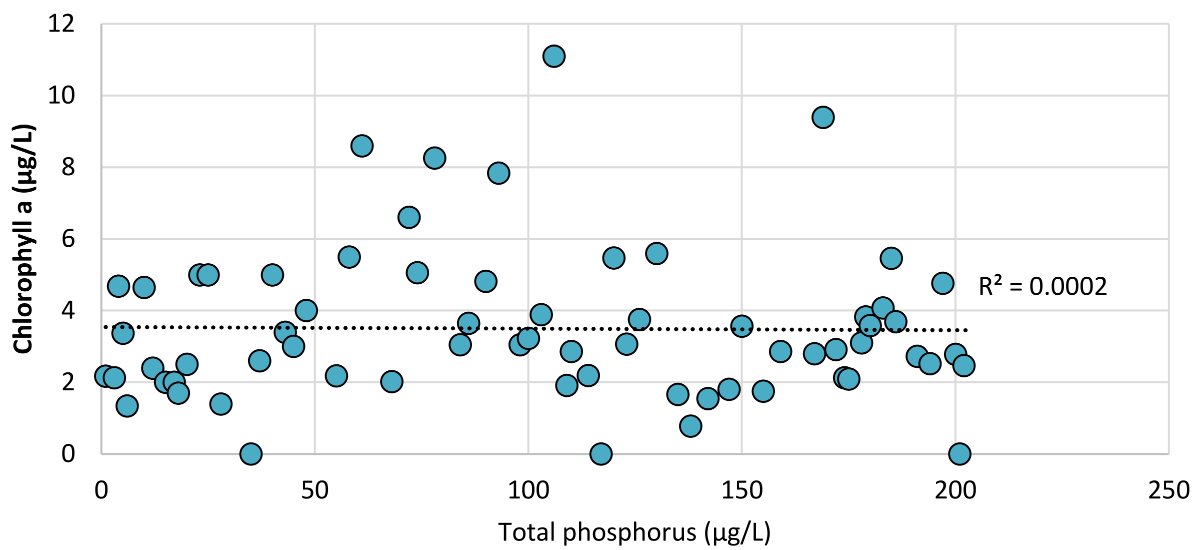
Nitrogen is a more volatile nutrient than phosphorus and different land cover and land uses affect nitrogen flux much differently than phosphorus. Additional study of nitrogen dynamics in both lakes is warranted as well as studies on the influence of septic systems, especially on Pipe Lake.

Chlorophyll a and total primary productivity were also modeled to assess the biological response of phytoplankton based on nutrient loading relationships because pelagic chlorophyll a is usually closely related to phosphorus concentrations in the water column. In Pipe Lake the water column phosphorus concentration accounts for only 0.02% of the variability in the concentration of chlorophyll a, while in North Pipe Lake it accounts for about 14%. These correlations are quite low compared to other Polk County lakes.

North Pipe Lake total phosphorus versus chlorophyll a, 1994-2016



Pipe Lake total phosphorus versus chlorophyll a, 1994-2016



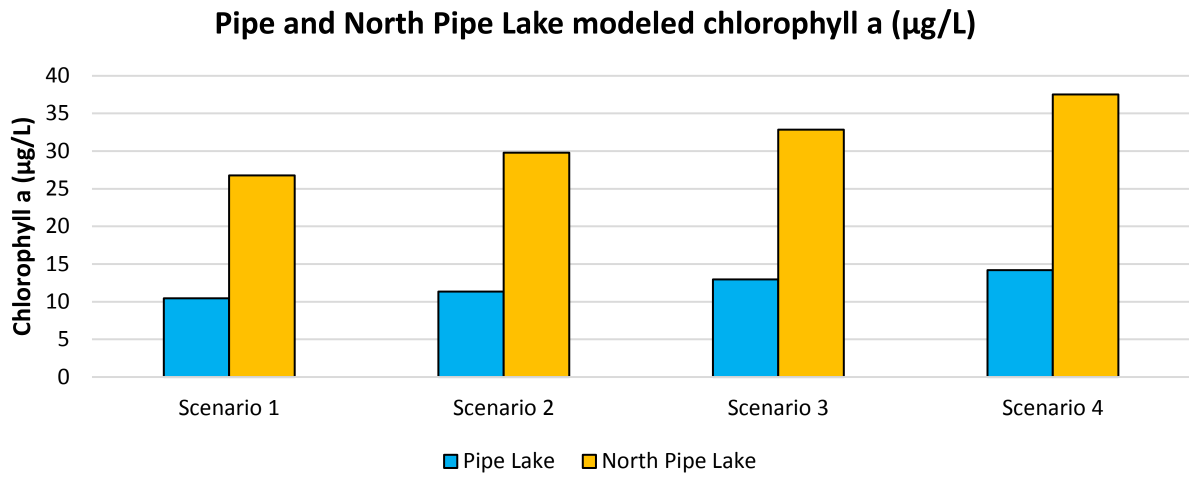
The chlorophyll a concentration was modeled based on the above scenarios using the equation:

$[chl.\mathrm{a}] = 0.55\{[P]_i/(1+\sqrt{T_w})\}^{0.76}$ where;

$[P]_i$ = incoming phosphorus to the lake; and

T_w = lake hydraulic retention time.

The average *in situ* chlorophyll a was at or well below modeled values in both lakes.

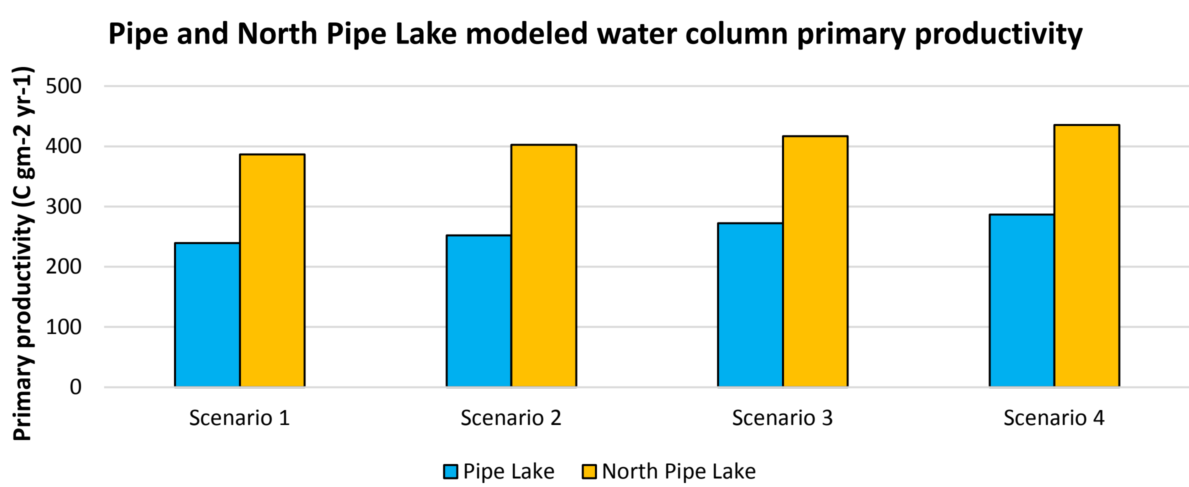


The annual rate of primary productivity of algae has also been related to the predicted phosphorus concentrations modeled for Pipe and North Pipe Lakes. The nonlinearity of the data results from the light-reducing, self-shading effects of dense algae populations. This well-known relationship can be represented by:

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

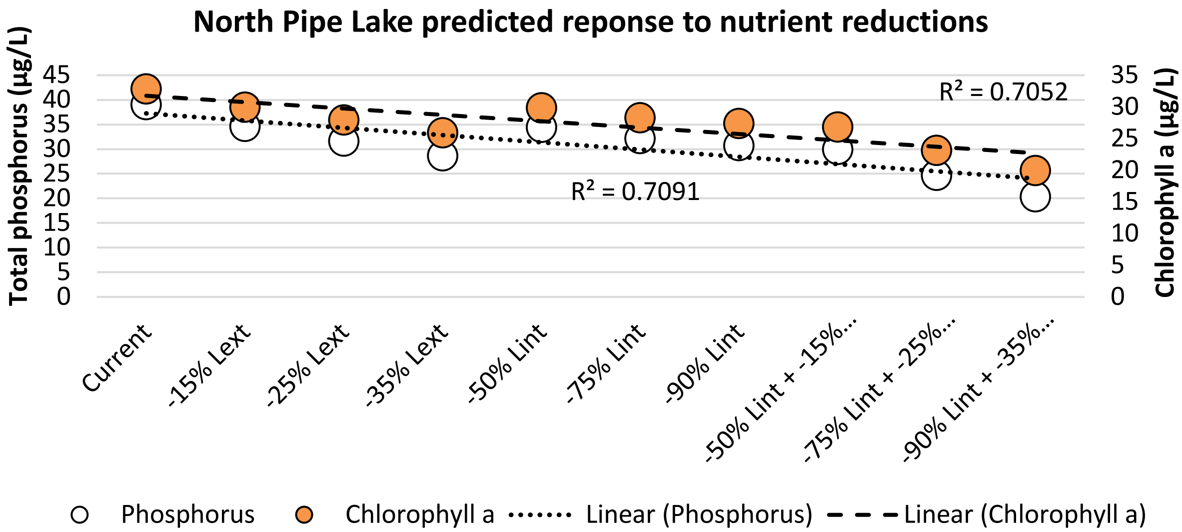
c = carbon;
$[P]_i$= incoming phosphorus to the lake; and
T_w = lake hydraulic retention time.

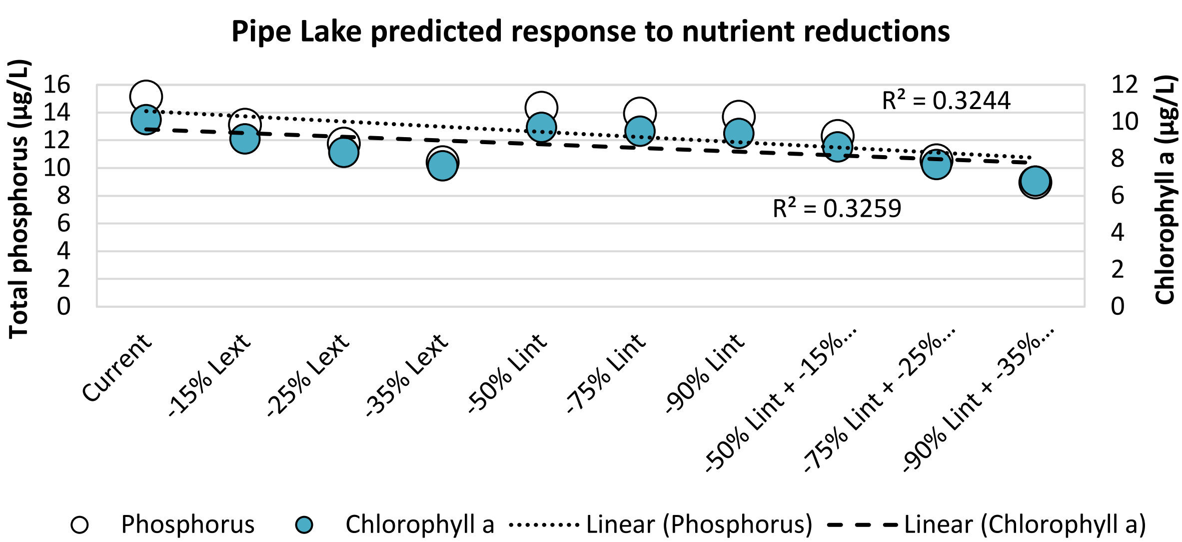
The relationship operates similarly to that of daily photosynthesis and is based on average chlorophyll a concentrations and light extinction due to turbidity, dissolved organic substances, and re-suspended sediment.



Models can be used to predict many different scenarios and can be useful to guide management decisions. The Reckhow Oxic Lake Model where z < 50 m/year model was used to predict both lakes response to nutrient reductions.

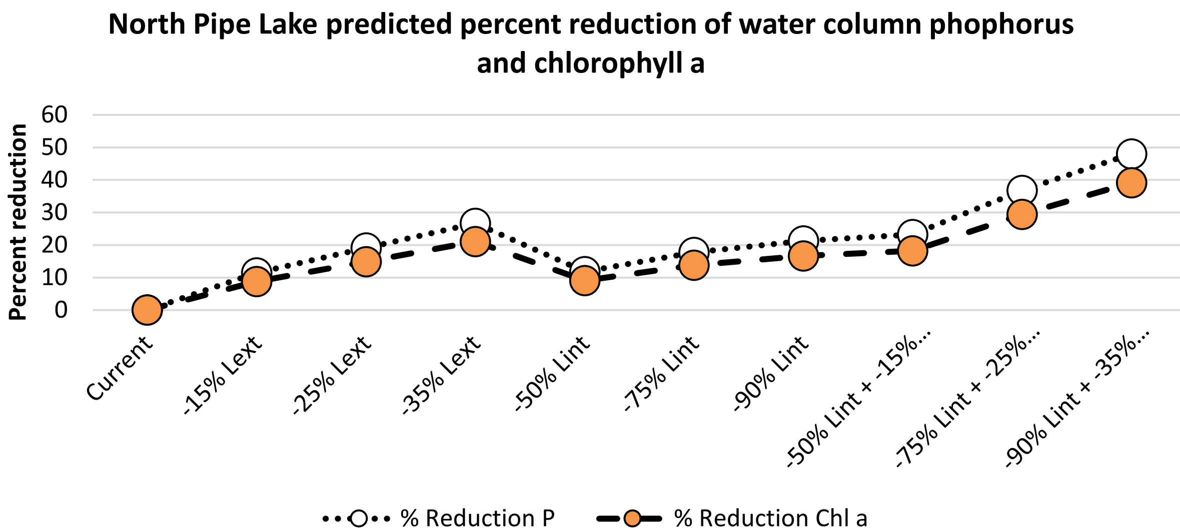
The lakes were modeled under current conditions and a 50%, 75%, and 90% reduction in internal loading. Moreover, additional external reductions were made of 15%, 25%, and 35%. There is a very strong linear correlation in the lake's chemical and biological response with R^2 values of 0.324 and 0.709 for phosphorus and 0.326 and 0.705 for chlorophyll a, respectively.

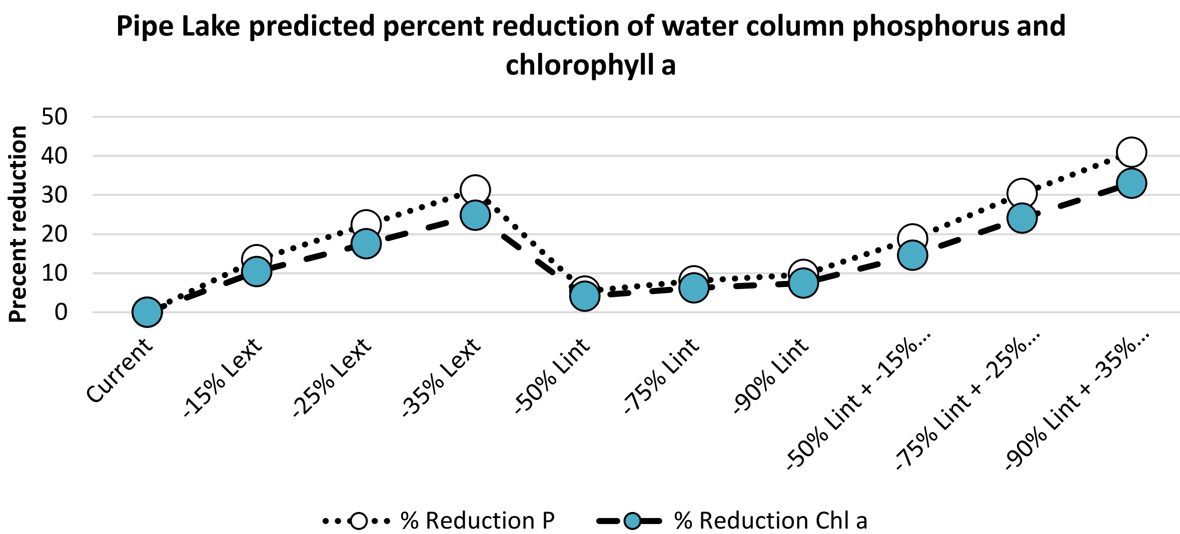




The modeling suggests that a reduction in the internal load would change the biological and chemical properties of the lakes water. Additional reductions on the land have a rather large impact on the water properties once a 25% watershed reduction is met.

When the data is plotted as a percent reduction in the concentration of phosphorus and chlorophyll a, it is easy to see that 15 % external load and a 50% reduction of the internal load would elicit a significant response in the algal community of North Pipe Lake. Pipe Lake demonstrated colossal reductions as a percent as the nutrient levels in the lake are already so low.

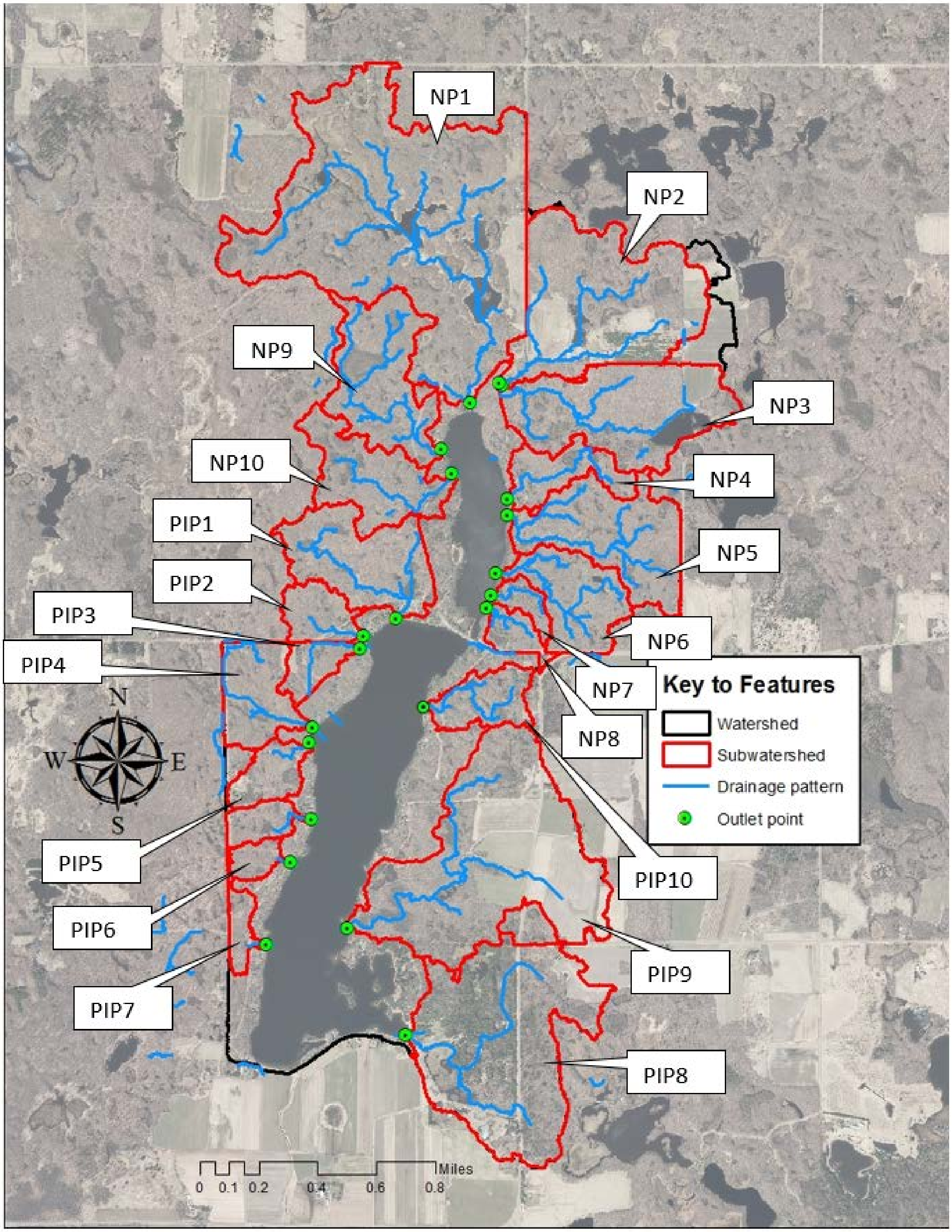




An enhanced understanding of North Pipe Lake's internal load would make management decisions easier and help the Protection and Rehabilitation District better manage funds for management activities. It is recommended that an internal load assessment be done for the lake in shallow areas. Since Pipe Lake has very low nutrient levels and a low watershed to lake ratio, shoreline practices, such as restoration, could make a significant impact on water quality and habitat. These practices are highly recommended and are well documented in academic literature.

Subwatersheds

In order to delineate the subwatersheds for Pipe and North Pipe Lakes, the ArcGIS Spatial Analyst Toolbox was used to manipulate LiDAR data. Hydrological conditions and flow patterns entering Pipe and North Pipe Lakes were modeled at a finer scale than the initial watershed modeling.



The drainage patterns indicate many areas of concentrated flow on both Pipe and North Pipe Lake that can be assessed and attended to as needed.

NP1 drains a complex of wetlands that drains to the lake. The wetlands should provide denitrifying conditions and limit the amount of nitrogen coming from this subwatershed.

Subwatershed NP2 (which contains a majority of the agricultural land use in the watershed), drains to the sediment pond that was constructed by the District, essentially eliminating agricultural inputs to North Pipe Lake. This fact warrants additional study of the nutrient inputs from the lake's sediment as part of the nutrient budget. NP3 joins at the outlet of NP2, but appears to be effectively filtered as it enters a wetland on the north end of the lake.

NP4-NP10 appear to have very defined channels draining to the lake, particularly NP5, NP6, NP9, and NP10. Channelized flow should be monitored in order to reduce erosion and sediment deposition to the lake.

PIP1 and PIP2 do not appear to have defined channels entering the lake. Native vegetation would be a suitable practice to reduce nutrient inputs from these subwatersheds.

PIP3-PIP10 do have defined channels, however, most of the channels are derived from low-lying areas and shoreland restoration would likely be a better solution for nutrient and sediment reductions on Pipe Lake from these subwatersheds.

Summary of Rules and Legislation

Comprehensive Land Use Planning

The Polk County Comprehensive Land Use Plan was adopted in 2009 and 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 plan is to provide general guidance to achieve the desired future development of the county and direction for development decisions. Lakes classification outlines restrictions on development according to lake features.

Plan information is online at:
http://www.co.polk.wi.us <Departments < Land Information < Comprehensive Plan

Town, City and Village Comprehensive Plans are online at:
http://www.co.polk.wi.us < Departments < Land Information < Comprehensive Plan < City, Village, and Town Comprehensive Plans

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

On September 15th, 2015, Polk County adopted a new zoning ordinance, including the comprehensive zoning ordinance and the shoreland zoning ordinance. These rules were rewritten for several reasons, including a newly adopted comprehensive plan for the county and newly adopted changes to the State of Wisconsin's administrative rule on shorelands (NR 115). The Polk County Comprehensive Land Use Ordinance applies to the unincorporated portions of the county where the towns adopted the ordinance. The Polk County Shoreland

Zoning Ordinance applies to all areas within 1000 feet of a lake, pond or flowage and within 300 feet from rivers or streams. Zoning of shorelands is required by the State of Wisconsin and covers impervious surface limits and setbacks from surface waters.

The ordinance is online at:
http://www.co.polk.wi.us < Departments < Land Information < Ordinances (Zoning)

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 online at:
http://www.co.polk.wi.us < Departments < Land Information < Ordinances (Zoning)

Animal Waste

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. Revisions of the Polk County Manure and Water Quality Management Ordinance began in 2016. The ordinance was reviewed by Corporation Counsel and WDNR. Publication of the ordinance and a public hearing took place in April 2017. The ordinance was brought to the Polk County Board for review in May 2017 and adoption in June 2017. Generally, the ordinance is a little less restrictive than the past ordinance. The ordinance regulates manure piles and manure storage.

The ordinance is online at:
http://www.co.polk.wi.us < Departments < Land & Water Resources < Ordinances.

Storm Water and Erosion Control

This 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.

The ordinance is online at:
http://www.co.polk.wi.us < Departments < Land & Water Resources < Ordinances.

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 animals are attached.

The ordinance is online at:
http://www.co.polk.wi.us < Departments < Land & Water Resources < Ordinances.

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 best management practices, 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: implementing information and education strategies, writing nutrient management plans, providing technical assistance to landowners and lakeshore owners, performing lake studies, collaborating with other agencies, working on a rivers classification system, setting up demonstration sites of proper BMP's, controlling invasive species, and revising ordinances to offer better protection of resources.

WI Agricultural Performance Standards (NR 151)

For farmers who grow agricultural crops

- ✓ Meet tolerable soil loss on cropped fields
- ✓ 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
- ✓ 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

Implementation Plan Development

Lake management plans help protect natural resource systems by encouraging partnerships between concerned citizens, lakeshore residents, watershed residents, agency staff, and diverse organizations. They 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 vision statement, guiding principles, and lake management plan goals presented below were created through collaborative efforts using current and past water quality data, a 2016 sociological survey regarding the needs of Pipe and North Pipe Lake Protection and Rehabilitation District residents, a series of three meetings by the Pipe and North Pipe Lake Management Plan Committee, and a meeting of the Pipe and North Pipe Lake Management Plan Technical Committee. Key study details were presented at Pipe and North Pipe Lake Protection and Rehabilitation District Annual Meetings over the course of the project. Additionally, the draft vision statement, guiding principles, and lake management plan goals were presented and opened up for comment at the 2017 District Annual Meeting.

The draft plan was posted on the Polk County Land and Water Resources Department website and opened for a 30 day public comment period ending on January 14th, 2018. A notice of public comment was published in the Cumberland Advocate on December 6th, 2017 and December 13th, 2017. No public comments were received. The plan was approved by the Pipe and North Pipe Lake Protection and Rehabilitation District on November 18th, 2017 and by the Wisconsin Department of Natural Resources in April 2018.

Implementation Plan

VISION an overall statement for what you want Pipe and North Pipe Lake to look like

Pipe and North Pipe Lake are clear lakes, free of nuisance algae blooms and aquatic invasive species, and supporting a diversity of wildlife and human uses.

GUIDING PRINCIPLE provides guidance on how the lake management plan will be implemented

Lake management decisions are driven by what is best for the lakes according to the inherent capabilities of the lakes and to past, present, and future data

An understanding of data drives technically supported lake management decisions and practices

Pipe and North Pipe Lakes residents are: engaged in actions to protect and improve the lakes, participate in implementing the lake management plan, and understand that lake management requires funding

Communication with lake users and homeowners regarding lake management should be easy to understand, concise, and frequent

Goal 1. Reduce nutrient loading to Pipe and North Pipe Lake to where water quality is at least maintained for Pipe Lake, improves for North Pipe Lake, and algae growth decreases in both lakes

North Pipe Lake is on the impaired waters list for an unknown pollutant with the impairment of excess algal growth. Chlorophyll a will be managed to remove North Pipe Lake from the Impaired Waters List.

Although most activities apply to both Pipe and North Pipe Lakes (unless otherwise stated), the primary focus for reducing nutrient loading on Pipe Lake is shoreline best management practices such as native planting, diversions, rock infiltration, and rain gardens. On North Pipe Lake, the primary focus is to determine the internal load on the lake and, if necessary, focus efforts on addressing internal sources of phosphorus. North Pipe Lake would also benefit from additional nitrogen sampling to better understand nitrogen as a source of nutrient loading.

A. Install 5 best practices per year (native plantings, diversion, rock infiltration, or rain gardens) to reduce phosphorus loads from the residential land use around Pipe and North Pipe Lake using the Healthy Lakes Grant program
   1. Provide information to homeowners regarding each practice and how it relates to improved water quality and decreased algae growth
   2. Identify both new and long term homeowners interested in installing best practices
   3. Target efforts using the results of the 2016 shoreline inventory
   4. Develop a program to offer incentives for shoreline practices that maintain and expand undeveloped areas along the shoreline
   5. Apply for and implement a Healthy Lakes Grant application
   6. Highlight best practices as demonstration projects either on individual properties or at the public access
   7. Install WDNR signs at Healthy Lakes project sites

B. Determine if septic systems are significantly impacting the lakes
   1. Provide landowners current septic system regulations and information
   2. Conduct an analysis to determine/identify areas of high septic load to the lakes (begin with conductivity readings to guide placement of mini piezometers)
   3. Compare areas with high septic loads with septic system inspection records to identify landowners who may require updated inspections
   4. Research grant opportunities to fund an incentive program to address high septic loads

C. Maintain the sediment pond on North Pipe Lake
    1. Visually inspect the inflow and outflow of the sediment pond at least annually
    2. Ensure that vegetation is maintained on the berm of the sediment pond
    3. Visually inspect and record any new invasive species present at the pond site
    4. Remove new invasive species (reed canary grass/cattail removal may not be feasible)
    5. Hire a contractor if maintenance is needed (i.e. fills in with sediment)

D. Continue to be mindful of the relationship between agricultural lands and water clarity and provide support as needed
    1. Meet once a year with the Polk County Land and Water Resources Department to review the current state of nutrient management plans in the watershed and identify recommended actions

Goal 2. Prevent the introduction of new invasive species and eradicate newly introduced invasive species

A. Ensure that lake residents and users understand the steps necessary to prevent invasive species
    1. Continue a successful Clean Boats, Clean Water monitoring and education program at the boat landing using volunteers and/or paid inspectors
    2. Continue participation in additional WDNR statewide programs including the Landing Blitz and Drain Campaign
    3. Ensure that signage at the boat landings is in place each year and updated as necessary
    4. Distribute brochures and the waterproof Pipe and North Pipe Lake map with aquatic invasive species information
    5. Work with the Polk County Sheriff's Department to encourage enforcement of the Do Not Transport Ordinance

B. Implement an annual monitoring program to quickly identify the introduction of new invasive species
    1. Contract with professionals to implement a monitoring program for aquatic invasive species at the boat landing and areas of likely introduction
    2. Contract with professionals to monitor the entire shoreline of Pipe and North Pipe Lake for aquatic invasive species
    3. Attend the Polk County Citizen Lake Monitoring Network Training for invasive species which trains volunteers to identify and monitor for aquatic invasive species
    4. Provide interested lake residents with the skills needed to identify aquatic invasive species of concern
    5. Review and update the Pipe and North Pipe Lakes rapid response plan

Goal 3. Increase knowledge of key issues affecting water quality as a means to increase stakeholder participation in District activities and actions by individuals

A. Develop a marketing effort to increase knowledge and participation
    1. Identify key knowledge that needs to be communicated to stakeholders
        i. Topics include: basic lake science, identification of aquatic invasive species of concern, impacts of septic systems on water quality, shoreline best management practices to improve water quality, and lake etiquette/safety
    2. Identify new methods to increase lake management/understanding
B. Develop a welcome package to communicate information to new property owners
    1. Determine a method to identify new property owners in a timely manner
C. Develop a well-defined and active communication system

Goal 4. Maintain and enhance the natural scenic beauty of Pipe and North Pipe Lake

A. Maintain and expand undeveloped areas along the shoreline and within the lake watershed
    1. Promote native plantings and no-mow areas to lake residents
    2. Identify undeveloped, highly erodible, and/or ecologically sensitive land
    3. Determine the feasibility of purchasing undeveloped, highly erodible, and/or ecologically sensitive land
    4. Prepare a Healthy Lakes Grant application and/or develop an incentive program to increase shoreline plantings

B. Maintain and expand in-lake habitat for wildlife
    1. Post signs to promote slow no wake within 100 feet of the shoreline
    2. Provide information on current fish stick locations and benefits
    3. Promote fish sticks to lake residents as a method to improve fish habitat
    4. Prepare a Healthy Lakes Grant application to increase fish sticks

C. Engage residents and users in promoting a healthy lake lifestyle
    1. Provide information and education on boater safety and regulations
    2. Provide information and education on loon nesting sites to minimize boater conflicts

Goal 5. Sustain the implementation of the plan and evaluate the progress of lake management efforts through monitoring and modeling

A. Implement a plan to ensure that goals are met
    1. Form committees to develop an action plan for each goal
    2. Action plans are reported to the commission and distilled for dissemination

B. Annually review and document plan implementation progress
    1. Document actions completed, in progress, or not completed within the timeline
    2. Determine remedial steps to move towards completing goals as forecasted
    3. Identify current and future barriers to implement the plan
    4. Report progress to Lake District members

C. Continue current data collection efforts
    1. Ensure that Citizen Lake Monitoring Network Volunteer is in place each year to collect phosphorus, chlorophyll, and secchi disk data
    2. Conduct spring and summer aquatic plant point intercept surveys
    3. Collect water samples to determine the effectiveness of the sediment basin on North Pipe Lake
    4. Collect stream samples during spring snowmelt and following heavy rainfall events

D. Expand data collection efforts depending on needs
    1. Repeat the 2015-2016 water quality study in five to ten years
    2. Collect a sediment core on Pipe Lake
    3. Implement a study to determine nutrient input from septic systems and holding tanks
    4. Add nitrogen and algae sampling to citizen monitoring efforts
    5. Implement a study to determine the hydraulic load from North Pipe to Pipe Lake
    6. Implement shallow water monitoring to determine areas of high internal loading on North Pipe Lake
    7. Determine if the thermocline is eroding on North Pipe Lake

E. Determine if North Pipe Lake is impaired
    1. Initiate a dialogue with WDNR to determine if future studies are needed to provide clarity on impairment status and if site specific nutrient criteria can be developed

F. Determine ecological and water quality changes on Pipe Lake

Acronyms used for partners in the following implementation table
WDNR = Wisconsin Department of Natural Resources
LWRD = Polk County Land and Water Resources Department
PLD = Pipe and North Pipe Lakes Protection and Rehabilitation District
CON = Consultant

Acronyms used for funding sources in the following implementation table
LPL = WDNR Lake Planning Grant Program
LPR = WDNR Lake Protection Grant Program
LPR-HL = WDNR Healthy Lakes Grant Program
AEPP = WDNR Aquatic Invasive Species Grant Program

GOAL 1. REDUCE NUTRIENT LOADING TO PIPE AND NORTH PIPE LAKE TO WHERE WATER QUALITY IS AT LEAST MAINTAINED FOR PIPE LAKE, IMPROVES FOR NORTH PIPE LAKE, AND ALGAE GROWTH DECREASES IN BOTH LAKES	TIMELINE	$ ESTIMATE	VOLUNTEER HOURS	PARTNERS	FUNDING SOURCES
A. Install 5 best practices per year (native plantings, diversion, rock infiltration, or rain gardens) to reduce phosphorus loads from the residential land use around Pipe and North Pipe Lake using the Healthy Lakes Grant program—**Healthy Lakes Committee**	**Priority**	Grant:$1,000/ practice; 33% match			LPR-HL
1. Provide information to homeowners regarding each practice and how it relates to improved water quality and decreased algae growth			5 hrs/ article		
2. Identify both new and long term homeowners interested in installing best practices					
3. Target efforts using the results of the 2016 shoreline inventory					
4. Develop a program to offer incentives for shoreline practices that maintain and expand undeveloped areas along the shoreline					
5. Apply for and implement a Healthy Lakes Grant application			80 hrs		
6. Highlight best practices as demonstration projects either on individual properties or at the public access					
7. Install WDNR signs at Healthy Lakes project sites					
B. Determine if septic systems are significantly impacting the lakes—**Commission**	**Priority**				
1. Provide landowners current septic system regulations and information			5 hrs		
2. Conduct an analysis to determine/identify areas of high septic load to the lakes (begin with conductivity readings to guide placement of mini piezometers)			24 hrs		LPL
3. Compare areas with high septic loads with septic system inspection records to identify landowners who may require updated inspections			10 hrs		
4. Research grant opportunities to fund an incentive program to address high septic loads					
C. Maintain the sediment pond on North Pipe Lake—**Water Quality Committee**	**Priority**				
1. Visually inspect the inflow and outflow of the sediment pond at least annually			2 hrs/yr		
2. Ensure that vegetation is maintained on the berm of the sediment pond			2 hrs/yr		
3. Visually inspect and record any new invasive species present at the pond site			2 hrs/yr		AEPP
4. Remove new invasive species (reed canary grass/cattail removal may not be feasible)			15 hrs/yr		AEPP
5. Hire a contractor if maintenance is needed (i.e. fills in with sediment)				CON	
D. Continue to be mindful of the relationship between agricultural lands and water clarity and provide support as needed—**Commission**					
1. Meet with LWRD to review the current state of nutrient management plans in the watershed and identify recommended actions	Annually			LWRD	

GOAL 2. PREVENT THE INTRODUCTION OF NEW INVASIVE SPECIES AND ERADICATE NEWLY INTRODUCED INVASIVE SPECIES	TIMELINE	$ ESTIMATE	VOLUNTEER HOURS	PARTNERS	FUNDING SOURCES
A. Ensure that lake residents and users understand the steps necessary to prevent invasive species—**Commission Chair**	**Priority**				
1. Continue a successful Clean Boats, Clean Water monitoring and education program at the boat landing using volunteers and/or paid inspectors			2 hrs/wk	LWRD	AEPP
2. Continue participation in additional WDNR statewide programs including the Landing Blitz and Drain Campaign			5 hrs/yr	LWRD	AEPP
3. Ensure that signage at the boat landings is in place each year and updated as necessary			1 hr/yr	LWRD	AEPP
4. Distribute brochures and the waterproof Pipe and North Pipe Lake map with aquatic invasive species information			5 hrs/yr		AEPP
5. Work with the Polk County Sheriff's Department to encourage enforcement of the Do Not Transport Ordinance					AEPP
B. Implement an annual monitoring program to quickly identify the introduction of new invasive species—**Commission Chair**	**Priority**				
1. Contract with professionals to implement a monitoring program for aquatic invasive species at the boat landing and areas of likely introduction	Monthly, 5-6 times		2 hrs/yr	CON	AEPP
2. Contract with professionals to monitor the entire shoreline of Pipe and North Pipe Lake for aquatic invasive species	Once per year		2 hrs/yr	CON	AEPP
3. Attend the Polk County Citizen Lake Monitoring Network Training for invasive species which trains volunteers to identify and monitor for aquatic invasive species	Spring, yearly		4 hrs/yr	LWRD	AEPP
4. Provide interested lake residents with the skills needed to identify aquatic invasive species of concern			10 hrs/yr	LWRD	AEPP
5. Review and update the Pipe and North Pipe Lakes rapid response plan	Annually		3 hrs/yr		AEPP

GOAL 3. INCREASE KNOWLEDGE OF KEY ISSUES AFFECTING WATER QUALITY AS A MEANS TO INCREASE STAKEHOLDER PARTICIPATION IN DISTRICT ACTIVITIES AND ACTIONS BY INDIVIDUALS	TIMELINE	$ ESTIMATE	VOLUNTEER HOURS	PARTNERS	FUNDING SOURCES
A. Develop a marketing effort to increase knowledge and participation—**Commission**	**Priority**				
1. Identify key knowledge that needs to be communicated to stakeholders					
Topics include: basic lake science, identification of aquatic invasive species of concern, impacts of septic systems on water quality, shoreline best management practices to improve water quality, and lake etiquette/safety					
2. Identify new methods to increase lake management/understanding					
B. Develop a welcome package to communicate information to new property owners—**Commission**					
1. Determine a method to identify new property owners in a timely manner					
C. Develop a well-defined and active communication system					

GOAL 4. MAINTAIN AND ENHANCE THE NATURAL SCENIC BEAUTY OF PIPE AND NORTH PIPE LAKE	TIMELINE	$ ESTIMATE	VOLUNTEER HOURS	PARTNERS	FUNDING SOURCES
A. Maintain and expand undeveloped areas along the shoreline and within the lake watershed—**Healthy Lakes Committee**	**Priority**				
1. Promote native plantings and no-mow areas to lake residents			2 hr/mo		
2. Determine the feasibility of purchasing undeveloped, highly erodible, and/or ecologically sensitive land					
3. Identify undeveloped, highly erodible, and/or ecologically sensitive land					
4. Prepare a Healthy Lakes Grant application and/or develop an incentive program to increase shoreline plantings			40 hrs		LPR-HL
B. Maintain and expand in-lake habitat for wildlife—**Commission**					
1. Post signs to promote slow no wake within 100 feet of the shoreline	**Priority**				
2. Provide information on current fish stick locations and benefits					
3. Promote fish sticks to lake residents as a method to improve fish habitat					
4. Prepare a Healthy Lakes Grant application to increase fish sticks					LPR-HL
C. Engage residents and users in promoting a healthy lake lifestyle—**Commission**	**Priority**				
1. Provide information and education on boater safety and regulations			5 hrs/yr		
2. Provide information and education on loon nesting sites to minimize boater conflicts			5 hrs/yr		

GOAL 5. SUSTAIN THE IMPLEMENTATION OF THE PLAN AND EVALUATE THE PROGRESS OF LAKE MANAGEMENT EFFORTS THROUGH MONITORING AND MODELING	TIMELINE	$ ESTIMATE	VOLUNTEER HOURS	PARTNERS	FUNDING SOURCES
A. Implement a plan to ensure that goals are met—**Commission Chair**	**Priority**				
1. Form committees to develop an action plan for each goal			2 hrs/yr		
2. Actions plans are reported to the commission and distilled for dissemination			5 hrs/yr		
B. Annually review and document plan implementation progress—**Commission**	**Priority**				
1. Document actions completed, in progress, or not completed within the timeline			15 hrs/yr		
2. Determine remedial steps to move towards completing goals as forecasted			5 hrs/yr		
3. Identify current and future barriers to implement the plan			10 hrs/yr		
4. Report progress to Lake District members			2 hrs/yr		
C. Continue current data collection efforts—**Water Quality Committee**	**Priority**				
1. Ensure that Citizen Lake Monitoring Network Volunteer is in place each year to collect phosphorus, chlorophyll, and secchi disk data			40 hrs/yr	WDNR, PLD	CLMN program
2. Conduct spring and summer aquatic plant point intercept surveys	Every 5 yrs		40 hrs	CON	LPL
3. Collect water samples to determine the effectiveness of the sediment basin on North Pipe Lake			5 hrs/mo	PLD, CON	LPL
4. Collect stream samples during spring snowmelt and following heavy rainfall events			5 hrs/mo	PLD, CON	LPL
D. Expand data collection efforts depending on needs—**Water Quality Committee**	**Priority**				
1. Repeat the 2015-2016 water quality study in five to ten years	2022-2027	Grant: $25,000; 33% match		LWRD, CON	LPL
2. Collect a sediment core on Pipe Lake		$15,000		LWRD, CON	LPL
3. Implement a study to determine nutrient input from septic systems and holding tanks				LWRD, CON	LPL
4. Add nitrogen and algae sampling to Citizen Lake Monitoring Volunteer efforts		Nitrogen $54, Algae $65 + SH	2 hrs/mo	PLD	LPL
5. Implement a study to determine the hydraulic load from North Pipe to Pipe Lake				LWRD, CON	LPL
6. Implement shallow water monitoring to determine areas of high internal loading on North Pipe Lake				CON	
7. Determine if the thermocline is eroding on North Pipe Lake					
E. Determine if North Pipe Lake is impaired—**Commission**					
1. Initiate a dialogue with WDNR to determine if future studies are needed to provide clarity on impairment status and if site specific nutrient criteria can be developed				WDNR, CON, LWRD	
F. Determine ecological and water quality changes on Pipe Lake—**Commission**					