Potential and Limitations of the Destratification System in Cherry Creek Reservoir

Findings from Data and Modeling

Cherry Creek Stewardship Partners 21st Annual Conference

Hydros Consulting

Christine Hawley

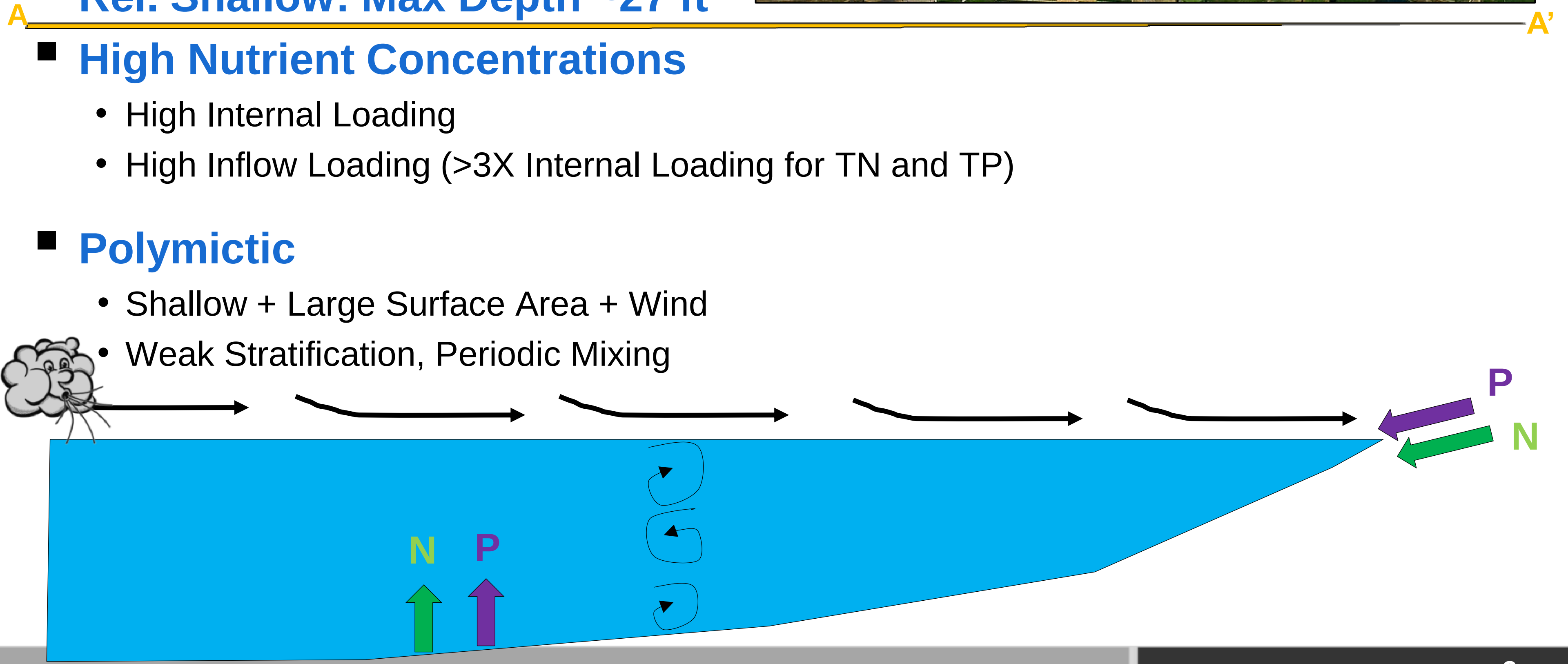
Nov. 6, 2019

Presentation Outline

- **What Is the Water-Quality Concern?**
- **How Was the Destratification System Supposed to Solve It?**
- **Does the Destratification System Meet Its Objectives?**
  - *Why or Why Not?*
- **What Would an Expanded Destratification System Do?**
  - *Numerical Modeling*
- **Summary and Path Forward**

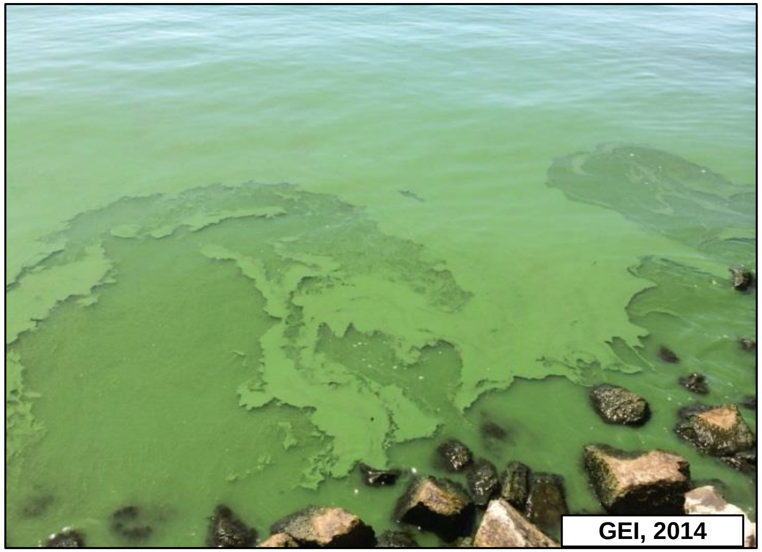
Background

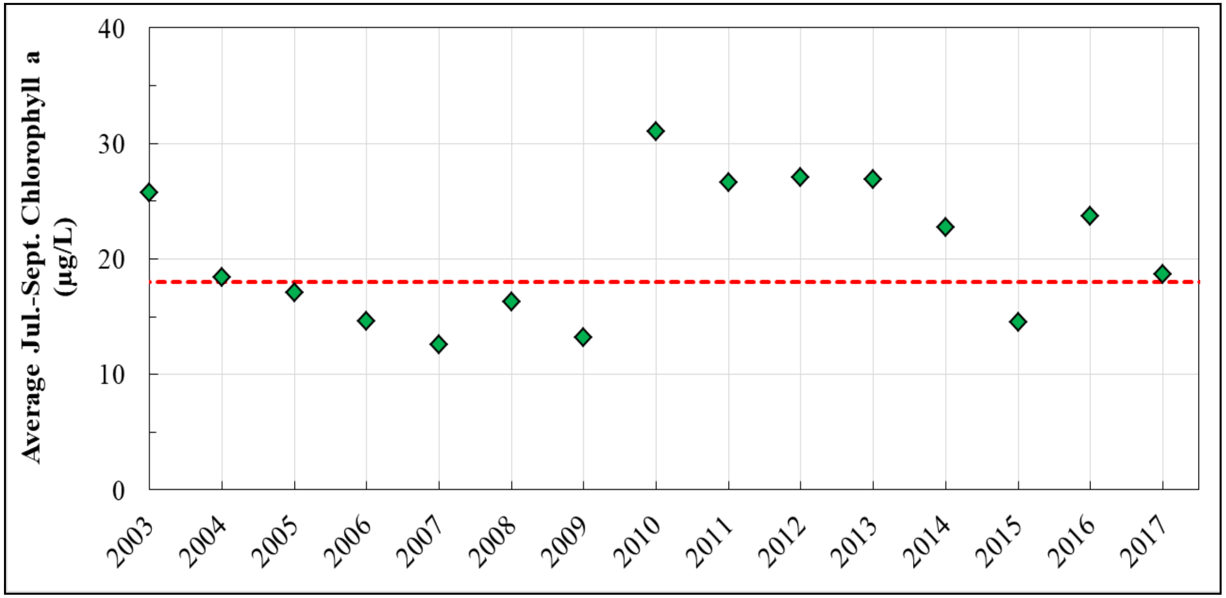
- **Cherry Creek Reservoir**
  - 13,000 Acre ft, 800+ Acres
  - Flood Control
  - Recreation
  - High-Quality Walleye Fishery
- **Rel. Shallow: Max Depth ~27 ft**
- **High Nutrient Concentrations**
  - High Internal Loading
  - High Inflow Loading (>3X Internal Loading for TN and TP)
- **Polymictic**
  - Shallow + Large Surface Area + Wind
  - Weak Stratification, Periodic Mixing



What is the Water-Quality Concern?

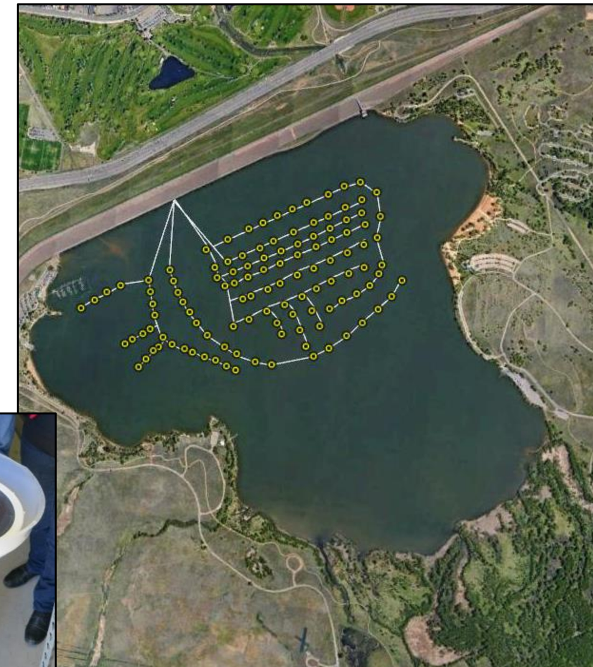
- Chlorophyll *a* > Standard (18 µg/L)
  - Allowable Exceedance Freq. - 1 in 5 Years
  - 9 of 16 Years (2003 – 2017)
- Nuisance Cyanobacteria Blooms
  - Disrupts Recreation
  - Toxin Potential
  - Fish Kills

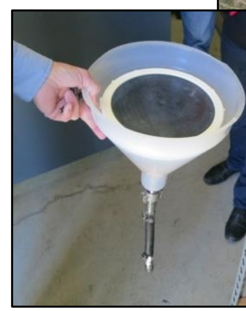




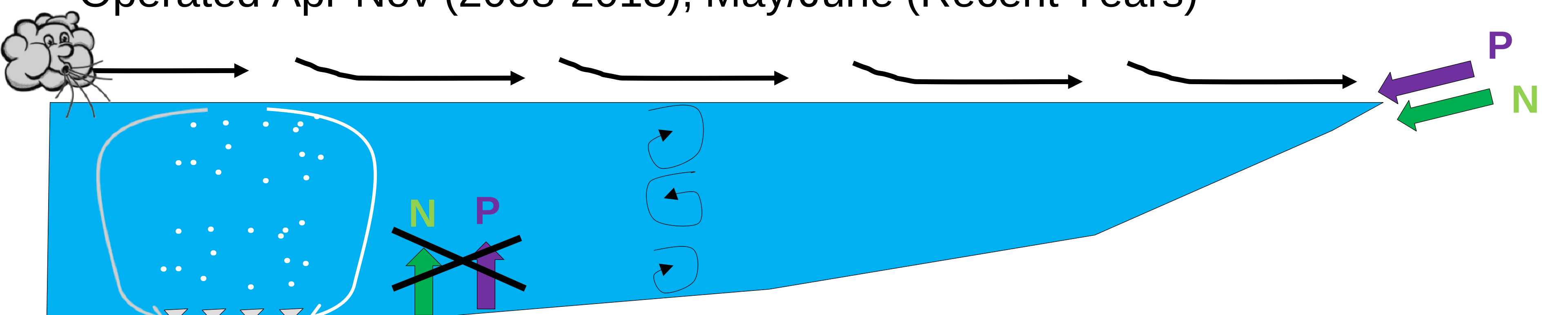
Destratification System

- Destratification System – Installed 2007 (AMEC, 2005)
- System Consists of:
  - 116 Diffuser Heads ~0.5 m above Bottom
  - Air Compressor
  - 2.4 SCFM Air Flow Per Head
  - Objectives: 1. Increase DO at Bottom to 5 mg/L (to Decrease Internal Loading)
    2. Decrease Chl *a* (by 8 µg/L Summer Avg.)
    3. Decrease Cyanobacteria



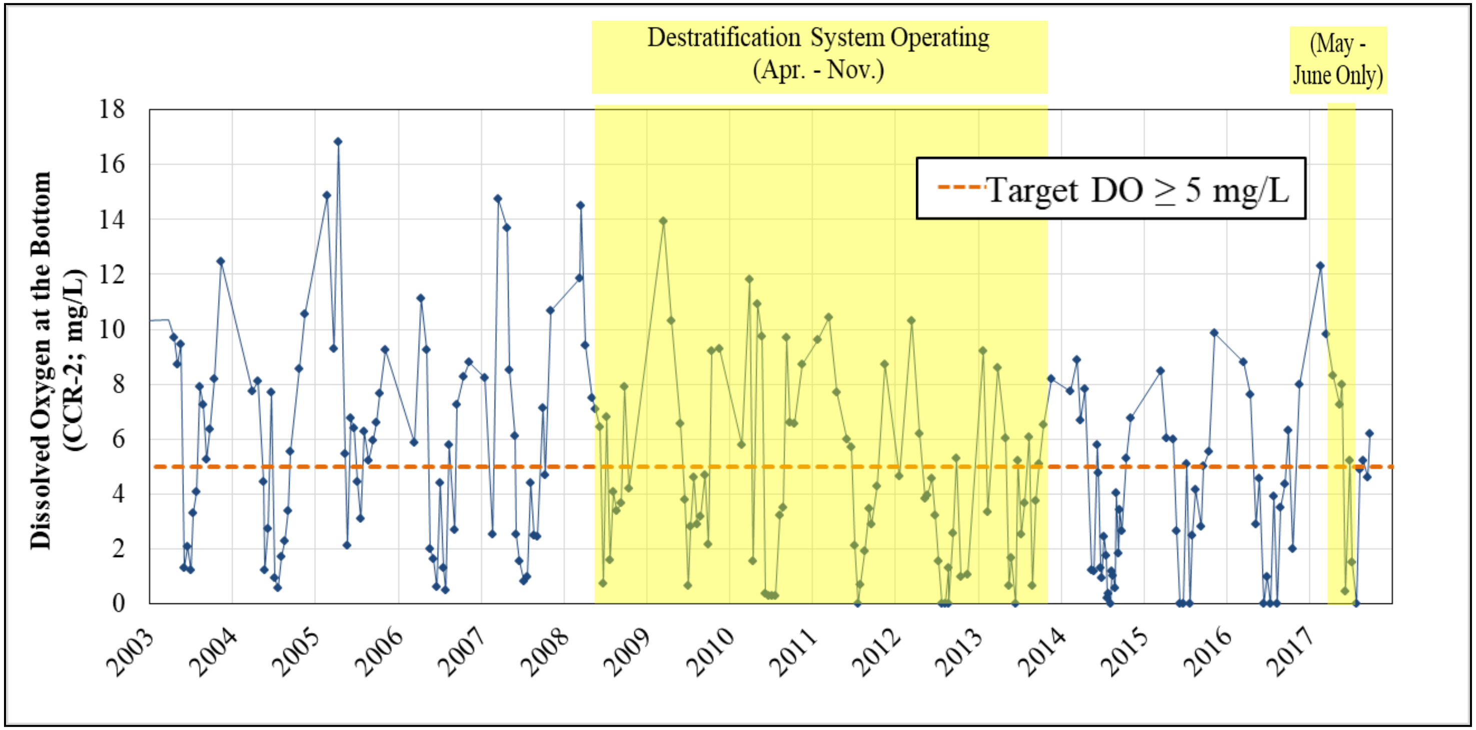


- Operated Apr-Nov (2008-2013), May/June (Recent Years)



Destratification System – Meeting Objectives?

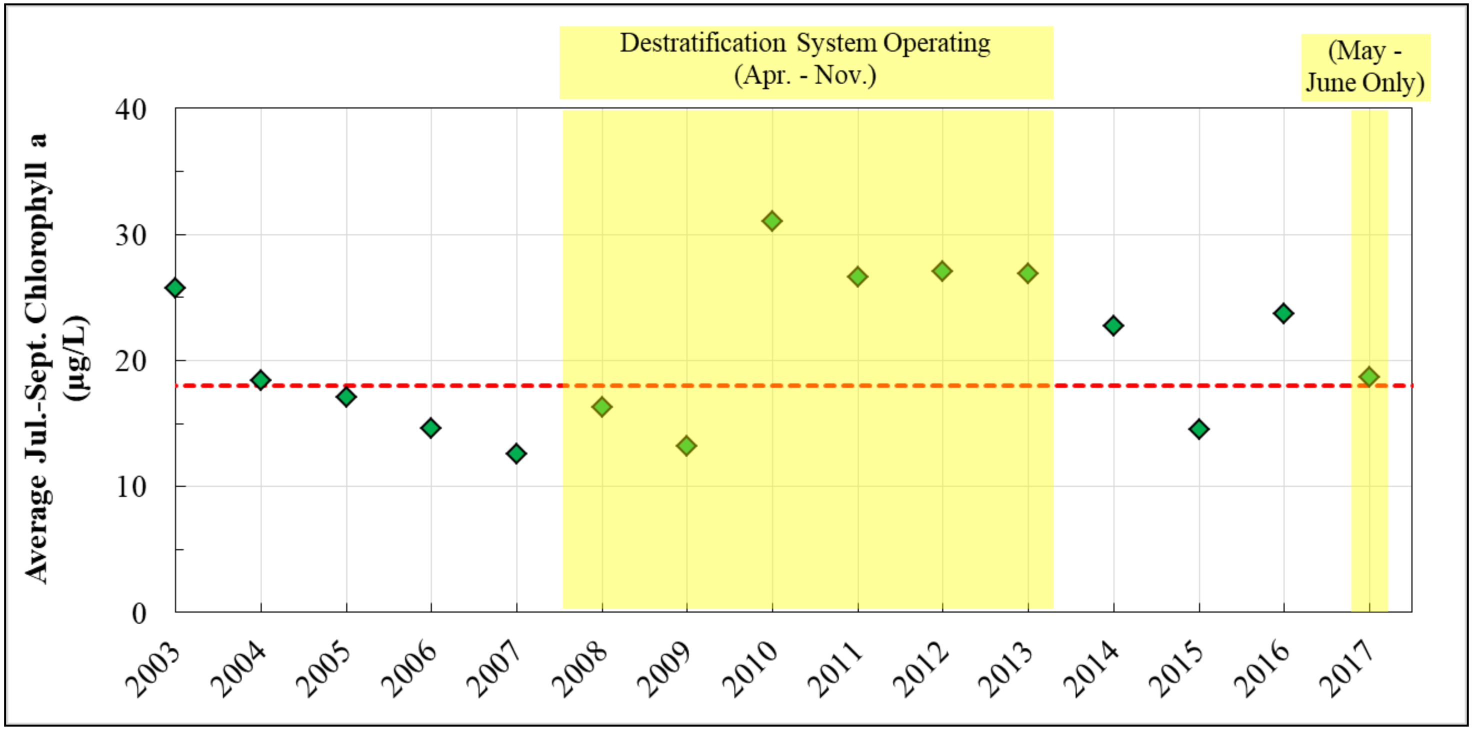
- Objective 1: Increase DO at Bottom to 5 mg/L (to Decrease Internal Loading)
  - No Clear Increase in DO at the Bottom during Operation
  - Well Below 5 mg/L Design Target



Destratification System – Meeting Objectives?

➢ Objective 2: Decrease Average Summertime Chl *a* by 8 µg/L

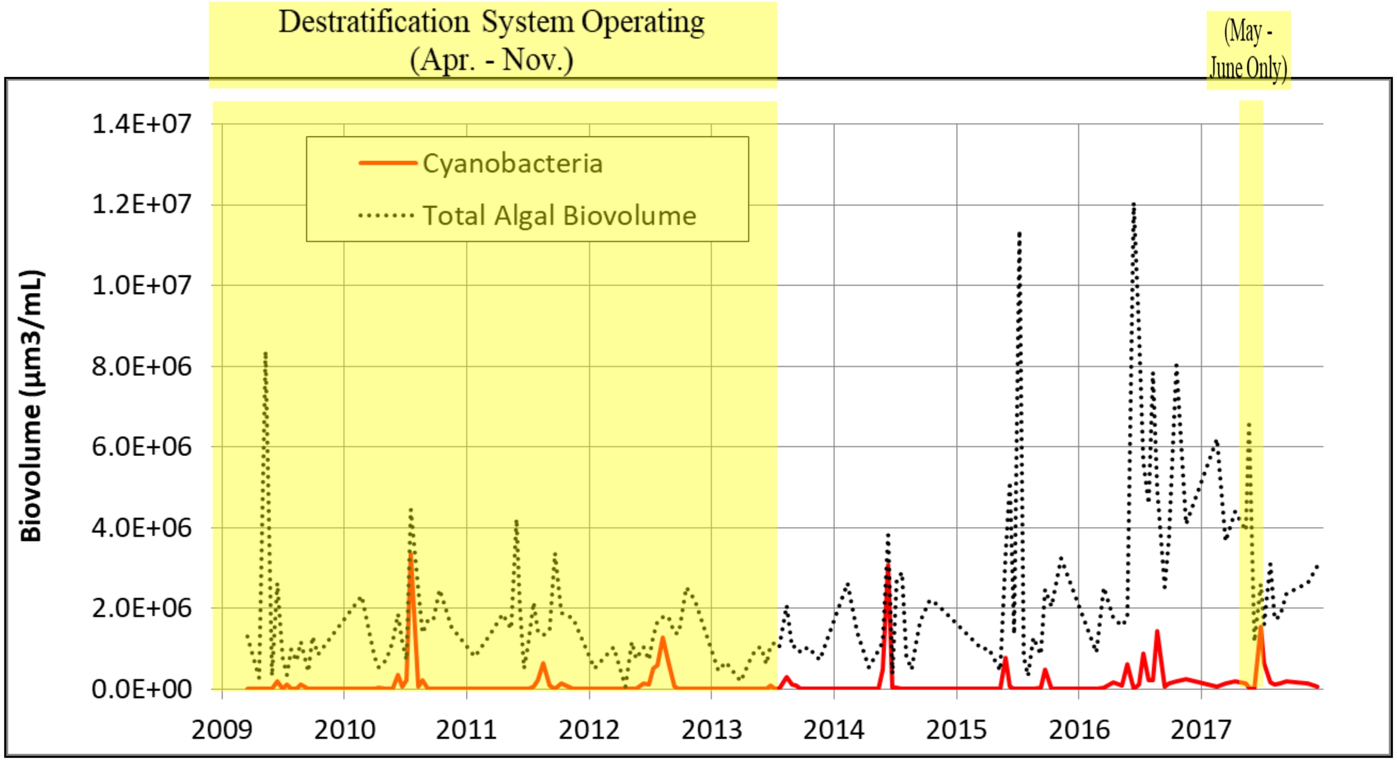
- No Clear Benefit in Observed Data
- Not Meeting Standard in Most Years with Summer Ops



Destratification System – Meeting Objectives?

➢ Objective 3: Decrease Cyanobacteria through Mixing

- Cyanobacteria Blooms Still Occurring Most Years
- Closer Look at Spring…

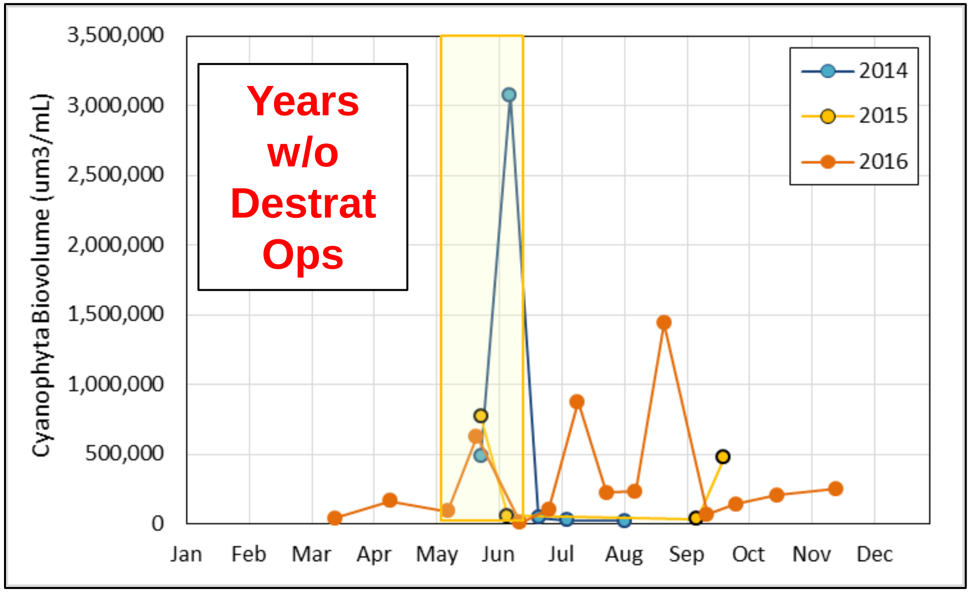


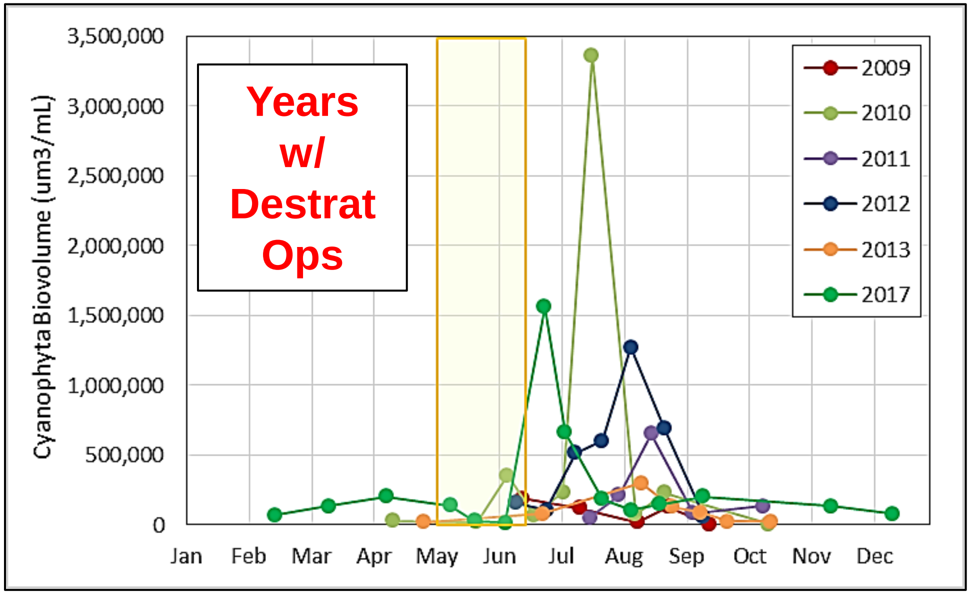
Destratification System – Meeting Objectives?

Spring – Destrat. Benefits!

Data Suggest Reduced Cyanobacteria (May/Early June)

- Why?
  - Buoyancy Advantage Disruption
  - Spring = Lower RTRM
  - Apparent in Temperature Data
- Effect Limited to Cyanobacteria In Spring
- No Paired Increase in DO or Decrease in Nutrients





Destratification System – What's the Problem?

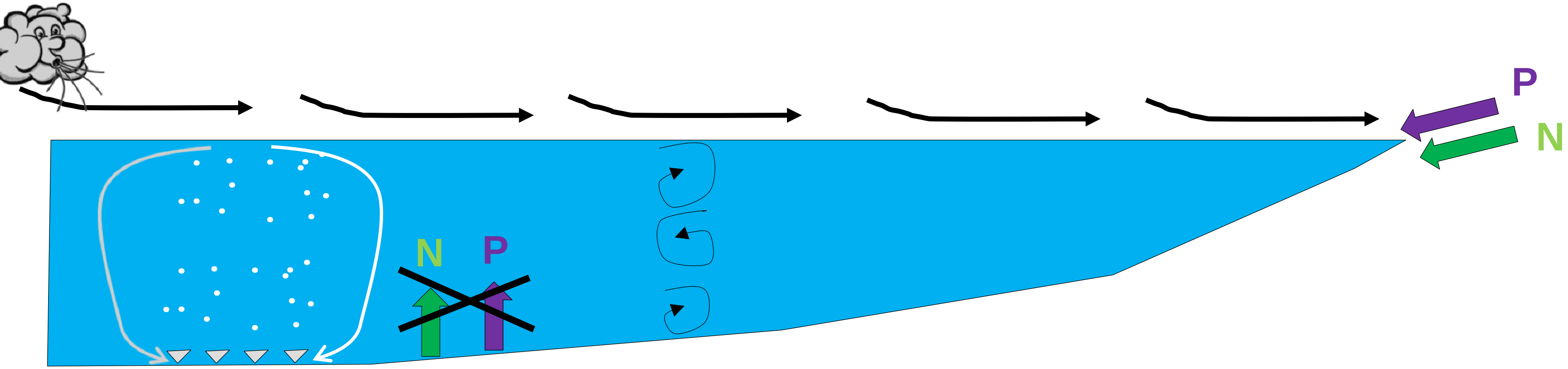
Recap:

- Not Increasing DO at Bottom → Not Reducing Internal Loading
- Not Reducing Summer Chl *a* or Summer Cyanobacteria
- Apparent Benefit in Spring - Reducing Spring Cyanobacteria

Why Isn't It Working as Intended?

- Fundamentally – Not Inducing Enough Mixing to Oxygenate Subsurface and Overcome Sediment and Water Column Oxygen Demand

CAN AN EXPANDED DESTRAT SYSTEM MEET OBJECTIVES?



What Would a Bigger Destratification System Do?

Need a Predictive Modeling Tool

Must Be Mechanistic → For Reliability of Predictive Capability

- Based on Fundamental Laws and Literature
- Simulates Underlying Controlling Processes
- Not Empirical

Applied Coupled Model (for CCBWQA)

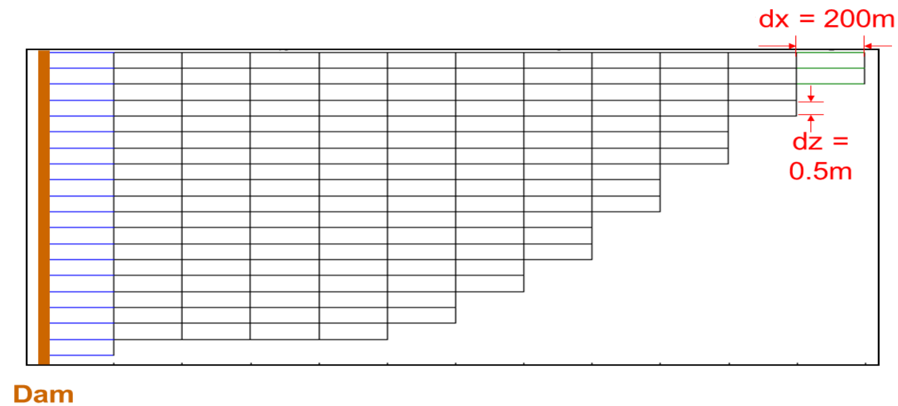
Hydrodynamic / Water-Quality Model + Bubble Plume Model

What Would a Bigger Destratification System Do?

Hydrodynamic / Water-Quality Model

Software: **CE-QUAL-W2**

- Hydrodynamics
- Water Quality
  - Temperature
  - Dissolved Oxygen
  - Nutrients
  - Algae / Chl *a*



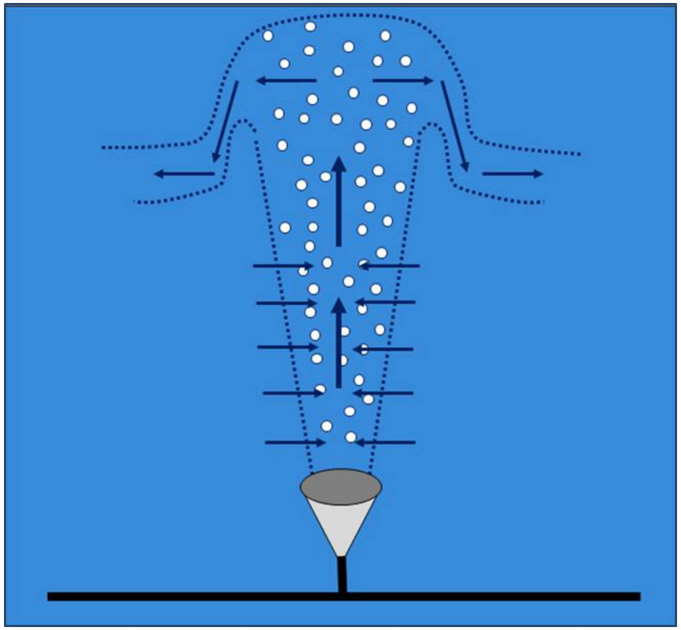
- Longitudinal and Vertical Variation

What Would a Bigger Destratification System Do?

Bubble Plume Model

Basis: Wüest et al. (1992)

- Simulates Each Bubble Plume Rising through Water Column
  - Volume of Water Moved / Mixing
    - Entrainment of Ambient Water
    - Detrainment of Plume
  - Effects on Water Temperature
  - Mass Transfer of O_2 from Bubble to Water



- Key Variables:
  - Gas Flow Rate / Gas Type (Air / O_2)
  - Diffuser Locations
  - Diffuser Diam. / Initial Bubble Size

What Would a Bigger Destratification System Do?

Simulations with the Coupled Model

- Simulated Current System and 22 Potential Expansions

    1. Additional Diffuser Heads (at 2.4 SCFM Each)
        - Range: 116 (Current) to 580 (5X)
    2. Higher Air Flow per Head
        - Range: = 2.4 SCFM (Current) to 24 SCFM (10X)
    3. Combinations
        - Range: Up To 5X Heads @ 10X Air Flow per Head = 50X Air

- Simulated 2008 – 2013

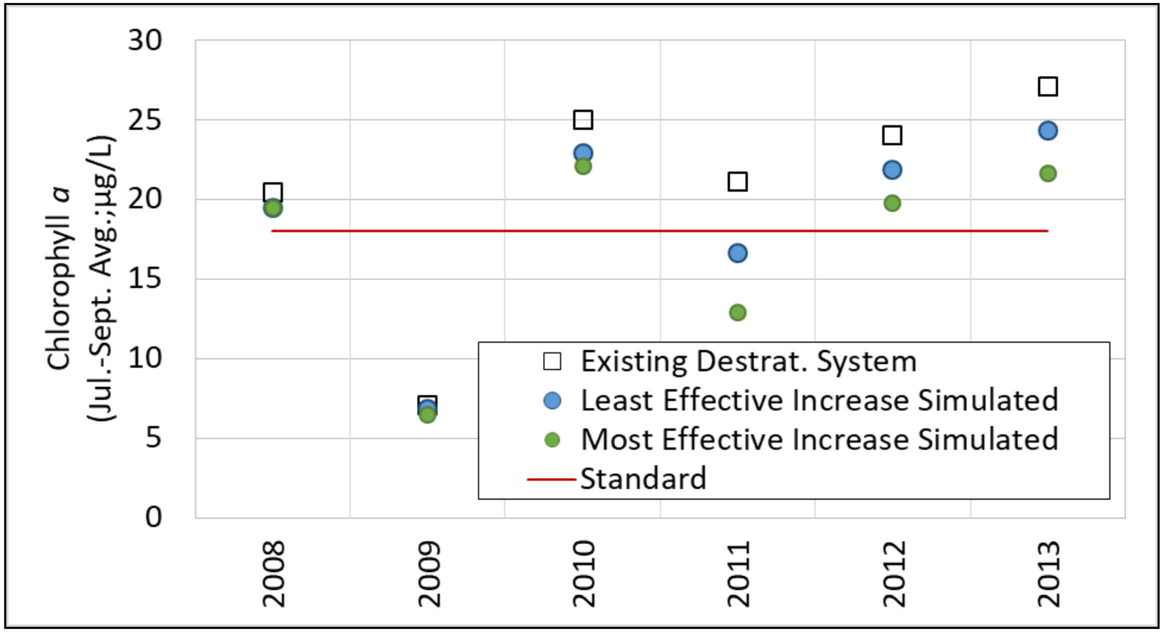
What Would a Bigger Destratification System Do?

Findings from Coupled Model Simulations

- Increased System Size Helps – *A Little*
  - Cannot Meeting Standard in All Years / Variable Year to Year
  - Biggest Avg. Decrease = -3.7 µg/L Chl *a* (Well below 8 µg/L)
  - Increasing DO at Bottom:
    - 3X System Reduces Hypoxic Days from 40/yr to 8/yr
    - Only 50X Keeps DO >2 mg/L at Bottom in All Years

Why Limited Chl a Benefit?

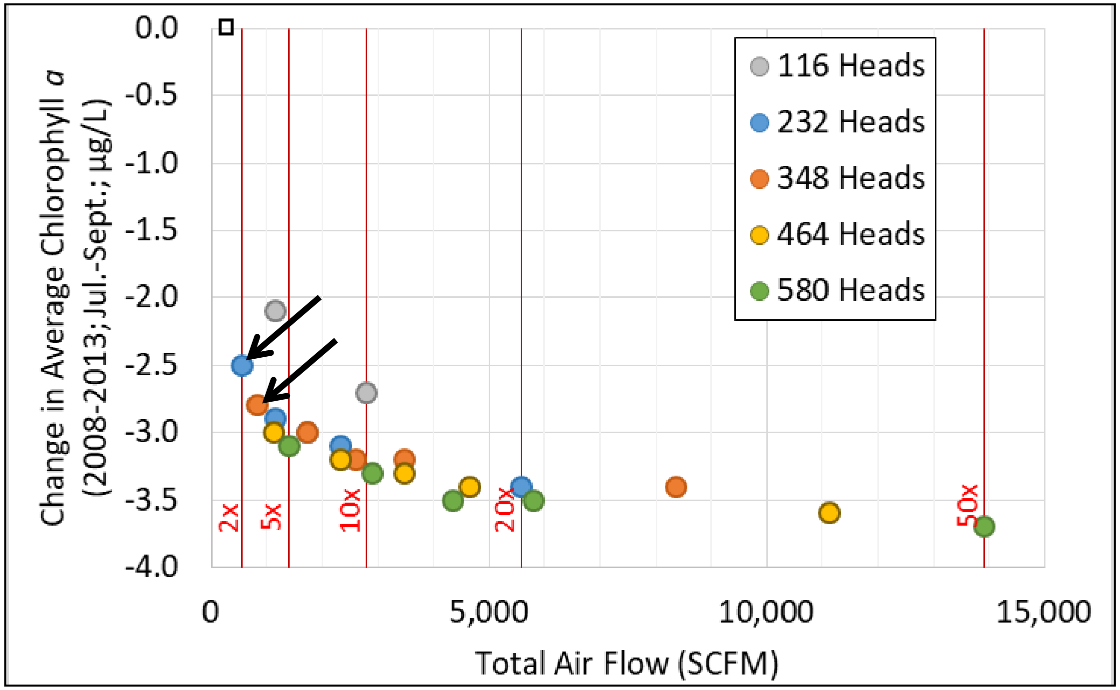
- Inflow Nutrient Loading
- Depth of Reservoir
  - Limits Bubble Travel Time and Mixing Effect



What Would a Bigger Destratification System Do?

Findings from Coupled Model Simulations

- Increasing # of Heads Greater Benefit than More Air per Head
  - More Water Moved by More Heads
  - Shallow Depth Minimizes Benefit of More Air per Head
- Diminishing Returns as System Size Increases
  - Most of Potential Can be Achieved with ~2X to 3X Increase in # Heads
  - Limited by Inflow Nutrients



Summary

- Water-Quality Concern
  - High Chl *a*
  - Cyanobacteria Blooms
- Current Destrat. System Not Achieving Its Original Goals
  - Not Increasing DO at Bottom
  - Not Meeting Summer Chl a Standard
  - Not Preventing Summer Cyanobacteria Blooms
  - May Be Reducing Spring Cyanobacteria Blooms
- Modeled Enlarged Destrat. Systems

  Hydrodynamic / Water-Quality Model + Bubble Plume Model

  - Could Further Decrease Chl *a*
  - Cannot Meet Current Chl *a* Standard / Diminishing Returns
- Destrat. System Effectiveness Limited By:
  - Shallow Depth of Reservoir
  - High Inflow Nutrient Loading

Path Forward / Options

- Continue to Target Watershed Improvements
- In-Reservoir Options:
  - Continue to Operate in Spring?
  - Enlarge Existing System??
    - Recognize Limited Potential Benefit
  - Consider Other Types of In-Reservoir Systems / Treatment?
    - Consider Conceptual System Understand
      - Shallow, Polymictic, High External Loading, Valuable Walleye Fishery, etc.
      - Limitations Face Most Options
    - WWE Presentation (Later in this Session)…
- Revisit Appropriateness / Attainability of Site-Specific Standard Value?