# Actions Taken To Prevent and Control HABs

Dr. Stephen J. Souza

Clean Waters Consulting
CWC

Dr. Fred Lubnow

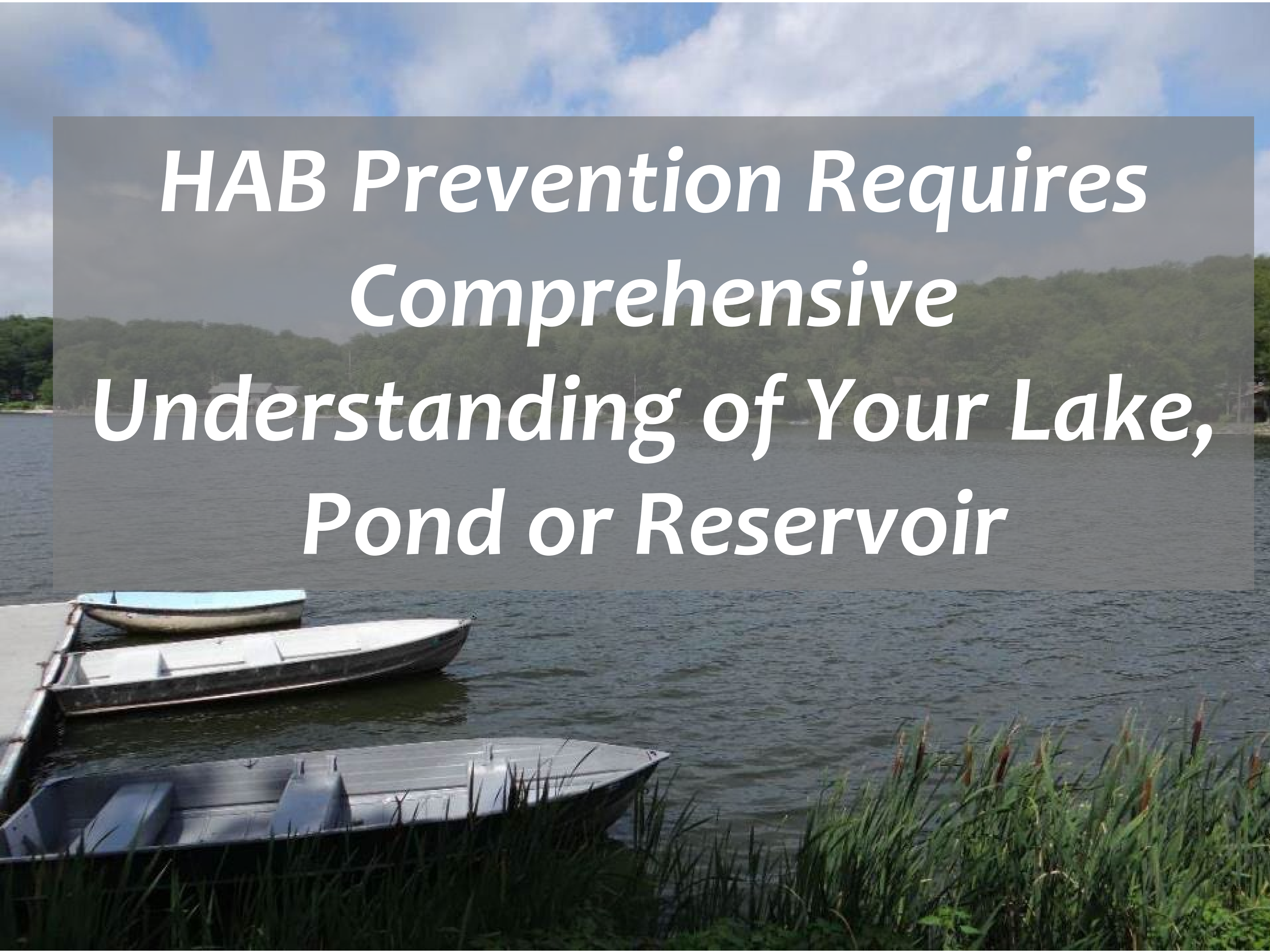
PRINCETON HYDRO

Dr. Robert Kortmann

GZA


Don’t Just Treat The Symptom….
Correct the Cause

# *HAB Prevention Requires Comprehensive Understanding of Your Lake, Pond or Reservoir*



# You Wouldn't Build A House Without A Plan

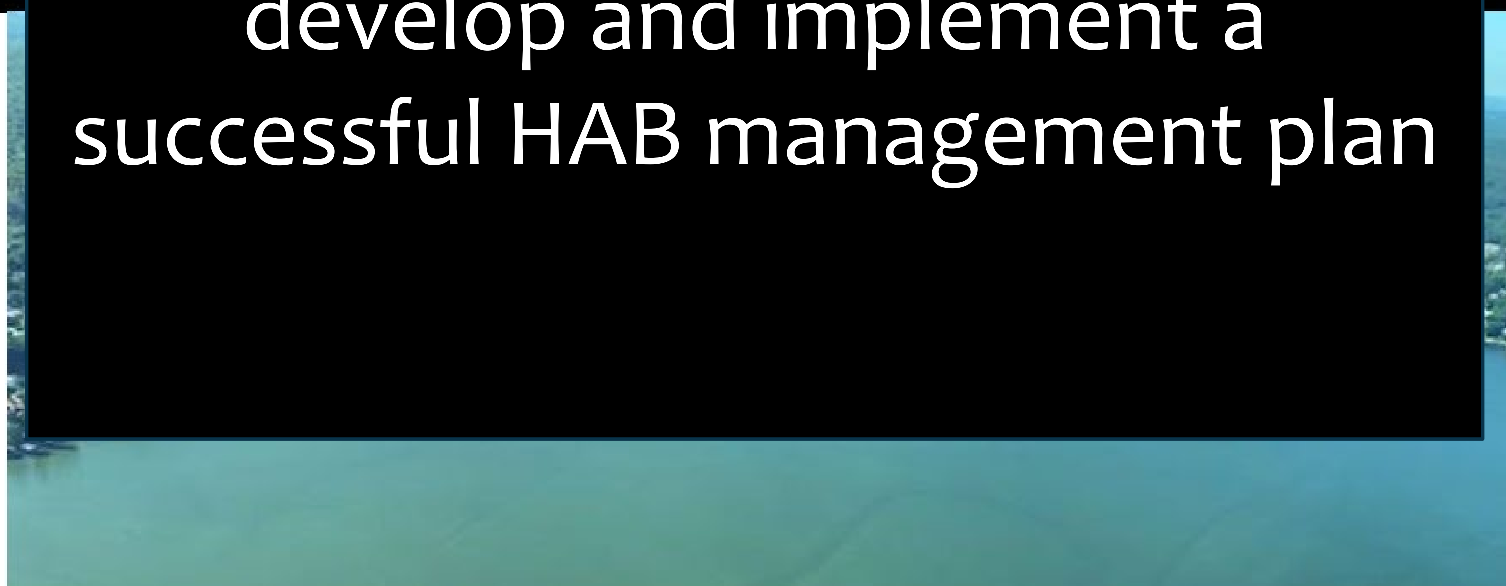
Successful control of HABs starts with comprehensive study of your lake and watershed

Collect the data need to ascertain why a HAB occurs

Use same data to develop HAB prevention and action plan

April 2024

Chapters 7, 8 and 9 provide the guidance needed to correctly develop and implement a successful HAB management plan



# Maintenance vs. Management

- HAB **maintenance** is reactive and aimed at addressing an existing or emerging HAB thereby lessening its severity or longevity… think **corrective actions**

- HAB **management** is proactive and aimed at controlling the ecological drivers responsible for a HAB… think **preventative actions**

# Staying Healthy Vs
# Trying to Get Healthy

# Corrective Actions

- When a bloom occurs need to lessen its intensity, duration, ecological impacts and socio-economic impacts:
  - Typically involves application of an algaecide
    - Copper based algaecides… copper sulfate
    - Non-copper algaecides - oxidizing agents e.g., GreenClean Pro
  - Filtration… still experimental but promising

# Why Not Just Bomb The Bloom With Copper Sulfate?


# The Paradox of Copper Sulfate Treatments

- $CuSO_4$ causes cyanobacteria cells to lyse
- Results in rapid release of large amounts of cyanotoxins and organic phosphorus.
- Cyanotoxins impact good algae and zooplankton.
- Cyanobacteria adept at bio-assimilating organic phos.
- CuSO4 reliance thus creates cyanobacteria “happy” environment.
- Also, rapid die-off of bloom can result in quick depression of DO leading to a fish kill.

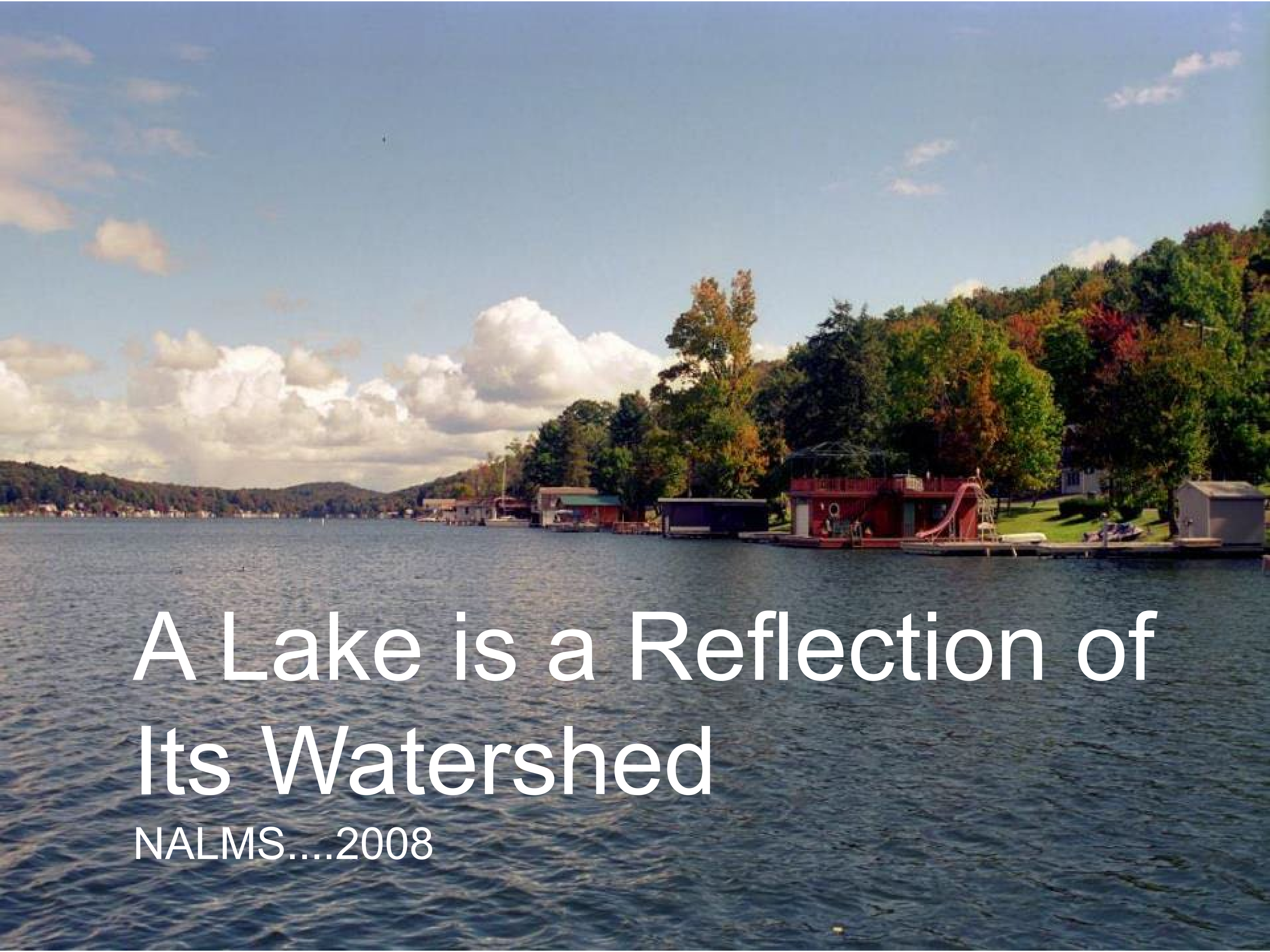
**Although algaecide treatments are part of the HAB “tool box” they are not the solution.**

# Preventative Actions

- A combination of hydrologic, climatic, biological and water chemistry factors set the stage for a HAB… varies from lake to lake and season to season.
- However, the amount and ratio of bioavailable phosphorus and nitrogen is most often the common denominator determining whether a HAB occurs.
- Thus, a key strategy for HAB prevention entails some means of nutrient limitation… less “food” = less productivity = less likelihood of a HAB.

So… HAB prevention requires putting your lake on a nutrient diet


The bad news…most New Jersey lakes are eutrophic (nutrient rich) making most susceptible to a HAB


A Lake is a Reflection of Its Watershed
NALMS....2008

# Phosphorus and Nitrogen Sources

- Inputs vary seasonally
- Internal sources
  - Sediment release and recycling
  - Decomposition of organic material (algae, weeds, fish, etc.)
- External sources
  - Stormwater runoff
  - Septic systems and wastewater
  - Rainfall
  - Waterfowl
- Need to identify, quantify and prioritize sources

# Nutrient Management Strategies

- **Source Controls:** Limit generation of nutrients
- **Delivery Controls:** Limit how much of generated nutrients reach lake
- **In-Lake Controls:** Limit recycling of nutrients or nutrient assimilation



# Source Control Strategies
# Limit Nutrient Generation

- Goose management
- Fertilizer management
- Septic management
- Pet and yard waste management
- Alternative lawn covers
- Erosion and sediment control

Accomplished through:

- Education and Outreach
- Municipal Ordinances
- HOA Rules
- MS4 Compliance

# Delivery Controls
# Intercept Nutrients Before Enter Lake

Stormwater Best Management Practices (BMPs):

- Rain barrels
- Rain gardens
- Lakeside vegetated buffers / aquascaping
- Porous pavements
- Vegetated swales
- Regional bioretention and bioinfiltration basins
- Biochar

Refer to NJ Stormwater Best Management Practices Manual
NALMS Lake and Reservoir Manual

# In-Lake Controls

- Nutrient inactivants*
- Floating wetland islands*
- Aeration / Circulation / Oxygenation*
- Biomanipulation
- Selective water release
- Sonic devices
- Cyanobacteria filtration systems

# Nutrient Inactivation

# Nutrient Inactivants

- Products that actively bind and make phosphates unavailable for cyanobacteria assimilation
- NOT ALGAECIDES… don't directly affect or kill algae or cyanobacteria
- Most effective and commonly used nutrient (phosphorus) inactivants:
  - Alum (aluminum sulfate and sodium aluminate)
  - Lanthanum (PhosLock and EutroSORB)
  - Polyaluminum chloride (PAC)

Before you begin –

- Conduct detail nutrient loading assessment
- Confirm nutrient inactivation is appropriate solution
- Conduct bench testing to arrive at correct dose rate and avoid environmental impacts

When you treat –

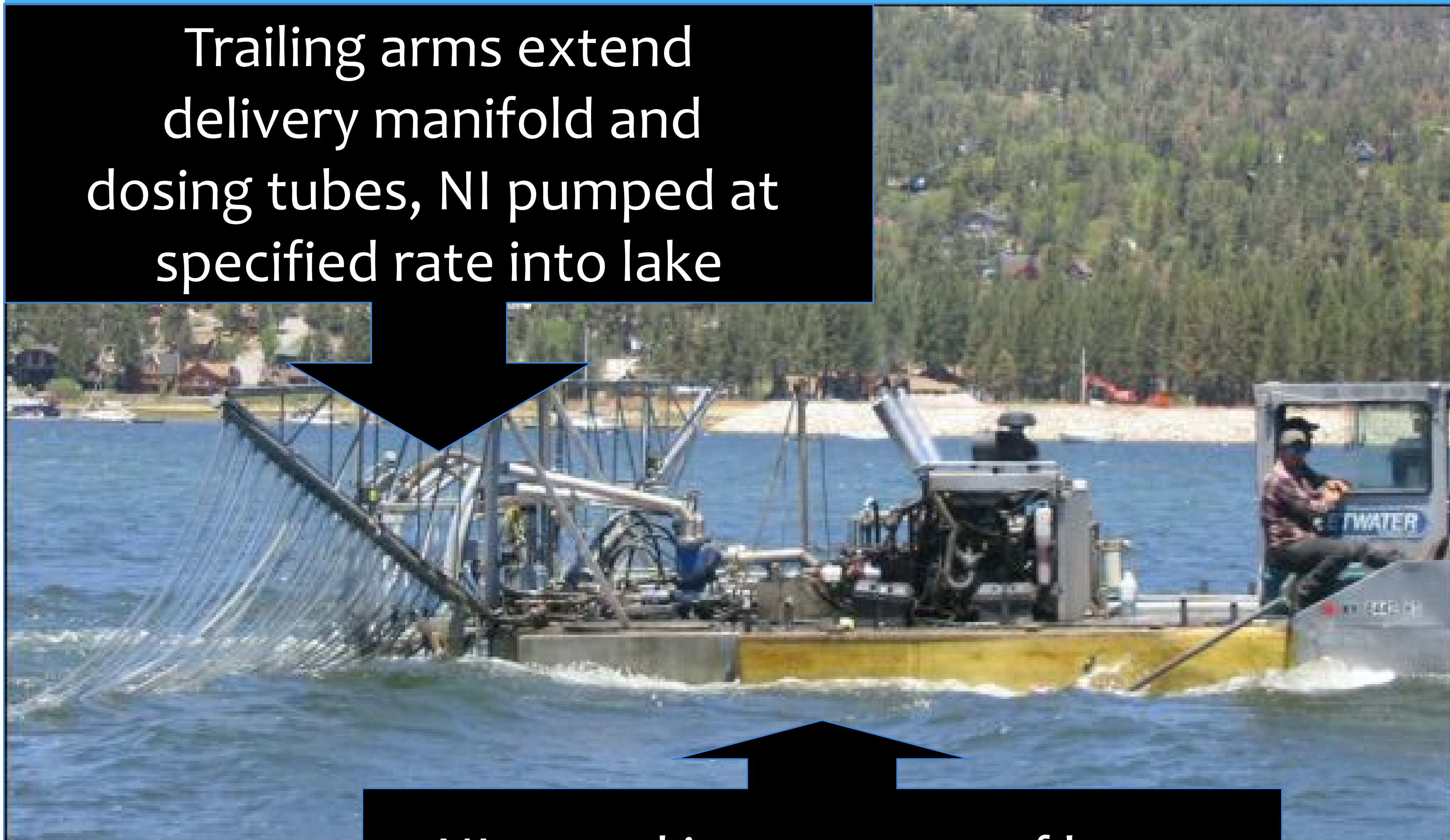
- Monitor water quality before and during treatment
- Monitor post-treatment to confirm effectiveness

# Modes of Application

- Moderate dose surface treatments to bind phosphates in water column.
- High dose applications to bind and control internal phosphorus loading (phosphates released from sediments during periods of hypolimnetic anoxia).
- Storm sewer injection systems to bind phosphates entering with runoff
- In-lake metered dosing to continuously control phosphates in water column originating from either external or internal sources

# Surface and Sediment Treatments

Trailing arms extend delivery manifold and dosing tubes, NI pumped at specified rate into lake

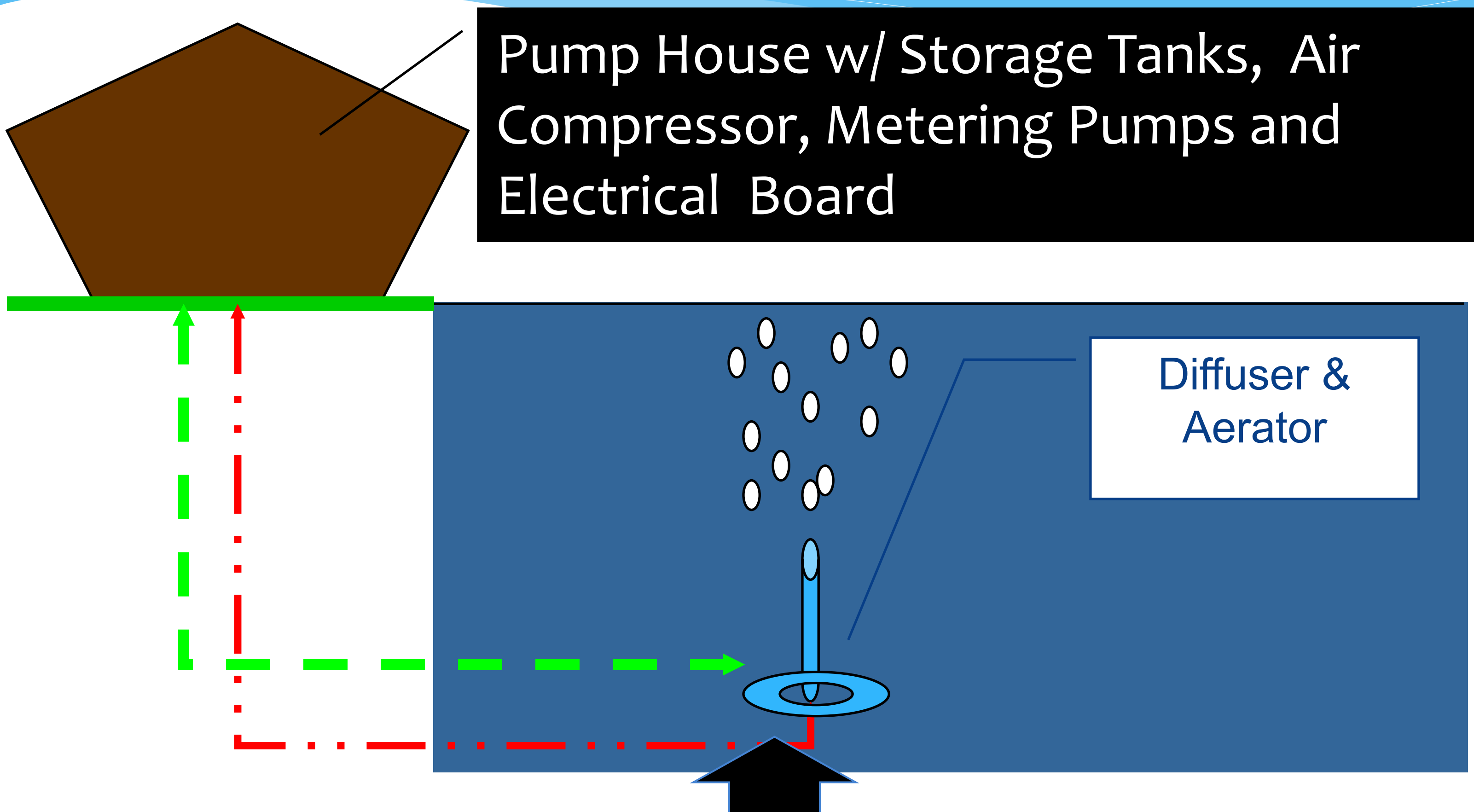


NI stored in pontoons of barge

# Storm Sewer Dosing Systems

Flow or rainfall activated dosing
of inactivant into storm sewer or catch basin

# Metered Dose In-Lake Injection System

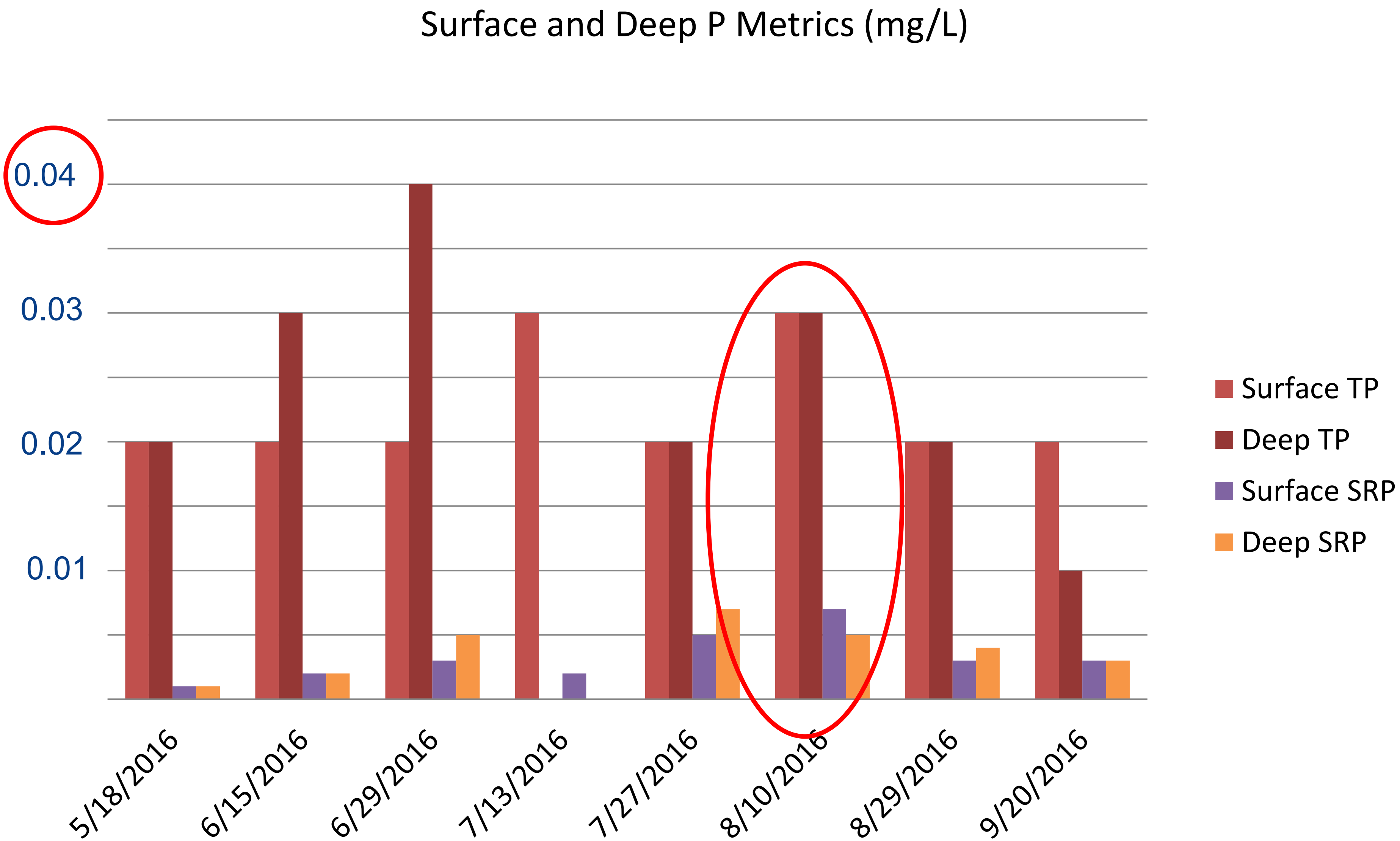



Inactivant pumped into lake and mixed in water using aeration system

# Water Quality Improvements

| | Pre-Alum | Post-Alum |
|---|---|---|
| Ave Secchi | 0.6 m (2 ft) | 2 m (6.5 ft) |
| Ave TP Conc | 0.266 mg/l | 0.04 mg/l |
| Ave SRP Conc | 0.02 mg/l | Usually ND |
| Ave Chl Conc | 48.7 g/ $m^3$ | 12 - 18 g/ $m^3$ |
| Cyanobacteria Dominant | YES | NO |

# Surface Vs. Bottom TP and SRP mg/L



# Floating Wetland Islands and Biochar

# Use of Biochar to remove nutrients

- Processed wood material that has a high affinity to remove pollutants.
- Conducted a feasibility assessment at Lake Hopatcong in 2020 of potential locations for installation.
- Resulted in selecting 4 streams, two stormwater ponds and two stormwater Manufactured Treatment Devices (MTDs).
- Had a training session with all four municipalities around the lake
- Relatively low in cost.
- Can subsequently be used as landscaping mulch.

# Use of Biochar Memorial Stormwater Pond

- Installed in some stormwater ponds; Memorial Stormwater Pond (Mt. Arlington).
- After 3 months TP removal rates for the ponds were 67% and 81%.
- After 3 months SRP removal rates for the ponds were 76% and 97%.
- As the manufacturer stated, the longer the contact time, the higher the removal rate.
- After 7.5 months TP removal rates were 50% and SRP removal was 0%

Figures 4.10: Duke – Mermaid Pool – Biochar Install

Table 4.2: Duke – Mermaid Pool - Total phosphorus

| Mermaid Pool - TP (mg/L) | | | | | | |
|---|---|---|---|---|---|---|
| | 4/20/2022 | 5/19/2022 | 6/28/2022 | 7/21/2022 | 8/25/2022 | 9/23/2022 |
| In | 0.04 | 0.03 | 0.04 | 0.40 | 0.29 | 0.20 |
| Out | 0.02 | 0.03 | 0.04 | 0.03 | 0.04 | 0.01 |
| % Change | -50% | 0% | 0% | -93% | -86% | -95% |

Table 4.3: Duke – Mermaid Pool - Total phosphorus

| Mermaid Pool - TP (mg/L) | | | | | | |
|---|---|---|---|---|---|---|
| | 6/7/2023 | 7/12/2023 | 8/28/2023 | 9/22/2023 | 10/6/2023 | 10/17/2023 |
| In | 0.15 | 0.41 | 0.42 | 0.40 | 0.30 | 0.24 |
| Out | 0.04 | 0.07 | 0.06 | 0.04 | 0.03 | 0.02 |
| % Change | -73% | -83% | -86% | -90% | -90% | -92% |

Before Biochar

After Biochar

# Floating Wetland Islands

Just installed in June 2022.

A 250 sq. ft. Island can remove approximately 10 lbs of TP

# Floating Wetland Islands

After installation and being in the cove for about a month.

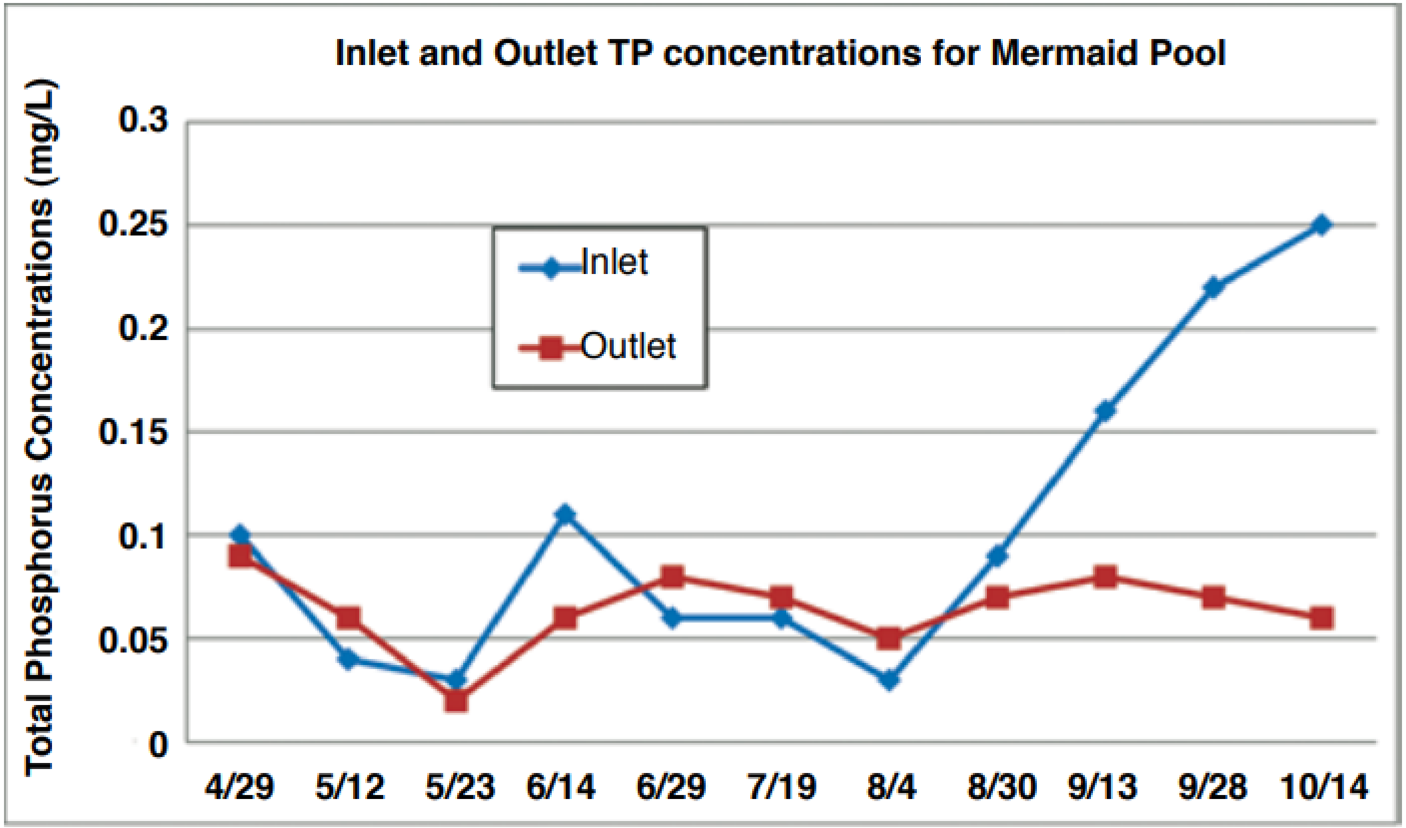
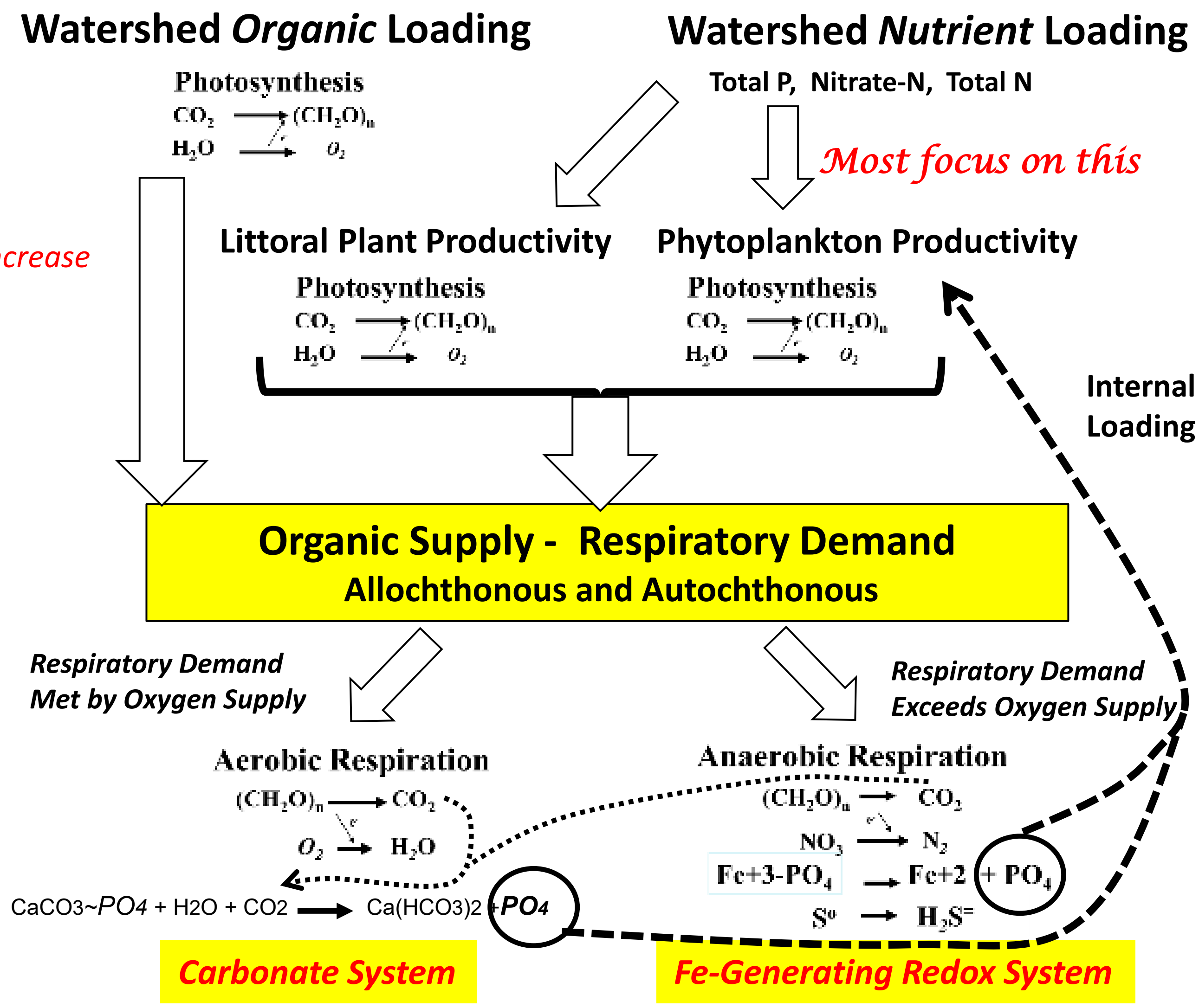



*Figure 7. Inlet and outlet total phosphorus concentrations at Mermaid Pool over the 2011 growing season.*

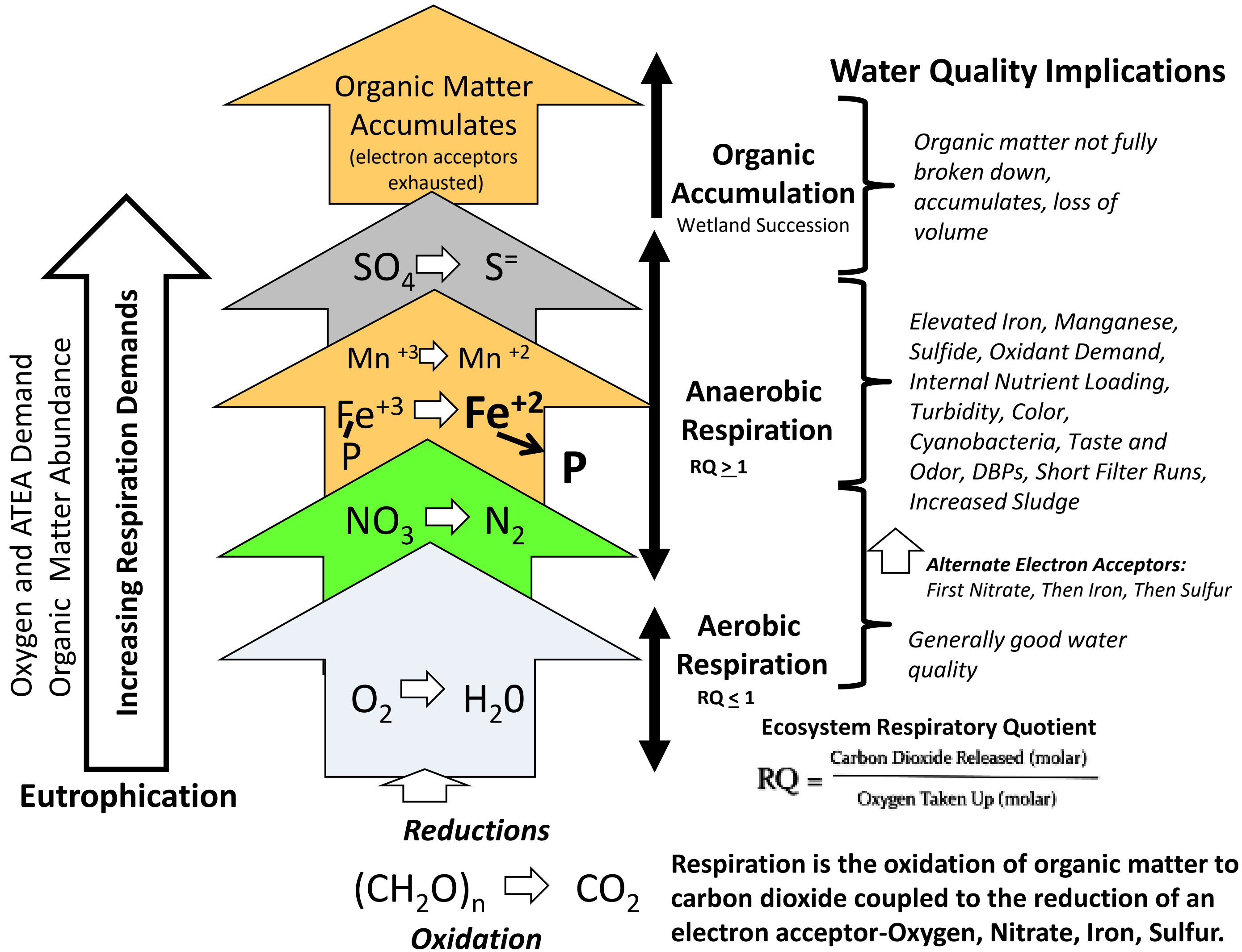
# Circulation, Aeration and Reoxygenation

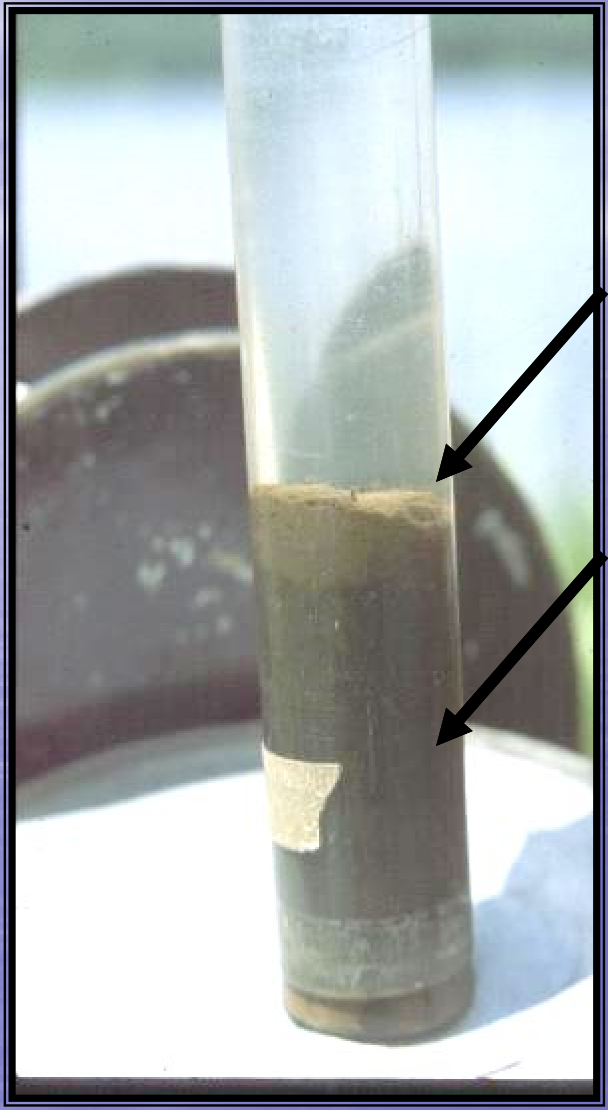
*Oxygen Loss doesn't cause an increase in Internal Loading, subsequent Anaerobic Respiration Does.*



**Photosynthesis happens in the Watershed Too!**

(Don’t ignore the allochthonous contribution to Organic Supply and Respiratory Oxygen Demand, especially in reservoirs!)


Water Quality Implications
Organic Matter Accumulates
(electron acceptors exhausted)
$SO_4$ ⇨ $S^=$
Mn $^{+3}$ ⇨ Mn $^{+2}$
$Fe^{+3}$ ⇨ $Fe^{+2}$
P
P
$NO_3$ ⇨ $N_2$
$O_2$ ⇨ $H_20$
Oxygen and ATEA Demand
Organic Matter Abundance
Increasing Respiration Demands
Eutrophication
Reductions
$(CH_2O)_n$ ⇨ $CO_2$
Oxidation
Organic Accumulation
Wetland Succession
Anaerobic Respiration
RQ ≥ 1
Aerobic Respiration
RQ ≤ 1
Organic matter not fully broken down, accumulates, loss of volume
Elevated Iron, Manganese, Sulfide, Oxidant Demand, Internal Nutrient Loading, Turbidity, Color, Cyanobacteria, Taste and Odor, DBPs, Short Filter Runs, Increased Sludge
Alternate Electron Acceptors:
First Nitrate, Then Iron, Then Sulfur
Generally good water quality
Ecosystem Respiratory Quotient
$RQ = \frac{\text{Carbon Dioxide Released (molar)}}{\text{Oxygen Taken Up (molar)}}$
Respiration is the oxidation of organic matter to carbon dioxide coupled to the reduction of an electron acceptor-Oxygen, Nitrate, Iron, Sulfur.



*In Fe-dominated systems:*

Oxidized Macrozone
Ferric Iron Complexes
(*Some* of the Fe binds P)

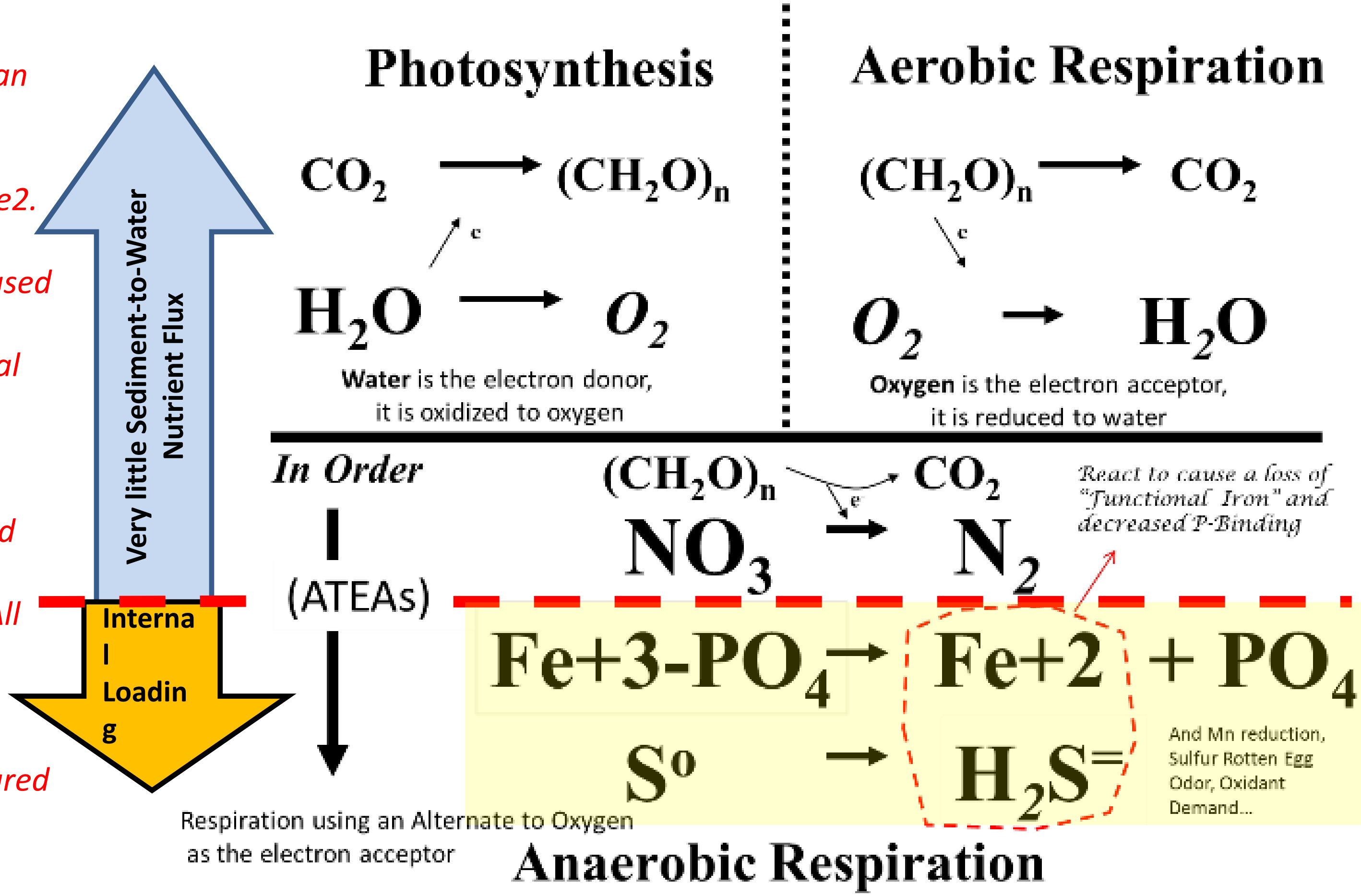
Deep Anaerobic Sediments
(with Ferr***ous*** Sulf***ide*** solids;
Note: both the iron and sulfur are chemically reduced and do not participate in biotic redox or P-binding any longer!)

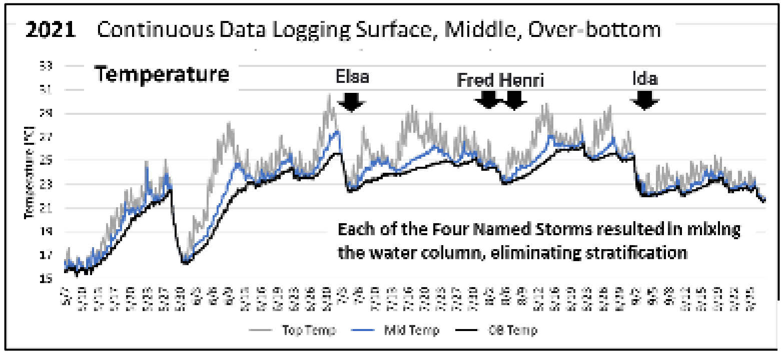
(Re: Roger Doyle, 1968)

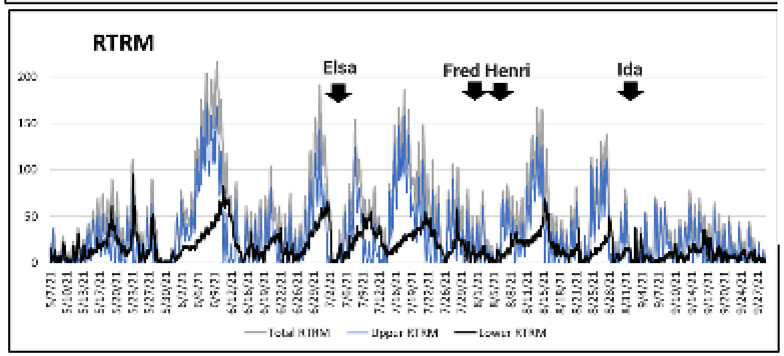
**Anoxia doesn't cause Internal Loading,**

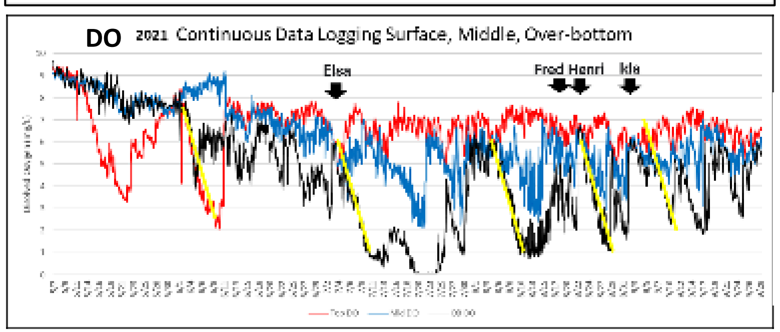
**Subsequent Anaerobic Respiration does after Oxygen and Nitrate are exhausted.**

- *Consumption of Oxygen can only be measured during early summer when DO is present at Time1 and Time2.*
- *Doesn't account for increased demand thru the summer.*
- *Doesn't account for Diurnal Fluctuations.*
- *Measuring Dissolved Inorganic Carbon (DIC) and Converting to Oxygen Equivalents accounts for All Respiration.*
- *Anaerobic Respiration Products should be measured in Anoxic Samples.*





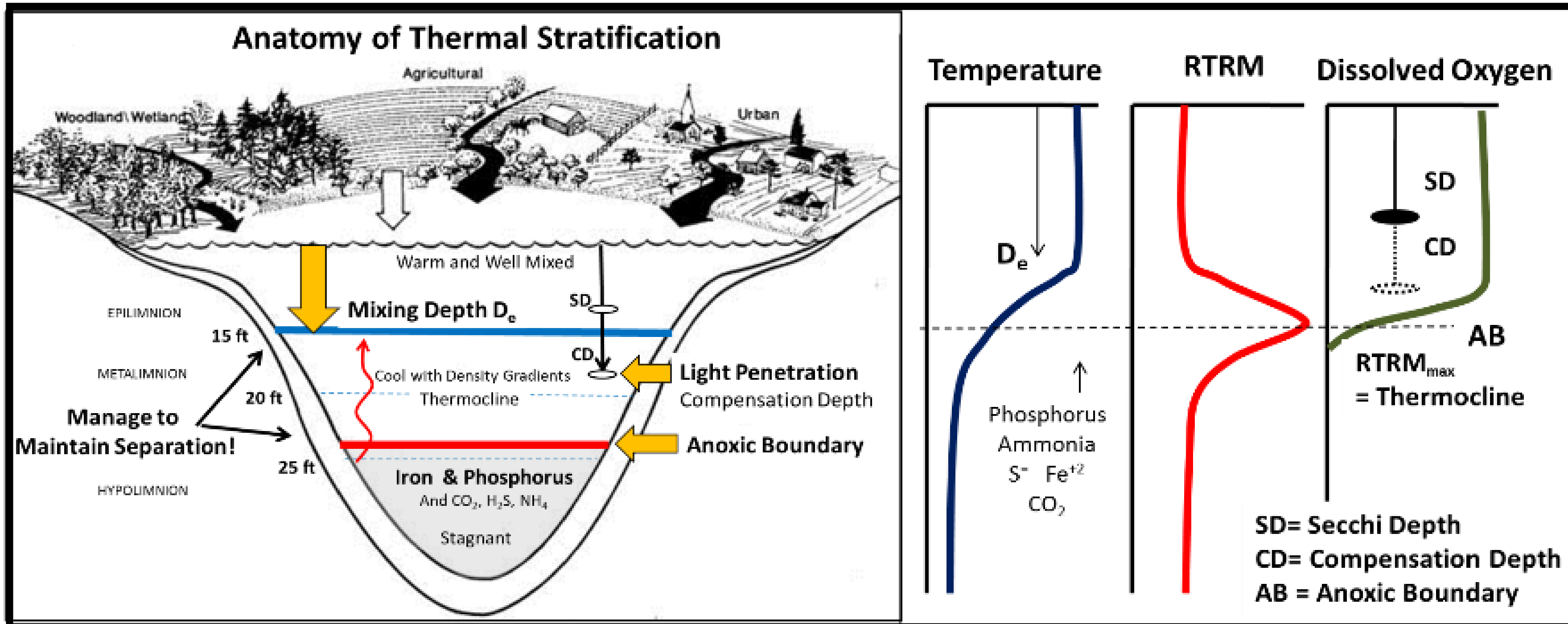

## Shallow Thermally Stratified Reservoir

The effects of Four Named Storms can be seen in the Continuous Data Logging.

The logged temperature data from surface-mid-bottom depths are used to compute RTRM to determine where the steepest density gradient is and whether more resistance to mixing exists above or below an intake.

**Over-Bottom Anoxia was revealed by Data Logging, missed by point-in time sampling.**

Diurnal DO Swing is several mg/L at times. Oxygen Consumption is rapid during calm weather, and Consumption Rate is Consistent (Yellow Lines).

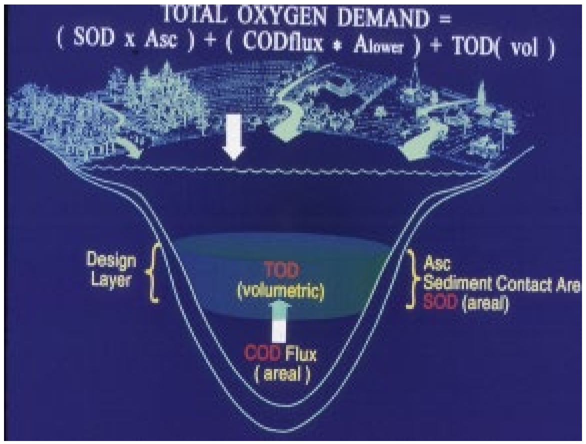



**To Control Internal Loading and Vertical Transport**

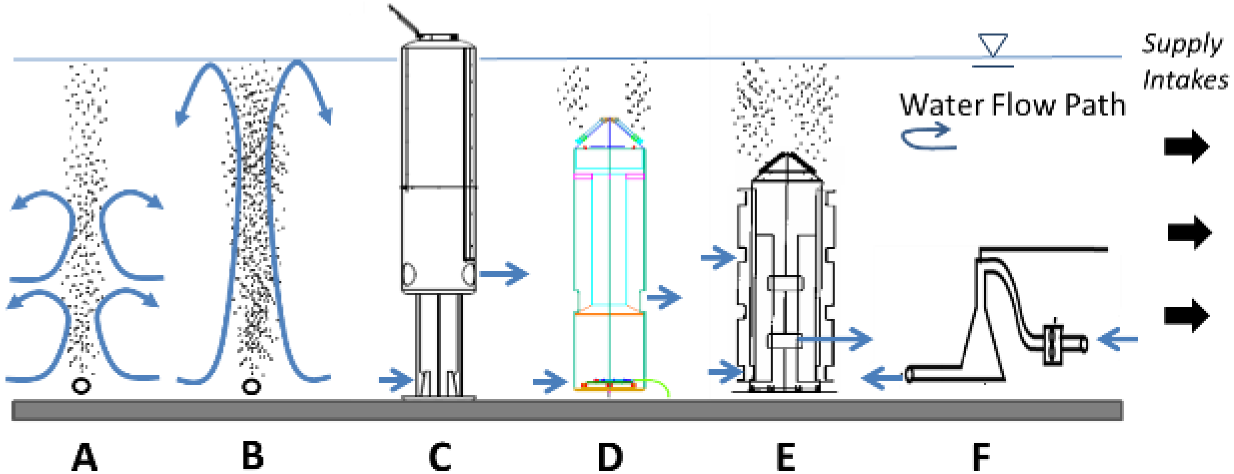
- **Maintain an aerobic sediment-water interface**
- **Maintain separation between Mixing Depth and Anoxic Boundary**
- **Add Sediment P-Binding Capacity: Al, Fe, Lanthanum, etc.**

***(Be careful with sulfur loading! $AlSO_4$ $CuSO_4$)***

(Kortmann, 2021)




*How many kg/day DO are needed to overcome all demands?*




## Schematic Diagrams of Aeration and Oxygenation Techniques

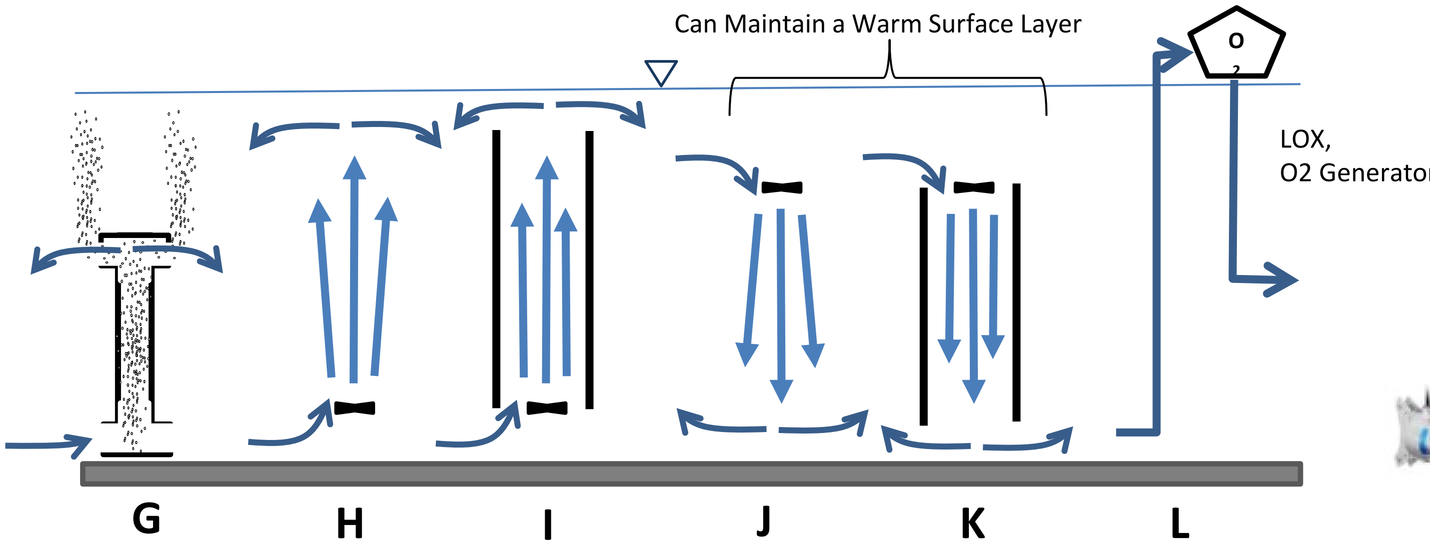
A variety of apparatus is available for managing thermal stratification and respiration in water supply reservoir systems. Some prevent stratification. Some adjust the location of the thermocline to expand epilimnetic mixing depth or establish high quality layers at the elevation of a raw water intake. Some add oxygen to the hypolimnion without changing stratification.

A. Line Diffuser with Low Enough Gas Flow to Maintain Stratification (Dense water falls out of the airlift plume)
B. Line Diffuser with High Enough Gas Flow to Prevent Stratification (Airlift plume pumps to the surface)
C. Traditional Full-Lift Hypolimnetic Aeration
D. Submerged Partial-Lift Hypolimnetic Aeration
E. Depth-Selective Layer Aeration
F. Conical Oxygen Contactor, A.K.A. "Speece Cone".

Modified from: Moore, et.al, 2015

**Any of the bubble pumping approaches can be done with air (21% oxygen) or enhanced air (>>21% oxygen)**

# Schematic Diagrams of Mechanical Circulation Techniques




G. Hybrid between Hypolimnetic Aeration and Diffused Air Artificial Circulatio

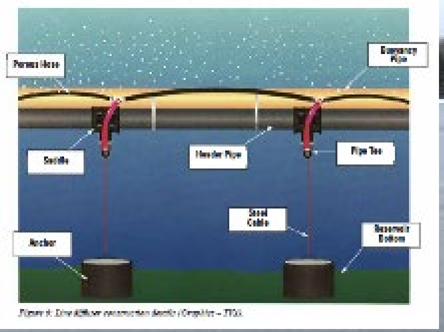
H. & I. Upward Circulation With and Without Containment (e.g. SolarBee)

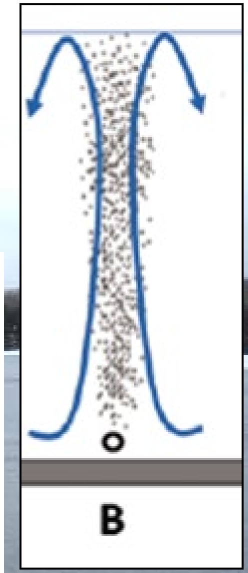
J. & K. Downward Circulation With and Without Containment (e.g. WEARS)

L. Sidestream Oxygenation

## Artificial Circulation

**Diffused Air Systems** (Many, Line Diffusers, Membrane Diffuser Modules)
**Mechanical UpFlow Systems** (e.g. SolarBee)
**Mechanical DownFlow Systems** (e.g. WEARS)
**Solar or Grid-tied Up or DownFlow**






**Hypolimnetic Aeration:** Full-Lift, Partial Lift, Air, Oxygen, Oxygen-Enriched Air

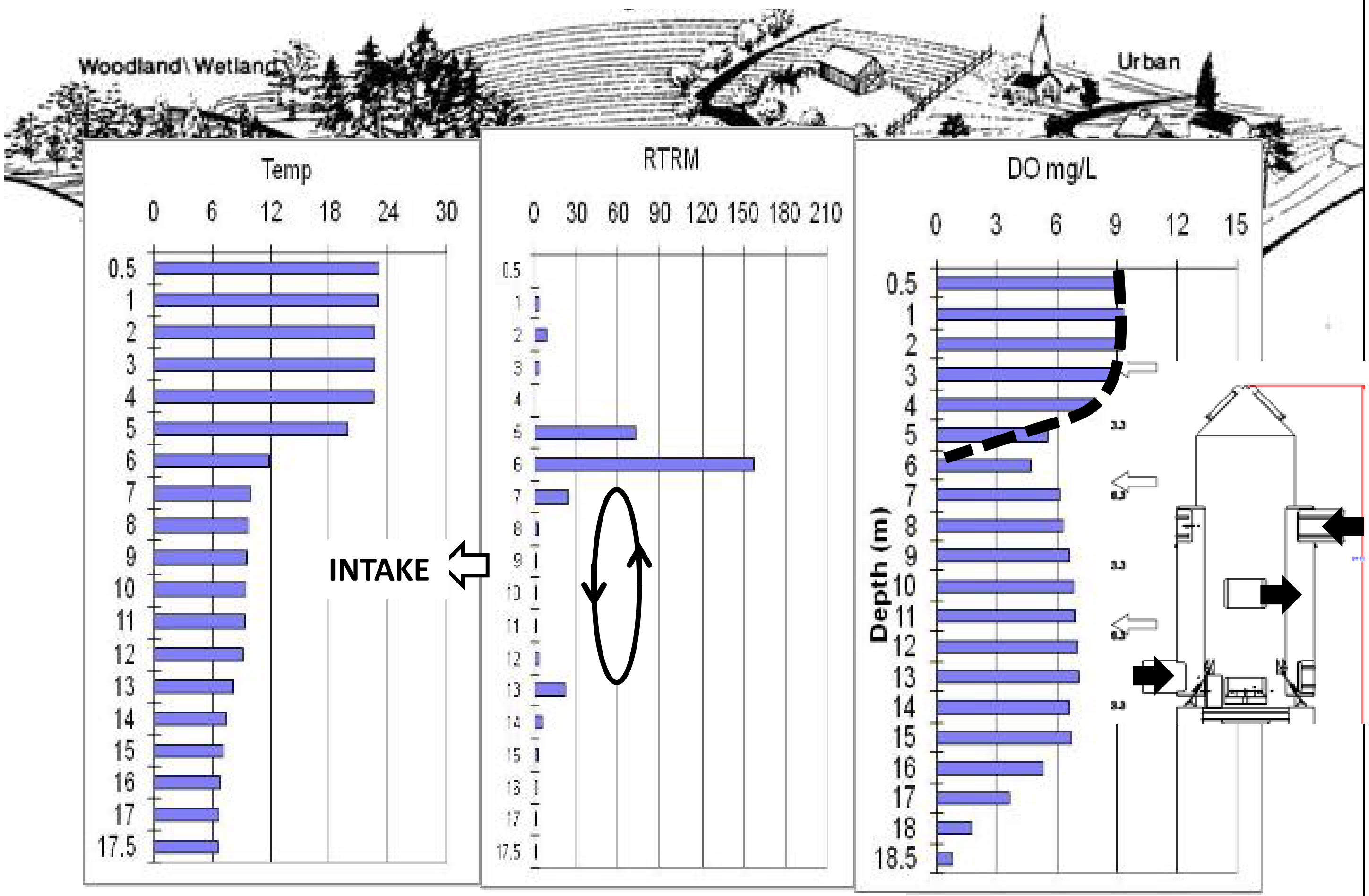


***Does anoxia ascend above the thermocline?***



Hypolimnetic Aeration and depth-selective Layer Aeration have been especially useful for managing source water reservoirs in relation to raw water intake locations.

# Layer Aeration- Summer Depth Profiles




Dashed line = Pre-Aeration

# Layer Aeration: Lake Shenipsit Water Supply

Decreased Anoxic Factor and Increased Separation of Mixing Depth and Anoxic Boundary

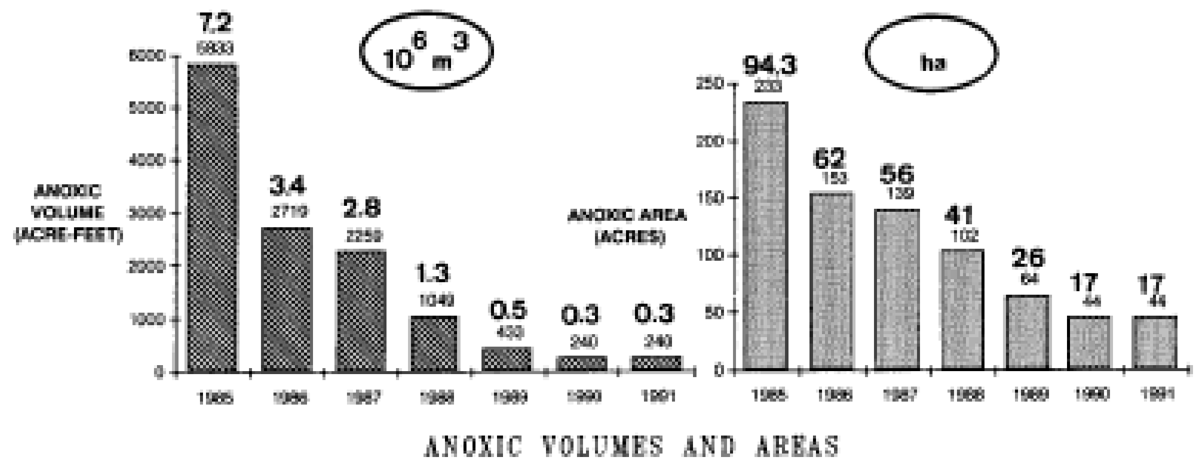
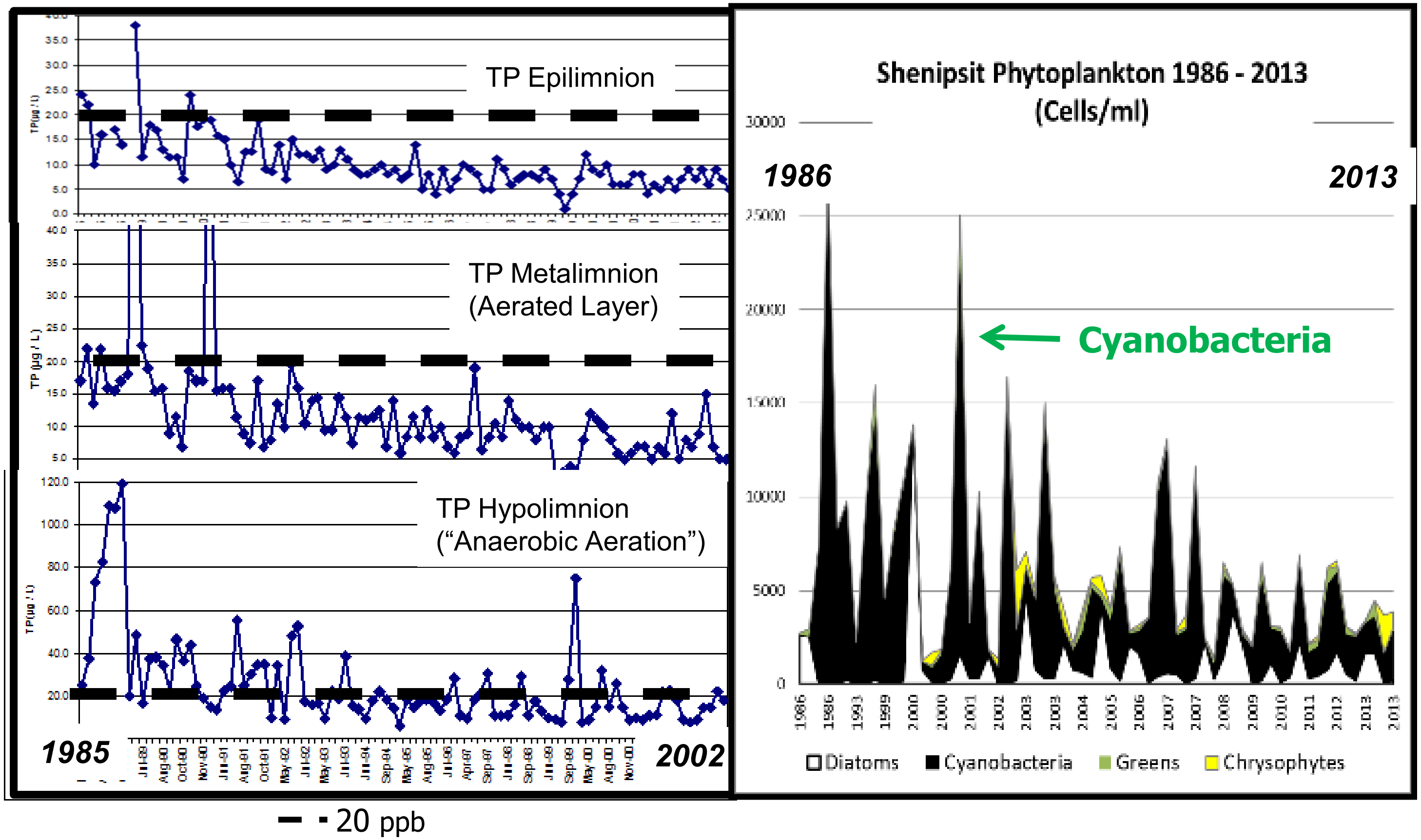



Figure 6.—Physical ecosystem responses to layer aeration from 1985-86 (pre-aeration) through 1991 (post-aeration).

Kortmann, et.al., 1994

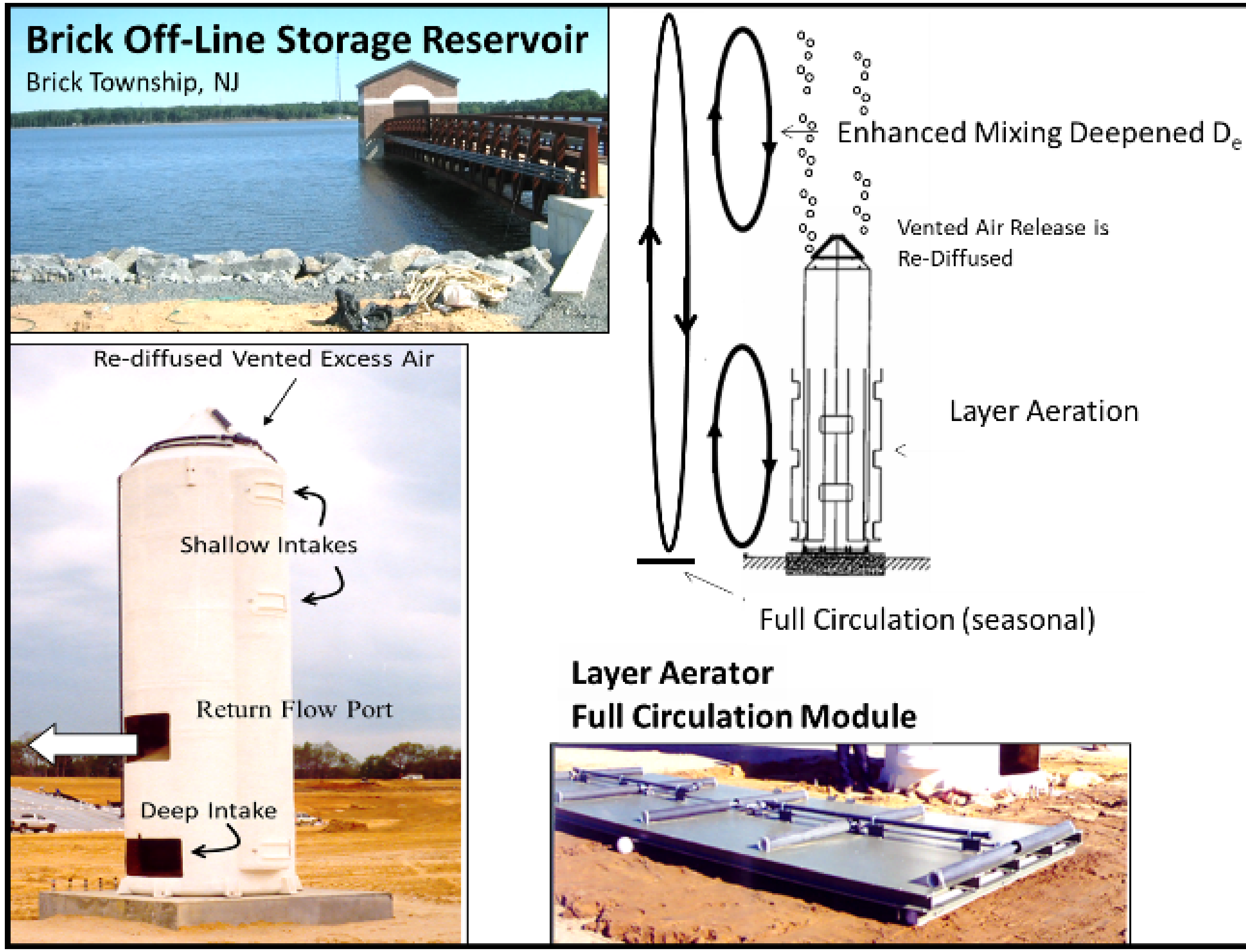
**Anaerobic Volume Decreased from 5,800 Acre-Feet to 243 Acre-Feet**
**Anaerobic Bottom Decreased from 233 Acres to 42 Acres**



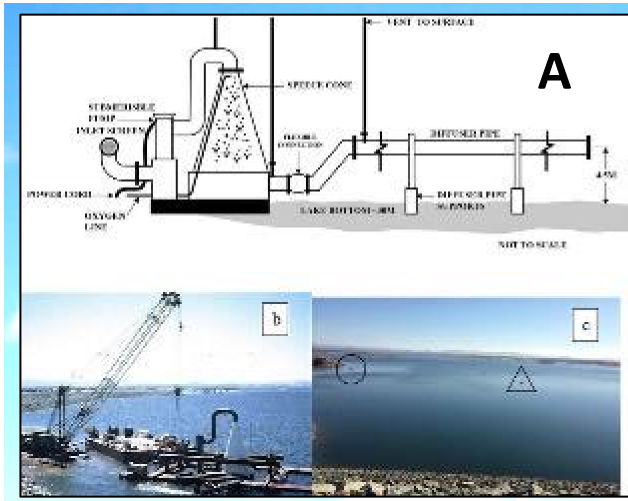

Layer Aeration decreased internal loading of phosphorus (SRP, TP) which decreased the abundance of phytoplankton (especially Cyanobacteria), increased light penetration (deepening the compensation depth), and improved habitat quality.

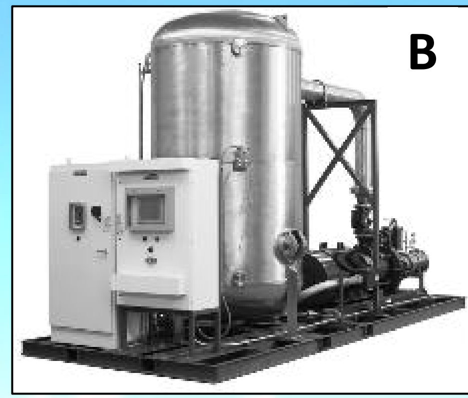
## Integrated System:

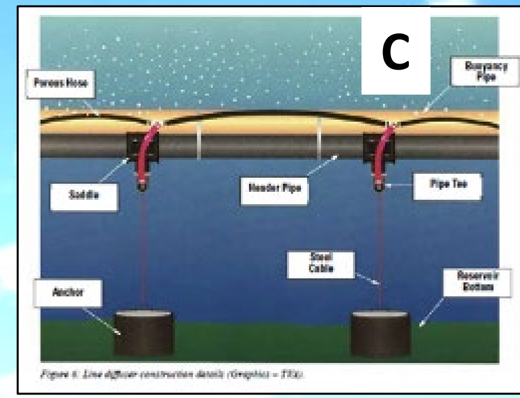
- Hypolimnetic Layer Aeration of Bottom Layer
- Full Artificial Circulation (Seasonal)
- Rediffused Vented Air to Increase Mixing Depth to disfavor cyanobacteria

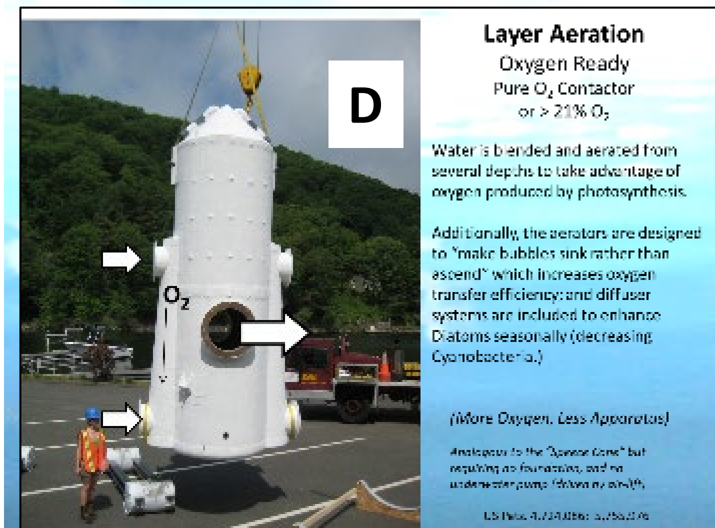



(Kortmann and Karl, 2011)




# Oxygenation Systems

A. Conical Gas Contactor (e.g. Speece Cone, In-Lake Pump)

B. Side Stream Oxygen Saturation System

C. Line Diffuser Oxygenation (Designed so the bubble air-lift pumping doesn't destratify, water falls out of the plume)

D. Oxygen Ready Layer Aerator with Conical Contactor Feature (Compressed air does the pumping)

# In Summary

# Managing HABs

- NJ’s lakes are nutrient rich and therefore susceptible to HABs…Key to preventing HABs is nutrient management.
- Need to identify, quantify and prioritize all nutrient sources and timing of nutrient inputs.

# Managing HABs

Requires the proper selection and implementation of both:

- **Corrective actions** (reactive **maintenance** activities to address an existing or evolving bloom… algaecide treatments)
- **Preventative actions** (proactive **management** activities to avoid, control or lessen the severity of a bloom… nutrient management, aeration, stormwater management, septic management)

# Thank you….Questions?

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Clean Waters Consulting
CWC

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