Evolution of Phosphorus Criteria for Lakes and Reservoirs

Tim Asplund and Matt Diebel
Wisconsin DNR

Wisconsin Lakes Convention
April 11, 2013

Acknowledgements

- Jim Baumann
- Paul Garrison
- Tim Simonson
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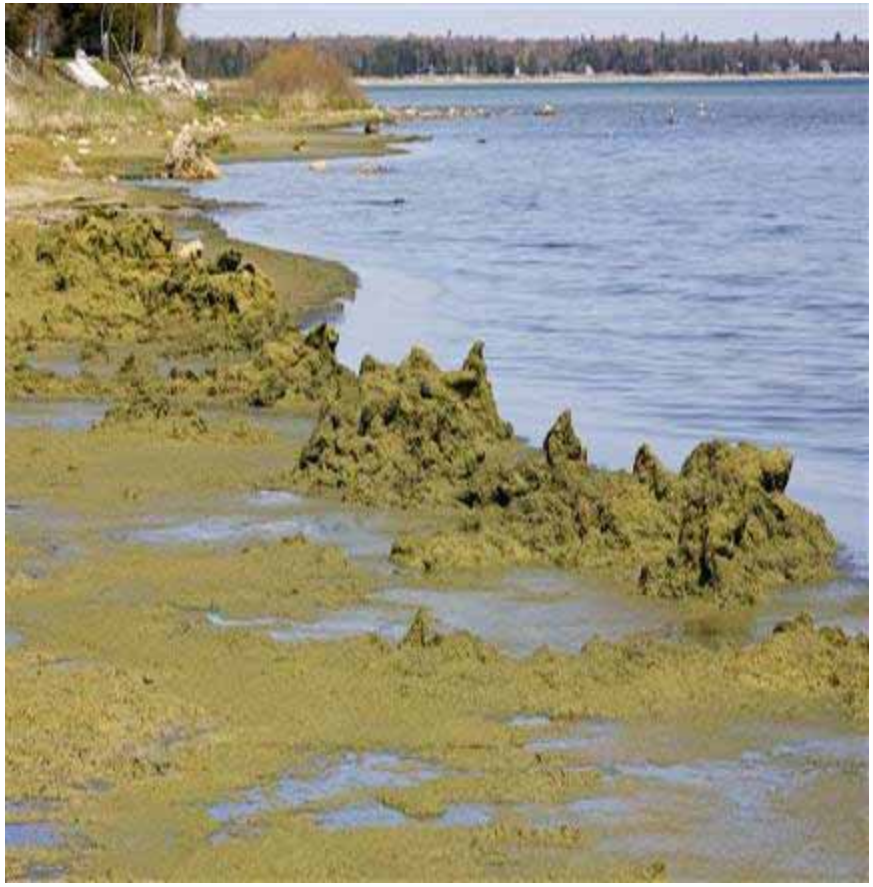
- Aaron Larson
- Kristi Minahan
- Gina LaLiberte
- Paul Cunningham
- Scott Van Egeren

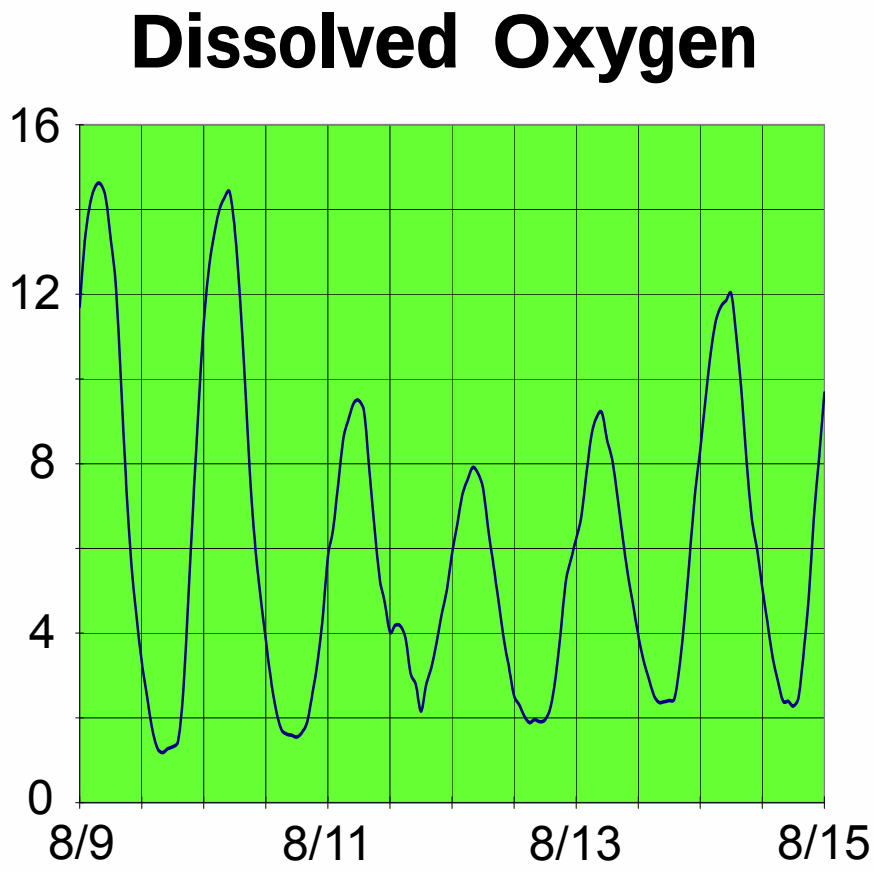
Phosphorus from many Point and Nonpoint Sources

Recreational Impairments



- **Discourage beach use**
- **Aesthetics of near-shore lake use**
- **Swimming impairments**

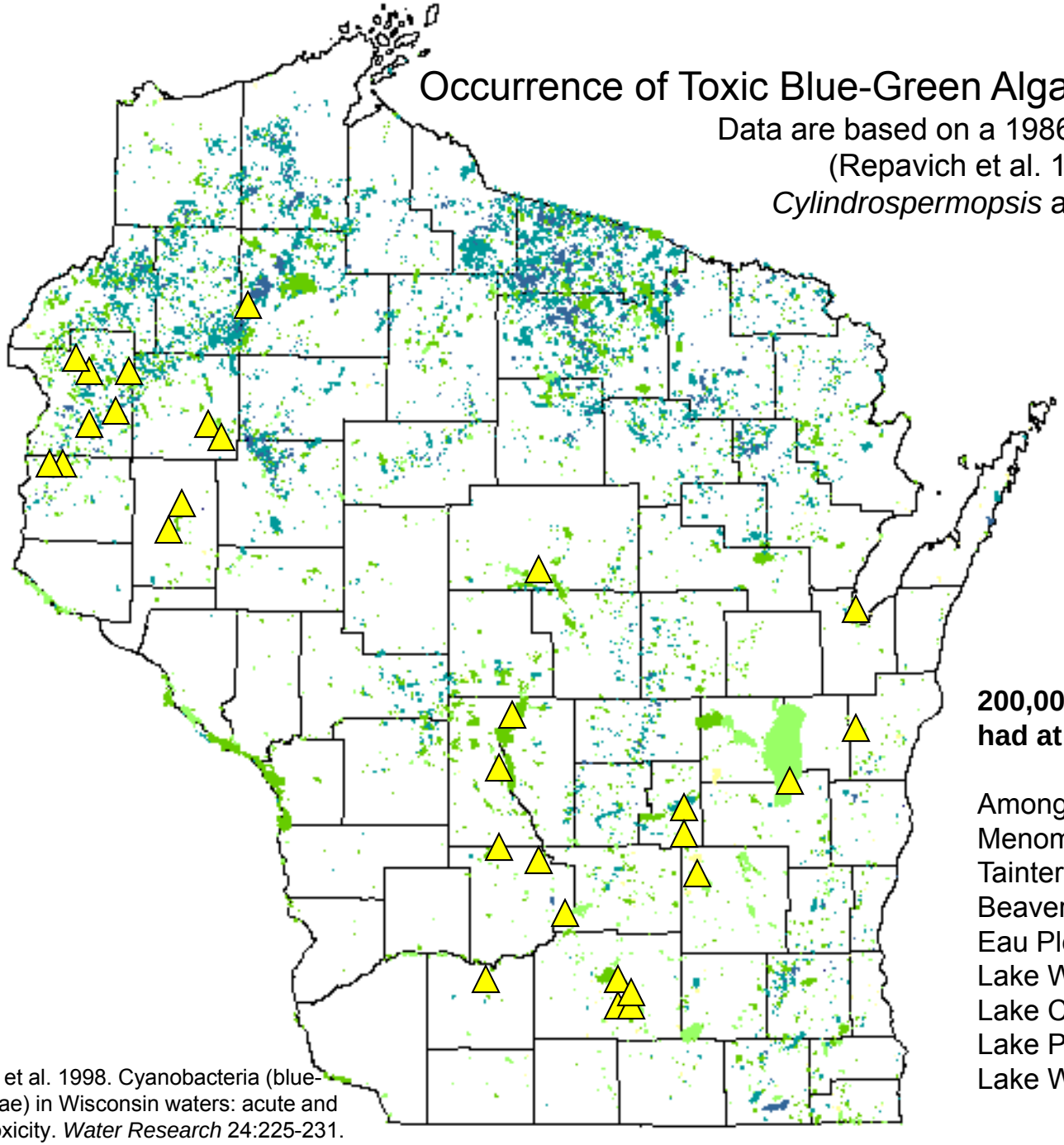
Fish and Aquatic Life Impairments



Human Health Concerns

Occurrence of Toxic Blue-Green Algae in Wisconsin Waters

Data are based on a 1986 survey for toxins in 86 lakes (Repavich et al. 1988) and DNR monitoring for *Cylindrospermopsis* and algal toxins in 2003-2006.



▲ Where Algal Toxins Were Found in High Levels

200,000 plus acres of lakes have had at least one toxic algae event.

Among the largest lakes affected:
Menomin Lake 1405 acres
Tainter Lake 1752 acres
Beaver Dam Lake 6542 acres
Eau Pleine Reservoir 6830 acres
Lake Wisconsin 9000 acres
Lake Castle Rock 13955 acres
Lake Petenwell 23040 acres
Lake Winnebago 137708 acres

Repavich et al. 1998. Cyanobacteria (blue-green algae) in Wisconsin waters: acute and chronic toxicity. *Water Research* 24:225-231.

"Phosphorus Rule"

- S. NR 102.06 – phosphorus water quality standards criteria for streams, lakes and Great Lakes
- Ch. NR 151 – additional nonpoint source performance standards and prohibitions – phosphorus index for farm fields
- Subch. III, NR 217 - water quality based effluent limits

Status

- NR 102 and NR 217 changes became effective December 1, 2010
- EPA approved NR 102 changes on December 30, 2010
- NR 151 changes became effective January 1, 2011
- Guidance being developed on a number of topics

Why Develop the Criteria?

- Obvious water quality problems in state caused by excess nutrient loading
- Numeric goals for protecting or restoring Recreational and Fish and Aquatic Life Uses
- EPA requirement

How Are Criteria Used?

- Goal for lake and stream management
- Used as a factor to determine impaired waters (or not impaired)
- Target for TMDLs
- Basis for water quality based effluent limits for point sources

Chapter NR 102 – P Criteria

- Rivers – 100 ug/l
- Streams – 75 ug/l
- Lakes and Reservoirs – 15 – 40 ug/l
- Lake Michigan – 7 ug/l
- Lake Superior – 5 ug/l
- No ephemeral streams, wetlands, LAL waters

Does not apply to:

- Lakes less than 5 acres in size
- Wetlands
- Waters impounded that don't have sufficient water residence time to be considered as a reservoir (e.g. millpond)

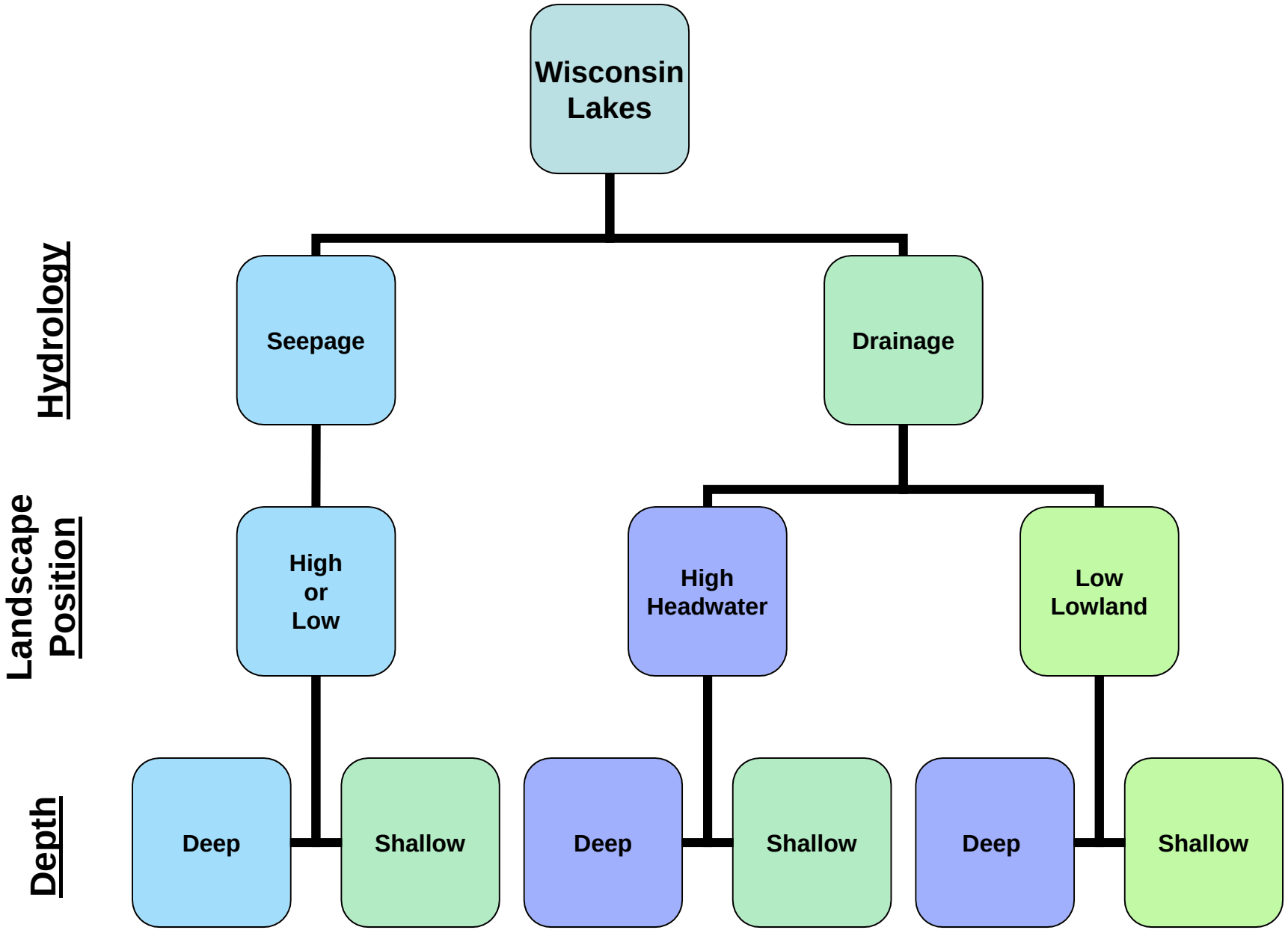
Specific Lake Criteria

- 2-story fishery lakes – 15 ug/l
- Stratified seepage lakes – 20 ug/l
- Stratified drainage lakes – 30 ug/l
- Stratified reservoirs – 30 ug/l
- Non-stratified lakes – 40 ug/l
- Non-stratified reservoirs – 40 ug/l

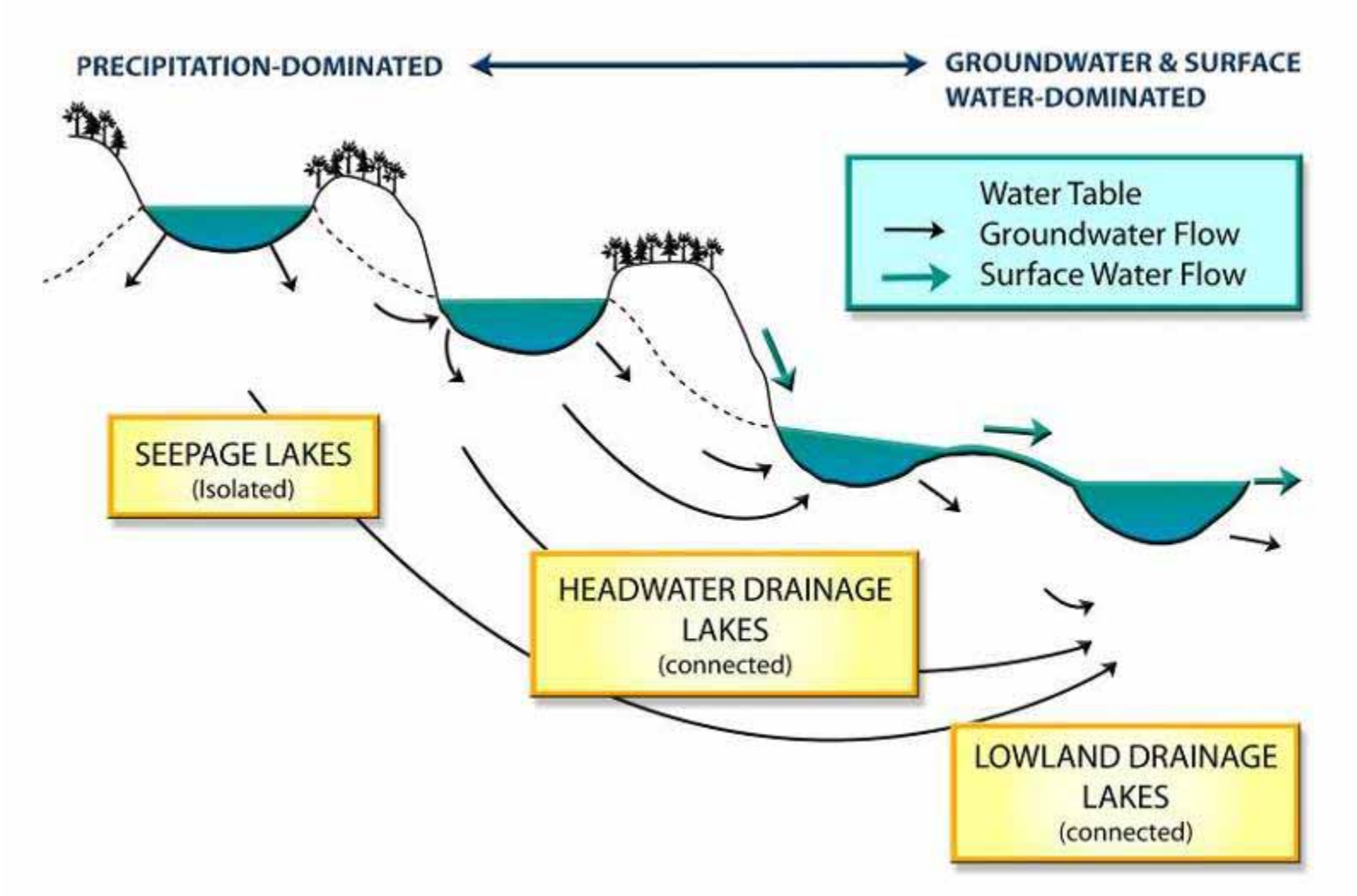
Definitions

- Seepage vs drainage
- Stratified vs non-stratified
- Two story fishery
- Reservoir vs lake
- Reservoir vs impounded water

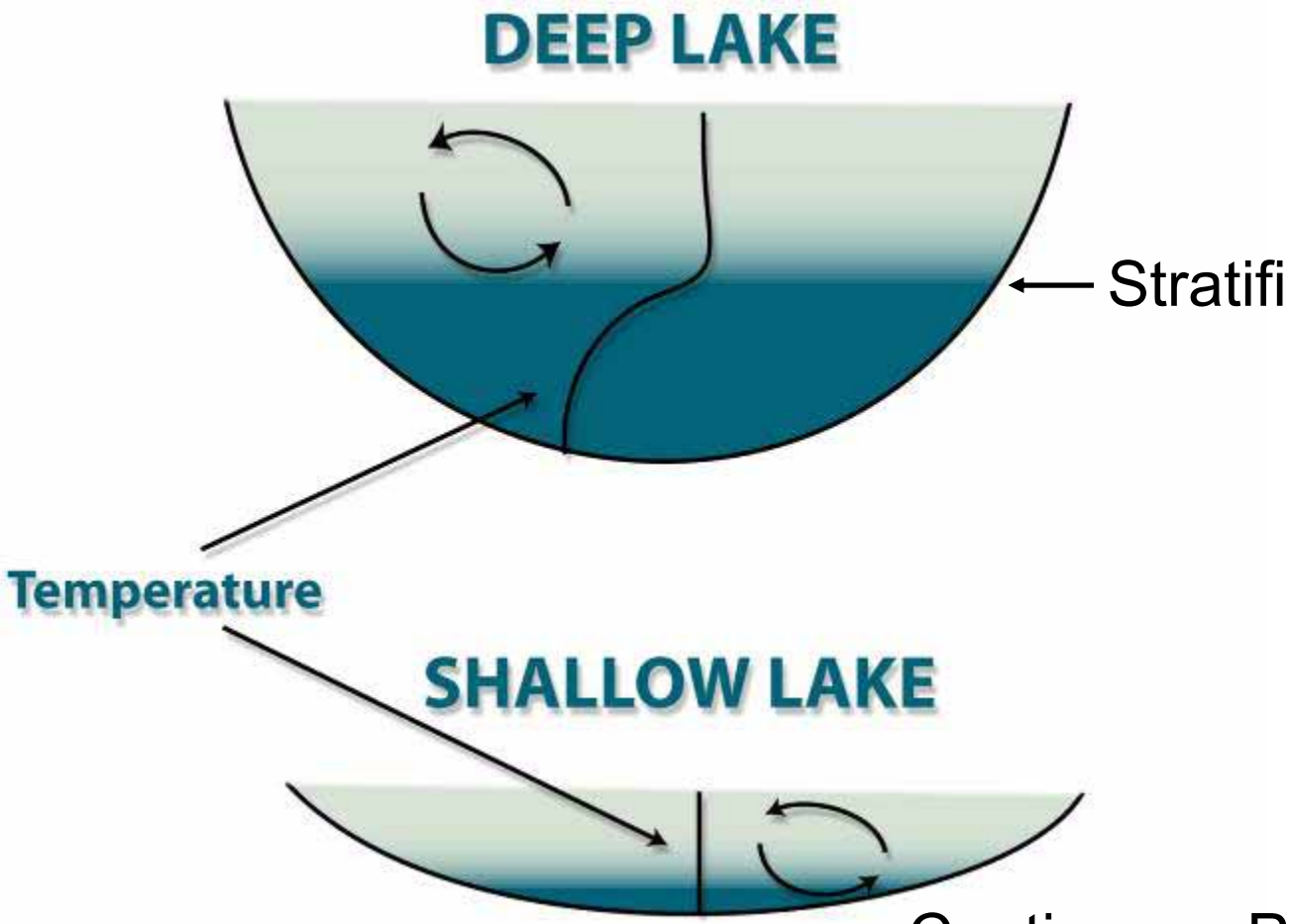
Wisconsin Lake Classification



LANDSCAPE POSITION

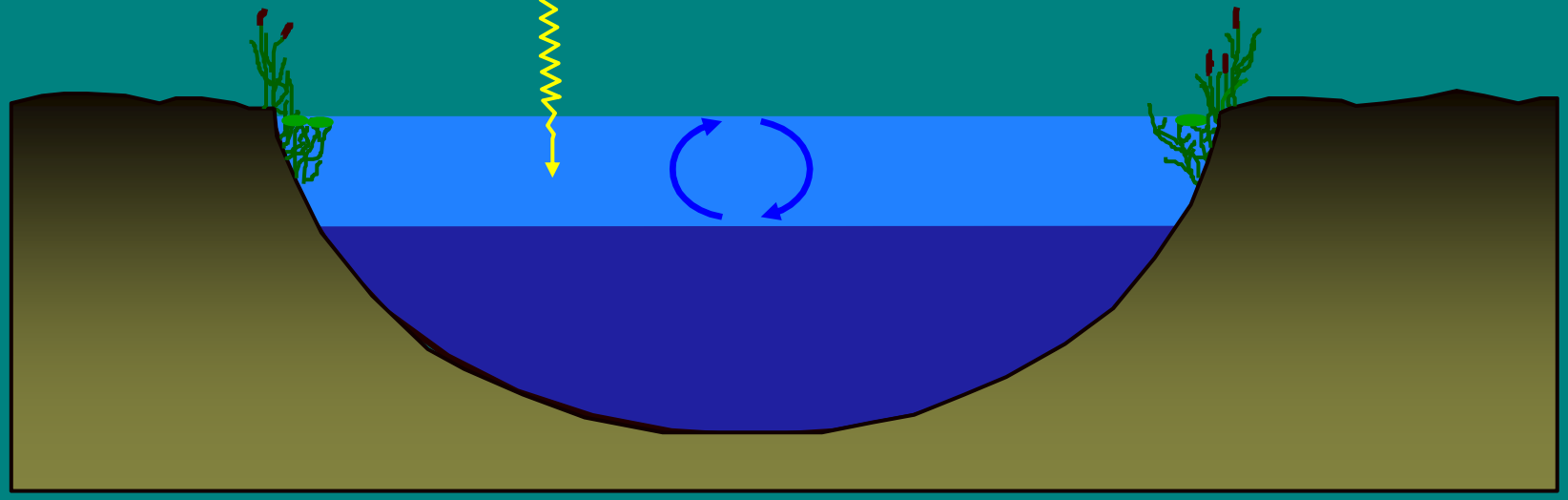


LAKE DEPTH MATTERS

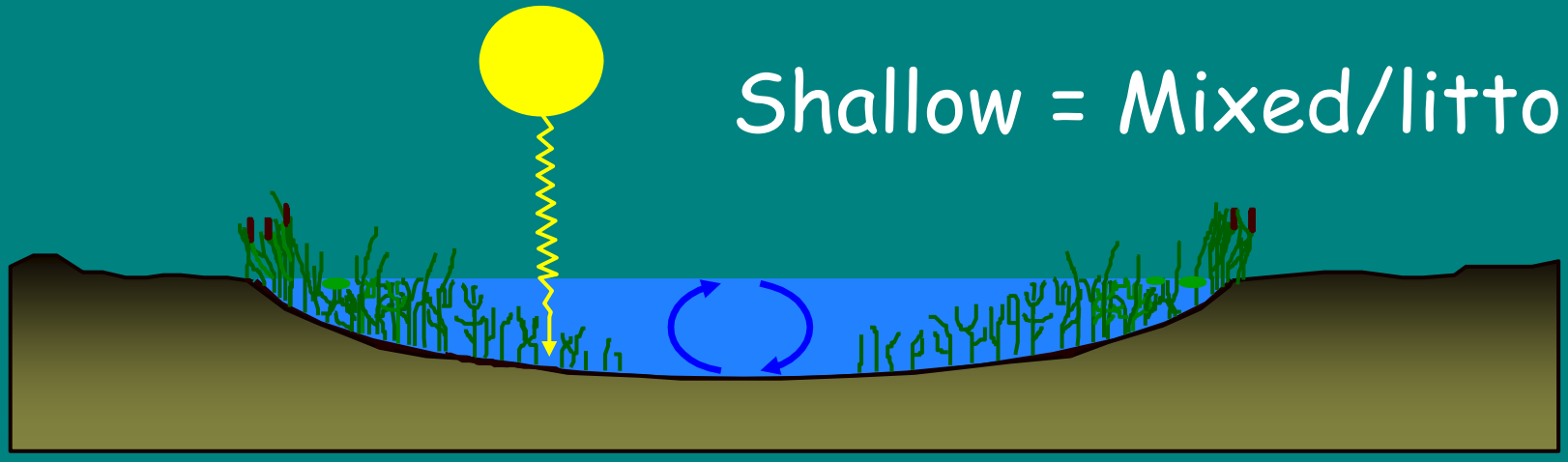


Continuous P Recycling

Deep = Stratified/pelagic



Shallow = Mixed/littoral



Defined by lake surface area to maximum depth ratio

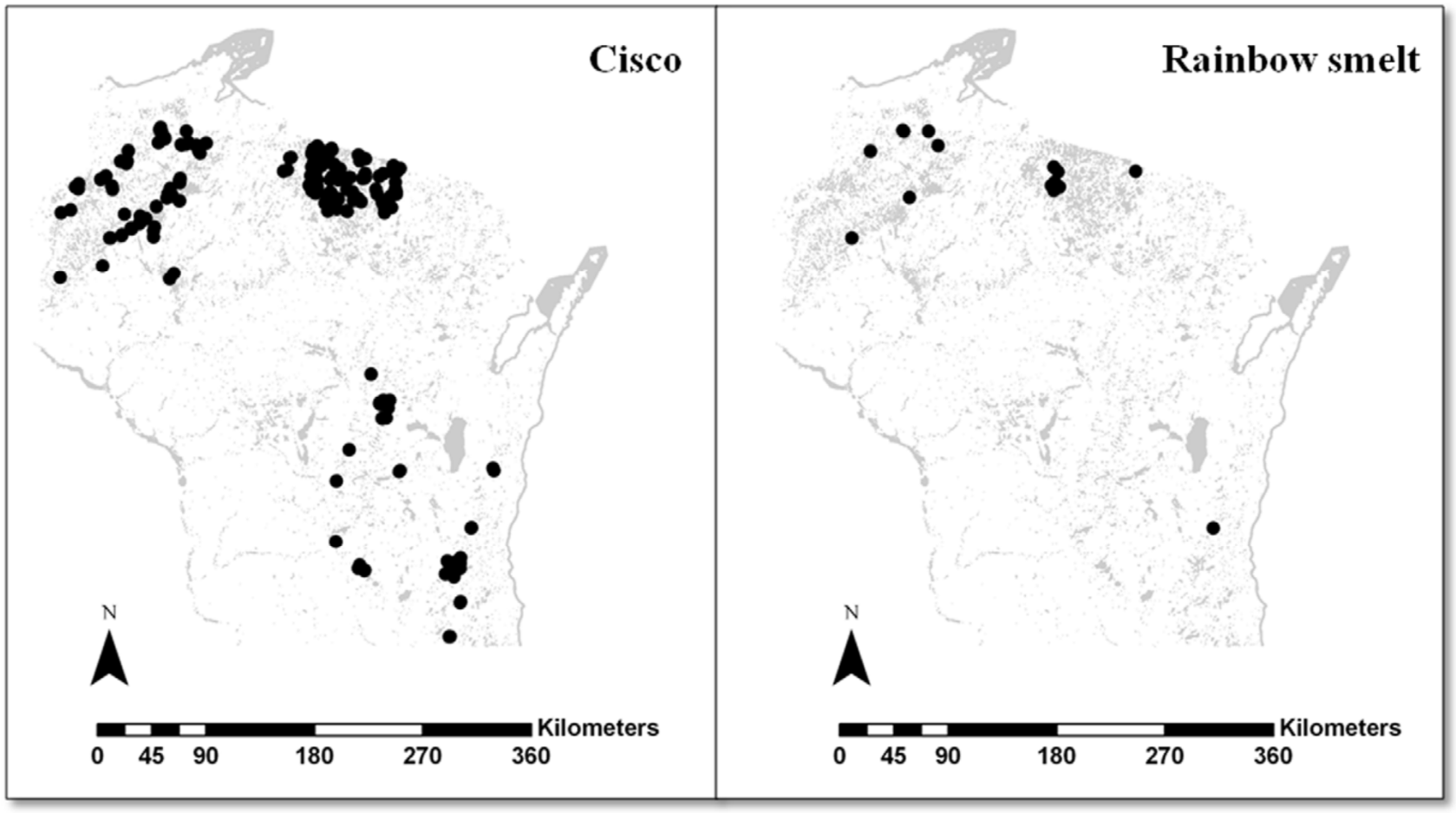
Natural Lake "Communities"

Natural Community	Stratification Status	Hydrology
Lakes less than 10 acres		
Small	Variable	Any Hydrology
Lakes 10 acres or greater		
Shallow Seepage	Mixed	Seepage
Shallow Headwater	Mixed	Headwater Drainage
Shallow Lowland	Mixed	Lowland Drainage
Deep Seepage	Stratified	Seepage
Deep Headwater	Stratified	Headwater Drainage
Deep Lowland	Stratified	Lowland Drainage
Other Classifications (any size)		
Spring Ponds	Variable	Spring Hydrology
Two-Story Lakes	Stratified	Any hydrology
Impounded Flowing Waters	Variable	Headwater or Lowland Drainage

Paleolimnology

- Indicator of previous ecological state
- Pre-settlement
- Undeveloped lakes
- Minimally impacted lakes
- Top/bottom (Tier 1) or full core (Tier II)

“Stratified two−story fishery lake” means a stratified lake which has supported a cold water fishery in its lower depths within the last 50 years.



(from Sharma et al. 2011)

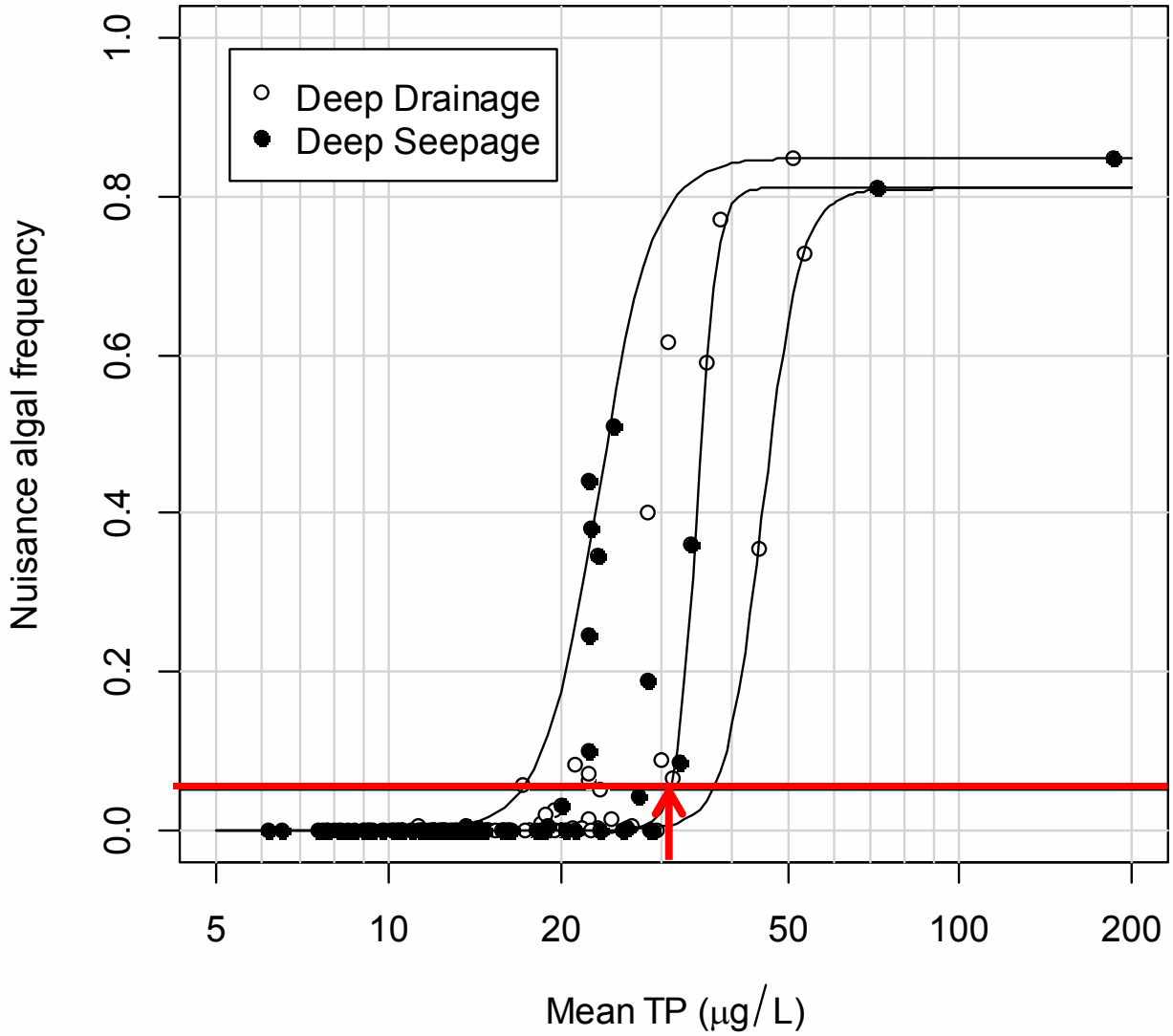
Reservoirs vs. Impounded Flowing Waters

- Both are waterbodies created or augmented by a dam, with at least half the depth due to the presence of the dam (otherwise it is a lake)
- Reservoirs have > 14 day residence time, so are subject to lake criteria
- Impounded flowing waters (< 14 day residence time) are subject to river/stream criteria

Basis for Lake Criteria

- Minimize risk of nuisance algal blooms –
  - 5% chance of 20 ug/l chl. *a* bloom
  - 1% chance of 30 ug/l chl. *a* bloom
- Prevent shift in shallow lakes from macrophytes to algal domination
- Protect sport fisheries
- Maintain dissolved oxygen in hypolimnion of 2-story lakes
- Protect and provide margin of safety for deep seepage lakes

Preventing nuisance algal blooms



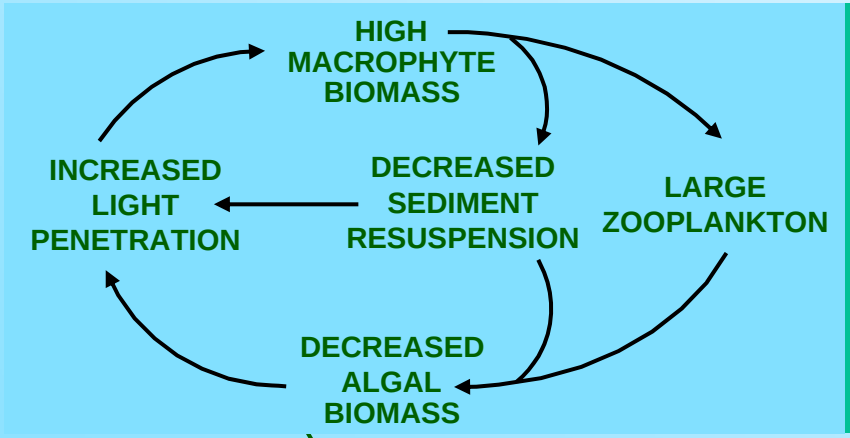
Stable States in Shallow Lakes

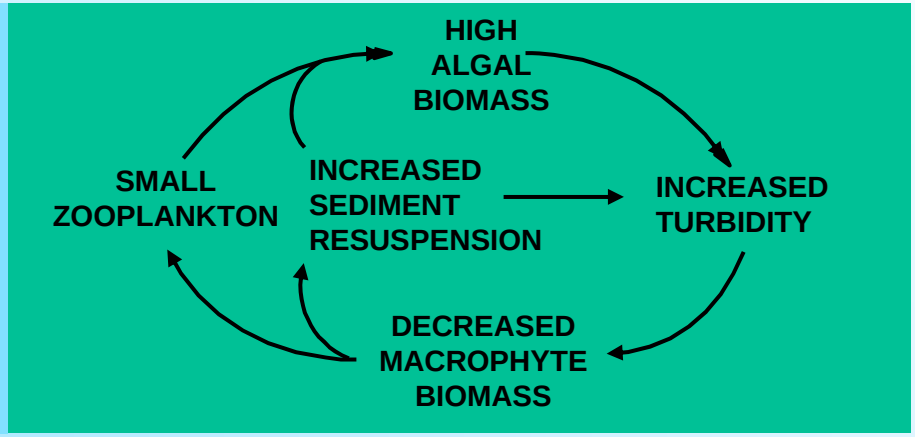
Clear State

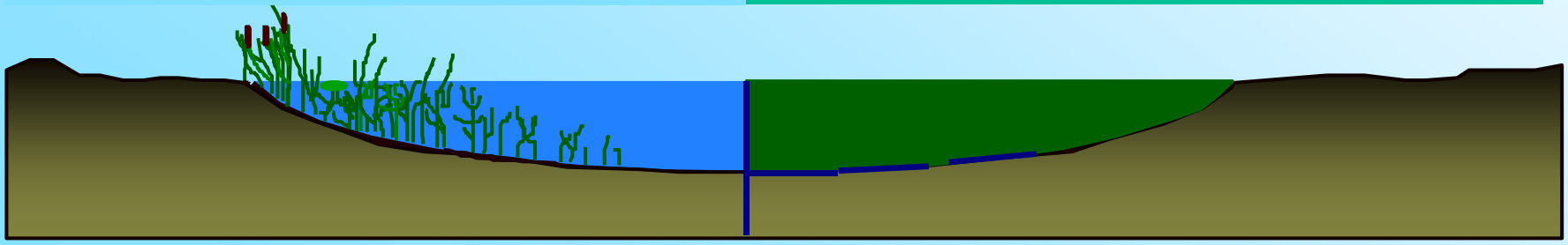
- clear water
- low algal biomass
- high macrophyte biomass

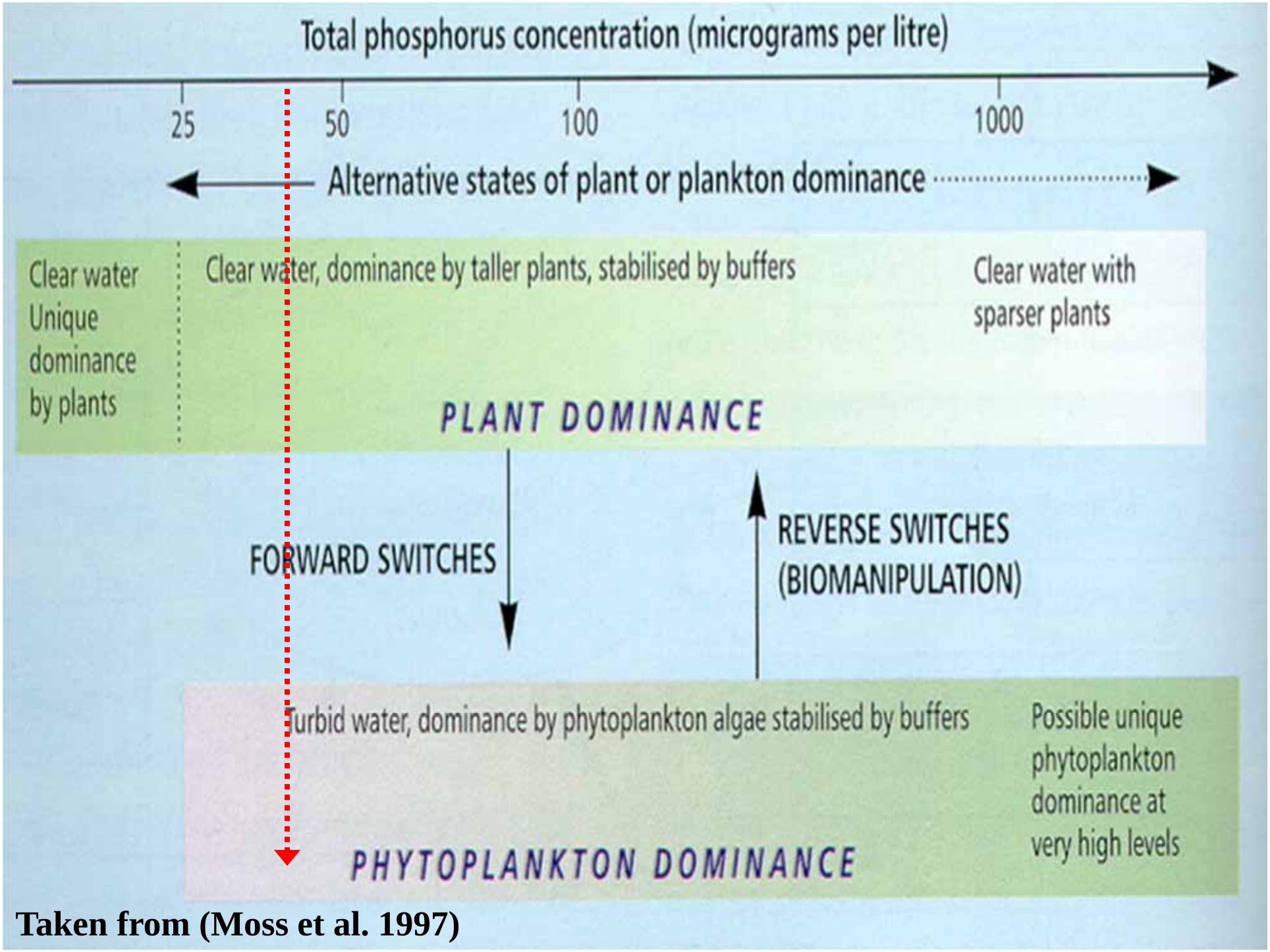
Turbid State

- murky water
- high algal biomass
- sparse macrophytes



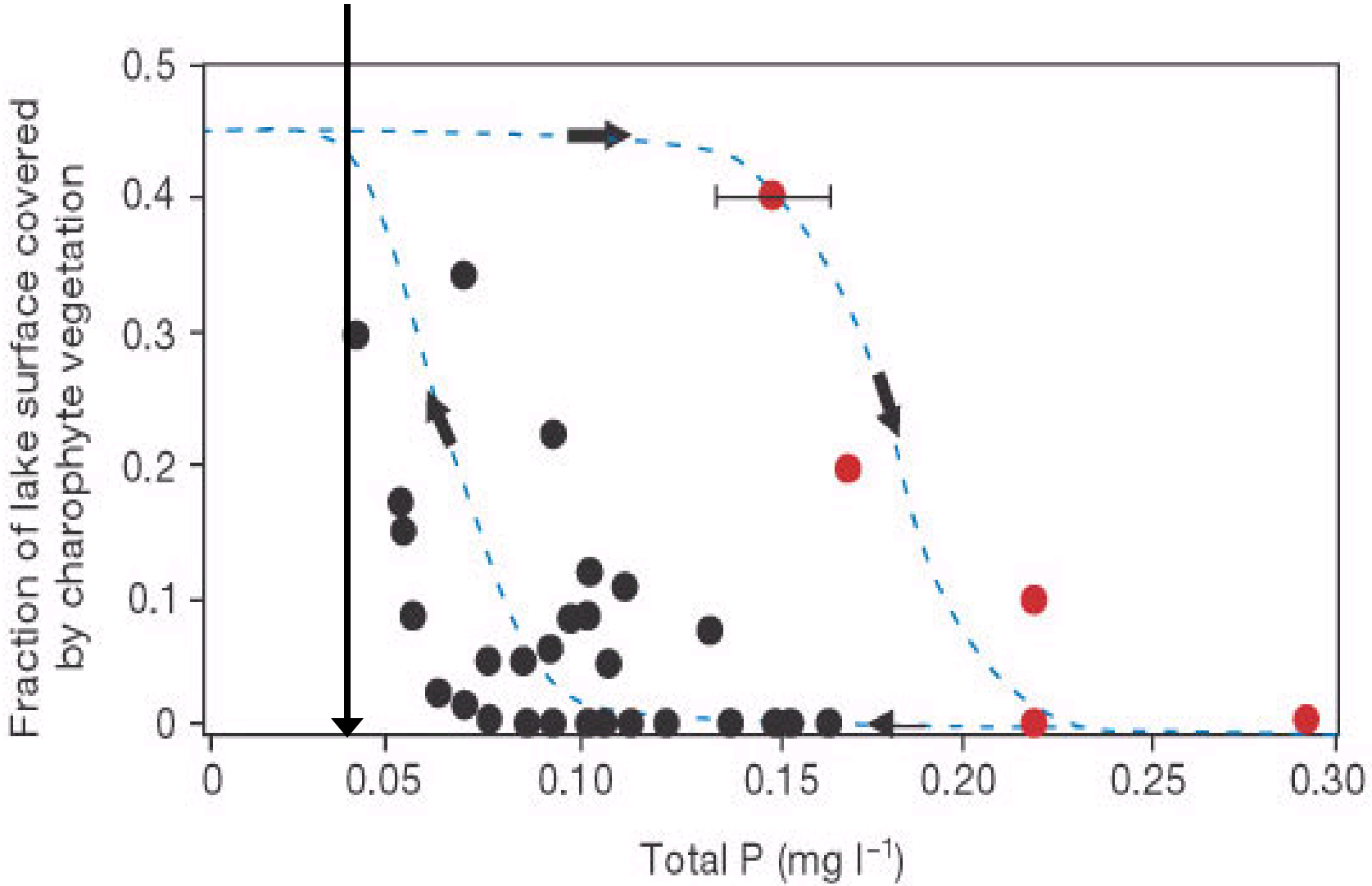




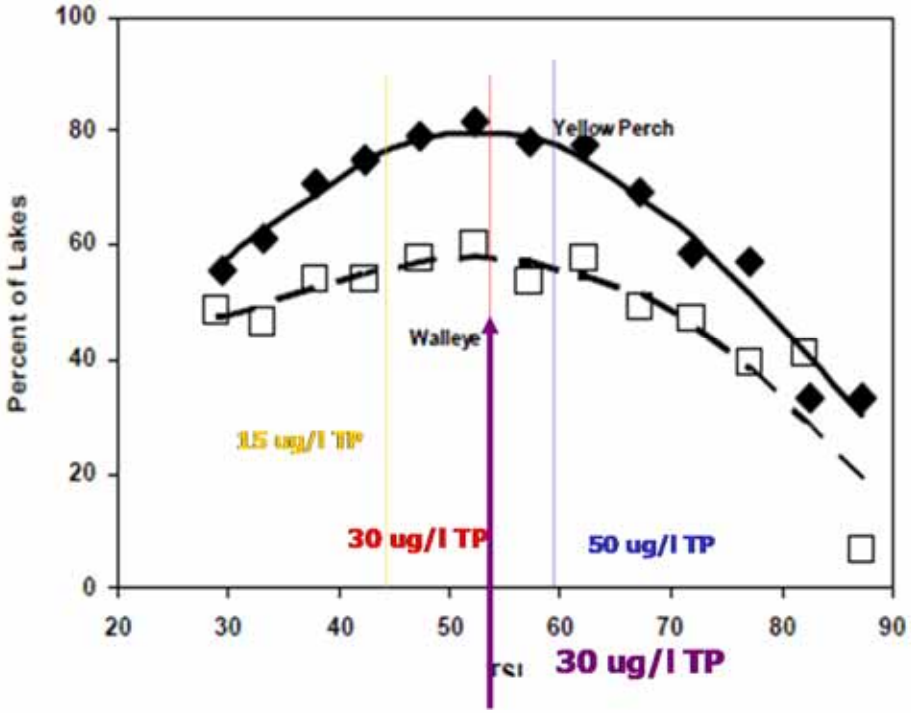


Taken from (Moss et al. 1997)

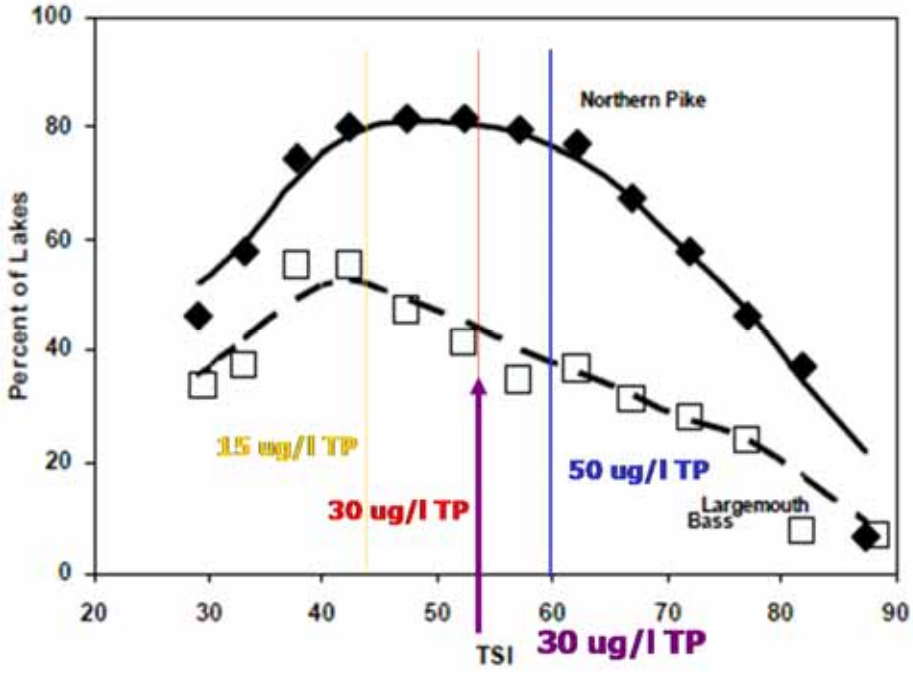
40 ug/L prevents “forward switch” to algal dominance in shallow lakes



Protecting Fish and Aquatic Life



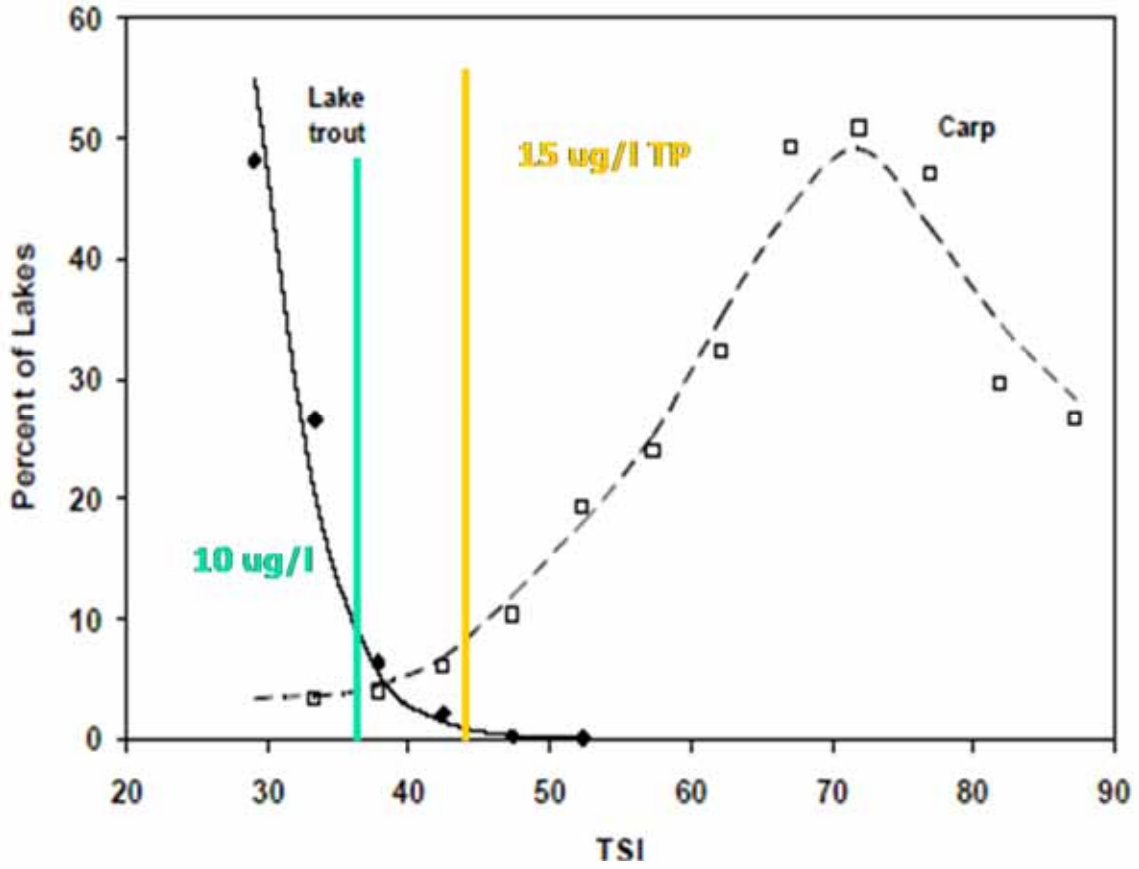
Cool water species



Warm water species

Source “Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria”, Third Edition, September 2005, Minnesota Pollution Control Agency; based on work by Schupp (MDNR) and Wilson (MPCA), 1992 and Schupp (MDNR) unpublished data.

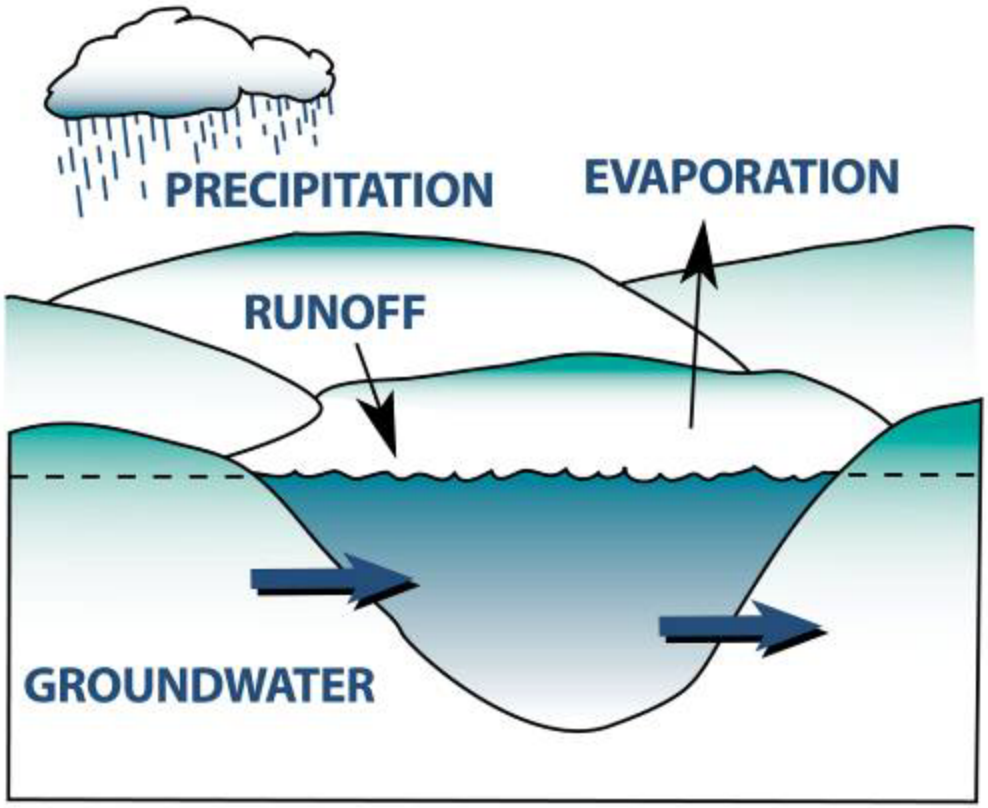
Why are two-story lakes 15 µg/L?



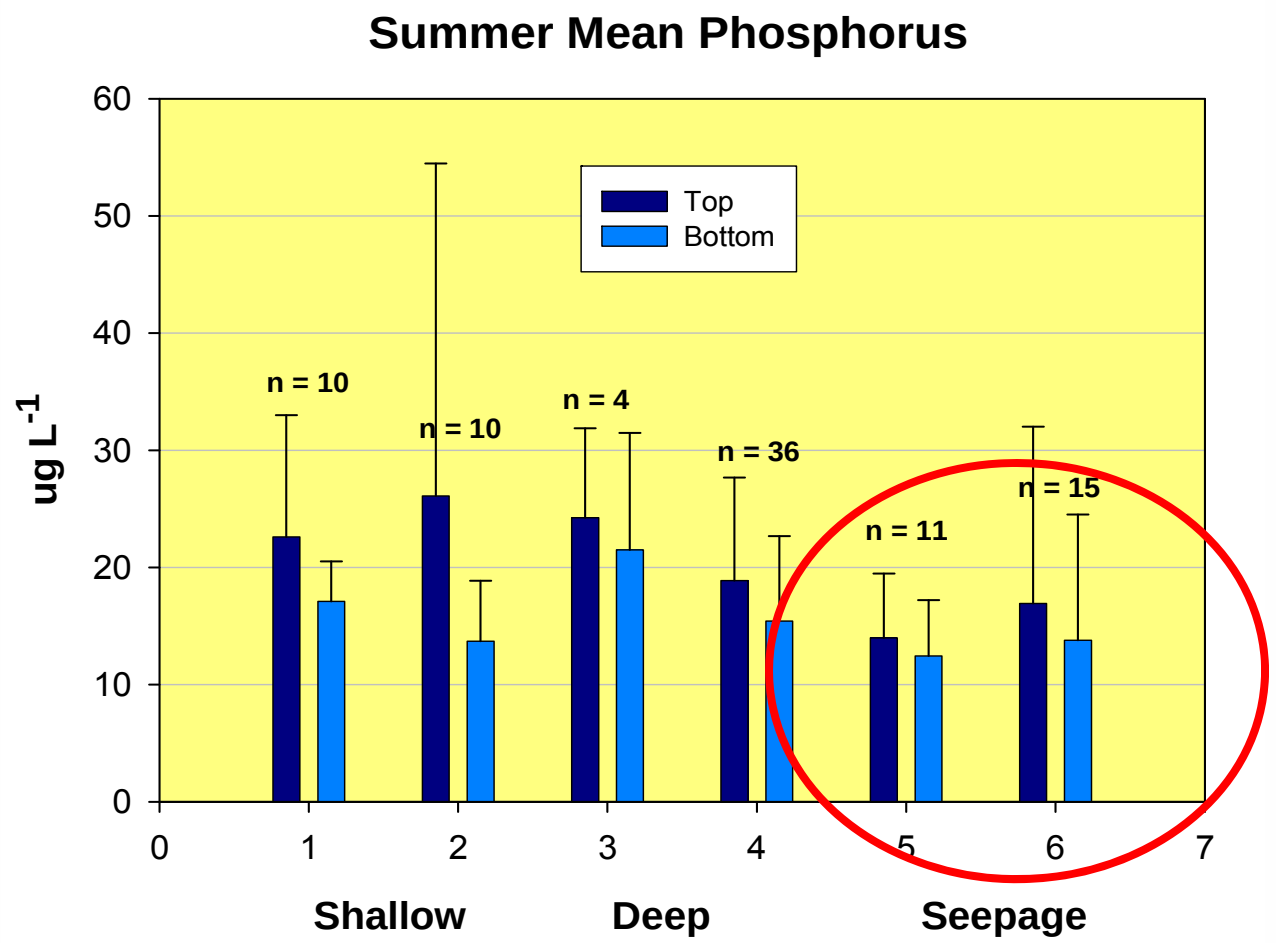
Source “Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria”, Third Edition, September 2005, Minnesota Pollution Control Agency; based on work by Schupp (MDNR) and Wilson (MPCA), 1992 and Schupp (MDNR) unpublished data.

Deep seepage lakes protected

- Long residence time
- Sensitive to P inputs
- Difficult to clean up once polluted



Phosphorus trends using lake bottom sediment core data



Source: Paul Garrison

Phosphorus Assessment

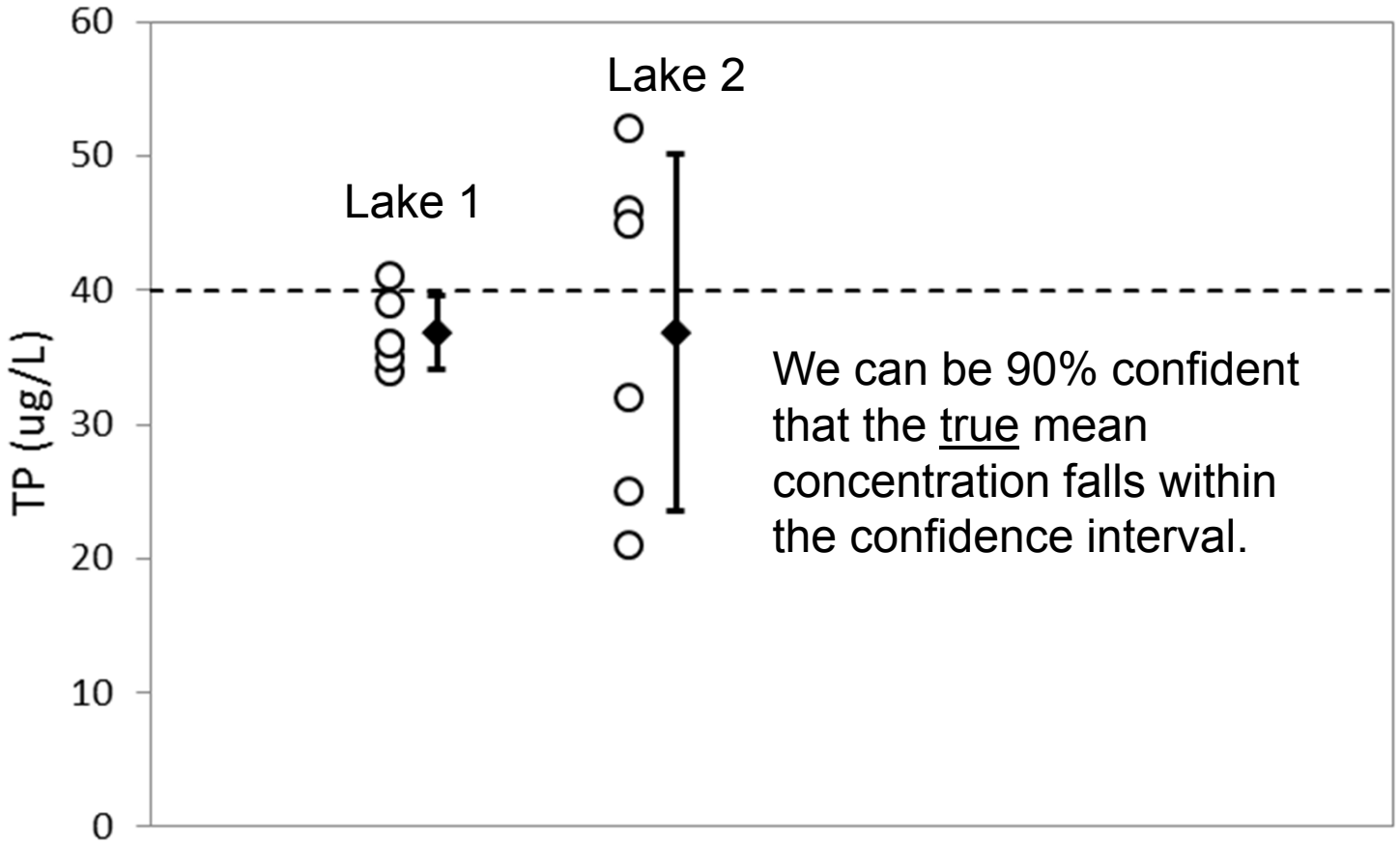
- Guidance in Wisconsin Consolidated Assessment and Listing Methodology (WisCALM)
- Data may be contributed by the public (period just ended for 2014 cycle).
- Data collected by Citizen Lake Monitors and entered into SWIMS are automatically used in assessments

http://dnr.wi.gov/topic/surfacewater/assessments.html

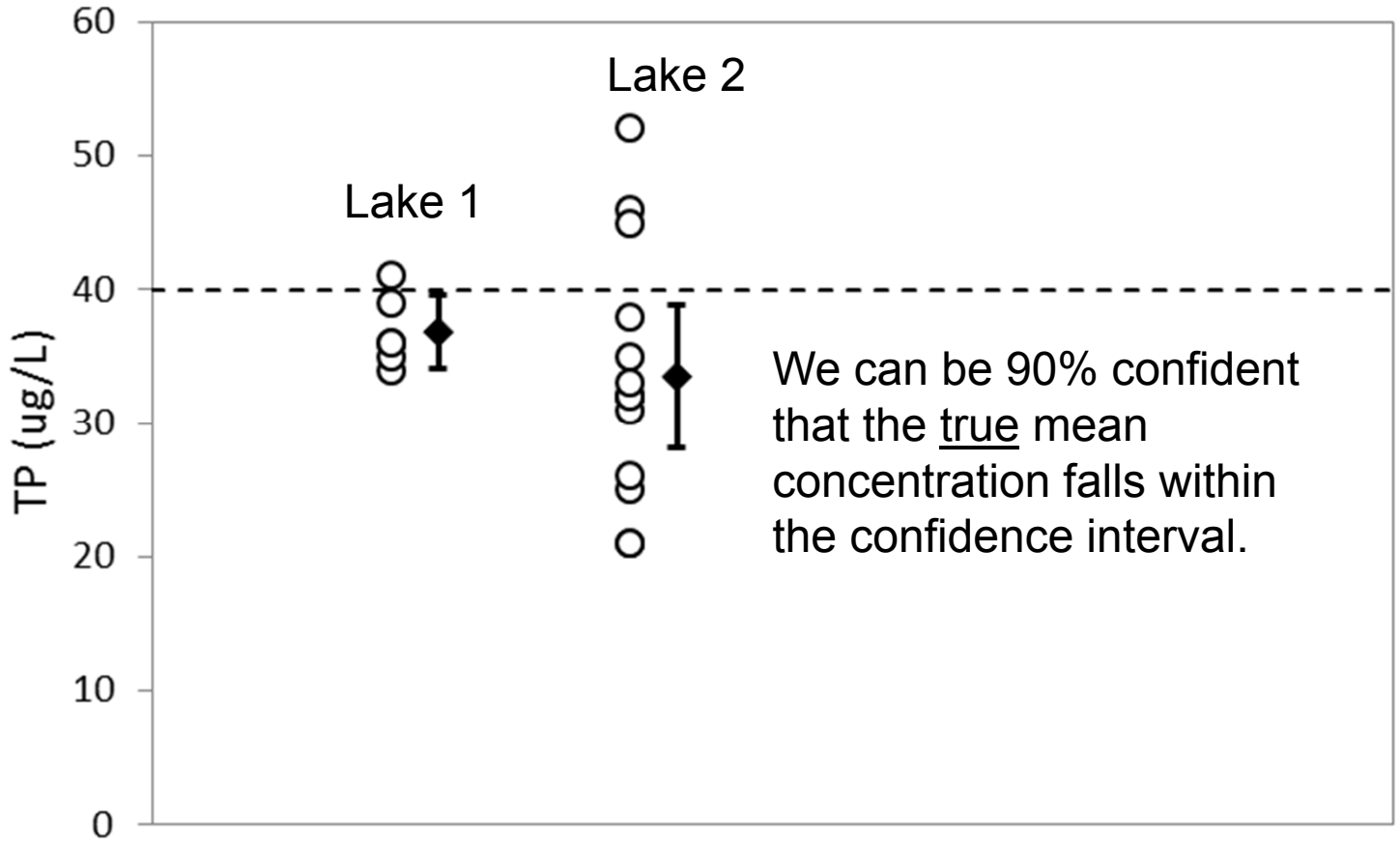
Data Requirements

- 6 samples collected over a minimum of two years
- June 1 - September 15
- Surface grab or integrated samples from top 2 m
- Chemical analysis by state-certified laboratory

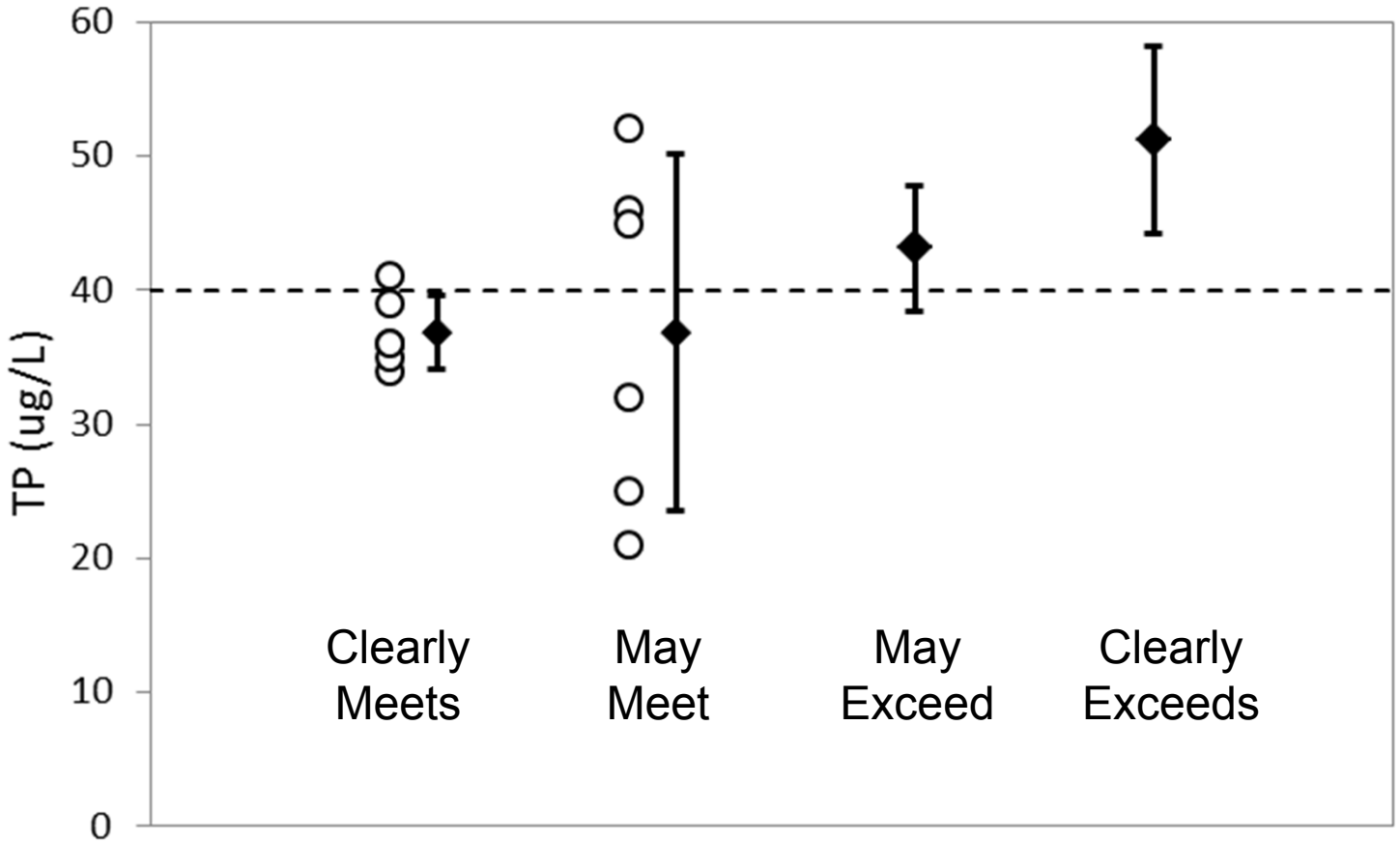
Confidence Intervals



Confidence Intervals



Confidence Intervals



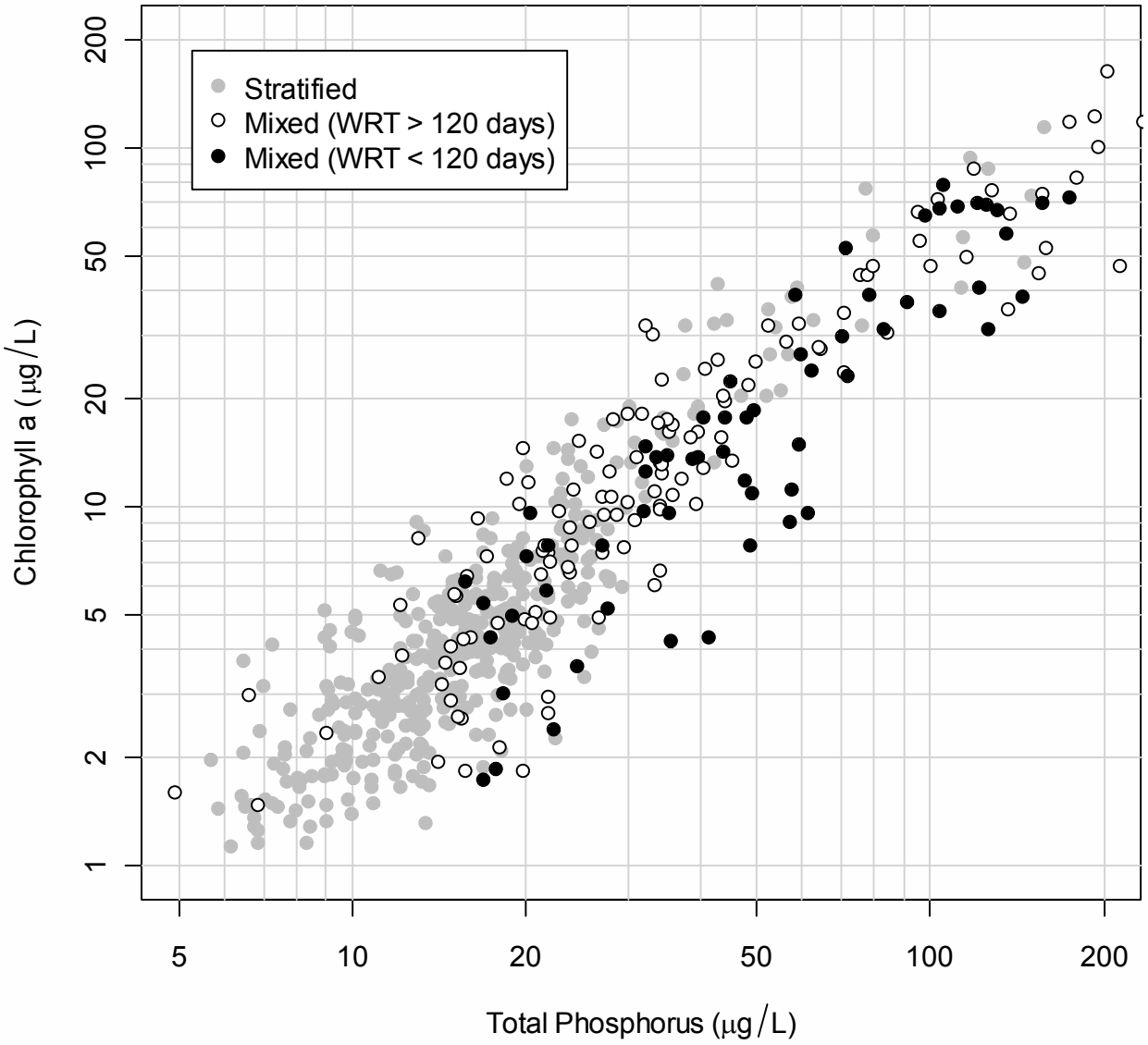
Site-specific Criteria

- Code "mentions" process for developing site-specific criterion
  - Must have scientific rationale
  - Must be adopted on a case-by-case basis by administrative rule
  - Must be approved by EPA
- Could be more or less restrictive than "default" criteria
- Chlorophyll a concentrations can be used as "biological confirmation" of a phosphorus impairment.

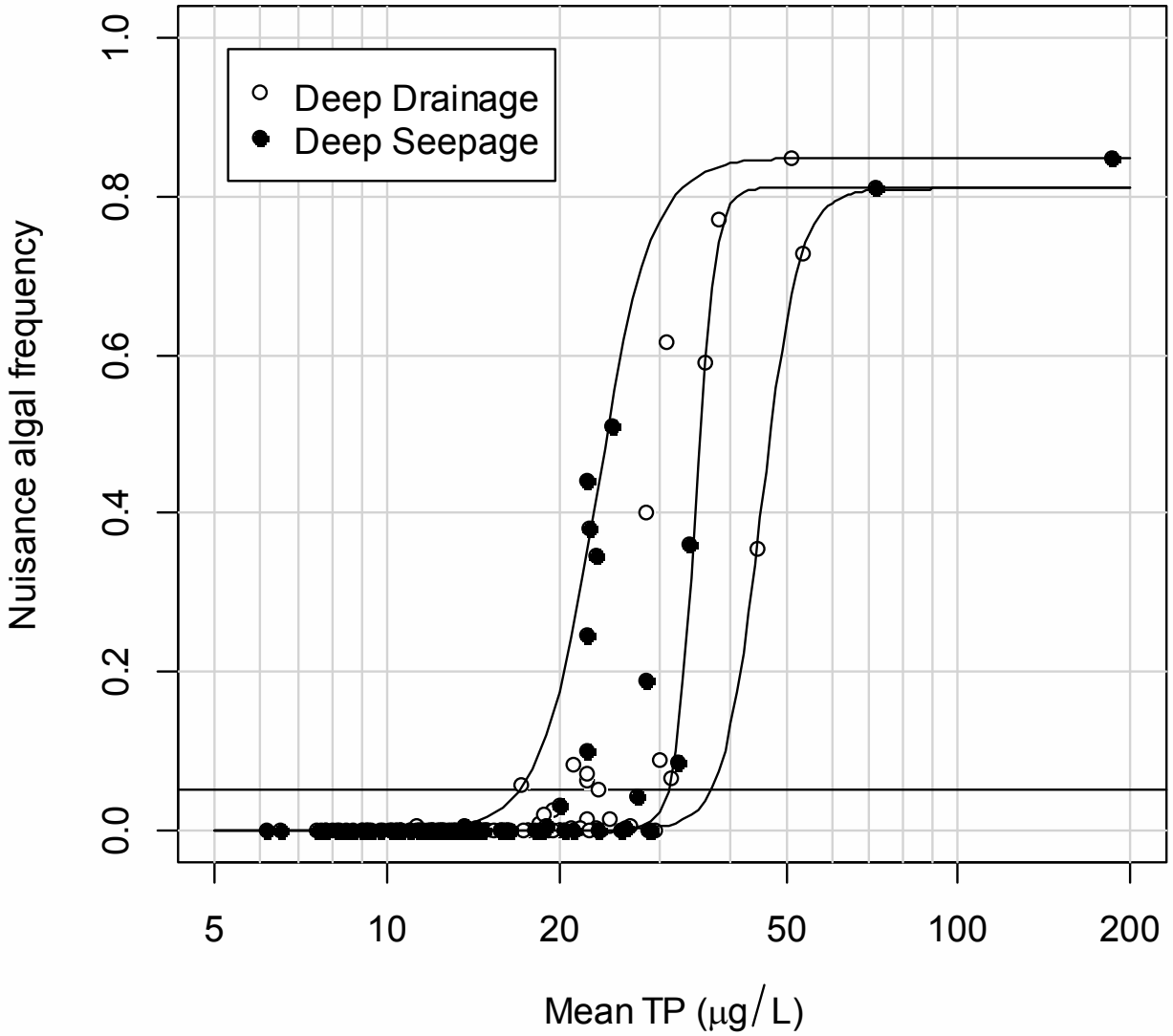
Site-specific Criteria Examples

- Preventing phosphorus increases in oligotrophic lakes
- Naturally high phosphorus concentrations in some lakes
- Short residence time in some reservoirs may allow for higher criteria

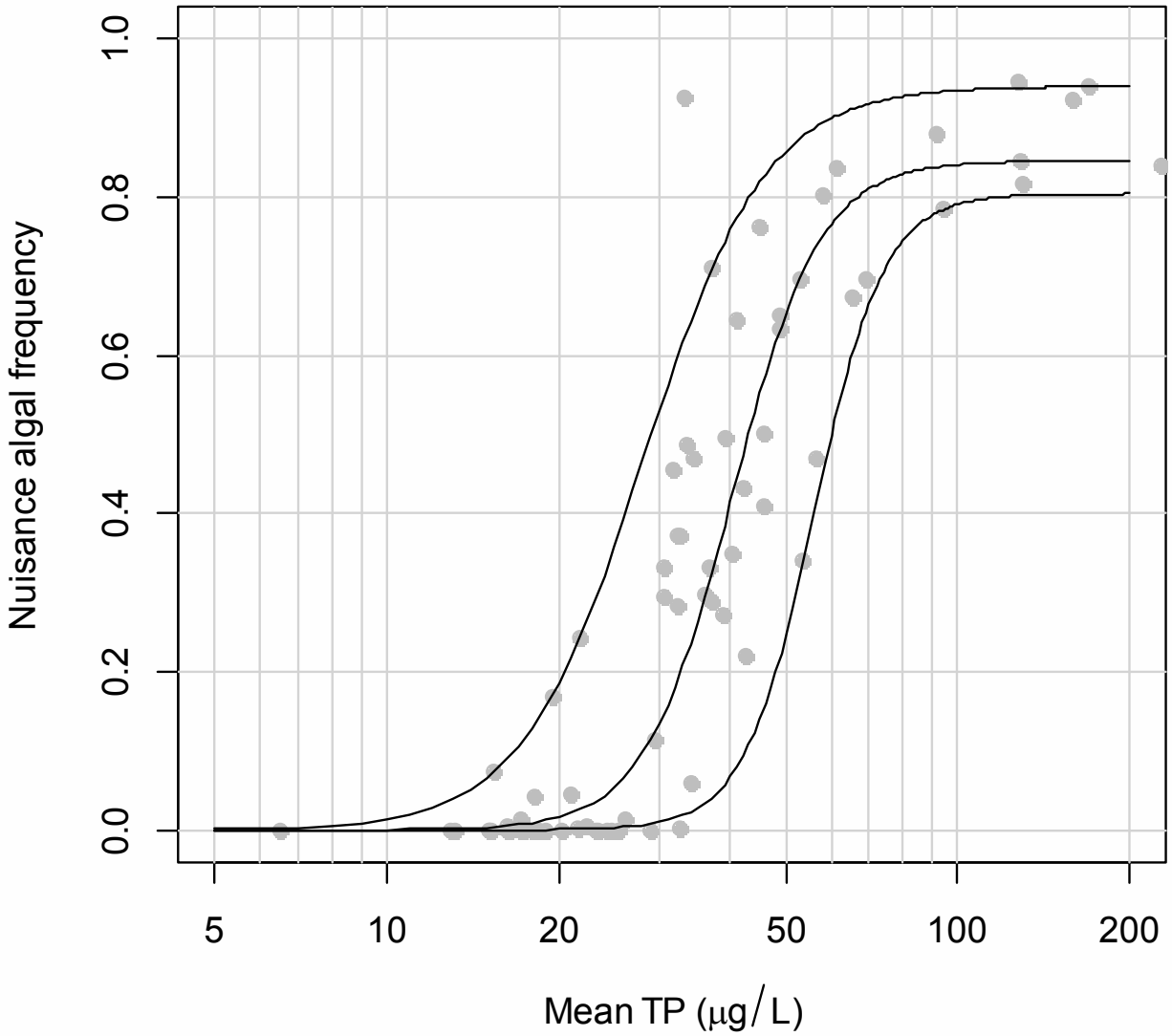
Site Specific Criteria



Site-Specific Criteria



Site-Specific Criteria



Adaptive Management

Why do it?

- Phosphorus standards require reductions in P loading from permitted facilities.
- In some cases, it may be less expensive to reduce nonpoint sources of P than to upgrade wastewater treatment systems.

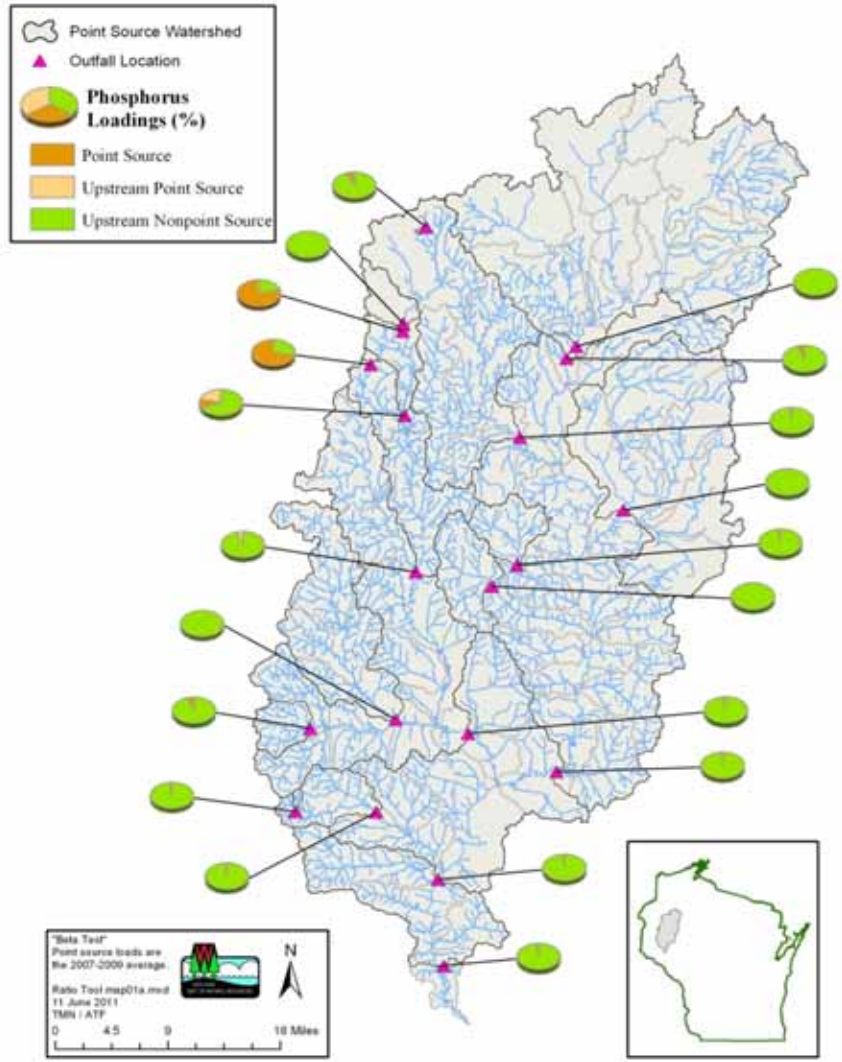
=?

http://dnr.wi.gov/topic/surfacewater/adaptivemanagement.html

Adaptive Management

Which facilities are eligible?

- The receiving water is exceeding the applicable P criteria.
- Filtration or equivalent technology would be required to meet the proposed phosphorus limit.
- Nonpoint sources contribute at least 50% of the total phosphorus entering the receiving water.



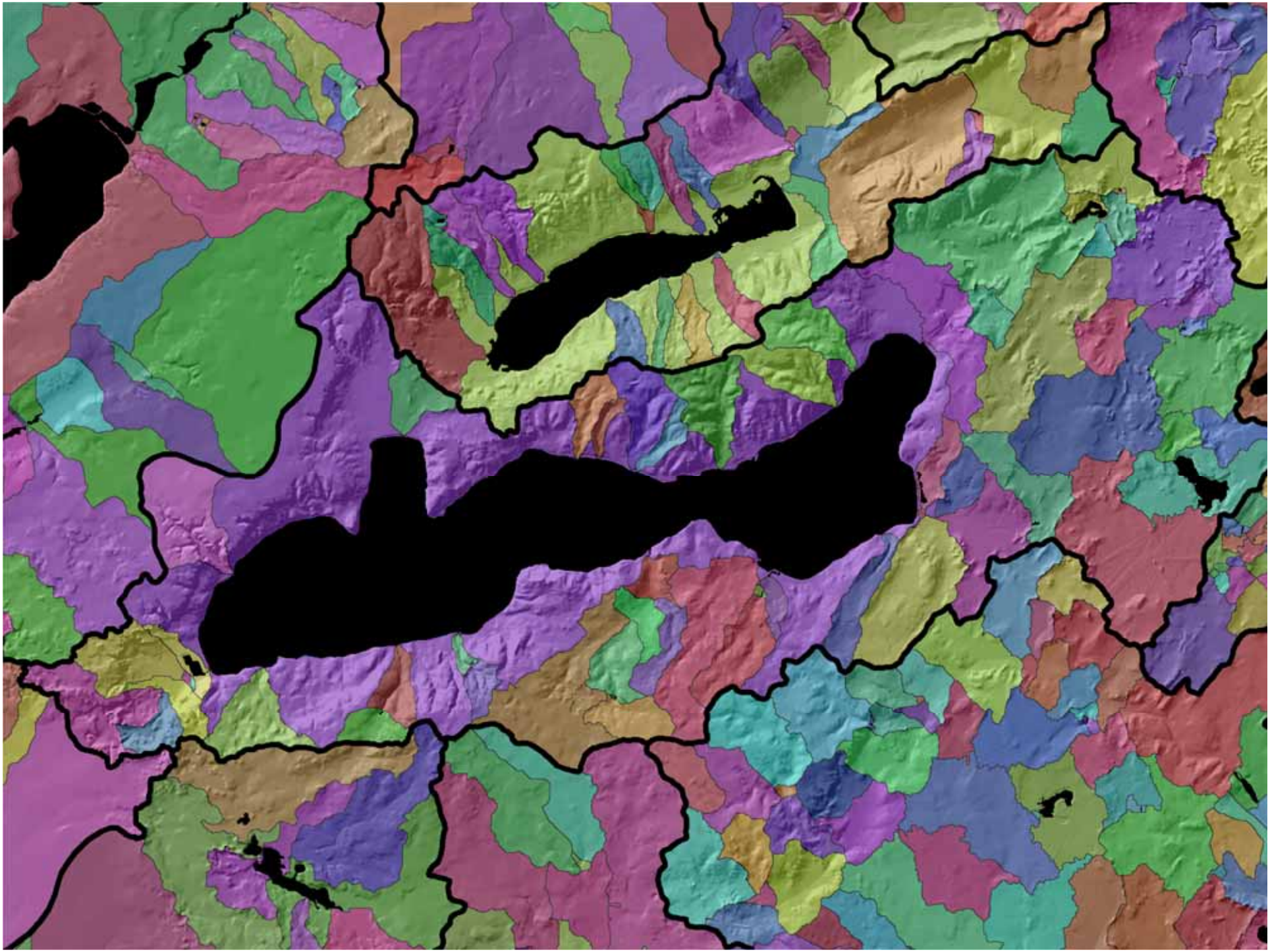
http://dnr.wi.gov/topic/surfacewater/adaptivemanagement.html

Adaptive Management

Roles of citizens

- Monitor phosphorus concentrations to document water quality problems.
- Encourage your water utility board to consider the option.
- Monitor phosphorus concentrations to document water quality improvements.

http://dnr.wi.gov/topic/surfacewater/adaptivemanagement.html



Wisconsin Department of Natural Resources

Intranet Surface Water Data Viewer

Layers · Legend · Find Location · Themes · Print · Select · ROW · SWAMP · SWIMS · WATERS · Hel

Full State | Zoom In | Zoom Out | Move | Zoom Last | Zoom to... | Identify | Select | Advanced Too

Coordinate Position

Lat/Lon:	42°33' N, 88°32' W
Decimal Lon/Lat:	-88.539197, 42.552608
UTM 16N:	373635, 4712283
WTM91 (x,y):	639929, 232168

Municipalities

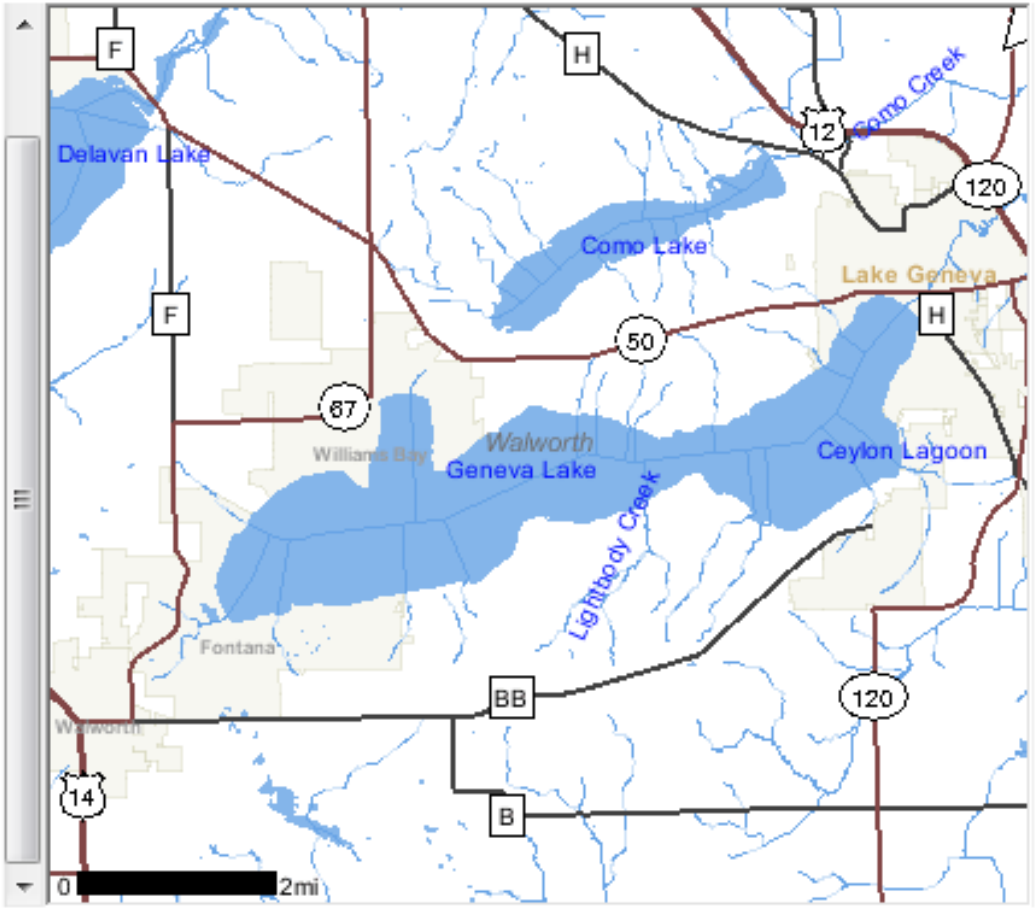
Year 2006 Area (Sq Mi):	4.48859956
Name:	Fontana

County Boundary

County Name:	Walworth
Federal FIPS Code:	127
DNR County Code:	65
DNR Region:	Southeast Region

24K Open Water

Feature Name: Lake Geneva
WBIC: 758300
TP Criterion: 20 ug/L
Surface Area: 5401 acres
Watershed Area: 73.87 sq km
Water Residence Time: 23 yr
Agriculture: 23%
Click here for more information.



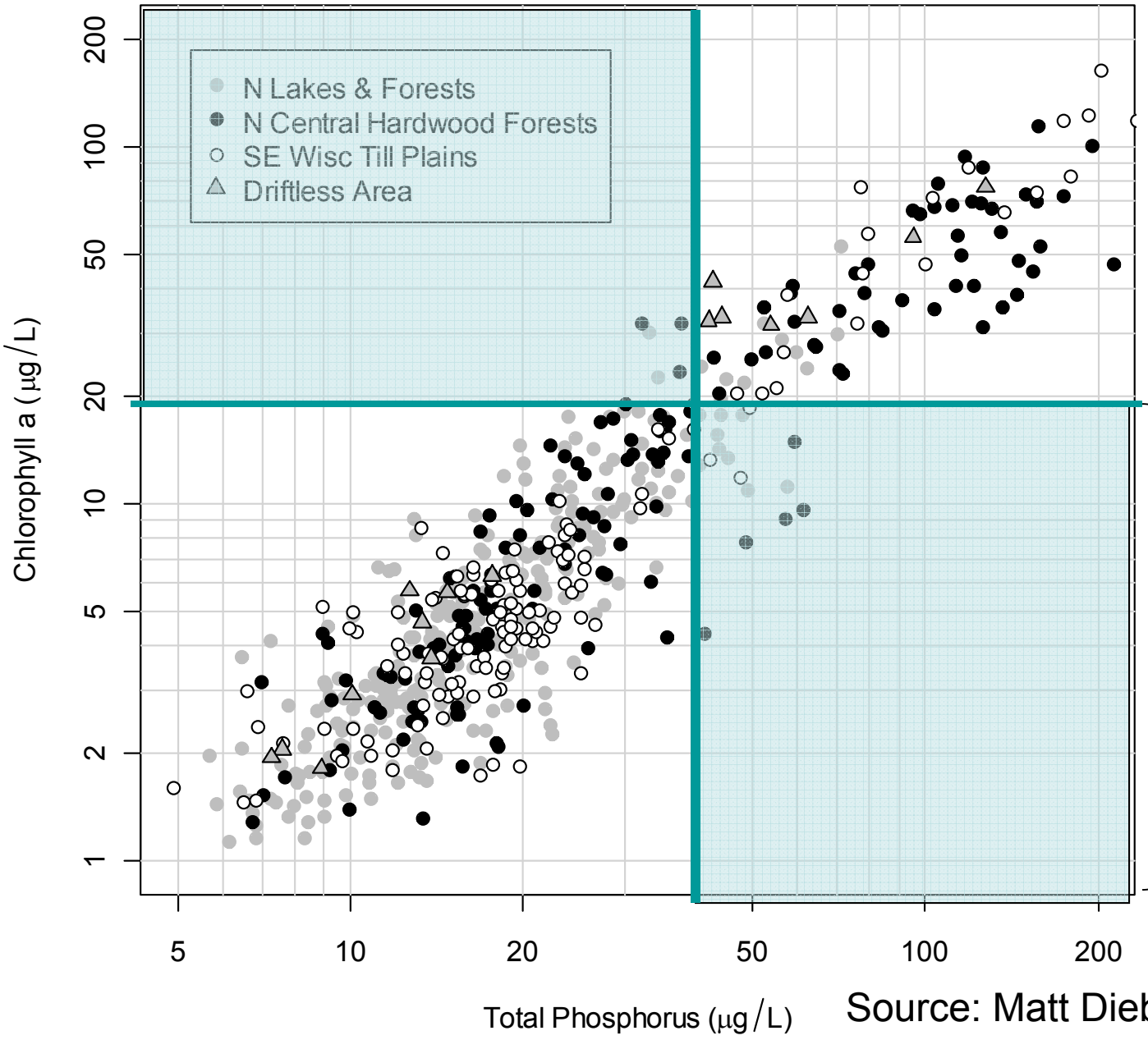
ale: 1: 147,488 go Selected Map Tool: Zoom In Zoom In

| DNR Webview | NHI Portal | Managed Lands | Data Resource Center | Surface Water Resource Guide | Comments | WTM Coordinate: X= 649081,


Thank You!

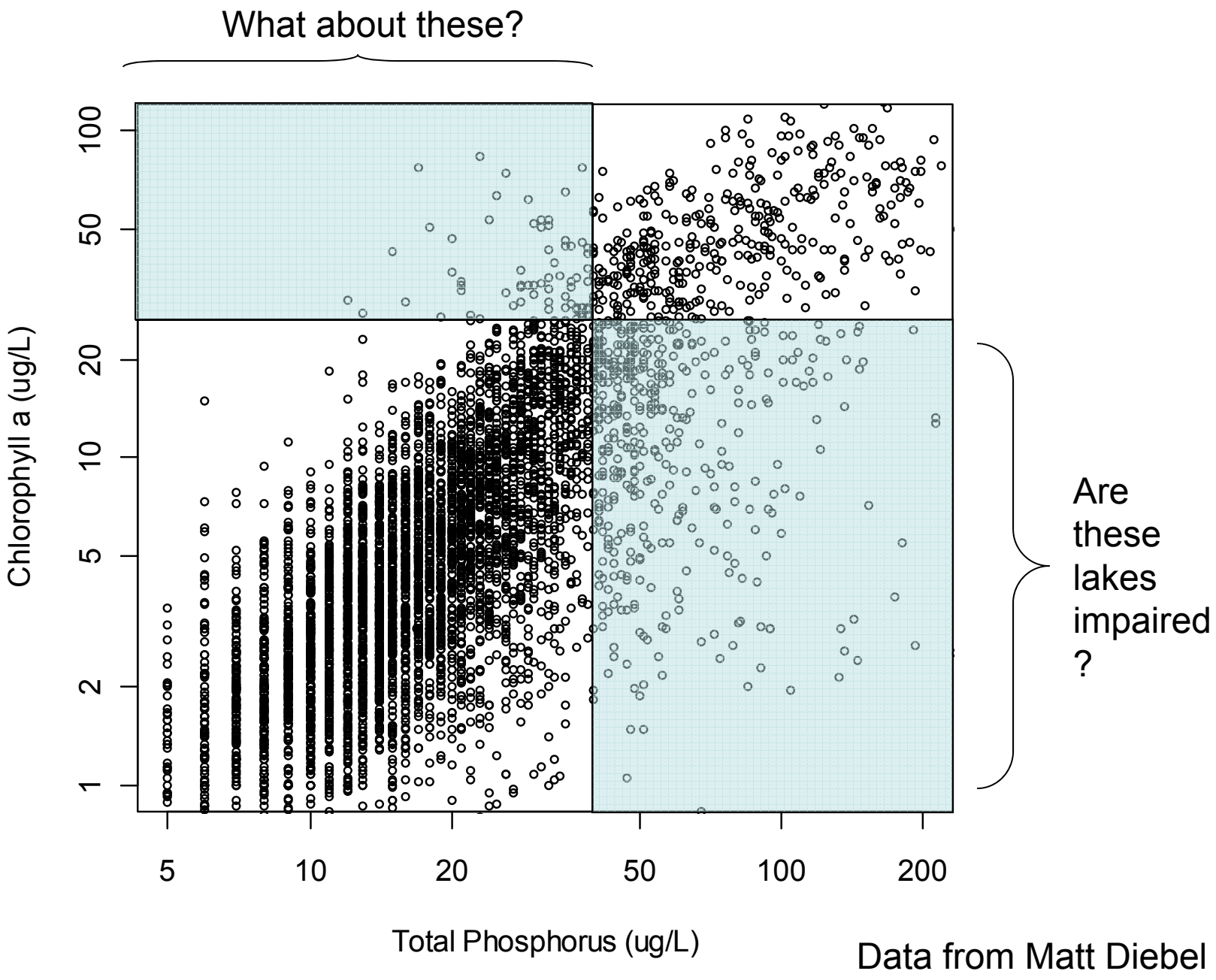
What about these?

TP:CHL a relationships in WI lakes



Are these lakes impaired ?

Source: Matt Diebel, WDNR


What about these?
Chlorophyll a (ug/L)
1
2
5
10
20
50
100
5
10
20
50
100
200
Total Phosphorus (ug/L)
Are these lakes impaired ?
Data from Matt Diebel

FAL and Recreation Thresholds

	Shallow			Deep			
	Headwater Drainage	**Lowland Drainage**	**Seepage**	**Headwater Drainage**	**Lowland Drainage**	**Seepage**	**Two Story Fishery**
TOTAL PHOSPHORUS							
REC	≥ 40 ug/l	≥ 40 ug/l	≥ 40 ug/l	≥ 30 ug/l	≥ 30 ug/l	≥ 20 ug/l	≥ 15 ug/l
FAL	≥ 100 ug/l	≥ 100 ug/l	≥ 100 ug/l	≥ 60 ug/l	≥ 60 ug/l	≥ 60 ug/l	≥ 15 ug/l
CHLOROPHYLL A							
REC*	≥ 25 ug/l	≥ 25 ug/l	≥ 17 ug/l	≥ 14 ug/l	≥ 12 ug/l	≥ 10 ug/l	≥ 6 ug/l
FAL	≥ 60 ug/l	≥ 60 ug/l	≥ 60 ug/l	≥ 27 ug/l	≥ 27 ug/l	≥ 27 ug/l	≥ 10 ug/l

*Chl a Recreation Thresholds should only be used as loose guidance.

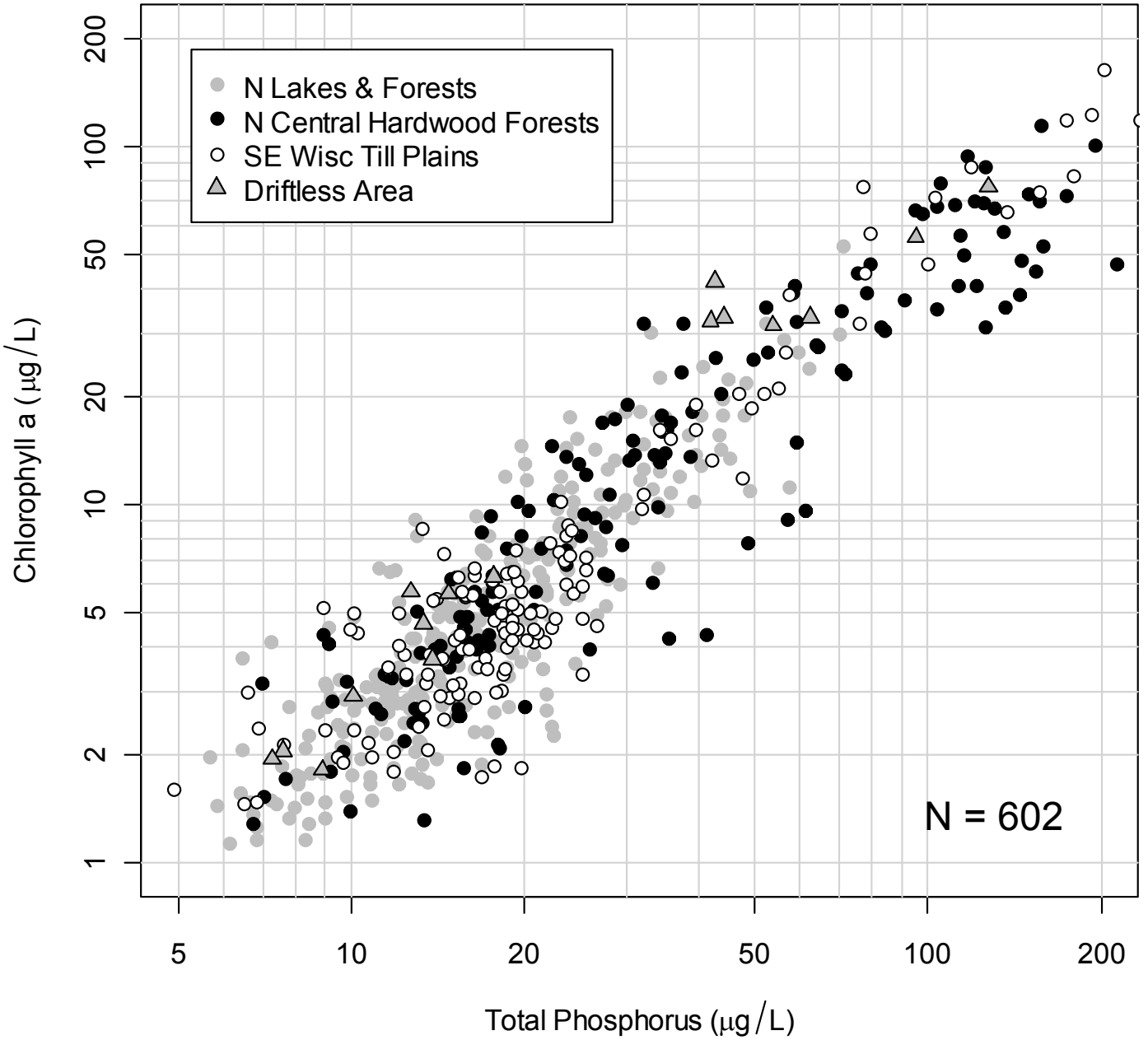
What data do we use to determine whether TP criteria are exceeded?

	Minimum data requirements
Years	Last 5 yrs prioritized (can go back 10 yrs)
Stations	Deep hole stations (additional stations may be specified)
Season	June 1-Sep 15
Timing	1 sample/mo., separated by 15 days
Frequency	3 samples for each of 2 yrs
Exceedance → Flag	2 yrs exceed (or majority of yrs)

Phosphorus Assessment Method for Lakes and Reservoirs

- Current Method (2012 WisCALM)
  - TP criteria in Sec. NR 102.06(4) Wis. Adm. Code
  - Five year assessment period (Jun 1- Sep 15)
  - Minimum of 3 samples in each of two years
  - Deep Hole station, or representative site (multiple stations can be averaged)
  - Two annual average values must exceed
  - Biological impairment must be observed to list as an impaired water

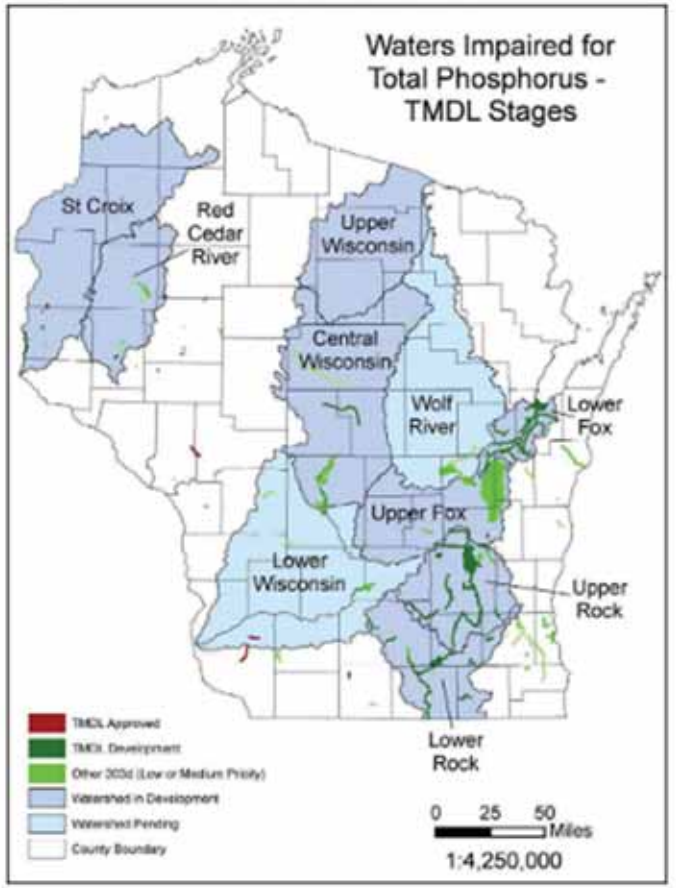
Ecoregions


N Lakes & Forests
N Central Hardwood Forests
SE Wisc Till Plains
Driftless Area
N = 602
Chlorophyll a (µg/L)
Total Phosphorus (µg/L)
1
2
5
10
20
50
100
200
5
10
20
50
100
200

2012 Impaired Waters List

Addressing the Cause – Reducing Nutrients in the Watershed

- Impaired waters 303 (d)
- TMDLs
- Point and non-point source reduction
- Grants



The WDNR is actively developing several large-scale basin-wide TMDLs – many of these are in basins with chronic severe algal blooms and measured toxins

Proposed 2012 List Updates

- 32 new water listings
  - 20 streams and lakes (total phosphorus)
  - 6 lakes (mercury in fish tissue)
  - 5 beaches (E. coli)
  - 1 stream (copper and zinc)
- 25 water delistings
  - 21 beaches (E. coli)
  - 3 streams (degraded habitat)
  - 1 lake (aquatic toxicity)

Top Five Pollutants on 2012 Impaired Waters List