Development of HABs / Cyanotoxin Management Plan

New York State Federation of Lake Associations, Inc.
26th Annual Conference

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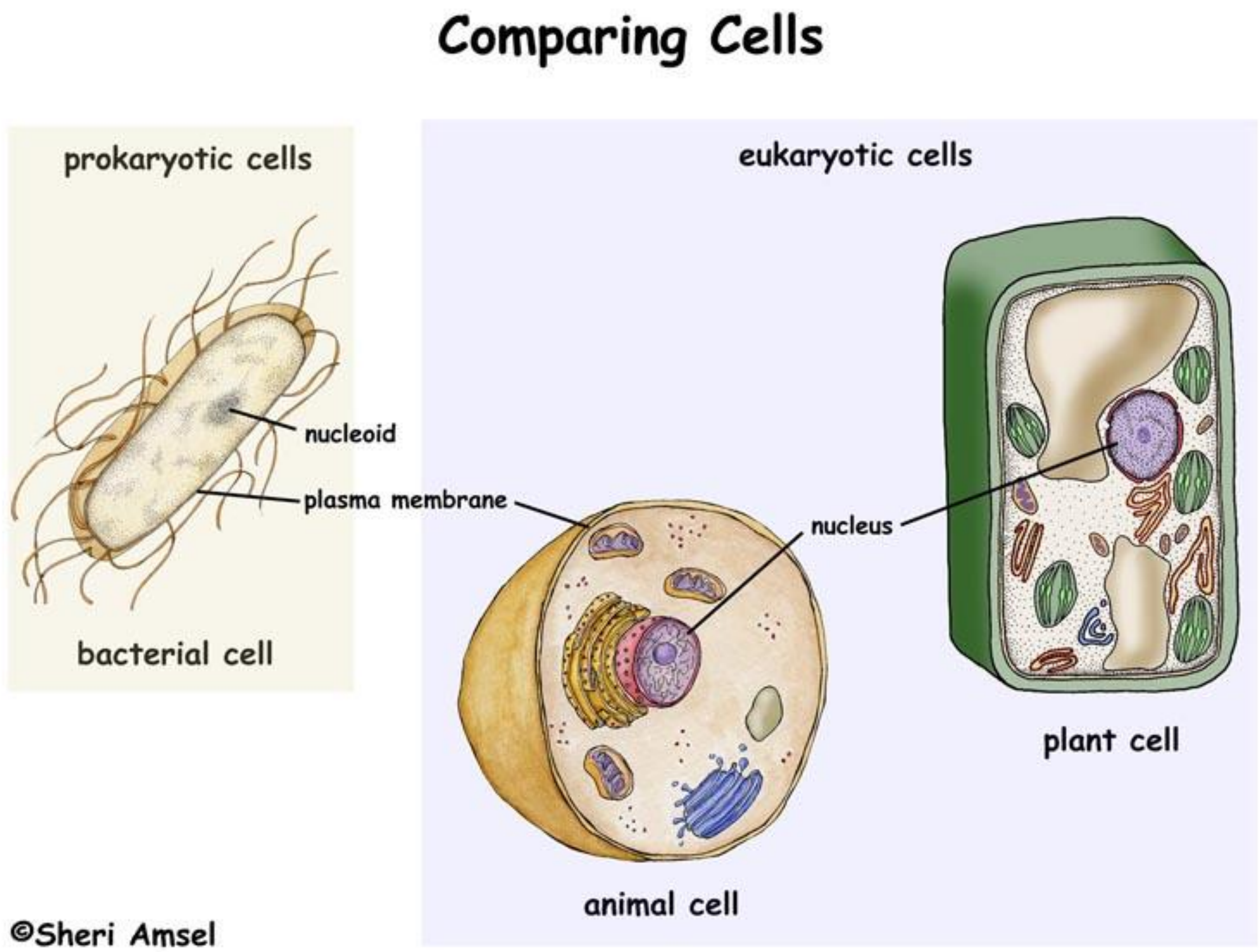
Comparing Cells
prokaryotic cells
eukaryotic cells
nucleoid
plasma membrane
nucleus
bacterial cell
plant cell
animal cell
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Eukaryotes

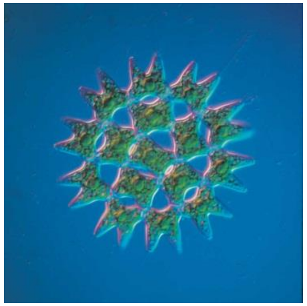
Prokaryotes

Anabaena (blue-green alga) Bloom

Euglena Bloom

Freshwater Algae

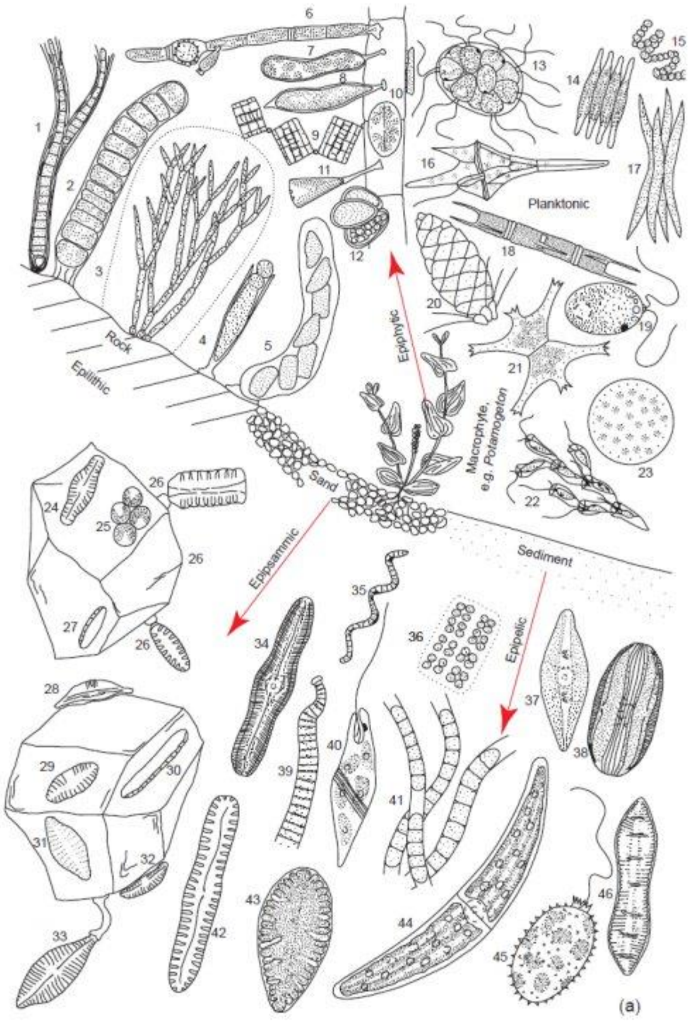
- Phytoplankton (free floating algae)
- Filamentous Mat Algae (benthic algae)
- Macro-algae (stoneworts)



Harmful Algae Blooms (HABs)

Algal groups

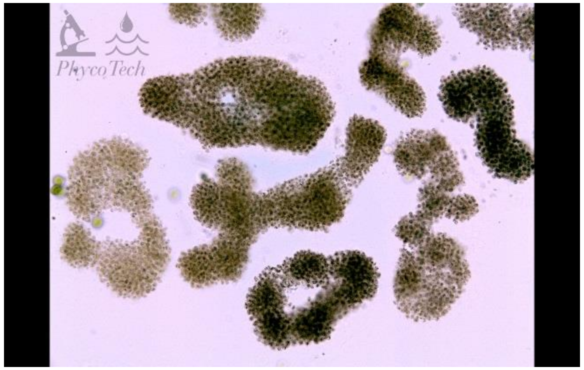
- Green algae
- Chrysophytes
- Diatoms
- Dinoflagellates
- Euglenoids
- **Blue-green algae**
- Others

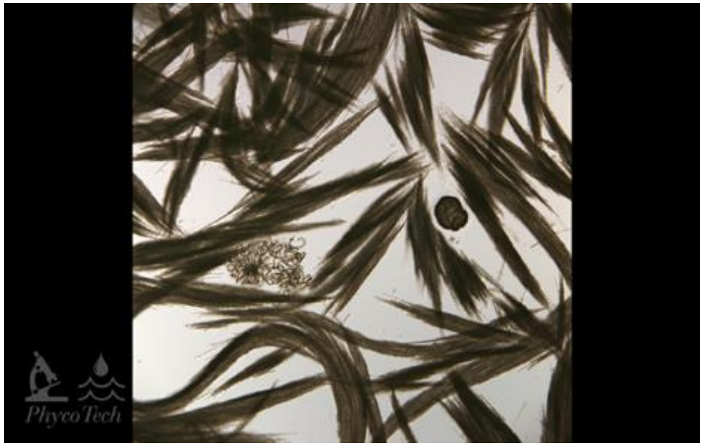


Blue-Green Algae (Cyanobacteria) and Cyanotoxins

- While non-blue-green algal blooms can produce problems (e.g. turbid waters, taste and odor problems), they do not produce cyanotoxins.
- Thus, confirmation needs to be conducted that the existing bloom is in fact a blue-green algal bloom.
- Microscopic examination of the collected samples.
- Also, blue-green algal blooms typically do not occur between December and March, with increasing probability of blooms occurring as you move from spring through summer and fall

Common Blue-green Algae





Adaptations of Blue-green Algae

- Can photosynthesize in a variety of light intensities
- Have resting spores called akinetes
- Some can fix gaseous nitrogen (heterocysts)
- Some can regulate their position in the water column through gas vacuoles
- Generate colonies and cyanotoxins that make them unpalatable

Akinetes

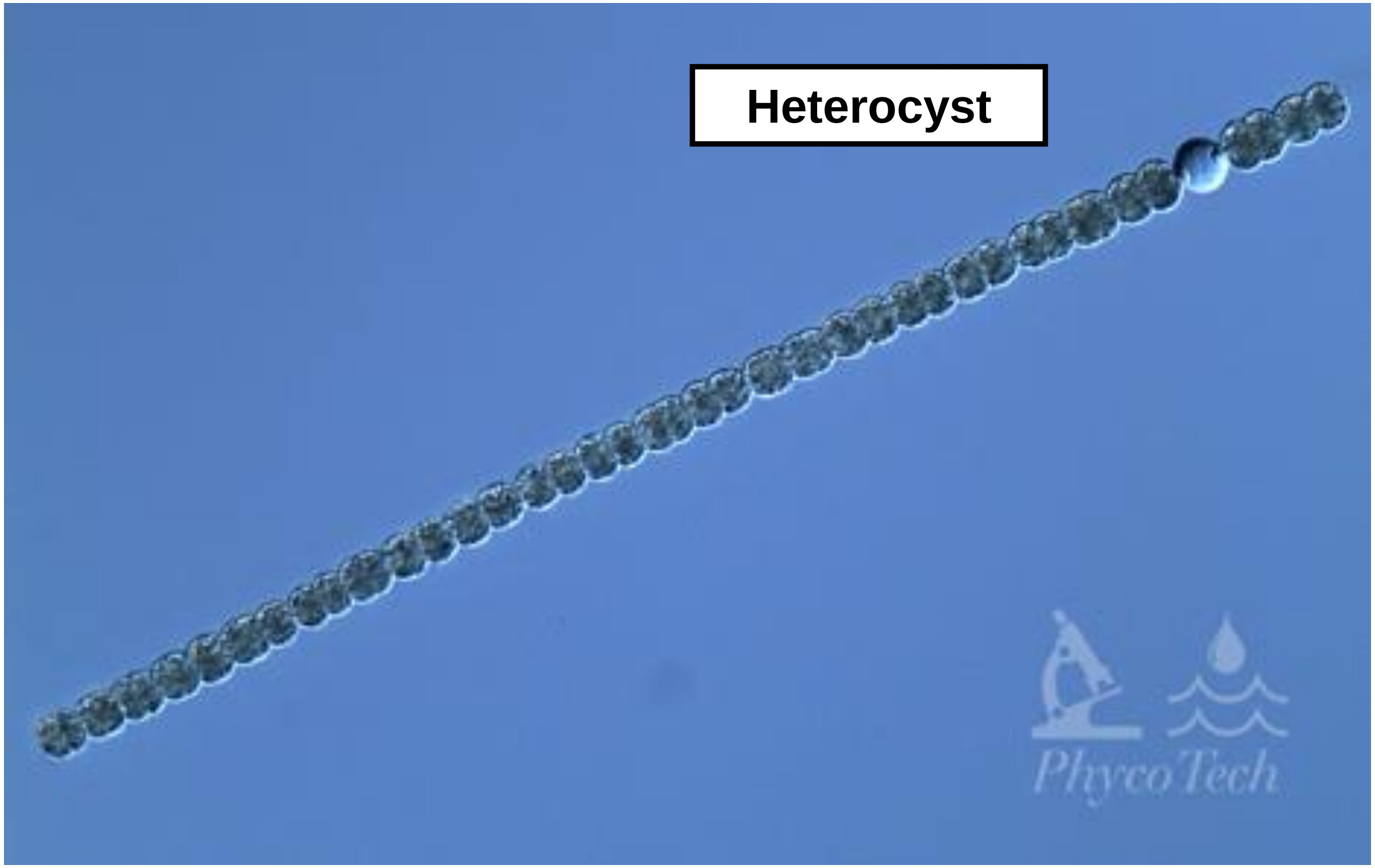
- Resting cells that form from one cell or fusion of two or more neighboring cells.
- Thick cell walls and store "food."
- Tend to be produced toward the end of the growing season.
- Basically used to survive harsh conditions.
- When a lake mixes, it can transport the akinetes back to the surface where they germinate

Akinetes

Heterocysts

- Specialized cells that produce thick, multi-layered cell walls that are air tight.
- Maintain an micro-environment in the heterocyst that is anoxic (no oxygen)
- The cell then has the ability to “fix atmospheric nitrogen.
- Thus, they are not dependent on external sources of nitrogen (nitrate-N or ammonia-N).

Heterocysts



Gas Vacuoles and Gas Vesicles

- Gas vacuoles (also called aerotopes) are membrane-bound organelles in the blue-green algal cell that fills with gas.
- Gas vacuoles are clusters of gas vesicles.
- Essentially provide a means for planktonic blue-green algae to control / regulate their position in the water column through buoyancy.

Symptoms of the Problem

- Nuisance surface scums / turbid conditions
- Cyanotoxins
- Taste & Odor problems
- Potential fish kills

Cause of the Problem

- Stormwater / surface runoff
- Erosion of streambanks and shoreline
- Wastewater discharge or septic systems
- Internal Phosphorus Loading
- Geese or other organisms (pets, livestock)

Conditions that Result in an Blue-Green Algal Bloom

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

What are Cyanotoxins?

- Diverse group of chemical substances produced by blue-green algae which show specific toxic impacts on vertebrates.
- Some are **neurotoxins** (anatoxin-a, anatoxin-a(s), saxitoxins)
- Some are **hepatotoxins** (**microcystins**, nodularin and **cylindrospermopsin**)
- Dermotoxins (lyngbyatoxins and aplysiatoxins)
- Documented impacts on humans, livestock and pets

Lake Erie and Toledo, Ohio

- Early August of 2014 massive cyanobacterial algal bloom in the western end of Lake Erie.
- The cyanotoxin microcystin was found in dangerous levels in the finished municipal water.
- Half a million people were warned not to drink the water.

Lake Erie, August 2014

Cyanotoxins are NOT Taste and Odor Compounds

- Cyanotoxins are colorless, tasteless and odorless compounds
- Taste and odor compounds such as Geosmin and MIB can be produced by cyanobacteria (blue-green algae) and some actinobacteria
- Blue-green algae can produce T&O compounds and not produce cyanotoxins and they can produce cyanotoxins but no T&O compounds

US EPA's Concern Over Cyanotoxins

- In May of 2015 US EPA developed Health Advisories for two cyanotoxins in drinking water supplies
- In November 2016 EPA released Draft Human Health Recreational Ambient Water Quality criteria and/or Swimming Advisories for freshwater recreational waterbodies
- Monitoring under EPA's Unregulated Contaminant Monitoring Rule (UCMR-4) will occur between 2018 and 2020.

What Defines a Drinking Water Health Advisory?

- 10-Day Drinking Water Health Advisories (HAs) for microcystins and cylindrospermopsin.
- Children (younger than 6) **> 0.3 µg/L for microcystins and > 0.7 µg/L for cylindrospermopsin**
- Others (adult) >1.6 µg/L microcystins and 3.0 µg/L for cylindrospermopsin.
- HA is not legally enforceable federal standard
- 10-day HAs reflect exposures and effects for a 10 kg (22 lbs) child consuming 1 liter of water per day.

What Defines a Recreational Water Health Advisory?

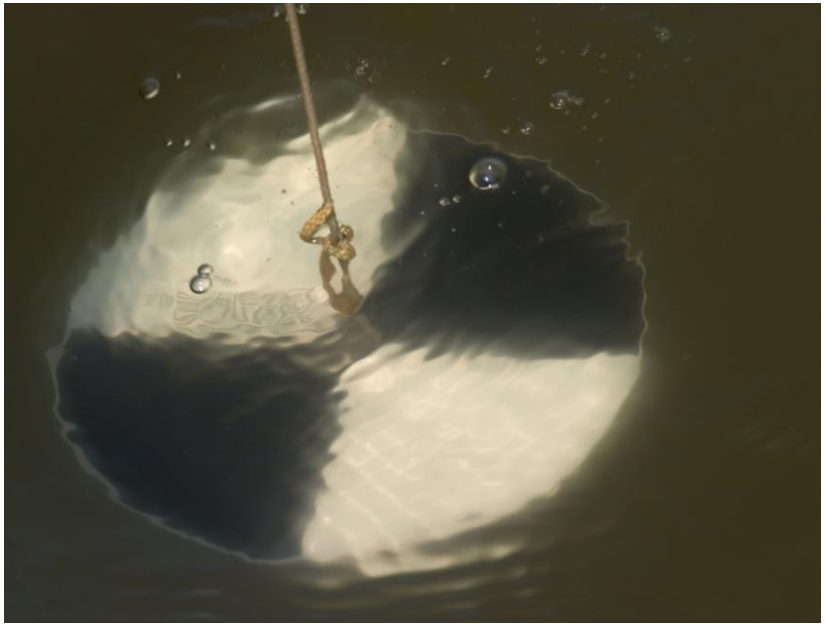
- Draft Human Health Recreational Ambient Water Quality Criteria and/or Swimming Advisories for freshwater recreational waterbody Advisories (HAs) for microcystins and cylindrospermopsin.
- Microcystins >4 µg/L
- Cylindrospermopsin >8µg/L
- Swimming Advisory - not to be exceeded per day
- Recreational Criteria for Waterbody Impairment -not exceeded more than 10 % of days per recreational season up to one calendar year.

Stepwise Monitoring for Cyanotoxins

- **General observations** (color / appearance of water; water clarity measured with Secchi disk)
- **Collection of sample** – identification of algae
- **Quantification of sample** – if blue-green algae present, at what concentrations? Typically, 15,000 cells / mLs is the threshold when a cyanotoxin sample is collected
- **Field cyanotoxin measurement**
- Possibly collect sample for **laboratory analysis of cyanotoxins**. Raw and finished water

General Observations

- Changes in plant operations (decline in filter runs, increase product use, increase in pH)
- Color / turbidity of water
- Surface scums / mat algae
- Tastes or odors
- Decline in water clarity



Algal Identification and Enumeration

- Simple ID – are blue-green algae present or dominant?
- Focus the counts (cells / mLs) on the blue-green algae
- While most blue-green algae appear to have the ability to generate cyanotoxins, not all can
- Multiple cyanotoxins

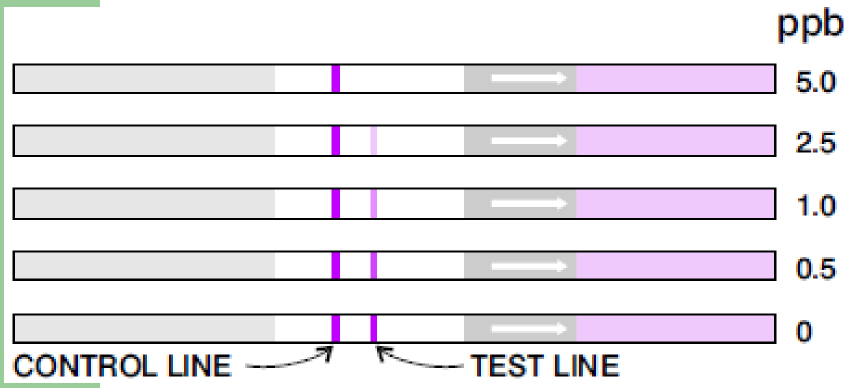
WHO CYANOBACTERIA CELL COUNT ACTION LEVEL	
SPECIES	**ACTION LEVEL**
Microcystis spp. or another singular genus	2,000 cells/mL or 5,000 cells/mL
Combination of all potentially toxic cyanobacteria species present	15,000 cells/mL

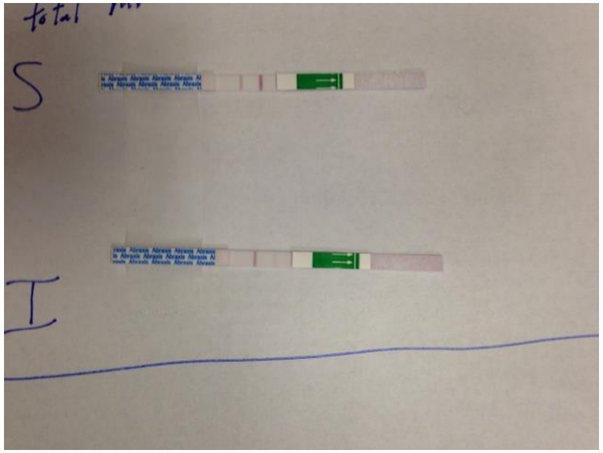
EPA/WHO Guidance

Relative Probability of Acute Health Effects	Cyanobacteria (cells/mL)	Microcystin-LR (µg/L)	Chlorophyll-a (µg/L)
Low	< 20,000	<10	<10
Moderate	20,000-100,000	10-20	10-50
High	100,000-10,000,000	20-2,000	50-5,000
Very High	> 10,000,000	>2,000	>5,000

https://www.epa.gov/nutrient-policy-data/guidelines-and-recommendations#what3

Monitoring Cyanotoxins (field-based)





Monitoring Cyanotoxins (field-based)

- Rapid immune-chromatographic test
- Used for qualitative screening of cyanotoxins
- Detection limit of 0.3 µg/L
- A quick preliminary screening (yes/no) screening tool
- Confirmation of a “hit” requires the use of one of the conventional lab testing procedures (e.g., ELISA or HPLC)
- Beware of false positives!

Monitoring Cyanotoxins (lab-based)

- Commonly used lab techniques
  - High performance liquid chromatography (HPLC)
  - Enzyme-linked immunosorbent assay (ELISA)
  - Protein phosphatase inhibition assay (PPIA)
- Higher level of accuracy
- More costly
- Takes time for results
- Dedicated lab

Do NOT collect samples for cyanotoxins with plastic containers – use glass only

In-Situ Technologies

- **Flow Cam** – great for potable water companies or organizations that focus on one or a few lakes
- **Meters or probes** – measure chlorophyll or a pigment unique to blue-green algae such as phycocyanin
- **Drones** – simple visual assessments or retrofitted with capacity to collect hyper-spectral data

York River, VA
(western side of Chesapeake Bay)

EPA/WHO Guidance

Relative Probability of Acute Health Effects	Cyanobacteria (cells/mL)	Microcystin-LR (µg/L)	Chlorophyll-a (µg/L)
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Very High	> 10,000,000	>2,000	>5,000

https://www.epa.gov/nutrient-policy-data/guidelines-and-recommendations#what3

Management Options - Proactive

- Nutrient control
- Controlling external sources
- Controlling internal sources
- Modifying depth of withdrawal
- Using alternative sources of water
- Biomanipulation (once blue-green algae are under control)

Management Options - Reactive

- Copper-based algicides
- Alternative products (oxidizers like GreenClean)
- Use alternative sources of water
- Avoid blooms by withdrawing water from alternative depths
- Nutrient stripping of water column (proactive and reactive)
- Increase flushing

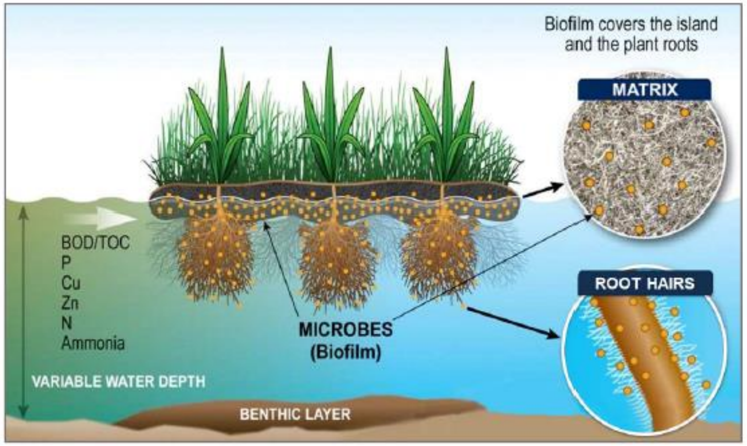
Nutrient Control (External Sources)

- Reducing non-point source (NPS) pollution entering the lake or reservoir.
- Watershed-based measures (stormwater management, green infrastructure, septic / wastewater management, agricultural BMPs) are effective, long-term solutions.
- However, does the lake association or water purveyor own the land where the NPS pollution is being generated?
- Frequently, land ownership is limited to immediately along the shoreline.

Nutrient Control (External Sources)

- Focus on shoreline / streambank stabilization
- Measures that can remove nutrients from the water column (not necessarily internal loading)
- Phosphorus Stripping
- Bacterial products / Barley Straw
- Floating Wetland Islands

Floating Wetland Island



Floating Wetland Islands

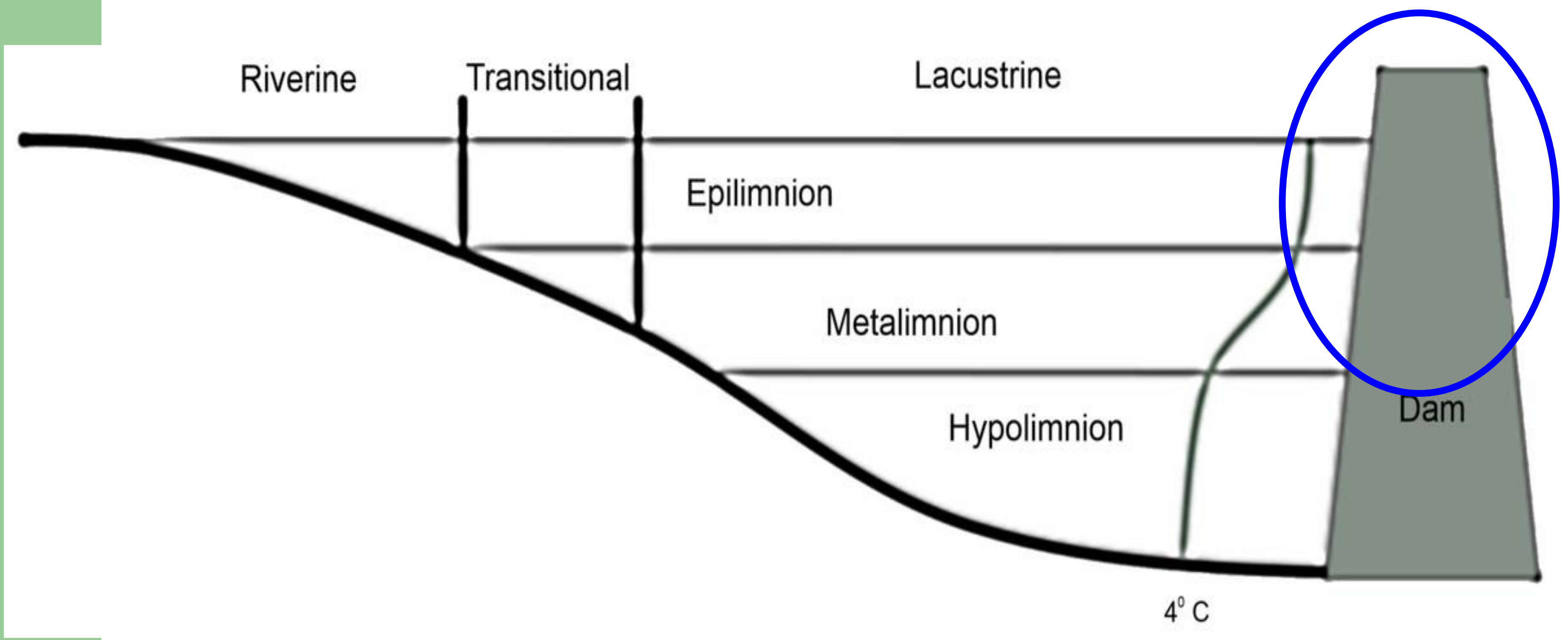
Floating Wetland Islands (The Hideout; 2018)

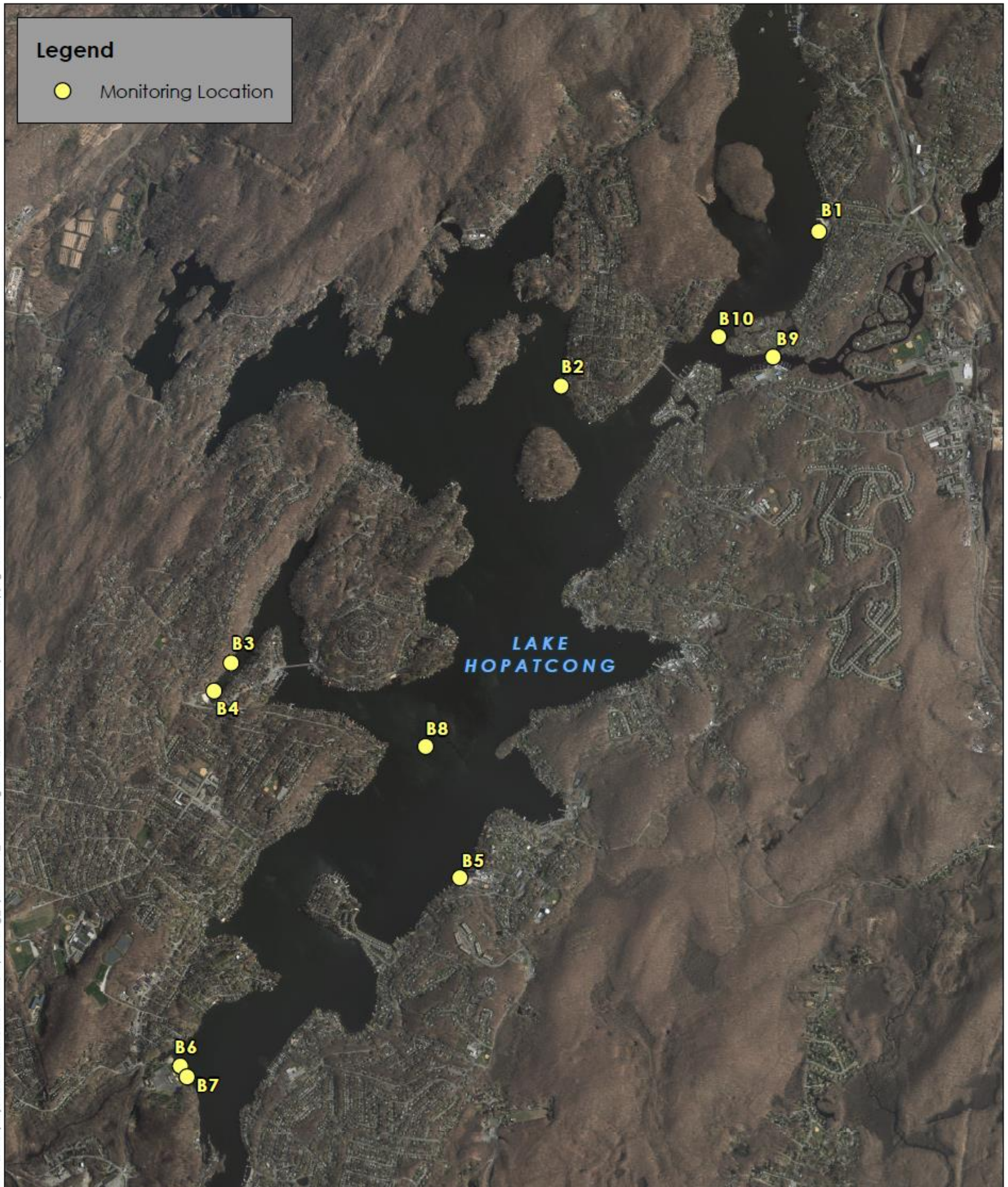
Frances Slocum Lake
September 2017

Nutrient Control (Internal Sources)

- However, phosphorus can also originate from the deep-water sediments, particularly in the deep, main body of the reservoir.
- Typically the Intake structures are immediately adjacent to the deepest section of the reservoir.
- If the bottom water are depleted of dissolved oxygen over the summer / fall months, internal phosphorus loading can be high.

Side Profile of a Reservoir





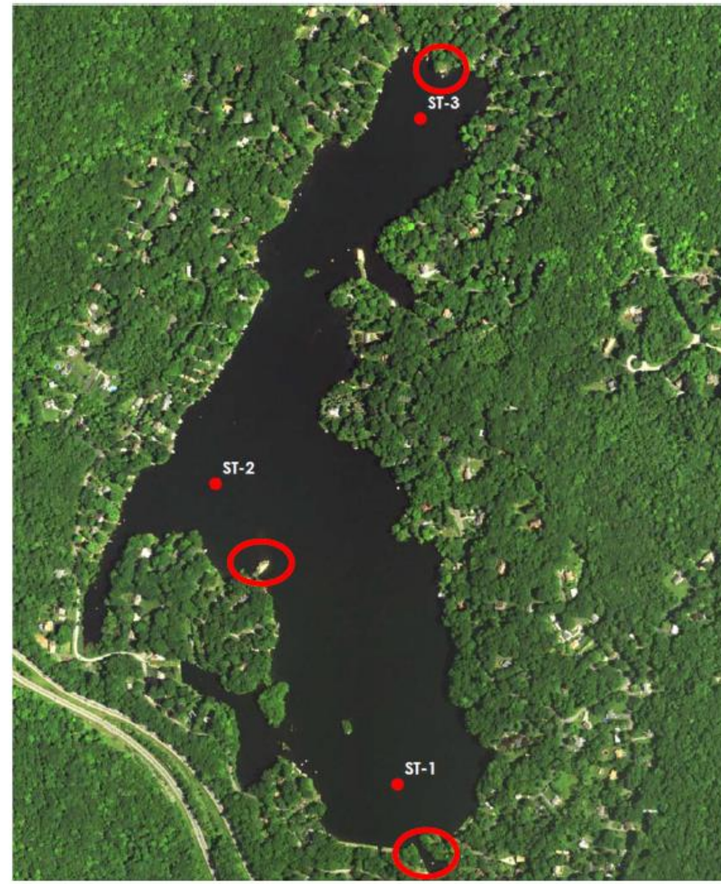
NOTES:
1. Monitoring locations are approximate.
2. 2015 orthoimagery obtained from NJ Office of Information Technology (NJOIT), Office of Geographic Information Systems (OGIS).

0 2,000 4,000 Feet

CYANOTOXIN MONITORING LOCATION MAP

LAKE HOPATCONG
MORRIS AND SUSSEX COUNTIES

PRINCETON HYDRO
SCIENCE DESIGN ENGINEERING



Conditions that Result in an Blue-Green Algal Bloom

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

In-Lake vs. Watershed vs. Cyanotoxin Plan

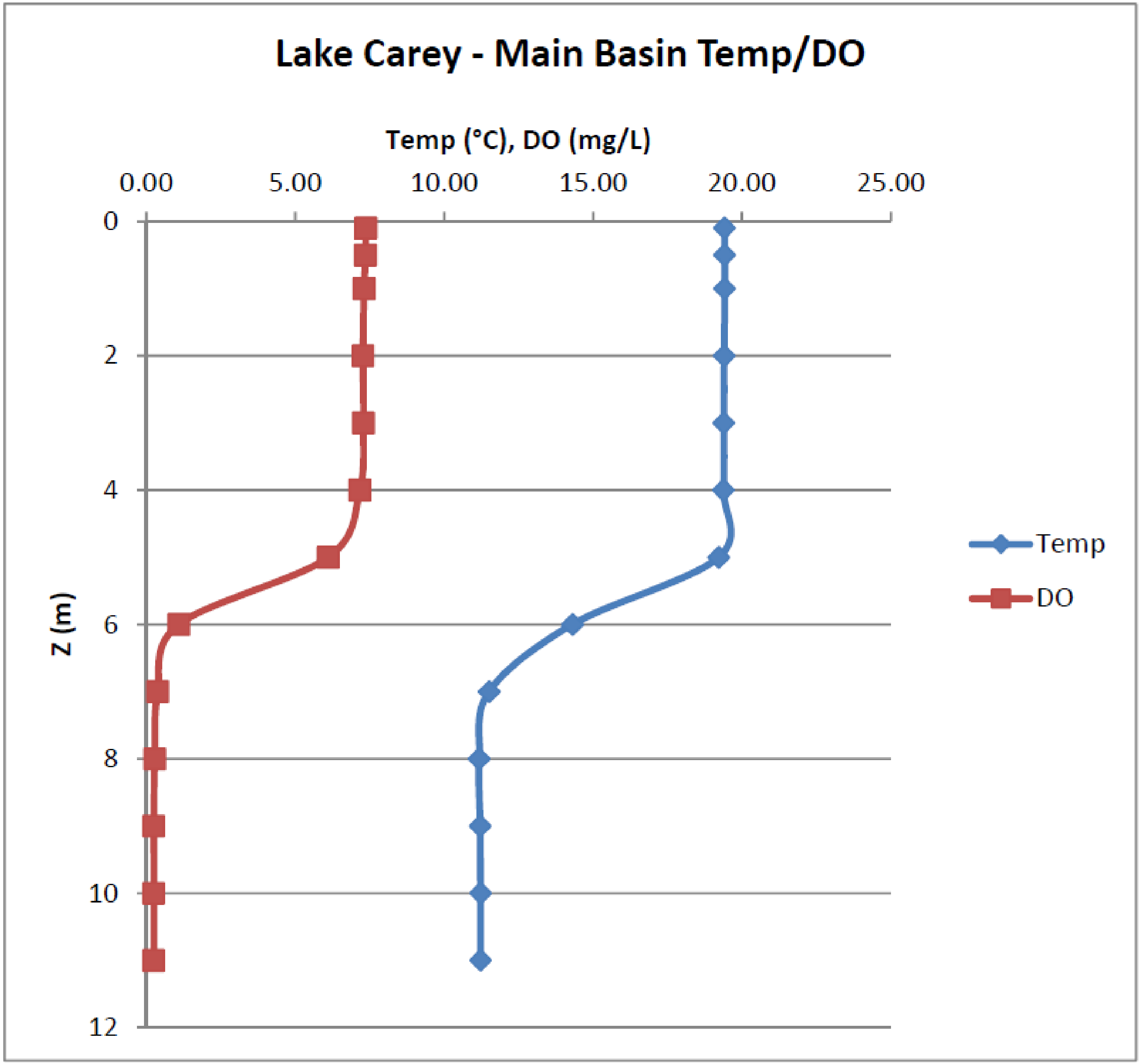
- In-lake management plan focuses on in-lake issues (frequently associated with managing submerged aquatic vegetation).
- Watershed Implementation Plan focuses on both watershed-based and in-lake issues (US EPA / State approved plans)
- Cyanotoxin plan focuses on minimizing or avoiding the development of near-shore HABs

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

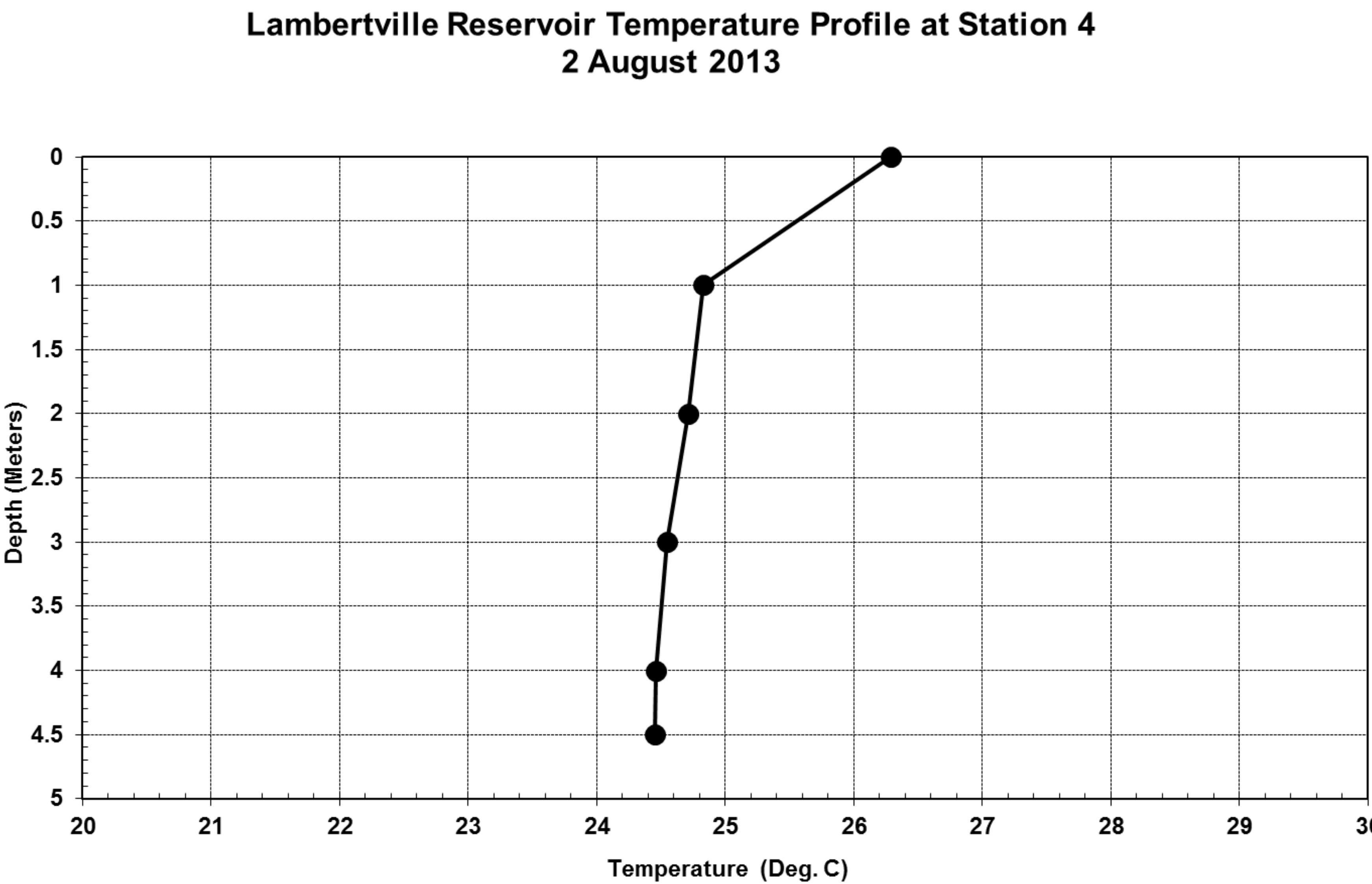


Lake Carey - Main Basin Temp/DO
Temp (°C), DO (mg/L)
0.00
5.00
10.00
15.00
20.00
25.00
0
2
4
6
8
10
12
Z (m)
Temp
DO

Benefits of Aeration

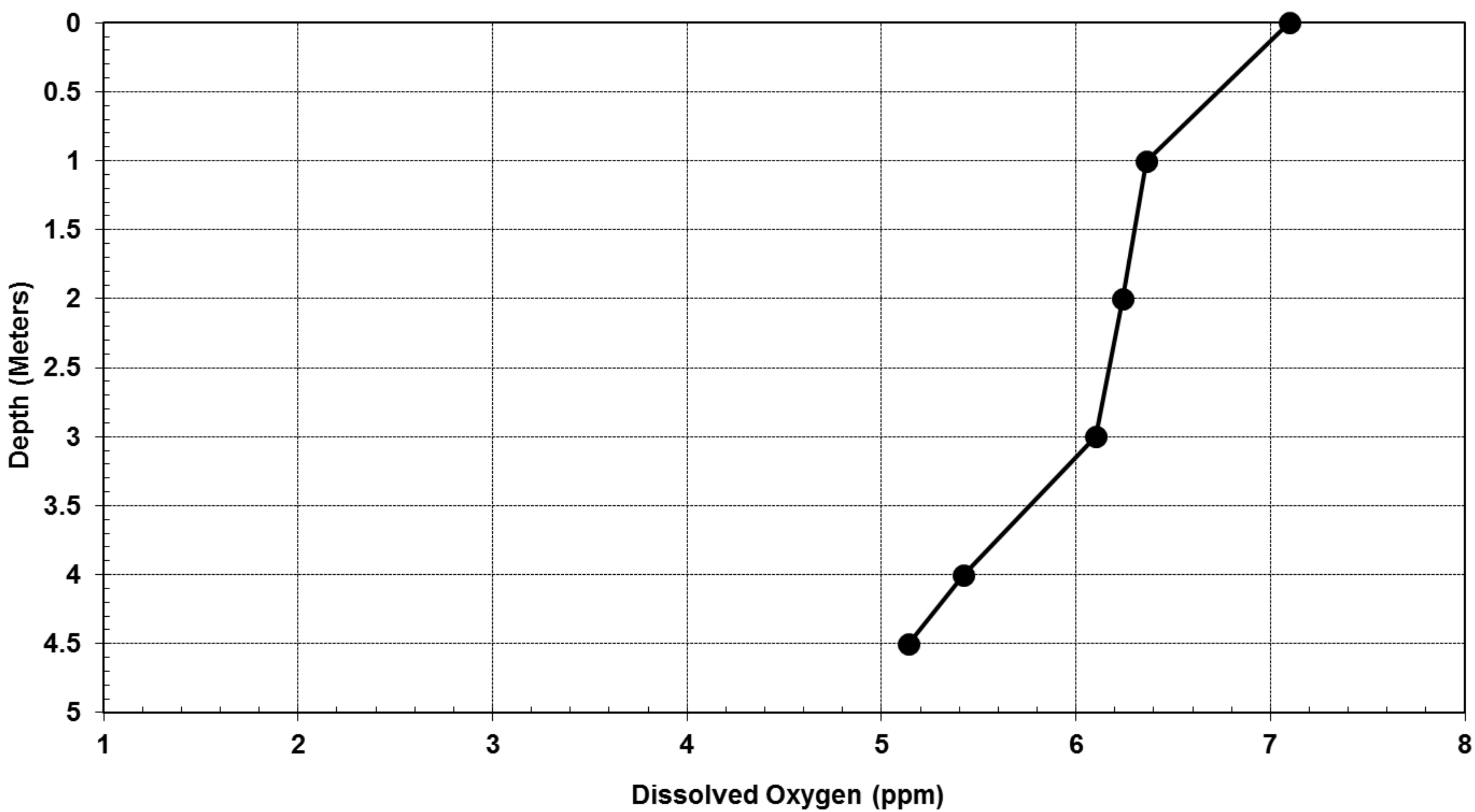
- Maintains measurable amounts of dissolved oxygen throughout the water column over the summer season
- Reduces the release of phosphorous from bottom sediments, which can fuel algae growth
- Provides de-stratification, which makes it more difficult for blue-green algae to develop concentrated surface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

Installation of De-stratification / Aeration System



Lambertville Reservoir Temperature Profile at Station 4
2 August 2013
Depth (Meters)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
20
21
22
23
24
25
26
27
28
29
30
Temperature (Deg. C)

Lambertville Reservoir Dissolved Oxygen Profile at Station 4
2 August 2013



Near-Shore Circulation / Mixing

- Mixing of water adjacent to the intakes for potable water supplies
- Mixing of near-shore areas to increase flushing
- Horizonal mixing of coves or isolated areas to both increase mixing and flushing

Nutrient Inactivation

- 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.
- May be a viable option for New York lakes in the near future.

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)

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

PACl Treatment Francis Slocum Lake May 2018

Phosphorus Stripping

- Proactive means of limiting or delaying the development of algal blooms
- Lower dose applications of alum or similar products to strip the water column of available inorganic phosphorus
- Typically conducted in May or early June – after the snowmelt and spring storms but before summer establishment of blue-green algae.

Phosphorus Stripping

- Need some information on phosphorus in the water column over the spring and summer seasons.
- If blue-green algal blooms are already well established, not recommended.
- Will not eliminate blue-green algal blooms but can reduce the severity and delay their seasonal establishment.

Algicides (Reactive Strategies)

- Most, but not all, are copper-based products.
- Immediately effective and can quickly control nuisance densities of both planktonic and mat algae.
- Relatively low in product and application costs.
- Permitted activity (need a certified applicator to file a permit with the State and need to use approved products)

Algicides (Reactive Strategies)

- Relatively short duration of improvement.
- Can produce secondary algal blooms.
- Long-term applications favor more copper resistant species / strains.
- Impacts non-target organisms.
- Accumulates in the sediments.
- Potential to contribute toward fish kills.
- **Can release cyanotoxins and T&O compounds into the water column**

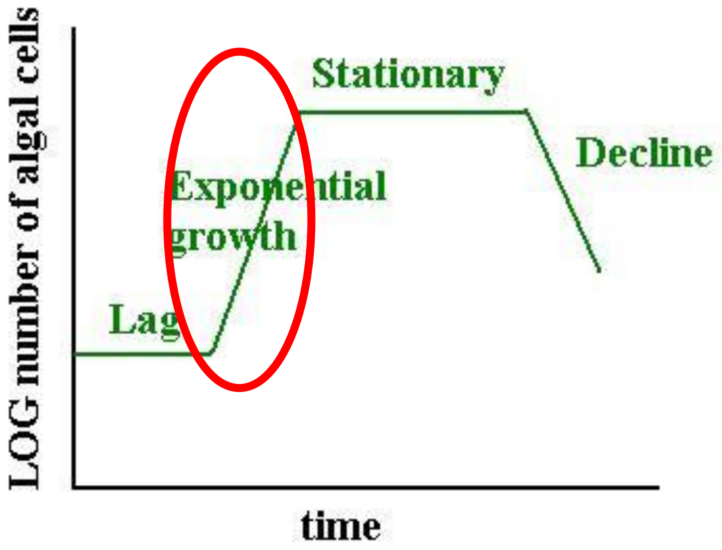
Algicides – impacts on cyanotoxins and T&O compounds

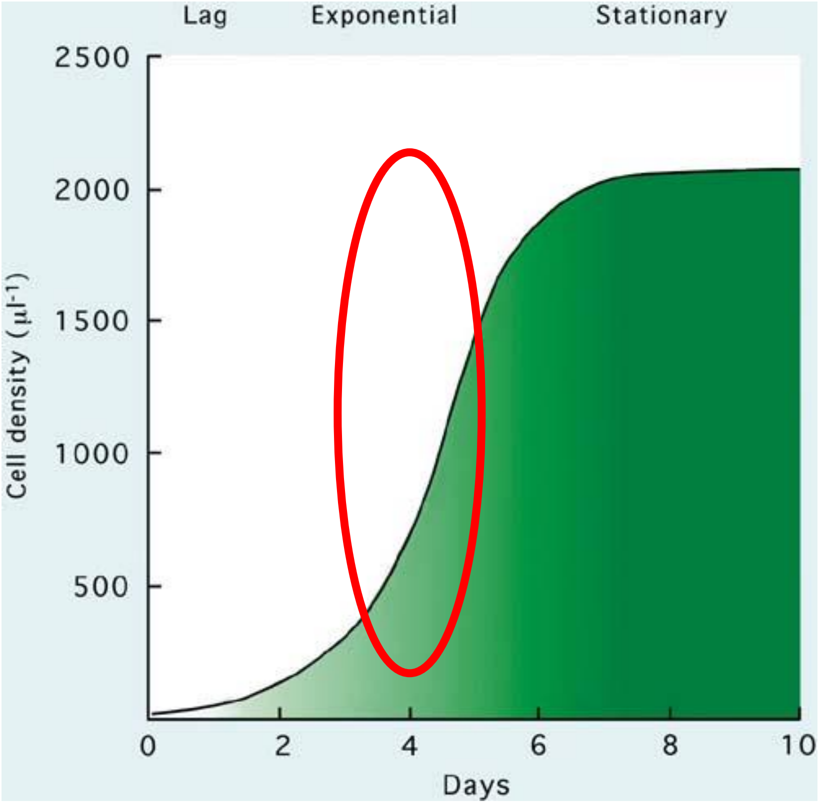
- If a bloom has a measurable amount of cyanotoxins in the water, copper-based algicides should be avoided.
- If the majority of the cyanotoxins are within the algal cells (dissolved vs. total microcystins), depend on in-plant measures to reduce the cyanotoxins (e.g. settling)

So should copper algicides be used?

- If the targeted algae is not a blue-green, not as much of a concern (e.g. diatoms, green algae).
- Chelated copper products are more effective, reducing the need for additional applications.
- Try to be more "proactive" in application of copper-based products (use historical data to your advantage)
- Be selective in their use and link them to seasonal changes and water quality conditions.

A “Proactive” Approach





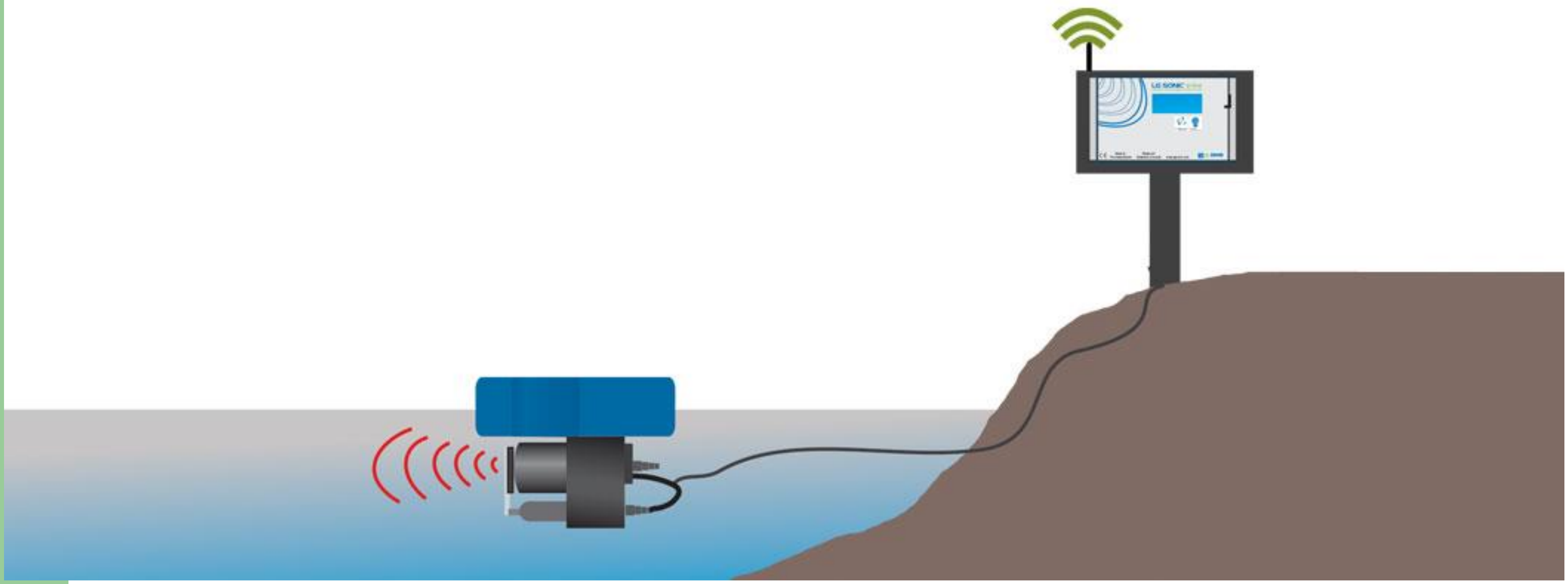
Alternative Products

- Strong oxidizers (GreenClean)
- More expensive than copper-based algicides but do not product or introduce any toxic materials (e.g. copper)
- In contrast to copper-based algicides, tends to be added on a more routine basis
- **Possibly effective at reducing both cyanotoxins and T&O compounds**
- Other potential in-water options including bacterial products and Ultrasonic devices

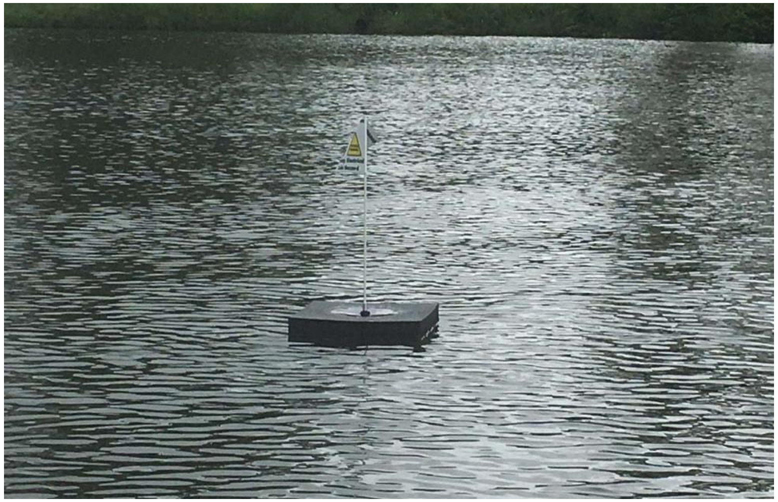
Ultra-Sonic devices

- Non-chemical means of controlling algae, particularly blue-green algae.
- Forces the collapse of blue-green alga gas vacuoles so they can not migrate through the water column.
- Need stable source of power.
- Somewhat expensive.
- Not a large amount of data on the effectiveness of the systems.

Ultra-Sonic devices



Ultrasonic Unit Used in a New York Lake (2018)



Cove / Beach Cyanotoxin Options (in-cove)

- Floating Wetland Islands
- Mixing or circulation of the water
- Barriers around swimming areas
- Careful use of copper-based products (chelated products)
- Possible use of alternative products
- Possible nutrient stripping
- Bacterial products

Cove / Beach Cyanotoxin Options (sub-watershed)

- Stormwater management; green infrastructure
- Biofiltration / rain garden BMPs; possible in parking lots
- Goose management
- Pet management
- Septic management

Pet Wastes

- Detailed studies have revealed that a 44 lbs dog can produce approximately 2 lbs of TP per year.
- Reveals the importance of "pooper scooper" ordinances.

Linking the HAB / Cyanotoxin Plan to the WIP

- Making sure that the WIP recognizes the importance of focusing on select areas within the lake and watershed for HABs / cyanotoxins
- At the same time the HAB / Cyanotoxin Plan needs to understand that implementing measures in the WIP will translate to benefits to areas that experience HABs / cyanotoxin problems.


BEACH CLOSED
Harmful Blue-green Algae Blooms
No Swimming or Wading
Contact can make people and animals sick
If contact occurs, rinse with clean water.
If symptoms occur, contact a medical provider.
If you see blooms or scum outside the beach,
don't swim, fish or boat in those areas. Keep kids and pets away.
Learn more: www.health.ny.gov/HarmfulAlgae


WARNING
Avoid Harmful
Blue-green Algae Blooms
while swimming, fishing and boating
Keep kids and pets away from areas with blooms or scum.
Swim, fish and boat in areas with no blooms or scum.
Contact can make people and animals sick.
If contact occurs, rinse with clean water.
If symptoms occur, contact a medical provider.
Blooms can look like streaks, spilled paint, pea soup, floating clumps or dots.
6637
Learn more: www.health.ny.gov/HarmfulAlgae and on.ny.gov/hab
7/18

What Data are needed to develop a HAB / Cyanotoxin Plan?

- Multiple years of water quality data, linked to regional weather conditions.
- Recently conducted bathymetric survey (within the last 5 to 10 years).
- Development of a pollutant loading analysis for the reservoir on an annual and monthly basis.
- Watershed Assessment
- Any historical data and experiences with past management activities.

THANK YOU

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