Lake Reclamation Beyond TMDLs:

Project Experience Demonstrating

the Essential Need for Positive Controls on Internal Nutrient Loading

and the Importance of Ecosystem Structure to Restore Water Quality

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Outline

- Section 319(h) of CWA
- Three legged stool of lake/reservoir WQ reclamation
  - ✓ Ecosystem structure
  - ✓ Methylmercury
  - ✓ Internal nutrient loading
- Conclusions

Section 319(h) of CWA

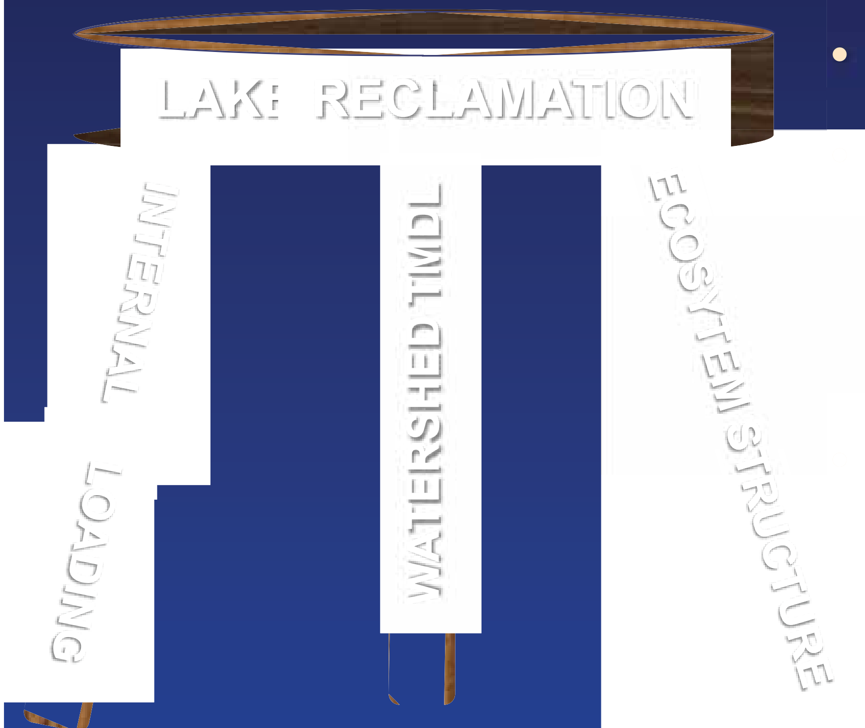
"Lake protection and restoration activities are eligible for funding under Section 319(h) …

However, *Section* 319 funds **should not be used for in-lake work …**

…unless the sources of pollution have been addressed sufficiently to assure that the pollution being remediated will not recur."

- **The 319 act calls in-lake work "palliative"**
- **Sometimes, it is**
- **We shall see, however, that it can be fundamental**
- **Watershed approaches alone are typically incapable of restoring lake water quality**

Lake water quality reclamation stands on three legs



- Non-degradation: TMDLs strong
- Internal impairments: TMDLs weak
  - ✓ Internal nutrient loading
  - ✓ Ecosystem impairments
- Integrated strategies necessary

Ecosystem structure and water quality

Water clarity and ecosystem structure

In the two zones shown, the TP concentration is equal inside and outside of exclosure

Zone 1: clear water: no algae growth, no panfish

Zone 2: turbid water: algae growth, lots of panfish

Riley Lake, Chanhassen, Minnesota
Photo: Dave Florenziano
Experiment: Sorenson and Bajer

Ecological Controls on Water Clarity

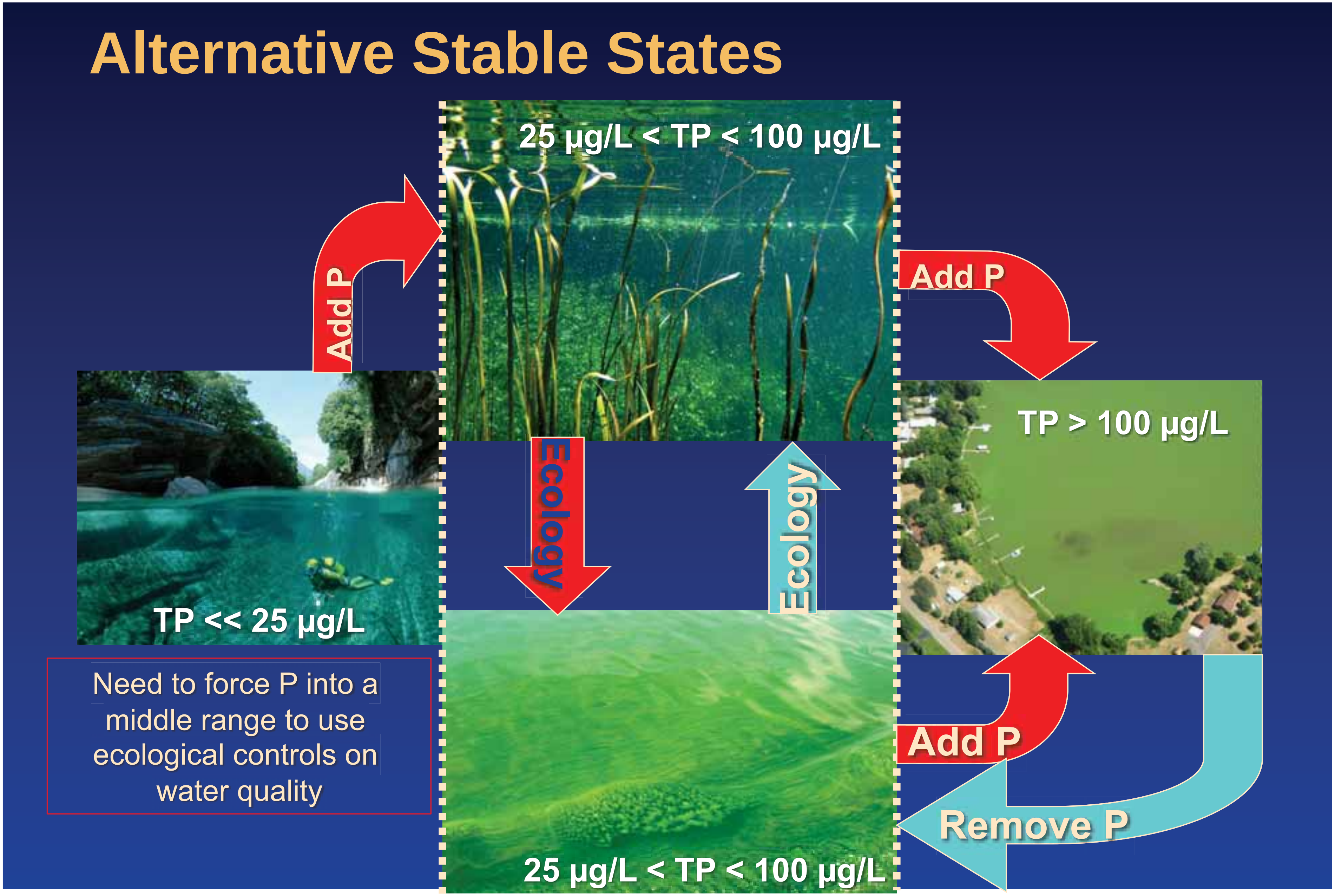
Daphnia vertical diel migration

- Night algae grazing
- Escape planktivorus fish predation

Panfish (e.g., perch, sunfish)

Large predators (e.g., pike) control planktivores => more *Daphnia*

- Daytime in plants or dark (aerobic) hypolimnion


Alternative Stable States
25 µg/L < TP < 100 µg/L
Add P
TP << 25 µg/L
Need to force P into a middle range to use ecological controls on water quality
Add P
TP > 100 µg/L
Ecology
Ecology
Add P
Remove P
25 µg/L < TP < 100 µg/L

But biomanipulation is deeply, deeply complex

Lake Wingra, Madison, Wiscosin
Photo: Emily Seivers, UW-Madison
Experiment: Lathrop et al

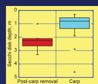
Recent carp studies have opened another huge area of biomanipulation practice

Carp and ecosystem change

- **Start with clear water, submersed macrophyte stable state**
- **Carp destroy it, sending system to turbid, algae dominated stable state.**
- **Nutrient controls will fail to restore until carp population reduced to much less than 100 kg/ha (~100 lbs/ac)**

- Carp removal Lake Susan, Chanhassen, MN 2009-2010
- Final removal in February 2010.
- About 90% of population removed
- Current population << 100 lbs/ac

Lake Susan, Chanhassen, MN:
Carp Harvest Effect on Water Transparency



2009

1971 - 2008

p < 0.001

n = 8

n = 48

SPRING

SUMMER

- Data from failed alum treatment
- Worked great, but carp wrecked it

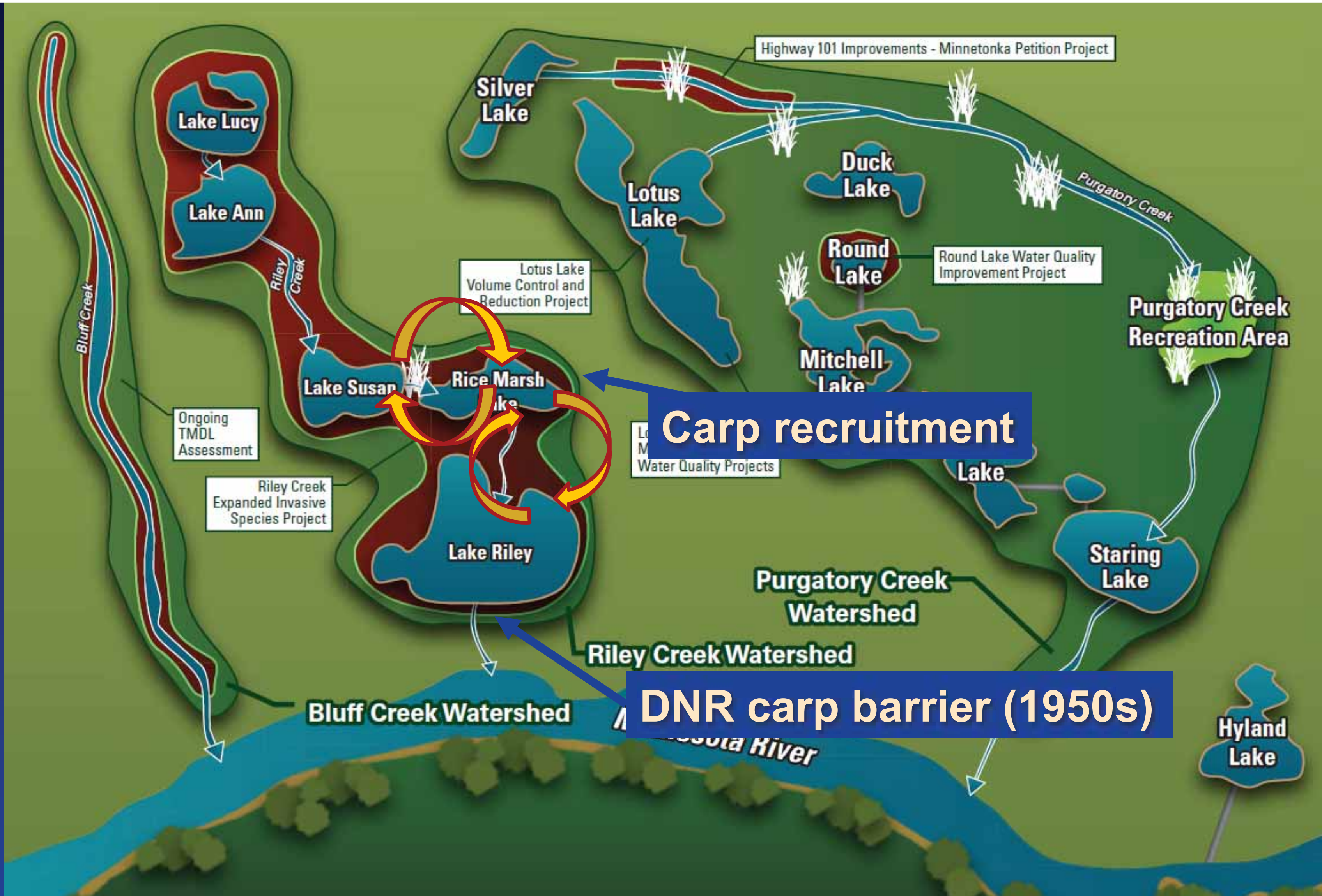
Managing carp

- Smart, very hardy, extremely fecund
- Standard fish surveys don't count them
- Need to know basic fisheries biology to manage
  - Carp sexually active to age 50 years
  - Very uneven recruitment. Why?
  - *Lepomis* populations eat ALL eggs, fry, and juveniles < 1"
  - But not after winter fish kills
  - Carp must have access to winter fish kill lakes to recruit

Recipe for carp-free watershed

- **Tag, track, net out to << 100 lbs/ac**
- **Install carp barrier to invasion**
- **Aerate fish kill lakes for 50 years**

Photo: Dave Hanson

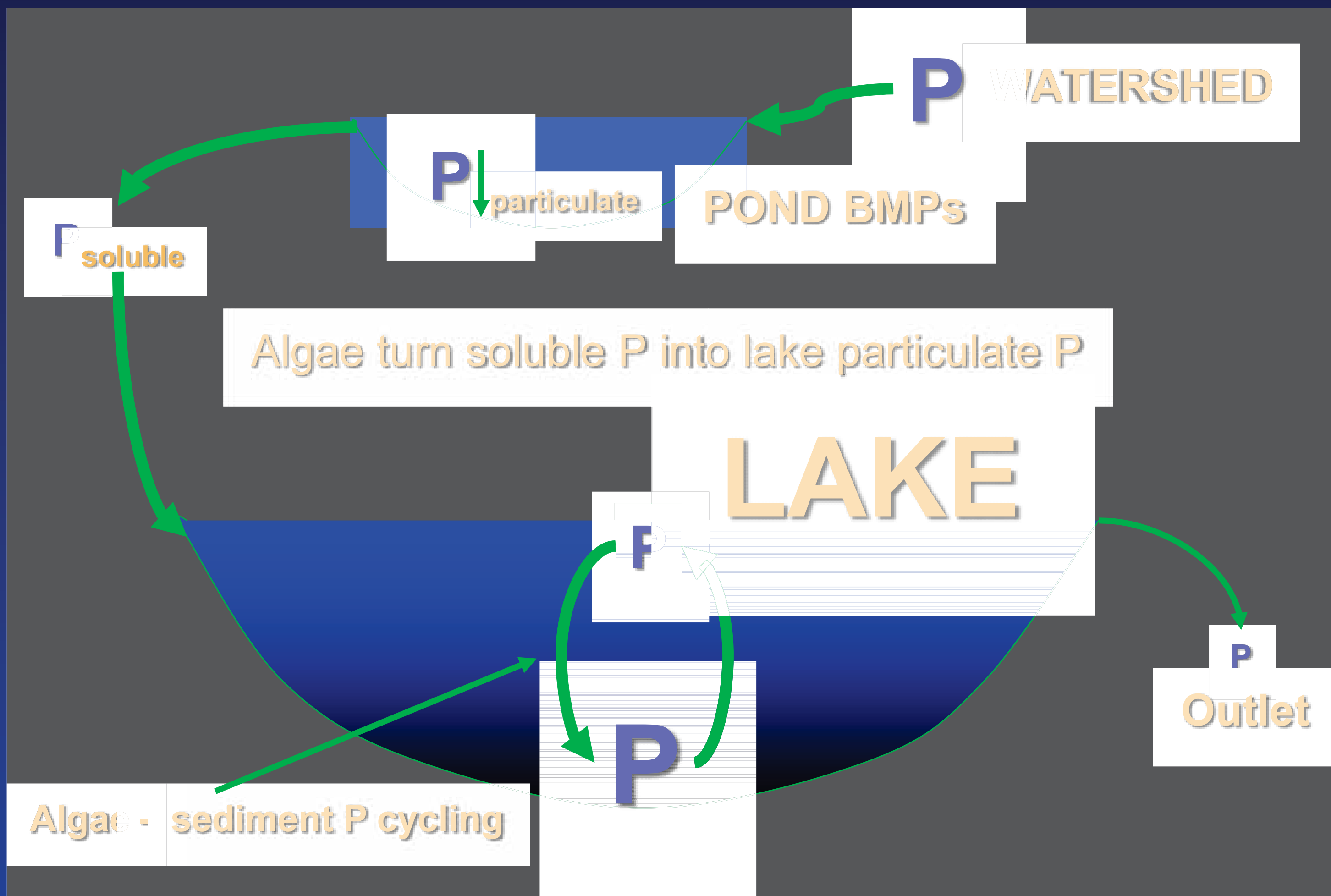


Carp management is a watershed-wide effort

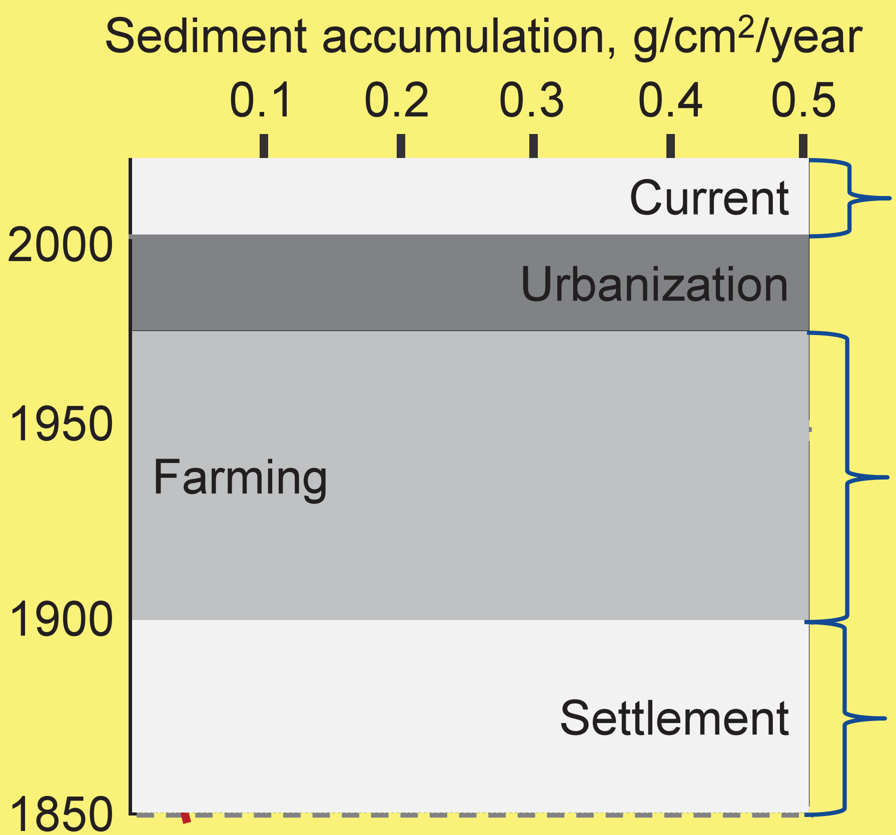
Potamogeton crispus

- Grows under ice except in heavy early snowfall years
- Forms canopy on surface
- Shades out native plants
- Complete senescence in late June
  - Massive putrescible load to lake
  - ~ 250 – 500 tons wet weight to Mitchell Lake, Eden Prairie, MN
  - ~ 140 – 280 mg P m^{-2} senescence loading
  - Senescence P spike + 40 - 100 µg/L

Internal nutrient loading



History of impairment matters: paleolimnology



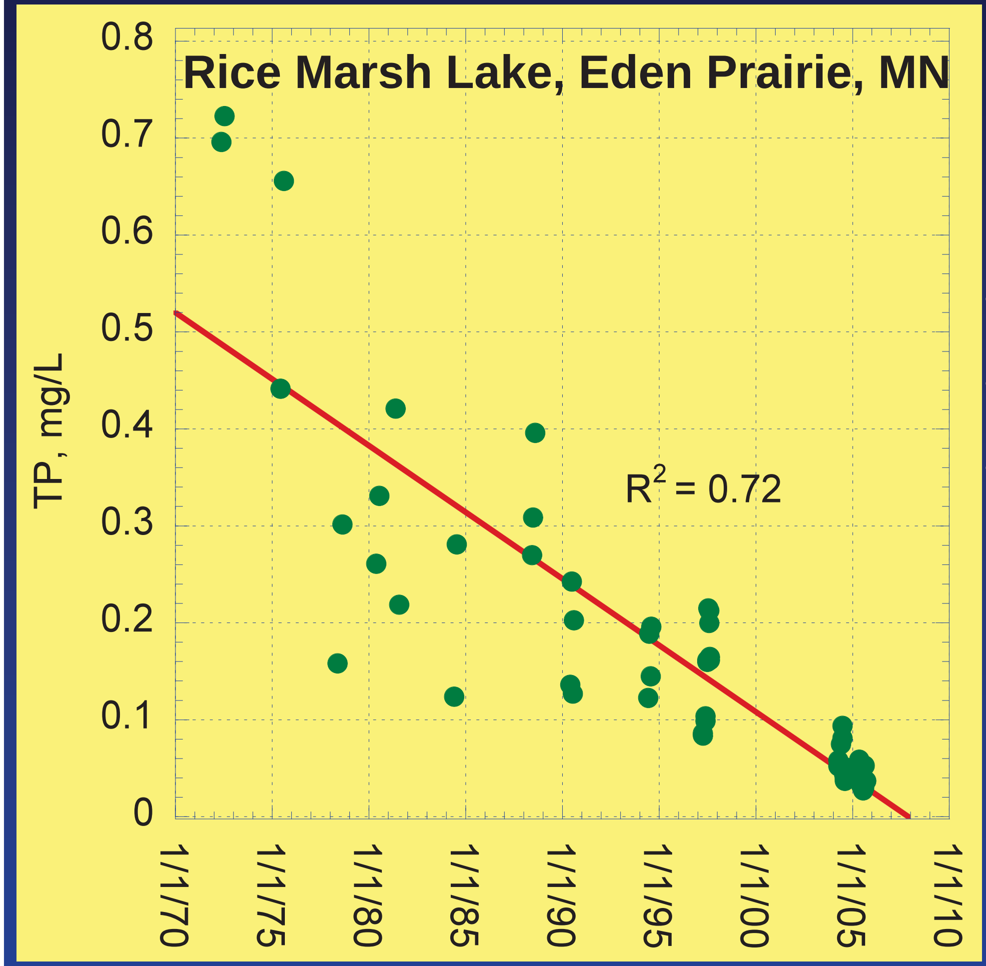
- Sedimentation slightly over presettlement
- Summer TP at 89 **µg/L**
- **Water quality is legacy of sedimentation**

- Highest sedimentation
- Big swings in water quality

- Bottom has low oxygen in summer
- Probable summer TP ~ 40 **µg/L**

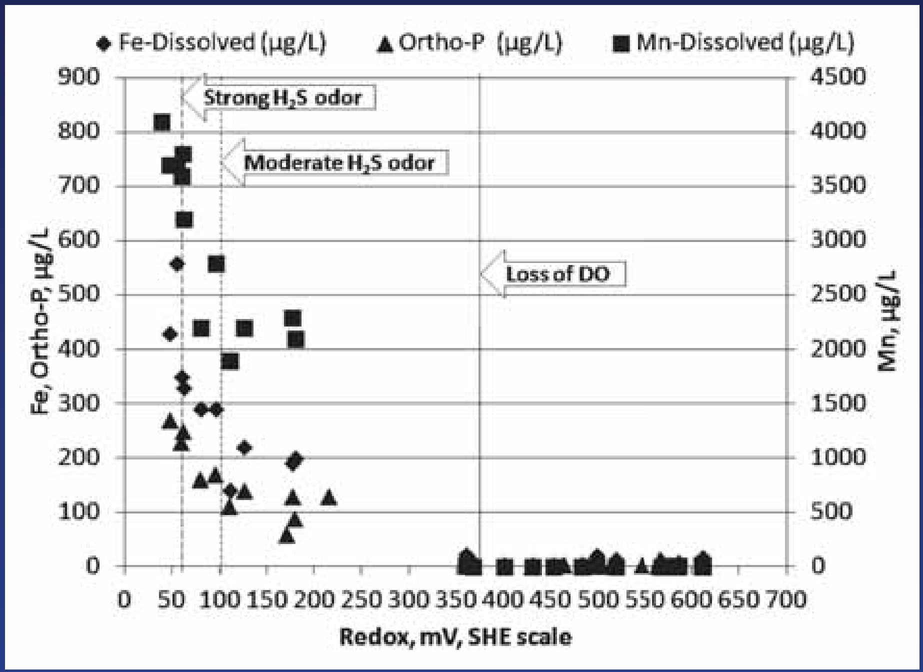
Mitchell Lake, Eden Prairie, MN

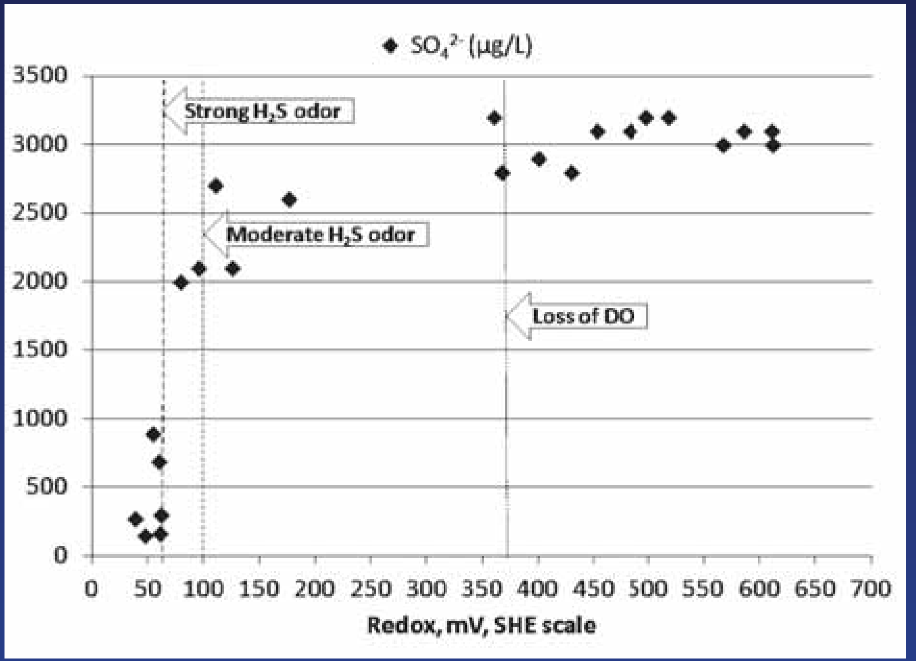
How long does laissez-faire recovery take?



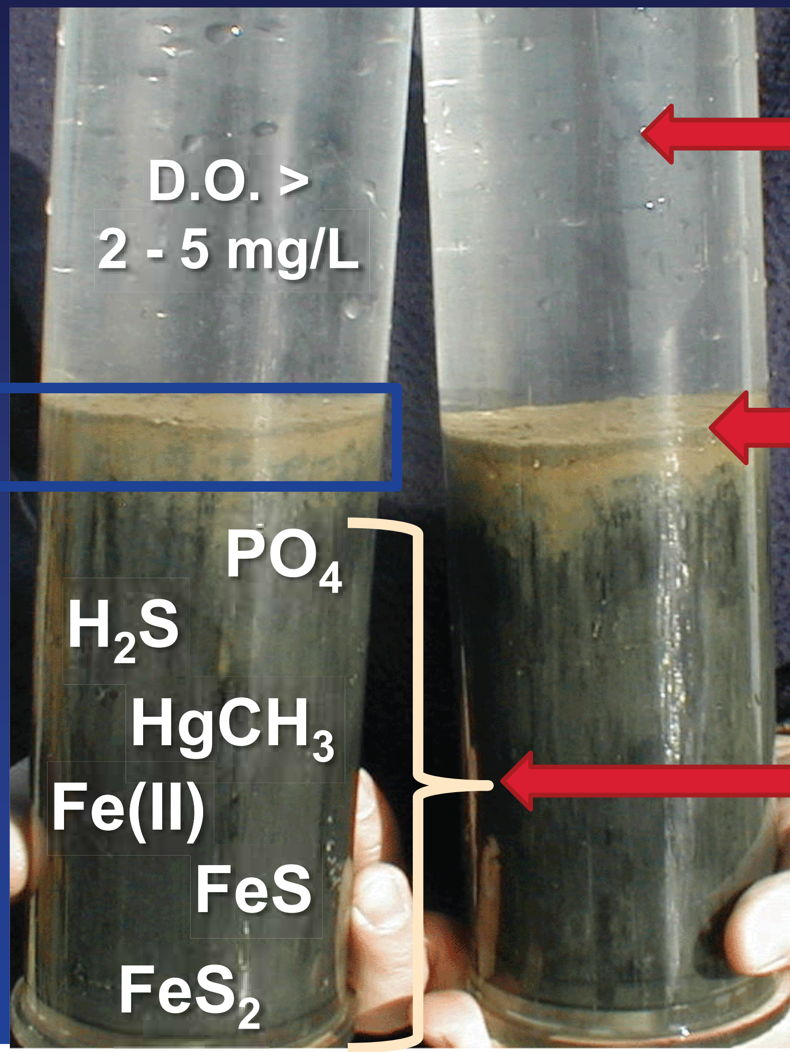
- **Shallow lake (79 ac, max depth 11 ft)**
- **Sewage discharge stopped ~1970**
- **If watershed controls were work:**
  - How long to effective?
  - How long after effective to work?
  - <u>Is 50-100 years to goal good policy?</u>

Sediment – water interactions I





Redox management in sediments

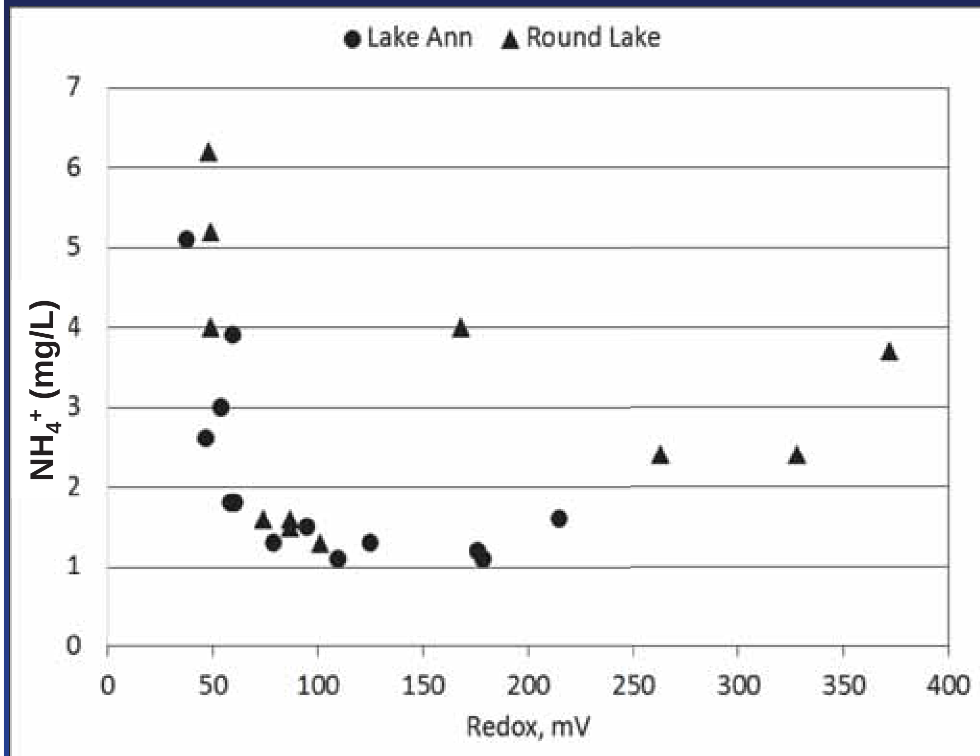


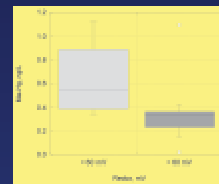
Inject O_2 or NO_3 …

to create F(III) cap

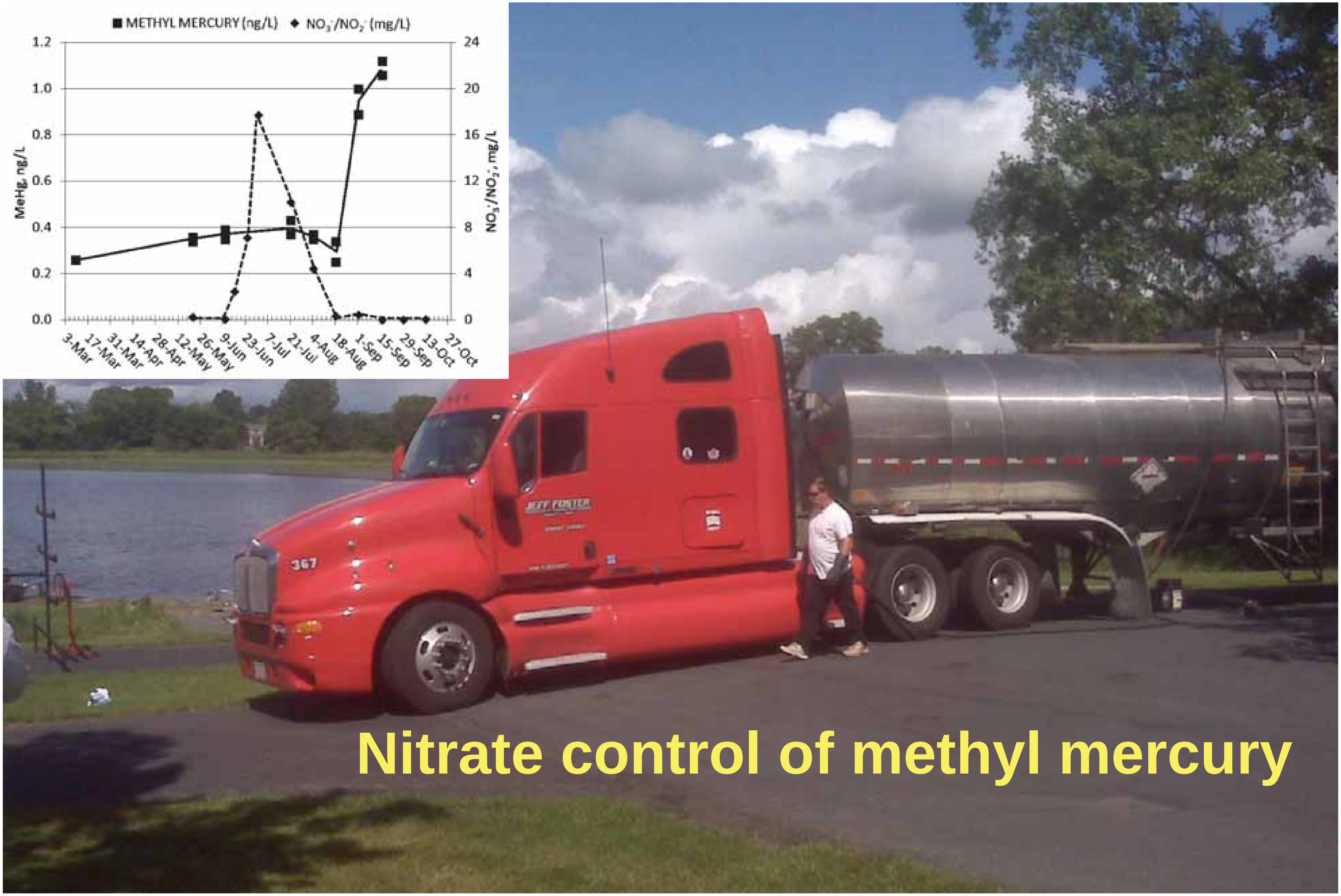
… and keep these compounds in sediment.

Monomethyl mercury ($HgCH_3^+$)



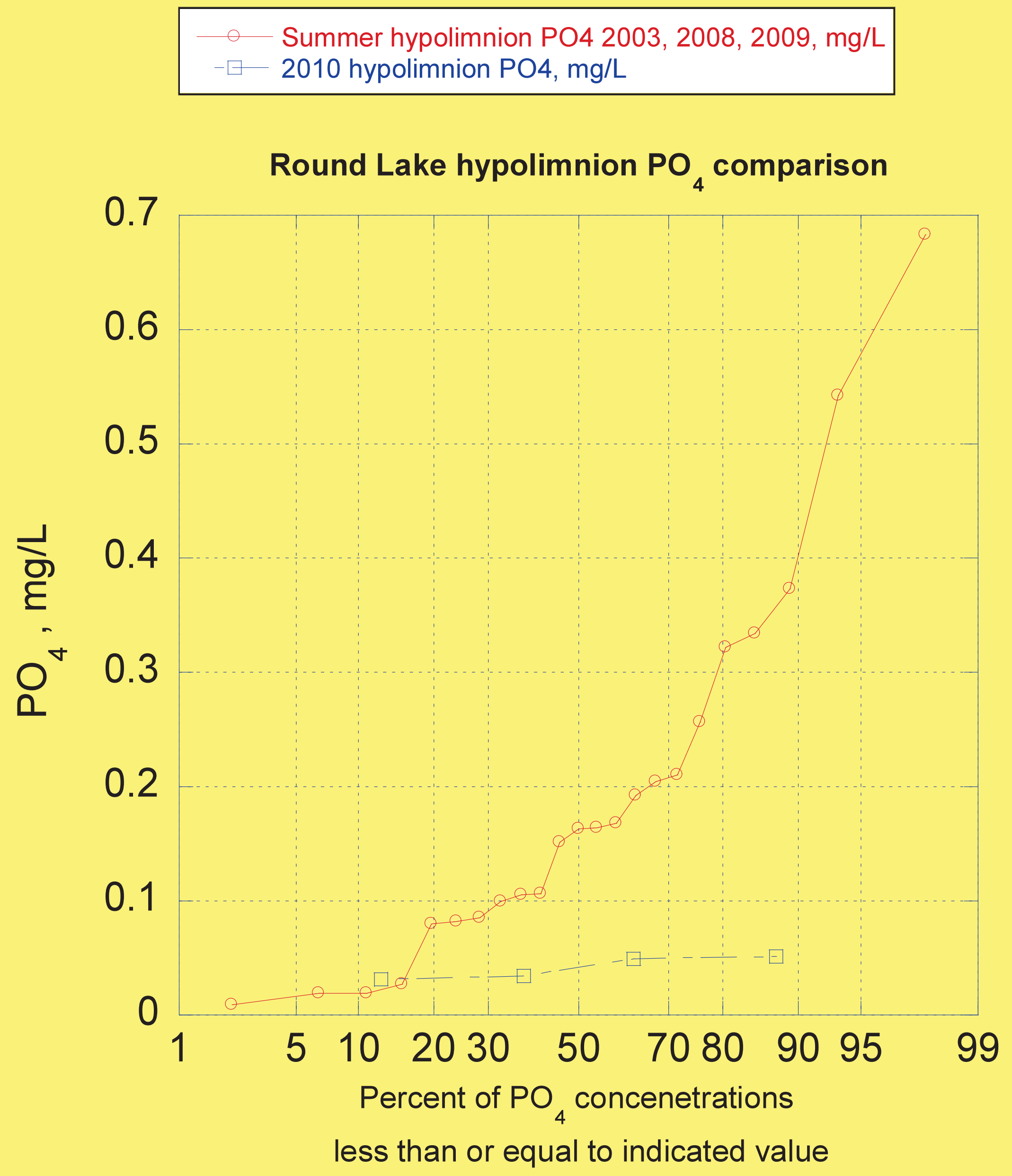


$HgCH_3^+$ (ng/L)

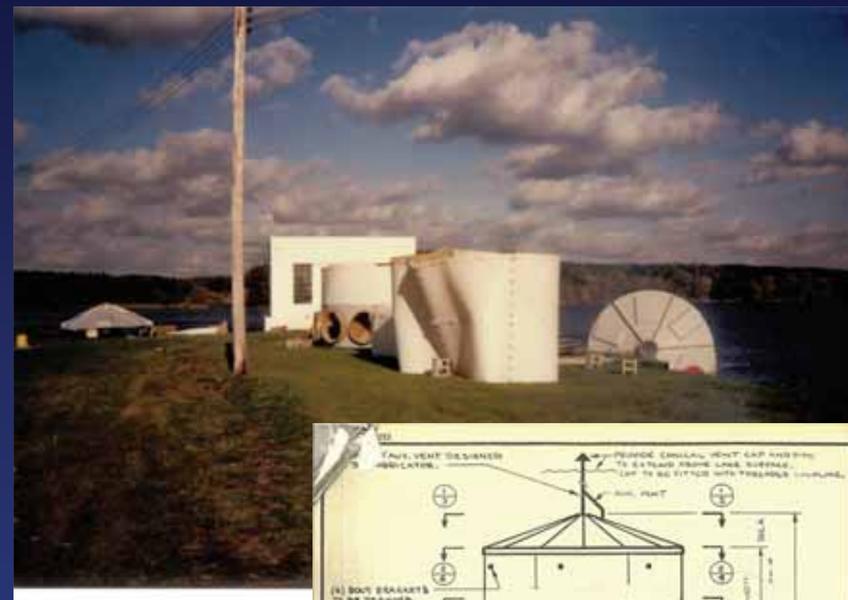


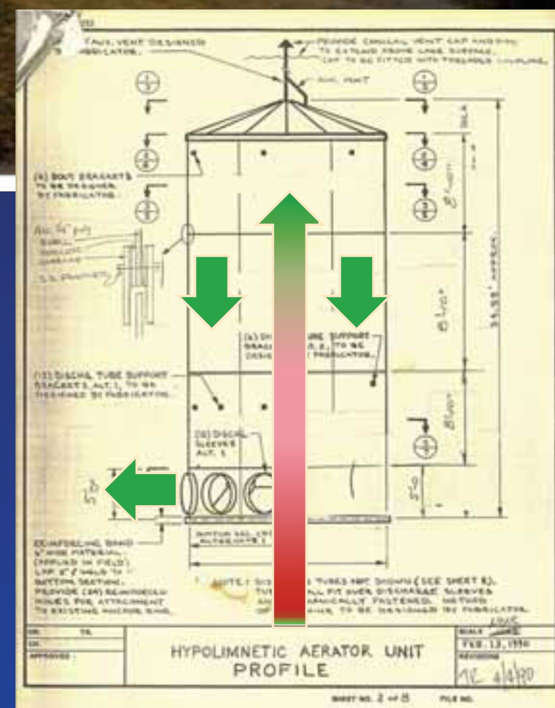
■ METHYL MERCURY (ng/L) ◆ NO3⁻/NO2⁻ (mg/L)
MeHgₜ, ng/L
NO3⁻/NO2⁻, mg/L
1.2
1.0
0.8
0.6
0.4
0.2
0.0
24
20
16
12
8
4
0
3-Mar 17-Mar 31-Mar 14-Apr 28-Apr 12-May 26-May 9-Jun 23-Jun 7-Jul 21-Jul 4-Aug 18-Aug 1-Sep 15-Sep 29-Sep 13-Oct 27-Oct
367
JEFF FOSTER
Nitrate control of methyl mercury

Effect of nitrate addition on phosphate



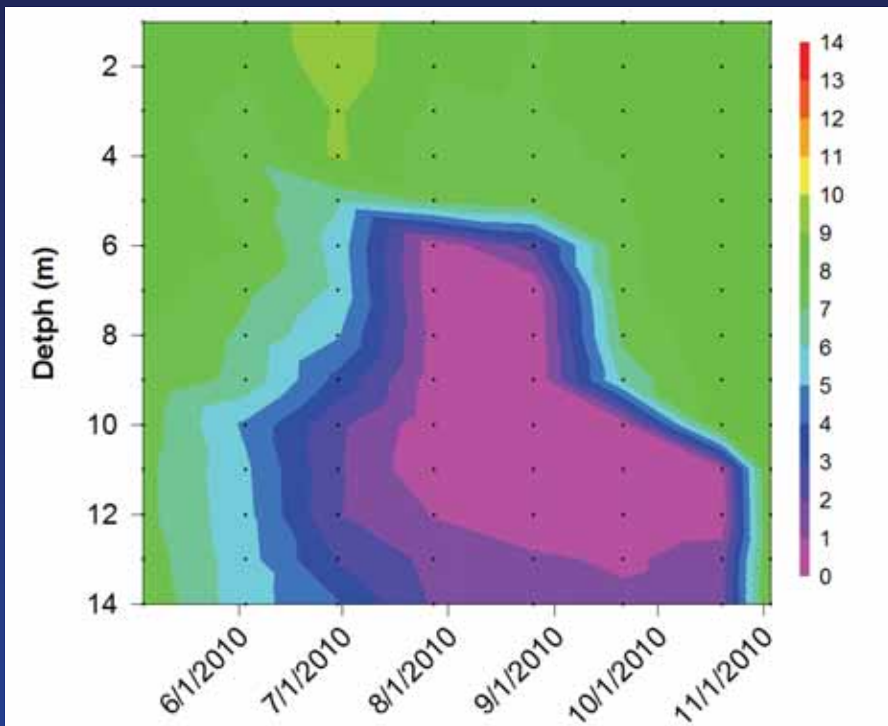
Vadnais Aerators Installed



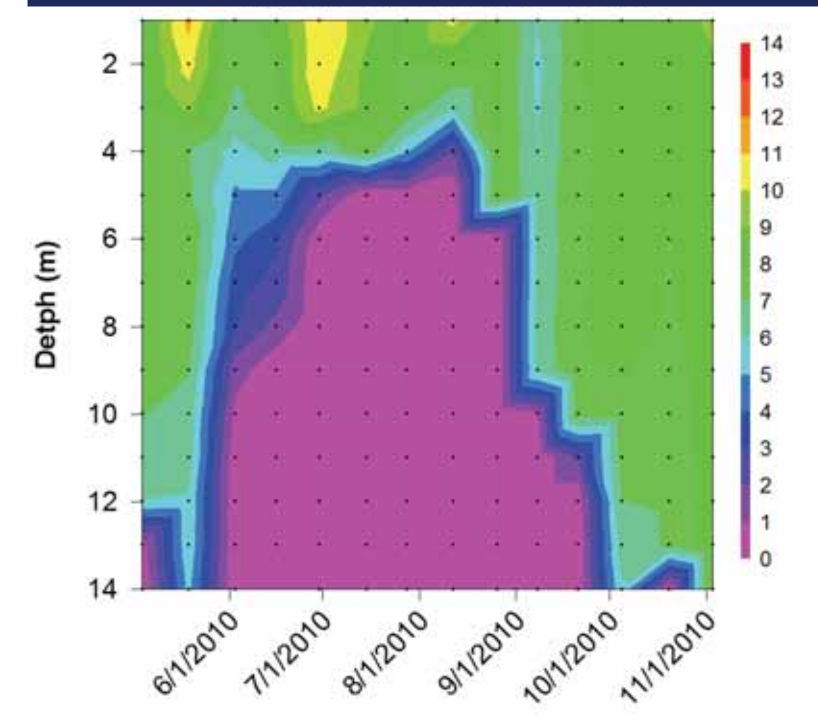


Summer 2010 Dissolved Oxygen Performance

Lake Vadnais - Aerator Operational

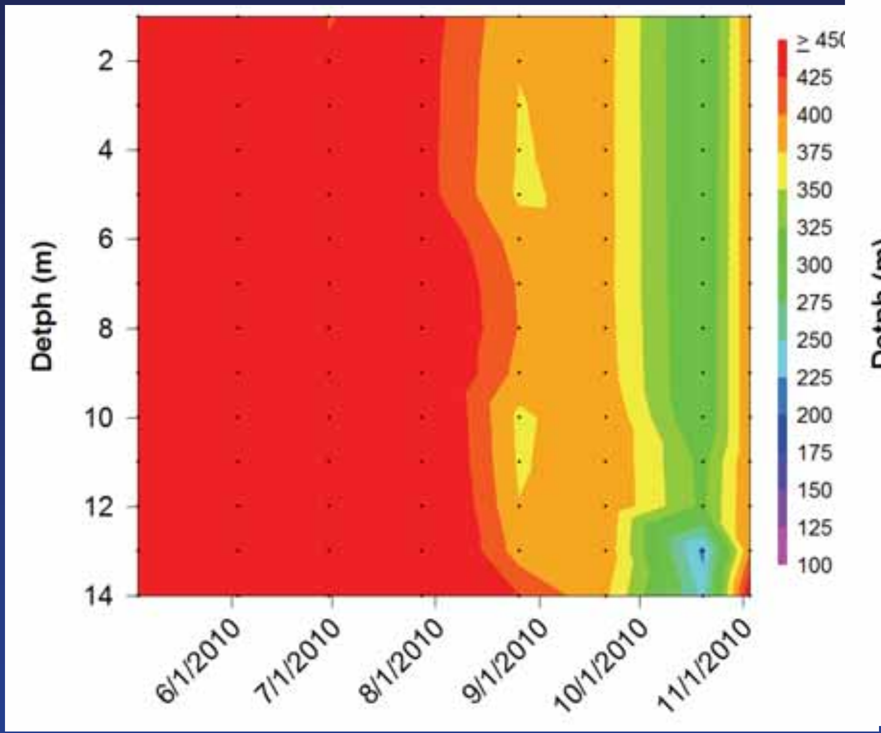


Pleasant Lake - Aerator NOT Operational

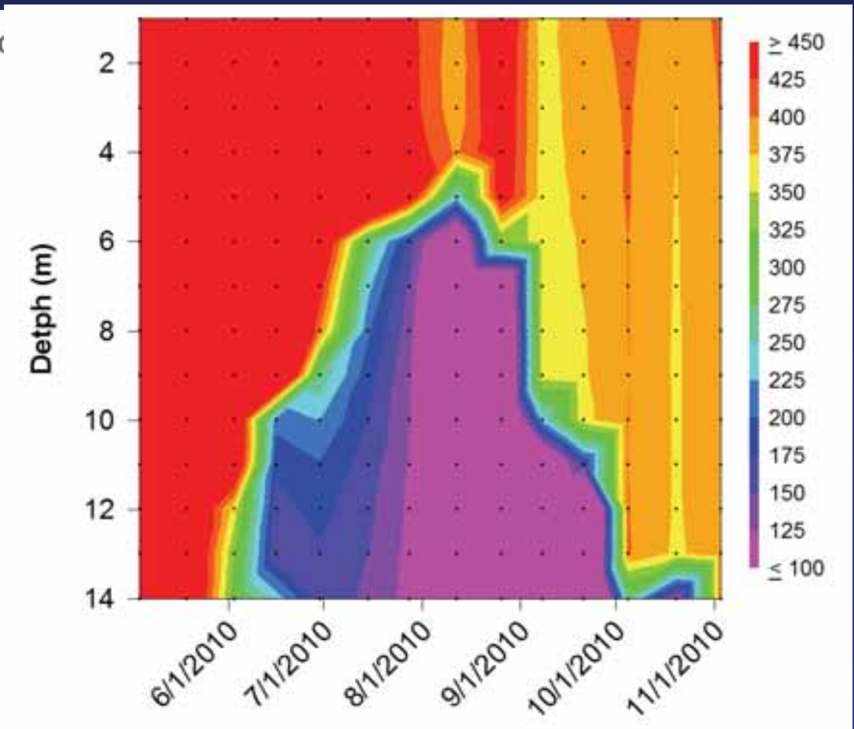


Summer 2010 ORP Performance

Lake Vadnais - Aerator Operational

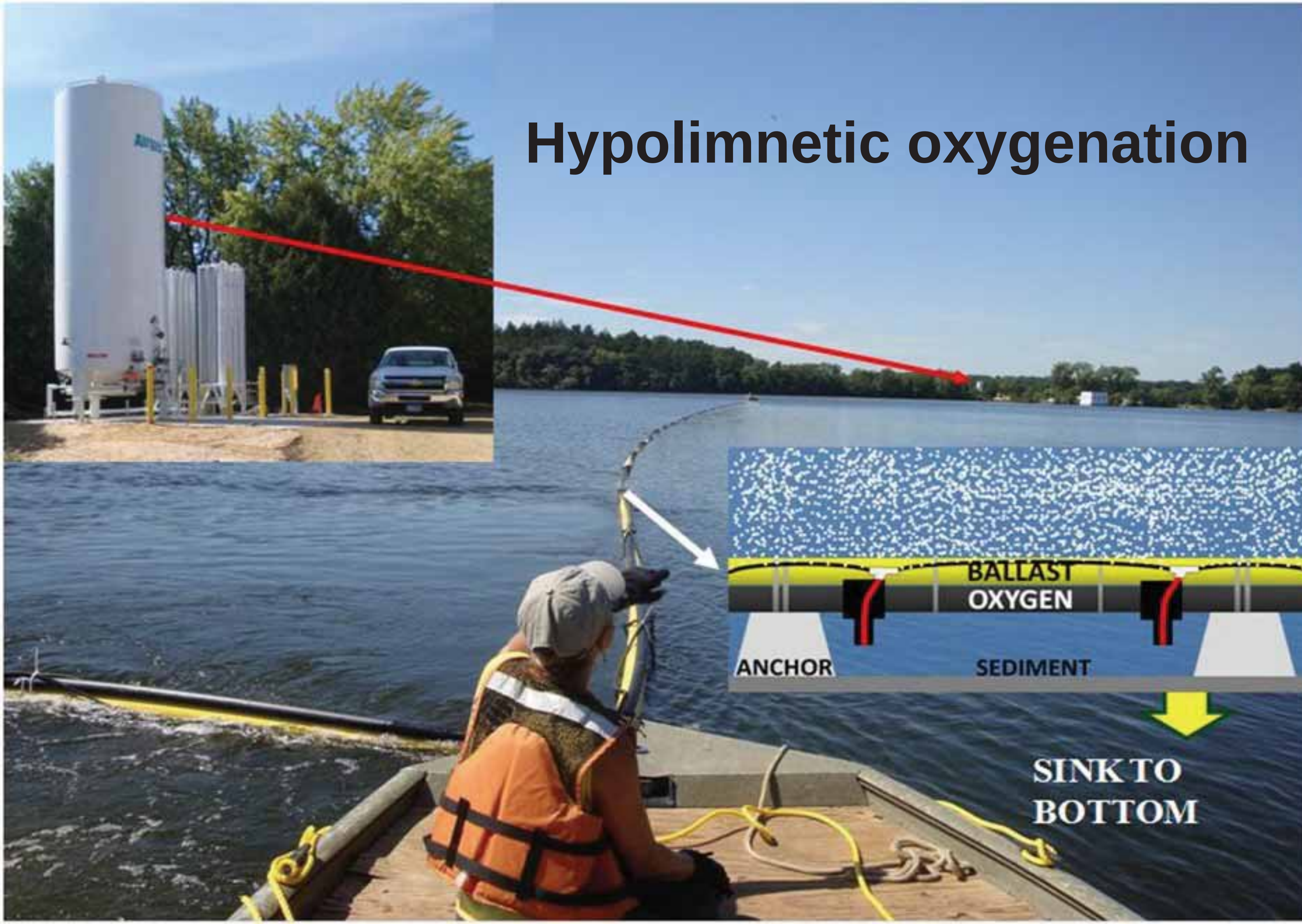


Pleasant Lake - Aerator NOT Operational



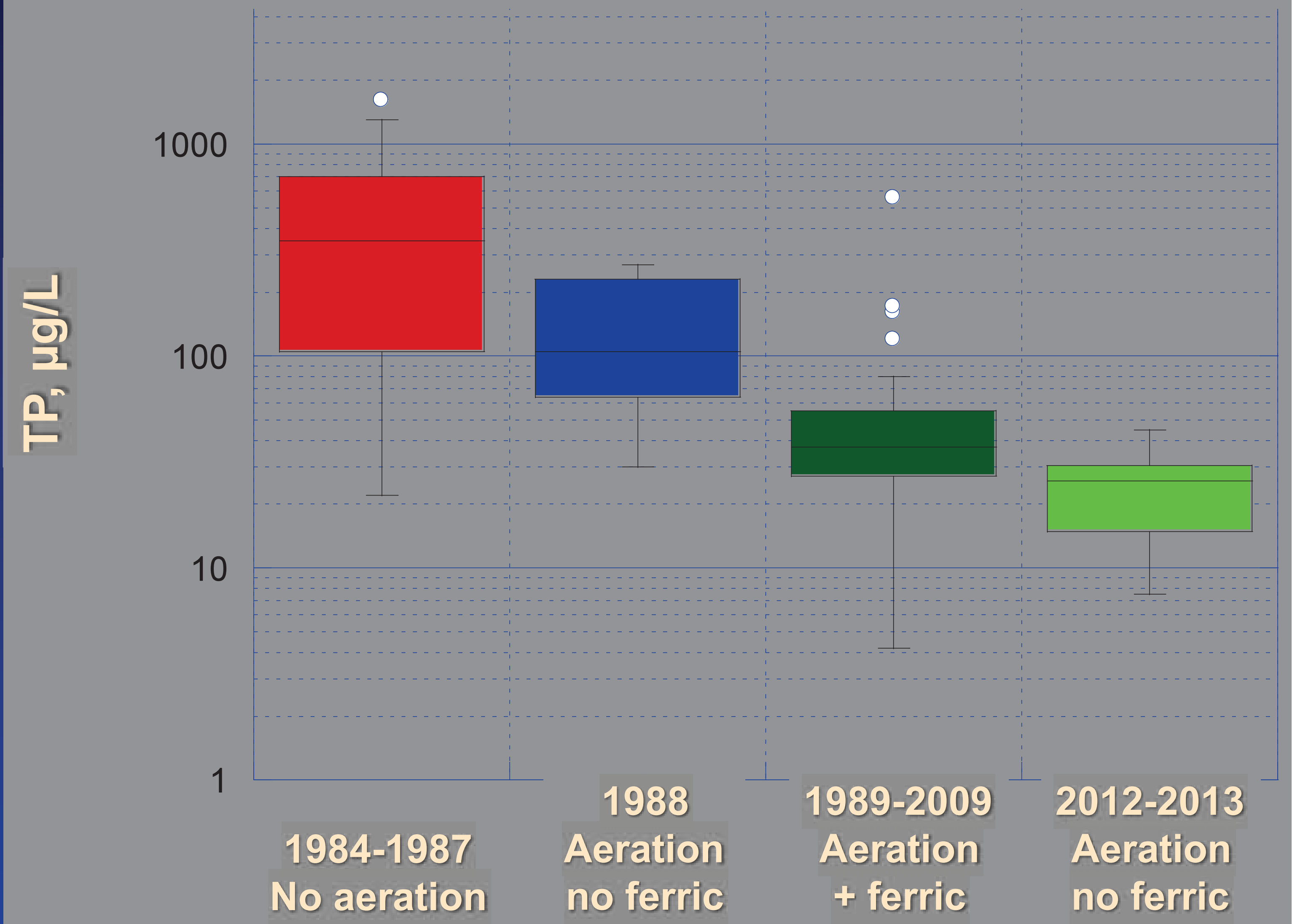
Vadnais Aerators Removed

Hypolimnetic oxygenation

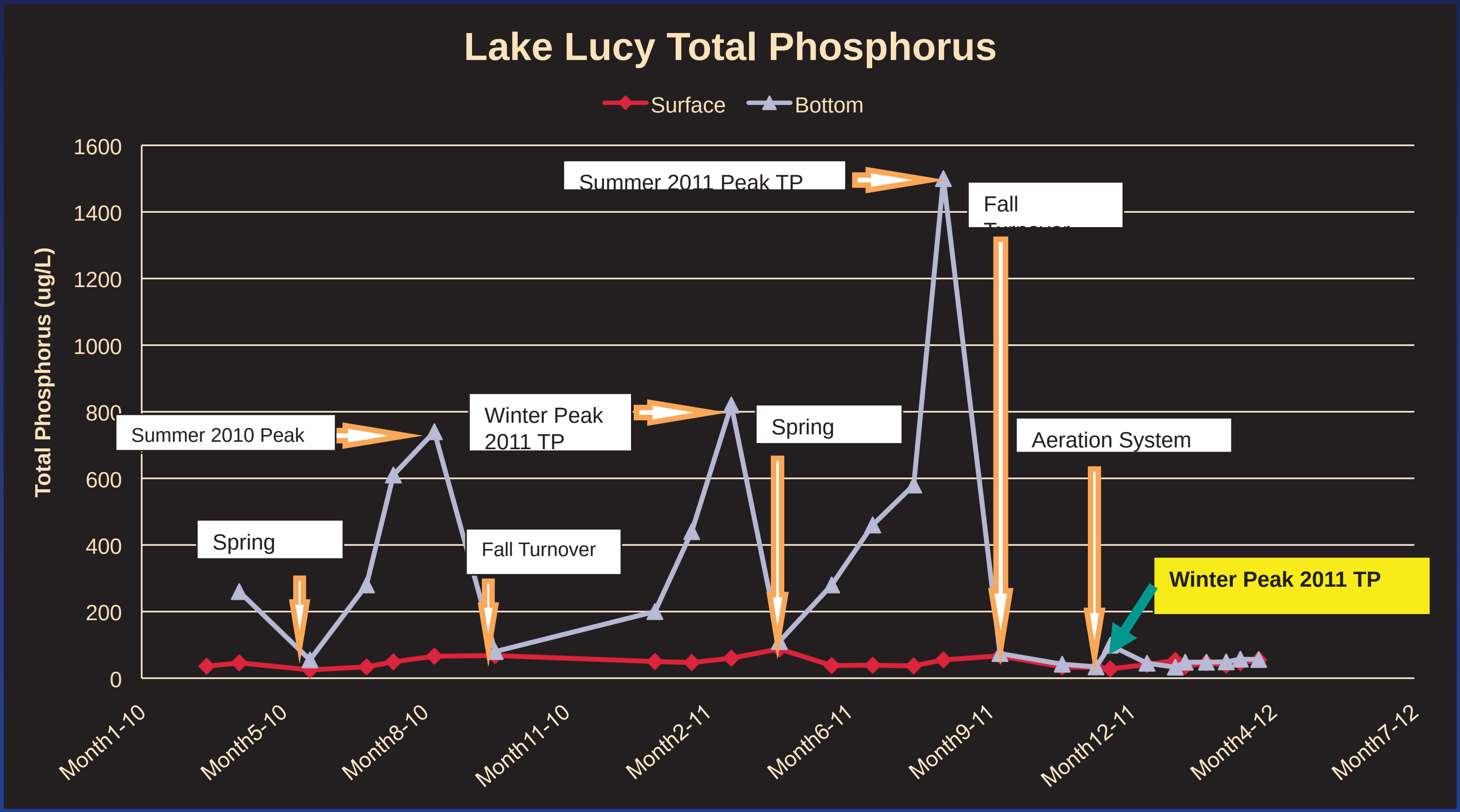


Vadnais hypolimnion TP results

Median differences all significant to $p < 0.01$

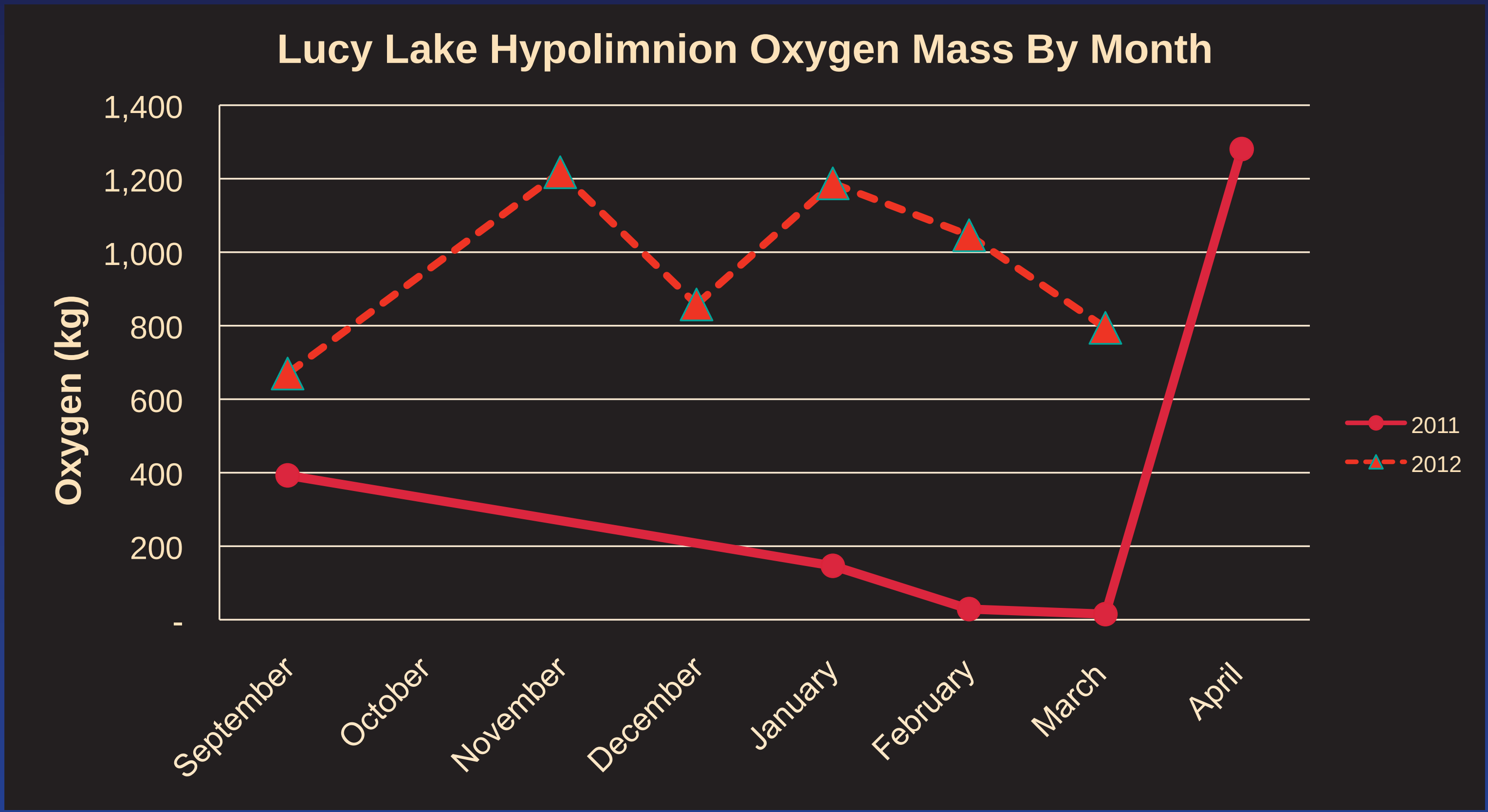


What about the winter? Highly dynamic

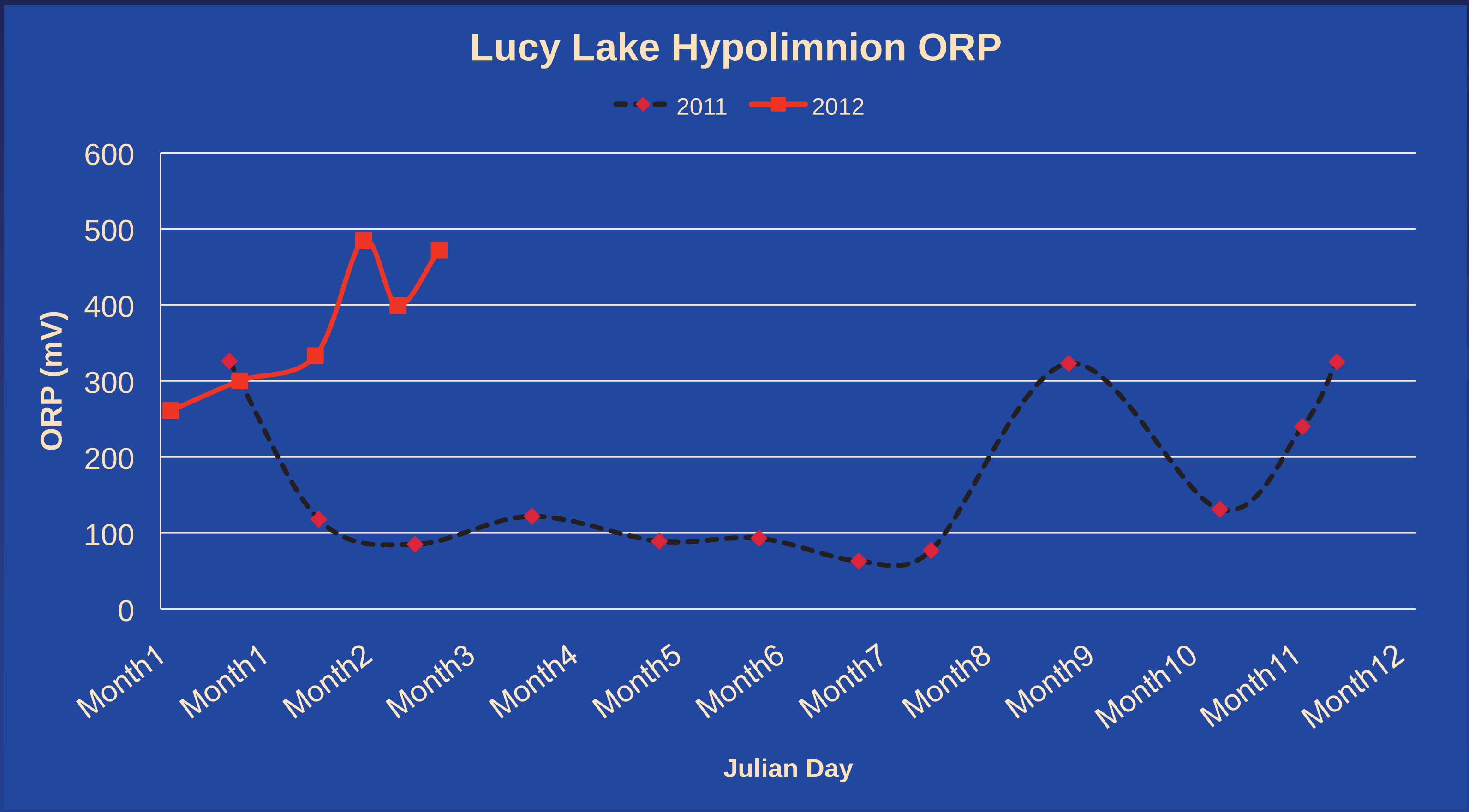


Ice Preserving Aeration System - IPAS

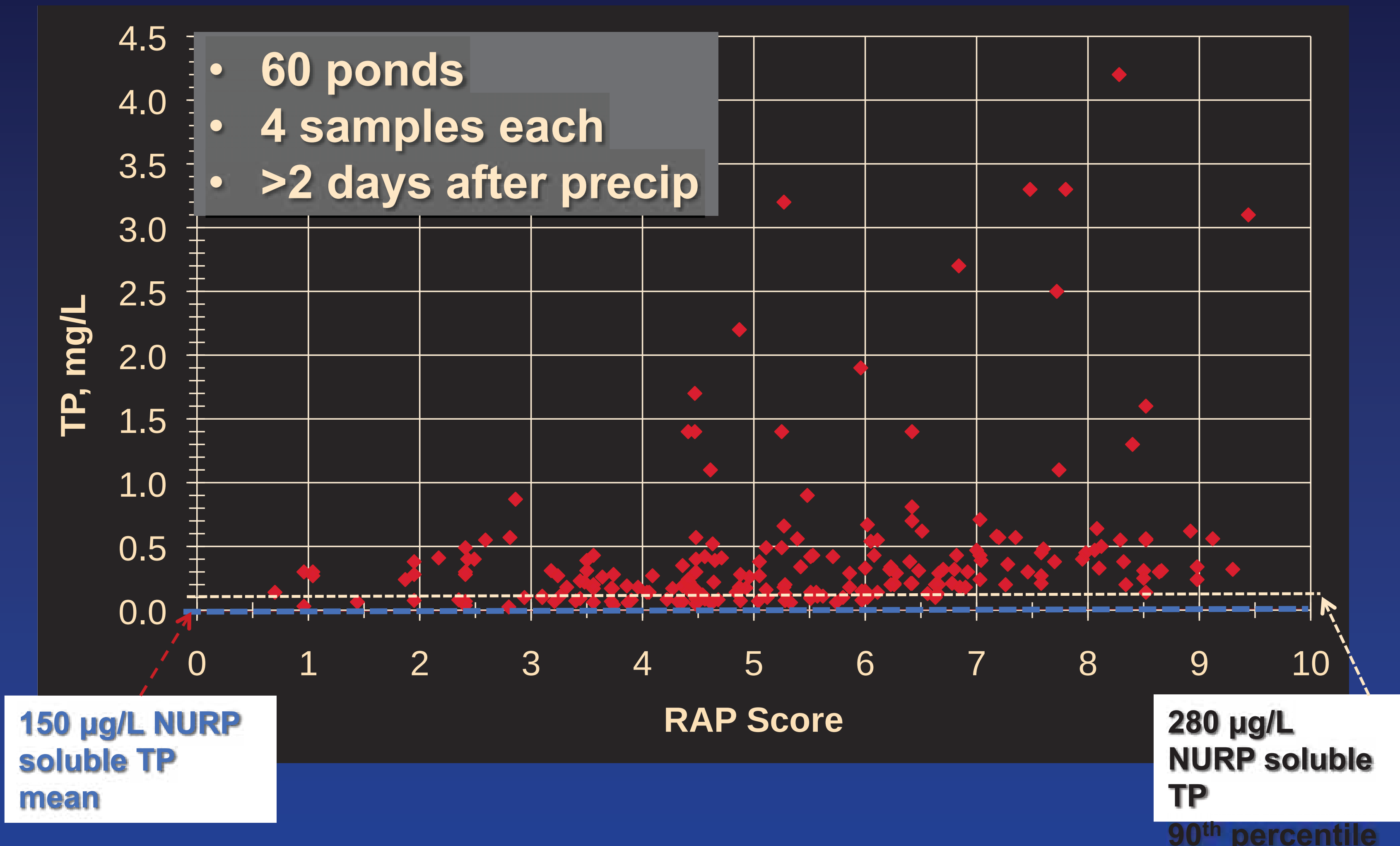
Oxygen Performance



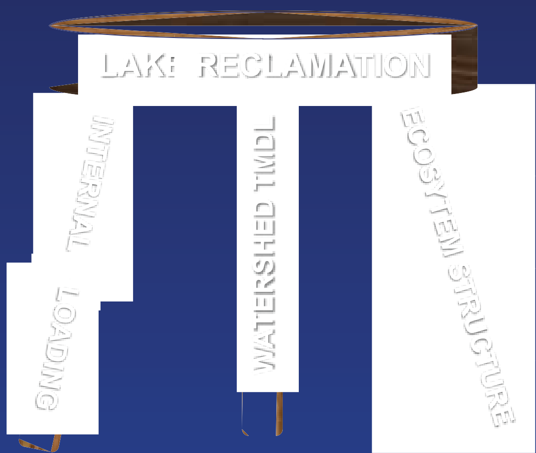
Lucy Redox Control



But aren't stormwater ponds just little lakes?



Conclusions



- The stool needs all three legs
- Ecosystem structure and internal loading profoundly affect water quality
- Watershed only approach omits critical science
- Many technical opportunities to address the “forgotten legs”

Questions?