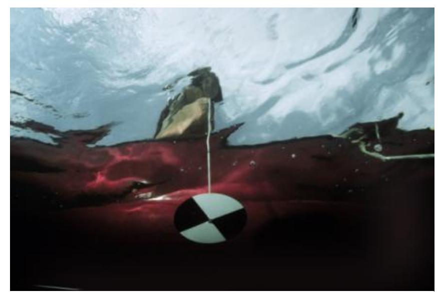
-4-
WATER QUALITY AND ALGAL CONDITIONS

"High quality water is more than the dream of the conservationists, more than a political slogan; high quality water, in the right quantity at the right place at the right time, is essential to health, recreation and economic growth."

-- Edmund S. Muske, U.S. Senator (1966 Senatorial speech)

4-1 INTRODUCTION

Public opinion surveys consistently show that safe water quality and good clarity are top factors contributing to local quality of life and the enjoyment of Lake Ripley.[1] These surveys also reveal a general perception that water clarity averages clear to somewhat cloudy in appearance, with the poorest conditions following large rainfall events and busy motor boating weekends. This chapter reviews the current status and long-term trends related to a host of factors that can be used as measures of water-quality conditions. Primary focus is given to the last 24 years during which regular monitoring has occurred. For an even longer-term perspective, Chapter 9-1 presents the results of sediment-core analyses that were used to reconstruct lake and watershed conditions over the last 260 years.



An underwater view of a Secchi disc being lowered into the lake to measure water clarity. Source: UW-Extension

4-2 LAKE HYDROLOGY AND MORPHOMETRY

Lake Ripley formed during the last glacial period from a kettle depression left behind by the retreating ice sheets. It receives most of its water from the watershed in the form of overland flow and stream drainage. There is both a perennial (unnamed) inlet and outlet that serve to move water through the system. The inlet enters the lake at its southeast corner, and the outlet exits to Koshkonong Creek at its northwest corner. While the outlet is partially obstructed by a rock-rubble spillway, Lake Ripley is not classified as an impoundment or flowage since the "dam" has only a negligible impact on lake depth. Although surface water represents the predominant source of water to the lake, groundwater can contribute as much as 30% of the lake's water supply.[2]

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[1] Lake Ripley Management District. 1999, 2005 and 2007. Lake Ripley Property Owner Opinion Survey.

[2] Wisconsin Department of Natural Resources, Wisconsin Department of Agriculture, Trade and Consumer Protection, Lake Ripley Management District, and Jefferson County Land Conservation Department. 1998. Nonpoint Source Control Plan for the Lake Ripley Priority Lake Project. Wisconsin Nonpoint Source Water Pollution Abatement Program. Publication WT-512-98.

Lake morphometry, or bathymetry, describes a lake's physical characteristics. Lake Ripley's physical characteristics can be described in terms of lake volume (7,561 acre-feet of water), surface area (423 acres), shoreline length (4.1 miles), fetch (1.3 miles), mean depth (18 feet) and maximum depth (44 feet). In terms of surface area, approximately one-third of the lake is less than five feet deep, while about 41% is greater than 20 feet deep. The deepest point occurs near the lake's center, and approximately 1,000 feet from the east shoreline. Although fairly deep at its center, almost half of the lake's surface area lies over water depths of less than 10 feet.

Lake Ripley is somewhat round in shape except for a wide peninsula that divides its southern half into two prominent bays. It consequently has a relatively low shoreline-development factor (SDF), which describes the degree of irregularity in the shape of the shoreline. SDF relates shoreline length to the circumference of a circle with the same area as the lake. A perfectly circular lake would have the lowest SDF of 1.0. As shoreline irregularity increases, so does the SDF that measures the lake's propensity to be impacted by shoreline use. High SDF values may imply greater safety risks and ecological consequences.[3] Reasons include: 1) increased shoreline development per unit of surface area; 2) tighter and more confined recreational spaces; 3) additional shoreline subjected to wake-induced erosion; and 4) greater probability for near-shore, shallow-water depths that are most vulnerable to motor boat impacts.

Lake Ripley's SDF is a relatively low 1.7. However, the lake's modest size, well developed shoreline, and extensive shallow areas tell a different but more complete story. For example, in terms of potential lake-bottom impacts from motorized boat traffic, over one-third of the total lake surface is represented by less than 5-foot water depths. Taken together, these characteristics suggest a greater vulnerability to shoreline-use impacts than what the lake's shape and correspondingly low SDF would otherwise imply. While Lake Ripley is physically capable of accommodating diverse recreational uses at one time, consideration should be given to space, depth and ecological limitations that may affect these uses. Ignoring such limitations will only invite additional user conflict and environmental degradation in the future. A bathymetric map of Lake Ripley is included as Figure 31 below.

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[3] Wagner, Kenneth J. 1991. Assessing Impacts of Motorized Watercraft on Lakes: Issues and Perceptions. Proceedings of a National Conference on Enhancing States' Lake Management Programs. Northeastern Illinois Planning Commission.

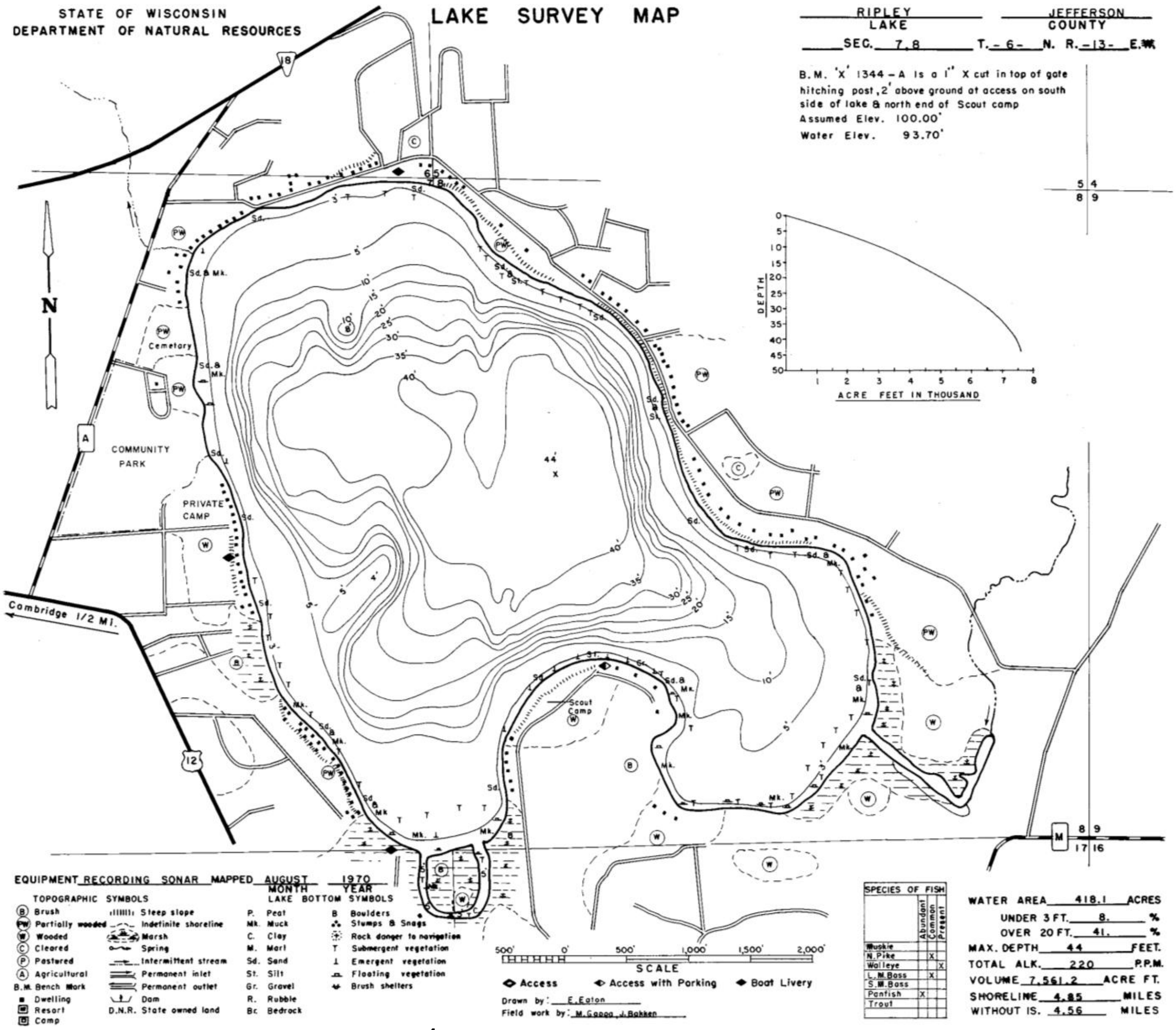

Figure 1: Lake Ripley Bathymetry[4]

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[4] Wisconsin Department of Natural Resources. 1970. Lake Survey Map.

4-3 HYDRAULIC RETENTION TIME AND FLUSHING RATE

Hydraulic retention time is the average length of time water remains in a lake before it is entirely replaced, or recharged, with "new" water. It is calculated by dividing the volume of water passing through the lake per year by the lake volume. Its reciprocal value is the lake's flushing rate, or the number of lake volumes replaced per year by inflow. Retention time is strongly influenced by the size of the lake in relation to its watershed, and how the lake is supplied with water. Rapid water exchange (flushing) rates allow problematic nutrients such as phosphorus to be flushed out of the lake quickly. Lakes with higher flushing rates respond best to management practices that decrease nutrient input, mainly since nutrients cannot accumulate and get constantly recycled with spring and fall mixing. Small drainage lakes with bigger watersheds generally fit this category. With longer retention times, the effects of watershed protection may not be apparent for a number of years. Nevertheless, lakes with long retention times tend to have the best water quality since they are usually deeper with smaller watersheds.

Average retention times range from several days for some small impoundments to many years for large seepage lakes. Residence times of natural lakes commonly range from 1-10 years. Long residence times result in greater nutrient retention and recycling in most lakes. Lake Ripley, as a small drainage lake with modest watershed, has an average retention time of 2.85 years. This estimate was derived from the Wisconsin Lake Modeling Suite (WiLMS) using standard watershed-input variables, and suggests that the lake would best be served by nutrient reduction strategies targeted within the contributing watershed. Chapter 9-2 should be consulted for additional information related to the WiLMS analysis.

4-4 THERMAL PROPERTIES OF WATER COLUMN

Thermal stratification occurs in deep lakes during stable weather conditions when the water column forms horizontal water layers of varying temperatures and densities. As air temperatures rise in the spring, a temperature-density barrier begins to form in deeper water bodies between the warmer, lighter surface water that is heated by solar energy and the underlying denser, colder water. This barrier is marked by a sharp temperature gradient called the thermocline. The zone where the thermocline occurs is known as the metalimnion. It separates the warmer, less dense, upper zone of water called the epilimnion, from the cooler, denser, lower zone called the hypolimnion.

Summer stratification generally occurs in lakes like Lake Ripley where depths are greater than 20 feet. However, depending on their shape, small lakes can stratify even if they are less than 20 feet deep. In larger lakes, the wind may continuously mix the water to a depth of 30 feet or more. Lake Ripley can be viewed as a deep lake in the context of its potential to thermally stratify and resist lake-wide mixing of the water column.

Lakes may also undergo a second stratification period during the winter months. Because water density peaks at 39°F, winter stratification develops with a temperature difference of only 7°F between the top and bottom (39°F on the lake bottom versus 32°F right below the ice). This explains why ice floats and forms at the water's surface. The ice layer at the surface helps maintain stratification by preventing wind from mixing the water column. The ice also helps insulate the water beneath it, which prevents deeper lakes from freezing solid. Larger, deeper lakes with greater water volumes tend to lose and absorb heat more slowly, meaning they are usually the last to freeze and thaw.

The temperature and density of the water column will be fairly consistent from top to bottom in both the early spring and late fall. The uniform water density allows the lake to mix completely, replenishing the bottom water with dissolved oxygen and recycling algae-forming nutrients up to the surface. This destratification process is called spring and fall turnover (or overturn). Due to its morphometric characteristics, Lake Ripley is classified as dimictic, meaning "twice mixing." However, warming can sometimes occur too rapidly in the spring for this lake-wide mixing to be effective, especially in small sheltered kettle lakes. Figure 32 illustrates how temperatures throughout the water column change during each season.

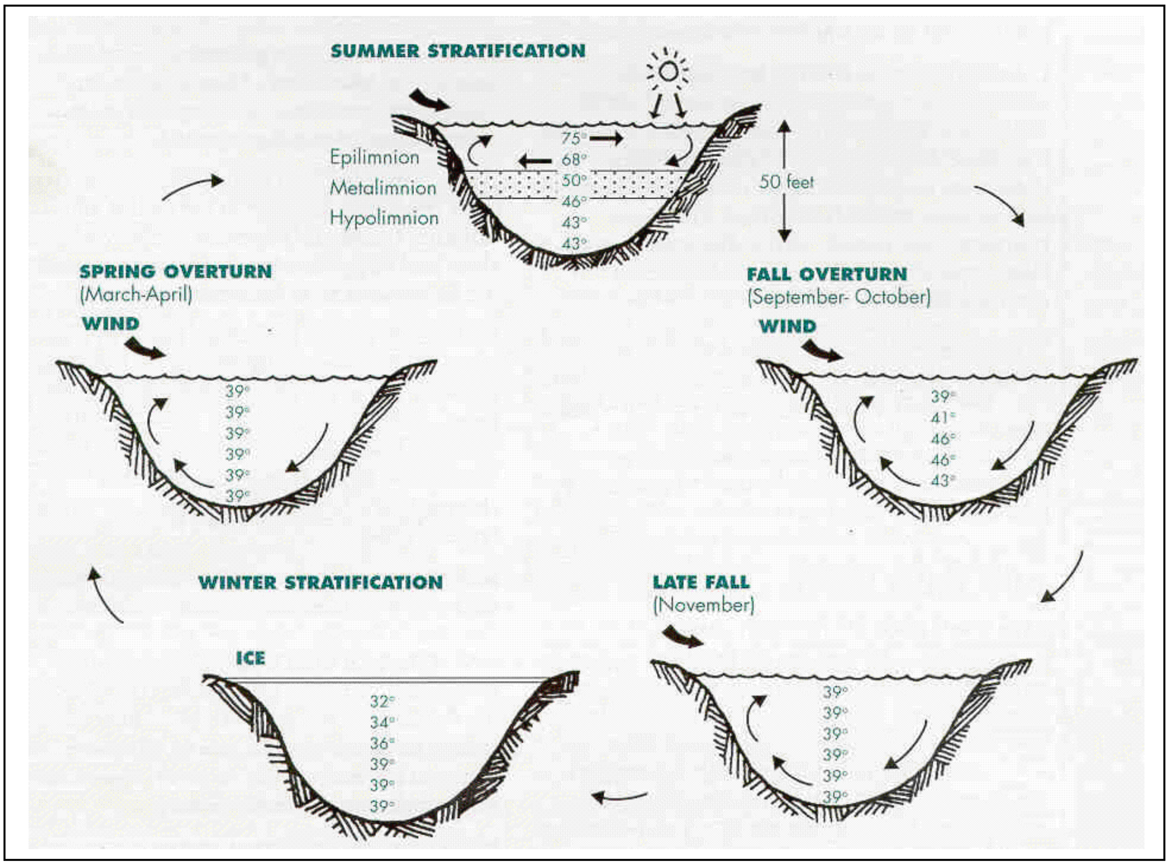

Figure 2: Illustration of Lake Thermal Regime[5]

Lakes that experience strong thermal stratification, like Lake Ripley, are frequently subject to oxygen depletion in the hypolimnion. As algal cells, plant debris and other organic material fall into the hypolimnion to decay, oxygen becomes depleted to the extent that anaerobic conditions

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[5] Shaw, Byron, Mechenich, C. and Klessig, L. 1996. Understanding Lake Data. Publication RP-09-96-3M-275.

may develop. A strong sulfur odor is frequently associated with such waters. This oxygen deficiency can stress a cool water fishery, and may cause the mobilization of phosphorus from nutrient-rich bottom sediment into the overlying water. During turnover, this fertile water gets mixed throughout the water column, creating a situation that favors late-season algal blooms.

4-5 DISSOLVED OXYGEN AND TEMPERATURE PROFILES

Dissolved oxygen is one of the most critical factors affecting lake ecosystems, and is essential to all aquatic organisms that require aerobic conditions to live. The solubility of oxygen is dictated by water temperature. Basically, the colder the water temperature, the more oxygen it is able to hold in solution. Water temperature is also important as it influences the rate of photosynthesis, the metabolic rates of aquatic organisms, and the sensitivity of organisms to toxicity, parasites and disease.

Dissolved oxygen is more abundant in water that is well mixed and in greater contact with the atmosphere. Areas in a lake that support photosynthesis will further enhance dissolved oxygen levels during daylight hours, but could deplete levels during the evening as a result of plant decay and bacterial respiration. This helps explain why oxygen levels fluctuate throughout the water column depending on variables such as time of day, water depth, plant biomass, water clarity and temperature. When dissolved oxygen concentrations become depleted, the survival of fish and other oxygen-dependent aquatic life becomes compromised. The water quality standard for oxygen in “warm water” lakes like Lake Ripley is 5.0 mg/L. This is the minimum amount of oxygen needed for most fish to survive and grow.

The amount of oxygen present within the hypolimnion of deeper lakes plays an important role in the mobilization of phosphorus from the bottom sediments into the surrounding water column. As thermal stratification isolates the hypolimnion from the atmosphere, the surface supply of oxygen from the atmosphere is sealed off. The remaining dissolved oxygen is often rapidly consumed when respiration rates increase due to excessive decomposition of organic material that settles to the bottom. Phosphorus can be chemically converted into a more soluble state and released from bottom sediments when the overlying water becomes devoid of oxygen, or anoxic. These anoxic conditions commonly occur within the hypolimnions of deeper, eutrophic lakes where the rate of decomposition and bacterial respiration exceeds the rate of photosynthesis and natural aeration. When the lake eventually destratifies (mixes), any phosphorus that was mobilized from the bottom sediments is transported throughout the water column where it becomes available for algae growth. Anoxic conditions are also capable of developing in weedy, shallow lakes, especially during non-daylight hours when bacterial and microbial respiration is likely to exceed photosynthesis.

Lake Ripley, while generally well oxygenated, does go anoxic below the 20-25-ft. water depth during the summer stratification period. However, the lake is not considered to be susceptible to winterkill conditions (low winter oxygen resulting in fish kills). This is primarily due to sufficient depths and an ample water volume that prevents “freeze-out” conditions.

4-6 ACIDIFICATION

A lake's pH is a measure of the concentration of hydrogen ions in the water. Lower pH waters have more hydrogen ions and are more acidic than higher pH waters. A pH of 0 indicates that a particular water sample is highly acidic, while a pH of 14 suggests a highly basic sample (7 is considered neutral). Every 1.0 unit change in pH represents a tenfold change in hydrogen ion concentration. Therefore, a lake with a pH of 6 is ten times more acidic than one with a pH of 7.

Low pH is shown to increase the solubility of certain metals that can become toxic in higher concentrations, such as aluminum, zinc and mercury. It is also harmful to the survivability of fish and other aquatic organisms. In Wisconsin, pH ranges from 4.5 (acid bog lakes) to 8.4 (hard water, marl lakes like Lake Ripley), with a statewide mean of 7.2.[6] Lakes having good fish populations and productivity generally have a pH between 6.7 and 8.2. Lower pH lakes are often found in the northern part of the state where acid rain has a greater impact on surface waters due to the limited buffering capacity of regional soils. Natural, unpolluted rainfall is relatively acidic, and typically has a pH of between 5 and 6. However, rainfall varies from a pH of 4.4 in southeastern Wisconsin to nearly 5.0 in northwestern Wisconsin. Fortunately, naturally acidic precipitation is usually neutralized as it is exposed to acid-buffering carbonates in the environment.

Like most other lake-quality measures, pH varies naturally over short timeframes and even within the lake's water column. The amount of dissolved carbon dioxide in a lake—which is influenced by photosynthesis and respiration processes—generally affects pH levels. For instance, as carbon dioxide levels increase, pH will correspondingly decrease, and vice versa. Long-term water chemistry data indicate that the average pH of Lake Ripley's surface waters is 8.5. This value is higher than the statewide average but fairly typical for a southeastern Wisconsin lake, indicating that the system is well buffered from acidification. Acidity effects on different fish species is presented in Table 12 below.

Table 1: Effects of acidity on fish[7]

Water pH	Effects	Comparable Acidity
7.0		Distilled water
6.5	Walleye spawning inhibited	
6.0		Pear juice
5.8	Lake trout spawning inhibited	
5.5	Smallmouth bass disappear	Spinach juice
5.2	Walleye, burbot, lake trout disappear	
5.0	Spawning inhibited in many fish	Carrot juice

[6] Shaw, Byron, Mechenich, C. and Klessig, L. 1996. Understanding Lake Data. Publication RP-09-96-3M-275.

[7] Adapted from: Olszyk, D. 1980. Biological Effects of Acid Rain. Testimony, Wis. Public Service Commission Docket No. 05-EP-2. 5 pp.

4.7	Northern pike, white sucker, brown bullhead, pumpkinseed sunfish, rock bass disappear	
4.5	Perch spawning inhibited	Beer
3.5	Perch disappear	
3.0	Toxic to all fish	

It should be noted that ammonium hydroxide (NH_4OH) can form and cause low-level toxicity to fish if water pH is neutral to alkaline. The water quality standard for fish and aquatic life is 0.02 mg/L of NH_4OH. Ammonium hydroxide is a form of ammonia, which, in turn, is a form of nitrogen found in organic materials and many fertilizers. Ammonia is the first form of nitrogen released when organic matter decays. It can be used by most aquatic plants and is therefore an important nutrient. Depending on water temperature, ammonia can also rapidly convert to nitrate (NO_3^-) if oxygen is present.

4-7 ALKALINITY AND HARDNESS

Alkalinity (or hardness) is a measure of the amount of carbonates (CO_3), bicarbonates (HCO_3) and hydroxide (OH) present in the water. Therefore, a lake's alkalinity is affected by the types of minerals found within watershed soils and bedrock. Hardness and alkalinity increase the more the lake water comes into contact with minerals containing bicarbonate and carbonate compounds. These compounds are usually found with two hardness ions: calcium (Ca) and magnesium (Mg). If a lake receives groundwater from aquifers containing limestone minerals such as calcite and dolomite, hardness and alkalinity will be high. High levels of hardness (>150 mg/L) and alkalinity can cause marl to precipitate out of the water. Marl appears as a white or gray accumulation on the lake bottom caused by the precipitation of calcium carbonate ($CaCO_3$). While marl deposits cause the gradual infilling of lakes, they also bind to phosphorus, resulting in lower algae populations and better water clarity than would otherwise be possible.

Hard water lakes, like Lake Ripley, tend to be more productive in terms of algal growth, and support larger quantities of fish and aquatic plants than soft water lakes. They are also usually located in watersheds with fertile soils that add phosphorus to the lake. However, phosphorus precipitates with marl, thereby controlling the amount of this nutrient that is available for algal growth. If the soils are sandy and composed of quartz or other insoluble minerals, or if direct rainfall is a major source of lake water, hardness and alkalinity will be low. Lakes with low amounts of alkalinity are more susceptible to acidification by acid rain and are generally unproductive.

Alkalinity is expressed as milligrams per liter (mg/L) of calcium carbonate ($CaCO_3$) per liter of water, or as microequivalents per liter (µeq/l). 20 µeq/l is equal to 1 mg/L of $CaCO_3$. Lake Ripley has high alkalinity that generally ranges from 160-260 mg/L $CaCO_3$, with a mean of 192 mg/L $CaCO_3$, and "low" sensitivity to acid rain due to its significant buffering capacity. It is further classified as a marl lake with "hard" to "very hard" water. Table 13 shows relative hardness levels for lakes with varying concentrations of calcium carbonate ($CaCO_3$), with typical values for Lake Ripley highlighted. Table 14 shows relative sensitivity levels of lakes to acid rain based on alkalinity values.

Table 2: Categorization of hardness by mg/L of calcium carbonate ($CaCO_3$)

Level of Hardness	Total Hardness as mg/L $CaCO_3$
Soft	0-60
Moderately hard	61-120
Hard	121-180
Very Hard	>180

Table 3: Sensitivity of lakes to acid rain based on alkalinity values[8]

Sensitivity to Acid Rain	Alkalinity (mg/L $CaCO_3$)	Alkalinity (µeq/l $CaCO_3$)
High	0-2	0-39
Moderate	2-10	40-199
Low	10-25	200-499
Nonsensitive	>25	>500

4-8 LAKE TROPHIC STATUS

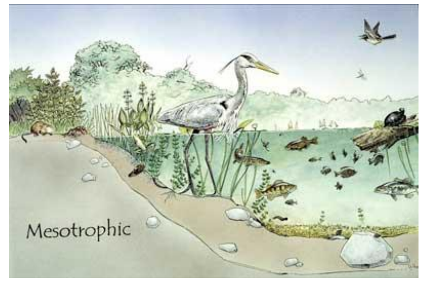
Lakes are routinely characterized and evaluated according to their trophic status. Trophic status describes the level of nutrient enrichment (fertility) and primary productivity (plant and algal growth) in a lake. It is determined by assessing water clarity, phosphorus and chlorophyll-*a* data. Carlson's Trophic State Index (TSI) is a continuum scale of 0 to 100, corresponding with the clearest and most nutrient-poor lake possible, to the murkiest and presumably most nutrient-rich lake possible. Each major division of the scale (10, 20, 30, etc.) represents a doubling in algal biomass and decreased water clarity.

Lakes undergo a natural aging process, called eutrophication, as sedimentation and decay increase fertility and cause lakes to fill in over thousands of years. This process moves a lake's trophic status toward higher points along the index. As seen on Lake Ripley, human activities that increase the rate of nutrient enrichment can compress the eutrophication timeframe to only a few years or decades. This is called accelerated or cultural eutrophication. Water bodies that receive excessive amounts of nutrients (i.e. phosphorus) from their watersheds are most likely to become eutrophic, with a corresponding increase in the production of weeds and algae.

Lakes can be divided into four nutrient-enrichment categories: oligotrophic (TSI 0-40), mesotrophic (TSI 40-50), eutrophic (TSI 50-70) or hypereutrophic (TSI 70-100). Oligotrophic lakes are generally clear, deep and free of weeds or large algal blooms. They are low in nutrients, well oxygenated, and not capable of supporting large fish populations. However, these lakes often develop a food chain that can sustain a very desirable fishery with large game fish. Mesotrophic lakes lie between the oligotrophic and eutrophic stages. They have moderately clear water and may become devoid of oxygen in their bottom waters, causing phosphorus

[8] Adapted from: Taylor, J. W. 1984. The Acid Test. *Natural Resources Magazine*. Wisconsin Department of Natural Resources. 40 pp.

release from the sediment. Eutrophic lakes have poor water clarity, are high in nutrients, and support a large biomass of aquatic plants and animals. They are usually either weedy or subject to frequent algal blooms, or both. Although capable of supporting large fish populations, these lakes are also more susceptible to oxygen depletion. Rough fish like carp are commonly found in eutrophic lakes. Finally, hypereutrophic lakes are those that are super-enriched with nutrients like phosphorus. These lakes experience heavy algal blooms throughout the summer, and may even experience fish kills. Rough fish dominate in hypereutrophic lakes. It is important to recognize that lakes can shift between trophic states. This shift can be in a negative or positive direction, and would depend on watershed condition and level of management intervention.



Under ideal water-quality scenarios, Lake Ripley would reflect mesotrophic characteristics. Source: Wisconsin Lakes Partnership

Lakes dominated by aquatic plants tend to have high amounts of phosphorus tied up in the bottom sediments, and relatively low phosphorus in the water column. Conversely, lakes that produce mostly algae have high phosphorus concentrations in the water. Most lakes have a fairly stable ratio of aquatic plants to algae. TSI values represent the portion of nutrients (phosphorus) that are found in the water column, as evidenced by the amount of algal growth (chlorophyll-*a*). Therefore, if most of the available nutrients are held in the sediments of a lake with heavy plant growth, its true nutrient status cannot be accurately measured using TSI calculations.

Lake Ripley is best described as meso-eutrophic. It fluctuates between mesotrophic and eutrophic conditions with a summer mean TSI of about 50. A similar lake left undisturbed might be expected to maintain a TSI value near 40. The trophic status of Wisconsin lakes based on chlorophyll-*a* concentration, water clarity (Secchi-disk transparency), and total phosphorus concentration is presented in Table 15 below.

Table 4: Trophic classification of Wisconsin lakes based on total phosphorus, chlorophyll-*a*, and Secchi depth values[9]

Trophic Class	Trophic State Index (TSI)	Total Phosphorus (µg/L)	Chlorophyll-*a* (µg/L)	Secchi Depth (ft)
	100			
Hypereutrophic				
---------------------	--------70----------	--------96.0---------	------56.0-------	---------1.6--------
Eutrophic				
---------------------	--------50----------	--------24.0---------	--------7.3-------	---------6.5--------
Mesotrophic				
---------------------	--------40----------	--------12.0---------	--------2.6-------	--------13.1--------
Oligotrophic				
	0			

[9] Lillie, R.A., S. Graham and P. Rasmussen. May 1993. Trophic State Index Equations and Regional Predictive Equations for Wisconsin Lakes. Wisconsin Department of Natural Resources. Research Management Findings #35 technical bulletin.

4-9 PHOSPHORUS AS DRIVER OF ALGAL GROWTH

Phosphorus (P) and nitrogen (N) are the two essential nutrients that most directly influence aquatic plant and algal growth; the extent of which depends on the relative abundance and availability of each nutrient. These often problematic nutrients typically enter lakes in the form of polluted runoff that may contain eroded soil, manure, pet waste, chemical fertilizers and organic debris—among other material. The erosion of stream banks, construction sites, shorelines and farmland all contribute sediment and fertile runoff to downstream lakes. Failing septic systems around smaller, non-sewered lakes can also contribute to nutrient-loading problems.

Plants need phosphorus and nitrogen to grow. However, phosphorus reduction is often the focus of lake-rehabilitation programs because it is: (1) in short supply relative to other critical nutrients and therefore dictates the rate of algal growth; and (2) it is easiest to manipulate since the element has no gaseous component in its biogeochemical cycle. N:P ratios are used to determine which nutrient most "limits" or controls algal productivity by comparing the relative availability of each nutrient within the water column. Because the essential nutrient is in short supply, it effectively limits the amount of primary productivity the lake is capable of supporting. A N:P ratio greater than 15:1 near the water surface is indicative of a lake that is phosphorus limited. A ratio from 10:1 to 15:1 indicates a transition situation, and a ratio less than 10:1 usually indicates nitrogen limitation. Lakes with intermediate ratios can be limited from time to time by either element, but by reducing phosphorus availability, this element can be made the limiting factor.

The limiting nutrient for algal growth in Lake Ripley is phosphorus. Typical N:P ratios in excess of 27:1 were measured during Water Resource Appraisal monitoring in 1993.[10] This is not surprising since phosphorus is the key nutrient affecting the amount of algal growth in the vast majority of Wisconsin's lakes. Sources of phosphorus to the lake include row-crop agriculture (70.3%), urban/residential areas (17.4%), pasture and mixed agriculture (5.5%), atmospheric deposition (4.1%), wetlands (1.8%), and forest (0.8%).[11] Groundwater and the lake bottom are also sources of phosphorus, but their relative contributions have not been fully quantified. Phosphorus is commonly released from nutrient-rich bottom sediment due to physical disturbance, high pH levels, or anoxic conditions. Algal blooms could then form, especially if the phosphorus is able to mix into the water column during the summer growing season.

Summer mean total phosphorus concentrations and associated TSI values from 1986-2009 are illustrated in Figures 33 and 34. Total phosphorus includes the amount of phosphorus in solution (reactive) and particulate form. Surface total phosphorus concentrations for Lake Ripley during the summer are generally indicative of a meso-eutrophic system, with average and median "summer mean" values of 20.3 µg/L and 18.8 µg/L, respectively. Most recorded values were clustered in the range of 10-25 µg/L, but with a relatively big spike in 1990 following a drought year when phosphorus recycling from anoxic sediments may have been a factor. It is actually much more typical for phosphorus concentrations to be higher during wet years (as evidenced in 1993 and 2008) and lower during drought years (as evidenced in 1988-89), demonstrating the

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[10] Wisconsin Department of Natural Resources, and Lake Ripley Management District. 1994. Lake Ripley Water Resources Appraisal.
[11] Wisconsin Lake Modeling Suite (WiLMS) analysis, Version 3.3.18.1

impacts of watershed nutrient sources on lake water quality. No strong trend is evident toward increasing or decreasing phosphorus concentrations over the 23-year monitoring period.

When phosphorus concentrations exceed 20 µg/L at the time of spring turnover in natural lakes and impoundments, these water bodies may occasionally experience nuisance levels of algal growth.[12] In hard water lakes like Lake Ripley, where limestone is dissolved in the water, marl (calcium carbonate) precipitates and falls to the lake bottom. These marl formations absorb phosphorus, reducing its overall concentration in the water column as well as any related algal growth. Hard water lakes often have clear water, but may be weedy since rooted aquatic plants can still get their required nutrients from the sediments.

[12] Shaw, Byron, Mechenich, C. and Klessig, L. 1996. Understanding Lake Data. Publication RP-09-96-3M-275.

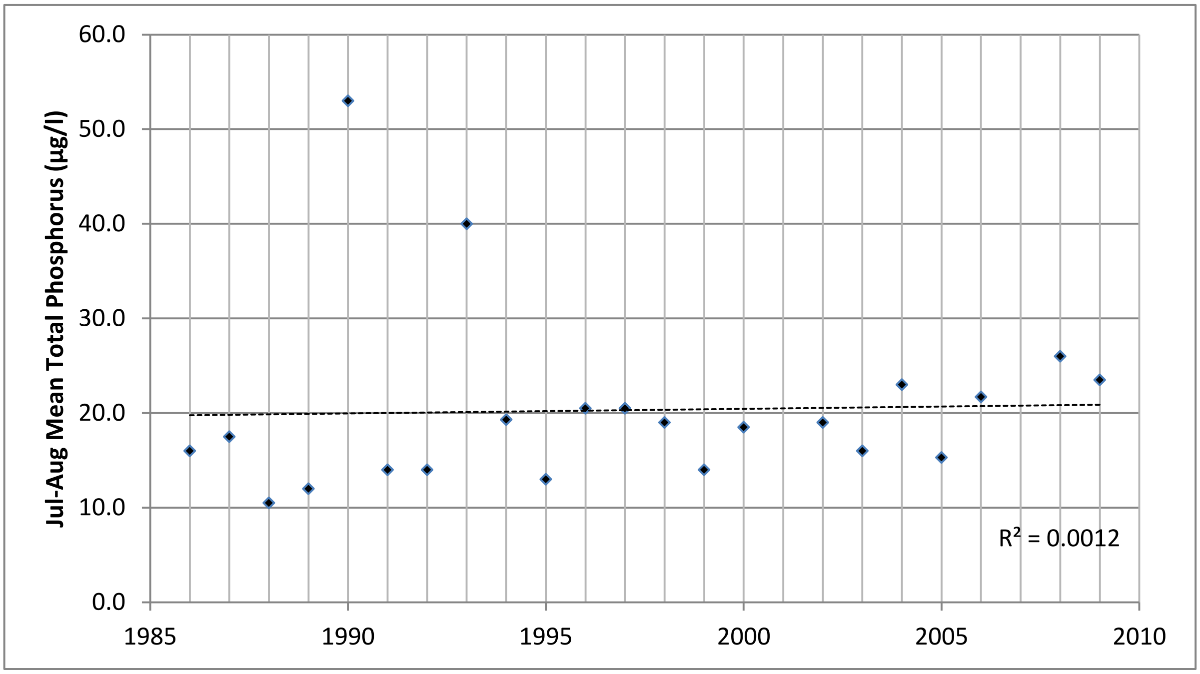

Figure 3: July-August Mean Total Phosphorus Measurements (1986-2009)

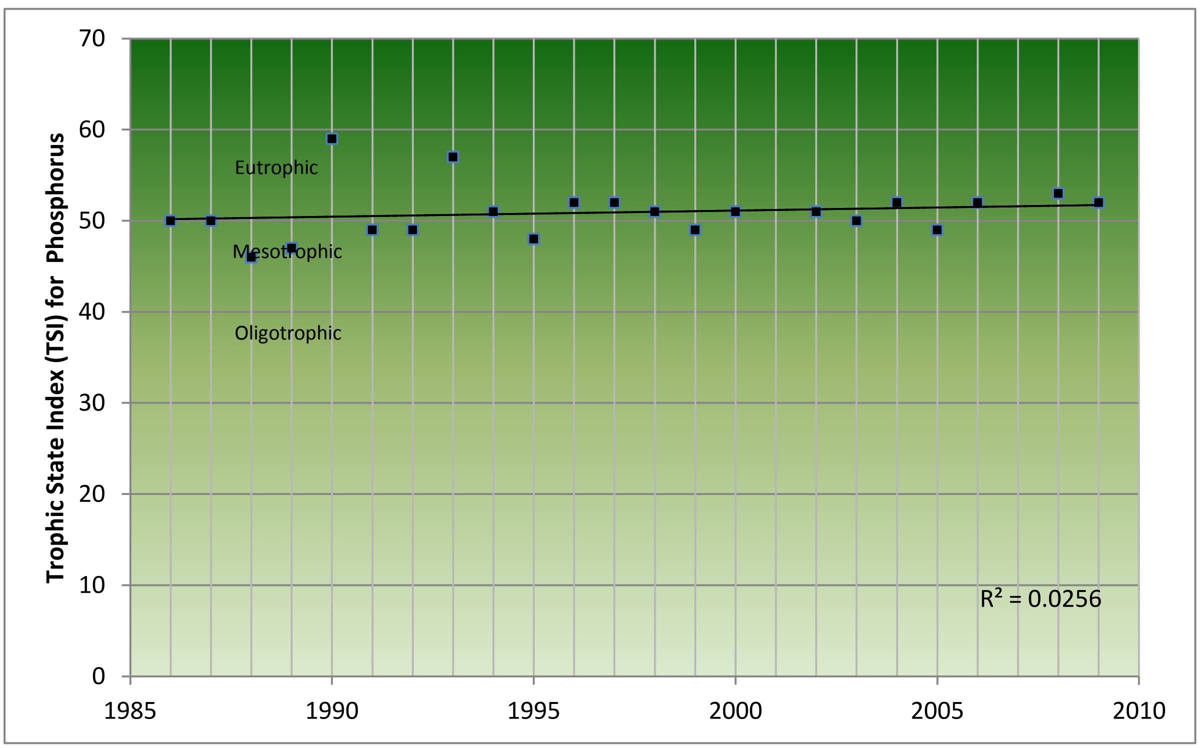

Figure 4: TSI Based on Corresponding Total Phosphorus Readings (1986-2009)

4-10 ALGAE

Algae are single-celled plants that occur either suspended in the water (phytoplankton) or attached to rocks and other surfaces (periphyton, or filamentous algae). Algae are the primary producers that form the base of the aquatic food chain. They are an essential part of the lake ecosystem, and provide food for most other lake organisms, including fish. The amount of sunlight and nutrients that are available in a lake, among other factors, will dictate algal abundance. Populations vary widely from day to day given their rapid growth and death rates.

A blue-green algal scum on the surface of a eutrophic lake. Source: Missouri DNR

In eutrophic lakes, high nutrient fertility can cause nuisance algal blooms that make the water appear green and murky. Blue green algae—which in actuality are a type of bacteria called cyanobacteria—are even known to produce a floating green scum thick enough to shade out aquatic plants and impair recreational use of the water. In fact, some blue-green algal blooms can release chemicals that are toxic to other organisms, including humans. High concentrations of wind-blown algae may accumulate on shorelines where they die and decompose, causing noxious odors, unsightly conditions and oxygen depletion.

Filamentous algae is often found attached to plants and rocks, especially in eutrophic lakes. Source: LakeLawnandPond.com

Controlling nuisance algal populations in lakes is a difficult undertaking. Because phytoplanktonic algae are microscopic plants that are free-floating in the water column, managing the whole lake rather than just the problem areas is necessary. Since algal populations are caused by high nutrient concentrations, attempting to eliminate algae by attacking it directly with chemical herbicides (algacides) offers only a short-term fix that may become a costly management approach over the long run. The best way to manage excessive algae is to both reduce the supply of nutrients like phosphorus into the lake, and then control the availability of nutrients that are already contained within the lake. This represents a "bottom-up" approach to algae control.

A supplementary "top-down" approach, called biomanipulation, uses food-web manipulations to help manage algae. By influencing predator-prey relationships, such as through the stocking of gamefish or removal of rough fish, conditions can be made more or less favorable for algal growth. For example, as the number of top predators (i.e., bass and walleye) increase, the number of planktivorous fish (i.e., bluegill and perch) should decrease, resulting in less predation on algae-consuming zooplankton. This, in turn, means higher populations of zooplankton that can graze on problem algae. Zooplankton populations can also be enhanced through the availability of sufficient plant cover where these tiny animals can escape fish predation. However, too much plant cover can encourage the overpopulation of planktivorous fish, which can then overgraze on zooplankton and encourage greater algal growth.

Chlorophyll-*a*, the green pigment found in all photosynthesizing organisms, is commonly used as an indicator of algal biomass in lakes when sampled from the open water. Chlorophyll-*a* values for Lake Ripley during the summer months are generally indicative of a meso-eutrophic system, with average and median "summer mean" values of 8.6 µg/L and 7.8 µg/L, respectively. Chlorophyll-*a* concentrations and associated TSI values from 1986-2009 are illustrated in Figures 35 and 36 below. No strong trend is evident toward increasing or decreasing chlorophyll-*a* concentrations over the 23-year monitoring period.

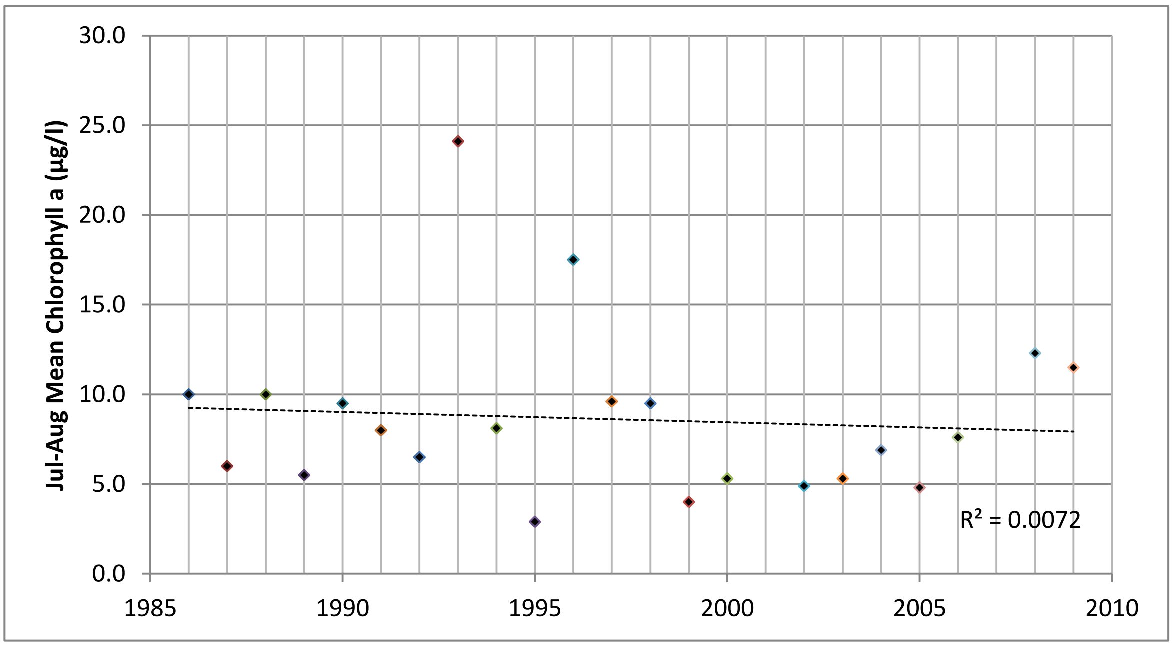

FIGURE 5: CHLOROPHYLL-*A* MEASUREMENTS (1986-2009)

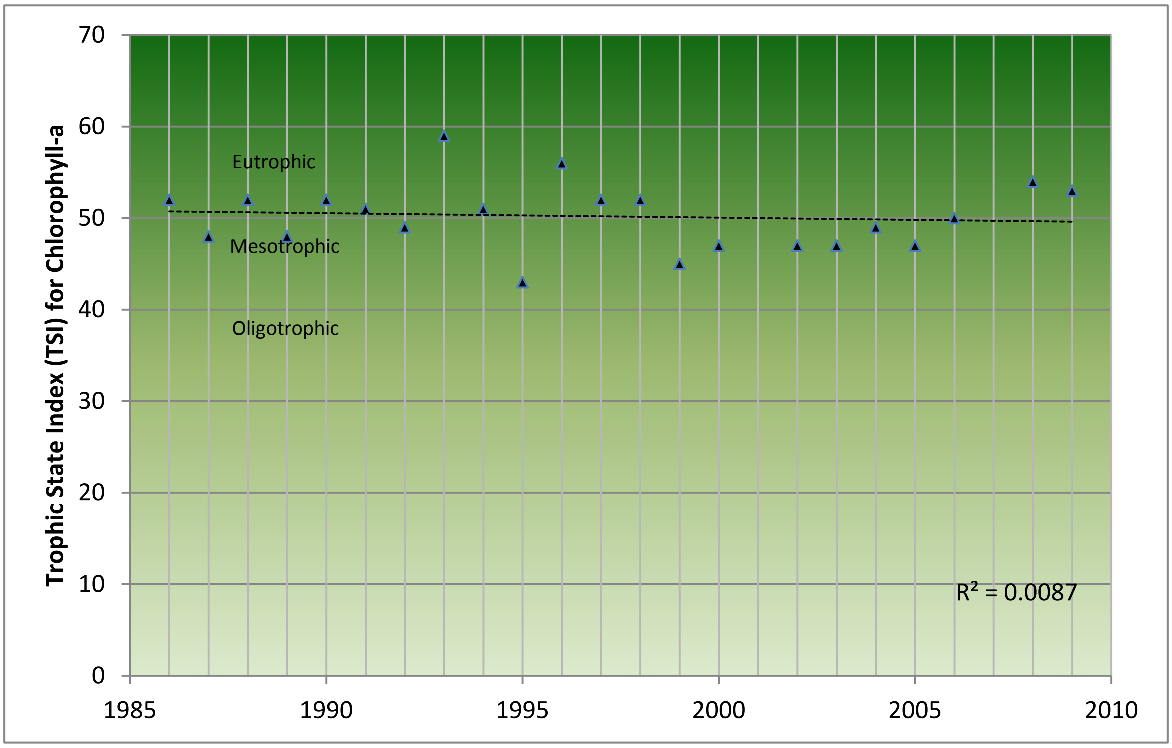

Figure 6: TSI Based on Corresponding Chlorophyll-*a* Readings (1986-2009)

4-11 WATER CLARITY

Clarity is only one facet of water quality, but it is an important one for both aesthetic and ecological reasons. People want to be able to observe fish, see to the bottom, and not have to think twice to swim with their eyes open. In fact, studies have shown that people are willing to pay a higher premium for properties located on clearer waterways (see Appendix C). Water clarity (also known as transparency) is necessary for the survival of many types of fish, submersed plants and other aquatic life. Clarity affects the ability of fish to find food, the depth to which plants can grow, and even the temperature and dissolved oxygen content of the water.

Water transparency measurements are taken with a device known as a Secchi disc, which is used to evaluate the clarity of a lake's water column. A Secchi disc is an eight-inch-diameter, black-and-white patterned plate that is lowered into the water until it reaches a depth at which it is no longer visible from the water surface. The recorded depth can be compared to values from other lakes and used as an indicator of overall water clarity. Clarity is generally highest after the spring thaw, reflecting a season of low productivity for algal populations, and lowest during peak algal production in the summer. Clarity is also usually lower during and shortly after busy boating weekends when sediment on the lake bottom gets stirred up, or after heavy rainfall washes muddy runoff into the lake. Since clarity can fluctuate over the course of a single day and for various reasons, frequent and long-term monitoring is needed for the purpose of assessing trends.

Generally, sunlight can penetrate to a depth equal to 1.7 times the Secchi depth. The depth to which light is able to penetrate defines the lakes's photic zone, and roughly coincides with the depth where there is enough oxygen to support fish and other aquatic life. Transparency may be affected by factors such as turbidity (suspended sediment and particulate matter), water color, and free-floating algal cells. Secchi depth measurements are often used in conjunction with chlorophyll-*a* and total phosphorus concentrations to determine a lake's trophic status and overall water quality condition.

Lake Ripley summer mean Secchi-depth measurements and associated TSI values from 1973-2009 are illustrated in Figures 37 and 38 below. Over this timeframe, individual Secchi measurements ranged from 2.5 to 9.5 feet during the July-August period, with average and median "summer mean" values of 6.0 and 5.8 feet, respectively. These values generally reflect a meso-eutrophic system, with an average TSI of 52. There appears to be a trend toward increasing water clarity conditions over the roughly 36-year monitoring period.

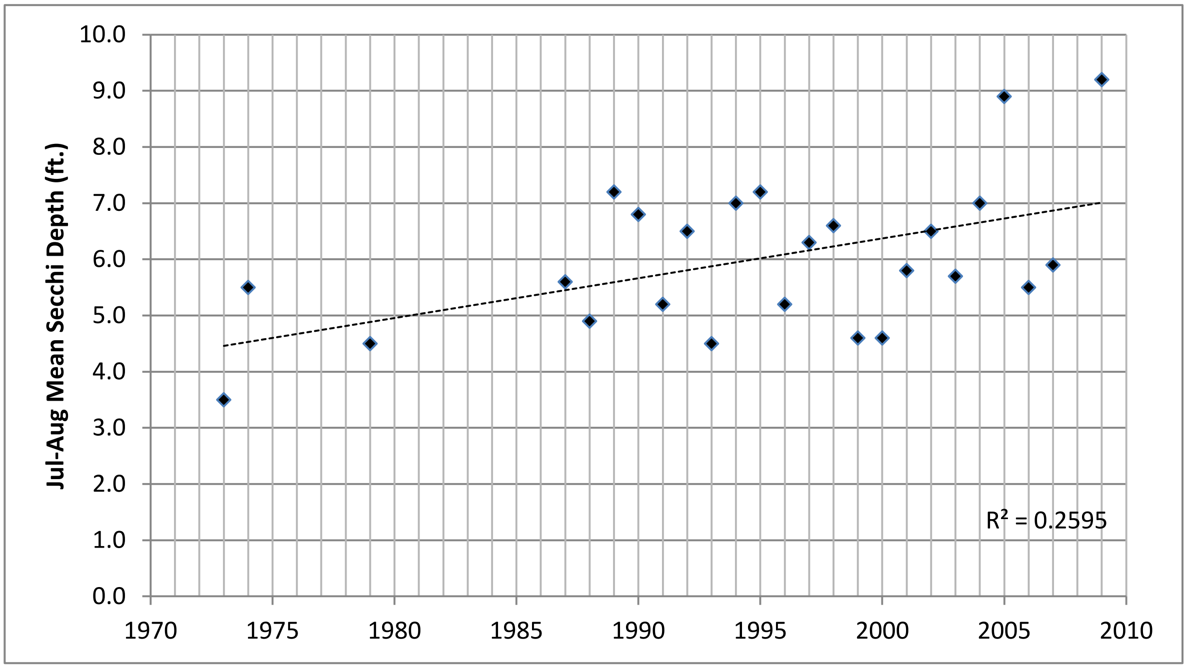

Figure 7: Secchi Depth Measurements (1973-2009)

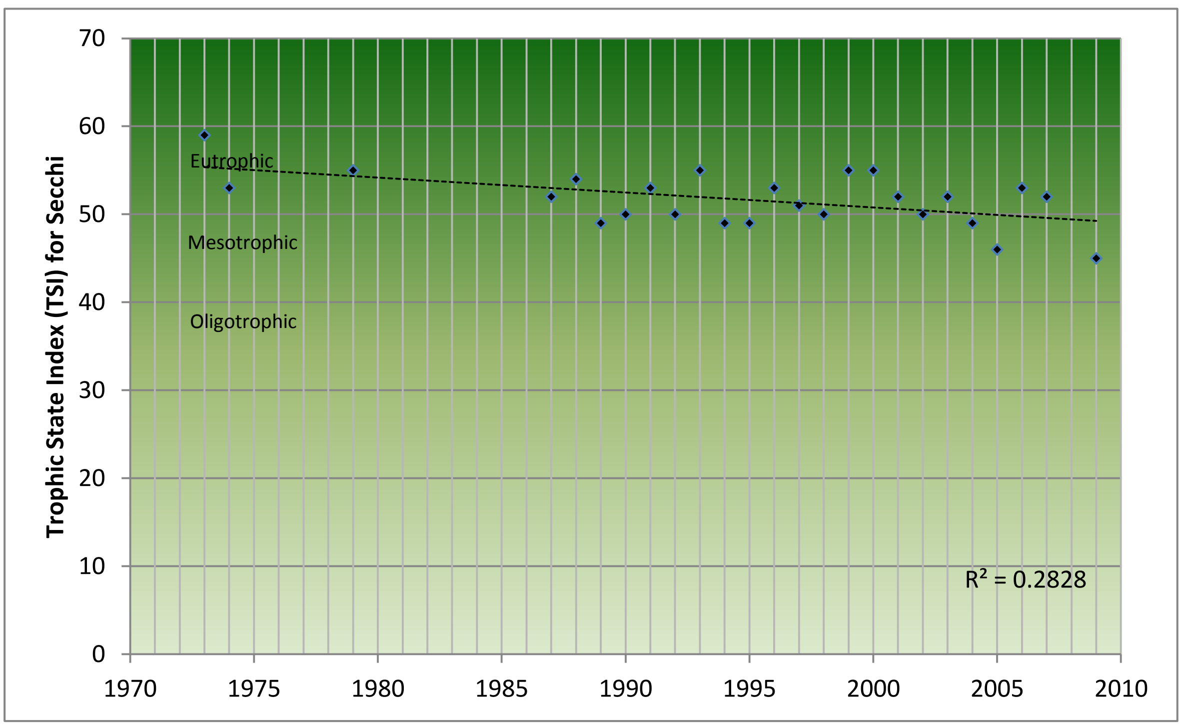

Figure 8: TSI Based on Corresponding Secchi Depth Readings (1986-2009)

Carlson's Trophic State Index is mostly intended as a predictor of algal biomass. Consequently, TSI for chlorophyll-*a* is a better predictor than either of the other two indices. However, useful insights can be gained by evaluating the interrelationships among all three indices, such as the identification of other environmental factors that may influence algal biomass. For example, when TSI for chlorophyll-*a* is greater than TSI for Secchi depth, large particulate algae may dominate in the lake. In contrast, when TSI for Secchi depth and total phosphorus are both greater than TSI for chlorophyll-*a*, light attenuation may be due to water color or turbidity, rather than algae. The interrelationships of the three indices are shown in Figure 39 below. The data plot suggests that large-particulate algae likely dominated in 1990, 1993, 1994, 1996, 1998 and 2009, while suspended sediment may have played a dominant role in 1987, 1995, 1999, 2000, 2002, 2003 and 2006.

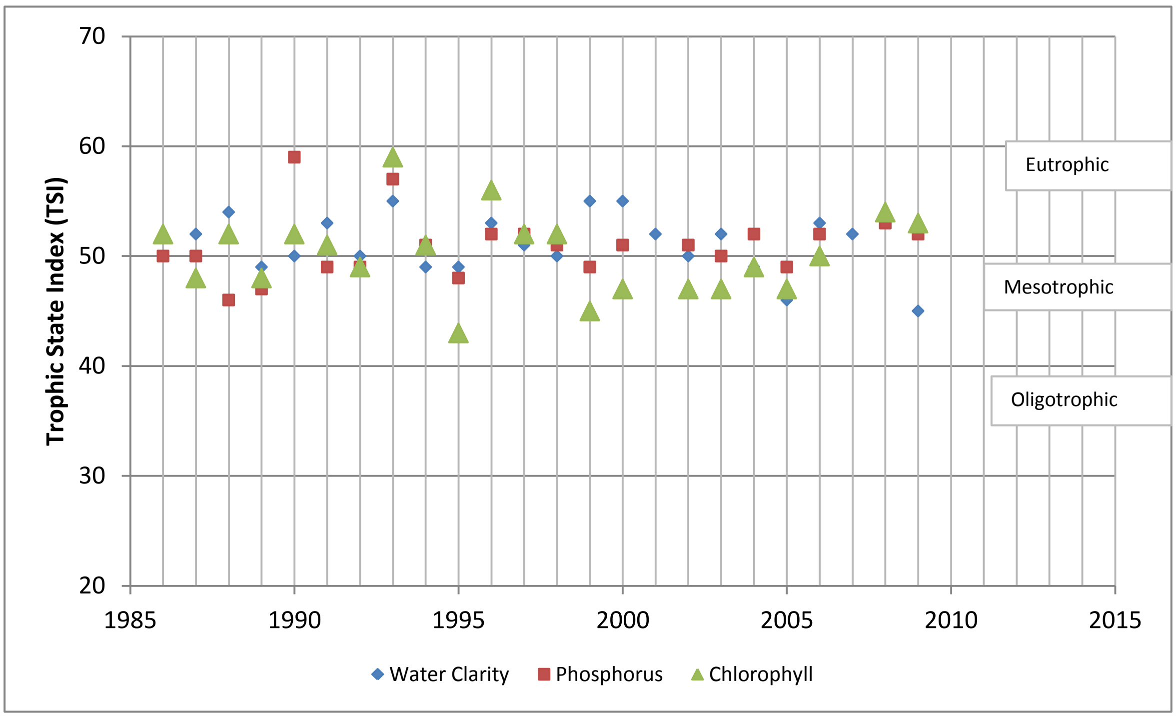

Figure 9: TSI Chart of Combined Secchi Depth, Total Phosphorus and Chlorophyll-*a* Readings (1986-2009)

4-12 WATER QUALITY INDEX

Lillie and Mason (1983) classified all Wisconsin lakes using a random data set collected in the months of July and August.[13] The water-quality index that was developed is based on surface total-phosphorus and chlorophyll-*a* concentrations and Secchi depths. Applying the water-quality index to Lake Ripley, total-phosphorus and chlorophyll-*a* concentrations were on average

[13] Lillie, Richard A., and John W. Mason. 1983. Limnological Characteristics of Wisconsin Lakes. Wisconsin Department of Natural Resources. Technical Bulletin No. 138.

indicative of "good" water quality, while Secchi depths were on average indicative of "fair" water quality. Table 16 shows the total phosphorus, chlorophyll-*a* and Secchi depth ranges that correspond with each water quality ranking. Typical value ranges for Lake Ripley are highlighted.

Table 5: Water quality index for Wisconsin lakes based on total phosphorus, chlorophyll-*a* and Secchi depth values

Water Quality Index	Total Phosphorus (µg/L)	Chlorophyll-*a* (µg/L)	Secchi Depth (ft)
Excellent	<1.0	<1.0	>20.0
Very good	1.0-10.0	1.0-5.0	10.0-20.0
Good	10.0-30.0	5.0-10.0	6.5-10.0
Fair	30.0-50.0	10.0-15.0	5.0-6.5
Poor	50.0-150.0	15.0-30.0	3.3-5.0
Very poor	>150.0	>30.0	<3.3

A number of biotic indices can also be used to make snapshot evaluations of localized water quality conditions. The lake's aquatic plants, fish and benthic macroinvertebrates (insects, insect larvae, crustaceans, snails and mussels living on the bottom) are excellent indicators of lake health. While some species are adaptable to a range of water quality conditions, others will only be present under the most favorable conditions due to varying sensitivities to pollution. For example, macroinvertebrate species that require good water quality include waterpenny beetle larva, mayfly nymph, gilled snail, caddis fly larva, stonefly nymph, dragonfly nymph, scud, panaria (flatworm), and various mussels. Conversely, those that can tolerate poor water quality include leech, midge larva, black fly larva, horsehair worm, and mosquito larva.

4-13 BACTERIA

High E. coli (*Escherichia coli*) bacteria counts are commonly used as an indicator of beach contamination, as they may be associated with the presence of dangerous pathogens. In addition, some strains of the bacteria can cause gastrointestinal illnesses in humans. E. coli are found in the intestines of warm-blooded animals, but can appear where untreated sewage, pet waste, cow manure and goose droppings enter waterways. Evidence also indicates that this type of bacteria does not always come from harmful, land-based sources, but can be naturally present in beach environments. Consequently, samples taken on windy days or after heavy beach use can lead to high bacteria counts due to sediment disturbance.

The Jefferson County Health Department monitors the Ripley Park beach for bacteria on a weekly basis throughout the summer. When advisory levels set by the U.S. Environmental Protection Agency are reached (235 colony forming units per 100 m/l), the health department notifies the beach manager. The beach manager may then post warning signs or can decide to temporarily close the beach. Beach closings are generally recommended when bacteria levels exceed 1,000 cfu per 100 m/l. Table 17 lists bacteria levels documented at the Lake Ripley Park beach over the last three years. Since point sources for bacterial contamination have not been identified, readings that exceed advisory levels may be the result of geese activity or high runoff events that can wash pet waste, manure and other nonpoint source pollutants into the lake.

Table 6: Lake Ripley Beach E. coli bacterial counts[14]

Date and Time	E Coli Value	E Coli Units
08/24/2009 12:55	22	PER 100 ML
08/17/2009 10:40	222	PER 100 ML
08/11/2009 13:00	2400	PER 100 ML
08/04/2009 11:45	1	PER 100 ML
07/31/2009 11:30	184.2	PER 100 ML
07/24/2009 11:15	276	PER 100 ML
07/14/2009 11:45	61	PER 100 ML
07/08/2009 11:20	38	PER 100 ML
07/02/2009 13:35	276	PER 100 ML
06/29/2009 13:15	649	PER 100 ML
06/26/2009 11:43	2419	PER 100 ML
06/16/2009 10:50	83.9	PER 100 ML
06/09/2009 11:00	16	PER 100 ML
06/04/2009 10:55	1	PER 100 ML
08/28/2008 10:20	5.1	PER 100 ML
08/19/2008 10:55	1	PER 100 ML
08/12/2008 10:25	39	PER 100 ML
08/05/2008 11:23	290	PER 100 ML
07/30/2008 11:08	80	PER 100 ML
07/22/2008 11:26	96	PER 100 ML
07/14/2008 11:09	27	PER 100 ML
07/10/2008 12:17	210	PER 100 ML
07/03/2008 10:20	49.5	PER 100 ML
06/23/2008 10:18	58	PER 100 ML
06/04/2008 11:03	1	PER 100 ML
08/28/2007 11:50	2419	PER 100 ML
08/21/2007 10:41	32	PER 100 ML
08/14/2007 11:15	88	PER 100 ML
08/07/2007 10:45	1986.3	PER 100 ML
07/31/2007 06:30	410	MPN
07/30/2007 11:57	980	PER 100 ML
07/25/2007 10:10	1050	PER 100 ML
07/18/2007 10:45	220	PER 100 ML
07/12/2007 12:43	2400	PER 100 ML
07/05/2007 12:40	6	PER 100 ML
06/29/2007 11:28	75	PER 100 ML
06/22/2007 10:22	1203.3	PER 100 ML
06/12/2007 11:07	20	MPN
06/07/2007 13:30	613	MPN

[14] Jefferson County Health Department online records (www.wibeaches.us)