Honeoye Lake Water Quality Monitoring for 2003-2010
Jack Starke
November 8, 2010

Honeoye Lake is the shallowest of the eleven Finger Lakes The lake produces a significant mass of macrophytes that grow on the lake bottom in waters less than 4.5 meters in depth each summer. In addition, in some years the lake experiences a problematic blue-green algae (cynobacteria) bloom of 1-8+ weeks, which severely affects water clarity, is aesthetically unpleasing, and can be toxic. A monitoring program was initiated to better understand the lake dynamics in response to a severe blue-green algae bloom in the summer of 2002, which lasted from mid-July into late-September. In the fall of 2006 and 2007 an alum application was performed to reduce the release of phosphorus from the lake bottom sediment during periods of anoxia, with the hope of reducing the severity of late summer algae blooms.

For the past eight summers (2003-2010) monitoring has been done at Site D, the deepest point (9.3 m.) of water @ N42^{o}75000 W77.50833) in Honeoye Lake The 2003 data is from a more extensive study performed by Dr. Bruce Gilman. For each year the monitoring included temperature (T) and dissolved oxygen (DO) profiles from the surface to the bottom and water clarity measured using a Secchi disk. In 2003 and 2007-2010, chemical monitoring of phosphorus levels, both total phosphorus (TP) and soluble reactive phosphorus (SRP), at several depths and chlorphyll-a at the surface was also performed. . For 2008 an additional monitoring point, Site F (6.3 m.) of water @ N42.73019 W77.51150) in the south end of the lake was also done. For 2010 Secchi disk reading were taken at nine points around the lake every two weeks. This report summarizes the results of this monitoring program. All of the raw data is available in a spread sheet.

In addition, for five years (1996-2000) a regular sampling program was done as part of NYS Citizens Statewide Assessment Program (CSLAP). The CSLAP sampling program did not measure T and DO profiles, but did include measurements of Secchi disk water clarity and some chemical sampling including phosphorus and chlorphyll-a. Deep water total phosphorus measurements were only made in a single year (1998). Some of this data is included in this report since it was pre-alum application and supplements the 2003 data in an attempt to see if the data shows an effect of the alum application. Unfortunately there is very little data available from prior to the alum application, since it was the severe algal bloom of 2002 that led to a monitoring program that supported the decision proceed with an alum application.

All data collection and analysis from 2004-2010 was performed by volunteers at no cost. The chemical analysis was paid for by the Honeoye Lake Watershed Taskforce (HLWTF) in 2007 and 2010, by a grant from Finger Lakes/Lake Ontario Watershed Protection Alliance (FL-LOWPA) in 2008, and by a grant from Ontario County Water Resources Council in 2009. The CSLAP sampling from 1996-2000 was paid for by New York State as part of their program to collect baseline data for many of the lakes in NYS.

Purpose

Lake water quality sampling is important to help understand the factors that affect water clarity and the growth of rooted plants (macrophytes) and algae. Both macrophytes and algae are photosynthetic and many of the factors that affect their growth are the same as for terrestrial plants: availability of: water, nutrient levels, temperature, sunlight, substrate, and the absence of inhibitory conditions. Obviously, the availability of water is not an issue with algae or macrophytes, unlike terrestrial plants where rainfall is probably the biggest factor. For plants in Honeoye Lake, as in most freshwater lakes, the nutrient that limits their growth is phosphorus. For all of the larger Finger Lakes the limiting nutrient for plant growth is phosphorus. For the smaller Finger Lakes (Conesus, Canadice, and Honeoye) nitrogen may be the limiting nutrient, based on data from (Halfman 2005) and Calinan(2001). For eutrophic lakes this is not unusual, and being a nitrogen limited gives a competitive advantage to blue green algae, since it can use free nitrogen from the atmosphere. Since the lake may be nitrogen limited, it is even more important to reduce minimize phosphorus levels to minimize algal blooms. The focus of the water quality sampling is monitor phosphorus.

There is a wide variation in the levels of total phosphorus that exists in lake water, tributary flow (Zhu 2010), and lake bottom sediment (Gilman 2001)):

Lake Water -surface	9-70 ug/l
Lake Water- bottom	4-450 ug/l
Tributaries –normal flow	2-65 ug/l
Tributaries- storm events	10-550 ug/l
Bottom Sediment	300,000-1,200,000 ug/l

The high level of bottom sediment nutrients and its soft nature is ideal for macrophyte growth. The availability of sunlight is probably the biggest factor that affects the growth of macrophytes and is dependent not only on the time of year, but also on water clarity. The greater the water clarity the deeper sunlight can penetrate to fuel macrophyte growth. It is the lack of sunlight that prevents macrophytes from growing in waters deeper than about 4.5 meters. In the near shore region the physical disturbance of waves and rocky bottom can also minimize plant growth.

For algae, which grows suspended in the water, the nutrient requirements are supplied from nutrients that flow into the lake from tributaries and directly from the shoreline (external loading) and from phosphorus released from anoxic bottom sediment (internal loading). The relative importance of internal and external loading is variable from year to year since it depends on environmental factor.

Although the effect of the major factors influencing macrophyte and algae growth is understood, the interaction of the many factors makes it extremely difficult to predict the magnitude of growth in a given year. Most of the factors are determined by weather conditions, over which there is no control. The only watershed factor that can be managed is nutrient inflow to the lake by controlling erosion. Within the lake, the intent of the alum application was to reduce the release of phosphorus release from the bottom sediment.

Honeoye Lake Trophic Status

Lakes are commonly classified as oligotrophic, mesotrophic, or eutrophic based on their biological productivity using measurements of total phosphorus (TP), chlorophyll-a, and Secchi Disk water clarity. Figures 1-3 summarize these parameters on a yearly basis since 1996. Table 1 summarizes the averages of these parameters. Based on the average values of TP and chlorophyll-a Honeoye Lake would be classified as eutrophic. The average Secchi Disk values would classify the lake as mesotrophic. This, however, may be due to the effect of zebra mussels clarifying the water as they filter feed on algae

Figure 1

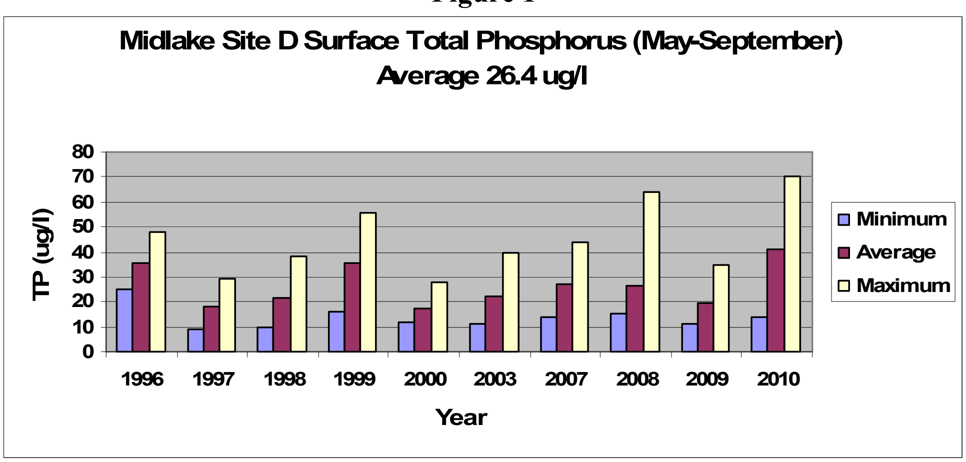


Figure 2

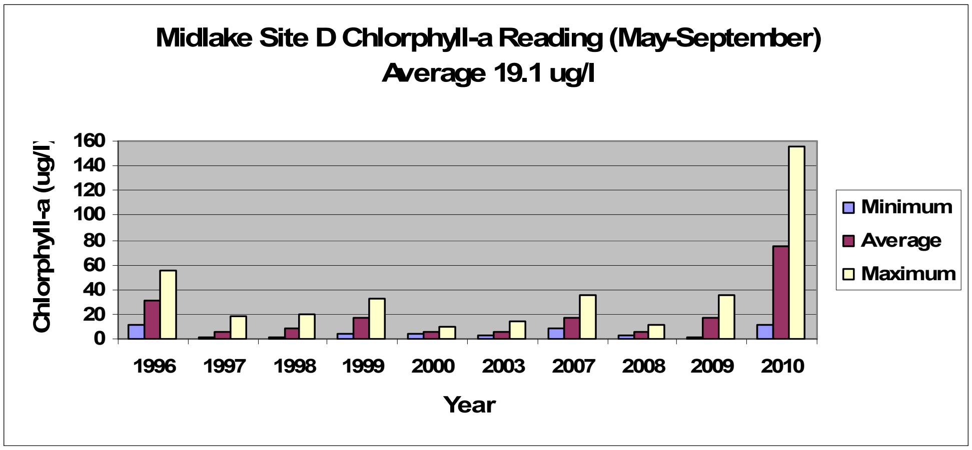


Figure 3

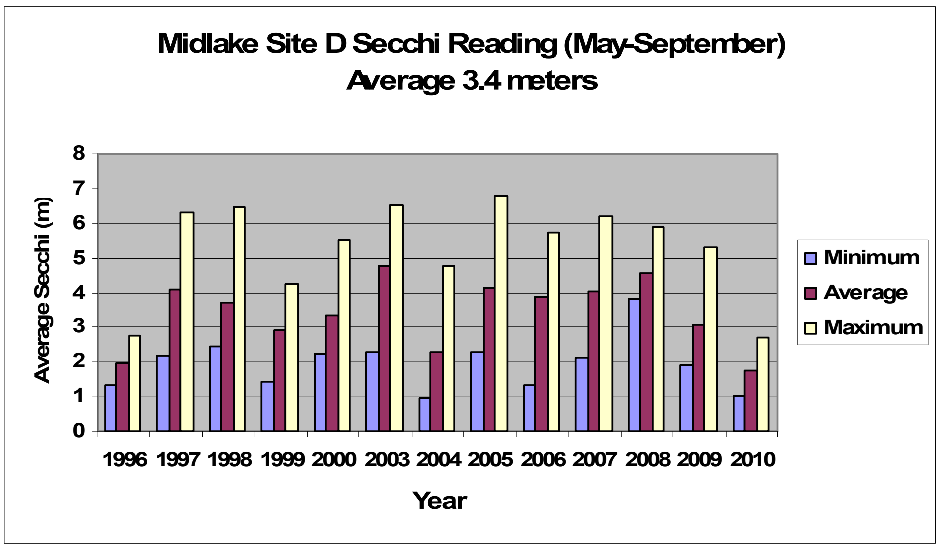


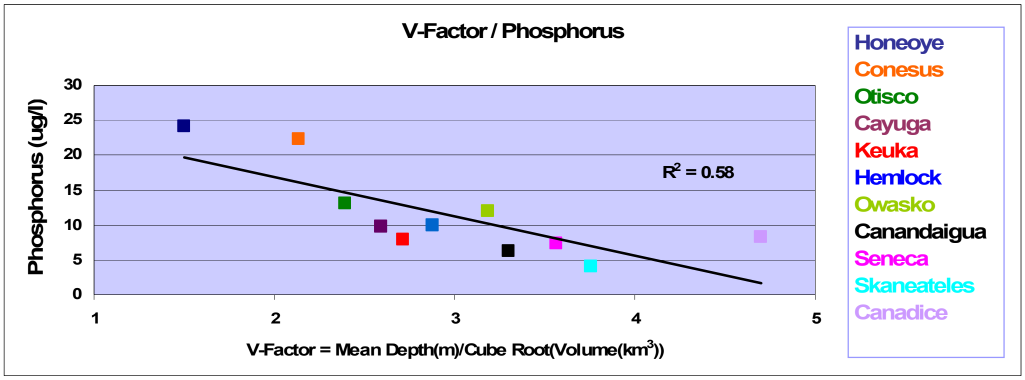
Table 1
Mid-Lake Site D

Parameter	Oligotrophic	Mesotrophic	Eutrophic	Average (1996-2008) Yearly Minimum	Average (1996-2008) Yearly Mean	Average 1996-2008) Yearly Maximum
TP (ug/L)	<10	10-20	>20	13.7	26.4	45.2
Chlorophyll-a (ug/L)	<4	4-10	>10	4.7	19.1	39.0
Secchi (m)	>4	2-4	<2	1.9	3.4	5.3

The measurements of TP in the above table were made during the summer. However, it is generally recommended that the TP should be measured during winter when there is little phosphorus bound up in living organisms. Two water samples were taken during winter through the ice in February 2008 and January 2009, where the surface TP was 29 and 23 ug/L respectively, which is consistent with classifying Honeoye Lake as eutrophic.

The above results are not surprising, given the shallow nature of Honeoye Lake. (Cooke 2001) identified the significance of depth on the trophic status of lakes and postulated that there was a strong correlation between the trophic indicators and what he defined as an Osgood Factor= depth/ square root (lake area). Figure 4 shows the average total phosphorus (TP) as a function of a slightly different factor for all of the Finger Lakes using data from (Callihan 2001). This figure shows that Honeoye Lake would be expected to be the most eutrophic of the Finger Lakes based strictly on lake morphology (i. e. depth & volume).

Figure 4



Summer Seasonal Variation

In an effort to understand the change in algae and rooted plant growth during the summer months, one must look at physical changes in the lake during the course the summer. The biggest driving factors are increased sunlight, warmer temperatures, and the release of phosphorus from the bottom sediment under anoxic conditions.

Figure 5 is a summary of the lake water temperature differential between the surface and bottom during the summer months. In the winter the lake is generally ice-covered and the water temperature below the ice is slightly stratified with temperatures of 2-4 degrees C with the warmest water at the bottom. With longer days and more sunlight in the spring the warmest water is near the surface and the water temperature differential between surface and bottom increases and generally peaks in late summer and then again begins decreasing during the fall. This temperature differential derived from the measured temperature profiles indicate that a weak thermocline forms during the summer months. Since Honeoye is shallow, compared to other Finger Lakes, its thermocline is fairly weak and can be easily broken by wind. For the deeper Finger Lakes the temperature differential can be as much as 20^{o} C, as compared to the 4^{o} C that commonly occurs in Honeoye.

The thermocline is important since it prevents highly oxygenated water near the surface from mixing into the water column all the way to the bottom, and along with the decay of organic matter in the bottom sediment causes the deep waters to become anoxic. It is this oxygen depletion at the bottom that plays a role in the release of phosphorus from the bottom sediment, which under the right conditions can fuel a significant late summer algal bloom.

Figure 5

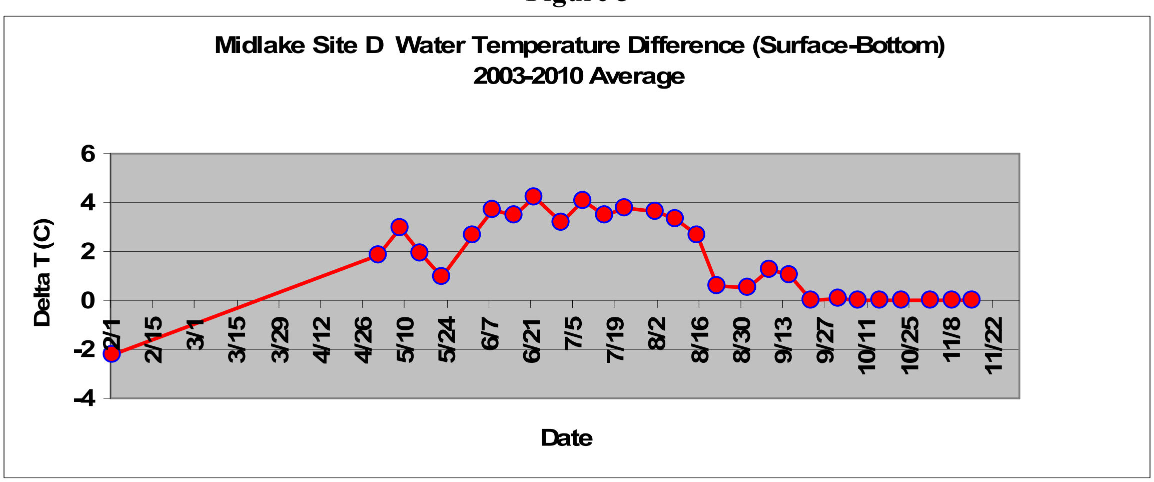


Figure 6 shows the dissolved oxygen (DO) at the bottom during the summer months, with the lowest DO levels occurring in late July / early August. Figure 6 also shows that while the Secchi clarity is around 5 in the spring it drops below 3 in late summer, with the drop in clarity slightly lagging the reduced DO. The data in this figure are averages over the years 2003-2010. Looking at measured dissolved oxygen profiles upon which the data in Figure 6 is based in a slightly different manner, the number of days of hypoxia / anoxia (DO<2) at different depths is shown in Table 2. The missing data for 2004 in Table 2 is due to a malfunction of the DO meter for several weeks that summer.

Figure 6

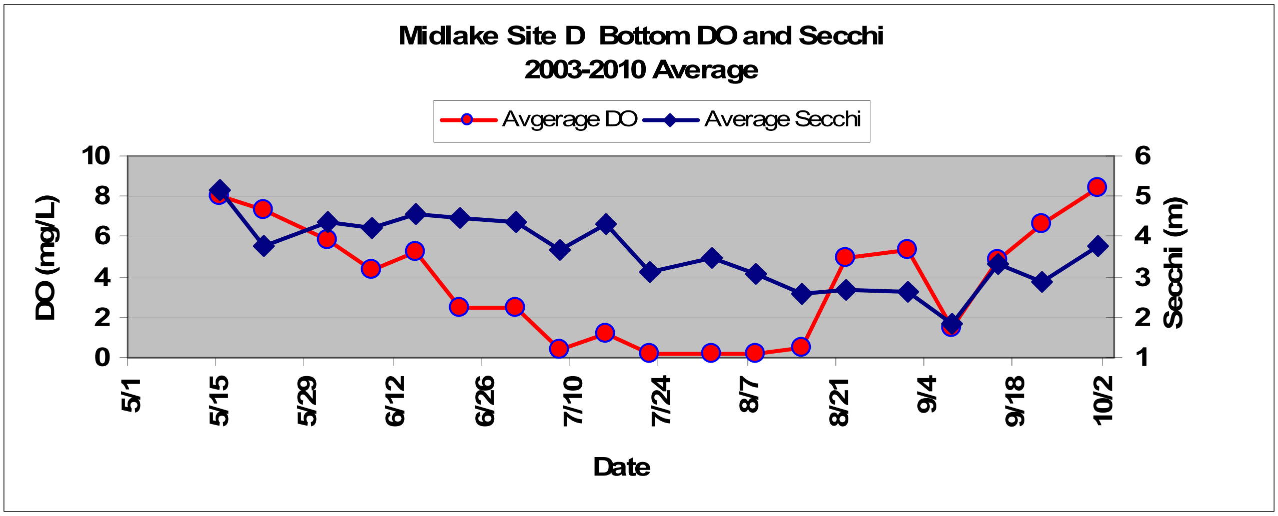


Table 2
Summer Days with DO<2

	9m	8m	7m	6m
2003	56	28	28	14
2004	56	?	?	?
2005	63	63	49	7
2006	49	28	0	0
2007	91	56	21	0
2008	56	56	7	0
2009	56	14	0	0
2010	70	56	28	0
AVG.	62.1	43.0	19.0	3.0

Figures 7-10 shows the variation of TP and SRP during the summer at the surface and at 8m. The data confirms that summer stratification and the resulting bottom anoxia results in higher levels of phosphorus at the bottom during late summer, especially prior to the alum application in 2006-7 (Figures 8).

Figure 7

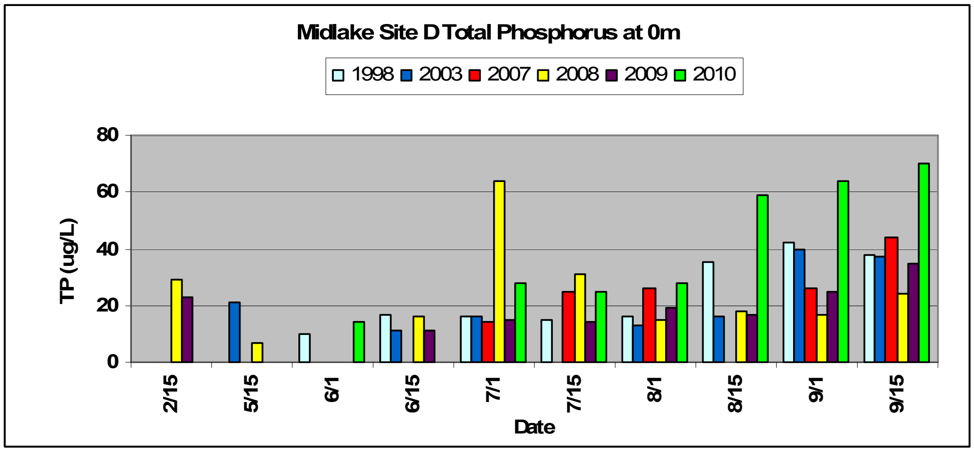


Figure 8

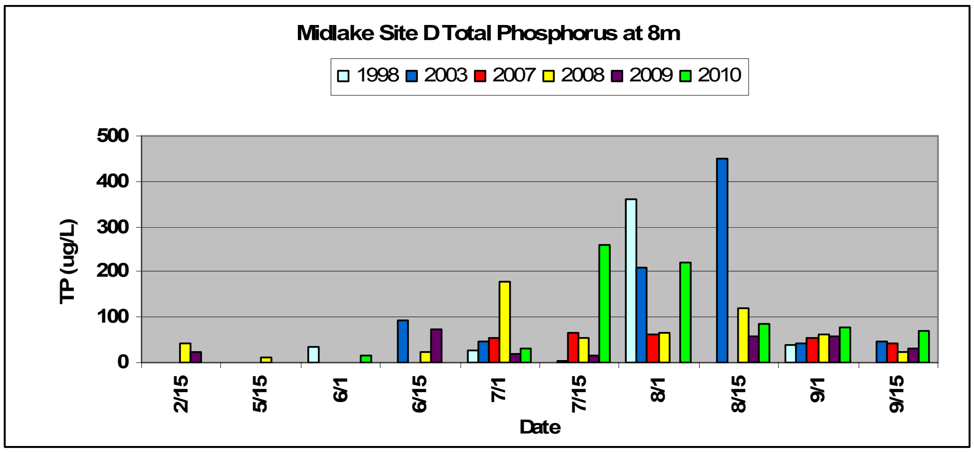


Figure 9

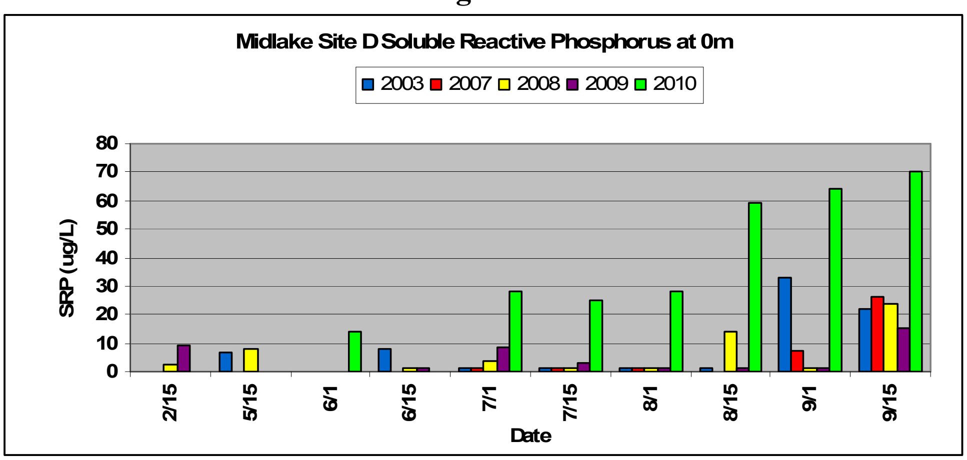
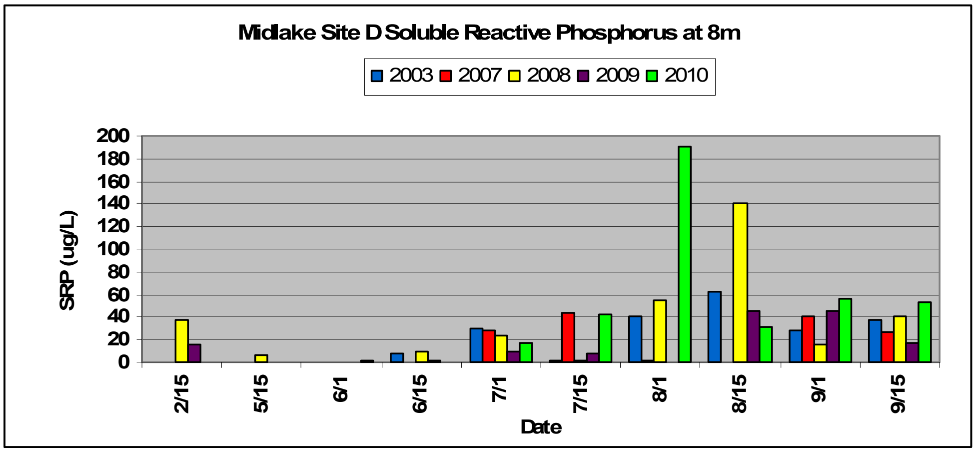
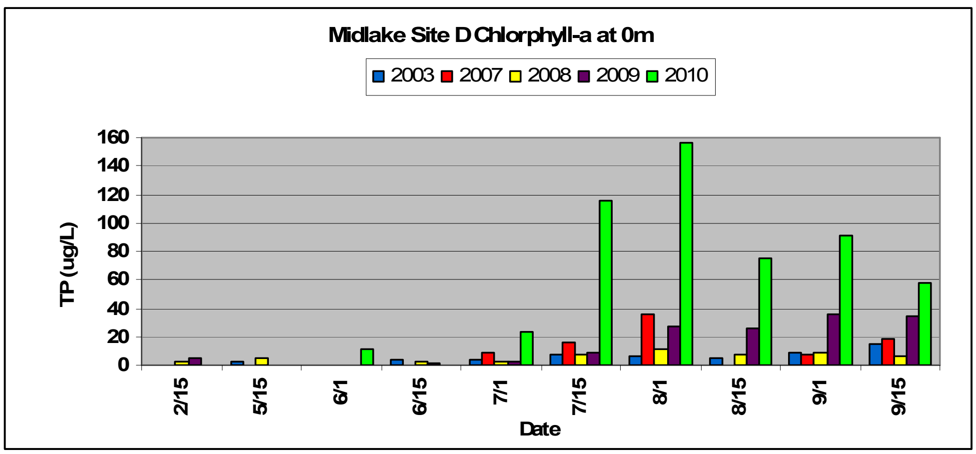


Figure 10



The increase in phosphorus released from the bottom sediment during periods of anoxia in late summer generally causes an increase in algae growth as measured by chlorophyll-a (Figure 11), which results in the poorest water clarity to occur in mid-August / early September (Figure 6). These results are for the deepest location (Site D) in the lake.

Figure 11



Subjective Impression of Algal Blooms Compared to Objective Measurements

Each year the severity of an algal bloom on Honeoye Lake is different and it is difficult / impossible to predict, as might be expected due to the variability in climatic conditions each summer. Late summer algae blooms, which obtain their nutrients from the water column, are dominated by the following species: *Anabaena, Fragilaria, Microcystis, Aphanizomenon* and *Melosira*. It is this latter group which obtains nutrients from the water column which should be affected by the alum application, since it reduces phosphorus release from the bottom sediment.

My recollection, supported by others involved in lake issues, would rate blooms as follow: 2002 severe-initiated alum investigation, 2004 – significant, 2007- early summer bloom insignificant fall bloom, 2008- best year ever –virtually no bloom, 2009- moderate bloom, 2010 – severe bloom starting in mid-July followed by “blue paint along shoreline in late August through September.

In 2002, which many may rate as the most severe and long lasting algae bloom, there was no water quality testing to compare to the subjective impression.

In 2004, although there was no measurement of chlorophyll-a but Secchi disk reading were as low as 1m. (Figure 3) which would support the subjective impression of a significant algae bloom.

The early summer algal bloom in 2007 was due to a *Gleotrichia* as identified by Dr. Bruce Gilman and Princeton Hydro. .A *Gleotrichia* bloom is very different than the normal late summer algal bloom, in that rather than obtaining nutrients from the water column, it is a shallow water species that obtains nutrients from the lake bottom sediment. This bloom is not strongly evident in either the Secchi readings (Figure 3) or the chlorophyll-a readings (Figure 11)

In 2008 the lake had the best water clarity that anyone can remember and is borne out by the Secchi Disk readings (Figure 3) where lowest reading throughout the entire summer was about 4 m. rather than the typical summer minimum of about 2m. Similarly the chlorophyll-a readings (Figure 11) were lower than average.

In 2009 the lake exhibited a moderate bloom as is evident from Secchi reading of about 2m (Figure 3) and fairly high levels of chlorophyll-a in August (Figure 11). Dr Bruce Gilman identified the presence of primarily ***Anabaena*****,** with some *Aphanizomenon* and *Microcystis* in late summer. The summer of 2009 had above average rainfall which may have caused a higher than normal level of external loading.

In 2010 there was severe bloom which is borne out by the data, with some of the lowest Secchi readings of 1-2 m. (Figure 3) and extremely high levels of chlorophyll-a starting in mid-July through September (Figure 11). In early September Dr. Bruce Gilman identified a significant population of *Microcystis,* which, when tested by the Department of Health, was toxic. The summer had numerous heavy rainstorms (one 4 inches in ½ hour) that did significant flooding damage in the southern portion of the lake's watershed, which would have increased external loading and the summer had higher than normal temperatures that exacerbated algal blooms.

Year to Year Variation in Algal Blooms- Is the alum working?

There are many factors that affect algae productivity and the type of algae including temperature, sunlight, nutrient availability, and calm water. All of these factors have both a seasonal and year to year variation. Increased sunlight and temperatures is the major reason that algal blooms only occur during the summer months. Phosphorus, which is the limiting nutrient, is available from two sources, external and internal. External source primarily enter the lake in water runoff carrying nutrient laden soil particles, and is heavily influenced by rainfall. Internal sources are from phosphorus that is released from the nutrient rich bottom sediment during periods of anoxia, which peak in late summer. On average approximately 60% of the total phosphorus loading is from external sources, but during the summer months internal sources can account for up to 80% (Souza 2005). **The purpose of the alum application was to address only one of the factors that affect algae, that is, to reduce the internal release of phosphorus from the bottom sediment.** While this is an important factor it does not assure that the alum application is a complete solution to the algae problem. The next few paragraphs discuss whether the data indicates that there has been a change in internal release of phosphorus from the bottom sediment due to the alum application.

Unfortunately there is very limited data (1998 & 2003) on phosphorus and chlorophyll-a levels prior to the alum application, making comparison of before and after difficult. TP is made up of phosphorus in several states:

TP= PP+SRP+OP, where
TP= Total phosphorus
PP= Non-soluble inorganic phosphorus
SRP= Soluble reactive phosphorus
OP= Organic phosphorus- P bound in living organism

The only measurements of phosphorus that were part of the sampling program were for TP and SRP.

Comparing TP levels in 1998 and 2003 which was before the alum application, with 2007-2010 levels after the alum application in Figure 8, there is about a 75% reduction in TP at the bottom in late summer. In 2010 the TP reduction was about 40% which might indicate that the effectiveness of the alum is decreasing, although it could also be due to increased external TP. However, since alum reduces the amount of phosphorus released from the bottom sediment under anoxic conditions, it would be expected that the phosphorus that would be most affected would be SRP. Comparing SRP before and after the alum application, no definitive conclusion can be drawn (Figure 10). It may not be possible to separate out the effect of the alum application, since there are so many factors that affect phosphorus and algae levels: temperature, sunlight, external phosphorus loading which is dependent on rainfall, and internal phosphorus loading which is dependent on conditions at the lake bottom sediment interface.

The biggest problem in trying to determine the effectiveness of the alum application is determining the relative importance of internal versus external phosphorus loading, both of which are dependent on a number of different environmental factors that change with time. Based on the above discussion while it appears to be reducing TP, it is impossible to definitively state that the alum is reducing the internal release of phosphorus. Unfortunately the question is still open.

Location Variation

In 2008 when two locations in the lake were monitored, Sites D & F, and had similar water clarity (Figure 12) and surface chlorphyll-a results (Figure 13). As expected, since Site F was only 6.3 m. deep, it never went anoxic at the bottom, with the DO always greater than 2 mg/L (Figure 14).

Sampling Site D, the deepest location (9.3 m), provides the most complete picture of lake water quality, and the additional information obtained by sampling shallow sites is probably not worth the cost and effort.

Figure 12

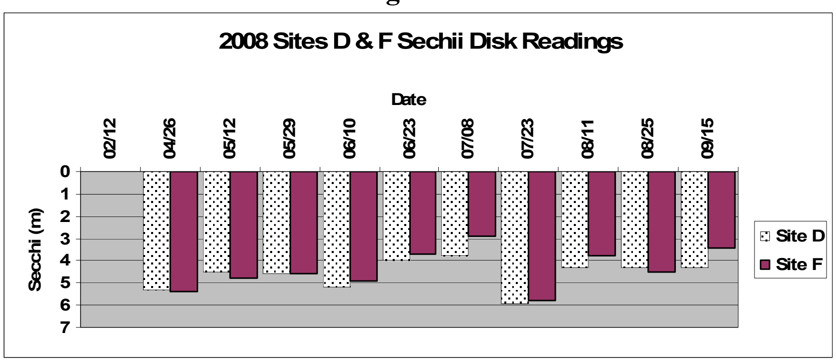


Figure 13

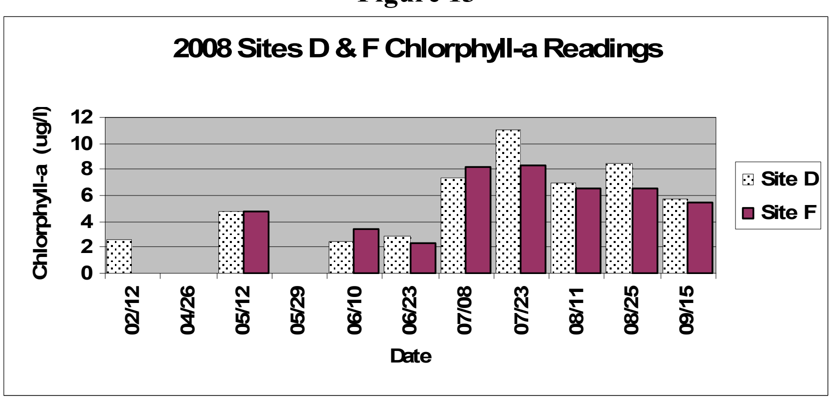
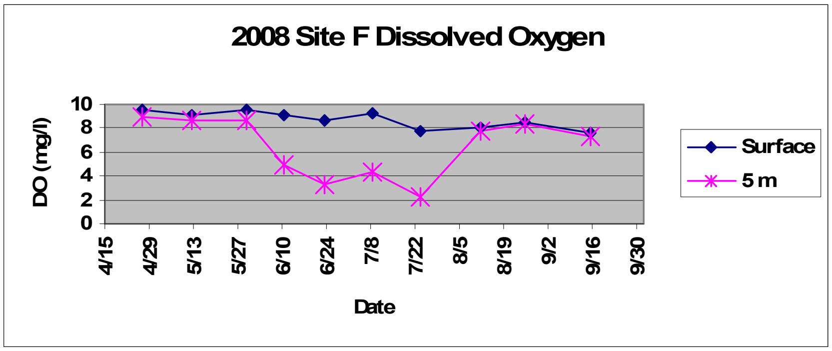


Figure 14



Additional Secchi Disk Reading in 2010

In 2010 Secchi disk reading were made at nine locations distributed around the lake (Figure 15) every two weeks to determine the variability of Secchi readings with location. I would like to thank Frank and Judy Powell for making these measurements. Figure 16 shows this variability to be greater than that obtained in 2008 when measurements were made at only two mid-lake sites (Figure 12). This is not particularly surprising since it the 2010 data includes some near shore locations, and with the intense algal bloom in 2010 the wind moves the algae to different locations which caused greater variability dependent on location. These reading also show low Secchi readings due to the significant algal bloom, which are consistent with the reading from the deepest point in the lake that was reported earlier in this report.

Figure 15
Secchi Measurement Locations

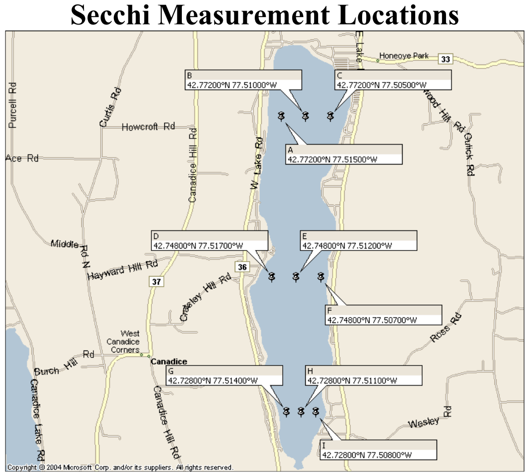
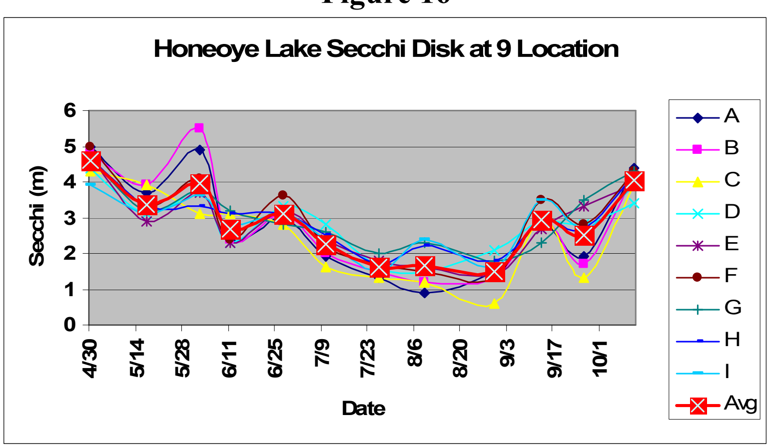


Figure 16



References

Callinan, Clifford W. P.E., Water Quality Study of the Finger Lakes, New York State Department of Environmental Conservation, July, 2001

Cooke, G. Dennis, et al, Shallow and Deep Lakes, NALMS-Lakeline Spring 2001

Gilman, Bruce, Significance of Deep Bottom Sediment to Phosphorus Dynamics in Honeoye Lake, Finger Lakes Community College, March 2001

Gilman, Bruce, HoneoyeLake2003-jps.xls spreadsheet, August 2008

Halfman, John, Water Quality of the Finger Lakes, New York, 2005-2008, Finger Lakes Institute, March, 2009

Kishbaugh, Scott & Hohenstein, Betsy, New York State Citizens Statewide Lake Assessment Program (CSLAP): 2000 Interpretive Summary Honeoye Lake, NYS Department of Environmental Conservation, January 2002

Kishbaugh, Scott & Hohenstein, Betsy, 115-HoneoyeL_new.xls spreadsheet, January, 2003

Souza, Stephan, Honeoye Lake Nutrient and Hydrologic Budget, Princeton Hydro LLC, November 2007

Starke, Jack, Weekly Honeoye Lake Monitoring Program for 2003-2009, January, 2010

Starke, Jack, IN LAKE MONITORING.XLS spreadsheet, November, 2010

Zhu, Bin, An Investigation of external Nutrient Loading from Eight Streams into Honeoye Lake, Finger Lakes Institute, January, 2009