Yardley Borough Environmental Advisory Commission
56 South Main Street
Yardley, Bucks County, PA 19067

ATTACHMENT 2

Princeton Hydro Lake Afton (Phase 1) Report

Scientists, Engineers &
Environmental Planners
Designing Innovative
Solutions for Water,
Wetland and Soil
Resource Management

5 November 2015

Ms. Michelle Sharer, President
Friends of Lake Afton
P.O. Box 529
Yardley, PA 19067

Sent via Email

Dear Ms. Sharer:

This letter report summarizes the water quality conditions of Lake Afton as based on the collected physical and chemical data, as well as related observations recorded during the sampling of the lake by Princeton Hydro on both 11 August 2015 and 15 September 2015. Explanations are provided of the significance of each monitored parameter. At the end of the report we provide both short-term and long-term recommendations for the management of the lake.

Data Collection

On each date, a Eureka Amphibian with Manta2 multi-probe was used to collect the *in-situ* data at two locations; mid-lake and the Buck Creek Inlet. Discrete water quality samples were also collected at these same two locations. The *in-situ* data consisted of the real-time measurement of temperature, dissolved oxygen (DO), pH, and specific conductivity. Water clarity was also measured at the stations with a Secchi disk. The water quality samples collected were transported by Princeton Hydro to a certified laboratory for the chemical analysis of total phosphorus (TP), soluble reactive Phosphorus (SRP), ammonia-nitrogen (NH_3-N), nitrate-nitrogen (NO_3-N), total suspended solids (TSS) and chlorophyll *a*. These data are provided in Tables 1 through 6 below. Finally, Princeton Hydro also collected a single phytoplankton and zooplankton sample from the mid-lake location.

Synopsis of Findings

Both of these waterways, Lake Afton and Buck Creek, are categorized as warm-water fisheries (WWF) by the Pennsylvania Department of Environmental Protection (PADEP). Therefore, discussion will focus on the PADEP water quality standards currently in place for water bodies categorized as WWF.

***In–situ* Data**

Table 1 – 2015 *In-Situ* Data

In-Situ Monitoring for Lake Afton 8/11/15								
Station	DEPTH (meters)			Temperature	Conductivity	Dissolved Oxygen	Dissolved Oxygen	pH
	Total	Secchi	Sample	(°C)	(mmhos/cm)	(mg/L)	(%)	(units)
Mid-Lake	1	1.0+	Surface	23.84	0.414	6.77	80.6	7.56
			0.50	23.82	0.415	6.24	76.1	7.43
			1.00	23.81	0.414	<1.0	11.2	7.34
Inlet	N/A	N/A	Surface	20.55	0.297	5.75	64.1	7.59

In-Situ Monitoring for Lake Afton 9/15/15								
Station	DEPTH (meters)			Temperature	Conductivity	Dissolved Oxygen	Dissolved Oxygen	pH
	Total	Secchi	Sample	(°C)	(mmhos/cm)	(mg/L)	(%)	(units)
Outlet	0.7	0.7+	Surface	19.17	0.329	4.29	40.1	7.27
			0.50	18.83	0.332	2.25	24	6.99
Mid-Lake	0.6	0.6+	Surface	21.17	0.315	6.59	73.4	7.17
			0.50	21.15	0.311	7.26	81.4	7.18
Inlet	N/A	N/A	Surface	17.25	0.425	7.51	77.5	7.35

Temperature - Water temperature is an important attribute of a lake due to the fact that most chemical and biologic processes in aquatic ecosystems are driven by and are directly affected by increases or decreases in water temperature. In general, there is a greater amount of biological productivity and cumulative aquatic community respiration in warm versus cool or cold water. Due to the specific heat properties of water, lakes take time to warm up and cool down. Water therefore provides a relatively stable environment for aquatic life. Even though a lake's surface water temperature will change seasonally with air temperature, daily differences in water temperature tend to be gradual, increasing from winter through the summer. The density of water also changes with temperature, becoming less dense with increasing water temperature. Lake's with uniform water column temperatures are easily mixed and circulated because the water column is of a uniform density. Conversely lakes that are thermally stratified do not vertically mix as easily. This can lead to significant differences in the water quality of the lake at the lake's surface versus near the lake bottom.

On 11 August 2015, the lake's water temperature from surface to bottom was uniform, varying marginally around 23°C (73°F). This was below the PADEP WWF standard of 87° F. On 15

September 2015, the lake's water temperature from surface to bottom was again uniform, varying slightly around 19°C (66°F), again below the PADEP WWF standard of 84° F. The uniform temperature of the water column is not surprising given that the lake is only 1 meter (3.3 feet) deep at its deepest point. As expected, these data show that the lake was not thermally stratified. The water column's uniform temperature means that it was also of uniform density. Such conditions facilitate water column circulation (both vertically and horizontally) by wind and wave action. This mixing prevents thermal stratification and the resulting anoxic conditions that will develop in the deeper waters of a lake during periods of stratification. The unstratified nature of the lake is positive and beneficial to the lake's overall ecological health.

Dissolved Oxygen - Dissolved oxygen (DO) is critical to the ability of a lake to support aquatic life. DO levels are controlled by the biological, chemical, and physical processes occurring both internal and external to a lake. Physical factors affecting DO include water temperature, which effects oxygen solubility, and water column mixing by wind and wave action. Because oxygen is produced during photosynthesis, during the day phytoplankton and aquatic vegetation photosynthetic activity cause DO levels to rise. Highly productive lakes may achieve super-saturated (>100%) DO concentrations during peak periods of photosynthetic activity. Conversely, at night due to cumulative community respiration and biological demands, lakes may experience drastic drops in DO concentrations. Additionally, sharp drops in DO may occur as a result of intense bacterial respiration following the treatment and die-off of large amounts of phytoplankton, mat algae and aquatic vegetation. Lakes with daily (diurnal) major fluctuations in DO are more prone to fish kills than lakes with consistent DO concentrations.

DO concentrations greater than 4.0 mg/L are generally considered necessary to support most aquatic life, in particular fish. Lower DO concentrations become progressively more stressful for most organisms with documented increases in mortality at DO concentrations ranging from 2.0 mg/L to 4.0 mg/L. DO concentrations less than 1.0 mg/L are considered anoxic (oxygen devoid). Under anoxic conditions, sediment ReDOX (the transfer of electrons between species) conditions change resulting in the release of dissolved phosphorus, metals and minerals from the sediments into the overlaying water. The phosphorus "recycled" from the sediments during these periods of anoxia can stimulate additional algal growth independent of external phosphorus sources. The impact of this "recycling" of phosphorus-rich waters can be especially important in shallow, well mixed lakes. Thus, although many lake managers associate the importance of measuring dissolved oxygen with the ability to support a healthy fishery, tracking DO levels is important for a number of other reasons, including understanding what triggers and controls algae blooms.

At the time the lake was sampled on 11 August, both submerged and floating algal mat growth was present in specific locations. As a result, the lake's DO concentrations measured on 11 August were below saturation, ranging from a high of 6.77 mg/L (80%) at the top, to an anoxic state (<1.0 mg/L) near the bottom. It appears the DO concentrations were affected by these algal mats. These mats most likely reduce lake mixing caused by wind and wave action, as well as blocking the sunlight from reaching the bottom in those specific areas. With the near bottom DO concentrations anoxic, there were obvious measurable (and statistically significant) differences in concentrations and saturation levels between the upper and lower reaches of the lake on 11 August. Additionally, the DO of the Inlet was even less saturated, with a concentration of 5.75 mg/L (64%). While these DO concentrations are above the PADEP WWF minimum concentration of 4.0 mg/L, they are reduced.

On 15 September, the presence of these algal mats had been reduced by a recent algaecide treatment, however the decomposing mats still had an effect on the lakes DO. The decomposition process can utilize the DO present in the lake, and when the DO is limited to begin with, this can make for a less than desirable scenario. Once again, the mid-lake portion of the lake hovered around 80% saturation (6.59 – 7.26 mg/L). Given that the lake has an aeration system, it is clear that DO concentrations should be higher.

While we only collected data on two dates, the observed differences, especially on 11 August, are noteworthy given that the lake has a maximum depth of only 1 meter and the fact that the lake was not thermally stratified. Such conditions should facilitate relatively consistent DO concentrations from surface to bottom. The 11 August DO data suggests that at times the lake may experience conditions that result in both DO depression and anoxic conditions. This warrants closer evaluation, but can only be assessed through the collection of additional data over the entirety of the growing season (April through September). However, at a minimum, the DO concentrations did remain above the PADEP WWF minimum standard of 4.0 mg/L.

pH - pH is a measurement of the concentration of free hydrogen ions present in water. It is expressed on a logarithmic scale from 1 to 14. Each one unit change in pH represents a ten-fold increase or decrease in hydrogen ion concentration. The pH of distilled water is 7, which is considered neutral. Water with a pH of 6 is ten times more acidic than distilled water, whereas water with a pH of 8 is ten times more alkaline than distilled water. Most water bodies in the northeast have average pH values between 6 and 9. The optimal pH for most aquatic organisms ranges between 6 and 8. The PADEP WWF standard for pH is between 6 and 9. The amount of pH fluctuation that occurs in a lake temporally is determined in part by the waterbody's alkalinity. More alkaline, hard water lakes (having greater amounts of calcium carbonate ($CaCO_3$)), are bettered buffered against to large temporal shifts pH shifts than are low alkalinity, soft water lakes.

Stormwater runoff, direct precipitation, wastewater and industrial discharges, along with groundwater intrusion, can affect the pH of a lake. Chemical parameters that are significantly influenced by pH include phosphorus, ammonia, iron, and trace metals. The pH of a lake will also fluctuate as a result of photosynthesis, increasing as the amount of weed and algae growth increases. It is therefore not unusual to record high pH values during periods of excessive algae or aquatic weed growth. As a result of this pH / productivity relationship, it is also not unusual to measure the highest pH reading in a lake during the peak of the growing season when vegetation and algal growth peaks. Similarly, higher pH readings usually occur around mid-day when in-lake productivity peaks. pH may also be a function of the lake's geologic setting and origin or the limited amount of watershed development (runoff from forested land tends to be more acidic than from developed lands). It may also be due to spring or groundwater inputs, both of which can have lower pH than surface runoff and inflow. Thus, pH is an important water quality indicator as it both affects and is affected by a lake's chemical and biological processes.

On 11 August, the pH of Lake Afton and Buck Creek ranged from 7.34 to 7.59. On 15 September the pH ranged from 6.99 to 7.35. These pH levels are neutral to slightly alkaline. This somewhat surprising given the amount of overall algal growth present, as it would be expected to be higher. As noted above, typically this will elevate a lake's pH into the alkaline range (>7.5). The lake's pH was relatively consistent from surface to bottom; that is, no significant in-lake variability in pH was observed.

Specific Conductivity - Conductivity is a measure of dissolved ions, typically salts and other inorganic substances, present in lake water. While the majority of the dissolved solids measured in lake water are the result of natural processes, road salts, nutrients and/or sediments transported with stormwater runoff can cause conductivity to spike. Similar to pH, a lake's conductivity can also be influenced by the amount of productivity and vice versa. As such, waterbodies with extremely low levels of productivity have conductivity values less than 0.1 mmhos/cm, while highly productive waterbodies often have conductivity values greater than 0.5 mmhos/cm. The conductivity of most local lakes ranges from 0.2 – 0.3 mmhos/cm.

The conductivity measured in Lake Afton and Buck Creek on 11 August ranged between 0.297 and 0.415 mmhos/cm. This is a relatively compact range, and the conductivity values are considered moderately high for an eastern Pennsylvania lake. For example, the conductivity in lakes underlain by a limestone rich geologic formation can be as high as 0.4 to 0.5 mmhos / cm. The apparent high amount of dissolved substances in the waters (moderate to hard water) of Lake Afton and Buck Creek is most likely a combined function of the lake's geologic origins, source water inputs and the developed nature of the watershed, with the latter having the highest influence. The specific conductance readings are in keeping with the pH measurements, and most likely reflect developed surficial inflow, which will tend to have more dissolved solids and higher conductivity than both spring and groundwater runoff. This is especially evident given that the conductivity concentrations found in the lake were approximately 25% higher than those found in the Creek.

Water Clarity - Secchi depth is a standard measure of water clarity obtained by lowering a Secchi disk (a 9" diameter disk of contrasting black and white quadrants) through the water column. As the disk is lowered and raised in the water column, the average of the depth at which the disk is no longer visible and the depth at which it can once again be seen is considered the Secchi depth. This depth equates to approximately the point at which the incident sunlight is only about 10% of that measured at the surface. This is called the compensation depth which is the depth at which photosynthesis is highly limited. At depths greater than the Secchi depth, little algal (phytoplankton) or weed growth is expected to occur. Based on Princeton Hydro's in-house database of northeastern US lakes, most lake users perceive a waterbody as having unacceptable clarity when the Secchi depth is <1 meter.

Lake Afton is a shallow lake (≤ 1 meter) overall. On 11 August, even though portions of the lake supported significant benthic and surficial mat algae growth, the water was clear and it was possible to view the Secchi disk to the bottom of every shallow station, up to depths a great as 1.0 meter at the deepest station. The combination of very shallow water depth and clear water column is a primary factor that can causes the lake to be prone to high benthic and mat algae densities.

<u>Depth-Discrete Laboratory Data</u>

The discrete water samples were collected at the mid-lake station of the Lake and the Buck Creek inlet. At both stations water samples were collected approximately 0.5m below the surface of the water. These samples were transferred by Princeton Hydro to a PA certified laboratory and analyzed for total phosphorus (TP), soluble reactive Phosphorus (SRP), ammonia-nitrogen (NH_3-N), nitrate-nitrogen (NO_3-N), total suspended solids (TSS) and chlorophyll *a*. The following provides an interpretation of the resulting lab data.

Phosphorus - Phosphorus is the primary nutrient needed to support the growth of phytoplankton and submerged aquatic vegetation. However, compared to the other nutrients and minerals needed by vegetation and algae, phosphorus is often available in limiting amounts. This means that in most lakes and ponds, as the concentration of phosphorus increases, the amount of weed and algae growth also increases. The PADEP has no surface water quality standard for total phosphorus. However, TP concentrations as low as 0.03 mg/L can trigger nuisance algal blooms. The intensity and frequency of nuisance algal blooms typically increase as TP concentrations exceed 0.06 mg/L.

Two (2) forms of phosphorus were measured as part of the 11 August and 15 September sampling events; total phosphorus (TP) and soluble reactive phosphorus (SRP). Total phosphorus measures all the phosphorus present in the water column; inorganic and organic, particulate and dissolved. Some of this phosphorus is already incorporated into the tissue of phytoplankton and zooplankton or bound to suspended sediment particles. Thus, not all of the measured TP is available for uptake and use by algae or SAV. Nonetheless, most water quality models are based on measured TP concentrations. SRP is the form of phosphorus that can be easily assimilated by both planktonic and benthic algae. Although this form is usually not present in the water column in great amounts, it is the primary form of phosphorus that stimulates algae blooms. Thus, when elevated amounts of SRP are measured, an algal bloom is likely to be experienced.

Table 2 – Lake Afton Phosphorus Concentrations

Sample Location	11 August 2015		15 September 2015	
	TP (mg/L)	SRP (mg/L)	TP (mg/L)	SRP (mg/L)
Mid-Lake	0.02	0.01	0.03	ND <0.002
Inlet	0.11	0.058	0.06	0.028

The in-lake sample had TP concentrations that were relatively low (0.02 mg/L and 0.03 mg/L). However, the TP concentration measured at the inlet was at least double, if not five times as much as the lake, (0.11 mg/L and 0.06 mg/L). There is currently no PADEP standard for Phosphorus, in any form. Based on these two sampling events, it is most likely that the inlet is a significant source of TP to the lake, particularly during storm events.

The concentration of SRP measured in the lake samples was detected at both low (non-detectable) and high (0.010 mg/L) concentrations. However, the concentration of SRP detected in the inlet sample was consistently elevated (0.058 mg/L and 0.028 mg/L). Again, based on these sampling events, it is most likely that the inlet is a significant source of SRP to the lake, particularly during storm events.

Total Suspended Solids - Total suspended solids (TSS) are a measure of the amount of particulate material in water. This particulate material may consist of fine soil particles, algae and zooplankton cells as well as other organic or inorganic suspended material. While there is again no PADEP standard for TSS, in general, TSS concentrations greater than 25 mg/L will give a waterbody a murky or muddy appearance.

Table 3 – Lake Afton Total Suspended Solids (TSS) Concentrations (mg/L)

Sample Location	11 August 2015	15 September 2015
Mid-Lake	ND <3	6
Inlet	16	15

The two sampling events of the Lake revealed low TSS concentrations (ND <3 and 6 mg/L). This is almost to be expected given the lake's exceptional clarity and low amounts of planktonic algae. However, the Inlet samples again revealed higher TSS concentrations when compared with the Lake (16 mg/L and 15 mg/L). It should be noted that during storm events at the mouth of the various storm water outfalls present in the lake, elevated TSS levels due to the discharge of storm water runoff into the lake are most likely present. Thus, although the lake proper tends to have very low TSS levels, concentrations most likely peak within the Inlet and at outfalls during storms. Evidence of the sediment carried into the lake as a result of storm events exists in the form of deltas that have accreted at the mouth of some of these pipes. However, the lake's overall surface water TSS concentrations currently remain minimal.

Nitrogen - While phosphorus is the primary nutrient limiting relative to algal and aquatic plant growth, nitrogen is another extremely important nutrient. Nitrogen occurs in the environment in a variety of forms; particulate and dissolved, inorganic and organic. The two forms most easily assimilated by algae and aquatic plants are ammonia-N and nitrate-N. Both are dissolved, inorganic forms of nitrogen. Nitrate-N tends to be more mobile in surface and groundwater relative to ammonia-N and can be generated through microbial activities, such as nitrification. However, bacterial decomposition of organic matter tends to generate reduced forms of nitrogen such as ammonia-N and not nitrate-N. As a result of rapid assimilation by algae and aquatic plant of nitrate-N, the concentration of this nutrient tends to be relatively low in lakes and ponds. For sources of potable water, the Federal and State concentration limit for nitrate-N is 10 mg/L. While no ecological standard exists for nitrate-N, concentrations greater than 1 mg/L will support excessive amounts of algal and aquatic plant biomass. We have found that concentrations of nitrate as low as 0.3 mg/L are associated with streams displaying evidence of eutrophication (algae buildup on rocks, excessive weed growth, etc.).

Nitrate-Nitrogen - Although phosphorus is the primary limiting nutrient in most lakes, nitrogen plays an important role in algal growth and development. Nitrogen occurs in a variety of forms; particulate and dissolved, inorganic and organic. Of the various forms of nitrogen, nitrate-N (NO_3-N) is a readily assimilated, easily utilized form used to support algae growth. Nitrate concentrations of less than 0.3 mg/L are typically associated with low to moderately productive lakes, whereas concentrations exceeding 0.6 mg/L are characteristic of more productive lake ecosystems. While there is no PADEP surface water standard for nitrate-N, the USEPA has a 10.0 mg/L standard for potable (drinking) water.

Table 4 – Lake Afton Nitrate-Nitrogen (NO_3-N) Concentrations (mg/L)

Sample Location	11 August 2015	15 September 2015
Mid-Lake	0.10	0.03
Inlet	1.20	2.40

As per Table 4, the NO_3-N concentrations within the Lake were low, ≤0.10 mg/L. However, the NO_3-N concentration at the inlet was again substantially higher than that of the lake. As with the TP concentration measured at the inlet, the nitrate concentration is indicative of watershed-based sources.

Ammonia-Nitrogen - Unlike nitrate, the lake's ammonia concentrations remained consistently lower. This is expected, and is due to the ammonia-nitrogen formed by bacterial decomposition occurring within the lake being converted to nitrate-nitrogen on a consistent basis due to the lakes shallow and oxygenated state. The conversion of ammonia, in the presence of oxygen, to nitrate is through nitrification. The PADEP WWF standard is based on the un-ionized ammonia-nitrogen concentration. On 11 August, the un-ionized concentration in the lake was 0.002 mg/L (1.3%) while on 15 September, the un-ionized concentration was Non-Detectable (<0.6%).

Table 5 – Lake Afton Ammonia-Nitrogen (NH_3-N) Concentrations (mg/L)

Sample Location	11 August 2015	15 September 2015
Mid-Lake	0.13	0.01
Inlet	0.10	0.02

Chlorophyll a - Chlorophyll *a* (Chl *a*) is the primary photosynthetic pigment of algae and is used as a surrogate measure of phytoplankton algal biomass. The phytoplankton algae are the microscopic algae present in the water column. Typically, a severe or nuisance phytoplankton algal bloom is associated with Chlorophyll *a* concentrations in excess of 25 to 30 mg/m^3. As per Table 6, the lake's Chlorophyll *a* concentration was low at 10.2 mg/m^3 and 3.7 mg/m^3. These low Chlorophyll *a* concentrations are in keeping with the fact that the majority of the lake's productivity was in the form of benthic mat algae and not planktonic algae. Because Chlorophyll *a* is a water column measurement if most of the lake's productivity is in the form of benthic mat algae, rather than phytoplankton, the corresponding water column Chlorophyll *a* concentrations should also be low.

Table 6 – Lake Afton Chlorophyll *a* Concentrations ($\mu g/M^3$)

Sample Location	11 August 2015	15 September 2015
Mid-Lake	10.2	3.7

<u>Phytoplankton (Algae) and Zooplankton</u>

The Friends of Lake Afton community had also expressed to Princeton Hydro in advance of our study that algae mats at times impact portions of the lake. On both 11 August and 15 September, *Pithophora* (a filamentous, green mat-algae) was observed in the lake and were significant enough in overall density and distribution to be impacting the lake's aesthetics, possible recreational use and overall water quality. Additionally, *Spirogyra* was also observed growing along the bottom of the lake as scattered mats. *Spirogyra* is a considered a cold water alga. Unlike *Pithophora*, this wispy, bright green filamentous alga does not tend to form dense surface mats. Also, it typically dies off, or decreases significantly in density as water temperatures rise. Although not expected, the presence of Spirogyra in lakes and ponds even in August and September is not uncommon.

Princeton Hydro collected a surface water phytoplankton (algae) sample during both the 11 August and 15 September sampling events. These samples were analyzed in our in-house laboratory. The dominant algae were chlorophytes (green algae), with both the filamentous *Spirogyra* and *Microspora* the most commonly encountered forms present in the samples. Other algal-types present in the lake's surface phytoplankton sample were dinoflagellates and other chlorophytes. No blue-green algae (cyanobacteria) were observed. This is important as many cyanobacteria are linked to severe aesthetic water quality impacts and have been increasingly linked to health related issues that affect humans and pets.

A sample was also collected for zooplankton analysis. Zooplankton are micro-animals that exist in the open waters of a lake or pond. Some zooplankton can control algae growth directly through by means of grazing. In turn, zooplankton are a source of food for fish, especially forage fish, pan fish and young game fish. The sample collected on 11 August was characterized by relatively low zooplankton numbers. Only one (1) zooplankton genera was identified, the rotifer *Keratella*. On 15 September, zooplankton numbers were higher, with the herbivorous (algae-eating) *Daphnia spp.* being present along with two species of the copepod genus *Cyclops*.

Preliminary Lake Management Recommendations

It must be stressed that the conclusions drawn in this report and the recommendations that follow are based on the data collected during only two sampling events. Additionally the sampling was conducted at the end of the summer when typically overall algae productivity tends to peak and water quality problems most-often reach their worse levels. Furthermore, the latter part of the summer of 2015 was characterized by extremely dry weather. The lack of rainfall and inflow decreases water circulation, lake flushing and promotes conditions that can actually exacerbate algae blooms and further impair water quality. Nonetheless, the Lake Afton data collected on both 11 August and 15 September are consistent in many ways with data that we have collected over the years from other eutrophic (highly productive) waterbodies located within the same regional area.

The following are our preliminary recommendations. We have developed for the community a list of both short and long-term management recommendations for the lake. The short-term recommendations are intended to primarily address the "symptoms" of eutrophication; that is algae blooms, turbidity and conditions that detract from the public's perception of the lake. The long-term management recommendations are aimed more at addressing the "causes" of the lake's problems. These measures are aimed more at slowing or reversing the lake's rate of eutrophication or to mitigate or ameliorate some of the secondary impacts arising from dense algae blooms or the accumulation of sediment in the lake.

1. Additional Data Collection – while it is possible to derive basic recommendations for the short term management and restoration of the lake, our recommendations are based on two data points. To truly successfully manage a lake is standard practice to develop a management plan and use that plan to guide management and restoration activities. To develop such a plan requires a somewhat robust database. As such, our primary recommendation is to implement a more comprehensive analysis of the lake's physical, chemical and biological attributes and then use that data to craft a Lake Management and Restoration Plan.

- While the results of *in-situ* and discrete laboratory parameters measured in 2015 for the most part comply with PADEP Surface Water Quality Standards, some of these parameters are close to or exceed the established threshold levels for a "healthy" eutrophic lake. It is therefore highly recommended that a seasonal monitoring program be implemented to track both the lake's and the inlet's water quality over both the short and long term. These data could also be used to better understand what conditions stimulate the lake's *Pithopthora and Spyrogyra* blooms and the limited density of the lake's zooplankton community. A better database would provide the Friends of Lake Afton community with better insight of what is both causing and how to better control or prevent these future algae blooms. In effect this is the difference between managing the lake and maintaining the lake. Emphasis should be placed on a better understanding how the Buck Creek inlet (watershed-based) and in-lake nutrient sources affect the ecology of the lake. At a minimum, a four-event monitoring program (sampling conducted in May, July, August and September) should be implemented. A monitoring program of this type would cost in the range of $13,000 annually.

- It is also strongly recommended that a detailed Watershed and Lake Management Plan be prepared for Lake Afton. The need for such a plan is supported in the community's recognition that the long-term improvement of the lake will require improved management of the lake's watershed. A Plan could be used to guide the Friends of Lake Afton in pursuit of grant monies or to implement some of the projects of greatest interest such as shoreline restoration, storm water management and maintenance dredging.

  Along with the data developed through the yearlong comprehensive sampling of the lake, the primary components of such a Plan are:

  - A bathymetric survey (accurate mapping of the lake's existing water depth and the distribution and pattern of accumulated sediment),
  - Computation of the lake's annual nutrient and sediment loadings (calculation of the amount of nitrogen, phosphorus and sediment entering the lake from both internal and external sources), and
  - Measurement of the lake's hydrologic budget (computation of the lake's monthly rate and volume of inflow and outflow and its seasonal flushing rate).

  These data are critical to the proper selection, prioritization, design and fiscal budgeting of future watershed-based BMPs that may be of interest to the Friends of Lake Afton.

  A pollutant loading analysis involves accurately quantifying the Lake's internal and external (watershed and storm event) nitrogen, phosphorus and sediment loads (lbs/year by source). The data generated through the pollutant loading analysis ensure that the most significant sources are prioritized for management using the most technically sound and cost-effective management measures.

  The bathymetric data (water depths and sediment thickness) primary tells you where and how much sediment needs to be removed for the lake to improve overall water depth. It is also used in concert with the hydrologic data to calculate the lake's hydraulic residence time and annual flushing rate, two important parameters directly related to the trophic state of the lake, the deposition rate of sediment and the assimilation rate of nutrients by algae and weeds. The Management Plan will collate all of these data (biological, physical and chemical) using trophic state analytical tools. The data will then enable us to more succinctly identify for the Friends of Lake Afton which projects to prioritize, how much these projects will cost and how the completion of these projects will improve the lake. As previously noted, the Lake Management Plan can also be used as the technical foundation for grant applications; the source of money used to implement many of the larger more costly projects. Such grant sources includes the PADEP Growing Greener, 319 and Act 13 funding sources.

2. Immediate Short-Term Recommendations

- The combination of the lake's shallow water depth, good water clarity and an ample amount of sediment-sourced nutrients creates the perfect environment for the development of mat algae blooms. During our study of the lake we observed wide-spread nuisance densities of algae. The extent and density of algae growth supports the need for algae control measures, at a minimum at least in specific areas of the Lake. At a minimum the Friends of Lake Afton should be prepared to implement a chemical treatment program to control nuisance algal blooms. We thus recommend that the Friends of Lake Afton secure a pesticide application permit for the 2016 growing season from the PADEP. The permit does not obligate the Friends of Lake Afton to conduct any treatments, but does provide you with the authorization to do so if the community so desires. Conversely, without the permit it is not possible to treat the lake to control or lessen the severity of algae problems.

- Another option to control algal mats would be to mechanically remove the algal mats from the lake. Although more expensive than chemical control techniques, the mechanical harvesting option does not require a permit, completely removes the nutrients stored within the algae from the water column and does not result in the introduction of pesticides into the lake. Furthermore the harvesting can be done selectively to target only the algae mats impacting the use of given areas of the lake. This approach would negate the re-introduction of nutrients (from the dead algae) thus decreasing the occurrence of any late summer algae blooms, such as those observed on 11 August, and avoiding the need for a major whole lake algaecide treatment.

- The DO measured from the surface to bottom on both 11 August and 15 September was adequate to support a healthy warm water fishery. However we did record a slight measureable decline in DO closer to the bottom of the lake. Although minor, this decline in DO warrants closer study given that the lake was non-stratified (well mixed) on the dates of our survey. The observed DO depression may be simply due to the lake being isolated from prevailing, mixing winds due to the surficial algal mats present or perhaps it could have been caused by the die-off of these mats. Overall it is difficult to tell from only two dates of data collection what was responsible for this decline near the lake's bottom in DO. However at this point there does not appear to be any definitive data sporting the need for additional aeration of the lake.

- Our cursory inspection of the road network in the immediate surrounding watershed identified numerous possible direct sources of sediment, nutrient and pollutant loading to the lake. Should the Friends of Lake Afton chose to defer for now on the preparation of an actual Lake and Watershed Management Plan, at a minimum the Friends of Lake Afton should look more closely at the role that stormwater runoff has on the transport of nutrients and sediment into the lake and what measures could be taken to decrease such inputs. This could begin with a basic stormwater study involving the collection of water quality data over the course of a number of storm events. This could also be accomplished by modeling the lake's watershed and computing the lake's annual pollutant load using computer models (this is actually part of the Lake Management Plan effort described above.

- Finally, the public should be educated with regards to feeding the numerous waterfowl present on the Lake. These waterfowl can contribute large amounts of phosphorus to the lake on a daily basis as a result of defecation. <u>In fact four (4) geese generate the equivalent daily amount of phosphorus loading to the lake as does one (1) septic system.</u> Waterfowl droppings also create both sanitary and aesthetic problems that affect the lake's users. An easy, attractive, passive means of limiting (but not eliminating) geese use of the lake would involve the creation of a vegetated buffer strip around the Lake and the lake's Inlet area. The buffer need not be exceedingly wide 5-10' is sufficient) nor continuous (although that is more desirable). This is a proven, low-cost method of controlling geese use of the lake. The buffer would also act as a filter to help reduce nutrient and sediment inputs and reduce other pollutant loading (i.e, bacteria, oil and grease) from adjacent lands. The buffer strip would also help stabilize the shoreline preventing its erosion and assist in preventing wind-blown debris from entering the lake.

In closing, our data collection efforts in August and September 2015 at Lake Afton revealed conditions consistent with a eutrophic (highly productive) waterbody. Although there is nothing "wrong" with a waterbody being eutrophic. Such waterbodies tend to support nuisance densities of algae growth. Overall, the lake's water quality was ranked satisfactory, especially with respect to clarity and surface water nutrient concentrations. No extensive nuisance submerged or emergent aquatic vegetation growth was observed. However, the lake was experiencing nuisance algal mat problems (a common occurrence of this lake). Currently excessive mat algae densities are controlled by the application of copper sulfate, a standard algaecide used in lakes, ponds and reservoirs throughout the Commonwealth. While this can be an effective, PADEP supported short-term management tool, such treatments can trigger secondary water quality impacts. This includes dips in the lake's DO concentrations (caused by the rapid die off of the algae), the rapid release of organic nutrients, and a decline in zooplankton densities. Such secondary impacts can actually perpetuate additional algae growth as a result of the release and recirculation of the nutrients present within the algal cells.

But more importantly these treatments are only dealing with the symptom of the lake's eutrophication not the cause of the lake's problems.

Mechanical mat removal is an option that does not trigger some of the secondary impacts attributable to algaecide applications. Although relying solely on mechanical harvesting to address the lake's algal problem may be too expensive, it may be possible to implement a more integrated mat algae control program the combines the use of both the mechanical removal (to control dense mats) and then use the copper sulfate algaecides to deal with the less dense growth. Thus the mechanical removal becomes the key control and the algaecide applications become more of a maintenance tool. This approach would likely improve the overall ecological balance of the lake and reduce the total amount of copper sulfate used in the lake's management.

If you have any questions or comments, feel free to contact me or Dr. Souza at (908) 237-5660.

Sincerely,

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Cc: Stephen J. Souza, Ph.D.
Central File