# A Changing Lake

## Addressing Low Dissolved Oxygen and High Phosphorus in Wisconsin's Deepest Natural Inland Lake, Green Lake

# Introduction

## Stephanie Prellwitz

Executive Director
Green Lake Association

# Green Lake

Green Lake County

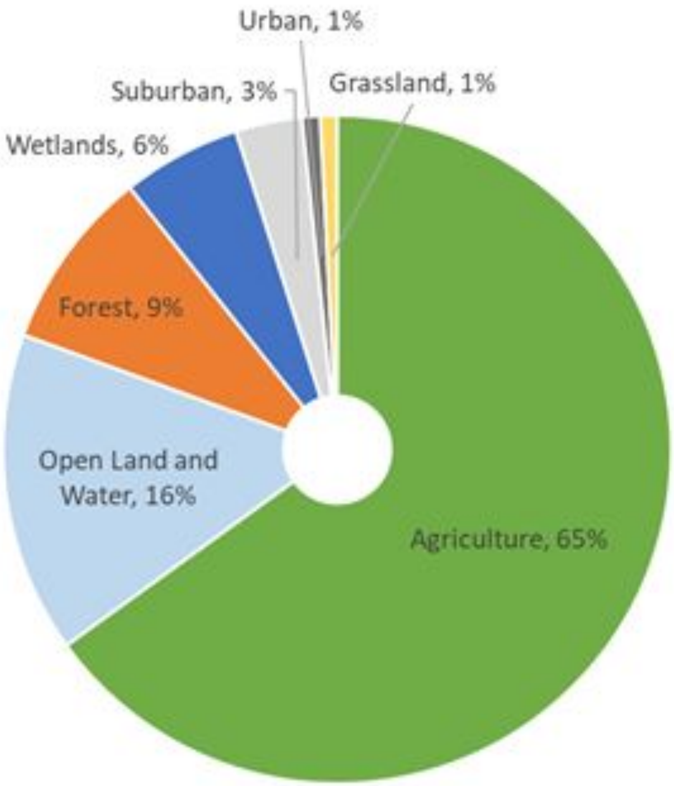
Deepest natural inland lake in Wisconsin

Area: 7,660 acres

Max Depth: +/- 235 feet deep

Two-story lake

# Green Lake Watershed

# Lake Aging

**All lakes age**
(accumulate nutrients + grow more plants)

**Human pressures accelerate lake aging**

Less Nutrients → More Nutrients

Oligotrophic

Mesotrophic

Eutrophic / Hypereutrophic

# Phosphorus

Stream samplers and computer models allow us to closely estimate how much phosphorus enters Green Lake annually.

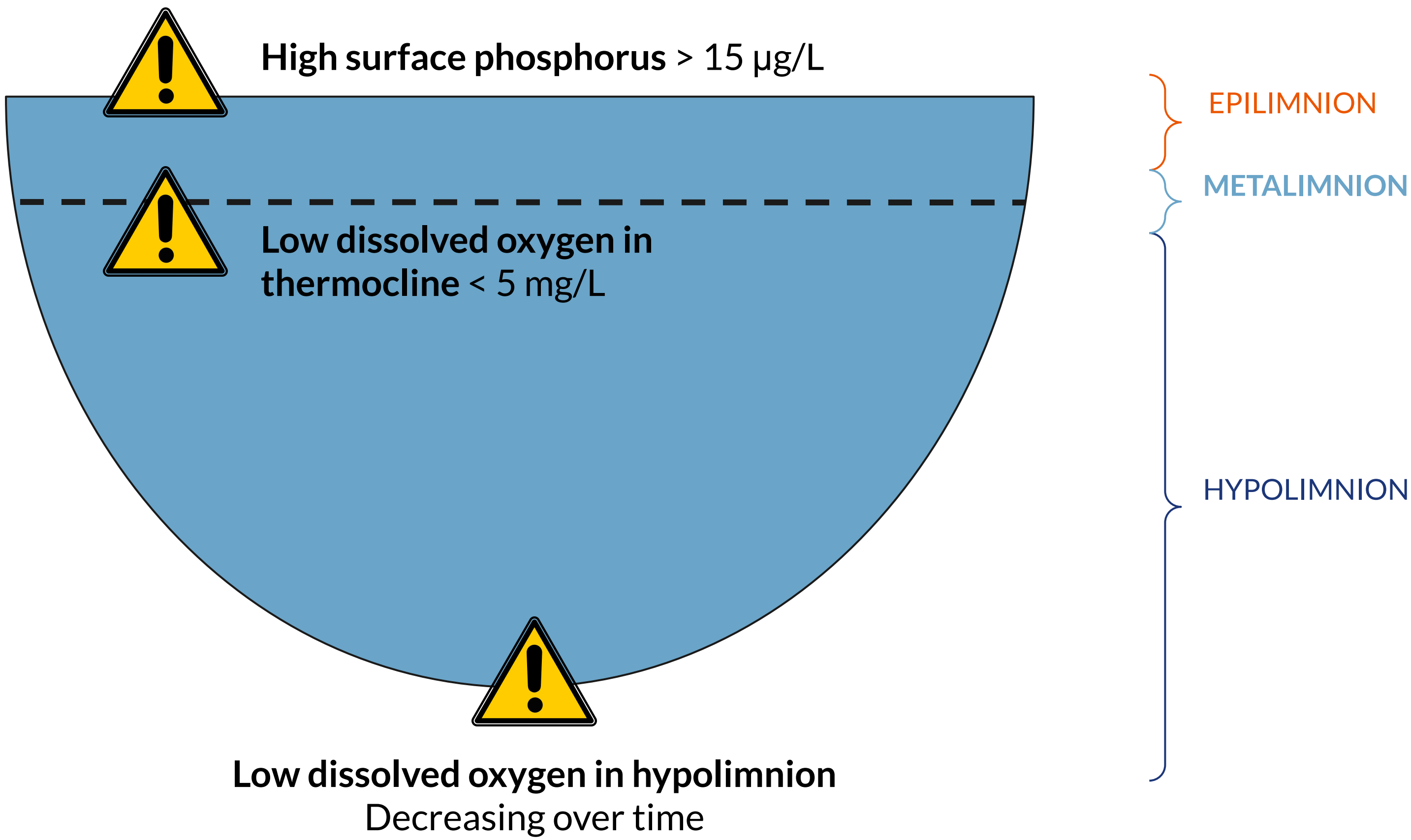
**Between 2014 and 2018, an average of**

**20,800 lbs**

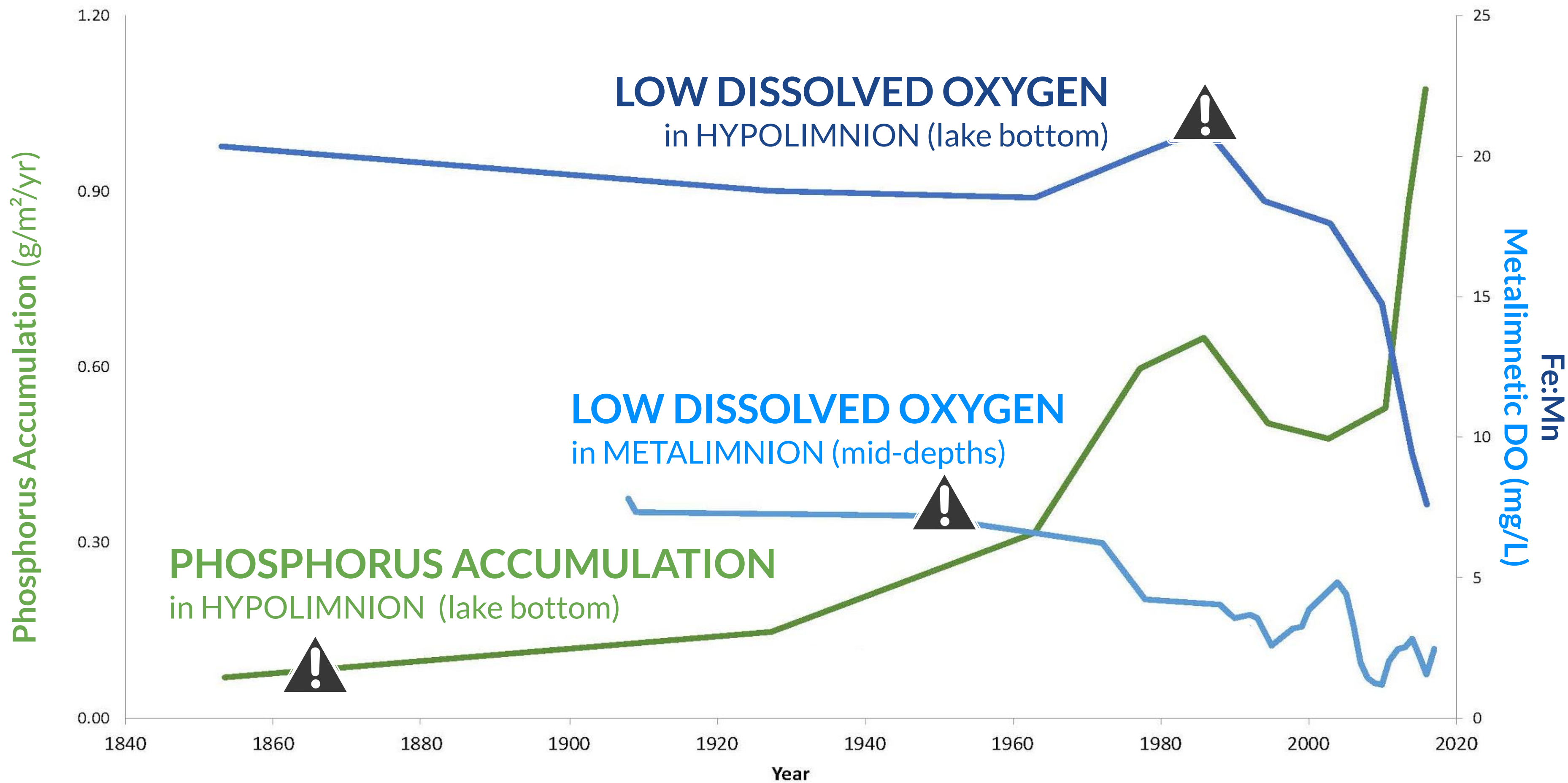
**of phosphorus entered Green Lake**

+25% in P loading from 2016

# Green Lake's Water Quality



# Green Lake's Water Quality Trends

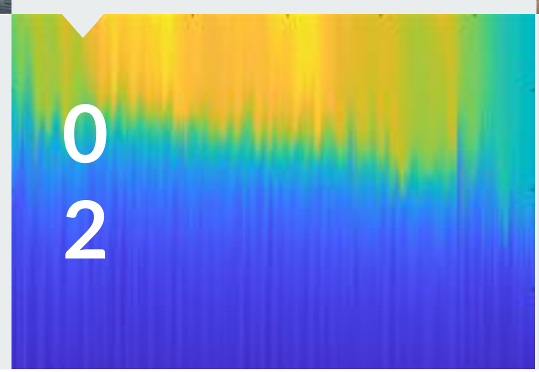



Sediment cores by P. Garrison, 2016

# Green Lake Research Study


Implement a **COMPREHENSIVE LAKE SAMPLING CAMPAIGN**

**DEVELOP LAKE MODELS** to understand the mechanisms causing its dissolved oxygen and phosphorus issues





Determine potential **MANAGEMENT STRATEGIES** to meet water quality goals

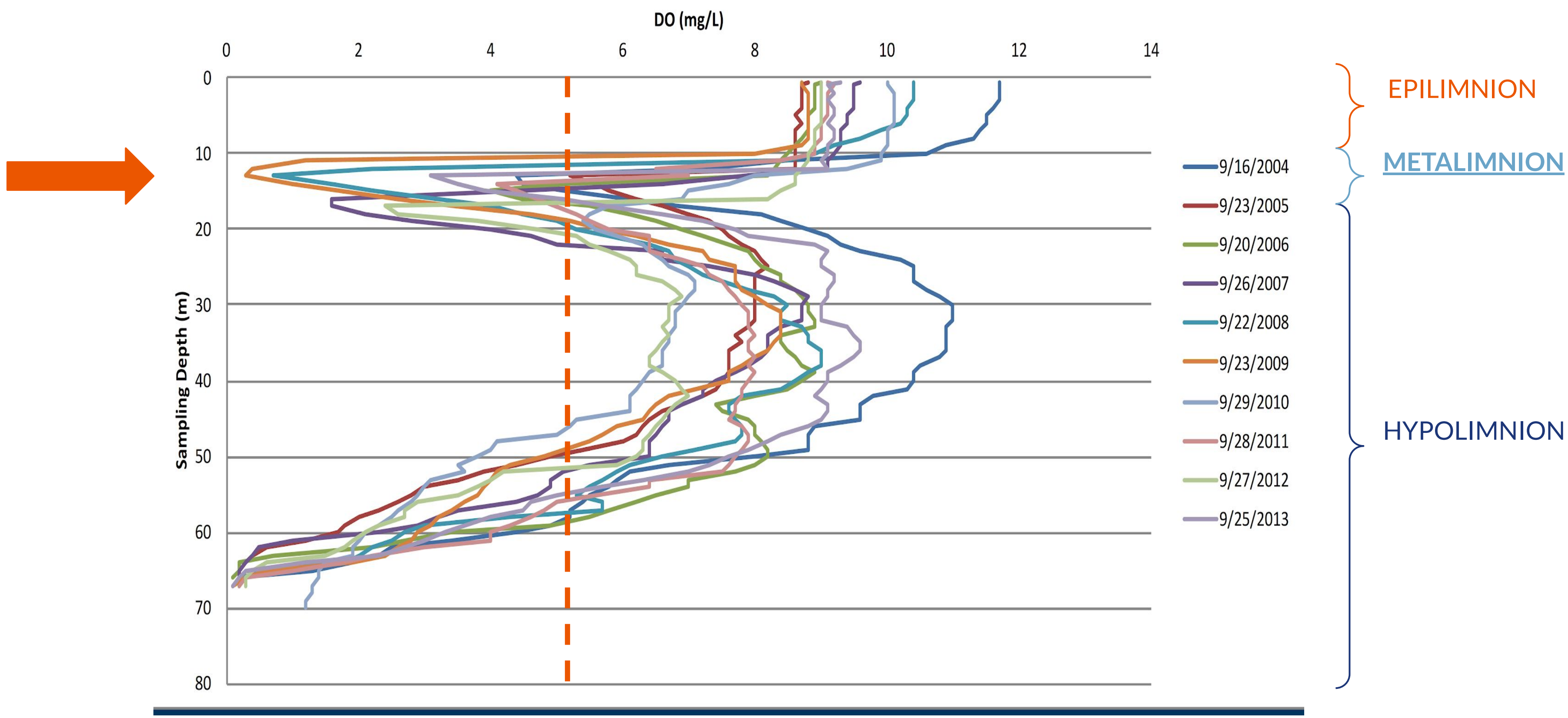
# Dissolved Oxygen Impairment


## Cory McDonald

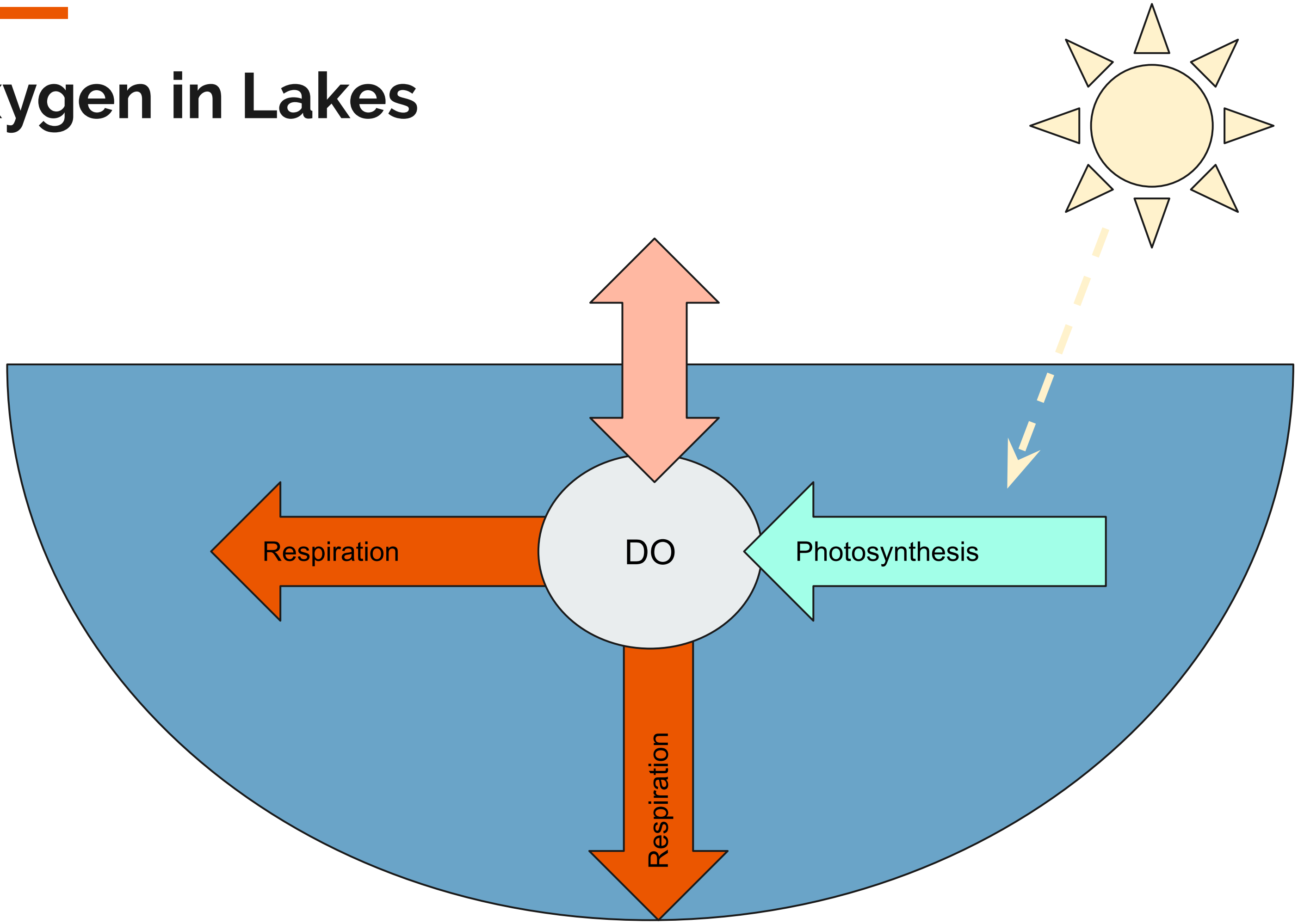
### Mahta Naziri Saeed

Department of Civil and Environmental Engineering
Michigan Technological University

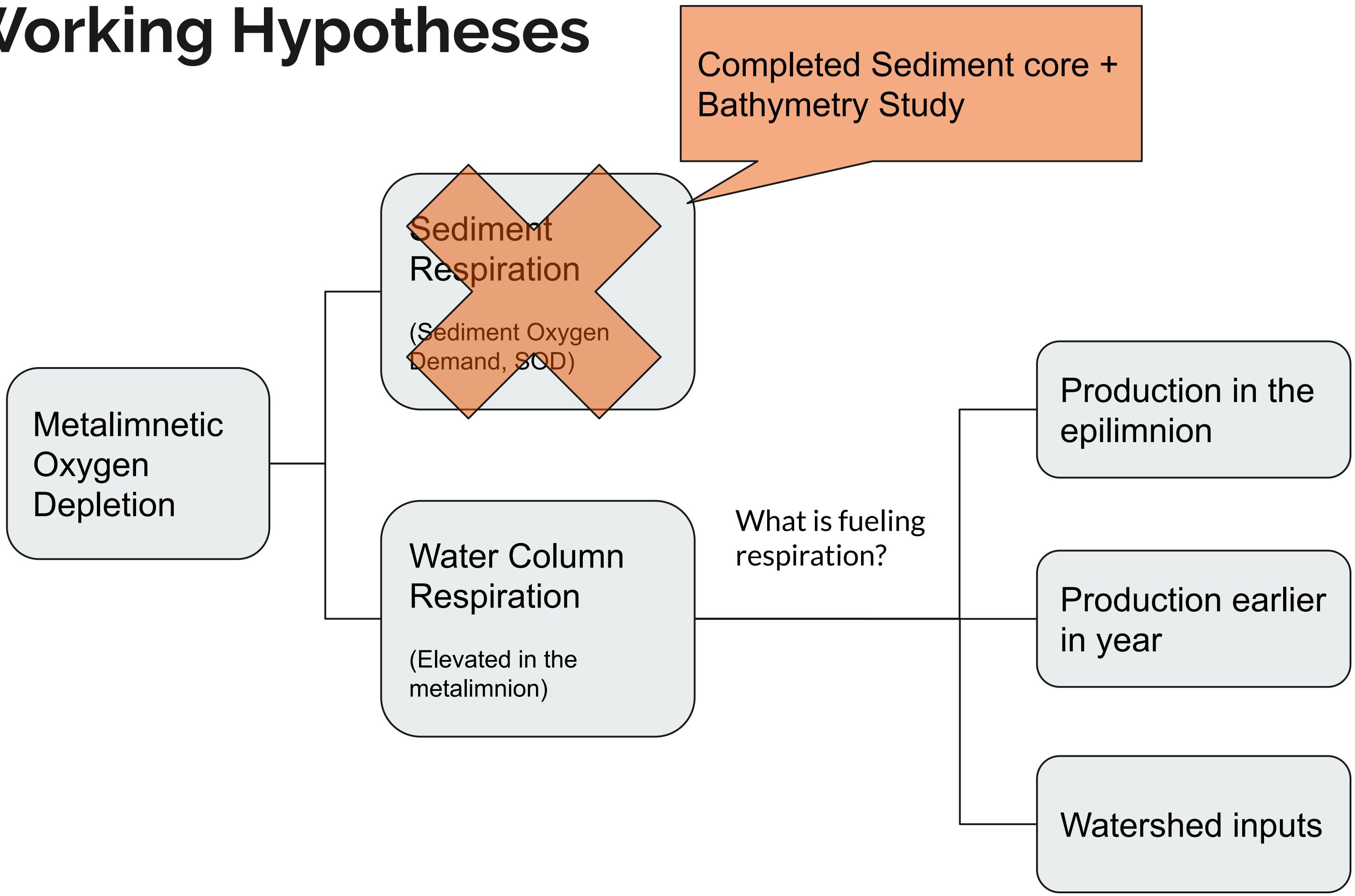

# Dissolved Oxygen Profiles



# Oxygen in Lakes

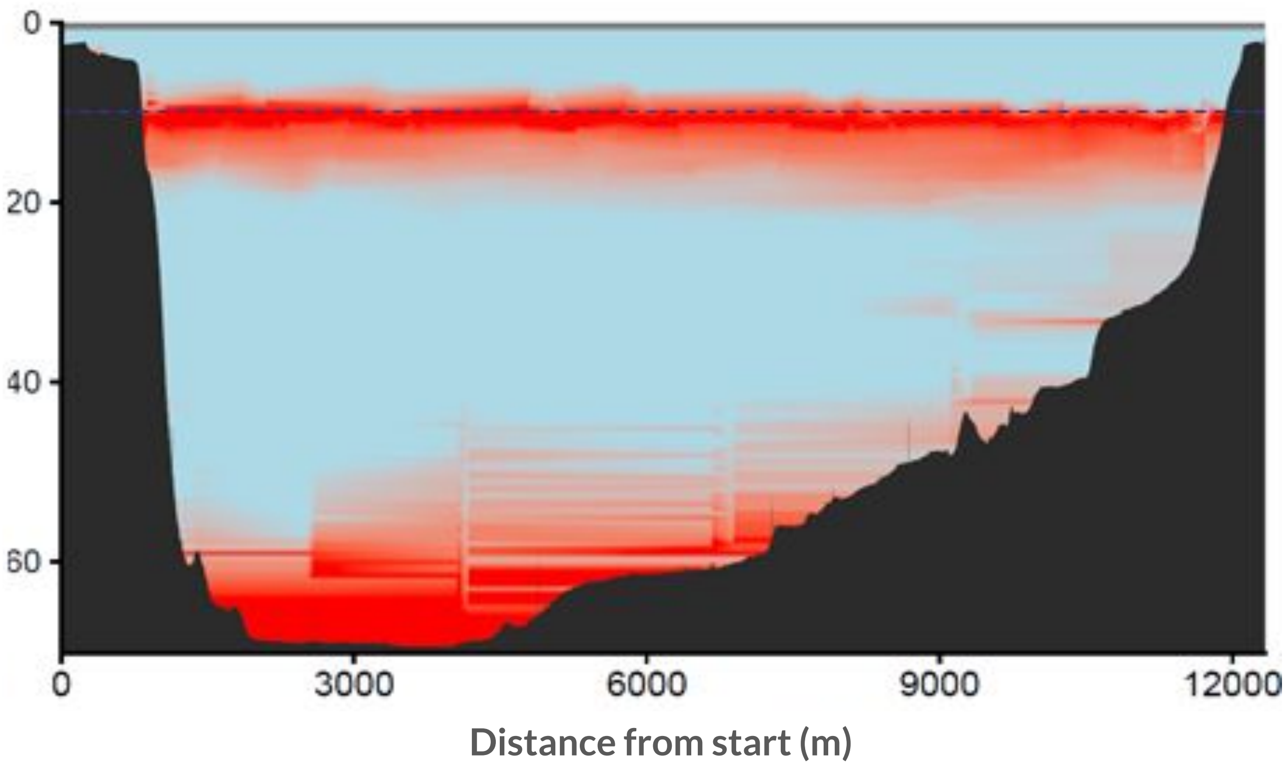


# Working Hypotheses

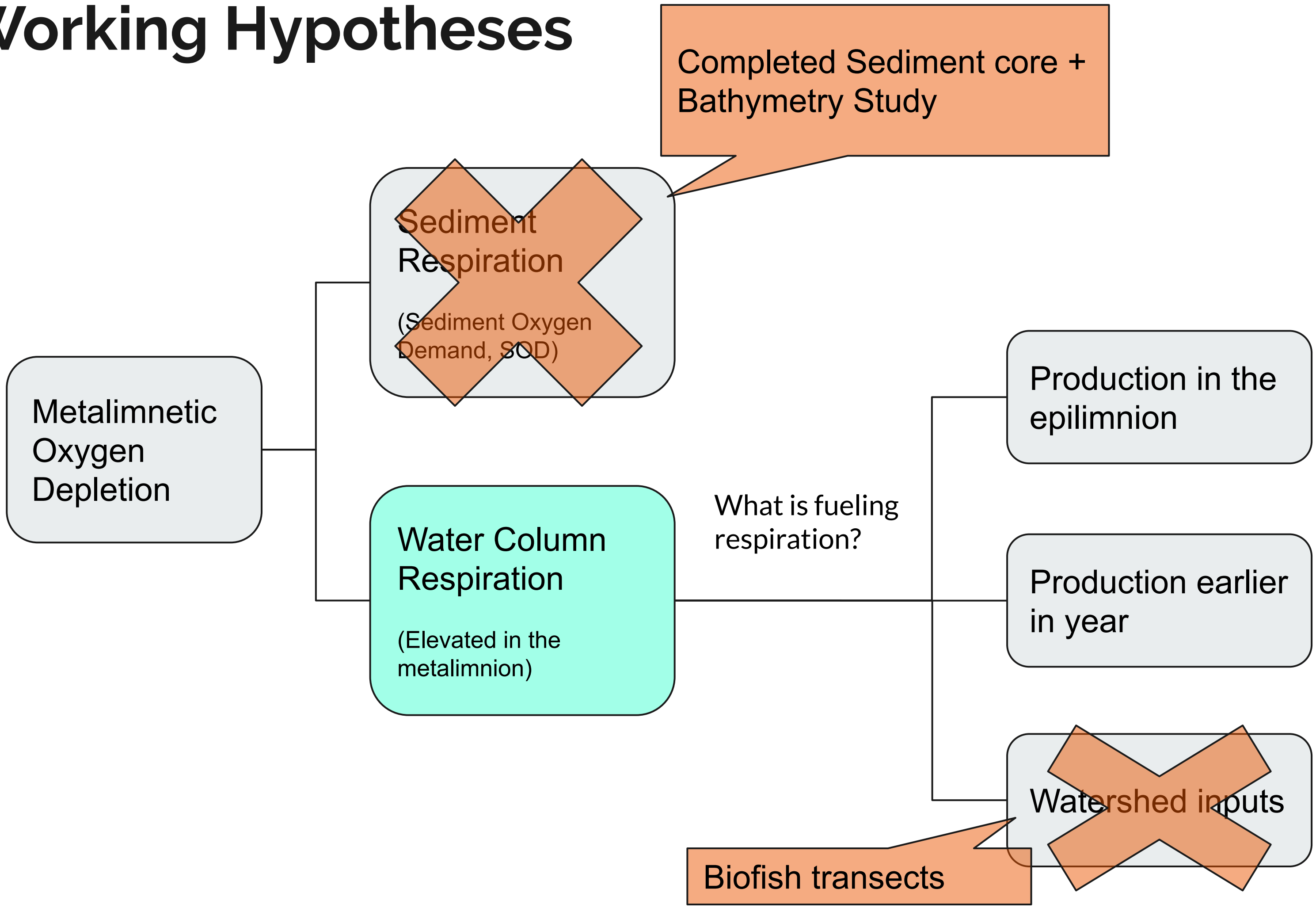


# Watershed Sources?

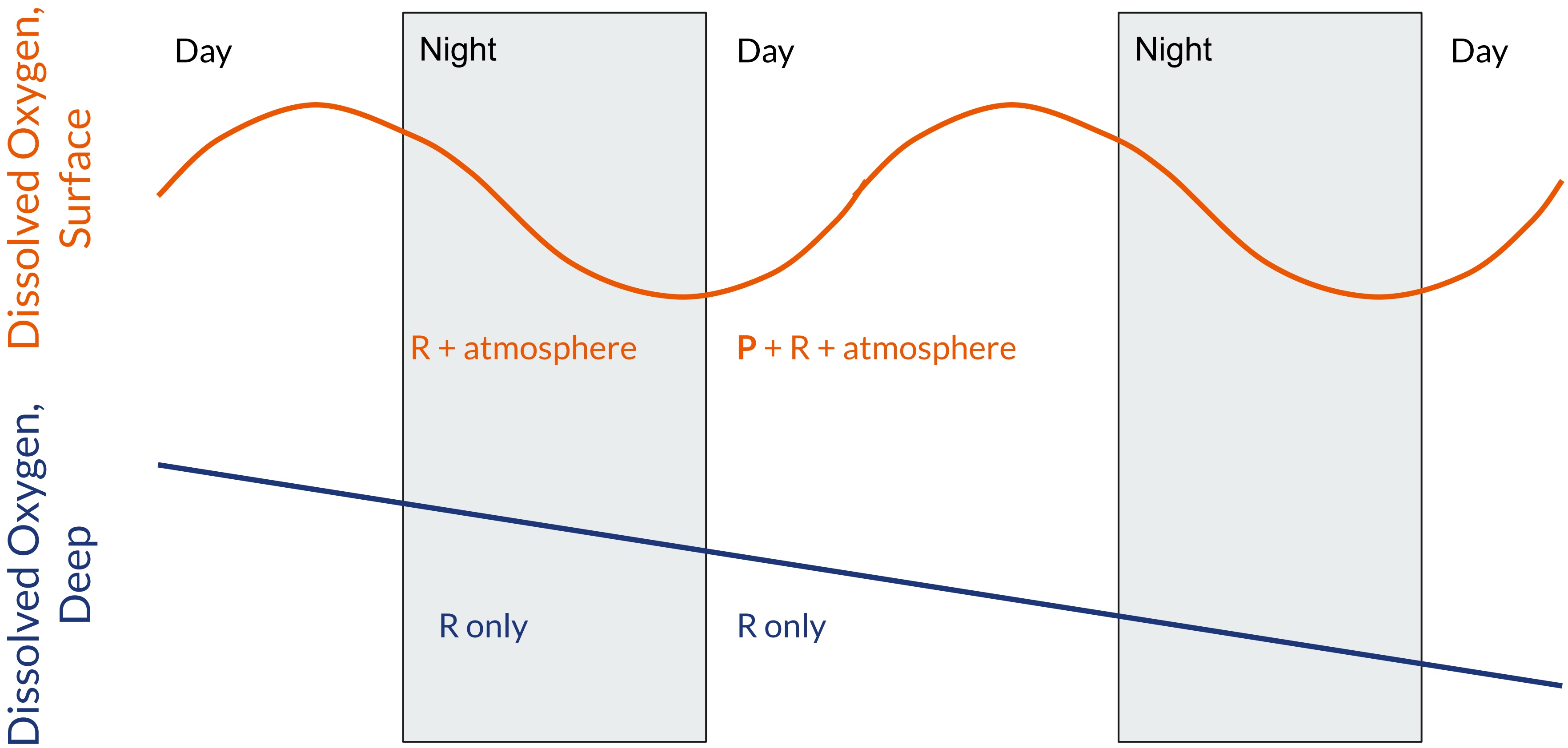
USGS transect, west to east, across lake:



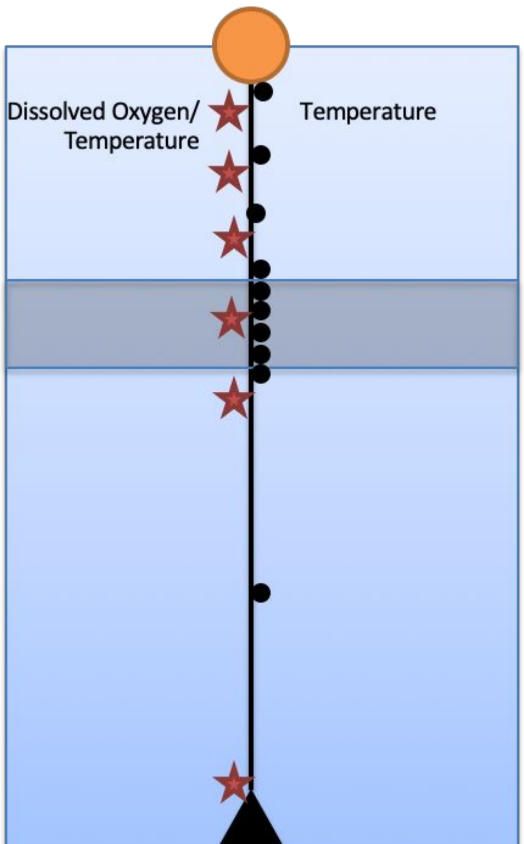
# Working Hypotheses

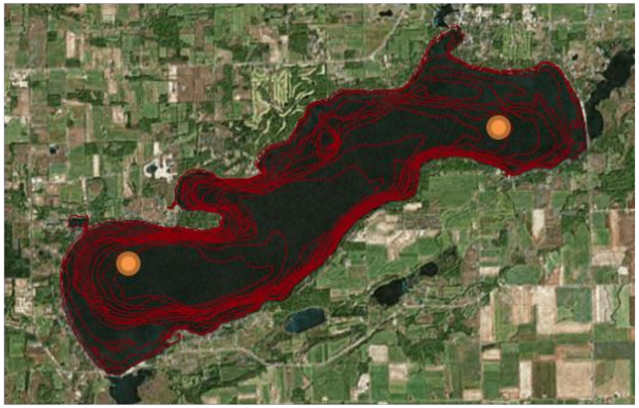


# Photosynthesis (P) and Respiration (R)

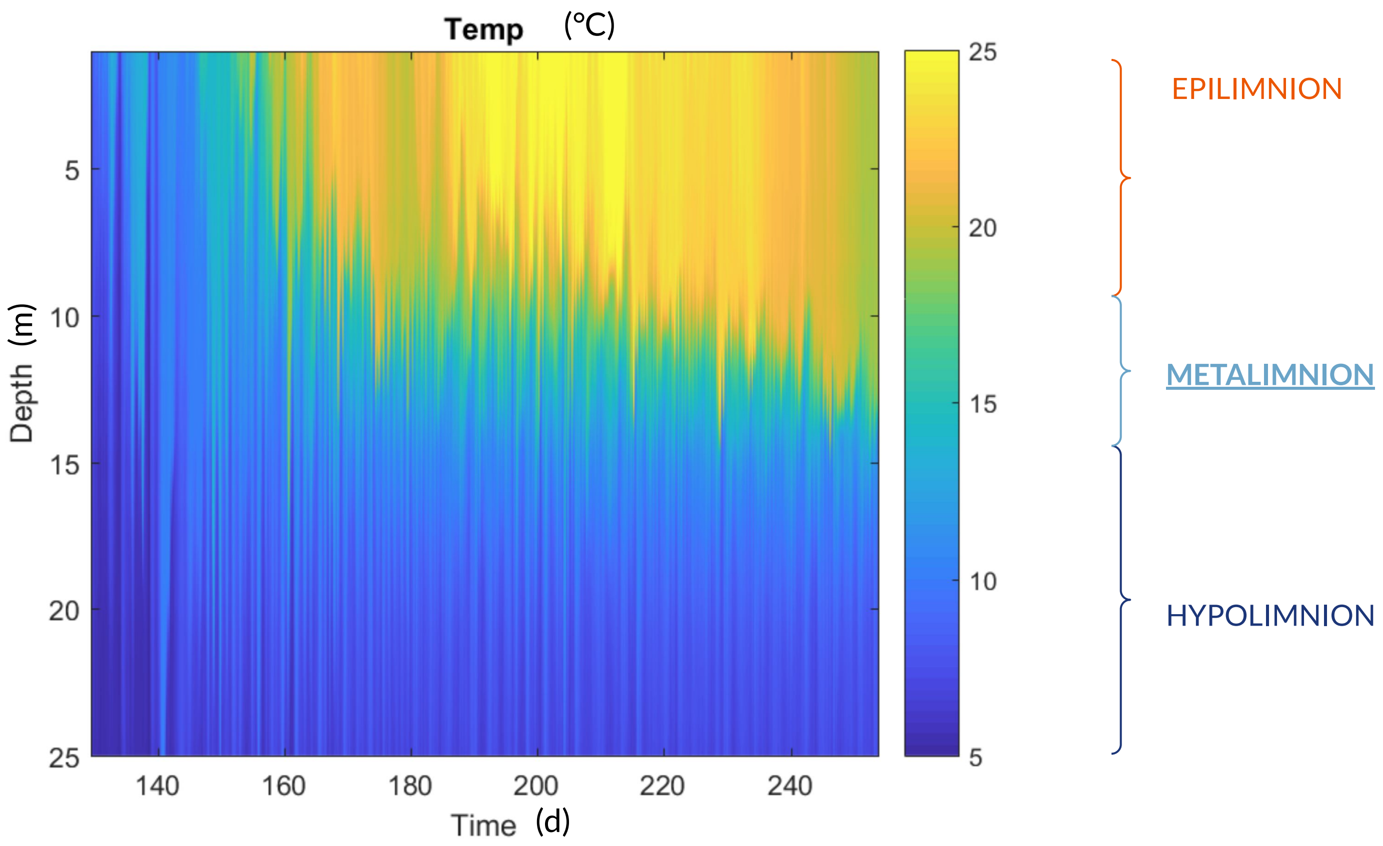


# High-Frequency Monitoring Buoys

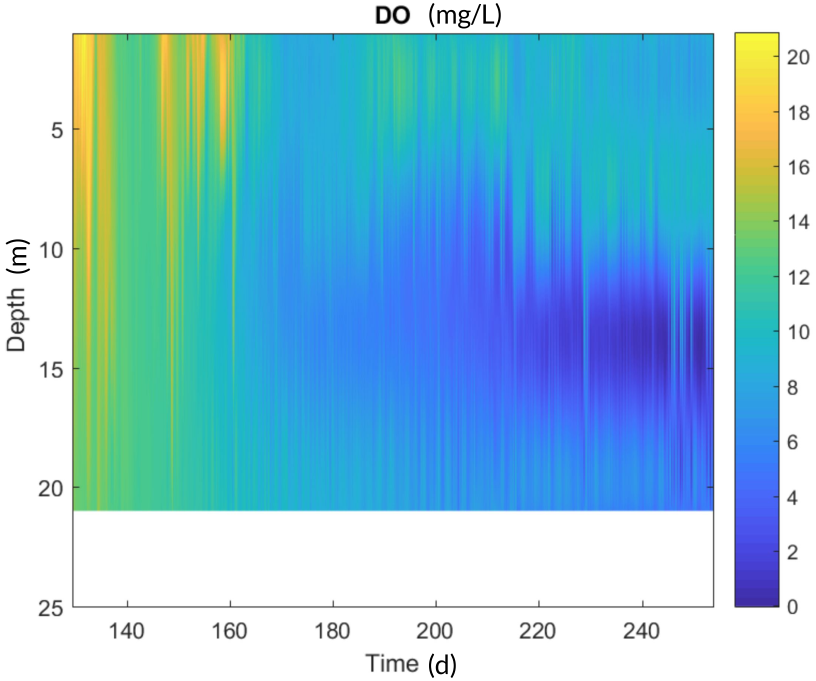


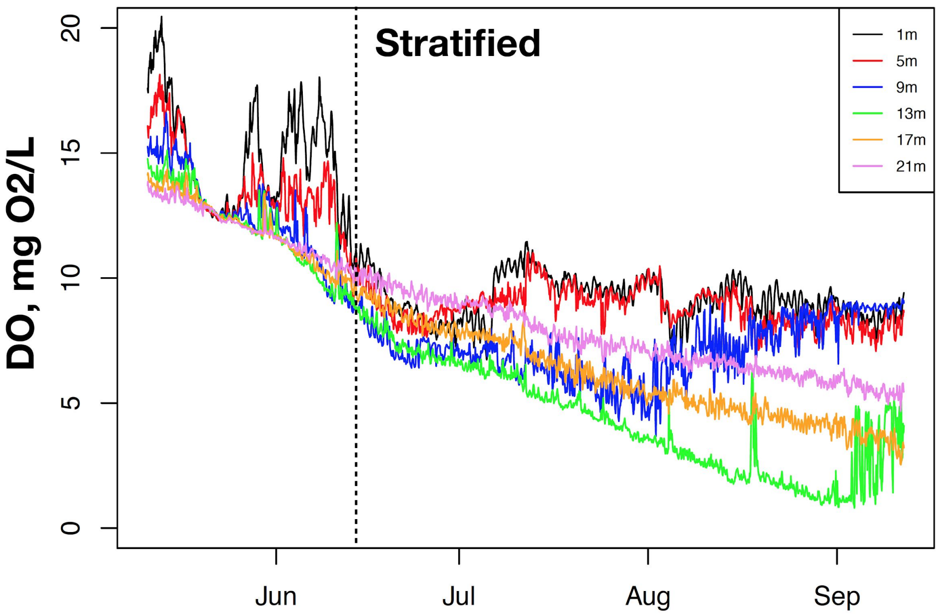



# Buoy Data - Temperature



# Buoy Data - Oxygen

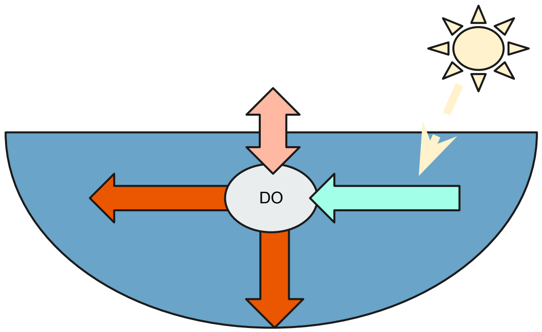


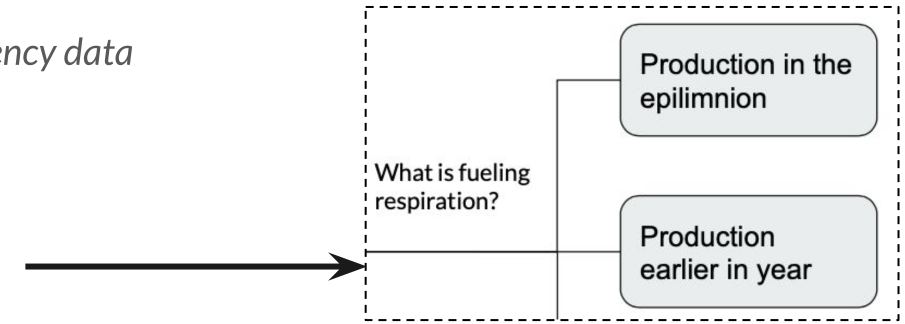



# Oxygen Modeling

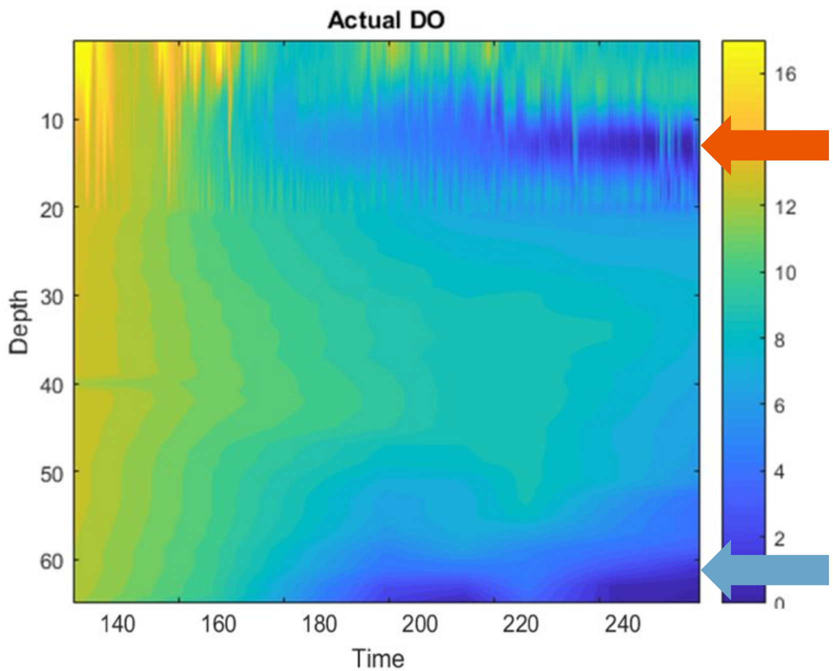
Model approach considers:

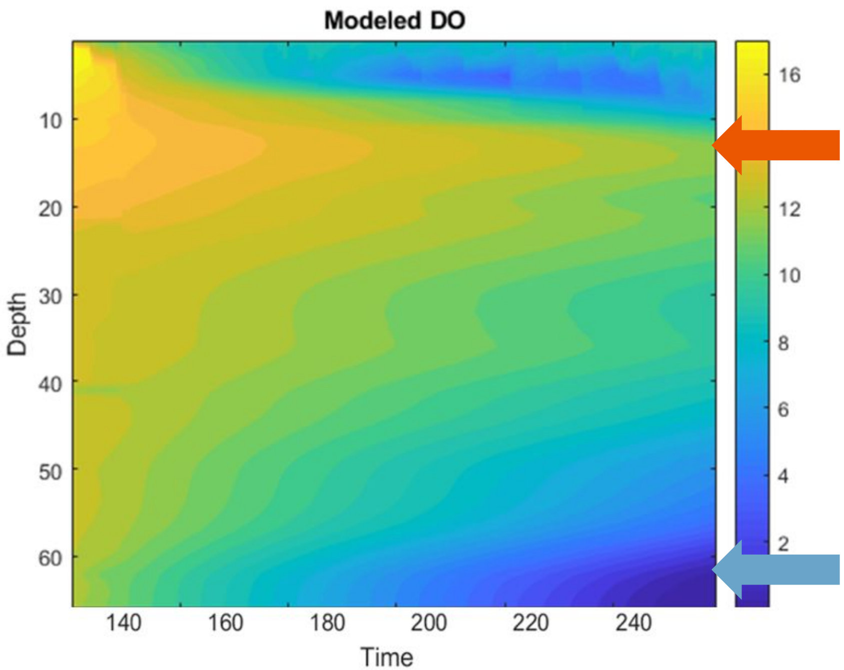
1. Lake physics
   a. Vertical water movement/mixing
   b. Heat (temperature)/stratification
   c. Light availability
   d. Air-water oxygen transfer
2. Biological Processes
   a. **Photosynthesis**
      i. *Inferred from high-frequency data*
   b. **Sediment respiration**
   c. **Water column respiration**
      i. With/without settling



# Oxygen Model **Air/Water Exchange + Sediment** Respiration



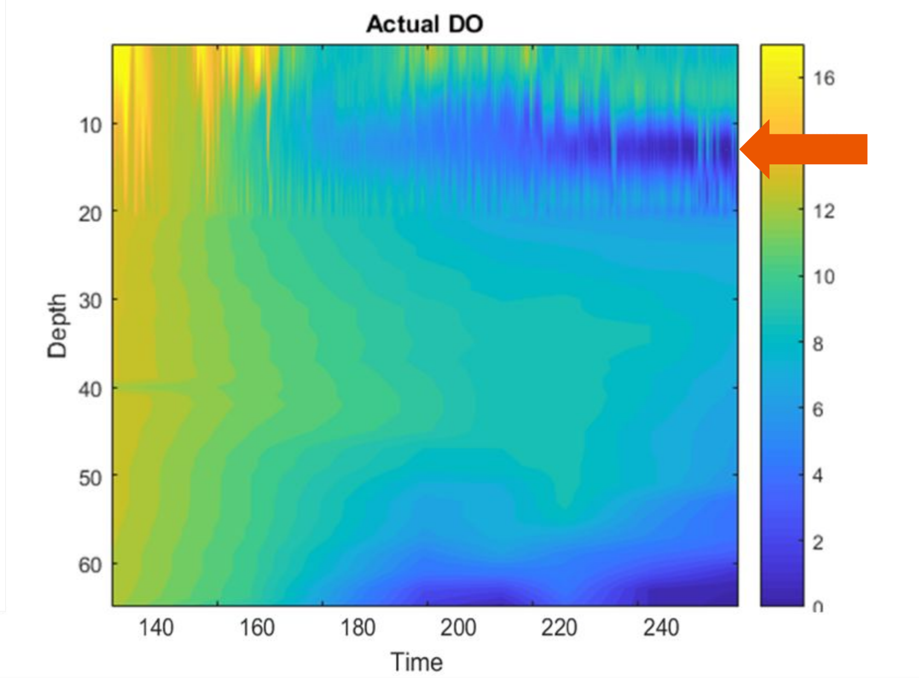




DATA

MODEL

## Oxygen Model Air-water exchange and water column respiration only

(no sediment or settling)

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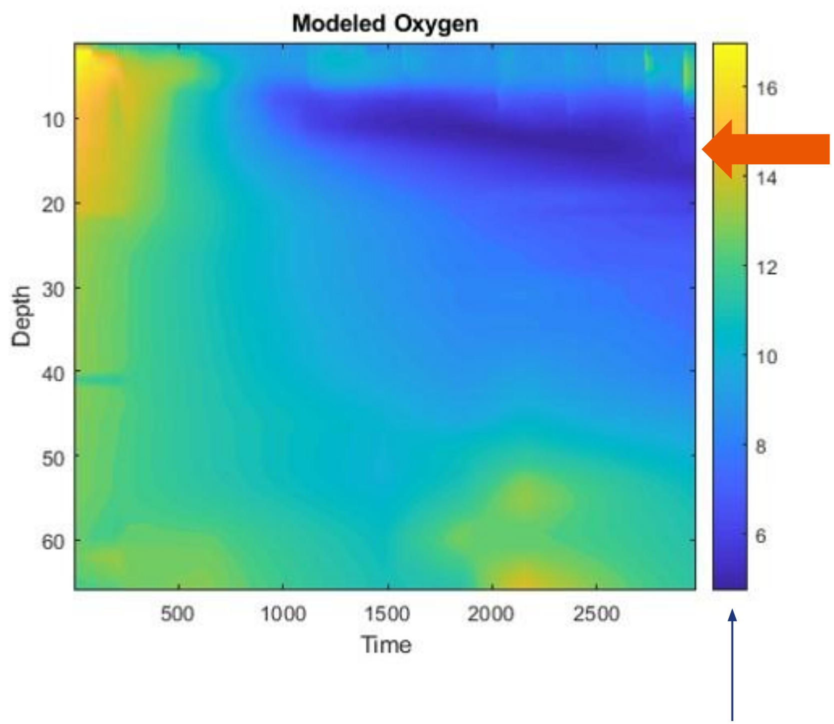



MODEL

# Summary/Preliminary Conclusions

1. **High-frequency measurements** using deployed sensors allows **oxygen producing/consuming processes to be directly modeled**

2. Modeling results confirm that **respiration in the metalimnion is likely the cause of low DO**
   - Preliminary results suggest that springtime productivity—not necessarily summer—may be directly linked to the oxygen minimum

# Phosphorus and Dissolved Oxygen Impairment

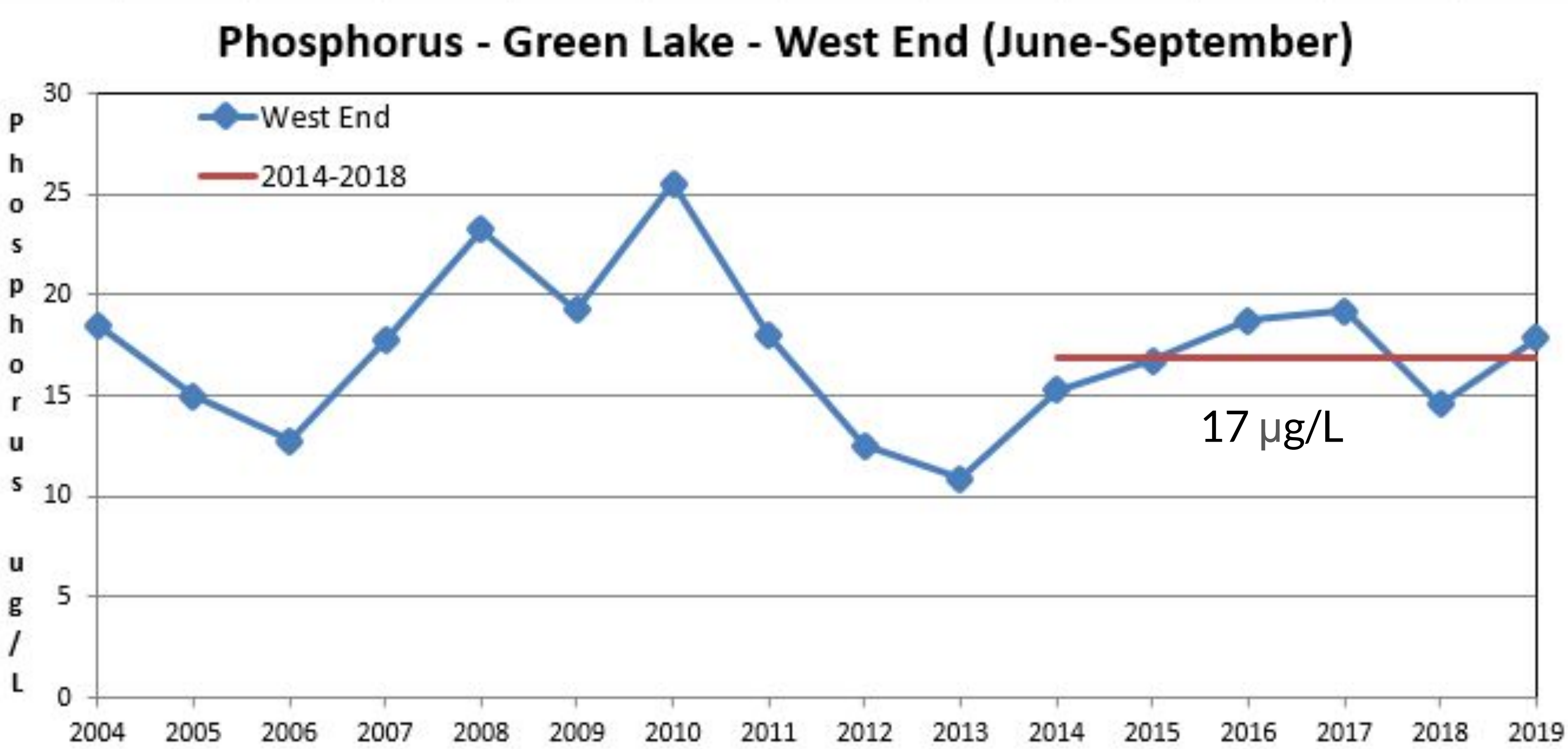

## Dale Robertson

### Ben Siebers

U.S. Geological Survey
Upper Midwest WSC


## Green Lake Now Eligible to be Impaired for Phosphorus

Based on Wis. DNR criteria of 15 µg/L



# Calculating Phosphorus Reductions Required to Delist Green Lake

Canfield Bachman Model

$$\text{P concentration} = \frac{L}{Z\,(1.62\,(L/Z)^{0.458} + 1/\tau}$$

Where:

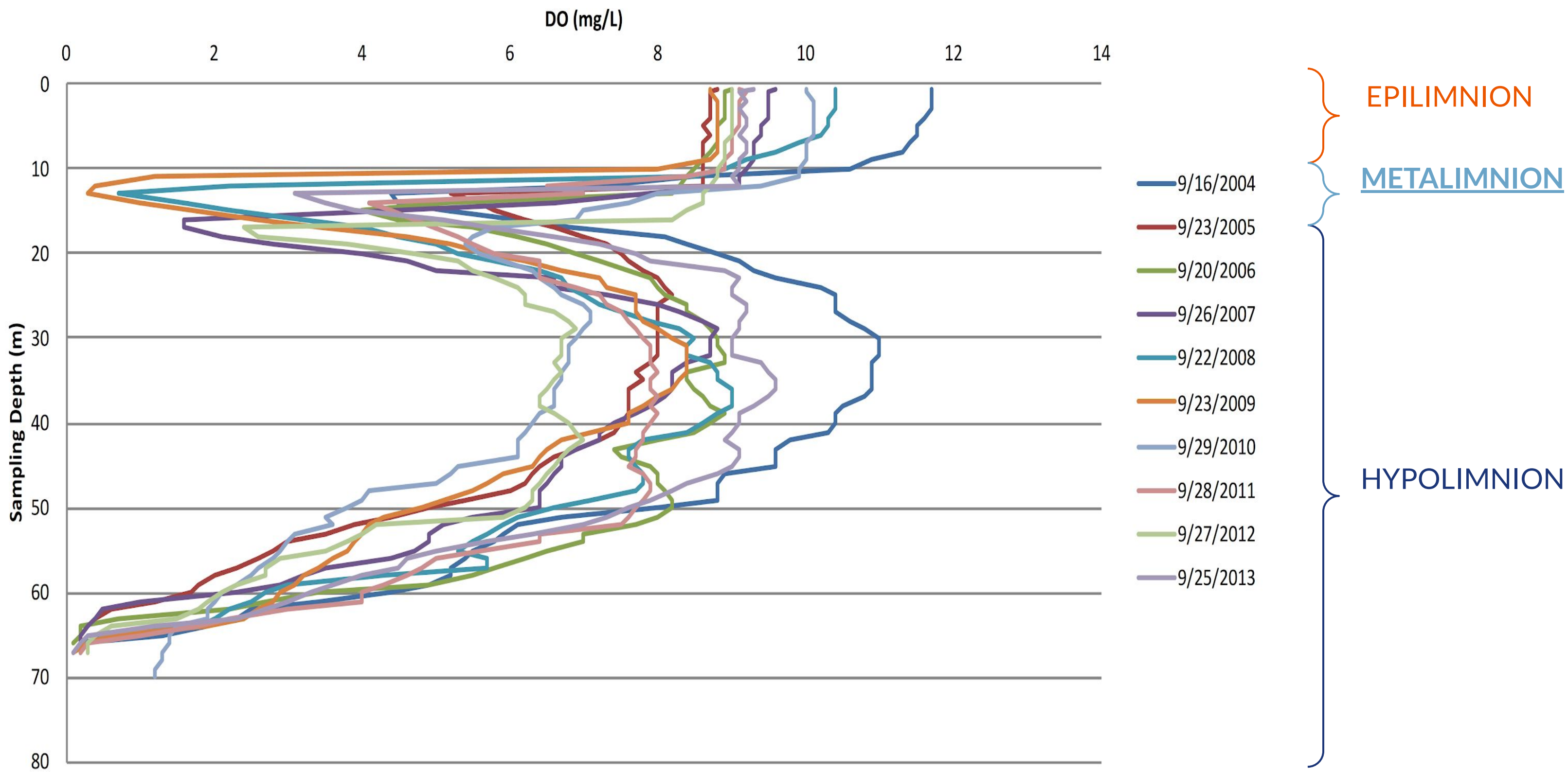
**L = P loading**

Z - Mean depth

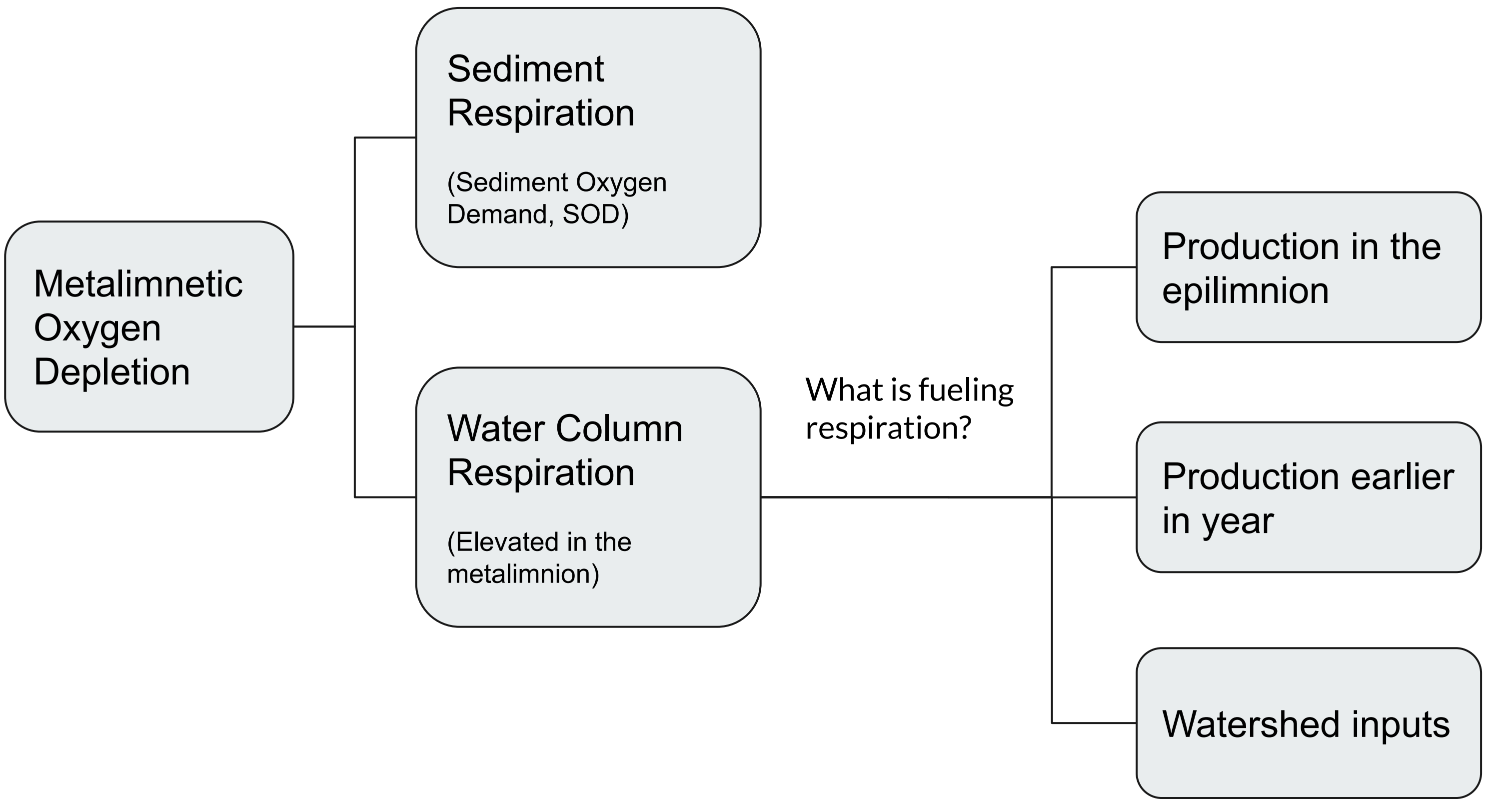
τ = Residence time

# Green Lake Impaired for DO in the Metalimnion

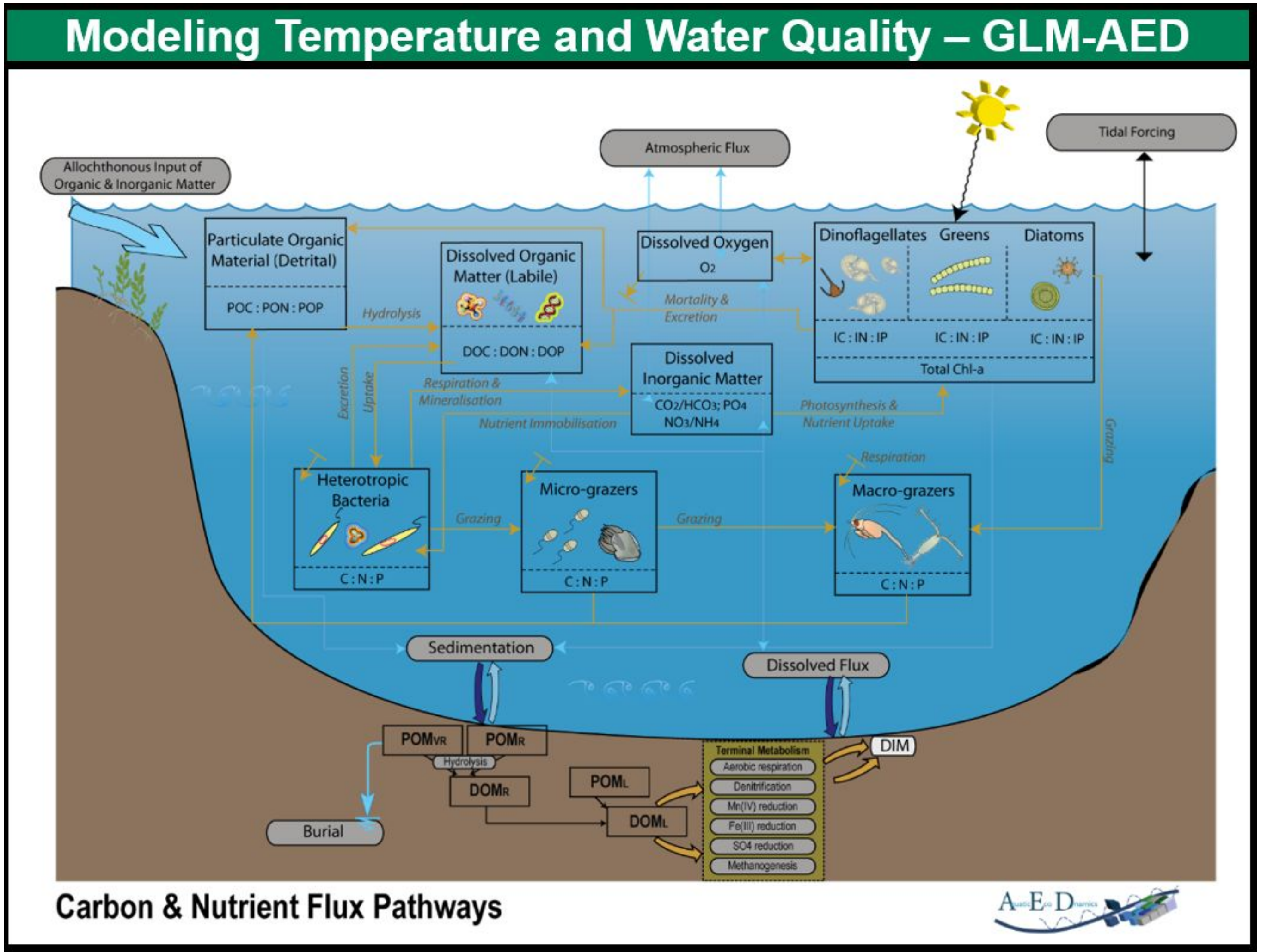
Metalimnetic Oxygen Minimum



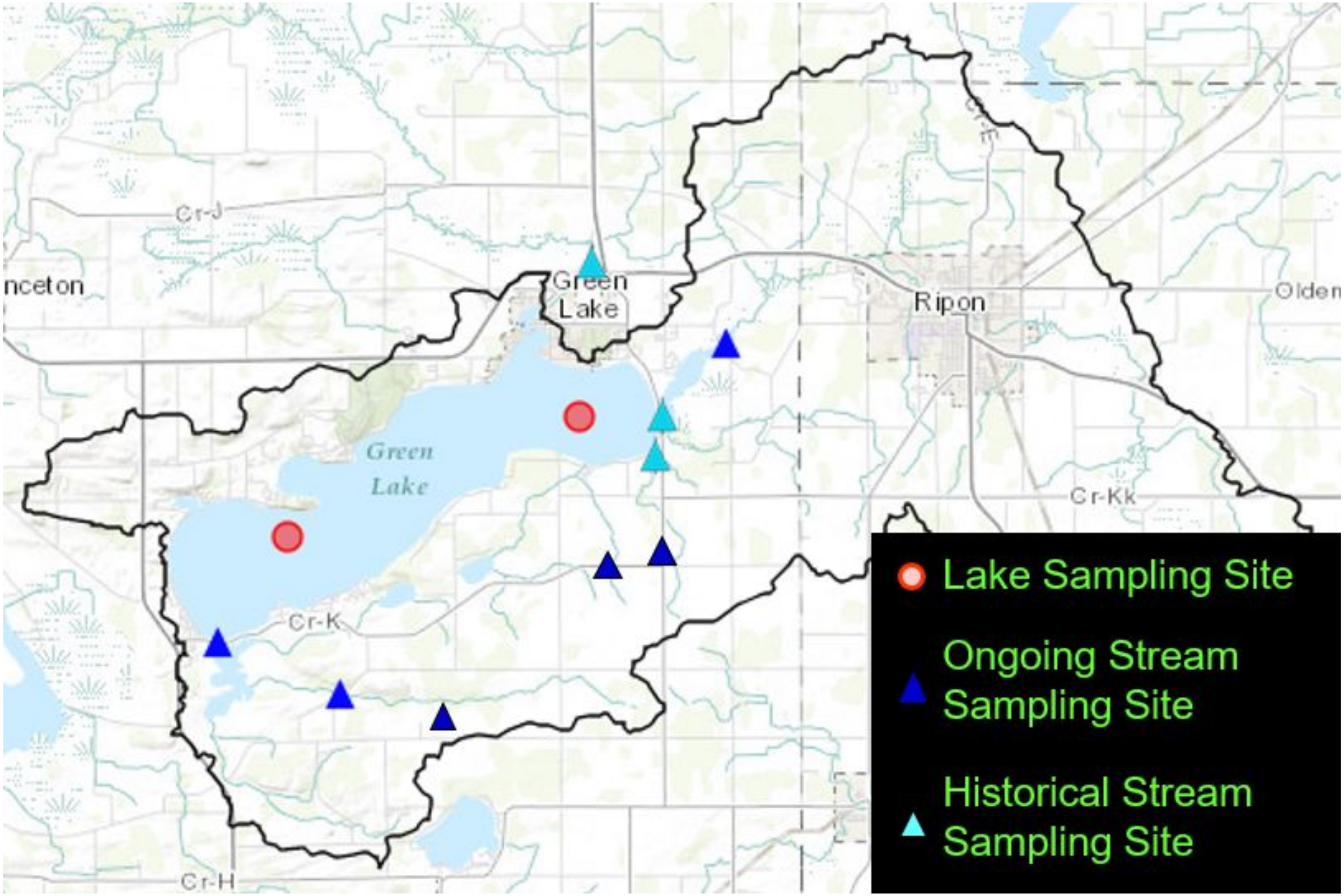
## Goals to Examine Each of These Hypotheses



# Modeling Approach to understand hypoxia and determine how much of the phosphorus input needs to be reduced to it.

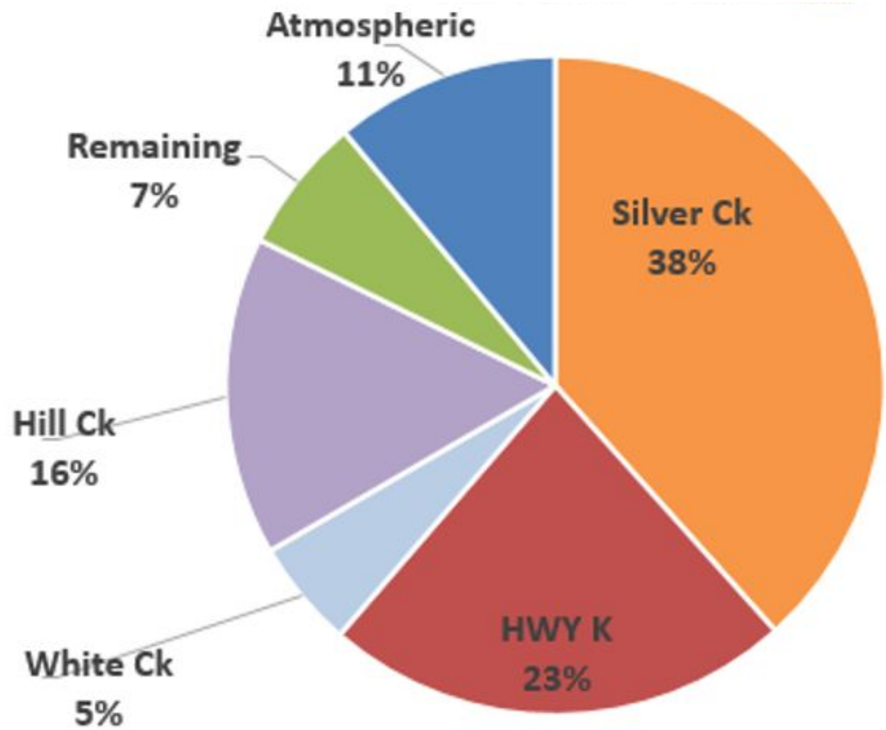


# Detailed Monitoring Program - needed for both modeling approaches



# Annual Phosphorus Loading to Green Lake

Full description of how much P is input to the lake and where it is coming from for remediation

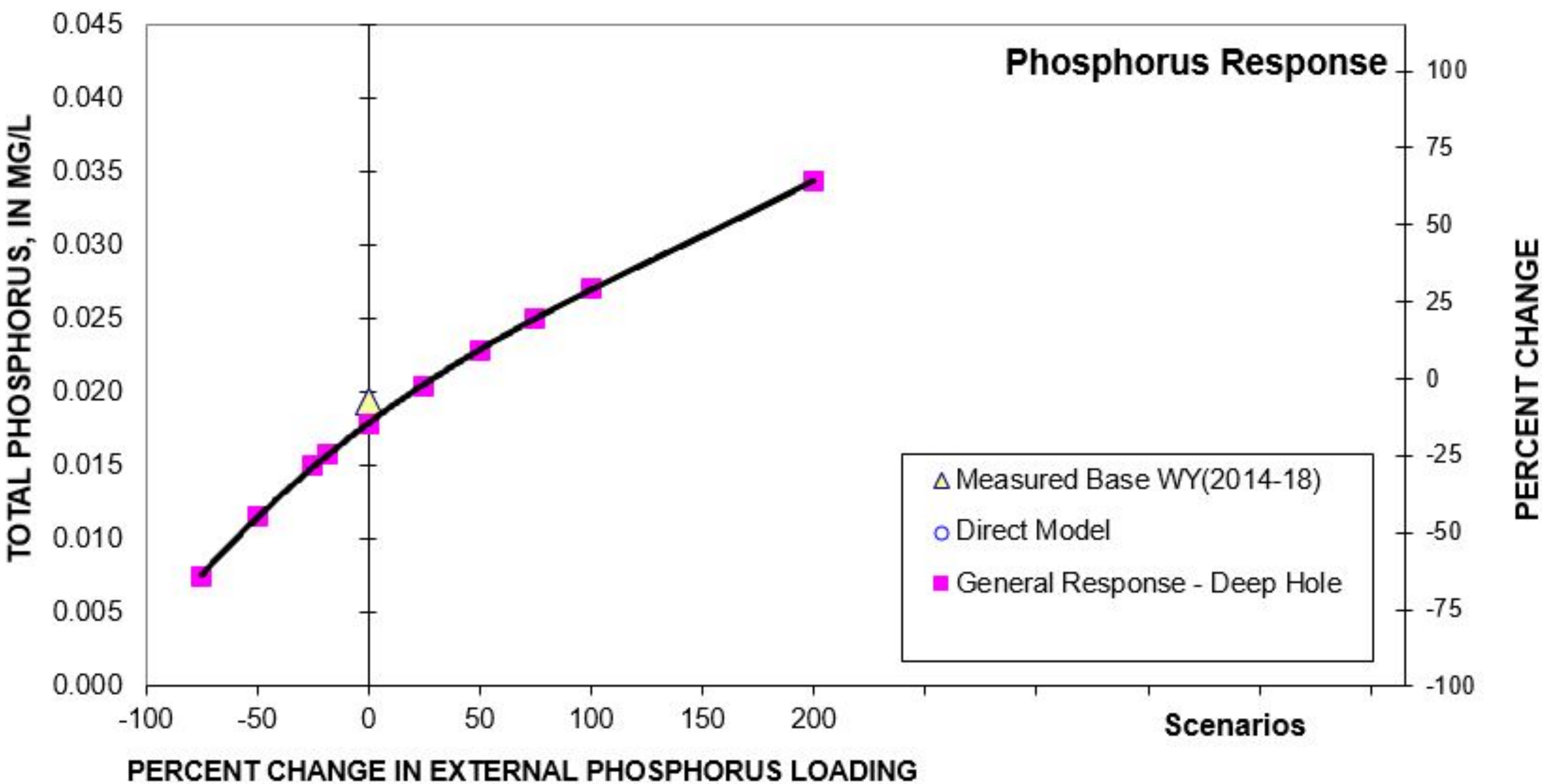



Between 2014 and 2018:

**20,800 lbs**

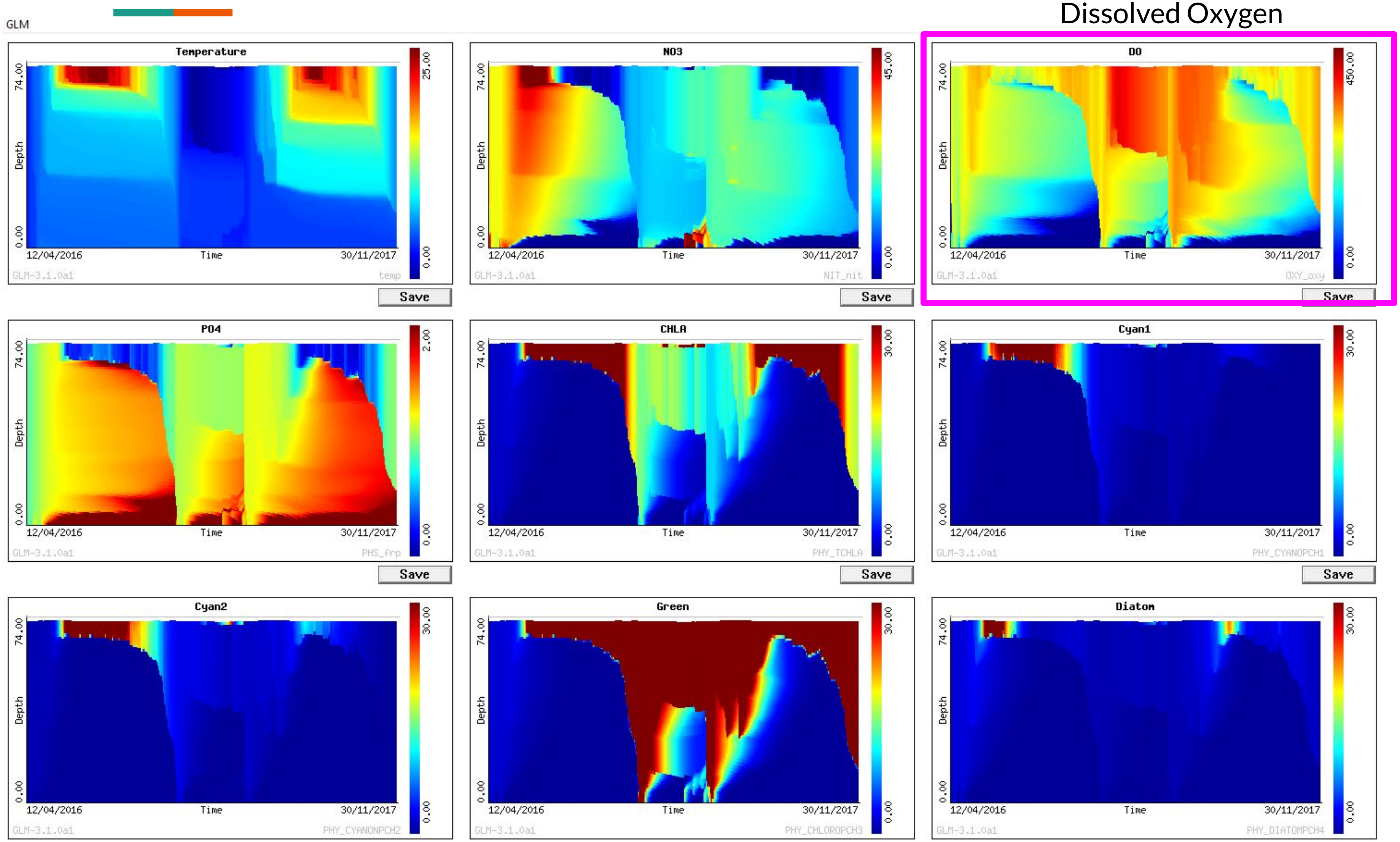
# How Much Does P Input Need to be Reduced?

With Canfield Bachman Phosphorus Model



# Result of GLM-AED to determine what causes MOM and what can be done to reduce it

Dissolved Oxygen



# Preliminary Conclusions

1. **18% reduction** in external P loading to get Green Lake's **West End** to be delisted for total P.

2. **42% reduction** in external P loading to get entire lake (**East End**) to be delisted for total P.

# Preliminary Conclusions

3

**Worsening MOMs occur during years with higher P loading**

↑ P concentration

↑ Productivity (chl a concentration)

↓ Clarity in epilimnion

4

**More modeling is still needed**

↓ P loading needed to ↑ hypolimnetic oxygen

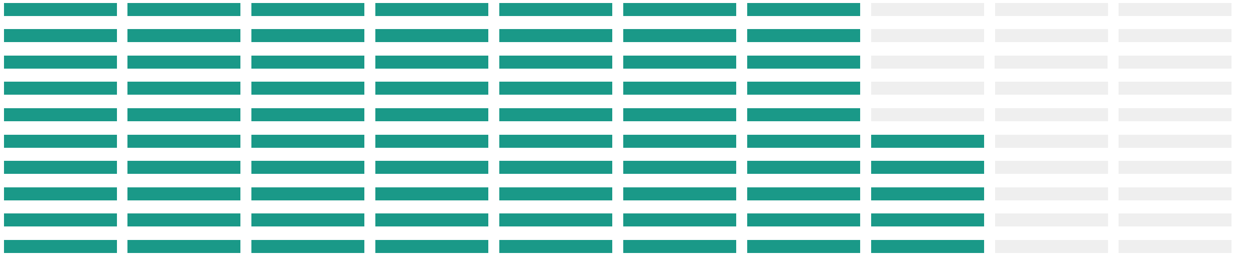
# Next Steps

## Stephanie Prellwitz

Executive Director
Green Lake Association

# Water Quality Strategy

## Current Phosphorus Loading



High Lake P

Low DO

## Future Phosphorus Loading

✓ Lower Lake P

✓ Higher DO

An Overly Simplistic

# Project Timeline

**2012+**

Implement

**BMPs**

In lake and watershed to reduce phosphorus loading

**2020**

Complete the

**LAKE STUDY**

to understand required P reductions to meet water quality goals

**2021**

Measure

**WATER QUALITY CHANGES**

via in-lake + stream samplers

**2050?**

Achieve

**WATER QUALITY GOALS**

that support a resilient lake

# Lake Management Planning Team

01

Contorium of local, state, and federal entities

Guided by a Lake Management Plan (that we really use!)

Strong relationships with landowners

# BMP Prioritization
02

Use various tools to **prioritize location and type** of best management practices

Combining funding sources to (frequently) make **practices free to the landowner**

**$2 million+ in BMPs** between 2012-2019

# Other Research Initiatives
03

**Estuary Study** with UW-Madison

**Legacy Phosphorus Study** with UW-Madison

**Social Science Study** with Purdue

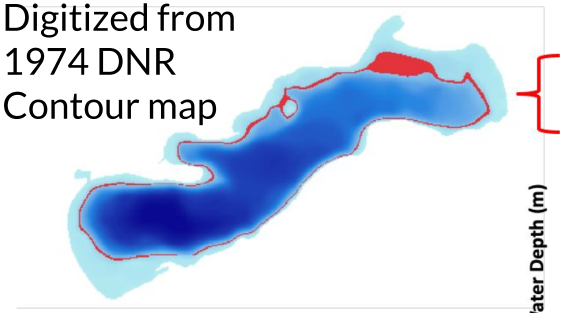
**Layering Social Science and Physical Data Proposal** with USGS, UW-Madison, and Purdue

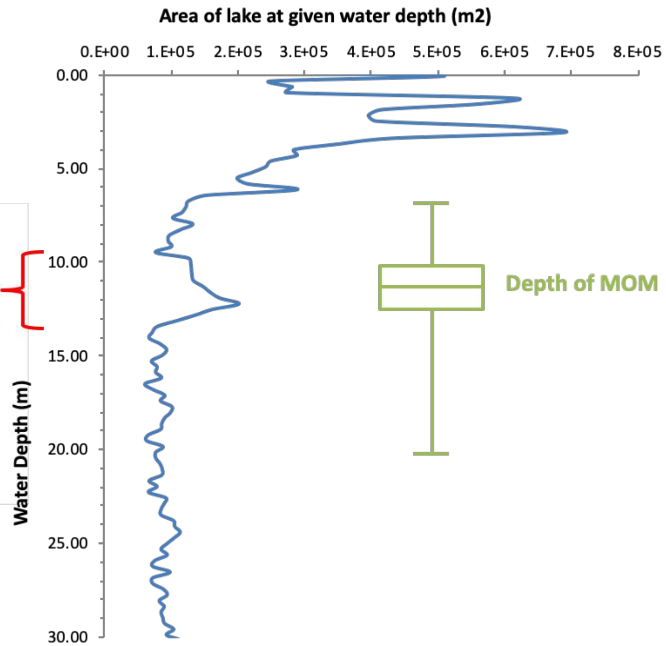

Rachel Johnson, UW-Madison

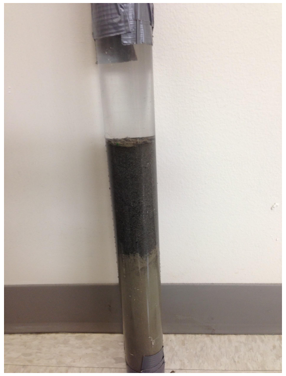
# Questions?

# Sediment Oxygen Demand

Digitized from
1974 DNR
Contour map



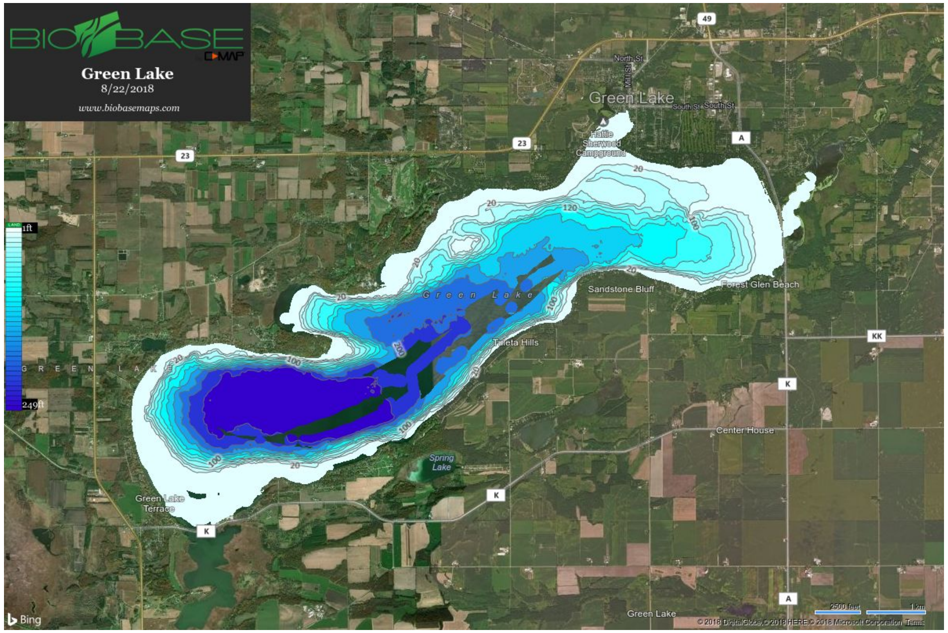


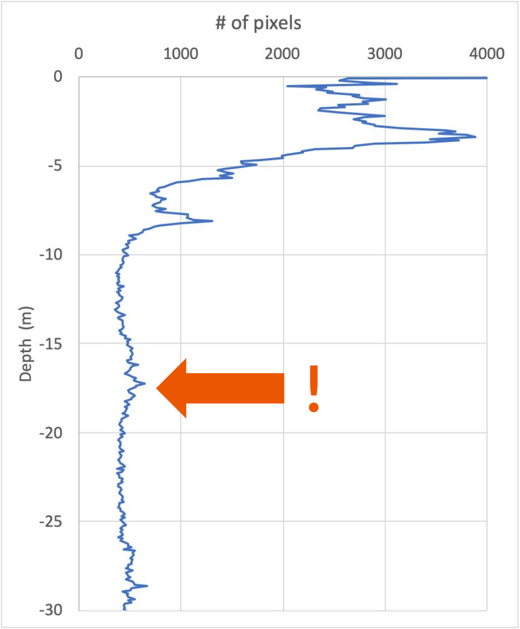



Sediment Cores
For Incubations

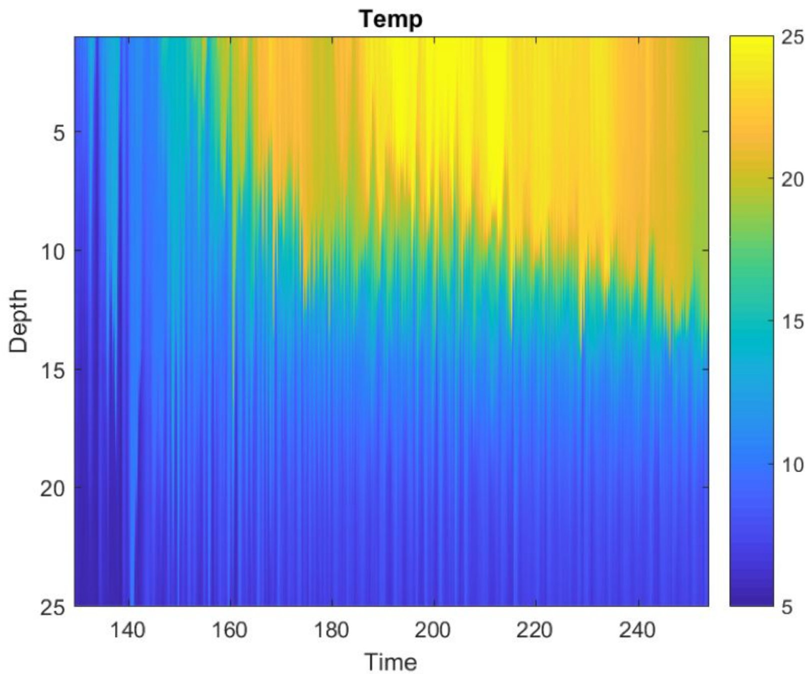
# Sediment Oxygen Demand

Updated bathymetry by P. Meshak, River Run Tackle, August 2018



# Physical Model (Temperature)

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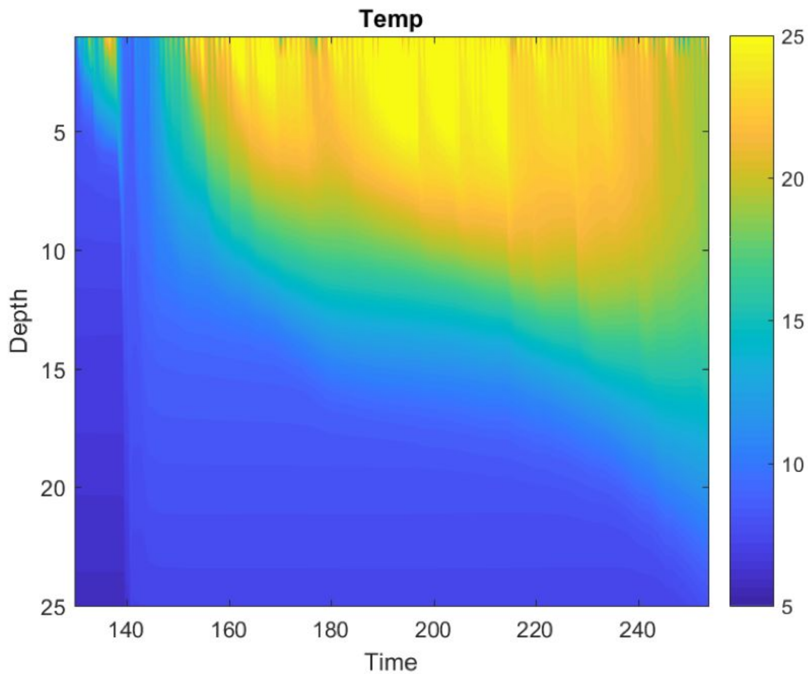


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