Long-Term Rehabilitation of Delavan Lake, Wisconsin, USA: Importance of Biological Interactions

Dale Robertson

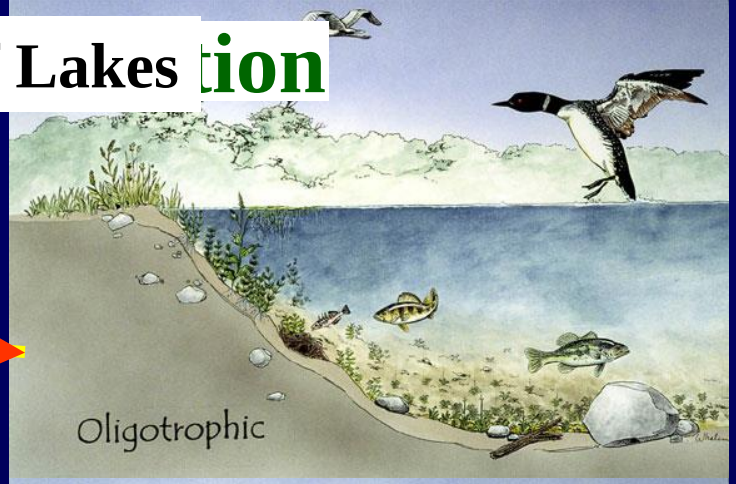
U.S. Geological Survey, Wisconsin Water Science Center

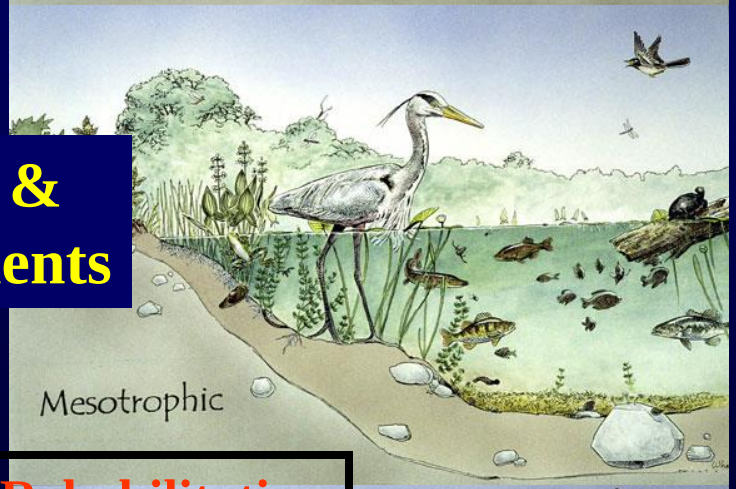
In Collaboration with:
Delavan Lake Sanitary District
Town of Delavan
Wisconsin DNR
University of Wisconsin
U.S. Army Corps of Engineers
U.S. EPA
U.S. Dept. of Agriculture

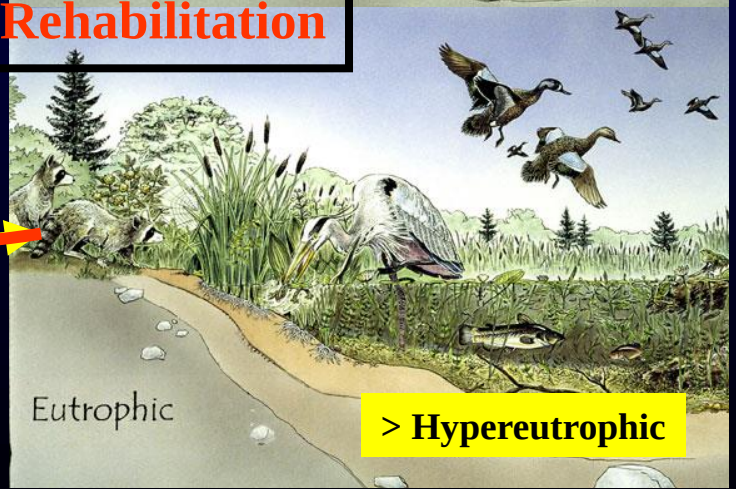
USGS

Excess Nutrients – One of the most extensive water-quality problems

Types of Lakes tion







Time & Nutrients

Lake Rehabilitation

Oligotrophic – *Young*

- Low Nutrient Conc.
- Low Productivity.
- Clear Water
- Desirable Fishery but often limited

Mesotrophic

- Moderate Nutient Conc.
- Increased Productivity
- Occasional Algal Bloom
- Good Fishery

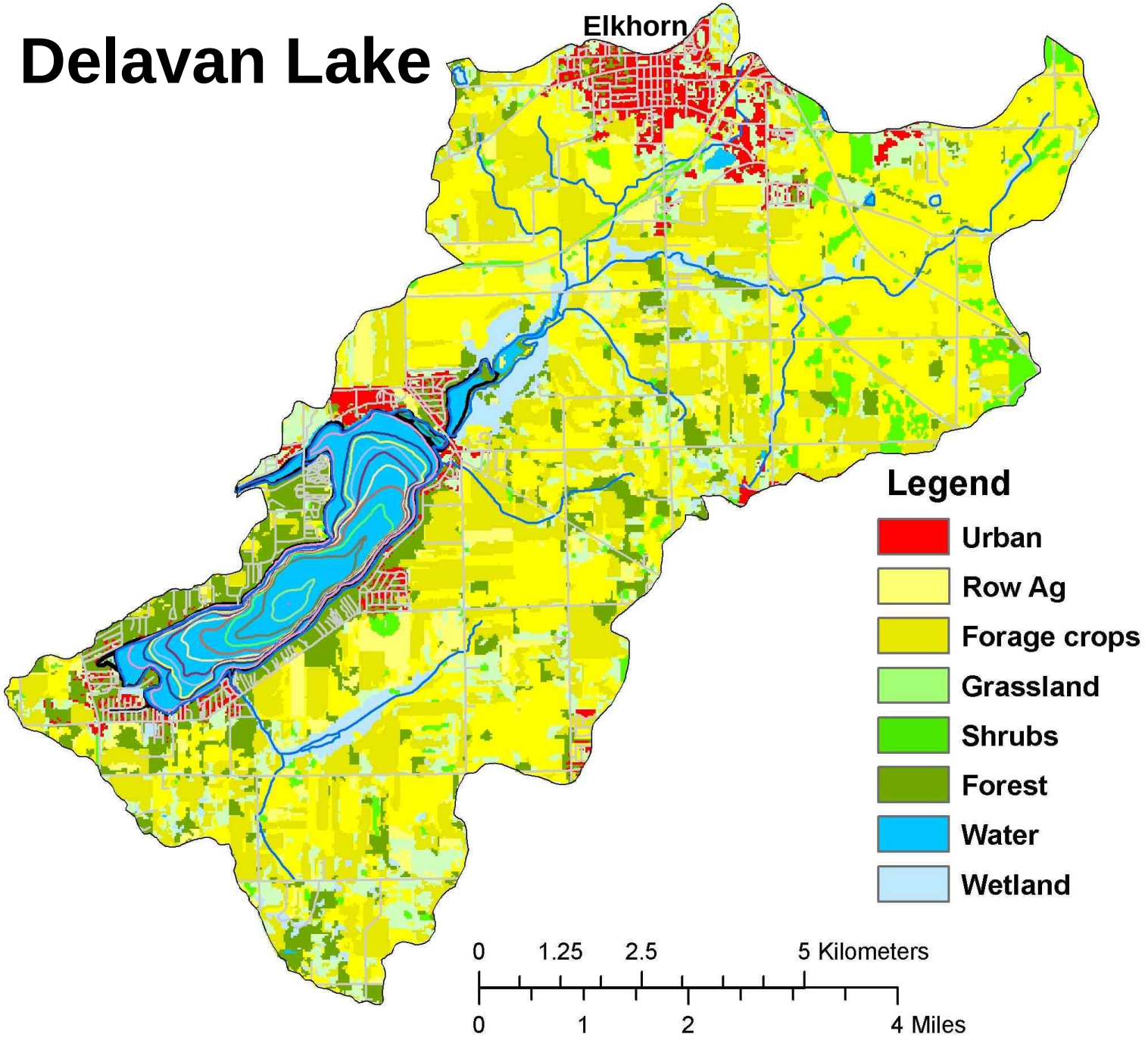
Eutrophic - *Old*

- High Nutrient Conc.
- Very Productive
- Frequent Algal Blooms
- Freq. Deep DO Depletion
- Rough Fish Common

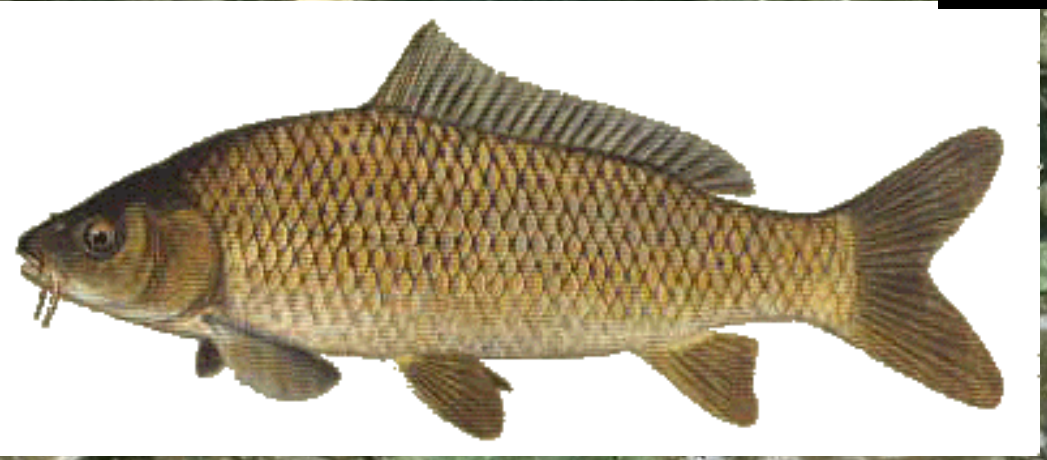
Delavan Lake

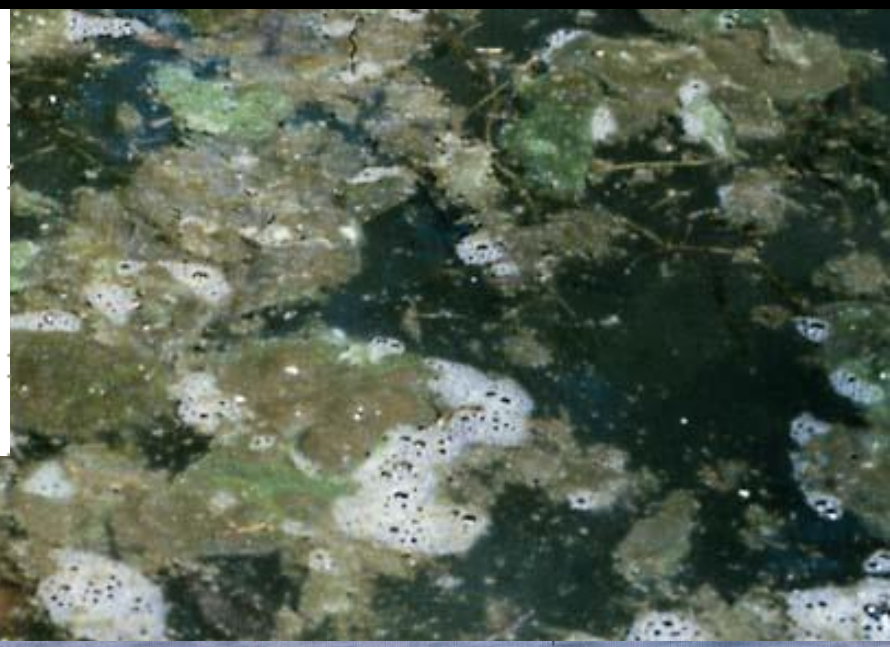
Morphometry
Area – 700 ha; 3.7 mi^2
Fetch – 6 km; 3.5 mi
Max Depth – 16.5 m; 54 ft

Delavan Lake



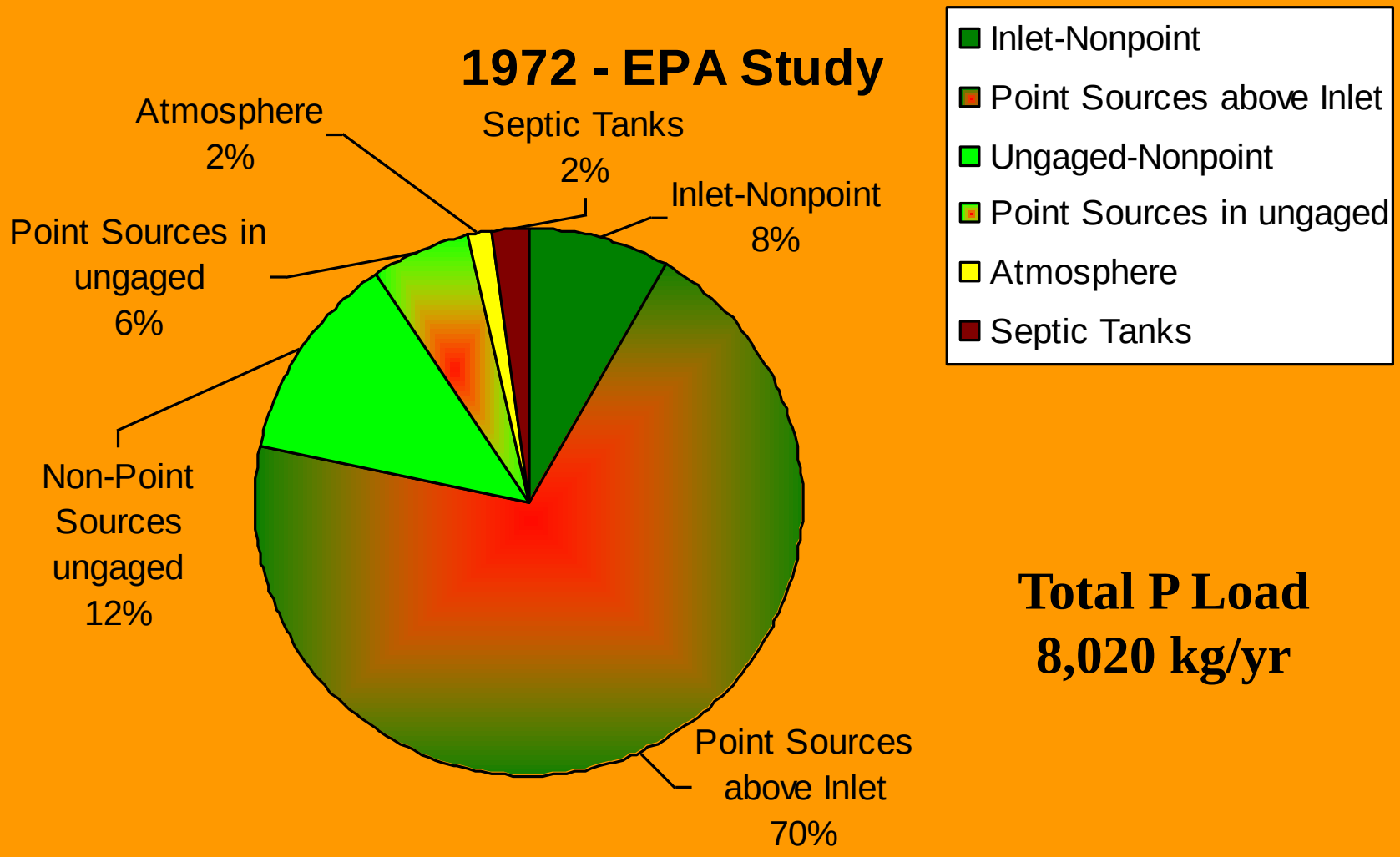
Delavan Lake – ~1970s





Delavan Lake - Goal

Sources of Phosphorus to Delavan Lake



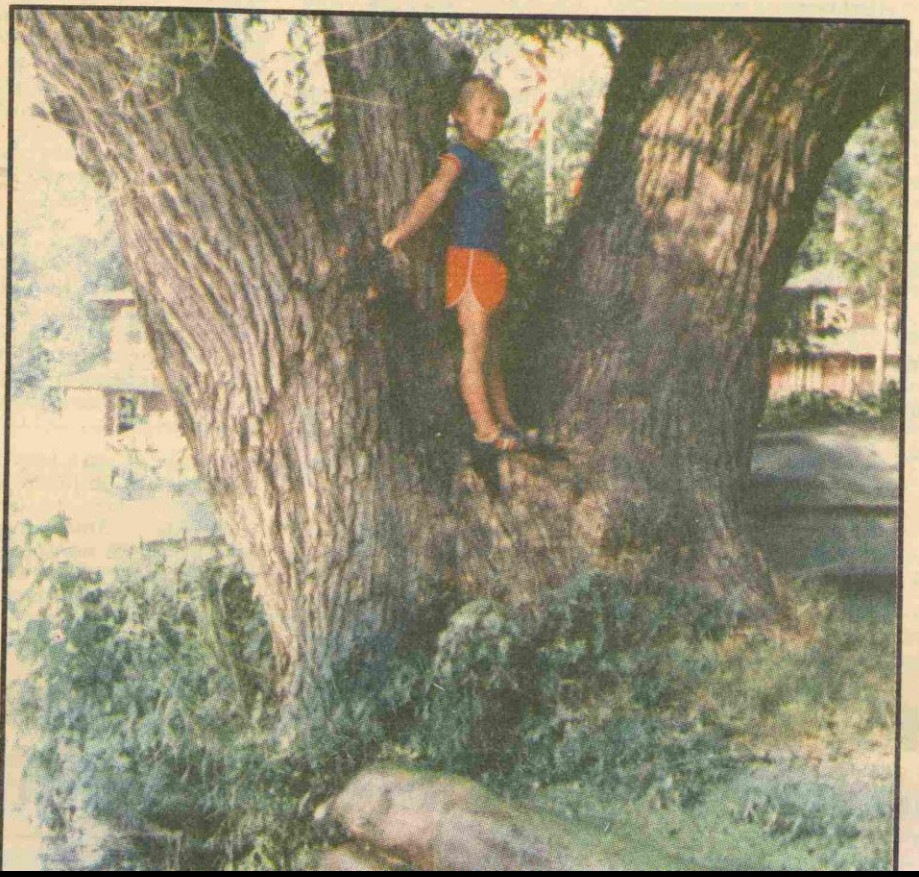
Total P Load
8,020 kg/yr

Point Sources Contribute ~76% of the Phosphorus Loading to the Lake

Sewerage Treatment Plant

WALWORTH COUNTY Week

Supplement to *The Janesville Gazette, published in Walworth County*—Tuesday, July 19, 1983



Algae in Delavan Lake triggers health worries, sends vacationers home

By Jon Henkes

DELAVAN LAKE—Year-round residents and vacationers at public and private beaches here have been warned that swimming in the lake may be hazardous to their health.

Concerned that decaying algae in the lake is emitting a toxic substance proven harmful to aquatic life, a state Department of Natural Resources official told lake residents last week to instruct their families and friends that swimming in Delavan Lake could produce gastrointestinal ailments such as nausea, vomiting and diarrhea.

That warning prompted the exodus of several vacationing families from the area, while prompting many others to drive to the city of Delavan's Mill Pond swimming area or to Geneva Lake to go swimming.

At the town of Delavan lakefront park, where major improvements have recently been made to attract summer vacationers, about 250 beachgoers drove away in disgust on the weekend of July 9-10.

That disaster occurred, however, three days before the DNR announcement about potential health problems.

On July 9 and 10, a thick coating of dead algae permeated nearly the entire lake, the end result of the spraying of a chemical algaecide into the lake on June 30 and July 7.

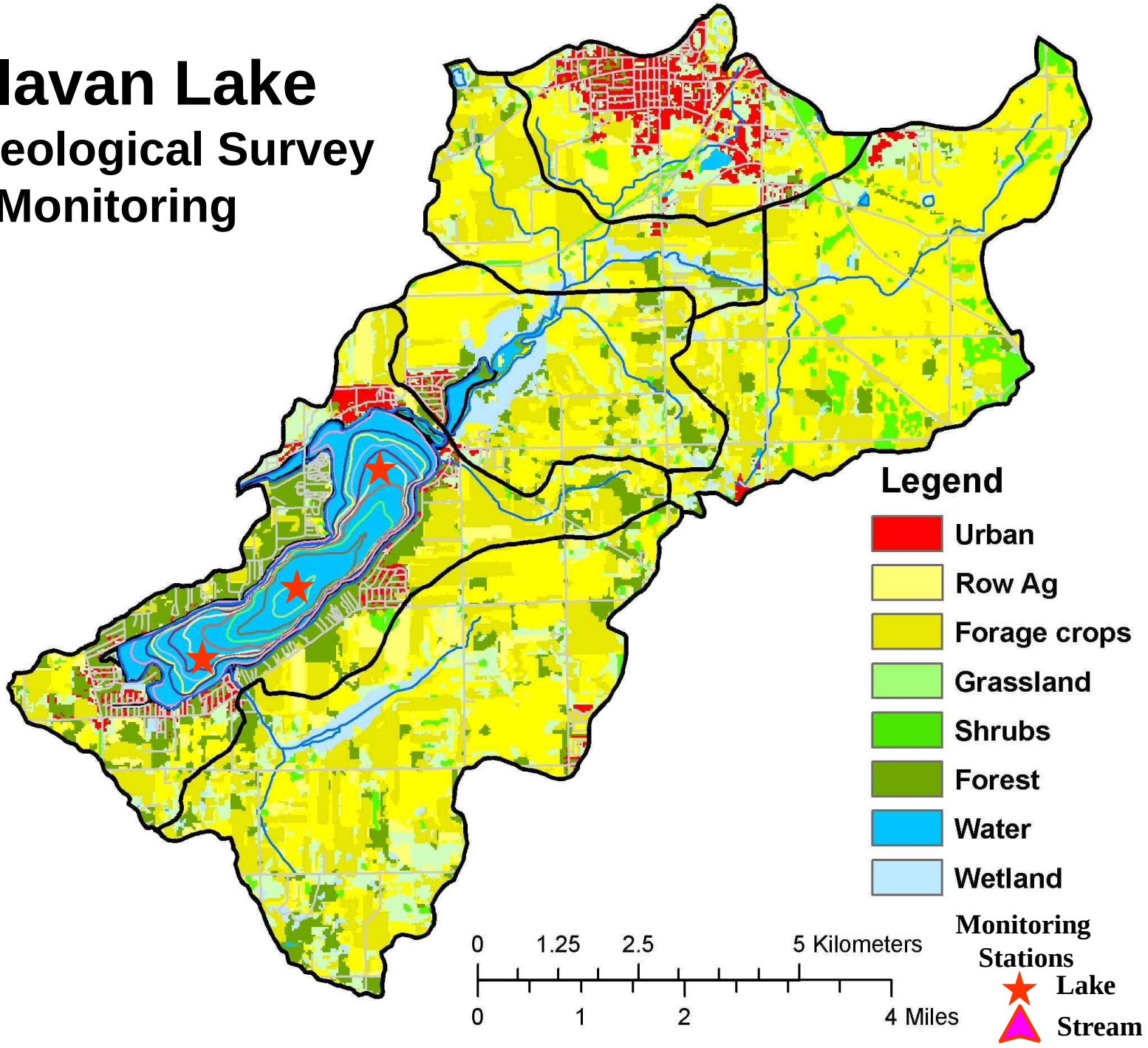
> *"Several families have requested refunds for their cottages and have packed their bags and left because of the algae. There were some children who became sick after swimming. The beach has been very quiet all week."*

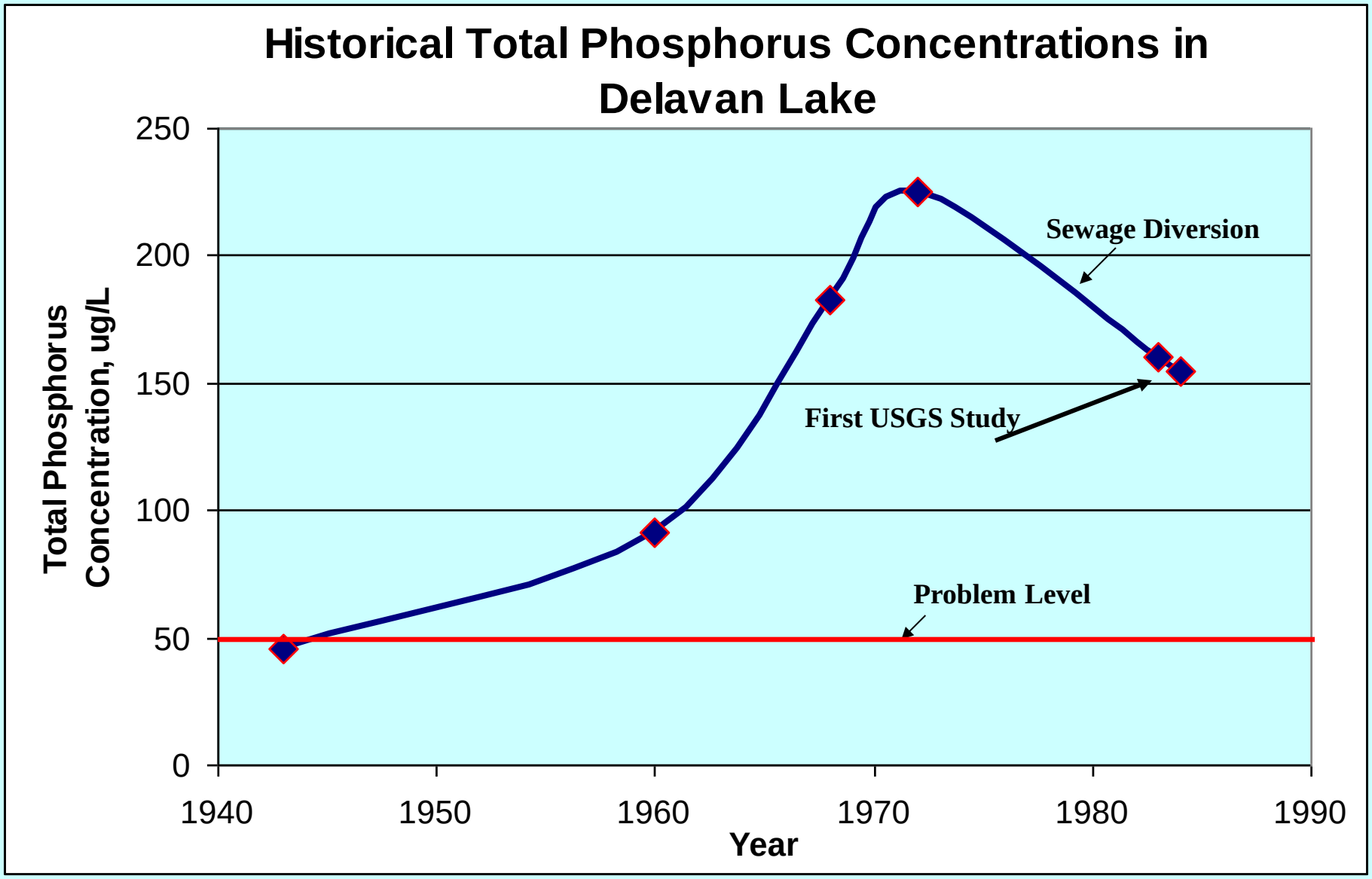
Visually uninviting the lake was not known then to contain toxic dead algae. Year-round lake resident Bill Morelli said

Turn to page 10

Delavan Lake

U.S. Geological Survey Monitoring

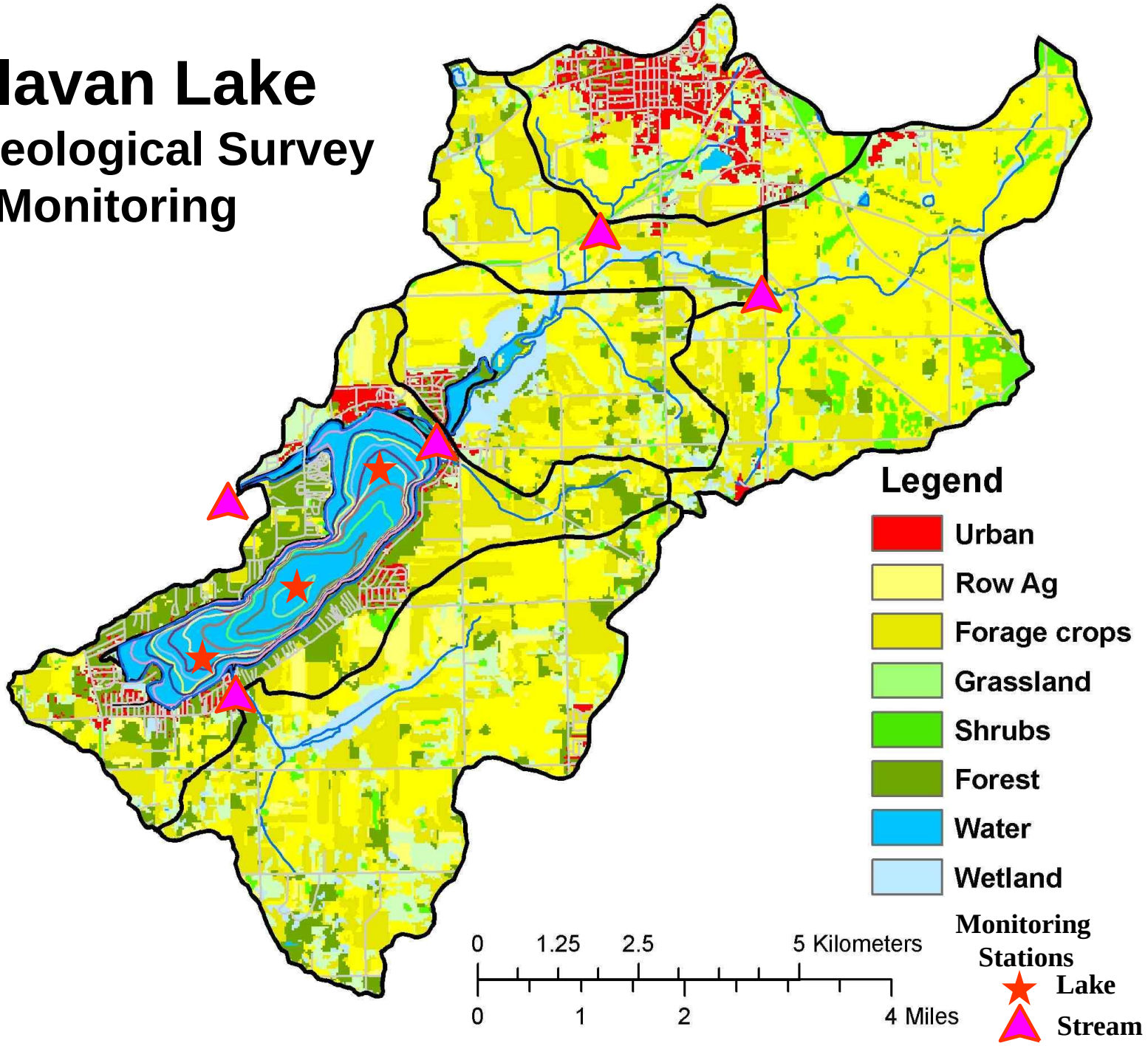




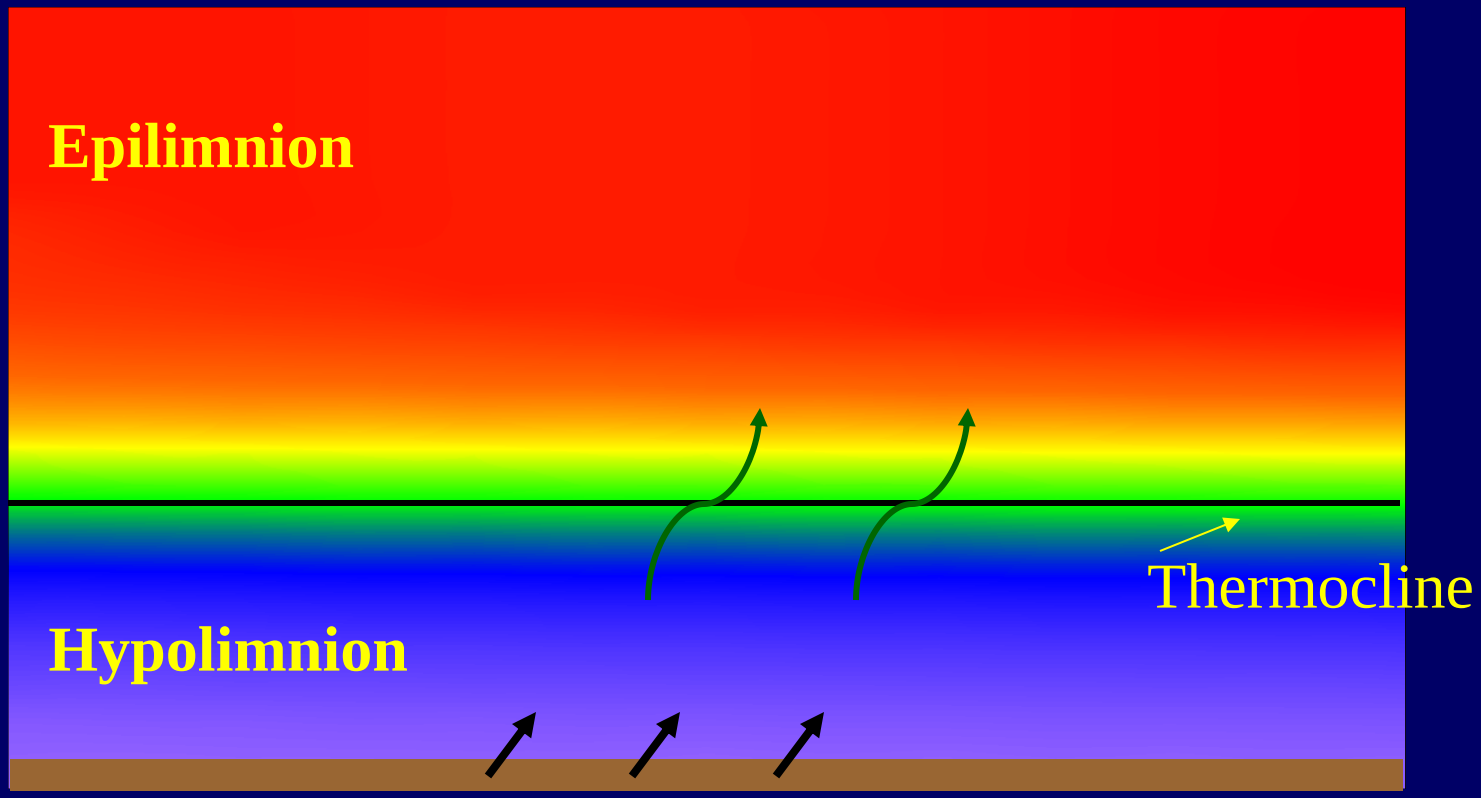
** Average Annual Concentrations

Delavan Lake

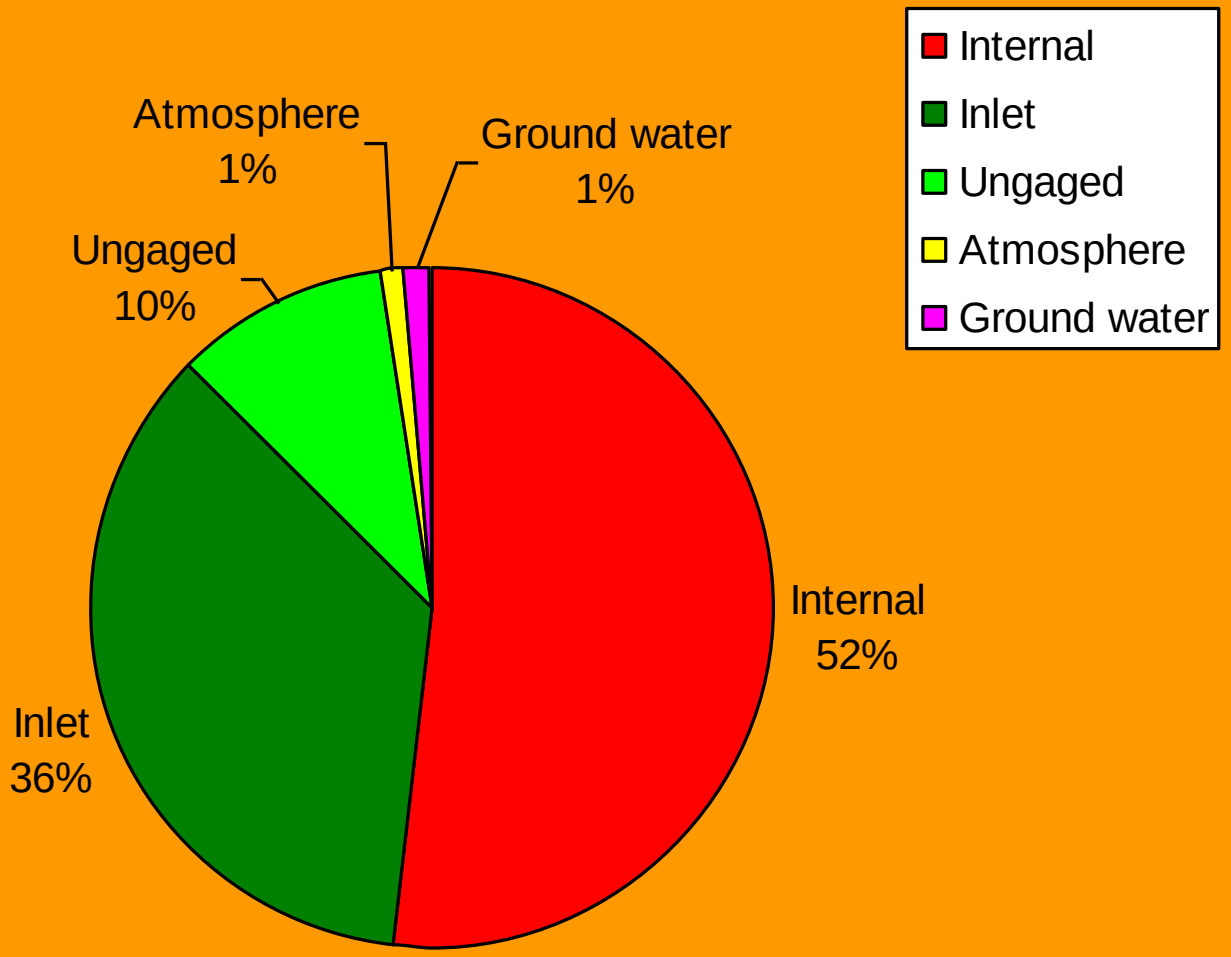
U.S. Geological Survey Monitoring



Internal Release of Phosphorus from Deep Sediment
"Internal Loading"



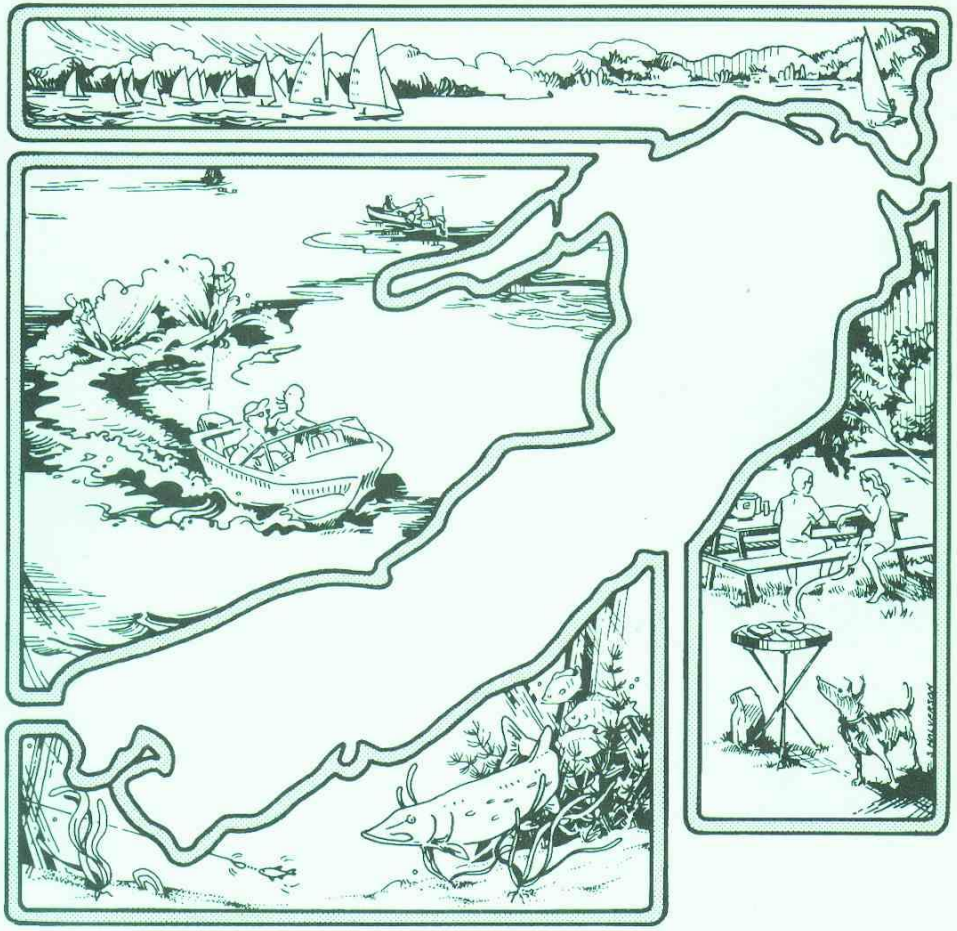
Phosphorus Budget For Delavan Lake – 1984-85



Total P Loading – 8,700 kg/yr

Delavan Lake: A Recovery and Management Study

Water Resources Management Workshop



Institute for Environmental Studies, University of Wisconsin—Madison
in cooperation with
Wisconsin Department of Natural Resources

September 1986

Goals for Delavan Lake Rehabilitation

Increase Water Clarity – Increase Average Summer Secchi Depth from ~1.0 m to at least 1.5 m

Water Quality Model

Decrease Average Summer Chlorophyll a concentration from ~30 – 50 ug/L to 14 ug/L

Water Quality Model

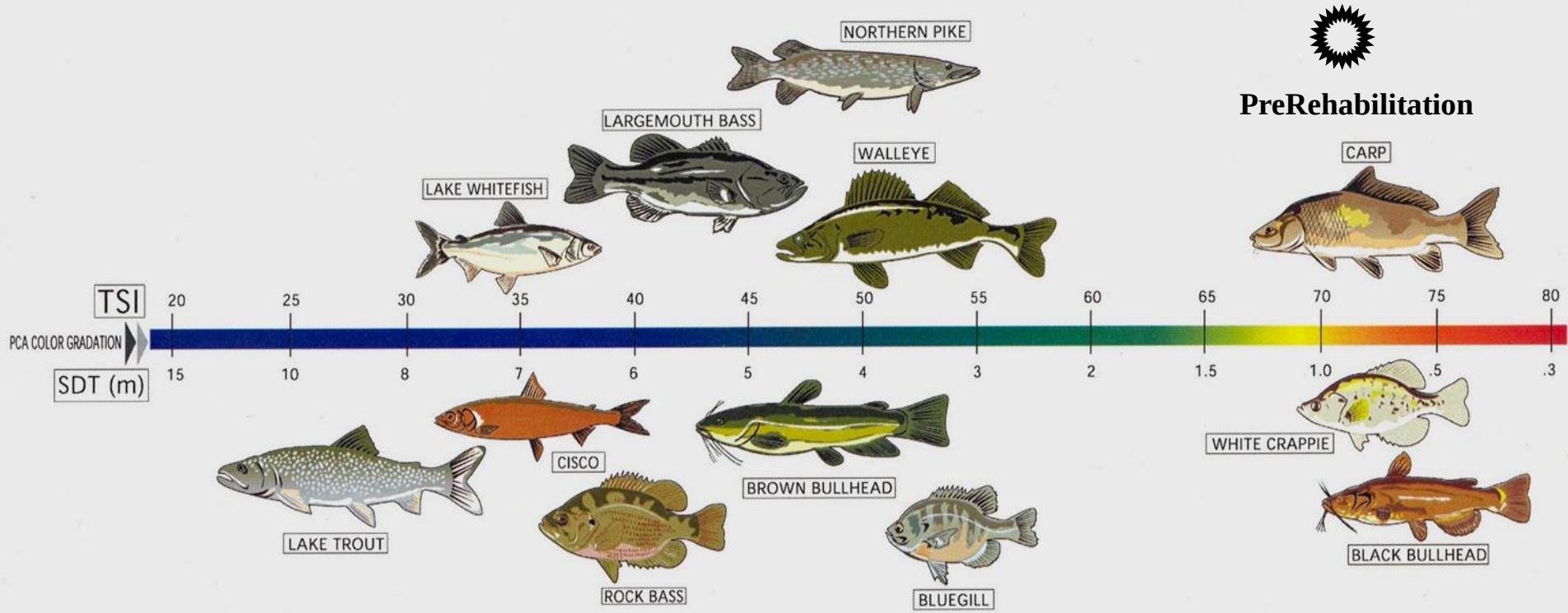
Decrease in lake spring P concentration from ~100 – 120 ug/L to about 34 ug/L

Lake Loading Model

Decrease P Loading to the lake from about 8,700 kg/yr to about 1,900 kg/yr

Typical conditions associated with trophic status

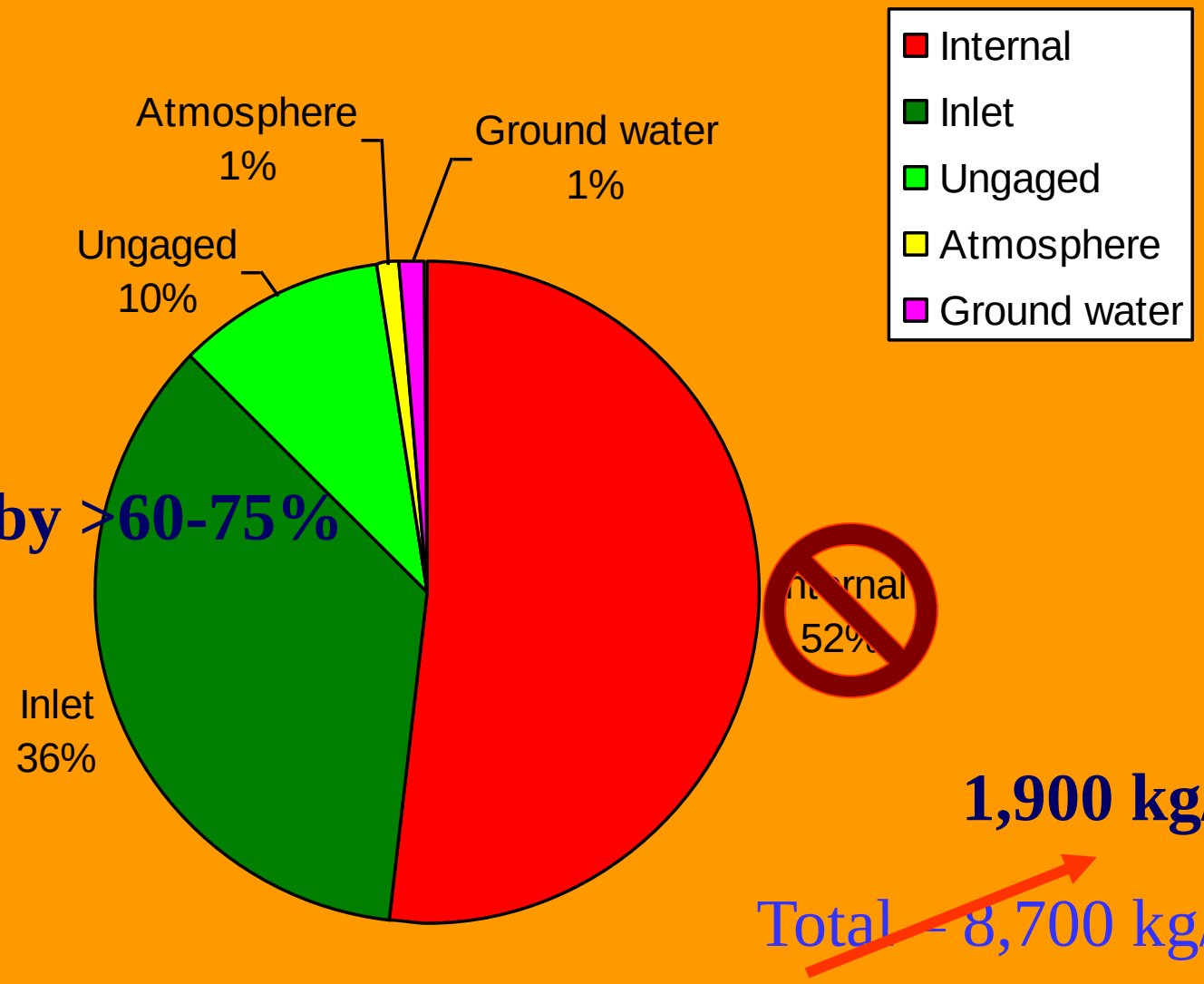
Oligotrophic **Mesotrophic** **Eutrophic** **Hypereutrophic**



Every change of 10 in the TSI corresponds to a doubling of a lake's algae biomass and a halving of water clarity.

Based on work of Dennis Schupp MDNR Fisheries

Phosphorus Budget For Delavan Lake – 1984-85



Reduce by >60-75%

1,900 kg/yr

Total – 8,700 kg/yr

WDNR > Dingle Johnson Funds

Local Support > Cash and In-kind

State Government

Dept. Ag. > Nonpoint Funds

USGS > Cooperative Funds

USEPA > Clean Lake Funding

> <u>Water Pollution Control Project</u> House Public Works Committee

> <u>Natural Prototype Project</u> for Rehabilitating Lakes

>> ~$ 7 Million

Project Kickoff Celebration

External Sources

Watershed Management - BMP’s

The county has ordered removal of drainage tile on the land off Mound road.

Farmer Told Remove Tiles, Pumps

Investigation of a farmland drainage system by county and state officials has resulted in an order to remove pumping stations and drain tiles from almost six acres of property near Delavan Lake.

In a letter released last week, Frank Dobbs stated that construction of the

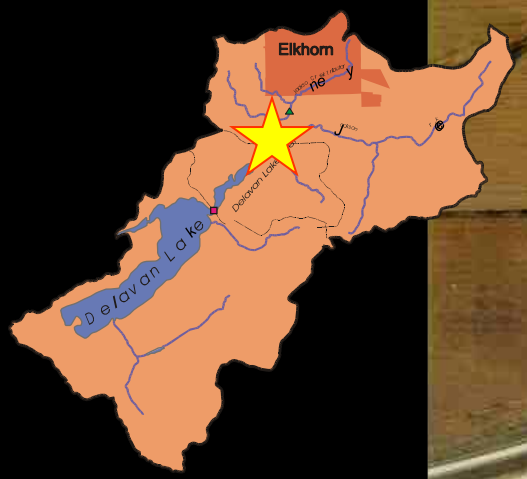
(DNR) traveled to the property Sept. 20. Based on an inspection of the construction site, Dobbs said he was able to determine that parts of the drainage system violate the county's zoning ordinance.

Town Of Delavan officials were the first to notify county authorities of the

diameter plastic pipe in the ground. Those pipes are then connected to an excavated pit which contains a pump. The pump transports water drained from the pipes into the pit into Jackson Creek.

When completed, the system will allow the property to be used as tillable farmland.

External Sources – Wetland Construction



SEDGE MEADOW

USGS STATION

North Pond

WET PRAIRIE

West Pond

WET PRAIRIE

East Pond

SEDGE MEADOW

WEIR

SHALLOW WATER MARSH

USGS STATION

Delavan Lake Inlet

Jackson Creek Wetland

Jackson Creek Short-Circuiting

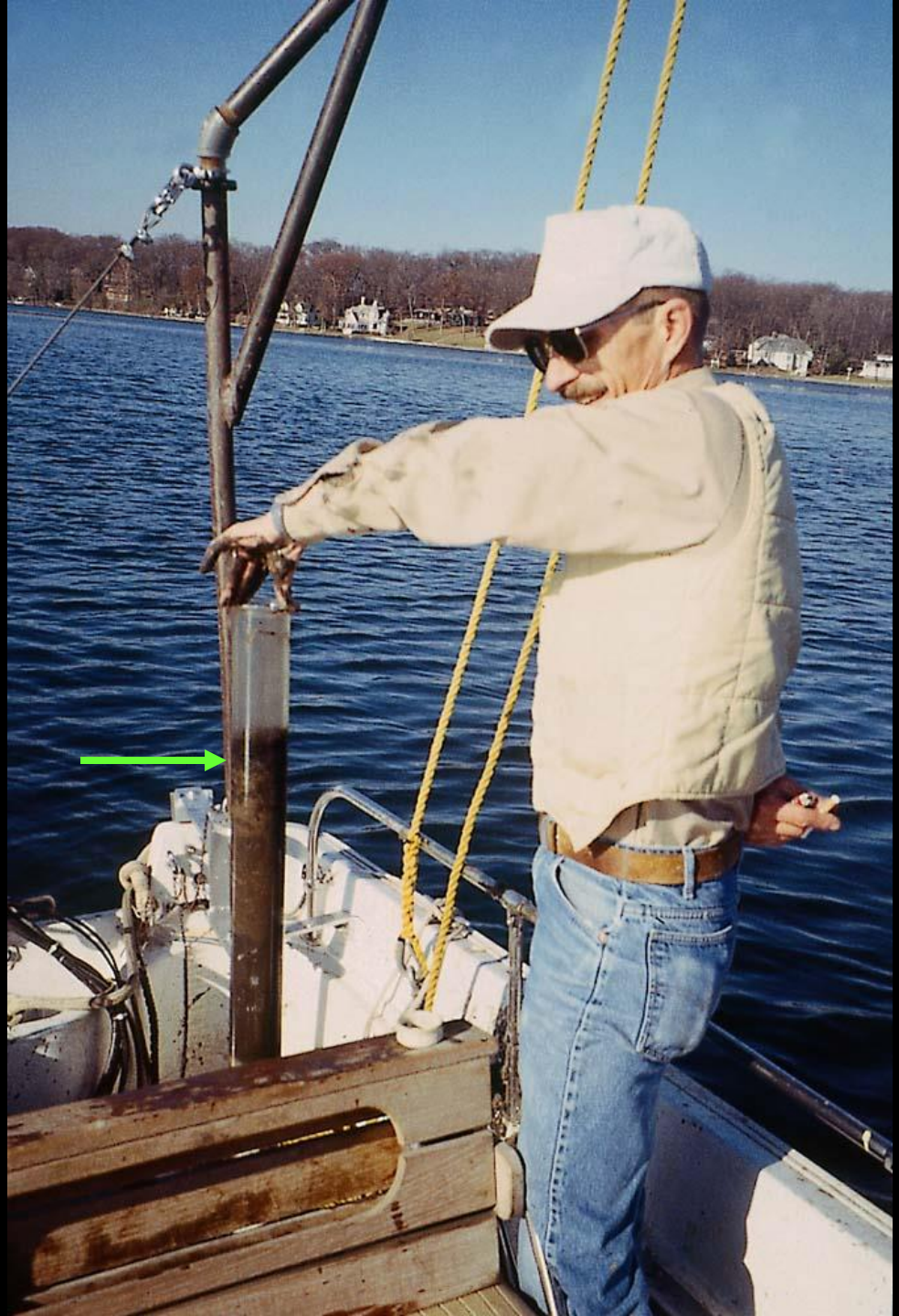

CATERPILLAR


DAM

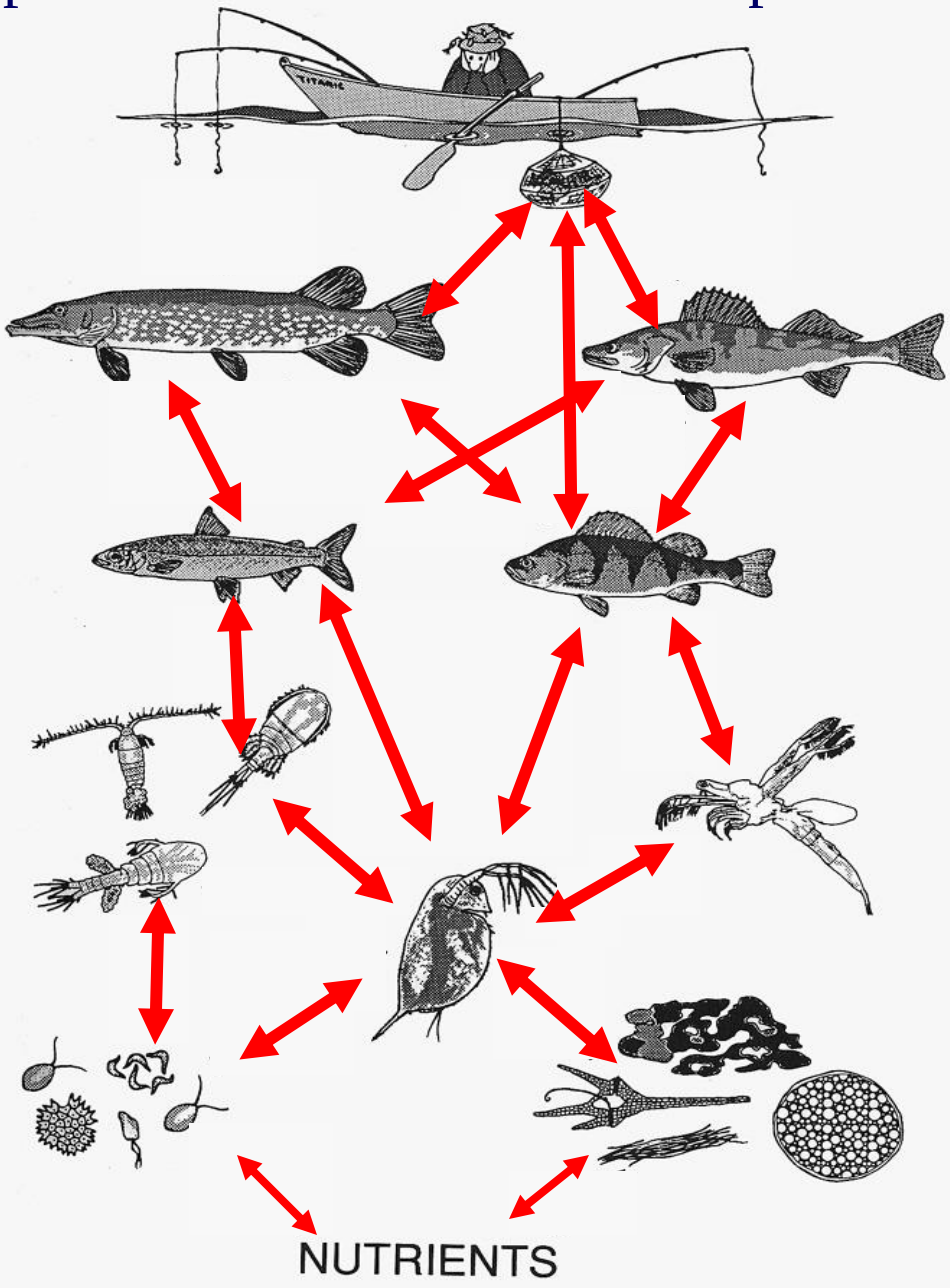
Removal of Internal P Sources

Chemical Application of Alum (aluminum sulfate)

$$Al^{+3}_{2}(SO_4^{-2})_3 + PO_4^{-3} \longrightarrow Al\,PO_4\ (Solid) + SO_4^{-2}$$

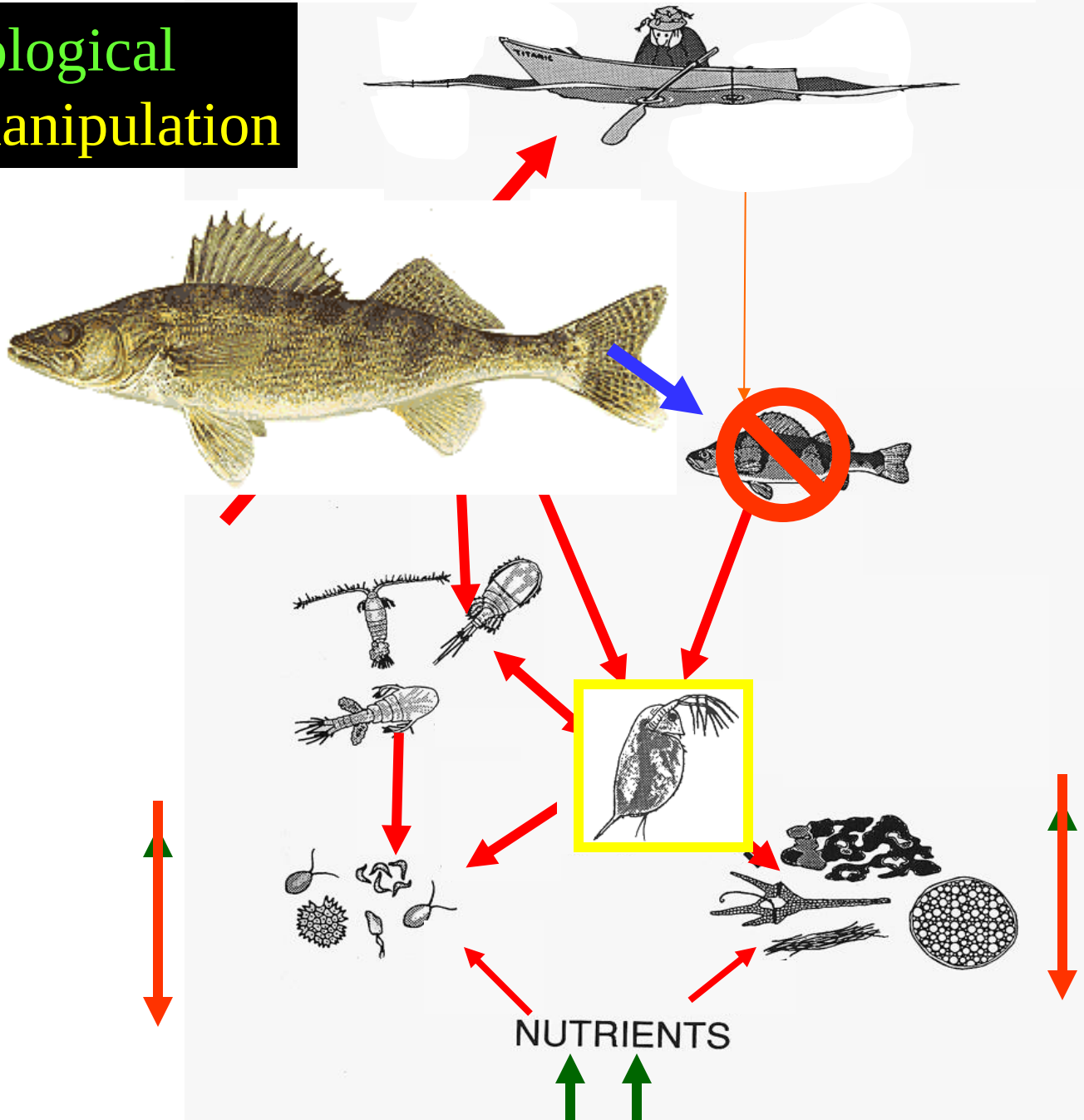


Typical Food Web of a Mesotrophic Lake

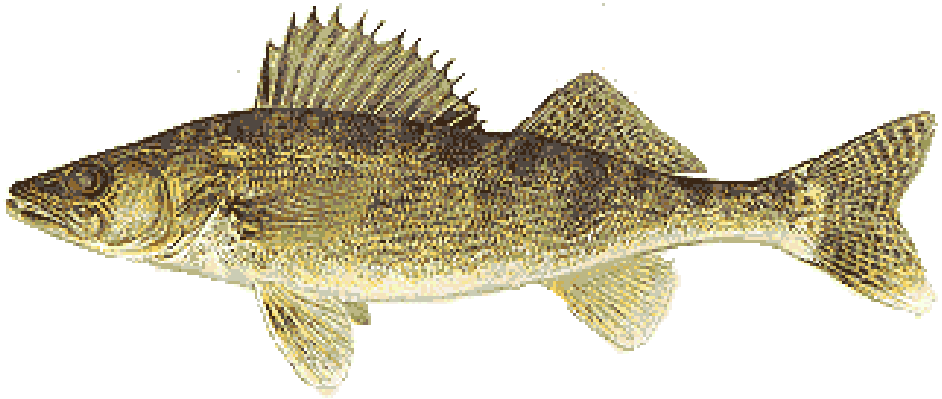


Delavan Lake - Postmanipulation

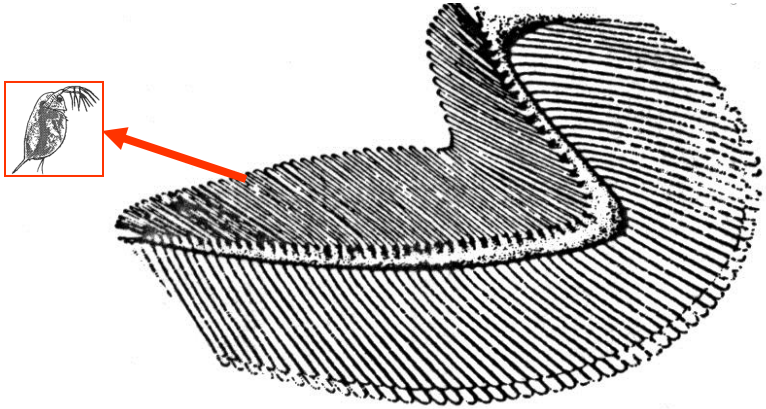
Biological - Biomanipulation



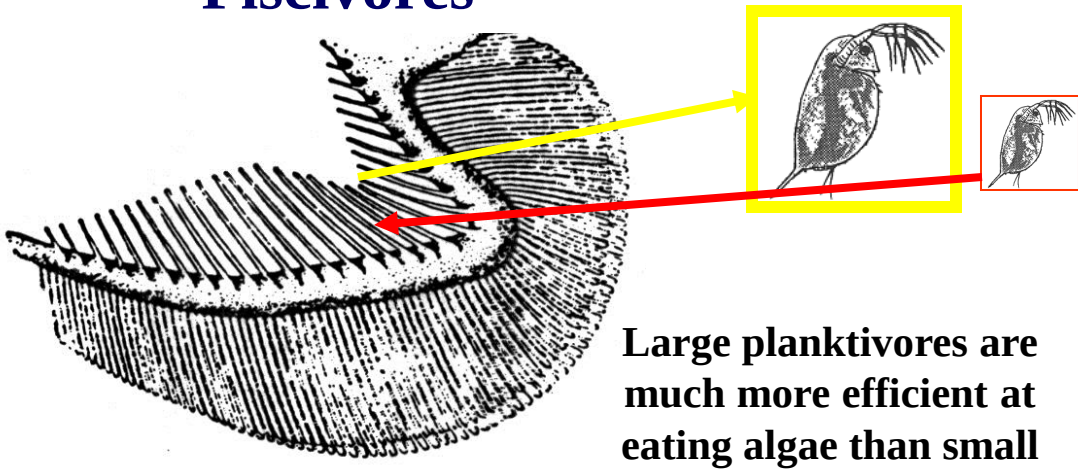
Planktivores



Piscivores

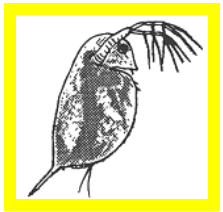


PREmanipulation



POSTmanipulation

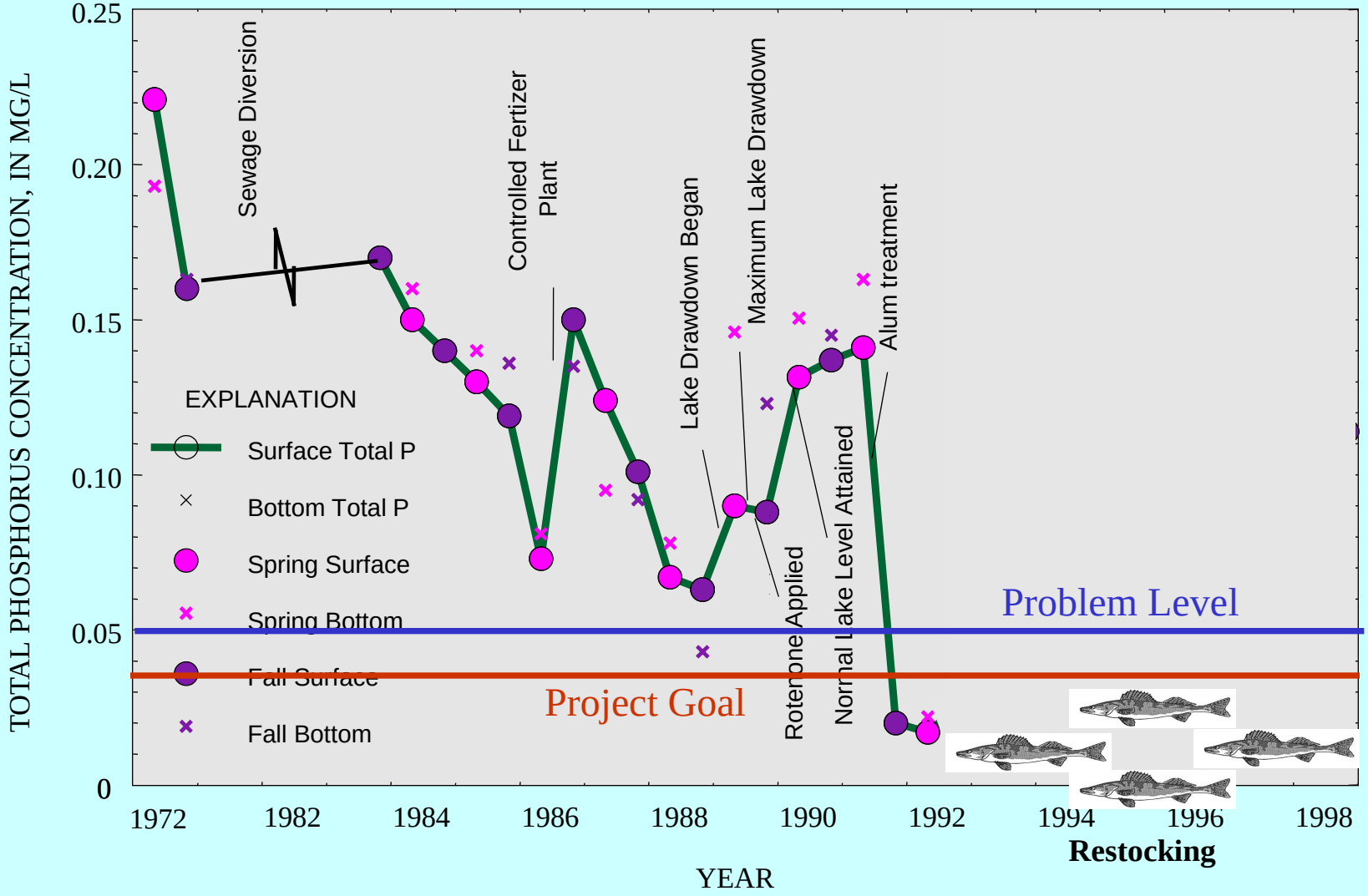
Large planktivores are much more efficient at eating algae than small planktivores



Restructing of the Fish Community

Trucking in Rotenone

DELAVAN LAKE TOTAL PHOSPHORUS CONCENTRATIONS, 1972-1992



TECHNICAL EXCELLENCE AWARD

Honoring The

DELAVAN LAKE PROJECT

- 1991 -

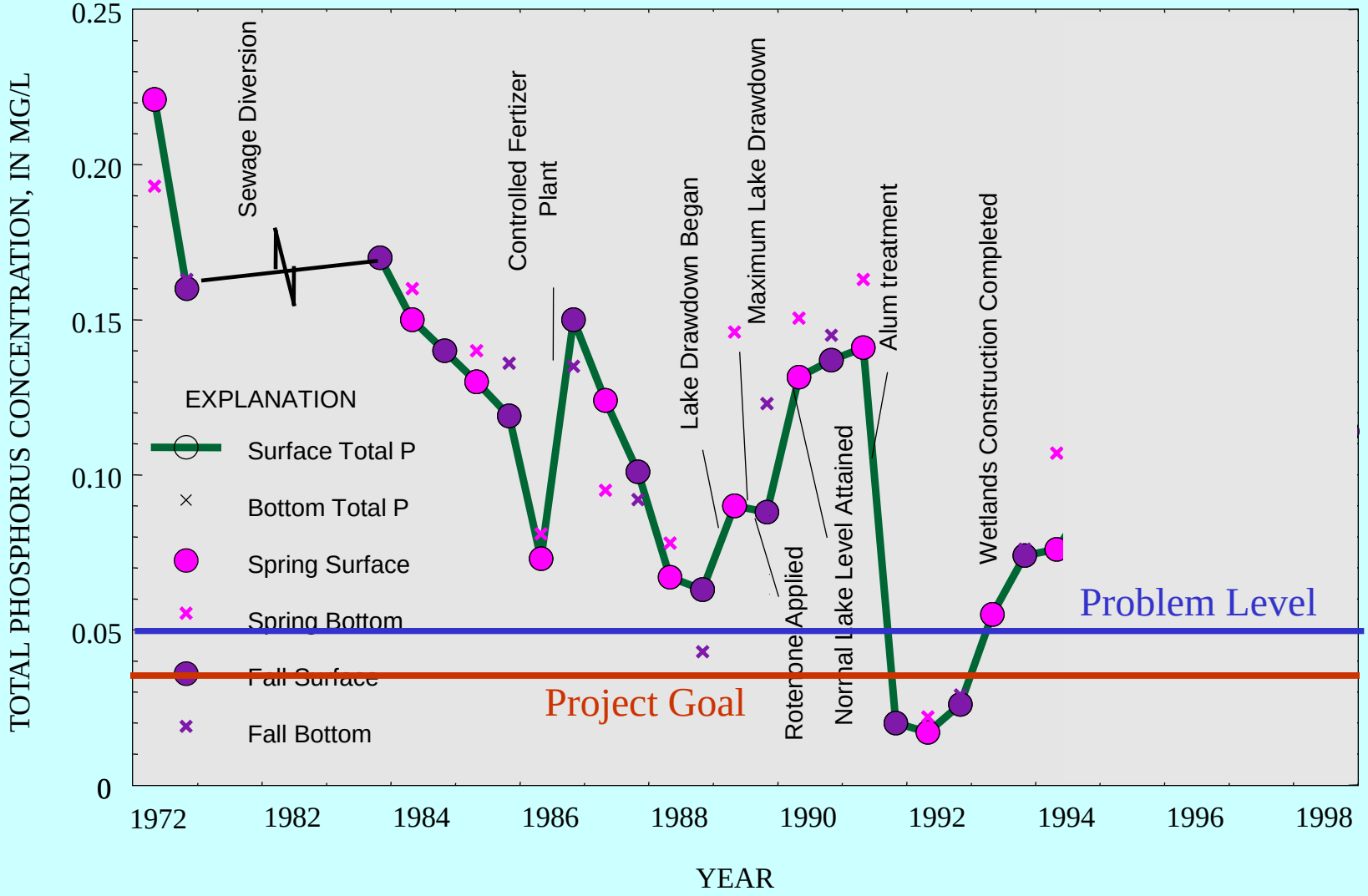
In Recognition Of
Outstanding Achievement In Lake
Restoration, Protection and Management

North American Lake Management Society

****

Midwest Floods of 1993

DELAVAN LAKE TOTAL PHOSPHORUS CONCENTRATIONS, 1972-1994



/dale/projects/delavan/lakesum/laketp.g2
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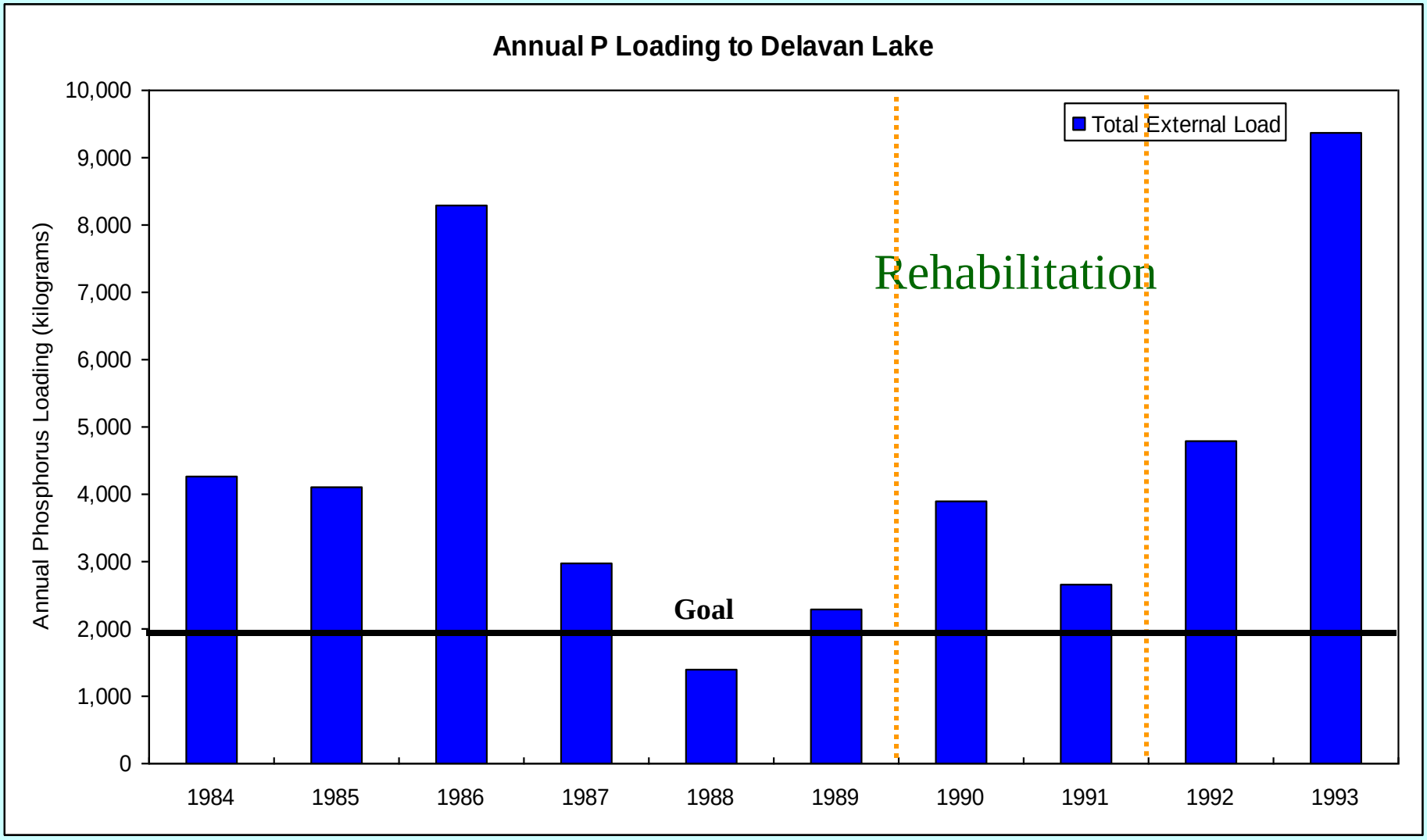
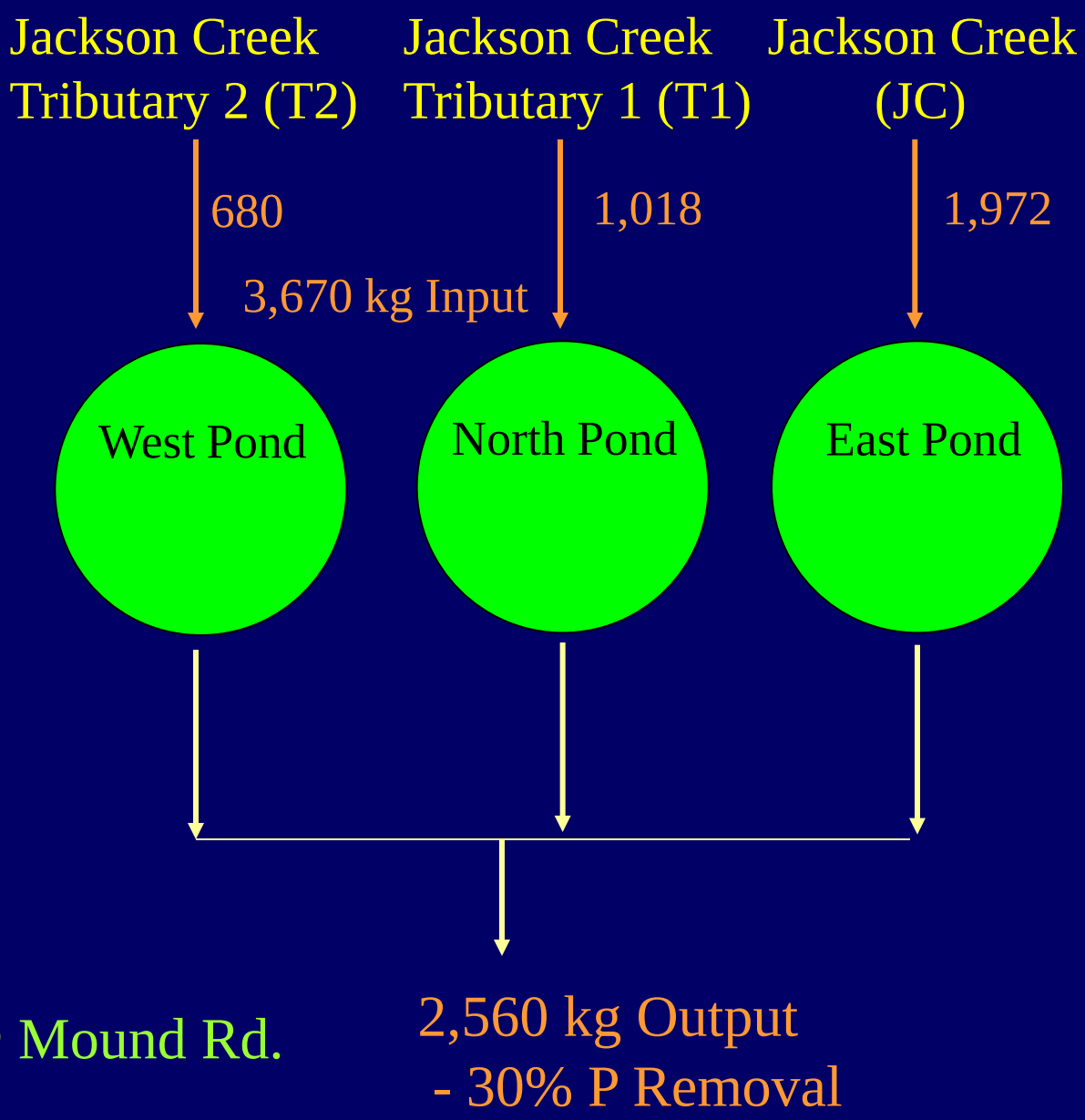
Long-term monitoring of phosphorus loading

Phosphorus Loading to Delavan Lake




SEDGE MEADOW
USGS STATION
North Pond
WET PRAIRIE
West Pond
WET PRAIRIE
East Pond
SEDGE MEADOW
WEIR
SHALLOW WATER MARSH
USGS STATION
Delavan Lake Inlet
Jackson Creek Wetland

Phosphorus Budget - kg's



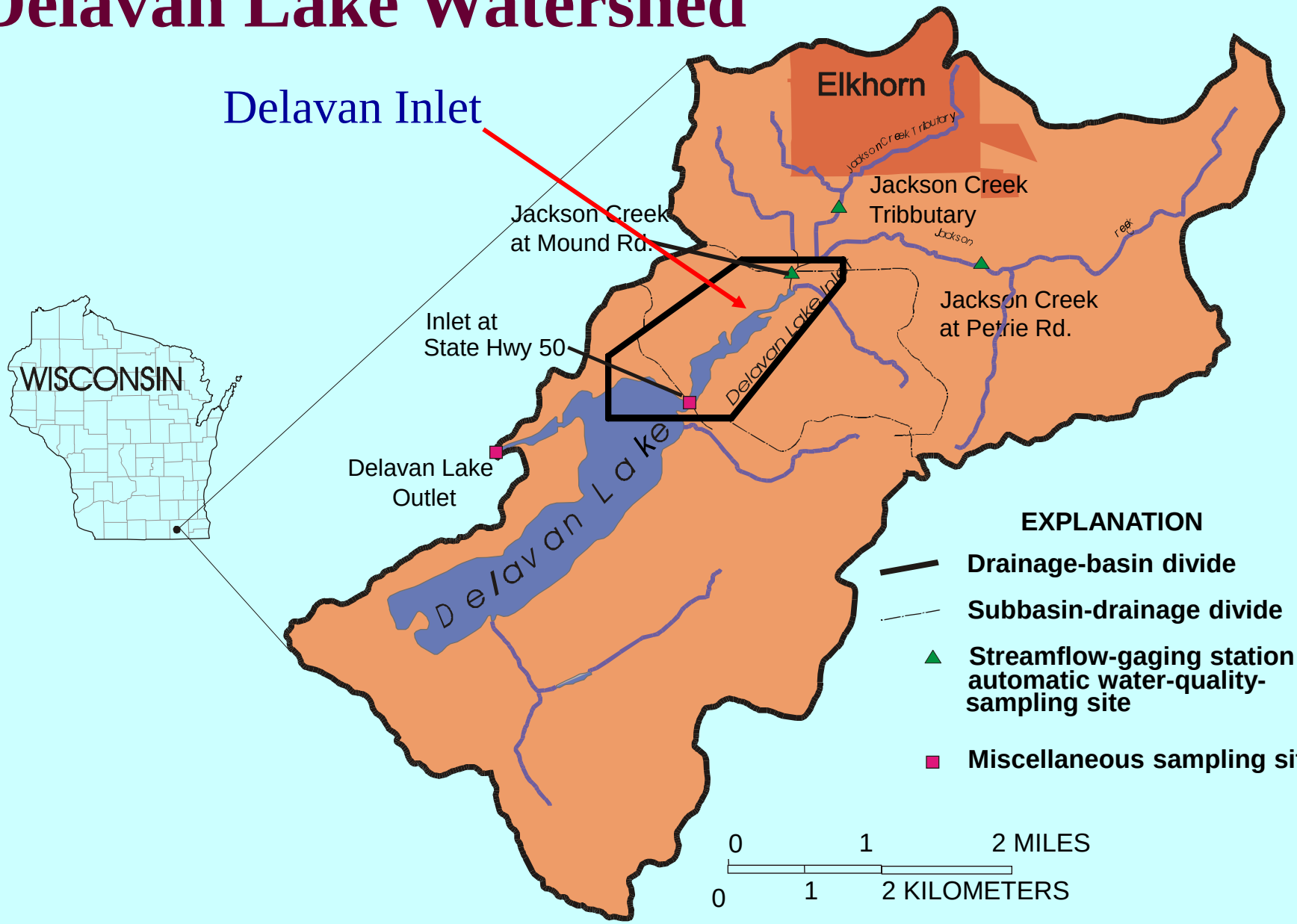
Tributary inflow

Pond Accumulation

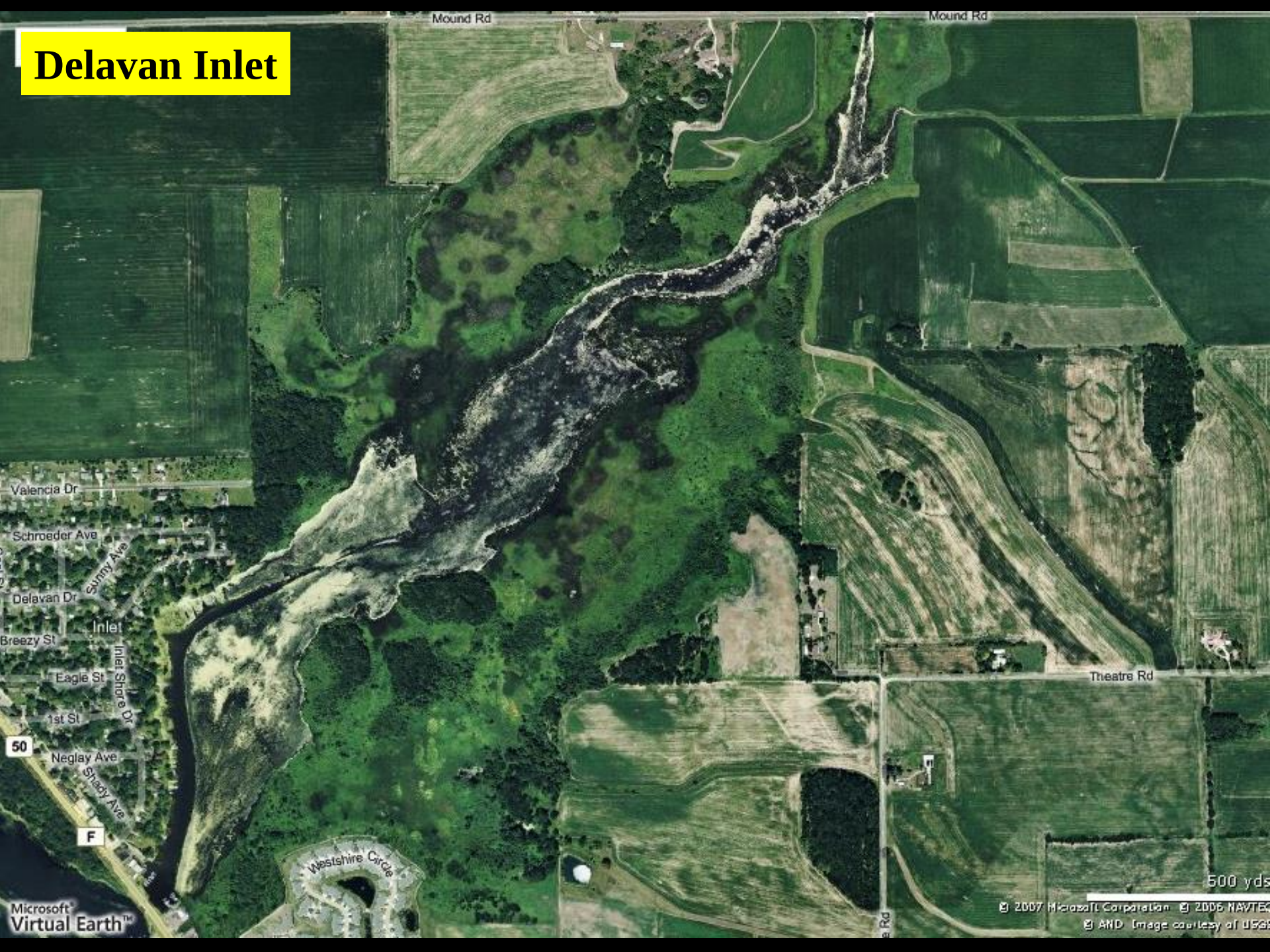
Estimated Pond Loss

Phosphorus outflow @ Mound Rd.

Delavan Lake Watershed



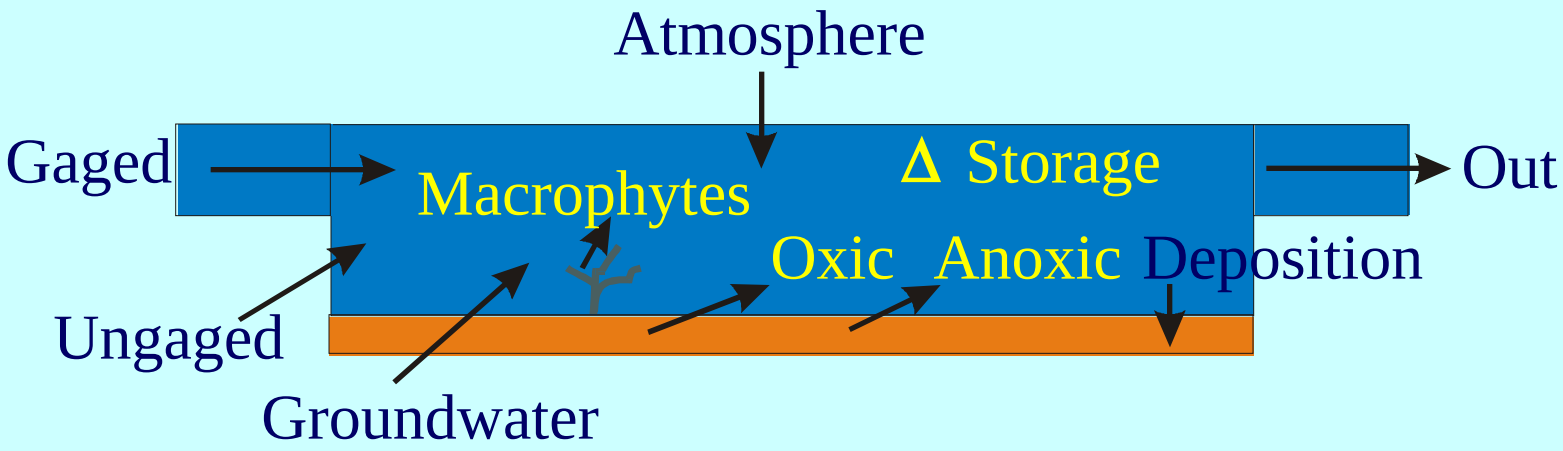
Delavan Inlet


Delavan Inlet
Mound Rd
Mound Rd
Valencia Dr
Schroeder Ave
Sunny Ave
Delavan Dr
Inlet
Breezy St
Inlet Shore Dr
Eagle St
1st St
50
Neglay Ave
Shady Ave
F
Westshire Circle
Theatre Rd
500 yds
Microsoft Virtual Earth™

Phosphorus Budget for Delavan Lake Inlet (where is the phosphorus coming from?)

External Sources Internal Sources

$$P_G + P_{UG} + P_{ATM} + P_{GW} + \{(P_{SO} + P_{SA} + P_{MAC}) + \Delta S - P_{DEP}\} = P_{OUT}$$

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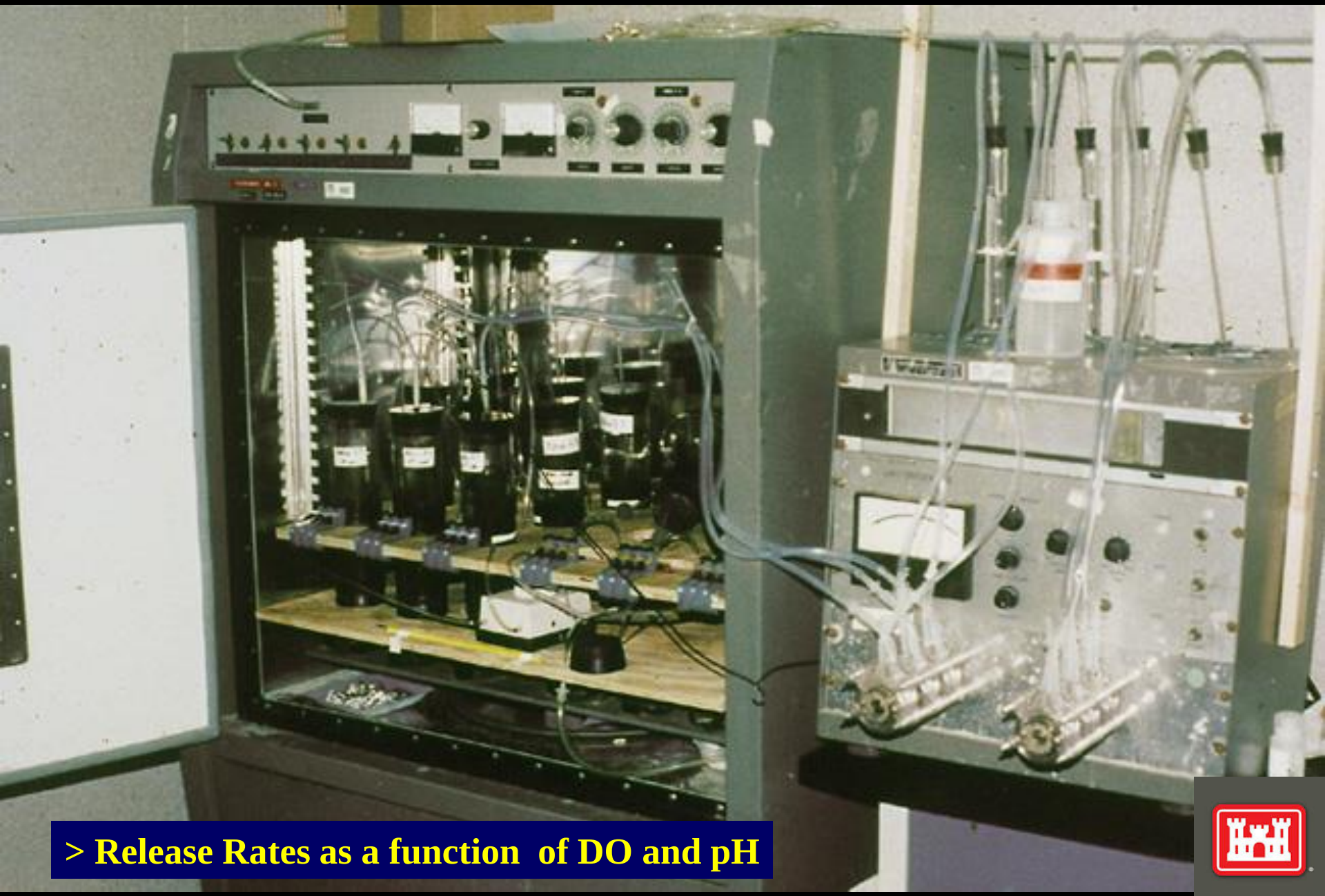
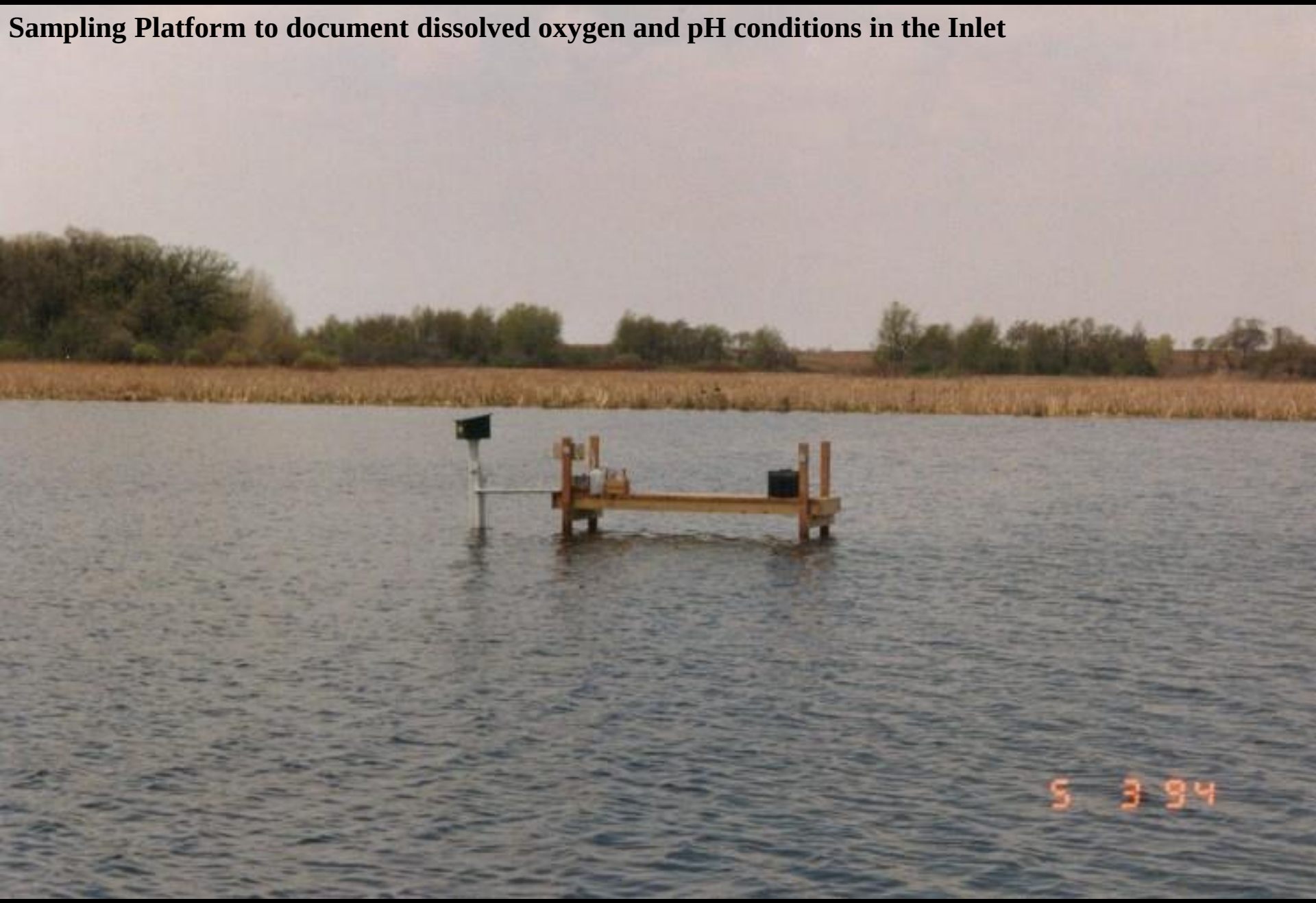


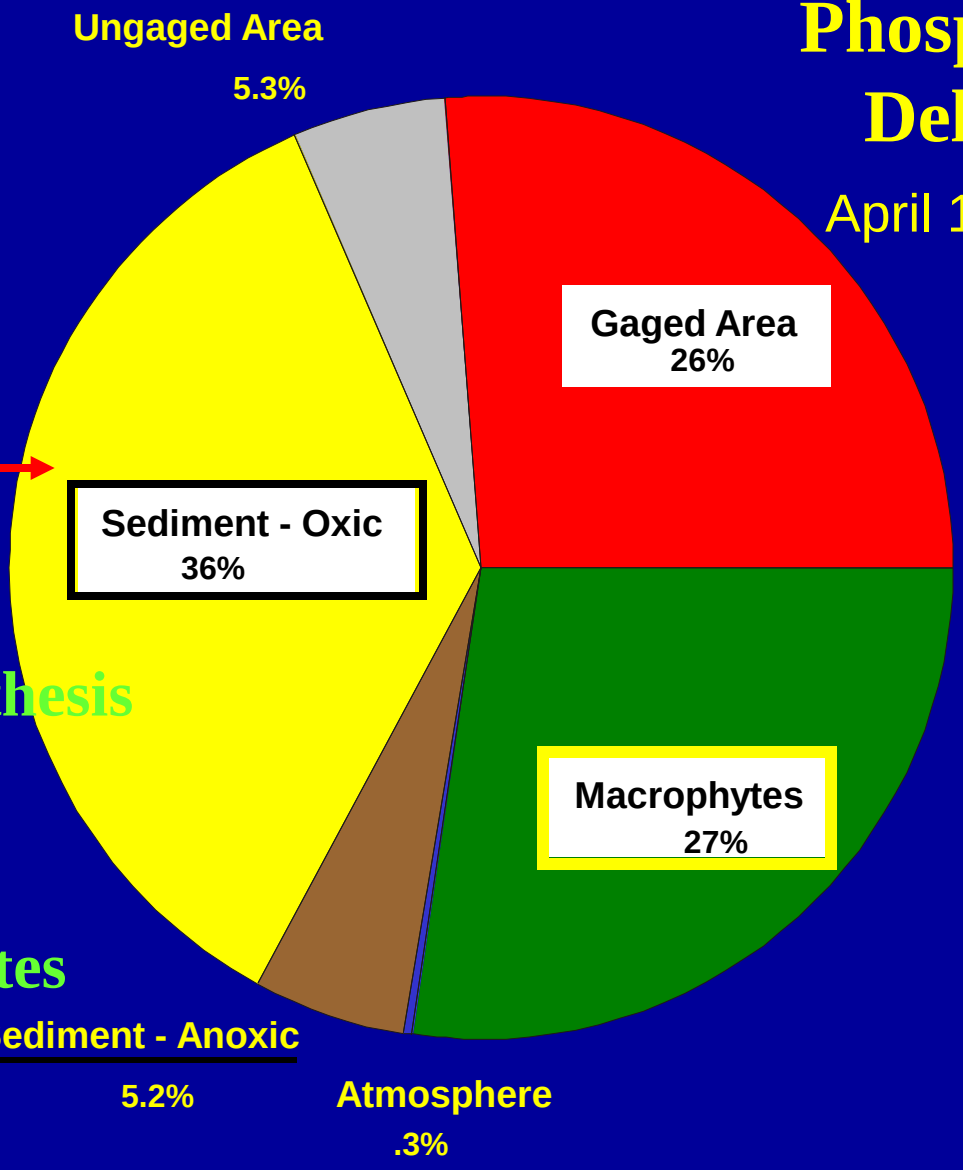
> Release Rates as a function of DO and pH

Sampling Platform to document dissolved oxygen and pH conditions in the Inlet



Phosphorus Budget for Delavan Lake Inlet

April 14 - September 30, 1994



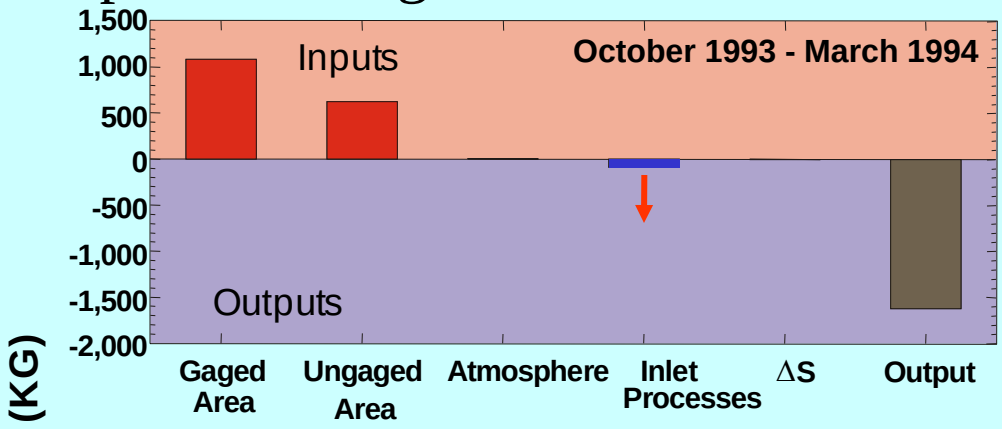
pH ^^

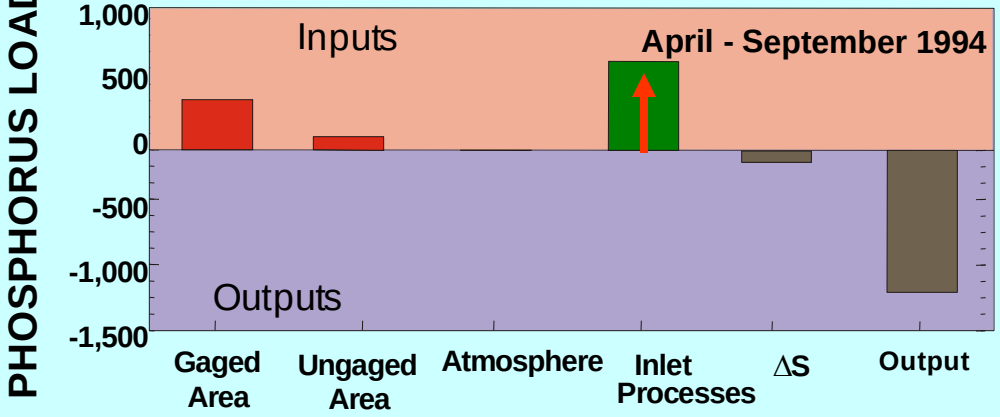
photosynthesis

macrophytes

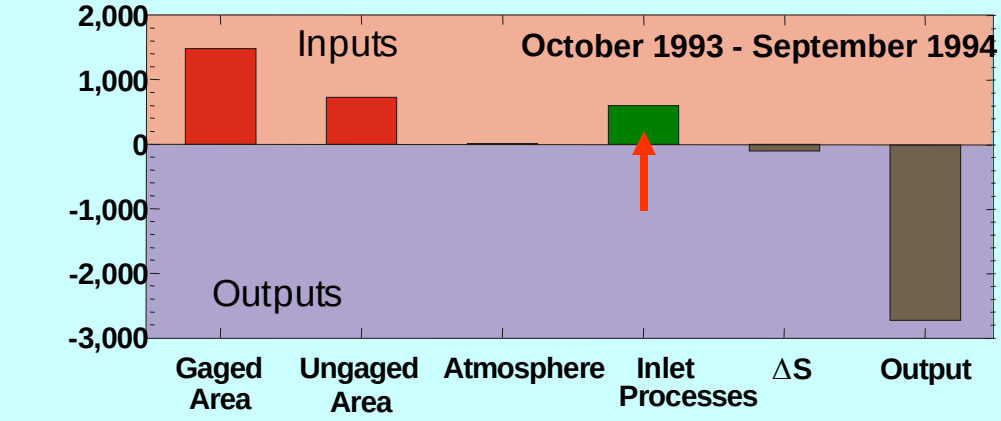
clarity

Phosphorus Budget for Delavan Lake Inlet





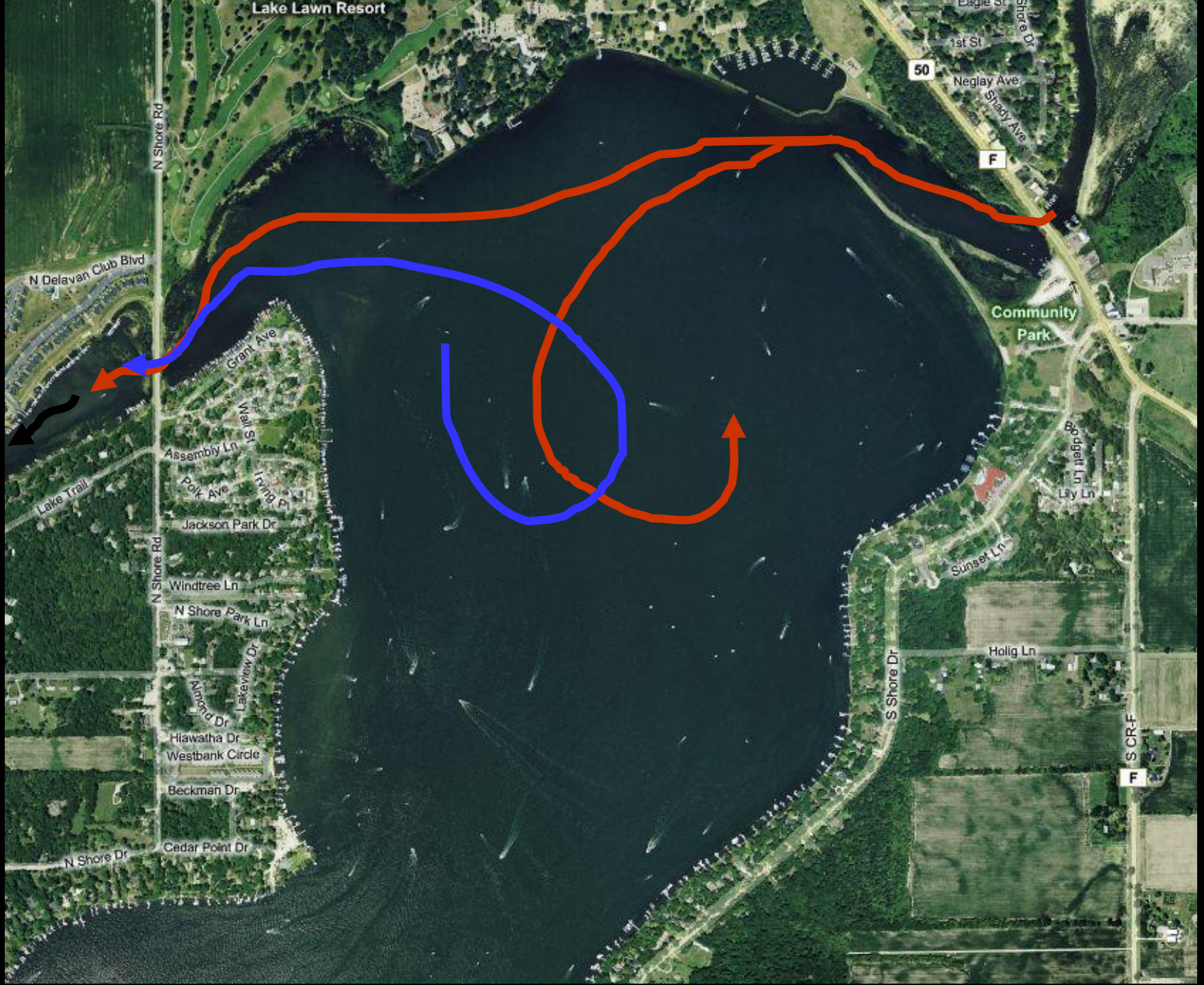
Detailed Study

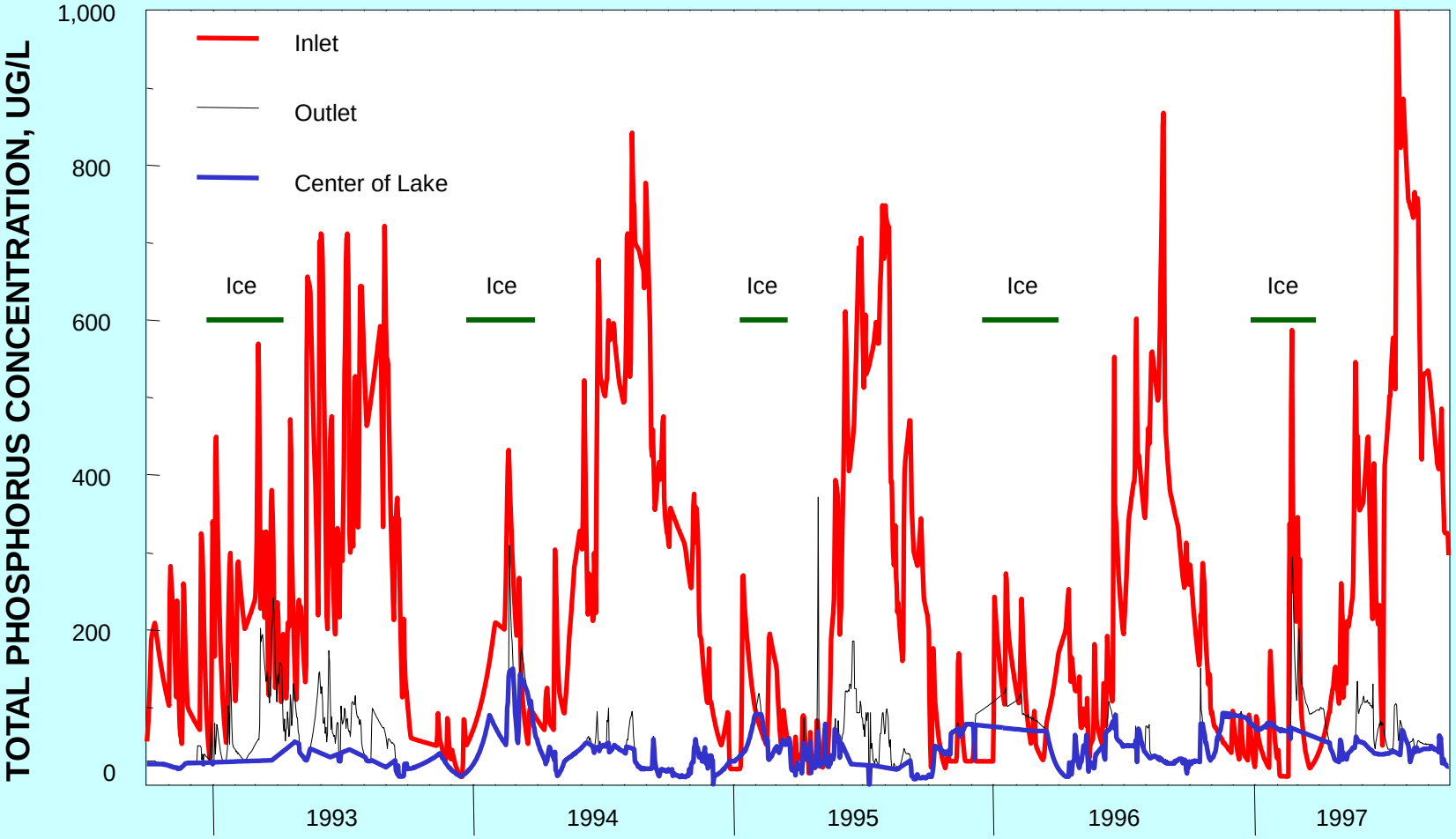


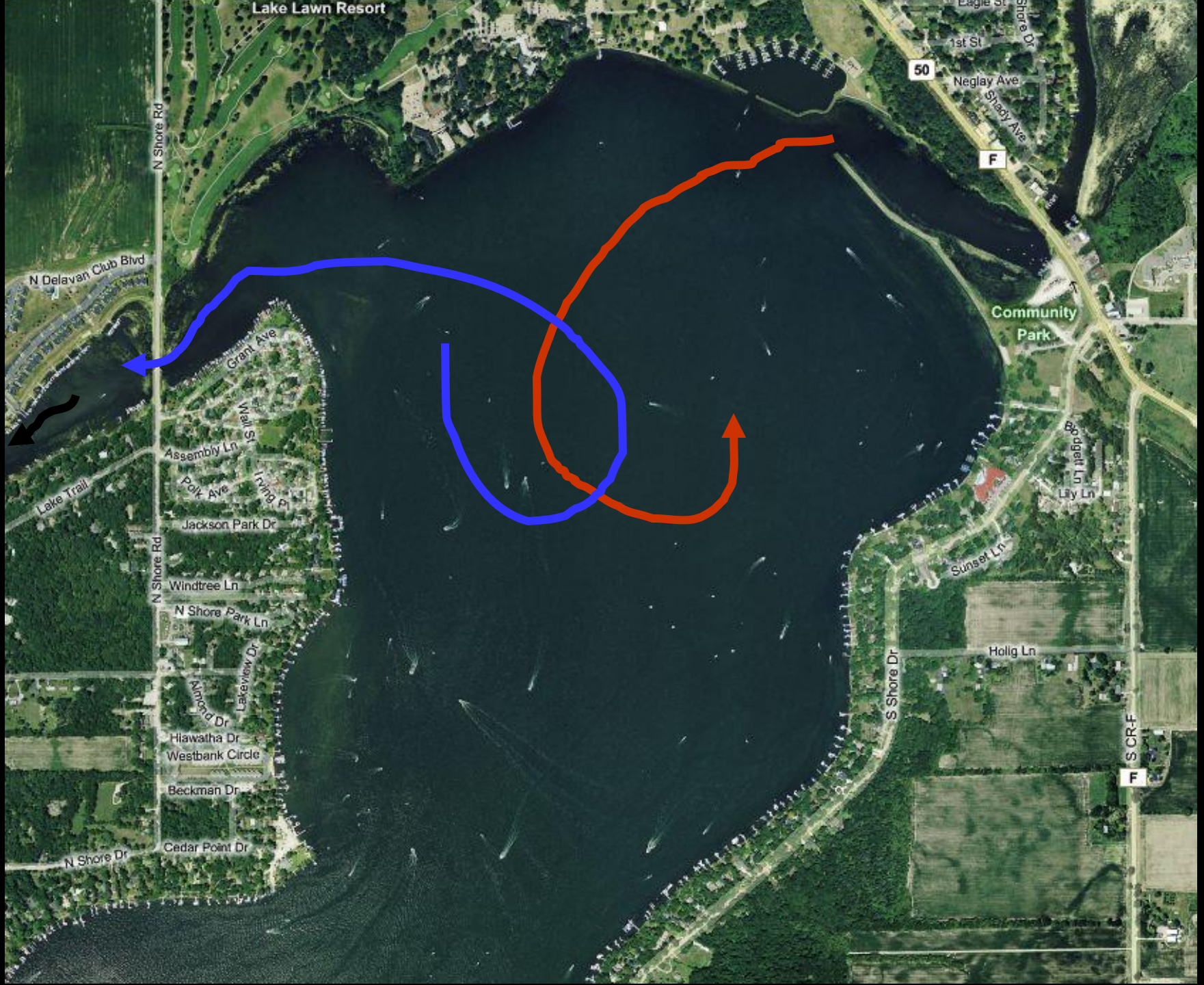
Annual Budget

30% ↑

Jackson Creek Short-Circuiting


Lake Lawn Resort
N Shore Rd
N Delavan Club Blvd
Grant Ave
Wall St
Assembly Ln
Polk Ave
Irving Pl
Lake Trail
Jackson Park Dr
N Shore Rd
Windtree Ln
N Shore Park Ln
Lakeview Dr
Nimrod Dr
Hiawatha Dr
Westbank Circle
Beckman Dr
Cedar Point Dr
N Shore Dr
1st St
Eagle St
Shore Dr
50
Neglay Ave
Shady Ave
F
Community Park
Bridgett Ln
Lily Ln
Sunset Ln
Holig Ln
S Shore Dr
S CR-F
F


TOTAL PHOSPHORUS CONCENTRATION, UG/L
1,000
800
600
400
200
0
Inlet
Outlet
Center of Lake
Ice
Ice
Ice
Ice
Ice
1993
1994
1995
1996
1997


Lake Lawn Resort
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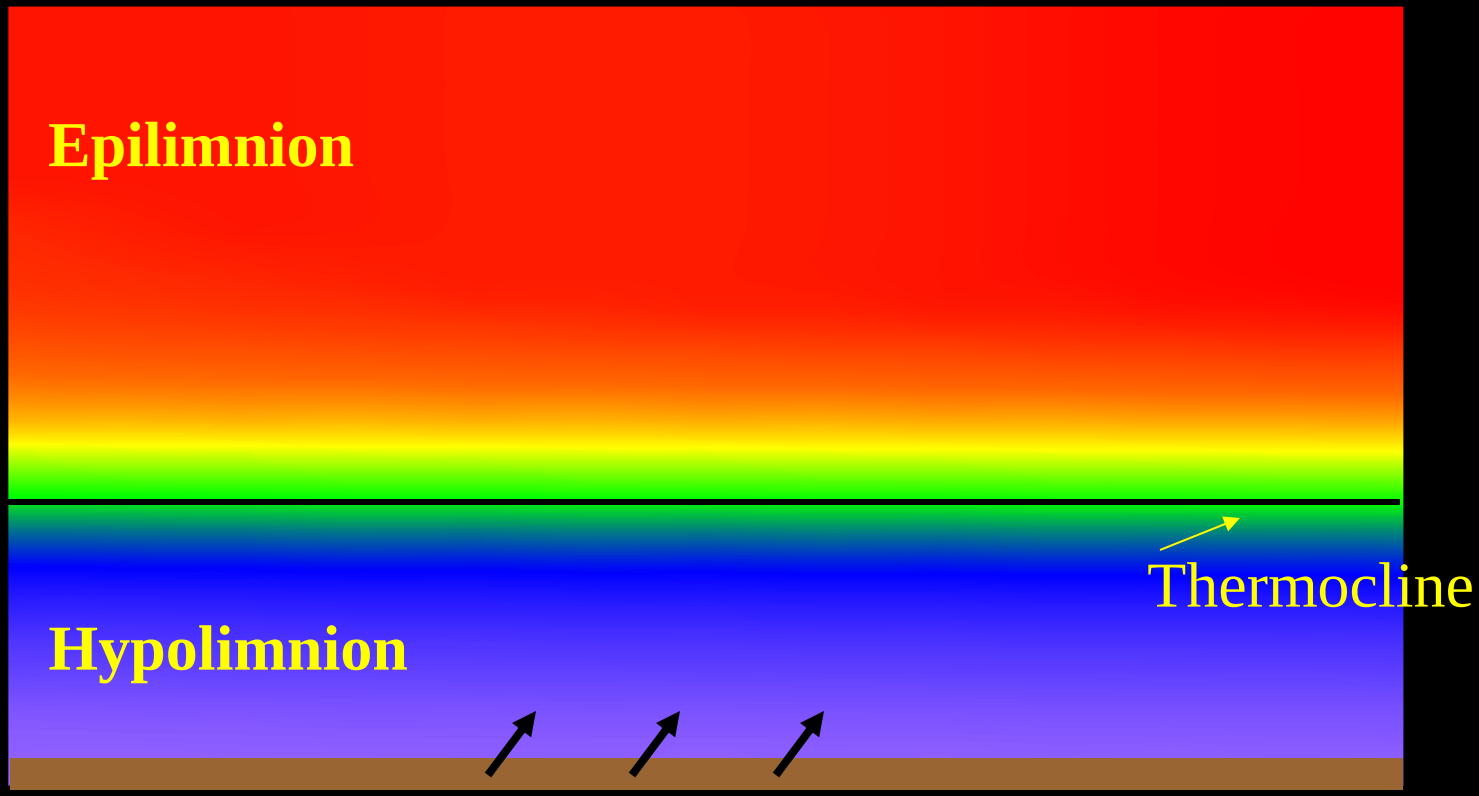
Nimrod Dr
Hiawatha Dr
Westbank Circle
Beckman Dr
Cedar Point Dr
N Shore Dr
Eagle St
Shore Dr
1st St
50
Neglay Ave
Shady Ave
F
Community Park
Bridgett Ln
Lily Ln
Sunset Ln
Holig Ln
S Shore Dr
S CR-F
F

Internal Sources Chemical Application of Alum

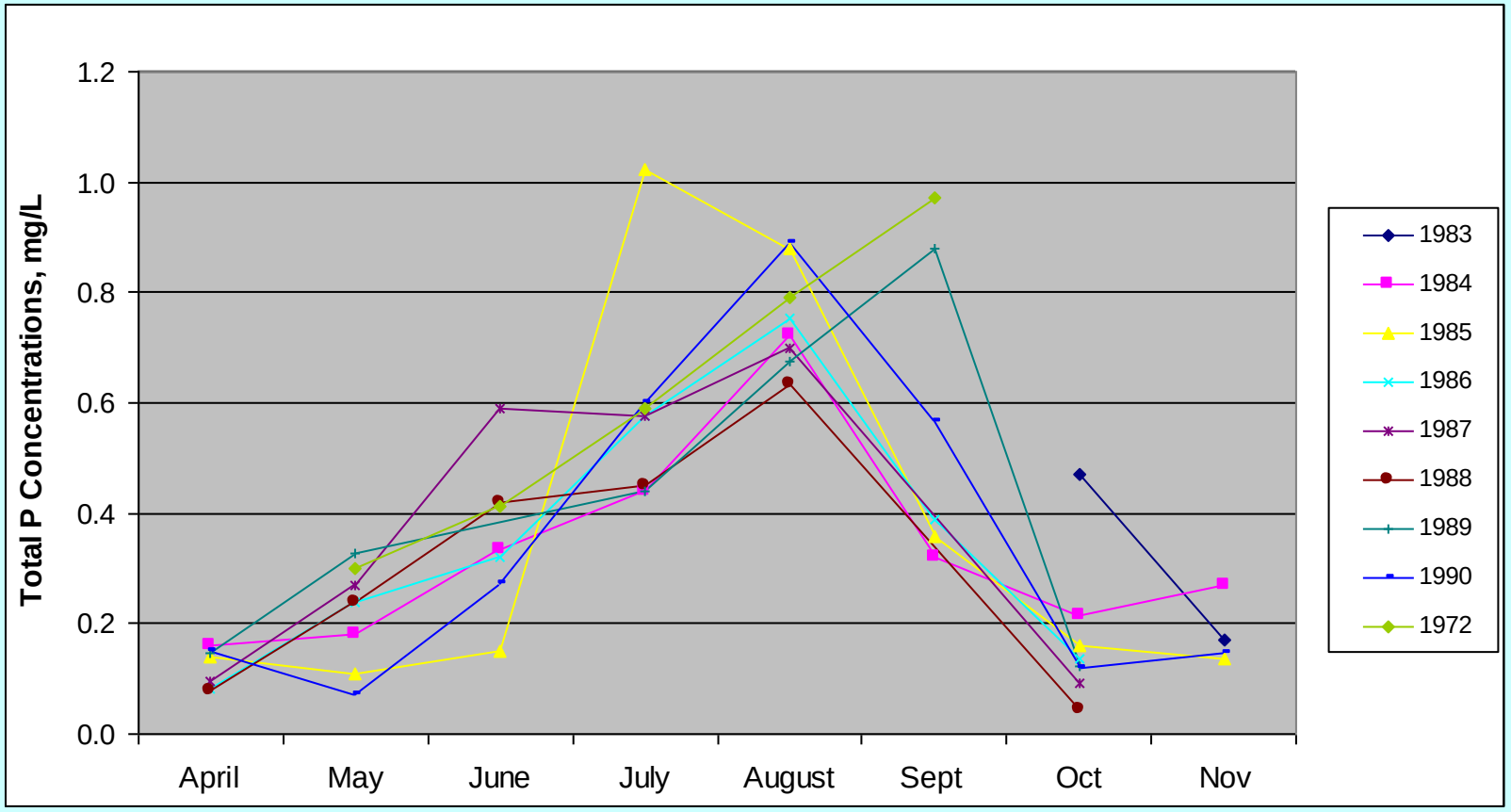
Internal Release of Phosphorus from Deep Sediment
"Internal Loading"



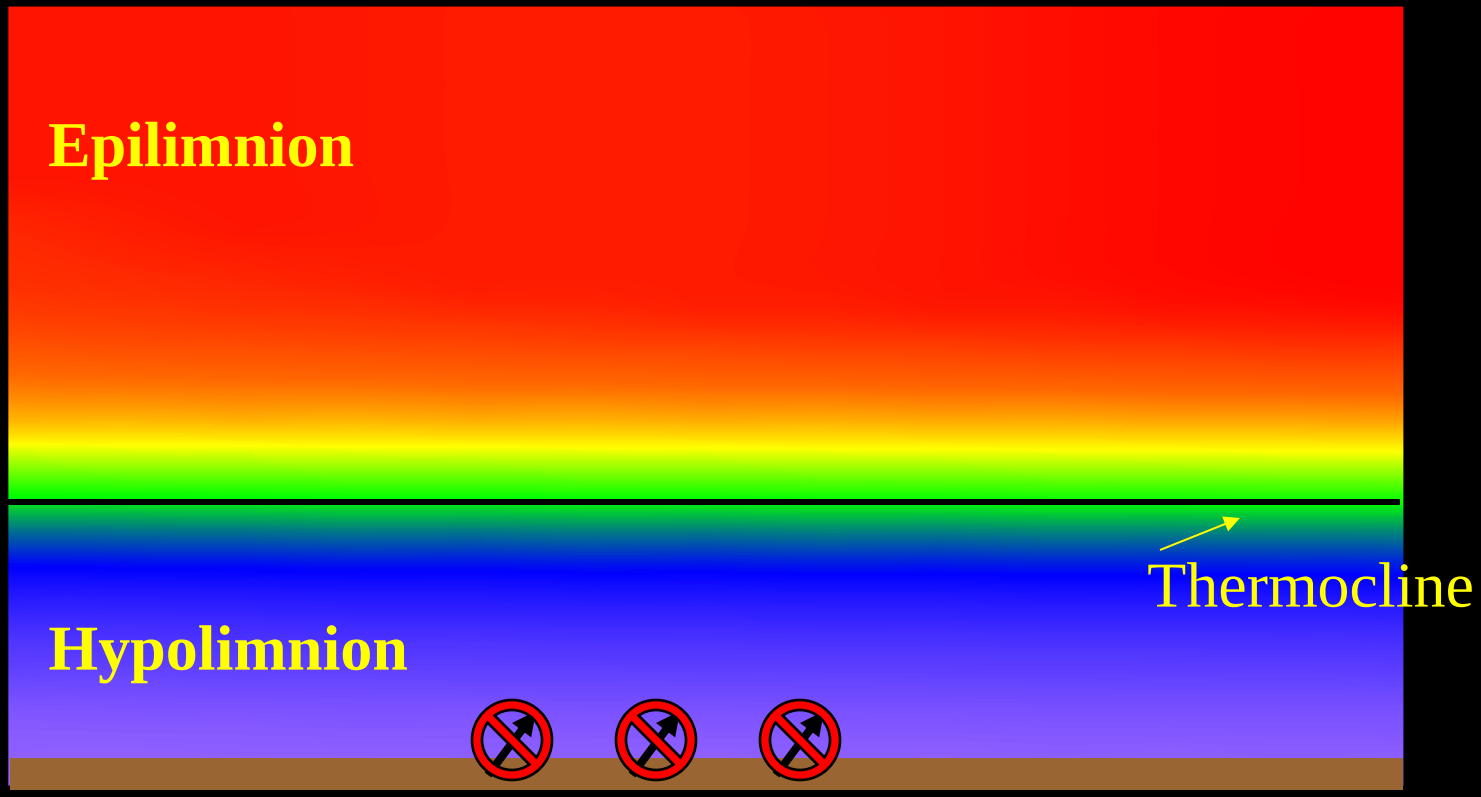
Internal Loading

Near Bottom Total Phosphorus Concentrations

PRIOR to Alum Application



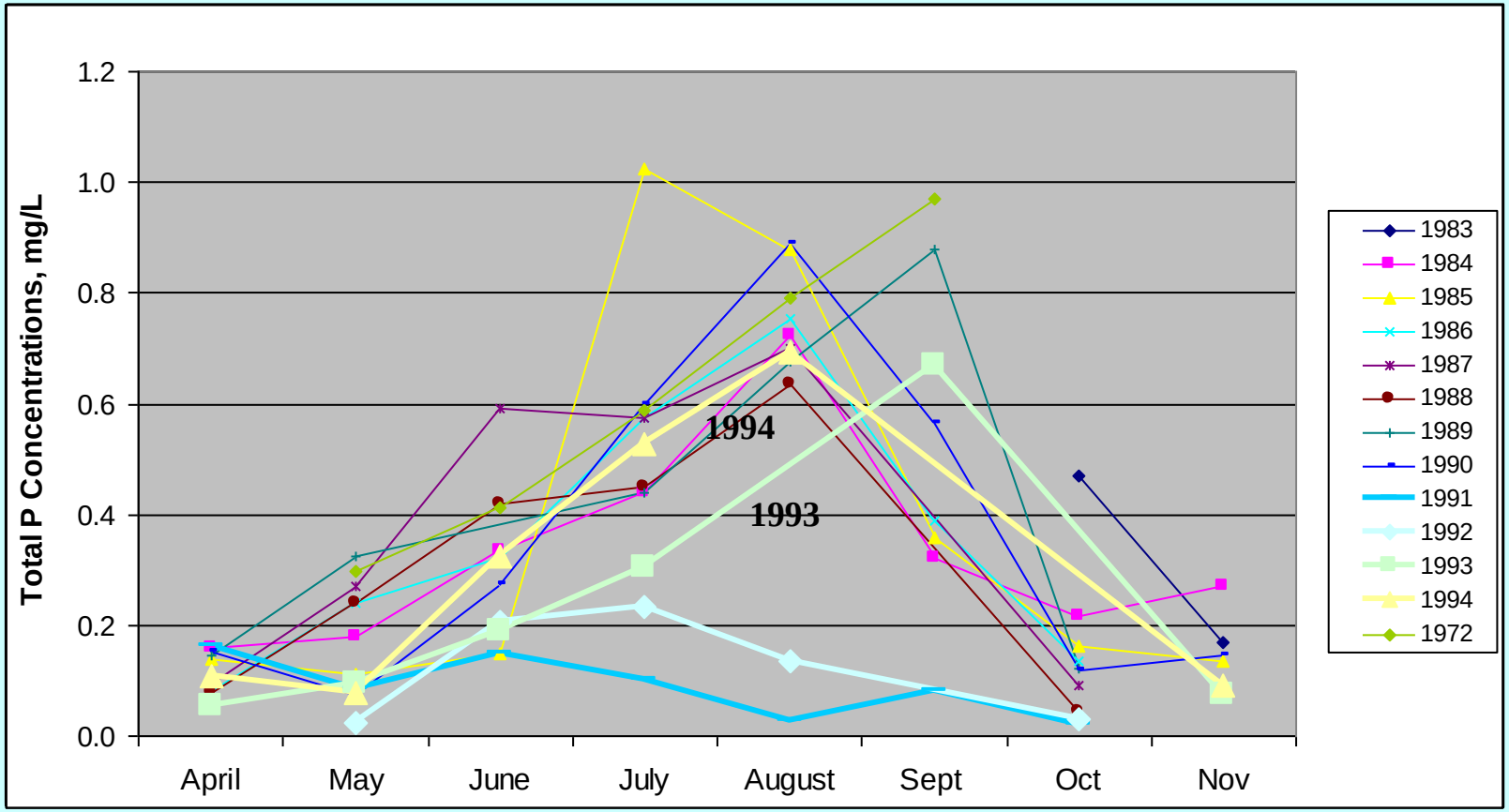
Eliminating "Internal Loading"



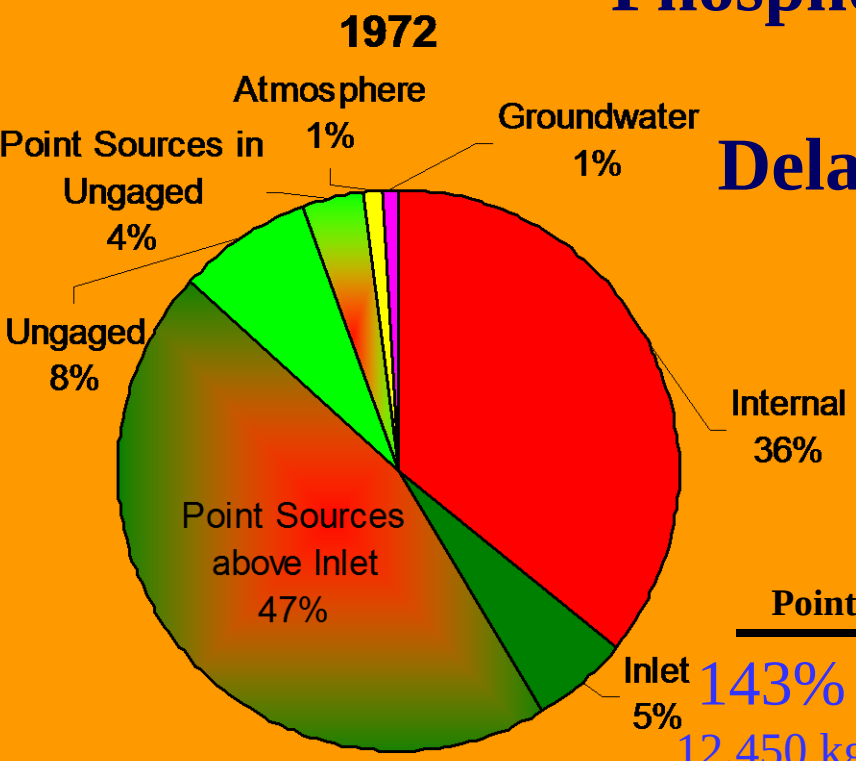
Internal Loading

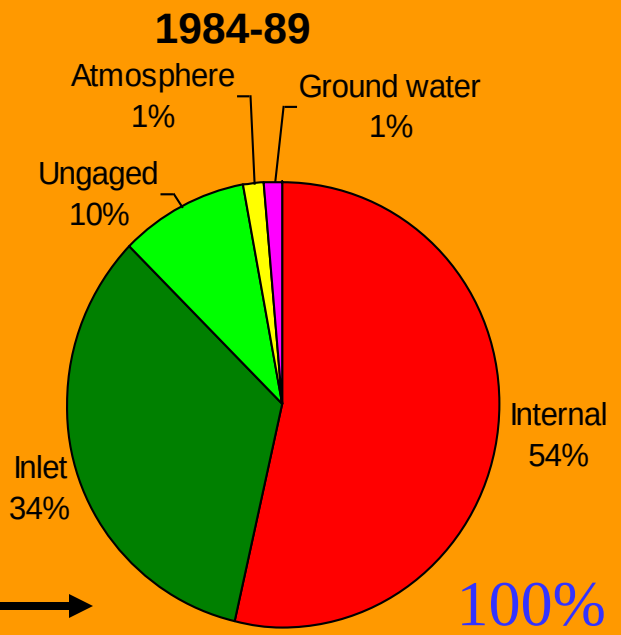
Near Bottom Total Phosphorus Concentrations

AFTER Alum Application



Phosphorus Budgets For Delavan Lake



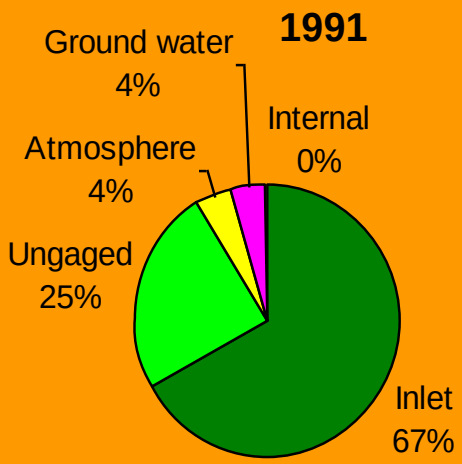


Point Source Removal

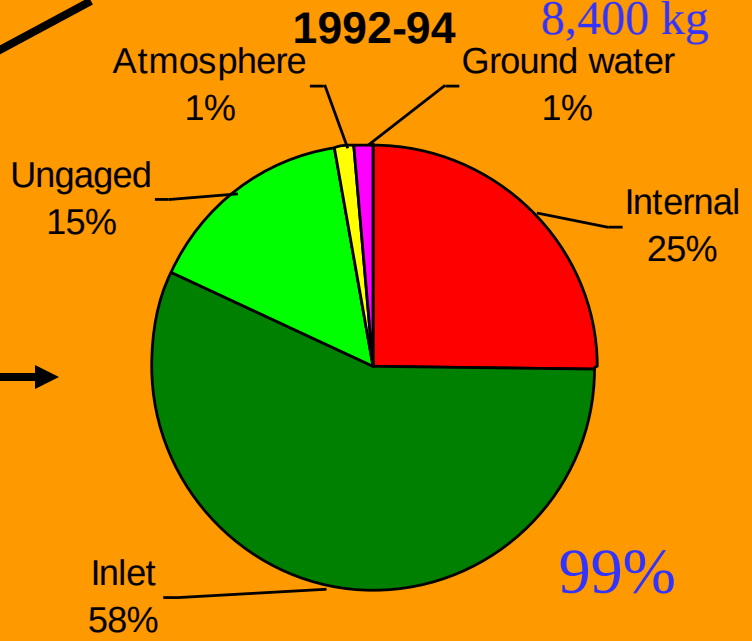
143%
12,450 kg

100%
8,400 kg

Internal Load Removal



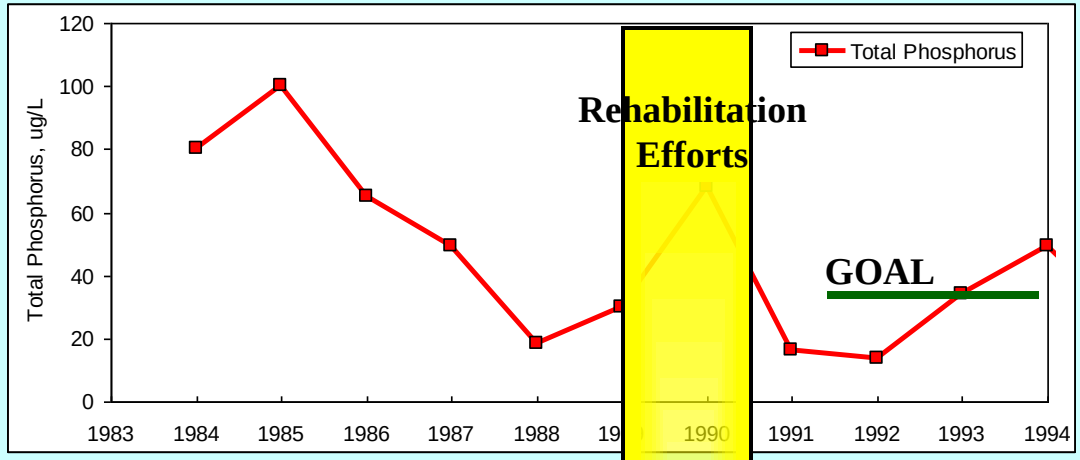
32%

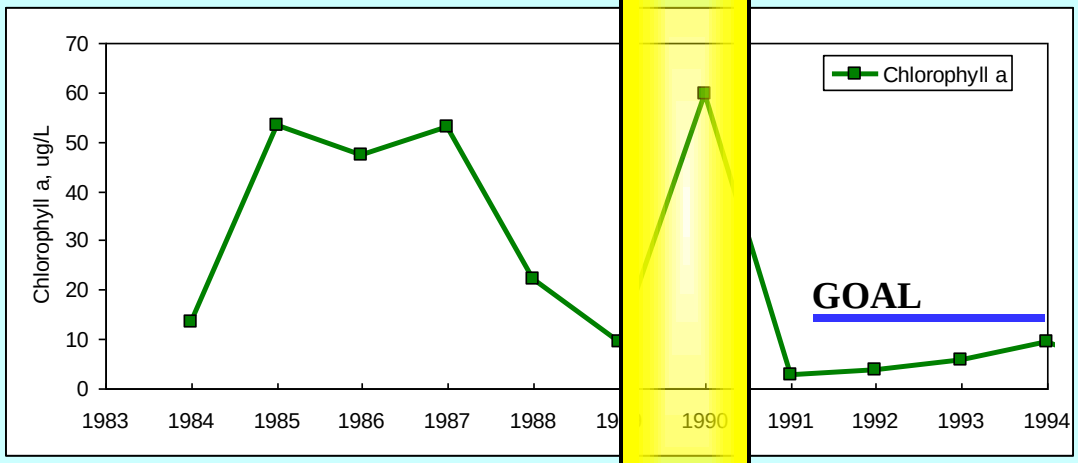


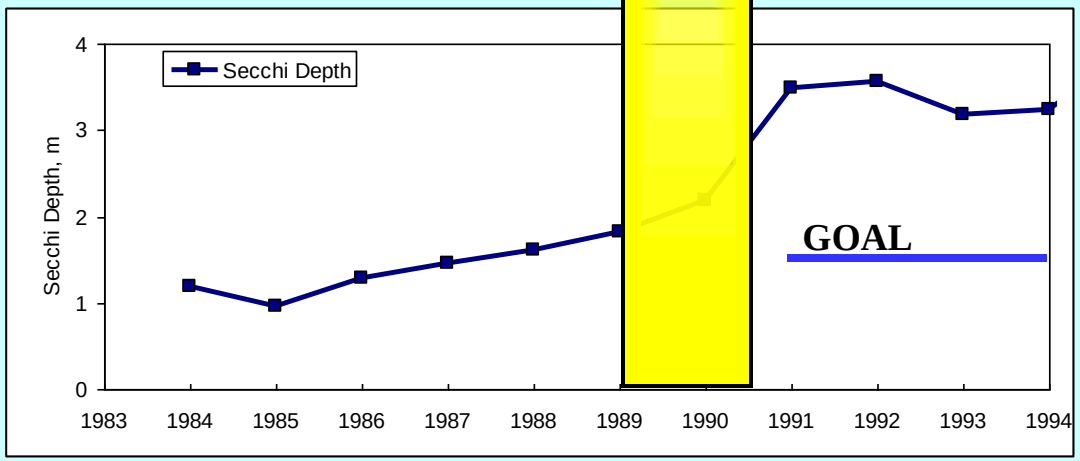
99%

In-lake Water Quality

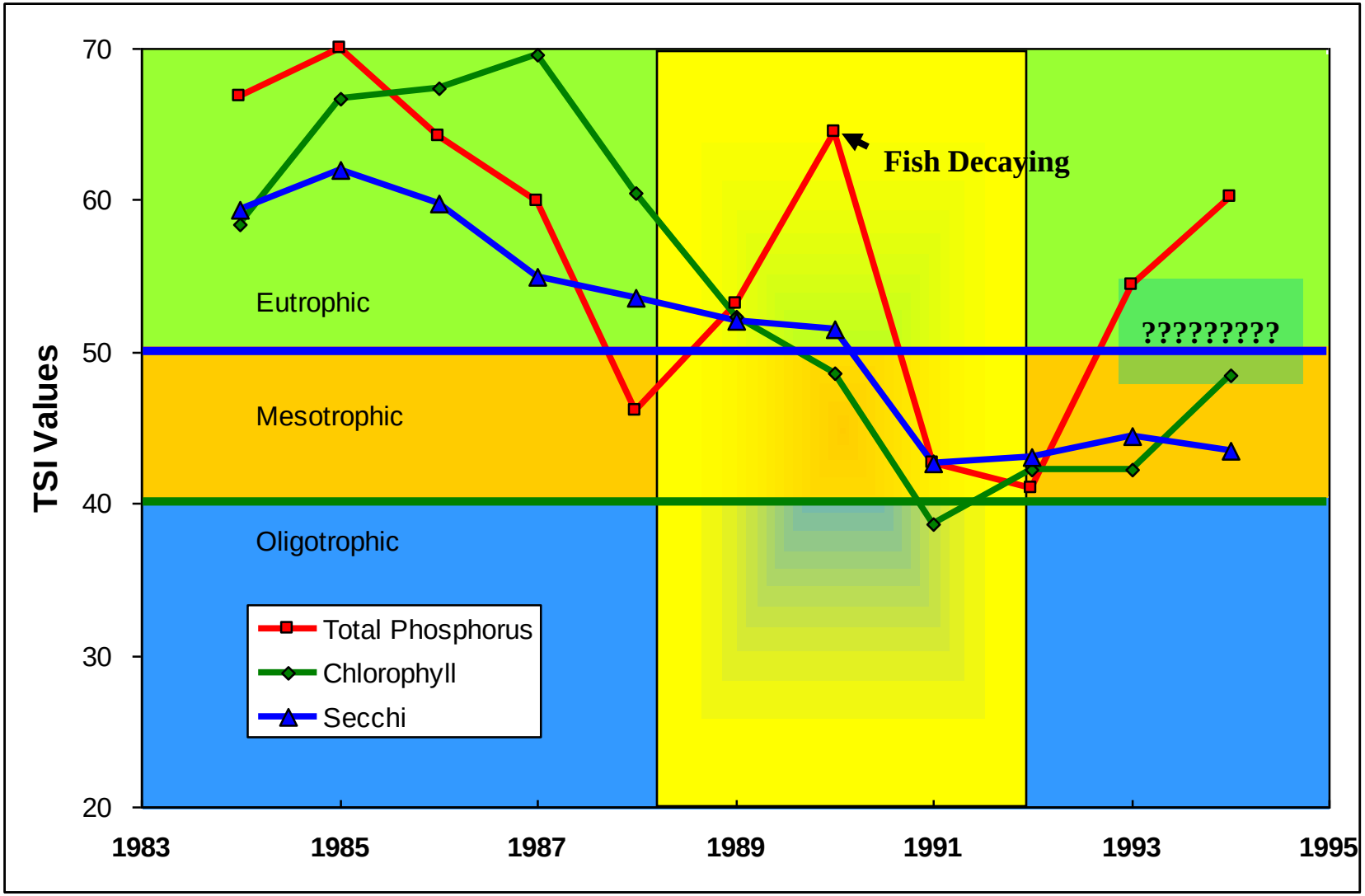
Summer Average
June - August



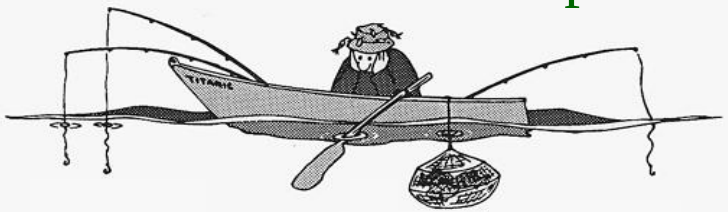




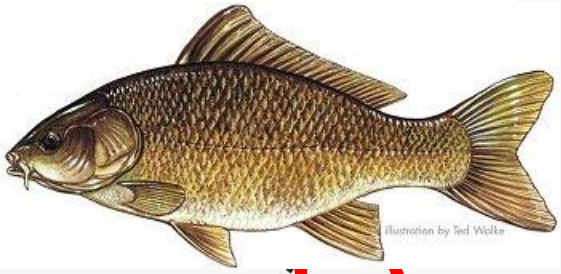
Trophic State of Delavan Lake

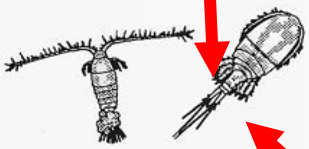


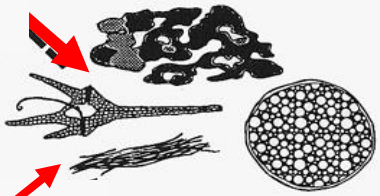
Delavan Lake - Premanipulation



Carp & Buffalo

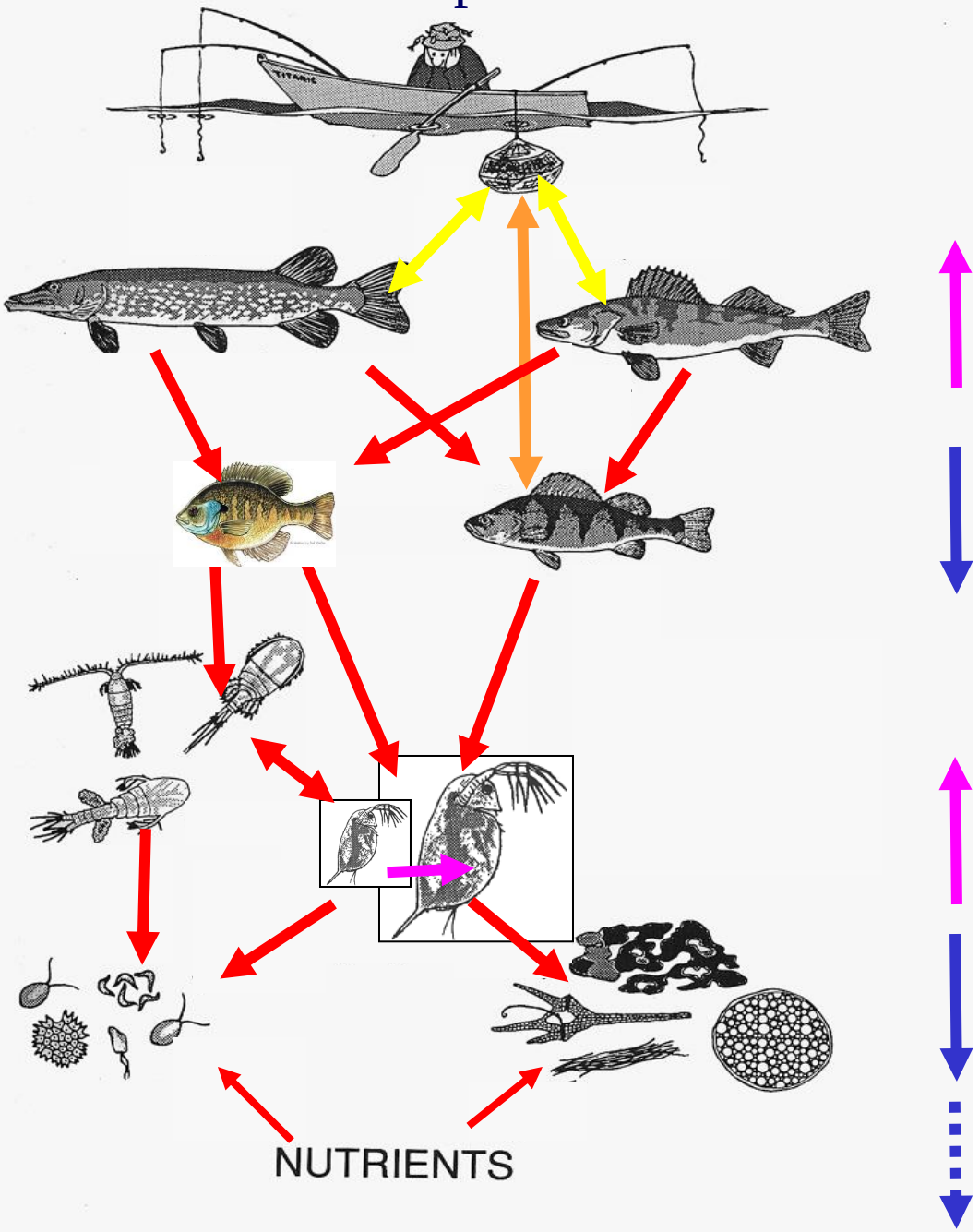


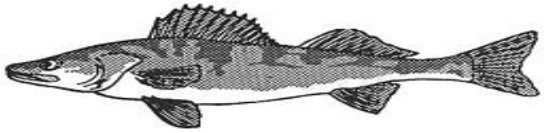


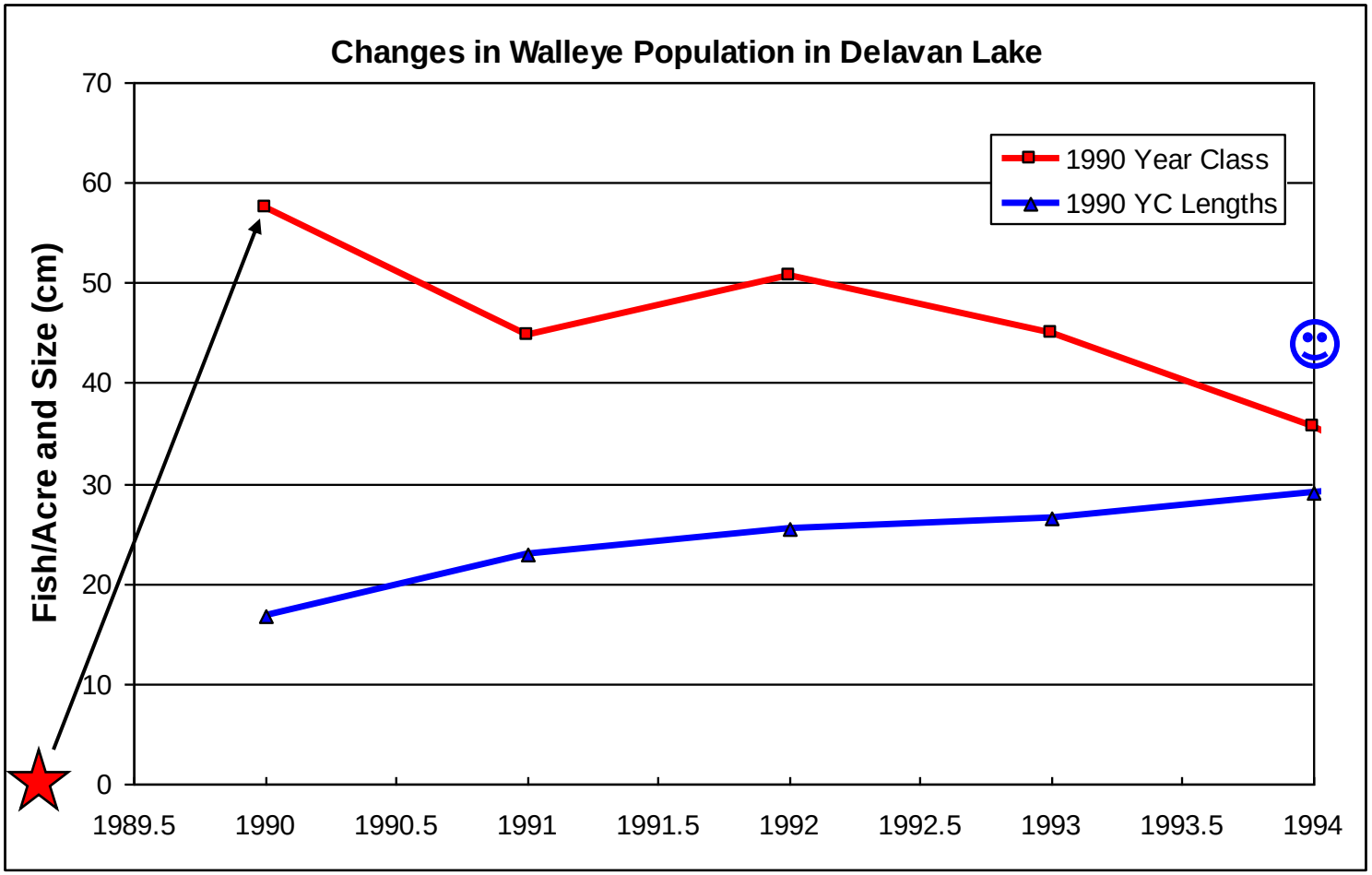


NUTRIENTS

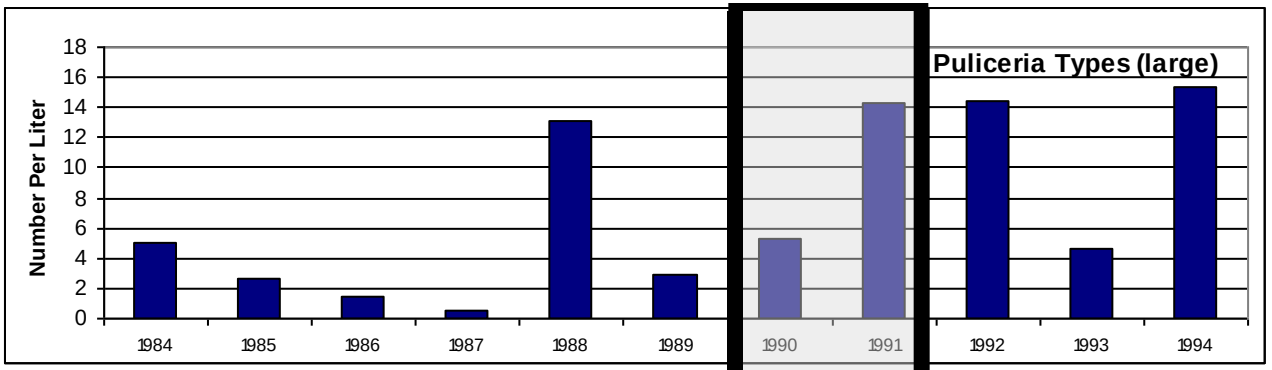
Post-manipulation

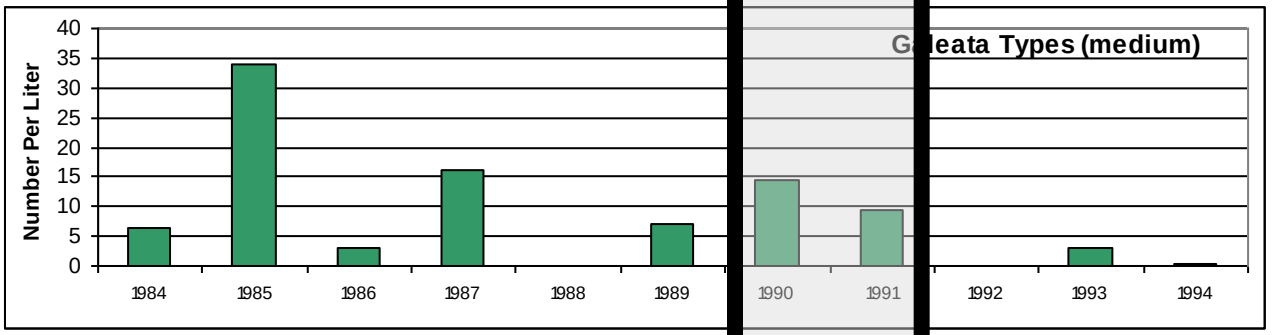


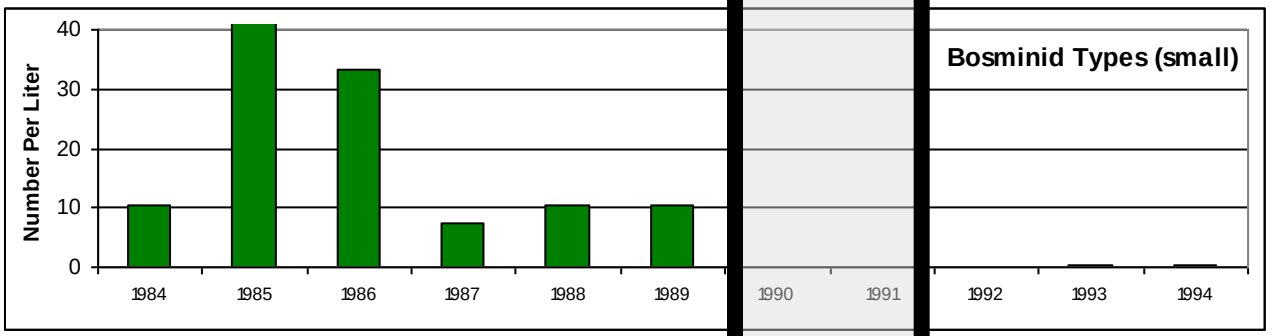


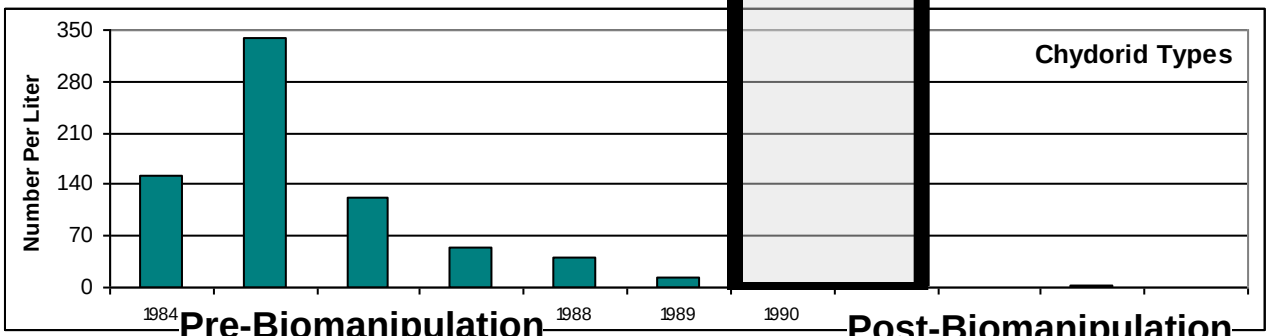

Changes in Walleye Population in Delavan Lake
Fish/Acre and Size (cm)
70
60
50
40
30
20
10
0
1989.5
1990
1990.5
1991
1991.5
1992
1992.5
1993
1993.5
1994
1990 Year Class
1990 YC Lengths

Zooplankton Populations

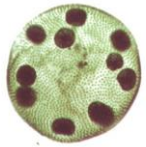




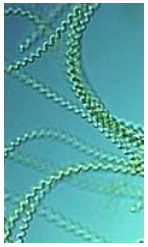




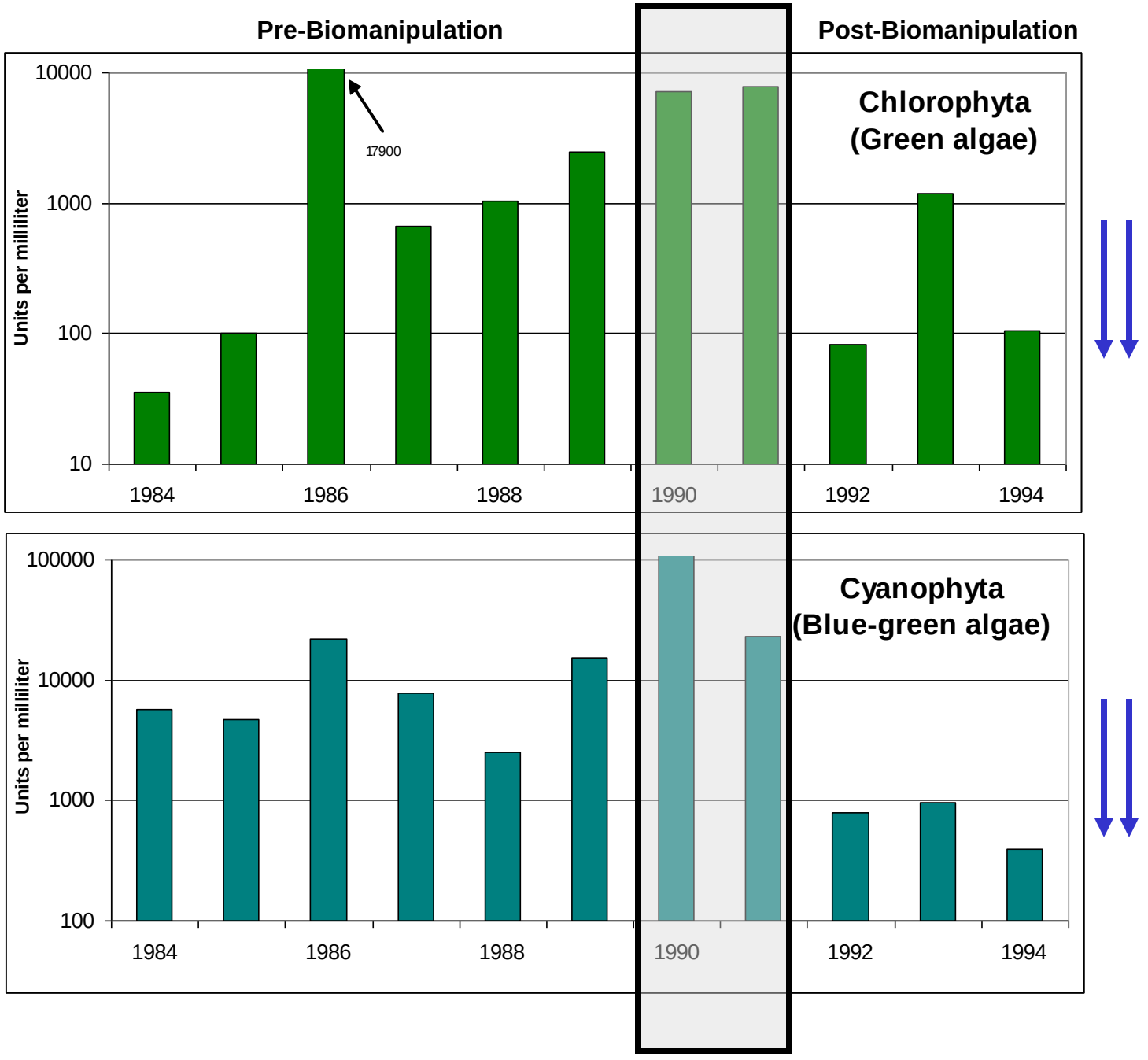
Phytoplankton Populations



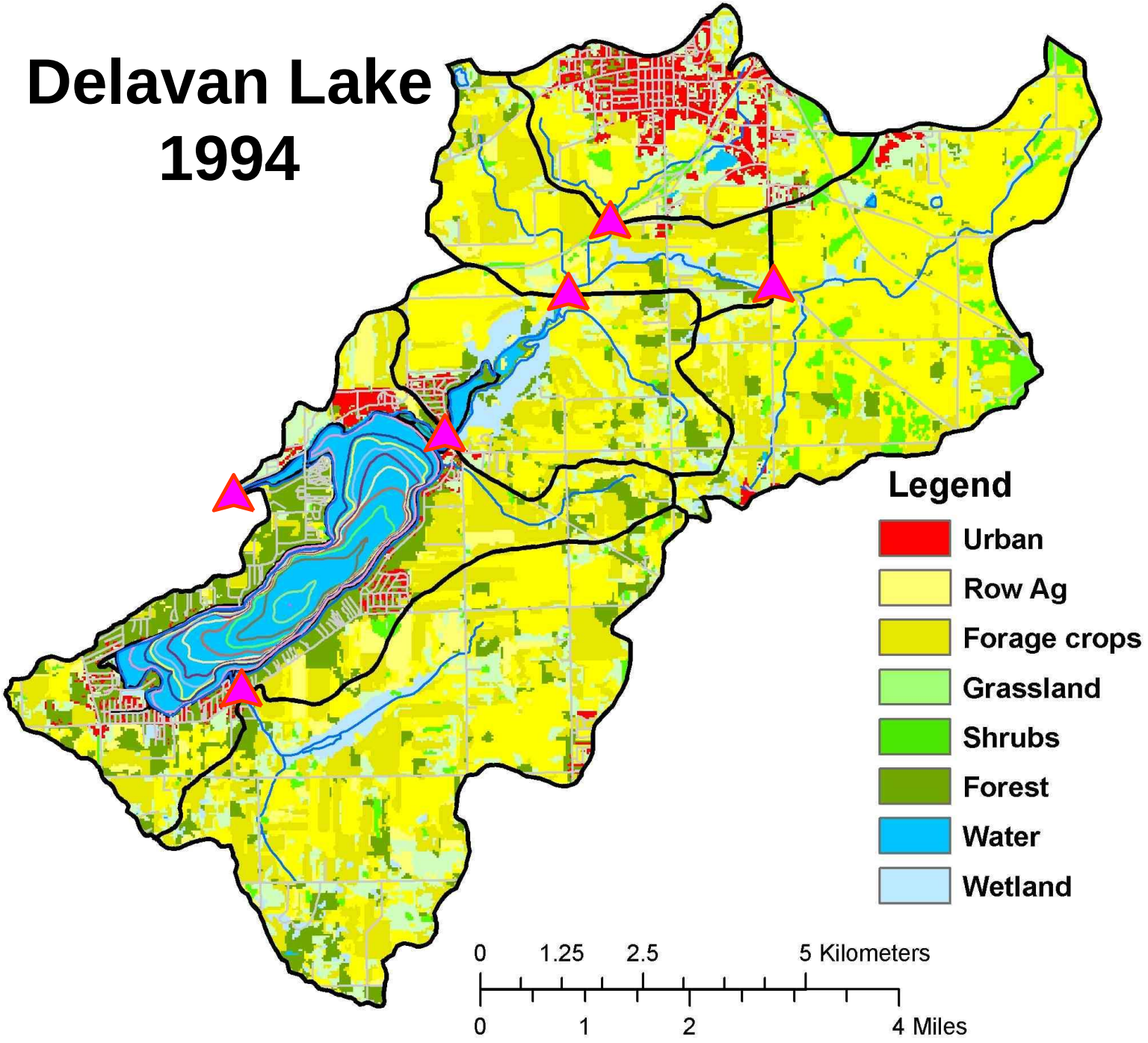
Green Algae



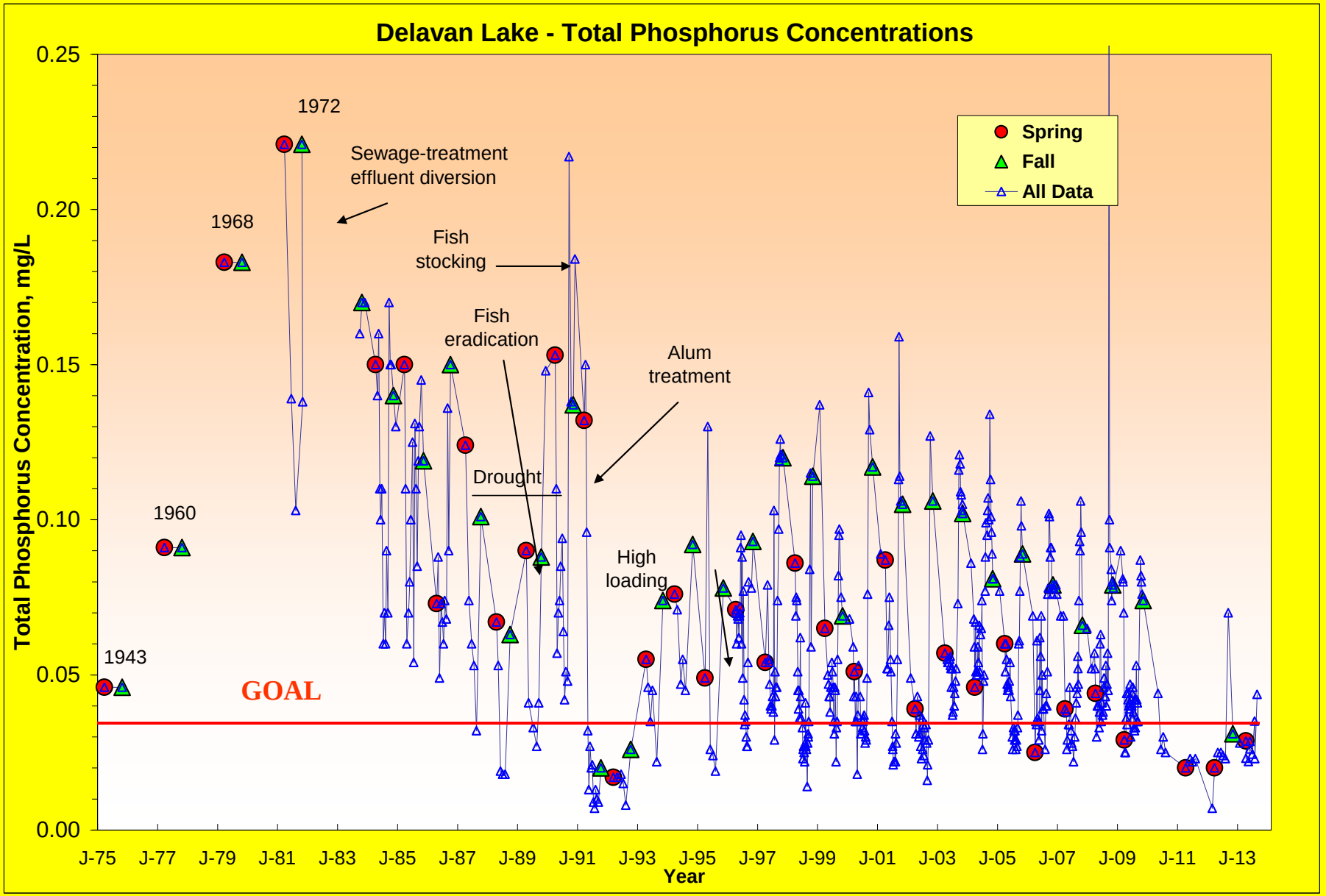
Bluegreen Algae

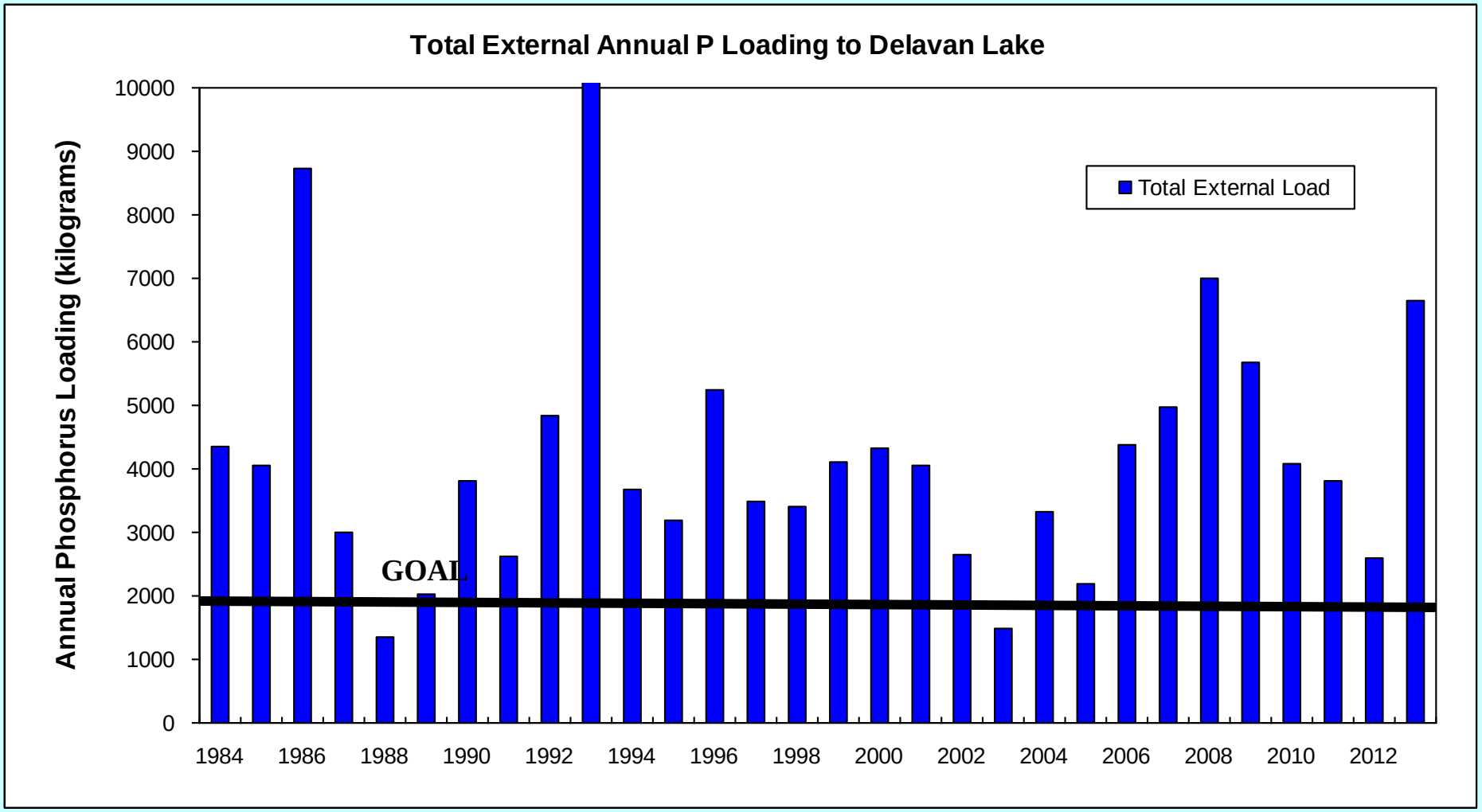


Delavan Lake
1994



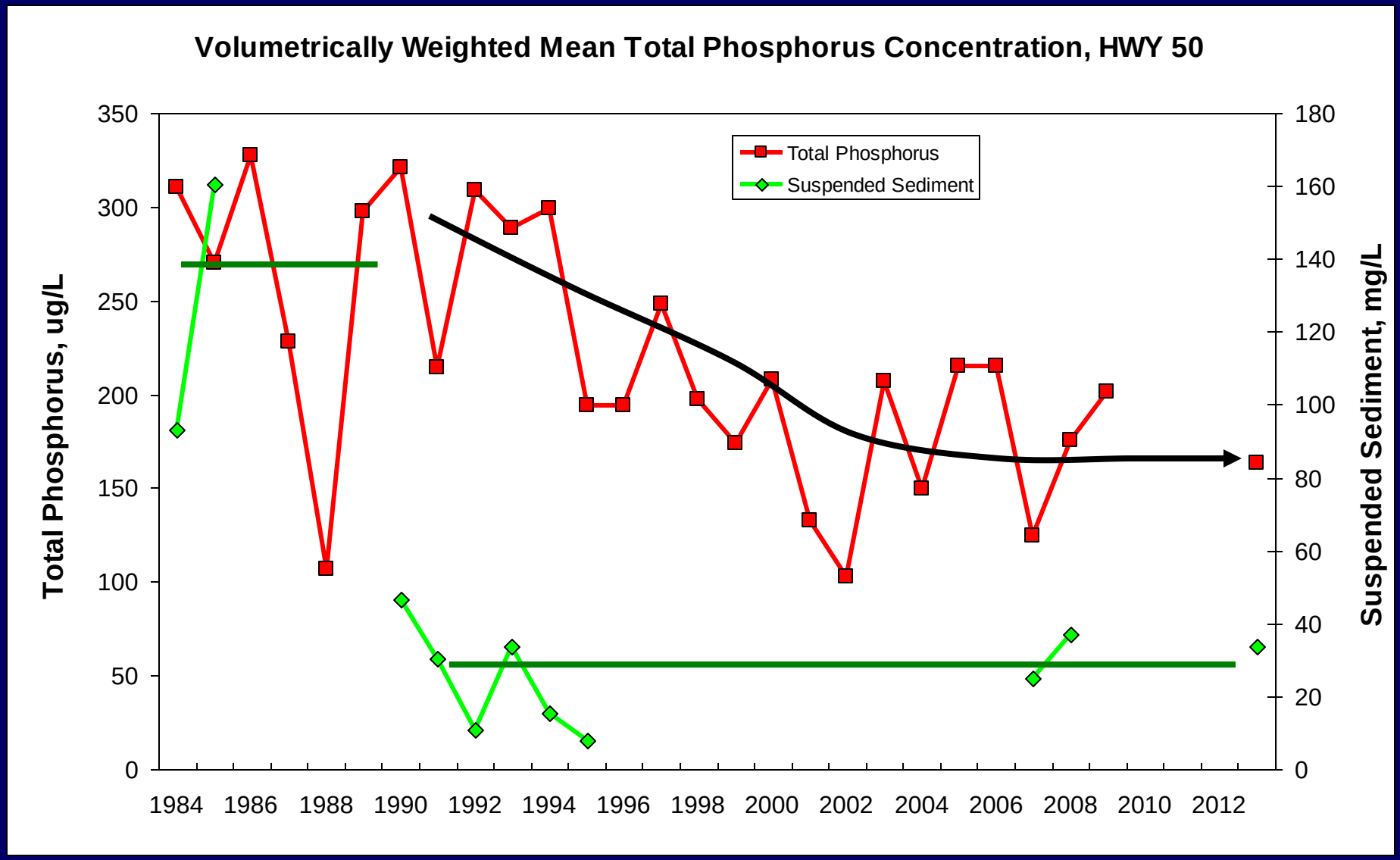
But, where have things gone since 1994??


Delavan Lake - Total Phosphorus Concentrations
Total Phosphorus Concentration, mg/L
0.25
0.20
0.15
0.10
0.05
0.00
J-75
J-77
J-79
J-81
J-83
J-85
J-87
J-89
J-91
J-93
J-95
J-97
J-99
J-01
J-03
J-05
J-07
J-09
J-11
J-13
Year
Spring
Fall
All Data
1943
1960
1968
1972
Sewage-treatment effluent diversion
Fish stocking
Fish eradication
Drought
Alum treatment
High loading
GOAL

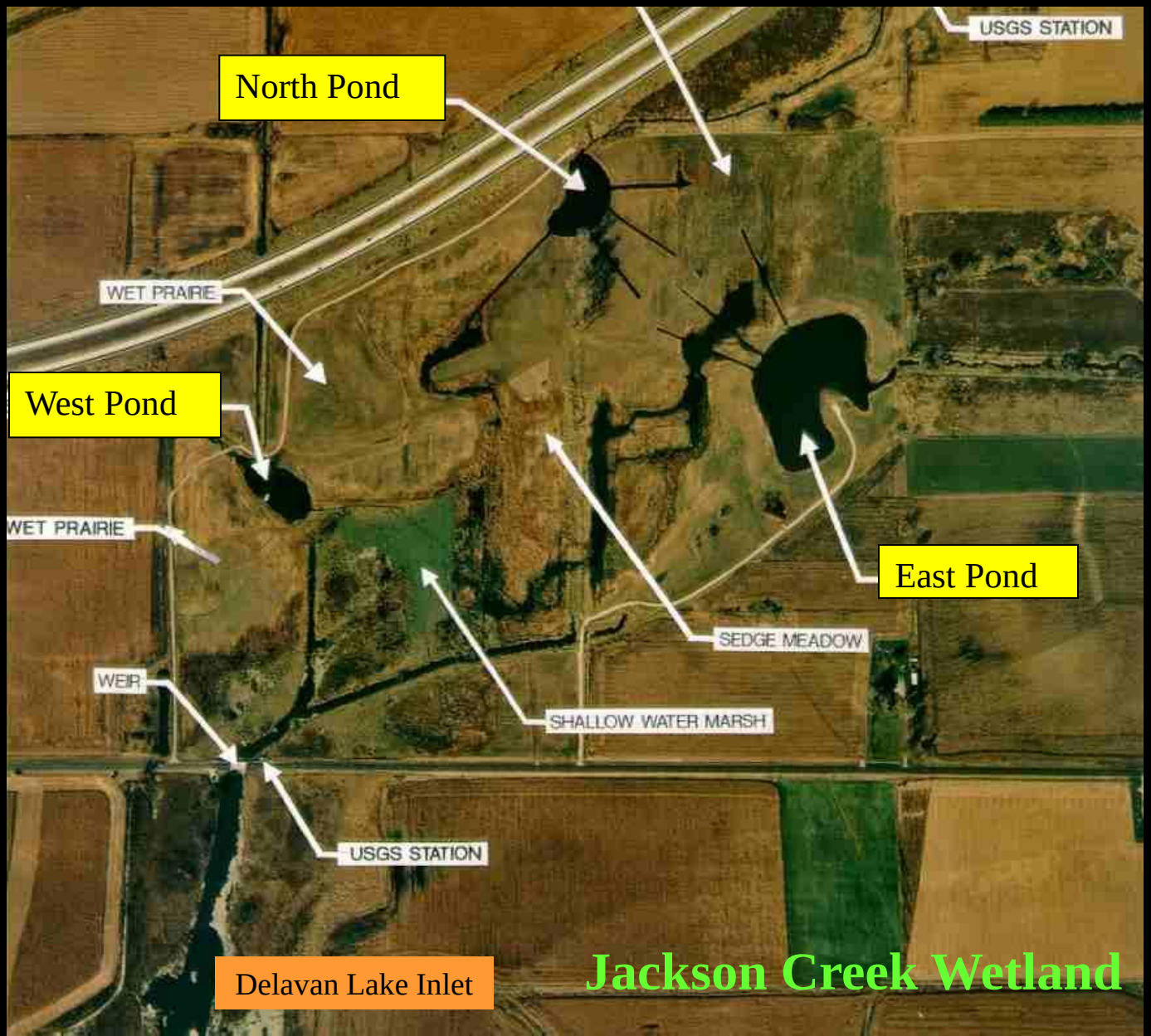


Total External Loads do not appear to have changed much

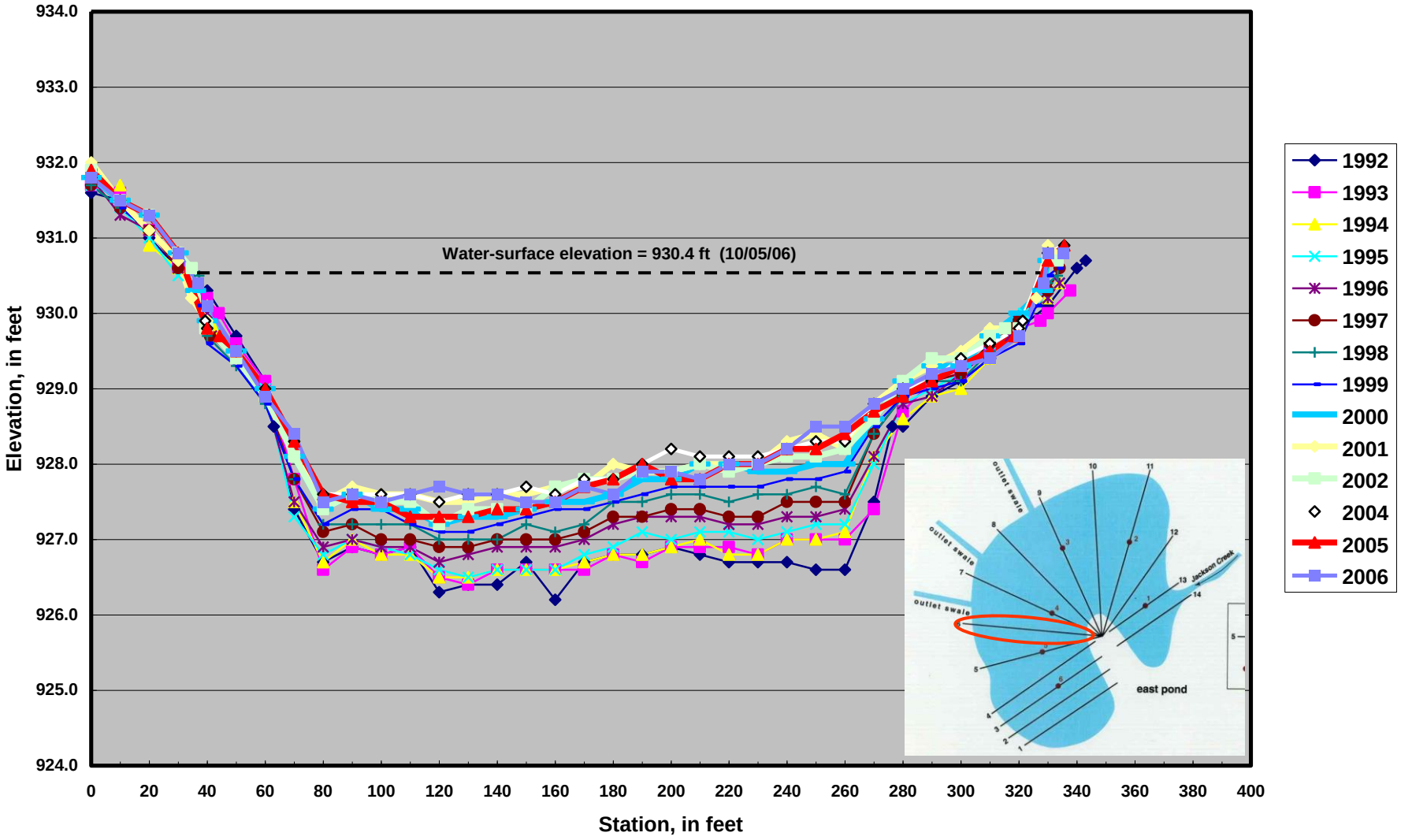
Changes in the Watershed Appear to Be Working

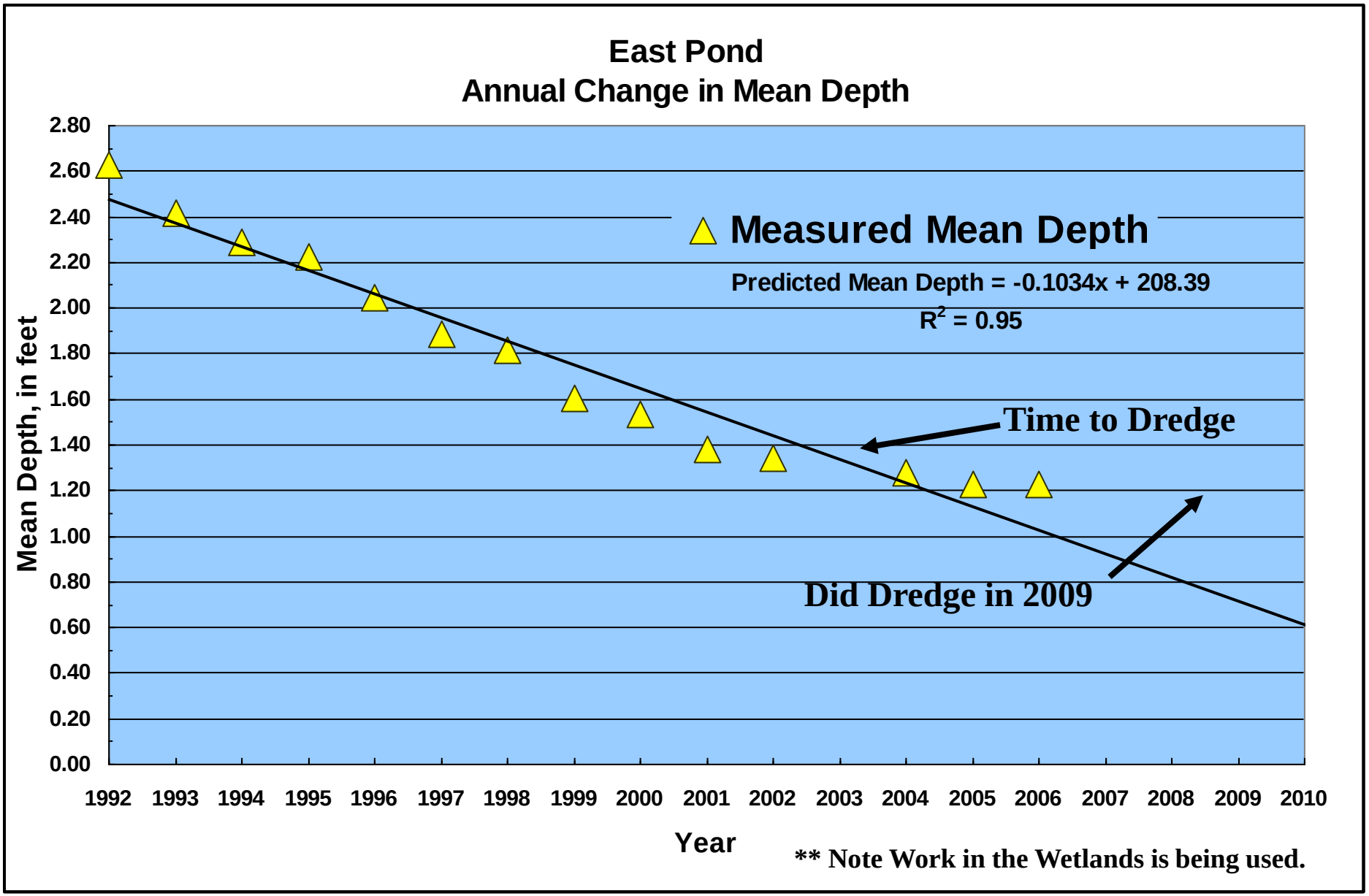


Were the Wetlands Part of the Reason for the Success?

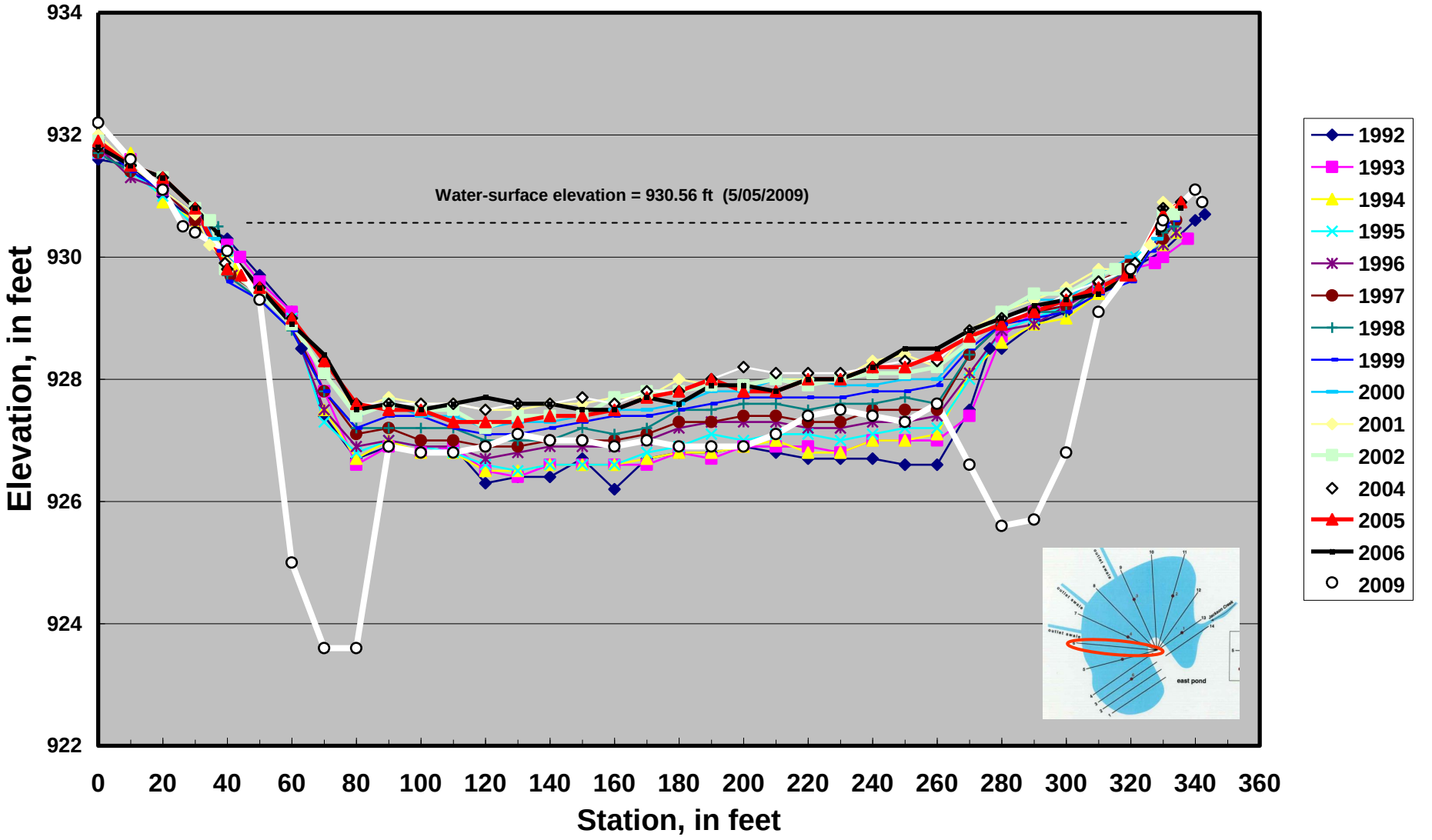


East Pond, Cross Section Number 6



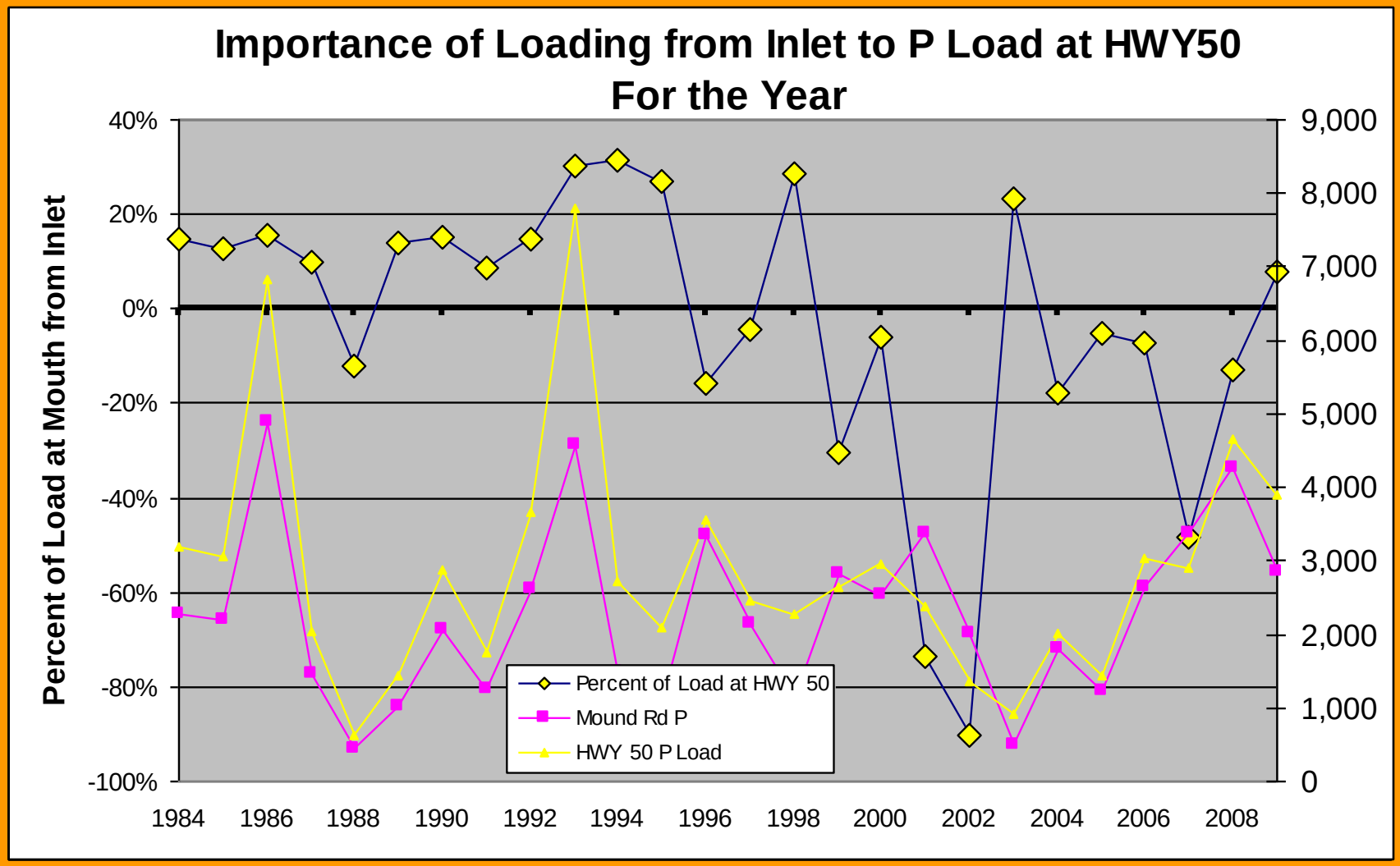

East Pond
Annual Change in Mean Depth
Mean Depth, in feet
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Measured Mean Depth
Predicted Mean Depth = -0.1034x + 208.39
R2 = 0.95
Time to Dredge
Did Dredge in 2009
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year
** Note Work in the Wetlands is being used.

East Pond, Cross Section Number 6



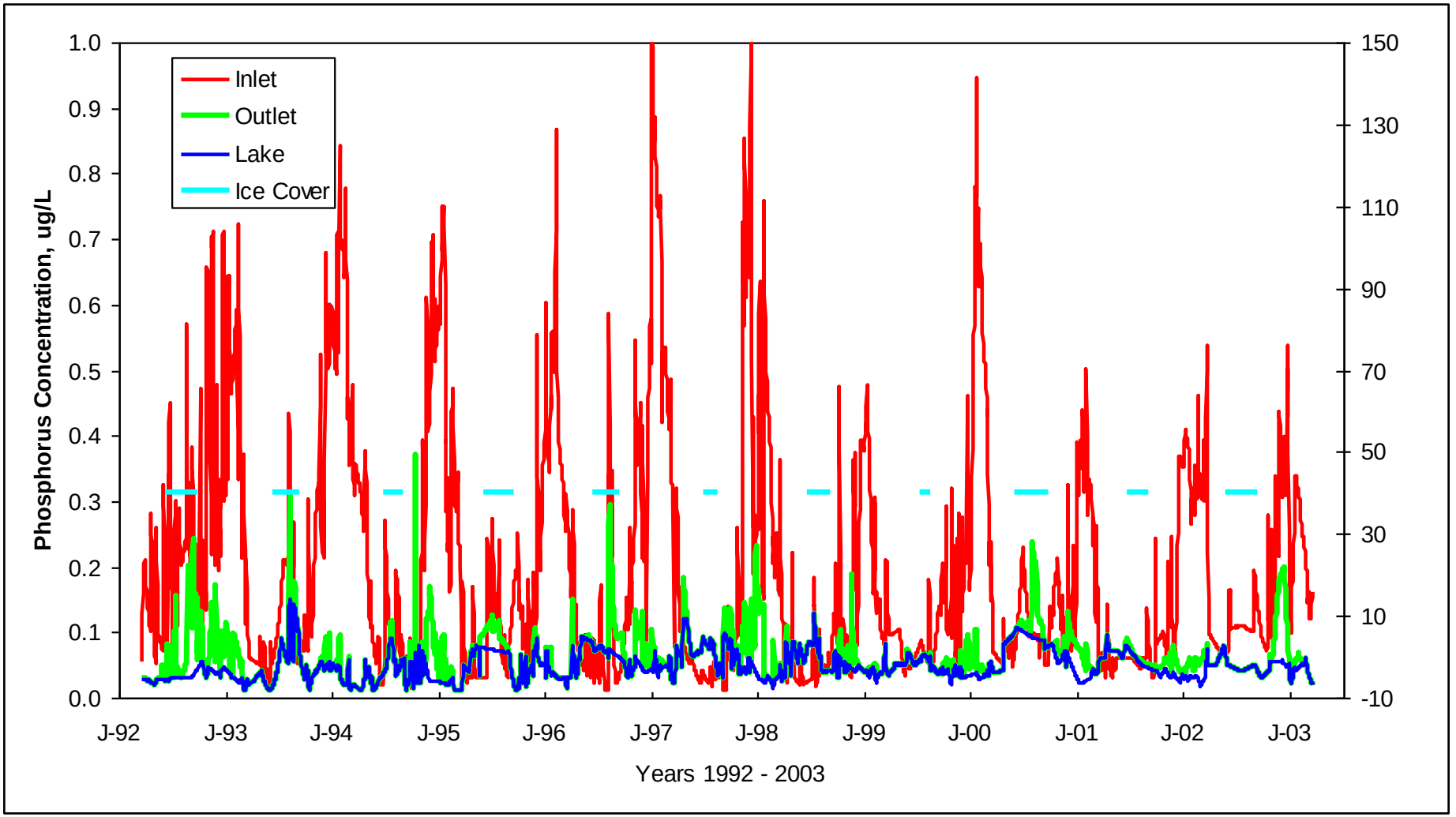
To extend the life of the Wetlands – Dredging was conducted in 2009


Did changes in the Inlet have an affect on changes in Concentrations??


Importance of Loading from Inlet to P Load at HWY50 For the Year
Percent of Load at Mouth from Inlet
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Percent of Load at HWY 50
Mound Rd P
HWY 50 P Load

Did Short Circuiting Start to Occur??

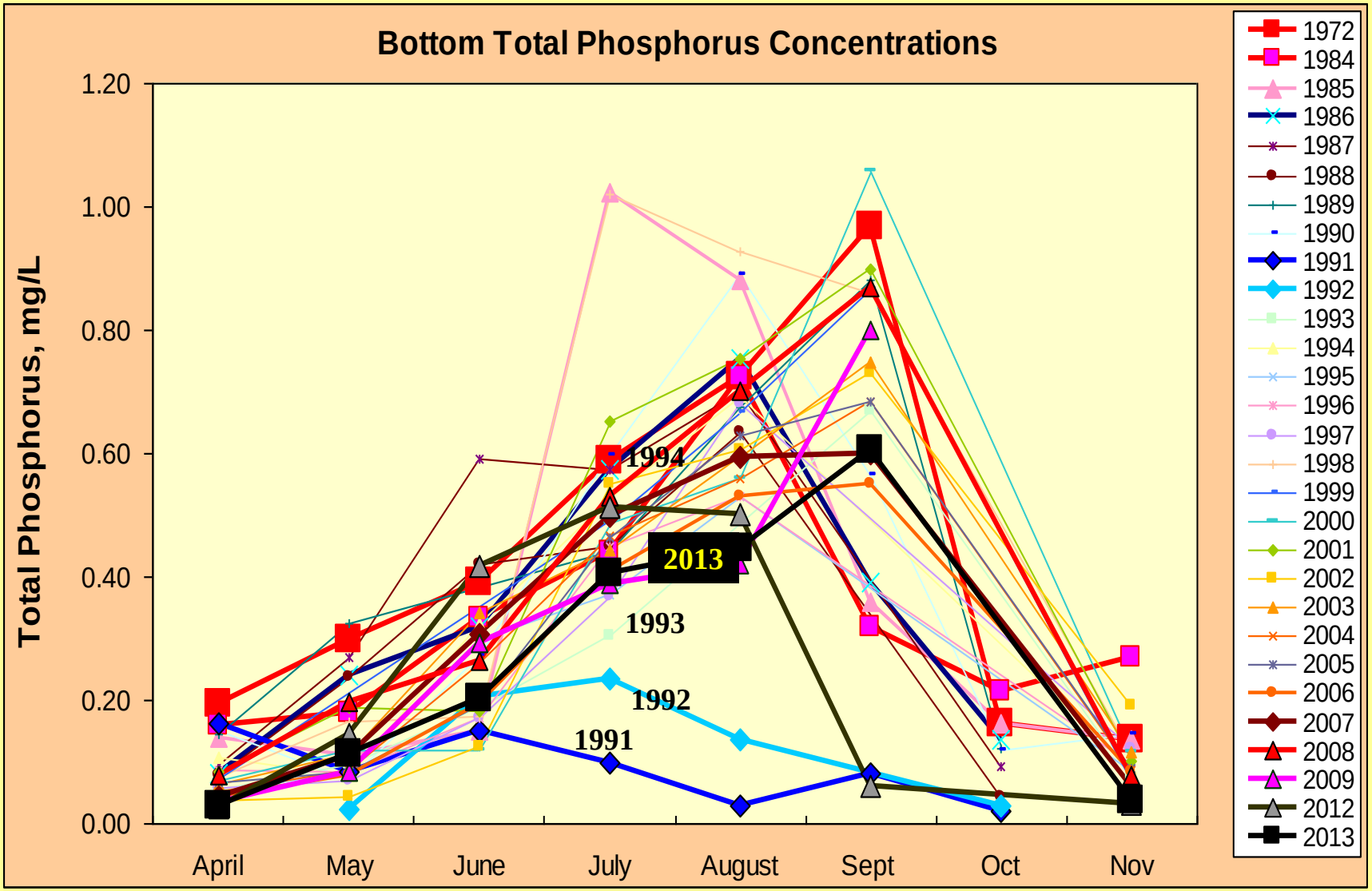
Short-Circuiting



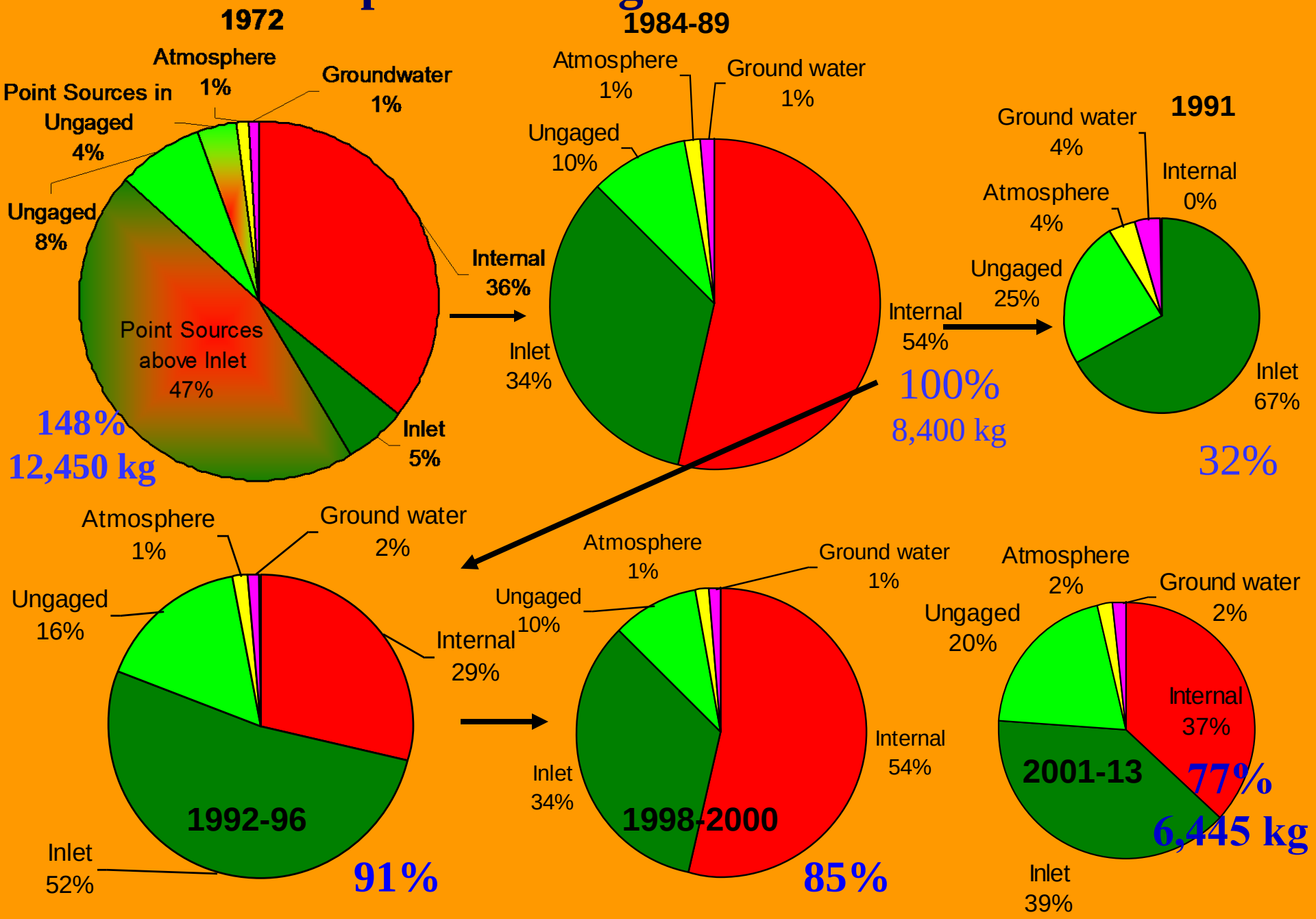
Did Internal Loading Stop Occurring??

Internal Sources Chemical Application of Alum

Internal Loading

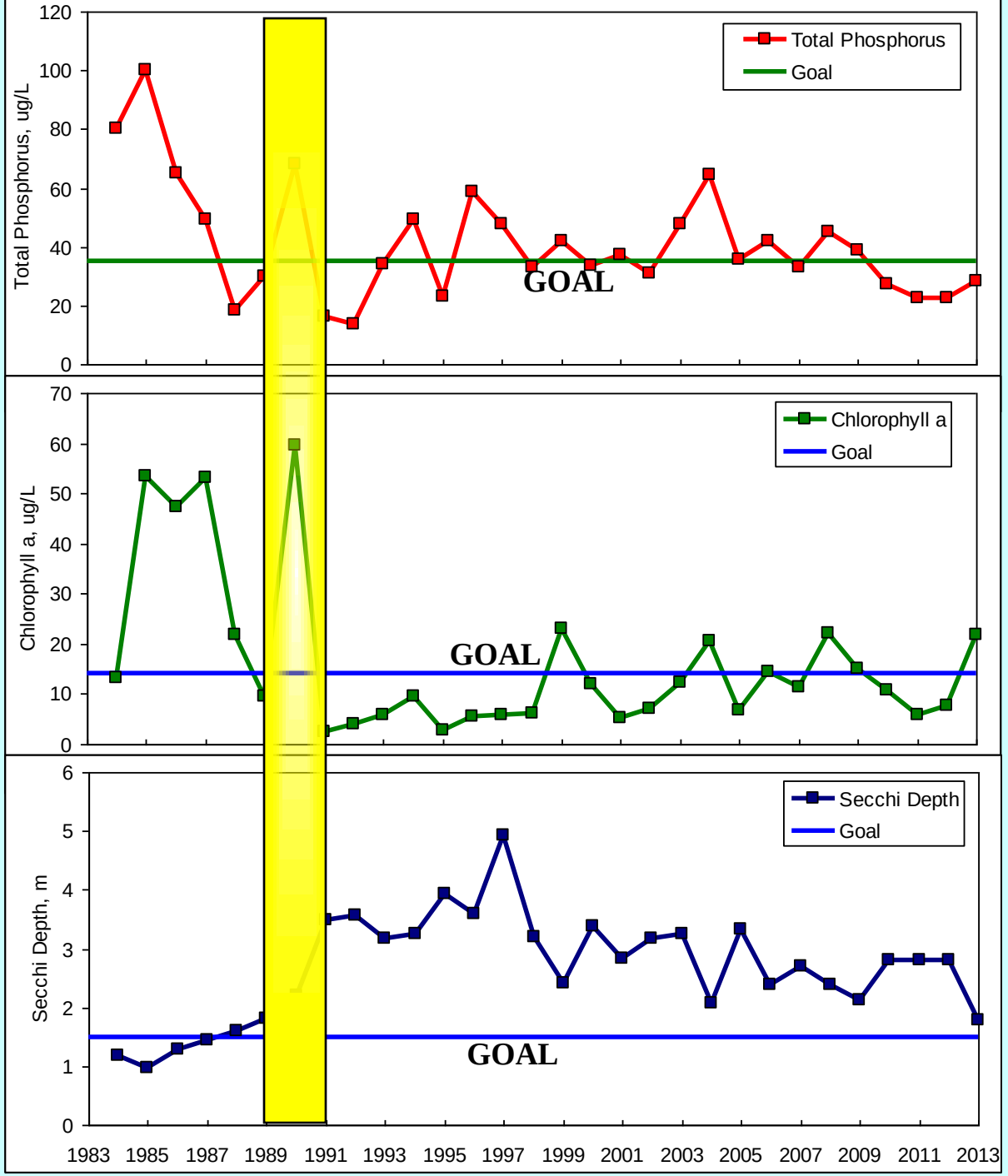


Phosphorus Budgets For Delavan Lake

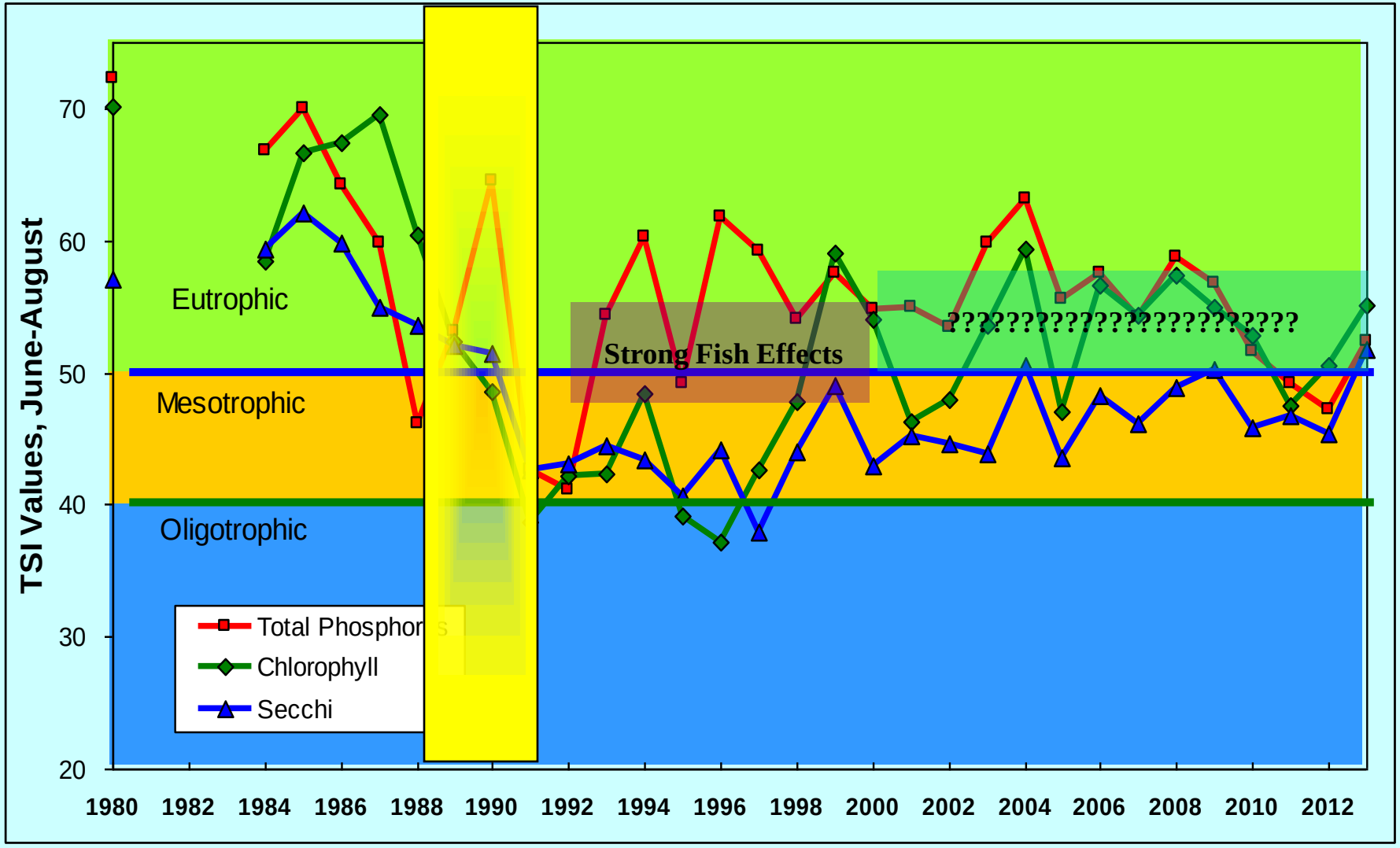


In-lake Water Quality

Summer Average
June - August

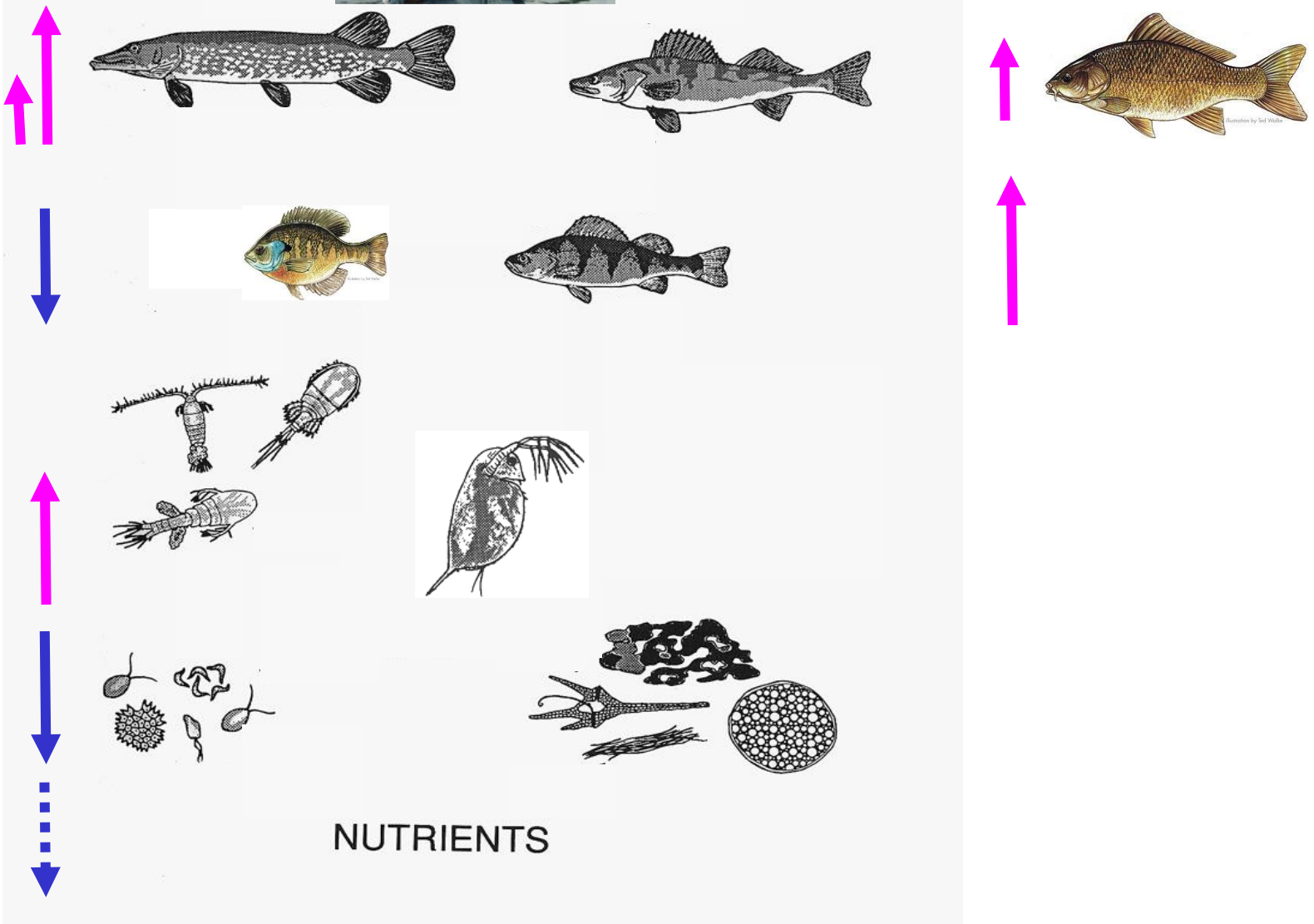


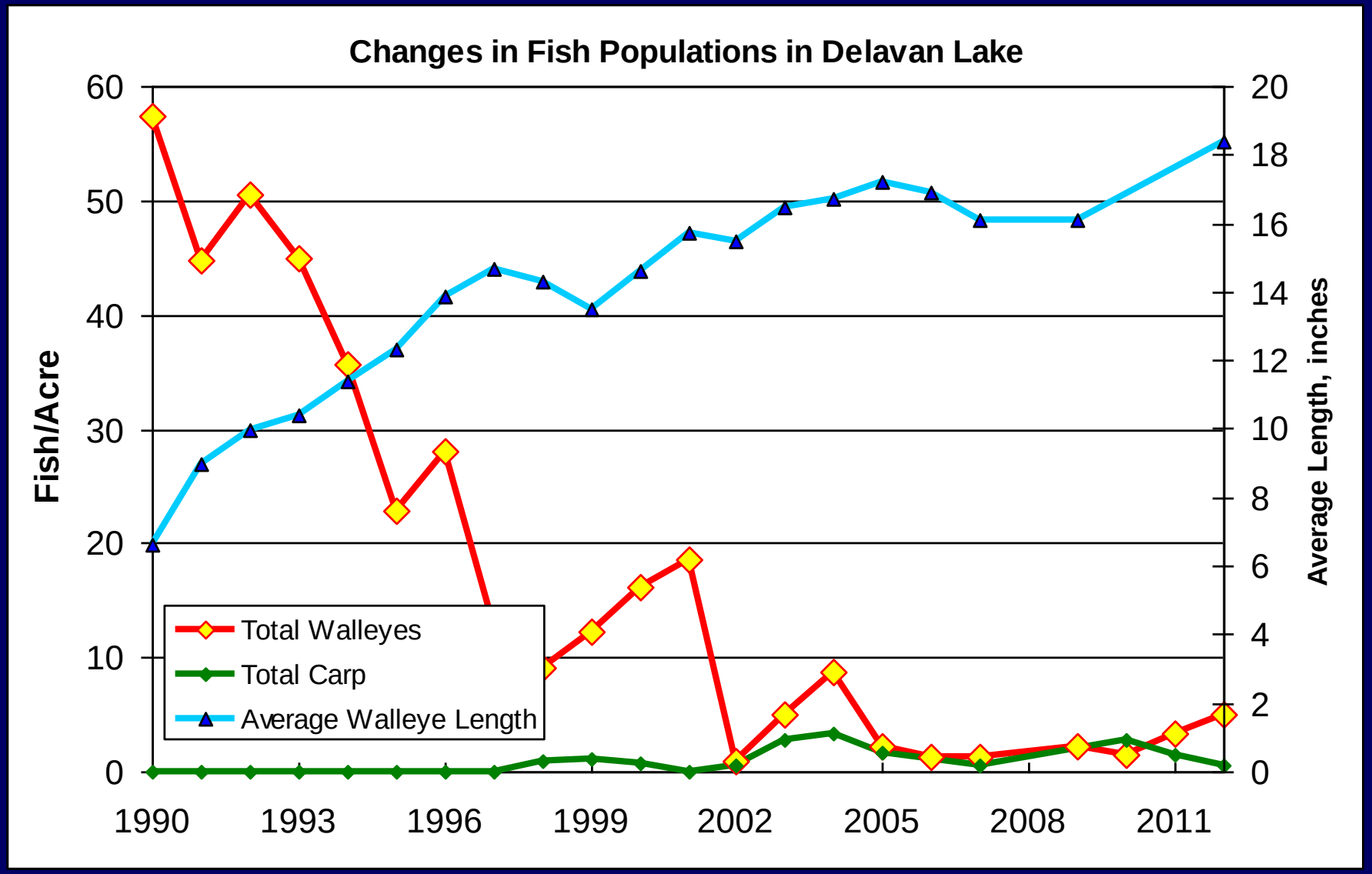
Trophic State of Delavan Lake



Manipulated

Post-Manipulated




Changes in Fish Populations in Delavan Lake
Fish/Acre
Average Length, inches
60
50
40
30
20
10
0
20
18
16
14
12
10
8
6
4
2
0
1990
1993
1996
1999
2002
2005
2008
2011
Total Walleyes
Total Carp
Average Walleye Length

LAKE DELAVAN
A FISHERY ON THE MOVE

■ *Geremachek Johnson*

FISHING HAS SLOWED SOMEWHAT RECENTLY ON THIS 2,000-ACRE SOUTHEASTERN WISCONSIN LAKE. HOWEVER, DELAVAN STILL PROVIDES EXCELLENT ACTION ON WALLEYES, BASS, PANFISH, NORTHERN PIKE AND EVEN SOME MUSKIES.

A strange thing happened in April 1998, when workers removed walleyes from Lake Delavan. What's going on? Is Lake Delavan's well-publicized late-1980s restoration project still working?

Yes, according to biologists, who are just fine-tuning the lake's management. And although fishing has slowed somewhat since the glory days immediately after the rehabilitation project, Delavan still provides excellent action on walleyes, bass, panfish, northern pike and even some muskies.

New Age, New Strategies

In one of Wisconsin's largest, most expensive lake rehabilitation projects, Lake Delavan was drawn down and treated in the late 1980s. Fishing was closed for two years. When the lake reopened, anglers found numerous species willing to bite.

In those days, fishing was sensational, which isn't unusual with newly restored lakes. Bluegill anglers caught buckets of big fish, walleye anglers had great catch-and-release action, and fishermen caught nice northerns, legal bass and even muskies. The lake gained a reputation as a sure bet. Almost any lure would work.

Fishing on Delavan has slowed since then, but biologists believe the lake is still on the right track.

A Fall 1998 survey revealed one surprise, though. Carp, which hadn't been seen since the restoration project, have returned to Delavan. Twelve carp between 14 and 20 inches were caught during the survey, although biologists had installed fish barriers to prevent this. However, Doug

covers about 2,000 acres and has a maximum depth of about 50 feet. It's narrow, and has dropping northern and southern shorelines like Geneva.

Jackson Creek flows into the shallow northern end near the park and public boat launch at Highway 50. On the northern shoreline, the lake's outlet flows toward Turtle Creek in the city of Delavan. This shallow area holds several bays. The outlet forms a bay and channel. Also, Lake Lawn Resort has a harbor on the lake's northeastern end, and a rock-bordered peninsula shapes a huge channel at the boat launch.

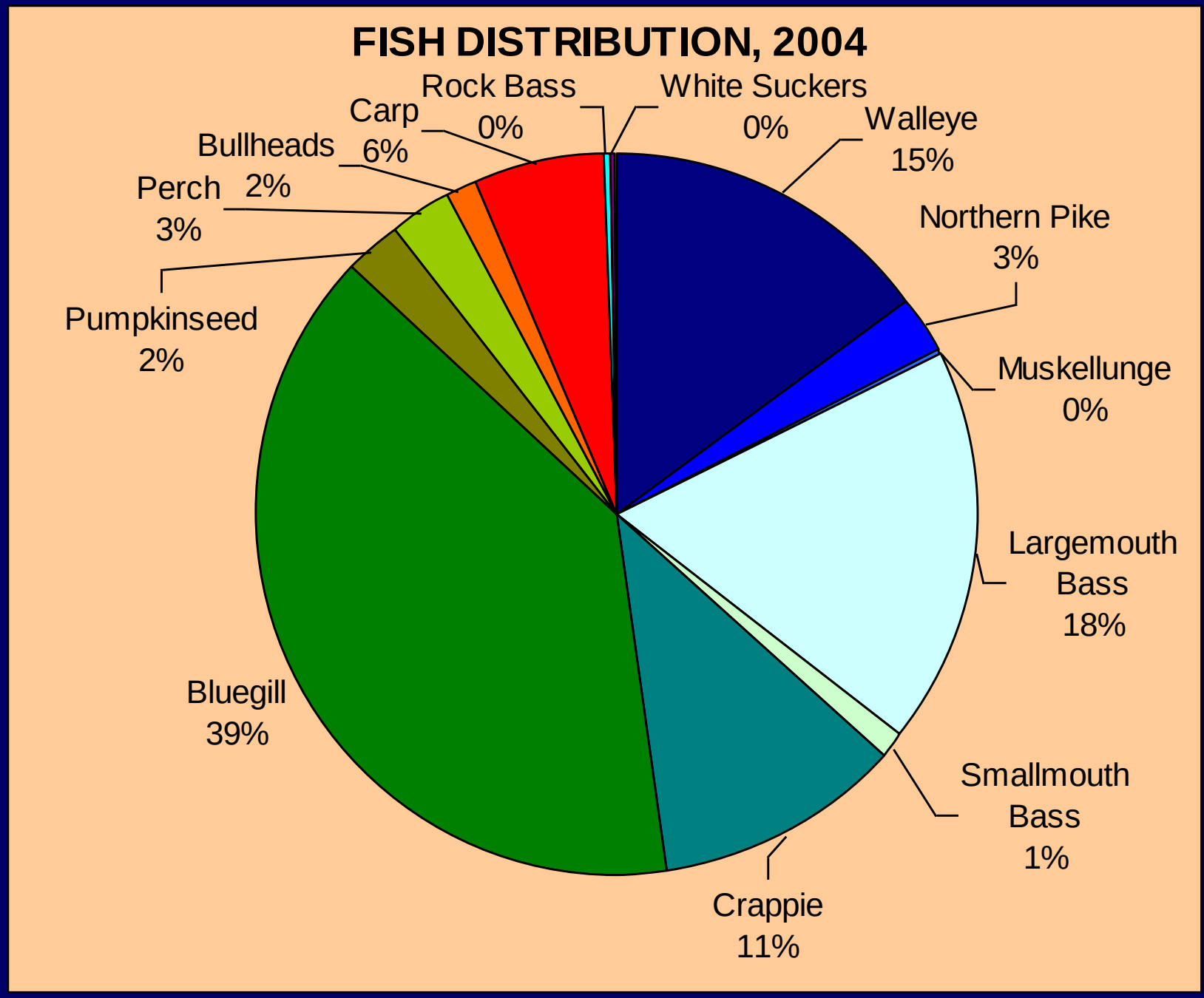
Delavan's far southwestern end has two shallow bays and some channels. The bays are separated by a peninsula called The Island. Another inlet, called Brown's Channel or Brown's Market, lies just north of The Island.

The lake also features several points. Cedar Point, or Yacht Club Point, juts out from the northern shoreline and creates the narrowest part of the lake. Willow Point sticks out from the lake's southwestern end, and an unnamed point juts out from South Shore Drive.

Walleyes Abound

In April 1998, biologists removed about 5,500 walleyes from Delavan and stocked them in other area lakes. They might remove more fish to further reduce Delavan's walleye population.

Why? A Fall 1998 survey indicated Delavan held too many walleyes. The survey catch rate was 72 fish per hour. Walleyes ranged from 5.9 to 19.9 inches, and the


FISH DISTRIBUTION, 2004
Rock Bass 0%
White Suckers 0%
Walleye 15%
Carp 6%
Bullheads 2%
Perch 3%
Northern Pike 3%
Pumpkinseed 2%
Muskellunge 0%
Largemouth Bass 18%
Bluegill 39%
Smallmouth Bass 1%
Crappie 11%

Badger State Crappie Hotspots

Do you have an itchin' for some open-water fishin'? The crappies in these waters can fill your needs.

by Dan Small

Wisconsin anglers itching for some open-water action would do well to plan an outing or two for crappies this spring. Hundreds of lakes throughout the Badger State offer good fishing for crappies, which in many cases are the most abundant panfish available. Abundant does not always mean easy to catch, however. These speckled panfish can be downright closed-mouthed at times, refusing even the most delicious morsel presented oh-so delicately on light tackle. At other times, they will bite anything you throw at them and do it so fast that you have a hard time keeping a line in the water.

Both black and white crappies inhabit Wisconsin waters. Black crappies have dark specks scattered all over a white body in uneven rows that thin out from the top of the fish to the bottom. White crappies look paler and bleached out by comparison, with distinct dark vertical bars over a creamy background. They frequent the same habitat and can be caught by the same methods. Most anglers can't tell them apart.

In winter, crappies often suspend at middepth in the water column, either in the middle of a lake or adjacent to a steep dropoff or other deep structure. In spring, as spawning time approaches, they gradually move shallower until they are in a few feet of water in reeds, over a marl or hardpan bottom, or along rock riprap.

Crappie populations are cyclical on most lakes, with a couple boom years followed by three or four bust years before their numbers rebuild. The lakes detailed here are waters where crappie numbers are currently high, or where consistent natural reproduction sustains them at high levels for years at a time. In other words, these are some of the very best crappie hotspots in the Badger State.

DELAVAN LAKE

Delavan Lake is one of our state's great fish-management success stories. In 1989, this 2,072-acre Walworth County lake was drawn down, poisoned to remove carp, then refilled and stocked with a variety of game fish and panfish. The result has been a tremendous fishery that has stayed strong for well over a decade, according to Department of Natural Resources fisheries biologist Doug Welch.

Crappies are abundant here, and there are several strong year-classes currently available. In winter, they suspend over deep water. When the ice goes out, you'll still find them suspended, where jigging spoons will take them.

When the water begins to warm, look for papermouths on shallow bars, along deep weed edges and around emergent bulrushes. Good spring spots include the mouth of Brown's Channel and near the public landing off Highway 50 on South Shore Drive, the best landing on the lake.

Anglers do well with small minnows and tiny jigs tipped with small plastic tails or Berkley Gulp baits. Scale down your offerings and your line diameter when crappies are shallow, because they often bite very lightly during this pre-spawn period.

For bait, tackle, guide service and fishing information, try Brian Gates at Geneva Lake Bait & Tackle in Williams Bay, (262) 245-6150.

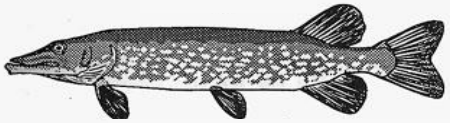
BEAVER DAM LAKE

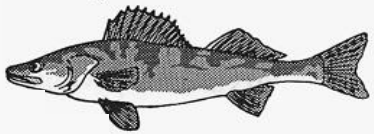
Located in western Dodge County, this 6,500-acre lake is my favorite for spring crappies. There is little structure in this shallow, sprawling lake, so crappies roam the open water most of the year. In spring, though, they move onto the flats along the north shore where they will spawn in a month or so.

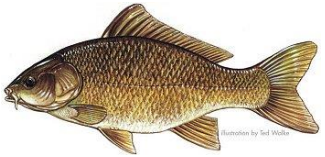
DNR fisheries biologist Laura Stremick-Thompson surveyed the crappies there last October. She found

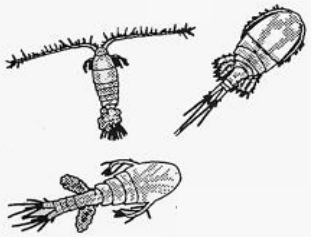
Manipulated

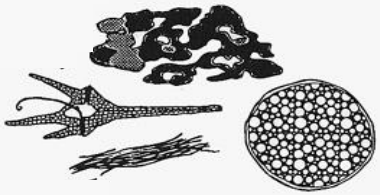
Post-Manipulated





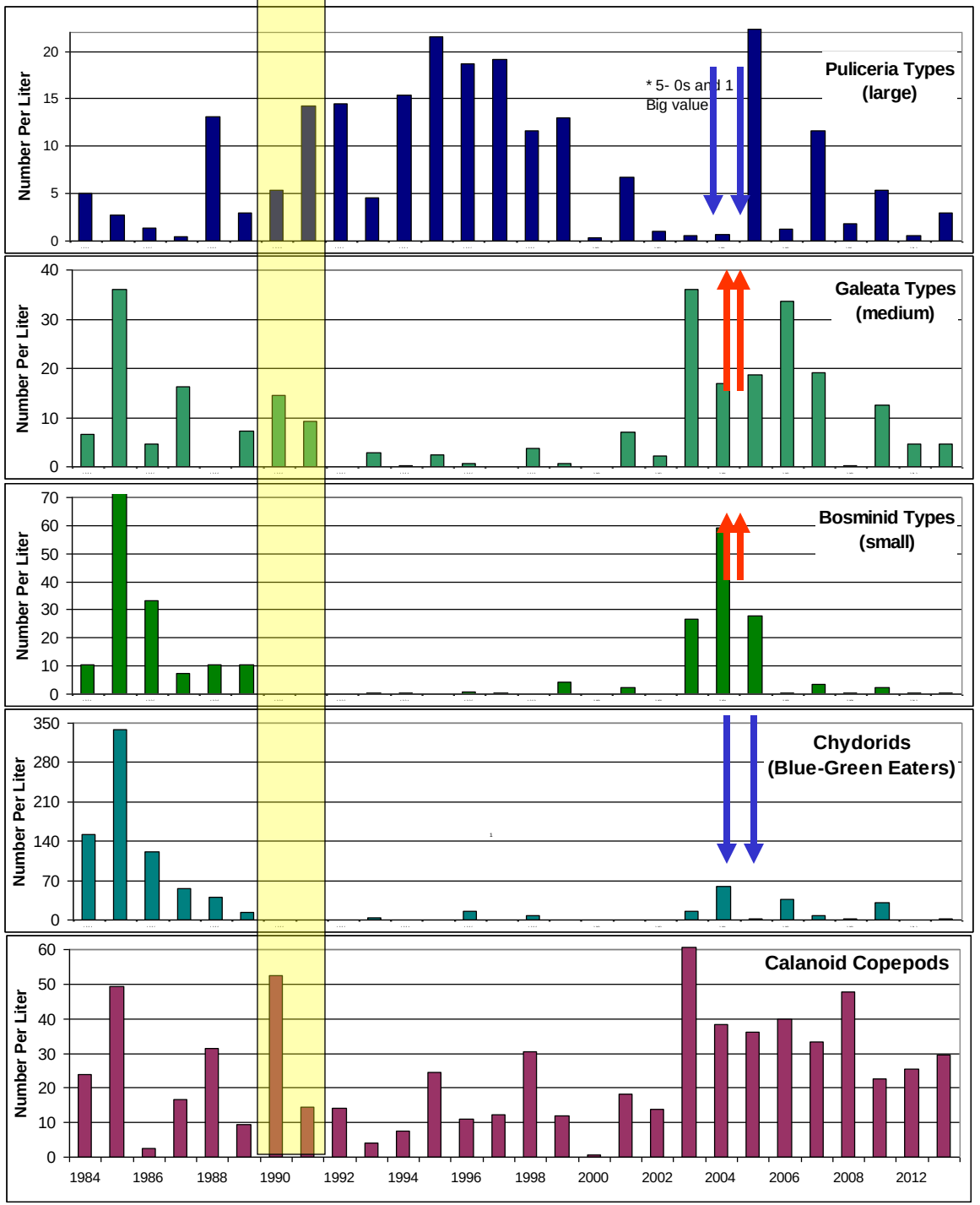




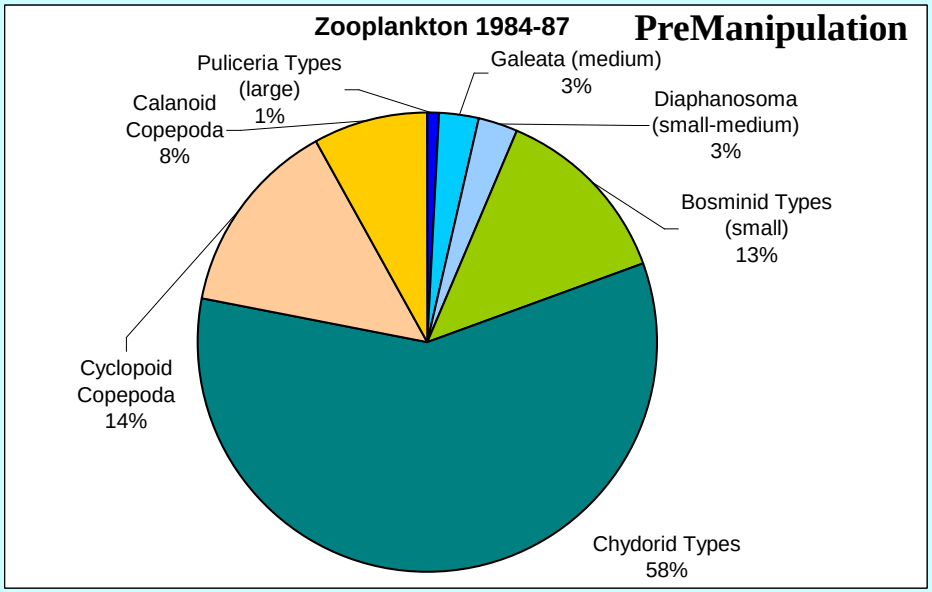


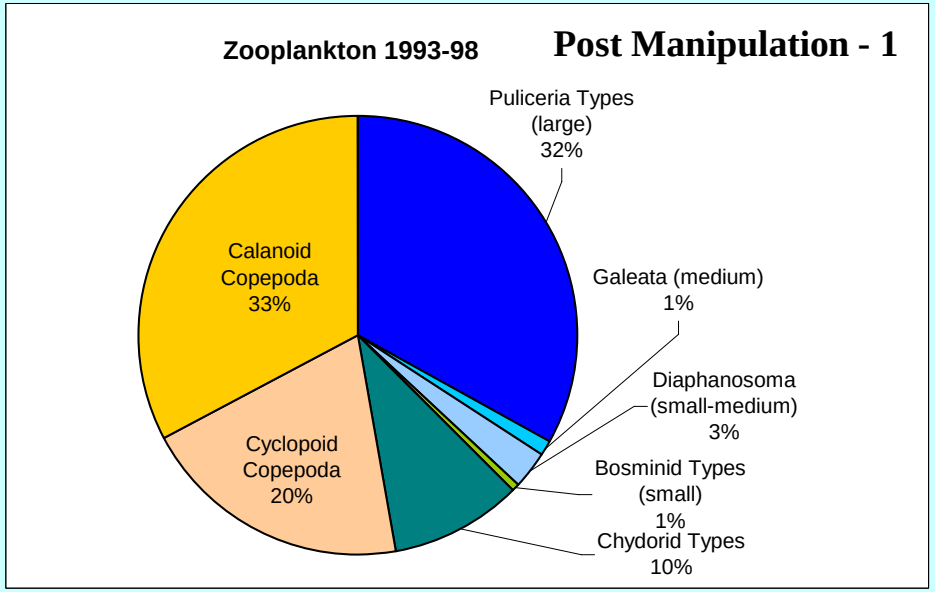
NUTRIENTS

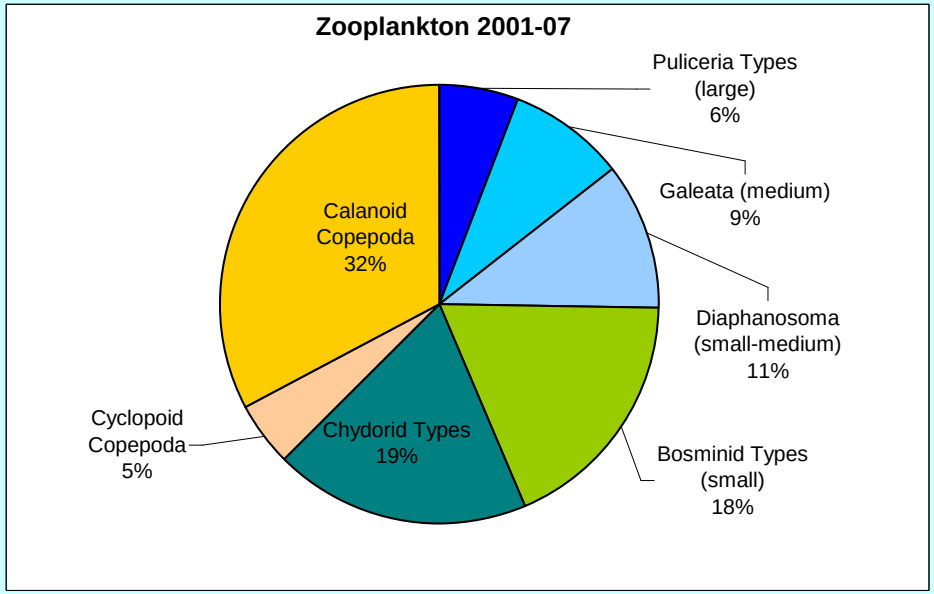
Zooplankton Populations



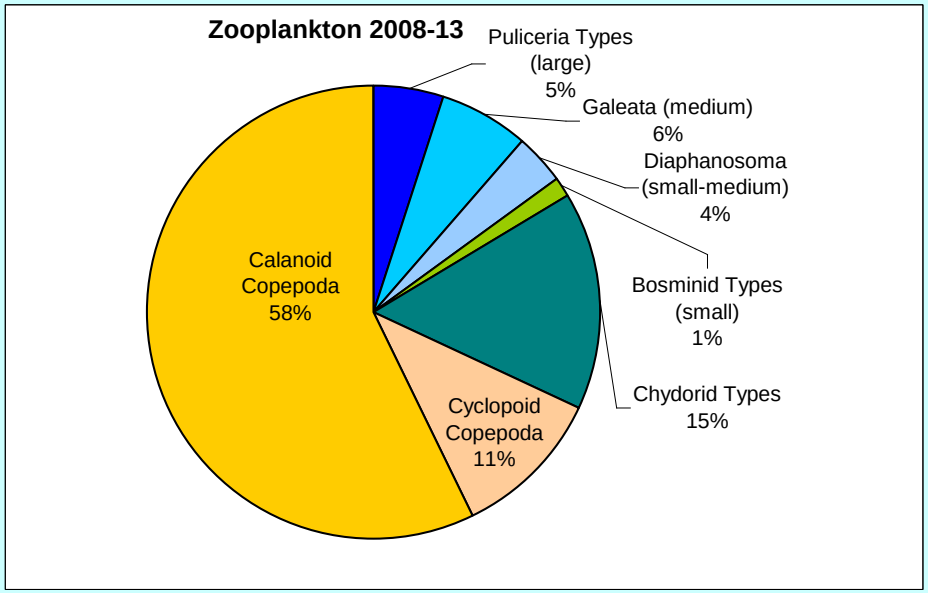
Four Different Biological Periods





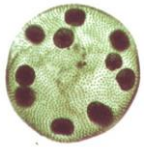


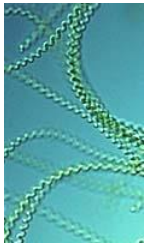
Post Manipulation - 2

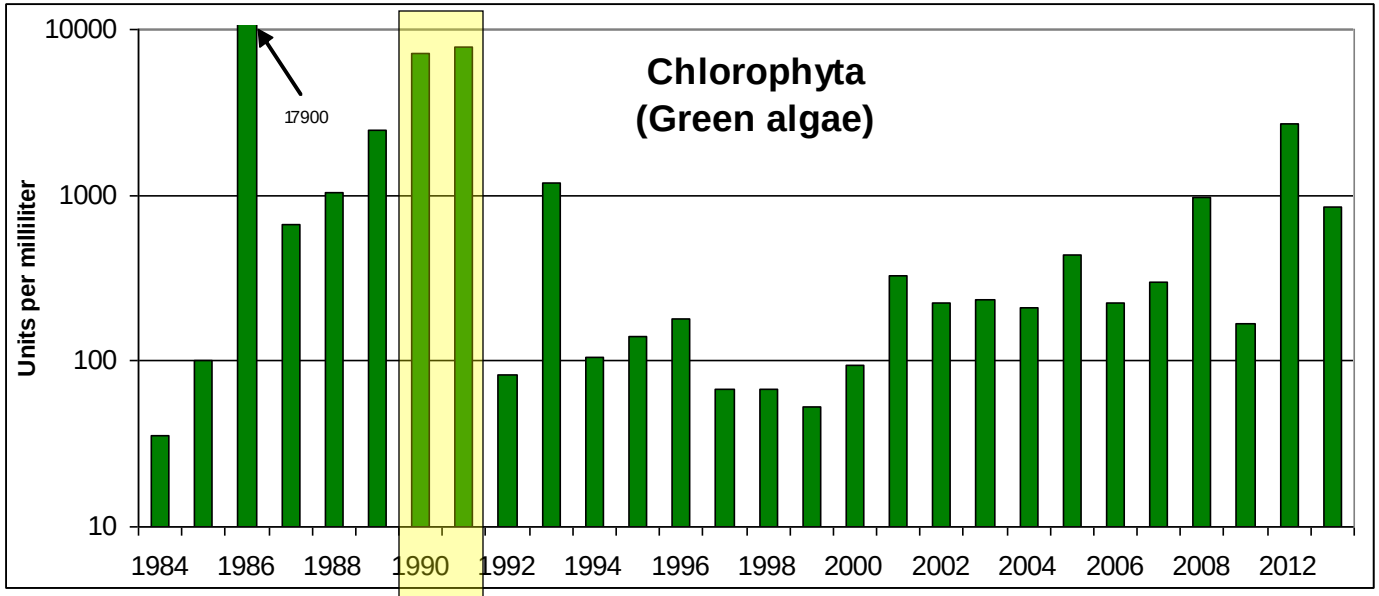


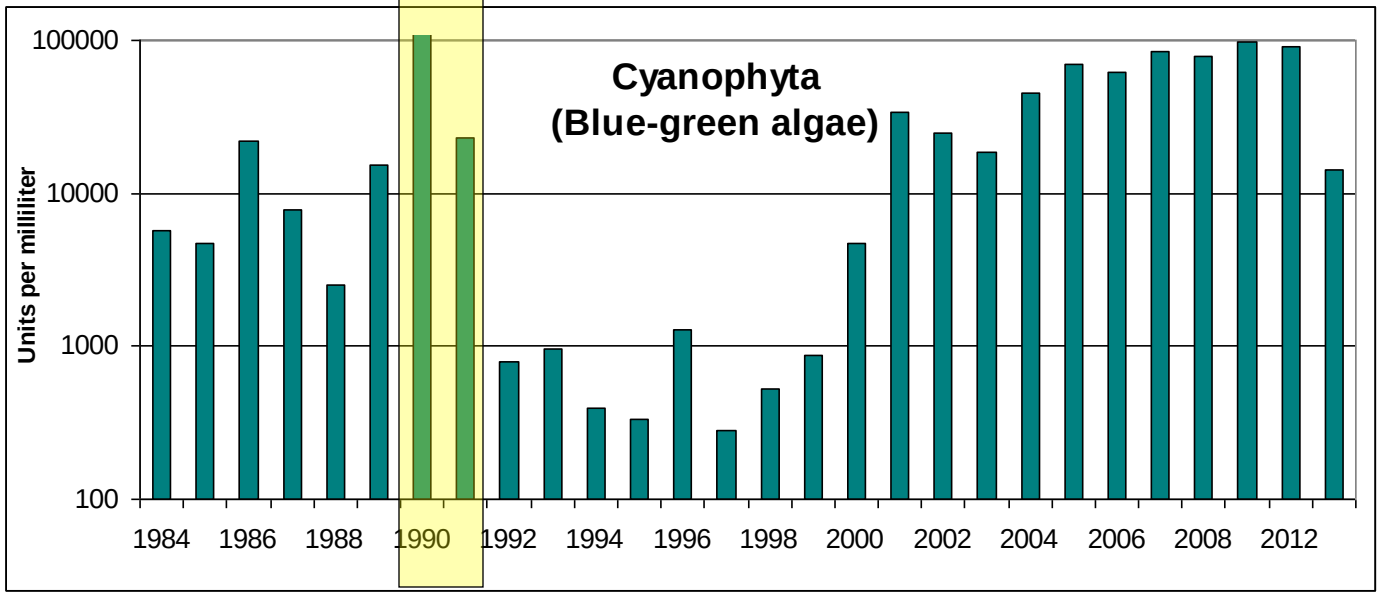
Post Manipulation - 3

Phytoplankton Populations



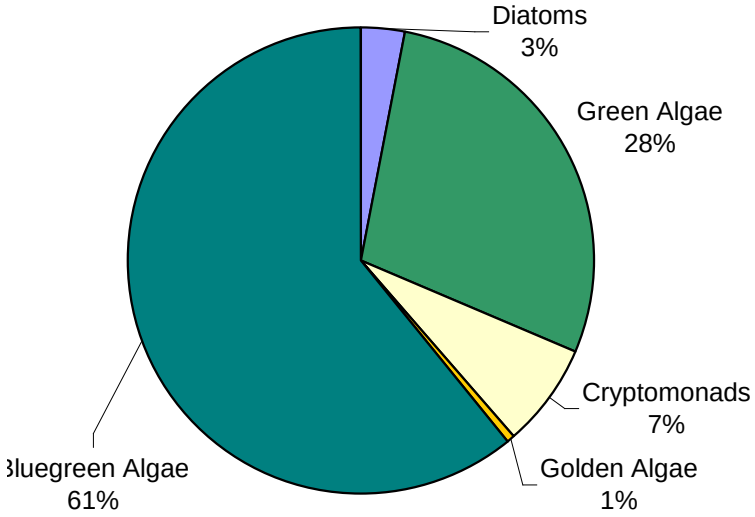






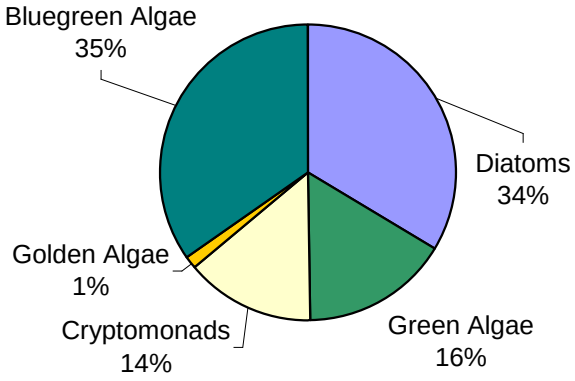
Phytoplankton Population - 1984-87

PreManipulation

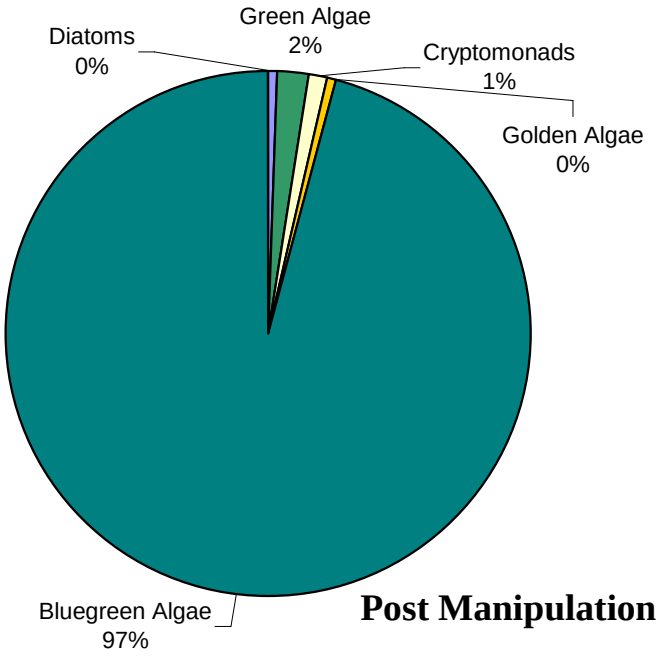


Phytoplankton Population - 1993-98

Post Manipulation - 1

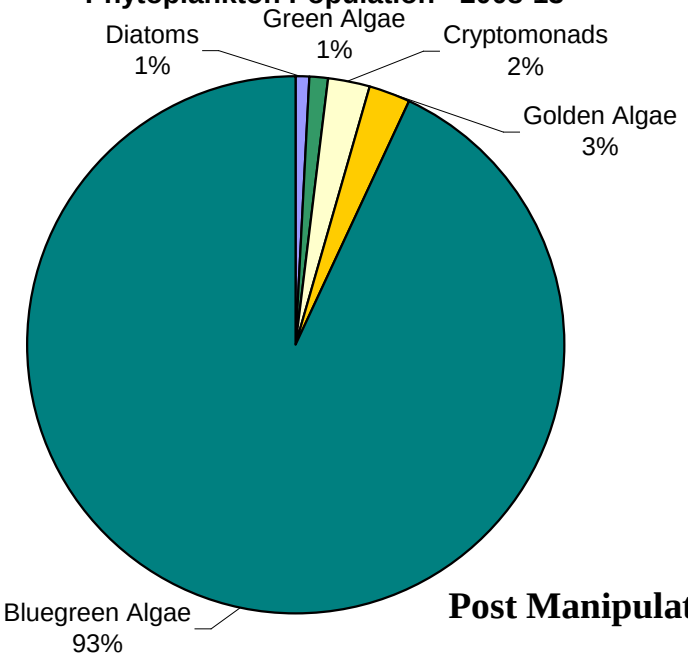


Phytoplankton Population - 2001-07



Post Manipulation - 2

Phytoplankton Population - 2008-13



Post Manipulation - 3

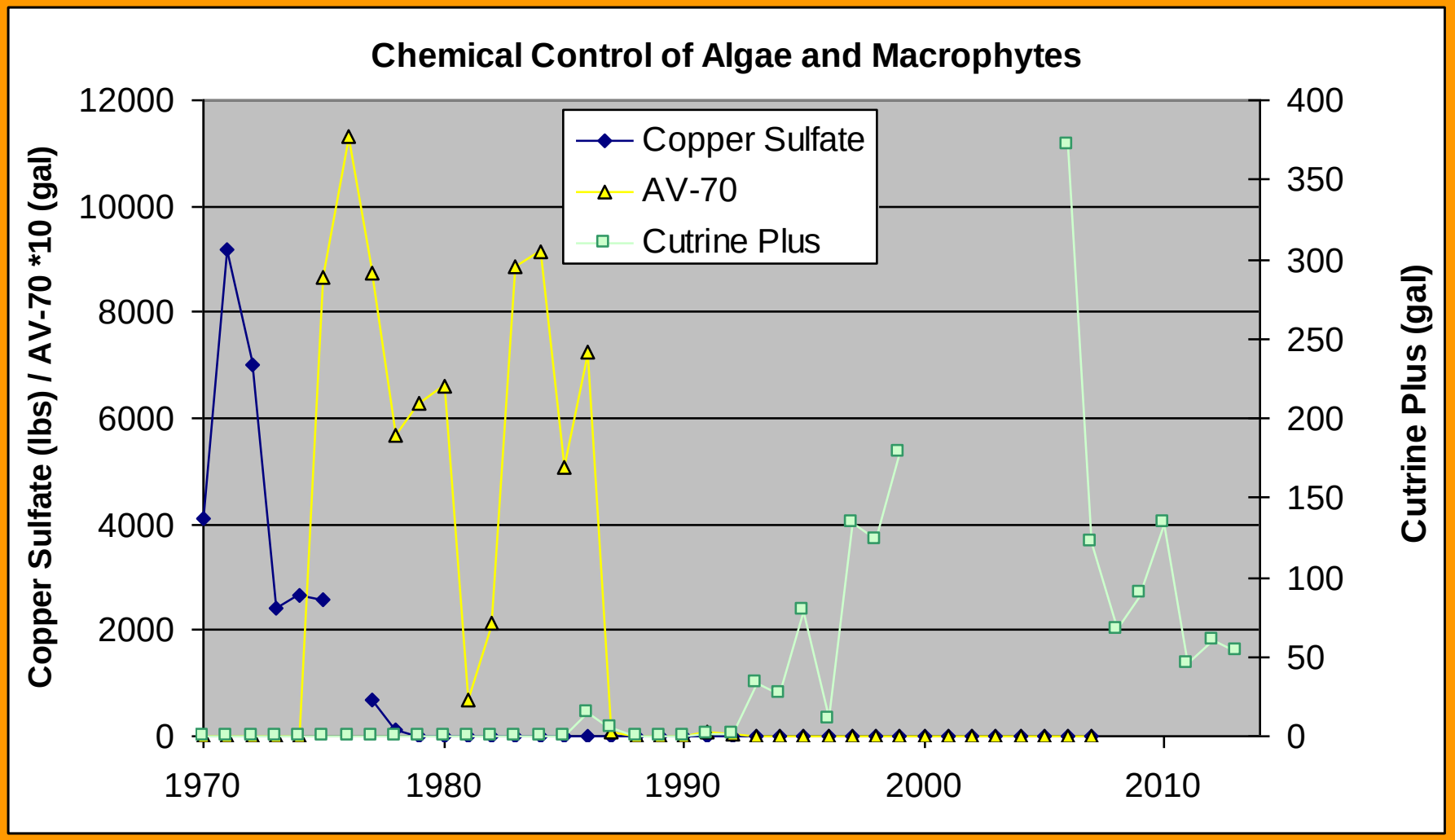
Increased Macrophyte Production

Filamentous Algae Growth

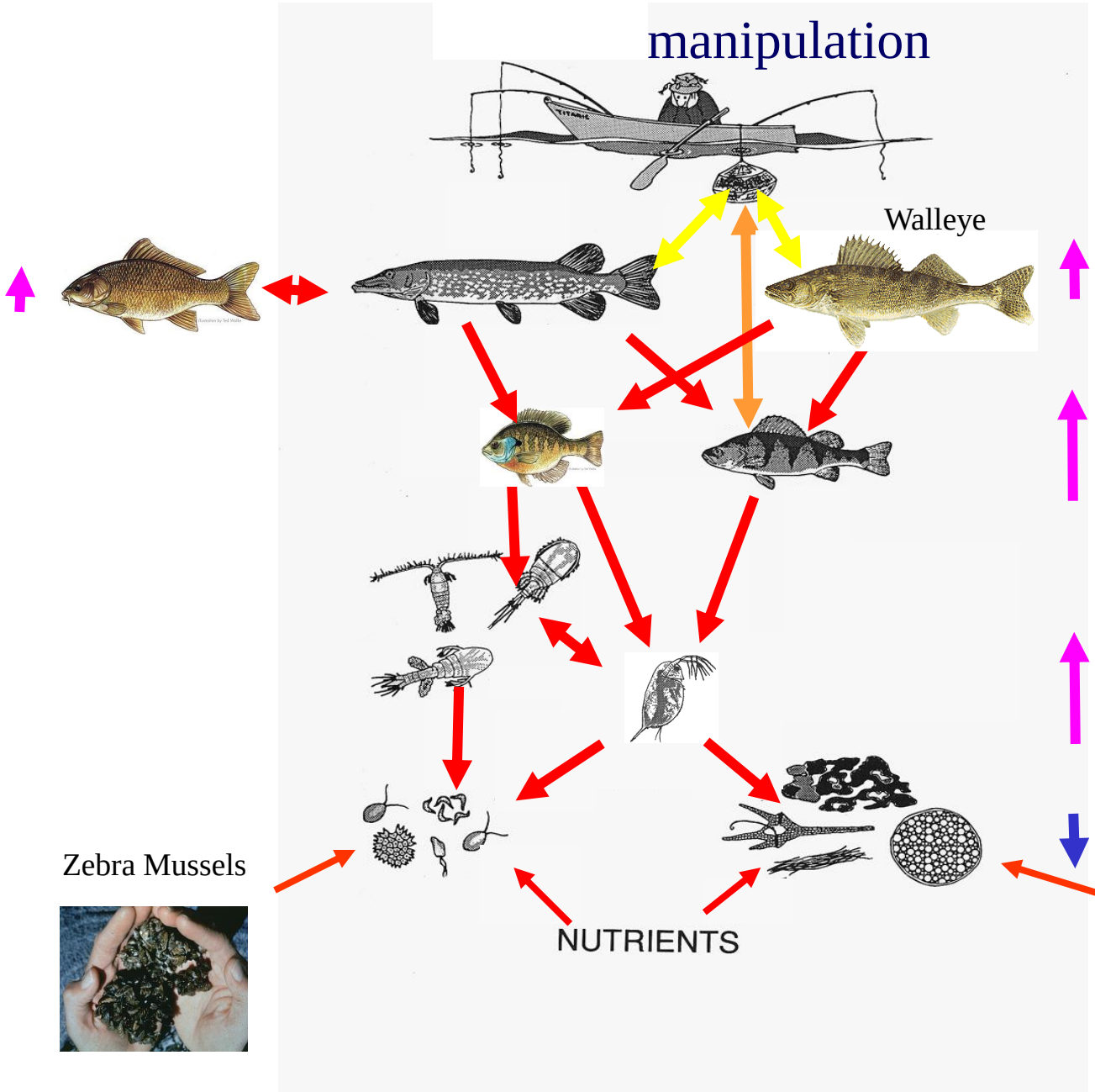
- Growth high in all shallow regions without macrophytes


Introduction of Zebra Mussels

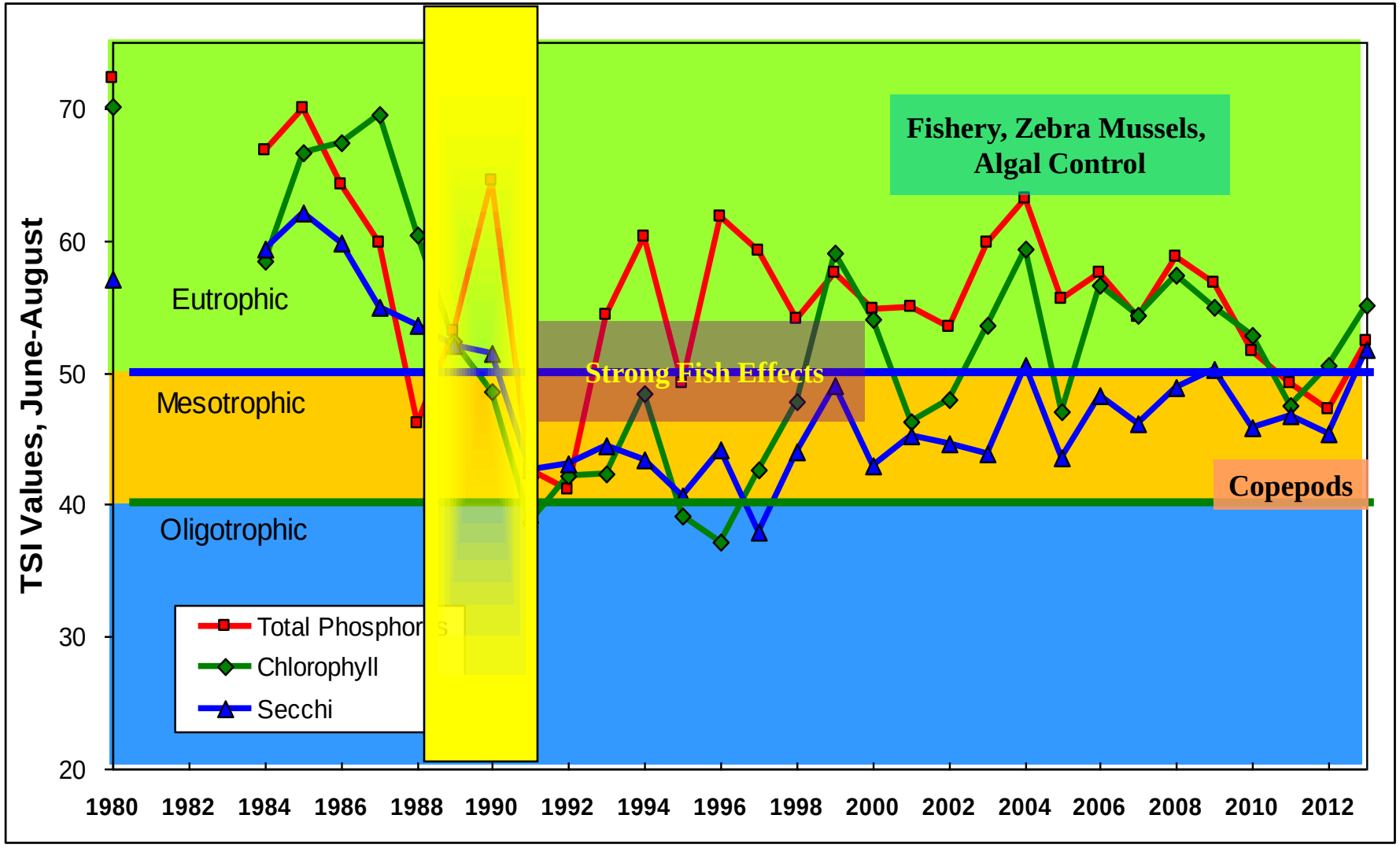

Delaware Lake
Sanitary District
Handy Tips To Conserve Water
• Take shorter showers
• Only do full loads of wash
• Run dishwasher when fully loaded
• Water lawn & garden as needed, early A.M.


Chemical Control of Algae and Macrophytes
Copper Sulfate (lbs) / AV-70 *10 (gal)
Cutrine Plus (gal)
Copper Sulfate
AV-70
Cutrine Plus
12000
10000
8000
6000
4000
2000
0
400
350
300
250
200
150
100
50
0
1970
1980
1990
2000
2010

Biomanipulations in Delavan Lake



Trophic State of Delavan Lake



Conclusions

Rehabilitation Program

1. Overall the Rehabilition was a Success, but the level of Success depends on what part is examined.

2. Phosphorus concentrations on inflows have dropped almost 50%.

3. Water clarity and fish populations remain good, but clarity is decreasing, especially late in the summer.

4. Macrophyte and filamentous algae growth very high, now mid- and late-summer algal blooms.

5. Walleye populations have declined, but now a strong fishery; the lack of carp, and possibly effects of zebra mussels maintain a weak trophic cascade.

6. Need to fix the source of the problem (phosphorus loading), otherwise any action will be a temporary fix.

Continuing to Look to the Future

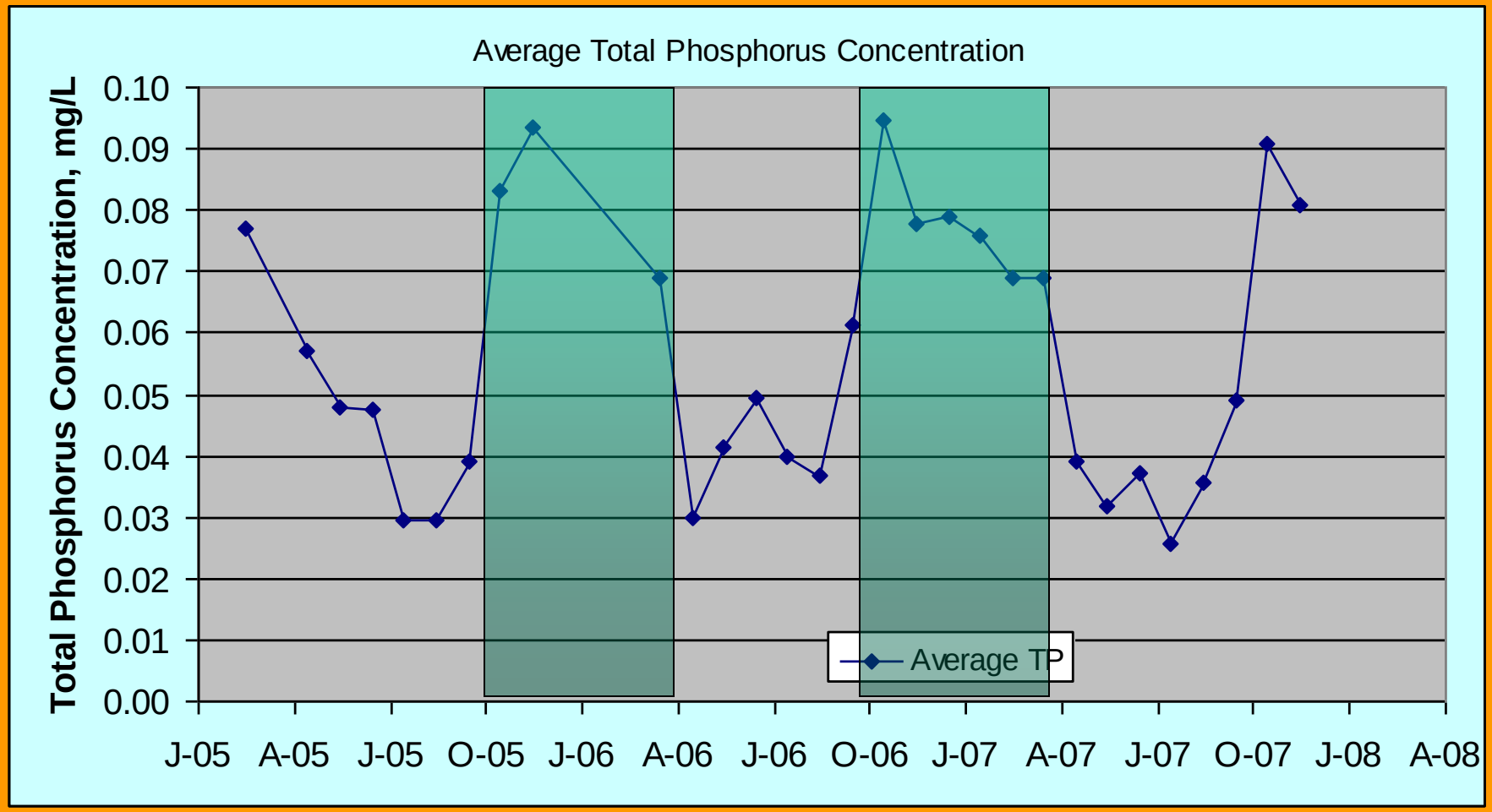
Could Algal Blooms Again Become More Common?
Extensive Algal Blooms of 2007


Will Climate Change Affect Productivity??


Will potential future development affect the Phosphorus loading to the lake??


What can be done to protect the lake??

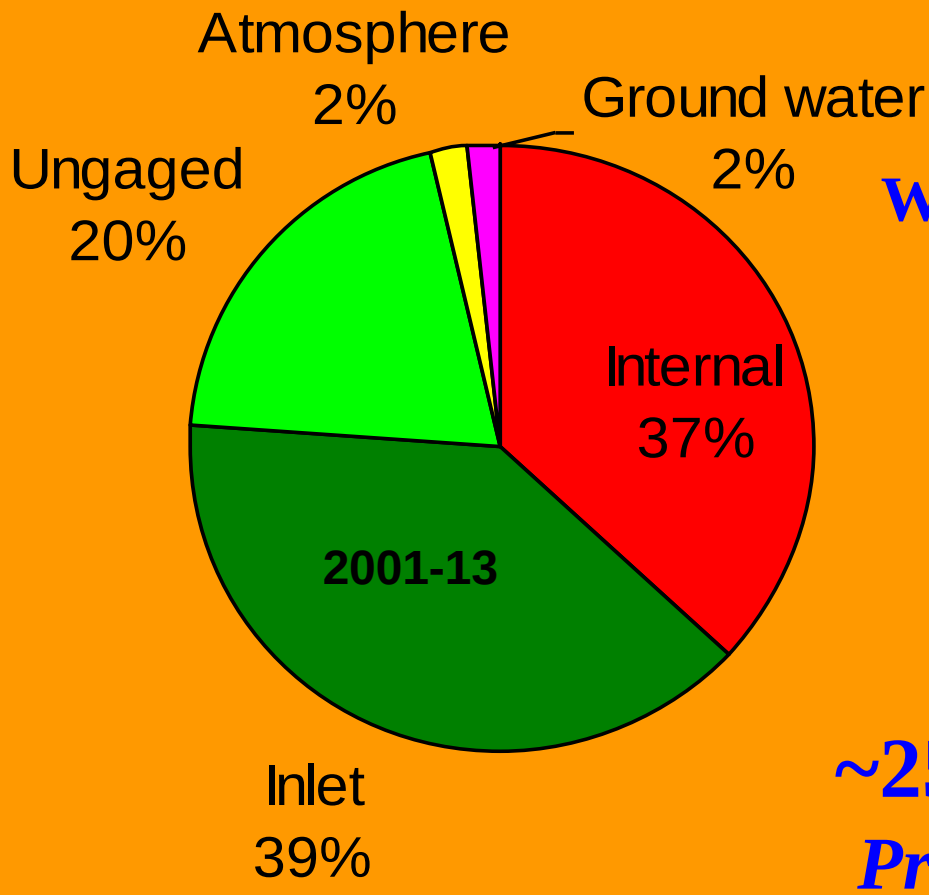
Examination of Possible Actions



Considering modifications to lake withdrawal patterns

Examination of Possible Actions

Total Phosphorus Loading in 2001-13

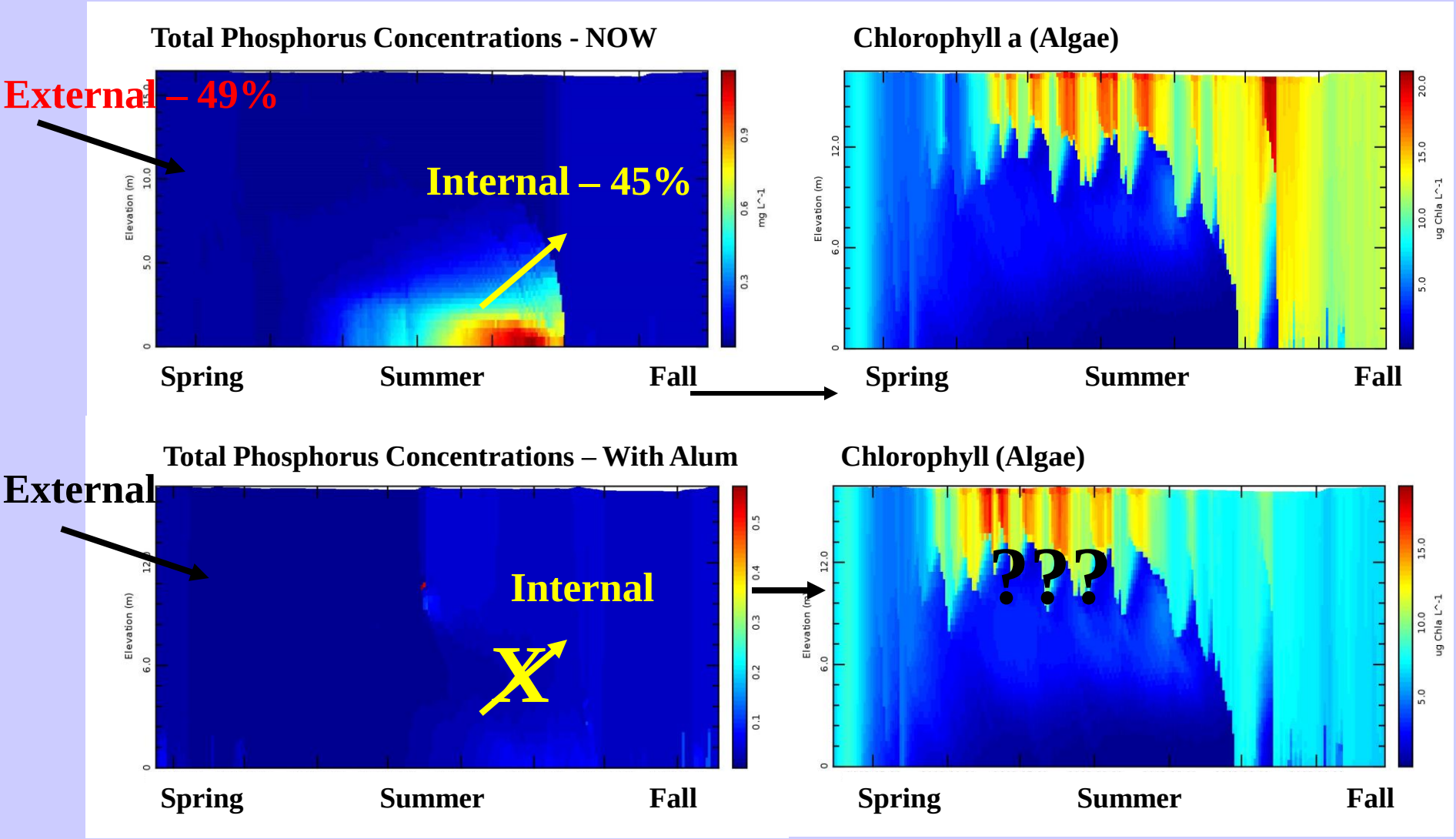


Would another Alum Treatment help?

~25% Reduction So Far

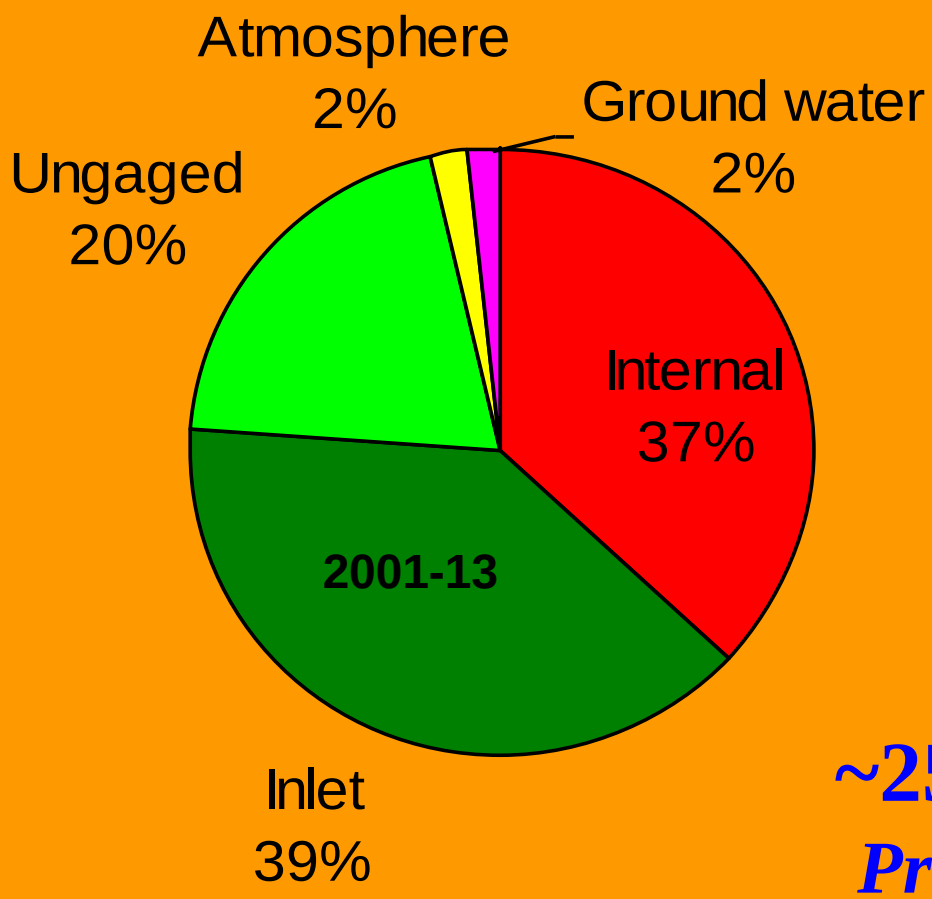
Present Loading ~6,000 kg

Evaluation of the Importance of Internal Phosphorus Loading with DYRESM-CAEDYM



Examination of Possible Actions

Total Phosphorus Loading in 2001-13



Where to Go from here??

Alum Treatment?

Biomanipulation?

~25% Reduction So Far

Present Loading ~6,000 kg

Use Scientific Information in the Long-term Maintenance of Delavan Lake, Wis.

Long-Term Rehabilitation of Delavan Lake, Wisconsin, USA: Importance of Biological Interactions

Questions??

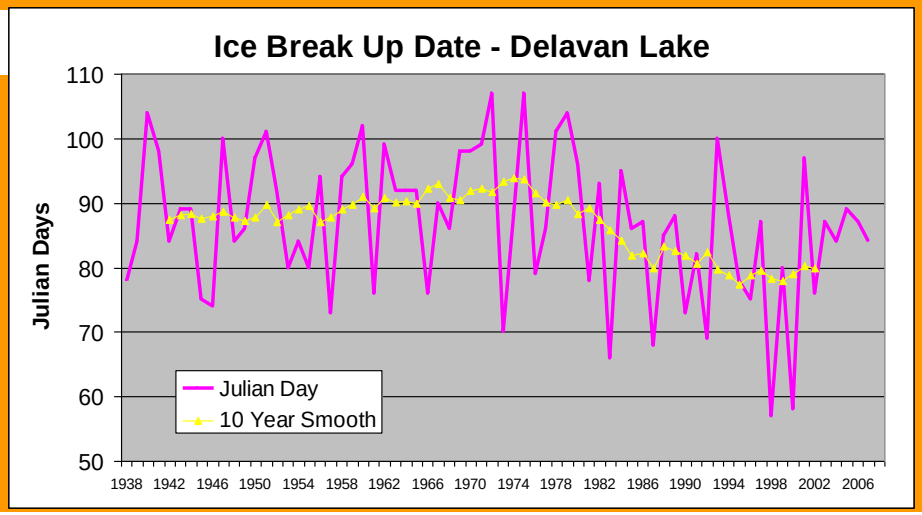
Dale Robertson
U.S. Geological Survey
Contact Information
Email: dzrobert@usgs.gov
Tele: 608-821-3867

Net Effect of Fall Winter Drawdown							
Inches Removed	Meters	Area (m2)	m3	liters	Delta TP	Extra TP (mg)	Net TP Loss (kg)
6 inches	0.15	6963558	1,061,246	1,061,246,207	0.05	53062310	53
9 inches	0.23	6963558	1,591,869	1,591,869,310	0.05	79593465	80
12 inches	0.30	6963558	2,122,492	2,122,492,413	0.05	106124621	106
24 inches	0.61	6963558	4,244,985	4,244,984,826	0.05	212249241	212
36 inches	0.91	6963558	6,367,477	6,367,477,239	0.05	318373862	318

Changes in Lake & Reservoir Ecosystems Caused by Climate Change

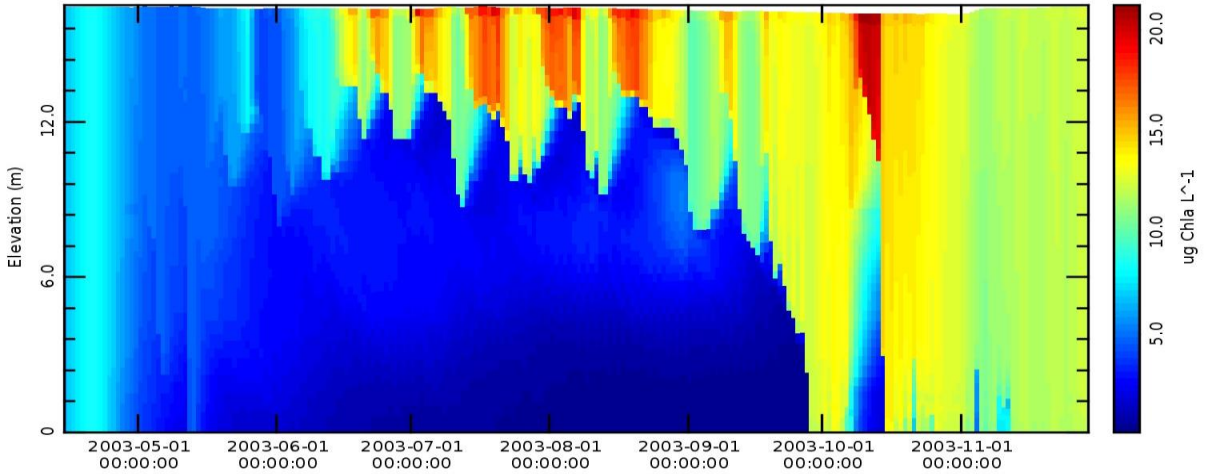
(USGS Climate Change Proposal – Robertson, Green, Heisey, and Hamilton)

Ice Cover



Productivity

Chlorophyll a (Algae)



Establishing New Water Quality Goals for Delavan Lake

Justification:

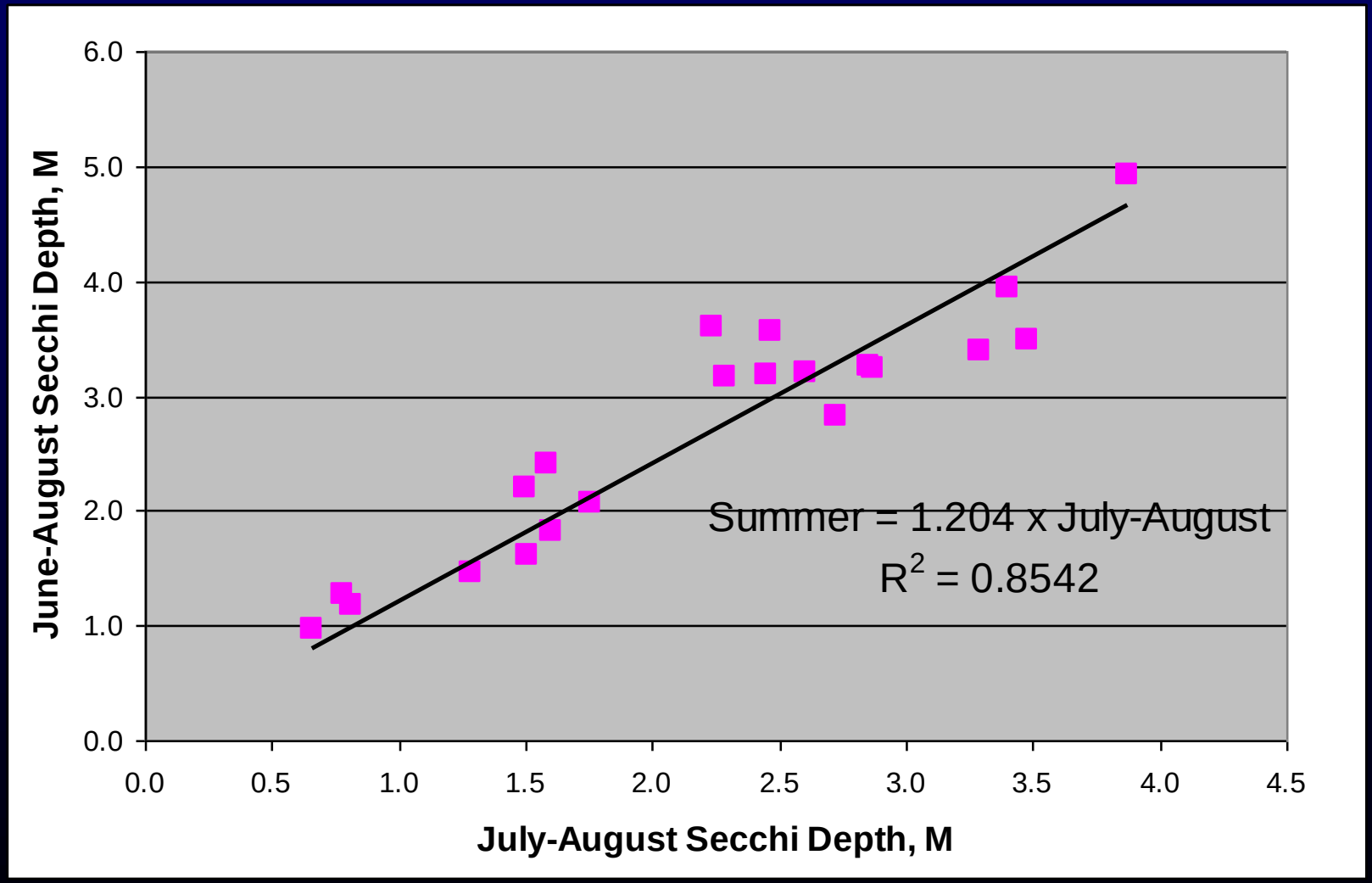
1. Although water clarity is good now, it could decrease as the biomanipulation and other factors change (act more like a typical lake).

Given the present loading and a TSI_{TP} of 55.6
Expect a Chlor a of 13.1 ug/L - - 8.1 ug/L measured
Secchi depth of 1.33 m -- 3.1 m measured

2. Strong seasonality in Secchi Depth and Chlorophyll; therefore, want to set a goal for just July/August

Goal: 1.5 m average Secchi Depth for July/August

What Summer average Secchi Depth is needed to obtain a 1.5m July/August Secchi depth ? >>1.8 m



Goal – 1.8 m Summer Average Secchi Depth

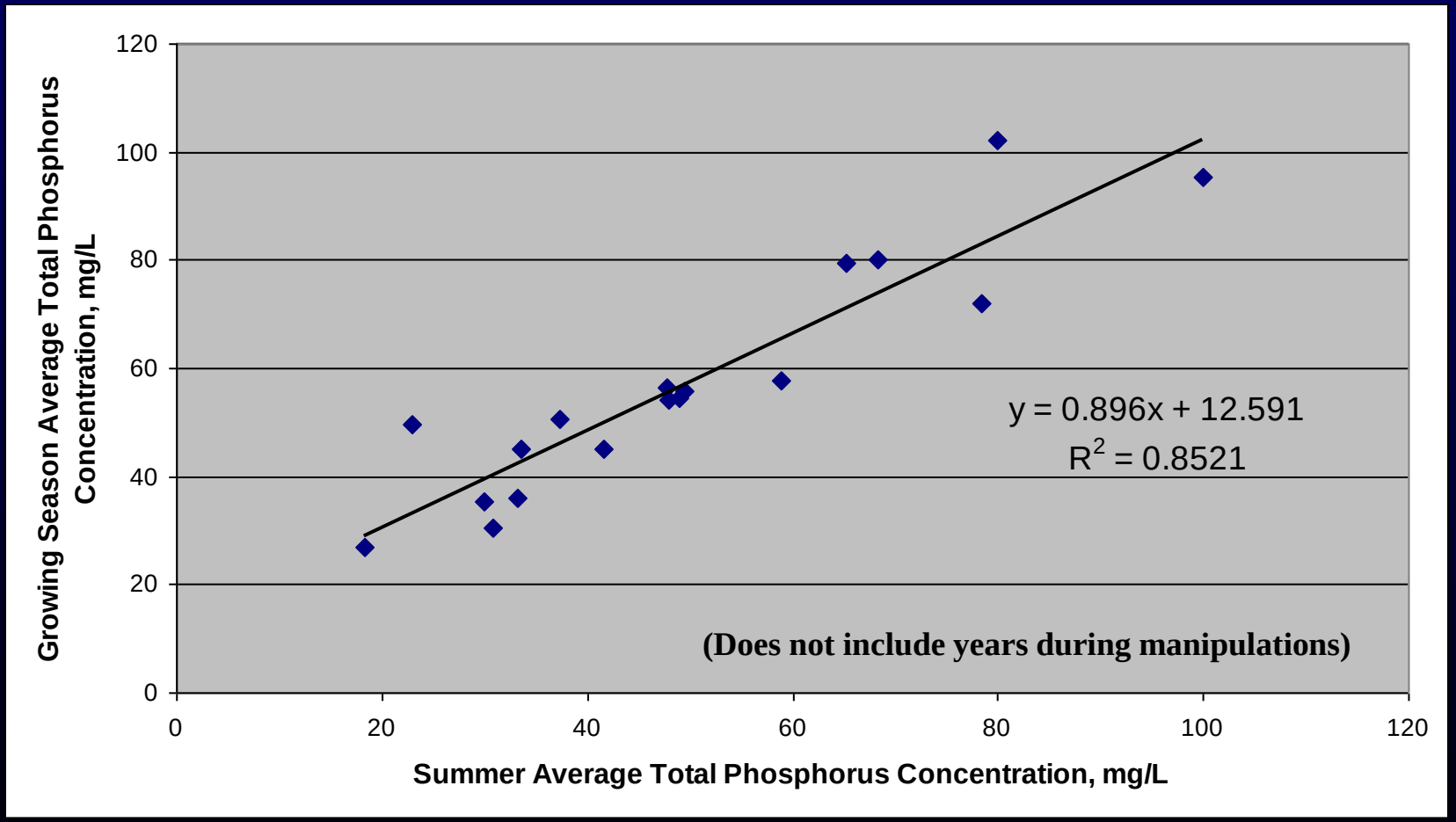
1.8 m Summer Secchi >> TSI of 51.45

TSI of 51.45 >> Summer average Chlorophyll a of 8.4 ug/L

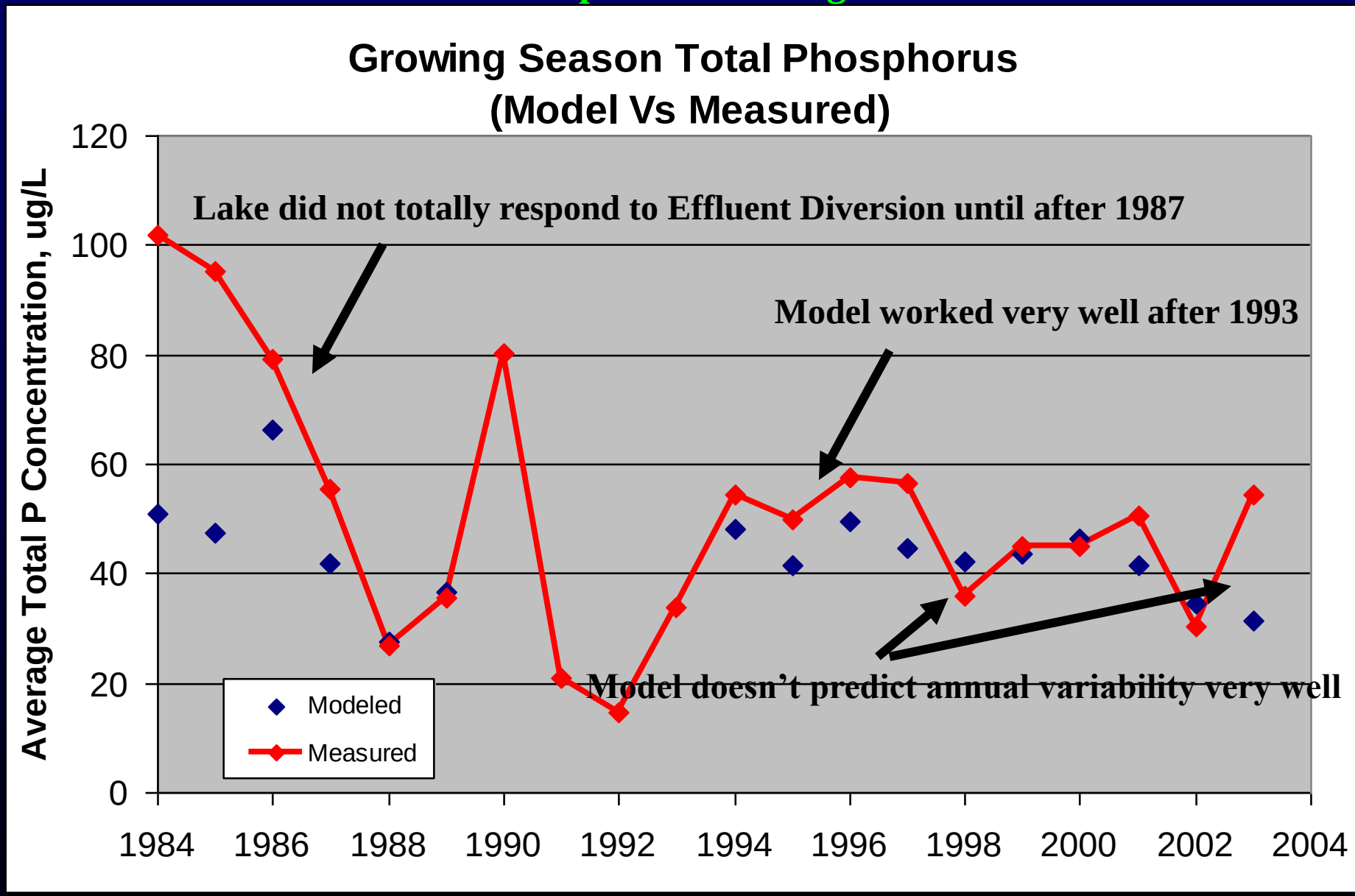
TSI of 51.45 >> Summer AverageTotal Phosphorus of 26.6 ug/L

What Growing Season Total Phosphorus is needed to obtain a 26.6 ug/L Summer Total Phoshorus Conc ?

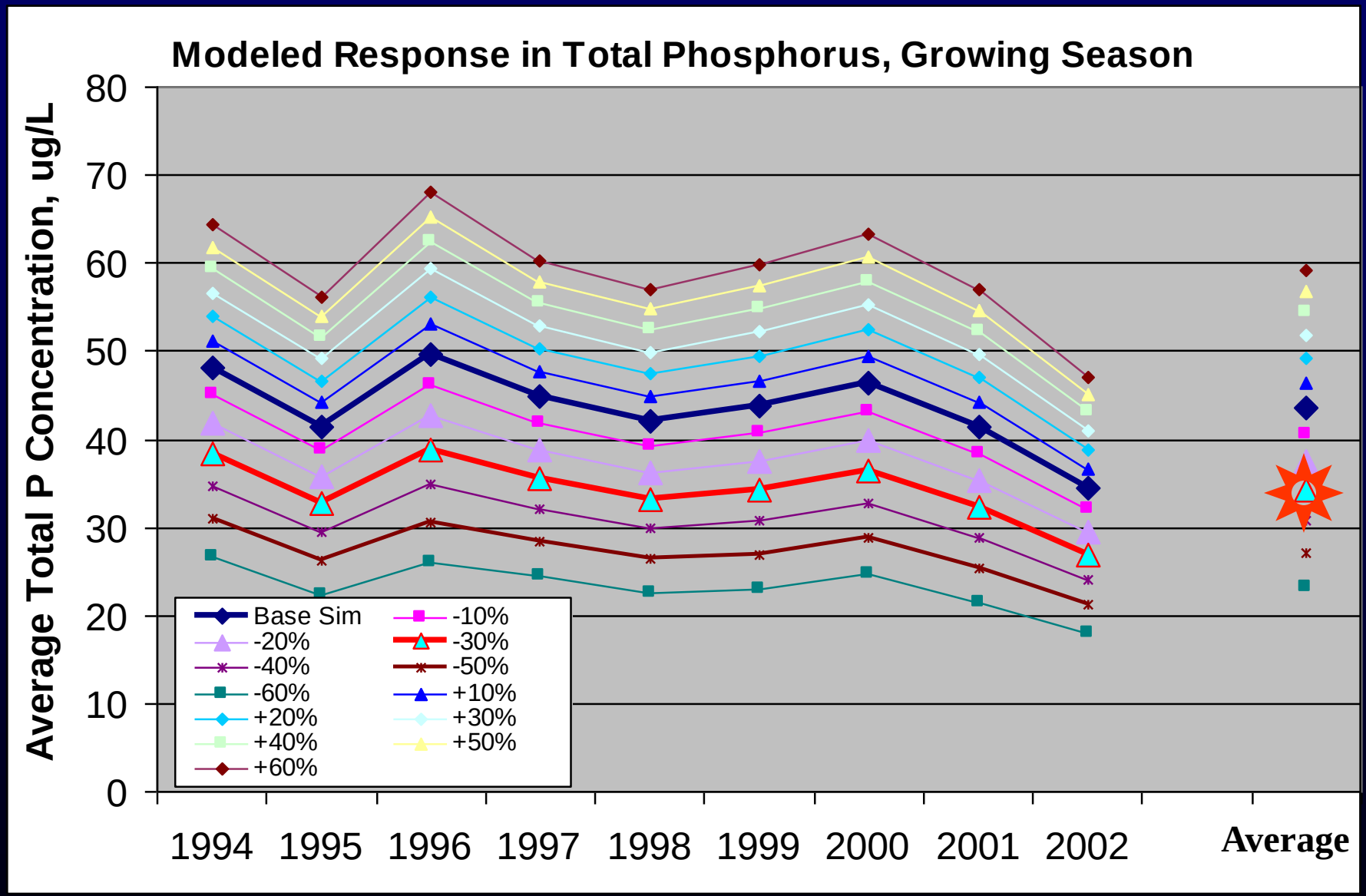
>>>> 36.4 ug/L



Used Empirical Models to predict Delavan Lake's response to Total Phosphorus Loading



To Reach the 1.5 m Secchi Goal for July/August need a 24.5-32% reduction in Total Phosphorus Loading

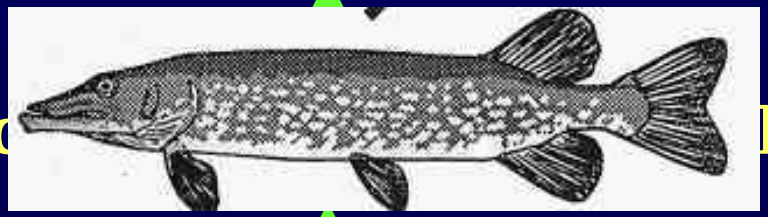


Establishing New Goals for Delavan Lake

Maintain Water Clarity – Average July/Aug Secchi

pth at ~1.5 m (~1.81 June/Aug Secchi)

81 m Sec



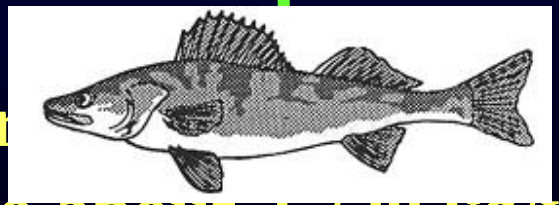
TSI of 51.45

TSI of 51.45 equates to a summer TP of 26.6 ug/L or

rowing Season TP of 36.4 ug/L

Decrea

ter



the lake from about

3,800 kg/yr to about 2,720 kg/yr (28% reduction)

Rehabilitation Efforts

1981 - Sewage Diversion from the City of Elkhorn

1989-91

External Treatments

1. Better WatershedManagement - Use of BMPs
2. Construction of Wetland on Jackson Creek Tributary

Internal Treatments

1. Short Circuiting of Primary Inflow
    - Original plan
    - extend peninsula
    - build channel
  - Implemented
    - slightly extended peninsula
    - small channel
2. Alum Application
    - eliminate TP release during anoxia
3. Biomanipulation -
    - remove all fish
    - develop a fishery to result in large zooplankton

Evaluation of the Importance of Internal Phosphorus Loading with DYRESM-CAEDYM