# Solving Mona Lake's Phosphorus and Harmful Algal Bloom (HAB) Problem


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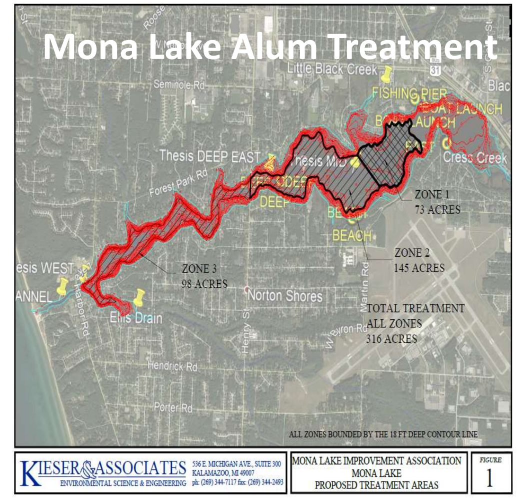
KIESER & ASSOCIATES
ENVIRONMENTAL SCIENCE & ENGINEERING

# 30+ Years on Lake & Watershed Management



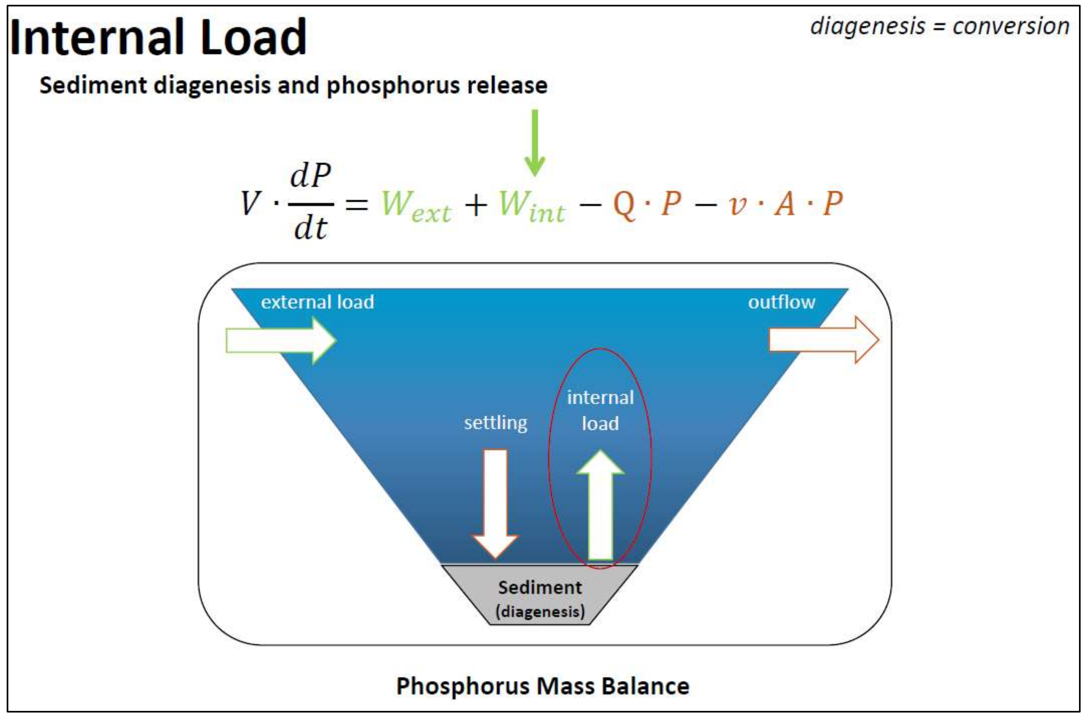


- Science & engineering-based solutions
- Planning & Management
- Policy Innovations
- Technology applications
  - Plant management
  - Modeling
  - Monitoring
  - Treatment
  - Biocontrols
  - Restoration

- 20+ lakes under management in Midwest
- Regional/national/international
- Large lakes (Tahoe – CA/NV; Simcoe-Ontario; Black, Walloon & Gull, MI)

# Understanding a Lake System… and Engineering the Right Solution

- Complex lake water quality problems require in-depth analyses, engineering, and monitoring…not quick-fix solutions
  - Understand the system – treat the cause, not the symptoms
  - Engineer a solution – well-designed management lowers uncertainty
  - Monitor the results – provides verification and allows for informed adjustments



# Today…the Mona Lake Saga

Chapter 1: Identifying the problem

Chapter 2: What’s causing the problem

Chapter 3: Setting goals

Chapter 4: Assessing restoration options

Chapter 5: Engineering the solution

Chapter 6: Pull the trigger

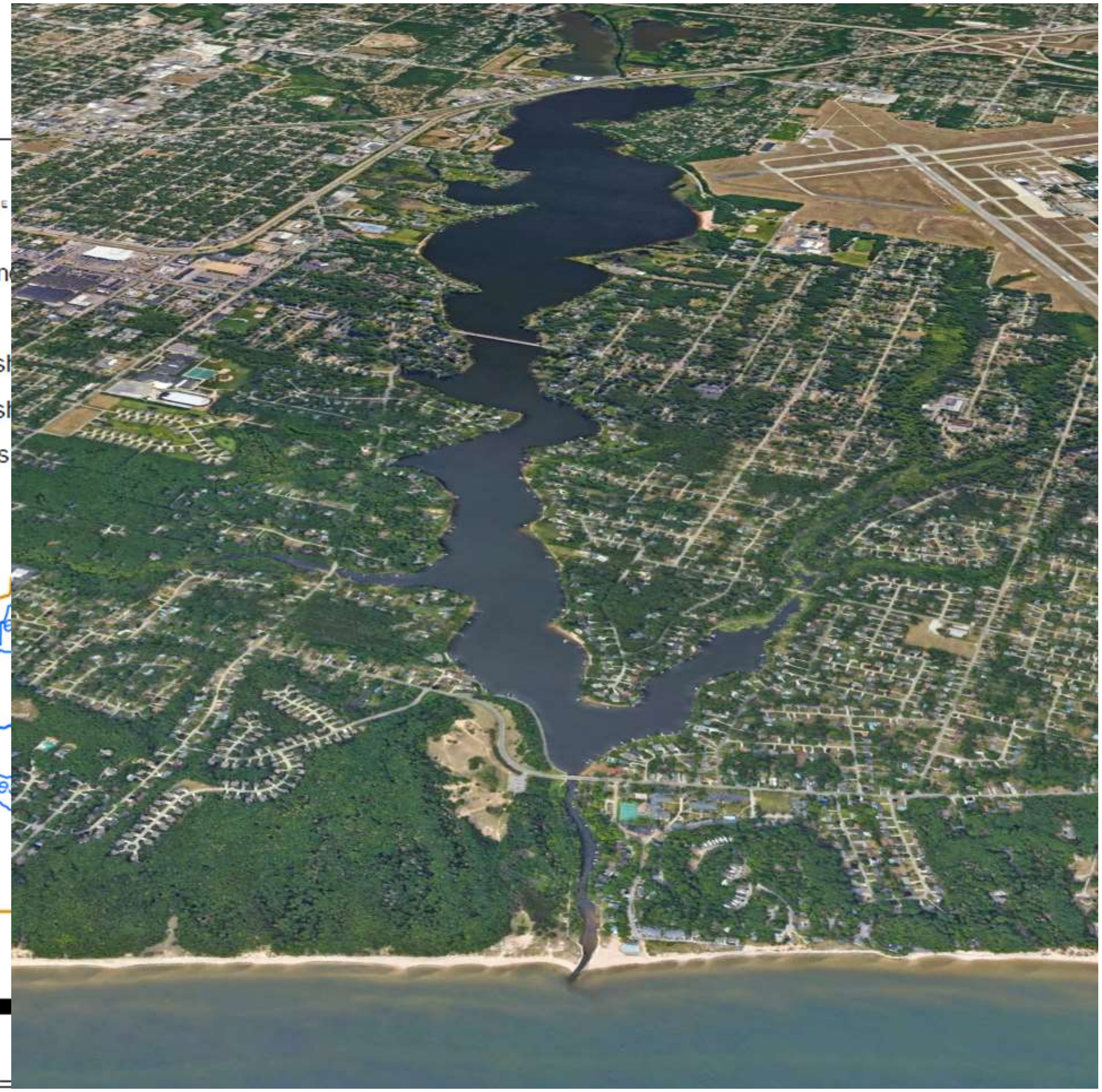
Chapter 7: Assessing outcomes

# Chapter 1: Identifying the problem

Understanding the complexity of lake systems

# About Mona Lake

- Drowned river mouth lake near Muskegon, MI
- 695 acres
- 42ft maximum depth (~15 ft average)

# Phosphorus and HABs

- Harmful Algal Blooms (HABs) seemingly everywhere
- Western Lake Erie Basin with big P & HABs problems
- Agriculture often the culprit
- But for Mona Lake?

Grand Rapids Press News Service 3 / 7

**Mona Lake algae**

Don Fischer dips his hands into toxic algae that had built up in a large area on Mona Lake in this file photo from 2008.

# Identifying t

- Consistent formai blooms
  - Unsightly
  - Harms recreatioı
  - Impact fisheries
- Some were HABs Algal Blooms)
  - Contain toxin-prı cyanobacteria
  - Hazardous to huı and pets
- High levels of P
- Mona Lake Water
  - Gotta fix this!

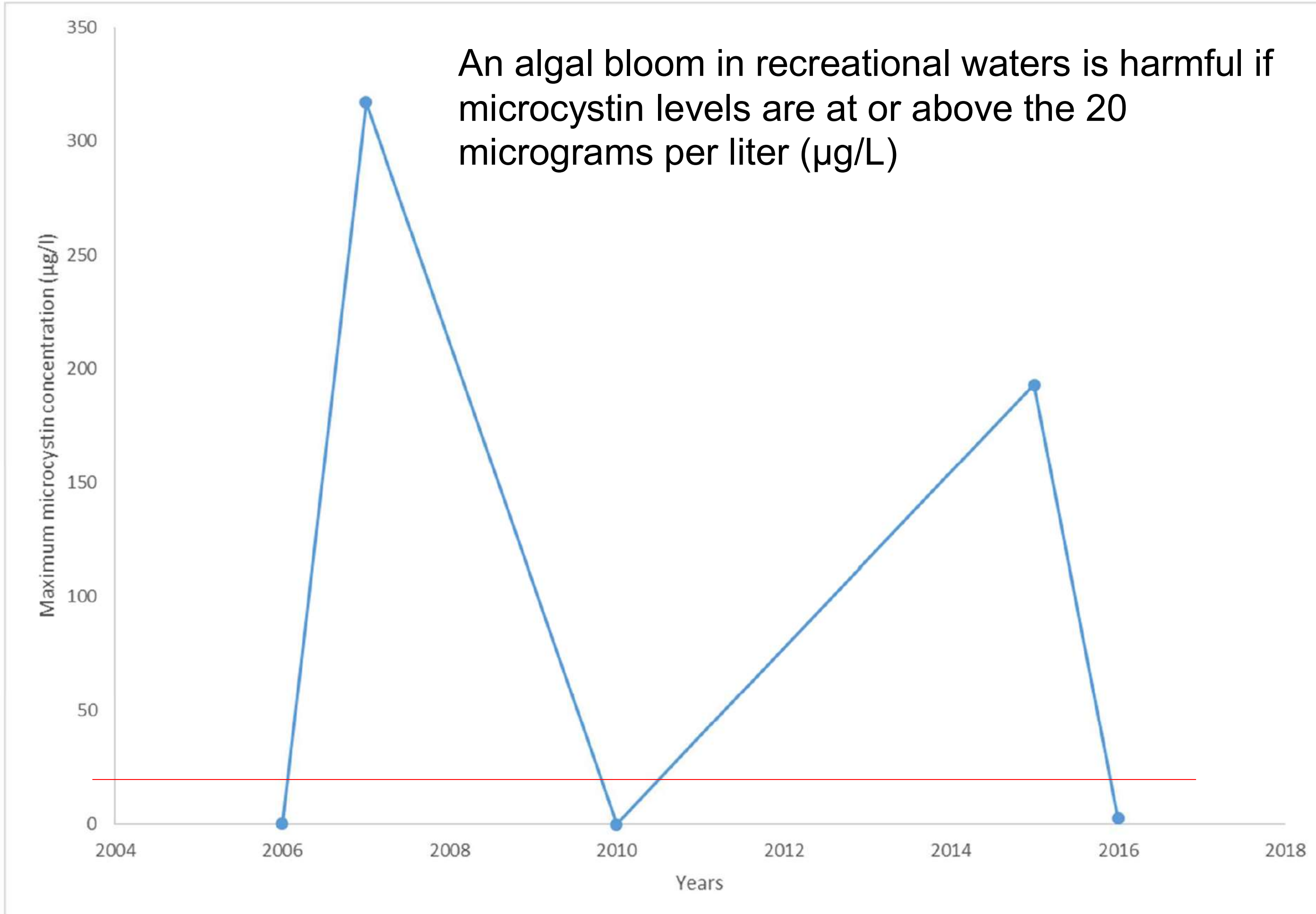


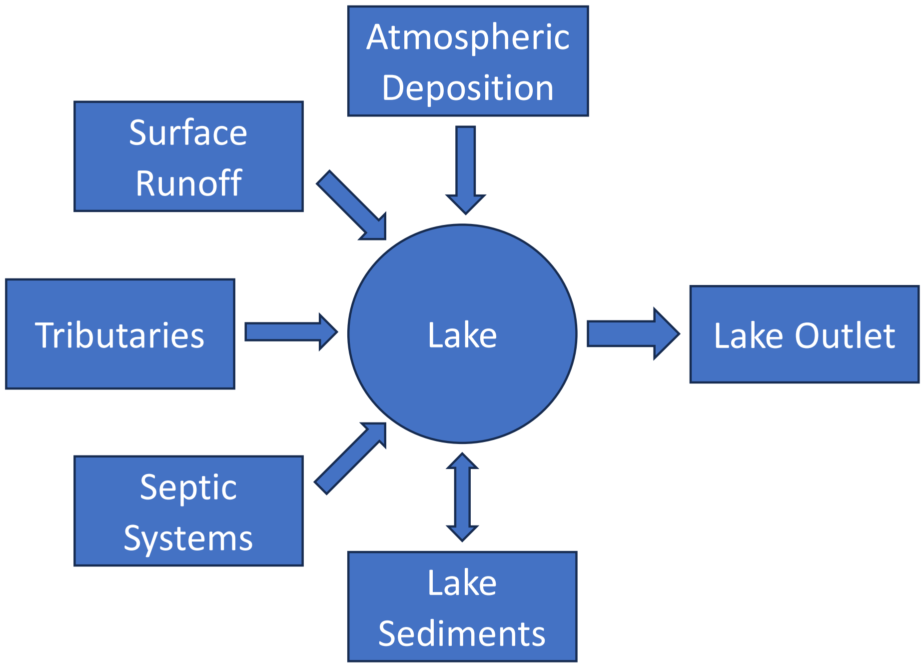

Figure 12. Maximum microcystin concentrations detected in Mona Lake. Microcystin concentration data are from the following sources: 2006: Rediske et al. (2007), 2007: R. Rediske personal communication in Gillett et al. (2015), 2010: Rediske et al. (2011), 2015: Holden (2016), and 2016: this report.

# Chapter 2: What’s causing the problem

Determining causal factors

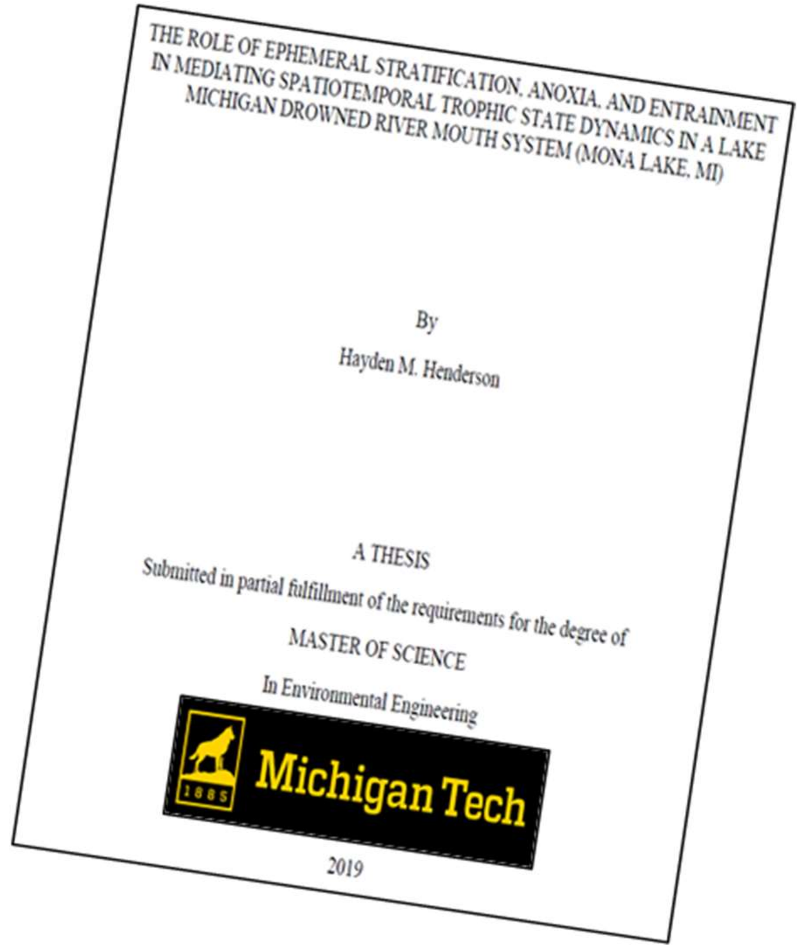
# Identifying the Cause

- Algal blooms often driven by excess phosphorus (P)
- High P in Mona Lake considered the primary causal factor…though other conditions will influence
  - Examine past reports
  - Conduct new studies
  - Develop preliminary mass balance



# Michigan Tech Study on Mona Lake

- K&A supported Michigan Tech effort to collect data in 2017-2018
  - Dr. Martin Auer
  - Hayden Henderson
- Data collected in-lake and for tributaries
  - Anonymous lake resident/MTU alumnus funder MTU research
  - Mona Lake Watershed Council funded K&A support
- ***Enabled understanding of internal and external loading***



THE ROLE OF EPHEMERAL STRATIFICATION, ANOXIA, AND ENTRAINMENT IN MEDIATING SPATIOTEMPORAL TROPHIC STATE DYNAMICS IN A LAKE MICHIGAN DROWNED RIVER MOUTH SYSTEM (MONA LAKE, MI)

By

Hayden M. Henderson

A THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

In Environmental Engineering

Michigan Tech

2019

# External Loading

- Largest exterior load to Mona Lake largely “shut off” (celery flats) circa 2015
- Calls into question, impacts of creeks and drains flowing into the lake

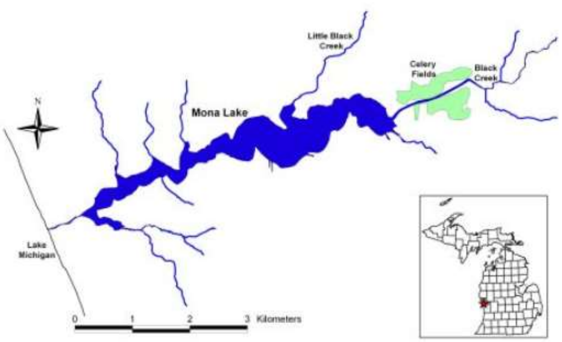
# Muck Fields as a Source of Phosphorus to Mona Lake

*During summer months, plumes of algae-laden water can be seen flowing from the muck fields into Black Creek, presumably carrying high concentrations of phosphorus.*

The Mona Lake watershed faces some of the most serious water quality challenges in west Michigan. The two major tributaries to Mona Lake, Black Creek and Little Black Creek, are impacted by too much sediment and high nutrient levels, and have impaired biotic diversity. Phosphorus levels in Mona Lake are very high, in the eutrophic to hypereutrophic range, and have been implicated in potentially toxic blue-green algae blooms in the lake.

Phosphorus source control is a major priority in the Mona Lake watershed. Black Creek has been identified as a major contributor of phosphorus to Mona Lake. Abandoned muck farms used for celery production, but now converted into shallow lakes, abut Black Creek just before it enters Mona Lake. These muck fields may be releasing phosphorus to Black Creek, and consequently, to Mona Lake.

Our goal is to determine to what degree these muck fields serve as a source of phosphorus to Mona Lake.




To accomplish this, we are sampling water quality, including phosphorus concentrations, in Black Creek upstream and downstream of the muck fields. In addition, we are analyzing the sediments in the muck fields for phosphorus content and sorption/desorption dynamics.

Based on the results of this study, we will identify mitigation strategies for controlling any phosphorus coming from the muck fields. Our results and recommendations will be provided to stakeholders for resource management decisions.

# External Loading Analysis

- Black Creek dominates external loading
- External loading higher during spring, though 2018 saw spikes in late summer

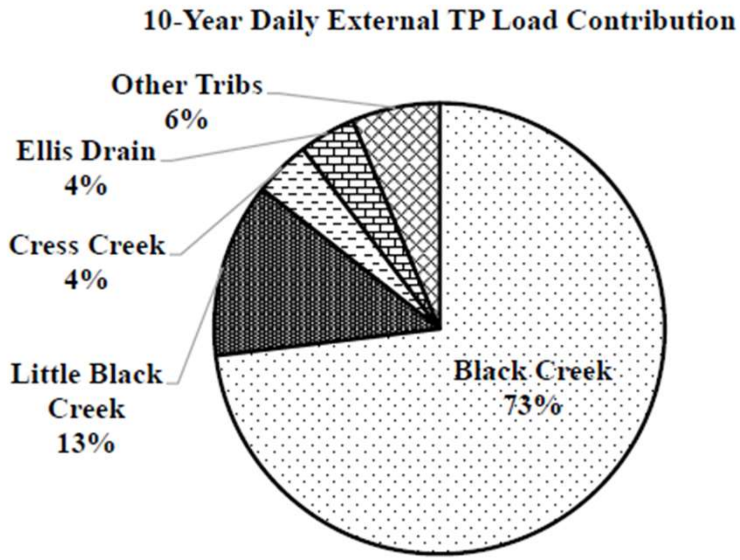



Figure 4-15 Total phosphorus load fractions for each tributary in the Mona Lake Watershed. 'Other Tribs' refers to small creek area as presented in the Mona Lake Watershed Atlas (Annis Water Resources Institute 2003).

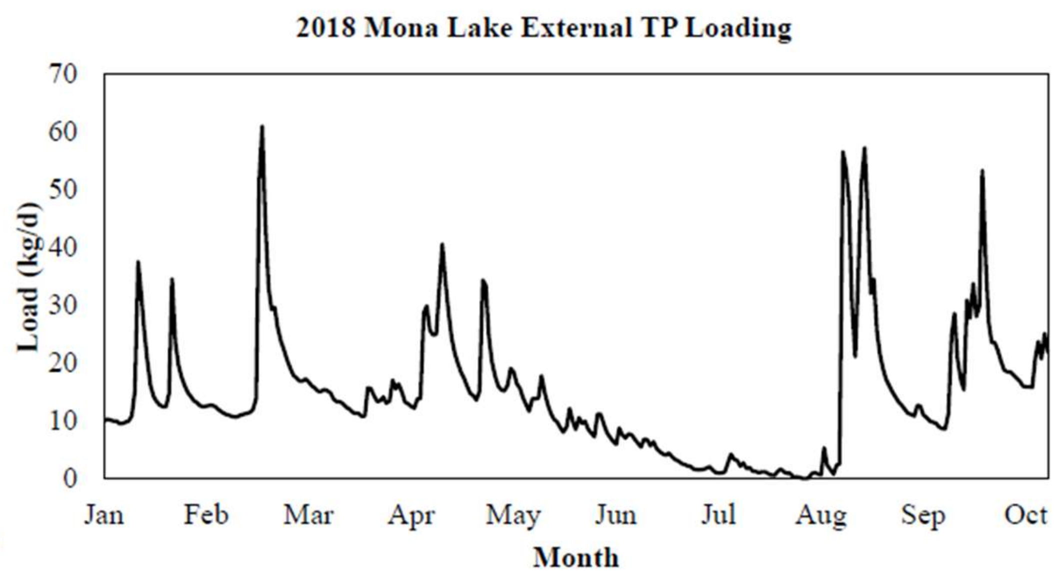
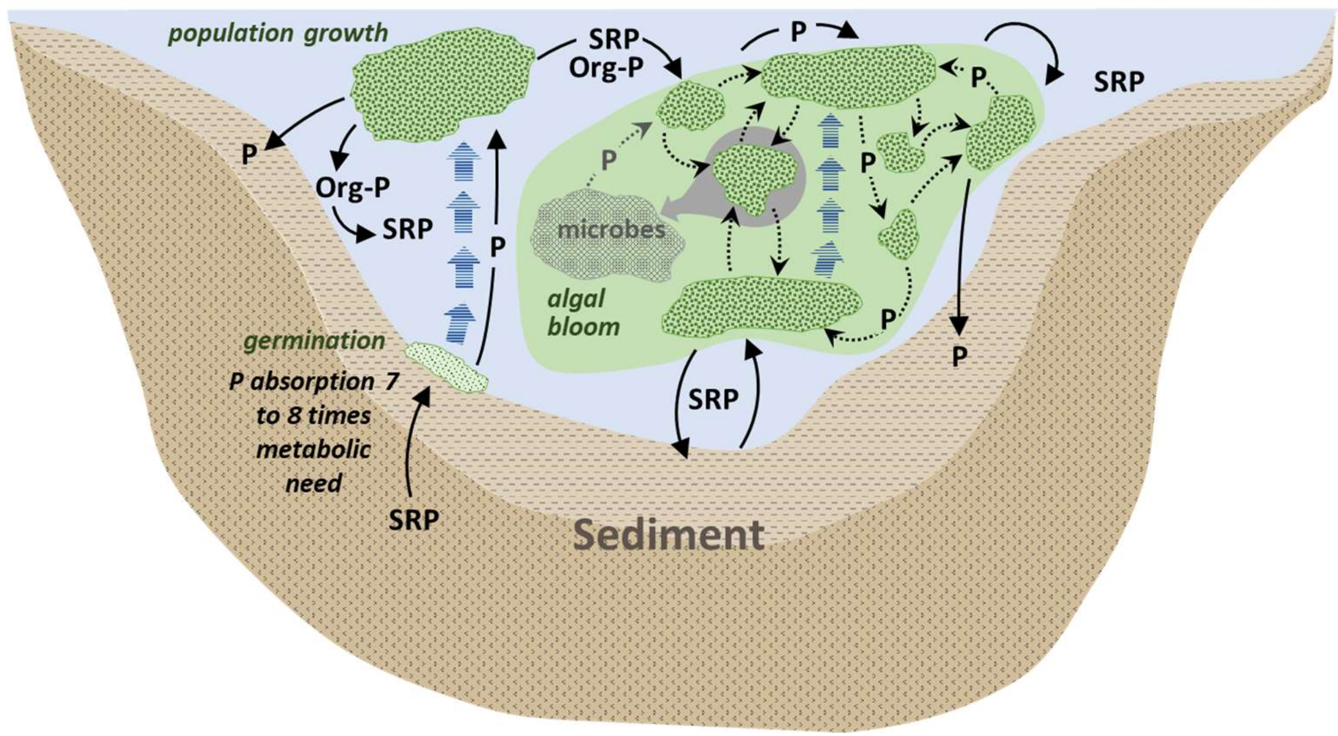



Figure 4-16 External loading (tributary summation) in 2018.

Henderson, H. M. (2019). The role of ephemeral stratification, anoxia, and entrainment in mediating spatiotemporal trophic state dynamics in a Lake Michigan Drowned River Mouth System (Mona Lake, MI) (Doctoral dissertation, Michigan Technological University).

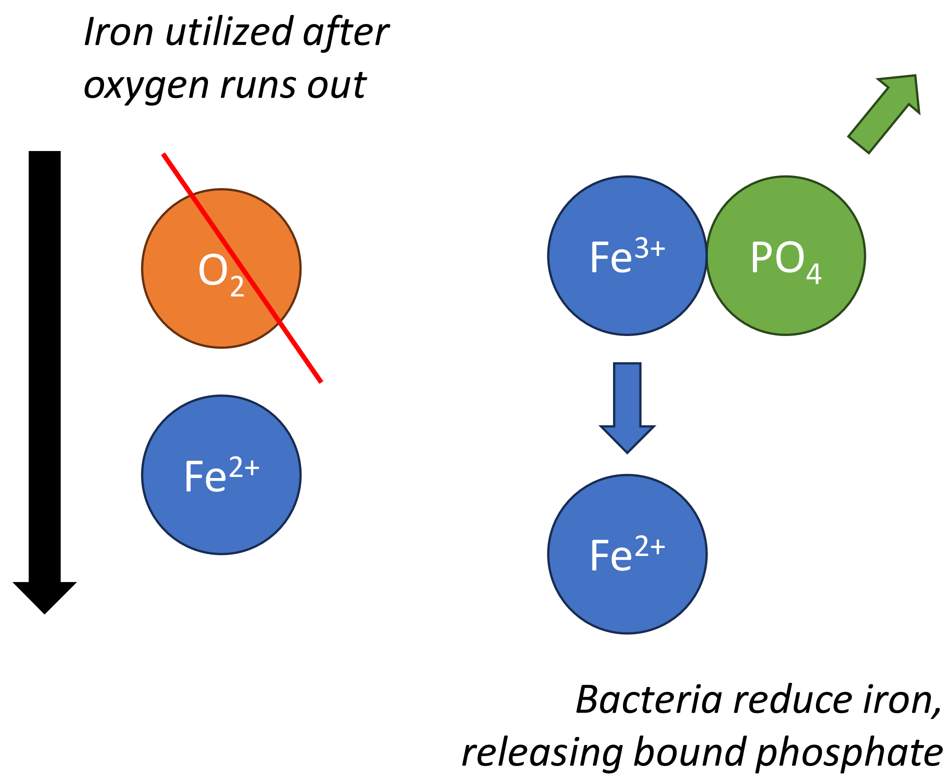
# Internal Loading

- Mona lake water quality sampling showed high P concentrations
- P loading comes from legacy P stored in lake sediment
- Sediment will release P under low-oxygen conditions



# The Chemistry of Sediment-P Release

- Oxygen used as an electron carrier in respiration
  - Under anoxia, sediment bacteria can use iron instead
- Sediment-P bound to insoluble ferric (+3) iron
  - Bacteria reduce iron to ferrous (+2) and release attached phosphate ($PO_4$)



# Critical In-Lake Monitoring (2017-2018)

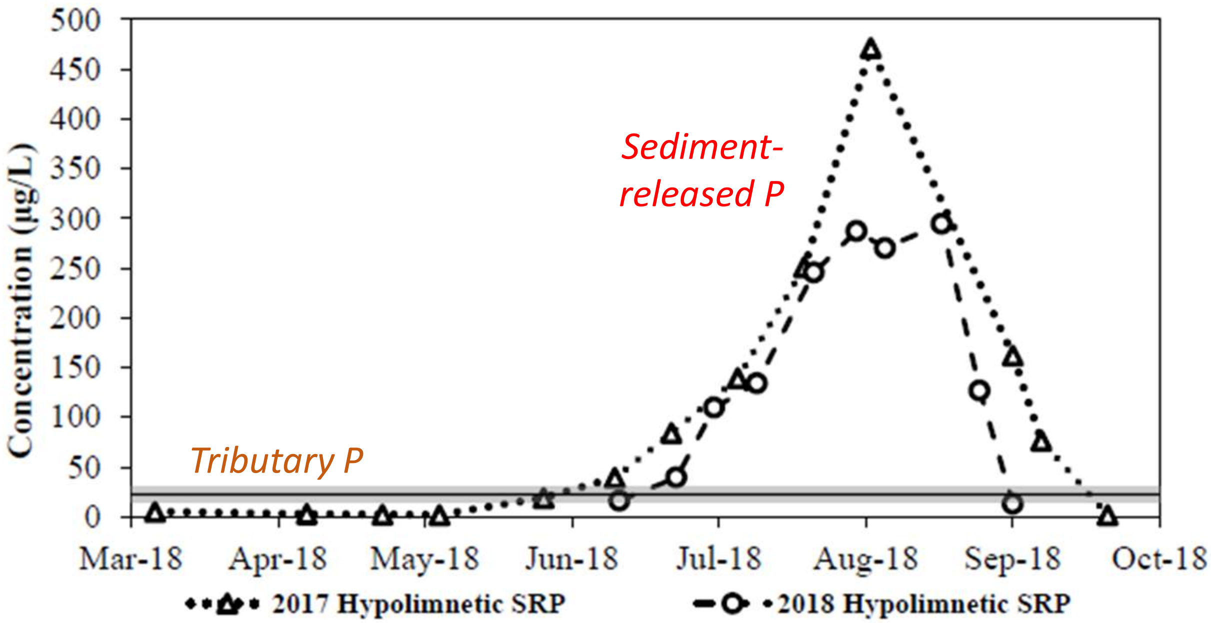



Figure 4-30 Mean tributary SRP (2017/2018) and mean hypolimnetic SRP (2017 and 2018), illustrating lake bottom water concentrations higher than discharge concentrations, pointing to the source of internal loading. Solid line indicates tributary mean while shaded area illustrates tributary SRP range (mean plus and minus the standard deviation).

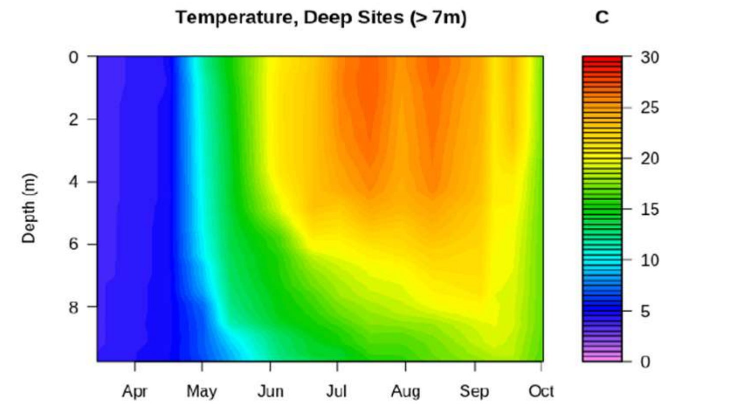



Figure 4-6 Composite of Deep East, Deep West, and West station thermal succession, 2018

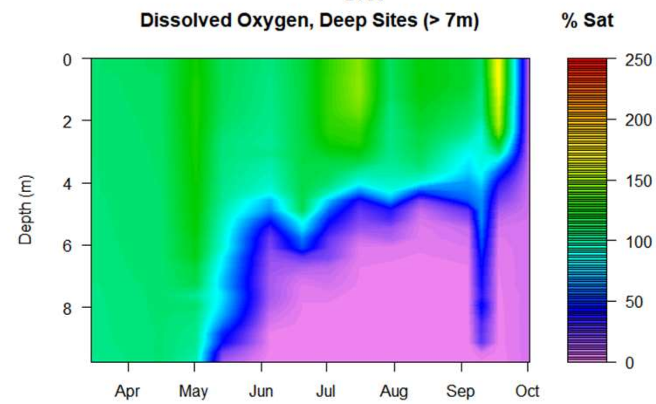
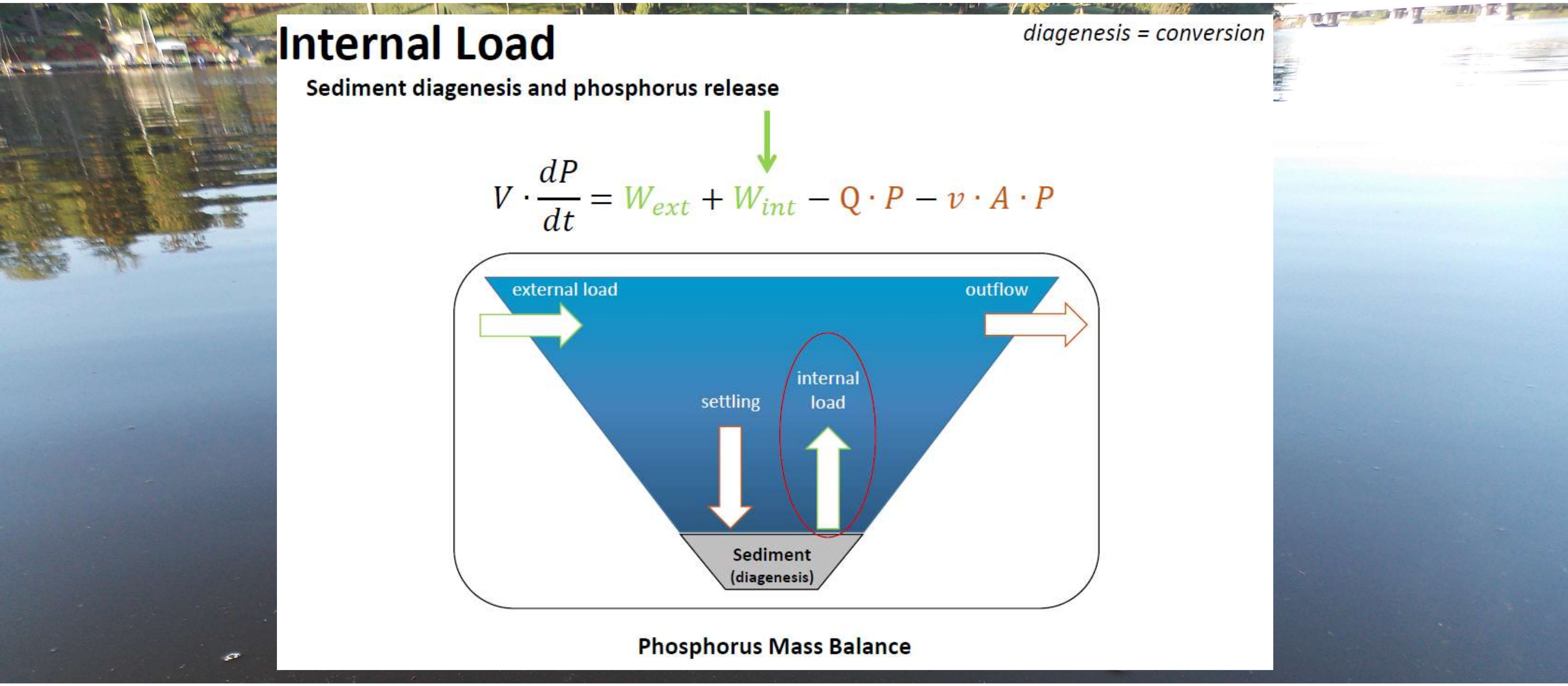



Figure 4-7 Composite of Deep East, Deep West, and West station dissolved oxygen succession, 2018, as percent saturation .

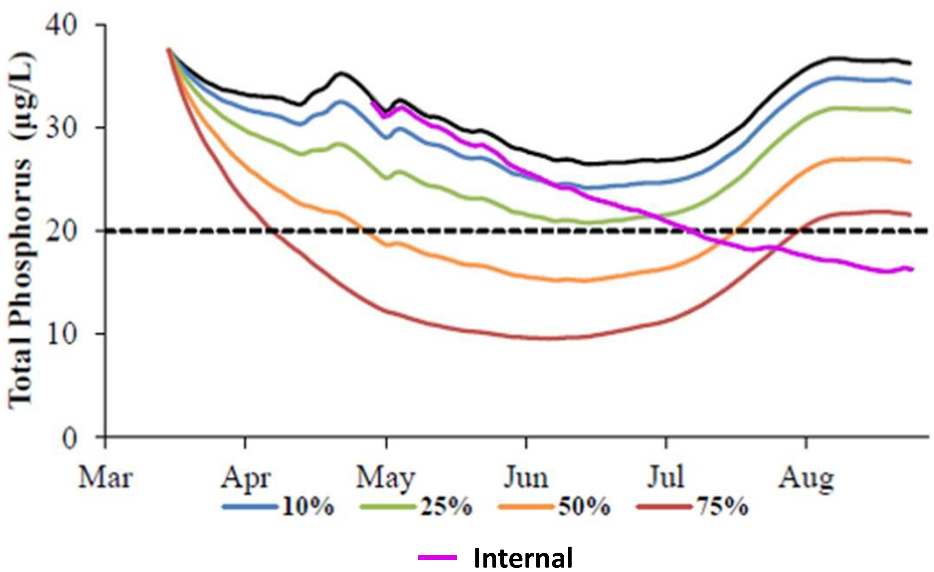
Henderson, H. M. (2019). The role of ephemeral stratification, anoxia, and entrainment in mediating spatiotemporal trophic state dynamics in a Lake Michigan Drowned River Mouth System (Mona Lake, MI) (Doctoral dissertation, Michigan Technological University).

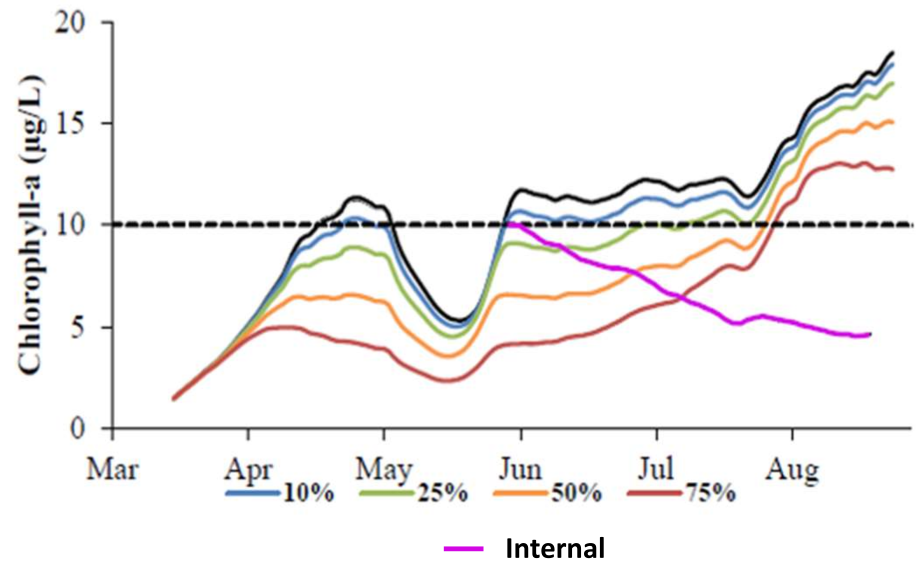
# …Primary Restoration Target



# Target Confirmed…
# Internal Load Management the First Priority

- > 25% External load reduction is unlikely
- Internal reduction outperforms external reduction during critical months (July/August)

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# Chapter 3: Setting goals

What is the end game?

# Desired Outcomes and Available Resources

- What is the end goal?
  - Fewer algal blooms?
  - None at all?
- What is the expected time frame of outcomes?
  - 5 years? 10? 20?
- Available resources ($) and over what time-period?

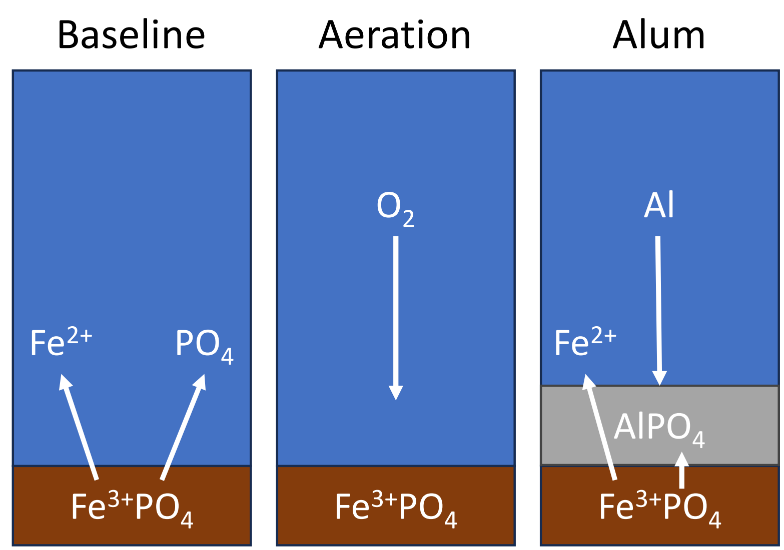
Kendra Stanley-Mills / The Muskegon Chronicle 1 / 7

# Chapter 4: Assessing restoration options

Understanding benefits, limitations and costs…

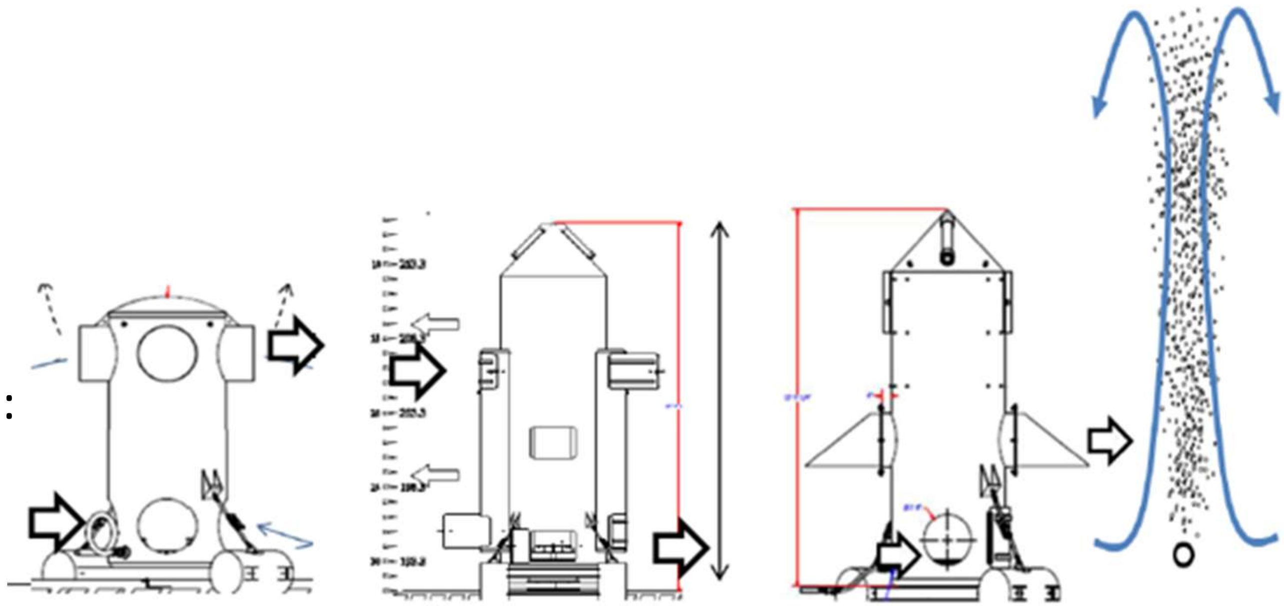
# Possible Solutions

- Solution goal: prevent lake sediment P release
- Options:
  - Oxygenate bottom waters (hypolimnion) to prevent P release (iron-bound P solubilizes)
    - Hypolimnetic aeration
    - Destratification
  - Chemically bind P too tightly to be released
    - Alum treatments



# Hypolimnetic Aeration and Destratification Options

- Introducing oxygen to bottom waters (hypolimnion) limits iron reduction and sediment P release
- Two options for doing this:
    - Hypolimnetic aeration towers (multiple configurations)
    - Destratification via diffuser lines



1 2 3 4

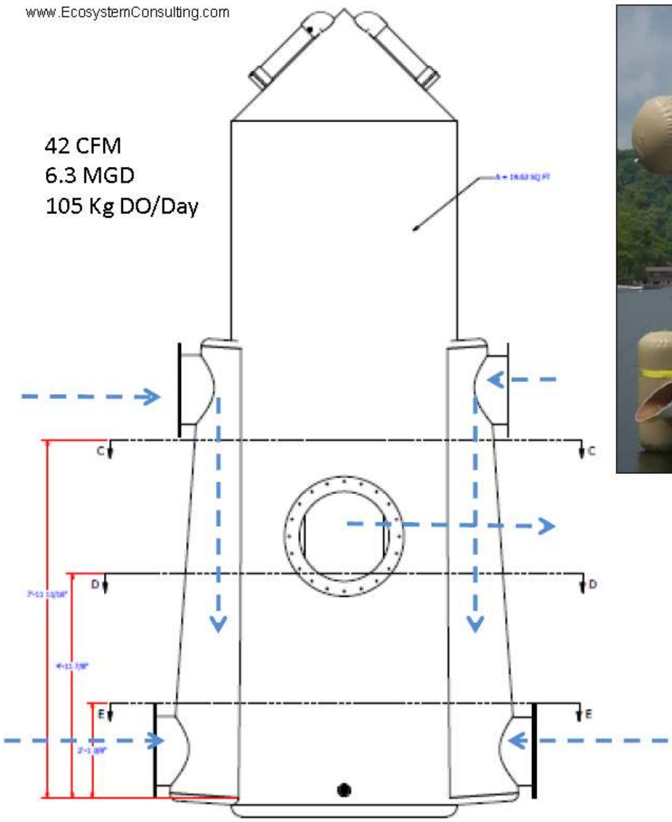
1. *CMD layer aeration*
2. *Downward circulating layer aeration*
3. *Traditional hypolimnetic aeration*
4. *Destratification via diffuser lines*

# Aeration Towers

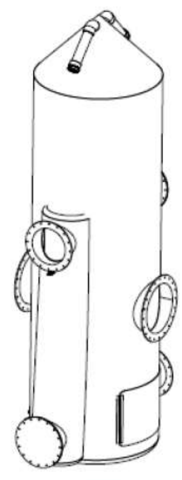
# Diffuser Lines

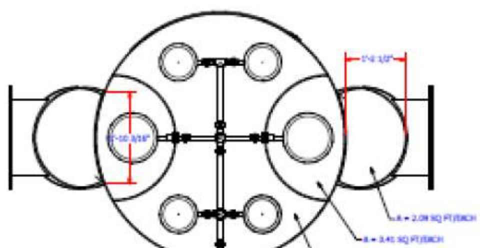
**PIP6-X Layer Aerator**

www.EcosystemConsulting.com




*Air-Lift Diffusers*

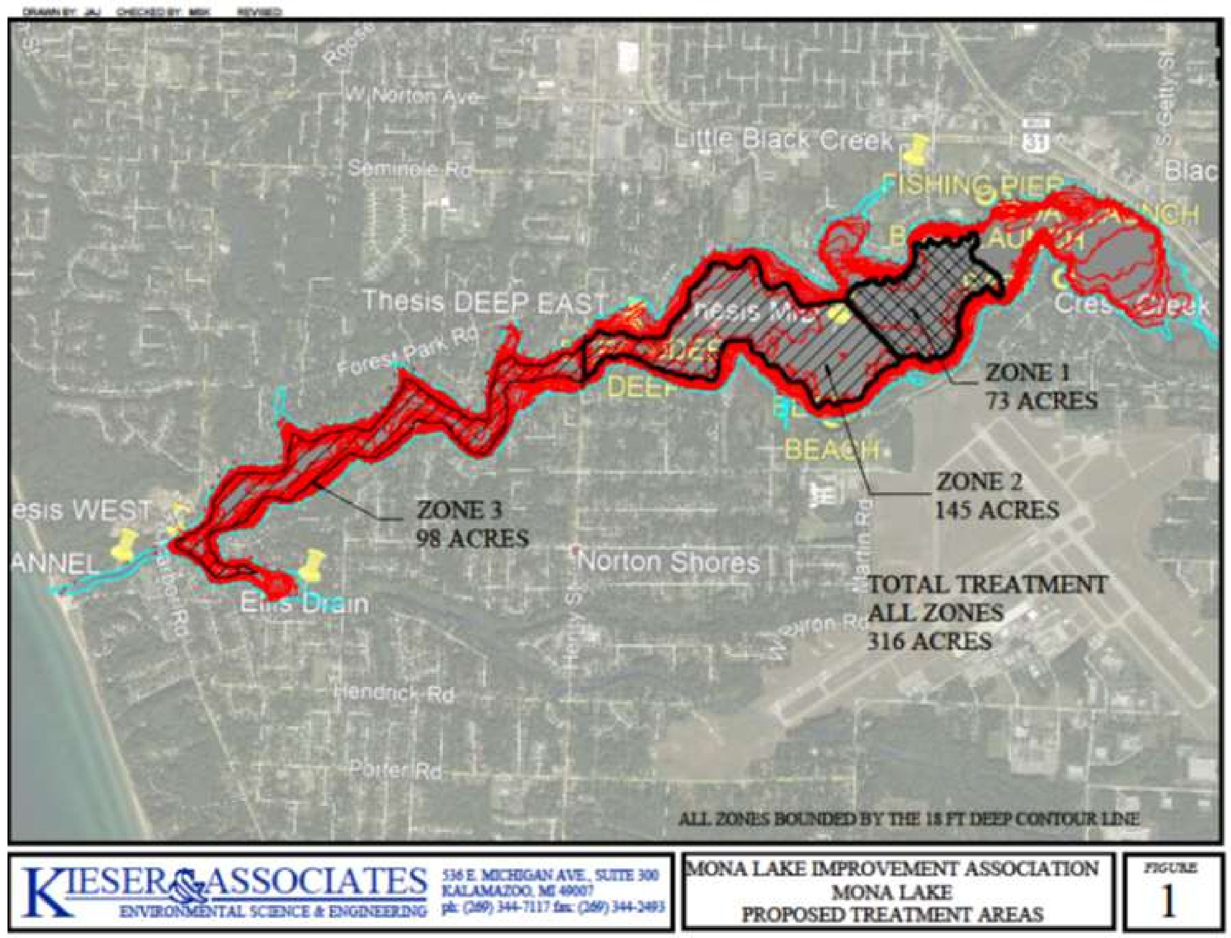



US Pat. 5,755,976

# Technical & Regulatory Considerations

- 3,200 acre-feet of volume requiring aeration
- EGLE has concerns and additional permitting requirements when destratification is possible
  - Hypolimnetic aeration does not destratify
  - Diffuser lines will destratify (for this volume and application)



# Alum Treatment

- Aluminum added to lake via controlled dosing
- Binds P in water column as well as at sediment surface
- Al-P bond holds well under low/no oxygen conditions, preventing re-release

# Treatment Scenarios and Expected Costs

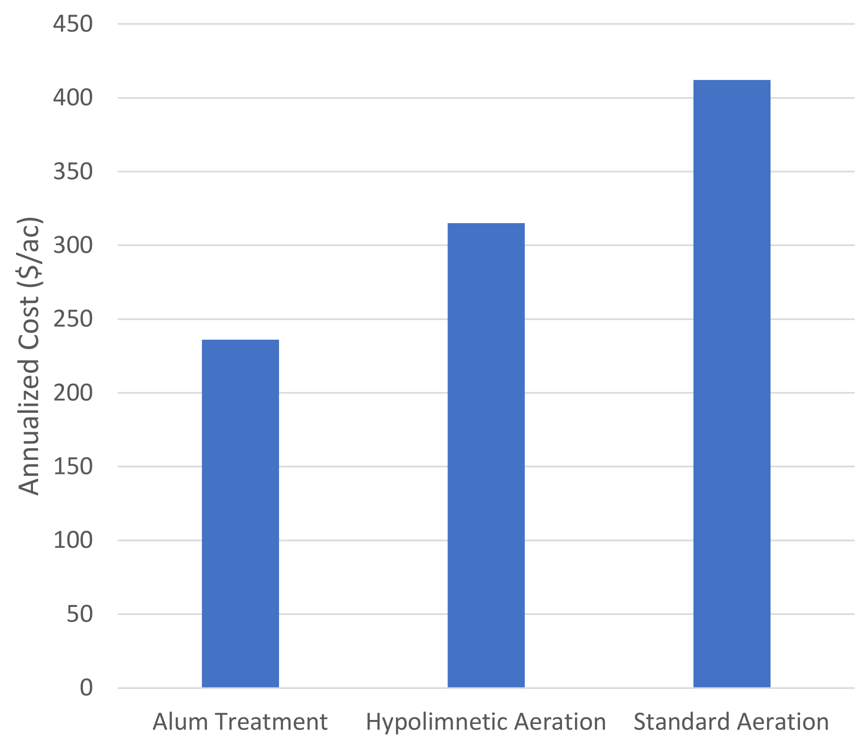
**Table 1. Mona Lake sediment treatment project scenarios and costs.**

| In-Lake Restoration Option | Alum Lump Sum/ Aeration Capital Costs | 18% K&A Engineering /Permitting /Monitoring /Modeling | 10-year O&M Costs | Line Item Totals | Annualized Costs (10 years) | Annualized $/acre |
|---|---|---|---|---|---|---|
| **1. Alum** | | | | | | |
| *HAB Aquatic Solutions* | | | | | | |
| 73 acres | $ 146,000 | $ 26,280 | $ - | $ 172,280 | $ 17,228 | $ 236.00 |
| 316 acres | $ 632,000 | $ 113,760 | $ - | $ 745,760 | $ 74,576 | $ 236.00 |
| **2. Hypolimnetic Aeration (non-destratification)** | | | | | | |
| *Ecosystems Consulting* | | | | | | |
| One Unit (up to 73 Acres) | $ 150,000 | $ 35,100 | $ 45,000 | $ 230,100 | $ 23,010 | $ 315.21 |
| Four Units (316 acres) | $ 600,000 | $ 140,400 | $ 180,000 | $ 920,400 | $ 92,040 | $ 291.27 |
| *Canadian Pond* | | | | | | |
| Two Units (73 Acres) | $ 180,000 | $ 54,000 | $ 90,000 | $ 324,000 | $ 32,400 | $ 443.84 |
| Ten units (316 acres) | $ 900,000 | $ 270,000 | $ 450,000 | $ 1,620,000 | $ 162,000 | $ 512.66 |
| **3. Aeration (destratification)** | | | | | | |
| *General Environmental Systems* | | | | | | |
| 73 acres | $ 225,000 | $ 45,900 | $ 30,000 | $ 300,900 | $ 30,090 | $ 412.19 |
| 316 acres | $ 900,000 | $ 183,600 | $ 120,000 | $ 1,203,600 | $ 120,360 | $ 380.89 |

- 3 solutions analyzed
  - Alum application
  - Hypolimnetic aeration
  - Destratification
- Multiple configurations considered for hypolimnetic aeration
  - Different suppliers
  - Different quantities

# Techno-Economic Analysis

- All 3 options deemed technically feasible
  - Compatible with Mona Lake system
  - Capable of limiting sediment-P release
- Each had different price points
  - Alum treatments most economical



# Getting it right…

*Benefits of Alum:*

- Effectiveness of alum treatments for sediment-P suppression are well-studied and demonstrative
- One-time dosing with no capital equipment or O&M
- Can be spread over 3 years allowing more time for fundraising without reduction in water quality benefits (though no cost savings)
- Benefits typically last for 10-20 years

*Drawbacks with Alum:*

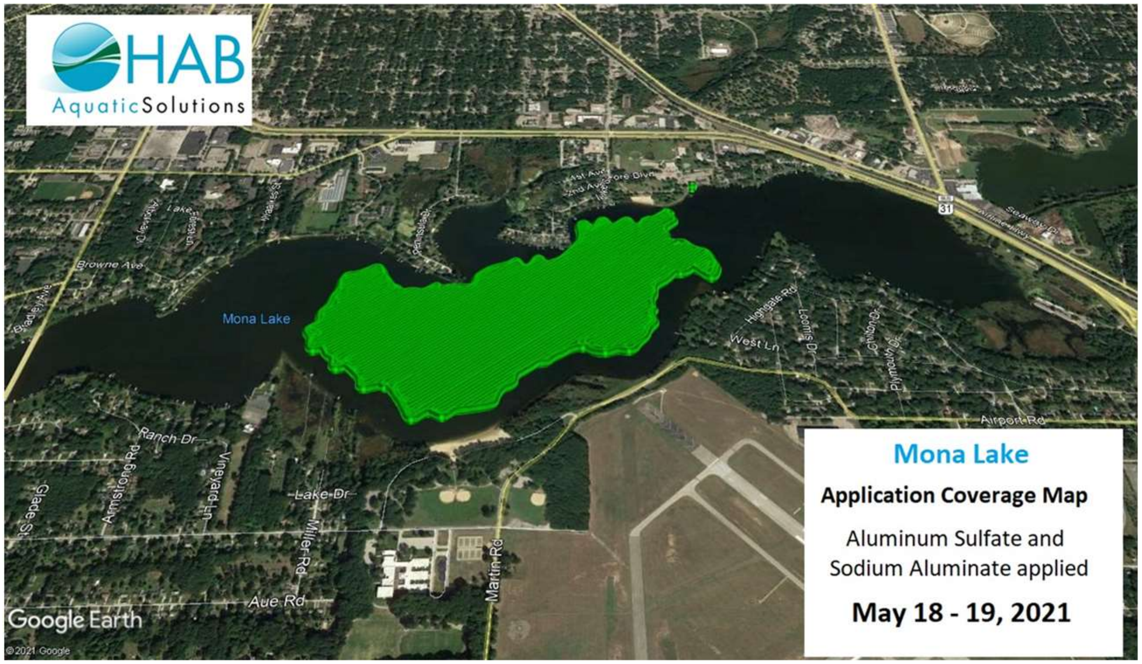
- If external watershed P load reductions are not achieved, the 10-20 year expected treatment life effectiveness may be diminished
- Sediment P is locked in place, and cannot be flushed out; release could occur after 10-20 years

# Chapter 5: Engineering the solution

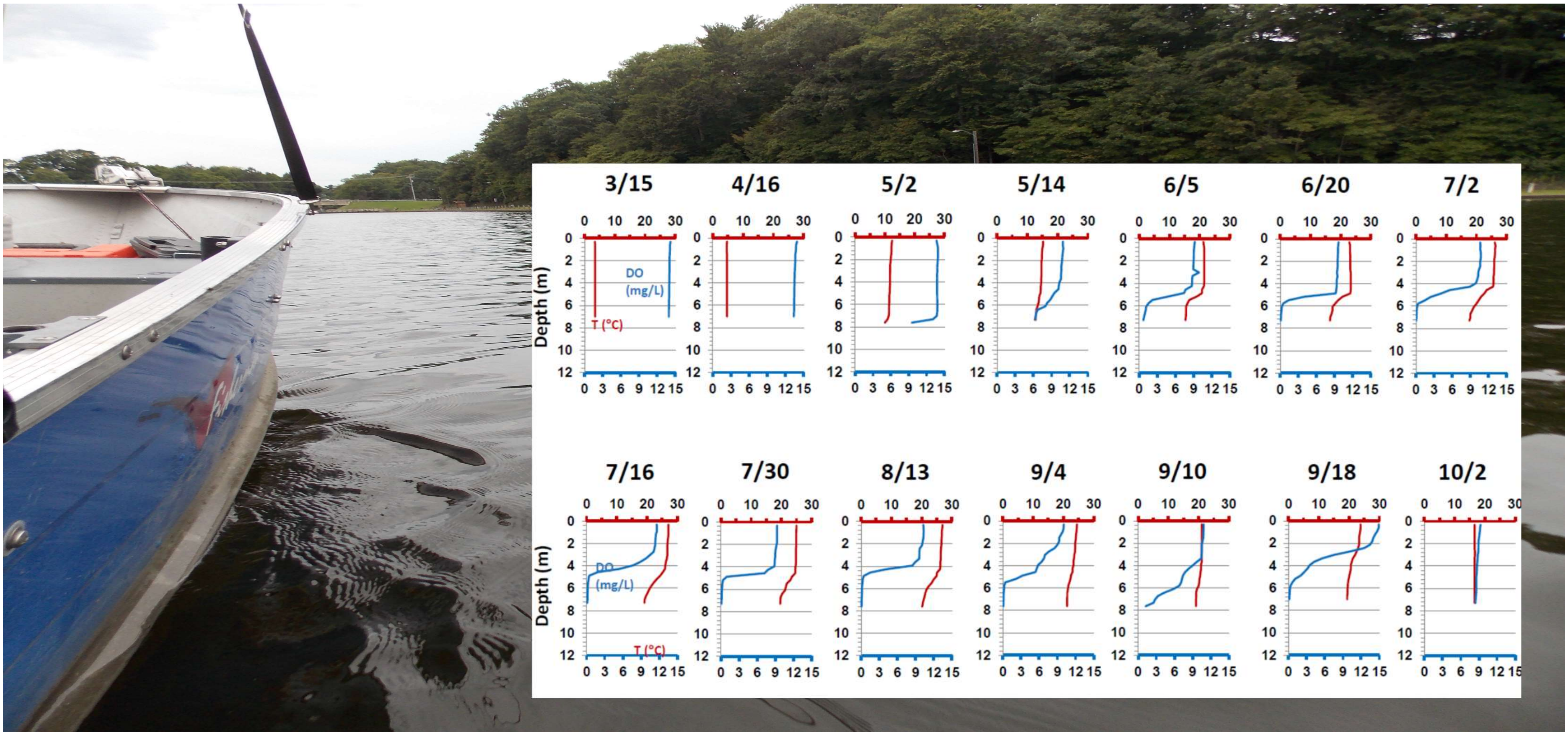
Defining key elements

# Engineering the Alum Solution

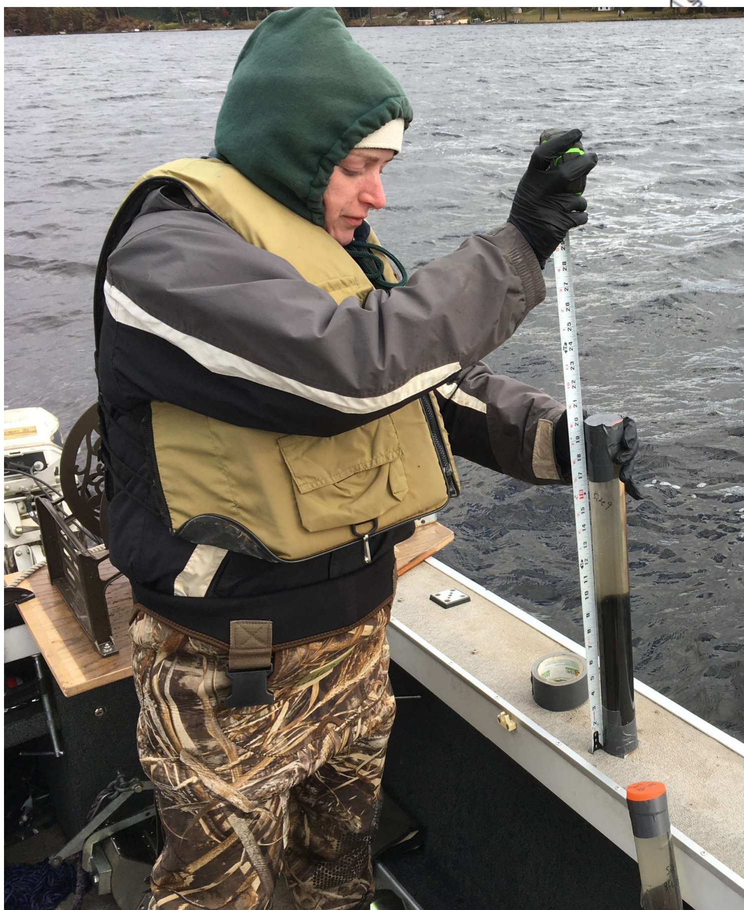
- Engineering design
  - Sediment sampling and analysis
  - Alum Dosing Requirements based on sampling
  - Bidding Documentation and bidding support
  - Application oversight and monitoring

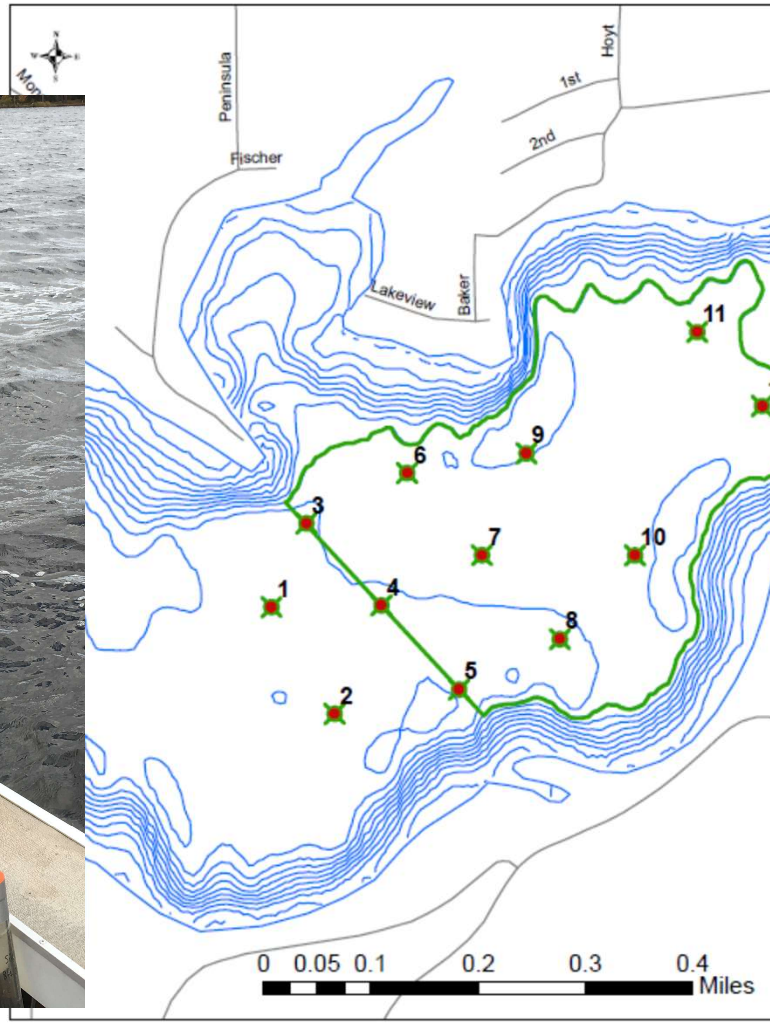


# Additional Data Needs – Water Quality



# Sediments






| Site ID | Data Gathered, 11/5/19 ***(Note: Sonar recorded at all stations and throughout survey area)*** |
|---|---|
| **1** | WQ, In-Tact Sed Core (0.9ft) |
| **2** | In-Tact Sed Core (1.3ft) |
| **3** | Ponar Grab |
| **4** | Ponar Grab |
| **5** | Ponar Grab |
| **6** | Ponar Grab |
| **7** | WQ, Ponar |
| **8** | Ponar Grab |
| **9** | In-Tact Sed Core (0.83ft) |
| **10** | Ponar Grab |

# Engineering Continued

- Permitting
  - Alum application permitting through Rule 97 Certificate of Compliance.
  - Yearly monitoring monthly from application through summer and early fall.
  - Analysis and Yearly reporting required by permit and status of efficacy of treatment.
- Treatment to be spread over 3 applications
  - All applications targeted same area, used variable dosage rates
  - 50% in 2021
  - 25% in 2022
  - 25% in 2023

# Projected 2021-24 Alum Program Costs

| **Category** | **3-year Costs ($)** |
|---|---|
| Alum | 252,326 |
| K&A Design | 26,000 |
| K&A Monitoring/ Reporting | 41,000 |
| *Subtotals* | *319,326* |
| **10-year Annualized Cost/acre** | **213** |

# Chapter 6: Pull the trigger

When all is ready, implement

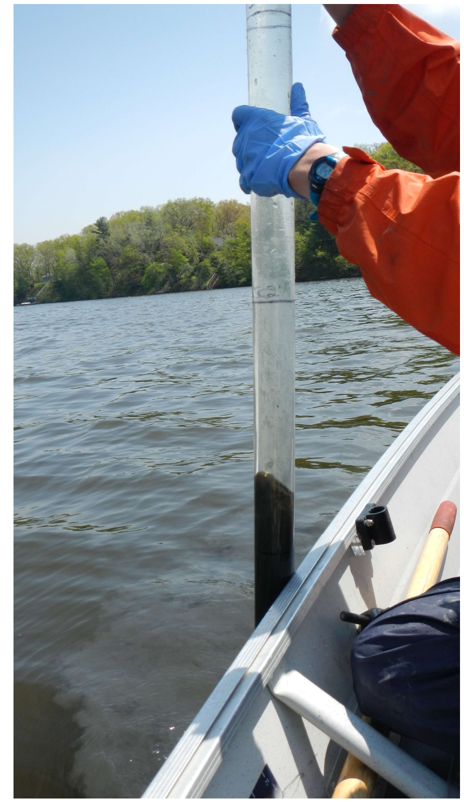
# Mona Lake Alum Treatments


# Chapter 7: Assessing outcomes

Is it working and do we need to adapt?

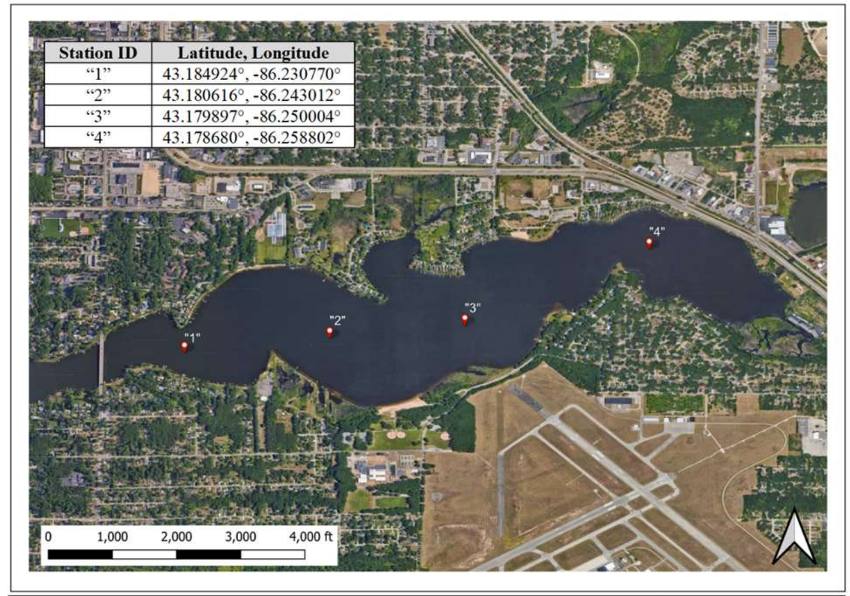
# Monitoring for Impacts and Effectiveness

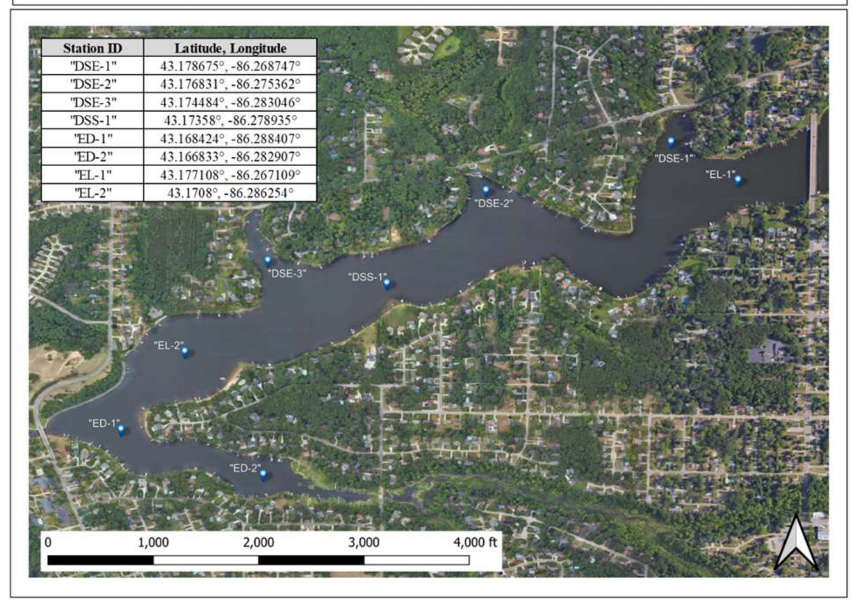
- Monitoring allows understanding of management impacts
  - Multiple locations – spatial resolution
  - Multiple times – temporal resolution
  - Multiple parameters: assess P but also possible secondary impacts
  - Multiple media: sediment and water
- <u>Baseline monitoring</u>: assess conditions prior to treatment
- <u>During treatment</u>: monitor for adverse impacts
- <u>After treatment</u>: assess performance outcomes and effectiveness



# Mona Lake Treatment Monitoring

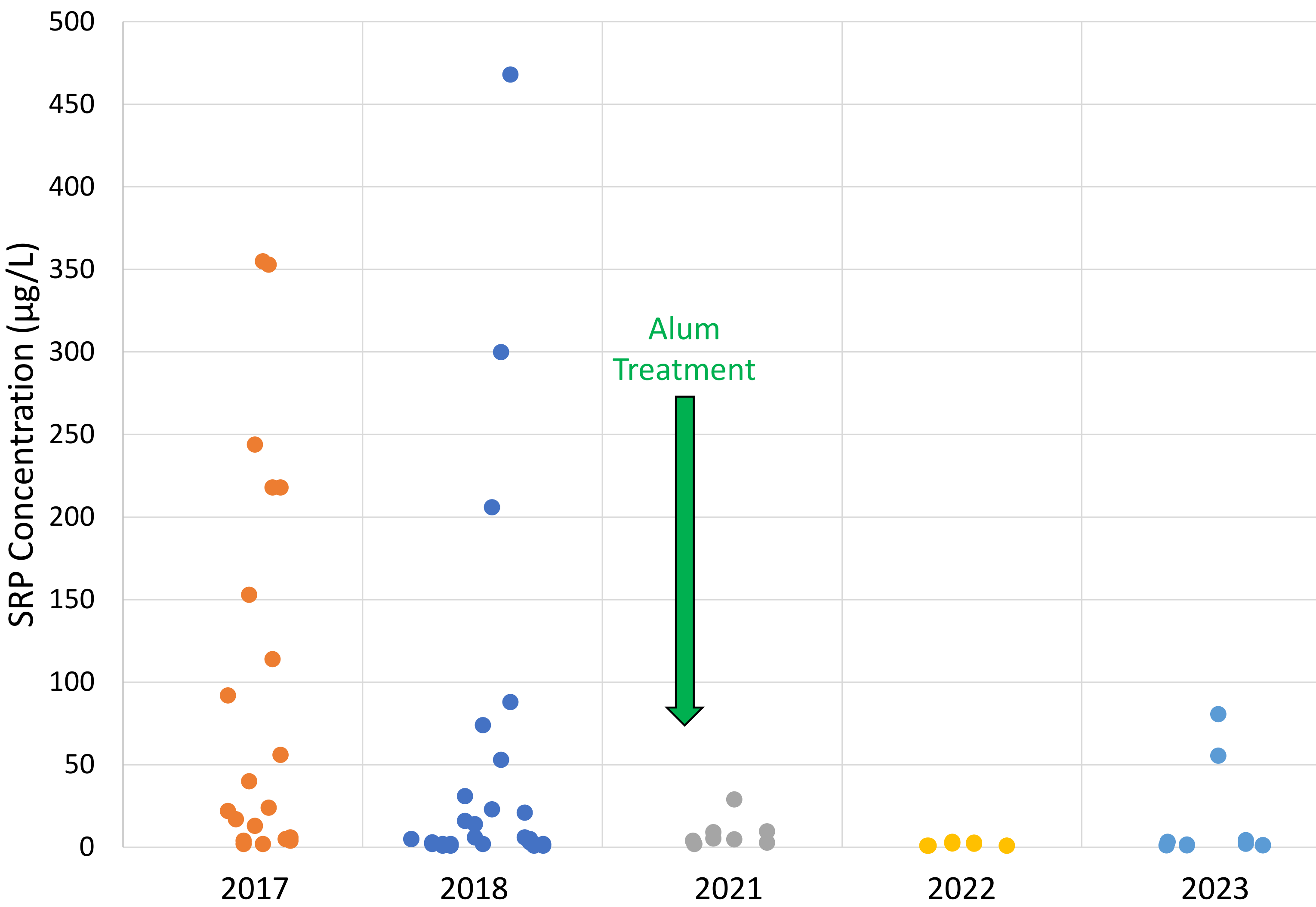
| Analytical Parameter | Parameter Type (Analyst) | Collection Method | Preservation or Filtration | Unit | Reporting Limit | Analytical Method |
|---|---|---|---|---|---|---|
| Water Depth | Field (K&A) | Sonar | NA | ft | 0.1 | Data Sonde |
| Dissolved Oxygen | Field (K&A) | YSI ProODO YSI ProSolo | NA | mg/L | 0.01 | Data Sonde |
| Temperature | Field (K&A) | YSI ProODO YSI ProSolo | NA | °C | 0.1 | Data Sonde |
| Specific Conductance | Field (K&A) | YSI Pro30 | NA | µmhos/cm | 0.01 | Data Sonde |
| pH | Field (K&A) | Oakton pH Testr50 | NA | SU | 0.01 | Data Sonde |
| Turbidity | Field (K&A) | Global Water WQ770 | NA | NTU | 0.1 | Data Sonde |
| Total Phosphorus | Lab (GLEC) | Van Dorn | Cooled to <6°C, $H_2SO_4$ to pH <2 | mg/L | 0.5 | SM 4500 P E 2011 |
| Soluble Reactive Phosphorus | Lab (GLEC) | Van Dorn | Field-filtered, 0.45 µm filters, frozen | mg/L | 0.0019 | SM 4500-P F |
| Nitrate-Nitrogen | Lab (Merit) | Van Dorn | Cooled to <6°C | mg/L | 0.5 | E 300.0 |
| Chlorophyll *a* | Lab (GLEC) | Depth-Integrated Composite Sampler | Filtered through 0.45 µm filter, 1 drop of MgCO3, filter frozen | µg/L | 0.01 | USEPA 445.0 Rev. 1.2 |
| Sediment Mobile-Phosphorus | Lab (GLEC) | Petite Ponar Dredge | Cooled to <6°C | mg/kg | 0.1 | SM 4500-P F |



# Mona Lake Treatment Results

- Greatly reduced SRP in bottom waters (hypolimnion)



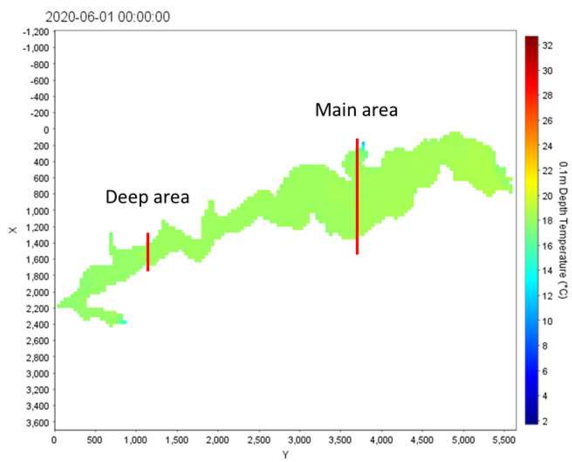
Mona Lake hypolimnetic TP and SRP percent reduction in peak TP and SRP conditions to peak SRP values in 2017 and 2018 (pre-alum treatment).

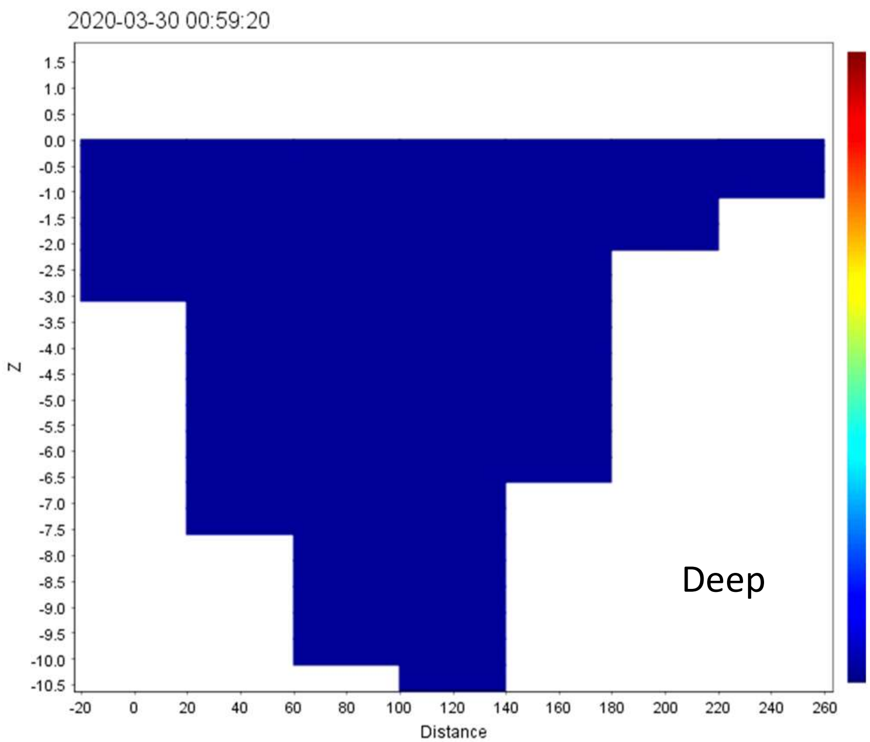
| Sampling Station | TP Reduction over 2017 levels | TP Reduction over 2018 levels | SRP Reduction over 2017 levels | SRP Reduction over 2018 levels |
|---|---|---|---|---|
| S2 | 83% | 86% | 94% | 92% |
| S3 | 96% | 94% | 50% | 70% |
| S4 | 98% | 97% | 63% | 83% |

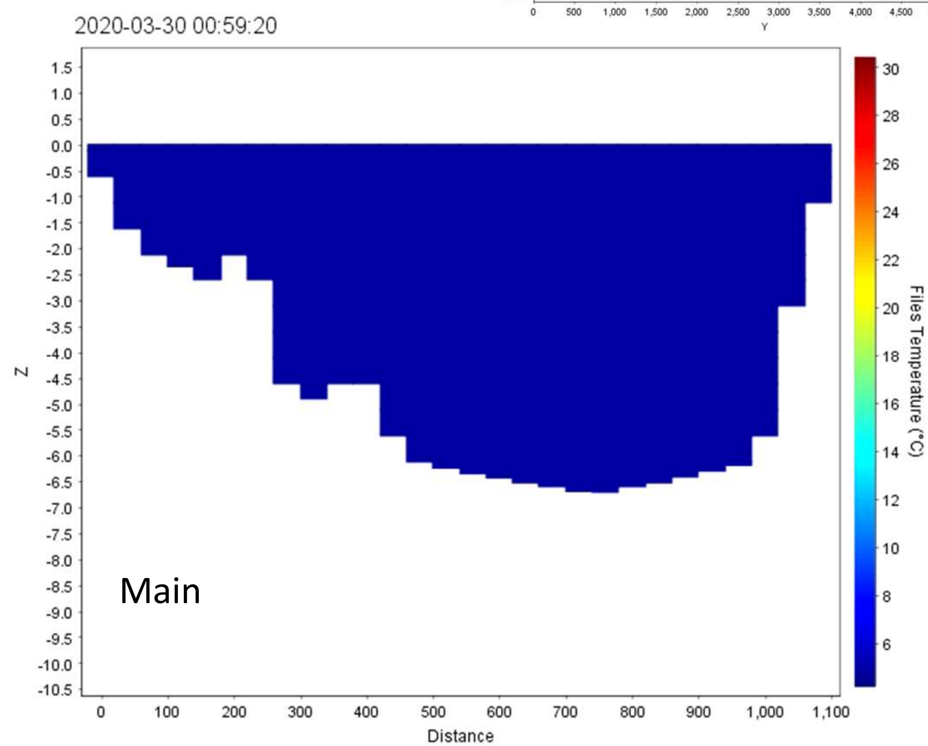
# Demonstrable Treatment Benefits

- Immediate TP water column removal (44% before/after treatment reductions)
- SRP remained ~5.5 *u*g/l in bottom waters all 2021, 2022 and mostly in 2023
- Dramatic bottom water P reduction within ***and*** downstream of treatment areas
- Late August/early September 2021 with sustained westerly winds
  - Top to bottom low SRP levels (2.8 - 22 ug/l) up to 50 times lower than previous years
- Alum treatment suppressed sediment release in downstream untreated S4 areas above Henry Street Bridge
- Water clarity improved from historic 3.5-5 feet to 5-7.6 feet
- Sediment oxygen demand was suppressed (1-3 mg/L DO in bottom waters compared to previous <1)
- NO REPORTED ALGAL BLOOMS after May 2021 treatment to present

# Confirming Spatial Application Considerations with Temperature Stratification

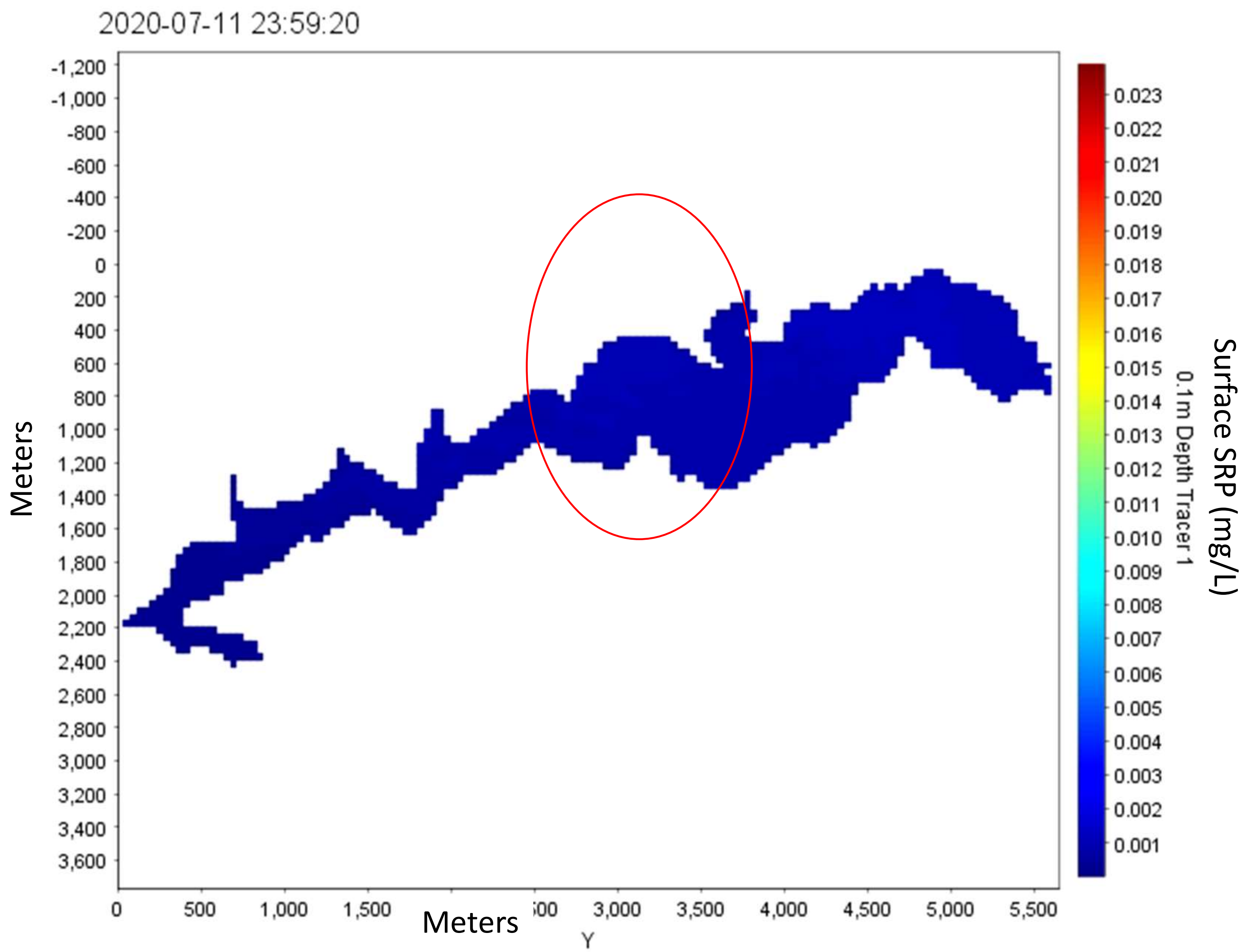


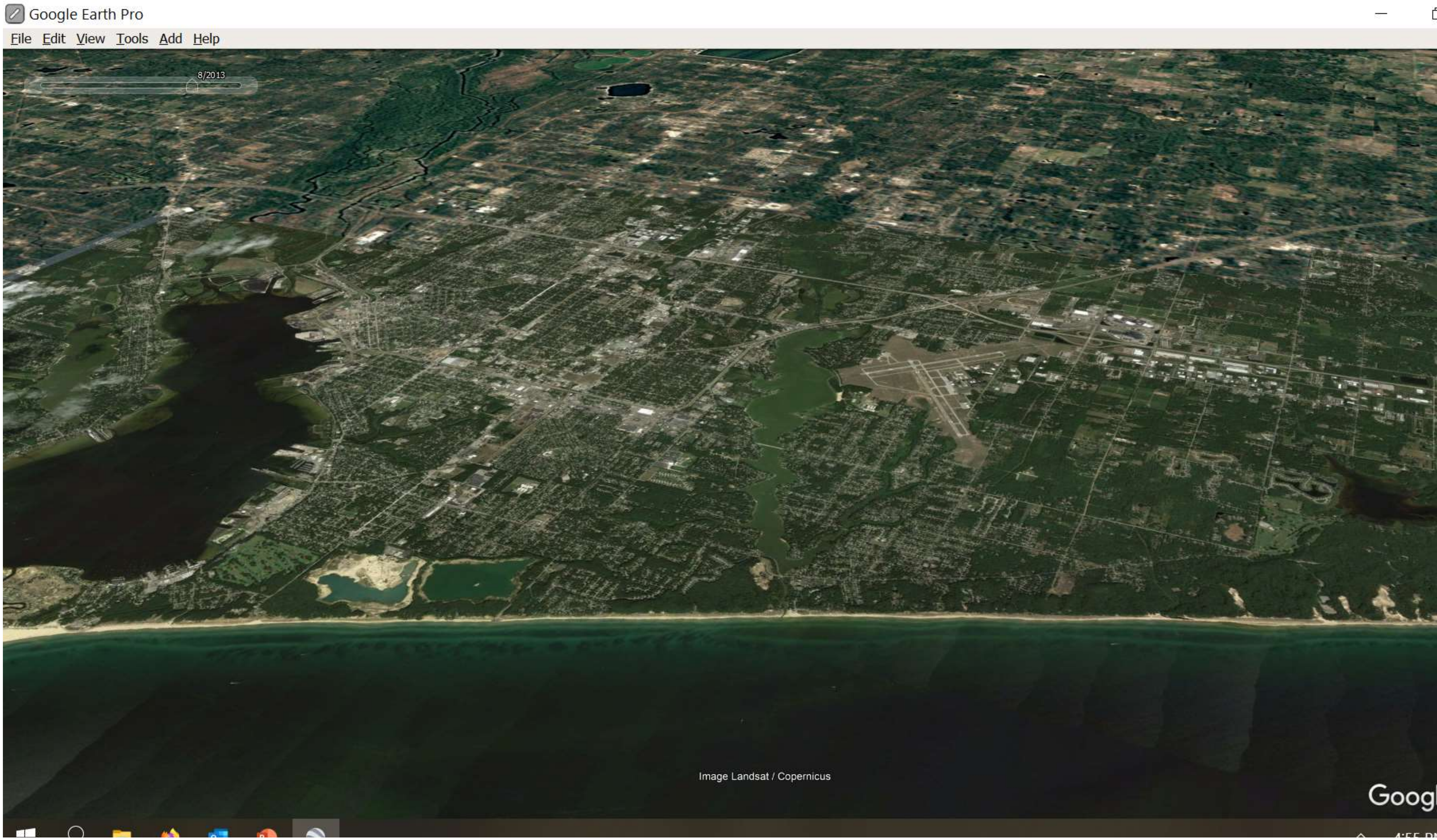
# Confirming Longitudinal Application Considerations for Mixing

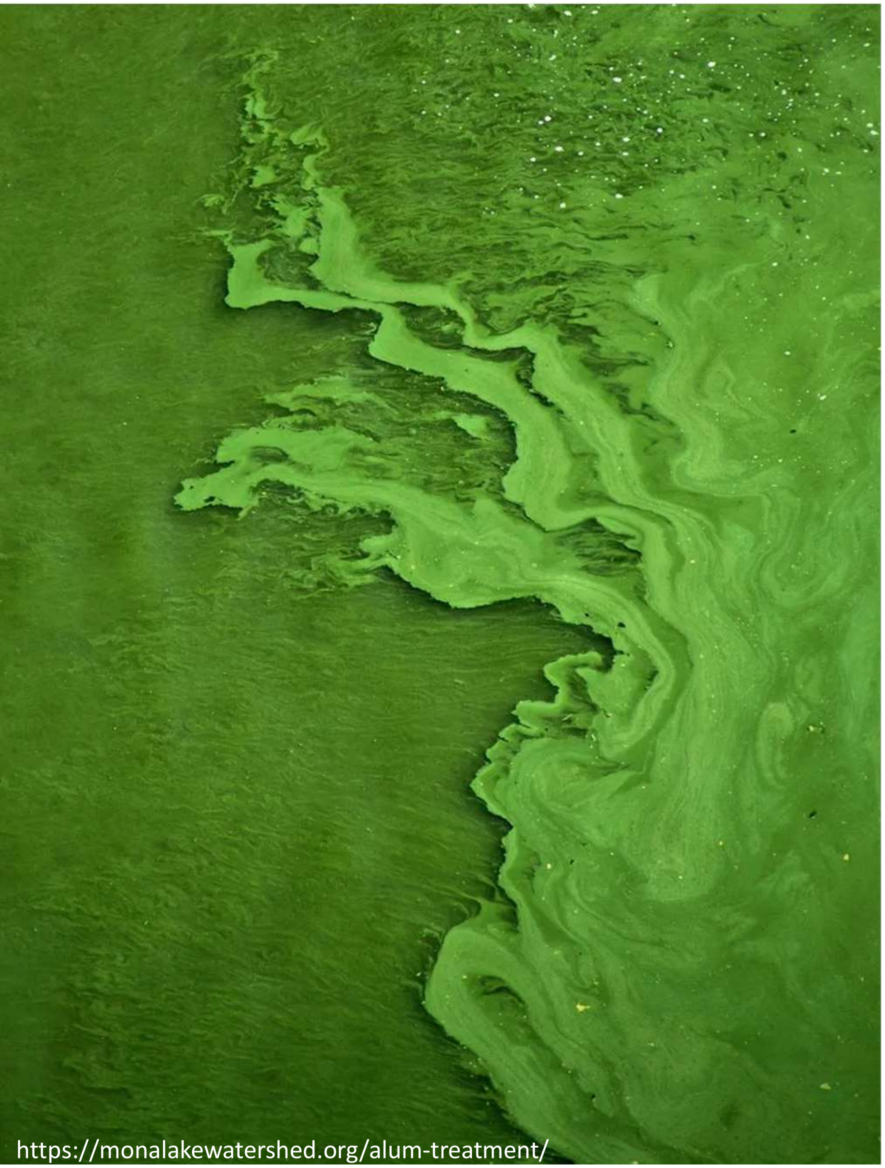
- Treatment area constrained by budget – where is optimal?
- Ability to forecast longevity of benefits
- Identification of triggers for future applications



Aug
2013

July
2022






# Algae Treatment at Mona Lake Follows Decades of Study, Cleanup

By Lynn Moore | MLive **May 20, 2021**

MUSKEGON, MI – Plagued for decades with excessive algae blooms, Mona Lake should be noticeably clearer after chemical treatment was applied following 20 years of study.

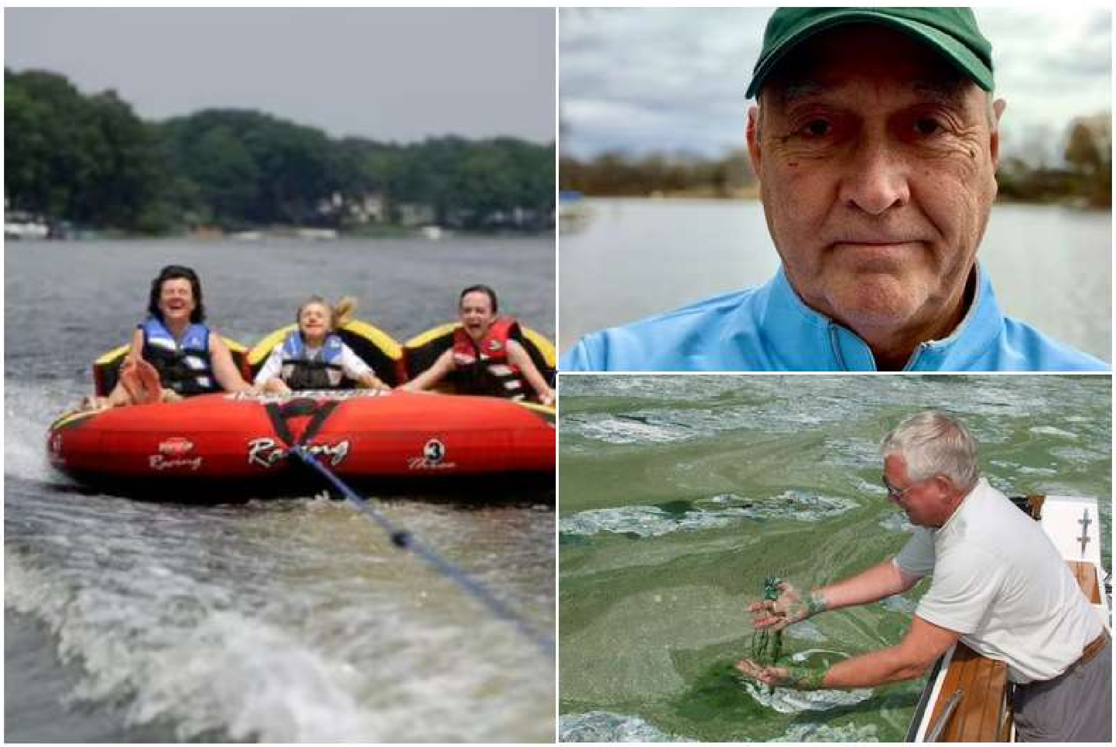
Separate studies determined that the lake primarily in Norton Shores was plagued with high amounts of phosphorous that, when released from the mucky lake bottom, caused excessive toxic algae blooms that severely degraded water clarity.

The eastern portion of the lake was treated with alum – a chemical compound that binds with phosphorous and sinks it to the bottom, essentially capping it.

"We've been working on this for 20 years almost," said Don Trygstad, chairman of the Mona Lake Watershed Council. "It's a slow process. I signed up to do this knowing it would take years and years and years." The council, comprised mainly of lakefront homeowners, has been dedicated to combatting the algae – and raising funds to do so — since it formed in 2003.

# From sewage flow to 7-foot clarity: The 20-year story of Mona Lake’s comeback

Updated: Apr. 04, 2022, 2:52 p.m. | Published: Apr. 04, 2022, 2:50 p.m.



# Success requires well-thought out, multi-step process

Step 1 – Contact the right people (successes, not anecdotes)
Step 2 – Teaming provides rigor
Step 3 – Measure the right things
Step 4 – Determine the correct issues
Step 5 – Fully assess options and costs
Step 6 – Identify the pros and cons
Step 7 – Determine the optimum implementation strategy
Step 8 – Forecast expected responses
Step 9 – Implement
Step 10 – Monitor performance and outcomes
Step 11 – Adapt
Step 12 – Celebrate…but recognize the journey is never over

# Takeaways

- Sound science & engineering is the cornerstone to lake restoration
- Performance is everything
- Don't just jump at any 'pre-canned' solution
- Beware "shiny objects" and 4-color brochures

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