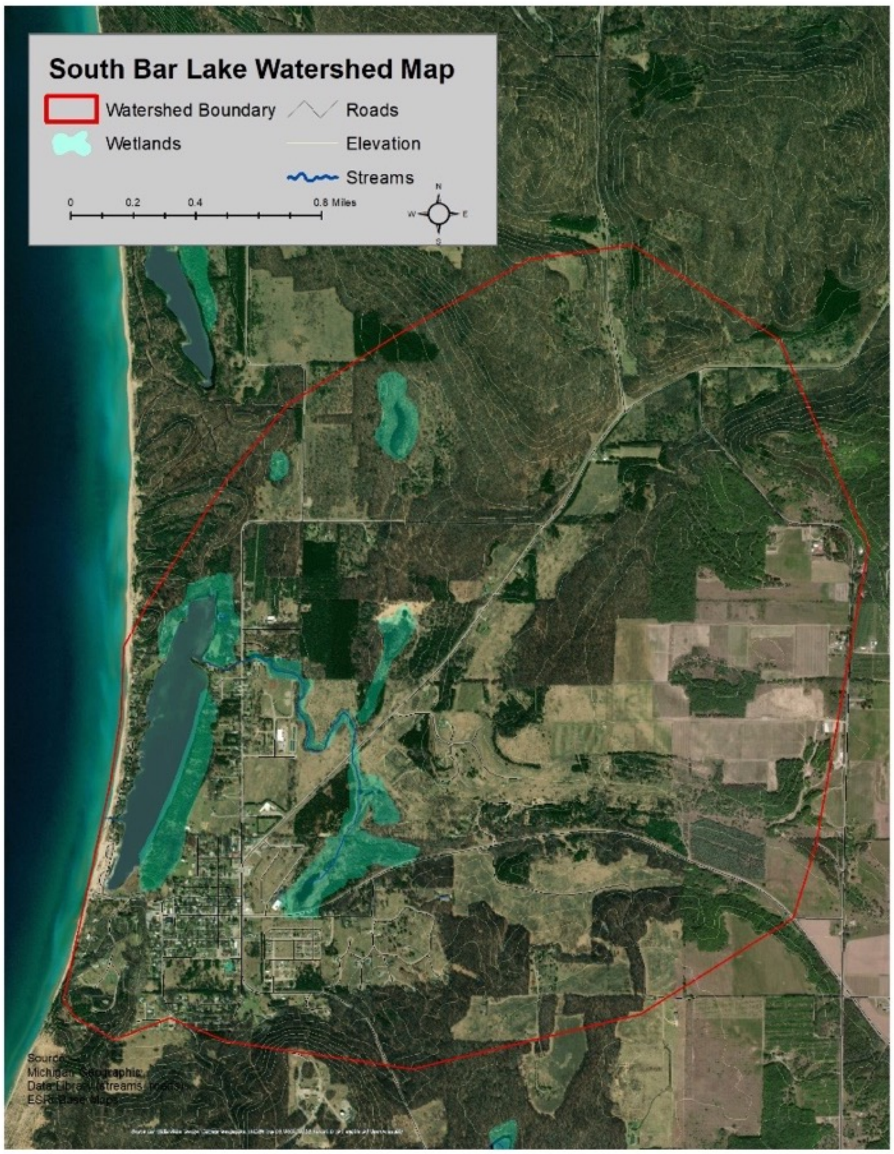
South Bar Lake Water Quality Report

August 2020



by

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South Bar Lake Water Quality

Background

This water quality study of South Bar Lake was funded by the Village of Empire in late-March 2019 in cooperation with the members of the South Bar Lake Association, South Bar Lake Cooperative Lake Monitoring Program (CLMP) Volunteers, and Village of Empire Council and Planning Commission. S. Bar Lake is located within the jurisdictional boundaries of the incorporated Village of Empire and Empire Township, Leelanau County, Michigan (see Figure 1). Like many places in Leelanau County, S. Bar Lake is a prime recreational area for locals and tourists alike due to its close proximity to Lake Michigan and Sleeping Bear Dunes National Lakeshore and its headquarters. S. Bar Lake is approximately 81 acres in size, and is considered part of the Betsie-Platte Watershed 8-digit Hydrologic Unit Code or HUC 04060104 and the 12-digit HUC 04060104-0403 referred to as the "Bar Lakes Watershed" in Leelanau County. The watershed immediately surrounding S. Bar Lake was interpreted and preliminary mapped by Grobbel Environmental & Planning Associates, and is referred herein to as the S. Bar Lake watershed. S. Bar Lake is considered slightly mesotrophic, while most lakes in Northern Lower Michigan are oligotrophic or slightly mesotrophic.

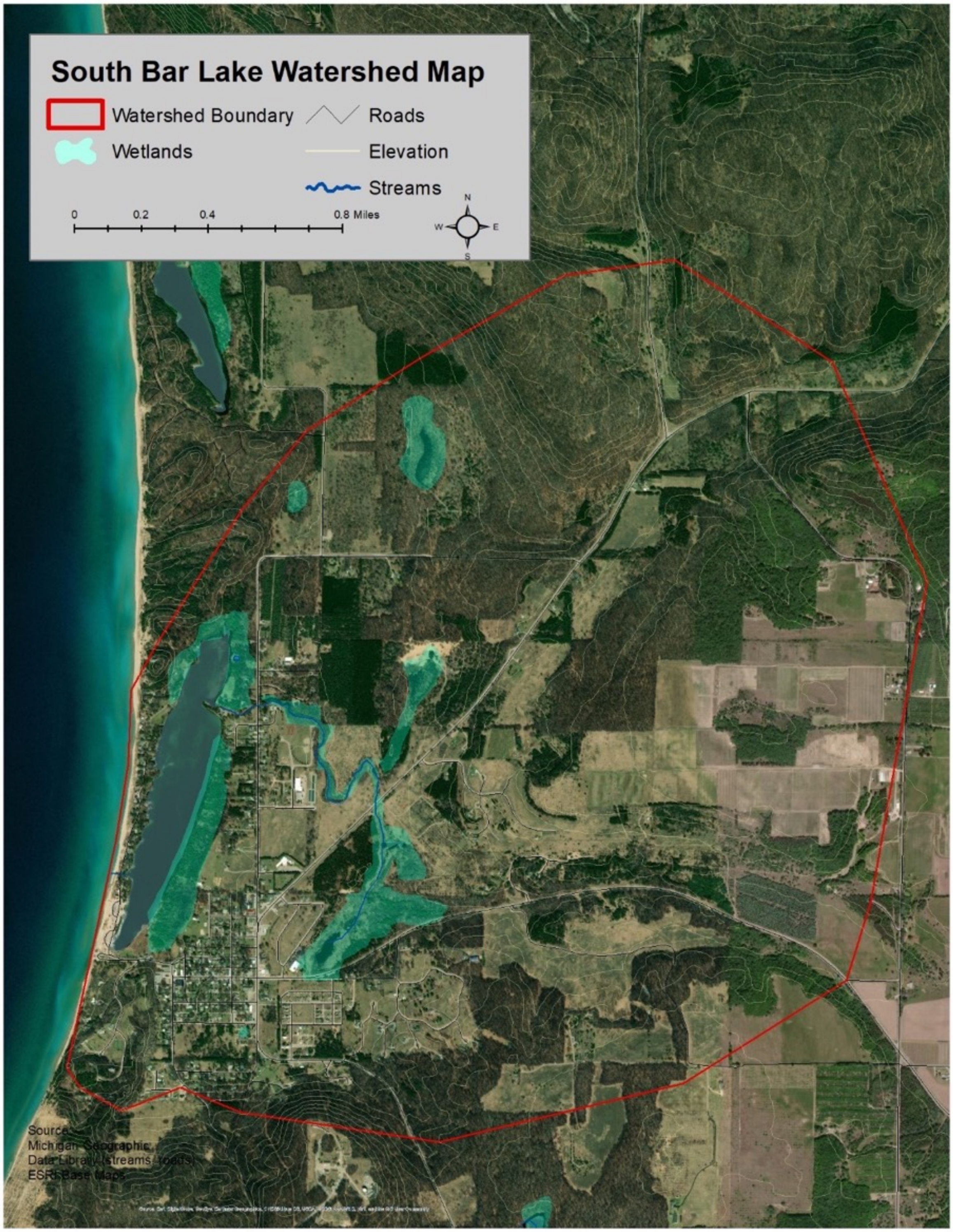
S. Bar Lake is relatively shallow at thirteen (13) feet maximum depth, owing to the is geomorphologic history as a former embayment of Lake Michigan closed off from the lake from dune formation similar to N. Bar Lake, the Glen Lakes, Little Traverse Lake, Herring Lakes and others in the region. S. Bar Lake is heavily-used seasonally for sunbathing, swimming, boating and fishing.[1] Exemplary public park facilities and lake accesses exist at the Village of Empire Beach Park at the southwest end of the lake accessible from Niagara Street and South Lake Michigan Drive. S. Bar Lake is naturally

[1] Fish found within S. Bar Lake are reported as bluntnose minnow, large mouth bass, small mouth bass, yellow perch, Johnny darter, and Iowa darter (npshistory.com)

shallow and has reportedly been a discharge location of historic logging waste/saw dust, resulting in the potential for significant aquatic plant growth throughout the lake and making recreational activities, such as swimming and boating, somewhat less desirable. Maintaining or improving water quality and limiting nutrient/pollutant input will importantly assist in the maintenance of this important aquatic and recreational resource in the future.

As early as 2009, when the Village of Empire contracted with the Great Lakes Environmental Center (GLEC) of Traverse City, Michigan to complete a preliminary assessment of water quality and nutrient input to S. Bar Lake, lake study results indicated that the water quality of S. Bar Lake is acceptable but not as high as other lakes in the Grand Traverse region (GLEC, 2014). This study concluded that this may be due to S. Bar Lake's specific physical characteristics, but may also result from water quality impacts from surface water runoff (GLEC, 2014). The 2014 study included evaluating nutrient loading three times during the year and partnering with The Watershed Center Grand Traverse Bay to perform a shoreline vegetation buffer inventory on S. Bar Lake, a *Cladophora* (i.e., a nuisance algae) survey, and an assessment of road/stream crossings of S. Bar Lake inlet tributaries. The results of the 2014 study prompted this more comprehensive study to summarize existing and gather contemporary water quality data, and to provide recommendations for the future.

Figure 1. S. Bar Lake Watershed Map



Groundwater monitoring well data has been collected from 2006 to 2018 by Village Department of Public Works Director, John Friend, and a summary of these groundwater monitoring results are also summarized in this report. As part of this study, Grobbel Environmental & Planning Associates also collected groundwater monitoring well samples in 2019 and those results are also included in this report.

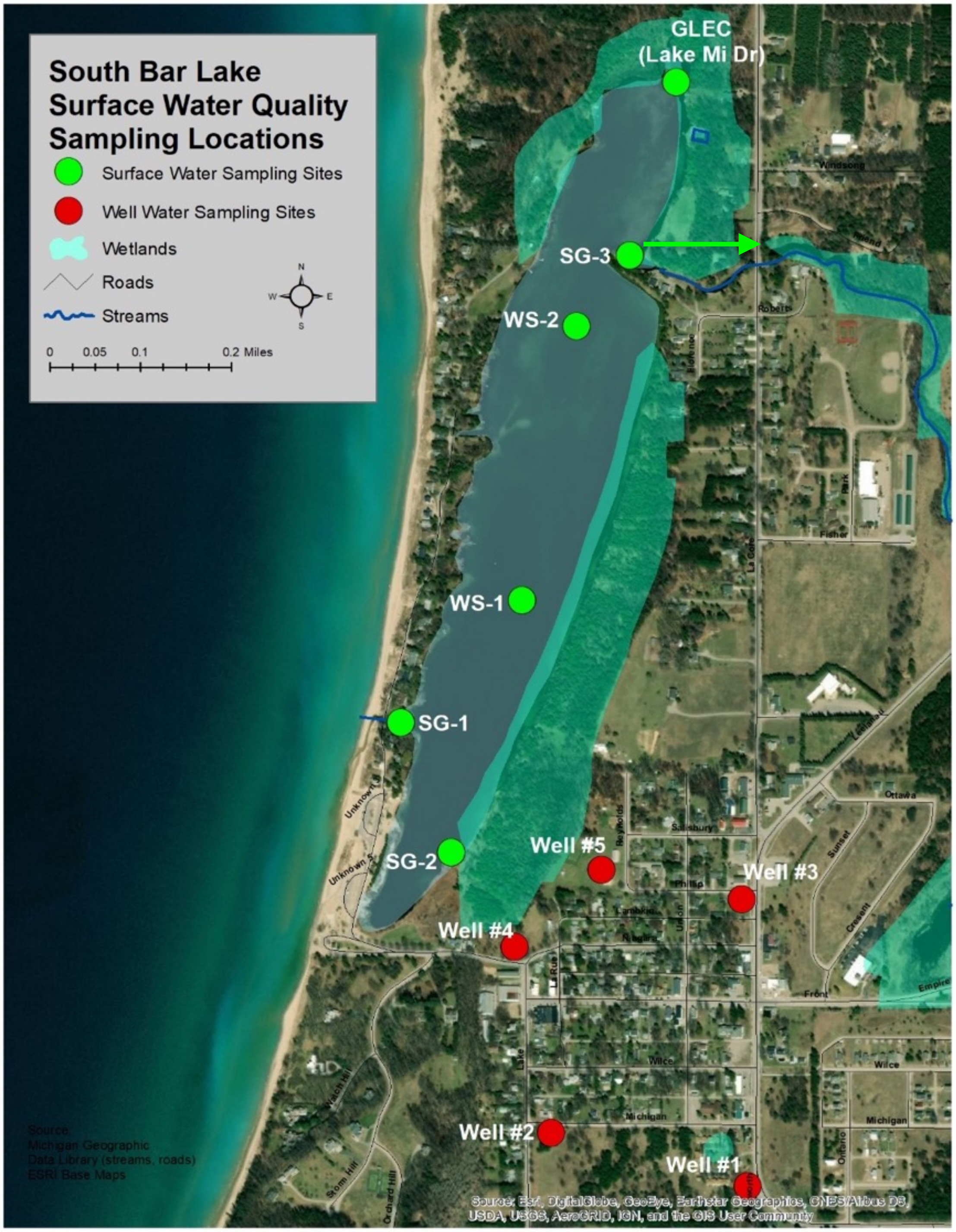
South Bar Lake Association

The South Bar Lake Association (SBLA) consists of owners of property bordering S. Bar Lake and other interested citizens. The association is “for the purpose of maintaining, promoting and protecting the health and natural beauty of S. Bar Lake and its supporting ecosystems.” The association goal is to be a support group, information resource and community voice.

The SBLA, since 2011, conducts annual water quality tests in support of the State of Michigan Cooperative Lakes Monitoring Program (CLMP). Data collected is reported to MiCORPs, and a report generated by the State. Data collected includes Total Phosphorus (in ppb, Spring overturn 3 weeks after ice-out and late Summer), Secchi disk readings (in feet, done weekly during summers), Chlorophyll-a (in ppb, 5 times per summer, every other year), tri-annual aquatic plant identification and density mapping (done 2014, 2017 with the assistance of Dr. Jo Latimore). Results of the SBLA testing efforts were included in this study.

In 2019, the Village of Empire contracted with Grobbel Environmental & Planning Associates to collect additional data and summarize the water quality results to date. Dr. Christopher Grobbel of Grobbel Environmental & Planning Associates sampled at five (5) locations (see Figure 2 below) in June and September of 2019. These correspond to four of the GLEC sampling locations also shown in Figure 2, however one of the GLEC locations (i.e., Lake Michigan Drive) was not sampled in 2019.

Figure 2. Water Sample Locations - S. Bar Lake



Sample location Key:

SG-1 - latitude 44 degrees 48’ 55.58” N & longitude 86 degrees 04’ 00.22” W

SG-2 - latitude 44 degrees 48’ 47.00” N & longitude 86 degrees 03’ 54.40” W

SG-3 - latitude 44 degrees 49’ 28.82” N & longitude 86 degrees 03’ 30.95” W

WS-1 - latitude 44 degrees 49’ 02.69” N & longitude 86 degrees 03’ 50.50” W

WS-2 - latitude 44 degrees 49’ 18.53” N & longitude 86 degrees 03’ 45.83” W

Water quality parameters

Below is a summary of the water quality parameters collected and the standards for each parameter.

Nutrients (i.e., Phosphorus and Nitrogen)

Nutrients, such as nitrogen and phosphorus, are essential for plant and animal growth and nourishment, but the overabundance of certain nutrients in water can cause a number of adverse health and ecological effects. Phosphorous and nitrogen are considered a “limiting nutrients” in fresh water aquatic systems. These nutrients are required for biological growth, but slight increases can lead to water quality degradation, change from cold water to warm water aquatic biological systems and toward higher lake trophic or productivity levels. An example would be going from an oligotrophic or low productivity associated with low phosphorous and nitrogen concentrations to mesotrophic (i.e., moderate productivity associated with medium phosphorous and nitrogen concentrations) or eutrophic (i.e., high productivity associated with high phosphorous and nitrogen concentrations) status.[2] Eutrophic and high nutrient regimes in freshwaters re generally considered being less desirable for recreation and lower quality waters. South Bar Lake is on considered to be mesotrophic, as will be explained in the summary of data below.

[2] Wetzel, Robert G., Limnology, Lake and River Ecosystems, 1.3 the Phosphorous Cycle, The Importance of Nutrient Loading to Aquatic Ecosystems, Third Edition, Academic Press, 2001, pp. 274-275.

Phosphorus (P)

Phosphorus (P) is an essential nutrient for all life forms and is the eleventh-most abundant mineral in the earth's crust. It is needed for plant growth and is required for many metabolic reactions in plants and animals. Organic phosphorus is a part of living plants and animals, their by-products, and their remains. Generally, phosphorus is the limiting nutrient in freshwater aquatic systems. That is, if all phosphorus is used, plant growth will cease, no matter how much nitrogen is available. Phosphorus typically functions as the "growth-limiting" factor because it is usually present in very low concentrations. The natural scarcity of phosphorus can be explained by its attraction to organic matter and soil particles. Any unattached or "free" phosphorus is quickly removed from the aquatic system by algae and larger aquatic plants. Excessive concentrations of phosphorus can quickly cause extensive growth of aquatic plants and algal blooms. Several detrimental consequences may result.

Phosphorus may accumulate in bottom sediment, both in deposited clays and silts and deposited organic matter. In such cases, phosphorus and other nutrients may be released from the sediment in the future. This results in an internal phosphorus loading. Because of this phenomenon, a reduction in phosphorus inputs may not be effective in reducing algal blooms for a number of years.

Phosphorus enters surface waters from both point and non-point sources. The primary point source of phosphorus is sewage treatment plants. Additional phosphorus originates from the use of industrial products, such as toothpaste, detergents, pharmaceuticals, and food-treating compounds. Non-point sources of phosphorus include both natural and human sources. Natural sources include 1) phosphate deposits and phosphate-rich rocks which release phosphorus during weathering, erosion, and leaching, and 2) sediments in lakes and reservoirs which release phosphorus during seasonal overturns. The primary human non-point sources of phosphorus include runoff from: 1) land areas being mined for phosphate deposits; 2) agricultural areas; and 3) urban/residential areas.

Finally, high nutrient concentrations interfere with recreation and aesthetic enjoyment of water resources by causing reduced water clarity, unpleasant swimming conditions, objectionable odors, blooms of toxic and nontoxic organisms, interference with boating, and "polluted appearances." The economic implications are significant for many communities.

Water Quality Standards for Phosphorus[3]

Rule 60 of the Michigan Water Quality Standards (Part 4 of Act 451) limits phosphorus concentrations in point source discharges to 1 mg/L of total phosphorus as a monthly average. The rule states that other limits may be placed in permits when deemed necessary. The rule also requires that nutrients be limited as necessary to prevent excessive growth of aquatic plants, fungi or bacteria, which could impair designated uses of the surface water. The Michigan Department of Environmental Quality, Part 201 Cleanup Criteria state the groundwater surface water interface standard for Total Phosphorous in surface waters is 10 mg/L.[4]

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[3] michigan.gov/documents/deq

[4] MDEQ: Table 1. Groundwater. Residential and Non-residential Part 201 Generic Cleanup Criteria and Screening Levels/ Part 213 Risk-based Screening Levels, December 30, 2013, Footnote (EE), R299.49.

Nitrogen[5]

Nitrogen, in the forms of nitrate, nitrite, or ammonium, is a nutrient needed for plant growth. About 78% of the air that we breathe is composed of nitrogen gas, and in some areas of the United States, particularly the northeast, certain forms of nitrogen are commonly deposited in acid rain.

Although nitrogen is abundant naturally in the environment, it is also introduced through sewage and fertilizers. Chemical fertilizers or animal manure is commonly applied to crops to add nutrients. It may be difficult or expensive to retain on site all nitrogen brought on to farms for feed or fertilizer and generated by animal manure. Unless specialized structures have been built on the farms, heavy rains can generate runoff containing these materials into nearby streams and lakes. Wastewater-treatment facilities that do not specifically remove nitrogen can also lead to excess levels of nitrogen in surface or groundwater.

Nitrate can get into water directly as the result of runoff of fertilizers containing nitrate. Some nitrate enters water from the atmosphere, which carries nitrogen-containing compounds derived from automobiles and other sources. More than 3 million tons of nitrogen is deposited in the United States each year from the atmosphere, derived either naturally from chemical reactions or from the combustion of fossil fuels, such as coal and gasoline. Nitrate can also be formed in water bodies through the oxidation of other forms of nitrogen, including nitrite, ammonia, and organic nitrogen compounds such as amino acids. Ammonia and organic nitrogen can enter water through sewage effluent and runoff from land where manure has been applied or stored.

[5] USGS article Nitrogen and Water http://water.usgs.gov/edu/nitrogen.html

Water Quality Standards for Nitrogen

There is no specific Michigan water quality standard for nitrogen in surface waters. However, when a lake or stream does not meet designated uses, a Total Maximum Daily Load (TMDL) may be developed to determine the maximum daily load of a pollutant that a water body can assimilate and meet water quality goals. This load is then allocated to point source discharges, non-point source discharges, and a margin of safety reserve (i.e., to account for technical uncertainties). Water quality goals relating to nutrients state that "nutrients shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached, suspended, and floating plants, fungi, or bacteria, which are or may become injurious to the designated uses of the surface waters of the state.[6]"

TMDL development is a public process that works best with the involvement of all affected parties. This is particularly important during the discussion on allocation and implementation issues. Participation by local communities and landowners leads to more representative TMDLs that can be readily implemented, which can lead to faster improvements in water quality.

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[6] Michigan Department of Environmental Quality, Nutrient Framework to Reduce Phosphorous and Nitrogen Pollution, October 2013.

Following development of a draft TMDL, the document is noticed for public comment. After appropriate modifications are made in response to public comments, the TMDL is sent to the U.S. Environmental Protection Agency for approval. Upon approval, the state is required to implement the TMDL so the water body will meet applicable WQS. The TMDL is implemented through existing programs, such as the National Pollutant Discharge Elimination System permits for point source discharges and non-point source control programs, to achieve the necessary pollutant reductions for meeting the goal established in the TMDL.

Through 2013, 15 TMDLs have been written to ad-dress nutrient impairments in southern Lower Michigan waters. In Michigan, total phosphorus (TP) is most often the nutrient causing nuisance plant-based water quality impairment and most of nutrient TMDLs address TP loads. These TP TMDLs add up to a total reduction of approximately 150,000 pounds of phosphorus per year. To date there has not been a need for a TMDL on any water bodies in the S. Bar Lake.

The U.S. Environmental Protection Agency (EPA) has set the maximum contaminant level (MCL) for nitrate at 10 milligrams per liter and nitrite at 1 milligram per liter.

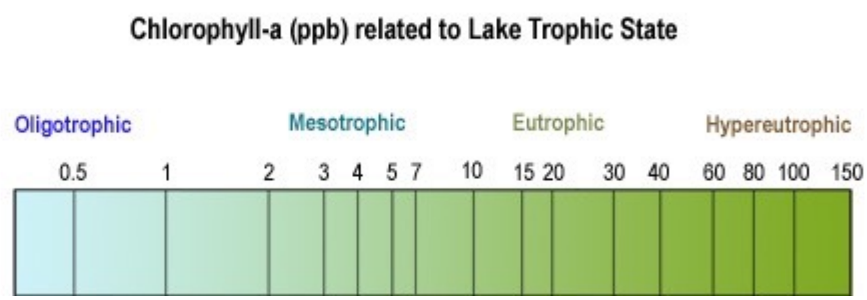
Chlorophyll-a

Chlorophyll-a is the green component in plants used for photosynthesis. It is used in water quality sampling to measure the magnitude of the algal community and to classify the trophic status index (i.e., TSI) of an inland fresh water lake. Higher concentrations can indicate poor water quality.

Although algae are a natural part of freshwater ecosystems, too much algae can cause aesthetic problems such as green scums and bad odors, and can result in decreased levels of dissolved oxygen. Some algae also produce toxins that can be of public health concern when they are found in high concentrations. One of the symptoms of degraded water quality condition is the increase of algae biomass as measured by the concentration of chlorophyll-a. Waters with high levels of nutrients from fertilizers, septic systems, sewage treatment plants and urban runoff may have high concentrations of chlorophyll a and excess amounts of algae.[7]

Water Quality Standards for Chlorophyll-a

Typically readings below 4 indicate an oligotrophic status and readings above 4 indicate a mesotrophic status.



(source: https://www.rmbel.info/primer/chlorophyll-a/)

Bacteria[8]

Bacteria are among the simplest, smallest, and most abundant organisms on earth with a reproduction or "re-generation" rate as short as 20 minutes for some bacteria species

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[7] https://www.epa.gov/national-aquatic-resource-surveys/indicators-chlorophyll

[8] michigan.gov/documents/deq

(e.g., *Escherichia coli*). While the vast majority of bacteria are not harmful, certain types of bacteria cause disease in humans and animals. Concerns about bacterial contamination of surface waters led to the development of analytical methods to measure the presence of waterborne bacteria. Since 1880, coliform bacteria have been used to assess the quality of water and the likelihood of pathogens being present. Although several of the coliform bacteria are not usually pathogenic themselves, they serve as an indicator of potential bacterial pathogen contamination. It is generally much simpler, quicker, and safer to analyze for these organisms than for the individual pathogens that may be present. Fecal coliforms are the coliform bacteria that originate specifically from the intestinal tract of warm- blooded animals (e.g., humans, water fowl, deer, beavers, raccoons, etc.)

Bacteria Sources

Human sources of bacteria can enter water via either point or non-point sources of contamination. Point sources are those that are readily identifiable and typically discharge water through a system of pipes. Non-point sources are those that originate over a more widespread area and can be more difficult to trace back to a definite starting point. Failed on-site wastewater disposal systems (i.e., septic systems) in residential or rural areas can contribute large numbers of coliforms and other bacteria to surface water and groundwater.

Animal sources of bacteria are often from non-point sources of contamination. Concentrated animal feeding operations, however, are often point source dischargers. Agricultural sources of bacteria include livestock excrement from barnyards, pastures, rangelands, feedlots, and uncontrolled manure storage areas. Storm water runoff from residential, rural, and urban areas can transport waste material from domestic pets and wildlife into surface waters. Land application of manure and sewage sludge can also result in water contamination, which is why states require permits, waste utilization plans, or other forms of regulatory compliance. Bacteria from both human and animal sources can cause disease in humans.

Bacteria-laden water can either leach into groundwater and seep, via subsurface discharge, into surface waters or rise to the surface and be transported by overland discharge. Bacteria in overland discharge can be transported freely or within organic particles. Overland discharge is the most direct route for bacteria transport to surface waters. Underground transport is less direct, because the movement of water and bacteria is impeded by soil porosity and permeability constraints.

Water Quality Standards for Bacteria

Rule 62 of the Michigan Water Quality Standards (Part 4 of Act 451) limits the concentration of microorganisms in surface waters of the state and surface water discharges. Waters of the state which are protected for total body contact recreation must meet limits of 130 *Escherichia coli* (i.e., *E. coli*) per 100 milliliters (ml) water as a 30-day average and 300 *E. coli* per 100 ml water at any time. The limit for waters of the state which are protected for partial body contact recreation is 1000 *E. coli* per 100 ml water.

Discharges containing treated or untreated human sewage shall not contain more than 200 fecal coliform bacteria per 100 ml water as a monthly average and 400 fecal coliform bacteria per 100 ml water as a 7-day average. For infectious organisms which are not addressed by Rule 62, The Department of Environmental Quality has the authority to set limits on a case-by-case basis to assure that designated uses are protected.

General Chemistry Water Quality Parameters: (Temperature, Dissolved Oxygen, Conductivity, and pH)

Temperature/Thermal Pollution[9]

Thermal pollution occurs when humans change the temperature of a body of water. Thermal pollution can be caused by storm water runoff from warm surfaces such as streets and parking lots. Soil erosion is another cause, since it can cause cloudy conditions in a water body. Cloudy water absorbs the sun's rays, resulting in a rise in water temperature. Thermal pollution may even be caused by the removal of trees and vegetation which normally shade water ways, such as creeks, drains, and streams.

Thermal pollution can result in significant changes to the aquatic environment. Most aquatic organisms are adapted to survive within a specific temperature range. As temperatures increase, cold water species, such as trout and stonefly nymphs, may be replaced by warm water species, like carp and dragonfly nymphs. Thermal pollution may also increase the extent to which fish are vulnerable to toxic compounds, parasites, and disease. If temperatures reach extremes of heat or cold, few organisms will survive.

In addition to thermal pollutions' direct effects on aquatic life, there are numerous indirect effects. Thermal pollution results in lowered levels of dissolved oxygen, since cooler water can hold more oxygen than warmer water. Low dissolved oxygen levels will cause oxygen-sensitive species to die.

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[9] michigan.gov/documents/deq

Photosynthesis and plant growth increase with higher water temperatures, resulting in more plants. When these plants die, they are decomposed by bacteria that consume oxygen. This can result in a further drop in dissolved oxygen levels.

The metabolic rate of fish and aquatic organisms also increases with increasing water temperatures, and additional oxygen is required for respiration. Life cycles of aquatic insects may speed up in response to higher water temperatures. Animals that feed on these insects may be affected, especially birds that depend on aquatic insects emerging at specific times during their migratory flights**.**

Michigan Water Quality Standards for Temperature

Rules 69 through 75 of the Michigan Water Quality Standards (Part 4 of Act 451) specify temperature standards which must be met in the Great Lakes and connecting waters, inland lakes, and rivers, streams and impoundments. The rules state that the Great Lakes and connecting waters and inland lakes shall not receive a heat load which increases the temperature of the receiving water more than 3 degrees Fahrenheit above the existing natural water temperature (after mixing with the receiving water). Rivers, streams and impoundments shall not receive a heat load which increases the temperature of the receiving water more than 2 degrees Fahrenheit for cold water fisheries, and 5 degrees Fahrenheit for warm water fisheries.

These waters shall not receive a heat load which increases the temperature of the receiving water above monthly maximum temperatures (after mixing). Monthly maximum temperatures for each water body or grouping of water bodies are listed in the rules. The rules state that inland lakes shall not receive a heat load which would increase the temperature of the hypolimnion (the dense, cooler layer of water at the bottom of a lake) or decrease its volume. Further provisions protect migrating salmon populations, stating that warm water rivers and inland lakes serving as principal migratory routes shall not receive a heat load which may adversely affect salmonid migration.

Temperature and Dissolved Oxygen (DO) are intimately linked in northern temperate lakes such as Upper and Lower Herring Lake, because of the formation of a vertical temperature gradient during summer periods. Because cooler water is denser than warm water it settles to the bottom of the lake. As the sun continues to heat the lake surface layer, the warm/cool water density gradient becomes too great to allow mixing of surface and bottom water. The upper layer of warm water is called the epilimnion, the transition zone the thermocline, and the cooler bottom water the hypolimnion. This lack of vertical mixing creates environments where near-bottom oxygen can be reduced or depleted. Near bottom oxygen depletion occurs in both Upper and Lower Herring Lakes.

Dissolved Oxygen[10]

Dissolved oxygen (DO) refers to the volume of oxygen that is contained in water. Oxygen enters the water as rooted aquatic plants and algae undergo photosynthesis, and as oxygen are transferred across the air-water interface. The amount of oxygen that can be held by the water depends on the water temperature, salinity, and pressure. Gas solubility increases with decreasing temperature (i.e., colder water holds more dissolved oxygen). Gas solubility increases with decreasing salinity (i.e., freshwater holds more dissolved oxygen than salty water).

Once absorbed, oxygen is either incorporated throughout the water body via internal currents or is lost from the system. Discharging water is more likely to have high dissolved oxygen levels compared to stagnant water because the water movement at

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10 michigan.gov/documents/deq

the air-water interface increases the surface area available to absorb the oxygen. Oxygen losses readily occur when water temperatures rise, when plants and animals respire (breathe), and when aerobic microorganisms decompose organic matter.

Oxygen levels are also affected by a daily (i.e., “diurnal”) cycle. Plants, such as rooted aquatic plants and algae produce excess oxygen during the daylight hours when they are photosynthesizing. During the dark hours they must use oxygen for life processes.

DO may play a large role in the survival of aquatic life in temperate lakes and reservoirs during the summer months, due to a phenomenon called stratification (i.e., the formation of layers). Seasonal stratification occurs as a result of water's temperature-dependent density. As water temperatures increase, the density decreases. Thus, the sun-warmed water will remain at the surface of the water body (i.e., forming the epilimnion), while denser, cooler water sinks to the bottom (i.e., the hypolimnion). The layer of rapid temperature change separating the two layers is called the thermocline.

At the beginning of the summer, the hypolimnion of the lake will contain more dissolved oxygen because colder water holds more oxygen than warmer water. However, as time progresses, an increased number of dead organisms from the epilimnion sink to the bottom and are broken down by microorganisms. Continued microbial decomposition eventually results in an oxygen-deficient hypolimnion. If the lake has high concentrations of nutrients, this process may be accelerated. When the growth rate of microorganisms is not limited by a specific nutrient, such as phosphorus, the dissolved oxygen in the lake could be depleted before the summer's end.

The introduction of excess organic matter may result in a depletion of oxygen from an aquatic system. Prolonged exposure to low dissolved oxygen levels (i.e., less than 5 to 6 mg/l DO) may not directly kill an organism but will increase its susceptibility to other environmental stresses. Exposure to less than 30% saturation (i.e., less than 2 mg/l DO) for one to four days may kill most of the aquatic life in a system.

Low DO levels may occur during warm, stagnant conditions that prevent mixing. In addition, high natural organic levels will often cause a depletion of DO.

Michigan Water Quality Standards for Dissolved Oxygen

Rule 64 of the Michigan Water Quality Standards (Part 4 of Act 451) includes minimum concentrations of dissolved oxygen which must be met in surface waters of the state. This rule states that surface waters designated as cold-water fisheries must meet a minimum DO standard of 7 mg/l, while surface waters protected for warm water fish and aquatic life must meet a minimum DO standard of 5 mg/l.

Conductivity[11]

Conductivity is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. Compounds that dissolve into ions are also known as electrolytes. The more ions that are present, the higher the conductivity of water. Likewise, the fewer ions that are in the water, the less conductive it is. Distilled or deionized water can act as an insulator due to its very low (if not negligible) conductivity value. Sea water, on the other hand, has a very high conductivity.

Conductivity is dependent on water temperature and salinity/TDS 38. Water flow and water level changes can also contribute to conductivity through their impact on salinity. Water temperature can cause conductivity levels to fluctuate daily. In addition to its

[11] http://www.fondriest.com/environmental-measurements/parameters/water-quality/conductivity-salinity-tds/#cond17

direct effect on conductivity, temperature also influences water density, which leads to stratification. Stratified water can have different conductivity values at different depths.

Distilled water has a conductivity in the range of 0.5 to 3 µmhos/cm. The conductivity of rivers in the United States generally ranges from 50 to 1500 µmhos/cm. Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macro-invertebrates. Industrial waters can range as high as 10,000 µmhos/cm[12]

pH[13]

Water contains both hydrogen (H+) and hydroxyl (OH-) ions. The pH of water is a measurement of the concentration of H+ ions, using a scale that ranges from 0 to 14. A pH of 7 is considered "neutral", since concentrations of H+ and OH- ions are equal. Liquids or substances with pH measurements below 7 are considered "acidic" and contain more H+ ions than OH- ions. Those with pH measurements above 7 are considered "basic" or "alkaline," and contain more OH- ions than H+ ions.

Fresh waters usually have a pH between 6.5 and 8.5. While there are natural variations in pH, many pH variations are due to human influences. Fossil fuel combustion products, especially automobile and coal-fired power plant emissions, contain nitrogen oxides and sulfur dioxide, which are converted to nitric acid and sulfuric acid in the atmosphere. When these acids combine with moisture in the atmosphere, they fall to earth as acid rain or acid snow. In some parts of the United States, especially the Northeast, acid rain has resulted in lakes and streams becoming acidic, resulting in conditions which are

12 https://archive.epa.gov/water/archive/web/html/vms59.html

13 michigan.gov/documents/deq

harmful to aquatic life. The problems associated with acid rain are lessened if limestone is present, since it is alkaline and neutralizes the acidity of the water.

Most aquatic plants and animals are adapted to a specific pH range, and natural populations may be harmed by water that is too acidic or alkaline. Immature stages of aquatic insects and young fish are extremely sensitive to pH values below 5. Even microorganisms which live in the bottom sediment and decompose organic debris cannot live in conditions which are too acidic. In very acidic waters, metals which are normally bound to organic matter and sediment are released into the water. Many of these metals can be toxic to fish and humans. Below a pH of about 4.5, all fish die.

Michigan Water Quality Standards for pH

Rule 53 of the Michigan Water Quality Standards (Part 4 of Act 451) states that the hydrogen ion concentration expressed as pH shall be maintained within the range of 6.5 to 9.0 in all waters of the state.

Exotic/Invasive Mussels in the Great Lakes and Connecting Waters

The zebra mussel (*Dreissena polymorpha*) is a small freshwater mollusk that originated in the Black, Caspian, and Azov Seas region of the former Soviet Union. By the late 18th and early 19th centuries, the construction of extensive canal systems enabled the spread of zebra mussels to almost all major drainages of Europe.

In the United States, the first account of an established zebra mussel population occurred in 1988 from Lake St. Clair, located between Lake Huron and Lake Erie. By

1990, zebra mussels had been found in all five Great Lakes. Over the next two years they made their way out of the Great Lakes through canals and into the Illinois, Hudson, Arkansas, Cumberland, Hudson, Mississippi, Ohio, and Tennessee rivers. The zebra mussel has been documented in over 600 lakes and reservoirs in the United States.

Zebra mussels likely entered the Great Lakes when ships arriving from Europe discharged ballast water containing a variety of aquatic organisms, including zebra mussel larvae. The species rapid dispersal throughout the Great Lakes and major river systems was due to its ability to attach to boats navigating these waters. Zebra mussels have an even more troubling characteristic: the ability to stay alive out of water for several days under moist and reasonably cool conditions. Thus, overland dispersal is another possible means of range expansion. An increasing number of small lakes near, but not connected to, the Great Lakes are now inhabited by zebra mussels. Beginning in 1993, many trailered boats crossing into California and other western states were found to have zebra mussels attached to their hulls. These mussels, discovered at agricultural inspection stations by informed officials, were removed before the boats were allowed to continue.

Another exotic invader, the quagga mussel (*Dreissena rostriformis bugensis*), probably arrived at the same time as the zebra mussel. Although the quagga mussel closely resembles its cousin, it is not expected to have as great an impact on native mussels because it does not show a preference for using them as substrates. However, in the Great Lakes, the quagga mussel appears to be outcompeting the zebra mussel to near exclusion.

Emerging Threats to Michigan Inland Lake Water Quality[14]

Cyanobacteria in Michigan fresh water inland lakes are associated with blue-green algal blooms and are driven by the coincident onset of warmer seasonal water temperatures from climate change, and the increased input of nutrients (i..e, phosphorous and nitrogen) from manicured and fertilized lawns, stormwater and agricultural runoff, sewage from leading septic tanks and point source discharges. Such water quality degradation and risk to health are also closely associated with shallow inland lakes, reservoirs, etc. Cyanobacgeria, i.e, mycrocystin, are toxins that can cause skin rashes, throat irritation, breathing problems, flu-like illnesses, and neurological damage upon exposure, etc. to humans and animals/pets alike. Whether a population of Cyanobacteria produces microcystin in inland waters is dependent off whether they possess toxin-producing genotypes or id they are not, and may be seasonal present only, i.e., for only part of the year, in Michigan inland lakes. Typically, blue algae blooms are observed to occur in localized areas, such as a relatively stagnant cell, within a water body and mycrocystin is generally found in obvious algal mats, scums, etc. Clear waters area often possess little or no mycrocystin.

The number of Michigan inland lakes with nuisance complaints of blue-green algae or cyanobacteria increased from 9 in 2013 to 50 in 2018 with 65 confirmed cyanobacteria blooms. A majority of Michigan waterbodies with Cyanobacteria blooms were natural lakes at 43%, lakes with a flow control structure, such as S. Bar Lake at 32%, and reservoirs/impoundments at 25%. EGLE researches reported in 2019 that this severely negative water quality trend is associated with lake eutrophication and slowly moving north through the lower Peninsula of Michigan.[15] Also, there is widespread consensus

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[14] See EGLE, Water Resources Division, August 2019: Staff Report, "Algal Toxin Monitoring in Michigan Inland Lakes: 2016-2018 Results," Aaron Parker, MI/EGLE/WRD-19/013.

[15] Ibid., p. 15.

among researchers that watershed with 10% of more impervious surface experience water quality degradation from storm water runoff.[16]

Also, the invasive and exotic aquatic plant starry stonewort (*Nitellopsis obtusa*), an aggressive macroalgae that entered the waters of the Great Lakes in 1983 and has been becoming widespread in Michigan inland lakes in the lower peninsula since the early 2000s. Starry stonewort is able to grow in shallow and deep waters, i.e., up to 30 feet, and forms dense "meadows" that can cover large surface areas of inland lakes. These "meadows" in turn typically hinder recreational uses, shade out and cause the loss of beneficial and native aquatic plants, and may reduce fish habitat. Starry stonewort has been found in Portage Lake in Manistee County. It is believed that starry stonewort is transported lake to lake in the boat ballasts, attachment to anchors, trailers and other boat equipment from plant fragments and bulbuls, i.e., small star-like structures associated with starry stonework reproduction and found all over the plant through all times of the year.

[16] Brabec, E., S. Schulte, and P.L. Richards. 2009. Impervious surfaces and water quality: A review of current literature and its implications for watershed planning. Journal of Planning Literature 16: 499-514; Carey, R.O., G.J. Hochmuth, C.J. Martinez, T.H. Boyer, V.D. Nair, M.D. Dukes, G.S. Toor, A.L. Shober, J.L. Cisar, L.E. Trenholm, and J.B. Sartain. 2012. A review of turfgrass fertilizer management practices: Implications for urban water quality. HortTechnology 22: 280- 291.; Carey, R.O., G.J. Hochmuth, C.J. Martinez, T.H. Boyer, M.D. Dukes, G.S. Toor, and J.L. Cisar. 2013. Evaluating nutrient impacts in urban watersheds: Challenges and research opportunities. Environmental Pollution 173: 138-149; and Schueler, T.R. and H.K. Holland. 2000. The practice of watershed protection. Center for Watershed Protection, Ellicott City, MD.

S. Bar Lake Water Quality Monitoring Results

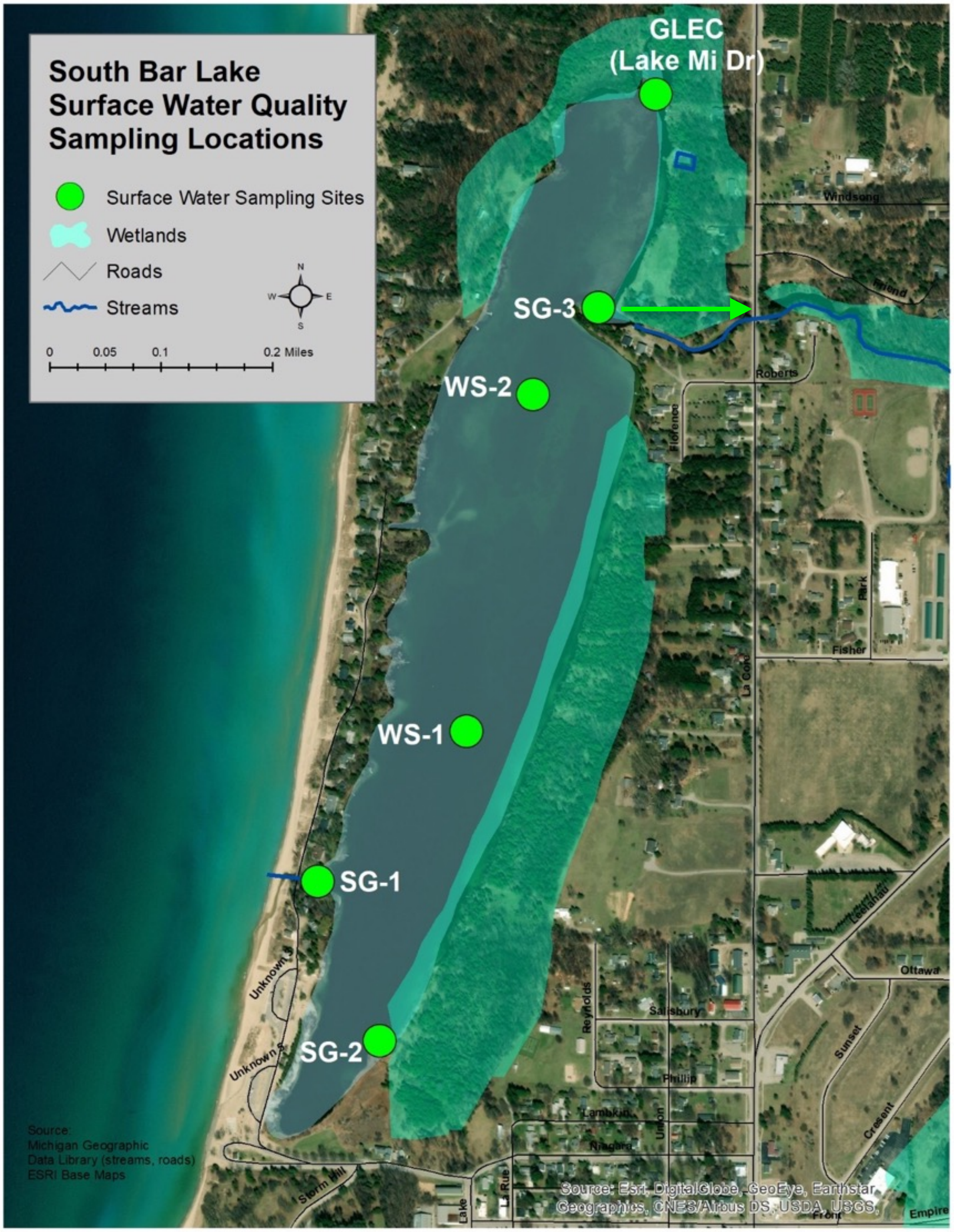
A considerable amount of water quality data has been collected from surface waters of S. Bar Lake over the last several decades and was compiled for this report. This historic water quality data was gathered various locations within the watershed during the period between 2006 and 2019 and is summarized below. This includes data collected by volunteers through the Cooperative Lakes Monitoring Program (CLMP), the Village of Empire and the Great Lakes Environmental Center (GLEC). For the purposes of this report, the results from all the data collected mentioned above are summarized below. Water quality parameters analyzed for S. Bar Lake included nutrients (i.e., Nitrites, Total Phosphorus), Chlorophyll-a, and Secchi disc readings. Well testing included sampling for nutrients (i.e., Ammonia/Nitrates/Nitrites, and Total Phosphorus), water levels, and conductivity.

Water quality sampling and analysis were also completed in June 2019 and September 2019. Five water sampling locations included two within South Bar lake (WS-1 and WS-2) and three along the outlets or tributaries (SG-1, SG-2 and SG-3) (see Table 1 and Figure 2 below). Water quality parameters analyzed included nutrients (i.e., Ammonia/ Nitrates/Nitrites, and Total Phosphorus), and E. coli. A hand-held Hydrolab was used at specific depths in the lakes and at all the stream locations to measure and record pH, conductivity, temperature, total dissolved solids and dissolved oxygen.

Table 1. Water Quality Sample Locations

Site ID	**Location**	**Latitude**	**Longitude**
WS-1	S. Bar Lake - South End	44 49’ 02.69”N	86 03’ 50.50”W
WS-2	S. Bar Lake - North End	44 49’ 18.53”N	86 03’ 45.83”W
SG-1	S. Bar Lake - Outlet	44 48’ 55.58”N	86 04’ 00.22”W
SG-2	Niagara St. Inlet	44 48’ 47.00”N	86 03’ 54.40”W
SG-3	Florence St. Inlet	44 49’ 28.82”N	86 03’ 30.95”W

Figure 3. S. Bar Lake Sample Locations



2009 GLEC Study - Summary of Results

In 2009 a study conducted by the Great Lakes Environmental Center (GLEC) measured phosphorus input to the lake at its three (3) primary inlets demonstrated the predominant source of nutrients to S. Bar Lake was at the south inlet, near Niagara Street at the north end of the Village of Empire. Similarly, nitrogen inputs at the south inlet and at the Florence Street inlet (i.e., mid-lake) were considerably higher than the northern most inlet.

2014 GLEC Study - Summary of Results

The GLEC 2014 study concluded that the overall water quality of the S. Bar Lake is generally good, albeit based upon a limited number of samples. Water quality parameters analyzed included total phosphorus, Secchi depth, chlorophyll-a, hypolimnion dissolved oxygen, percent organic matte, and an analysis of S. Bar Lake's trophic status index.

GLEC concluded that based on limited parameters, S. Bar Lake water quality was classified as marginally mesotrophic or of moderate water quality. S. Bar Lake is very shallow, which may result in elevated water temperatures and higher levels of aquatic plants and algae. These conditions likely also contribute to S. Bar Lake's mesotrophic status. The inlet at the South end, I.e., near Niagara St., although low flow, consistently showed the highest concentrations of phosphorus and nitrogen (GLEC 2014).

Results of the shoreline survey, *Cladophora* survey, road/stream crossings and stormwater runoff analysis indicated that land uses and parcel conditions surrounding S. Bar Lake are generally in good shape, and may not be contributing significantly to nutrient input to or accumulation within S. Bar Lake.

Specifically, the 2014 GLEC shoreline survey documented that more than 75% of the shoreline has an 'excellent' or 'very good' shoreline buffer. The shoreline buffer survey incorporated variables such as shoreline description, slope characteristics, structures present, greenbelt condition, turf presence/absence and density, vegetation diversity, and erosion present, if any. Ninety-one (91%) percent of the S. Bar Lake shoreline rated ‘good’ to ‘excellent’ as indicative of development quality and the maintenance of nearshore habitat, both of which are important for the maintenance of the general health of S. Bar Lake.

The *Cladophora* survey measured amounts of *Cladophora*, a filamentous algae, in the shallow water shoreline areas for the purpose of determining where phosphorous and/or nitrogen may be entering the lake. The *Cladophora* survey found a total of eleven (11) locations found in August of 2013. Possible causes for the *Cladophora* noted included ‘septic systems' and 'natural causes.’ These results indicate that there are no readily apparent sources for the *Cladophora,* such as lawn fertilization, lake-side dumping, animal waste, and/or bank erosion. The study recommended repeating *Cladophora* inventory/study annually to monitor changes.

A total of four (4) road stream crossings were analyzed in Spring 2014 using the "Great Lakes Road Stream Crossing Inventory,” and a map was created of the inventoried sites. The inventory documented various types of information for each crossing including: general information (i.e., GPS point, stream/road names), crossing information (e.g., type, structure shape, inlet/outlet type, length/width/height, velocity in crossing, depth of water), stream information (e.g., flow level, scour pool or upstream pond present), road information (e.g., type, ownership, surface, width, location of low point, approaches, slope of embankment), erosion information, and a site drawing. No major issues only minor erosion was found other than a large algal mat at Site #2 near the Florence St. Inlet, a concern for nutrients entering S. Bar Lake at that location.

The Watershed Center of Grand Traverse Bay (TWC) conducted a stormwater assessment for the Village of Empire. As stormwater is a major contributor of pollutants waterbodies, it is important to effectively manage stormwater inputs, including in small communities. In Spring 2014 TWC staff met with the Village's Deputy Clerk and toured the Village to conduct the stormwater assessment. There are a series of underground infiltration trenches installed within the Village in the past to direct stormwater to infiltrate to groundwater along Front St. and along the M-22 corridor. Previously stormwater from the downtown area of Empire along Front Street was channeled to the S. Bar Lake south inlet near Niagara and Lake Streets, but stormwater been only occasionally observed to enter the South inlet since the installation of these stormwater infiltration trenches.

The assessment also noted a raised berm/sidewalk along Niagara Street at Lake Street prevents overland surface runoff from entering the south inlet, and that flow in the this South inlet channel presently is from groundwater interflow or “venting.” Specific recommendations from the TWC study included continuing to encourage land management practices, were applicable, to minimize nutrient inputs to tributaries to S. Bar Lake, particularly for inputs which may result from runoff from the Village or areas near tributaries where nutrient loading may be significant. The GLEC 2014 assessment recommended: a) the investigation of possible sources of nutrients at Site #2 near the Florence Street Inlet, b) the correction of erosion issues due to road runoff at the outlet of S. Bar Lake; c) continued maintenance of the Village’s stormwater infiltration system; and d) the nutrient monitoring of tributaries and S. Bar Lake every 4-5 years as keys to maintaining S. Bar Lake water quality.

S. Bar Lake Watershed Hydrology

The discharge in cubic feet per second (i.e., cfs) was monitored twice in 2019 at three (3) locations. It was also sampled in 2013 and 2014 (See Figure 3). The results are shown below (Table 2, Figure 4). The inlet shows about the same discharge between spring and summer while the outlet to Lake Michigan has a much higher flow (11.44 cfs in the spring). Florence inlet showed a discharge of 6.2 cfs in May and 4.29 cfs in September. The inlet, SG-1 (outlet) showed a much higher discharge in 2019 compared to earlier years (2013 and 2014). The flow at the inlets SG-2 and SG-3 were higher in the spring compared to the fall, which is to be expected.

Figure 4: Flow (cfs) for Inlets to and Outlet of S. Bar Lake

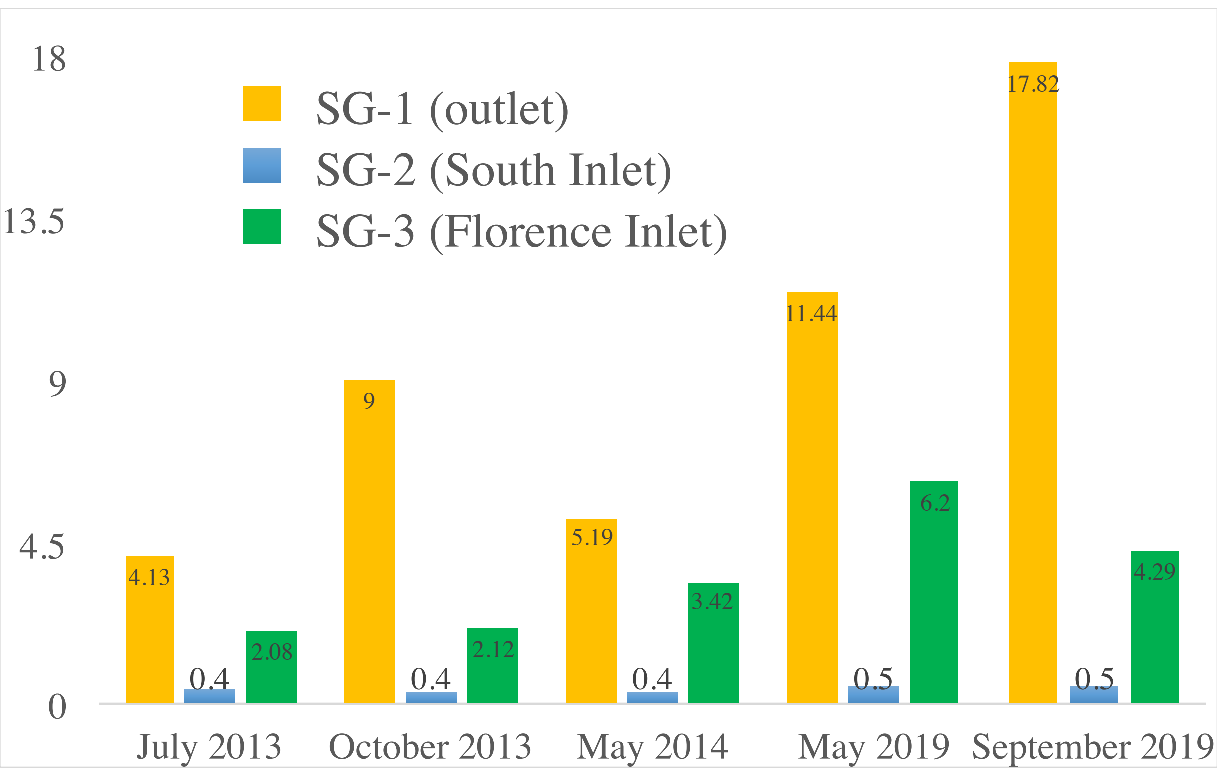


Table 2. Average Flow (cfs) per Year by Site

Site	2013-14	2019
SG-1	6.1	14.63
SG-2	0.39	0.50
SG-3	2.54	5.25

Nutrients

S. Bar Lake was sampled by GLEC for Total Phosphorus (TP) and Ammonia/Nitrite/Nitrate - Nitrogen (NOx) in the Summer and Fall of 2013 and in the Spring of 2014 at S. Bar Lake inlets (i.e., SG-2 and SG-3), the S. Bar Lake outlet (i.e., SG-1), and the middle of S. Bar Lake (i.e., WS-1). Data was also collected on TP from 2011 and 2019 through the MI Corps CLMP program. Water quality samples were also taken from five groundwater monitoring wells from 2006 to 2018. The data is summarized in Tables 3 through 6 below.

Table 3. Average Results of Total Phosphorus (TP), Nitrates (NOx), and loads for Sampling Locations on S. Bar Lake by GLEC from 2013 and 2014

Parameter	**South Lake (WS-1)**	**Lake Outlet (SG-1)**	**South Inlet (SG-2)**	**Florence Inlet (SG-3)**
TP (ug/L)	13.1	12.6	118.7*	6.6
NOx (mg/L)	0.558	0.43	4.48*	1.64
TP Loading - Lbs/Day	0.04	0.03	0.25*	0.09
NOx Loading -Lbs/Day	22.75	10.6	9.2	22.81*
Flow (cfs)	—	6.10	0.39	2.54

Table 4. Average Results of Total Phosphorus (TP), Ammonia (NH3), Nitrates (NO3) and Chloride (Cl) for Groundwater Monitoring Wells.

Parameter	Well 1	Well 2	Well 3	Well 4	Well 5
TP (ug/L)	0.5	0.09	0.17	0.83	0.27
NH3-N (mg/L)	0.06	0.10	0.06	0.06	0.06
NO3-N (mg/L)	2.2	1.4	3.3	9.4	2.9
Conductivity	865.8	494.1	526.1	640.3	608.8
Static Water Level (ft below ground surface)	12.5	13.9	13.5	8.3	10.4

Table 5. Average Results of Total Phosphorus (TP), Ammonia (NH3), Nitrates (NO3) and Chloride (Cl) for South Bar Lake comparing the GLEC data (2013-2014, the CLMP program (2011-2019) and 2019 data collected by Grobbel Environmental & Planning Associates

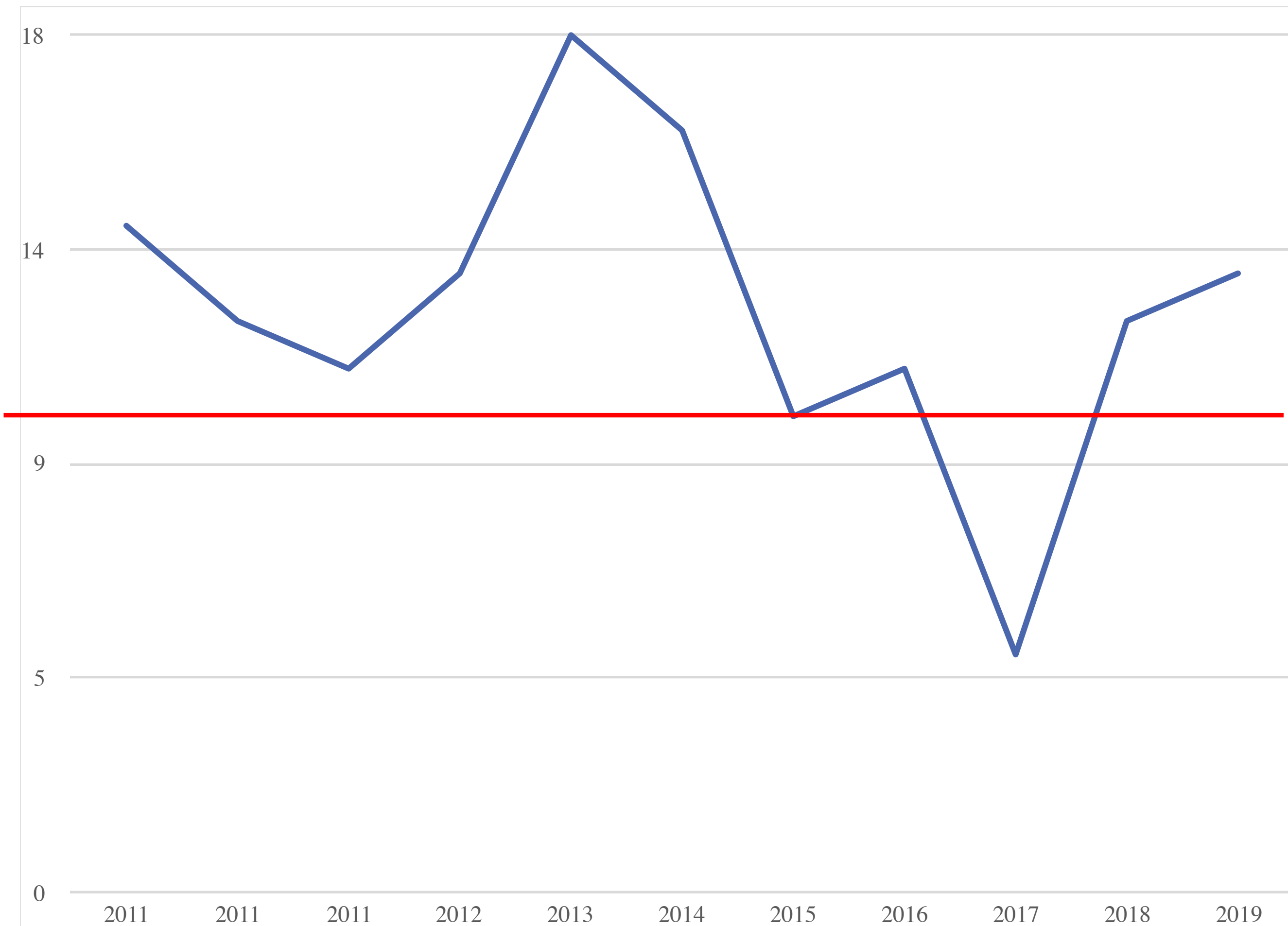
Parameter	GLEC (2013-2014)	CLMP (2011-2019)	2019
TP (ug/L)	13.1	11.9	ND*
NO3-N(mg/L)	NA	0.558	1.3
Cl (mg/L)	NA	3.6	NA

**ND- Non-detect, i.e., below laboratory detection limit of 20 ug/L*

Total Phosphorus (TP)

The average TP for South Bar Lake from 2011 to 2018 was often above the Michigan water standard of 10.0 ug/L (Figure 5, Table 7), with the exception of 2017. This data is from the MiCorps database gathered by SBLA Volunteers. Samples gathered in June and September of 2019 did not detect TP.

Figure 5. S. Bar Lake Total Phosphorus (TP) (ug/L)



Red line represents the EGLE TP water quality standard of 10 ug/L.

Table 7. S. Bar Total Average Phosphorous (ug/L) Summary – 2011-2019

Year	Avg TP (ug/L)
2011	11
2012	13
2013	18
2014	16
2015	14
2016	11
2017	5
2018	12

Groundwater Results for Total Phosphorus (TP)

From 2011 to 2018 the Village Department of Public Works Director, John Friend tested groundwater samples at five (5) well locations for TP, among other water quality parameters (see Figure 6 below).

Figure 6. Well Sampling locations in the Village of Empire

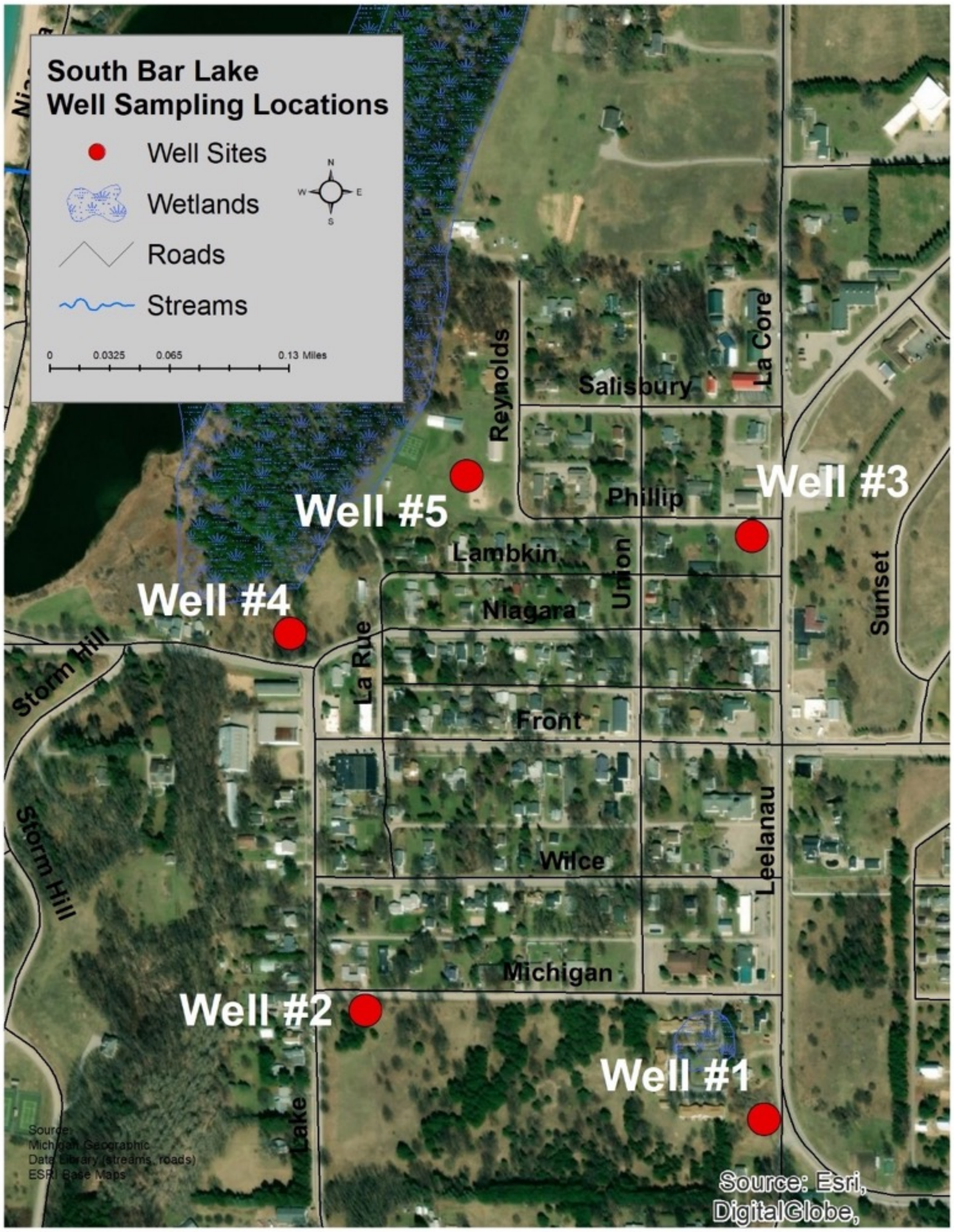


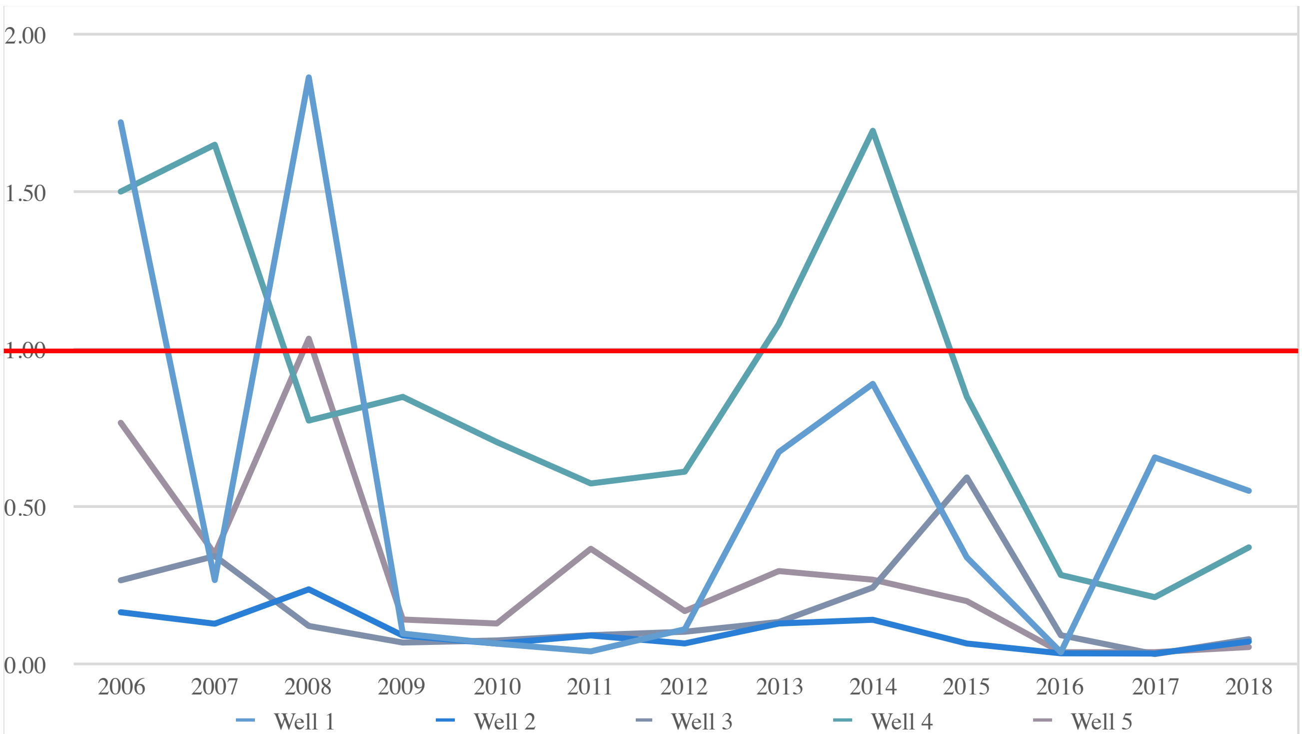
Table 8. Average TP (mg/L)* - Groundwater Monitoring Wells (2006 to 2018)

Year	Well 1	Well 2	Well 3	Well 4	Well 5
2006	**1.72**	0.16	0.27	**1.50**	0.77
2007	0.27	0.13	0.34	**1.65**	0.35
2008	**1.87**	0.24	0.12	0.77	**1.03**
2009	0.10	0.09	0.07	0.85	0.14
2010	0.06	0.06	0.07	0.71	0.13
2011	0.04	0.09	0.09	0.57	0.37
2012	0.11	0.06	0.10	0.61	0.17
2013	0.67	0.13	0.13	**1.08**	0.29
2014	0.89	0.14	0.24	**1.70**	0.27
2015	0.34	0.06	0.59	0.85	0.20
2016	0.04	0.03	0.09	0.28	0.04
2017	0.66	0.03	0.03	0.21	0.04
2018	0.55	0.07	0.08	0.37	0.05
Average	0.50	0.09	0.17	0.83	0.27

***Bold** indicates concentrations above Michigan GSI standard of 1.0 mg/L.

These results show that each groundwater monitoring wells (MW) MW-1, MW-4 and MW-5 have documented exceedances of groundwater/surface water criteria for TP. Monitoring wells 1 and 4 have documented the highest TP concentrations, although none of the monitoring wells average TP concentrations have exceeded the groundwater/surface water interface standard of 1.0 mg/L.[17] Near surface groundwater is interpreted to flow west-northwesterly through the Village of Empire.

Figure 7. TP (mg/L) for Groundwater Monitoring Wells (2011 to 2018)



Red line represents the EGLE TP groundwater/surface water interface quality standard of 1.0 ug/L.

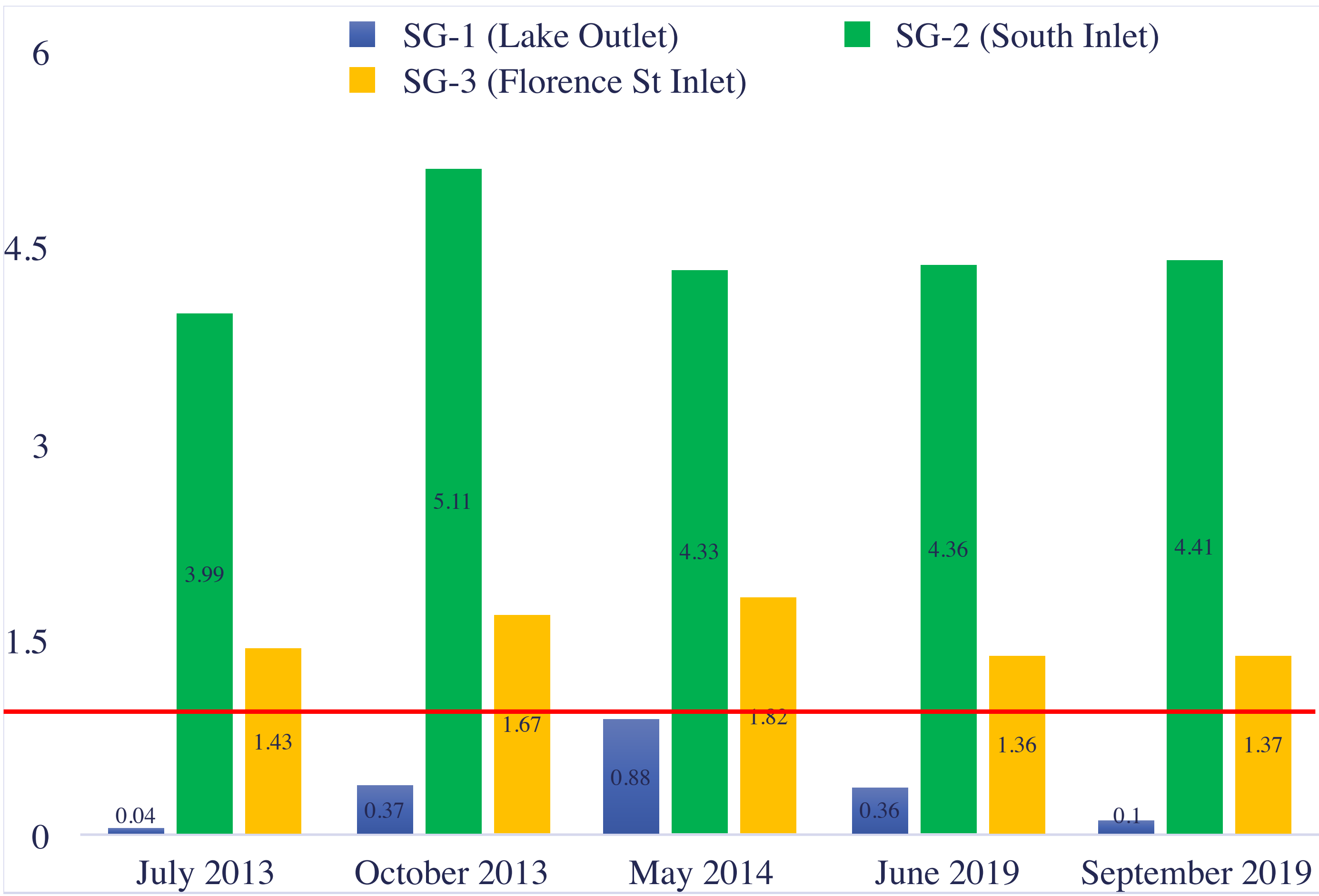
Nitrites (NO3)

Nitrates were sampled at the outlet and inlets in both 2013-14 and in 2019. Figure 8 below shows that the sampling results for the two inlets (SG-2 and SG-3) for Nitrite were

[17] EGLE Part 201 groundwater/surface water interface criteria is 1.0 mg/L (or 1,000 ug/L). See R299.49 Footnotes for Generic Cleanup Criteria Tables, Cleanup Criteria Requirements for Response Activity, Effective date December 30, 2013, GSI Criteria Updated June 25, 2018.

above the EPA's limit for drinking water (1 mg/L) and the natural level of ammonia or nitrate in surface water is typically low (less than 1 mg/L) **(see USEPA 57: Nitrates).** The South inlet at SG-2 showed the highest readings.

Figure 8. Nitrogen (NOx) results (mg/L) for Inlets and Outlets on S. Bar Lake



Red line represents the EGLE and USEPA drinking water quality standard of 1.0 mg/L

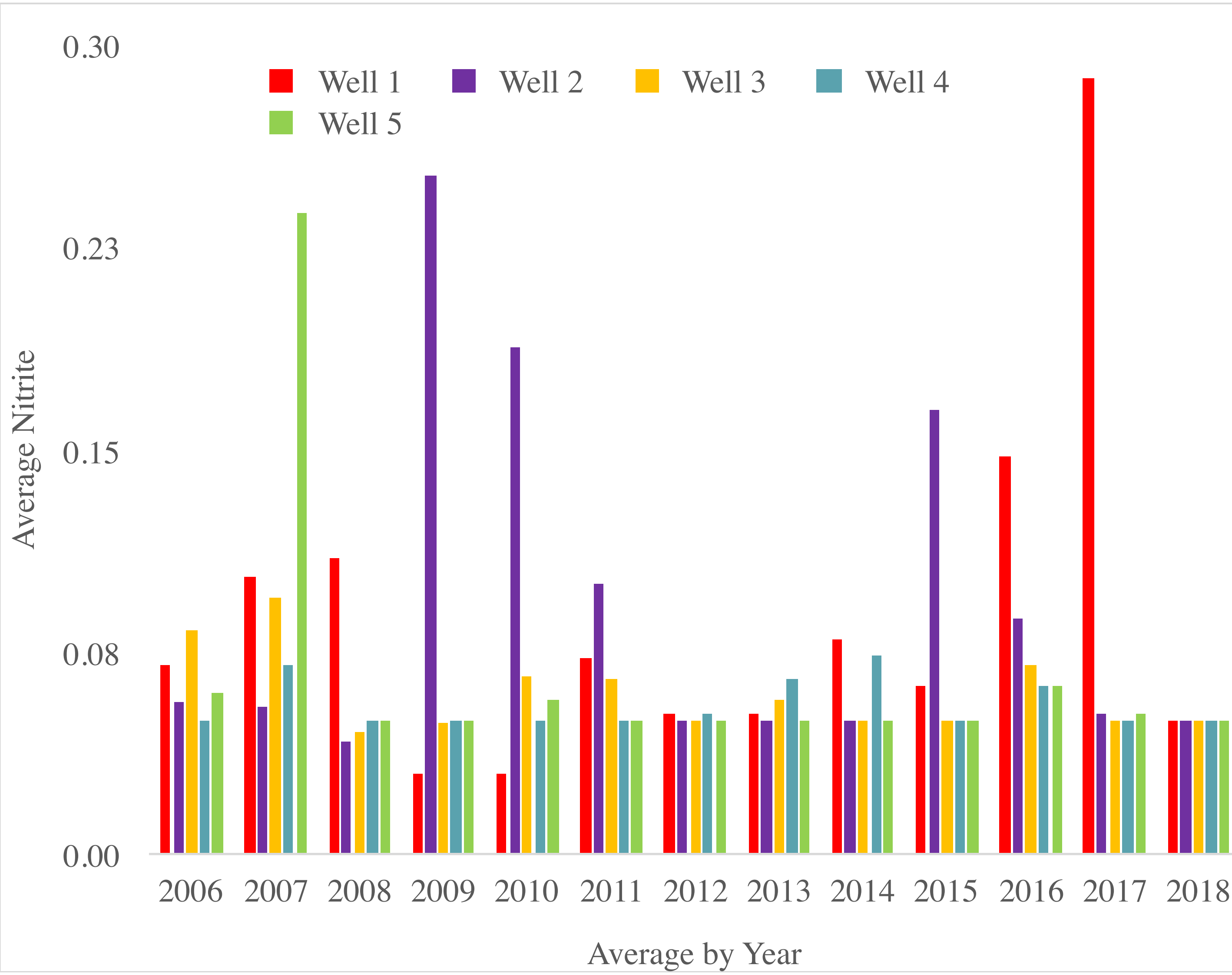
Groundwater results for Nitrogen (NOx)

From 2011 to 2018 the Village Department of Public Works Director John Friend tested groundwater samples at five well locations (see Table 9 and Figure 9 below). These results showed Wells 1, 2 and 5 to have the highest Nitrite concentrations, but none of the results for Nitrite were above Michigan EGLE's and the USEPA's limit for drinking water (1 mg/L). GSI criteria for NOx have not been promulgated.

Table 9. Average Nitrite (mg/L) Concentration by Year for Groundwater Monitoring Wells

Year	Well 1	Well 2	Well 3	Well 4	Well 5
2006	0.07	0.06	0.08	0.05	0.06
2007	0.10	0.06	0.10	0.07	0.24
2008	0.11	0.04	0.05	0.05	0.05
2009	0.03	0.25	0.05	0.05	0.05
2010	0.03	0.19	0.07	0.05	0.06
2011	0.07	0.10	0.07	0.05	0.05
2012	0.05	0.05	0.05	0.05	0.05
2013	0.05	0.05	0.06	0.07	0.05
2014	0.08	0.05	0.05	0.07	0.05
2015	0.06	0.17	0.05	0.05	0.05
2016	0.15	0.09	0.07	0.06	0.06
2017	0.29	0.05	0.05	0.05	0.05
2018	0.05	0.05	0.05	0.05	0.05
Average	**0.09**	**0.10**	**0.06**	**0.06**	**0.07**

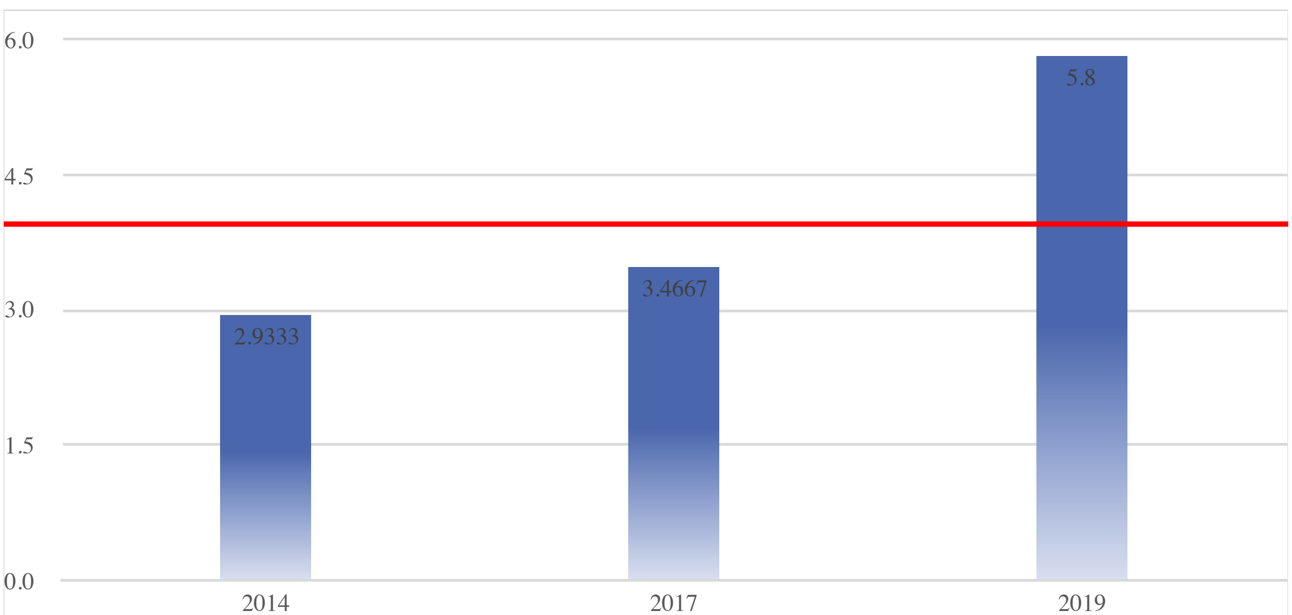
Figure 9. Nitrite (ug/L) for Groundwater Monitoring Wells (2006 to 2018)



Chlorophyll-a

Chlorophyll-a was sampled through the CLMP program and reported to MICorps in 2014, 2017 and 2019. See Figure 10 and Table 10 below. The average Chlorophyll-a concentrations in 2019 indicate S. Bar Lake posses a mesotrophic status. The reported increase in algae and aquatic plant growth from 2014 to 2019 is likely related to nutrient inputs of from the South (SG-2) Florence St inlets (SG-3) to S. Bar Lake, increased sunlight penetration of the water column due to the entry and presence of exotic/invasive filter feeders, and climate change.

Figure 10. Average Chlorophyll-a by year (ug/L)



Red line represents the TSI mesotrophic standard of 4.0 ug/L.

Table 10. Average S. Bar Lake Chlorophyll-a Concentrations (ug/L) (2014-2019)

Year	Average Chlorophyll-a (ug/L)*
2014	2.9
2017	3.5
2019	**5.8***
Average	**3.6**

*Average Chorophyll-a concentration of 4.0 ug/L is considered mesotrophic.

Tropic Status Index or TSI

According to the 2018 Data Report for South Bar Lakes compiled by the Cooperative Lakes Monitoring (CLMP) program, S. Bar Lake is rated between the mesotrophic and eutrophic lake classification. Specifically, S. Bar Lake has an average TSI score of 46, based on 2018 Secchi transparency and summer total phosphorus data. Although, this trophic status for S. Bar Lake trends slightly more mesotrophic than eutrotrophic. Long term trends indicate that the trophic status parameters have not changed beyond minor year-to year variation since monitoring began. The year 2018 had a higher summer phosphorus sample than has been typical (CLMP 2018 report).

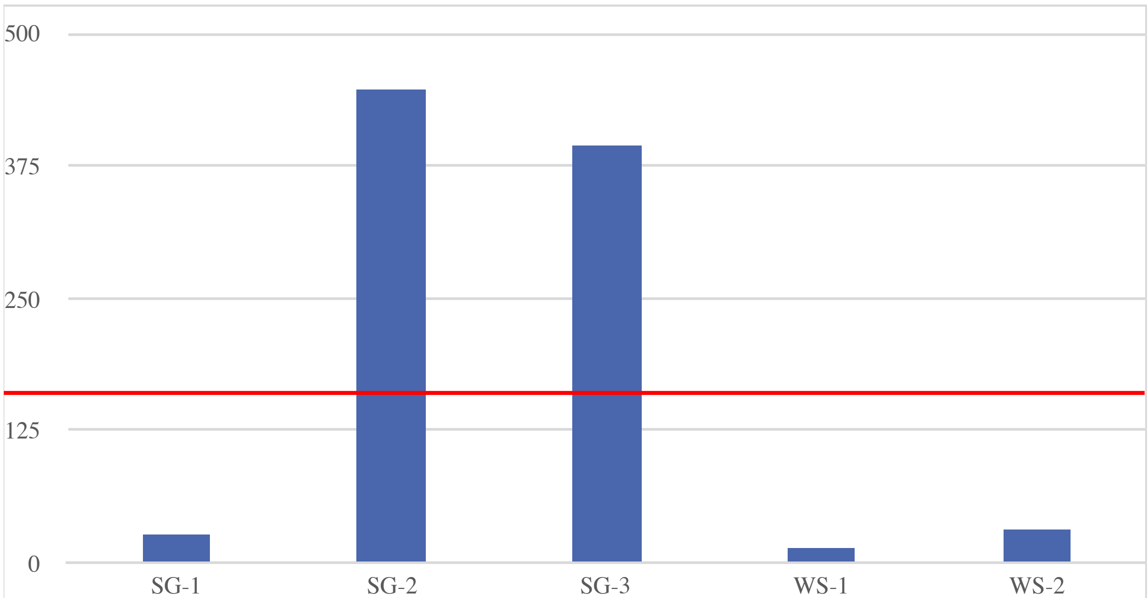
E. coli

E. coli are diverse group of bacteria that normally live in the intestines of humans and other warm-blooded animals. Most *E. coli* are harmless and actually are an important part of a healthy human intestinal tract. However, some *E. coli* are pathogenic, meaning they can cause illness, such as diarrhea or illness outside of the intestinal tract. Those

E. coli that can cause diarrhea can be transmitted through contaminated water or food, or through direct contact with animals or persons. Harmful *E. coli* strains are categorized into “pathotypes.” Six (6) *E. coli* pathotypes associated with diarrhea, and collectively are referred to as diarrheagenic *E. coli* include: 1) Shiga toxin-producing *E. coli* (STEC) —STEC may also be referred to as Verocytotoxin-producing *E. coli* (VTEC) or enterohemorrhagic *E. coli* (EHEC). These pathotypes are most commonly associated with food borne *E. coli* outbreaks; 2) Enterotoxigenic *E. coli* (ETC); 3) Enteropathogenic *E. coli* (EPEC); 4) Enteroaggregative *E. coli* (EAEC); 5) Enteroinvasive *E. coli* (EIEC): and 6) Diffusely adherent *E. coli* (DAEC). Water samples collected from within the S. Bar Lake Watershed were analyzed for total *E. coli* bacteria, including the above six *E. coli* pathotypes.

Average *E. coli* results within S. Bar Lake were relatively low, but the two inlets SG-2 and SG-3 documented E. coli results in 2019 exceeding the state limits for human health (see Figure 11, Table 11).

Figure 11. Average E. coli results* for S. Bar Lake Watershed (2019)



*Michigan water quality standards are 130 *E. coli* per 100 milliliters (mL) water as a 30-day average, and 300 *E. coli* per 100 mL water at any time.

Groundwater *E. coli* and BTEX Results

As general indicators of the potential for cultural impact on groundwater quality within the S. Bar Lake watershed, *E.coli* and BTEX (i.e., petroleum general chemistry parameters Benzene, Toluene, Ethylbenzene and Xylene isomers) were tested in all five groundwater monitoring wells on June 13, 2019. Results showed no detection for all well sites for BTEX. Only Well #1 (i.e., at Wood and M-22 Highway) detected *E. coli*, and that *E. coli* concentration was well-below state limits at 8 colonies/100 mL.

General Water Quality Parameters: (Temperature, Dissolved Oxygen, Conductivity, pH, and Oxidation/Reduction Potential)

Hydrolab profile data and water samples have were collected by Grobbel Environmental & Planning Associates in June and September of 2019.The sampling locations for the hydrolab are shown the same locations as shown in Figure 3 (page 20) (SG-1, SG-2, SG-3 and WS-1 and WS-3). Table 11 below shows the average hydrolab readings for 2019.

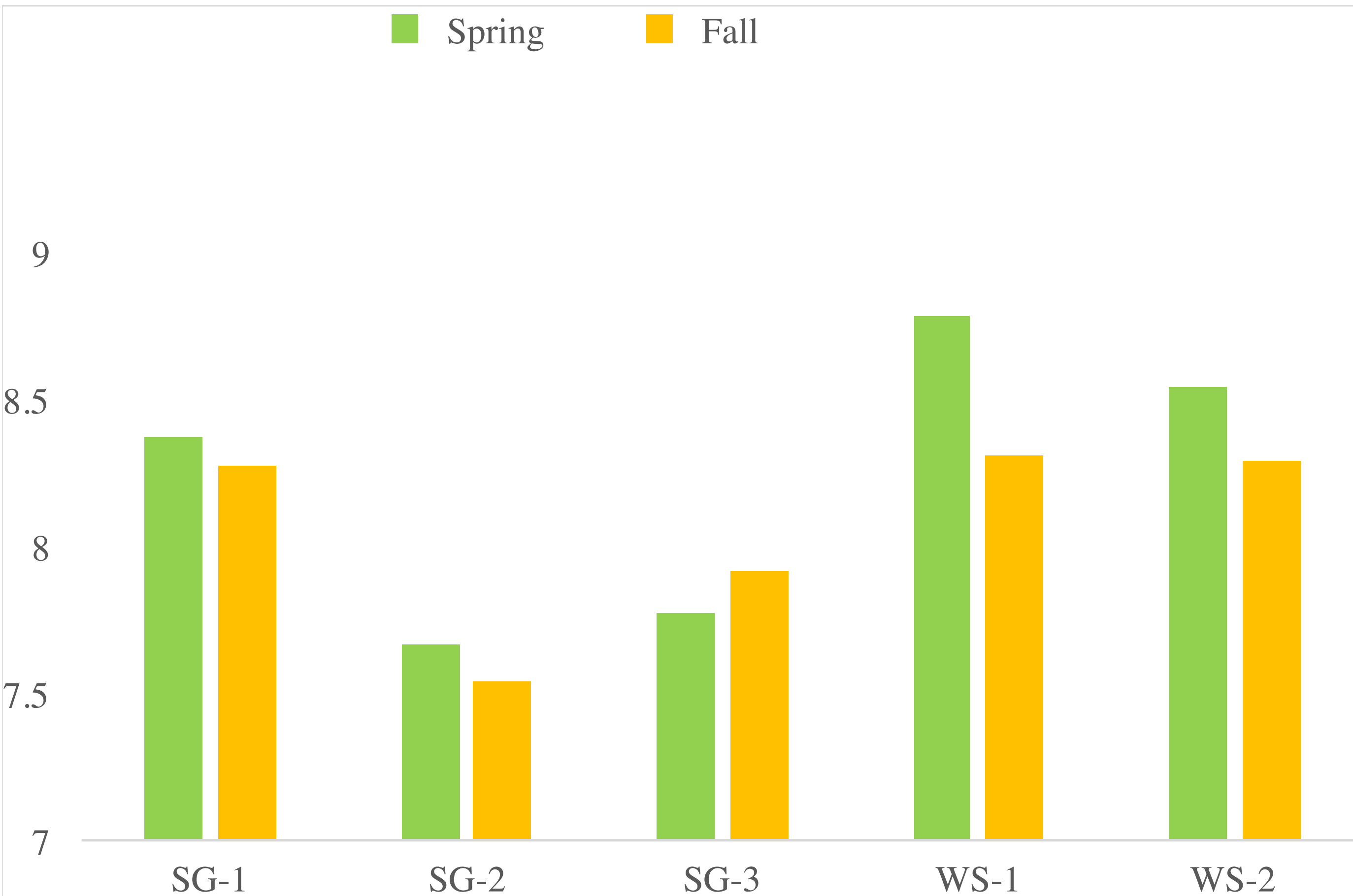
Table 11. Hydrolab Average Results for South Bar Lake Sampling Sites

Site	Temp (F)	pH	SpCond (aeS/cm	Dissolved Oxygen (mg/L)
WS-1	59.3	8.3	292.5	9.9
WS-2	50.9	7.6	297.2	10.6
SG-1	50.4	7.8	361.2	10.9
SG-2	65.6	8.5	283.0	12.8
SG-3	65.1	8.4	287.8	10.2
Average	**58.2**	**8.1**	**304.3**	**10.9**

pH

The pH was sampled for S. Bar Lake in June and September of 2019. The pH of S. Bar Lake was the highest in the Spring (8.6) compared to Fall. Figure 12 shows the results of the pH in S. Bar Lake in 2019 in June and September. The average pH for S. Bar Lake during 2019 was 8.1 and is within the Michigan water quality range of 6.5 to 9.0 in all waters of the State of Michigan.

Figure 12. Average pH for S. Bar Lake - 2019

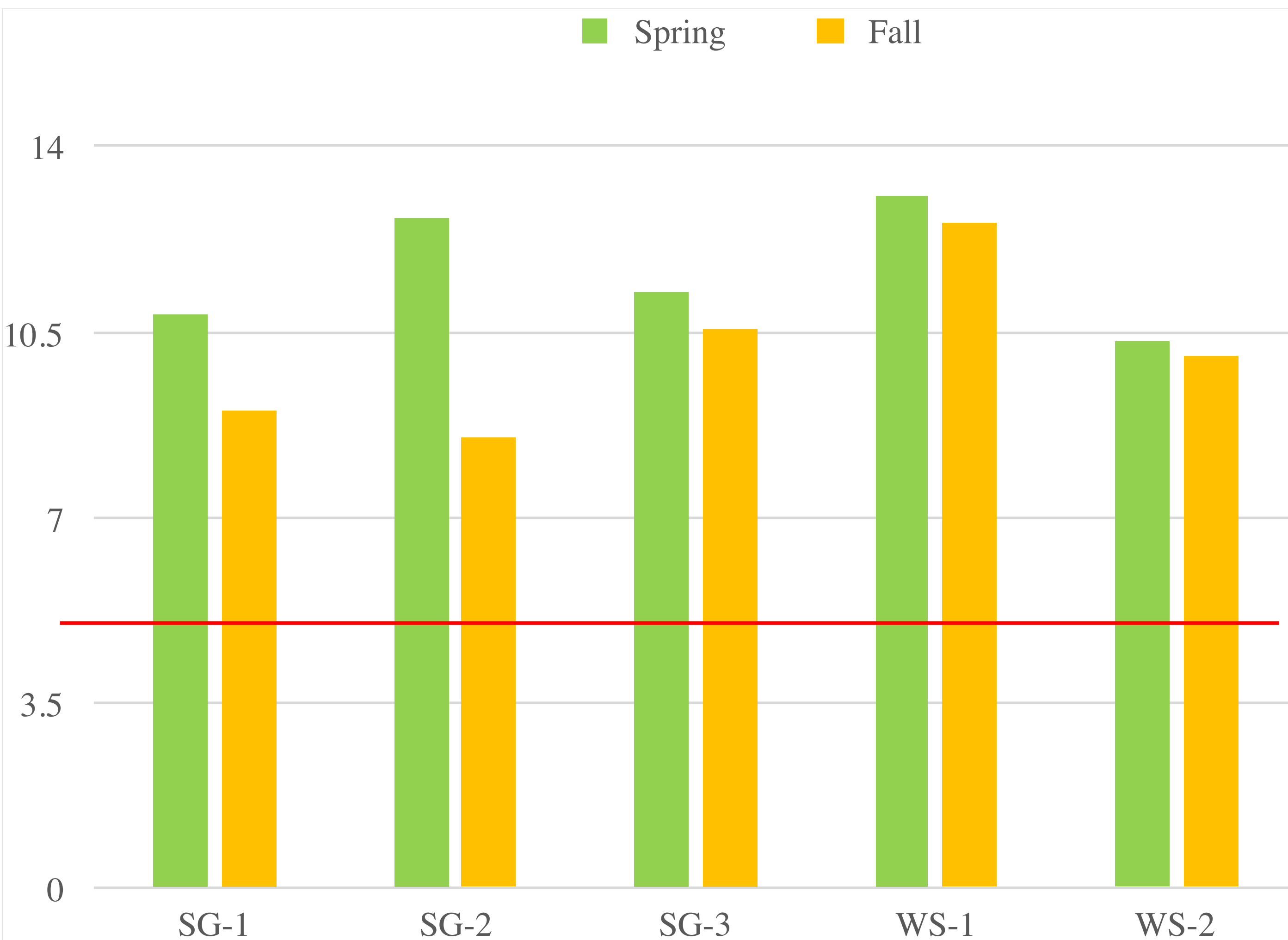


Dissolved Oxygen (DO)

Dissolved Oxygen (DO) was sampled using a hydrolab in S. Bar Lake in 2019 at two sampling locations and the two inlets and one outlet. Results show the readings are above the Michigan standards. These standards indicate that surface waters designated as cold-water fisheries must meet a minimum of 7 mg/l and warm water fisheries a minimum of 5 mg/L. S. Bar Lake is considered a warm water fishery (Figure 13). This is likely due to the increase nutrients and plant growth entering S. Bar Lake.

Figure 13: Average Dissolved Oxygen (DO) for S. Bar Lake - 2019

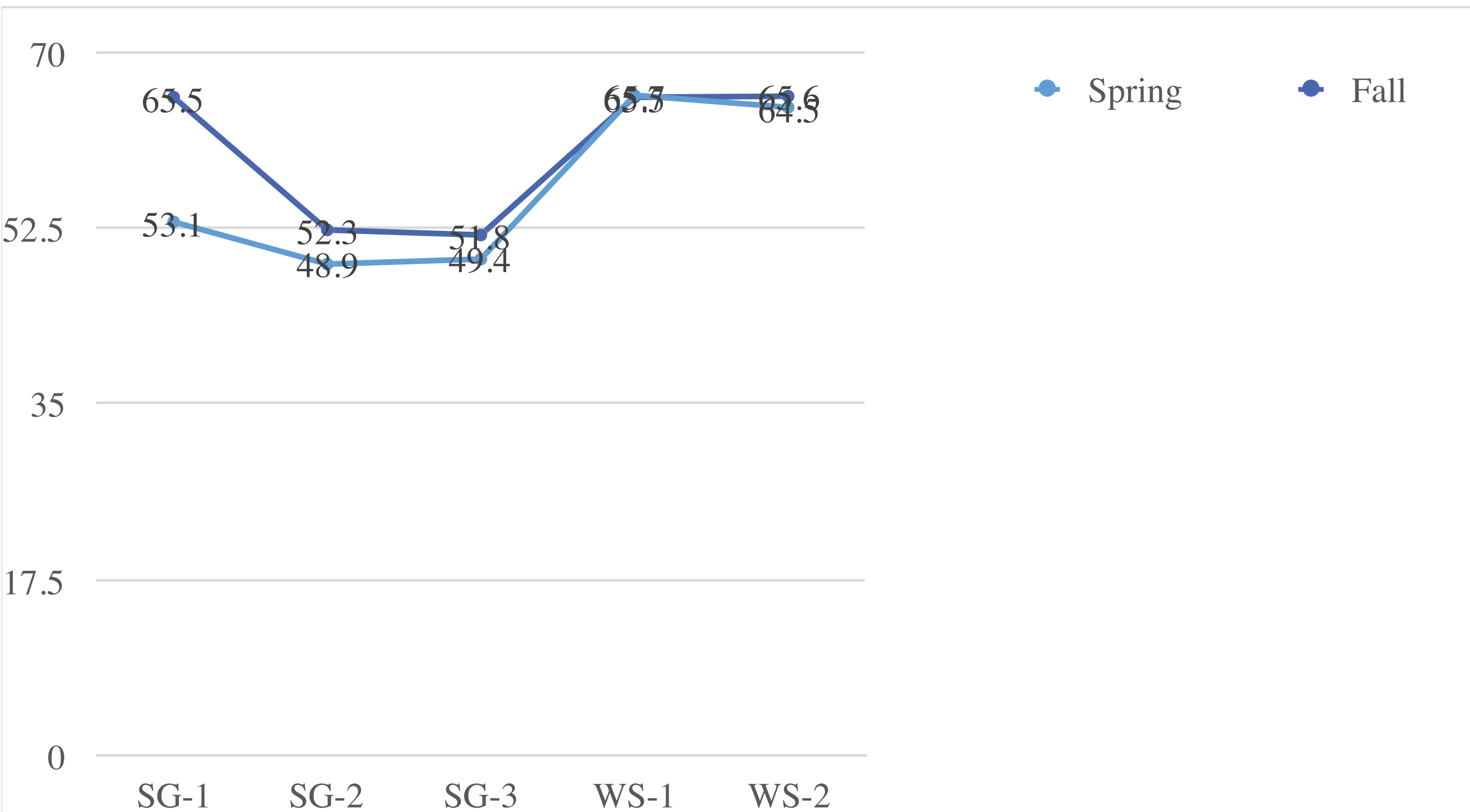
Red line represents the EGLE warm water fishery DO standard of 5.0 mg/L.



Temperature

South Bar Lake has an average temperature of 58.2 Degrees Fahrenheit from the 2019 temperature readings (Figure 14).

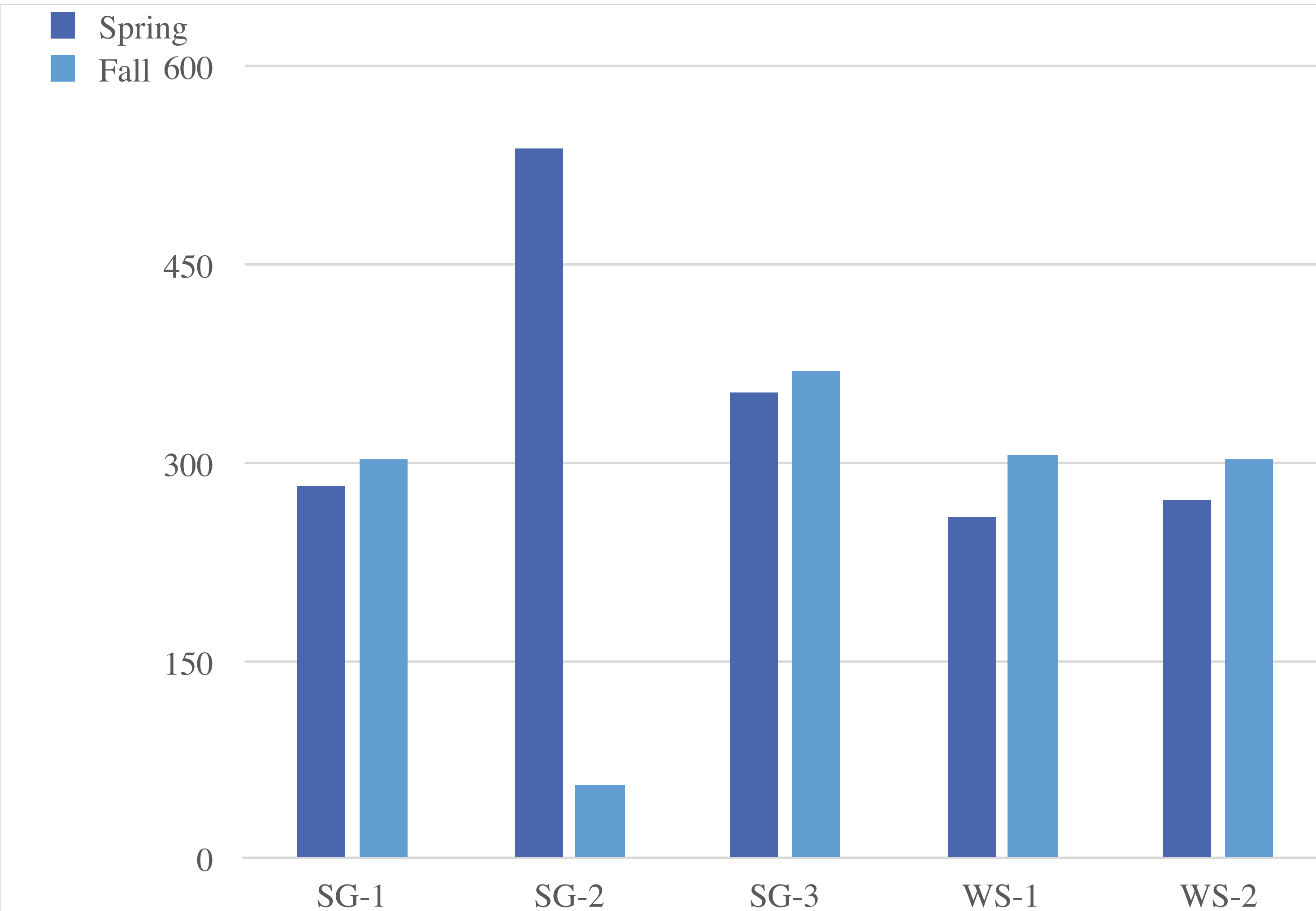
Figure 14: S. Bar Lake Average Temperature by Month



Conductivity

Conductivity was also measured using a hydrolab in 2019. Results show the inlet SG-2 to have the highest reading in the spring, i.e., over 500 units.

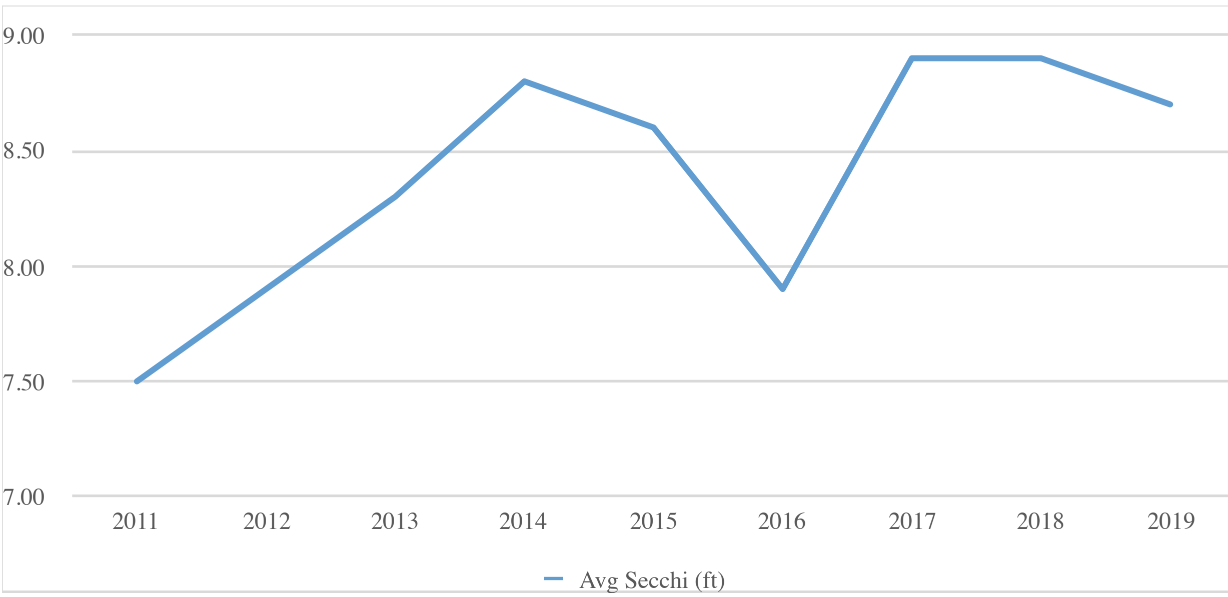
Figure 15. Conductivity readings for Spring and Fall 2019 in South Bar Lake (Inlets and Outlet)



Secchi Disc Readings

The SBLA sampled S. Bar Lake for water clarity or Secchi from 2011 to 2019. The results are summarized below (Figure 16). The near surface water column of S. Bar Lake has continually increased in clarity since sampling in 2011.

Figure 16. S. Bar Lake Secchi Measurements (in feet) 2011-2019



It is noted that the entry of exotic invasive mussels such as the zebra mussel into S. Bar Lake circa 2007-08 is a likely significant contributor to this trend of increasing water clarity, resulting also in the increased light energy penetration of the near surface water column to depth. S. Bar Lake riparian landowners and Village of Empire residents report observations of this increased lake clarity, and link this phenomenon to an observed increase in emergent aquatic plant growth since 2015-16.

Macrophyte Survey Summary

A survey of or predominant communities of aquatic plants or “macrophytes” in S. Bar Lake was completed on September 13, 2019 by Dr. Grobbel. This survey utilized and augmented the findings of the Michigan Cooperative Lake Monitoring Program (CLMP) plant surveys completed by volunteers from the South Bar Lake Association on August 11, 2014 and August 8, 2017. Key codes utilized in this study for these predominant macrophyte aquatic plants is as follows:

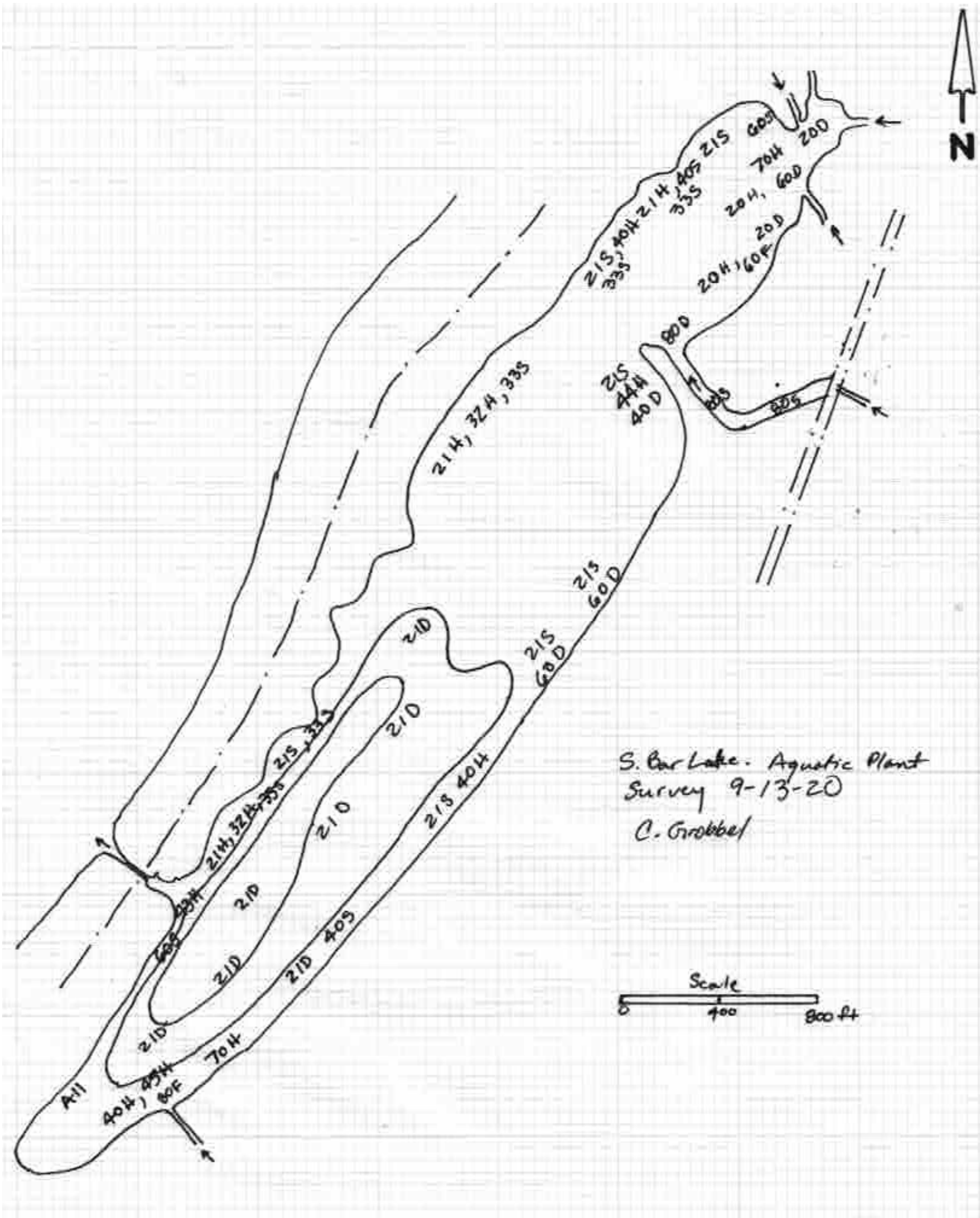
S. Bar Lake Macrophyte Key

#20 -Muskgrass* (*Chara spp*) (+)
#21 - Bushy pondweed* (*Najas spp.*) (+)
#32 - Thin-leaf pondweed (*Potamogeton spp.*) (+)
#33 - Flat-stem pondweed* (*Potamogeton zosteriformis*)(+)
#36 - Waterweed* (*Elodea canadensis*) (+)
#40 - Native watermilfoil* (*Myriophyllum spp.*) (0/-)
#43 - Floating leaf pondweed (*Potamogeton natans*) (+)
#44 - White-stem pondweed* (*Potamogeton praelongus*) (0)
#45 - Curly pondweed (*Potamogeton crispus*) (+)
#46 - Large-leaved pondweed (*Potamogeton amphlifolius*) (+)
#47 - Grass-leaved pondweed (*Potamogeton gramineus*) (+)
#52 - Sago pondweed* (*Stuckenia pectinata*) (0/-)
#60 - Softstem bulrush (*Schoenoplectus tabernaemontani*) (+/0)
#70 - Yellow pond lily (*Nuphar lutea*) (0/-)
#80 - Cladophora spp. (*filamentous green algae*) (-)
#90 - Phragmites (*Phragmites spp.*) (-)

(* = Michigan Cooperative Lakes Monitoring Program (CLMP) reported species in S. Bar Lake 2014 & 2017)

D = Dense
H = Heavy
S = Sparse
F = Found

+ = generally beneficial
0 = generally neutral
- = generally nuisance


N
S. Bar Lake. Aquatic Plant Survey 9-13-20
C. Grobbel
Scale
0
400
800 ft

Some key findings of the macrophyte survey included the presence of broad area of *Chara* exists within the central portion of the southern part of S. Bar Lake, dense to moderately dense areas of *Chladophora*, a significant indicator of high nutrient levels/ inputs, existing within the outlet of the Chippewa Run within the north-eastern portion of the lake, and a large floating algal mat forms later-summer in the relatively closed southern cell of the lake eastward of the southern boat launch at the Village of Empire Beach Park. Other significant changes from the 2014 and 2017 CLMP aquatic plant surveys was not observed. It is noted that troublesome exotic/invasive species of purple loosestrife and *Phragmites spp*. were not observed at the time of this aquatic plant survey.

Findings & Recommendations

Summary of Findings

- Recent research has linked the entry and long-term residence of exotic/invasive filter feeders such as zebra mussels/quagga mussels and the onset of climate change to an increase in inland lake clarity, thereby sunlight penetration, and enhanced biological productivity such as blue-green algae and its associated cyanobacteria. This trend has been observed to be moving north in the Michigan.
- Groundwater monitoring well results, i.e., at MW-1, MW-4 and MW-5, have documented exceedances of groundwater/surface water criteria for TP.
- The water quality of S. Bar Lake is acceptable, but not as high as other lakes in the Grand Traverse region.
- The results of the 2019 water quality testing in S. Bar Lake show nutrients to entering S. Bar Lake from its inlets at Florence St. inlet (SG-3) and the unnamed drain/stream leading from Niagara and Lake Streets (SG-2).
- Dense to moderately dense areas of *Chladophora*, a significant indicator of high nutrient levels/inputs, exist at the outlet of the Chippewa Run within the north-eastern portion of the lake, and a large floating algal mat forms later-summer in the relatively closed southern cell of the S. Bar Lake.
- Average *E. coli* results within S. Bar Lake at SG-2 and SG-3 in 2019 exceeded state limits for human health.
- Dissolved Oxygen (DO) sample results from S. Bar Lake in 2019 at its two inlets and its outlet exceeded Michigan water quality standards.

- The clarity of the near surface water column of S. Bar Lake has continually increased since 2011.
- There has been an increase in Trophic Status Index over the years in S. Bar Lake, accompanied by an increase in aquatic plant growth and Chlorophyll-a levels.
- The results of groundwater monitoring well sampling, including BTEX, indicate that chemical parameters of concern do not exceed the standards or preferred limits, and thereby do not currently represent a concern.
- Importantly, results indicate that S. Bar Lake is becoming mesotrophic resulting in concerns for increased future plant and algae growth. Even though the Secchi disc readings show an increase in clarity, the algae and plant growth has continued to increase.

Recommendations

1) The SBLA should continuing to monitor and participate in the CLMP program to monitor the trophic status of the lake, aquatic plant species inventory and to provide water quality data annually to monitor changes over time.

2) As study results indicate S. Bar Lake has become mesotrophic, the Village of Empire should consider annual water quality monitoring based on the results of this study.

3) The Village of Empire, Empire Township and SBLA Should develop programs to work closely with lakeshore residents to educate about and implement best management practices (BMPs) and BMP project outreach efforts.

4) The monitoring of blue-green algae and cyanobacteria should be undertaken 2 times per year as S. Bar Lake has demonstrated increased trophic level, i.e., between

mesotrophic and eutrophic levels, increased nutrification, and an overall increase in biological productivity.

5) Quagga and zebra mussel population sampling should be completed annually, and their impact on S. Bar Lake water quality and implications for biological health of the S. Bar lake should be further monitored and studied.

6) Follow-up *E.coli* monitoring at SG-3 and SG-2 2 times per year should be completed, including DNA sampling to determine if *E. coli* sources are human, i.e., leaking septic system(s), livestock, or from wildlife species. Also, the Village and SBLA are encouraged learn about new technologies such as qPCR to determine the source of the *E. coli* entering S. Bar Lake.

7) Groundwater monitoring well sampling should continue to determine the source(s) of relatively high TP concentrations at MW-1, MW-4 and MW-5.

8) Monitor for, treat as necessary, and educate the public about simple steps they can take to prevent the entrance of the exotic/invasive aquatic plant starry stonewort, purple loosetrife, *Phragmites*, etc. into S. Bar Lake.

9) Provide all residents/landowners with water quality protection information and best land use practices guidance, especially for shoreline landowners, to protect water quality. Such information includes but is not limited to proper use on non-phosphorous fertilizers and detergents, and fertilizing only during Spring green-up; proper location and maintenance of compost piles; maintenance of native vegetative shoreline buffers; installation and maintenance of bioswales, rain gardens, groundwater infiltration structures, and other dispersed small scale stormwater treatment and disposal; safe storage, use and disposal of potentially polluting materials such as fuels, lubricants, grease/oil, pesticides, fertilizers, etc.

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