2017 Report on the Health of the Norway Lakes

Prepared by Stephan Zeeman, Ph.D.

Protecting our Lakes:

The Lakes Association of Norway (LAON), with support from the Town of Norway, continued to monitor the health of the four Norway lakes: Pennesseewassee, Little Pennesseewassee (Hobbs Pond), Sand, and North Ponds in 2017. The voluntary boat inspection program for people bringing their boats into Lake Pennesseewassee continues, and has been successful at preventing invaders on two specific occasions. The level 3 invasive aquatic species screening of the four lakes occurred in September and October, and was conducted by lake scientists from Lake and Watershed Resource Management Associates (LWRMA). They again found no invasive aquatic plants in any of the lakes, the invasive shoreline plant called yellow iris is still in Pennesseewassee, but efforts are ongoing to try to eradicate it. Their full report is separate and may also be found on the LAON website http://norwaylakes.org/water-quality/.

Monitoring of the lakes' water chemistry took place from July 14 to September 15, 2017, during the time of the year when lakes and ponds are the most biologically productive and water quality problems are most likely to occur. Scott Williams and staff from LWRMA collected all of the water quality samples. The analysis what was found follows.

Overview

The table below shows the average values at the surface and bottom (except Secchi depth) of the lakes for primary water quality parameters measured.

Lake	Avg P Surface	Avg P Bottom	Avg Chl Surface	Avg Secchi	Avg O_2 Surface	Avg O_2 Bottom
Sand Pond	4.3 (5.9)	16.0	2.3 (2.8)	7.2 (7.4)	9.56	3.74
Hobbs	8.0 (6.7)	16.0	4.6 (4.3)	5.9 (5.3)	8.28	2.75
Norway	8.3 (9)	13.5	5.2 (4.3)	5.9 (5.8)	8.41	2.08
North	18.0 (17)	N/A	5.4 (2.8)	3.2 (2.8)	8.10	N/A

N/A – Not applicable, North Pond is so shallow, wind mixes it constantly.
(x.x) – Long-term average

The Total Phosphorus concentrations (Avg P) are not very different from the long term average, and are within normal variations seen in the lakes. This year again, Sand Pond had the best water quality of the four lakes. All of our lakes are classified as being mesotrophic (middle productive) based on the phosphorus values. The worrisome aspect is that bottom water concentrations of Total Phosphorus are relatively high, indicating that phosphorus has been building up in the lakes. This contributes to what lake scientists call internal loading, a buildup of phosphorus in the sediments which can then be released

during the summer when oxygen is depleted in the bottom water. We don't want our lakes to become highly productive (eutrophic), which would happen if the phosphorus concentrations increase. As can be seen from the above table, the oxygen values for our deep lakes are much lower in the bottom water. This happens because the lakes form two layers (stratify), a warm surface layer produced by solar heating, and a colder bottom layer. The oxygen in lakes enters the water in the surface layer via the atmosphere mixing with the water and also from photosynthesis in plant life such as algae (phytoplankton), which eventually die. The remains of dead algae, along with other microscopic plants and animals that live and die in the surface layer, sink to the bottom. Their decomposition then removes oxygen from the deep layer of the water. This is a vicious cycle - input of phosphorus leads to plant and animal growth, whose death leads to oxygen depletion, which releases more phosphorus from the bottom sediments, which leads to more growth, etc. until the lake is in real bad shape. Normal values of oxygen are in the range of 8-10 ppm in surface waters. Fish cannot live in waters with oxygen values below 3 ppm. We are not there, but we need to make every effort to prevent phosphorus getting into the lakes, which is the purpose of LAON's Watershed Protection Program. The Chlorophyll (Chl) values are also close to historical averages, and further show that the lakes are mesotrophic. The chlorophyll values in this year's data tend to show higher values in July, lower values in August, and slightly higher values in September. This is part of a seasonal trend, the July values reflecting the remnants of the Spring bloom (a natural phenomenon that occurs everywhere), the lower values in August are due to depletion of nutrients in the upper layer of water, and the September values increase because Autumnal mixing is stirring nutrients from the deeper water layer into the surface layer as they are being mixed by increasing storms and colder temperatures. Chlorophyll is a measure of how much algae is in the water, and algae thrive on phosphorus, so the two are linked. Secchi depth is a measure of water clarity, the clearer the water, the less algae there are. So this hopefully explains the connections among phosphorus, algae, oxygen and water clarity and why we measure those things.

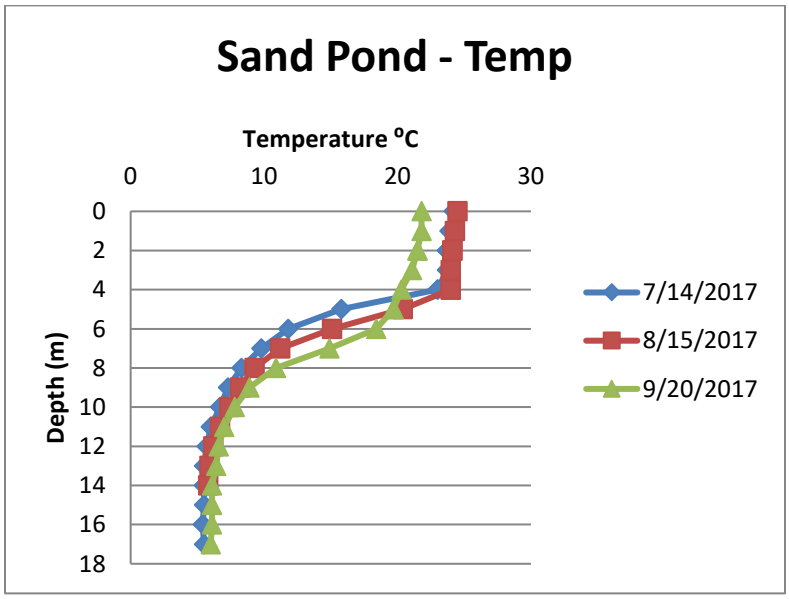
Data trend analysis was also carried on all of the data since 2005. This time was chosen to be recent, and to show possible current trends. The conclusion that can be drawn from this analyses is that the levels are staying relatively constant for now for all of our measurements. For more detail about lake ecology, what various water quality measures mean, and 40 year historical trends of measurements from our lakes, please find the 2015 report on the LAON website http://norwaylakes.org/water-quality/.

The figures in the trend analysis show the data with a linear regression and 95% confidence intervals around the regression line. While trend lines for total phosphorus may be showing a slight decline, we must keep in mind that the data are variable. Due to the limited data points, a few outliers (extreme data points that might or might not be accurate) can cause large changes in the trend line. The same is true for chlorophyll, a suggestion of a slight decline, but with much uncertainty. The pH values were fairly stable through this time period. There was perhaps a slight increase in Sand Pond. Apparent color due to decomposing vegetation was also very stable. Alkalinity was stable in most of the lakes, although there was a slight increase in Pennesseewassee. There was insufficient conductivity data to conduct an analysis.

Individual Lake Analyses

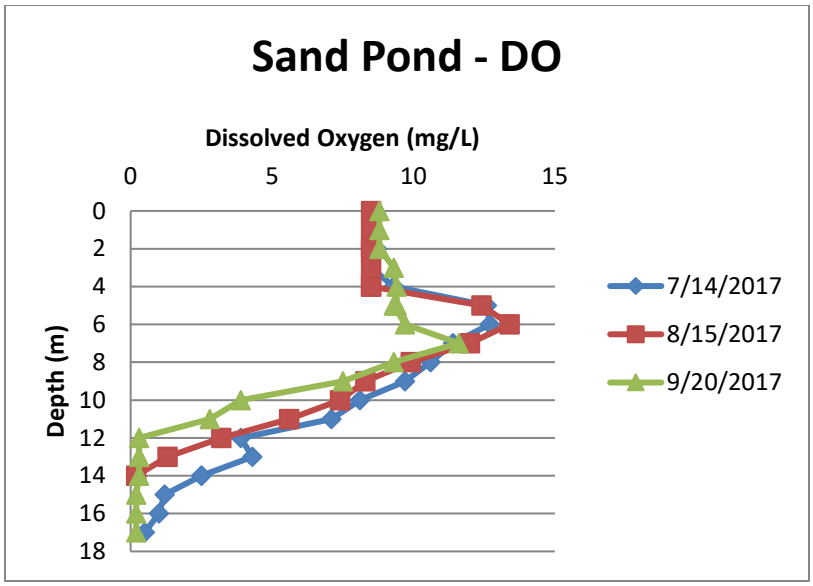
Sand Pond:

Sand Pond is the best of the four lakes in terms of water quality. The surface phosphorus concentrations, and algae were lower than in the other lakes. As a result water clarity was also greater. The lake does however exhibit oxygen depletion in the deep waters, and a source of phosphorus that is being released from the sediments. This is a warning that we need to be careful, or risk degradation of water quality with massive algae blooms.



Sand Pond was already strongly stratified (two-layered) by mid-July. This is seen by the almost uniform temperatures near the surface (upper 4 meters), followed by a decline in temperatures in the deeper waters. The available nutrients (e.g. phosphorus and nitrogen) had been reduced in the surface by algae growth during the spring bloom. This can be seen by the fact that there is an oxygen peak just below 4 meters indicating algae photosynthesis just below the surface layer. Algae often use this zone at the top of the thermocline (the region of rapid temperature change) to their advantage. Since the surface layer has been depleted of nutrients by algae growth, and is where more zooplankton feed on algae, this zone below the surface layer is a refuge for algae. This region also receives enough sunlight for photosynthesis, and is rich in nutrients from decomposition and regeneration from the sediments. This concentration of algae is known to lake ecologists as the “deep chlorophyll maximum.”

Phosphorus levels in the surface waters were less than 5 parts per billion (ppb), which is on the low end of concentrations seen in lakes. In the bottom waters however, they rose to 14-18 ppb, indicating an internal storage of phosphorus in the lake sediments which was being released due to the low oxygen environment in the deeper waters.



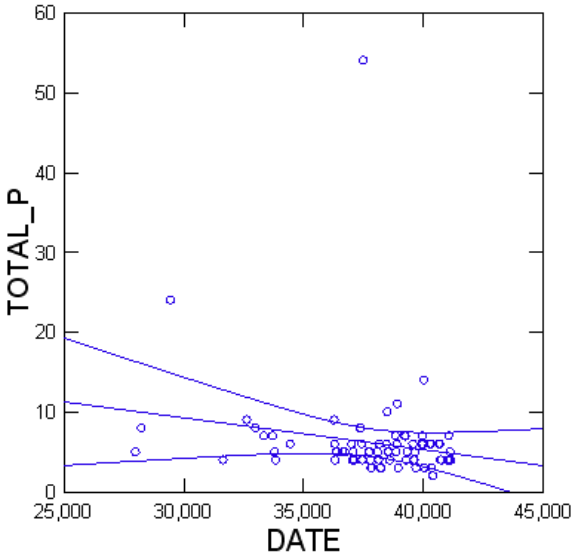
The Secchi depths ranged up to 7.8 meters, the clearest of any of the 4 lakes. The lower reading in July is indicative that the spring algae bloom was possibly just ending. Typically, a spring bloom occurs due to abundant nutrients after winter mixing and abundant light as the sun rises higher in the sky as seasons change. The bloom ultimately reduces the available nutrients in the surface after stratification due to solar heating takes place of the surface. The reduced nutrients lead to reduced algae growth in the surface, and to clearer waters later in the summer.

The chlorophyll concentrations at less than 3 are indicative of a relatively clean lake, and corroborate the Secchi disk readings. In fact, they parallel the Secchi depths, higher values of chlorophyll corresponding to decreased Secchi depths.

No data were collected for pH, color, conductivity, or alkalinity

Sand Pond	Date	Depth	DO	Secchi	Tphos	Chl	pH	Color-Apparent	Conductivity	Alkalinity
	7/14/2017	6	9.82	6.17	5	2.5				
	7/14/2017		5.23							
	8/15/2017	6	9.48	7.79	4	1.4				
	8/15/2017	16	4.38		14					
	9/20/2017	7	9.38	7.57	4	2.9				
	9/20/2017	16	1.60		18					

Trend Analysis (2005 to 2017). Please note limitations described in the Overview of this report.



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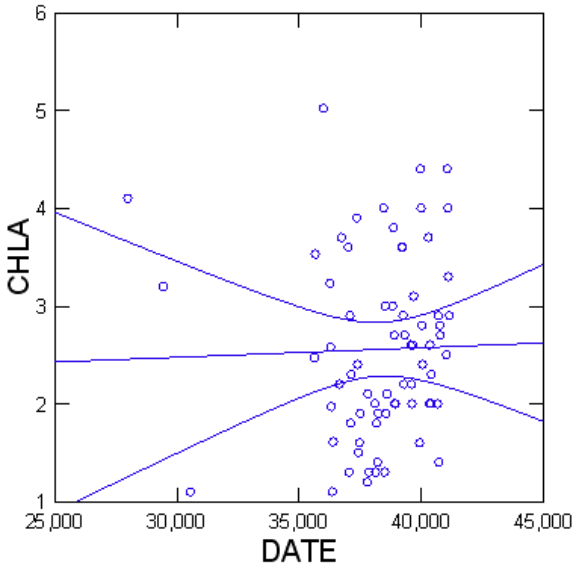

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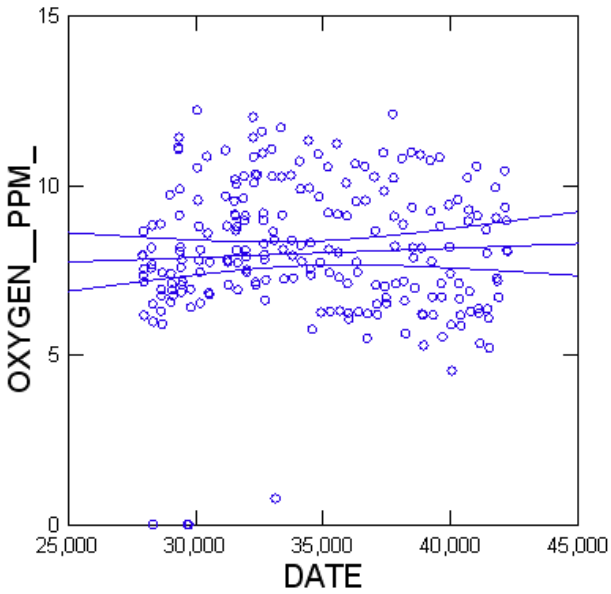

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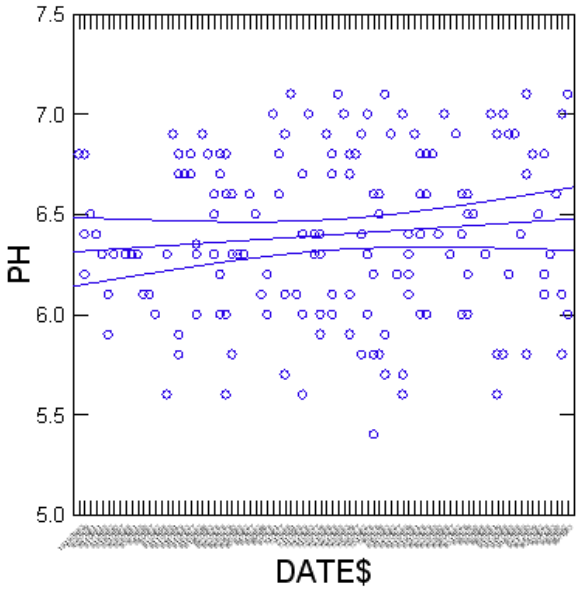

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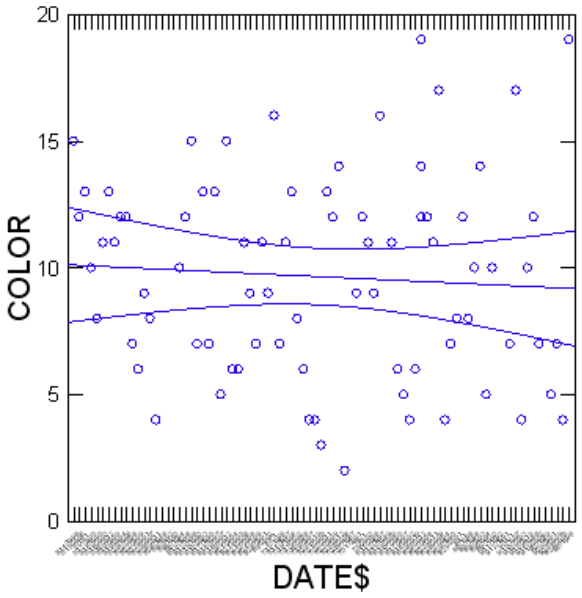

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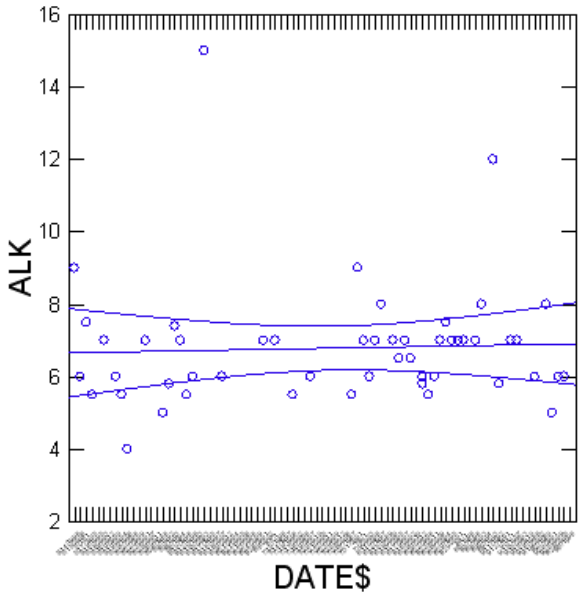
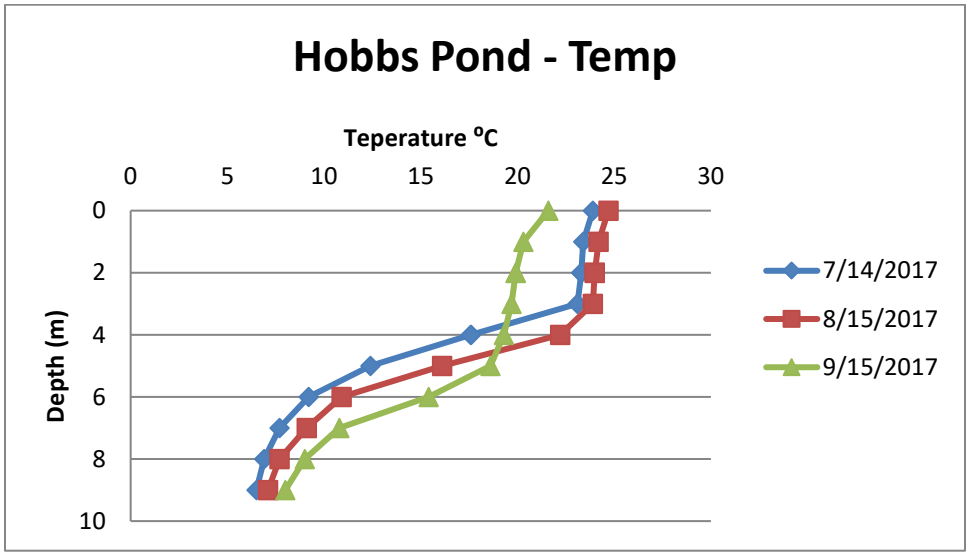


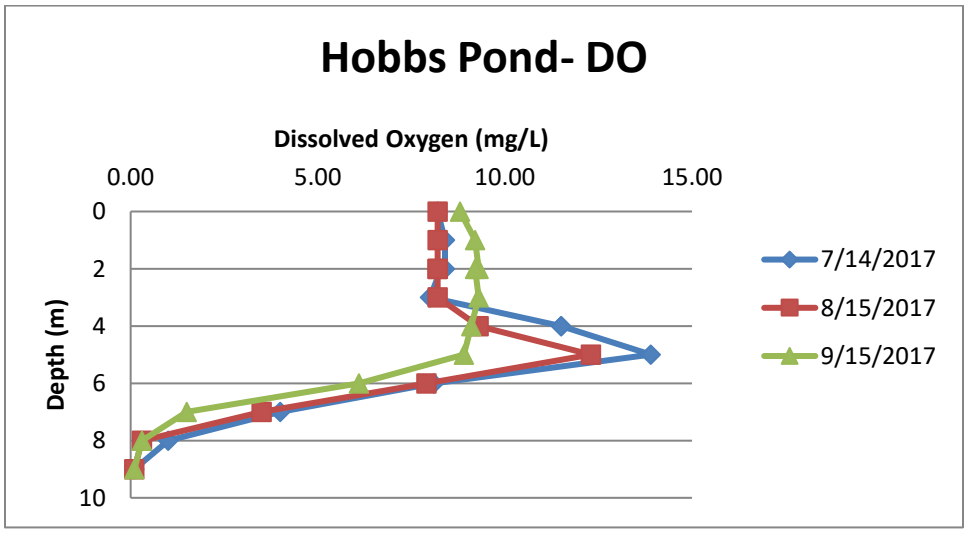
Results for LAKE$ = Sand Pond TYPE$ = C
Data for the following results were selected according to SELECT (DATE$ >= '01/01/2005')

Hobbs Pond (Little Penn):

Hobbs Pond, like the other lakes is considered a medium productive (mesotrophic) lake. This is determined from the chlorophyll levels (between 1.5 and 6.5) and the phosphorus levels (between 5 and 10 parts per billion at the surface). Total phosphorus in the bottom water is higher than in the surface (13-19 ppb) indicating the release of phosphorus from internal storage in the sediments due to the low oxygen concentration. The indicators have not changed significantly from the long-term average, indicating no changes in the lake status.



The lakes were strongly stratified by temperature (two-layered) by the time sampling began. The higher chlorophyll levels in July indicate that the Spring bloom was still occurring, while in August the low values indicate depletion of nutrients from the surface waters. This is verified by the phosphorus concentrations which declined from 10 to 5 ppb. The increase in phosphorus in September is due to the start of Autumnal mixing, which stirs the upper and lower water layers together.



The dissolved oxygen concentrations in Hobbs Pond were similar to those in Sand Pond. The surface layer was well oxygenated, but at the bottom, oxygen levels fell to zero due to decomposition of organic matter. Like Sand Pond, the water here also had a “deep chlorophyll maximum” as indicated by the peak

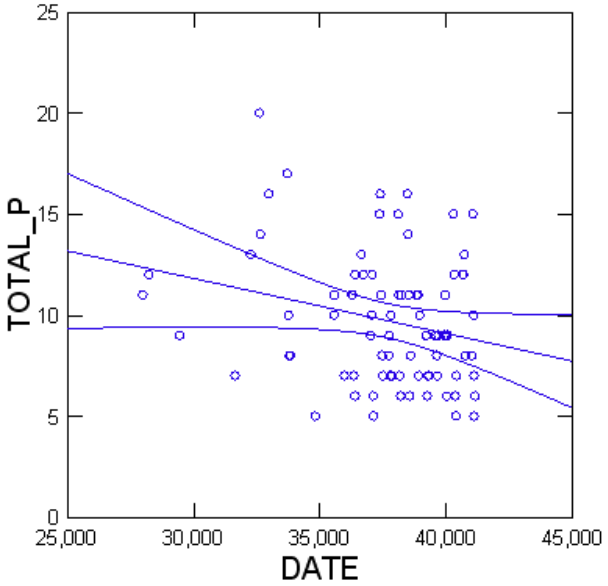
of oxygen just below the surface mixed layer at about 5 meters. These algae are taking advantage of the higher nutrient levels in the deep layer, while still getting enough sunlight for photosynthesis, which causes the oxygen peak.

Water clarity, as indicated by Secchi depth, was lower in July, but then increased in August and declined slightly in September. This is due to algae growth, which was high initially, as indicated by the Chlorophyll concentration, and declined in August due to nutrient depletion in the surface water (phosphorus dropped from 10 to 5 ppb). In September the chlorophyll increases again due to Autumnal mixing which stirs deeper waters into the surface layer, and increasing the depth of the surface layer. The mixing also brings the phosphorus contained in the deeper water to the surface where algae use it to grow.

The lake is slightly basic at a pH of 7.3, which is normal. The color is relatively low, and is mostly cause by humic acids from decaying vegetation. The Alkalinity of 94 is not very high, indicating that the lake is not well buffered against pH changes, however acidification does not seem to be a problem here.

Hobbs Pond	Date	Depth	DO	Secchi	Tphos	Chl	pH	Color-Apparent	Conductivity	Alkalinity
	7/14/2017	5	9.775	4.45	10	6.5		22		94
	7/14/2017		3.30							
	8/15/2017	5.5	8.94	7.60	5	1.7	7.3			
	8/15/2017	8.5	2.95		19					
	9/15/2017	7.5	9.11	5.72	9	5.6				
	9/15/2017	8	2.00		13					

Trend Analysis (2005 to 2017). Please note limitations described in the Overview of this report.



Results for LAKE$ = Little Pennesseewassee
QUALIFIER$ = EC
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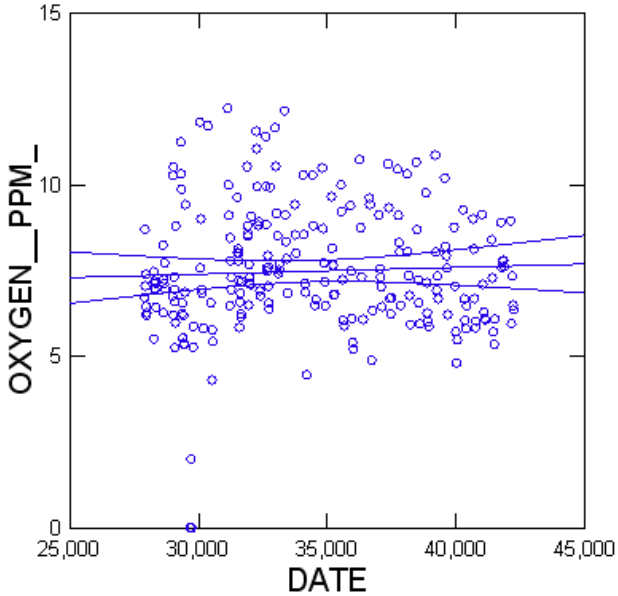

Results for LAKE$ = Hobbs 0367 STATISTICS$ = Arithmetic Mean
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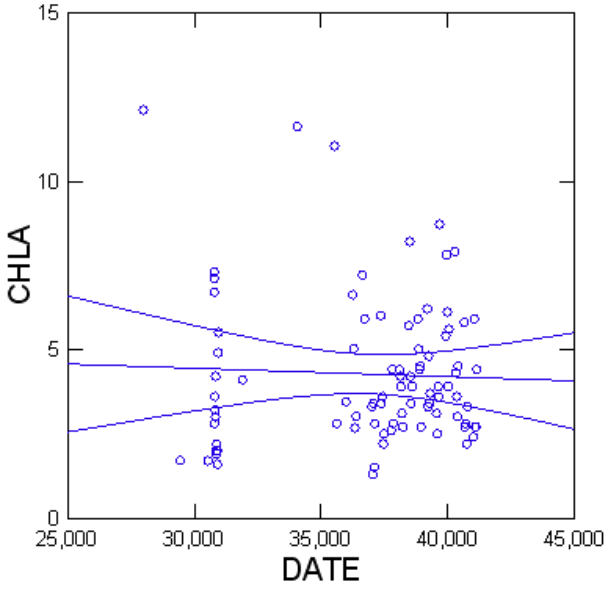

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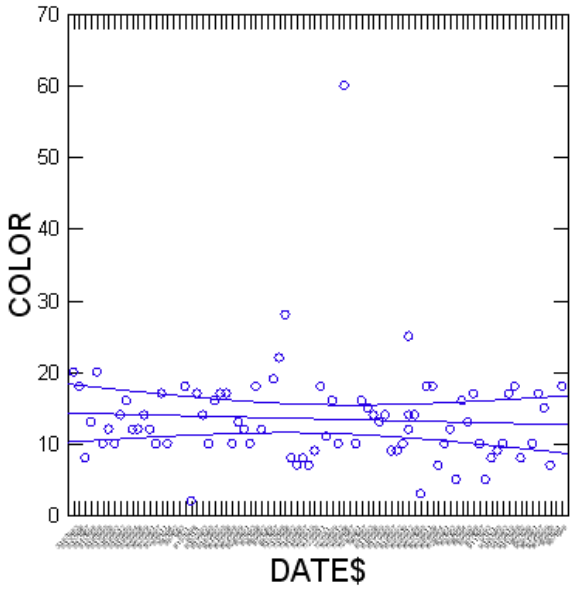

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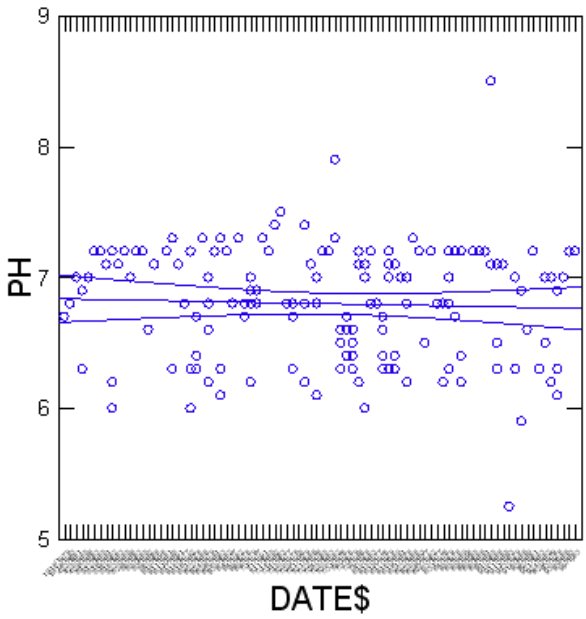

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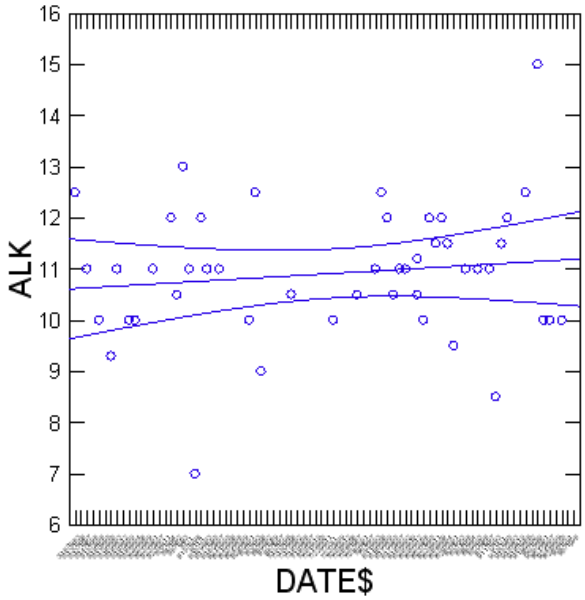
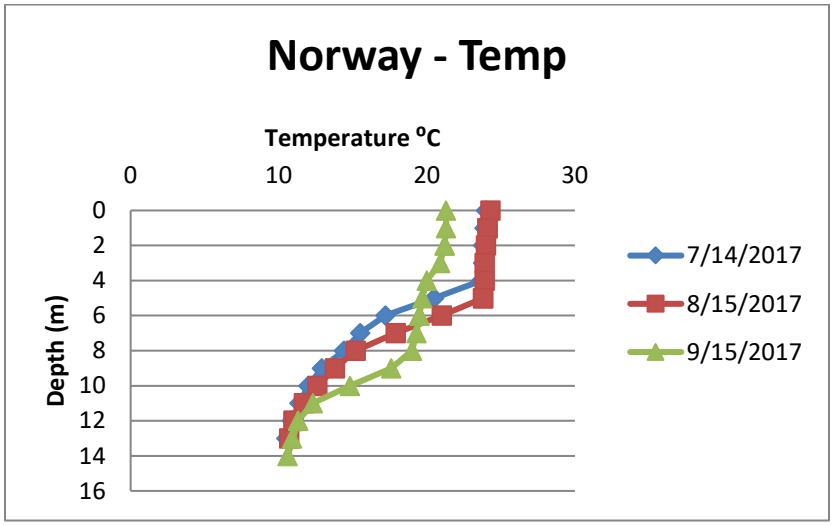


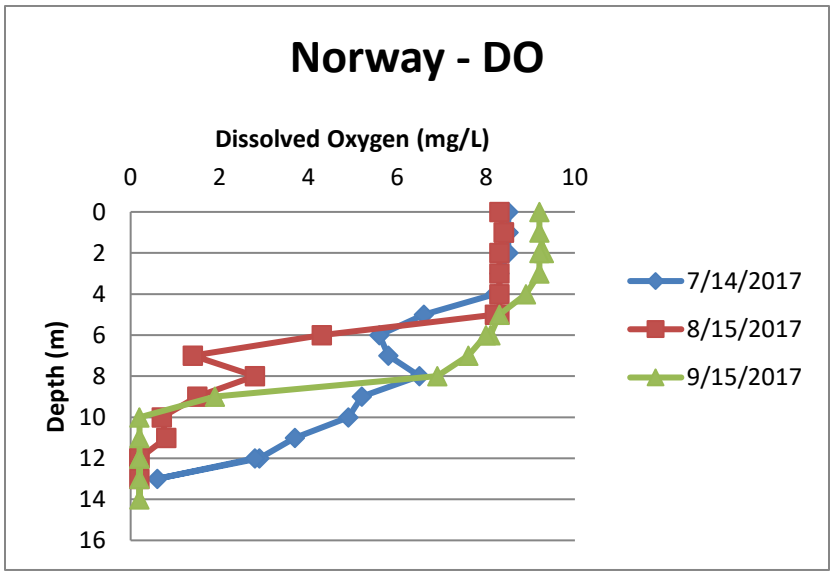
Results for LAKE$ = Little Penne TYPE$ = C
Data for the following results were selected according to SELECT (DATE$ >= '01/01/2005')

Lake Pennesseewassee (Norway Lake):

Lake Pennesseewassee (aka Norway Lake) is also a medium productive lake (mesotrophic) having moderate amounts of phosphorus and algae in the surface waters. Water clarity is on the order of 5 meters during the summer, which is also indicative of a mesotrophic lake. Like the other lakes in our area, oxygen depletion occurs in the bottom waters, and there is elevated phosphorus due to release from the sediments during times of low oxygen. This is a warning sign that phosphorus needs to be managed, or the lake could suffer massive algae blooms as has happened in other areas.



Pennesseewassee, like the other lakes was strongly stratified (two-layered) by mid-July. The surface layer thickened from 3 m to 5 m between July and August due to solar heating. Surface total phosphorus was 9 parts per billion (ppb) in July, and decreased slightly to 8 in August. This is consistent with Chlorophyll levels which also decreased during that same time from 7 to 3.8 showing that the algae were using up the nutrients in the surface layer. Bottom water concentrations of phosphorus were 13-14 ppb, indicating a release of phosphorus stored in the lake sediments caused by the low oxygen environment in the deeper waters.



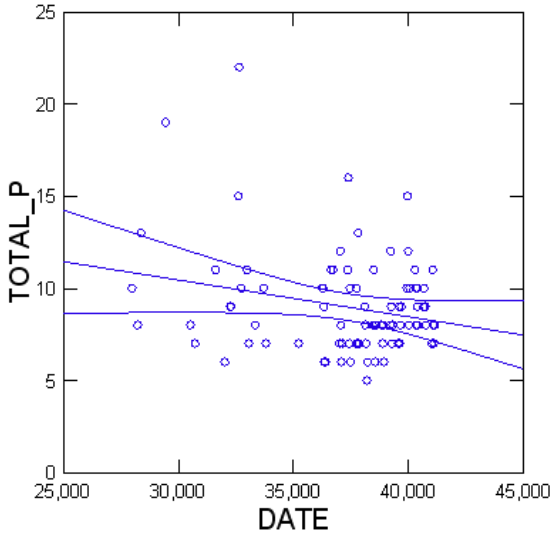
The dissolved oxygen in Lake Pennesseewassee showed interesting patterns this year. The July and August samples both show a decrease in oxygen at 6-7 meters, just below the start of the thermocline (rapid change in temperature). This is most likely due to decomposition of microscopic algae and zooplankton that had been growing at the base of the surface layer. This decomposition releases phosphorus back into the water and contributes to the elevated phosphorus levels in the deep water. The drop in oxygen here indicates higher respiration rates, although the cause is uncertain, it could be due to the high levels of phytoplankton earlier in spring and summer, as evidenced by the higher chlorophyll levels.

We see from the temperature profiles that the September sample shows the start of Autumnal cooling. Surface temperature declined from 24 C in August to 21 C in September. Fall mixing of the lake is also indicated by the oxygen profile, which shows higher concentrations than in the previous months in the surface waters. In addition the oxygen concentrations are higher to about 9 meters deep, and there is no evidence of the decreases at 6-7 meters.

Norway Lake	Date	Depth	DO	Secchi	Tphos	Chl	pH	Color-Apparent	Conductivity	Alkalinity
	7/14/2017	5	8.40	5.26	9	7		16	83	14
	7/14/2017		4.46							
	8/15/2017	5	8.31	5.43	8	3.8	7.49	18		
	8/15/2017	13	1.34		14					
	9/15/2017	7.5	8.54	7.02	8	4.9		11		
	9/15/2017	13	0.44		13					

The Chlorophyll (Chl) levels are relatively high in July possibly indicating that these algae are remnants of the spring bloom. The values indicate a moderately productive lake (high productivity is not good). The pH is good, at a slightly basic level. There is only a small amount of color in the lakes, due to decomposing vegetation, which release humic acids. The conductivity levels are low, which is good as high conductivity could indicate road salt adversely affecting the lake. The alkalinity is not very high. That means the lake has a relatively low buffering capacity, although the pH indicates that acidification is not a problem right now.

Trend Analysis (2005 to 2017). Please note limitations described in the Overview of this report.



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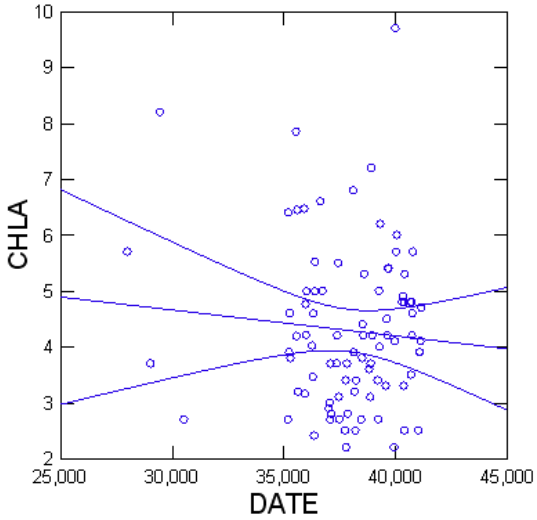

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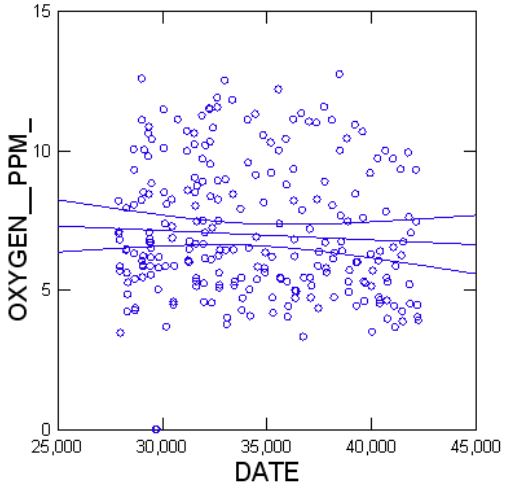

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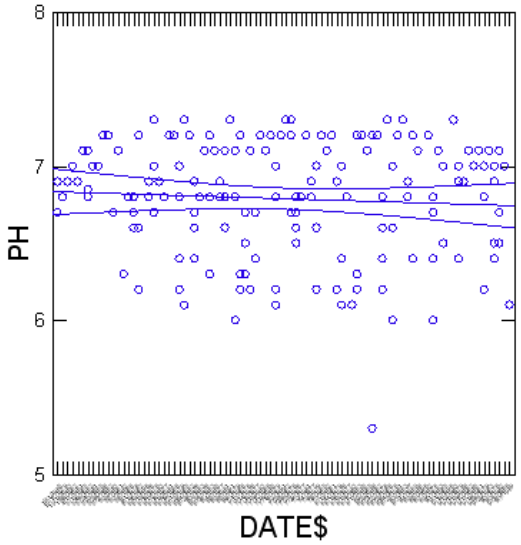

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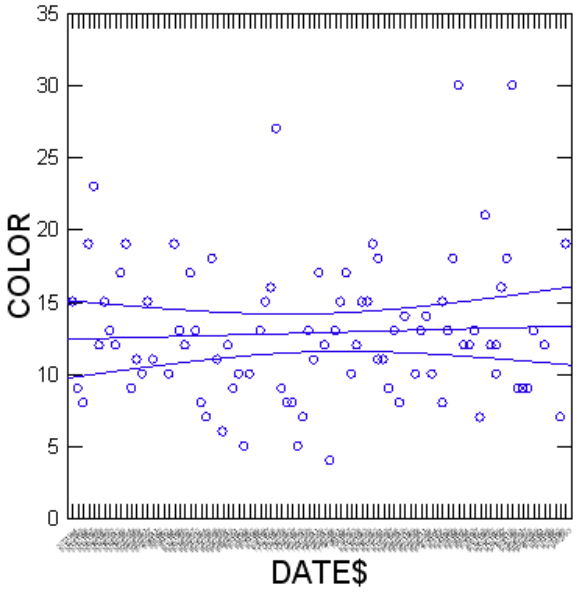

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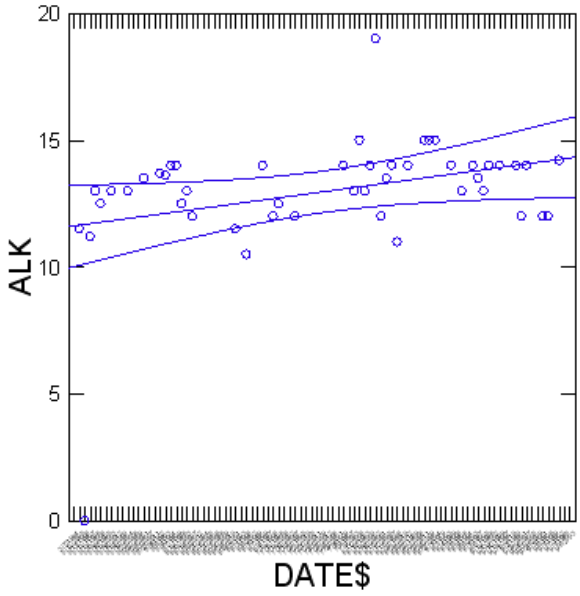

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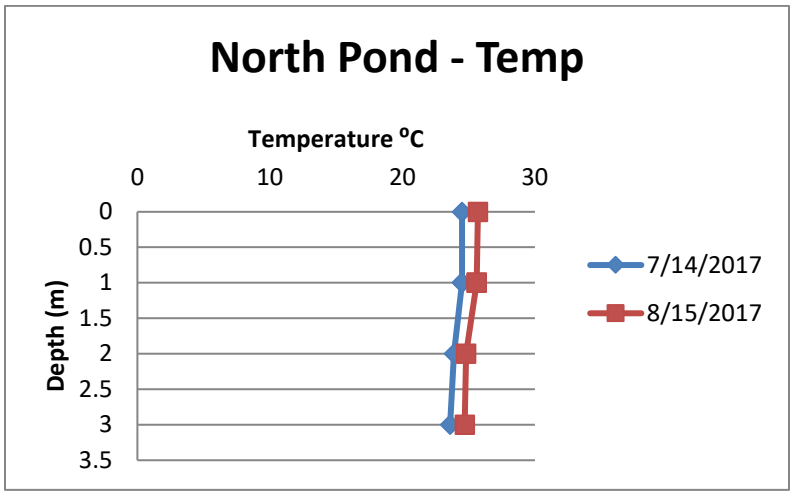
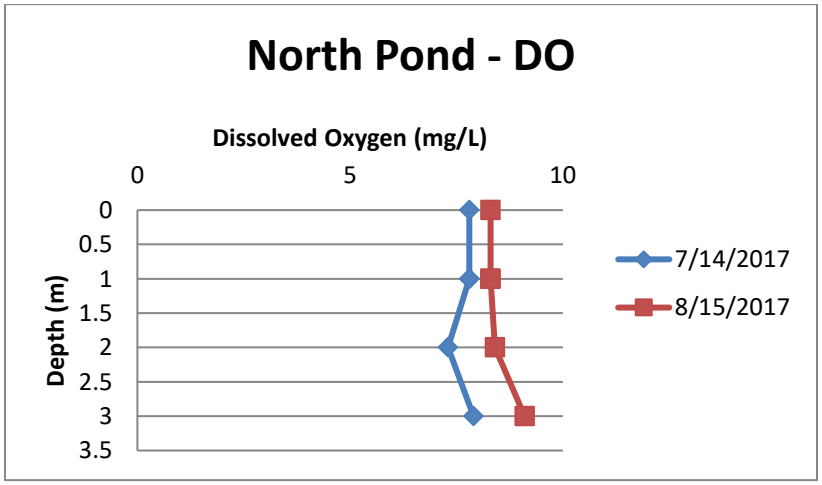
North Pond:



North Pond is relatively shallow in comparison to the other lakes. For that reason, it mixes quite easily from top to bottom with any wind. This means that it does not really form two layers for any length of time. This is evident from both the temperature and dissolved oxygen graphs, which are pretty much straight up and down. Unlike the other lakes which suffer from oxygen depletion in the bottom waters, North Pond has plenty of oxygen throughout the water column.

North Pond does have a high total phosphorus concentration, the highest of any of the lakes. This maybe from internal loading, as the bottom consists of very thick layers of peat. While these high concentrations do not seem to cause large scale nuisance algae blooms in the Pond, there have been numerous reports of higher than normal algae growth by metaphyton (the cloudy masses of green) in the past few years. It should also be kept in mind that North Pond is a water source for Pennesseewassee, so could contribute to the phosphorus concentrations in that lake.

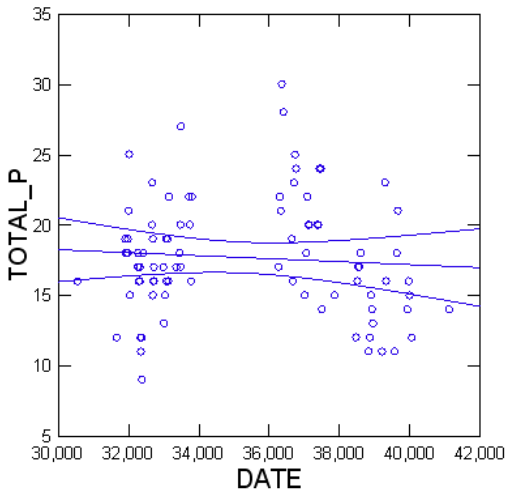


The chlorophyll levels are indicative that this lake is moderately productive (mesotrophic). As stated above, massive algae blooms do not seem to be a problem at this time. The pH is slightly basic, which is typical of lakes. The conductivity is relatively low, a good sign that road salt and other pollutants are not

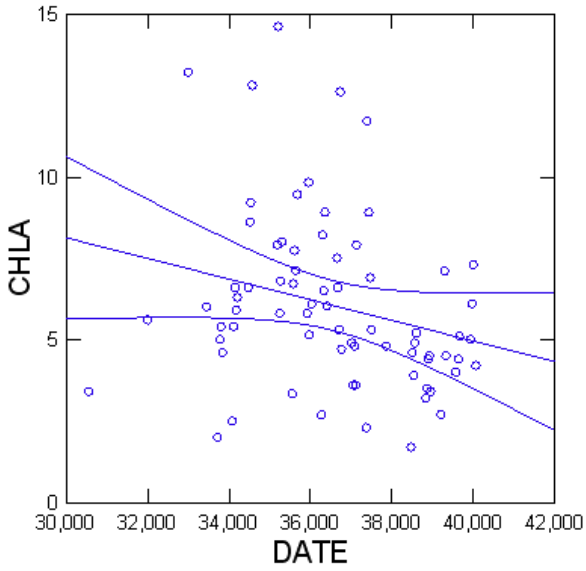
getting into the lake. The alkalinity, a measure of acid buffering capacity, is fairly low. This is could be a problem in some lakes prone to acidification, but the pH levels do not indicate that this is an issue here.

North Pond	Date	Depth	DO	Secchi	Tphos	Chl	pH	Color-Apparent	Conductivity	Alkalinity
	7/14/2017	0.5	7.72	3.19	19	8.1		23	55	10
	8/15/2017	2	8.48	3.27	17	2.6	7.21	25		

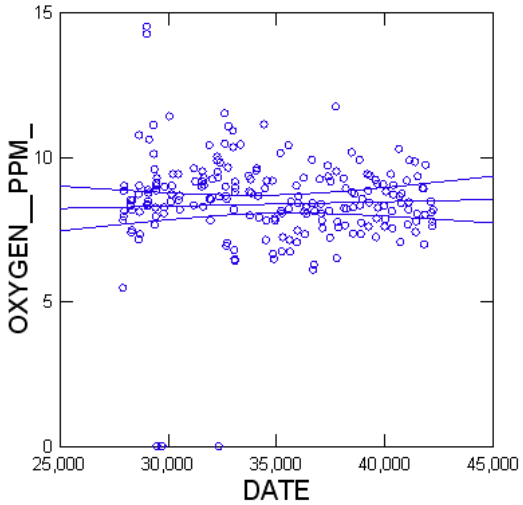
Trend Analysis (2005 to 2017). Please note limitations described in the Overview of this report.



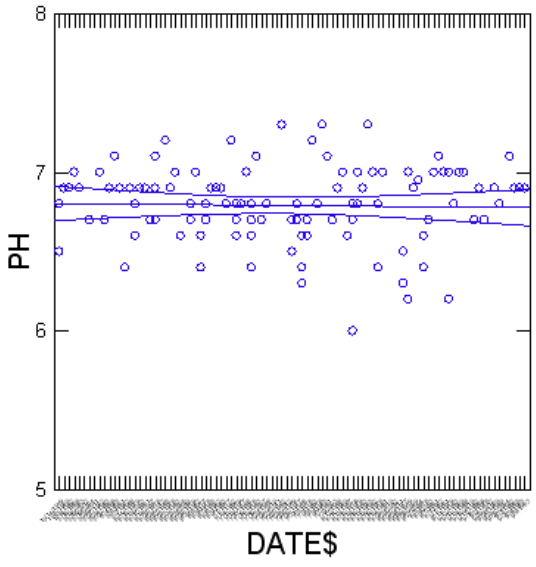
Results for LAKE$ = North Pond QUALIFIER$ = EC
Data for the following results were selected according to SELECT (DATE >= 01/01/2005)



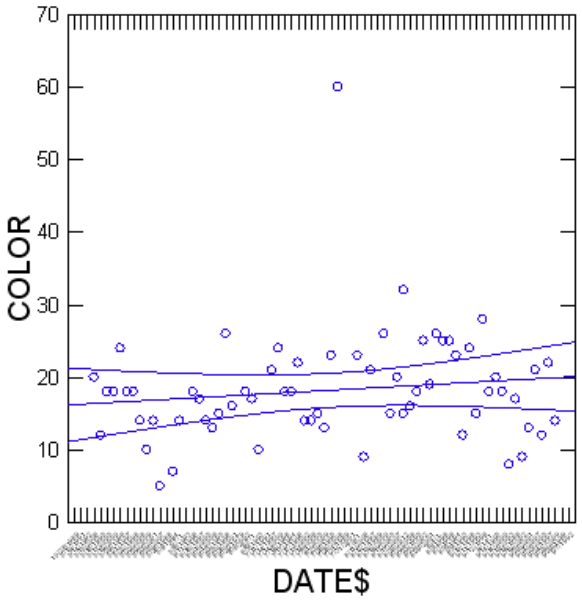
Results for LAKE$ = North Pond SAMPLE_TYPE$ = C
Data for the following results were selected according to SELECT (DATE >= 01/01/2005)



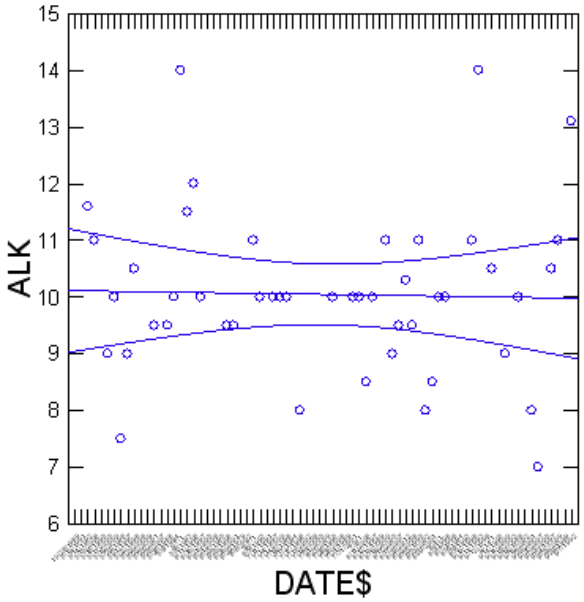
Results for LAKE$ = North 3500 STATISTICS$ = Arithmetic Mean
Data for the following results were selected according to SELECT (DATE >= 01/01/2005)



Results for LAKE$ = North Pond TYPE$ = G
Data for the following results were selected according to SELECT (DATE$ >= '01/01/2005')



Results for LAKE$ = North Pond TYPE$ = C
Data for the following results were selected according to SELECT (DATE$ >= '01/01/2005')



Results for LAKE$ = North Pond TYPE$ = C
Data for the following results were selected according to SELECT (DATE$ >= '01/01/2005')