

# North Lake Ecological Report

A Biological, Chemical, and Morphometric Lake Study  
Conducted by

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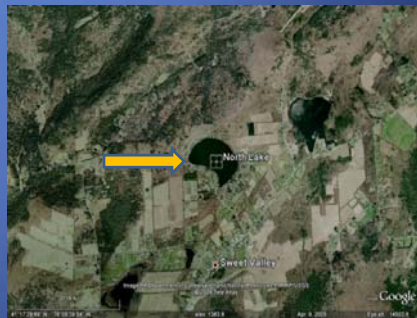
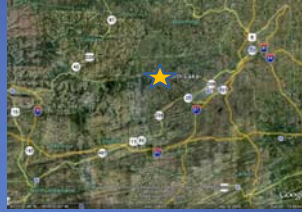
Presented to  
The North Lake Association  
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## Project Objectives

- Obtain limnological data from North Lake (chemistry, morphology, biology, etc.)
- Use the data to comparatively analyze environmental conditions prior to a remediation program in 2004 with present conditions
- Analyze the effectiveness of the CLEAN-FLO aeration system
- Use these data to make initial recommendations

## Geographic Setting/Geology

- Located in western Luzerne Co. ; Sweet Valley, PA
- Lake was formed by an ice gouge from the Illinoian and Wisconsin Ice sheets during the Pleistocene Epoch
- Lake age ~12,000 years



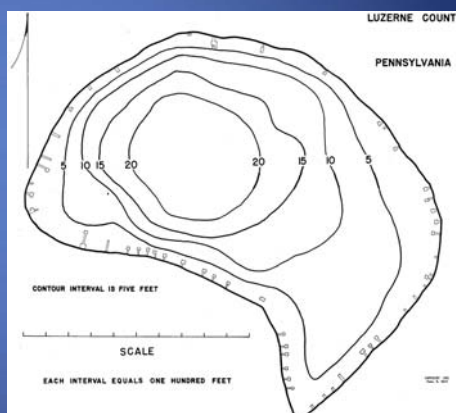
Map courtesy of: Google Earth

## Lake Morphometry

### Morphometric Parameters

Surface Area	38.9 acres
Watershed Area	137 acres
Catchment Area	175.9 acres
Volume	$1.253 \times 10^8$ gallons
Max Length	1,853 Feet
Max Breadth	1,474 feet
Max Width	907 Feet
Max Depth	22.1 Feet
Mean Depth	10.1 Feet

### Bathymetry of North Lake



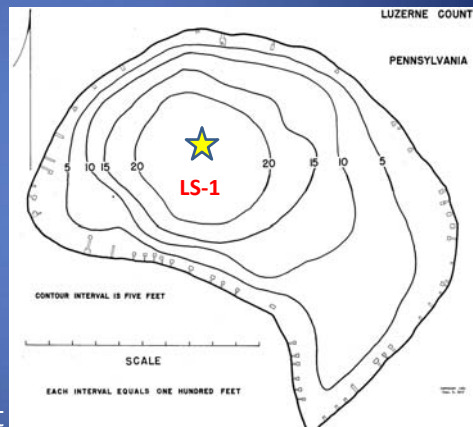
Reif, 1961

## Prior Studies, History, and Background Information

- 1963: lake was “crystal clear;” ~90% of residency was seasonal; indoor plumbing “unheard of”; 55 gallon drums sometimes received sewage wastewater.
- Mid 1970’s lake began to show noticeable changes; large increase in seasonal residency
- 1978: Dr. C Houseknecht Wilkes College quotes “septic sewage main threat to lake”
- Rapid decline in aquatic life; large blooms of cyanobacteria (blue-green algae) start to appear
- North Lake proposed a sewage wastewater system but was turned down by the surrounding community
- 2001-2004: Association hired EcoScientific Solutions to manage lake; began  $\text{CuSO}_4$  treatments/ CLEAN-FLO aeration system introduced and installed on lake bed.
- September 2008: Wilkes University Limnology Class Study

## Limnological Data

- Temperature
- Dissolved Oxygen
- pH
- Turbidity
- Light Transmissivity
- Phosphorus & Nitrogen
- Biology
- Loss on Ignition
- Theoretical Flush rate
- Bottom Sediment Core Sampling
- All measurements taken at Lake Station 1 (LS-1)



## Temperature

- Affects chemical, biological, and physical processes
- Increase in temperature decreases the dissolved oxygen
- Usually climate controlled, but humans can alter temperature such as the case at North Lake
- Spring and fall--uniform temperature profile throughout lake
- Area lakes usually stratify into 3 layers during summer/early fall--Epilimnion, Thermocline, and Hypolimnion

## Lake Stratification

- Epilimnion: warmest water and highest D.O. levels
- Thermocline: middle layer of water where a rapid decline in temp and D.O. is observed
- Hypolimnion: coldest layer and lowest, if any, D.O. levels

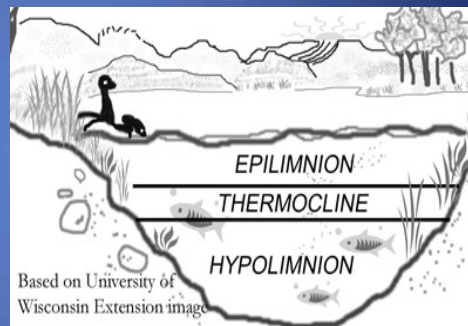


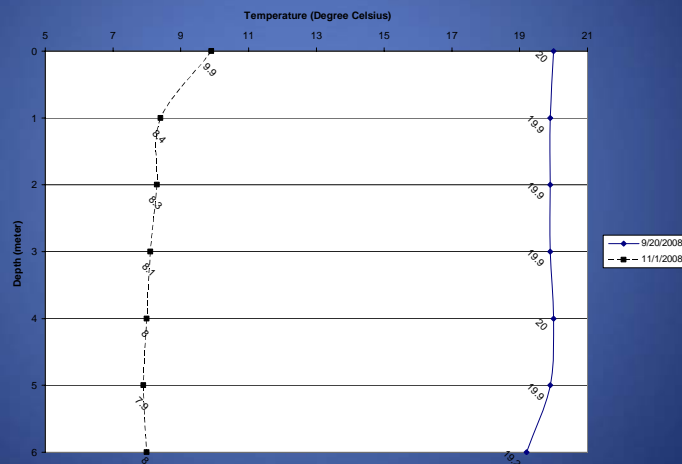
Image courtesy of: University of Wisconsin

## Lake Stratification (cont)

- In 1978 study, North Lake stratified
- Since introduction of diffusers, it has de-stratified
- This was expected and was a major objective of the system
- Temperature profiles are now consistent from top to bottom



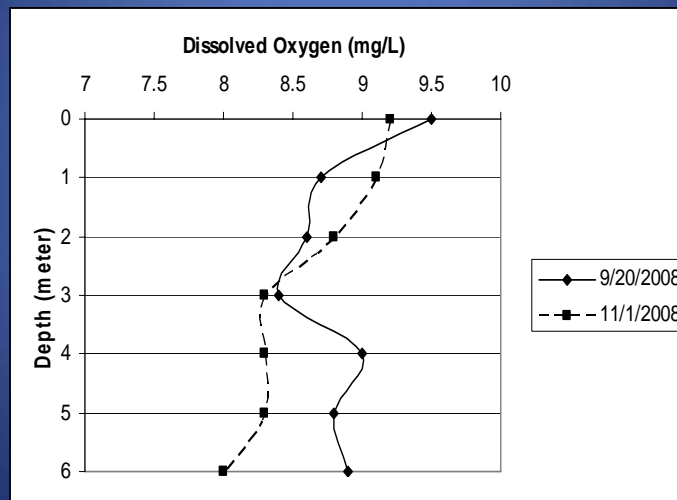
## Temperature Profile



## Dissolved Oxygen

- Temperature dependant (warmer water holds less D.O.)
- Photosynthesis and diffusion provide O<sub>2</sub> naturally
- Decomposition of organic matter, respiratory processes, and oxidation of inorganic wastes deplete it
- Important indicator of the "health" of lake
- Most organisms require minimum of 4 mg/L of D.O.
- North Lake is very well mixed and D.O levels remained high as expected
- However, some depths greater than 6m showed little, if any D.O. near bottom (anoxic conditions); CLEAN-FLO system was supposed to add oxygen to all depths and rid bottom of reduced gases

## Dissolved Oxygen (cont)

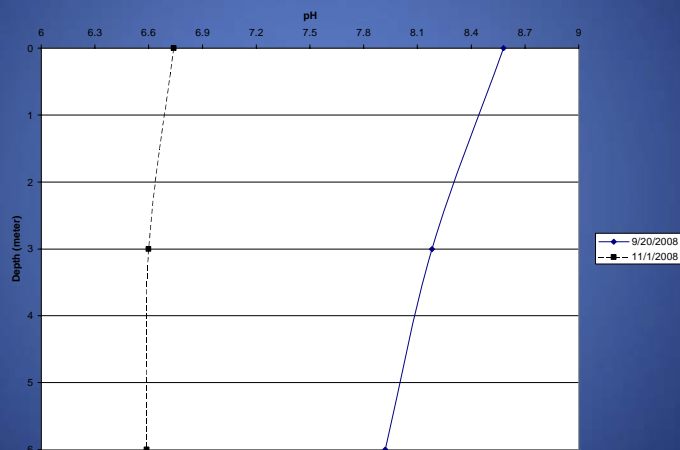


# pH

- Logarithmic scale of 0-14
- 7 is neutral (water)
- Major factor to chemical and biological processes
- North lake's pH was 6.74-8.58; Average to slightly above average
- Above average results due to more sunshine aiding photosynthesis, hence, lake was taking in more CO<sub>2</sub>



## pH Profile



# Turbidity and Secchi Disc

## Turbidity Meter

- Provides measure of water clarity and particulate matter (PM)
- PM includes algae, sand, silt, mud and plant matter
- Average lake value 5 ntu
- North Lake measured extremely high values between 18 and 44 ntu's
- High values were caused by the excessive amount of algae

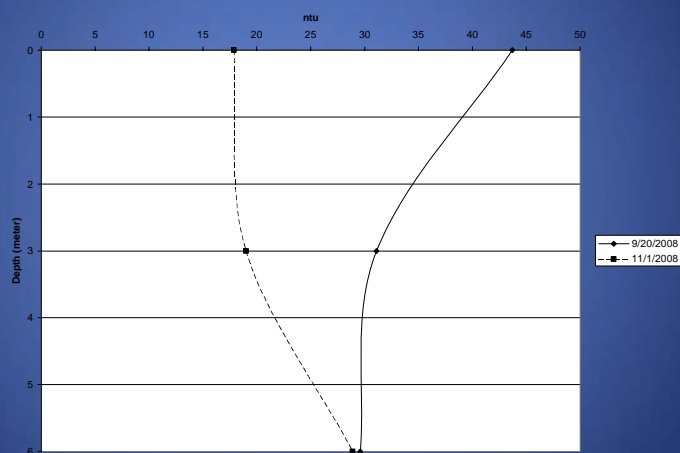
## Secchi Disc

- Easiest for common lake user to understand
- 20cm black and white circular disk
- Lowered through water column until no longer visible and depth recorded



Secchi Disc

# Turbidity Profile

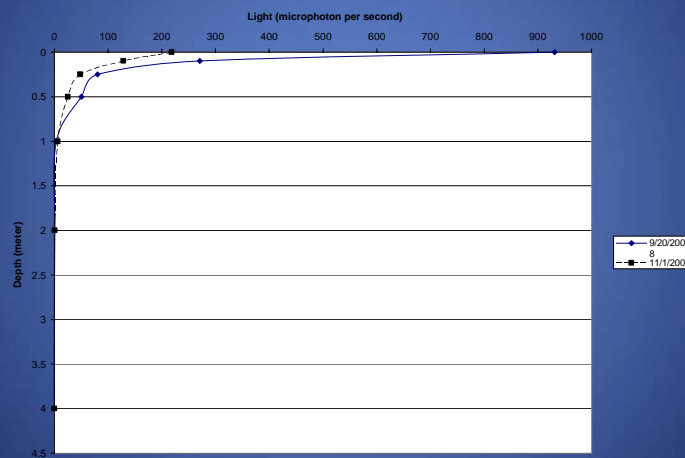


# Light Transmissivity

- Indicator of water quality
- Measures how much light penetrates water column
- Essential for photosynthesis
- Light is scattered by algae and other suspended particles
- Light can reach depths of tens of meters deep in clear lakes
- Light in North Lake dramatically declined after just a few centimeters
- Due primarily to lake's cyanobacteria bloom present at sampling time



# Light Profile



## Phosphorus and Nitrogen

- Main “pollutants” of lake
- Major nutrients of algae and macrophytes
- External and Internal loading
  - External sources include septic leachate, sewer effluent, dish detergent (soaps), run-off and precipitation
  - Internal loading from decomposition and sediments
- Nitrate/Nitrogen to total Phosphorus ratio (N:P) found to be 0.44. This low value suggests that the cause is from septic leachate

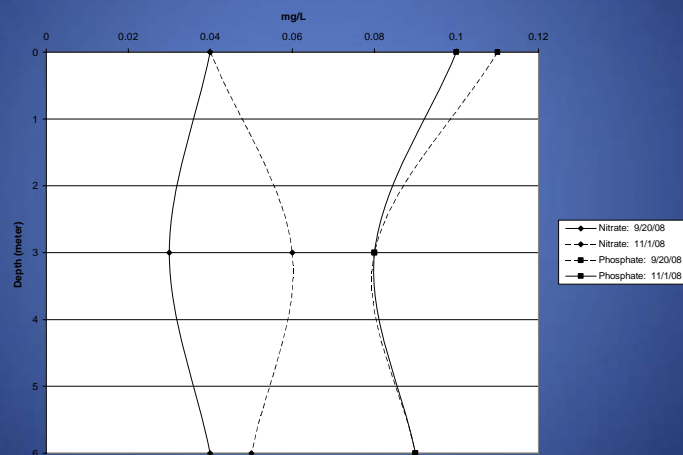
## Phosphorus

- Typically a limiting factor on algal production in freshwater lakes in this region
- Essential nutrient to all living species
- Normal range 0.01 to 0.03 mg/L
- Values below 0.01 indicate oligotrophic (nutrient poor) conditions; greater than 0.03 is eutrophic (nutrient rich), and in between, mesotrophic
- Oligotrophic, little productivity
- Mesotrophic, medium productivity
- Eutrophic, high productivity
- North Lake registered a high of 0.11 and mean value of 0.09 mg/L
- This is more than 3 times the expected phosphorus for a eutrophic lake
- North Lake is probably “Hyper-Eutrophic”, exhibiting excessive productivity

# Nitrogen

- Nitrogen cycle is complex
- Nitrogen can exist as oxidized forms such as nitrate ( $\text{NO}_3^-$ ), nitrite ( $\text{NO}_2^-$ ), or reduced forms such as nitrite ( $\text{NO}_2^-$ ) and Ammonia ( $\text{NH}_3$ )
- Ammonia is most commonly found near bottom
- The form of nitrogen depends upon dissolved oxygen concentrations

## Phosphorus/Nitrogen Profile



# North Lake Biology

## Phytoplankton

- Photosynthetic organisms that float freely
- Adapted for life of suspension
- Dependent upon wind and water currents for transportation
- Cyanobacteria (blue-green algae) are in this group

## Zooplankton

- “Animal-like” organisms that exist in plankton community
- 4 major groups: protozoa, rotifers and 2 subclasses of Crustacea—Copepods and Cladocerans

# Phytoplankton

- Cyanobacteria: (Blue-Green Algae) *Anabaena* and *Microcystis* dominate at North Lake
- They are responsible for obnoxious green surface scums
- Their excessive presence is the result of abnormally high concentrations of P and N
- Generally not grazed upon by zooplankton



Schindler trap used for collection of plankton

## North Lake Biology

- 1978 study found 35 species of plankton compared to 2008 study of only 15 species of plankton
- This was a 43% loss of diversity!
- Cyanobacteria, or blue-green algae was the dominant species in current study
- Cyanobacteria are the most undesirable form and responsible for obnoxious green surface scums, wind swept "green mats", and foul odors
- Highly adaptable species
- Can fixate its own N; therefore the overabundance of P provides a huge growth potential
- If P loads are reduced, cyanobacteria levels will drop
- *Microcystis* accounted for over 87% of the 15 species and is responsible for DEP's decision to close the lake recently
- Contains a toxin called microcystin which can cause numerous allergic reactions and health problems in humans and pets



## Zooplankton

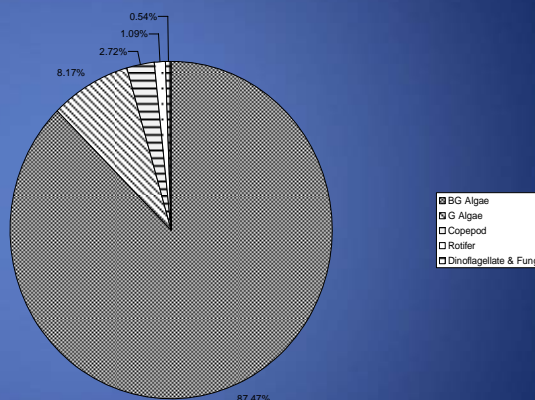
- Animal-like organisms
- Cladocerans dominant
- *Chydorus sphaericus*
- Small crustaceans commonly referred to as "water fleas"
- Feeds upon small algae and bacteria
- Does *not* feed upon toxic cyanobacteria
- Observed grazing phytoplankton, but excreting waste at high rate
- Did not appear to have noticeable impact on biomass



*Chydorus sphaericus*

## North Lake Biodiversity

- 43% loss of diversity since 1978!
- 1978 study found green algae dominant
- 2008 study found blue-green algae dominant



## Plankton Sampling

- Wisconsin Tow (vertical)
- Used to collect plankton samples of various sizes
- Consists of a fine mesh net which is volumetrically calibrated
- This can be used to calculate the lake's biomass density



Wisconsin net

## Bottom Sediments

- Accumulate lake's nutrients and acts as a repository
- Can add nutrients into water (internal loading)
- Can "date" the lake and reveal history of development
- D.O. meter revealed anoxic conditions present at water/sediment interface
- Core sample obtained and used for determining loss on ignition (LOI)



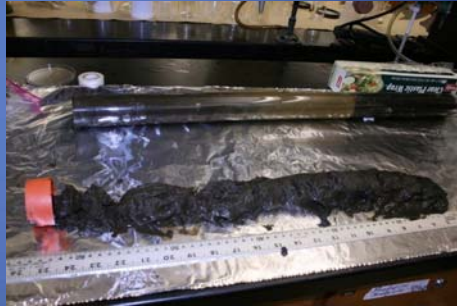
## Bottom Core Sampling

- Core sample taken at deepest point (22.1 ft)
- 63.5 cm L X 49 mm W
- Core was darker colored on top than bottom, suggesting increased amounts of organic matter introduced more recently in time
- LOI was conducted to verify this



North Lake's core sample

## Bottom Core Sample (continued)



## Bottom Core Sample (continued)



## Loss on Ignition

- Laboratory test used to determine amount of organic matter is in substance
- Core sample broken down into 6 sections
- Sample closest to top represents present time and sample near bottom represents a few hundred years ago
- Dried samples were burned in a 525°C furnace, then re-weighed to determine LOI
- Important test: showed how North lake's productivity changed over time
- More organic matter "burned off" translates to more organic matter that was present
- Data given as % organic matter lost



## Loss on Ignition (continued)

- Clearly shows more organic matter at present time
- % lost declines throughout time
- Core age at 50-60cm mark hundreds of years old
- Significant find since lake has never been this productive until recently
- Human impact is most likely cause

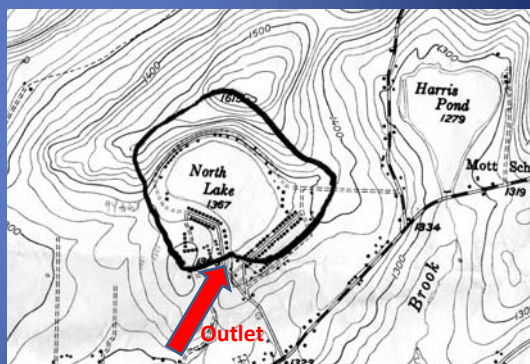
Sediment Depth (cm)	Loss on Ignition (%)
<b>0-10</b>	<b>38.9</b>
<b>10-20</b>	<b>38.8</b>
<b>20-30</b>	<b>31.2</b>
<b>30-40</b>	<b>27.7</b>
<b>40-50</b>	<b>28.1</b>
<b>50-60</b>	<b>24.3</b>

## Theoretical Flush rate

- Calculating “real” flush rate was beyond scope of study without a detailed knowledge of groundwater inputs
- Flushing rate has direct impact on water residence time (amount of time water stays in a system)
- A short residence time will benefit lake since it will flush “old” water out and replace with “new” water
- Residence time is affected by the water budget of a lake and watershed area
- Theoretical value will yield highest possible flush rate lake can achieve
- “Real” flush rate will be somewhat lower
- Calculated by determining long term average annual precipitation multiplied by watershed area
- Value then multiplied by a runoff coefficient to give the amount of water entering the lake annually
- Annual input of water to lake is then divided by the lake’s volume

## North Lake’s Watershed Area

- 137 acres
- An extremely small watershed area
- Long-term average annual precipitation for WB/Scranton 0.91m
- Theoretical flush rate determined to be 1.6 times/year
- Moderate value
- Positive attribute for lake



Map courtesy: USGS ; Area by Joel Antolik

## The CLEAN-FLO System and Artificial Circulation

- Artificial circulation (AC) and de-stratification are main objectives of this system
- Theoretically achieved by pumps, pipes, and bubbled air from diffusers resting just above bottom sediments
- Expected lake water quality improvements include aeration (increase in dissolved oxygen and expansion of suitable habitat)
- AC *may* also reduce *internal* loading of P by subjecting algal cells to higher hydrostatic pressures
- AC intended to mix the entire water column, therefore decreasing amount of time algae has in photic zone for photosynthesis; however, North Lake may not be deep enough for this to occur
- In some cases phytoplankton may increase following AC

## The CLEAN-FLO System and Artificial Circulation (cont)

### ADVANTAGES

- Increases dissolved oxygen concentrations at nearly all depths
- Increases suitable habitat for all organisms and fish
- Remediation tool to reduce phytoplankton biomass by light limitation



### DISADVANTAGES

- Increases water temperature
- For treatment of internal loading of P only
- Costly to operate/maintain
- Pipes & diffusers must be properly placed to avoid disturbance of bottom sediments rich in phosphorus and nitrogen (requires visual inspection)

## Conclusions

- Overall, water quality at North Lake has declined sharply since the first 1978 study by Wilkes College
- Recent CLEAN-FLO system has increased D.O. levels for some fish and zooplankton species.
- Nevertheless, North Lake exhibits dramatic losses in biodiversity in the past 30 years consistent with increasing eutrophication.
- Internal loading may have increased because of diffuser aeration and disturbance of bottom sediments
- Flush rate of 1.6 times/yr provides “hope” for lake *if* external P is taken care of first

## Recommendations

- Before any attempt to halt internal loading, external loading *must* be stopped--a sewer system is desperately needed and is most likely the ultimate solution
- If funds cannot be made available, every attempt to upgrade and maintain the existing septic system is recommended
- Lawn fertilizers should not be used within the watershed area
- Any detergents used should be “phosphorus-free”
- Some observed properties have steep embankments which are not vegetated; Plant trees, shrubs, or grass on such embankments
- Mud and silt naturally carry P into the water and can account for modest increases of P, therefore, all properties should participate in Best Management Practices for erosion control
- The dirt road traversing around the lake should be paved
- In some case studies, a reduction in external loading was sufficient to restore the water body
- Another form of remediation tool that may provide temporary relief is nutrient inactivation

## Recommendations (continued)

### *Nutrient Inactivation*

- Involves addition of alum (aluminum salts) which binds P (coagulation) and settles it to the bottom
- Forms 1-2" layer of "floc" on bottom
- Prevents P from being re-distributed in water column
- Works well in little or no oxygenated water
- If internal loading is high, it can reduce P enough to limit algal growth, or at least shift a blue-green dominant algae to one dominated by green algae and diatoms

## Recommendations (continued)

### Nutrient Inactivation

#### ADVANTAGES

- Very effective in reduction of internal P
- Long lasting (> 8 years)
- Virtually maintenance-free
- Does not directly kill phytoplankton, such as copper sulfate treatments of the past (those treatments rupture algal cells and release additional nutrients)
- Cost effective

#### DISADVANTAGES

- External P must be stopped and will not work if it is too high
- Decreases pH levels
- Aluminum toxicity by decreasing pH values
- Boat motors may disturb sequestered P

## Recommendations (cont)

### Nutrient Inactivation

- North Lake is a “borderline” candidate for this remediation tool
- pH is good but alkalinity may need to be increased
- Lake’s pH and alkalinity must constantly be monitored and managed
- Chance for aluminum toxicity is low
- Sufficient depth of lake makes it questionable



## Review of Final Recommendations

- External P must be stopped first before any other remediation effort
- Sewer system must be installed
- Maintain/upgrade existing septic systems
- The use of Lawn Fertilizers are strongly discouraged
- Buy only “Phosphate-Free” laundry detergents
- Limit the amount of “grey water” entering watershed area
- Residents should take proper erosion control measures around their properties
- Dirt road around lake should be paved

## Final Recommendations

1. Connect to sewer system
2. Visually inspect CLEAN-FLO system under operational conditions to determine impact on bottom sediments.
3. Explore possibility of alum treatment.
4. Enact horsepower restrictions on motorboats.

## End of Presentation

- I would like to thank everyone for their time and participation
- Special thanks to Mr. J.D. and Neil Paternoster, Mr. Carl Steinbrenner, Mr. Fred Frey, and The North Lake Association
- Questions will now be taken

