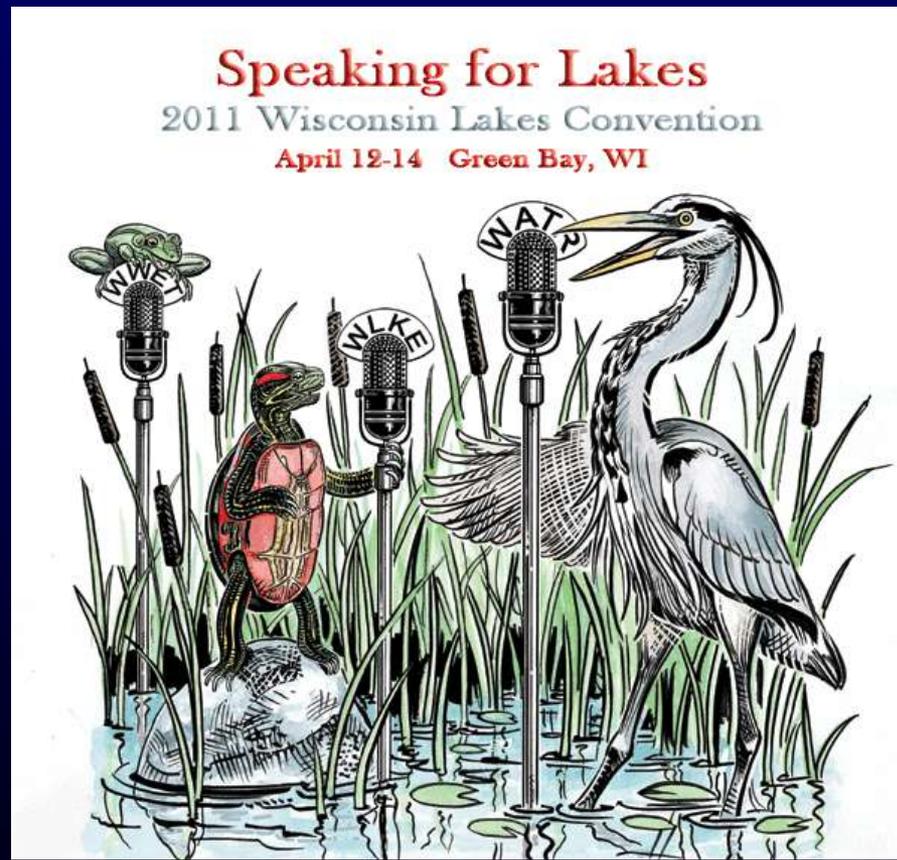


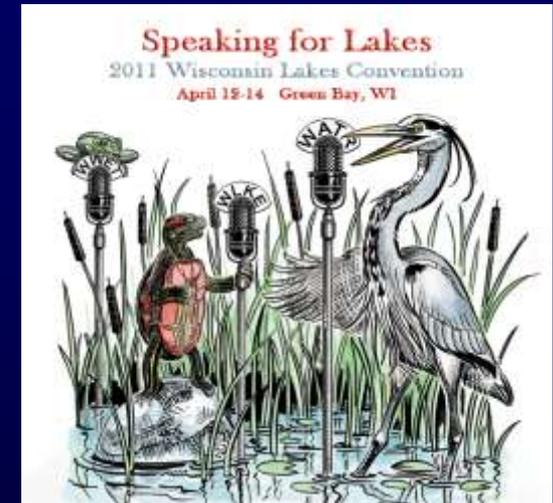
Adding Lake Levels to the Citizen Lake Monitoring Network



Adding Lake Levels to the Citizen Lake Monitoring Network

Outline

- Why Water Level Matters
- Adapting to Changes in Water Level
- How to Monitor Lake Levels
- BREAK
- How to Monitor Lake Levels (cont)
- Citizen Lake Monitoring Network Plan



Why Water Level Matters

Dale Robertson, Paul Juckem, and Tim Asplund





Typical Water Level



With very little precipitation, runoff and tributary input can disappear



Low water levels can turn parts of lakes into swamps



Or Worse



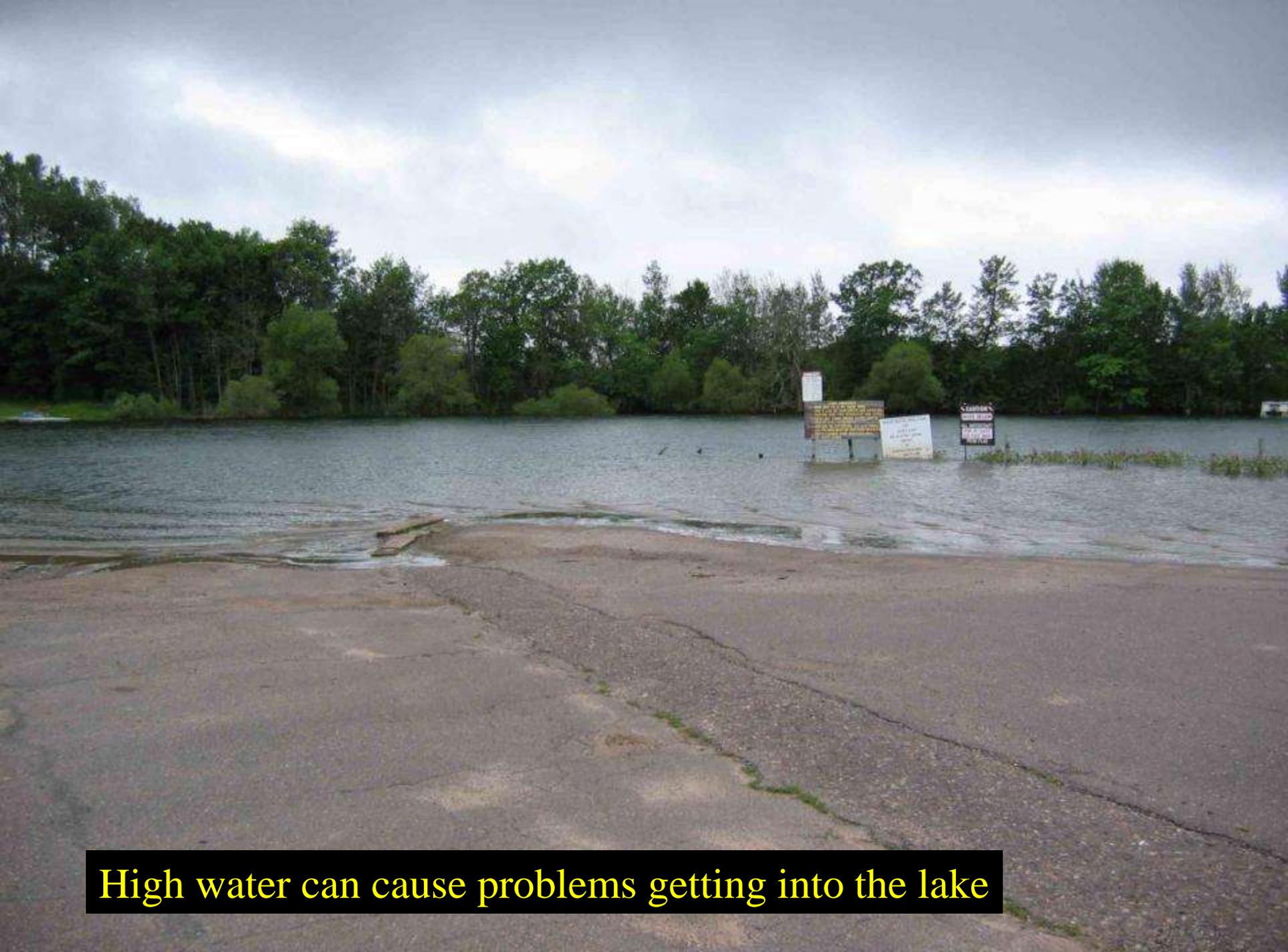
Bass Patterson Lake, Washburn County (E. Cook)



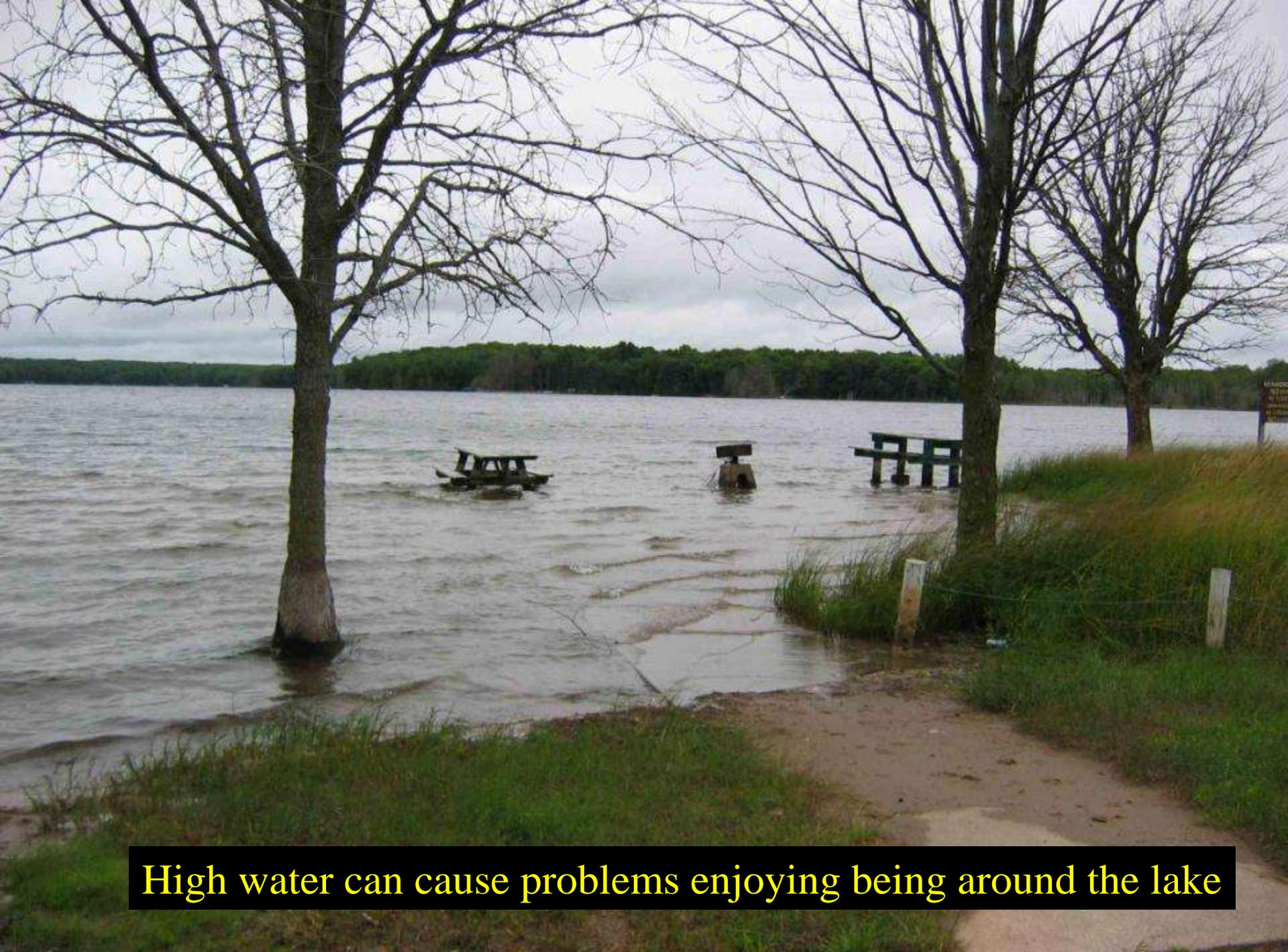
Twin Lake, Marquette County



Fallison Lake, Vilas County



High water can cause problems getting into the lake



High water can cause problems enjoying being around the lake



High water can cause extreme problems

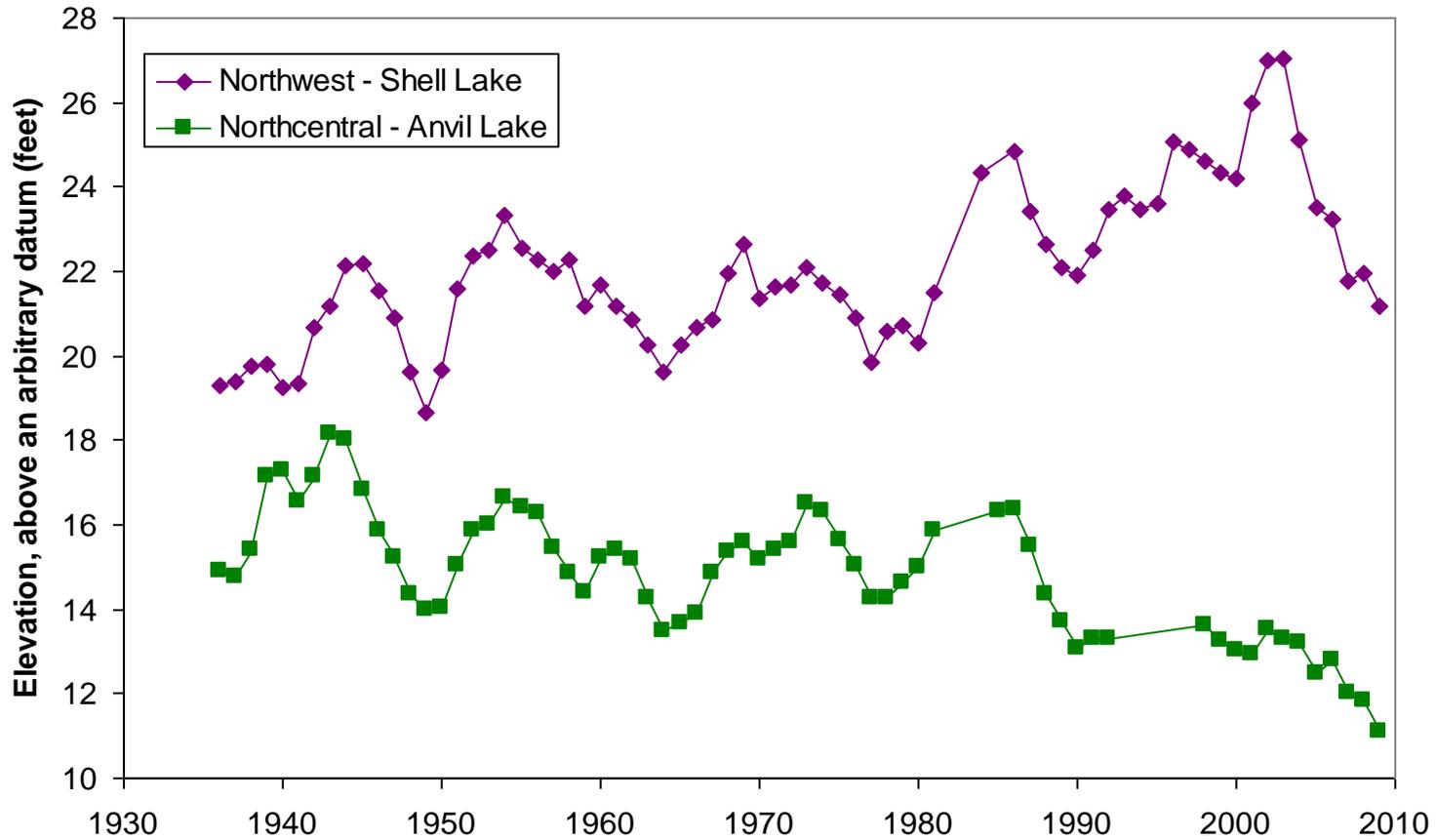
Many factors affect water levels

- Natural variability – Short-term drought and flood *cycles*
- Landscape position and lake type
- Human actions (water withdrawals, land management)
- Climate change (*trends*)

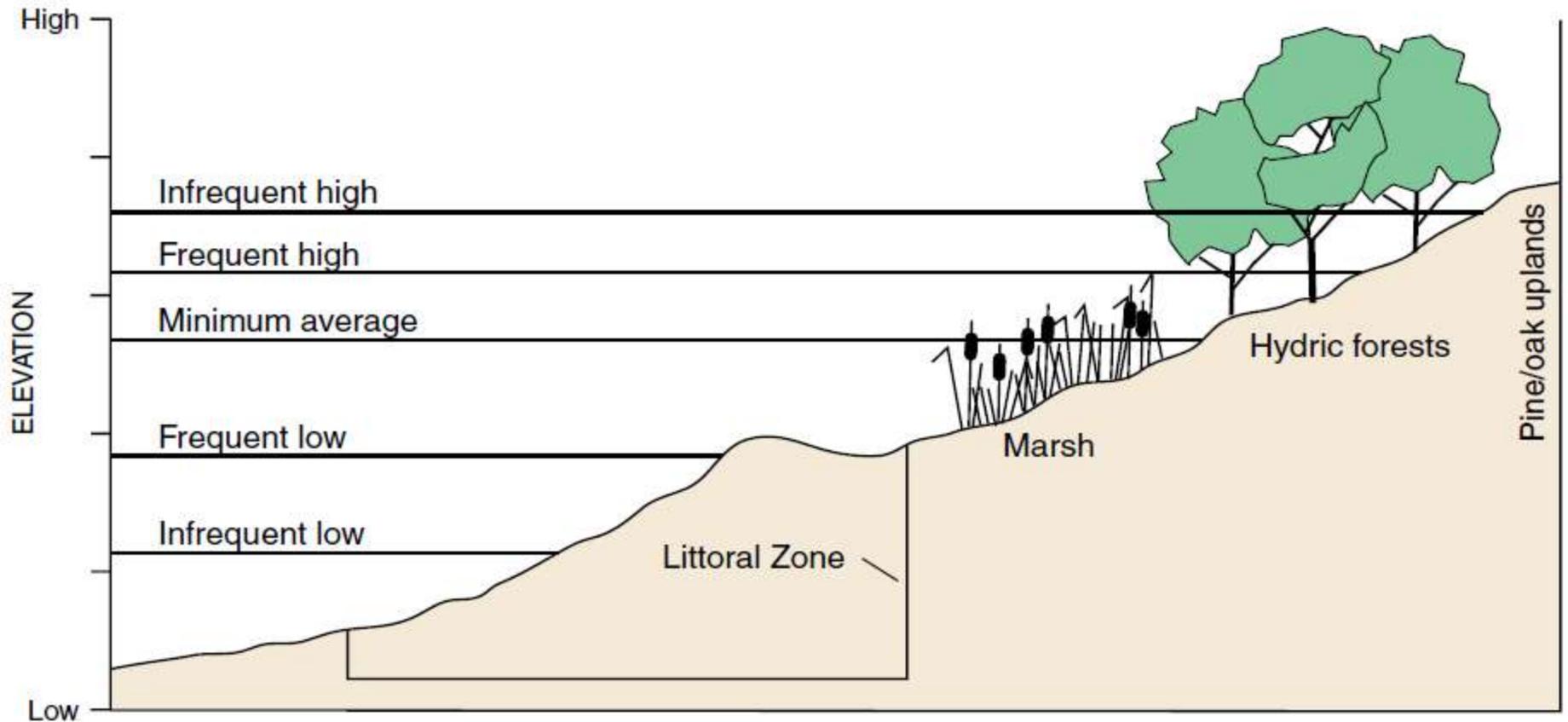
Many factors affect water levels

- Natural variability – Short-term drought and flood *cycles*
- Landscape position and lake type
- Human actions (water withdrawals, land management)
- Climate change (*trends*)

Lake Water Levels



Water levels vary naturally



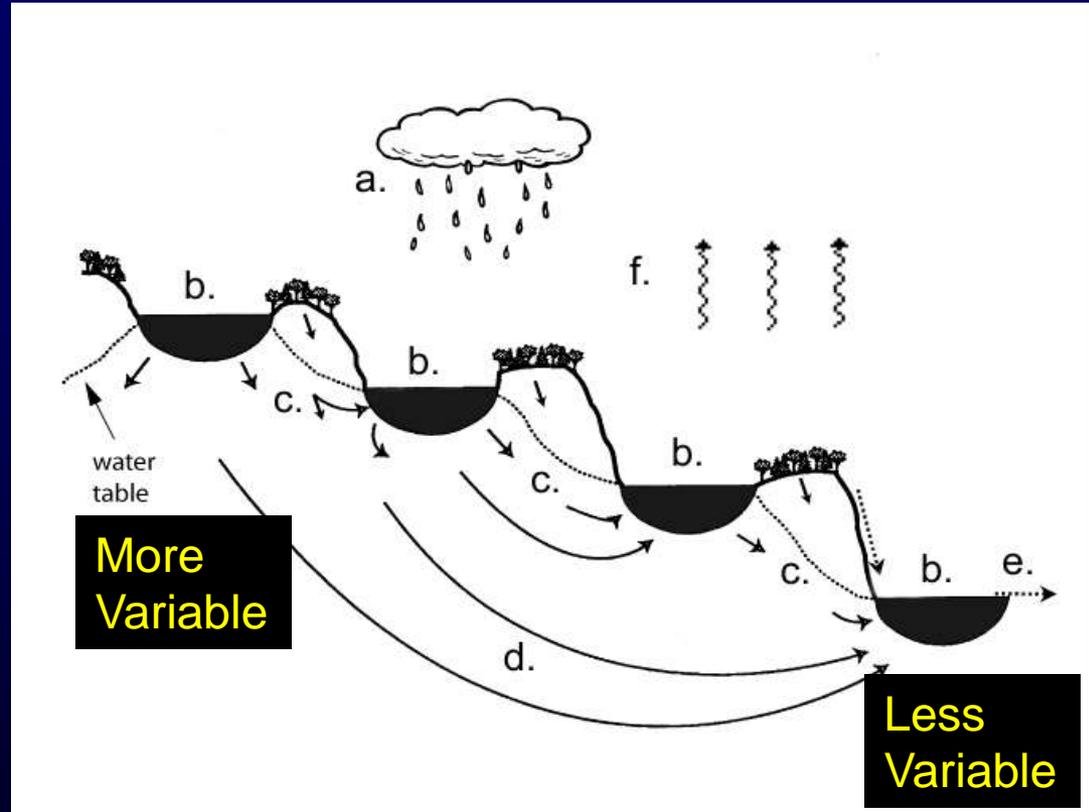
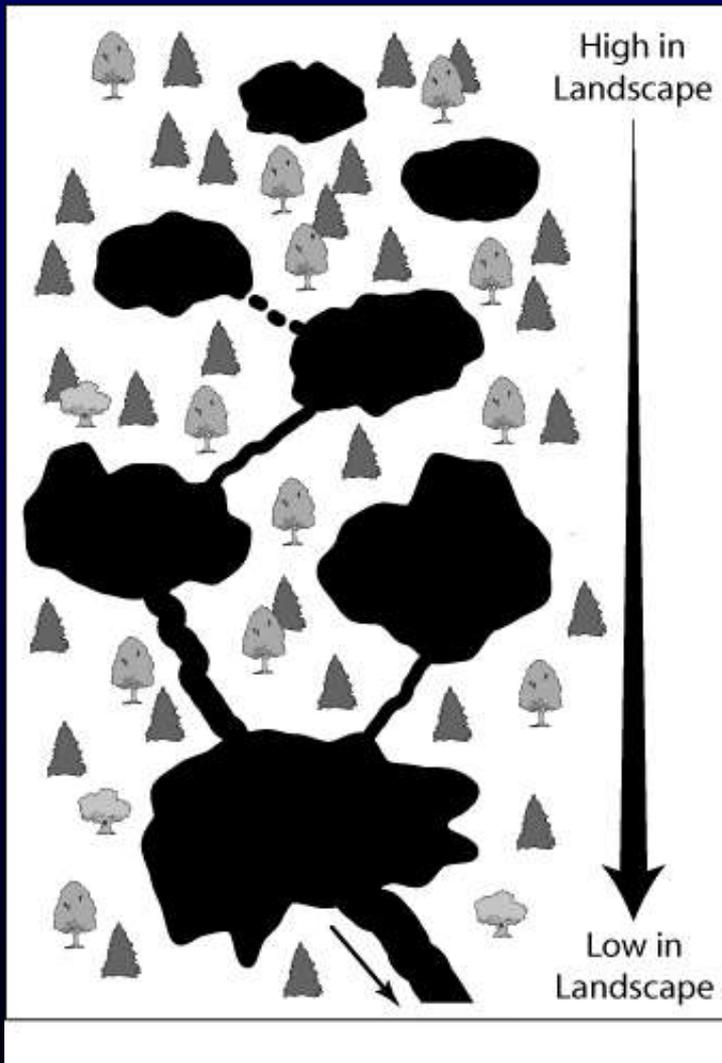
USGS Circular 1186

Source: USGS Circular 1186

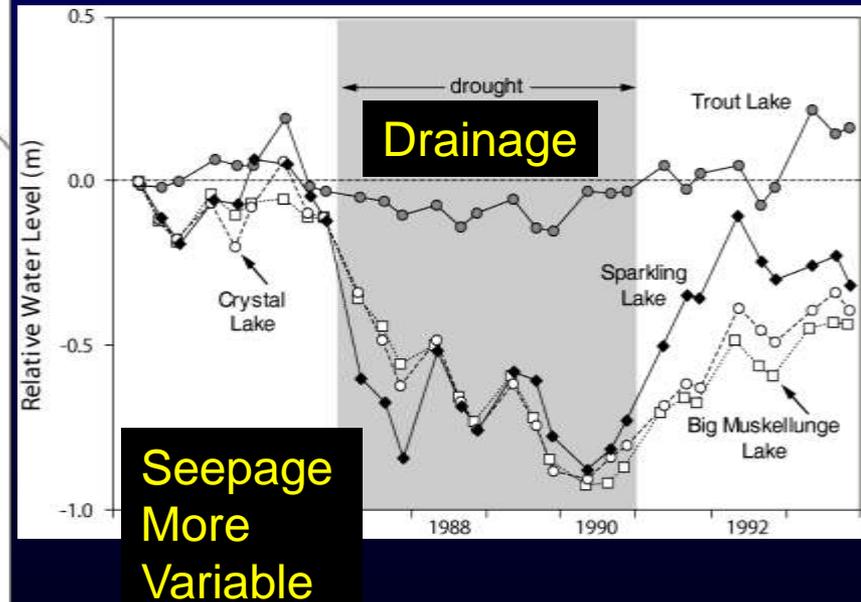
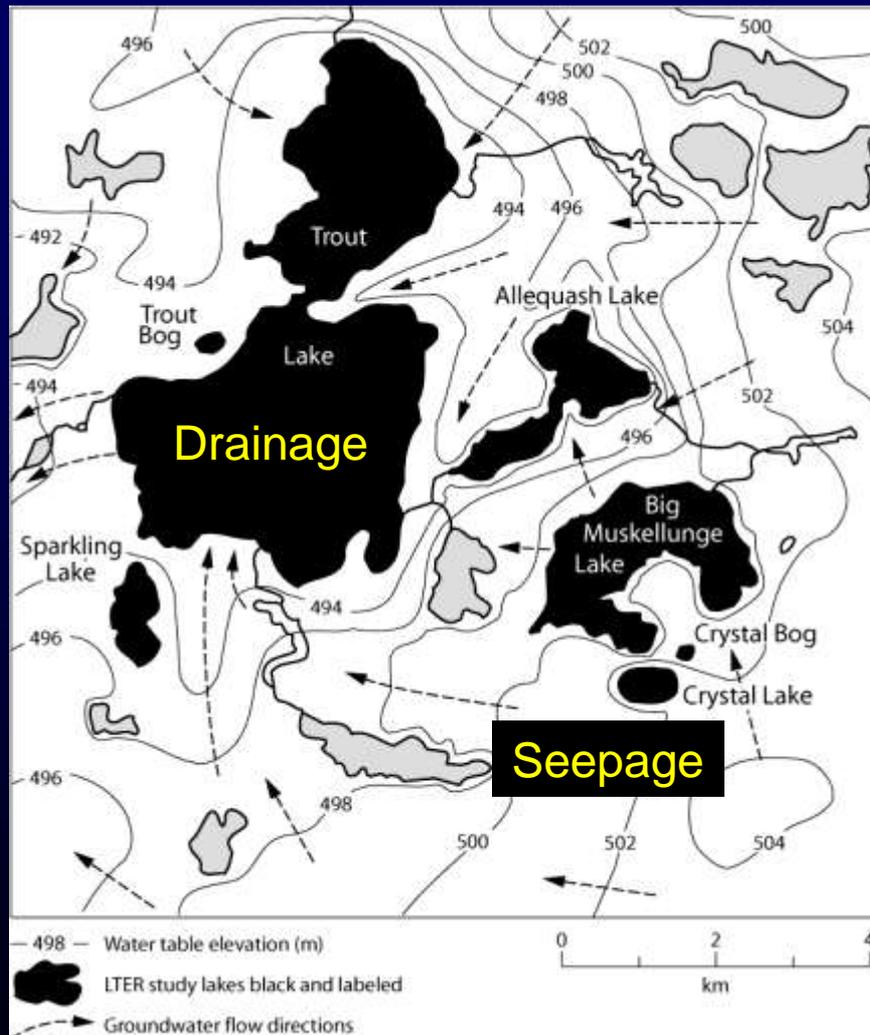
Many factors affect water levels

- Natural variability – Short-term drought and flood *cycles*
- Landscape position and lake type
- Human actions (water withdrawals, land management)
- Climate change (*trends*)

Landscape Position



Response is Dependent on Lake Type



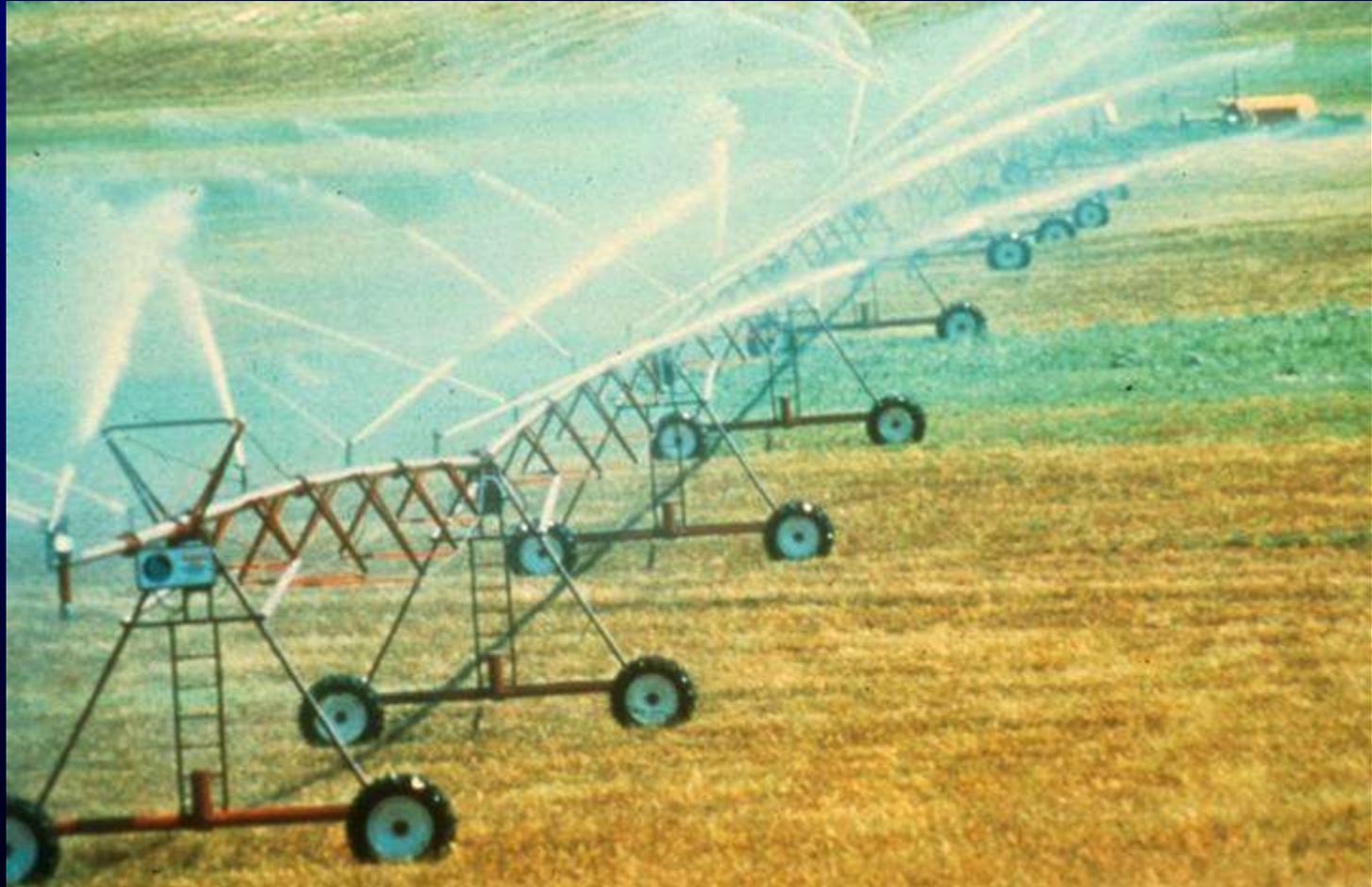
Many factors affect water levels

- Natural variability - Short term drought and flood *cycles*
- Landscape position and lake type
- Human actions (water withdrawals, land management)
- Climate change (*trends*)

Human water & land uses affect levels

- Groundwater withdrawal
- Pumping of lake water
- Land management

Human water & land uses affect levels

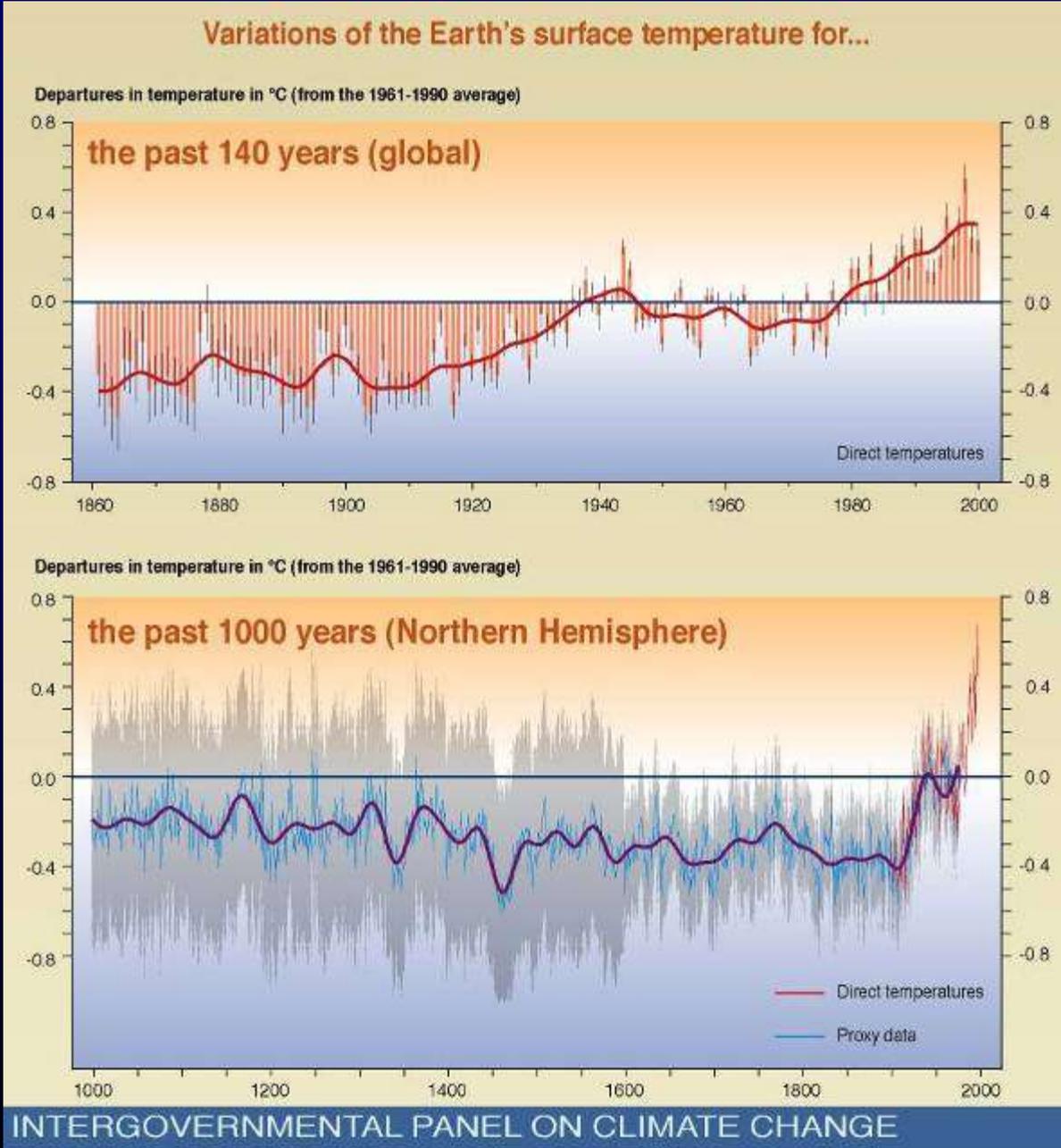


Many factors affect water levels

- Natural variability - Short term drought and flood *cycles*
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- Human actions (water withdrawals, land management)
- Climate change (*trends*)

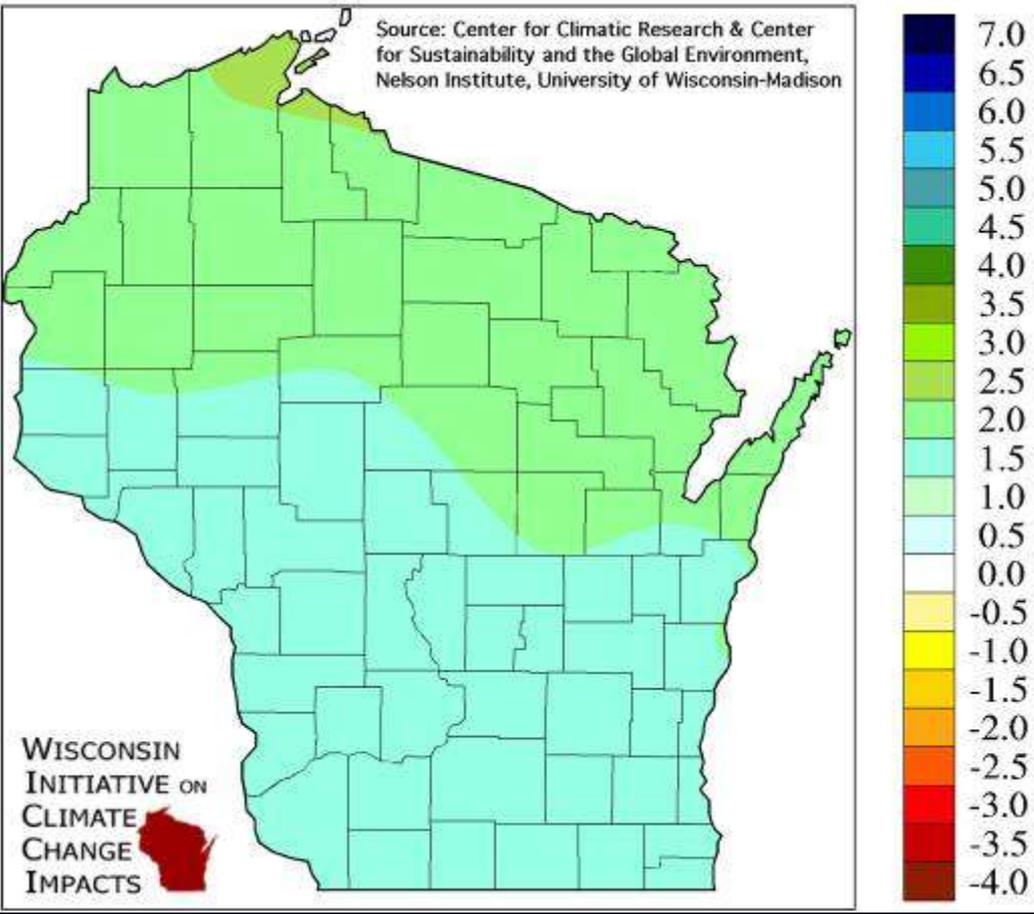
“Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level.”

IPCC, 2007

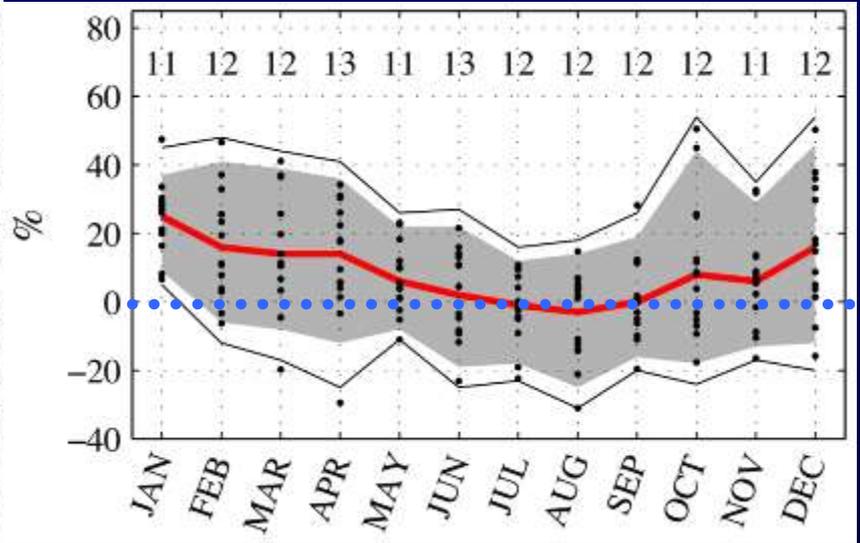


Projected Change in Precipitation from 1980 to 2055

Change in Annual Average (inches)



Probability Distributions of 14 Climate Model Projections by Month



Models predict winter and early spring will be wetter (0-40% increase).

Models uncertain about amount of summer rainfall

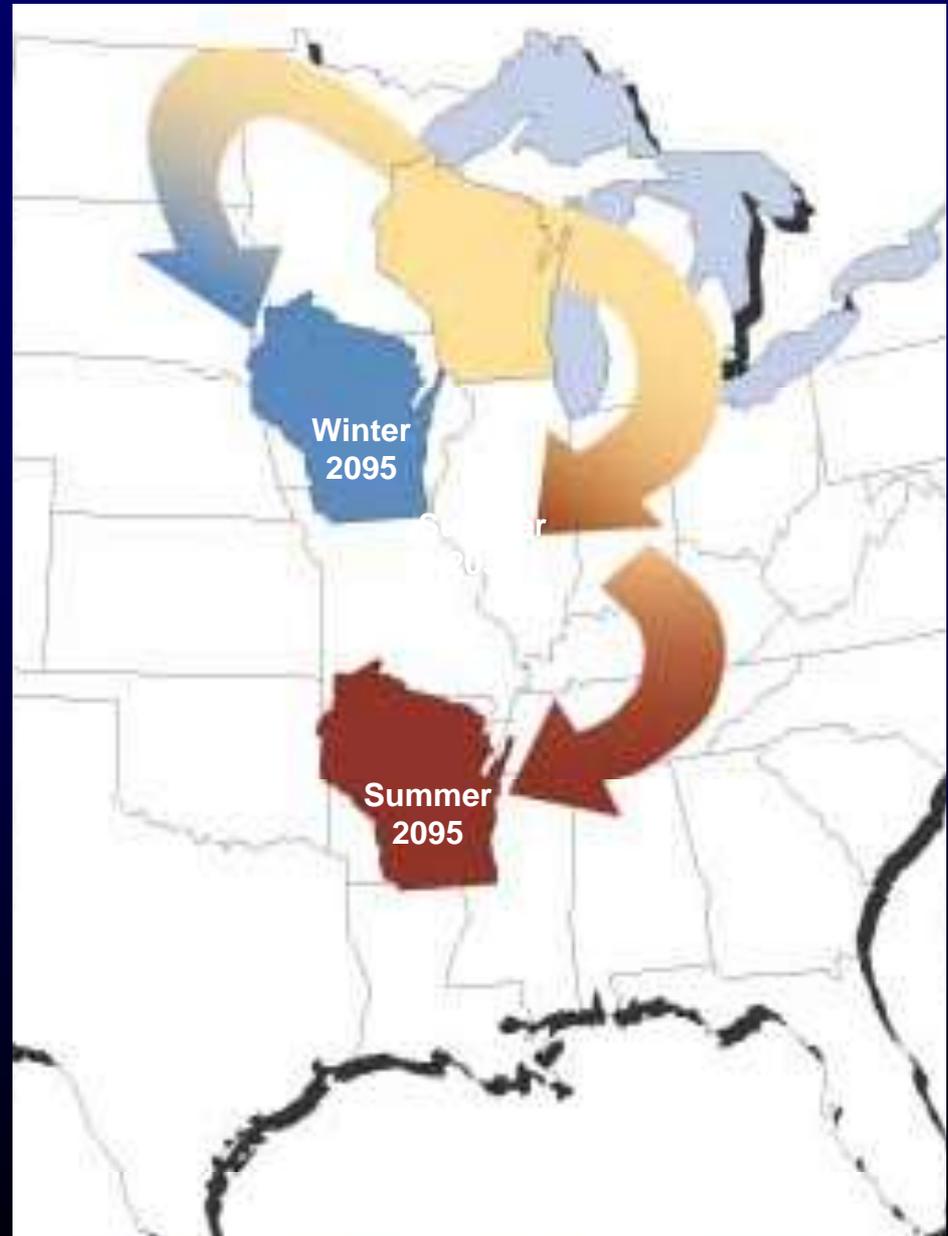
Source: Adapted from D. Vimont, UW-Madison

Changes in Groundwater Levels: Driven by changes in climate, pumping, or land use



Wisconsin's Migrating Climate

What does the future hold for Wisconsin?



Which one is in the future?



Not really sure could be either or both, so we should prepare for either

Implications of water level fluctuations

- Navigation
- Water availability and eco-hydrologic needs (competing demands)
- Financial and health concerns
- Water quality/clarity changes



High water causes problems with erosion and increases in nutrient inputs

How does changes in water level affect water quality and lake productivity?

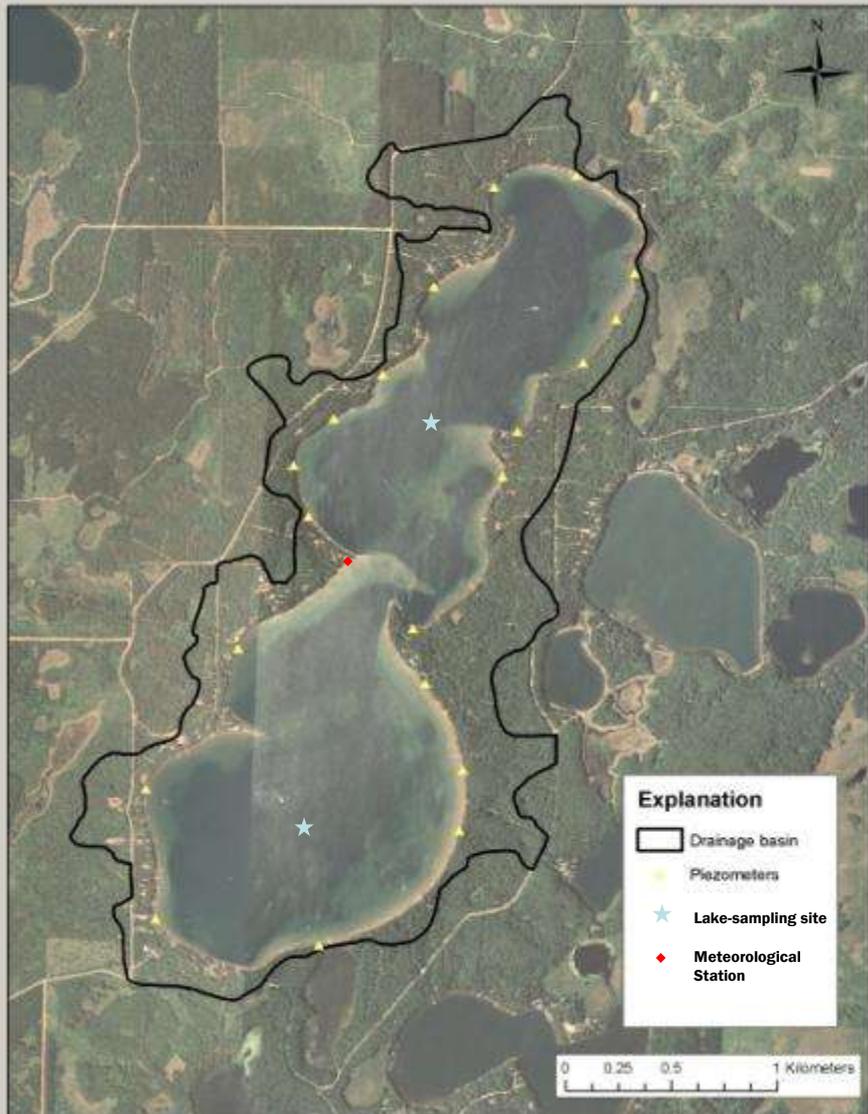
Effects of Changes in Hydrology and Water Level on Lake Productivity, with Implications to What May Occur with Climate Change

Dale Robertson, Bill Rose, and Paul Juckem

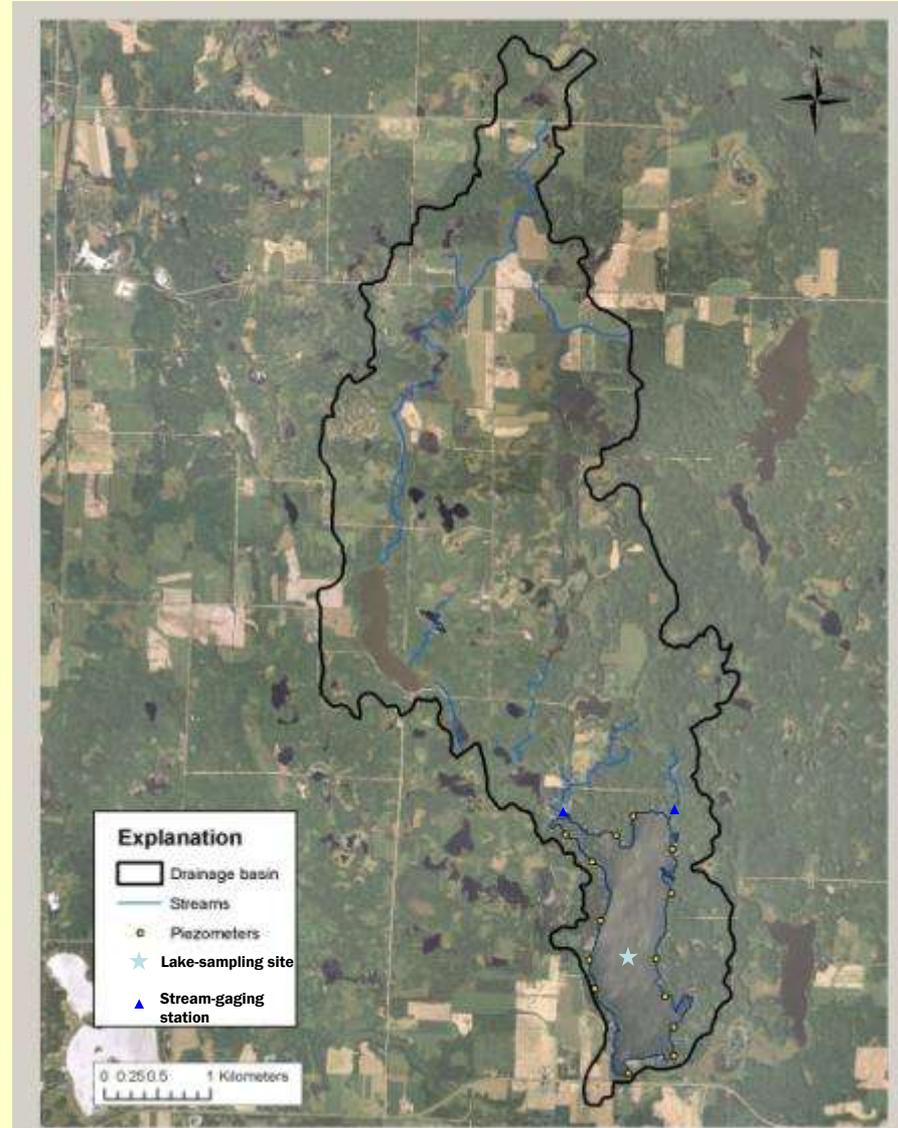


Study Sites – Two Deep Relatively Pristine Lakes

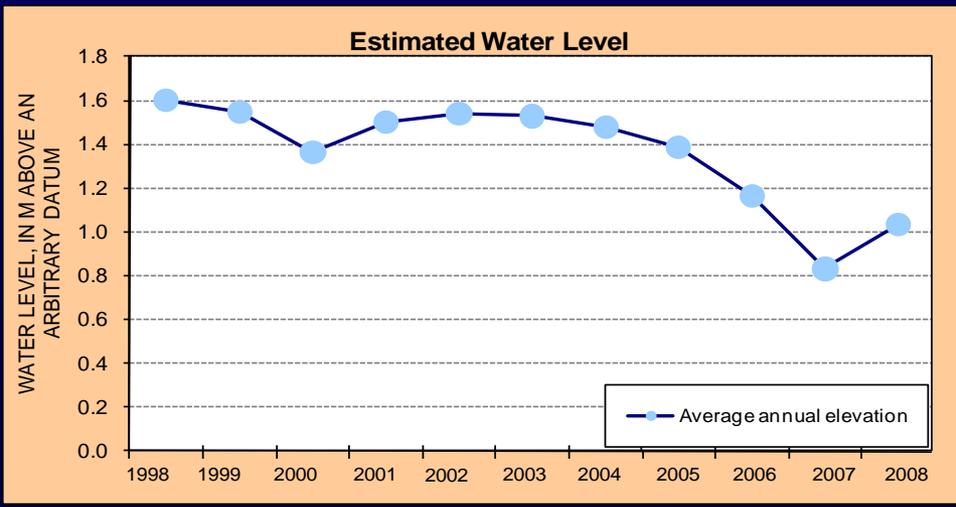
Whitefish Lake



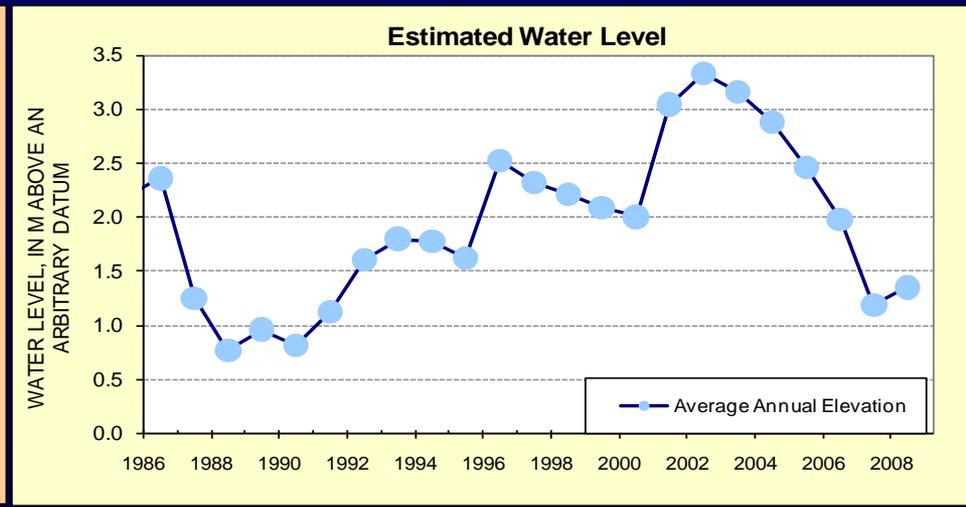
Silver Lake



Whitefish Lake



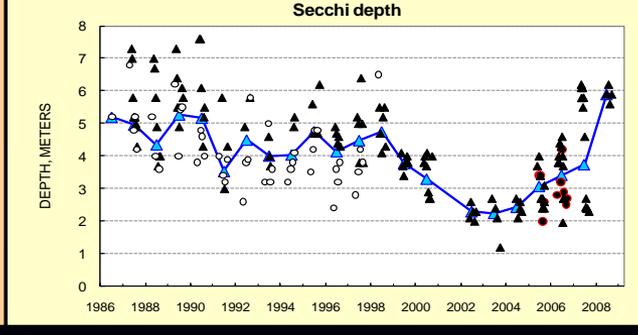
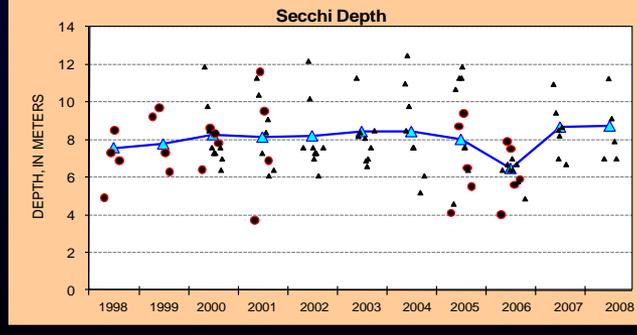
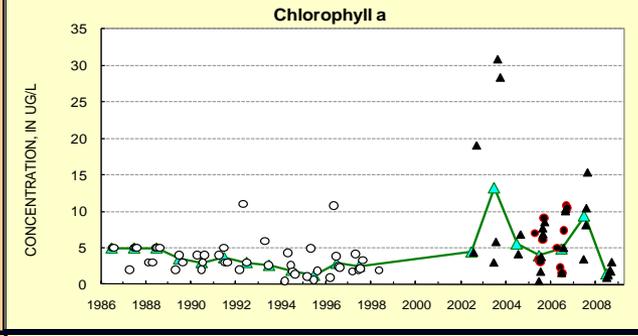
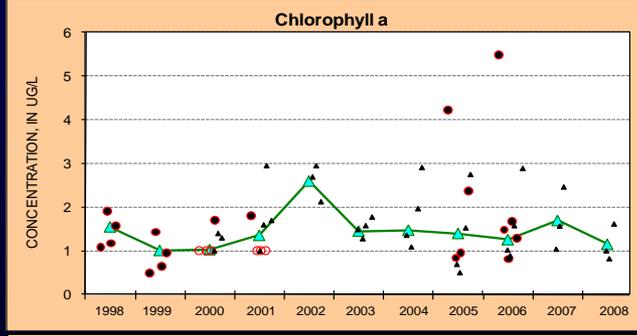
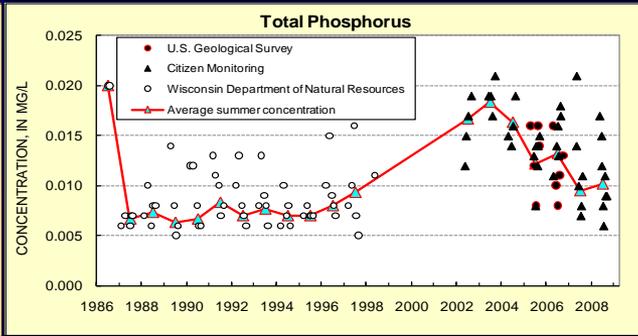
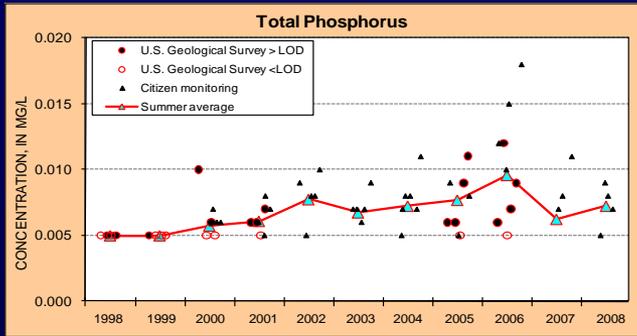
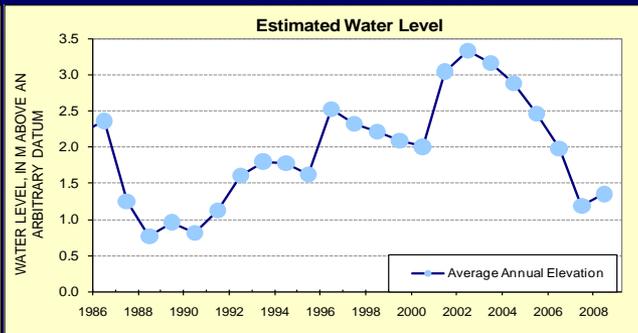
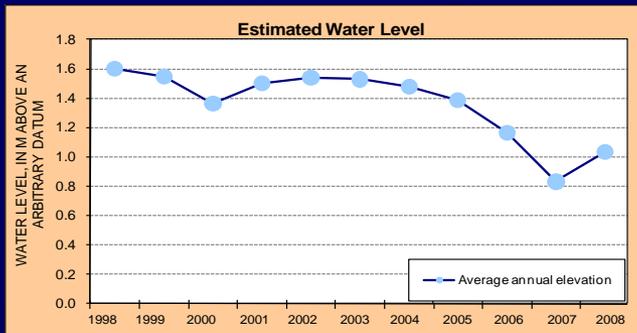
Silver Lake



Whitefish Lake

Silver Lake

Measured Changes in Lake Water Quality



Do these lakes respond to changes in nutrient loading the way we think they should?

$$\text{Phosphorus Conc} = \frac{L}{Z (1.62 (L/Z)^{0.458} + 1/\tau)}$$

Where: L = P loading

Z = Mean Depth

τ = Residence Time

Canfield & Bachman Natural Lake Model (1981)

Detailed Hydrologic Budgets



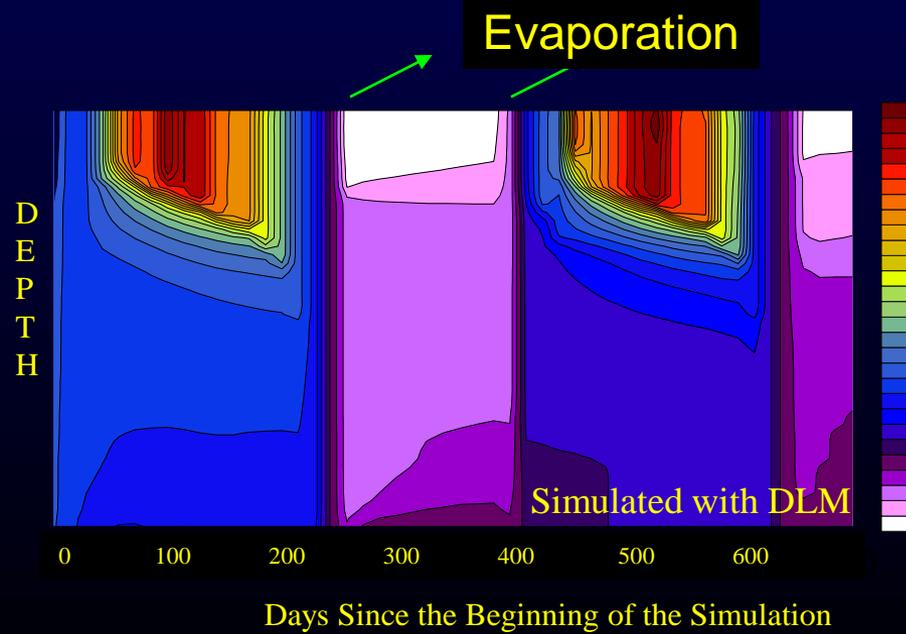
Stage and Δ Storage



Precipitation



Tributary Input



Detailed Phosphorus Budgets



Tributary Input



Nearshore Runoff



Atmospheric Deposition



Groundwater Input

Changes in Hydrology and Phosphorus Loading

Whitefish Lake

Silver Lake

Water Budget

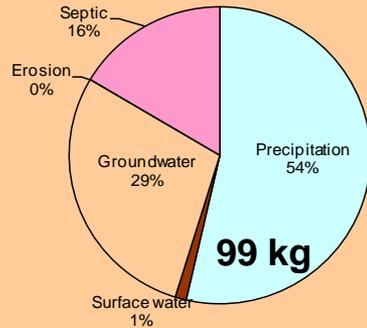
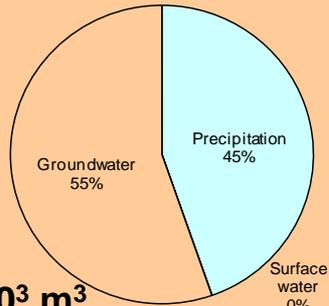
Phosphorus Budget

Water Budget

Phosphorus Budget

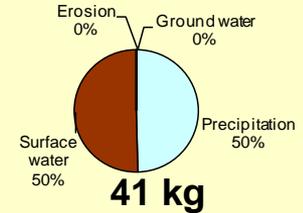
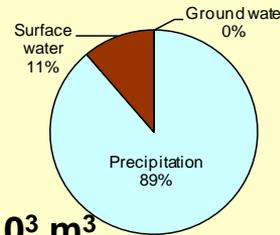
Dry Years

$5.6 \times 10^3 \text{ m}^3$



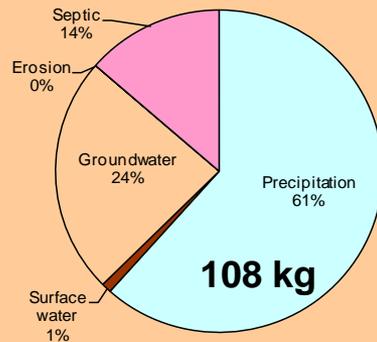
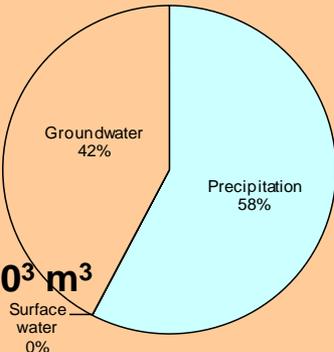
Dry Years

$1.0 \times 10^3 \text{ m}^3$



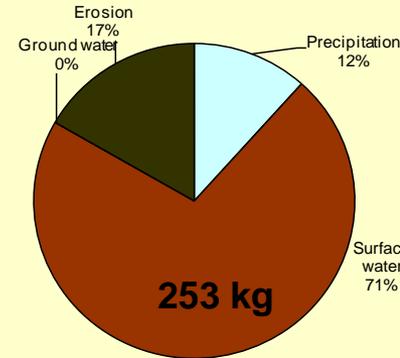
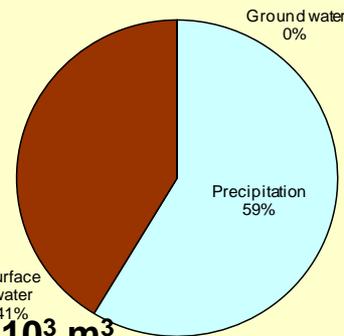
Wet Years

$4.2 \times 10^3 \text{ m}^3$



Wet Years

$2.5 \times 10^3 \text{ m}^3$



Application of the Eutrophication Model

$$\text{Phosphorus Conc} = \frac{L}{Z (1.62 (L/Z)^{0.458} + 1/\tau)}$$

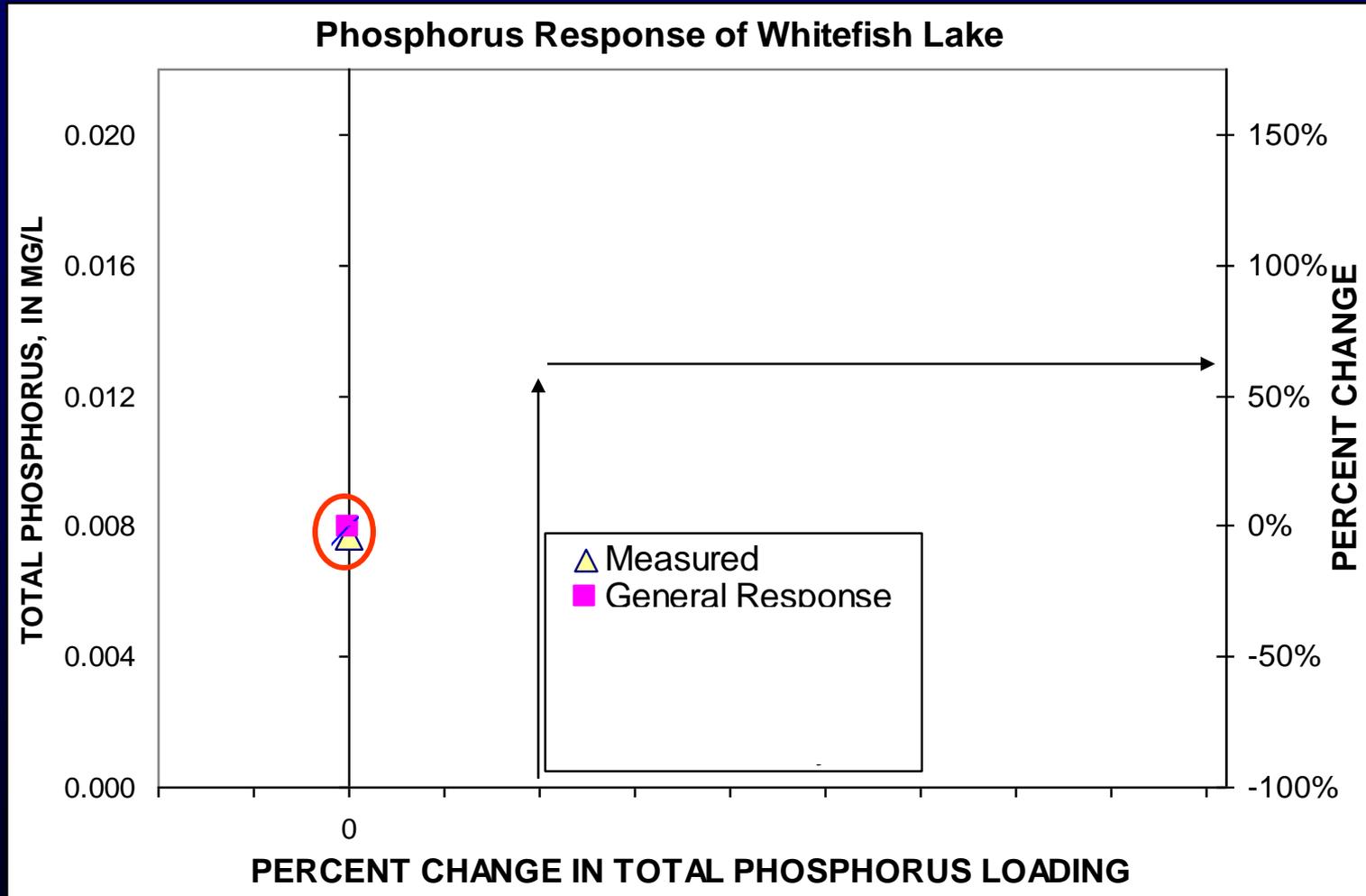
Where: L = P loading

Z = Mean Depth

τ = Residence Time

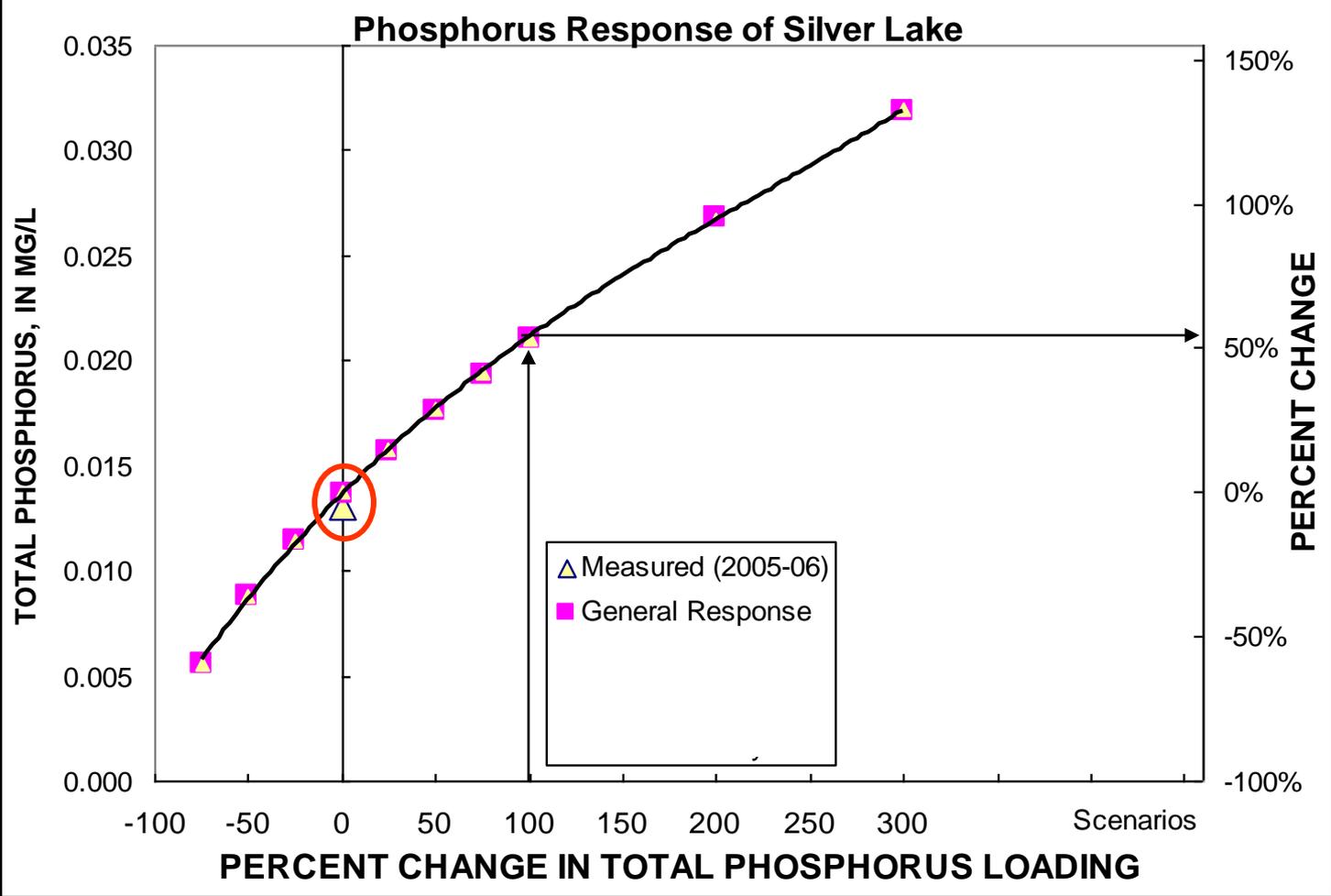
Canfield & Bachman Natural Lake Model (1981)

Whitefish Lake – Seepage Lake



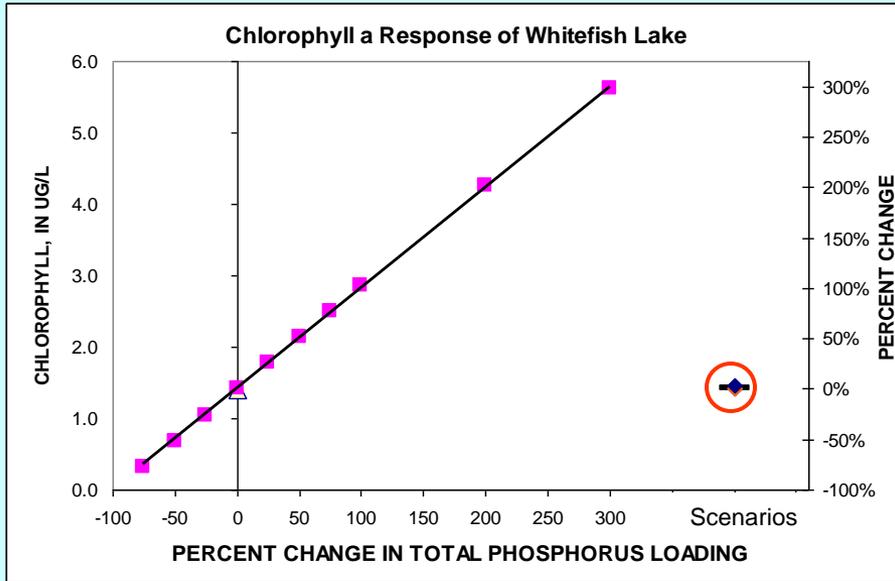
Phosphorus Response from Canfield & Bachman (1981) Natural Lake Model

Silver Lake – Terminal Lake

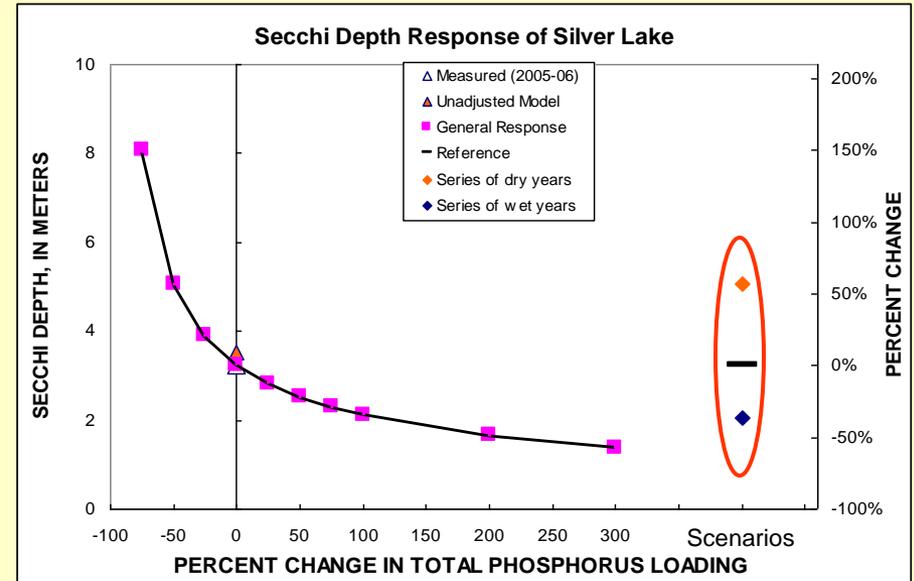
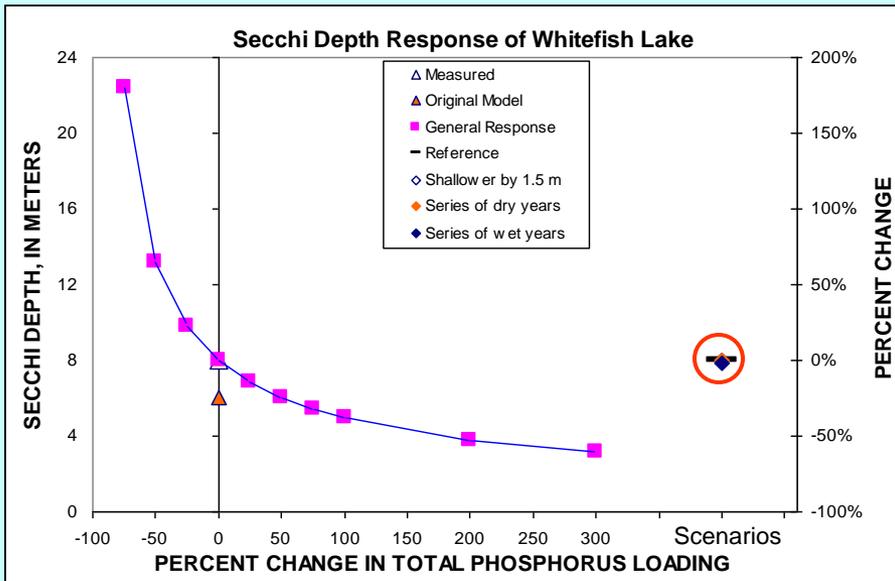
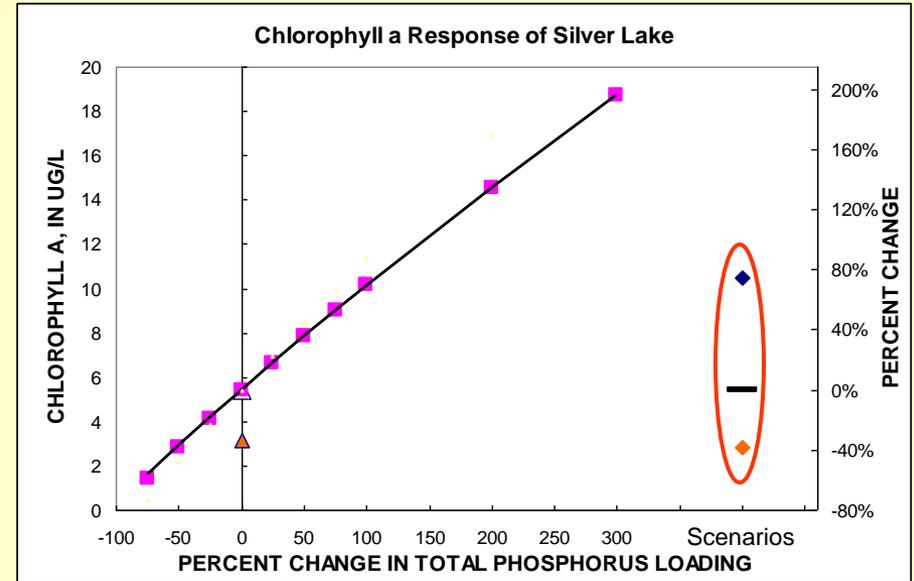


Phosphorus Response from Canfield & Bachman (1981) Natural Lake Model

Whitefish Lake – Seepage Lake

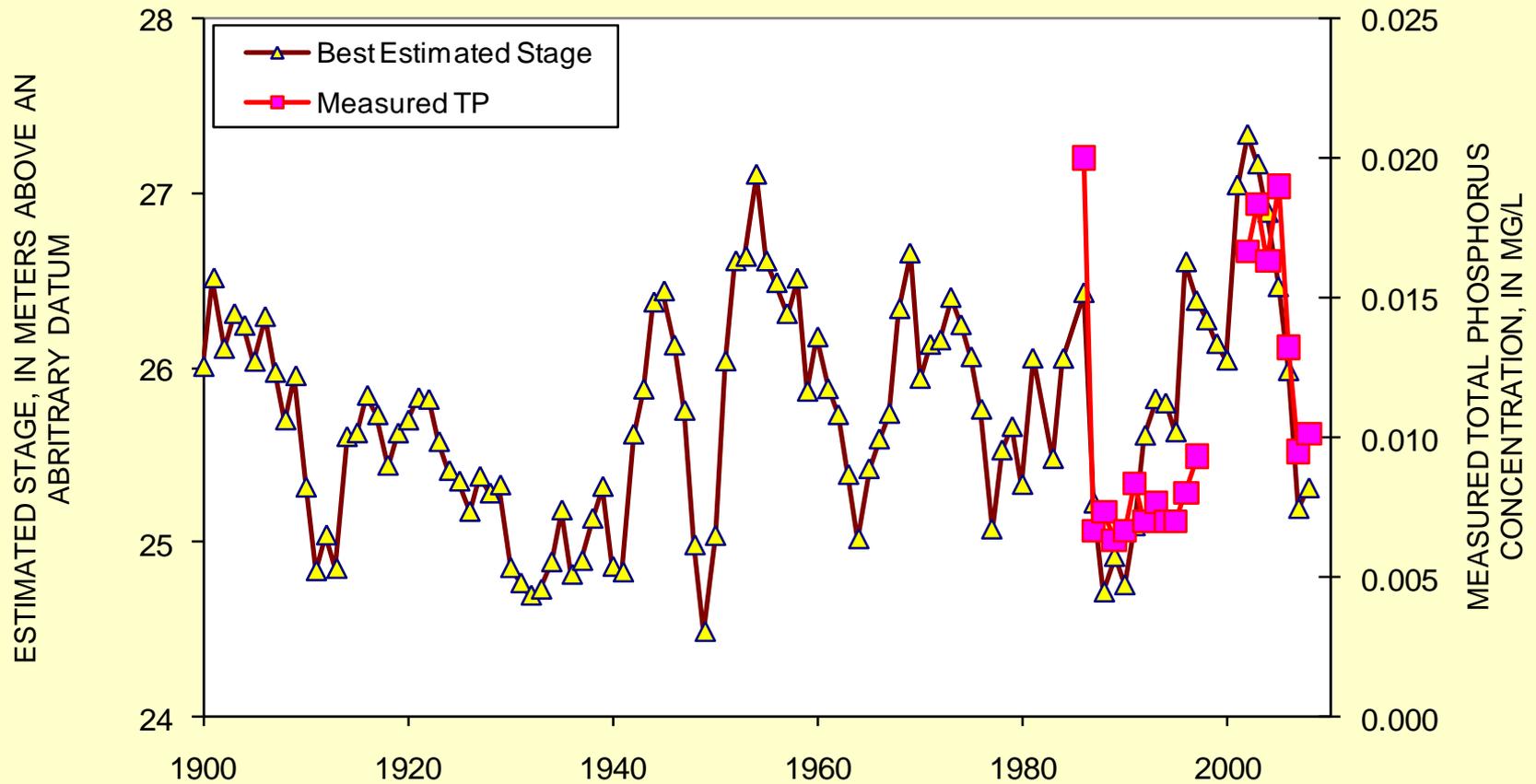


Silver Lake – Terminal Lake



Silver Lake

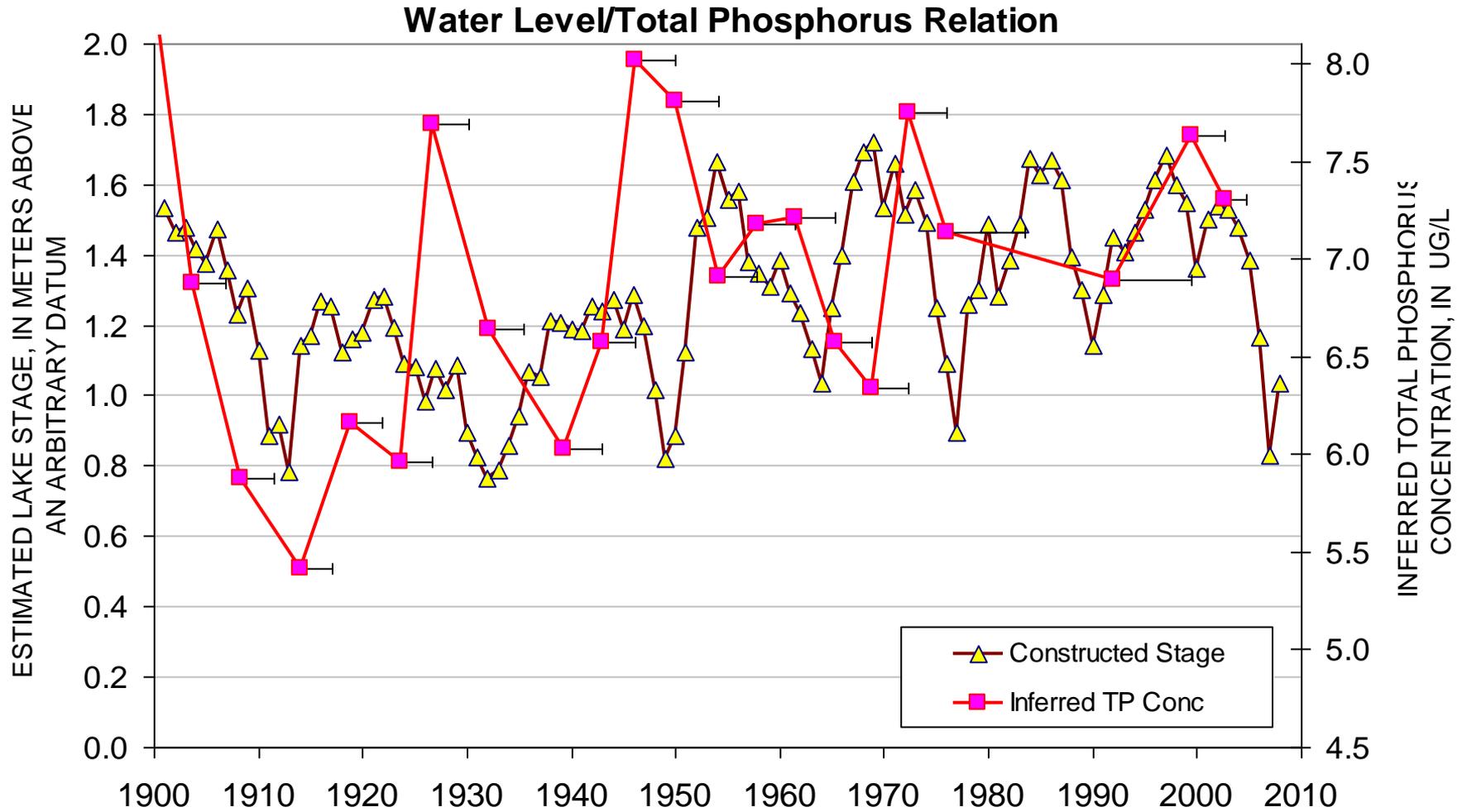
Silver Lake Water Level - Historical Water Quality





How has Whitefish Lake changed through time?

Whitefish Lake – Seepage Lake



Estimated from measured water levels in Whitefish Lake (2004 to 2007), water levels in Bluegill Lake (1986 to 2003), nearby measured precipitation (1900 to 1995)

But what about **Shallow Lakes?** – Should they behave differently from deep lakes?

1. Changes in depth can lead to changes in stratification and changes in internal phos. release > changes in phos. conc.

Internal Phosphorus Loading in Deep Stratified Lakes

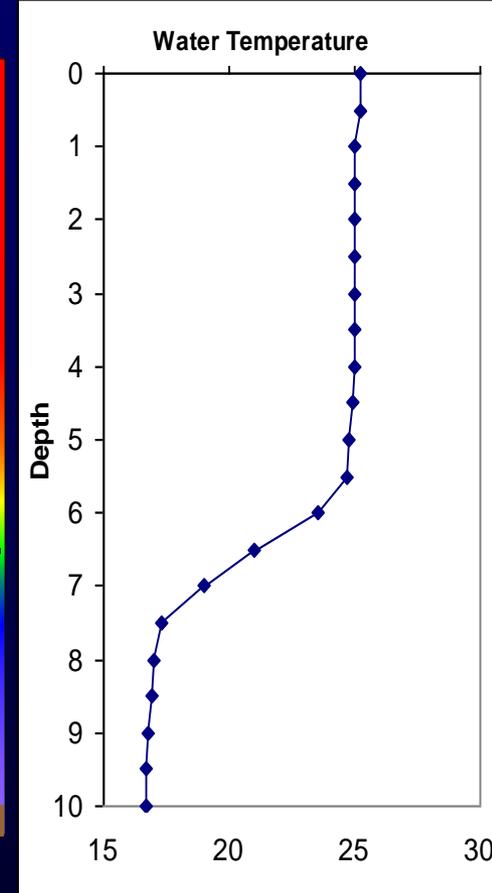
Epilimnion

Hypolimnion

Dissolved Oxygen ↓

Phosphorus

Thermocline



Internal Phosphorus Loading in Shallow Lakes

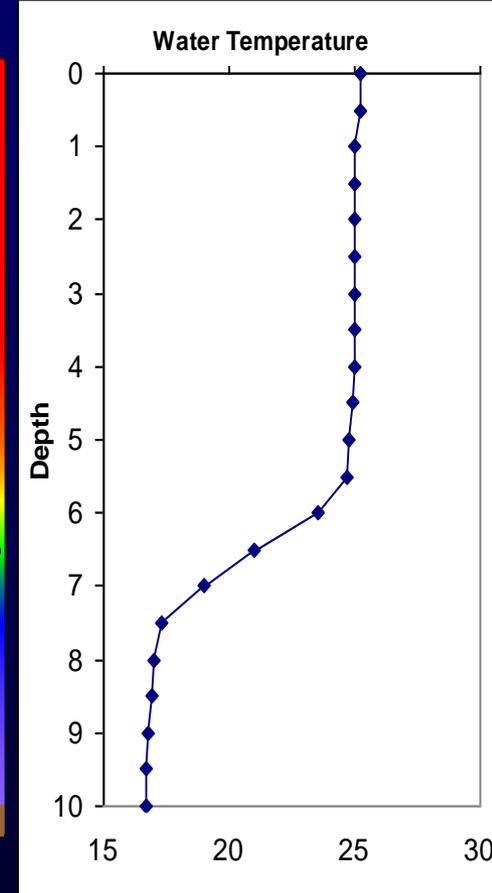
Epilimnion

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Dissolved Oxygen ↓

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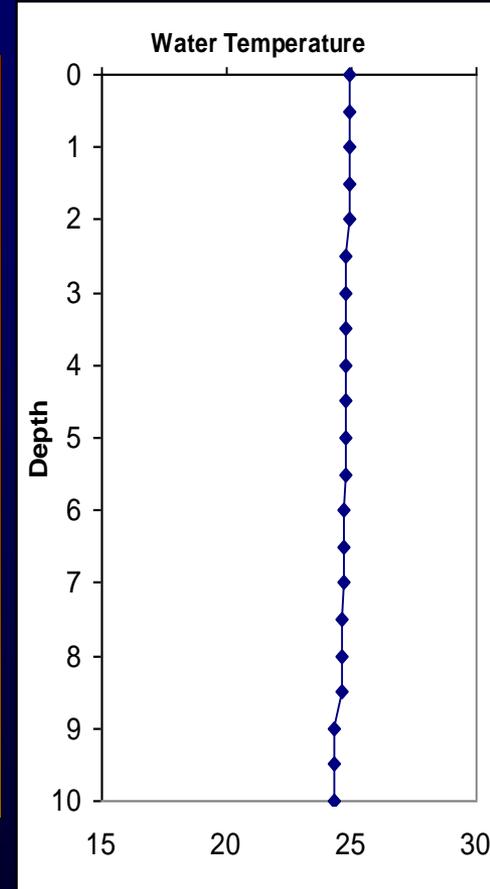


Internal Phosphorus Loading in Shallow Lakes

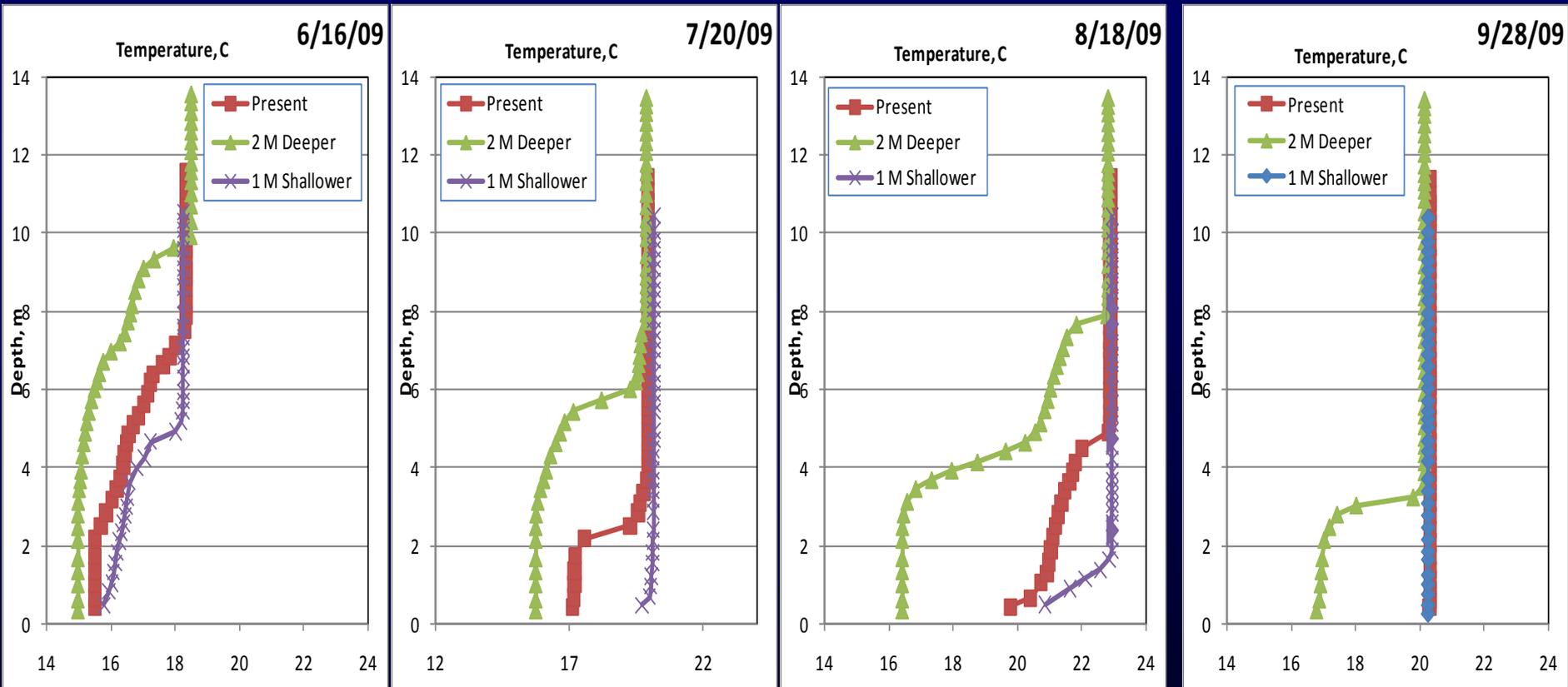
Epilimnion

Frequent Mixing Events

Phosphorus



Water Level may directly effect stratification and phosphorus release



Deep Lakes – Internal phosphorus release but may not mix upward

Shallower Lakes – Less stratification and potentially more phosphorus release

Very shallow lakes – may not stratify and have little phosphorus release

Why would shallow lakes behave differently from deep lakes?

1. Changes in depth can lead to changes in stratification and changes in internal phos. release > changes in phos. conc.
2. Changes in depth may lead to more of relative change in volume > larger changes in phos. concentrations.
3. Changes in depth may lead to larger changes in littoral areas > larger changes in lake ecology > changes in productivity.

Changes in water level may affect macrophyte growth



F. Koshere

Tomahawk Lake, Bayfield County

Conclusions

Changes in meteorology > changes in the water level of lakes

- much larger changes in lakes without outlets

Changes in water level, phosphorus input > changes in phosphorus and chlorophyll a concentrations, and clarity in deep lakes

Climate Change may affect future water levels in lakes and their water quality

- Changes are expected to be largest in lakes with large fluctuations in hydrological input

How do changes in hydrology and water level affect shallow lakes?

- Study on Shell Lake and potentially Anvil Lake

Information Needed with respect to Changes in Water Level:

1. A better understanding of how the water quality of shallow lakes respond to changes in hydrology and water level.
2. Approaches to adapt to changes in water level.
3. Documentation of changes in water levels in lakes across the State.