9353 Hill Road • Swartz Creek, MI 48473
(810) 635-4400 • Fax (810) 635-4404
www.lakeproinc.com

2016 Lower Long Lake Water Quality Review

Introduction

The goals of this testing protocol were to monitor various water quality parameters of the lake, compare results to historical data, and identify any potential risks to the health of Lower Long Lake. Water samples were taken at four different locations and tested for 14 parameters. Tests were conducted on a monthly basis from April through August. Tests were conducted with a Hanna Multiparameter Water Quality Meter or LaMotte SMART2 Colorimeter.

Test results were compared to historical data from the report "2015 Lower Long Lake Water Quality Review" by LakePro, Inc.

In this report, we included historical data from Water Quality Investigators. Their report provided annual averages for many of the parameters from 2002 to 2009. Including this data allows us to see more accurate trends in the water quality data. In order to make the analysis easier, we added annual averages for our data and trendlines on the graphs. The trend lines allow us to see the direction each water quality parameter is moving.

Results

Parameter	2016 Season Average	Target Range	Status
Temperature	72.4 ˚F	Less Than 75 ˚F	● Healthy
Dissolved Oxygen	7.5 mg/L	4.0 – 12.0 mg/L	● Healthy
Total Phosphorus	87 ppb	0 – 100 ppb	● Healthy
Phosphate	30 ppb	0 – 100 ppb	● Healthy
Nitrate	328 ppb	0 – 1,000 ppb	● Healthy
Chlorophyll-a	4.5 ppb	0 – 7.3 ppb	● Healthy
Transparency	21.2 feet	More than 6.5 feet	● Healthy
pH	8.4 S.U.	7.0 – 9.0 S.U.	● Healthy
Total Dissolved Solids	391 ppm	0 – 1,000 ppm	● Healthy
Conductivity	781 ppm	0 – 1,500 ppm	● Healthy
Alkalinity	129 ppm	100 – 250 ppm	● Healthy
Sulfate	12.4 ppm	3 – 30 ppm	● Healthy
Fluoride	0.08 ppm	0.01 – 0.30 ppm	● Healthy
Chloride	155 ppm	0 – 230 ppm	● Healthy

Year-End Discussion

Lower Long Lake's water quality was excellent this summer. The season average for every parameter was within its target range, showing there were no immediate concerns with the water quality.

Temperature and Dissolved Oxygen

The average water temperature in 2016 was similar to previous years. The preceding winter was mild and most Michigan lakes had less than average ice and snow cover. This led to warmer water temperatures in the spring. Summer temperatures quickly increased with little rainfall to cool the water. As a result, the water temperatures later in the summer were into the 80's.

There is a limit on how much dissolved oxygen can be in the water, which depends upon temperature. Because water temperatures were higher this summer, the water was able to hold less dissolved oxygen. Despite this disadvantage, Lower Long Lake had excellent dissolved oxygen concentrations throughout the summer. Dissolved oxygen is vital for a healthy aquatic ecosystem, so this year's concentrations were a positive for lake.

Nutrients, Plant Production, and Transparency

Nutrients in the water are the fuel for plant growth. Measuring the nutrient concentrations reveals the potential for nuisance plant growth. Phosphorus is a main nutrient necessary for aquatic plant growth, so it is important that this nutrient remains low in the lake. The total phosphorus was elevated in April, but returned within the target range throughout the summer. Phosphate, which is the form of phosphorus usable to plants, was also within the target range for all of the summer.

Nitrate is another major nutrient for aquatic plant growth. The nitrate concentrations remained within the target range all summer. It is important that residents fertilize and use their land responsibly to prevent additional nutrients from entering the lake.

We also measured Chlorophyll concentrations because it is the most direct indicator of plant production. The target for chlorophyll is below 7.2 parts per billion. For all tests this summer, the chlorophyll concentrations remained below the target level. These results showed that the plants did not grow to excess levels, despite the availability of nutrients. Plant management by harvesting also helped to keep the plant production at target levels.

A major effect of plant growth on the lake is the reduction of water clarity. Before algae forms the green mats of "scum" on the surface, it is suspended in the water column. Algae floating in the water can decrease water clarity even before you see a tint of green. This year the water clarity averaged a depth of 21.2 feet - the deepest of all lakes we tested this summer.

Trophic State Indices

In order to better understand the relationship between nutrients, plant production, and clarity, limnologists use Trophic State Indices (TSI) to score each category and examine the relationship between them. In general, lower scores indicate a less productive lake. In 2016, the TSIs for Lower Long Lake were:

Category	Water Quality Parameter	Trophic State Index (season average)	Classifciation
Nutrients	Total Phosphorus	68	Eutrophic
Plant Production	Chlorophyll	44	Mesotrophic
Clarity	Transparency	33	Oligotrophic

The TSI for Total Phosphorus classified the lake as Eutrophic, or highly productive. This is based on the high availability of nutrients to fuel high plant productivity. The TSI for Chlorophyll is lower than the nutrient index. This shows that despite the availability of nutrients, the plants did not grow to the levels supported by the nutrients. This could have been due to another limiting factor, poor growing conditions, or plant management. Finally, the TSI for Transparency is lower than both previous scores. This score confirms that plant growth did not match nutrient availability and, furthermore, the plant production did not decrease the transparency to the predicted level. This was a result of excellent water clarity.

9353 Hill Road • Swartz Creek, MI 48473
(810) 635-4400 • Fax (810) 635-4404
www.lakeproinc.com

Water Chemistry Parameters

It is important to monitor the basic water chemistry of the lake water. Shifts in these parameters can indicate major changes to the lake that may need to be further investigated.

The pH of the lake remained within the target range across all tests. This shows that despite changes in dissolved oxygen, alkalinity, and rainfall, the pH did not fluctuate to a point of concern.

The Total Dissolved Solids (TDS) showed there were low amounts of dissolved substances in the water. This parameter includes nutrients, salts, and other substances, so it is a positive that this parameter remained low.

Conductivity measures ionic molecules in the water and usually follows the TDS. This parameter measures the molecules in the water ability to conduct electricity. Thus, it is particularly sensitive to salts, which are excellent conductors. This summer, the conductivity was in the middle of the target range, indicating a normal amount of ionic molecules in the lake and no immediate concern of salts.

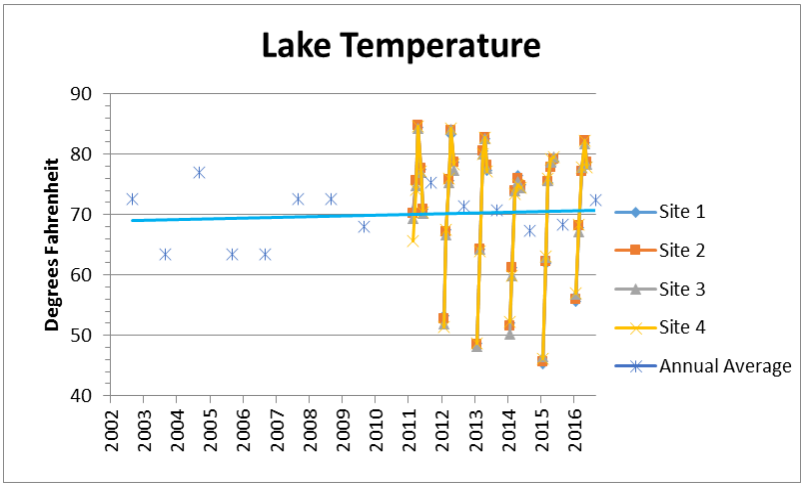
Alkalinity measures the concentration of one salt, Calcium Carbonate, which is beneficial to the aquatic ecosystem. The carbonate ions are able to accept protons from acids, making it a natural buffer. This means that as acidic substances enter the lake, the carbonate is able to buffer against severe changes in pH that could pose a threat to the ecosystem. This summer, the Alkalinity was at a healthy level for all tests.

Pollutants

We tested the lake for Fluoride, Sulfate, and Chloride as indicators of pollution. These molecules should be present in the water naturally, but elevevated levels can indicate pollution from within the watershed and may pose a risk to the ecosystem. All three parameters were within their target ranges throughout the summer.

9353 Hill Road • Swartz Creek, MI 48473
(810) 635-4400 • Fax (810) 635-4404
www.lakeproinc.com

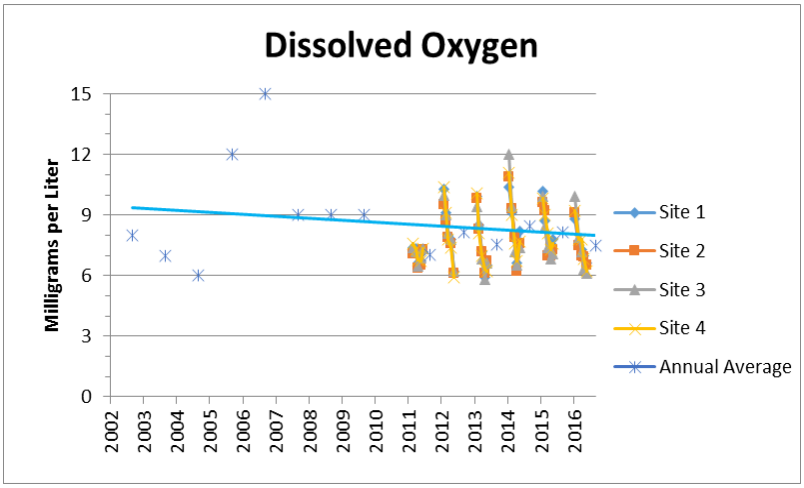
Historical Trends



Lake Temperature (°F)					
	April	May	June	July	August
Site 1	55.6	67.9	76.9	81.9	78.7
Site 2	55.9	68.1	77.2	82.2	78.6
Site 3	56.8	67.2	77.8	81.8	78.3
Site 4	57.0	68.4	77.8	82.2	77.9
			Season Average		72.4

Discussion

The long term trend for water temperature is slightly upward. This season's average was above the trend, which helped to raise it. Water temperature is dependent upon air temperatures and the dates selected for testing. For that reason, LakePro tries to select similar dates for testing each year. The main concern with increasing water temperatures is the reduction in dissolved oxygen solubility.

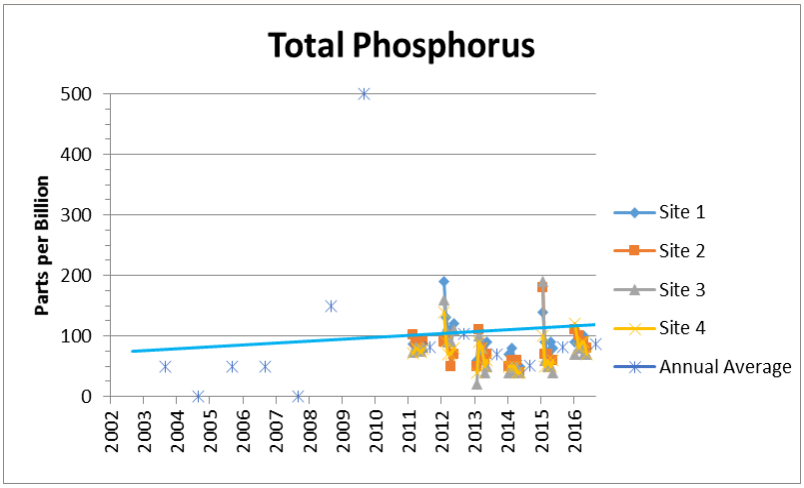


Dissolved Oxygen (mg/L)					
	April	May	June	July	August
Site 1	8.8	7.5	7.3	7.0	6.6
Site 2	9.1	7.5	7.0	6.9	6.5
Site 3	9.9	7.9	7.2	6.3	6.1
Site 4	9.2	7.8	7.8	6.8	6.2
			Season Average		7.5

Discussion

As temperatures slowly rose, the dissolved oxygen solubility decreased. Correspondingly, the season average dissolved oxygen concentrations show a slightly downward trend. Despite the downward trend, the dissolved oxygen remained at healthy levels throughout 2016.

9353 Hill Road • Swartz Creek, MI 48473
(810) 635-4400 • Fax (810) 635-4404
www.lakeproinc.com

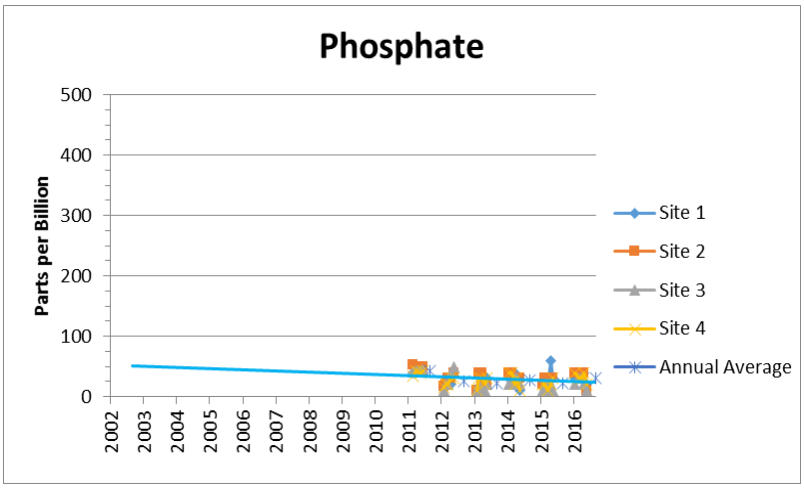


Total Phosphorus (ppb)					
	April	May	June	July	August
Site 1	90	90	90	100	80
Site 2	110	100	90	90	80
Site 3	70	80	80	70	70
Site 4	120	80	90	90	70
			Season Average		87
			Trophic State Index		68

Discussion

Lakes generally accumulate the substances and materials that flow into it, including nutrients. Since testing began in 2003, the trend for phosphorus is upward. The 2008 and 2009 concentrations were much higher than other years of testing, which pulled the trendline up. Without those two data points, the trend would look similar but would rest at a lower concentration.

There are ways to remove phosphorus, such as mechanical harvesting and heavy rain events that create excess flow. However, it is much easier to prevent excess nutrients from entering the lake. For this reason, it is vital that residents around the lake fertilize and use their land responsibly to prevent phosphorus from reaching the lake.

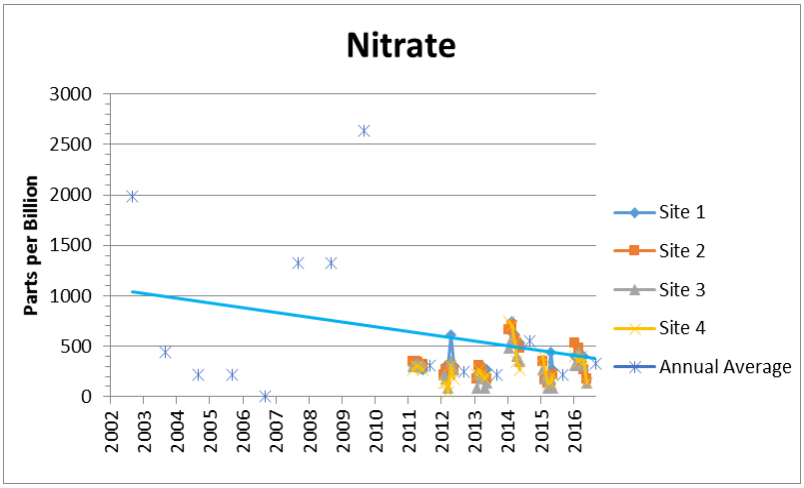


Phosphate (ppb)					
	April	May	June	July	August
Site 1	30	40	40	40	20
Site 2	40	40	30	40	10
Site 3	20	30	30	20	10
Site 4	40	30	30	40	20
			Season Average		30

Discussion

As more total phosphorus accumulates in the lake, so too will the phosphates. There is no historical data available for phosphates, so the trendline reflects the changes during the six years of LakePro's testing. The trend is downward, showing that mechanical harvesting, abundant rain, or responsible land management has had a positive impact on the nutrient concentrations in the lake.

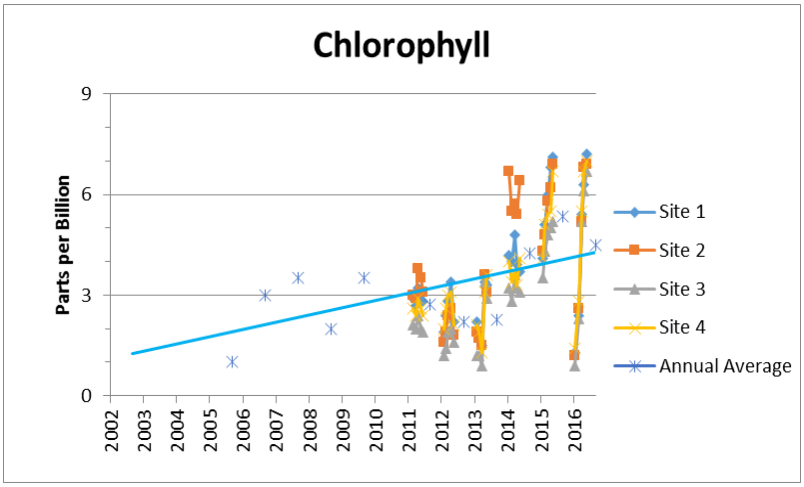
9353 Hill Road • Swartz Creek, MI 48473
(810) 635-4400 • Fax (810) 635-4404
www.lakeproinc.com



Nitrate (ppb)					
	April	May	June	July	August
Site 1	396	352	352	396	176
Site 2	528	484	308	264	176
Site 3	308	440	308	308	132
Site 4	396	352	396	352	132
			Season Average		328

Discussion

Similar to phosphorus, lakes generally accumulate more nitrate. The historical trend for nitrate is downward, with the past six years well within the target range. It is important that residents around the lake fertilize and use their land responsibly so as to prevent nitrate from reaching the lake.

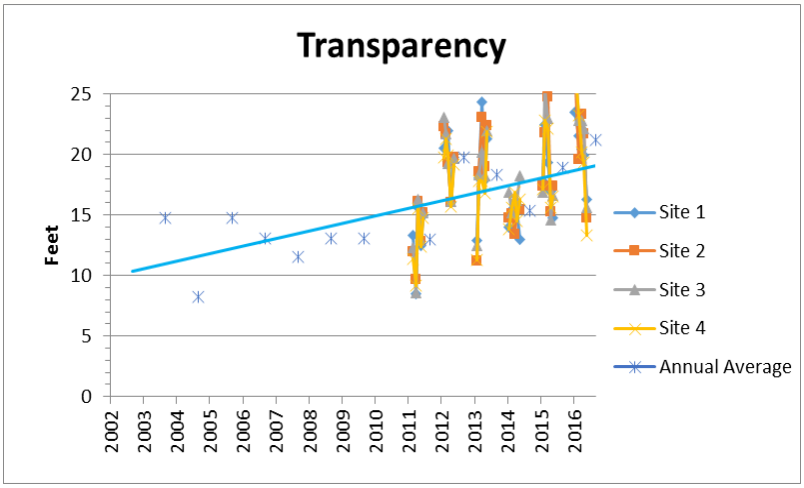


Chlorophyll (ppb)					
	April	May	June	July	August
Site 1	1.3	2.4	5.4	6.3	7.2
Site 2	1.2	2.6	5.2	6.8	6.9
Site 3	0.9	2.3	5.2	6.1	6.7
Site 4	1.4	2.8	5.5	6.7	7.0
			Season Average		4.5
			Trophic State Index		44

Discussion

Chlorophyll has an upward trend over the testing history. This shows that as the lake accumulates more nutrients, especially phosphorus, the plant growth worsens in the lake. The chlorophyll remained within the target range, but slowing or reversing the upward trend should be a goal for the lake management. Continuing to mechanically harvest will remove plant biomass and the nutrients within it. Responsible land management by residents around the lake will help stifle the source of excess nutrients, preventing further worsening of the plant growth.

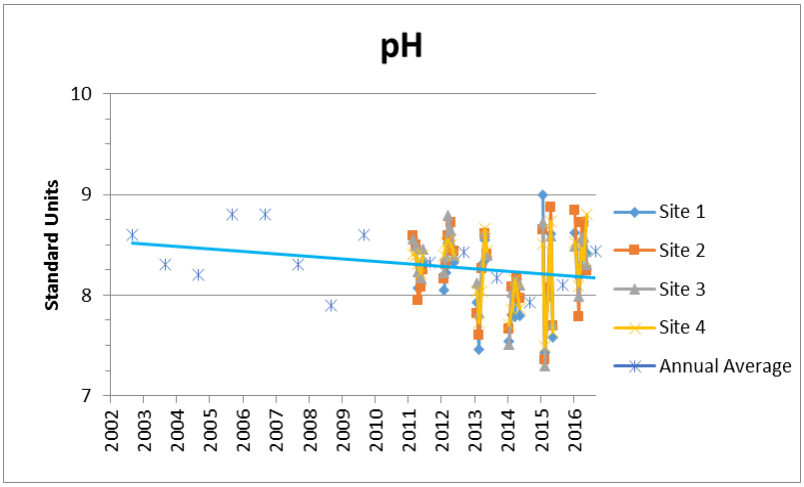
9353 Hill Road • Swartz Creek, MI 48473
(810) 635-4400 • Fax (810) 635-4404
www.lakeproinc.com



Transparency (feet)					
	April	May	June	July	August
Site 1	23.5	21.5	20.4	19.9	16.3
Site 2	27.5	19.6	23.3	21.7	14.8
Site 3	28.1	22.8	22.8	22.1	15.6
Site 4	27.5	23.2	20.2	19.3	13.3
			Season Average		21.2
			Trophic State Index		33

Discussion

More chlorophyll usually indicates higher amounts of algae in the water column, which clouds the water and reduces transparency. Despite the upward trend of chlorophyll, the transparency also trended upward. The improvement in water clarity could be due to better weather, fewer dissolved solids, or fewer suspended solids (e.g. sediment). The increasing transparency is positive for the appearance of the lake. However, more sunlight reaching deeper depths with higher nutrient levels may lead to worsening of the nuisance plant growth in the lake.

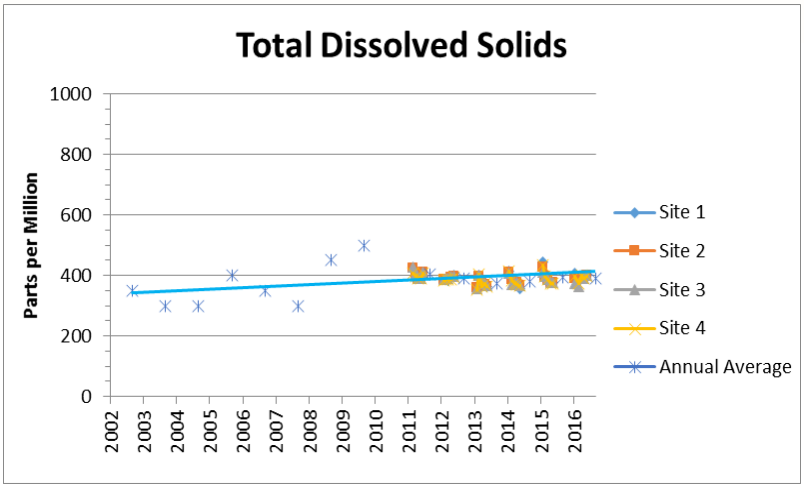


pH (Standard Units)					
	April	May	June	July	August
Site 1	8.62	8.18	8.23	8.73	8.42
Site 2	8.84	7.78	8.72	8.72	8.24
Site 3	8.49	7.99	8.57	8.58	8.30
Site 4	8.53	8.09	8.47	8.35	8.80
			Season Average		8.4

Discussion

The pH declined over the testing history. The shift has moved annual values away from 9 and closer to 8, the middle of the target range. This change has not had a major impact on the lake, but it is important to look for this trend to level off. If the pH continues to decrease toward 7 or below, it may indicate a problem with pollution or the oxygen production of the lake.

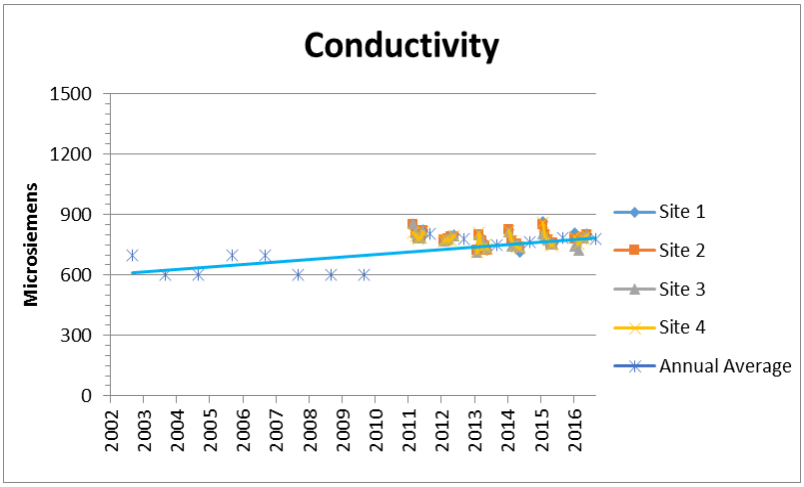
9353 Hill Road • Swartz Creek, MI 48473
(810) 635-4400 • Fax (810) 635-4404
www.lakeproinc.com



Total Dissolved Solids (ppm)					
	April	May	June	July	August
Site 1	406	388	391	392	401
Site 2	392	388	392	391	400
Site 3	374	362	392	392	399
Site 4	398	375	399	391	398
			Season Average		391

Discussion

The total dissolved solids increased over the testing history, showing that the lake is accumulating more substances. The increase has been slow and the past four years helped to flatten the trend.

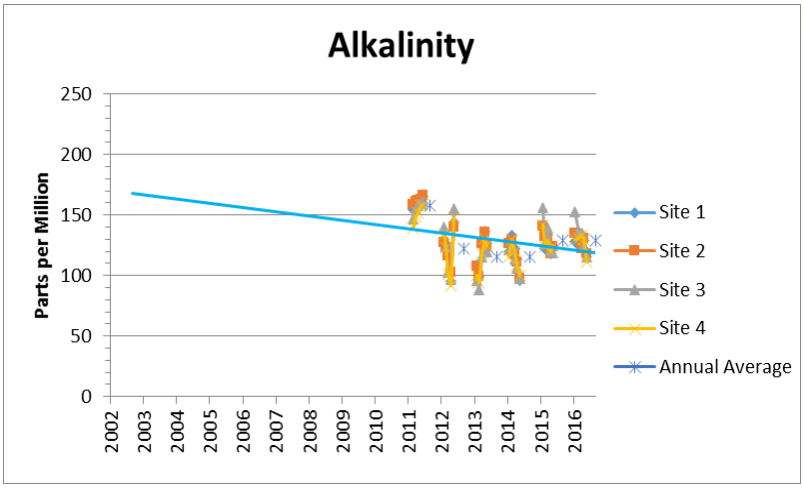


Conductivity (µS)					
	April	May	June	July	August
Site 1	811	776	782	783	803
Site 2	780	777	784	782	801
Site 3	742	722	784	783	799
Site 4	791	753	780	783	796
			Season Average		781

Discussion

Like the TDS, conductivity increased over the testing history. Conductivity is an extension of TDS and measures the amount of ionic molecules in the water (which conduct electricity; usually salts). We will look for this trend to slow in future years of testing.

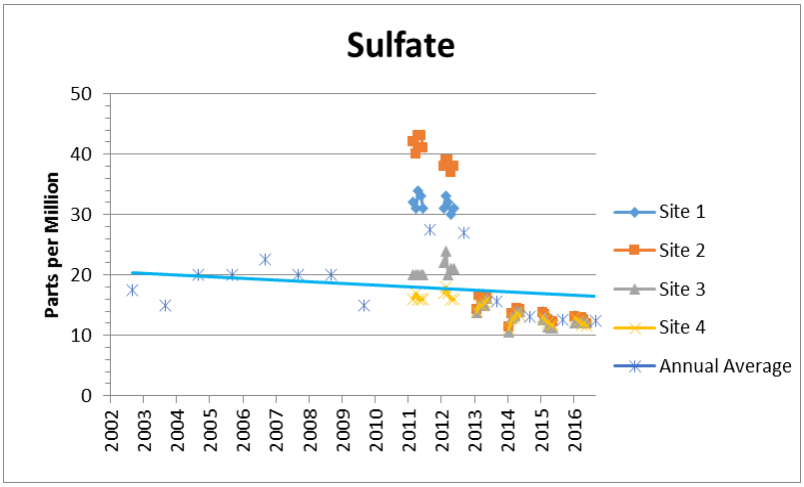
9353 Hill Road • Swartz Creek, MI 48473
(810) 635-4400 • Fax (810) 635-4404
www.lakeproinc.com



Alkalinity (ppm)					
	April	May	June	July	August
Site 1	128	125	134	129	120
Site 2	135	134	122	131	118
Site 3	153	137	135	124	115
Site 4	130	131	133	130	111
			Season Average		129

Discussion

Alkalinity was first included in 2011, so the historical data is limited. The long term trend for alkalinity is downward, but showed an upward swing over the past three years. As snow melt and rain infiltrate the ground, it will reach the natural groundwater aquifers where it will dissolve calcium carbonate and replenish the alkalinity when it enters the lake.

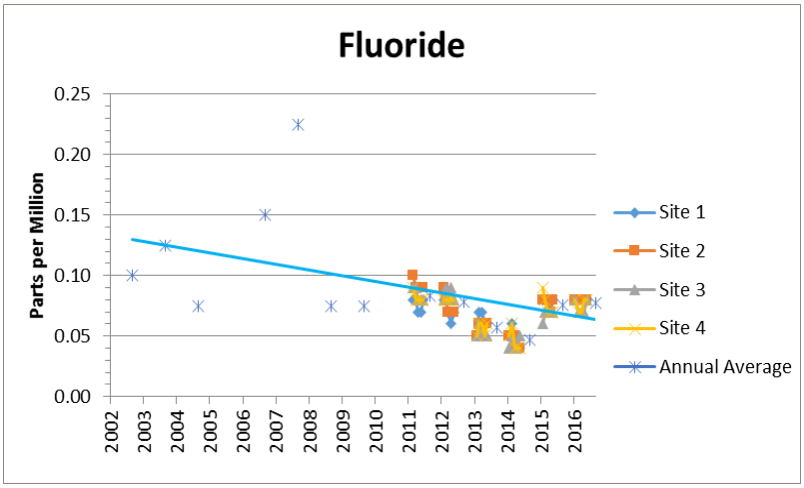


Sulfate (ppm)					
	April	May	June	July	August
Site 1	13.3	12.7	12.5	12.4	12.1
Site 2	13.1	12.3	12.9	12.6	11.9
Site 3	12.0	12.3	12.1	12.1	12.2
Site 4	12.9	12.4	11.8	12.0	11.5
			Season Average		12.4

Discussion

Sulfate decreased slightly over the course of testing and the four most recent years were below the trend line. It is important that this parameter stay within the target range and any sharp increases will be investigated.

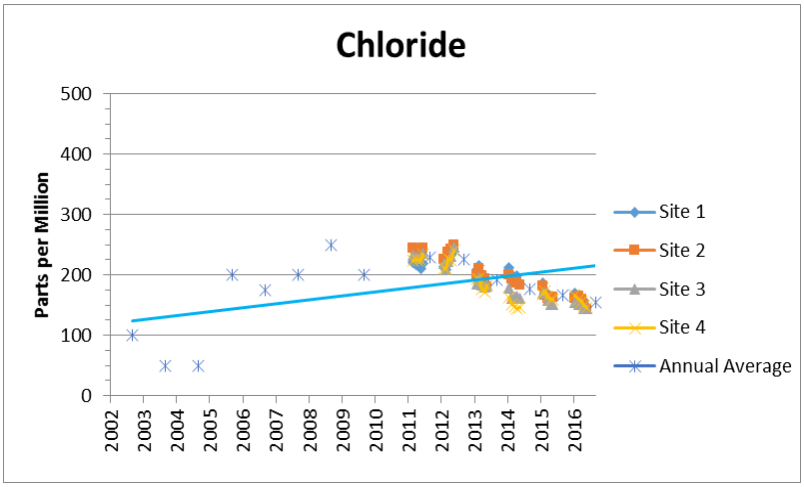
9353 Hill Road • Swartz Creek, MI 48473
(810) 635-4400 • Fax (810) 635-4404
www.lakeproinc.com



Fluoride (ppm)					
	April	May	June	July	August
Site 1	0.08	0.08	0.08	0.08	0.08
Site 2	0.08	0.08	0.08	0.08	0.08
Site 3	0.08	0.07	0.07	0.07	0.08
Site 4	0.08	0.07	0.07	0.08	0.08
			Season Average		0.08

Discussion

Fluoride decreased in the lake since testing began in 2002. It is important that this parameter stay within the target range and any sharp increases will be investigated.



Chloride (ppm)					
	April	May	June	July	August
Site 1	169	166	162	157	147
Site 2	162	164	159	151	143
Site 3	155	151	153	145	144
Site 4	167	160	157	149	146
			Season Average		155

Discussion

The trend line for chloride shows the chloride increased over the testing history, but individual data points show the chloride has been relatively consistent since 2005. With concerns about road salt entering lakes, it is important that this parameter remain within the target range and any increases will be investigated.

9353 Hill Road • Swartz Creek, MI 48473
(810) 635-4400 • Fax (810) 635-4404
www.lakeproinc.com

Analysis Information

Temperature:	The water temperature directly affects the amount of oxygen that is able to dissolve into the water. The temperature of surface waters is not indicative of the entire water column.
Transparency:	The ability of light to penetrate the water column is determined by the amount of dissolved and suspended particles in the water. Although aesthetically desirable, transparent water allows increased light to reach the lake bed and may result in vegetation growth.
pH:	pH is a measure of acidity or alkalinity. pH is a general measure of lake health and can roughly indicate the range of other measurements such as alkalinity and hardness.
TDS:	Total Dissolved Solids is the amount of all organic and inorganic substances in the water in a molecular or ionized state. Higher values generally indicate richer and more productive water. Lower values usually indicate cleaner and less productive water.
Conductivity:	Conductivity is a measure of the ability of water to conduct electricity. Dissolved ions in the water increase conductivity, thus TDS and Conductivity are closely related.
Alkalinity:	Alkalinity refers to the ability of the water to neutralize acids, mainly through the hydrogenation of carbonate ions. This is why the alkalinity is expressed as "ppm as $CaCO_3$". However, other basic molecules in the water can also contribute to alkalinity.
Dissolved Oxygen:	D.O. is a measure of the amount of oxygen dissolved in the water. This oxygen is available to fish and other animals for respiration. Vegetation generally increases DO, particularly during the day and early evening. Animals and other respiring organisms consume the oxygen, mostly during the day. Oxygen is also added to the lake through wave action, rain, fountains and aerators.
Total Phosphorus:	Phosphorus is an essential nutrient for plant growth. However, concentrations exceeding 100 ppb can impair the water and results in nuisance vegetation growth.
Phosphates:	Phosphate is the form of phosphorous that is most readily available to plants and algae.
Nitrate:	Nitrogen is also essential for plant growth. Nitrate is the predominant form of nitrogen in water. Excessive nitrate concentrations may also result in pollution and increased vegetation.
Chlorophyll-a:	Chlorophyll-a is a direct measurement of the amount of green pigment produced by plants and phytoplankton. This indicates the amount of plant growth and is used to calculate a Trophic State Index.
Sulfate:	Sulfate occurs naturally as minerals, such as calcium sulfate and magnesium sulfate. In fresh water, sulfate is usually the second or third most abundant anion. Other sources of sulfate include water material from pulp mills, steel mills, food processing operations, and municipal wastes. Under low oxygen conditions, sulfate can by reduced to hydrogen sulfide gas, which smells like rotten eggs.
Fluoride:	Fluoride may occur naturally or be added to public drinking water supplies.
Chloride:	Chloride is one of the major anions found in water and sewage. The presence of chlorides may be due to water passing through salt formations in the earth or pollution from industrial processes, domestic wastes, or road salt. The salt content of water affects the

distribution of plant and animal life in an aquatic system, based on the amount of slat they can tolerate.

Fecal Coliforms: Non-fecal coliforms are naturally found as soil organisms. Fecal Coliforms, such as *E. coli*, are coliforms found in the intestines of warm-blooded animals and humans. The presence of fecal coliforms indicates contamination from either animals or humans.

Trophic States

Oligotrophic: Water is very clear. Nutrient levels are generally low. Plant and algae productivity is also low. Sufficient dissolved oxygen in the bottom, cooler waters allows cold-water fish to survive, such as salmon and trout.

Mesotrophic: Water is moderately clear. Nutrient levels are slightly elevated. Plant and algae productivity is present, but generally not a nuisance. Oxygen and temperature in the lower portion of the lake allow walleye and perch to survive.

Eutrophic: Water is not clear due to high nutrients levels, increased turbidity, and excessive algal growth. There is no oxygen in the bottom, cooler waters, restricting the lake to warm water species, such as bass and bluegill.

Hypereutrophic: Nutrient levels are extremely high, promoting very high algae productivity. Blue-green algae blooms are likely. High turbidity and algae growth make the water opaque. Little plant growth is restricted to invasive plants. The only fish that can survive this environment are rough fish, such as carp, catfish, and mudminnows.

Sample Sites: