Conducting a Nutrient Inactivation Treatment for Internal Phosphorus Control for a Small Glacial Lake in Northern PA

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Objectives of Presentation

- Describe internal phosphorus loading and how it can negatively impact the water quality of a lake or reservoir.
- Describe methods of addressing / controlling the internal phosphorus load.
- Discuss Highland Lake and their management strategy.
- Provide information on the nutrient inactivation treatment conducted at Highland Lake to address its internal phosphorus load.
- Review the pre- and post-treatment water quality data.

<u>Symptoms</u> of the Problem

- Nuisance harmful algal blooms
- Closed beaches (*E. coli* / cyanotoxins)
- High densities of aquatic plants
- Turbid waters
- Sub-optimal fishery

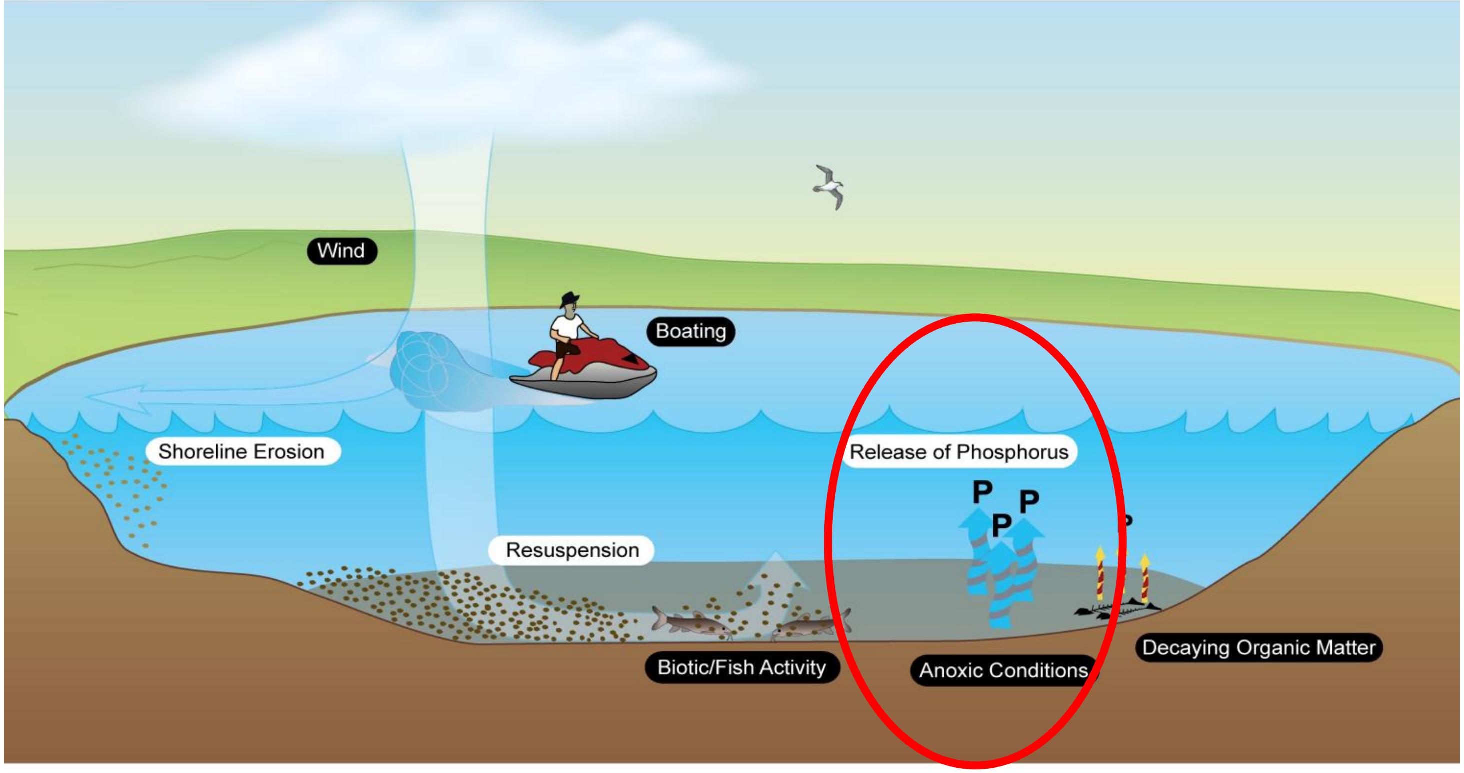
Cause of the Problem

- Stormwater / surface runoff
- Erosion of streambanks and shoreline
- Wastewater discharge (WWTP and/or septic systems)
- Other sources (geese, atmosphere)
- **Internal Phosphorus Loading**

Pollutant Loading Analysis

- Quantify the sources (causes) of pollution to a lake.
- Pollutants of concern are typically the nutrients phosphorus and nitrogen and total suspended solids
- In the northeastern US phosphorus is typically the primary limiting nutrient for algal growth in freshwater systems

Types of Internal Phosphorus Loading



Nutrient Control (External Sources)

- Reducing NPS pollution entering the lake.
- Watershed-based measures (stormwater management, green infrastructure, septic / wastewater management, agricultural BMPs) are effective, long-term solutions.

Nutrient Control (Internal Sources)

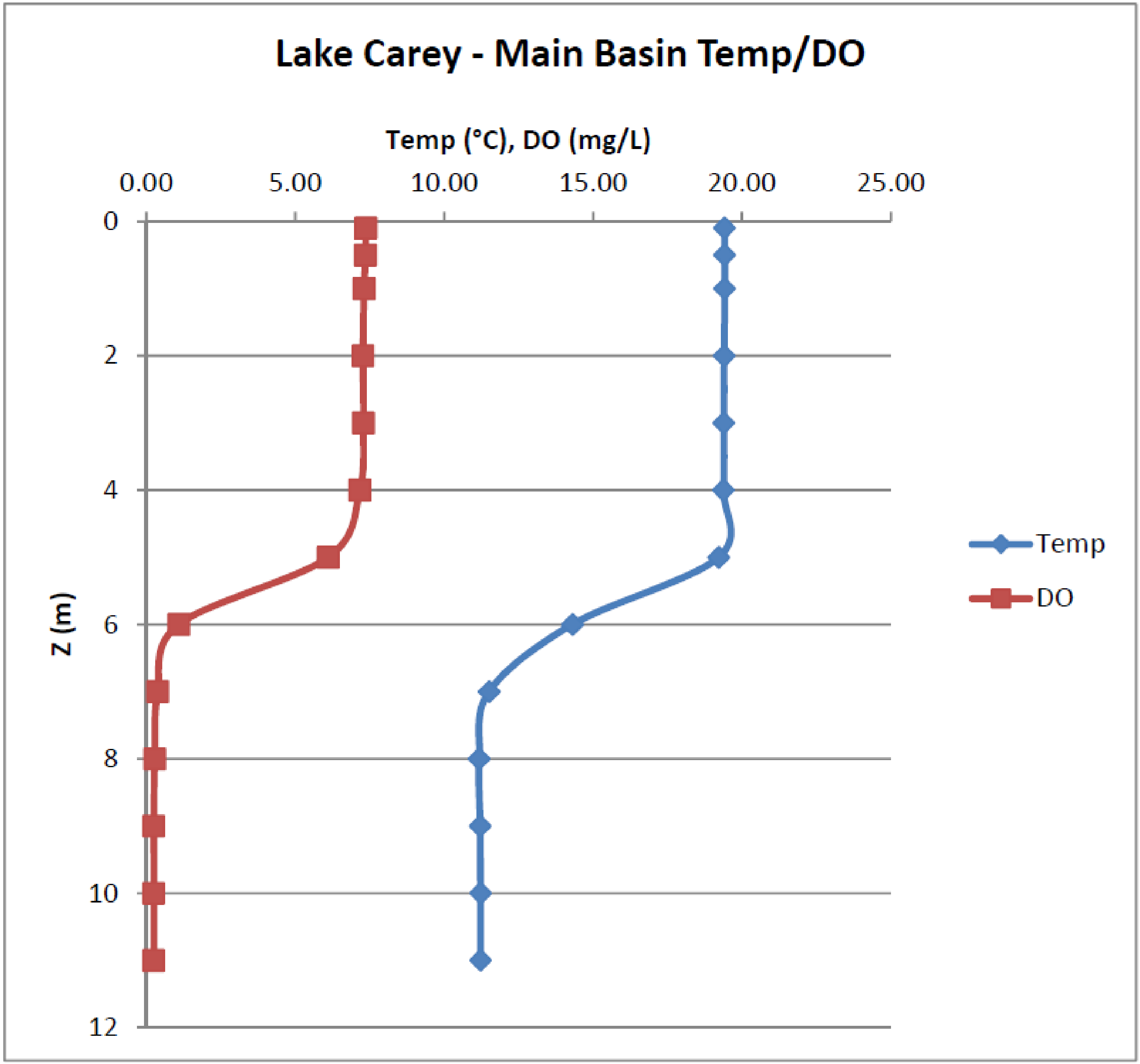
- However, phosphorus can also originate from the deep-water sediments, particularly in the deep, section of a lake or reservoir.
- Thermal stratification can lead to a depletion of dissolved oxygen (DO) in the deeper waters.
- If the bottom waters are depleted of dissolved oxygen over the summer / fall months, internal phosphorus loading can be high.

Nutrient Control (Internal Sources)

- In the absence of DO (< 1 mg/L), the bond between phosphorus and iron is broken and phosphorus migrates from the sediments into the overlaying waters.
- Seasonal turnover or storm events can transport some of this phosphorus-rich water to the surface trigging a bloom.
- Also, blue-green algae can move to the deeper water to assimilate this phosphorus (gas vacuoles).

Internal Load Control

- Destratification / Mixing of the water column
- Nutrient inactivation
- May need to address internal phosphorus loading if at least 25 to 30% of the annual TP load is due to internal loading and/or if at least 50% of the summer TP load is due to internal loading



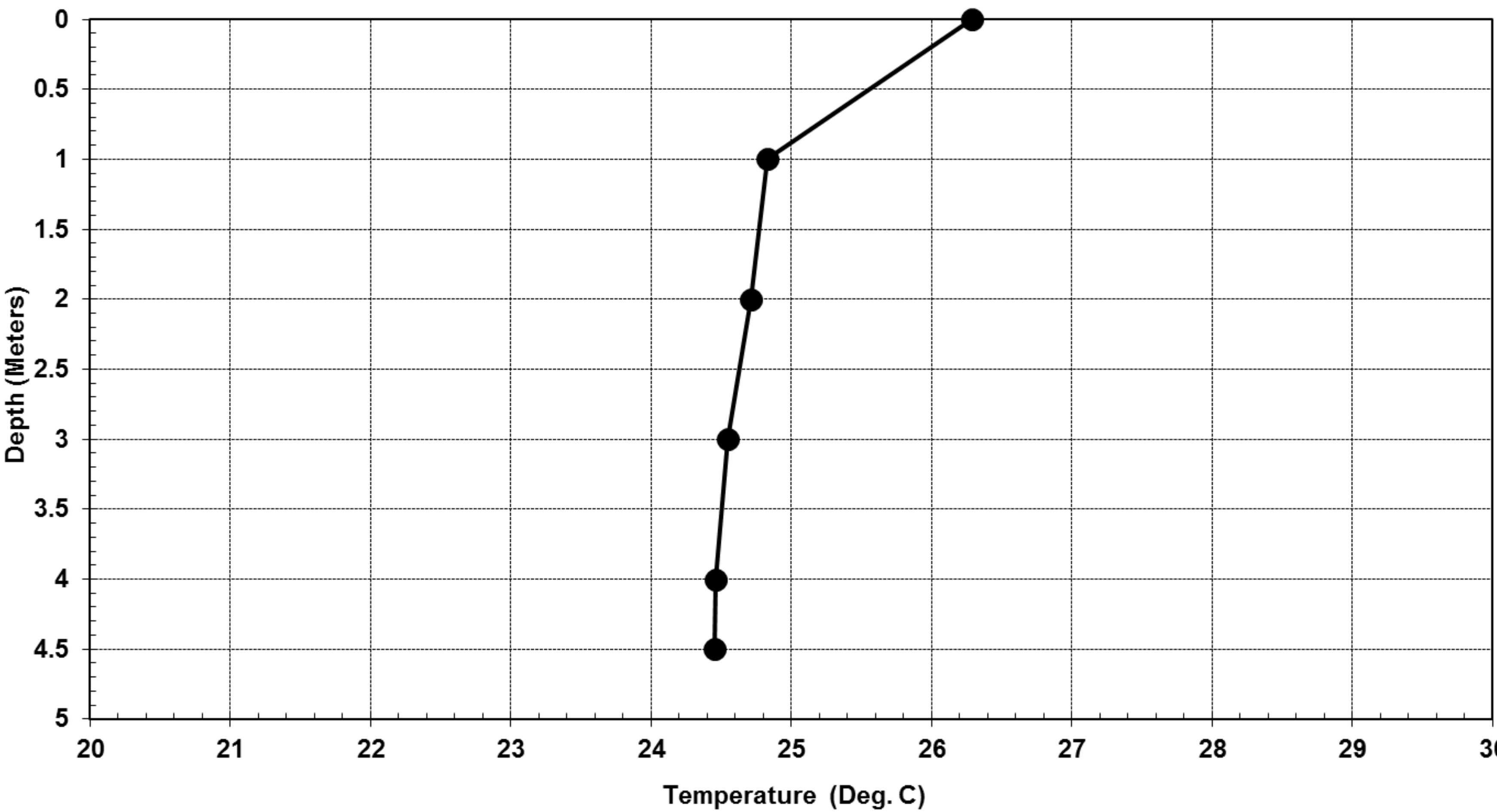
Lake Carey - Main Basin Temp/DO
Temp (°C), DO (mg/L)
0.00
5.00
10.00
15.00
20.00
25.00
Z (m)
0
2
4
6
8
10
12
Temp
DO

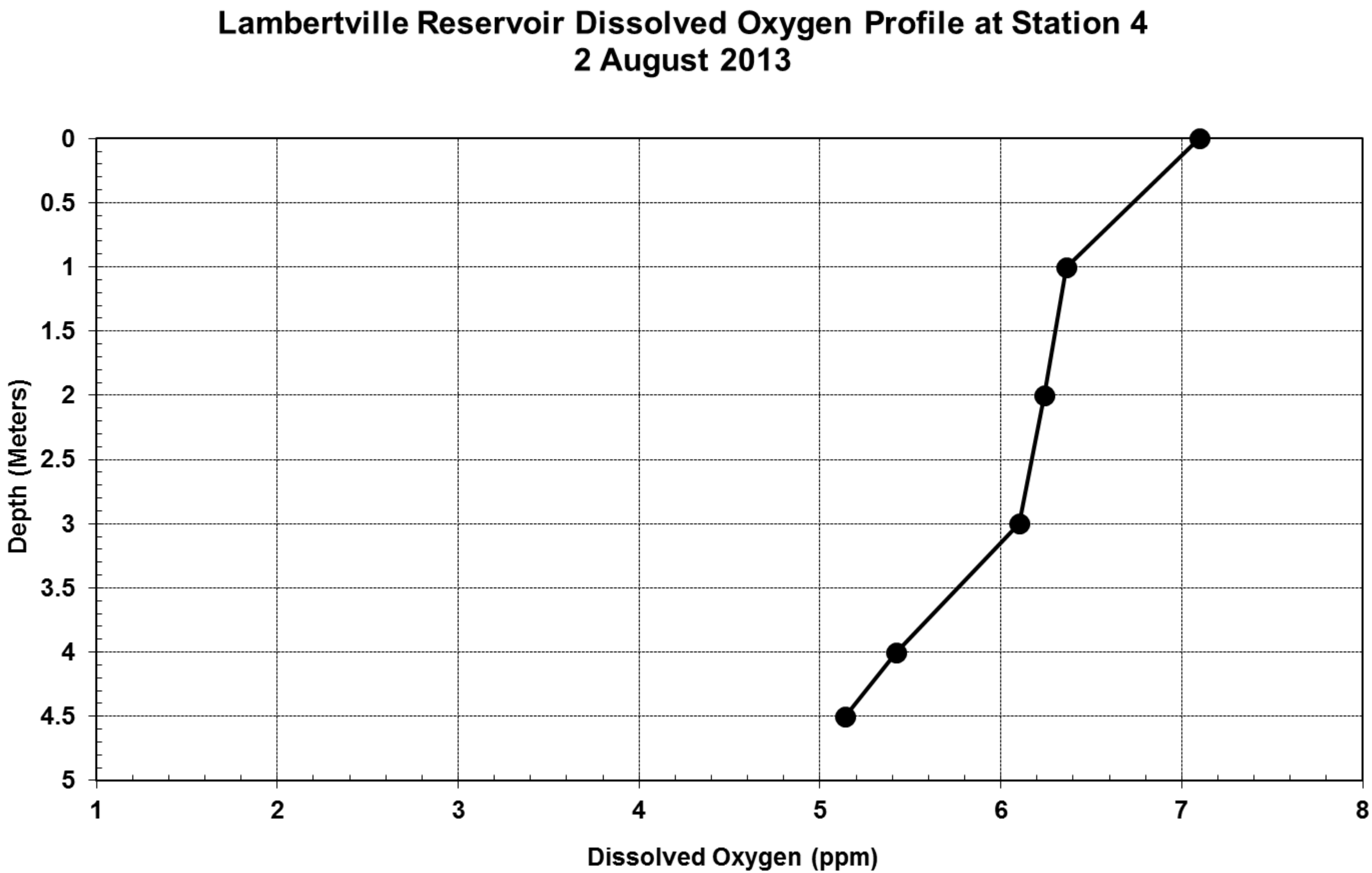
Benefits of Aeration

- Maintains measurable amounts of dissolved oxygen throughout the water column over the summer season
- Reduces the release of phosphorous from bottom sediments, which can fuel algae growth
- Provides de-stratification, which makes it more difficult for blue-green algae to develop concentrated surface scums

Installation of De-stratification / Aeration System

Lambertville Reservoir Temperature Profile at Station 4
2 August 2013




Lambertville Reservoir Dissolved Oxygen Profile at Station 4
2 August 2013
Depth (Meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
1
2
3
4
5
6
7
8
Dissolved Oxygen (ppm)

Aeration- Limitations

- Given amount of maintenance for installed infrastructure.
- Need a reliable source of power.
- Annual costs associated with maintenance and power
- Destratification of a lake can potentially eliminate cool and cold water fishery habitat.

Nutrient Inactivation

- Apply a product over the sediments such as alum, polyaluminum chloride, iron, lime or PhosLock^{R}.
- Used to inactive phosphorus available for algal growth.
- Can be very effective at reducing the internal phosphorus load; particularly aluminum-based products.
- No formal permit process but should go through regional PA DEP office.

Nutrient Inactivation - Limitations

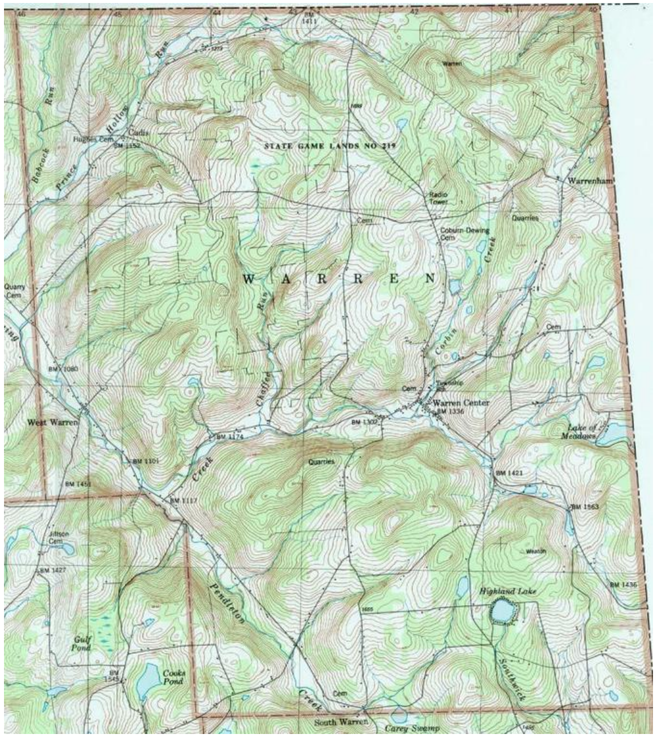
- Only used for the deep water sections of a lake.
- High flushing systems are not good candidates for nutrient inactivation.
- Need to conduct a bench test analysis to determine if alum (aluminum sulfate) can be safely used.
- If not, an alternative product can be used but tends to be more expensive than alum.

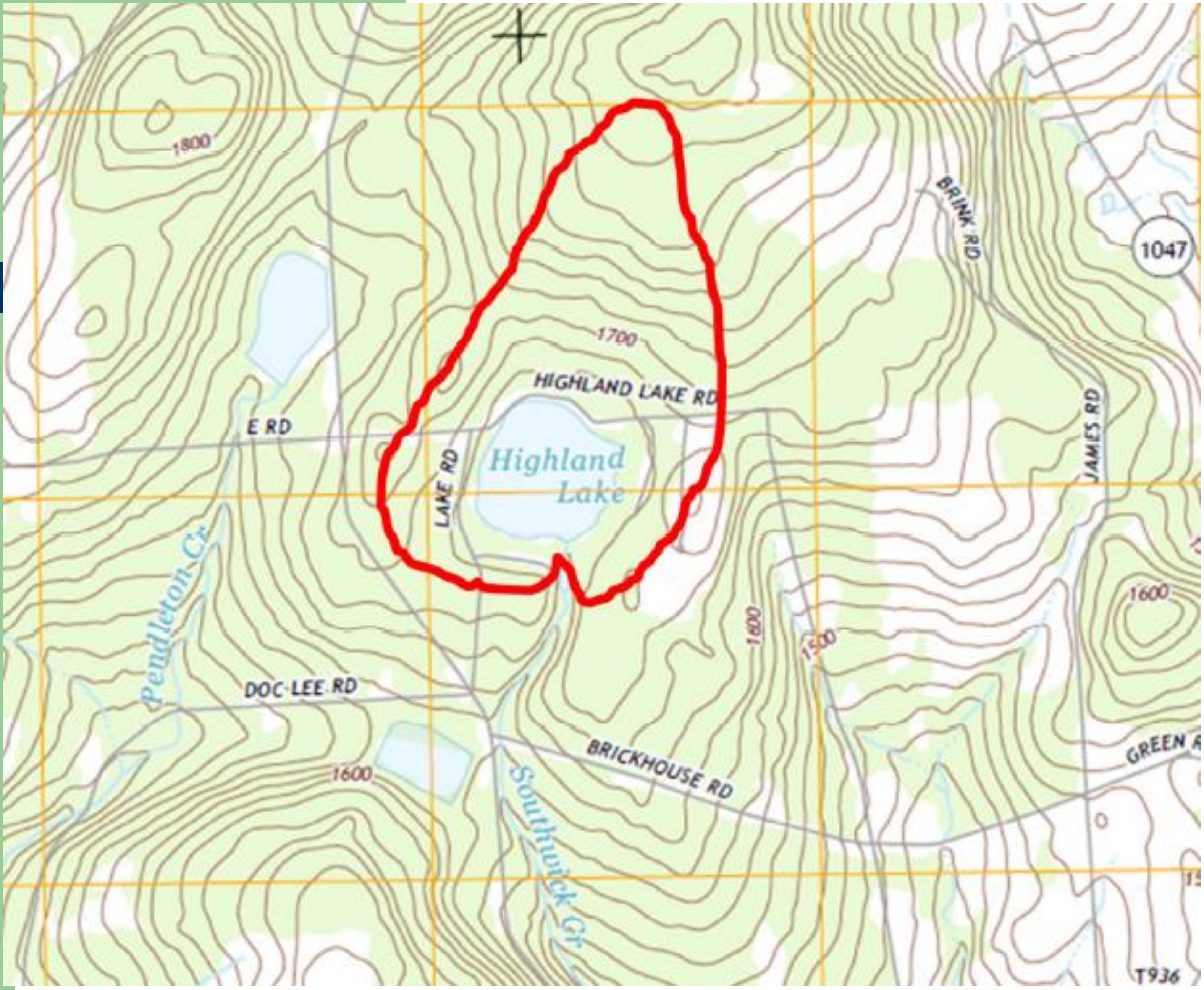
Polyaluminum Chloride Treatment of Stephen Foster Lake, Bradford County, PA (2011)


Schuyler
Tompkins
euben
Chemung
Tioga
Broom
Bradford
Susqueha
Tioga
Wyoming
Sullivan
Lycoming
Luzerne
Columbia
Montour


New York
hio
Pennsylvania
New Jer
est Virginia
Maryland
Virginia


Bradford County Pennsylvania
New York State
South Waverly
Sayre
Athens
Wells
South Creek
Ridgebury
Athens
Litchfield
Windham
Warren
Susquehanna County
Columbia
Springfield
Smithfield
Ulster
Sheshequin
Rome
Rome
Orwell
Pike
Le Raysville
Sylvania
Troy
Troy
West Burlington
Burlington
Burlington
North Towanda
Towanda
Towanda
Wysox
Standing Stone
Herrick
Stevens
Tioga County
Armenia
Granville
Asylum
Wyalusing
Wyalusing
Tuscarora
Alba
Canton
Canton
Leroy
Franklin
Monroeton
Monroe
Terry
Albany
New Albany
Overton
Wilmot
Wyoming County
Lycoming County
Sullivan County


W A R R E N
Warren Center
West Warren
South Warren
Highland Lake


1800
1700
HIGHLAND LAKE RD
E RD
LAKE RD
Highland
Lake
BRINK RD
1047
JAMES RD
Pendleton Cr
DOC LEE RD
1600
Southwick Cr
BRICKHOUSE RD
GREEN R
1600
1500
1600
T936

Highland Lake

- Approximately 30 acres in surface area
- Mean depth of approximately 15.8 feet
- Maximum depth of approximately 17.3 feet
- Watershed area of about 120 acres
- Almost 90% of the land is forested
- All homes within the watershed / community are on septic systems.

Highland Lake

- In 1996 a major infestation of hydrilla (*Hydrilla verticulata*) was documented in Highland Lake.
- Negatively impacts swimming and boating.
- In 1999 sterile grass carp were stocked in the lake.
- By the summer of 2000 the hydrilla was "substantially eradicated."
- Nuisance algal blooms since fall of 2013.

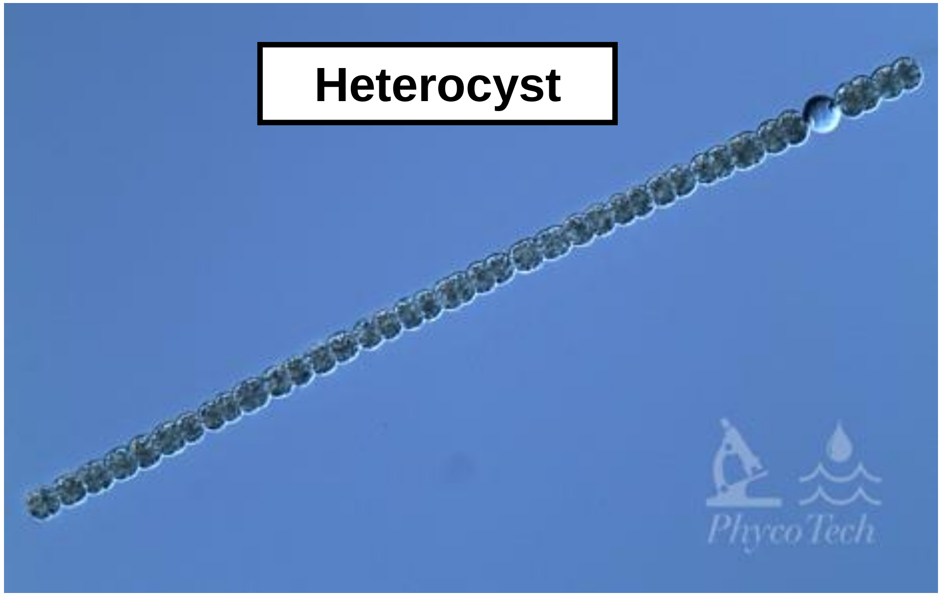
Highland Lake

- Blooms of blue-green algae, particularly the filamentous genus *Anabaena*.
- Creates nuisance surface scums and blooms.
- Can generate unpleasant odors.
- Not a good source of food for the base of the lake’s food web
- Can produce cyanotoxins.

Blue-Green Algae

- Can photosynthesize in a variety of light intensities
- Some can fix gaseous nitrogen (heterocysts)
- Produce very resilient resting spores (akinetes)
- Some can regulate their position in the water column through gas vacuoles
- Generate colonies, T&O compounds and cyanotoxins that make them unpalatable

Anabaena (Dolichospermum)



Conditions that Frequently Result in Nuisance Blue-Green Algal Blooms

- High seasonal temperatures
- Still water conditions / thermal stratification
- Total Phosphorus concentrations as low as 0.03 mg/L can generate nuisance blooms / scums

Annual Phosphorus Load Analysis

- Estimate surface runoff (stormwater), septic loading and atmospheric sources of phosphorus to determine the external (watershed) load.
- Then used existing and collected temperature / dissolved oxygen vertical profiles and some widely accepted phosphorus loading coefficients to determine the lake's internal phosphorus load.

Quantifying the Internal Phosphorus Load

- Analysis of available fractions of phosphorus in the sediments.
- Sediment / water core incubations.
- Black box modeling methodology.
- Using temp / DO vertical profiles and widely accepted loading coefficients, calibrated with empirical data on overlying phosphorus concentrations.

Annual TP Load for Highland Lake

Source	lbs	% contribution
Surface runoff / stormwater	35.8	13.2
Septic Systems	45.8	16.9
Atmospheric	17.0	6.3
Internal Loading	172.0	63.6
Total Annual TP Load	**270.6**	**100.0**

Targeted Internal P Load

- Of the 30 acres, 20 acres were targeted to be treated with an alum blanket.
- Estimate 5 years of control (858 lbs); and an alum efficiency of 50%.
- Resulting in 15 g of alum per cubic meter.
- Approximately 64 gallons per acre of alum

Bench Test Analysis

Table 2
Bench Test Results for Samples Collected at Highland Lake on 16 November 2016

Parameter	Before Bench Test	After Standard Alum	After Hyper Ion 2021
TP (mg/L)	0.03	0.03	0.05
TDP (mg/L	0.01	ND<0.01	ND<0.01
SRP (mg/L)	0.002	ND<0.002	ND<0.002
Dissolved Aluminum (mg/L)	ND<0.0911	ND<0.0911	ND<0.0911
Alkalinity (mg/L)	21	-	-
Chlorophyll a (mg/m^3)	14	-	-

ND = non-detect

Bench Test Analysis

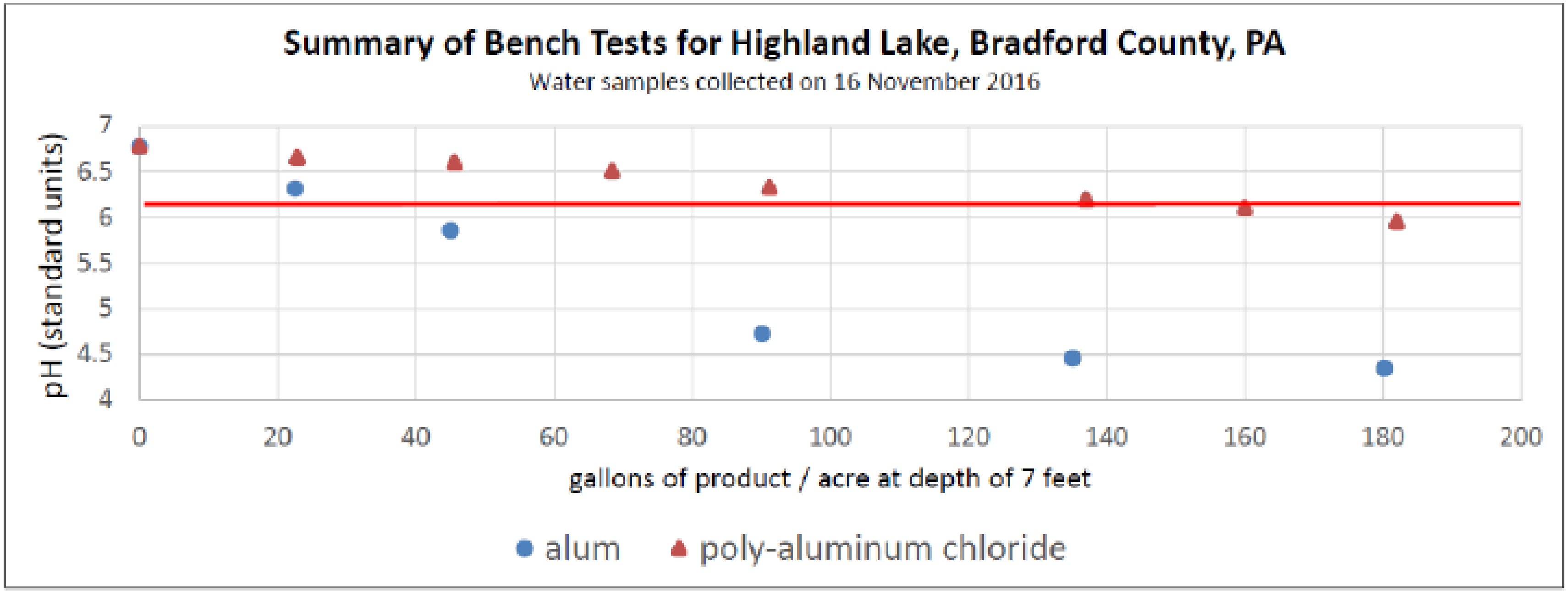


Figure 1 – Results of an alum bench test for alum (standard aluminum sulfate) and poly-aluminum chloride (Hyper+ Ion 2021).

Targeted vs. Maximum Dosage Rates

- Target of 64 gallons per acre of alum.
- Based on the bench test a dosage rate of 22.5 gallons per acre of alum reaches a pH of 6.2; at a rate of 45 gallons of alum per acre the pH falls to 5.86.
- Thus, standard alum (aluminum sulfate) was not recommended.
- However, the poly-aluminum chloride product reached a dosage rate of 137 gallons per acre at a pH of 6.2

Bench Test with another PACl product (EPIC WW58)

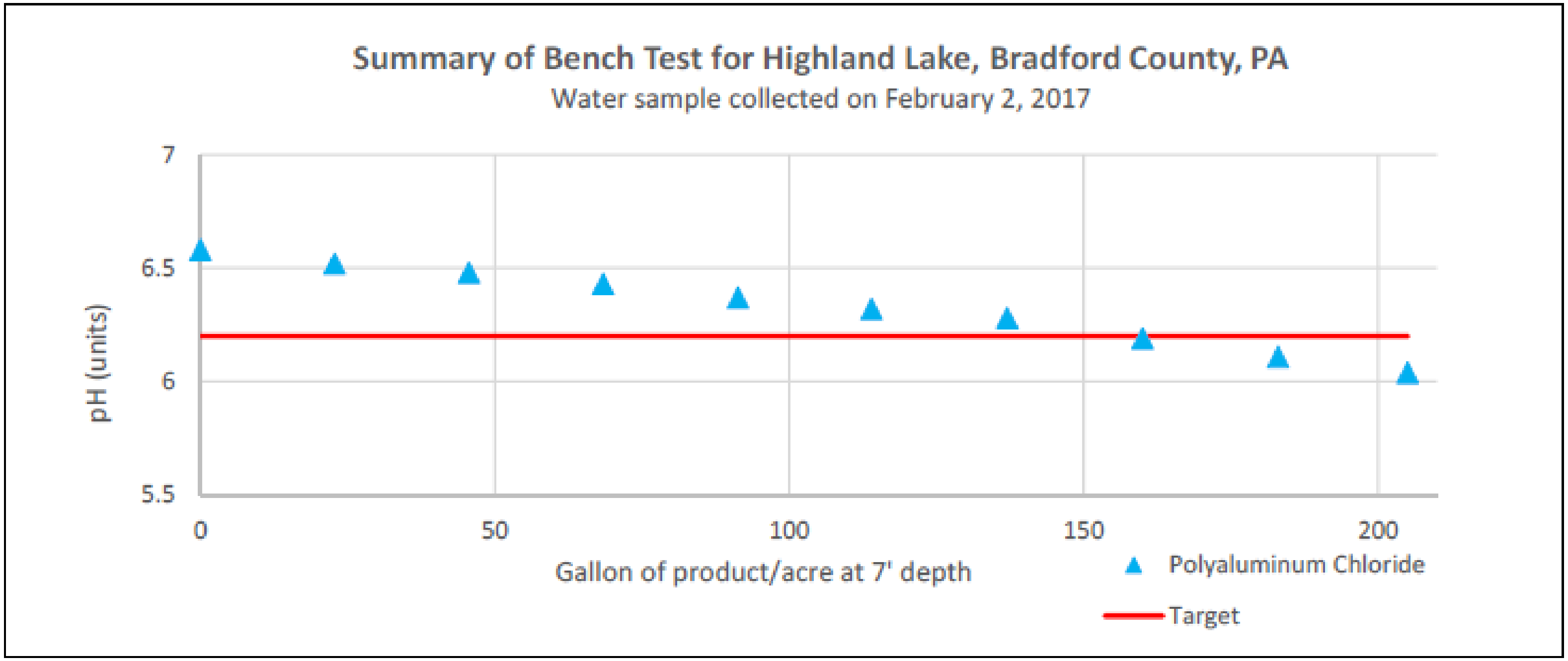


Figure 2 – Results of an alum bench test for poly-aluminum chloride (Holland Company).

Concluding Dosage Rate

- The EPIC WW58 resulted in a pH of 6.28 at a dosage rate of 137 gallons per acre and a pH of 6.19 at 160 gallons per acre.
- Given these results the EPIC WW58 product was selected for the treatment at a dosage rate of 100 gallons per acre.
- All data were submitted to the regional PA DEP office for review and the treatment was "permitted" like an pesticide.
- Approval was received 12th June 2017; treatment was conducted on 15th of June 2017.

Polyaluminum Chloride Treatment of Highland Lake, Bradford County, PA (2017)

Targeted Water Quality Criteria

- Secchi depth of at least 1.0 meters (3.3 feet) or greater (typically Secchi depths of < 1 meter are perceived by the layperson as being "dirty" or "scummy")
- Surface water TP concentrations of 0.03 mg/L or lower
- Bottom water TP concentration of 0.10 mg/L or lower
- Chlorophyll *a* concentration of 20 mg/m^3 or lower (typically chlorophyll *a* concentrations > 30 mg/m^3 are considered by the layperson as being unacceptable for recreational use)

Pre-treatment			9:30 AM	6/15/2017		
Depth (m)	Temperature (°C)	SpC (mS/cm)	DO (mg/L)	DO (% Sat.)	pH	Sal.
0	23.57	0.06	7.58	90.1	7.75	0.03
1	23.58	0.06	7.81	92.9	7.57	0.03
2	19.24	0.056	9.85	107.7	7.48	0.03
3	16.77	0.059	9.18	95.4	7.46	0.03
4	13.96	0.067	2.54	24.7	7.19	0.03
5	11.02	0.088	0.3	2.8	6.82	0.04
5.5	10.44	0.209	0.25	2.2	6.64	0.1

Secchi Depth: 2.3

Total Depth: 5.5

Water Color: green-stained

Notes: The lake is thermally stratified, with a sharp decrease in temperature between 1 and 2 meters in depth, and further decreases approaching the bottom. The bottom is currently experiencing anoxic conditions. Surface pH levels are currently relatively alkaline.

Post-treatment			4:30 PM	6/15/2017		
Depth (m)	**Temperature (°C)**	**SpC (mS/cm)**	**DO (mg/L)**	**DO (% Sat.)**	**pH**	**Sal.**
0	23.9	0.097	8.2	98.2	6.24	0.05
1	23.9	0.097	8	95.8	5.94	0.05
2	20.38	0.059	9.56	107.9	6.22	0.03
3	16.5	0.059	9.44	97.5	6.59	0.03
4	13.82	0.069	2.07	20.2	6.62	0.03
5	11.02	0.09	0.54	4.9	6.57	0.04
5.5	10	0.121	0.34	3	6.53	0.06

Secchi Depth: 3.2

Total Depth: 5.6

Water Color: blue

Notes: Water clarity and color have noticably changed. Additionally, pH has dropped as an effect of the PAC treatment. No plants and little algae have been observed all day.

During treatment, sub-surface pH dropped to as low as 5.52 in some areas, however, this was temporary, and pH would usaully increase again after a short period of time.


RICKY MACPHERSON 2017

Post-treatment			7/28/2017		
Depth (m)	Temperature (°C)	SpC (mS/cm)	DO (mg/L)	DO (% Sat.)	pH
0	23.63	0.065	10.04	118.4	8.48
0.5	23.42	0.07	10.18	119.6	8.55
1	23.15	0.065	10.34	121	8.62
2	23.07	0.065	10.07	117.3	8.31
3	22.01	0.072	1.35	14	6.74
4	15.12	0.125	0.53	5.1	6.75
4.5	14.11	0.144	0.32	3.2	6.84

Secchi Depth: 1.2

Total Depth: 4.5

Water Color: murky greenish brown

Notes: While the water was slightly murky and a greenish brown color, no large particulate material (e.g. globs or filaments) were identified in the water.

Additionally, it was noted by residents that there was a storm the previous day. These summer storms are well known to transport soil from the steep slopes of the watershed to the lake, giving the water a brownish turbid appearence. Thus, the murky appearence of the lake was at least partially attributed to inorganic material.

Additional Late Summer Sampling

- Bradford County Conservation District collected additional samples over the 2017 growing season.
- Discrete samples were forwarded to the PA DEP laboratory for analysis.
- During the 10 August 2017 sampling event, the Secchi depths were 1.5 and 16 meters

Type of Phosphorus	6/15/2017 (Pre)	6/15/2017 (Post)	7/28/2017 (Post)
Surface			
SRP	0.004	< 0.002	0.002
TDP	< 0.01	< 0.01	0.01
TP	< 0.01	< 0.01	0.03
Mid-Depth			
SRP	0.006	0.002	< 0.002
TDP	< 0.01	< 0.01	< 0.01
TP	0.02	0.02	0.03
Bottom			
SRP	0.004	0.004	< 0.002
TDP	< 0.01	< 0.01	0.01
TP	0.06	0.09	0.05

Additional Late Summer Sampling

- During the 10 August 2017 sampling event surface TP concentrations varied from 0.021 to 0.035 mg/L with a mean of 0.028 mg/L.
- The bottom water TP concentrations varied from 0.040 to 0.044 mg/L with a mean of 0.042 mg/L.

Chlorophyll *a* concentrations

- Before the treatment surface and mid-depth values were 6.2 and 15 mg/m^3, respectively.
- After the treatment surface and mid-depth values were <1.2 and 18 mg/m^3, respectively.
- Surface and mid-depth values on 28 July 2017 were both 28 mg/m^3.
- However, during the 10 August 2017 sampling event surface and mid-depth values were 8.7 and 10.3 mg/m^3, respectively.

Plankton

- During the treatment a mix of green algae, diatoms and blue-green algae.
- During the July event, a moderate bloom of the blue-green algal *Anabaena*.
- While blue-greens such as *Aphanizomenon* and *Anabaena* were still present in mid-August, the dominant plankton at this time was the flagellate *Cryptomonas*.
- Diatoms were the dominant group in fall 2017

Plankton Summary - 2017

Cells / mls and Depth	6.15.17 (Pre)	6.15.17 (Post)	7.28.17	8.10.17
BGA - SURAFCE	1,168	4,770	59,290	26,230
BGA - MID-DEPTH	182,054	214,544	76,422	N.S.
Total	**183,222**	**219,314**	**135,712**	

Note a Bloom of the cryptomonad *Cryptomonas* on 10 August 2017: 170,000 cells / mLs

Conclusions

- Secchi depth was consistently greater than 1 meters.
- TP concentrations were below their targeted threshold limits.
- A moderate bloom of the blue-green alga *Anabaena* was documented in July but conditions improved in August. The July bloom was arbitrated to the 1.5” of rain that fell the 4 days prior to sampling.

Recommendations

- Continue monitoring in 2018 to document the effectiveness of the PACl treatment.
- Local stabilization efforts should be designed and implemented to reduce the NPS pollutant loads that originate from the watershed.
- Septic Management.
- Design and implement a program to re-establish submerged and floating-leaved, native vegetation in the lake.

THANK YOU

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