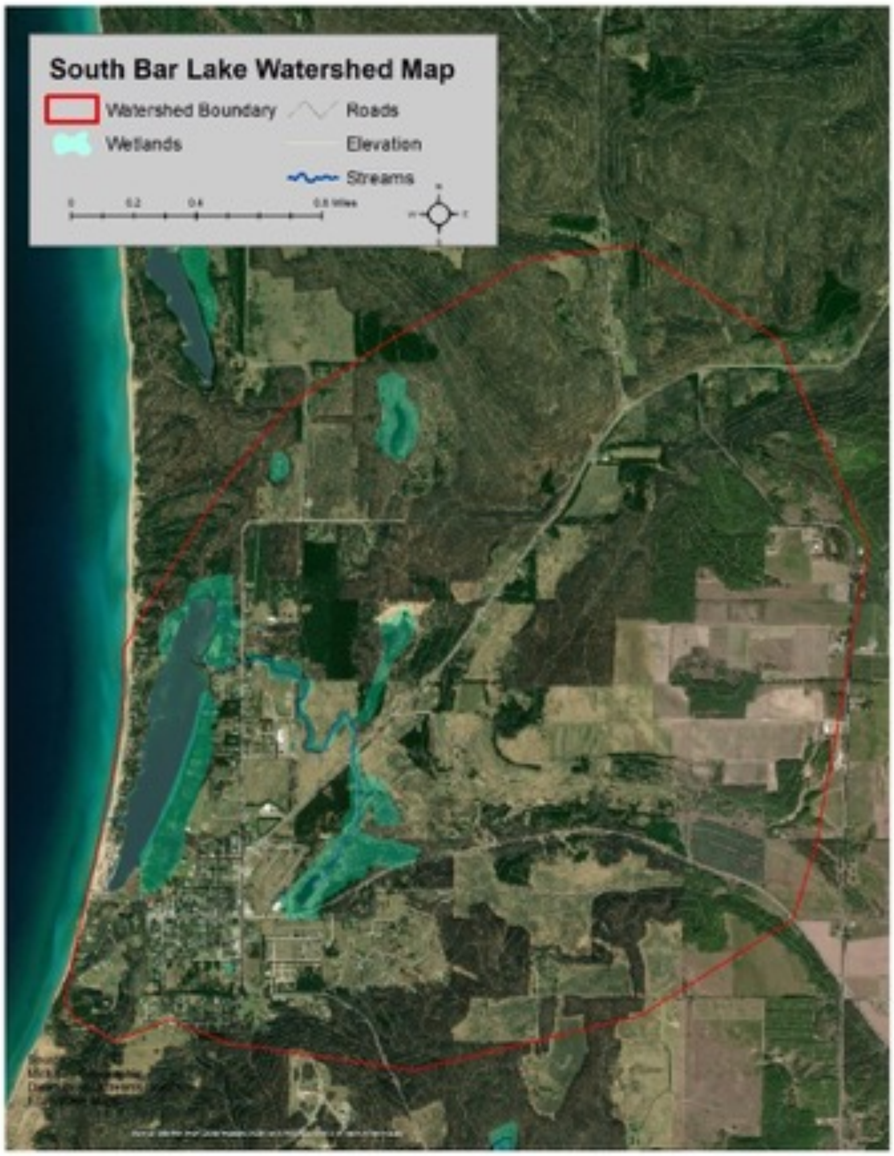
South Bar Lake Water Quality Report

October 2022



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 from 2020 through 2022 in cooperation with the members of the South Bar Lake Association and Empire Township. South 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, South 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. South 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 South Bar Lake was interpreted and mapped by Grobbel Environmental & Planning Associates, and is referred herein to as the South Bar Lake watershed. South Bar Lake is considered mesotrophic, while most lakes in Northern Lower Michigan are oligotrophic or slightly mesotrophic.

South Bar Lake is relatively shallow at thirteen (13) feet maximum depth, owing to its geomorphologic history as a former embayment of Lake Michigan closed off from the Great Lake from dune formation similar to North Bar Lake, the Glen Lakes, Little Traverse Lake, Herring Lakes and others in the region. South Bar Lake is heavily-used, but primarily 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 South Bar Lake accessible from Niagara Street and South Lake Michigan Drive. South Bar Lake is naturally shallow and was reportedly used historically

[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)

for the discharge of logging waste/saw dust. This history has likely contributed to 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 and necessarily 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 South Bar Lake. This GLEC study indicated that the water quality of South Bar Lake is acceptable, but not as high as other lakes in the Grand Traverse region (GLEC, 2014). This study also concluded that these conditions may be due to South Bar Lake's specific physical characteristics, but may also result from water quality impacts from surface water runoff (GLEC, 2014). The 2014 GLEC study included evaluating nutrient loading three (3) times during the year. GLEC partnered at that time with the Watershed Center Grand Traverse Bay to perform a shoreline vegetation buffer inventory of South Bar Lake, a *Cladophora* survey (i.e., a nuisance algae), and an assessment of road/stream crossings of South Bar Lake inlet tributaries. The results of the 2014 GLEC study prompted this more comprehensive study to summarize existing and gather contemporary water quality data, and to provide recommendations for the future.

From 2020 through 2022 , Grobbel Environmental & Planning Associates were contracted by the Village of Empire, in conjunction with Empire Township in 2022, to evaluate and summarize the findings previous studies, and perform and report additional water quality assessment, aquatic plant inventories, and flow and water quality analyses for major tributaries to and the outlet from South Bar Lake. The results of this 2022 study was reported to the Village of Empire, the South Bar Lake Association, and Empire Township during the Fall and Winter of 2022. A 2020 baseline water quality study by Grobbel Environmental and Planning Associates in part concluded that:

1) A likely linkage of the entry and long-term residence of exotic/invasive filter feeders (i.e., zebra mussels/quagga mussels) and the onset of climate change to an increase in inland lake clarity[2], increased sunlight penetration, and enhanced biological productivity such as blue-green algae and its associated Cyanobacteria. *This trend has also been observed to be moving north in the Lower Peninsula of Michigan.*

2) Groundwater monitoring well results, i.e., at MW-1, MW-4 and MW-5, have documented exceedances of groundwater/surface water criteria for the nutrient Total Phosphorous.

3) The water quality of South Bar Lake is acceptable, but not as high as other lakes in the Grand Traverse region.

4) 2020 water quality analyses of water in and entering South Bar Lake documented concerning levels of nutrients to entering South Bar Lake from its inlets at Florence Street inlet (SG-3) and the unnamed drain/stream leading from Niagara and Lake Streets (SG-2).

5) Dense to moderately dense areas of *Chladophora* (a significant indicator of high nutrient levels/inputs), exist at the Florence Street inlet (i.e., the outlet of the Chippewa Run) within the north-eastern portion of the lake.

6) A large floating algal mat forms in later-summer within the relatively closed southern portion of the South Bar Lake.

7) Average 2020 *E. coli* results within South Bar Lake at Niagara and Lake Streets (SG-2) and the Florence Street inlet (SG-3) exceeded Michigan water quality standards for human health.

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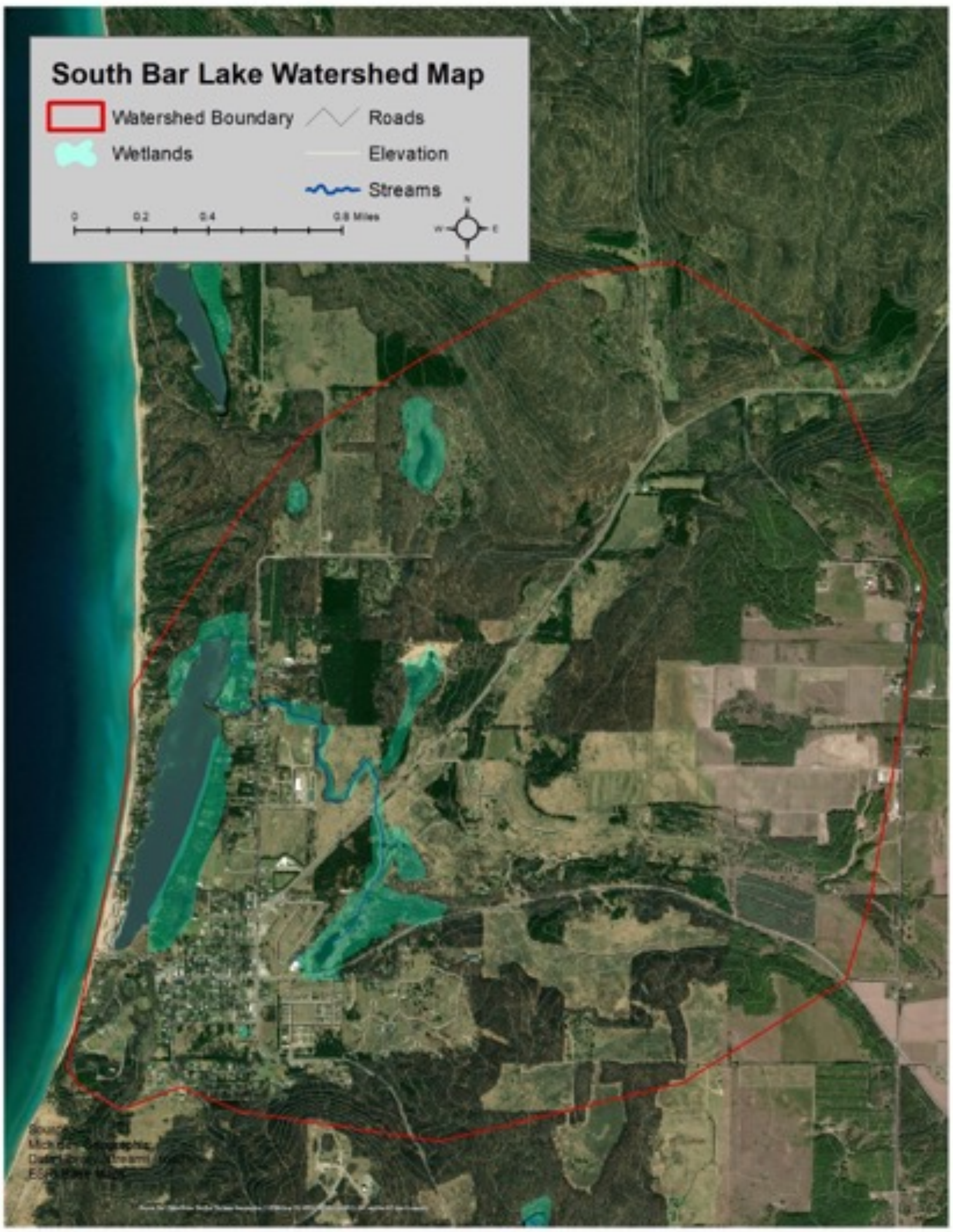
[2] The clarity of the near surface water column of South Bar Lake has continually increased since 2011.

8) Dissolved Oxygen (DO) sample results from South Bar Lake in 2020 at its two inlets and its outlet did not meet Michigan water quality standards.

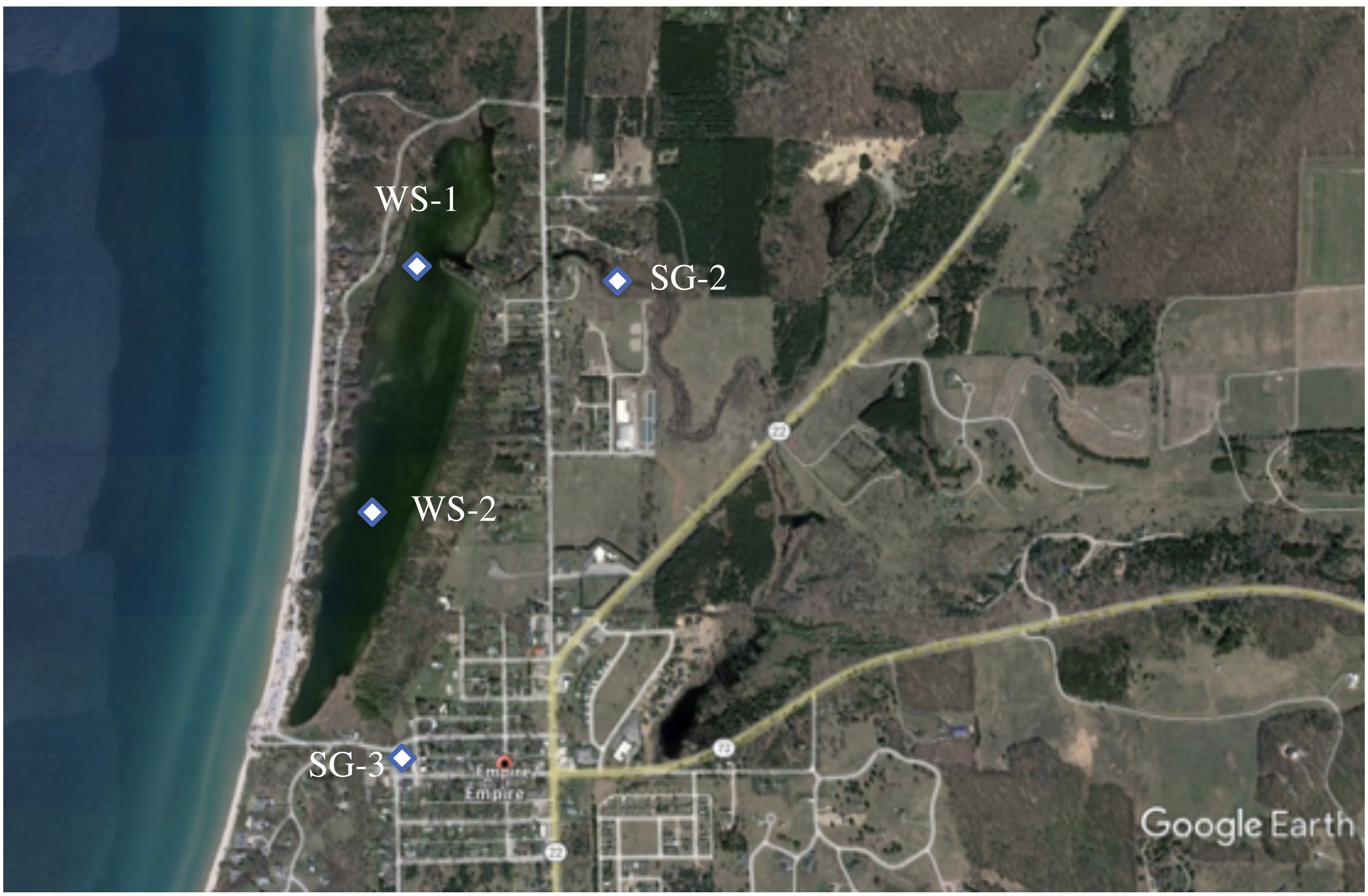
9) There has been an increase in Trophic Status Index to mesotrophic over recent years in South Bar Lake, accompanied by an increase in water column clarity and temperature, nutrients, Chlorophyll-a, and increased aquatic plant growth.

Figure 1. South Bar Lake Watershed Map



Christopher P. Grobbel, PhD and Gillian Grobbel of Grobbel Environmental & Planning Associates sampled at four (4) locations (see Figure 2 below) in 2022 to focus on source identification for high nutrient levels found in tributary waters to South Bar Lake from 2020 to 2022.

Figure 2. South Bar Lake Sample Locations - 2022



Sample Location Key:

SG-2 (stormwater) - latitude 44 degrees 49’ 20.51” N & longitude 86 degrees 03’ 24.25” W

SG-3 (upstream) - latitude 44 degrees 44’ 40.86” N & longitude 86 degrees 03’ 48.85” W

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

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

Water Quality Parameters

The following is a summary of the water quality parameters collected and analyzed in 2020 through 2022, and the relevant water quality 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.[3] 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 within the 2020 water quality report.

Phosphorus

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

[3] 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.

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[4]

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 Environment Great Lakes and Energy (EGLE), Part 201 Cleanup Criteria state the groundwater surface water interface standard for Total Phosphorous in surface waters is 10 mg/L.[5]

Nitrogen[6]

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 U.S., particularly the northeast, certain forms of nitrogen are commonly deposited in acid rain.

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4 michigan.gov/documents/deq

5 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.

6 USGS article Nitrogen and Water http://water.usgs.gov/edu/nitrogen.html

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.

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.[7]"

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.

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 federal Clean Water Act's National Pollutant Discharge Elimination System (NPDES) 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, fifteen (15) TMDLs have been written to address 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

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

150,000 pounds of phosphorus per year. To date there has not been a need for a TMDL on any water bodies in the South Bar Lake watershed.

The U.S. 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.[8]

Water Quality Standards for Chlorophyll-a

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

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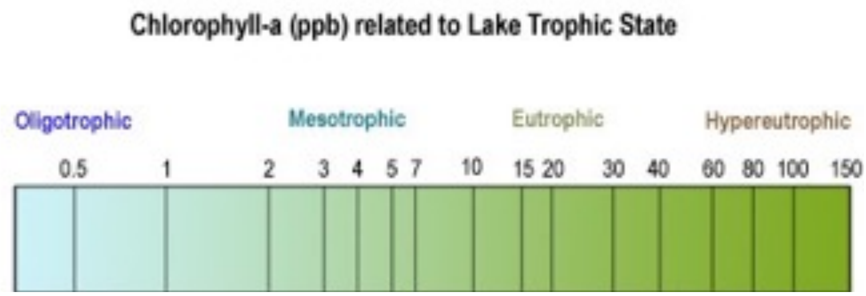
[8] https://www.epa.gov/national-aquatic-resource-surveys/indicators-chlorophyll



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

Bacteria[9]

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 (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.)

9 michigan.gov/documents/deq

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, EGLE 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/Thermal Pollution[10]

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.

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[10] michigan.gov/documents/deq

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 (DO), since cooler water can hold more oxygen than warmer water. Low DO levels will cause oxygen-sensitive species to perish.

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 DO 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 (i.e., 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 (i.e., 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 DO are intimately linked in deeper northern temperate lakes, 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. Due to its shallow depth, temperature stratification within the water column, mixing, and near bottom oxygen depletion has not been observed in South Bar Lake.

Dissolved Oxygen[11]

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 DO). Gas solubility increases with decreasing salinity (i.e., freshwater holds more DO 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 DO levels compared to stagnant water because the water movement at 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 (i.e., breathe), and when aerobic microorganisms decompose organic matter. DO 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 deeper 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.

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11 michigan.gov/documents/deq

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 DO 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[12]

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 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 U.S. 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 µmhos/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[13]

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

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

pH[14]

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 U.S., especially the Northeast, acid rain has resulted in lakes and streams becoming acidic, resulting in conditions which are 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 perish.

[14] michigan.gov/documents/deq

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[15]

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,

[15] 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.

reservoirs, etc. Cyanobacteria, i.e., *microcystin*, 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 *microcystin* is generally found in obvious algal mats, scums, etc. Clear waters area often possess little or no *microcystin*.

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 South 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.[16] Also, there is widespread consensus among researchers that watershed with 10% of more impervious surface experience water quality degradation from storm water runoff.[17]

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

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[16] Ibid., p. 15.

[17] 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.

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.

South Bar Lake Water Quality Monitoring Results

(2020-2022)

Water quality sampling was undertaken on June 12, 2022 and August 23, 2022. Four (4) water sampling locations including two within South Bar Lake (i.e., WS-1 and WS-2) from 2020 through 2022, and two (2) new locations were samples in 2022 to identify source areas (i.e., 2022 SG-2 and SG-3) (see Table 1 and Figure 2 above). Water quality parameters analyzed included nutrients (i.e., Total Inorganic Nitrogen 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, conductivity, and dissolved oxygen.

Table 1. Water Quality Sample Locations (2022)

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-2	Niagara St. (stormwater)	44 49’ 20.51”N	86 03’ 24.25”W
SG-3	Florence St. (upstream of dam)	44 48’ 40.86”N	86 03’ 48.85”W

South Bar Lake Watershed Hydrology

The discharge in cubic feet per second (*i.e.*, c.f.s.) was monitored once in 2022 at three (3) locations (see Table 2 and Figure 4 below). Flow at the outlet to Lake Michigan (SG-1) is variable depending upon whether its beach discharge location was blocked from sand sedimentation due to high Lake Michigan levels. Overall, flow at SG-1 (outlet) in 2022 evidenced about one-half the discharge observed 2020. Flow within the Niagara & Lake Streets (SG-2) and Florence Street inlets (SG-3) was about the same as in 2021.

Figure 4: Flow (cfs) for Inlets to and Outlet of South Bar Lake 2013-2022

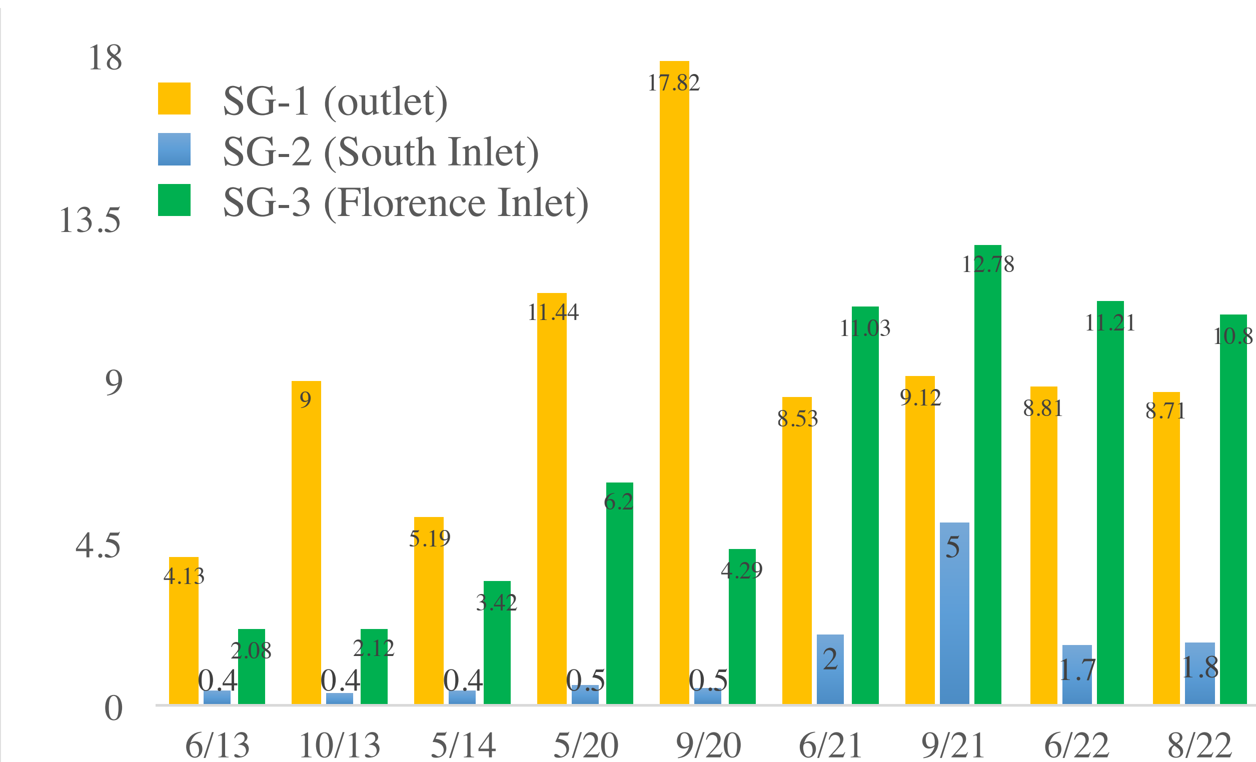


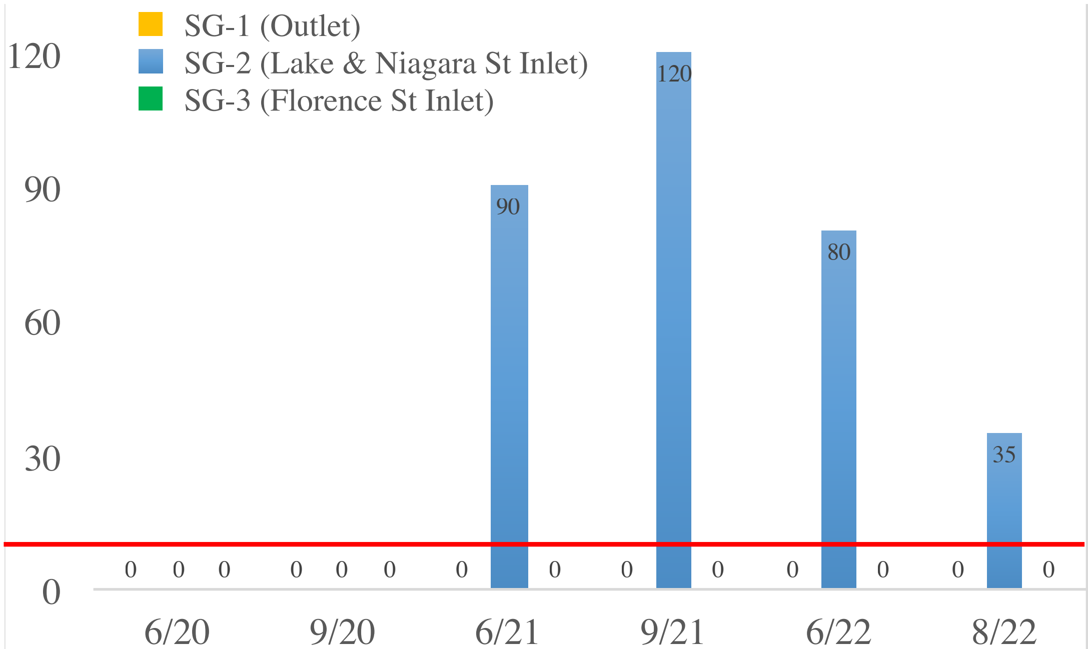
Table 2. Average Flow (cfs) per Year by Site

Site	2013-14	2020	2021	2022
SG-1	6.1	14.63	8.83	8.80
SG-2	0.39	0.50	3.50	1.75
SG-3	2.54	5.25	11.91	11.0

Total Phosphorus (TP)

TP for South Bar Lake and its tributaries during 2020 to 2021 was typically below the laboratory's detection limit of 30 ug/L with the exception of TP at SG-2 (at Lake and Niagara Streets) at 90 mg/L in June of 2021, 120 mg/L in September 2021, and 35 mg/L (within stormwater at Lake & Niagara Streets) in August of 2022. 2022 TP results document the contribution of Village of Empire stormwater to high phosphorous found at SG-2.

Figure 5.Total Phosphorus (TP) (ug/L) 2020-2022

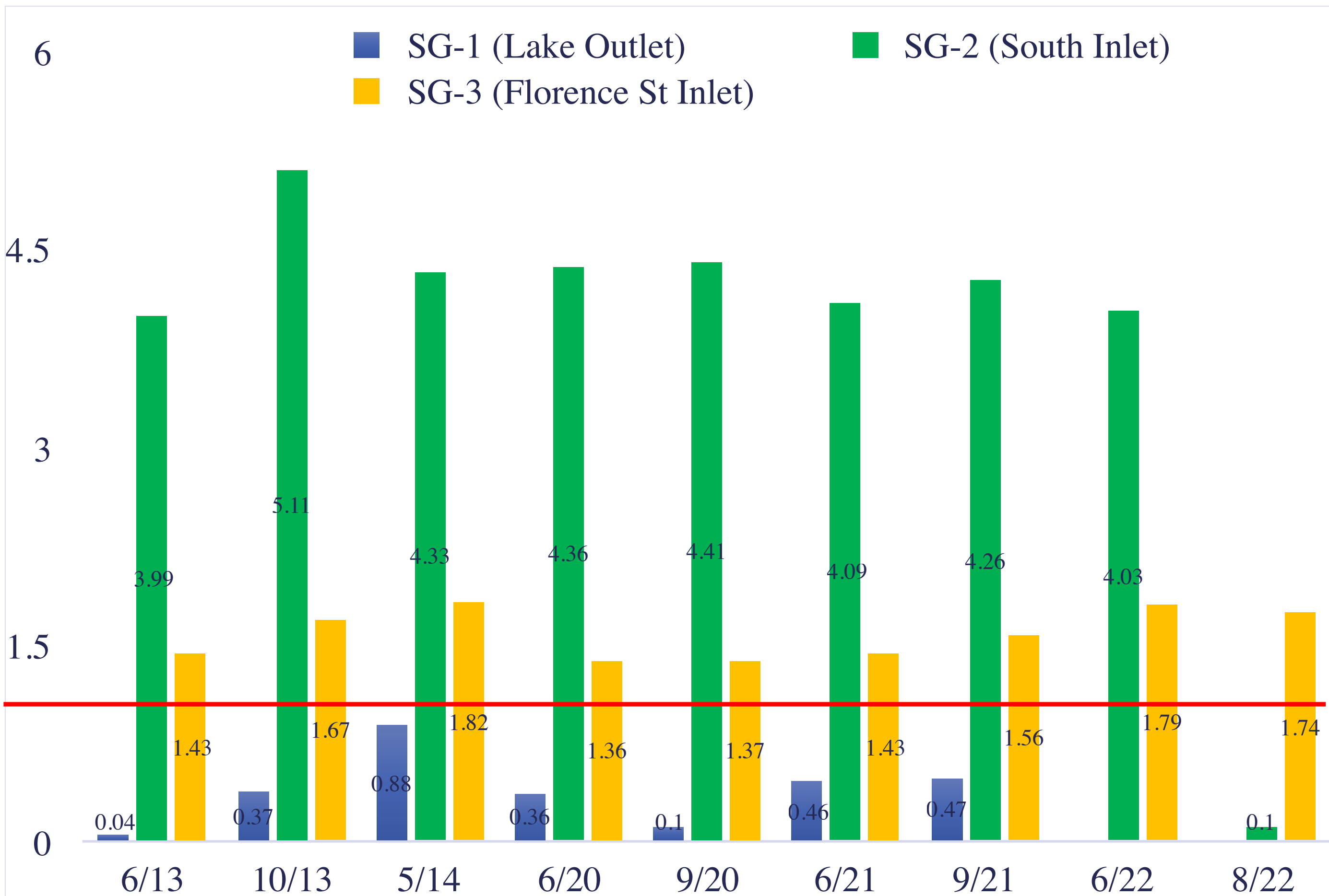


Red line represents the EGLE TP water quality standard is 10 ug/L.

Nitrogen

Total Inorganic Nitrogen (TIN) were sampled at the outlet and inlets of South Bar Lake from 2013 to 2022. Figure 6 below shows that the sampling results for the two inlets (SG-2 and SG-3) for Nitrite were typically above the EPA's limit for drinking water (1 mg/L), and the natural level of ammonia or nitrate in surface water (i.e., less than 1 mg/L, see U.S. EPA 57: Nitrates). The inlet SG-2 at Niagara and Lake Streets have consistently demonstrated high relative concentrations of TIN. Based on 2022 data, the source of relatively high nitrogen concentrations at SG-2 are not interpreted to be stormwater discharge from the Village of Empire (i.e., the subsurface stormwater collection system along Front Street). Based on the 1.74 mg/L Nitrogen-nitrate at SG-3 in 2022, relatively high nitrogen concentrations at SG-3 (at Florence Street) are determined to be from upstream or "above" the pond/impoundment on LaCore St. within the Chippewa Run.

Figure 6. Total Inorganic Nitrogen (TIN) Results (mg/L) (2013-2022)



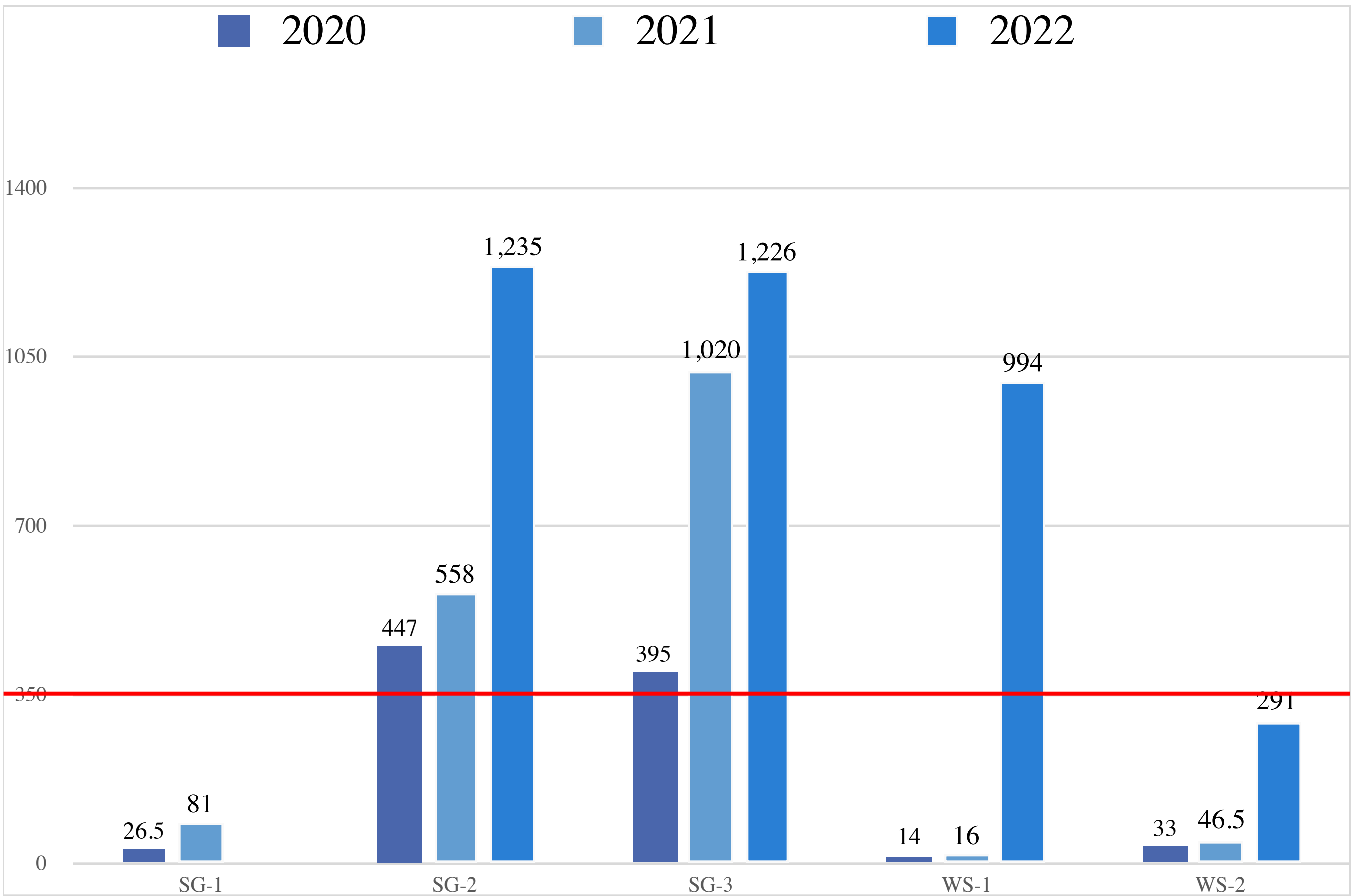
Red line represents the EGLE and USEPA drinking water quality standard of 1.0 mg/L

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 South Bar Lake Watershed were analyzed for total *E. coli* bacteria, including the above six *E. coli* pathotypes.

Average *E. coli* results within the open waters of South Bar Lake were relatively low from 2020 to 2022. However, WS-1 was 994 Colonies/100 mL in June 2022 and 291 Colonies/100 mL in August of 2022. Similarly, *E. coli* measured in 2022 at SG-2 (stormwater at lake & Niagara Streets) and SG-3 (upstream of the impoundment) documented high average levels of E. coli, 1,235 Colonies/100 mL and 1,226 Colonies/100 mL, respectively (see Figure 7 below). *E. coli* measured in 2020 through 2022 at the two inlets SG-2 and SG-3 documented results far exceeding the state limits for human health (also see Figure 7 below). The highest single measurement of *E. coli* during this period was greater than 2,419 Colonies/100 mL at SG-3 (Florence Street) on June 12, 2022.

Figure 7. Average E. coli results* for South Bar Lake (2020-2022)



*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.

DNA Analysis

Importantly, microbial source tracking was completed by the Department of Fisheries and Wildlife at Michigan State University, i.e., DNA analysis, during 2020 and 2021 to determine the source(s) of past high *E. coli* concentrations at SG-2 and SG-3. This DNA analyses found that E.coli were not from human, bovine or porcine sources, but the result of wildlife impact to both tributaries.[18]

General Water Quality Parameters

Hydrolab profile data and water samples have were collected by Grobbel Environmental & Planning Associates in June and September of 2020 and 2021, and June and August of 2022. Table 3 below shows the average Hydrolab results for 2020-2022.

Table 3. Hydrolab Average Results for South Bar Lake Sampling Sites (2020-2022)

Site	Temp (F)	pH	SpCond (aeS/cm	Dissolved Oxygen (mg/L)
WS-1	69.4	8.8	285.7	11.5
WS-2	69.0	8.5	289.2	11.2
SG-1	63.5	8.0	300.2	10.4
SG-2	62.3	8.3	516.7	10.5
SG-3	56.2	8.5	353.1	10.7

pH

The pH was sampled for South Bar Lake in June and September of 2020 and 2021, and June and August 2022. The pH of South Bar Lake was the highest in the Spring as compared to Fall. Figure 8 shows the results of the pH in South Bar Lake in 2020 and 2021. The average pH for South Bar Lake during 2020-2022 was 8.6, and is within the Michigan water quality range of 6.5 to 9.0 in all waters of the State of Michigan.

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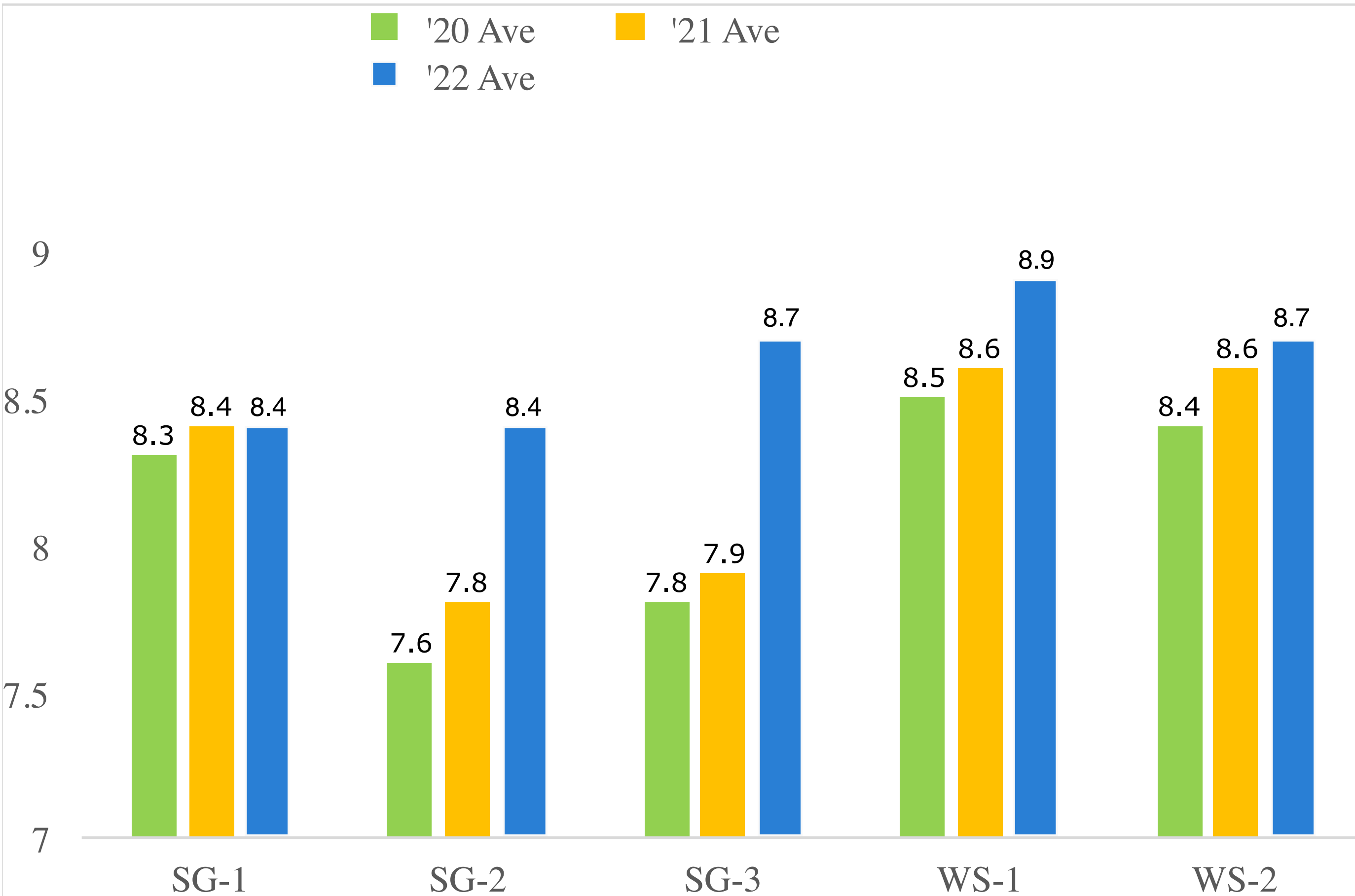
[18] Microbial Tracking Report, Grobbel Environmental, Department of Fisheries and Wildlife, MSU, Andri Rachmadi and Rebecca Ives, September 13, 2021

Figure 8. Average pH for South Bar Lake (2020-2022)

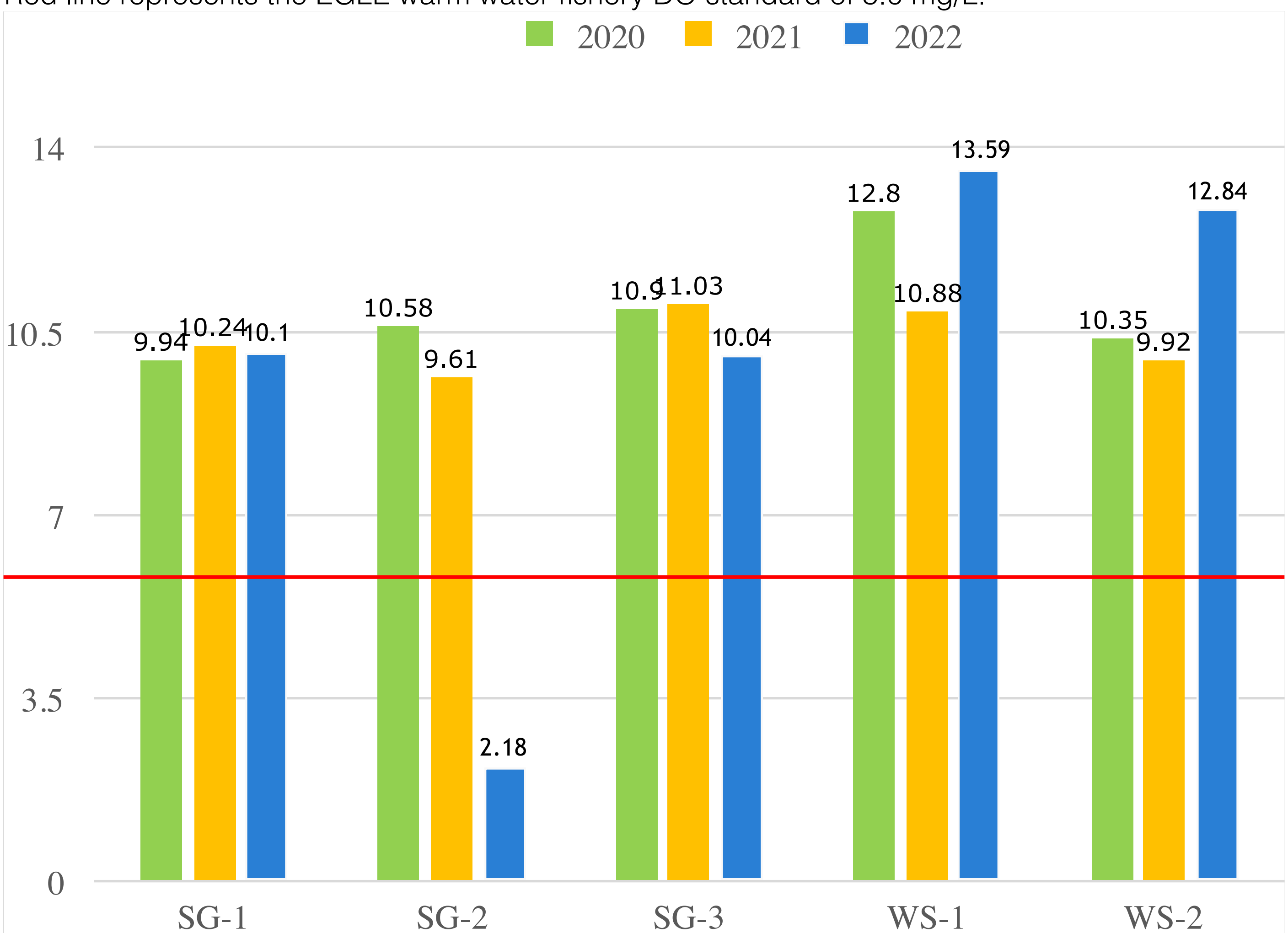


Dissolved Oxygen (DO)

Dissolved Oxygen (DO) was sampled using a Hydrolab in South Bar Lake in 2020 and 2021 at two sample locations, the two inlets and the outlet. Results show the readings are above and within the Michigan standards. Importantly, DO analysis at SG-3 within stormwater at Lake and Niagara Streets documented 2.18 mg/L in August of 2022, indicating a source of pollutants to South Bar Lake. 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. South Bar Lake is thereby considered a cold water fishery (Figure 9).

Figure 9: Average Dissolved Oxygen (DO) for South Bar Lake (2020-2022)

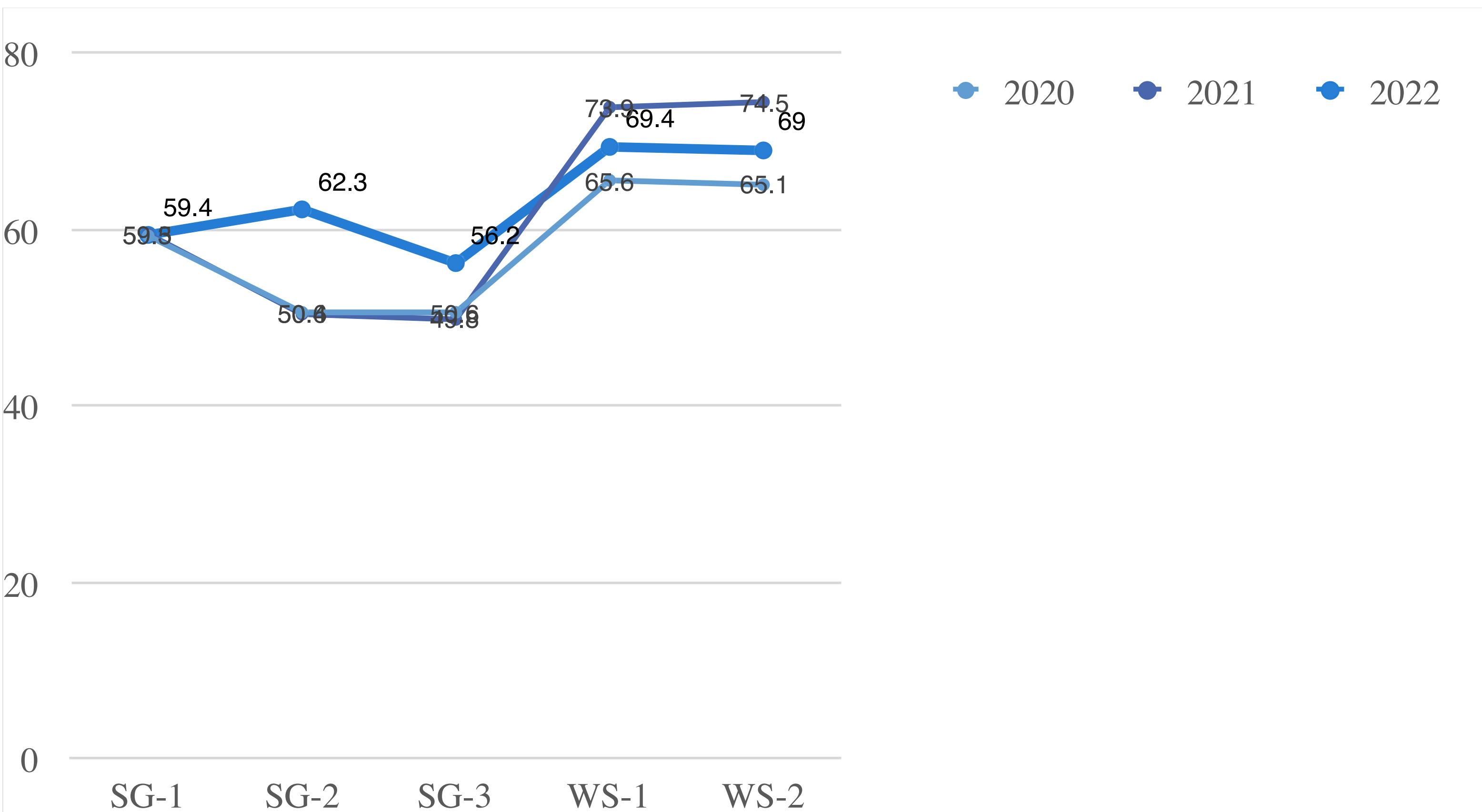
Red line represents the EGLE warm water fishery DO standard of 5.0 mg/L.



Temperature

While average water temperatures in tributaries to South Bar Lake remained relatively the same from 2014 to 2020, the average surface water temperature with the open waters of South Bar Lake increased significantly in 2021 and 2022 (Figure 10). This is likely due to increased sunlight penetration of the water column from exotic/invasive filter feeding mussels, and climate change.

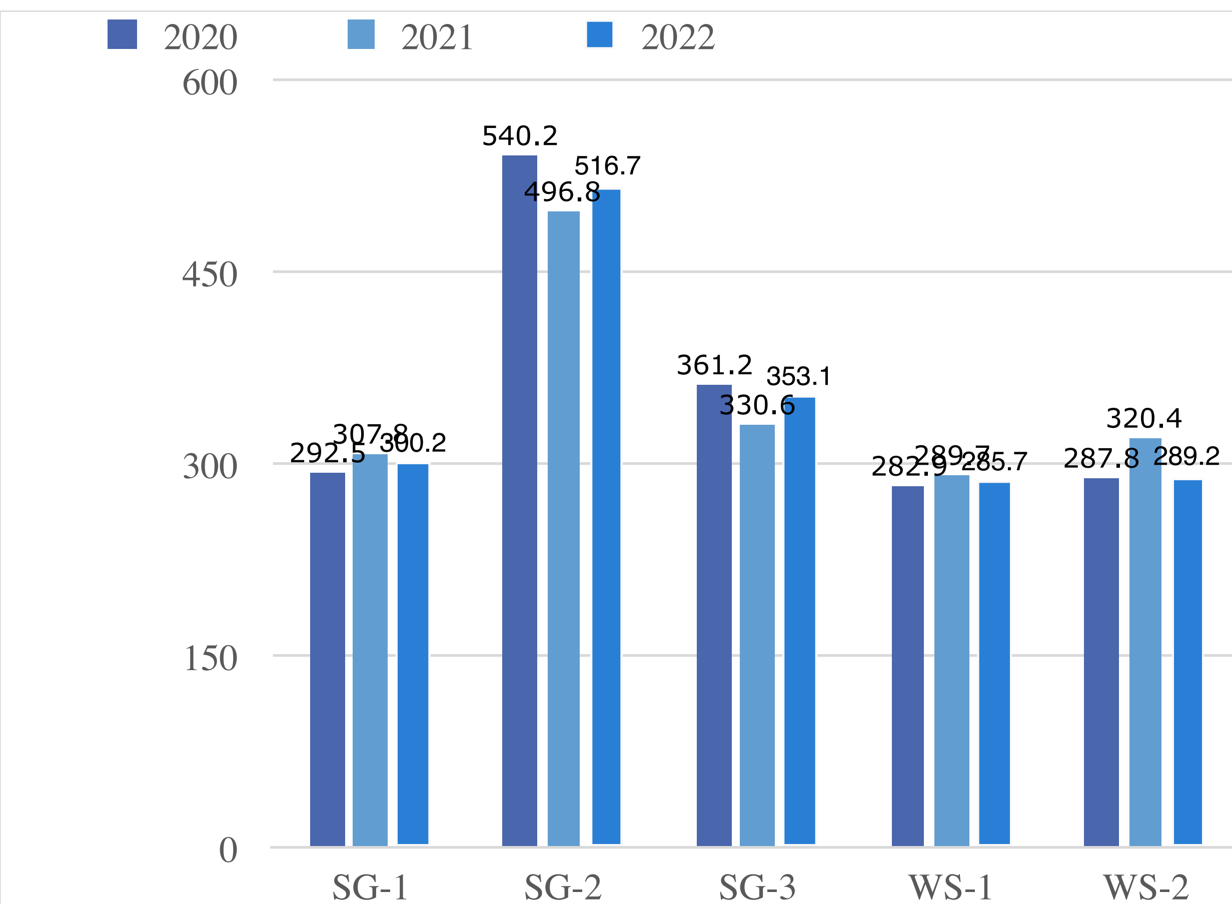
Figure 10: South Bar Lake Average Temperatures (2020-2022)



Conductivity

Conductivity was also measured using a Hydrolab in 2020 through 2022. 2022 results show relatively high conductivity, i.e., over 500 units, at SG-2 (i.e., Lake & Niagara Streets) and slightly elevated at SG-3 (i.e., upstream of the impoundment at Florence and LaCore Streets).

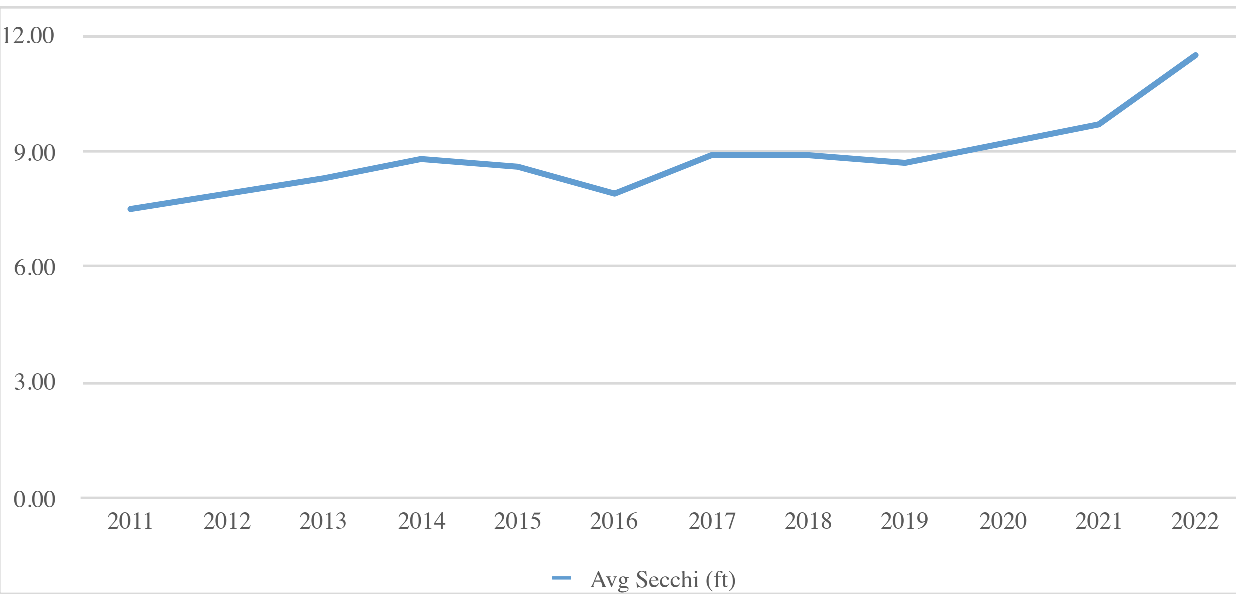
Figure 11. Conductivity for South Bar Lake (2020-2022)



Secchi Disc Readings

Figure 12 represents water column clarity within South Bar Lake using a Secchi disc from 2011 through 2022. The near surface water column of South Bar Lake has continually increased in clarity since sampling in 2011.

Figure 12. South Bar Lake Secchi Measurements (in feet) 2011-2022



It is noted that the entry of exotic invasive mussels such as the zebra mussel into South 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. South 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.

Findings & Recommendations

Summary of Findings

- Recent research links the entry and long-term residence of exotic/invasive filter feeders such as zebra and 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 lower Michigan.
- Flow within tributaries at SG-2 (i.e., Niagara & Lake Streets) and SG-3 (Florence Street) was substantially higher during measurements in 2021 and 2022 than in 2020, likely due to increased precipitation trends and enhanced infiltration to groundwater in the watershed within the past few years.
- Total Phosphorous concentrations remain of concern at SG-2 (i.e., Niagara & Lake Streets) at 90 mg/L in June 2021, 120 ug/L in September 2021, 80 ug/L in June 2022, and 35 ug/L in August 2022.
- Similarly, SG-2 (Niagara & Lake Streets) consistently demonstrates the highest relative input of nitrogen concentrations. The source of these relatively high nitrogen concentrations at SG-2 are interpreted to be stormwater discharge from the core of the Village of Empire and the subsurface storm water collection system along Front Street.
- *E. coli* measured at SG-2, SG-3 and WS-1 far exceed State limits for human health in 2022. The highest single measurement of *E. coli* during 2022 was greater that 1,249 Colonies/100 mL at SG-2 (Lake and Niagara Streets) and SG-3 (Florence Street) on June 12, 2022.
- DNA analysis confirms that sources of high E. coli concentrations within South Bar Lake waters and its tributaries is wildlife.

- Results show relatively high conductivity, i.e., over 500 units, at SG-2 (Niagara & Lake Streets)
- Dense to moderately dense areas of *Chladophora*, a significant indicator of high nutrient levels/inputs, exist at the outlet of the Chippewa Run to South Bar Lake within the north-eastern portion of the lake, and a large floating algal mat forms in late-summer in the relatively closed southern cell of the South Bar Lake.
- The clarity of the near surface water column of South Bar Lake has continually increased since 2011.
- There has been an increase in Trophic Status Index over the years in South Bar Lake, accompanied by an increase in aquatic plant growth and Chlorophyll-a concentrations.

Recommendations

1) The Village of Empire, Empire Township and the SBLA should continue to monitor water quality within the South Bar Lake watershed, and to participate in the CLMP program to monitor the trophic status of the lake, aquatic plant species inventory and report water quality data annually to monitor changes over time.

2) As study results indicate South Bar Lake has become mesotrophic, the Village of Empire should consider continued annual stormwater quality monitoring and reporting.

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

4) The sampling of blue-green algae for Cyanobacteria should be undertaken two (2) times per year as SouthBar Lake has demonstrated nuisance Chladophora, blue-green algal mats, an increased trophic level, i.e., mesotrophic, increased nutrification, and an overall increase in biological productivity.

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

6) Follow-up *E.coli* monitoring at SG-3 and SG-2 at least two (2) times per year should continue, 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 South Bar Lake.

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

8) Provide all residents/landowners with water quality protection information and best land use practices guidance, especially for shoreline landowners and downtown Village of Empire residents, 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 bio-swales, 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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