Hazen

THE VOICE OF THE RIVER
SINCE 1984
HENRY'S FORK FOUNDATION

# Hypolimnetic Oxygenation System Evaluation: Alternatives Analysis

Alex Gerling and Ricky Wood, Hazen and Sawyer

November 18, 2025

# Agenda

- Introductions
- Project Objectives
- Data Reconaissance
- Basis of Design
- Alternatives Analysis
- Recommendations

# Project Objective

*Improve water quality and fish habitat in Island Park Reservoir by evaluating oxygenation, aeration, and destratification strategies*

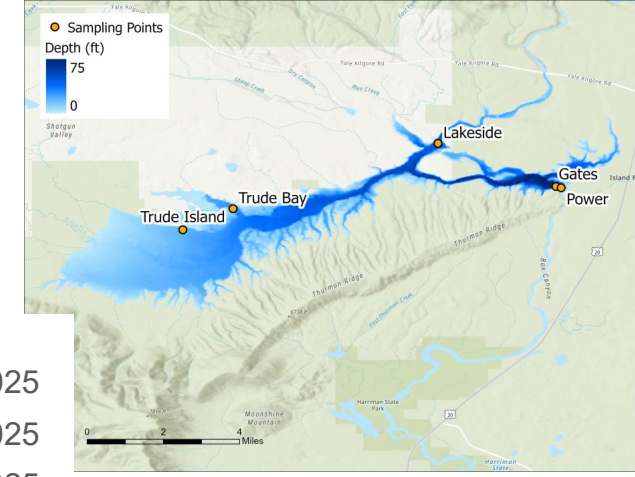
# Key Definitions

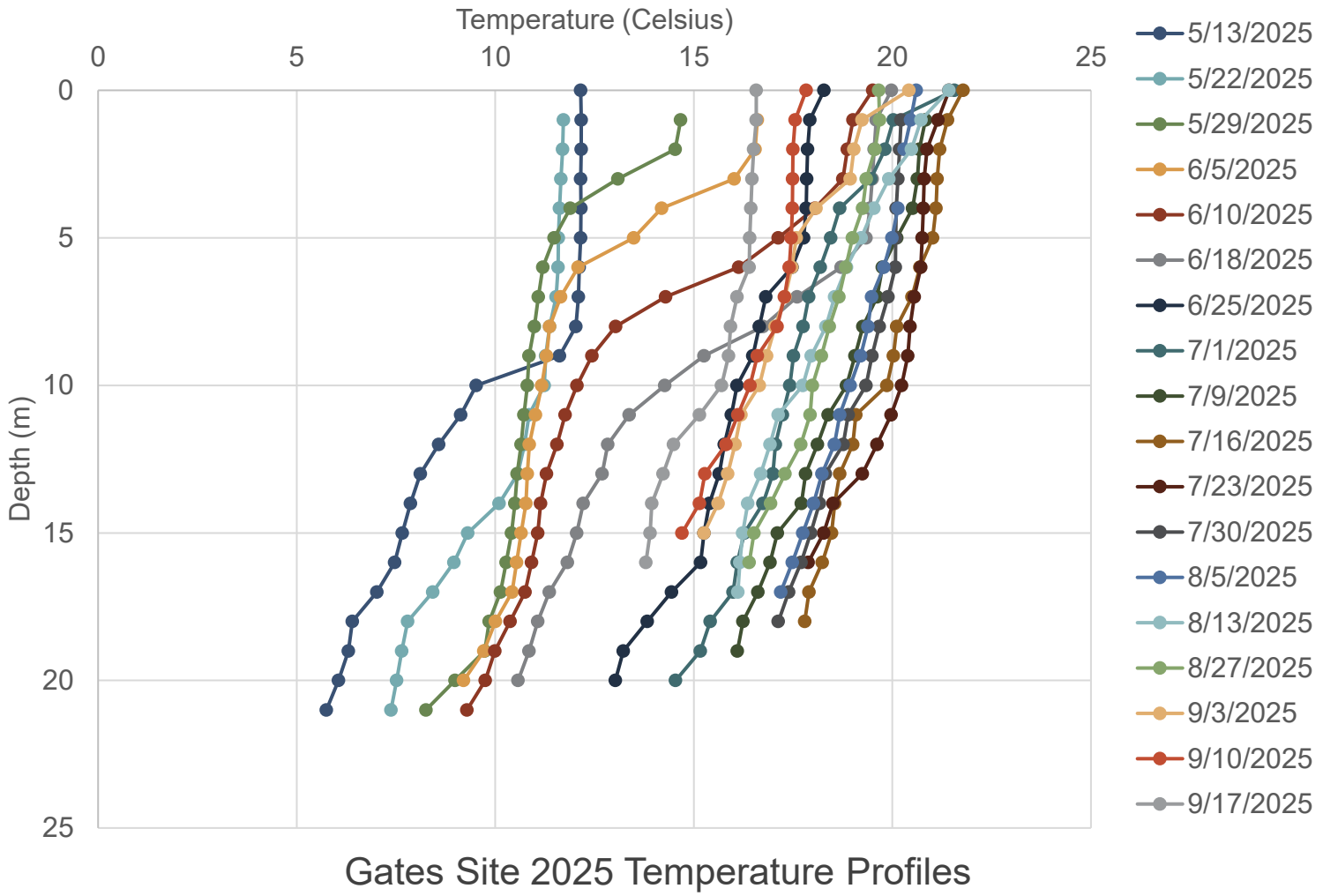
- **Stratification** = Development of distinct water layers, occurring seasonally due to warm air temperatures: Warm, surface water and cold, deep water
- **Thermocline** = Transition layer between warm, surface water (less dense) and cold, deep water (more dense)
- **Epilimnion** = Upper layer of stratified lake above the thermocline
- **Hypolimnion** = Lower layer of stratified lake below the thermocline (when deprived of surface contact, DO depletes)
- **Anoxia** = DO conditions < 0.2 mg/L
- **Hypoxia** = DO conditions < 3 mg/L
- **Hypolimnetic anoxia/ hypoxia** = Low DO concentrations in the bottom waters of a lake during stratification

# Data Reconaissance

# Profiles: Temperature

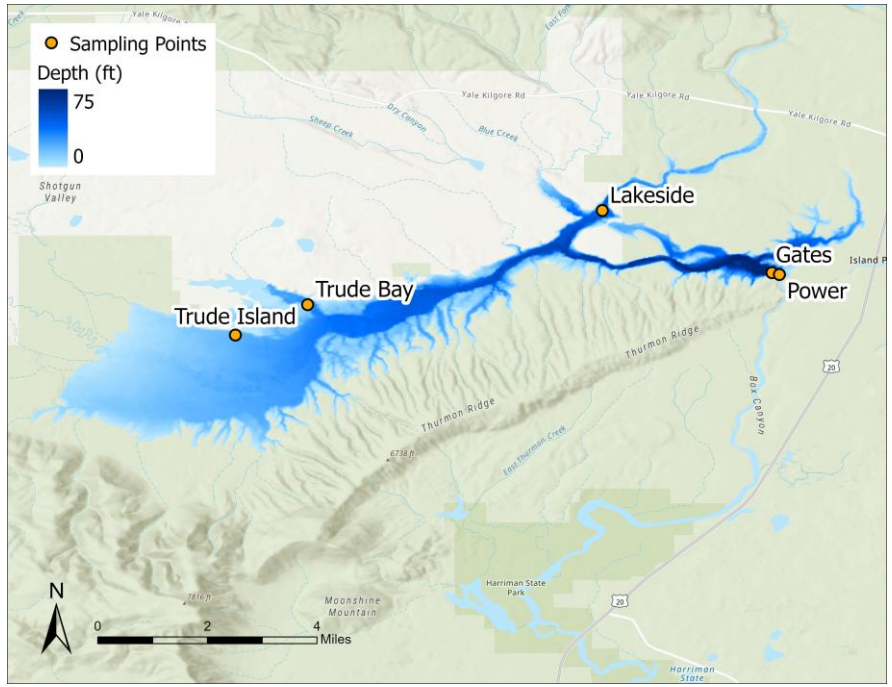
- Reservoir withdrawal disrupts thermal stratification

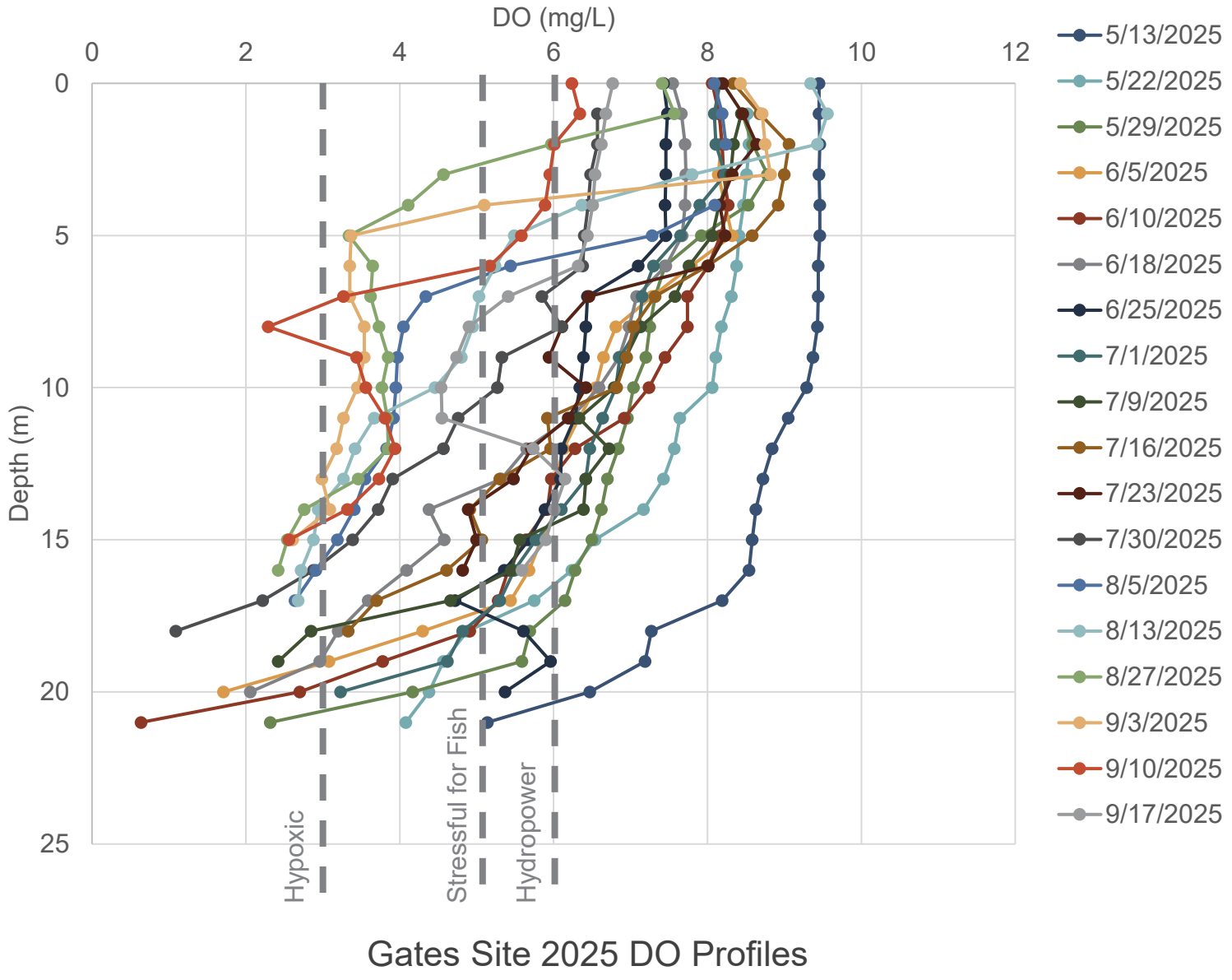


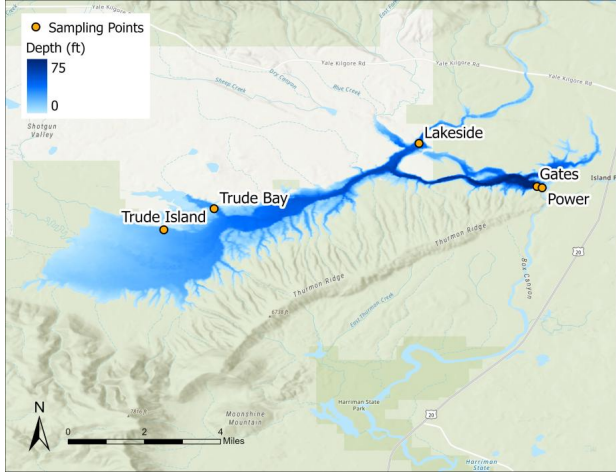
# Profiles: Dissolved Oxygen

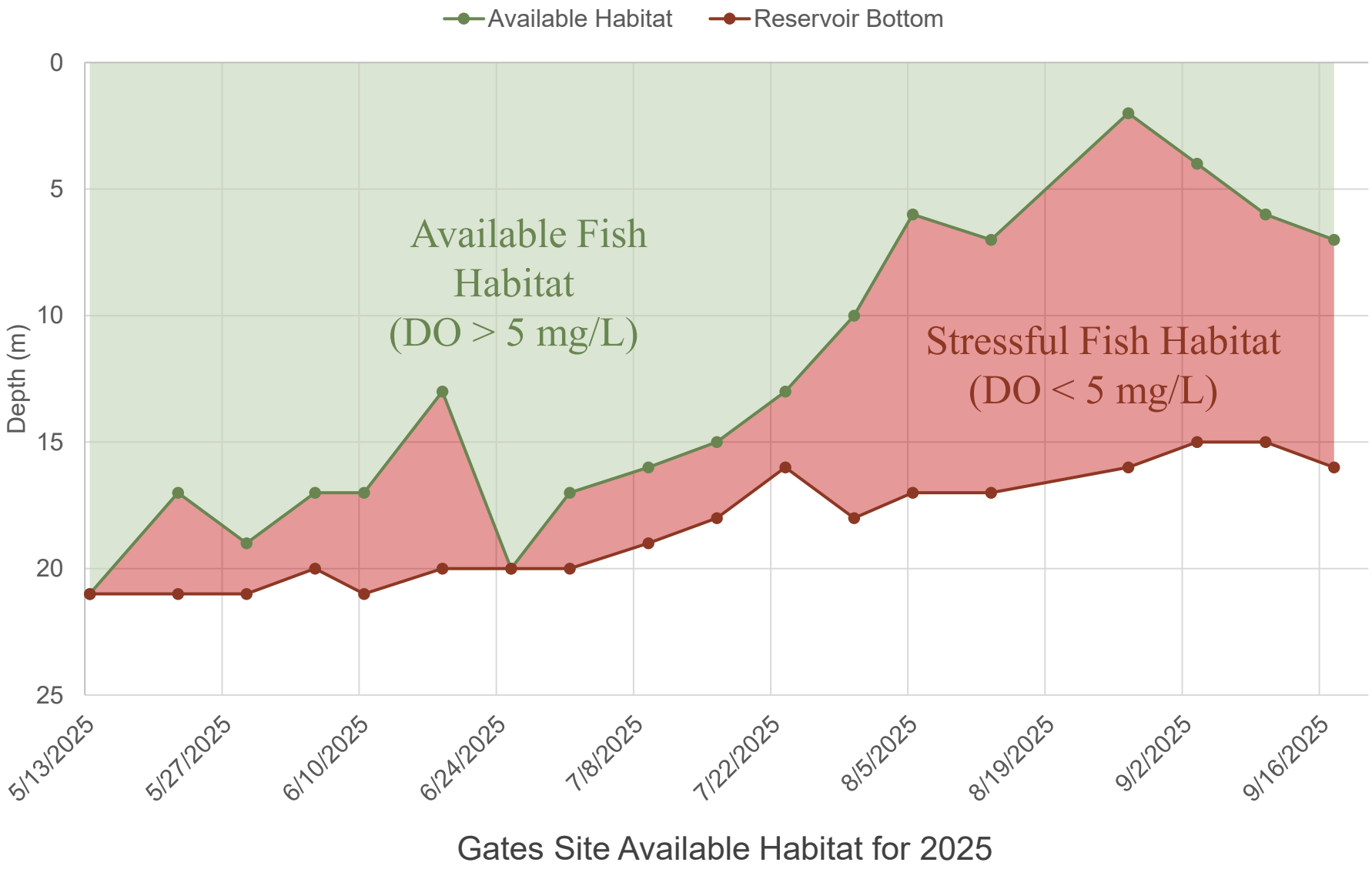
- DO levels are low but not “hypoxic”
  - **Hypoxia: DO < 2 mg/L**
- Hydropower generation DO > 6 mg/L
- Fish populations: Bare minimum DO > 5 mg/L, ideally higher
  - **Depends on life cycle period**



# Profiles: Dissolved Oxygen




Gates Site Available Habitat for 2025

# Carlson's Trophic State Index

*Multi-parameter assessment of system productivity and estimate eutrophication*

*Chlorophyll-a*

$$TSI_{Chla} = 9.81 \ln Chl_a + 30.6$$

*Total Phosphorus*

$$TSI_{TP} = 14.42 \ln TP + 4.15$$

*Secchi Disk*

$$TSI_{SD} = 60 - 14.41 \ln SD$$

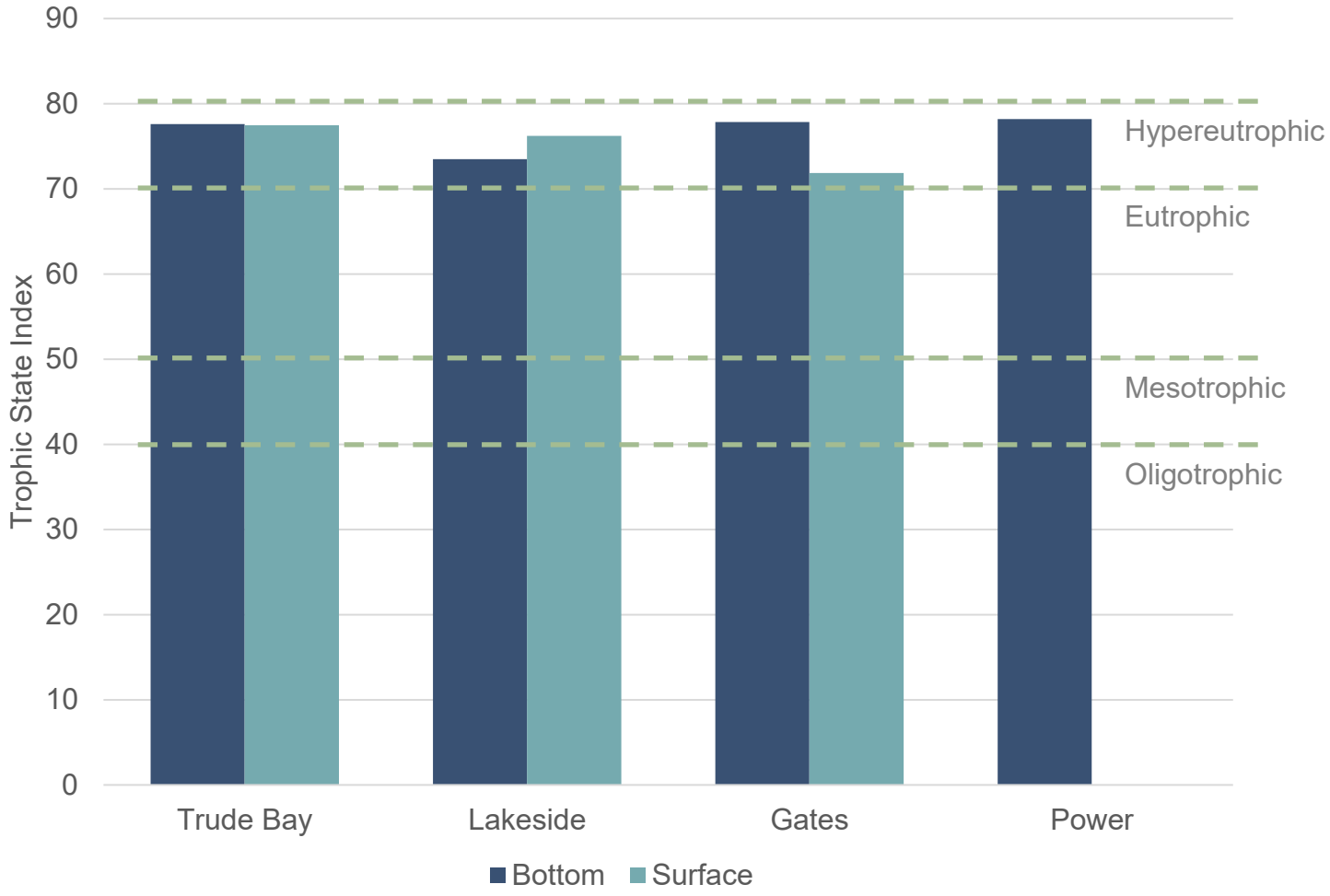
*Rating System**

| Trophic State Index (TSI) | Category | Attributes | Impact to Fisheries |
|---|---|---|---|
| 0 – 40 | Oligotrophic | High transparency, and well-oxygenated hypolimnion | Salmonid fisheries dominate |
| 40 – 50 | Mesotrophic | Moderate transparency, increased probability of anoxic hypolimnion | Hypolimnetic anoxia results in loss of salmonids. Walleye may predominate |
| 50 – 70 | Eutrophic | Anoxic hypolimnion, cyanobacteria dominance, algal scums | Warm-water fisheries. Bass may dominate |
| > 70 | Hypereutrophic | Dense algal scums and blooms, light limited | Rough fish dominate; summer fish kills possible |

**North American Lake Management Society (NALMS)*

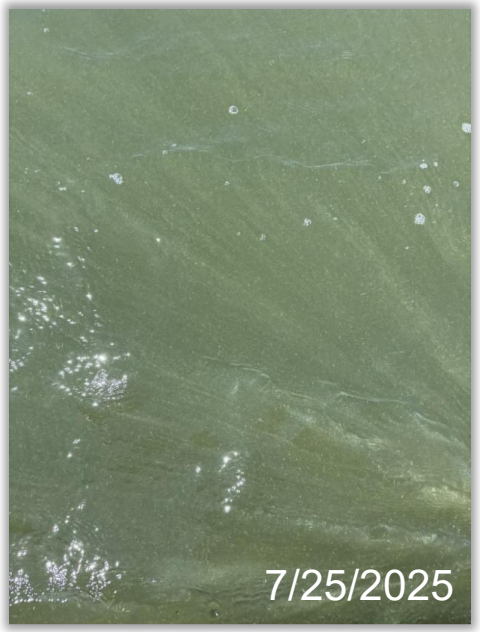
# Trophic State Index: TP

- TSI in Island Park Reservoir is ***hypereutrophic*** using total phosphorus
- High phytoplankton growth, likely causing oxygen depletion and other ecological impacts



# Overview of Nutrients

- TP very high throughout water column
  - **Key macronutrient for phytoplankton growth**
- Ammonia and Orthophosphate are elevated
  - **Ammonium is preferred source of nitrogen and can be rapidly consumed by cyanobacteria**
  - **Orthophosphate is the biologically available form of P that supports rapid growth**

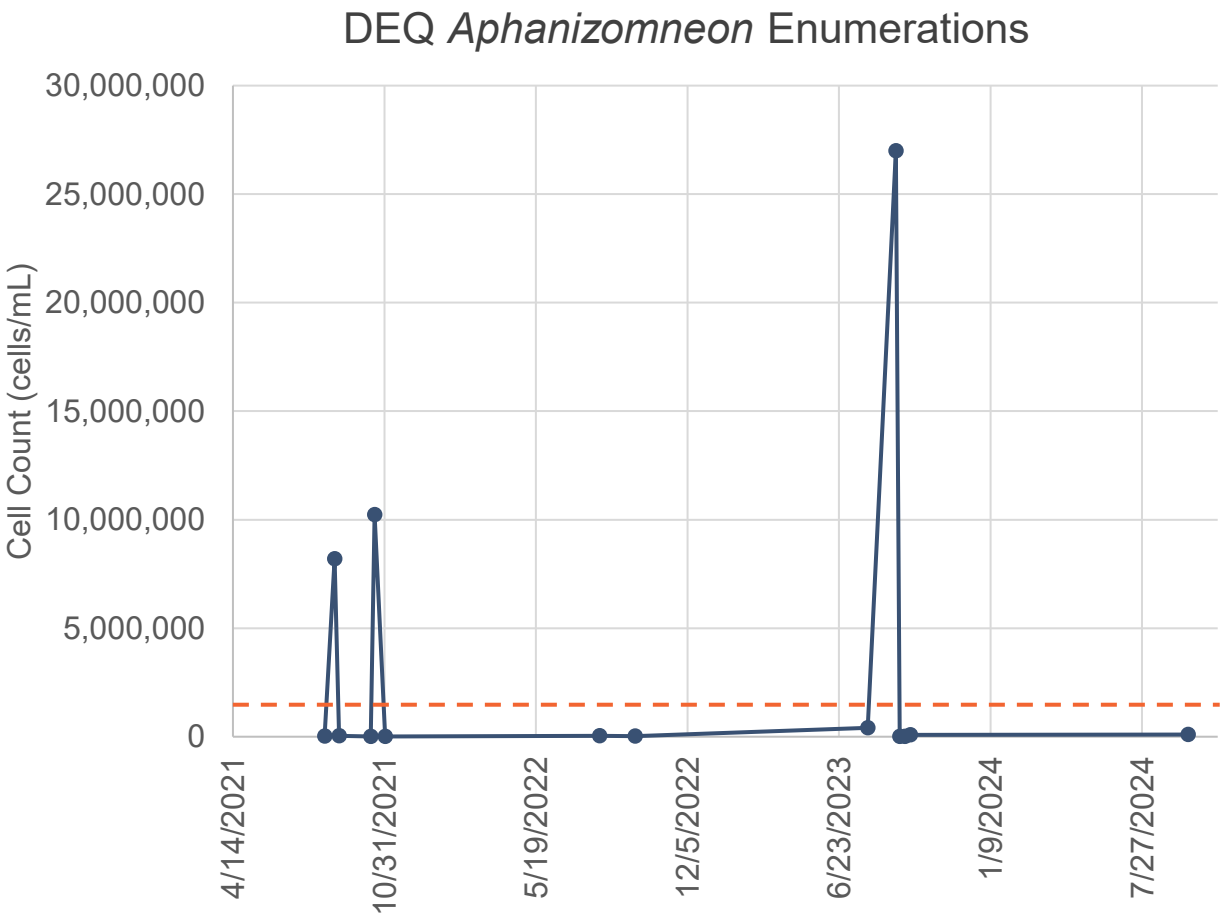


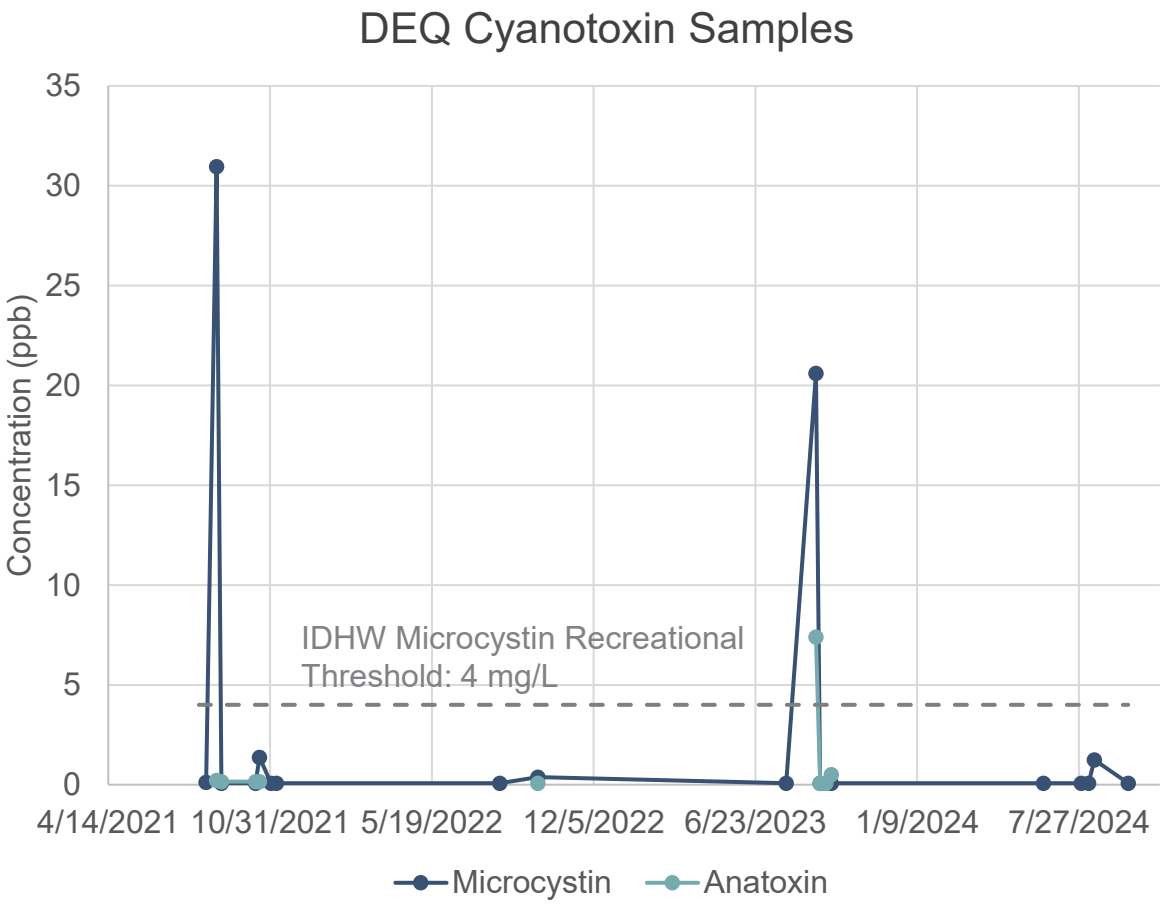


| Parameter | 2025 Seasonal Average |
|---|---|
| Total Phosphorus (mg/L) | 0.171 |
| Total Nitrogen (mg/L) | 0.30 |
| Ammonia (mg/L) | 0.110 |
| Nitrate & Nitrite (mg/L) | 0.035 |
| TKN (mg/L) | 0.26 |
| Orthophosphate (mg/L) | 0.015 |

# Historical Phytoplankton and Cyanotoxins

**Pending results from 2025 Enumerations and Cyanotoxins Analysis**



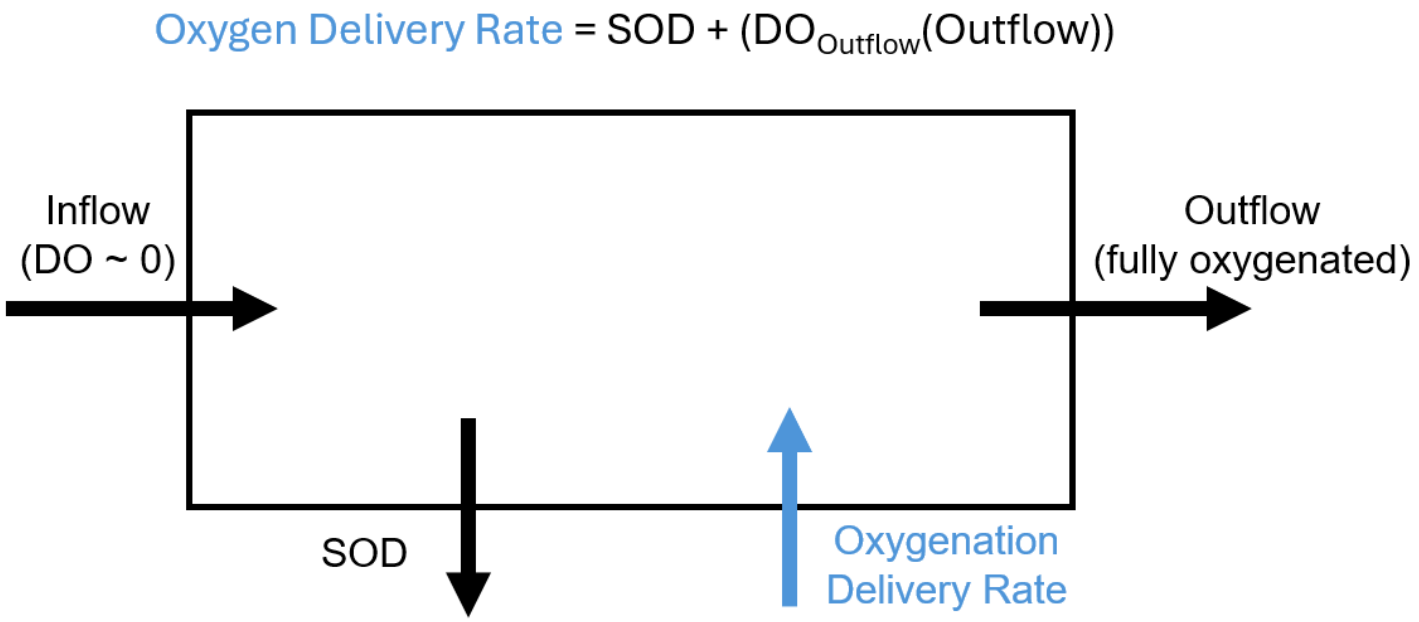




*EPA and WHO defines a HAB as >20,000 cells/mL*

# Basis of Design

# Oxygen Delivery Rate

- Key metric for system sizing and feasibility
- For Island Park Reservoir, three main factors:
  - **Sediment Oxygen Demand**
  - **Reservoir Outflows**
  - **Desired Dissolved Oxygen Concentration**



# Sediment Oxygen Demand

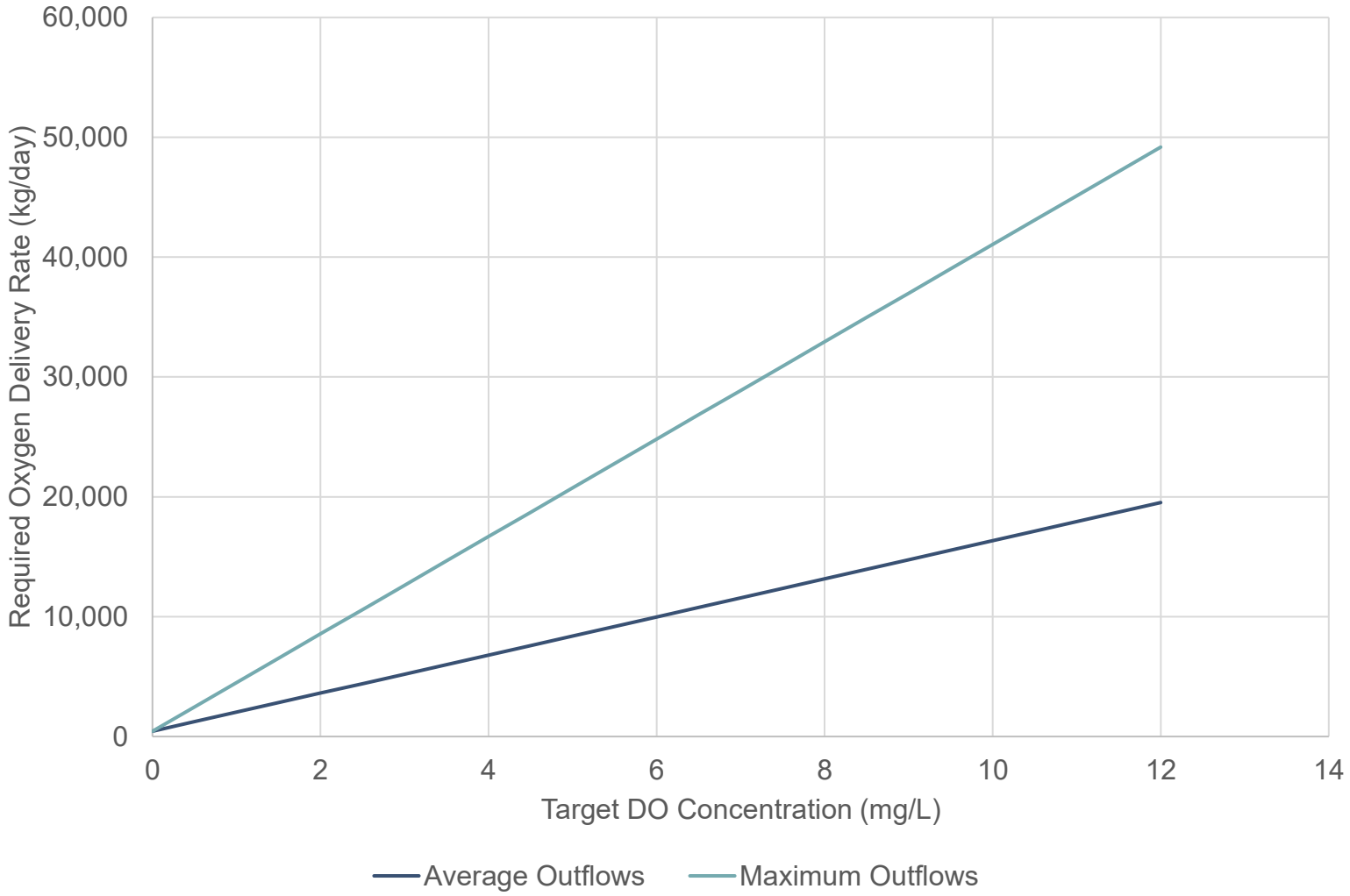
CLARITY RESOURCES GROUP
Oxygenation & Aeration Specialists

*Sediment Oxygen Demand (SOD) is the rate of oxygen depletion caused by biological and chemical oxygen consumption in the sediment (decomposition, nitrification, oxidation)*

- Sampling completed in June 2025 at Gates and Lakeside sites
- Statistical corrections applied:
  - Settling of chambers at site 1
  - Loss of Water Column Oxygen Demand data at site 2
  - Temperature correction: 12 -> 15 C
- **Recommended SOD for design: 1.15 g/m$^2$-day**

# Outlet Flows

- Two outlet flow conditions:
  - **Average Flow: 650 cfs**
  - **Maximum Flow: 1,660 cfs**
- Two DO Conditions
  - **Aquatic Life Criteria: 5 mg/L**
  - **Hydropower Criteria: 6 mg/L**
- Maximum outflow is used to assess feasibility and system sizing
- Average outflow is used for operations and maintenance analysis



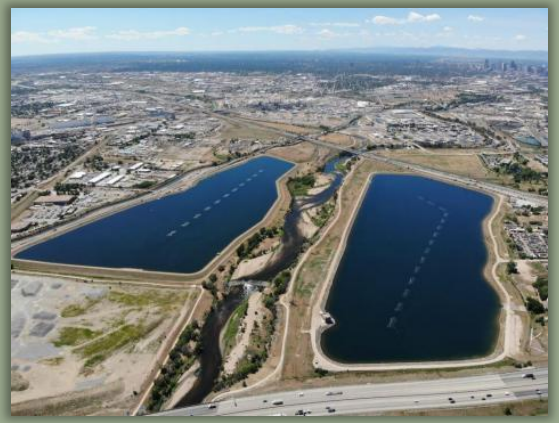
# Oxygen Delivery Rates

- Hydrologic Flows dominate oxygen depletion in preliminary analysis
- Effect of DO concentration on maximum delivery is substantial
  - **Can be mitigated if minimum desired DO is less than average desired DO**
- Sediment Oxygen Demand was nearly negligible for this analysis, but further study is recommended

| Parameter | 5 mg/L (Aquatic Life Criteria) | | 6 mg/L (Hydropower Criteria) | |
|---|---|---|---|---|
| | Average Outflow (650 cfs) | Maximum Outflow (1,660 cfs) | Average Outflow (650 cfs) | Maximum Outflow (1,660 cfs) |
| **Oxygen Depletion from SOD (kg/day)** | 439 | 439 | 439 | 439 |
| **Oxygen Depletion from Outflow (kg/day)** | 7,951 | 20,309 | 9,542 | 24,371 |
| **Total Oxygen Delivery Rate (kg/day)** | **8,391** | **20,748** | **9,981** | **24,810** |

# Alternatives Analysis

# Overview of Alternatives Considered



*Diffused Air / Destratification*

- Aeration
- Uses high and low flux sections to provide direct and indirect DO infusion
- Destratifies

*Speece Cone*

- Oxygenation
- 2 options: submerged or on shore application
- Utilizes a chamber to produce oxygenated water that is then reintroduced to the lake
- Maintains stratification

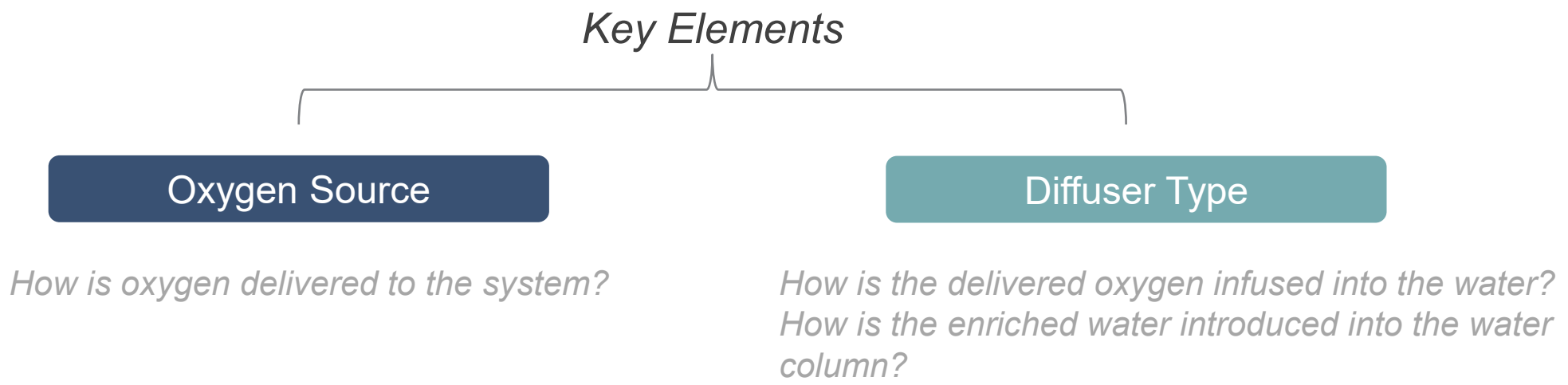
*Free Bubble Oxygenation*

- Oxygenation
- Utilizes linear micropore hose diffuser to introduce DO into the hypolimnion
- Maintains stratification


*Oxygen Saturation Technology*

- Oxygenation
- New technology with limited field applications
- Modular submerged chambers that generate supersaturated water that is then reintroduced to the lake
- Maintains stratification

# Key Elements of Alternatives Considered



# Combating Anoxia Requires the Infusion of Dissolved Oxygen

*Key Elements*

**Oxygen Source** — *How is oxygen delivered to the system?*

- **Pure Oxygen** ← *FBO Speece Cone*
  - **Liquid Oxygen (LOX)**
    - **Lease**
    - **Own**
  - **Onsite Generation (PSA)** — *OST*

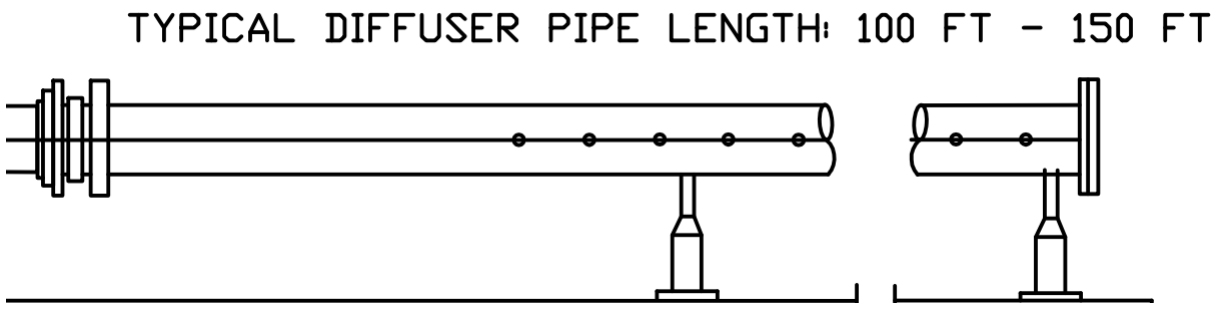
- **Compressed Air** — *DA/D*

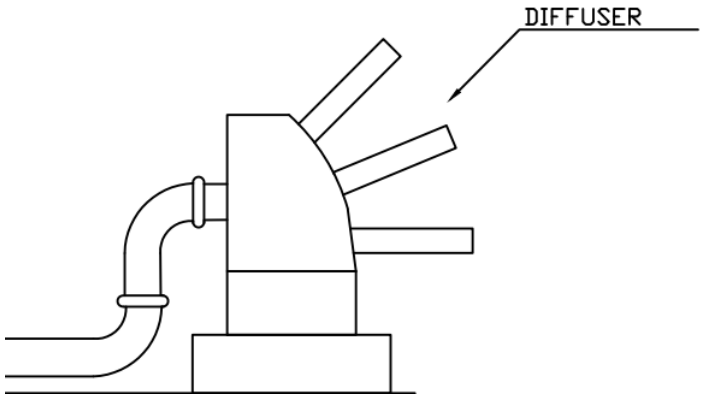
# Combating Anoxia Requires the Infusion of Dissolved Oxygen

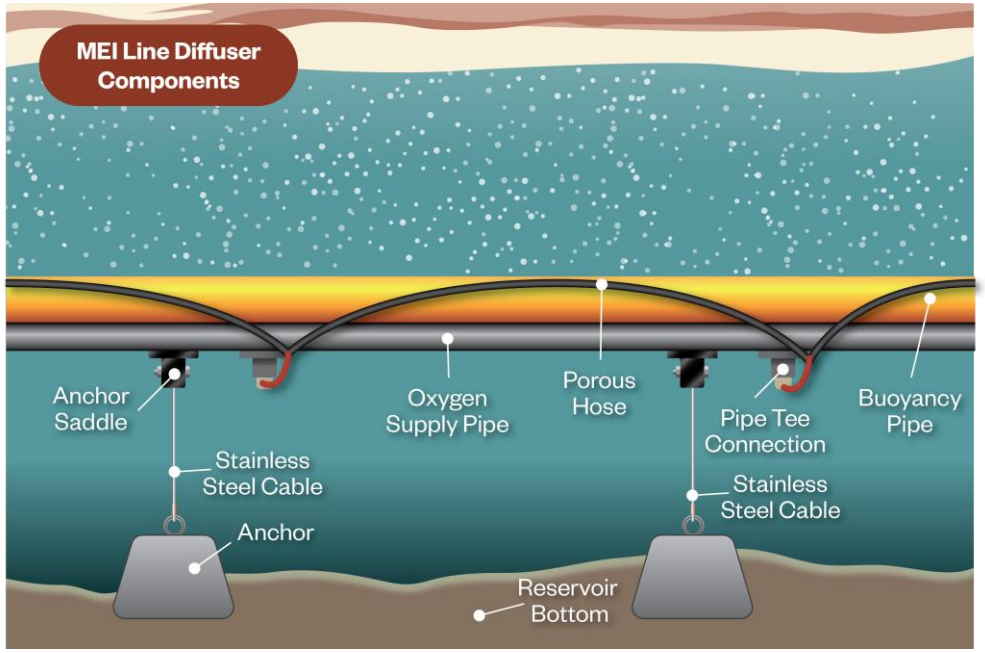
**Key Elements**:

**Diffuser Type**

- **Linear hose diffuser line (micropore)**
  - *DA/D, FBO*
- **Effluent canon (multi-port diffuser)**
  - *SC*
- **Engineered slotted pipe (multi-port diffuser)**
  - *SC, OST*



# Overview of Alternatives Considered: Oxygen Supply

| Technology | Vendor | Type of System | Oxygen Supply | Diffuser Type |
|---|---|---|---|---|
| Diffused Air / Destratification (DA/D) | Mobley Engineering Inc. (MEI) | Aeration | Compressed Air | Linear hose diffuser line |
| Free Bubble Oxygenation (FBO) | Mobley Engineering Inc. (MEI) | Oxygenation | LOX* | Linear hose diffuser line |
| Speece Cone | $ECO_2$ | Oxygenation | LOX* | Slotted Pipe or Effluent Canon |
| Oxygen Saturation Technology (OST) | Clarity Resources Group | Oxygenation | PSA | Slotted pipe |

**Lease LOX equipment*

# Recommended Alternative

**Free Bubble Oxygenation (FBO)**

- Designed for larger, deeper systems and hydropower facilitation
- Directly oxygenates target area (does not vertically mix)
- Use of LOX and buoyancy line reduced maintenance costs

**Unselected Alternatives:**

- Speece Cone: Potentially viable, but higher maintenance costs, lower delivery rate, and smaller spatial extent
- Oxygen Saturation Technology (OST): Less field-verified applications, not practical for large delivery rates
- Diffused Air/Destratification (DA/D): Not feasible for reservoir size and depth

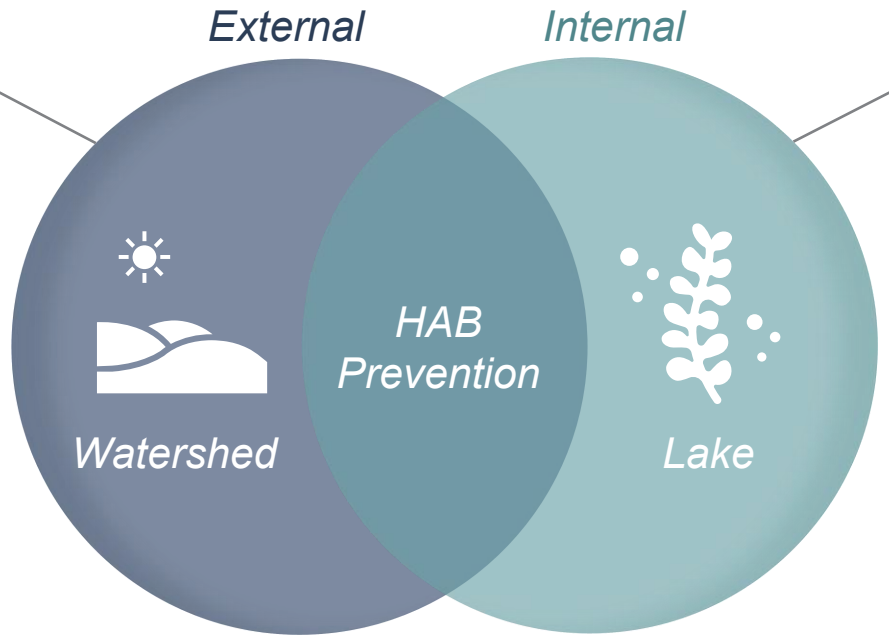
# Recommendations

# Core Components of Source Water Protection and Management

**No one "Silver Bullet" Solution**

## Source Water Protection

- Maintain quality of receiving waters
- Offset anthropogenic impact
- Watershed based




## Source Water Management

- Restore or maintain quality of source water
- Buffer impact of external influences
- In situ management

***Protection ≠ Management***

# Recommended Source Water Protection and Management Efforts

**No one “Silver Bullet” Solution**

## Source Water Protection

- Septic Systems
- Cattle Ranching
- Phosphorus Mine Inventory

## Source Water Management

- Routine Monitoring and Reservoir Assessment
- Recreation
- Algaecide Application
- Multi-Level Outlet

# Source Water Protection: Septic Systems

**Objective:** ***Assess septic systems condition to confirm or rule out their contribution to nutrient loads.***

**Key Actions**

- Conduct a septic systems inventory
- Engage Fremont County for data collection
- Conduct homeowner outreach

# Source Water Protection: Cattle Ranching

**Objective:** ***Assess the feasibility of agricultural BMPs to reduce water quality impacts and improve safety of herds***

**Key Actions**

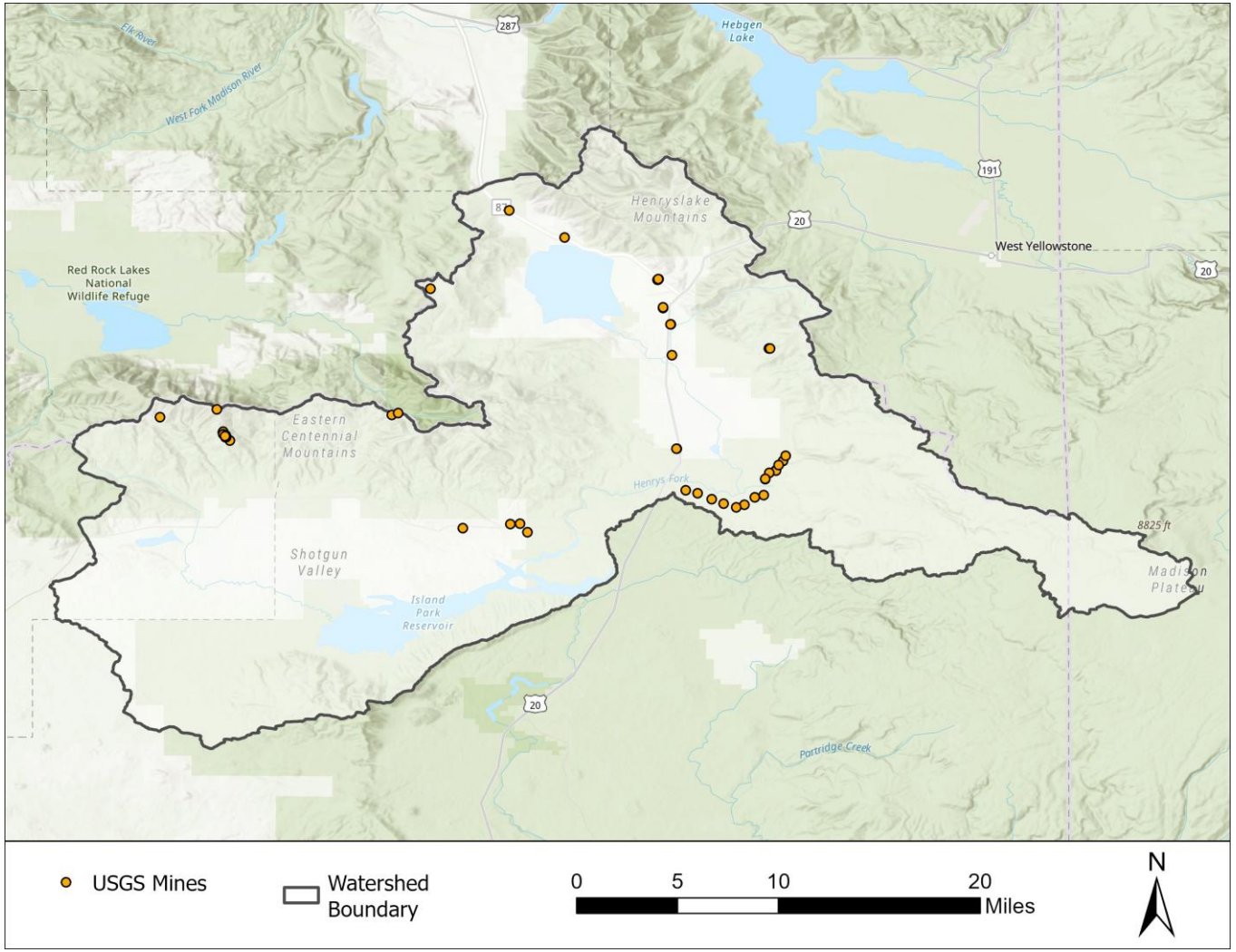
- Collaborate with landowners to determine best course of action
- BMP options:
  - **Vegetated buffer**
  - **Fence**
  - **Grazing rotation/herding improvements**
- Emphasize mutual benefit of keeping cattle away from water

# Source Water Protection: Phosphorus Mines Inventory

**Objective:** ***Assess the extent to which historical mines present a risk to water quality.***

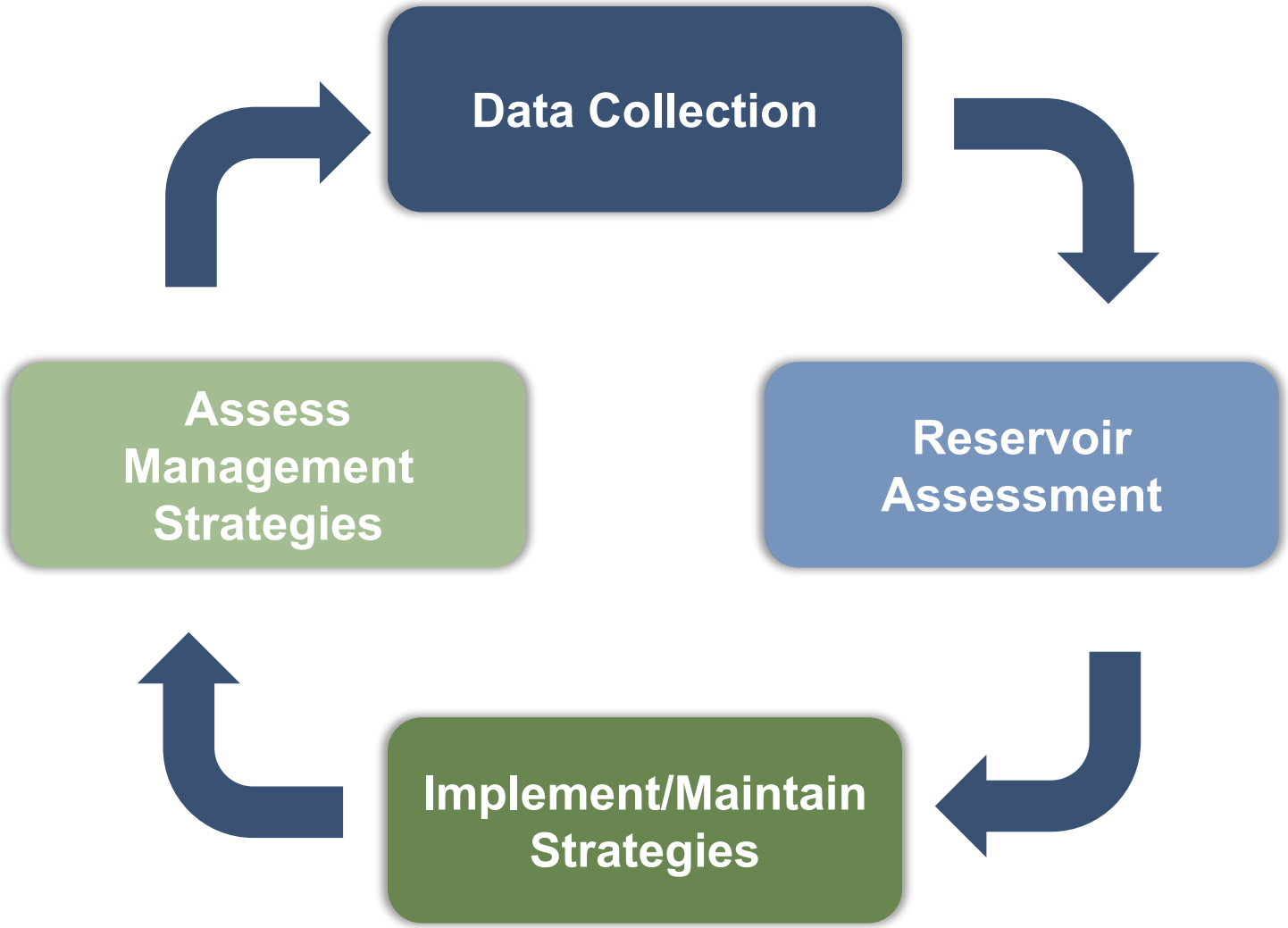
## Key Actions

- Compile a mine inventory
  - **USGS Mineral Resources, State Programs**
- Conduct field surveys to assess site conditions
- Prioritize sites for remediation
- Monitor streams near sites of concern



# Source Water Management: Routine Monitoring & Reservoir Assessment

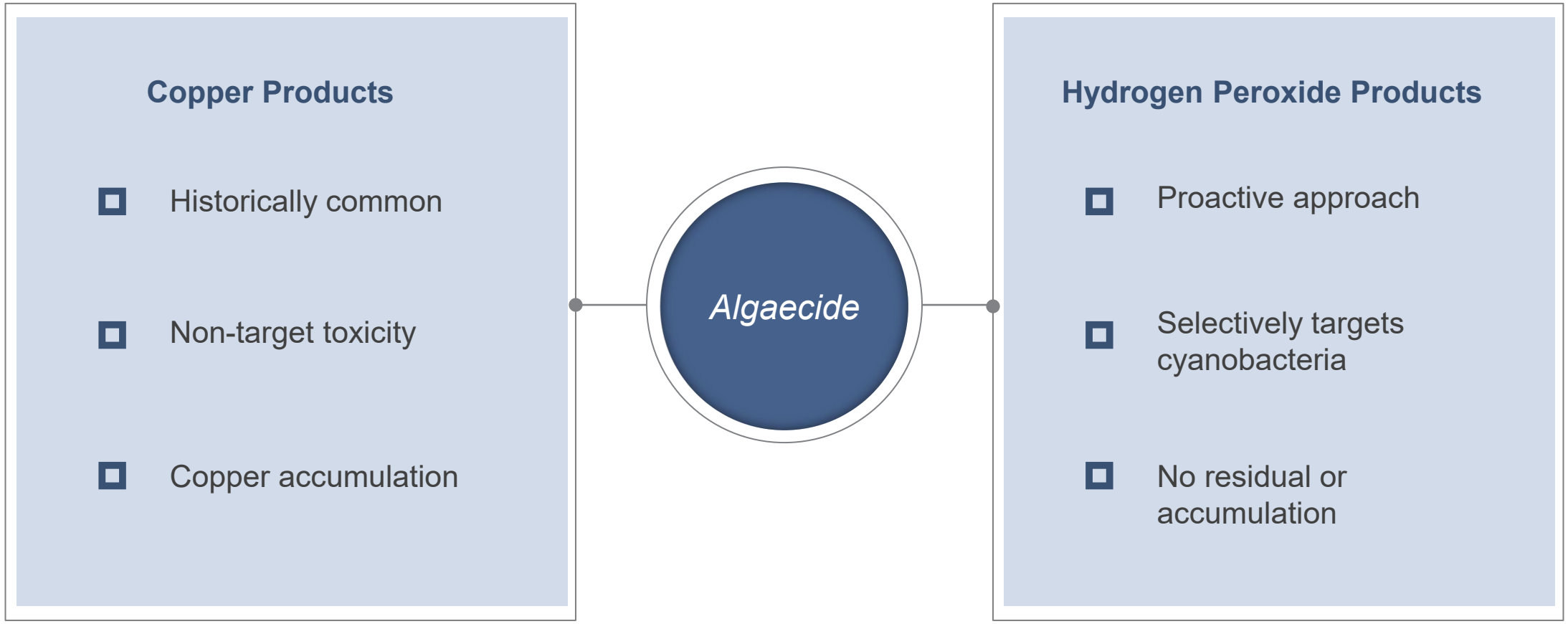
- Continue routine monitoring
- Understanding the limnology of Island Park Reservoir is key to assessing solutions
- Long-term management will require the use of multiple strategies in conjunction



# Source Water Management: Recreation

- Sediment resuspension from motorized watercraft likely impacting water quality
  - **Increases HAB risk**
- Recent U of Minnesota study demonstrated sediment resuspension up to 10 feet depth
  - **20 feet for wakeboats**
- Regulations would likely have a substantial impact
  - **No wake zones**
  - **Designated recreation zones**
  - **Educational signage**
- HABs present a risk to recreators
  - **Advisory signage recommended if cyanotoxin thresholds are exceeded**

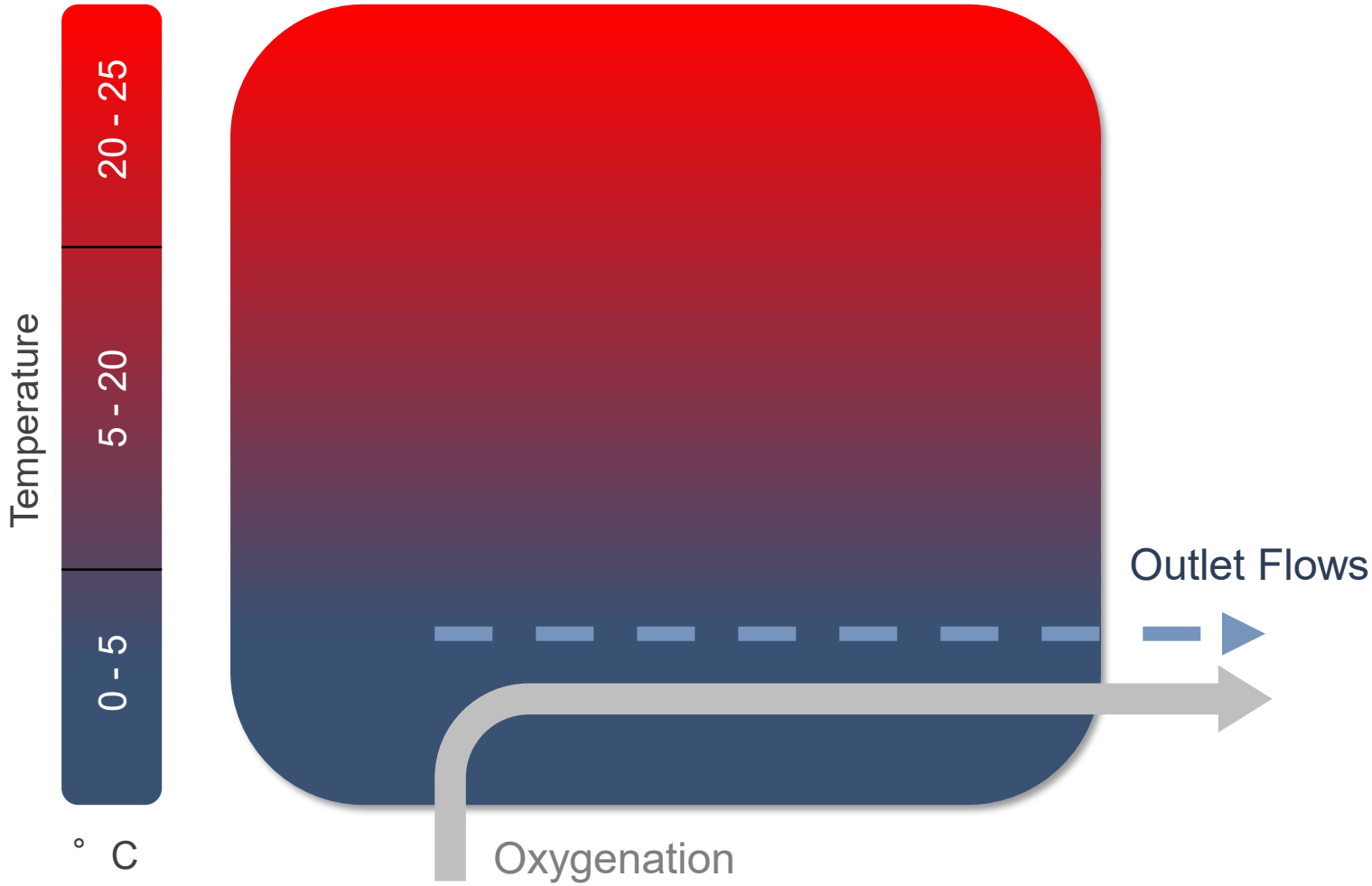
# Source Water Management: Algaecide Application




*Approach to treatment timing and areas are different based on type of product*

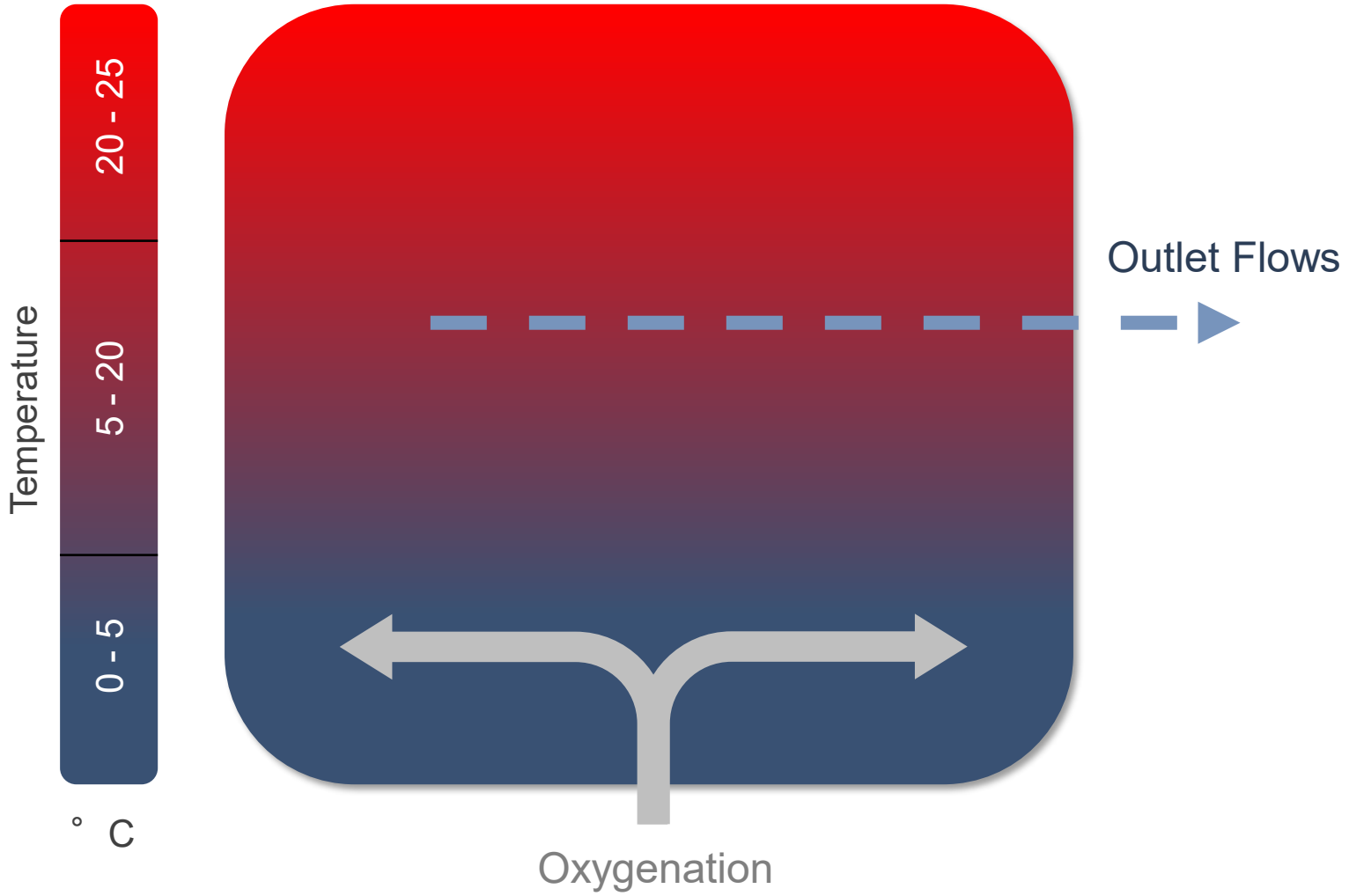
# Source Water Management: Multi-Level Reservoir Outlet

- Improves hydropower operational flexibility
- Allows for temperature control in summer months
- Reduces load on oxygenation system



# Source Water Management: Multi-Level Reservoir Outlet

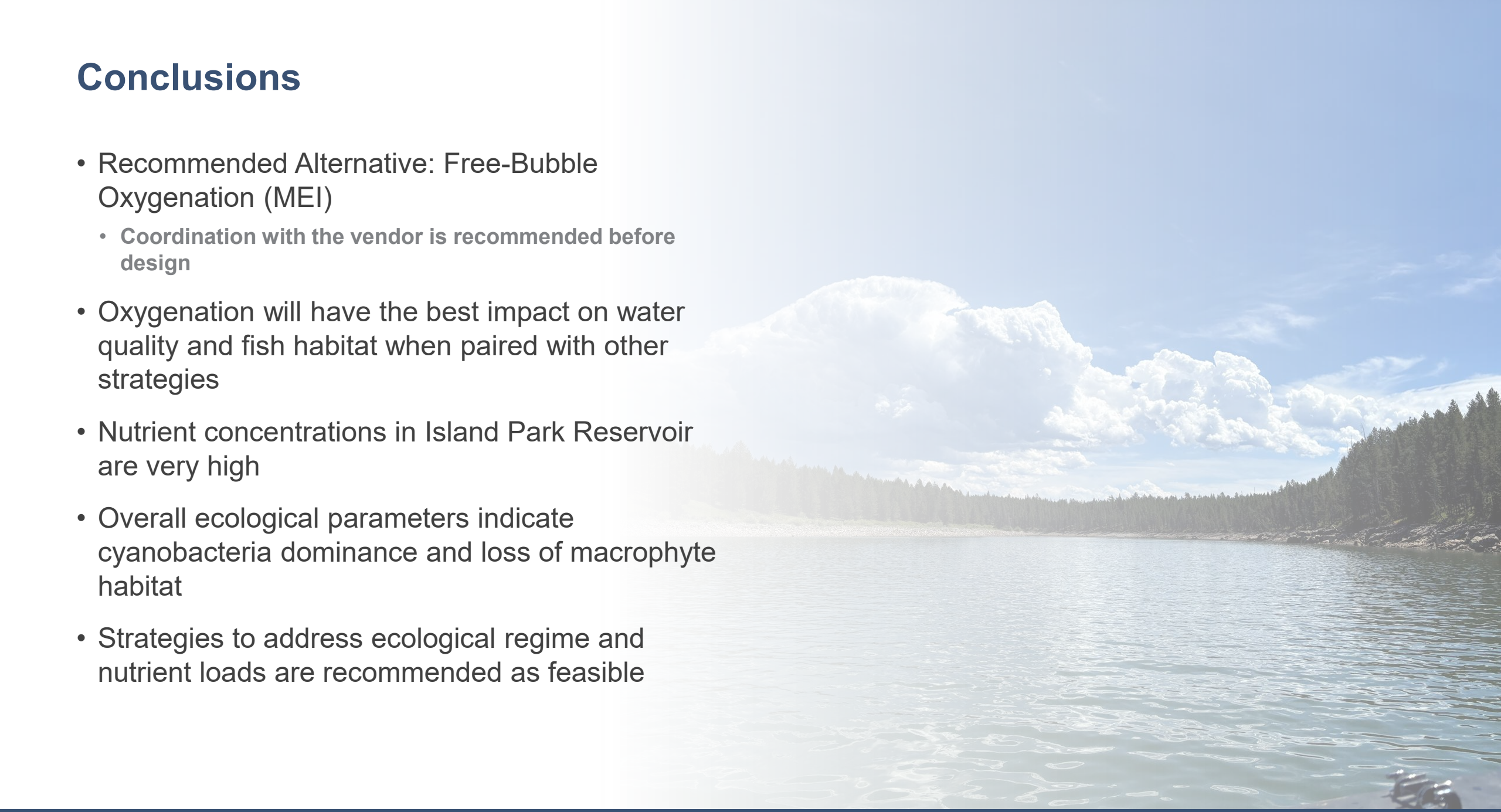
- Improves hydropower operational flexibility
- Allows for temperature control in summer months
- Reduces load on oxygenation system
- Maintains thermal stratification



# Conclusions

# Conclusions

- Recommended Alternative: Free-Bubble Oxygenation (MEI)
  - **Coordination with the vendor is recommended before design**
- Oxygenation will have the best impact on water quality and fish habitat when paired with other strategies
- Nutrient concentrations in Island Park Reservoir are very high
- Overall ecological parameters indicate cyanobacteria dominance and loss of macrophyte habitat
- Strategies to address ecological regime and nutrient loads are recommended as feasible



Hazen

# Onsite Generation (PSA) vs. Liquid Oxygen (LOX)