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MEMORANDUM

DATE: September 20, 2016

TO: Todd Nicklaus c/o Tug Lake Homeowners

SUBJECT: **Results of the Tug Lake Water Testing from August 26, 2016**

Introduction

Cason & Associates was contracted to conduct an initial water quality assessment of Tug Lake in Lincoln County Wisconsin, following a severe blue-green algae bloom that occurred during the summer of 2016. The bloom caused noxious odors and an unsightly appearance, reducing the recreational and aesthetic values of the lake. The water testing took place on August 26, 2016. At this time, the algae bloom had passed and the lake had returned to a normal appearance. The goal of the water testing was to gather information needed to prevent reoccurrence of algae blooms.

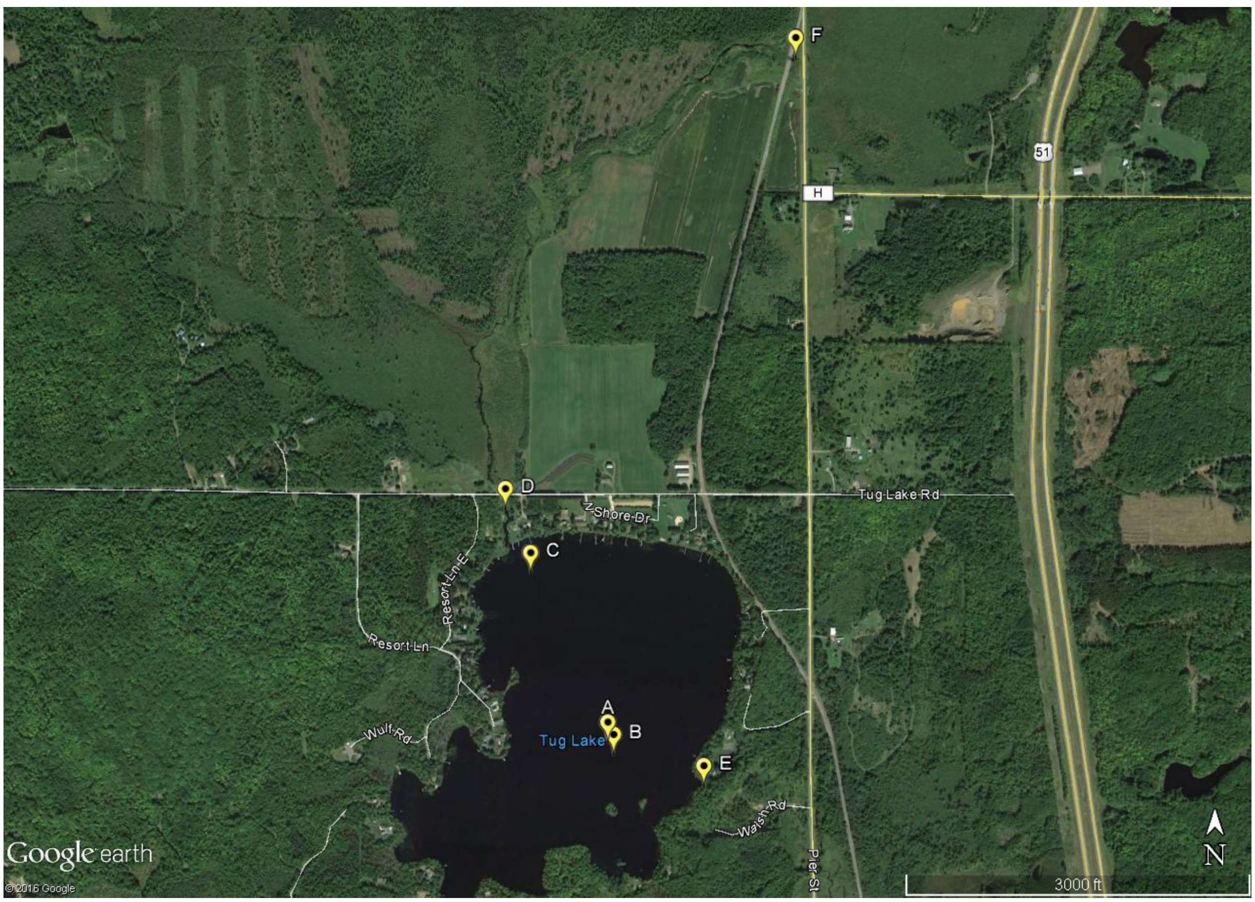


Figure 1. Tug Lake water testing sample points

Methods

Water testing took place at the 6 points shown on Figure 1. Dissolved oxygen and temperature profiles, a Secchi depth reading and a chlorophyll sample were taken over the deep hole of the lake (Point A). A second dissolved oxygen and temperature profile was taken off of the mouth of the inlet creek (Point C). Samples were collected for analysis of phosphorus and nitrogen parameters as well as chloride and potassium from the surface over the deep hole of the lake (Point A), the inlet creek (Point D) and below the Pier Street Bridge (Point F) on the inlet creek about 1.2 miles upstream of the lake. Additional samples were collected for analysis of total phosphorus from the lake bottom (Point B) and for Kjeldahl nitrogen at the outlet (Point E).

Results and Discussion

Dissolved oxygen and temperature data are shown in Tables 1 and 2. Table 1 provides the results collected over the deep hole of the lake at 21 feet of depth. Ideally, we would find 80 to 100 percent oxygen saturation from top to bottom in the water column. It is not unusual to find oxygen stratification in deeper, fertile lakes with limited water exchange during the summer months: however the severity of oxygen depletion found in the depths of Tug Lake was alarming. Dissolved oxygen concentrations were low in the upper water column, but the lake became essentially devoid of oxygen below 13 feet (Figure 2). When summer oxygen profiles exhibit this level of hypolimnetic oxygen depletion, winter fish kills due to low oxygen are likely. This occurrence warrants further investigation.

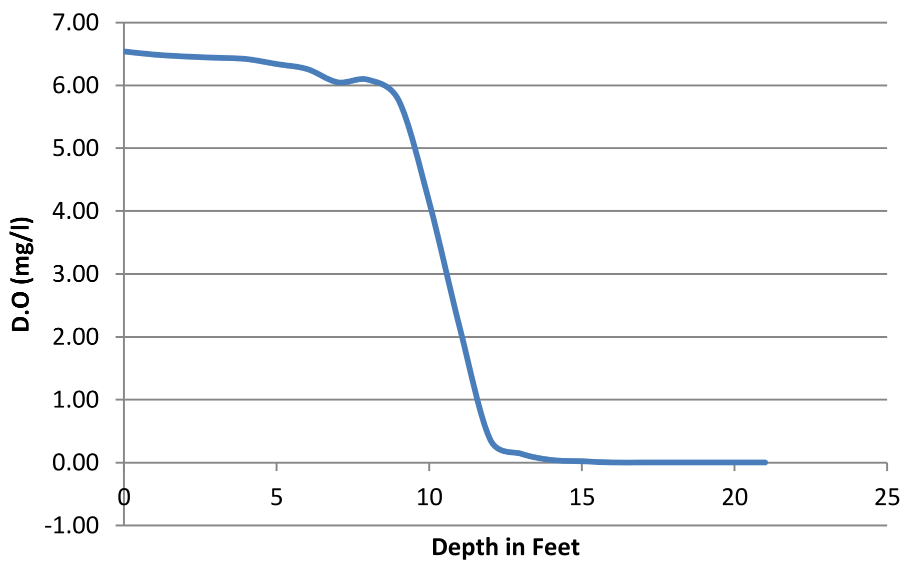
Table 1. Tug Lake Site A dissolved oxygen and temperature data.

Depth	Temp ©	D. O.	% Sat
0	21.7	6.54	74.3
1	21.8	6.49	74.0
2	21.9	6.46	73.7
3	21.9	6.44	73.5
4	21.9	6.42	73.2
5	21.9	6.34	72.4
6	22.0	6.26	71.6
7	21.9	6.05	69.1
8	21.9	6.09	69.5
9	21.8	5.76	65.6
10	21.4	4.14	46.5
11	20.6	2.14	22.6
12	19.5	0.36	4.0
13	18.5	0.14	1.4
14	16.7	0.04	0.4
15	15.0	0.02	0.2
16	14.0	0	0
17	13.5	0	0
18	13.1	0	0
19	13.0	0	0
20	12.4	0	0
21	12.1	0	0

Table 2. Tug Lake Site C dissolved oxygen and temperature data.

Depth (ft)	Temp (C)	DO (mg/l)	% Sat
0	22.1	6.67	76.3
1	22.1	6.65	76.2
2	22.1	6.54	74.8
3	22.1	6.58	75.0
4	22.1	6.38	72.7
5	22.0	6.37	72.8
6	21.8	6.49	74.1
7	21.8	6.50	74.0

Figure 2. Tug Lake Site A dissolved oxygen profile.



A strong thermocline was also found below 13 feet (Figure3), which indicates that the hypolimnion (lower water column) does not mix during summer.

A second dissolved oxygen and temperature profile was taken in front of the inlet at a depth of seven feet. This reading was taken to see if there was a greater oxygen demand resulting from the inflowing water. The results in Table 3 however, show that the temperature and oxygen concentrations were similar to those over the deep basin at corresponding depths.

Figure 3. Tug Lake Site A temperature profile.

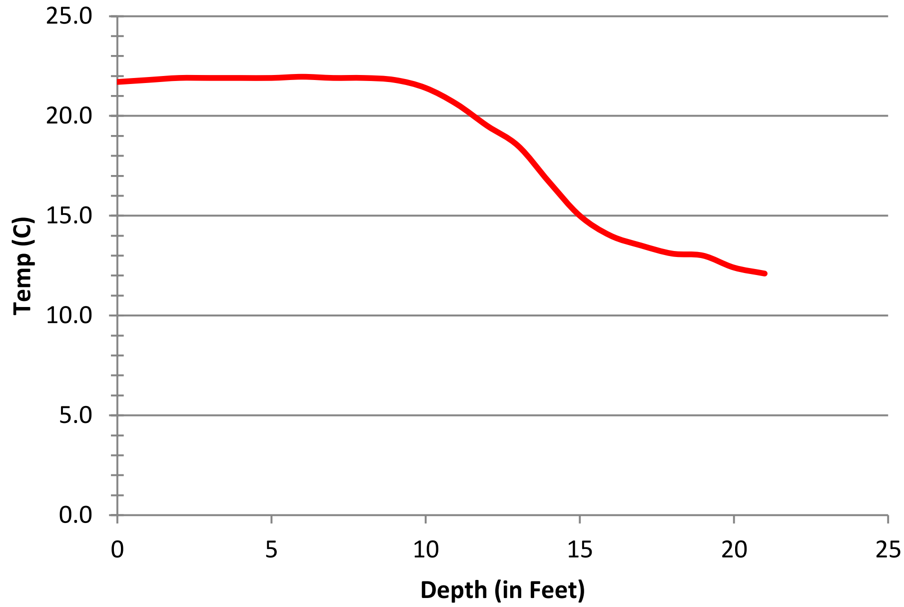


Table 3. Results of the water testing conducted on Tug Lake on August 26, 2016.

Sample Point	A	B	D	E	F
Total Phosphorus	36 ug/l	490 ug/l	89 ug/l		100 ug/l
Ammonia Nitrogen	0.088 mg/l		0.13 mg/l		0.078 mg/l
Nitrate + Nitrite	0.028 mg/l		0.047 mg/l		0.070 mg/l
Kjeldahl Nitrogen	0.091 mg/l		1.6 mg/l	0.87 mg/l	1.6 mg/l
Total Nitrogen	0.94 mg/l		1.65 mg/l		1.67 mg/l
N:P Ratio	26:1		19:1		17:01
Chlorophyll *a*	5.7 ug/l				
Chloride	7.7 mg/l		9.0 mg/l		22 mg/l
Potassium	0.52 mg/l		0.23 mg/l		0.37 mg/l
Secchi Depth	2.1 ft				

The water chemistry data collected on Tug Lake and its inlet creek are show in Table 3. A discussion of the results is provided below:

Phosphorus is an important growth nutrient for plants. Phosphorus concentrations are commonly the limiting factor in plant production in aquatic environments. Thus even small additions of phosphorus to a lake or pond may cause dramatic increases in plant and algae growth. Concentrations above 25 ug/l

(0.025 mg/l) may lead to nuisance algae blooms. Concentrations above 100 ug/l suggest nutrient pollution. The total phosphorus concentration found at Tug Lake's surface was 36 ug/l, which is high enough to cause an algae bloom. The concentration from the bottom sample however, was extremely high at 490 mg/l. This abnormally high concentration of phosphorus may be a by-product of dead and decomposing algae from the summer bloom. Indeed the water sample from the lower water column was very turbid. A second factor may be that a phenomenon called *internal nutrient cycling* is occurring. Under conditions of anoxia, as was found on the bottom of Tug Lake, a chemical reaction occurs which causes phosphorus to be released from organic sediments into the water column where it is then available for algae growth. It will be important to determine whether the high phosphorus concentration from Site B is a temporary occurrence due to dead algae or a long term problem due to internal nutrient cycling.

In addition to high hypolimnetic phosphorus concentrations, elevated concentrations were found at both sample points on the inlet creek. The likely culprit here is farm run-off. Based on the results though, it appears that the source is upstream of the Pier Street Bridge. Further watershed assessment is warranted.

Ammonia is a nitrogen compound that is produced by microbial decomposition of organic matter. Ammonia is rapidly converted to nitrate in the presence of dissolved oxygen. In a healthy lake, ammonia is usually non-detectable. Elevated ammonia concentrations may indicate pollution from fertilizers, manure or septic systems. Concentrations above 1.5 mg/l may be toxic to fish and other aquatic organisms. While ammonia was found at all three sample points, it was low enough not be of concern in itself. The highest concentration was at the inlet creek (Site D).

Nitrate and **Nitrite** are nitrogen compounds that are important for plant growth. Nitrate plus ammonia concentrations exceeding 0.3 mg/l may lead to nuisance algae blooms. High nitrate and nitrite levels may indicate pollution from fertilizers, animal wastes or septic effluent. The Nitrate + Nitrite and Ammonia concentration in Tug Lake was just below 0.3 mg/l, but it was elevated in the inlet creek, particularly above Pier St. This further suggests that agricultural activities are influencing the creek and lake.

Kjeldahl and **Total Nitrogen** – Kjeldahl nitrogen is organic (biomass) nitrogen plus ammonium. Kjeldahl nitrogen is added to Nitrate + Nitrite to determine total nitrogen. When the ratio of total nitrogen to total phosphorus exceeds 15:1, the lake is considered to be phosphorus limited. Therefore any additions of phosphorus will lead to algae blooms. This condition occurs infrequently and may be the result of very high phosphorus concentrations. The N:P ratios found in the inlet creek and Tug Lake were all above 15:1, indicating that the system in phosphorus limited. Still the ratio is not that high, so managing nitrogen inputs will be and important management goal.

Chlorophyll *a* is a pigment found in all plants, including algae. It is used to gauge the relative fertility or trophic state of lakes by measuring algal abundance in the water column. The result of 5.7 ug/l found in Tug Lake would rank the lake as oligotrophic and relatively infertile. The result would no doubt have been much higher during the summer algae bloom.

Chloride occurs naturally in lakes and ponds, and may fluctuate seasonally with runoff patterns. High levels of chloride (> 10 mg/l) however, may indication contamination from septic systems, fertilizers, animal wastes or road salts. At normal levels chloride is not toxic to aquatic life, but it may become toxic at higher concentrations. The chloride concentration was within the normal range within the lake and at the inlet, but was substantially elevated above Pier Street. This further suggests an agricultural influence to the Lake's water quality.

Potassium was tested because it is a common ingredient a synthetic crop fertilizers; however the results found in Tug Lake and the inlet creek were very low.

Secchi depth is a common measure of lake water transparency or clarity. It is often correlated with water quality. The result of 2.1 feet found in Tug Lake, would rank it as having very poor water quality, however the reduced transparency found during the August 28th assessment was due to tannic acid, not planktonic algae or suspended particles. Tannic acid found in Tug Lake is likely leachate from bogs in the watershed.

Conclusions and Recommendations

Two primary areas of concern were identified in this initial assessment. They are the lack of oxygen and high total phosphorus concentrations found in the lower water column of the lake, and the elevated nitrogen, phosphorus and chloride found in the inlet creek above Pier Street. It will be important to determine if the low oxygen – high phosphorus phenomenon was a singular event or if it will be recurring. Further testing is also warranted to assess seasonal inputs from the inlet creek and how they relate to water quality in the lake. These questions will need to be answered before management direction can be provided.

Table 4 outlines recommended future sampling dates and costs.

Table 4. Recommended additional sampling for Tug Lake, with cost estimates.

Timeframe	Sampling	Cost
Fall Turnover (early Nov.)	Deep basin D.O. and total phosphorus.	$950
Winter Peak (February)	Deep basin D.O. and total phosphorus.	$950
Spring Runoff (Apr-May)	Full D.O. and water testing of lake and inlet.	$1,723
Summer Peak (July)	Full D.O. and water testing of lake and inlet.	$1,723
August-September	Final report preparation	$920
Total		$6,266

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