



OCLAW 2013

## Twenty-two Years of Hypolimnetic Aeration: The Saint Paul Water Supply Experience



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# Outline

- Background
- Old Aeration System
- Hypolimnetic Oxygenation System Design
- New Hypolimnetic Oxygenation System Performance

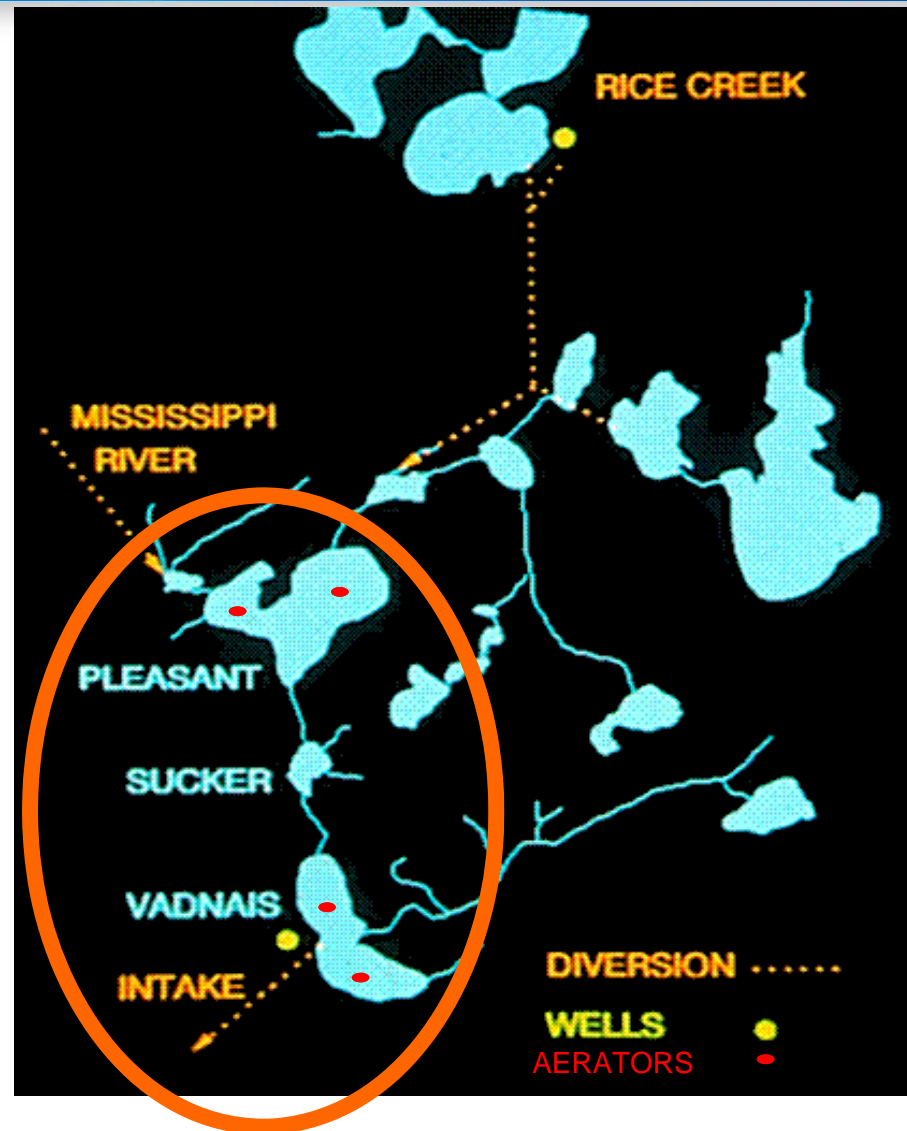
# Background: SPRWS



- St Paul Regional Water Services (SPRWS)
  - McCarrons Water Treatment Plant
  - Average Daily Flow = 43 MGD
  - Maximum Flow = 126 MGD
  - ~92,000 Metered Accounts
  - 400,000+ People Served

# Background: SPRWS Supply

- Source Water
  - Mississippi River (80-95%)
  - Local Watersheds (5-20%)

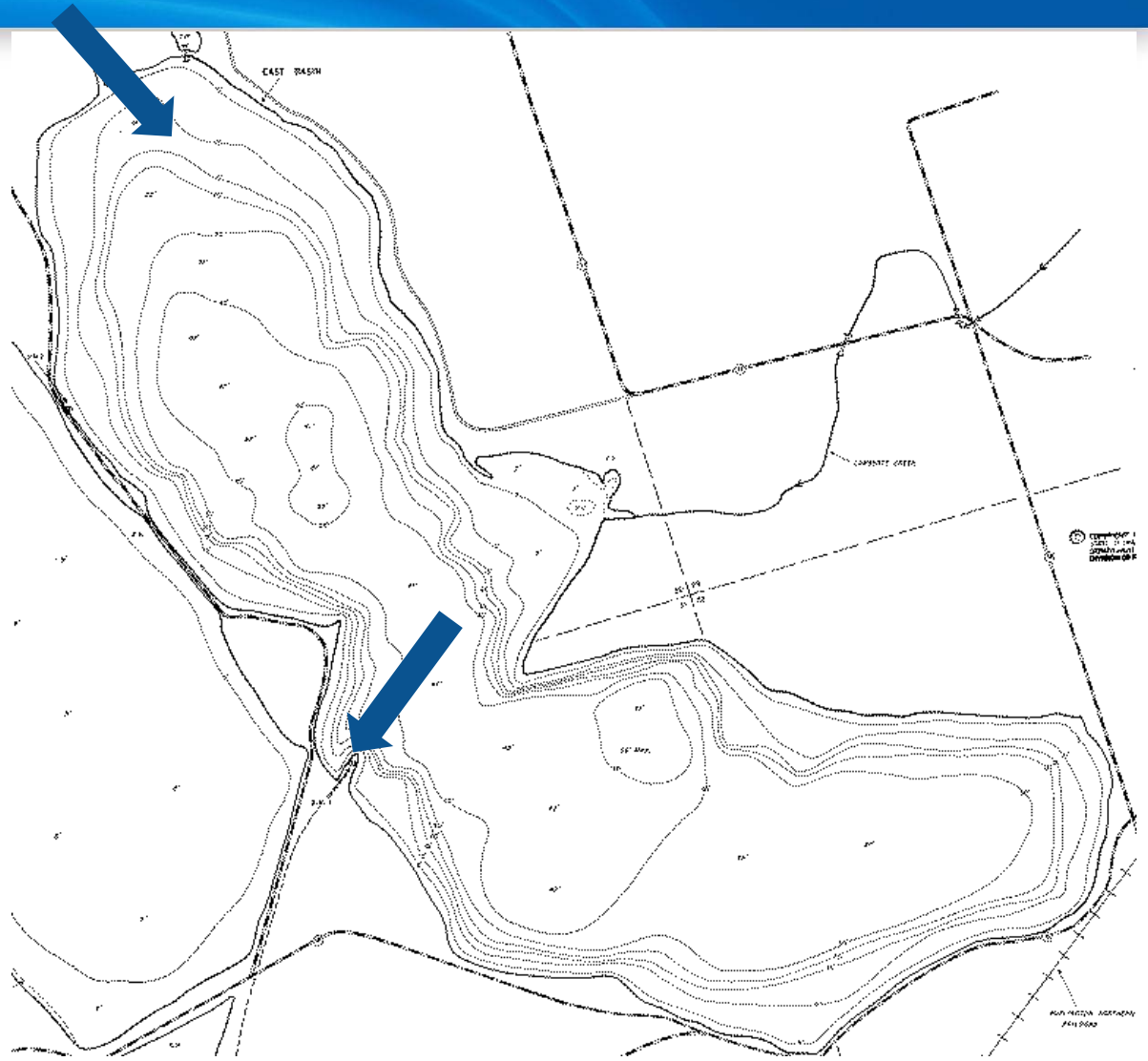




# Background : Lake Vadnais

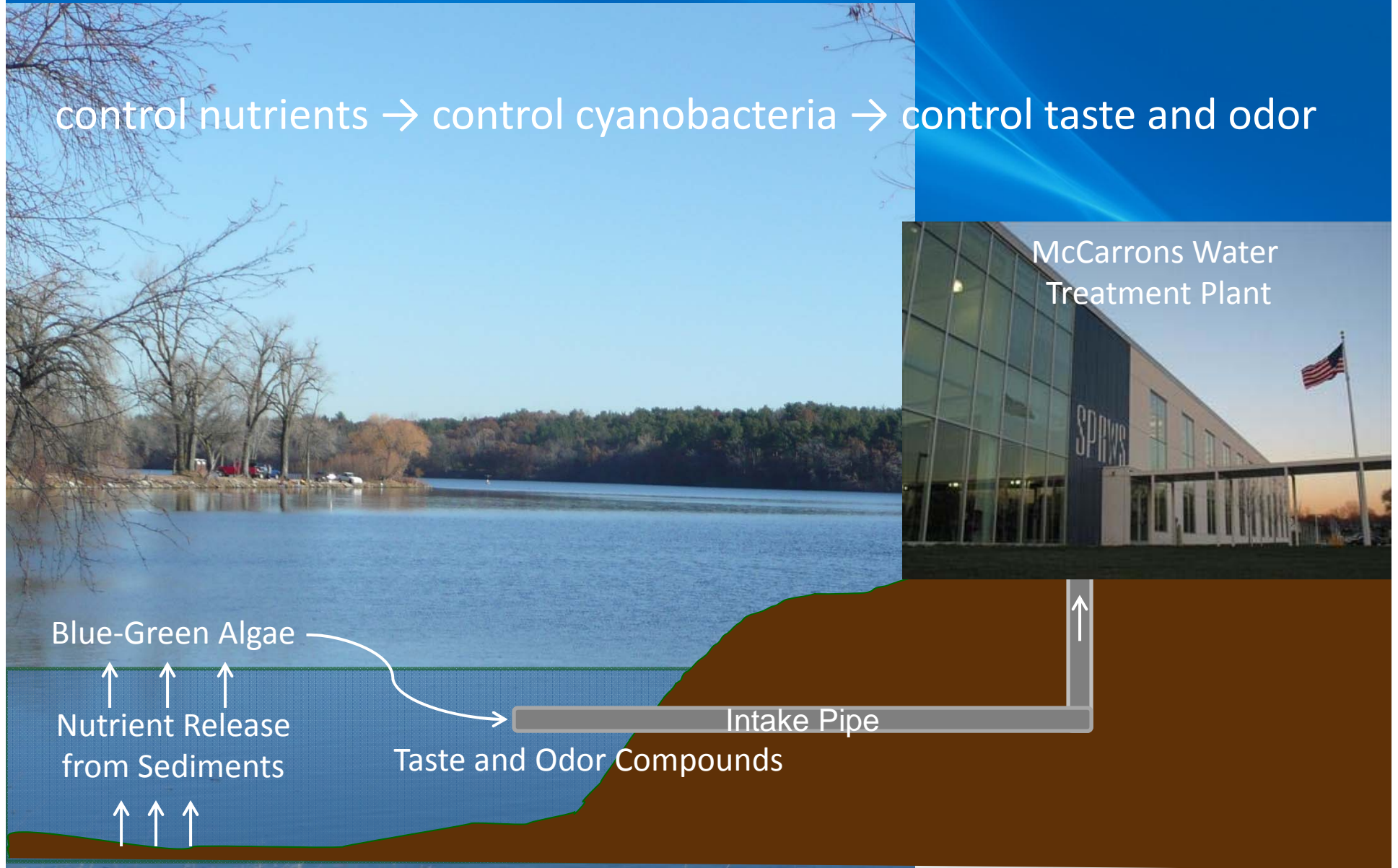
## ■ Lake Vadnais

- Area 385 Acres
- Average depth 7.7 m
- Max depth 17.6 m
- HRT 69 days



# Project Objectives

control nutrients → control cyanobacteria → control taste and odor



# Redox management (for sediments rich in Fe)

The diagram shows two vertical test tubes representing sediment columns. The left tube is labeled with chemical species in different layers:  $\text{FeO(OH):PO}_4$  at the top, followed by  $\text{PO}_4$ ,  $\text{H}_2\text{S}$ ,  $\text{MeHg}$ ,  $\text{Fe(II)}$ , and  $\text{FeS}$  at the bottom. A bracket groups the bottom four layers ( $\text{H}_2\text{S}$ ,  $\text{MeHg}$ ,  $\text{Fe(II)}$ , and  $\text{FeS}$ ). The right tube shows a similar sediment column with a green arrow pointing to the top layer, labeled 'Inject  $\text{O}_2$  or  $\text{NO}_3 \dots$ '. Another green arrow points to the sediment column, labeled 'to create F(III) cap'. A third green arrow points to the bottom layer of the sediment column, labeled '... and keep these compounds in sediment.'.

D.O. >  
2 - 5 mg/L

**$\text{FeO(OH):PO}_4$**

$\text{PO}_4$   
 $\text{H}_2\text{S}$   
 $\text{MeHg}$   
 $\text{Fe(II)}$   
 $\text{FeS}$

Inject  $\text{O}_2$  or  $\text{NO}_3 \dots$

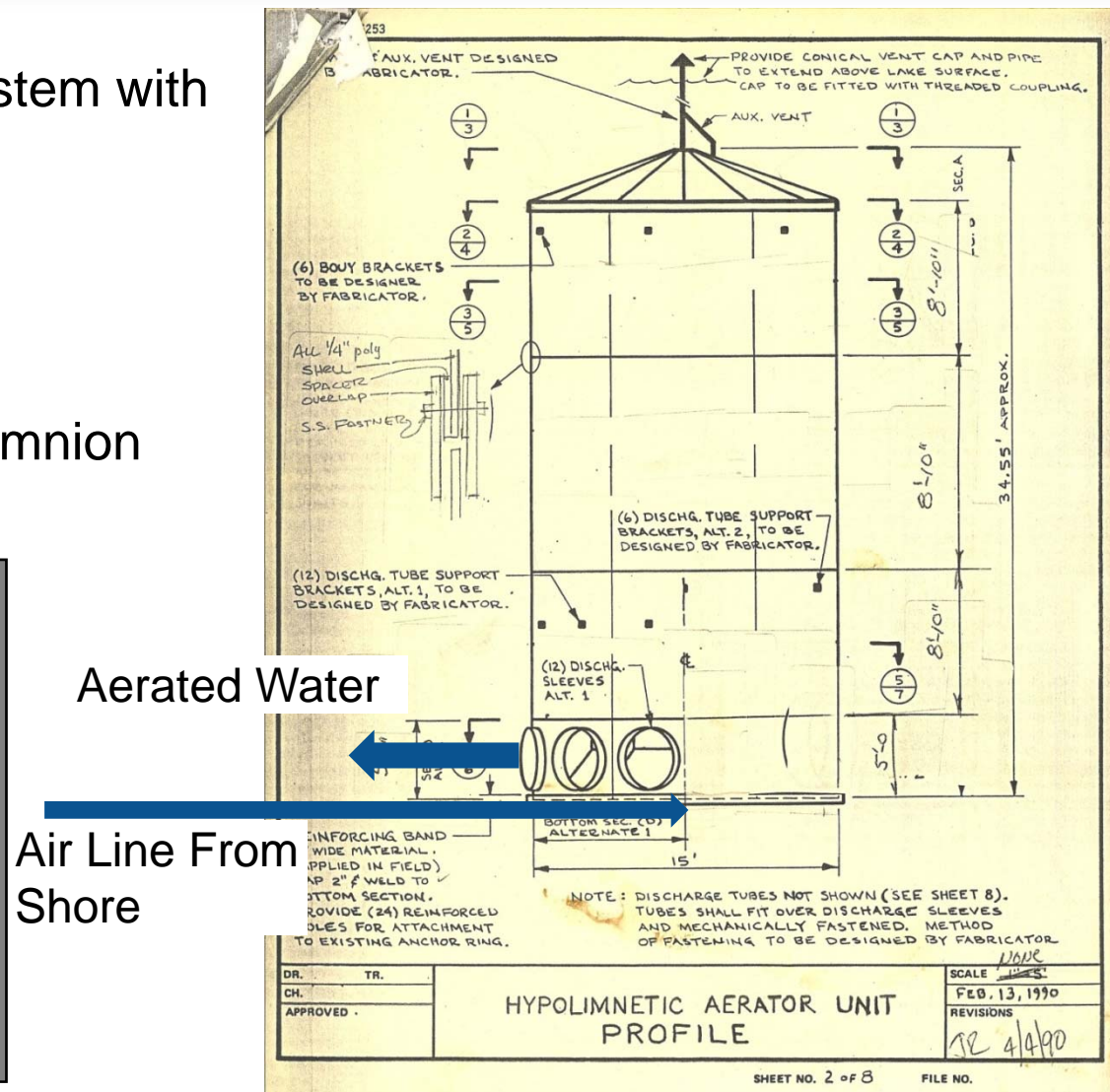
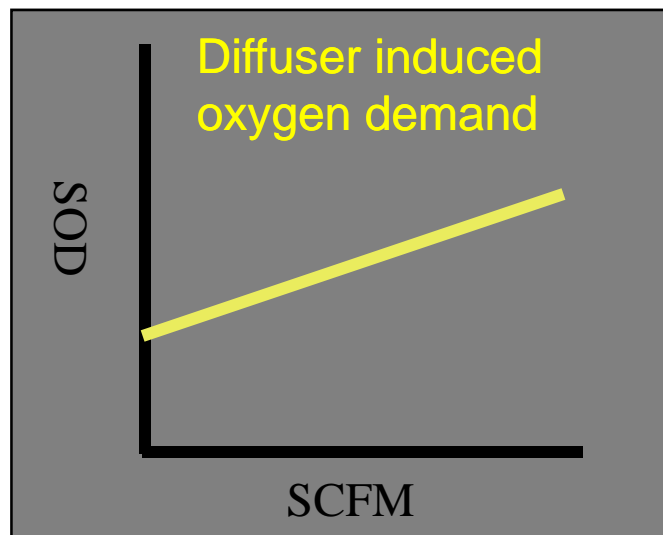
to create F(III) cap

... and keep these compounds in sediment.



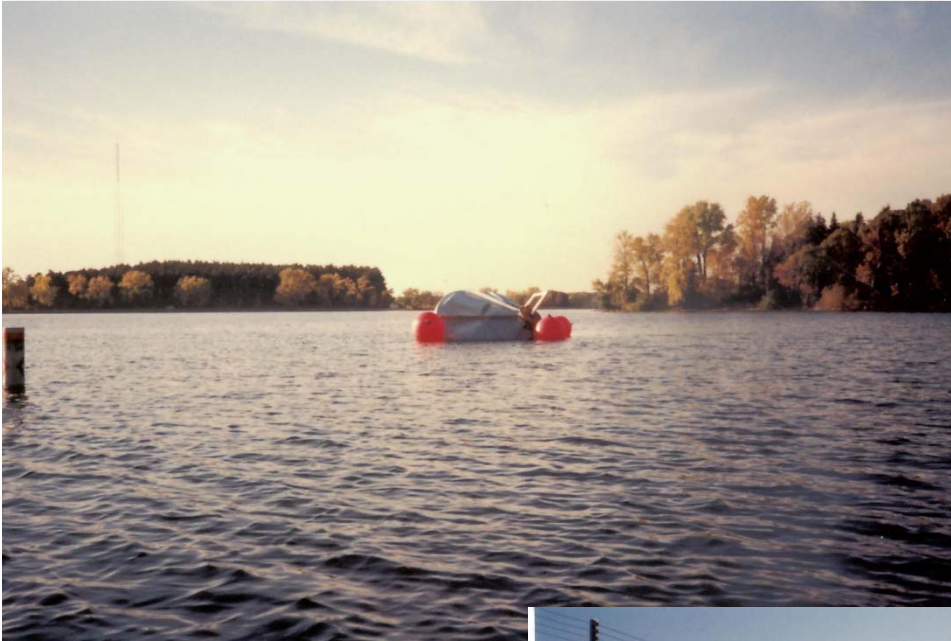
# Historical Aeration System

- Partial Lift Aeration System with Ferric Iron Injection
- Installed in late 1986
- Required Divers for Maintenance
- Aerators recycle hypolimnion every 4 days



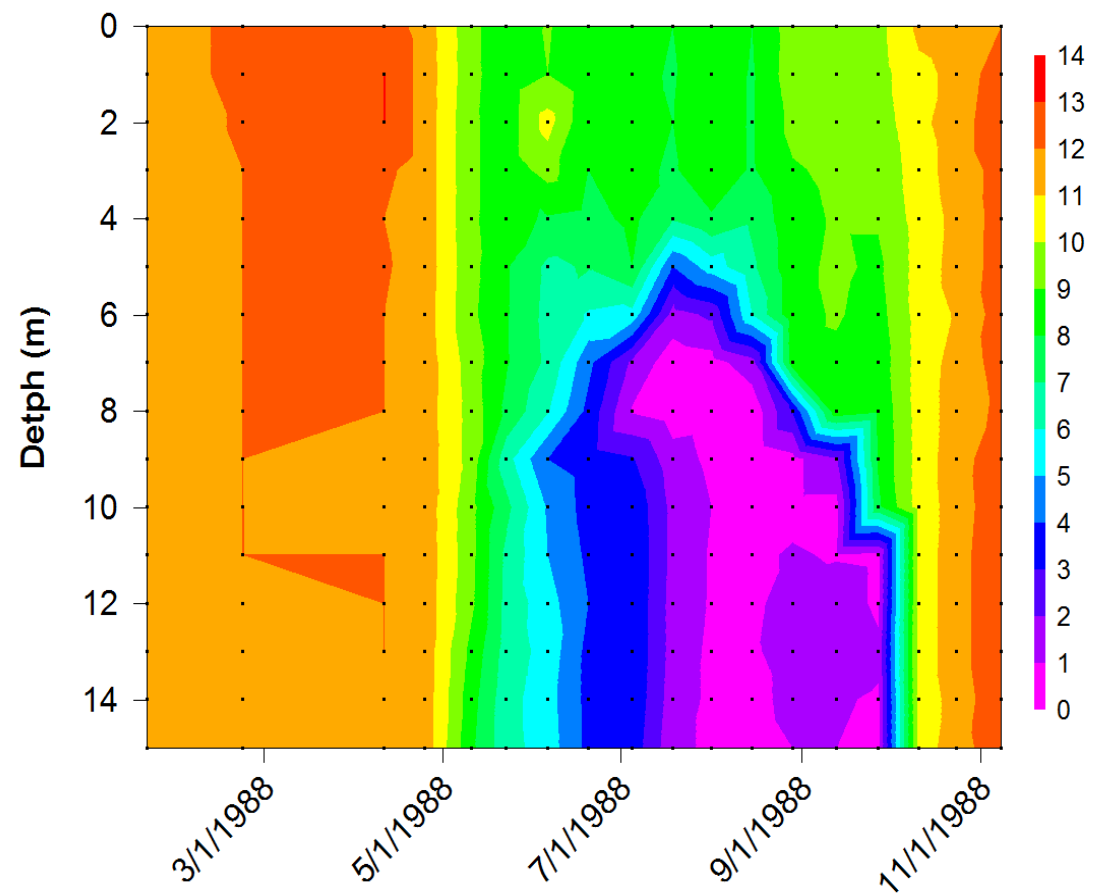
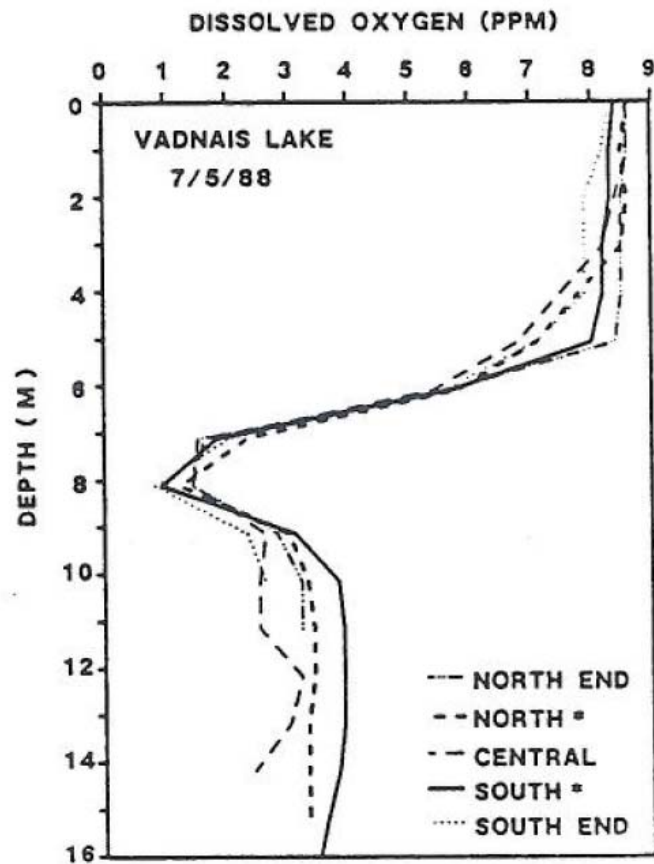


# Vadnais Aerators Installed



# Summer 1988 Performance

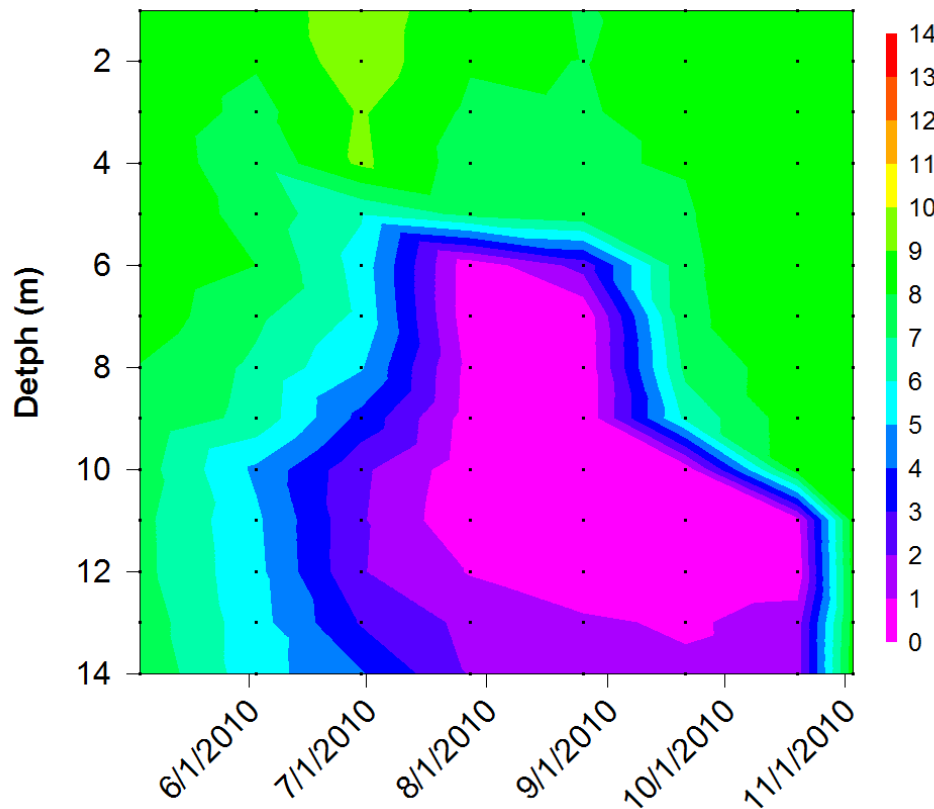
Figure 14  
Oxygen Profiles - July 5, 1988



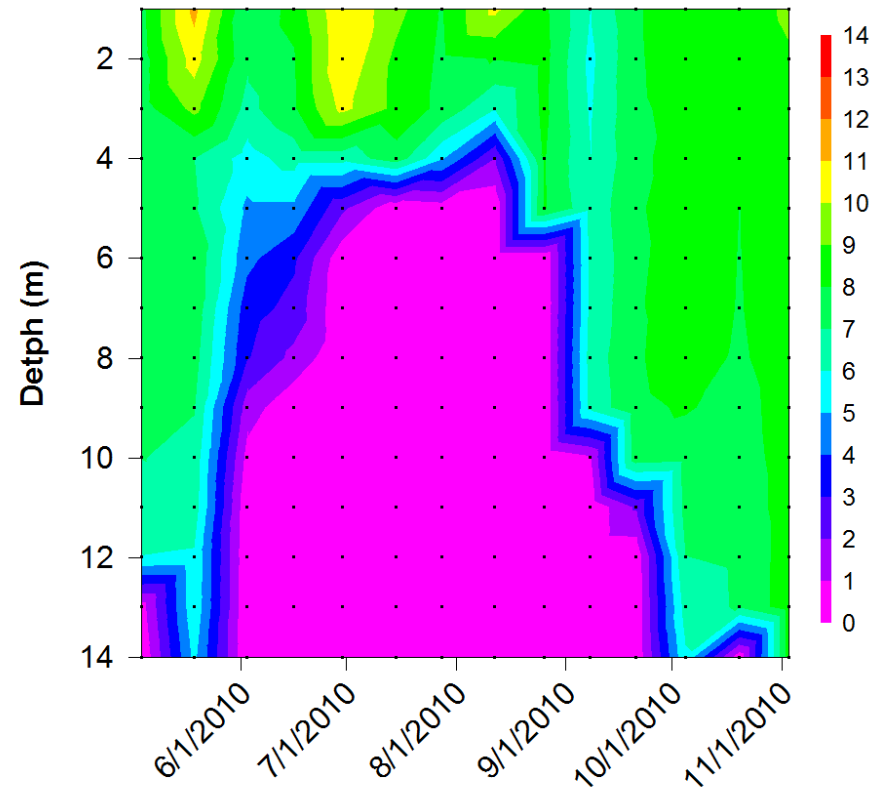
Design and Evaluation of Eutrophication Control Measures for the St. Paul Water Supply  
by William W. Walker Jr.

# Summer 2010 Dissolved Oxygen Performance

Lake Vadnais - Aerator Operational



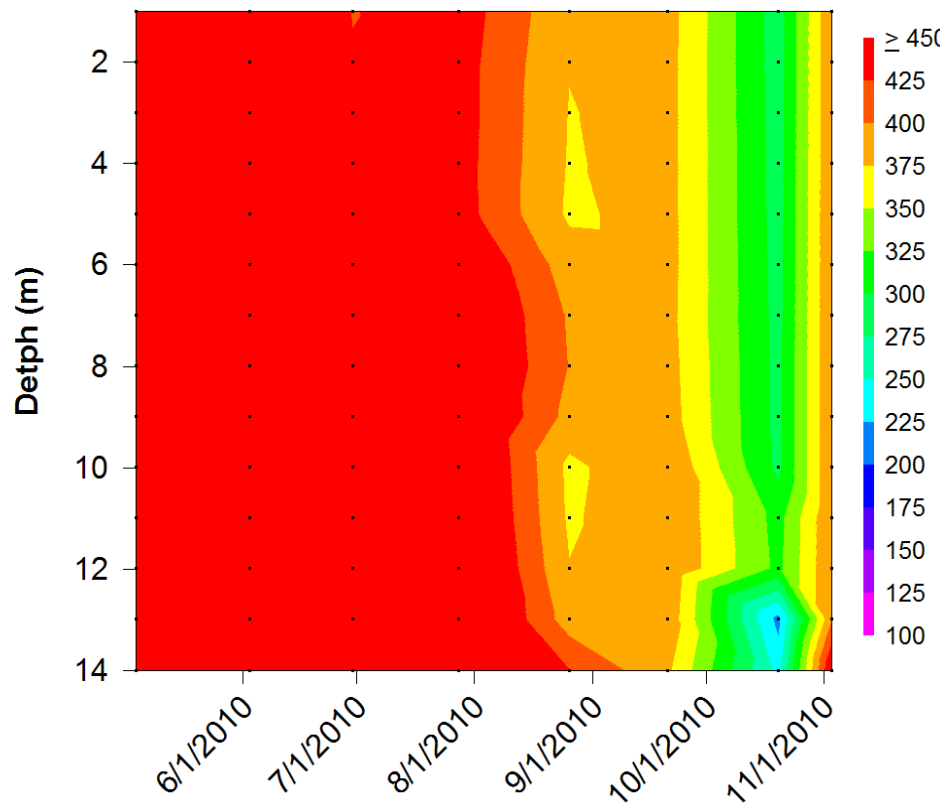
Pleasant Lake - Aerator NOT Operational



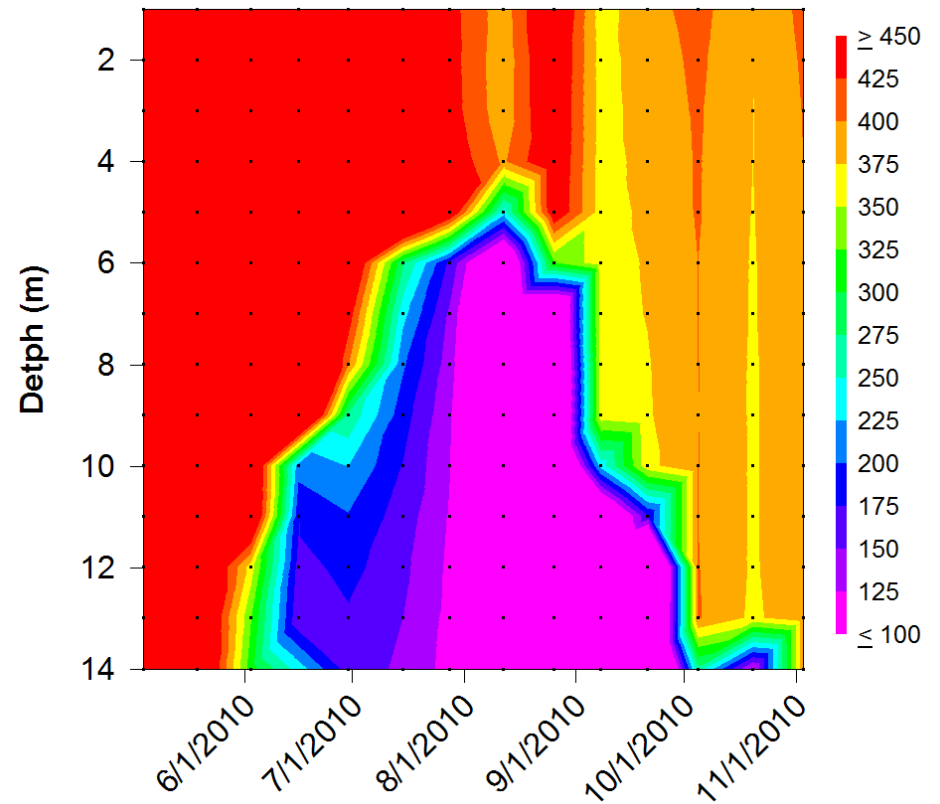


# Summer 2010 ORP Performance

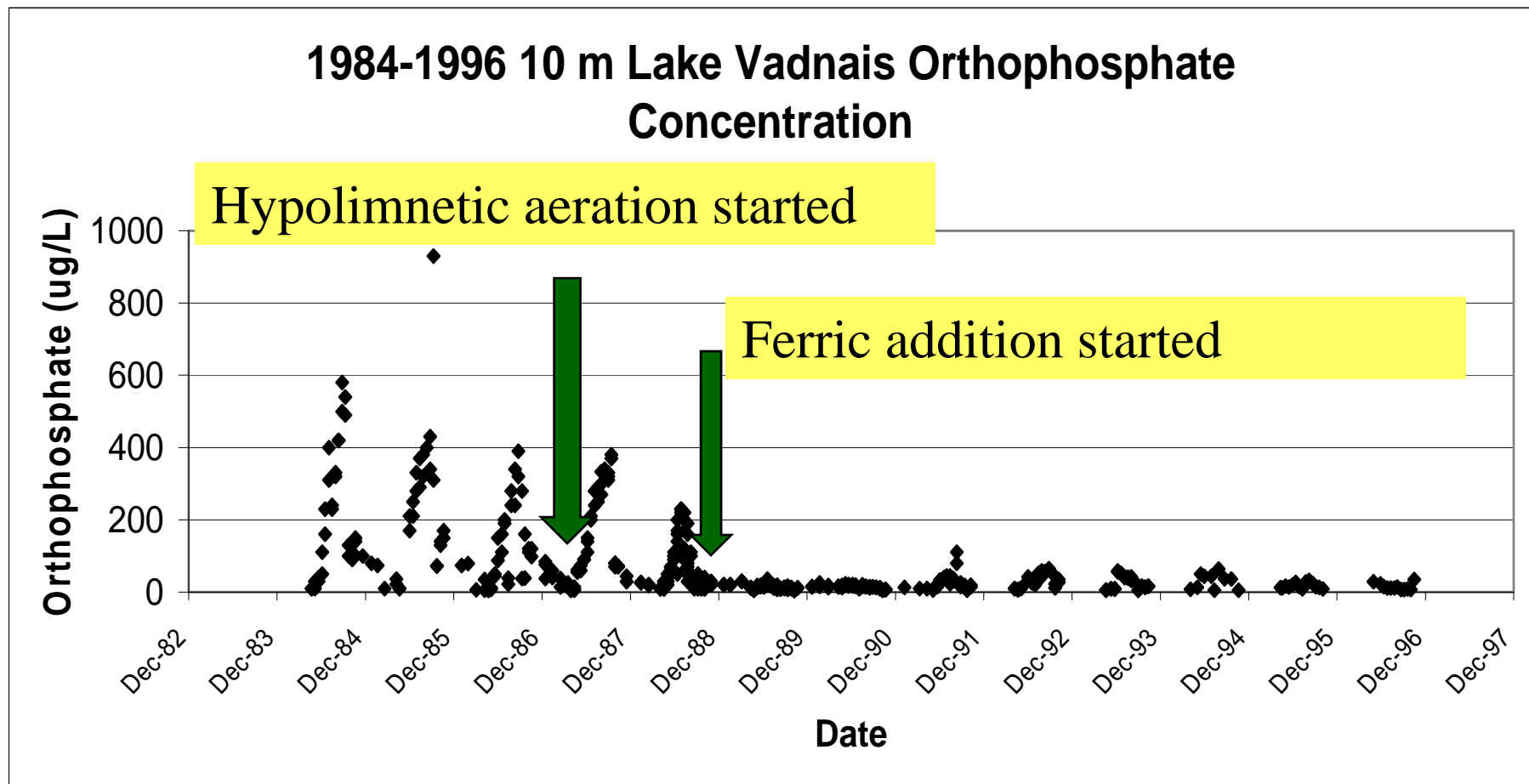
Lake Vadnais - Aerator Operational



Pleasant Lake - Aerator NOT Operational

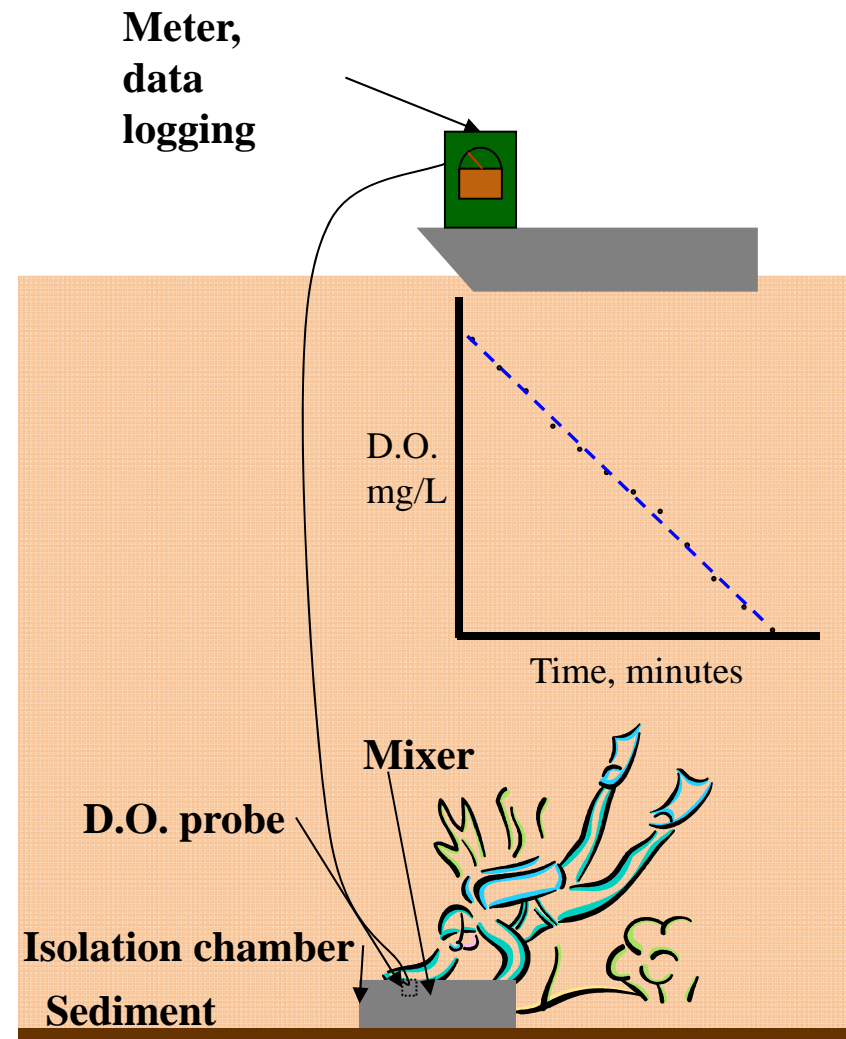


# Historical Aeration System Performance



# Hypolimnetic Oxygenation Design

- Key Design Parameter is Hypolimnetic Oxygen Demand
  - *In Situ* Sediment Oxygen Demand
  - *Ex Situ* Sediment Oxygen Demand
  - Hypolimnion Oxygen Mass Regression Analysis





# Hypolimnetic Oxygen Demand

## ■ SOD

- 3.7 g-O<sub>2</sub>/m<sup>2</sup> d

## ■ HOD = SOD x Area of Hypolimnion

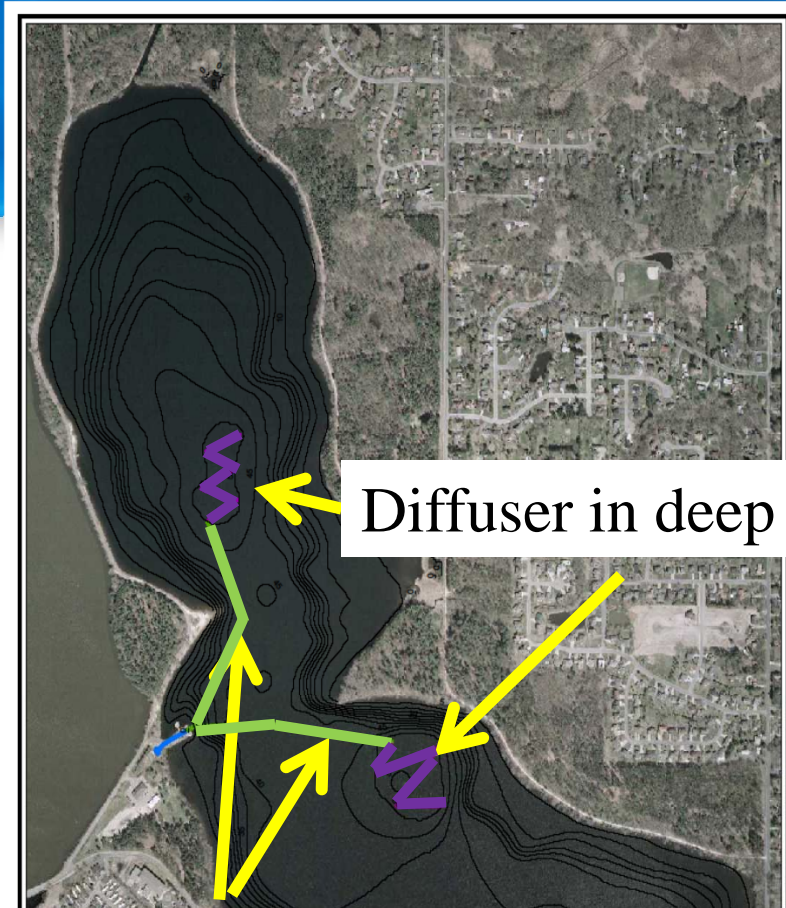
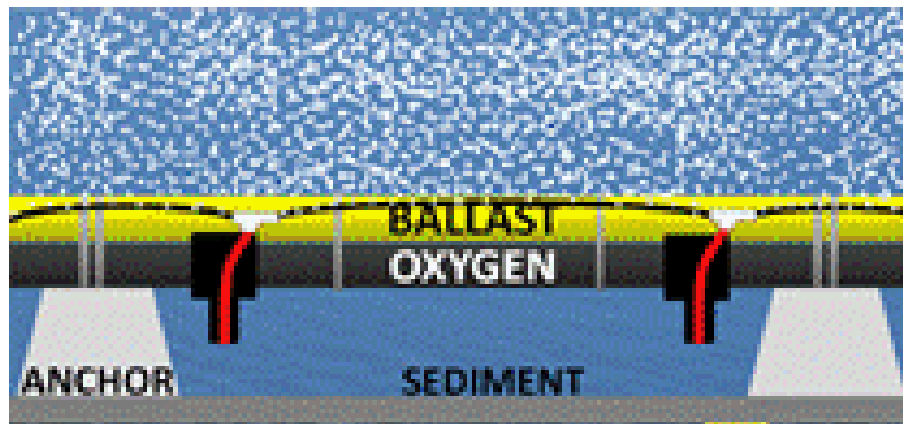
- 3,444 kg/d
- 4,374 kg/d with Sediment and Community Oxygen Demand

## ■ HOD: Mass Regression

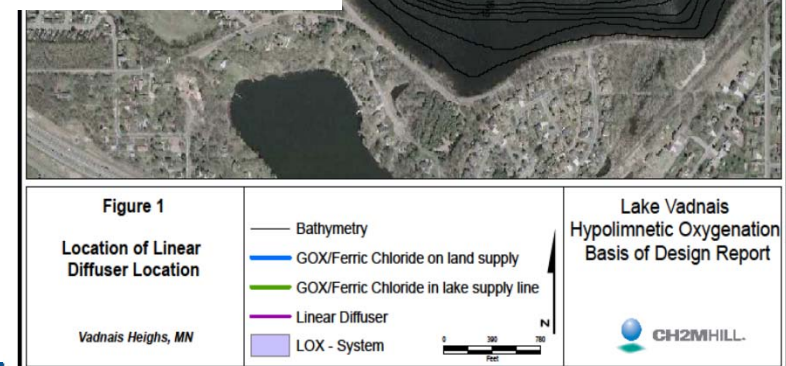
- 700 kg/d
- 2,660 kg/d with Turbulence from Diffusers Induced Demand

# Linear Diffuser Layout

- Advantages
  - Wide operating range (0-200% of design)
  - Experience with zebra mussels
  - All maintenance can be done on shore or from a boat
  - Well documented project history
  - Minimal mechanical equipment
  - Minimal power use with LOX
  - Lowest equipment cost



Supply lines



# Vadnais Aerators Removed



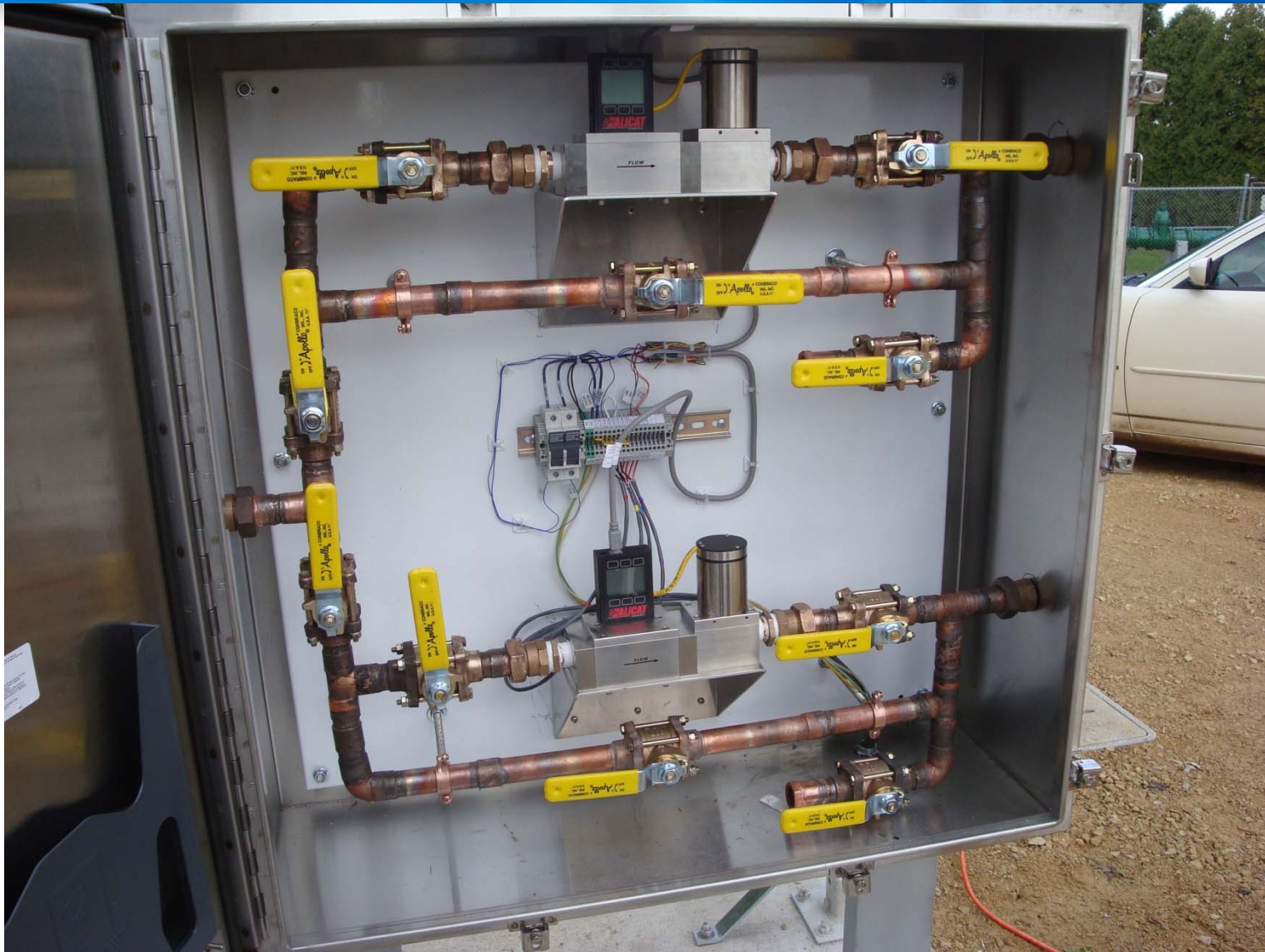


# Oxygen Supply

- 9,000 Gallon Oxygen Storage
- Twin 10,000 SCFH Vaporizers



# Flow Control





# Constructed On Site

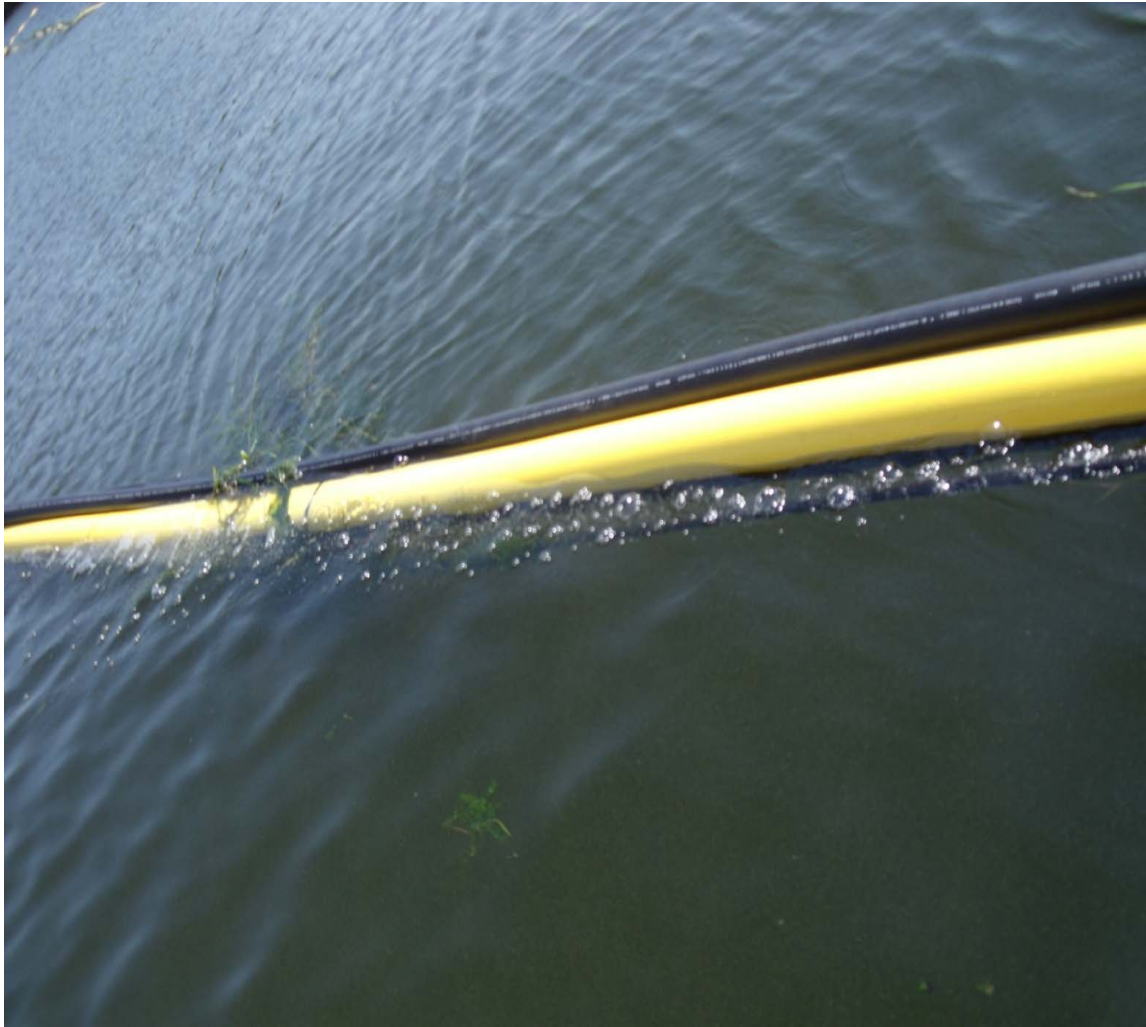




# Supply Lines



# Diffusers Checked for Damage



# Diffusers Moved Into Position





# Controlled Sinking of Diffusers



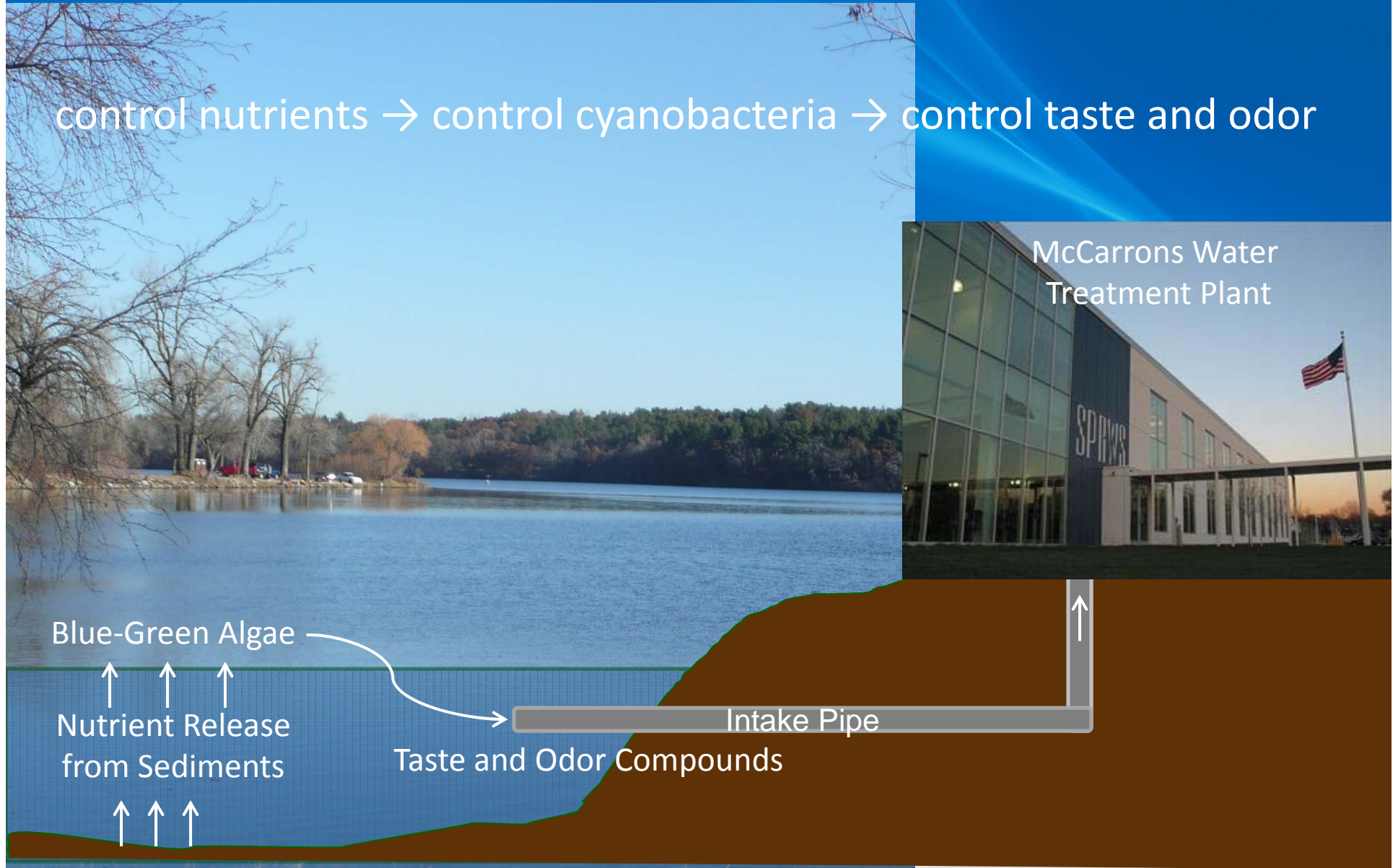


# Operational



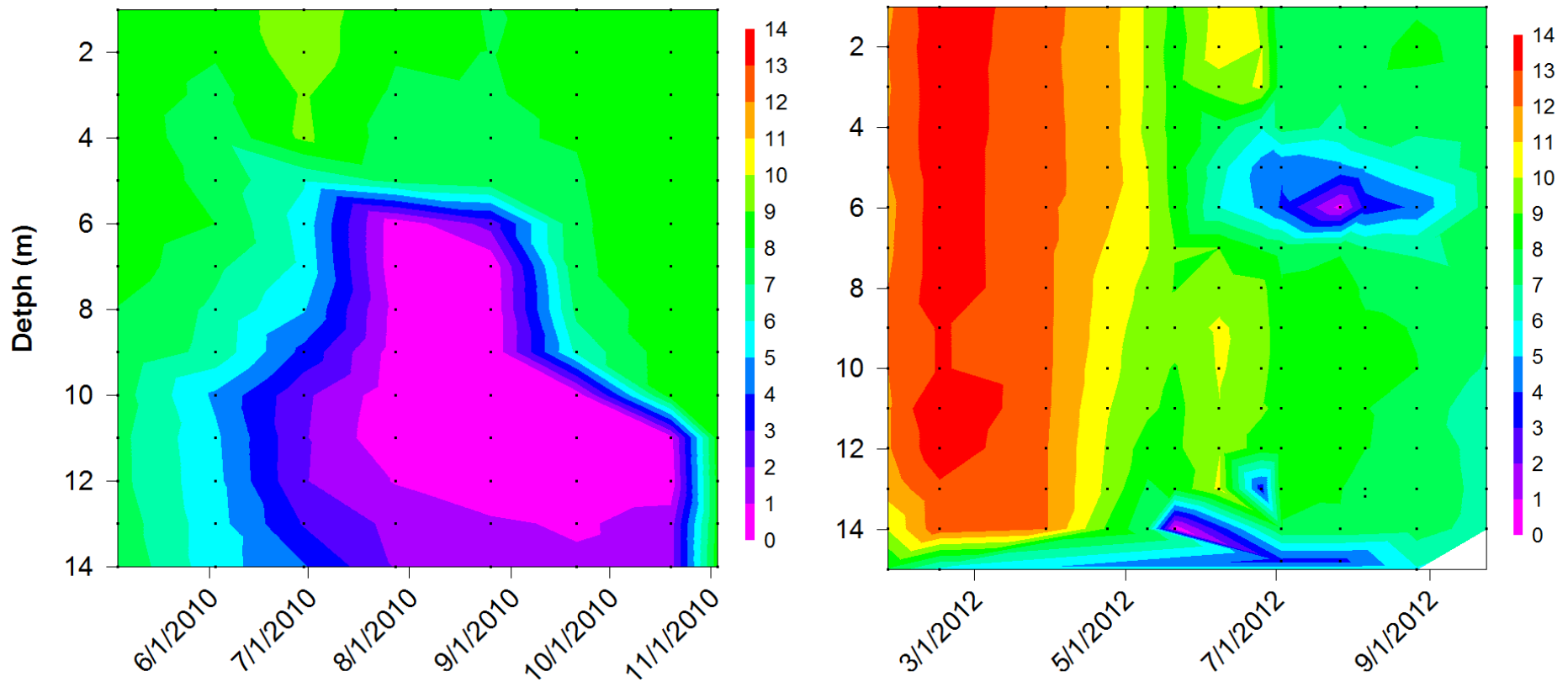
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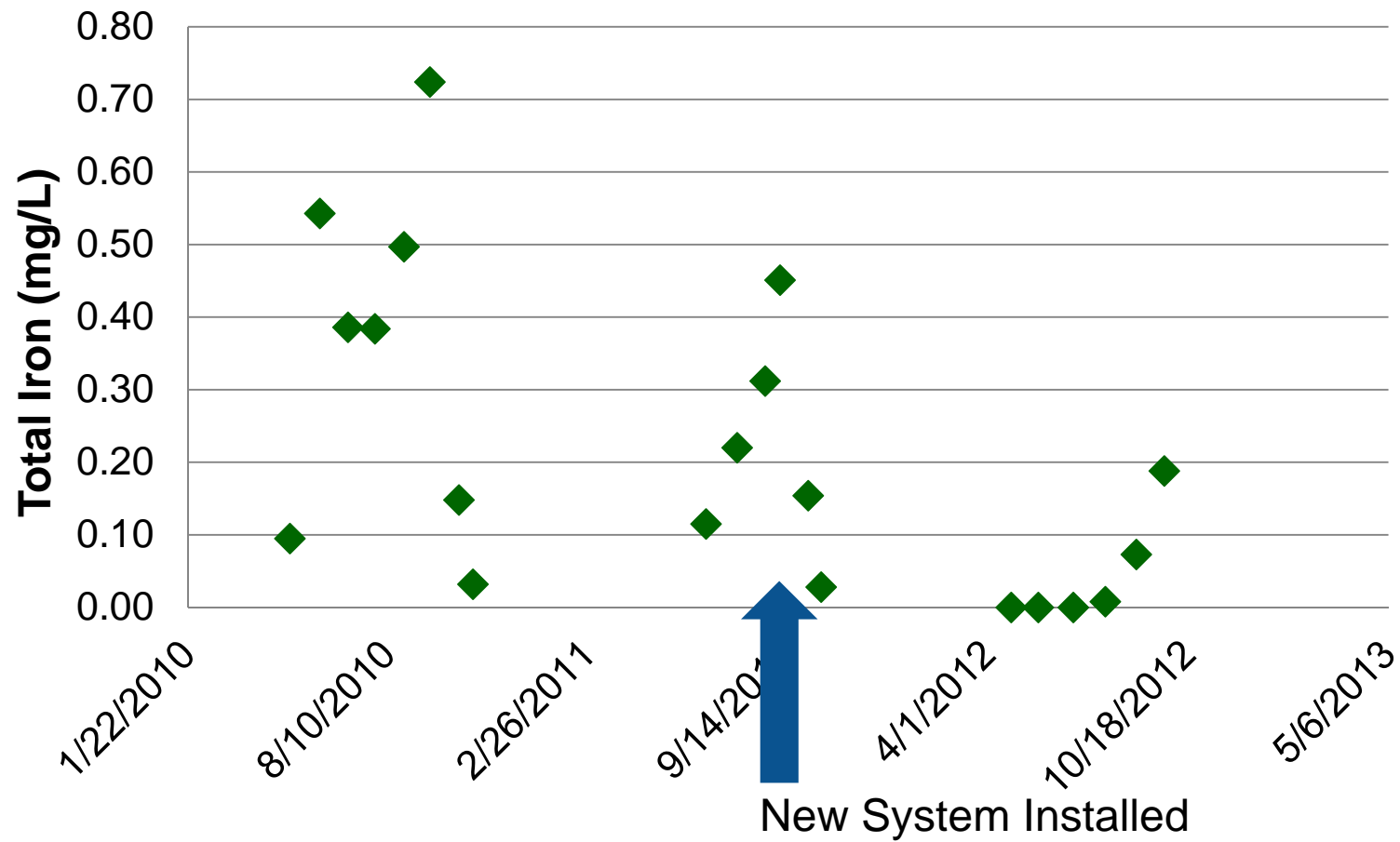
# Dissolved Oxygen Performance

2010 – Partial Lift Aerator Operational    2012 – Linear Diffuser Operational

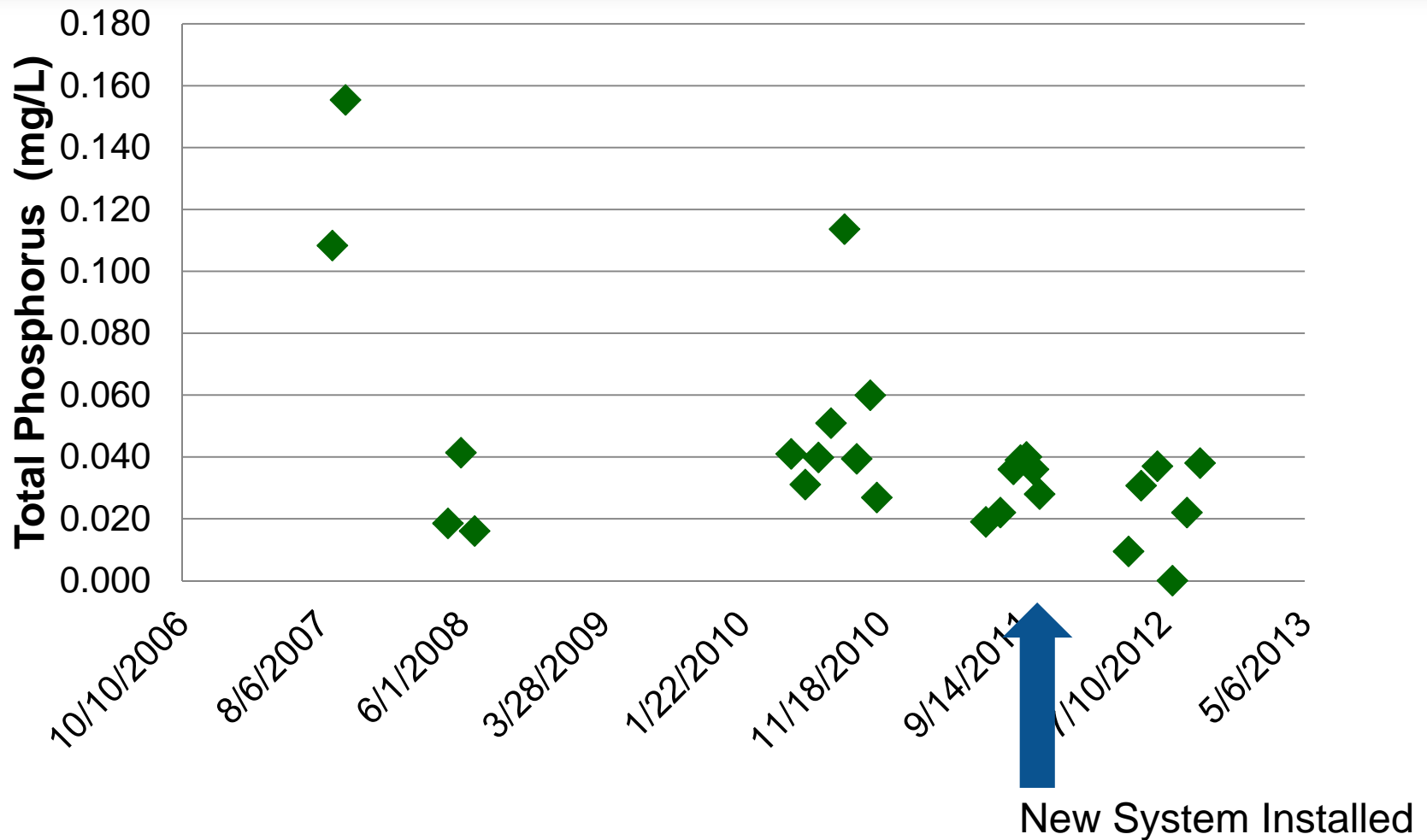




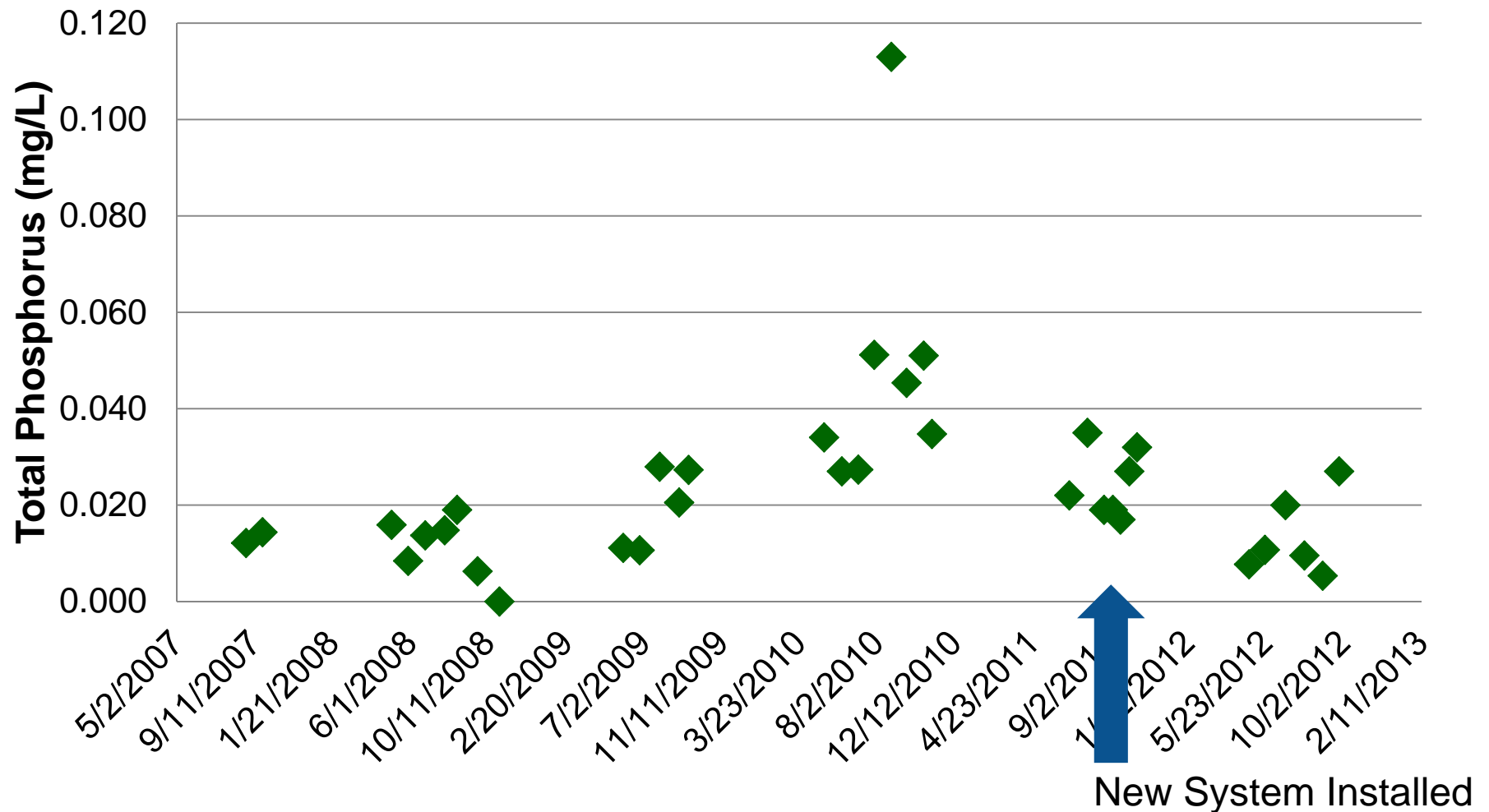
# Lake Vadnais Hypolimnion Total Iron



# Lake Vadnais Hypolimnion Total Phosphorus



# Lake Vadnais Epilimnion Total Phosphorus



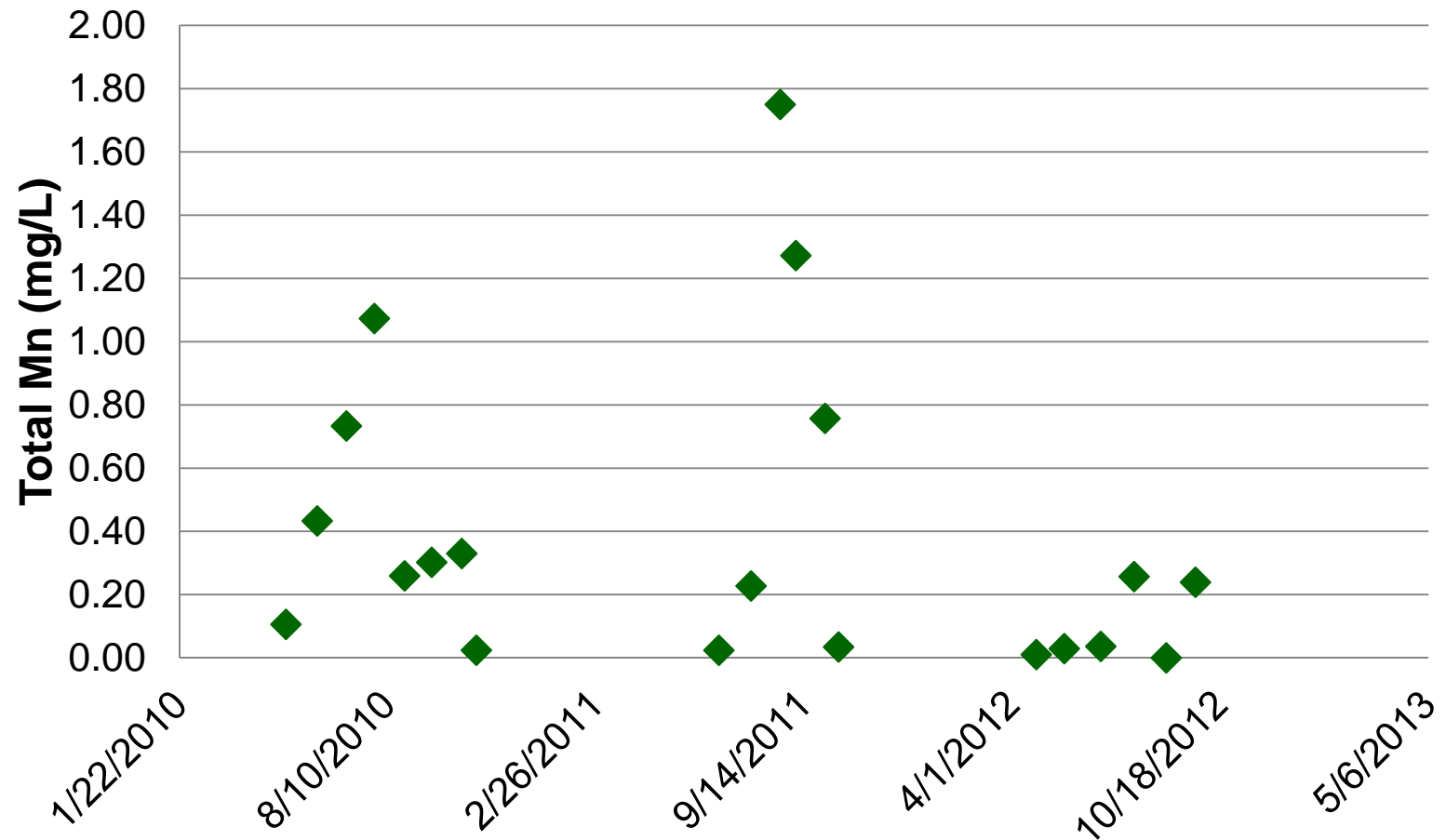


# Questions?

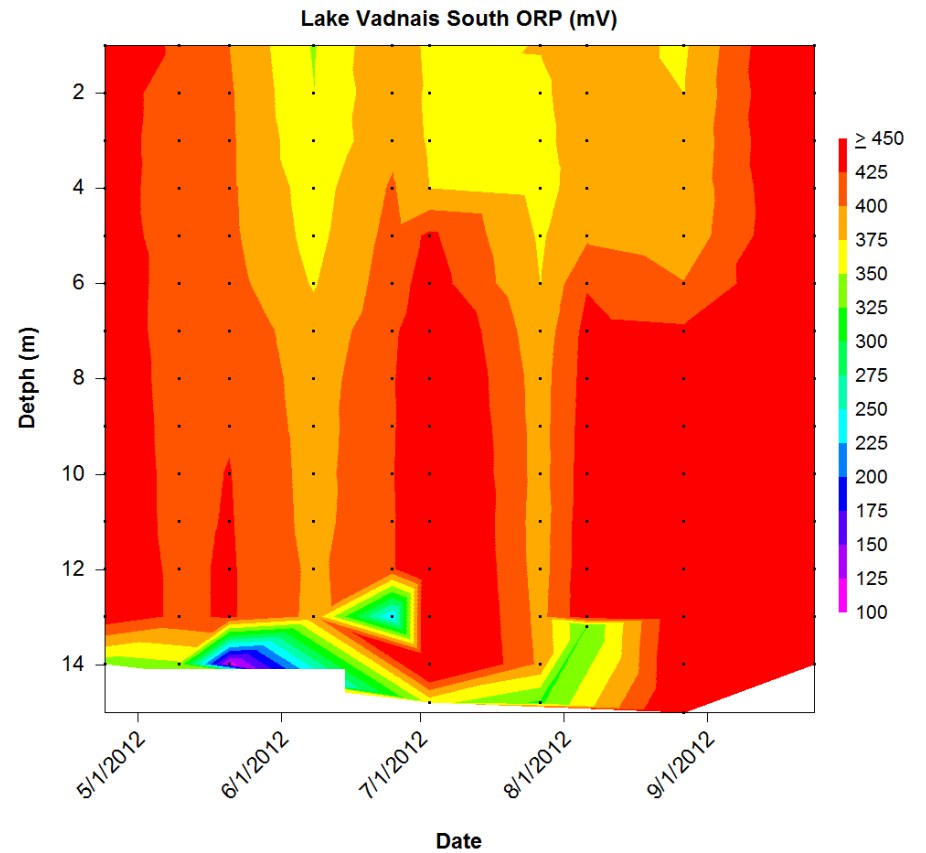
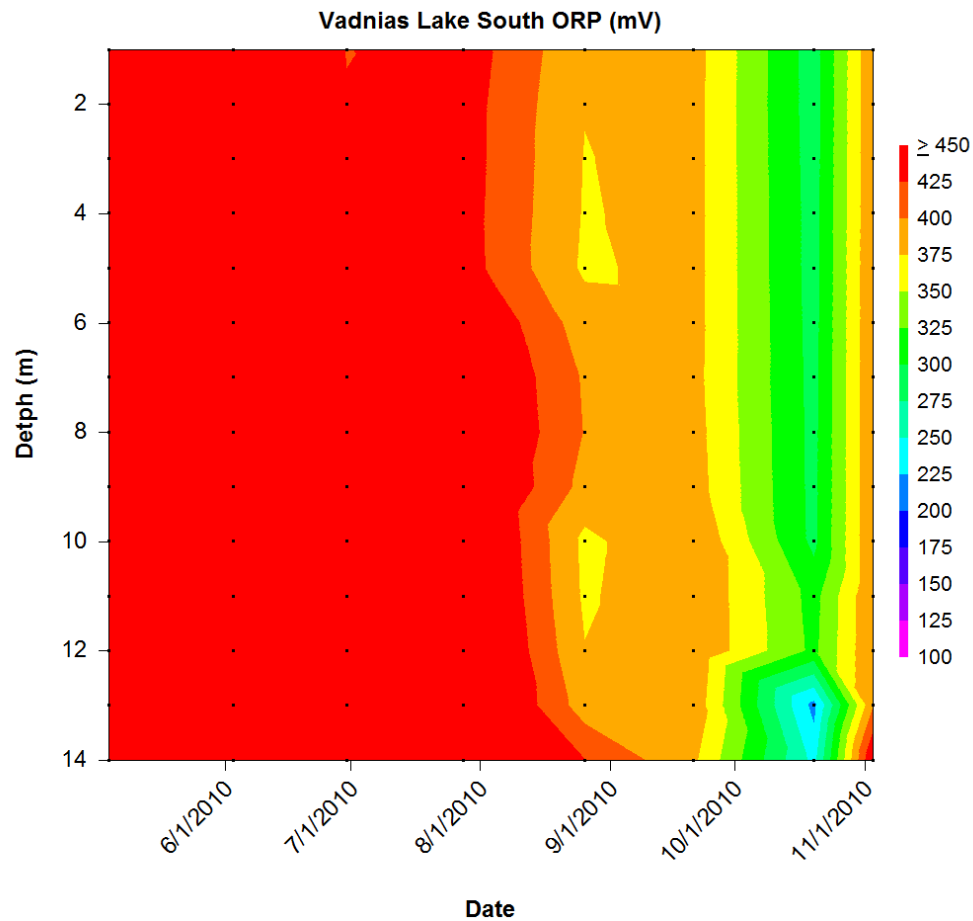


# New System Performance

## Vadnais South Hypolimnion Total Manganese

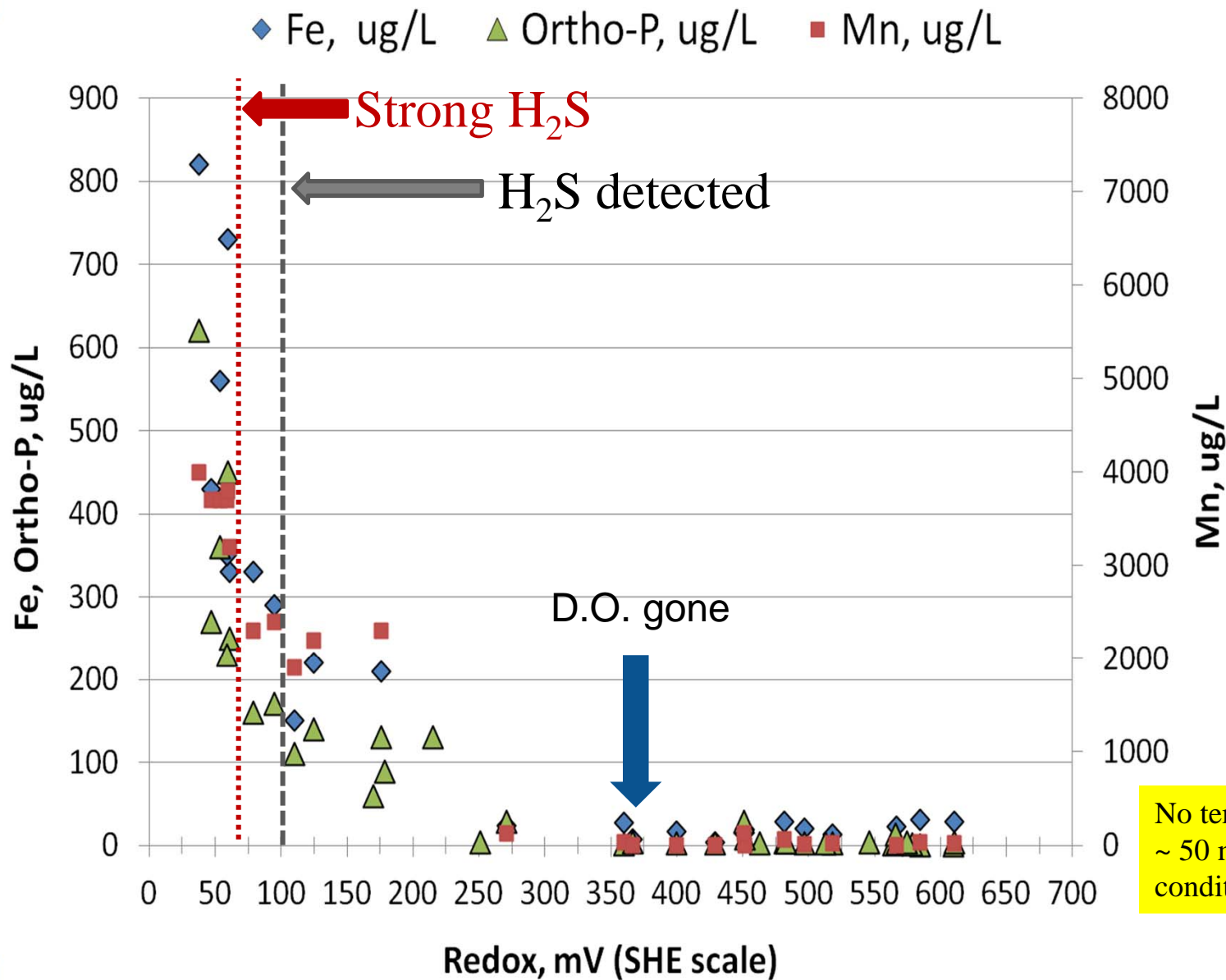


# Hypolimnion ORP





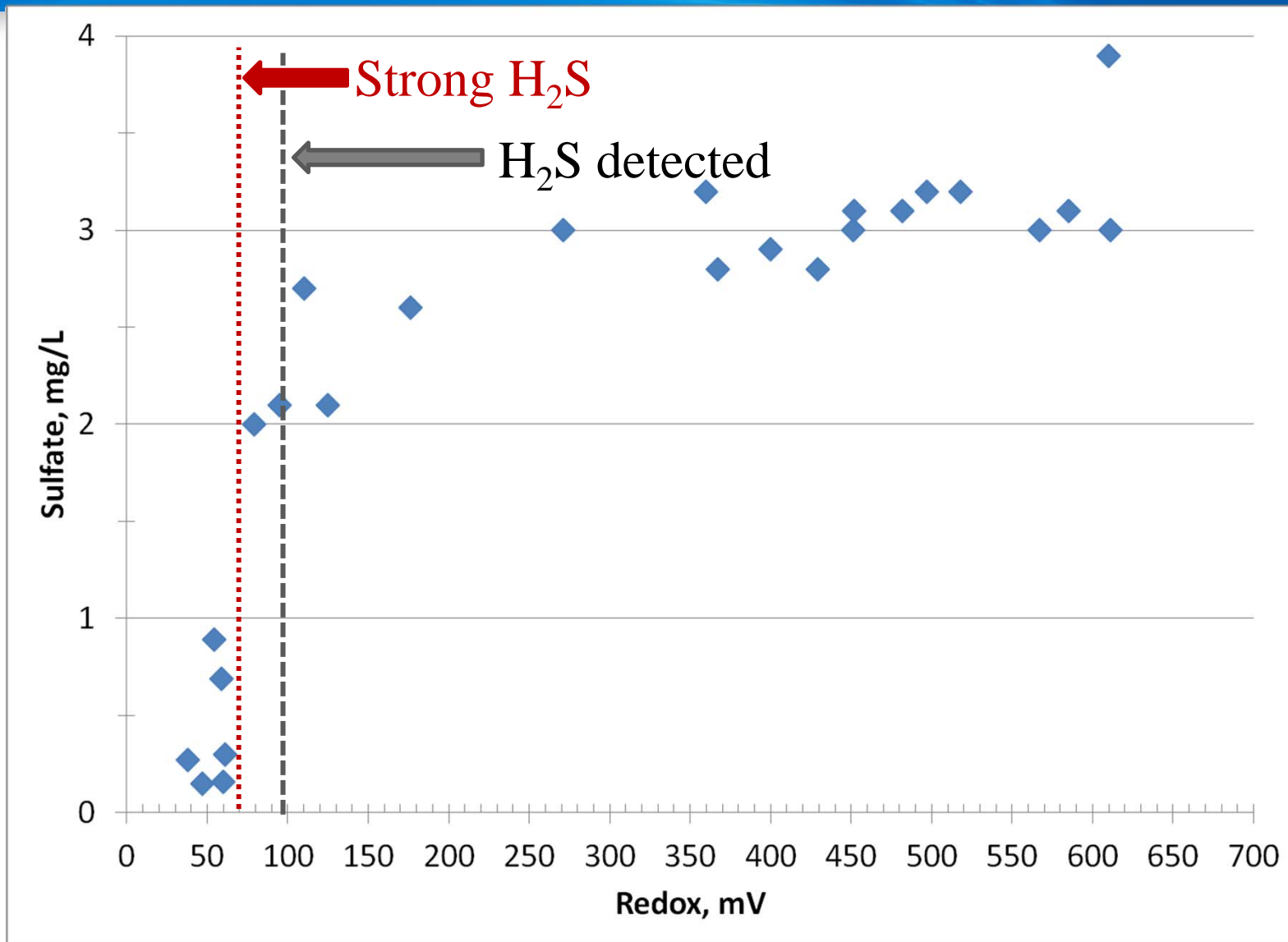
# The sulfur cycle in P-solubilization



Hypolimnion of Lake  
Ann, Chanhassen, MN  
Apr-Oct 2010

No temperature correction. Add  
~ 50 mV for standard  
conditions (25°C).

# $\text{SO}_4^{2-}$ loss associated with previous slide



# Pleasant Aerators Removed





# Sediment Oxygen Demand

