Aeration and Oxygenation… Why, How and What Makes Sense for Your Lake

Stephen J. Souza, Ph.D.
Clean Waters Consulting, LLC
Ringoes, NJ 08551
SJSouza.CWC@gmail.com

Thanks For Having Me!

New York State Federation of Lake Associations

The Unique Thermal Properties of Water

- Water has high specific heat, therefore it heats slowly when cold and cools slowly when warm.
- Results is a fairly stable environment.
- Water's temperature/density relationship is unique.
- Most liquids increase in density as they cool. Although water does the same, it reaches maximum density at 4°C, and then decreases in density as it approaches freezing.
- This is why lakes don't freeze from the bottom up.

Water Temperature and Dissolved Oxygen

- Water's temperature/density relationship affects the vertical mixing of the water column… can result in thermal stratification… more on this shortly.
- Water's temperature/density relationship also affects the solubility of oxygen (and other gasses)… cooler water can "hold" more oxygen than warmer water. … because cold water is denser, thus its volume is greater and can more oxygen can be solubilized.
- Thus, natural DO concentration at saturation decreases as water warms.

Dissolved Oxygen (DO)

Critical for aquatic life… also affects chemical processes and energy transfer

- DO concentration affected by water temperature and community respiration
- Peak DO mid-day due to photosynthesis
- Lowest DO near-dawn due to community respiration
- Supersaturated DO indicative of intense, sustained algae bloom

Oxygen Demand

- Community respiration (BOD) –
  - Biological oxygen demand (BOD), respiration by fish, zooplankton, other aquatic organisms (and even photosynthetic organisms) the more productive the system the greater the amount of respiration.
- Sediment oxygen demand (SOD) -
  - Driven by bacterial decomposition of settled organic material present in sediment… "legacy load"
  - During thermal stratification sediment oxygen demand (SOD) can quickly exhaust available DO in the hypolimnion or deeper reaches of lake.

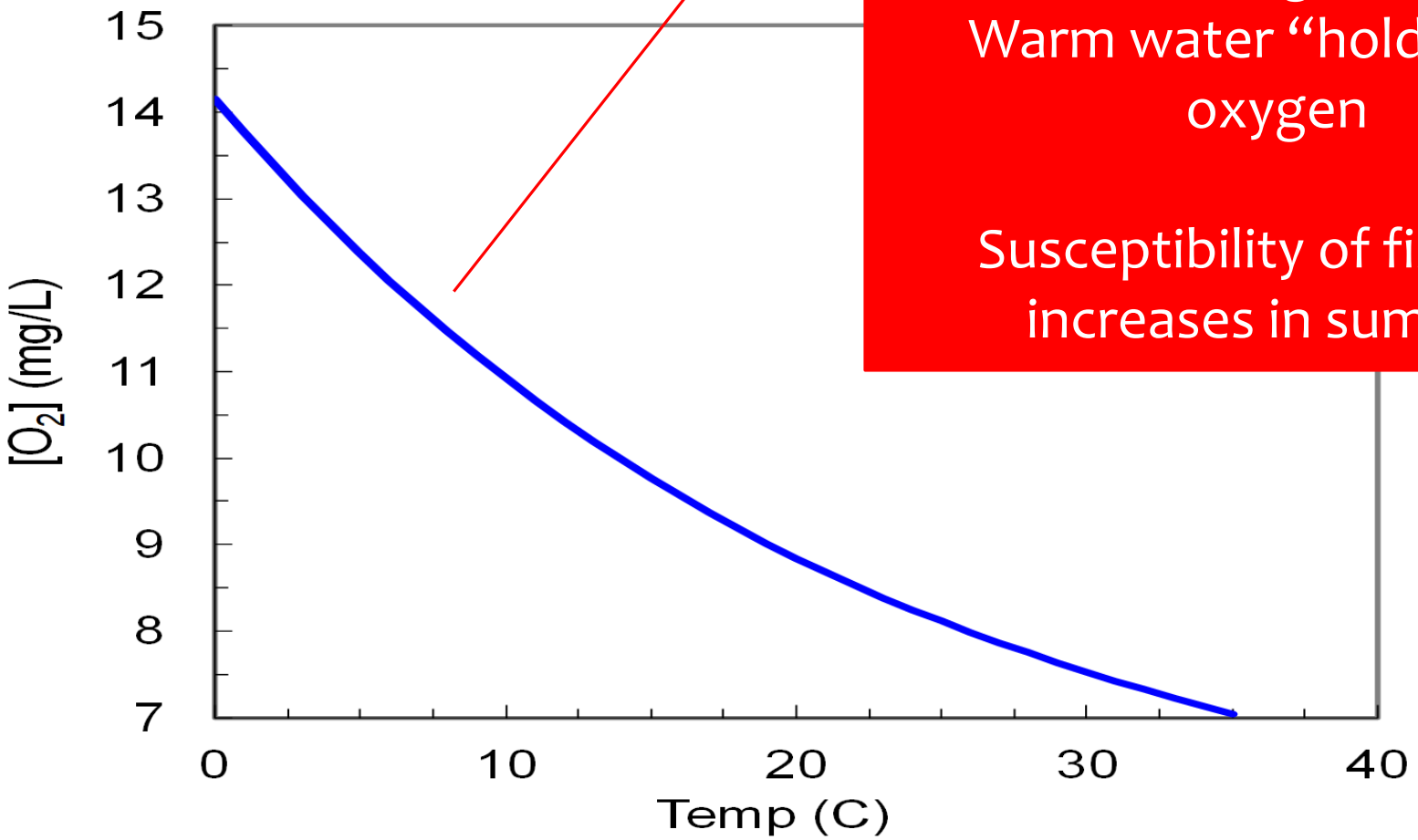
Defining Oxygen Levels

- **Oxic conditions**: measurable oxygen present (>0.06 mg/L)… ideally want > 4 mg/L
- **Hypoxic conditions**: <2 mg/L; stressful for all aerobic organisms
- **Anoxic conditions**: <0.06 mg/L; only anaerobic microorganisms can survive

Solubility of Oxygen in Water

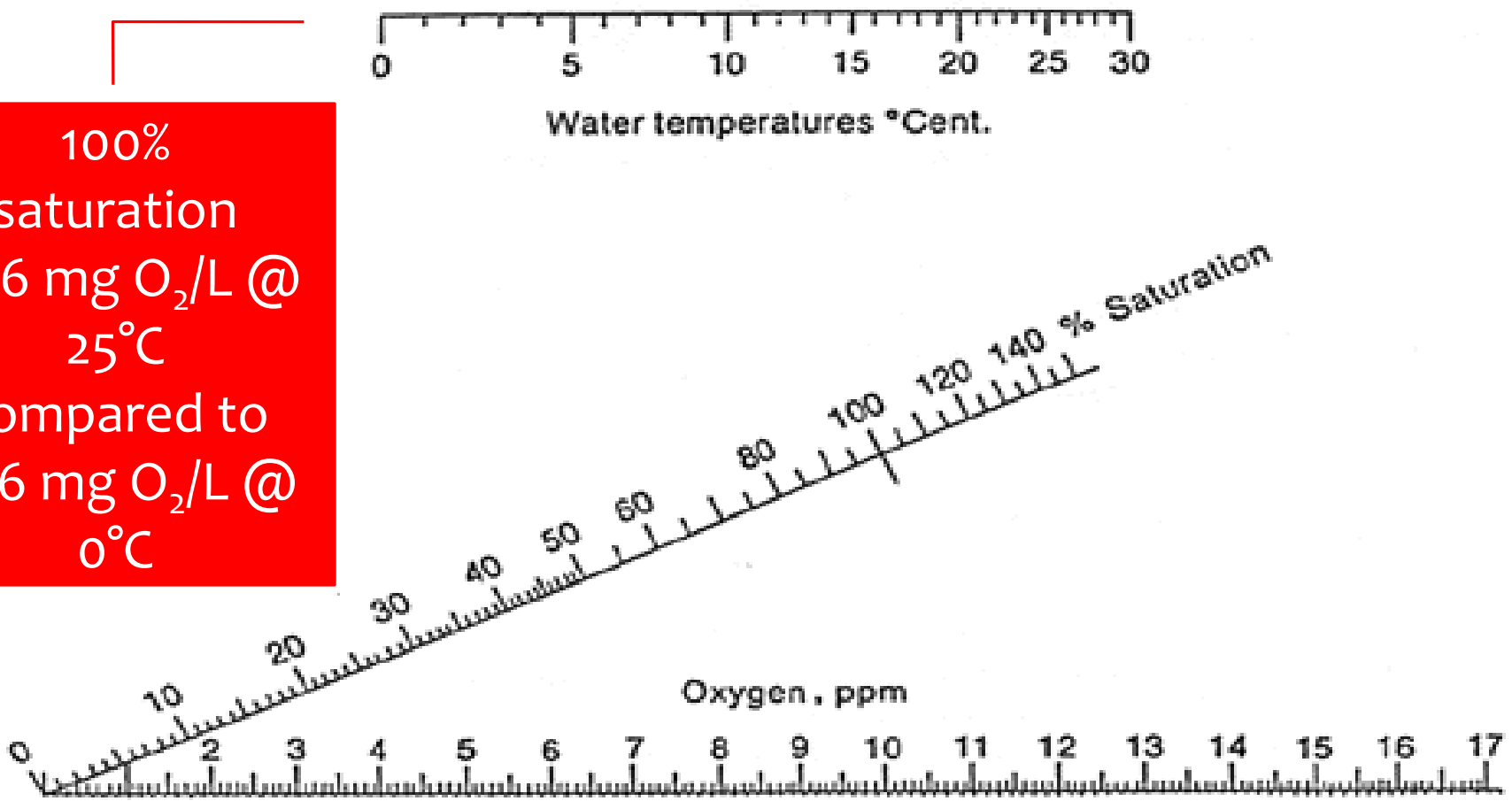
Solubility of oxygen decreases with increasing water temp
Warm water "holds" less oxygen

Susceptibility of fish kills increases in summer



Solubility of Oxygen in Water

100% saturation 8.26 mg O_2/L @ 25°C compared to 14.6 mg O_2/L @ 0°C



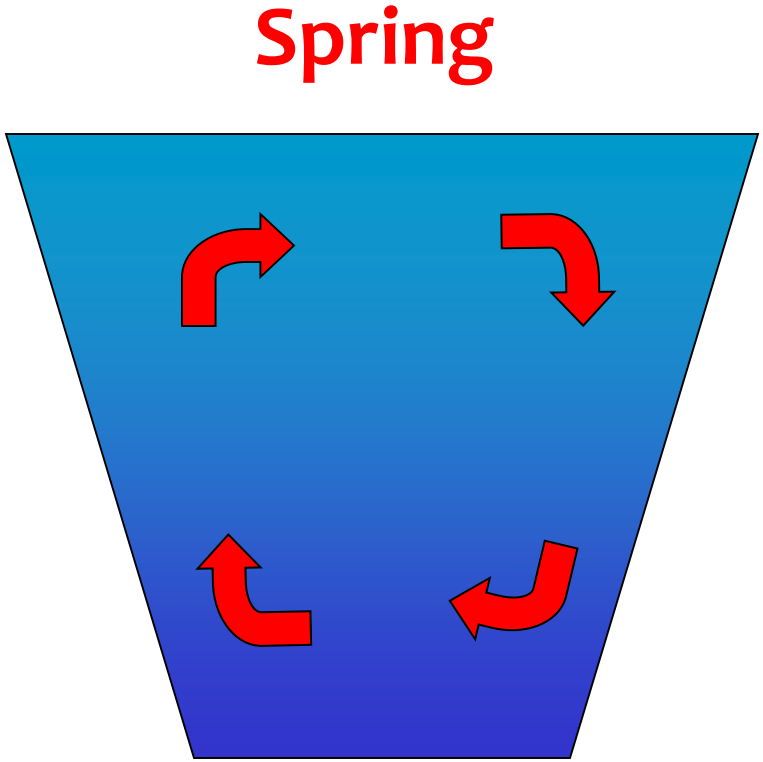
Source - https://waterontheweb.org/under/waterquality/oxygen.html

Thermal Stratification

- Stratification results from the development of distinct thermal and density layers… water becomes less dense as it warms.
- A 1-3°C temp difference between 1-meter depths can create enough of a density difference to impede the vertical mixing of the water column… results in thermal stratification.
- Waterbodies **>6 ft deep have the potential to thermally stratify**.
- **Dimictic** - stratify/destratify 2 times annually (spring and fall). Stable water column.
- **Polymictic** – stratify and destratify frequently. Unstable water column.

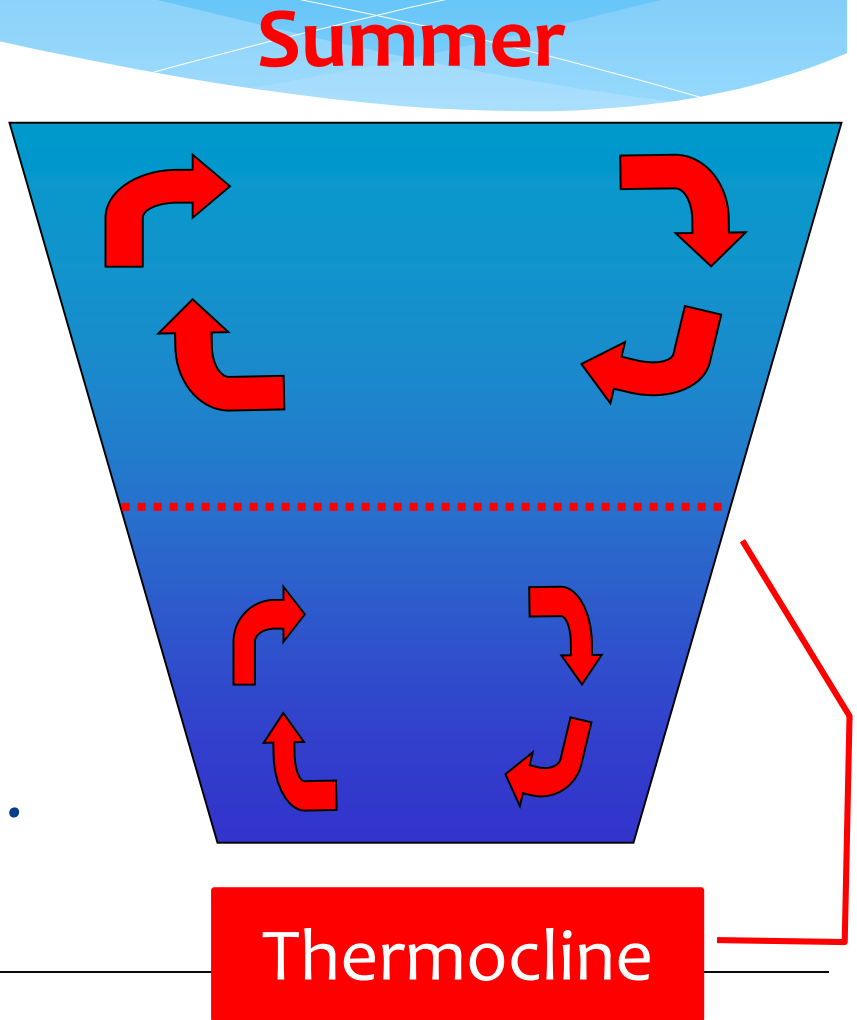
Water Temperature & Mixing

- Water column temperature uniform surface to bottom.
- Density differences are minimal.
- Lake freely circulates from top to bottom.



Water Temperature & Mixing

- Sun heats top of water column.
- Temperature differs from surface to bottom.
- Density differences lead to stratification.
- Vertical circulation impaired.



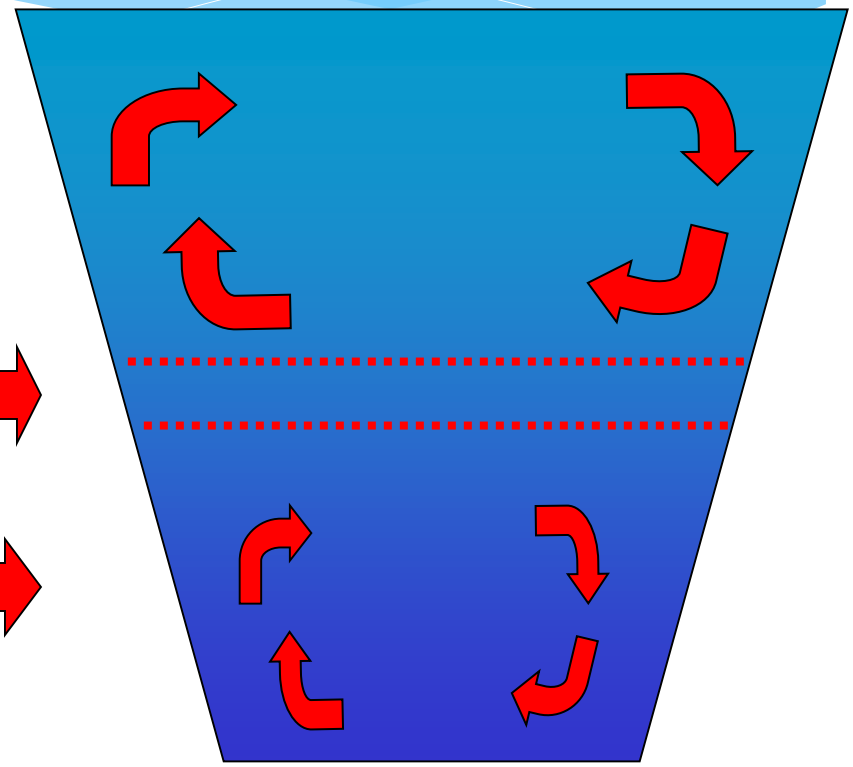
Water Temperature & Mixing

Summer

Epilimnion – Upper warm layer of lake

Metalimnion – Transition layer of lake

Hypolimnion – Deep cold layer of lake

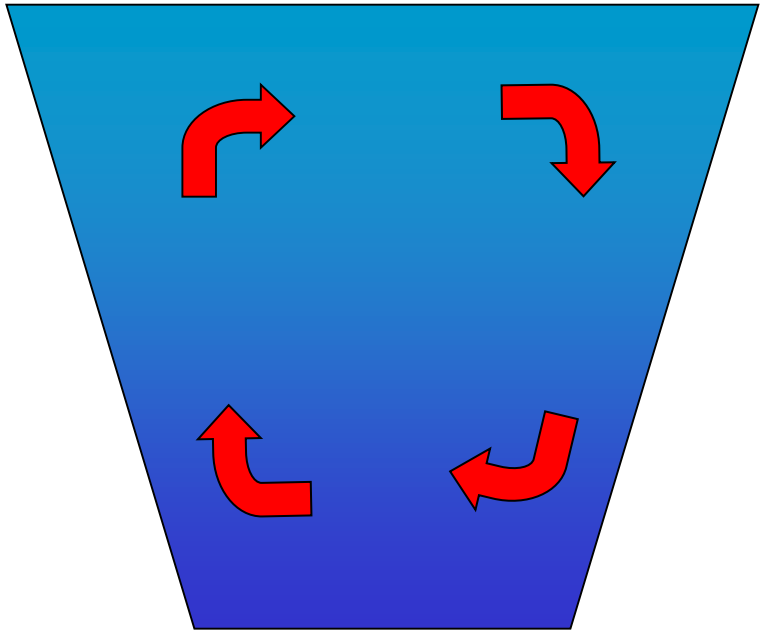


This "layering" more common for deep lakes… but can occur in lakes as shallow as 6 feet

Water Temperature & Mixing

- Water column cools, water column uniform temperature.
- Density differences minor, stratification breaks down.
- Water column can freely circulate from top to bottom.
- Lake “turns over”.

Fall

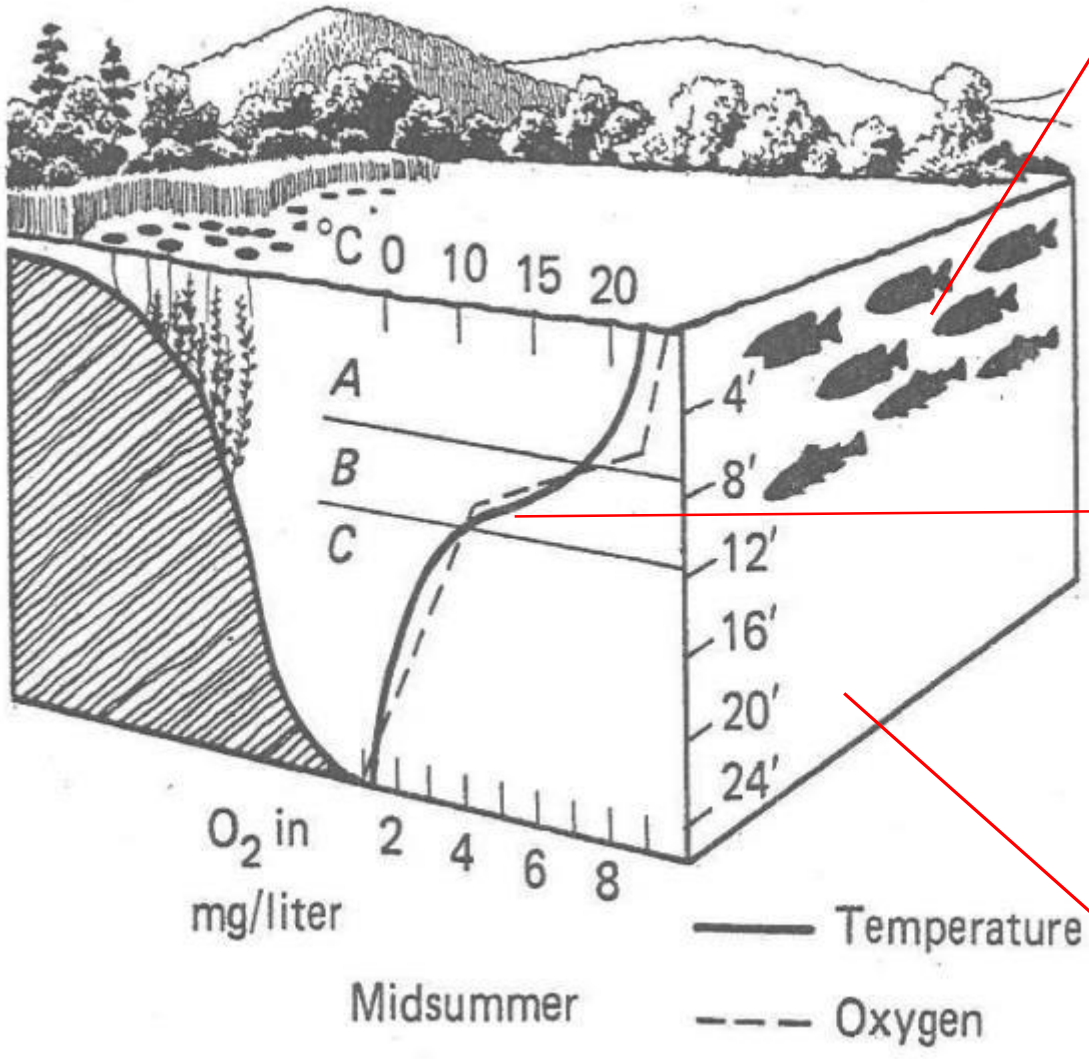


For a polymictic lakes this cycle can occur **daily**

Stratification Can Impact A Lake's Biology and Chemistry

Stratification, even if for short amount of time may result in a number of impacts…

- Hypolimnetic anoxia
- Internal nutrient and metal recycling
- Algae blooms/HABs
- Fish kills

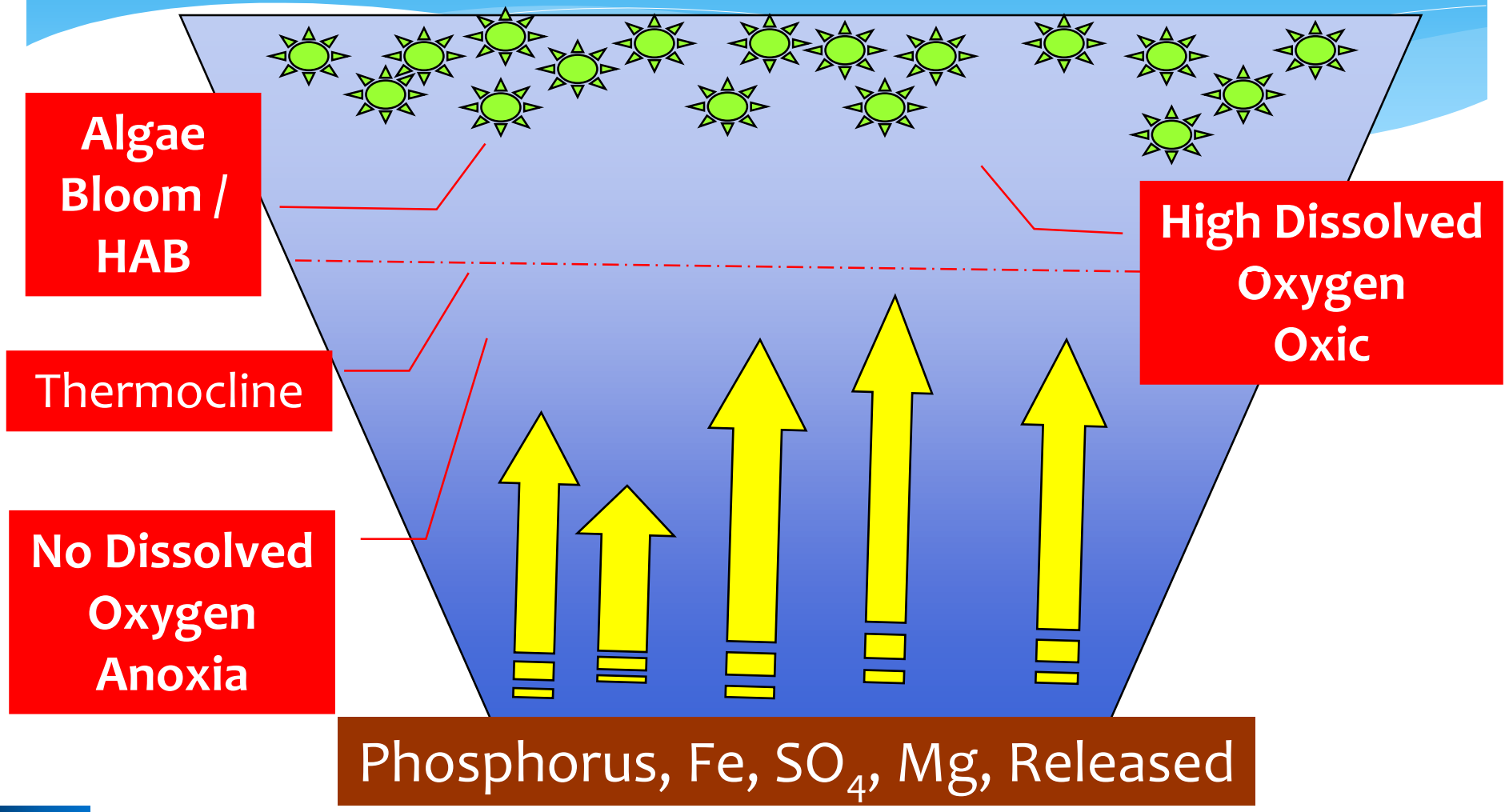


Oxic Zone… enough DO to support variety of aquatic life

Thermocline

Hypoxic/Anoxic Zone… not enough DO to support aerobic life

Relationship of Temperature, DO, Nutrients & Minerals



Aeration and HABs Management

Important tool to combat HABs

- Prevent stratification.
- Minimize or control internal phosphorus loading.
- Drive cyanobacteria cells into deeper water inhibiting bloom formation.
- Decrease accumulation of surface scums in confined areas.

Why Do We Aerate or Oxygenate Lakes, Ponds and Reservoirs?

- Prevent thermal stratification
- Improve or enhance vertical mixing
- Improve or enhance horizontal circulation
- Increase dissolved oxygen (DO) content
- Prevent internal recycling of phosphorus
- Reduce planktonic algae and cyanobacteria blooms
- Improve fish habitat and fish holding capacity
- Avoid below the ice, winter fish kills

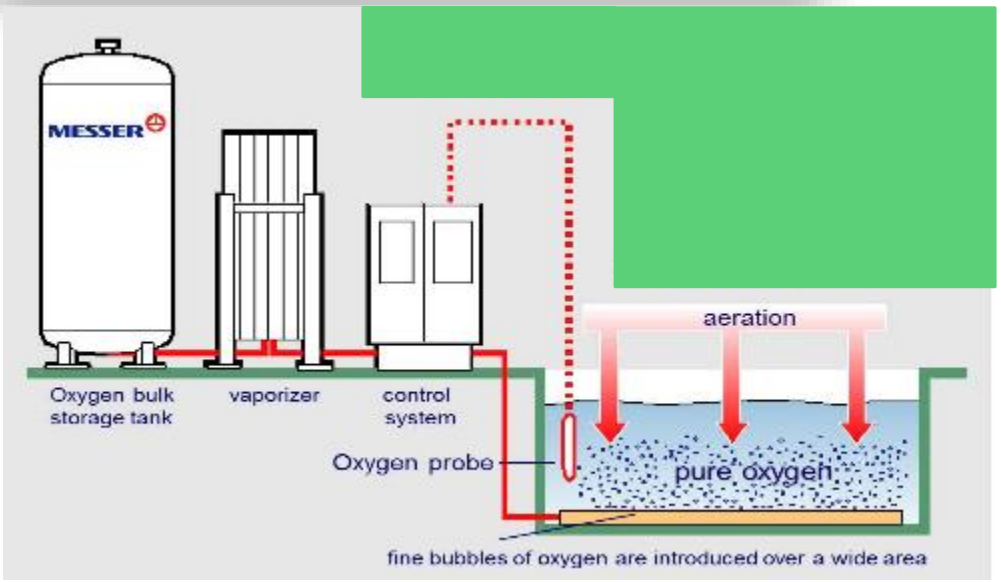
How Is This Accomplished?

Three basic approaches:

- **Circulate** – Move water horizontally to reduce stagnation and decrease the buildup of debris in "dead zones".
- **Mix** – Move water vertically to prevent thermal stratification and/or deep water dissolved oxygen depletion.
- **Oxygenate** – Infuse "pure" oxygen into the water to prevent/address deep water oxygen depletion and ecosystem oxygen demands.

“Aeration” Options

Compressed Air Full / Partial Lift



Pure O2 Injection

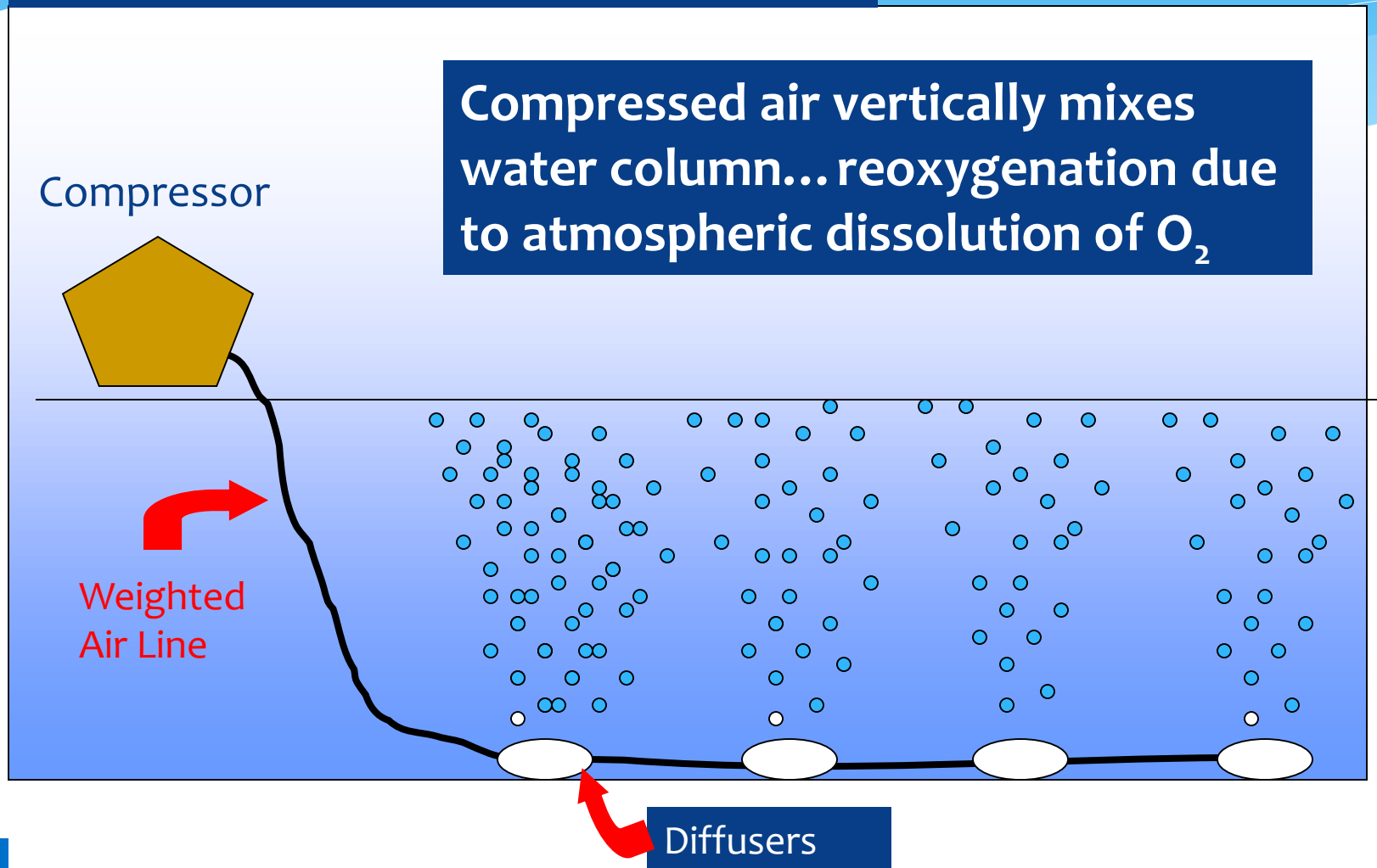
Aeration/Water Column Mixing

- Destratify and keep water column fully mixed
  - Mix – Maintain a vertical upwelling of water to prevent the onset of stratification.
  - Circulate – Horizontal movement of water to reduce stagnation and perhaps decrease the buildup of debris in “dead zones”.
- Maintain lake in stratified or partially mixed state
  - Hypolimnetic aeration (usually for deeper lakes)
  - Layer Air aeration (for deep and intermediate lakes)

Destratification Aeration

Submerged, Full Lift Aeration

Basic Submerged Aerator Setup



Effectiveness and Efficiency

Compressed air plays a small role in re-oxygenation of water column… primary role is to prevent stratification.

Reoxygenation mostly result of dissolution of atmospheric O_2 into water.

Water column mixing accomplished using perforated tubing, membrane diffusers or porous hose.

- Perforated tubing – Need high flow rates to be successful, best suited for deep lakes (> 10 ft).
- Diffusers and porous hosing – High transfer rates at low flow rates, well suited for shallow (< 8ft) lakes. Very efficient and most common option.

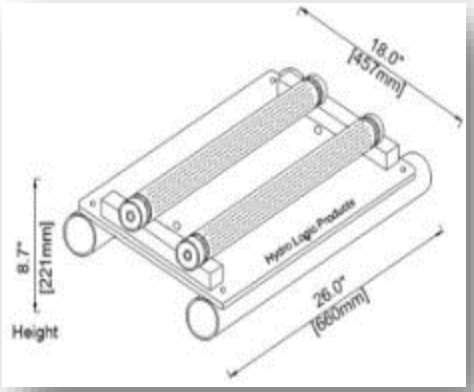
Fine pore air flow

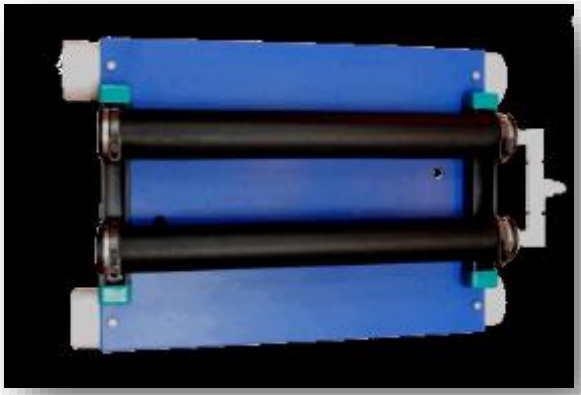
Compressed air diffuser

Weighted airline

Goal is to prevent thermal stratification, keep water column vertically mixed and in contact with atmosphere.

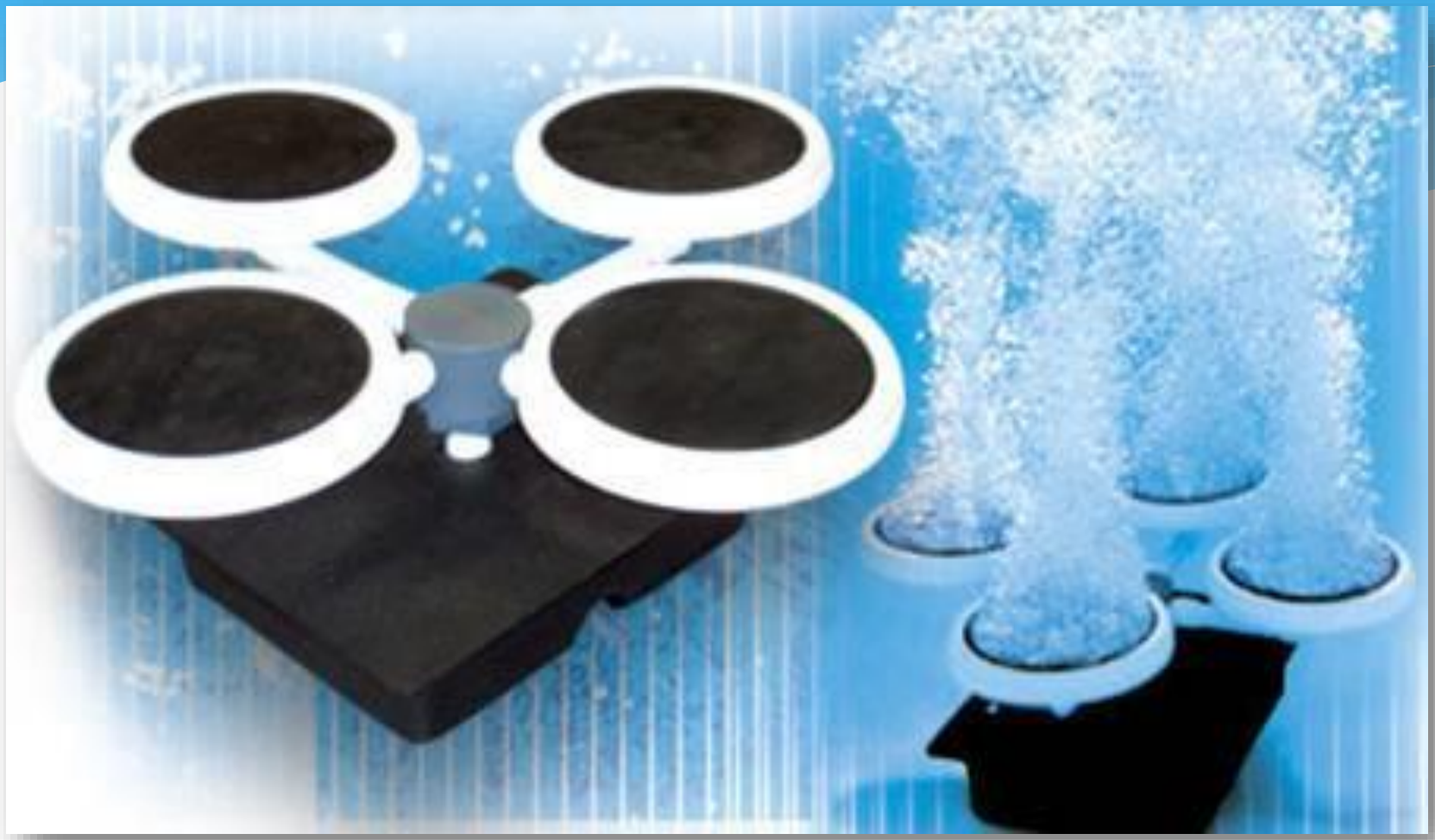
Fine Pore Aeration





Source – Hydro Logic Products

Fine Pore Aeration



Source – Vertex Water Features

Destratification Performance

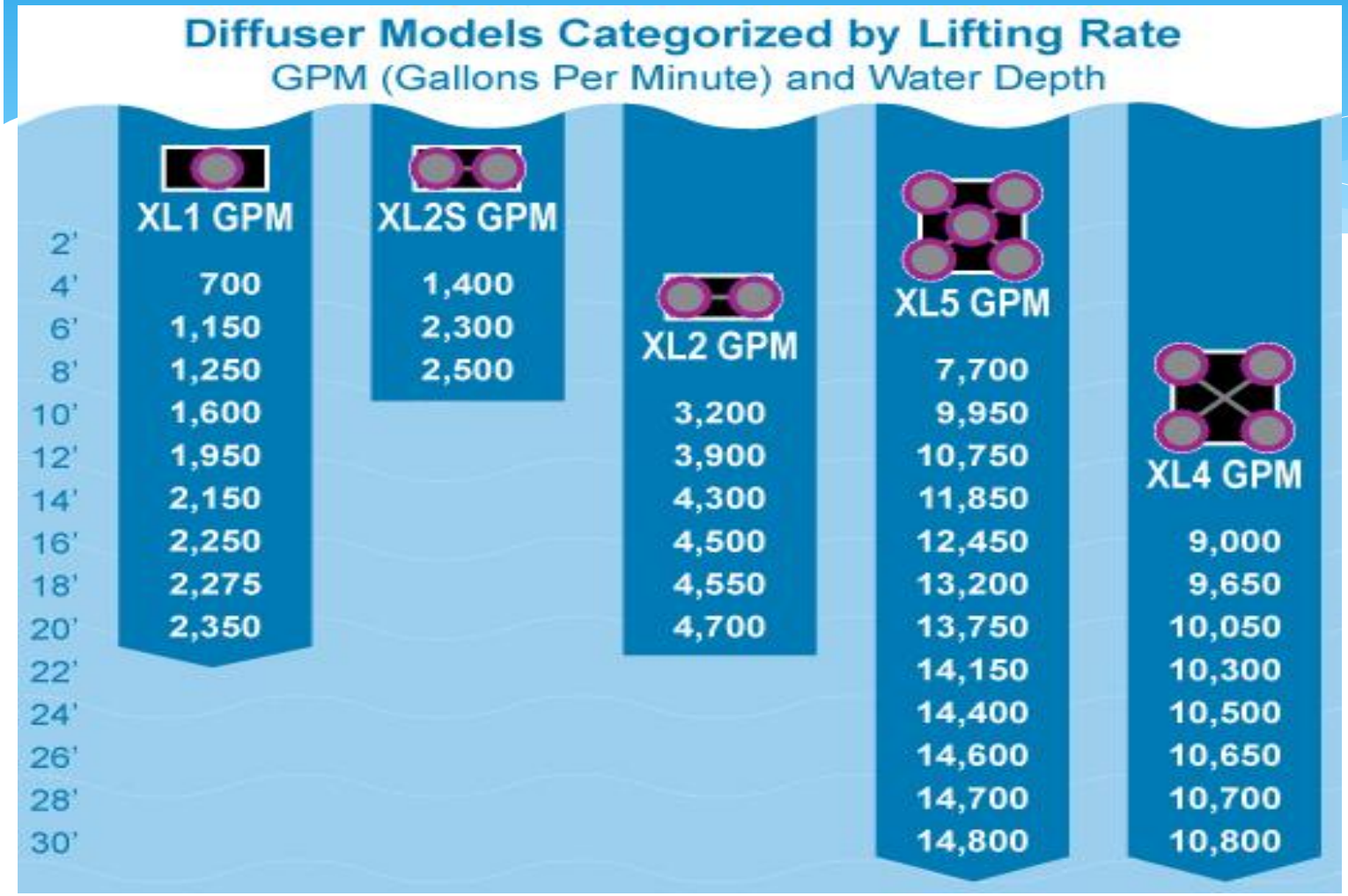
- Maximum efficiency of submerged aeration at a depth of 15 feet. For every 3 feet less in depth, efficiency decreases by approximately 50%
- Shallow lakes and ponds therefore needs more/larger compressors and more diffusers
- Water lift per 1 CFM can be in the range of 3,000 gallons/minute at a depth of 15 feet
- Mixing rates range from about 5,000 to 20,000 gallons/min/HP… amount of compressor HP function of lake shape, maximum depth and volume

Example Sizing / System Efficiency

- 3-5 acres, 8 ft deep.
- Powered by .75-1.5 hp rotary-vane compressor.
- 110V, single phase.
- Two diffuser pods (4 diffusers/head).
- Circulates up to ~15,000 GPM

Source – Vertex Water Features

Projected Water Mixing Capability



Based on .75 – 1.5 HP Compressor size

As per Vertex - https://vertexaquaticsolutions.com/water-quality-product-lines/pond-lake-aeration/aeration-system-specs/

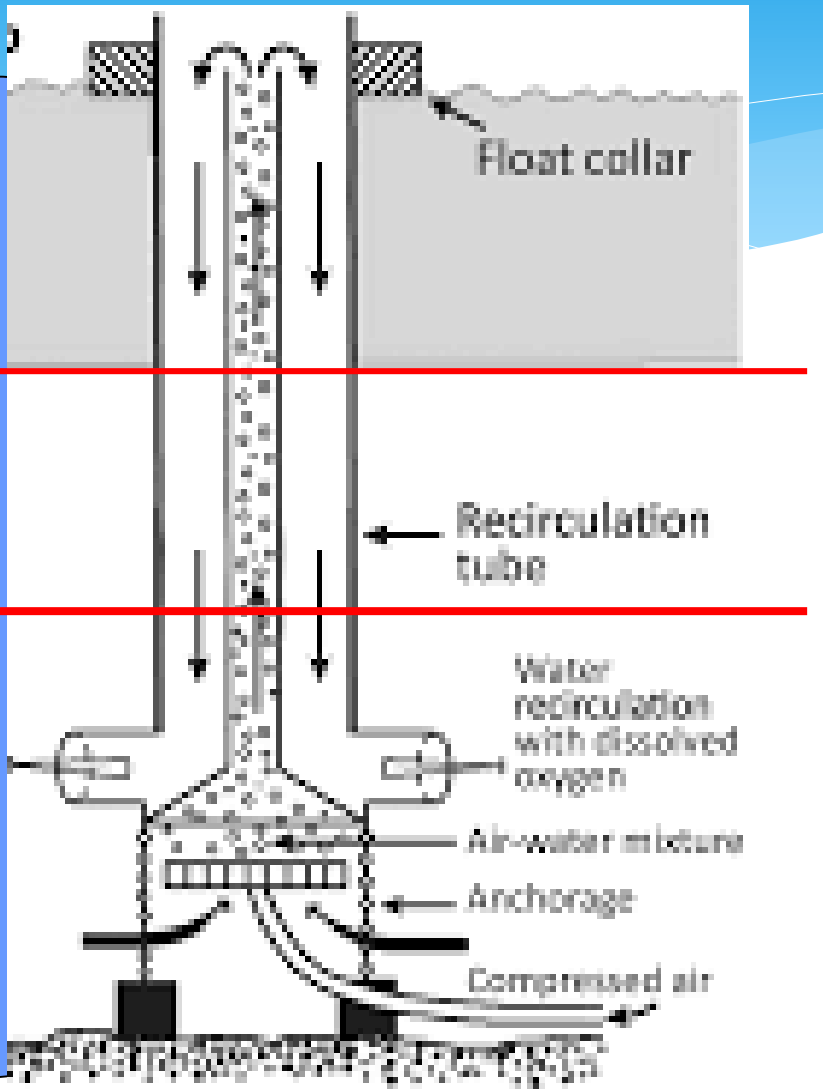
Hypolimnetic Aeration

- Partial lift aeration
- Used mostly for deep lakes (>20 ft)
- Designed to maintain stratification.
  - Cold water fishery
  - Minimize internal loading by maintaining just enough DO to prevent P and metal release from sediments.
- Some systems focus on maximizing metalimnetic DO concentrations (LayerAir© systems).

Conventional Hypolimnetic Aeration

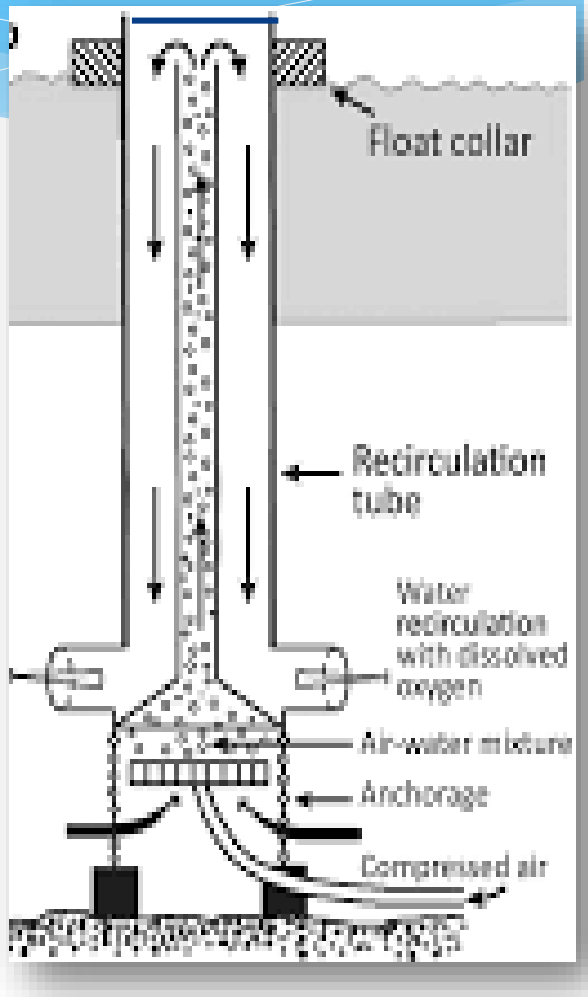
DO rich zone of lake

DO depleted zone of lake

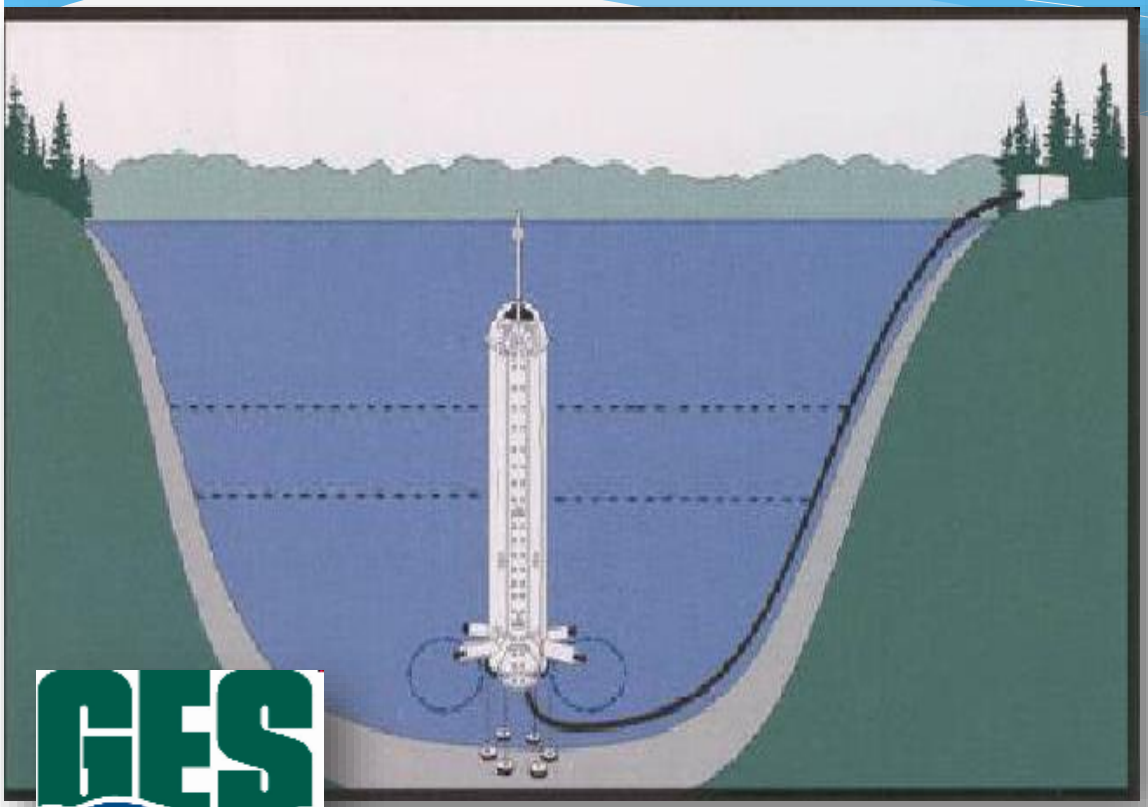


Like Your Lung's Capillaries

- "Tube within tube"
- Water from deep, DO depleted zone forced up within inner tube by compressed air.
- DO gained as DO poor and DO rich water come into contact and mix at top of tube.
- DO improved water returned to bottom.
- Some heat gain, but minimal so the thermocline is maintained.

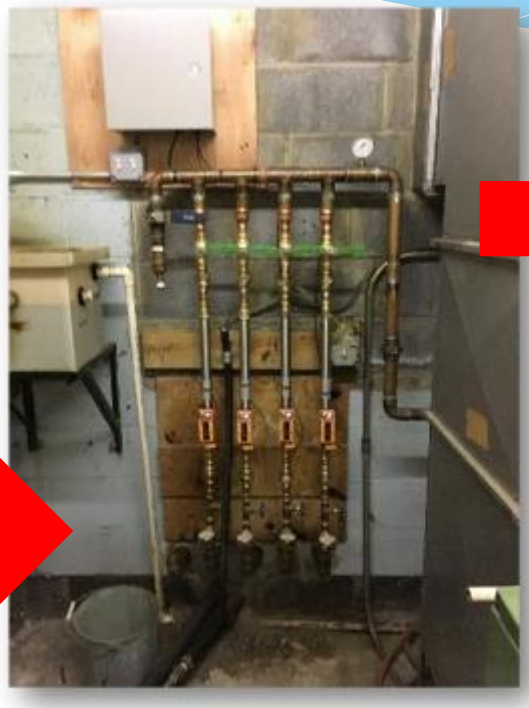


Conventional Hypolimnetic Aeration



General Environmental Systems - HYPOLIM ^{C} unit

Culver Lake Hypo Unit



Metalimnetic Aeration / LayerAir

LayerAir^{c} System

Ecosystem Consulting Services, Inc.

Layer Aeration System

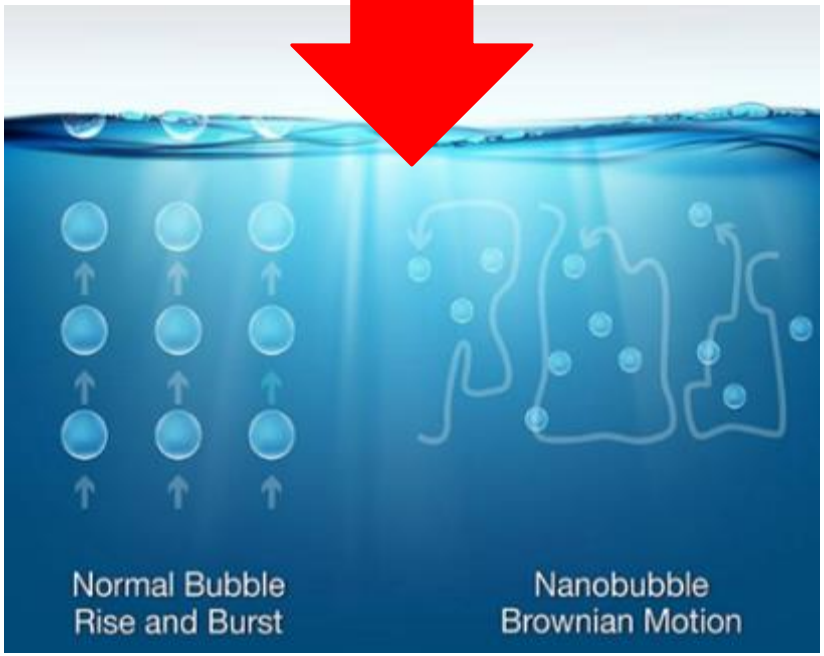
- “Tube in tube” design.
- Positioned above bottom.
- Emphasis circulating and maintain DO within metalimnion.
- Habitat benefits.
- “Two-story” fishery
- Internal P control.
- Disruption HAB development at thermocline.

Nano Bubble Technology

- Unit creates very small (< 200 nm) "nano bubbles" designed to increase oxygen transfer into waterbody...either within the water column or close to sediment interface.
- Neutral buoyant bubbles do not disrupt thermal stratification.
- Can be used to address community respiration deficiency or SOD caused by organic sediment.
- Most applications for ponds but systems installed in Lake Hopatcong...data available next year.

Nano Bubble Technology

Result… better oxygen transfer compared to standard destrat systems



In theory the bubbles neither fully dissipate nor rise to the surface

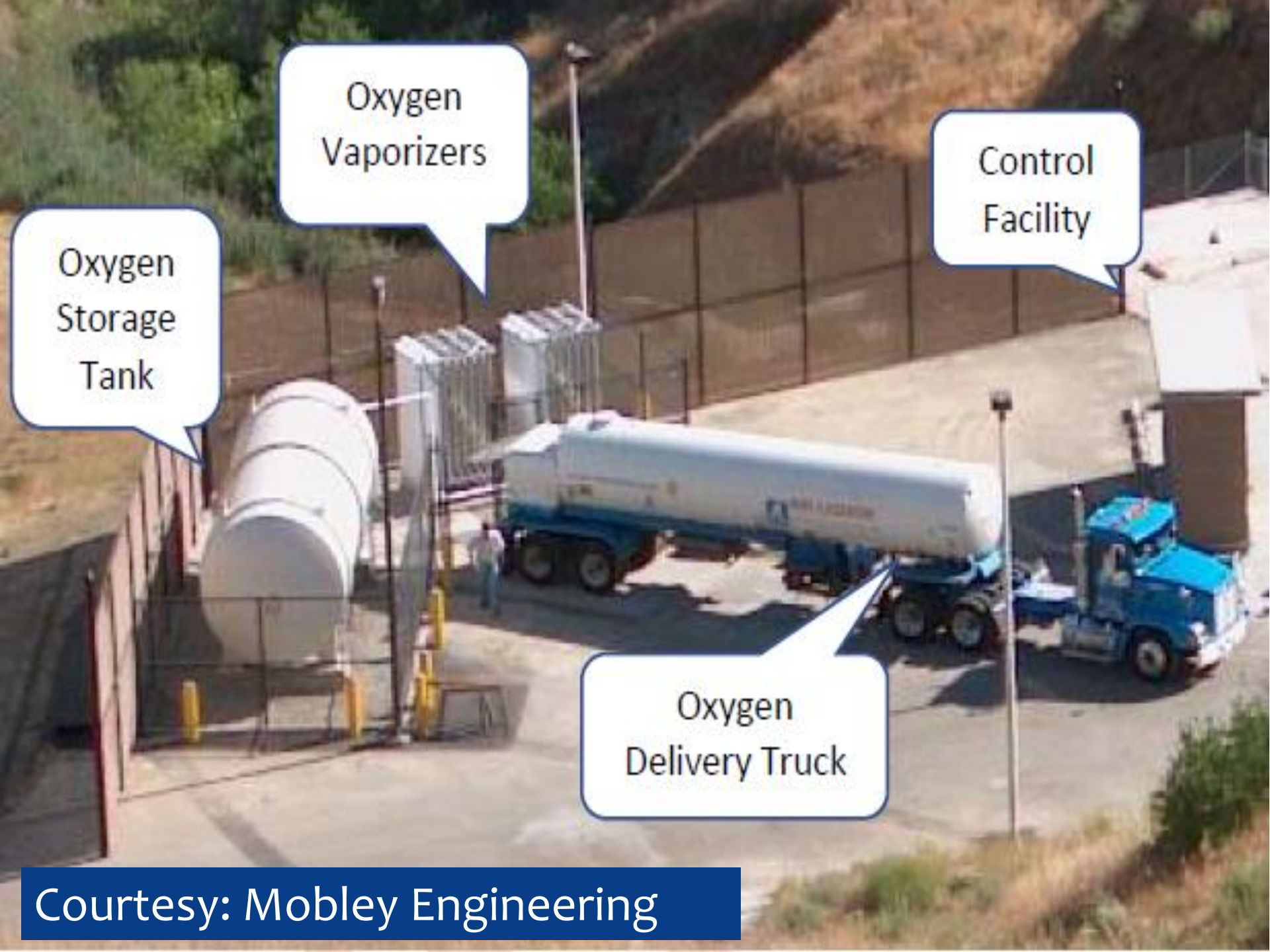
Nano Bubble Technology

Typical installation

Pure Oxygen Systems

Two Oxygen Source Options…

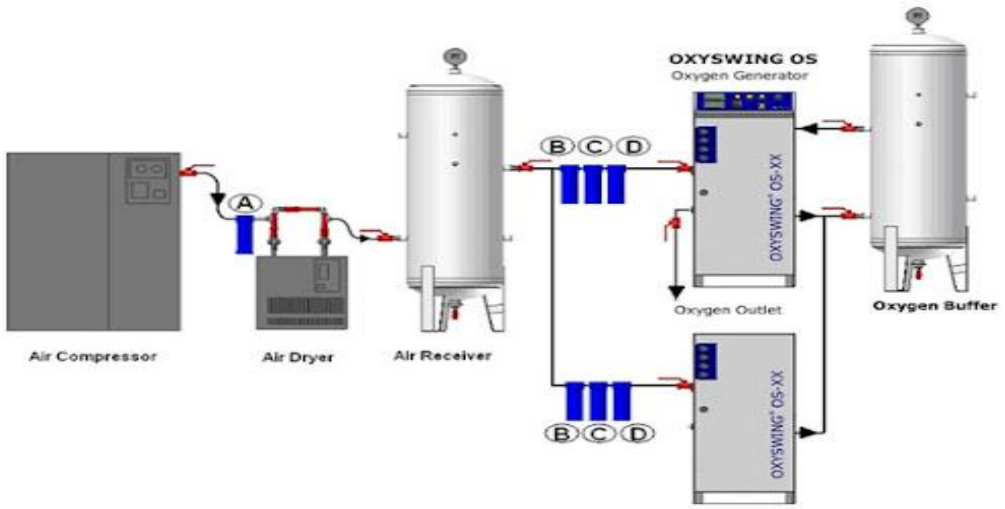
- On-site oxygen production
- On-site oxygen storage



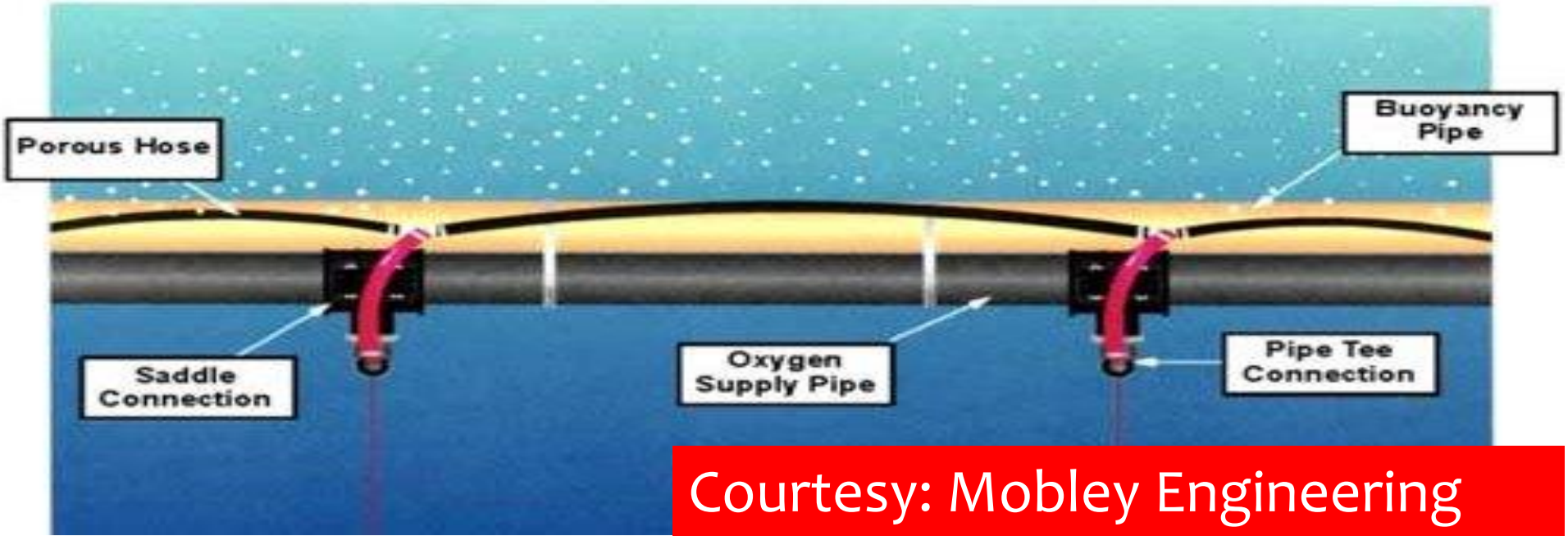
Courtesy: Mobley Engineering

On-Site Oxygen Generation

- Pressure Swing Adsorption (PSA) unit
- Strips N_2 from compressed atmospheric air, thereby increasing O_2 content to > 80%
- O_2 is <u>not stored</u> in large on-site tanks
- Does not disrupt lake's thermal profile

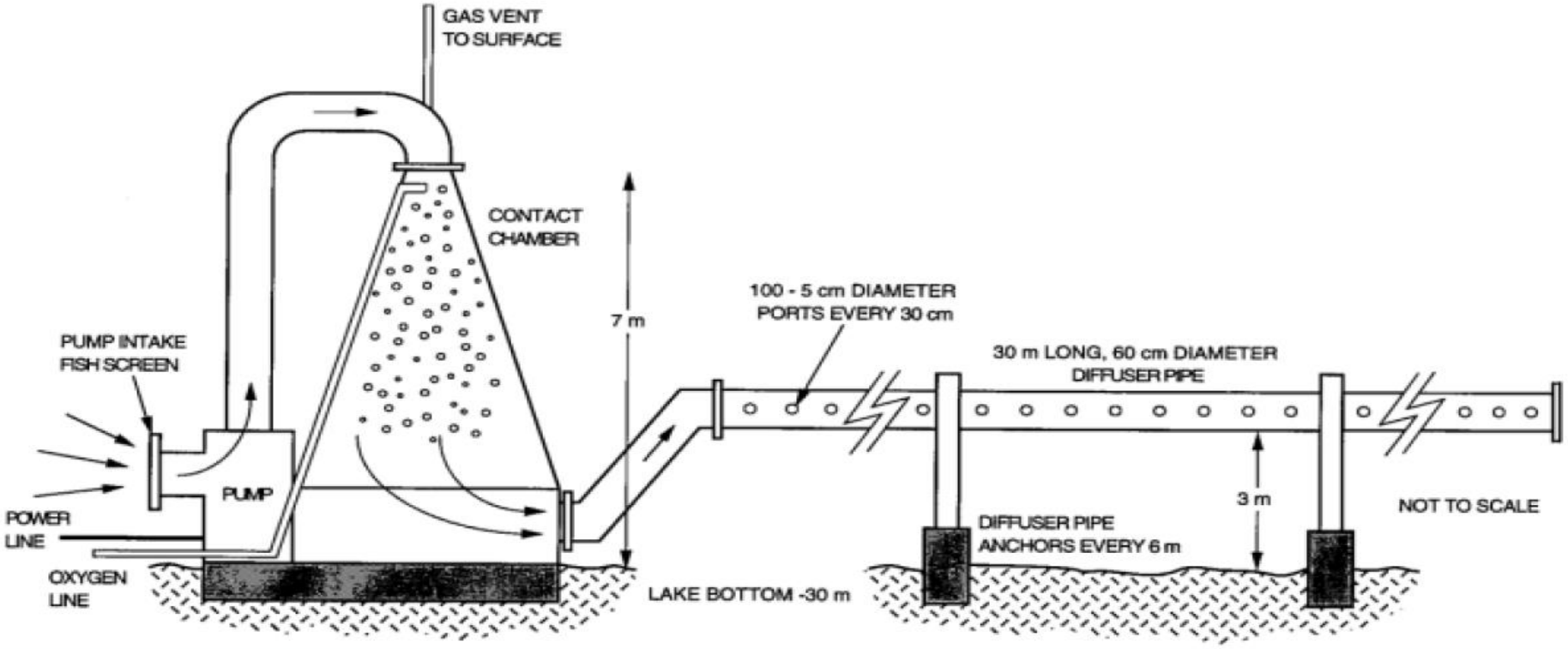


Line Aeration System

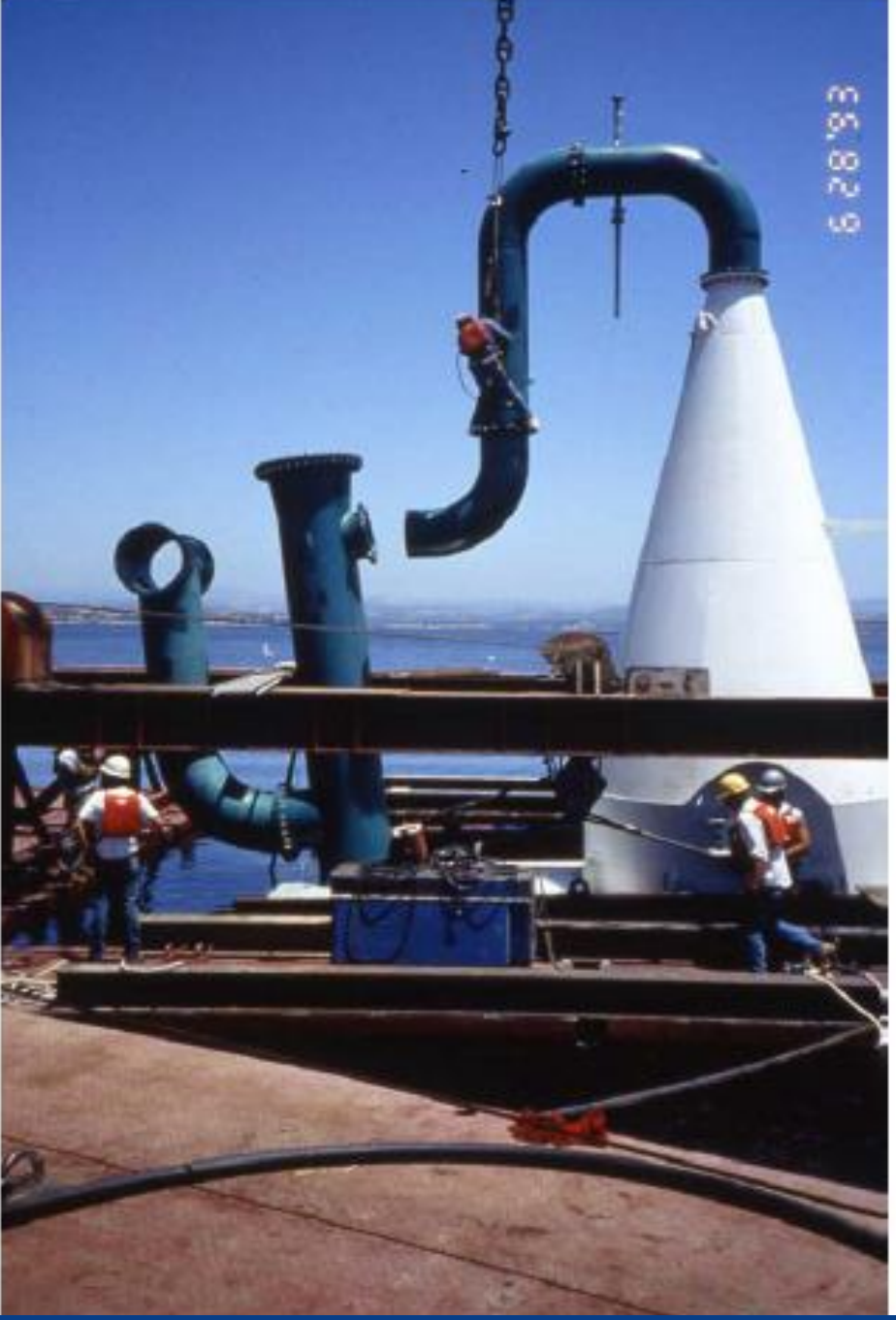


Courtesy: Mobley Engineering

Speece Cone



- Water pumped in from bottom of lake, mixed with oxygen and returned to bottom of lake
- Preserves stratification

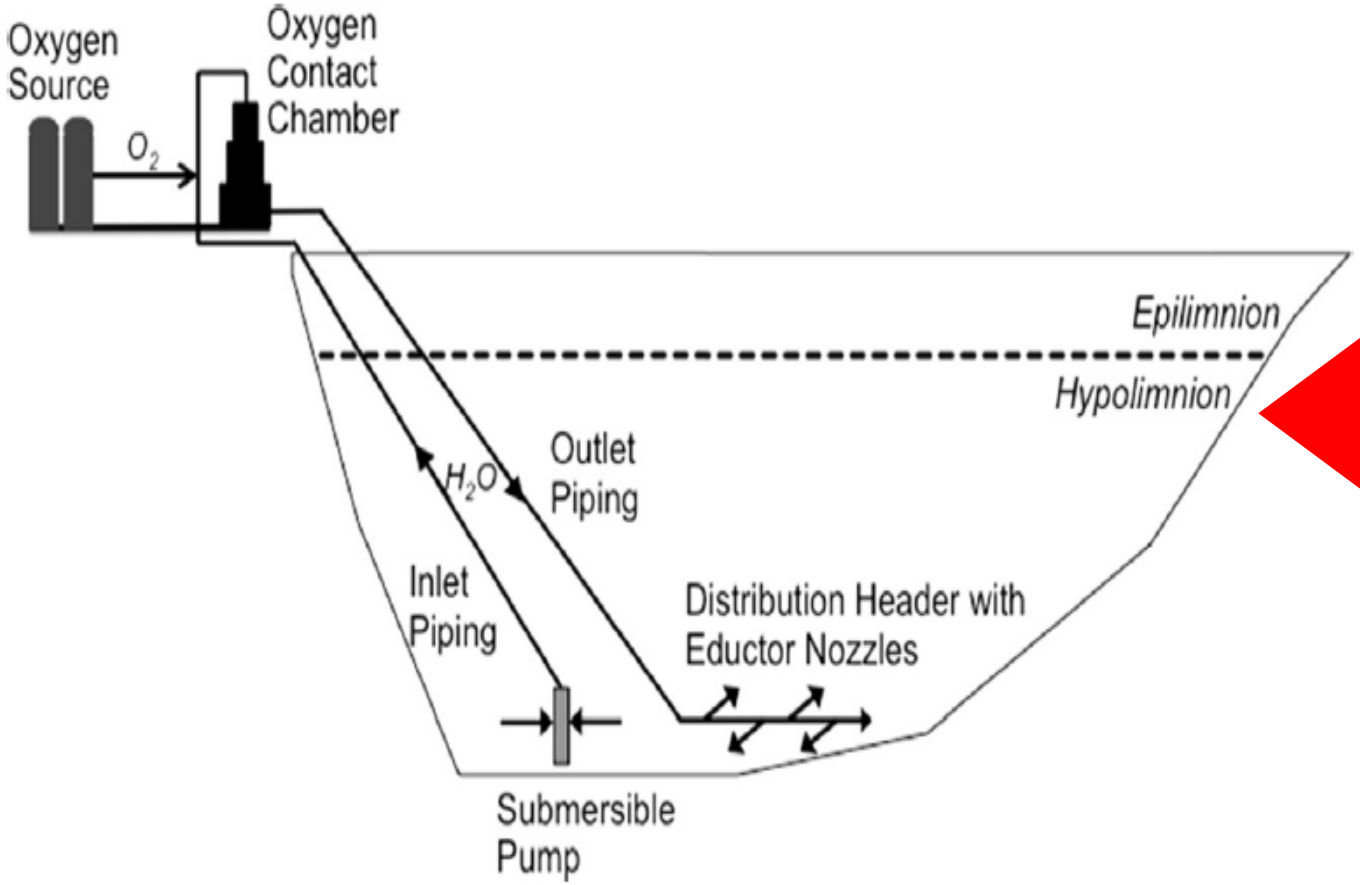


Source: Dr. John Little; JCL@VT.edu Intro to Oxygenation & Aeration Systems

Speece Cone

Courtesy of PAES W.A.T.E.R.
https://www.youtube.com/watch?v=3Cuibe1Pi4s

Sidestream Super Saturation Hypolimnetic Aeration



Water withdrawn from lake, mixed with O2 and returned to hypolimnion without disrupting thermocline

Source: Gerling, et. al. 2014 Water Research 67:129-143

Solar Powered Hypolimnetic Aeration

SolarBee®

Ozone Systems

- Ozone (O_3) strong oxidizer… rapidly breaks down organic compounds and material, including algae, bacteria and bacterial slimes.
- Potential means of oxidizing cyanotoxins.
- Transforms iron, manganese, and sulfur into insoluble metal oxides or elemental sulfur… eliminates odor and color problems.
- Can be used as a means of controlling bacteria; option to chlorine.

Ozone Systems

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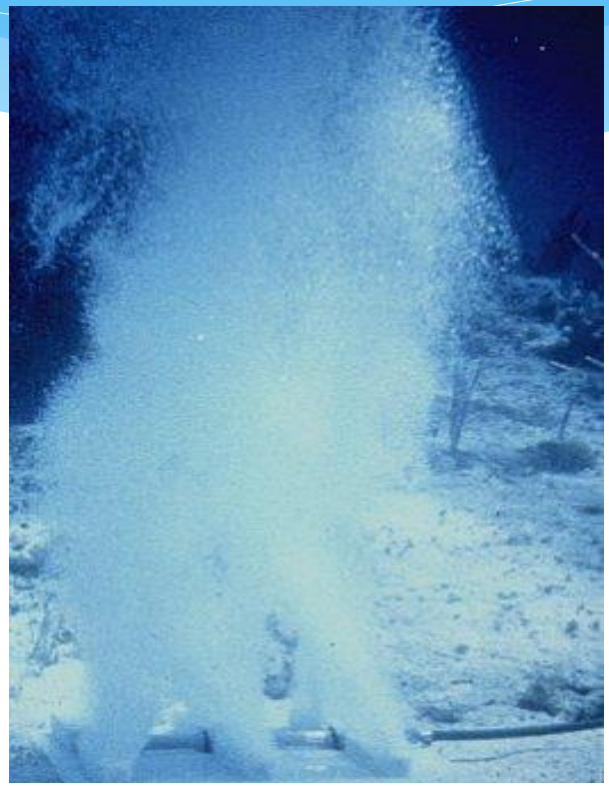


Used together with standard subsurface aeration system, which serves a “mixer”

Typical Ozone System

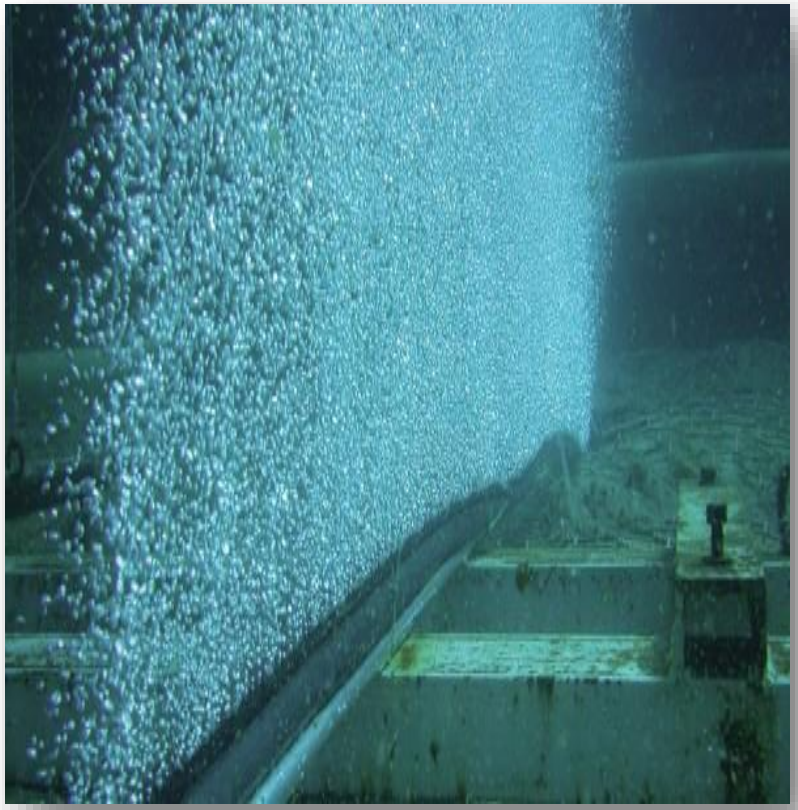
- Need 220/240 v, single phase electrical source
- Installed indoors or out
- Cost for 1-3 acre pond ~ $6,000

Lake Hopatcong
Nano Bubble / Ozone System

The goal of the installation is to use combination of nanobubbles and ozone to facilitate the break down of organic material including herbicides, pesticides, and HAB toxins.

Courtesy of Princeton Hydro - https://princetonhydro.com/innovative-aeration-technology/
Green Water Solutions - YouTube Video - https://www.youtube.com/watch?v=FxcoduggULw

Bubble Curtains



Bubble Curtains

- Keeps floating debris, algae and HAB surface scum out of confined areas (swim lanes, boat docks, etc.).
- Simple adaptation of submerged diffused aeration.
- Use multiple diffusers or perforated hose.
- Can be install with sediment boom.

Oh Yeah… Do I Need A Permit???

- Most likely yes… and a large aeration/oxygenation project will likely trigger a SEQRA review
- NYSDEC typically regulates structures placed on the surface or on the bottom of a lake
- NYSDEC regulates any disturbance of lake bottom
- Also need a NYSDEC permit to construct pumphouse and run air lines / water lines from land, through riparian area and into lake
- So, before you initiate a project check with NYSDEC as well as local and county entities.

In Summary

- Aeration, circulation and oxygenation are commonly implemented lake management strategies.
- These strategies are used to counter the negative impacts of dissolved oxygen (DO) depletion.
- Oxygen solubility and maximum DO concentration affected by water temperature and density.
- DO depletion often linked to thermal stratification.

In Summary

- Four basic strategies… full vertical lift, partial vertical lift, horizontal mixing, re-oxygenation.
  - Destratification aeration
  - Hypolimnetic aeration
  - Oxygenation

Can actually increase concentration of DO

In Summary

- Full lift, partial lift, and horizontal mixing makes use of compressed air… the compressed air does not inject oxygen into the lake, but rather circulates water column and increases contact of water with atmosphere or mixing of O2 rich and O2 poor water.
- Oxygenation techniques inject or mix O2 with the water.

In Summary

- Use data to determine which strategy is best suited for your lake… define your goals and evaluate how best to achieve desired end result… do your homework.
- When properly sized and installed can greatly improve water quality and restore or maintain habitat.
- Part of HAB abatement, control and management plan.

More Information

NALMS™ NORTH AMERICAN LAKE MANAGEMENT SOCIETY

www.nalms.org

NYSFOLA

New York State Federation of Lake Associations

More Information

Thank You… Questions

Stephen J. Souza, Ph.D.

Clean Waters Consulting, LLC
Ringoes, NJ 08551
SJSouza.CWC@gmail.com

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