BASICS OF LAKE SCIENCE

Wisconsin Lakes and Streams Convention, 2020

Susan Graham

Thank you to Buzz Sorge from whom most of these slides were adapted.

Courtesy of Wisconsin Lake Partnership

Wisconsin Department of Natural Resources
Wisconsin Association of Lakes
University of Wisconsin Extension

Outline

- What Makes a Lake?
  - Physical features
  - Chemistry
  - Biology

- Threats to Lakes
  - Habitat loss
  - Nutrient pollution
  - Aquatic invasive species
  - Climate change

- Additional Resources

Wisconsin's Glacial Legacy

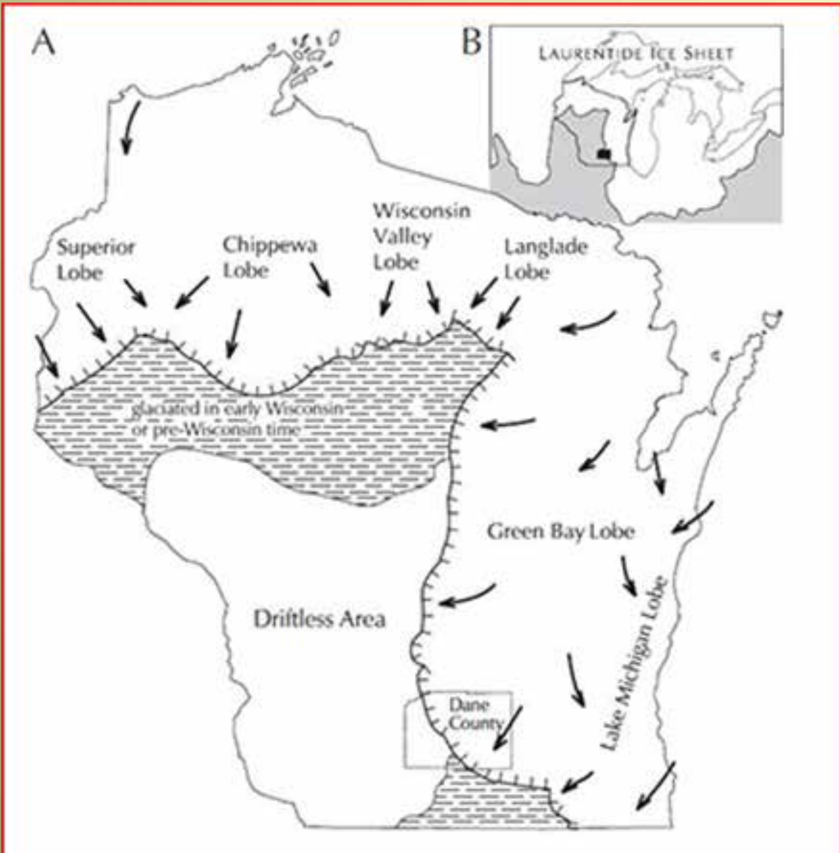
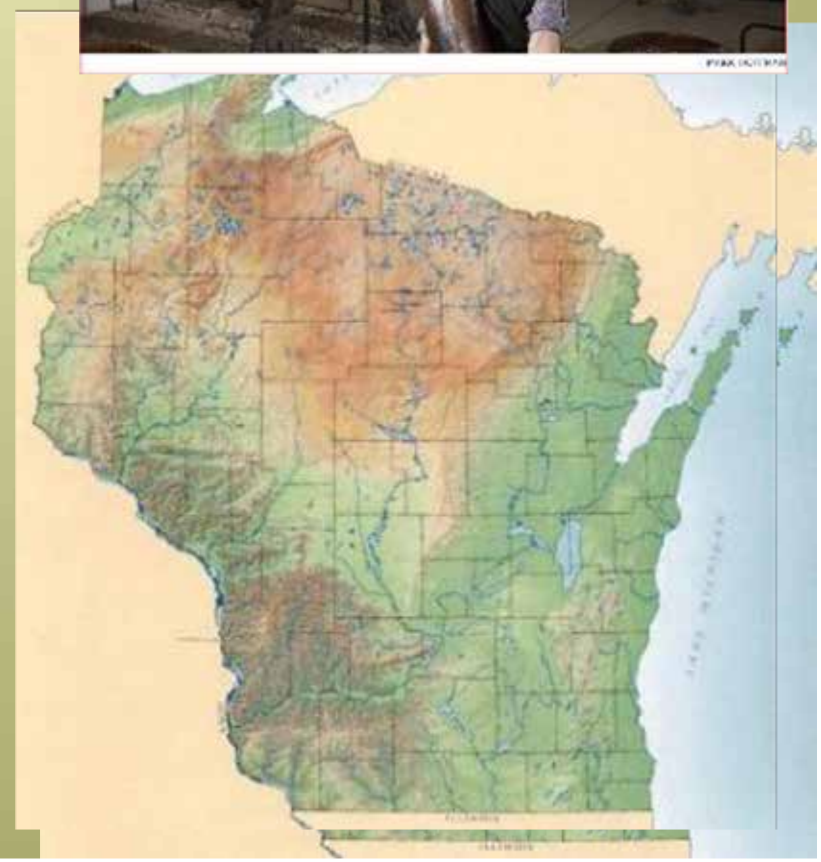
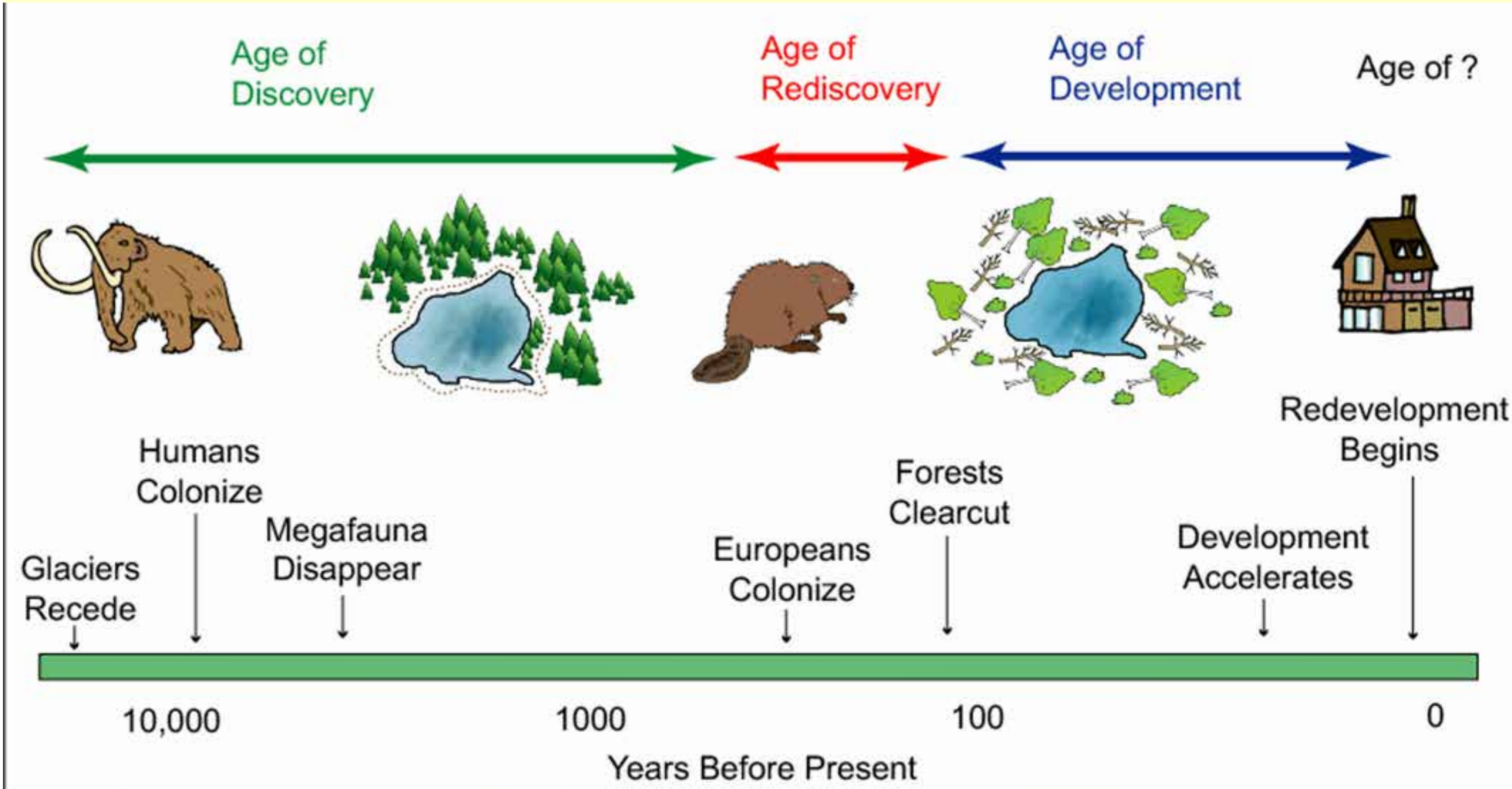


Figure 1. *Location of Dane County (**A**) in relation to the Laurentide Ice Sheet (**B**) and its lobes during the height of the Wisconsin Glaciation. Arrows show direction of ice flow; hachures indicate the edge of the ice sheet.*

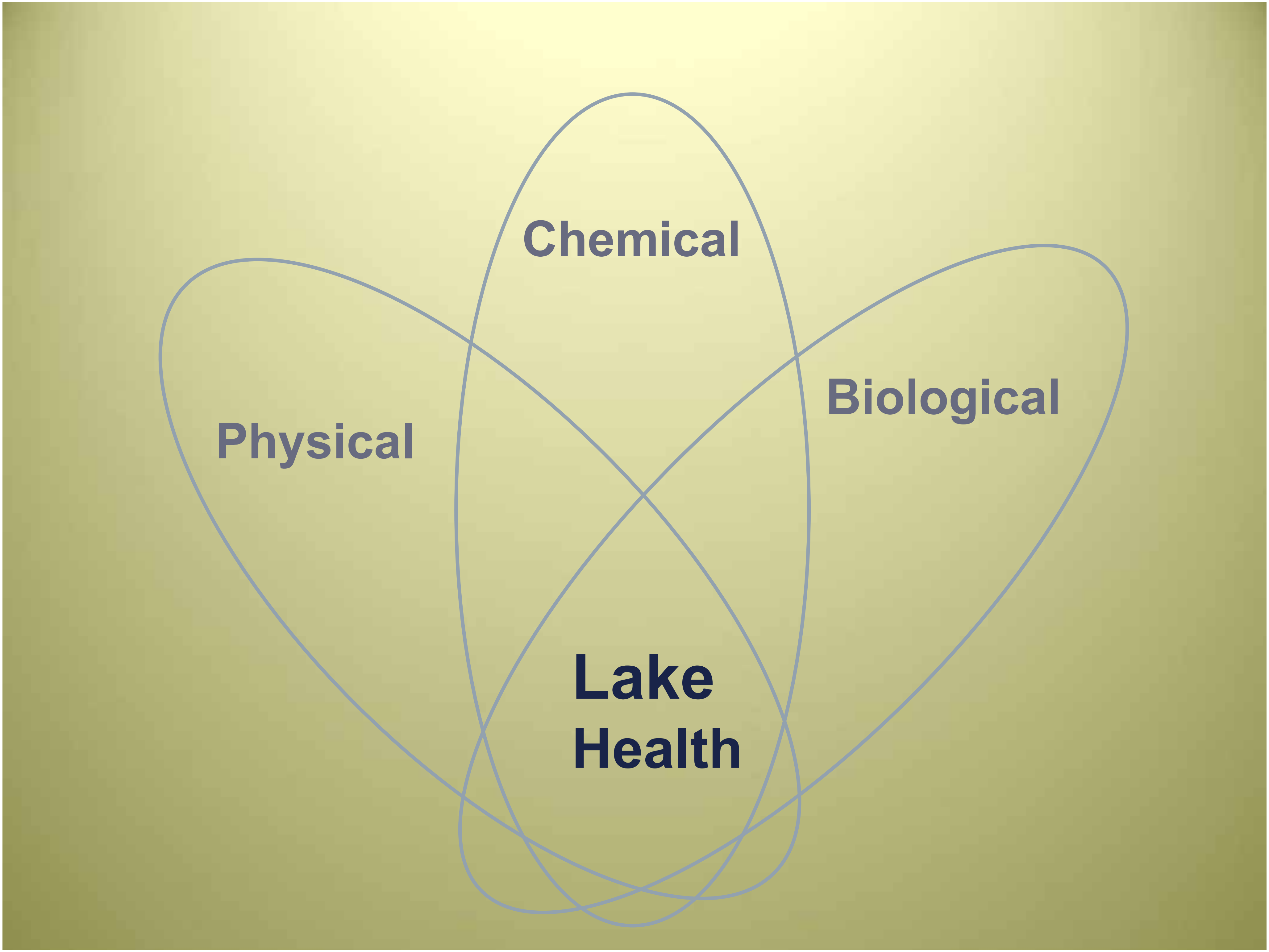
Wisconsin has one of the largest concentration of fresh water glacial lakes on the planet.



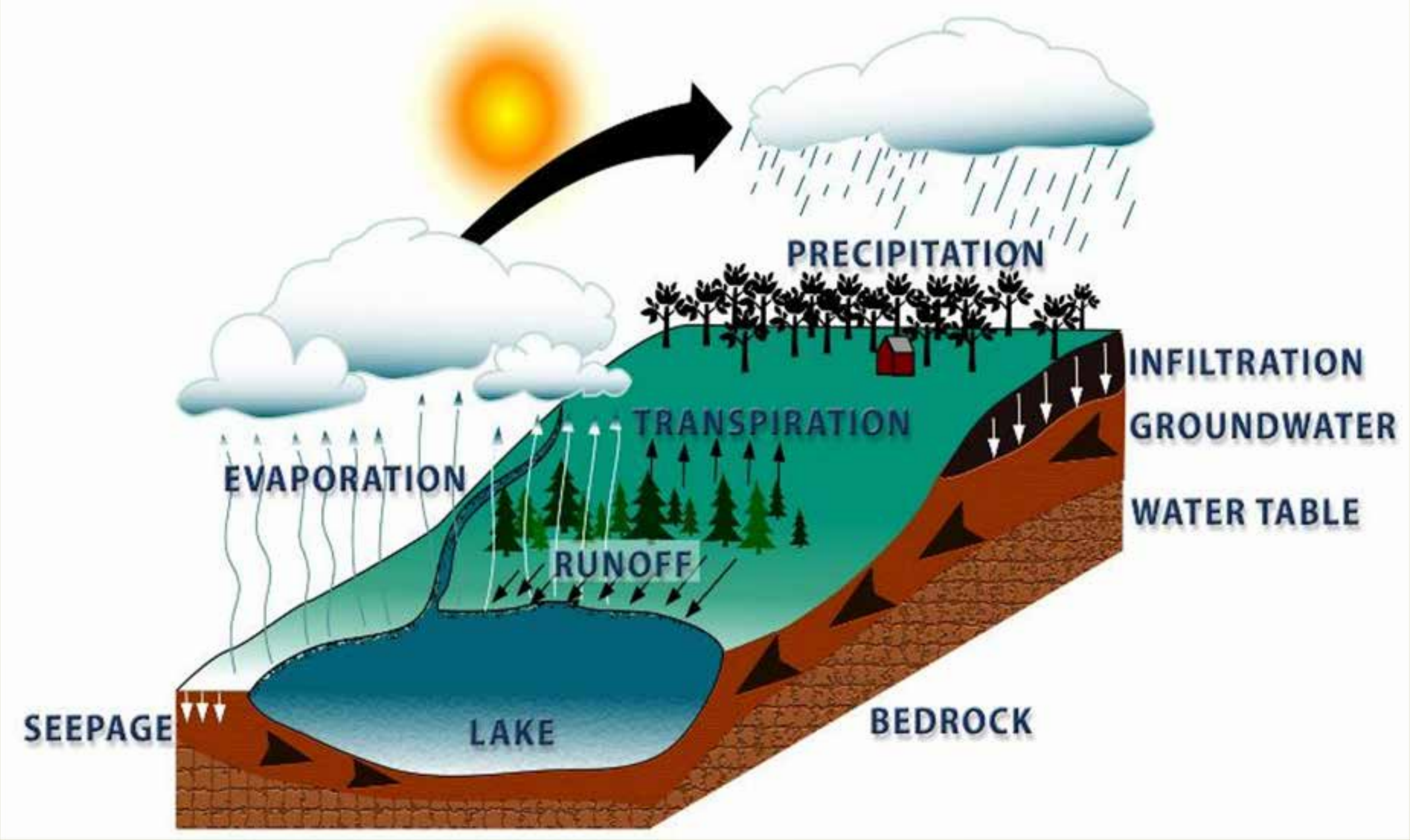
Land Use Changes Over Centuries



Steve Carpenter, University of Wisconsin Center for Limnology


Chemical
Physical
Biological
Lake
Health

HYDROLOGIC CYCLE

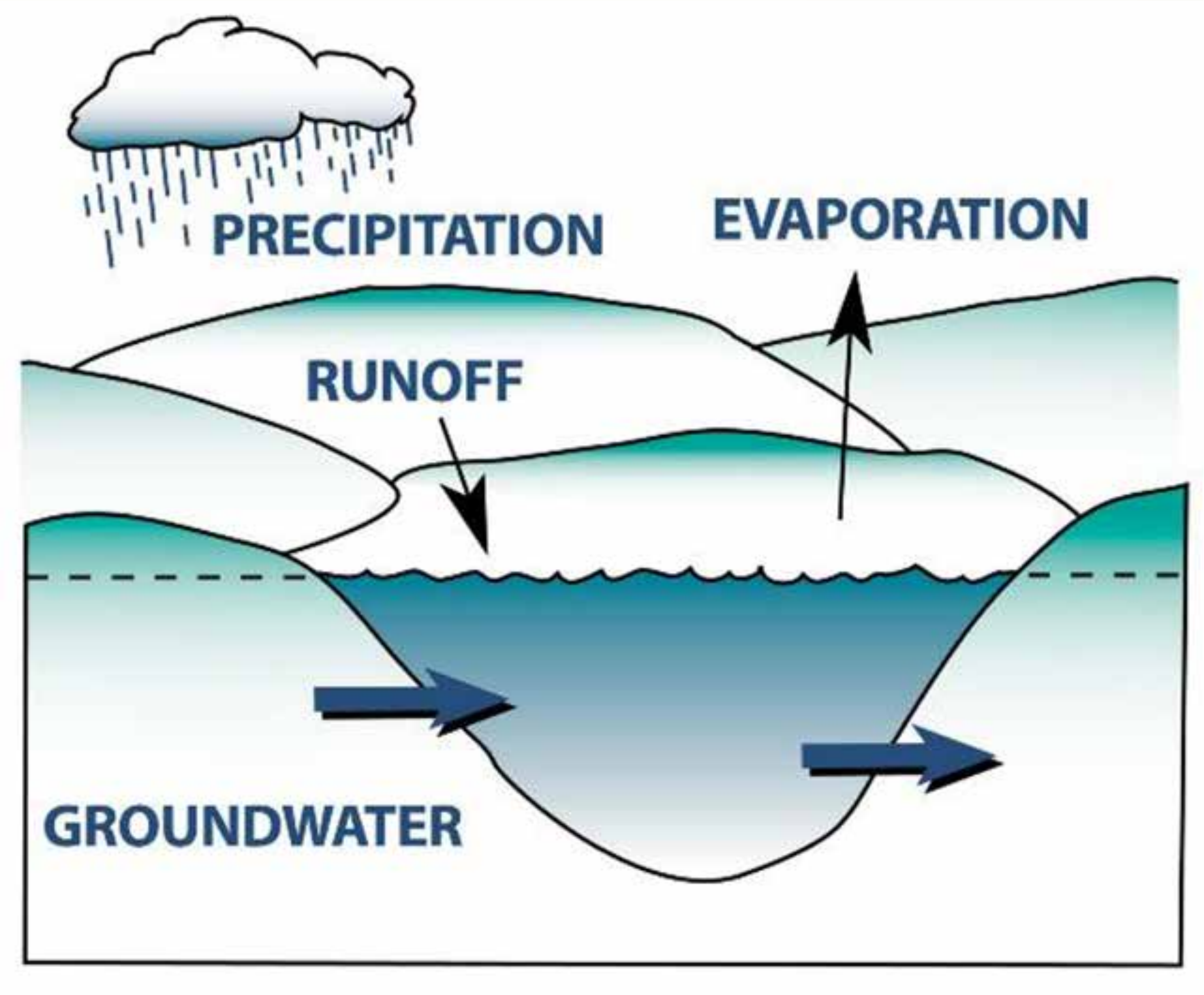


LAKE TYPES

- Seepage
- Groundwater Drainage
- Drainage
- Impoundments
- Oxbow

SEEPAGE LAKE

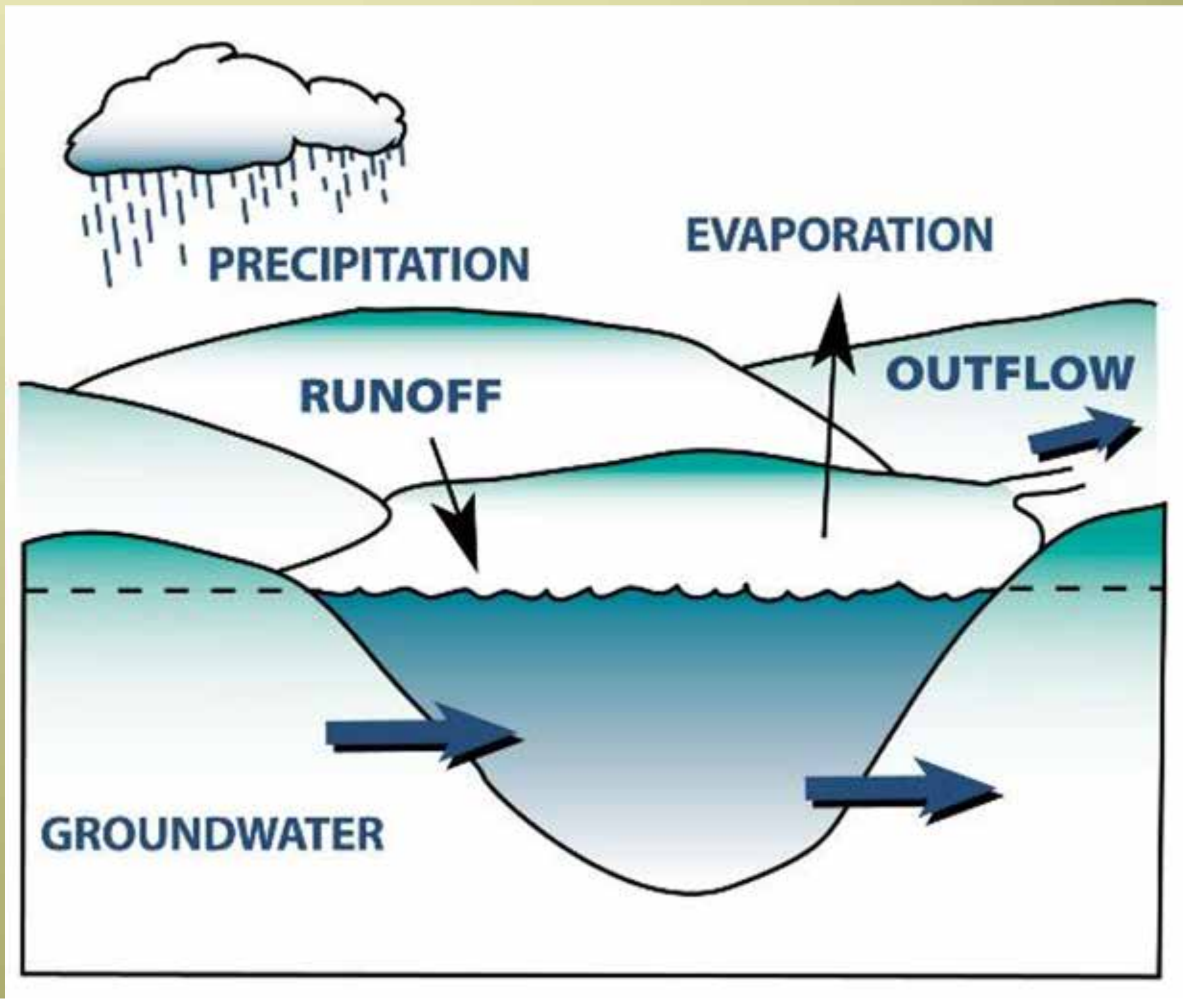
- Natural Lake
- Water Source
  - Groundwater
  - Precipitation
- No Stream Outlet/ Inlet



SEEPAGE LAKE

GROUNDWATER DRAINAGE

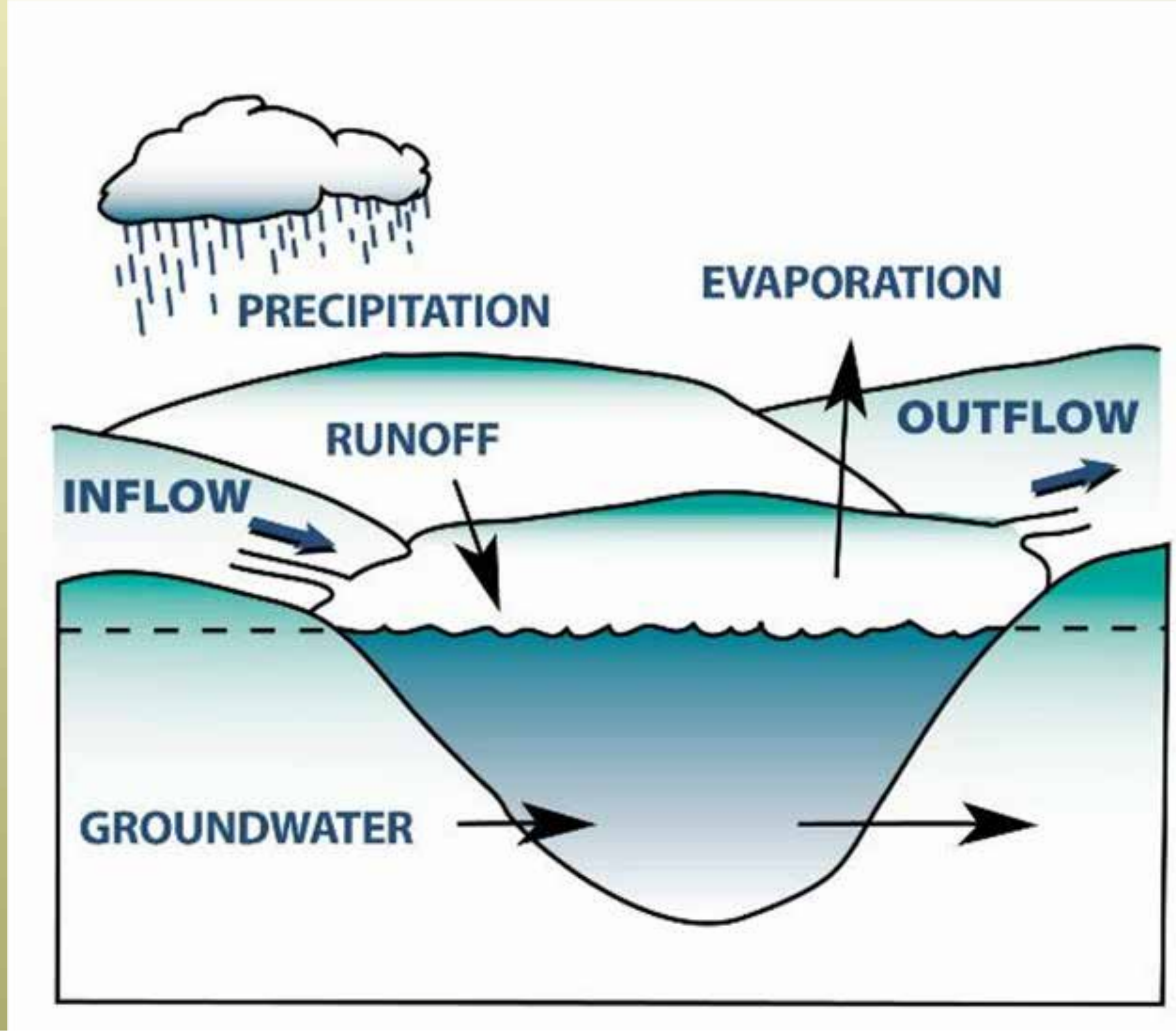
- Natural Lake
- Water Source
  - Groundwater
  - Precipitation
  - Limited Runoff
- Has Stream Outlet




GROUNDWATER DRAINAGE LAKE
Sand Lake, Chippewa County

DRAINAGE LAKE

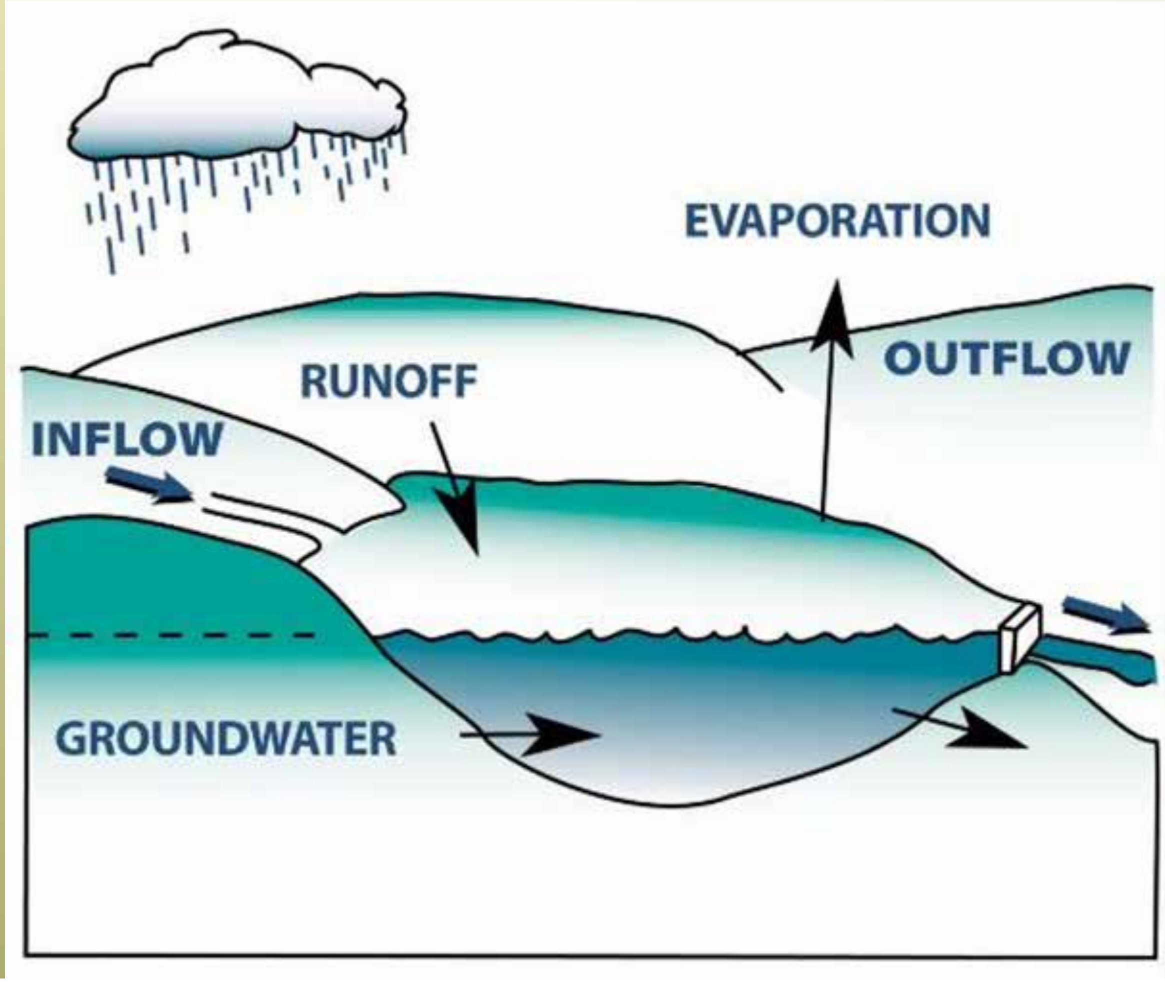
- Water Source
  - Streams
  - Groundwater
  - Precipitation
  - Runoff
- Stream Drained



DRAINAGE LAKE

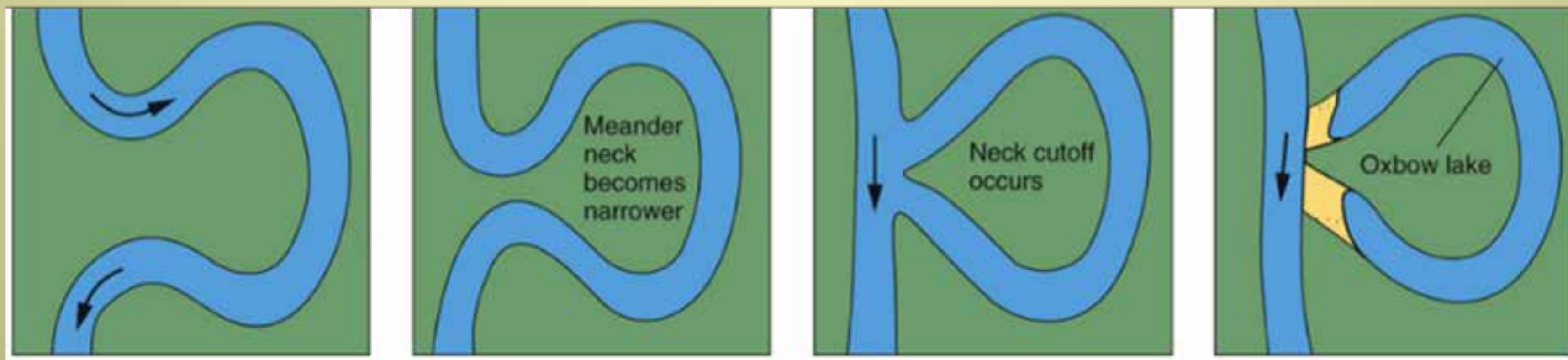
IMPOUNDMENT

- A manmade lake
- Dammed River or Stream



IMPOUNDMENTS

OXBOW LAKES



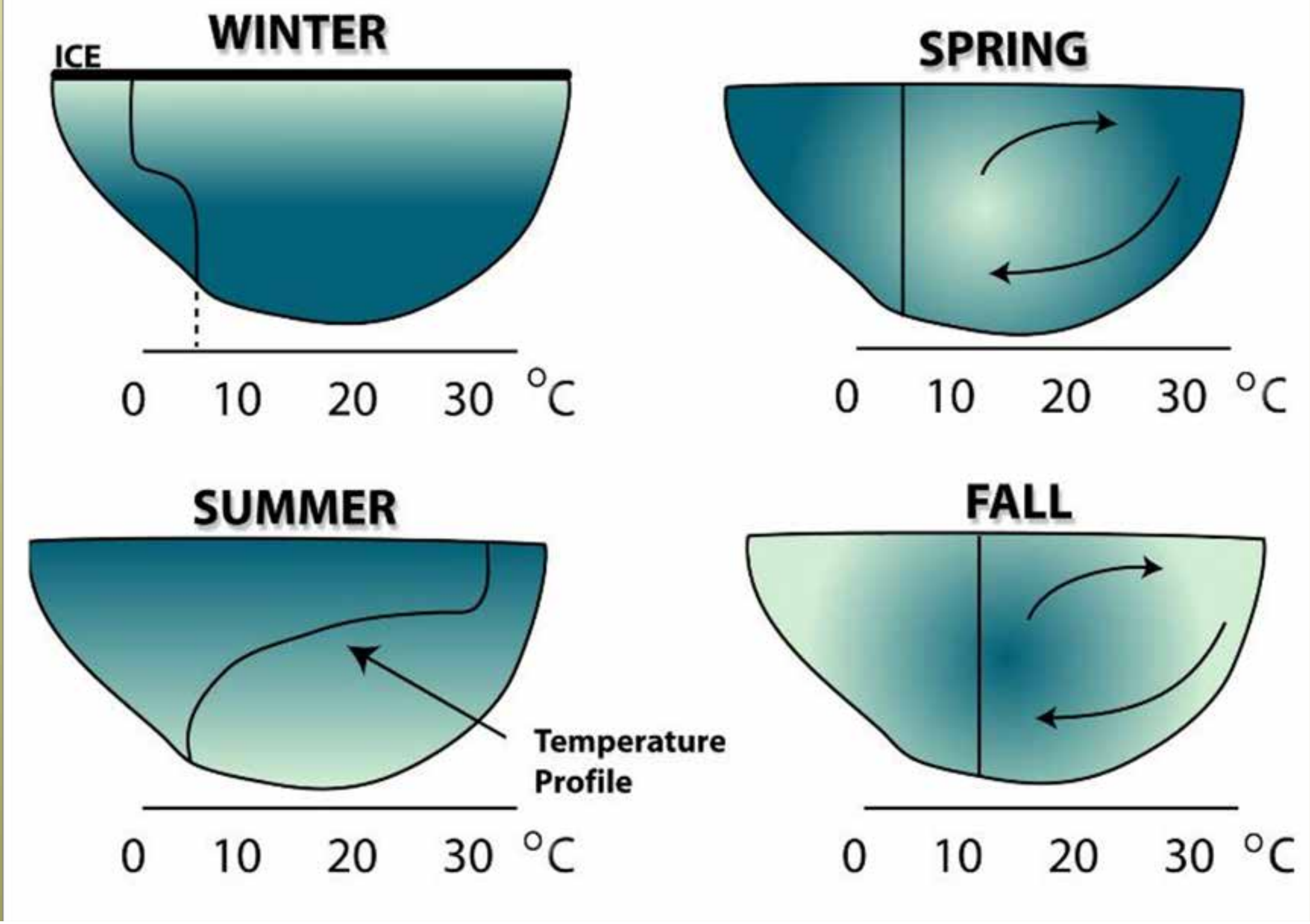
Meander
neck
becomes
narrower
Neck cutoff
occurs
Oxbow lake

Wood Slough
Google Earth

PHYSICAL CHARACTERISTICS

- Mixing / Stratification
- Lake Depth
- Retention Time / Flushing Rate
- Drainage Basin/ Lake Area Ratio
- Landscape Position

MIXING/ STRATIFICATION



LAKE DEPTH MATTERS

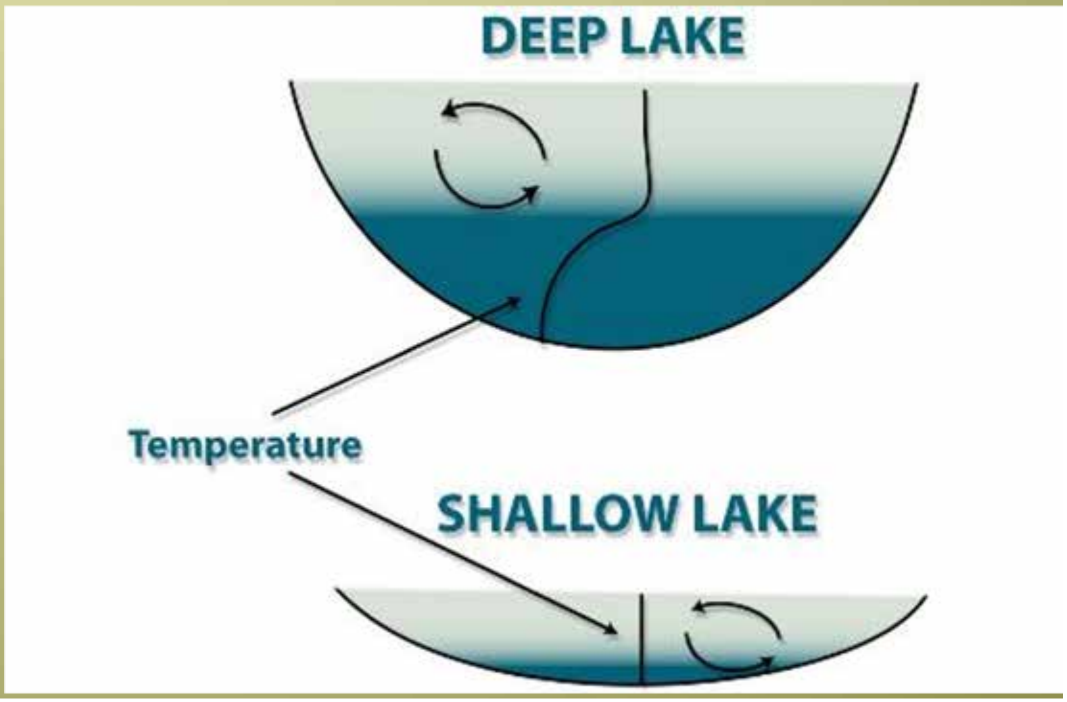
- **Deep Lakes**

  Stratify

- **Shallow Lakes**

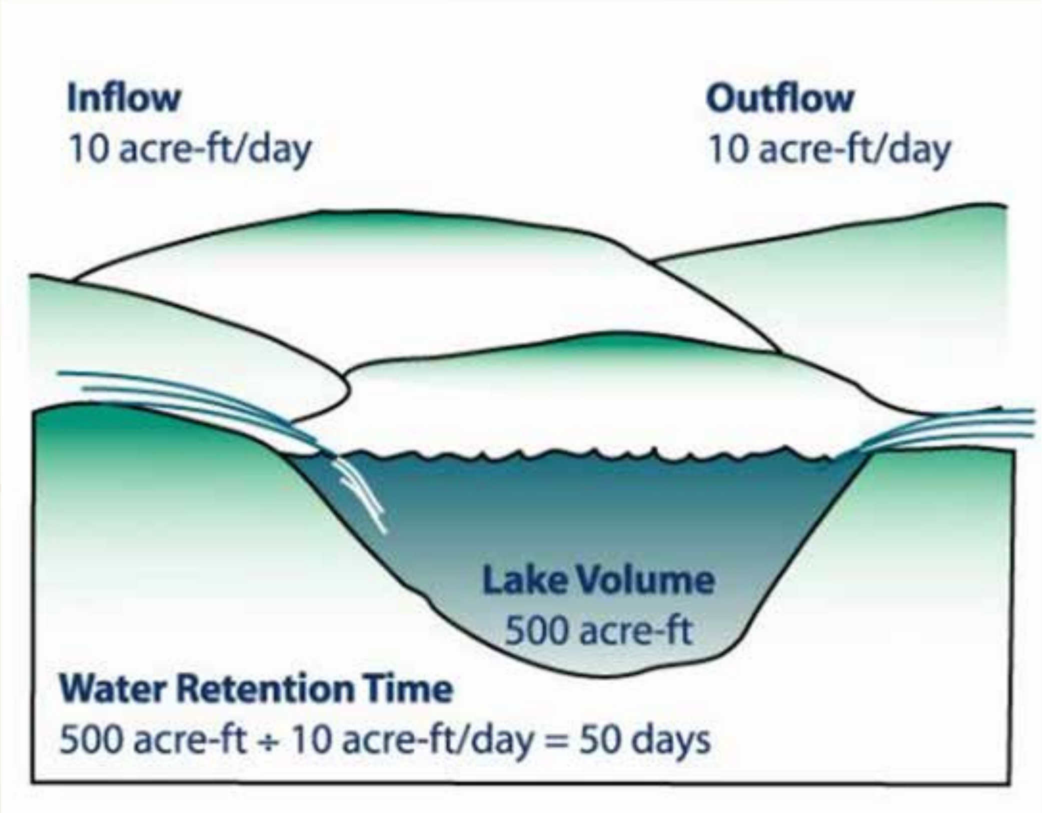
  -Continuous Nutrient Recycling

  -Dual states



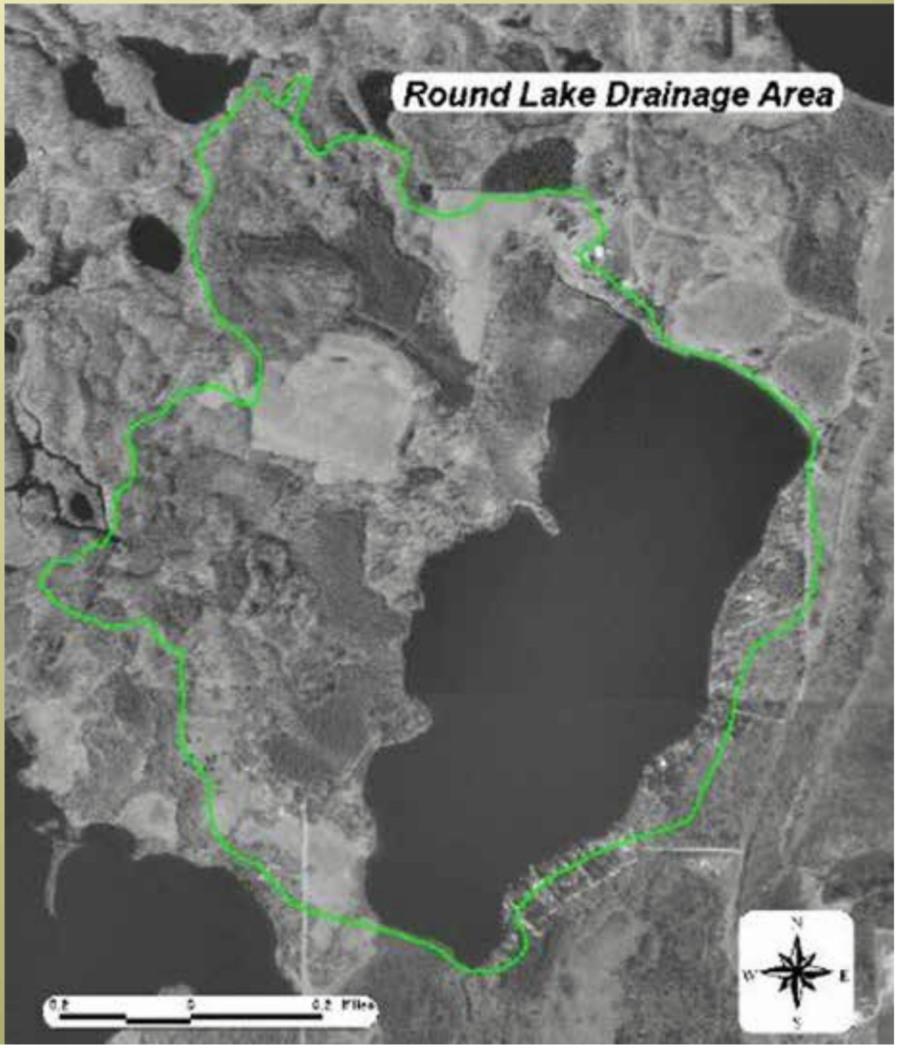
RETENTION TIME/ FLUSHING RATE

- How long would it take to fill a drained lake?
- Retention Time Matters
- Long Lake & Altoona
  - Long Lake, 7years
  - Lake Altoona, 22days

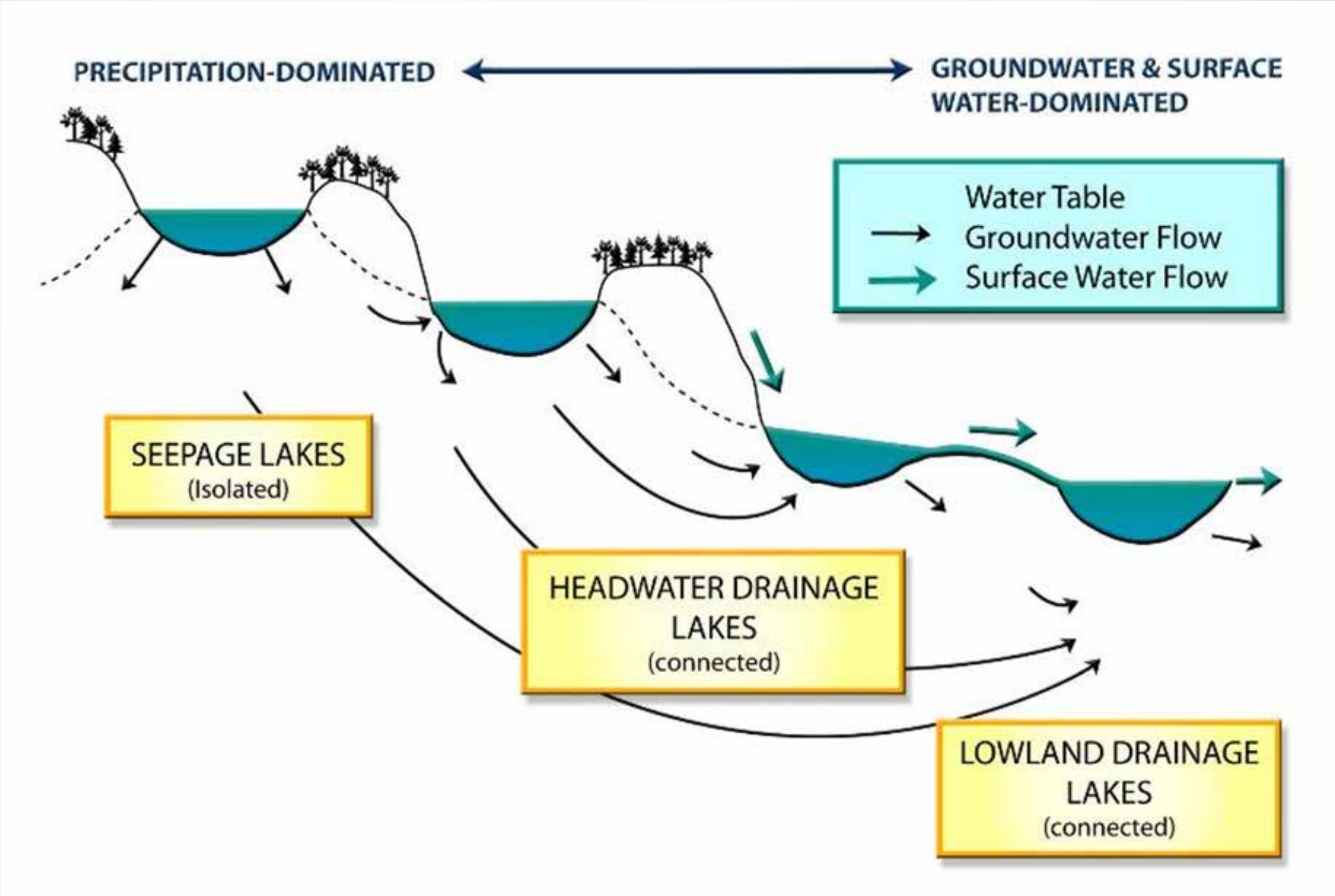


DRAINAGE BASIN/ LAKE AREA RATIO

- A lake is a reflection of its watershed
- Seepage Lake- small
- Drainage Lake- large watershed
  - Seepage Lake w/ drainage area mapped Round Lake

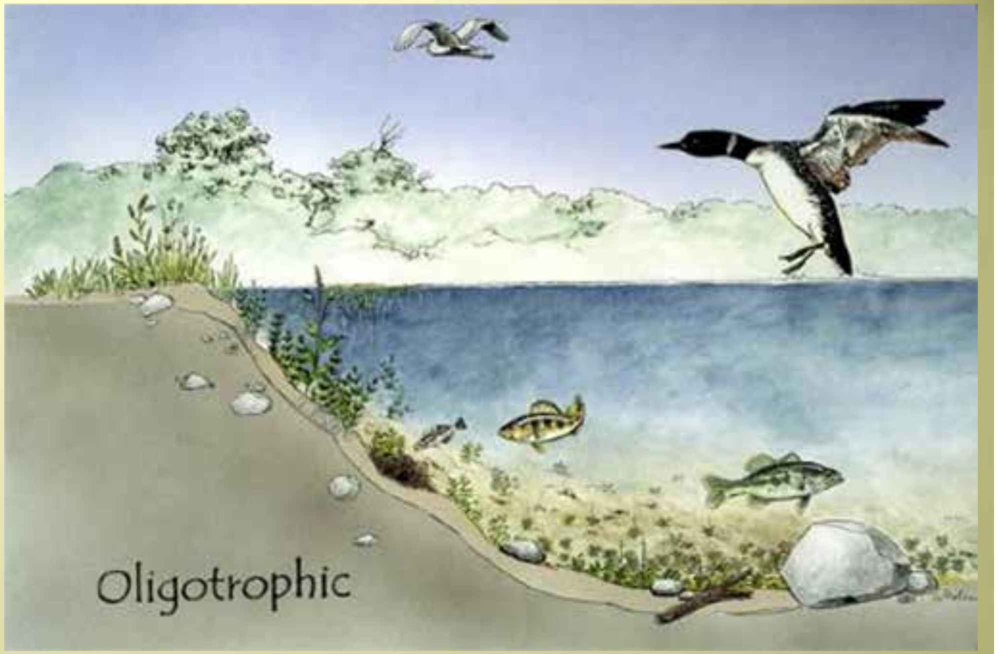


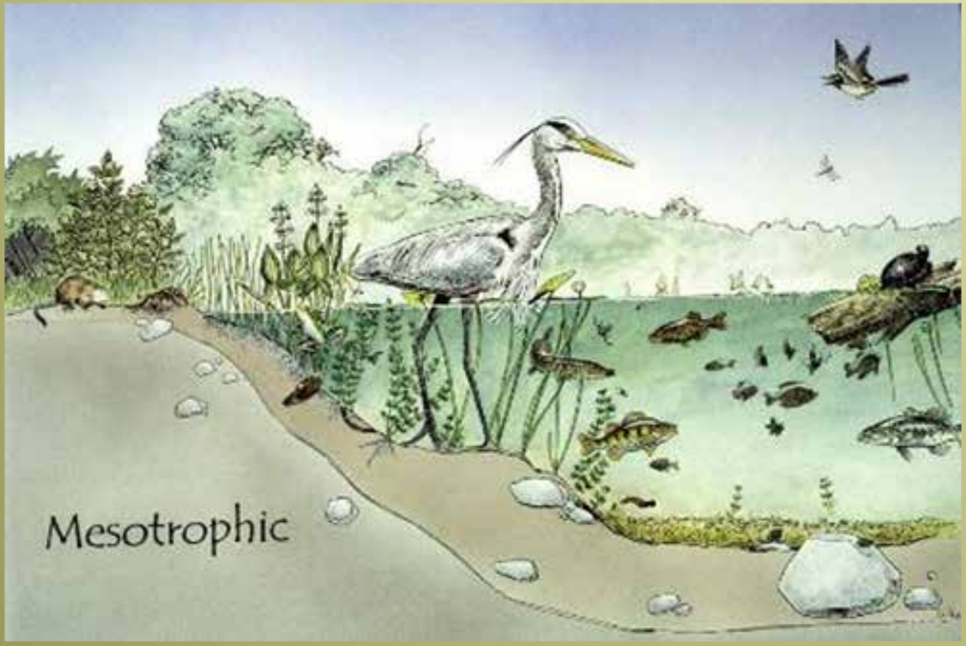
LANDSCAPE POSITION

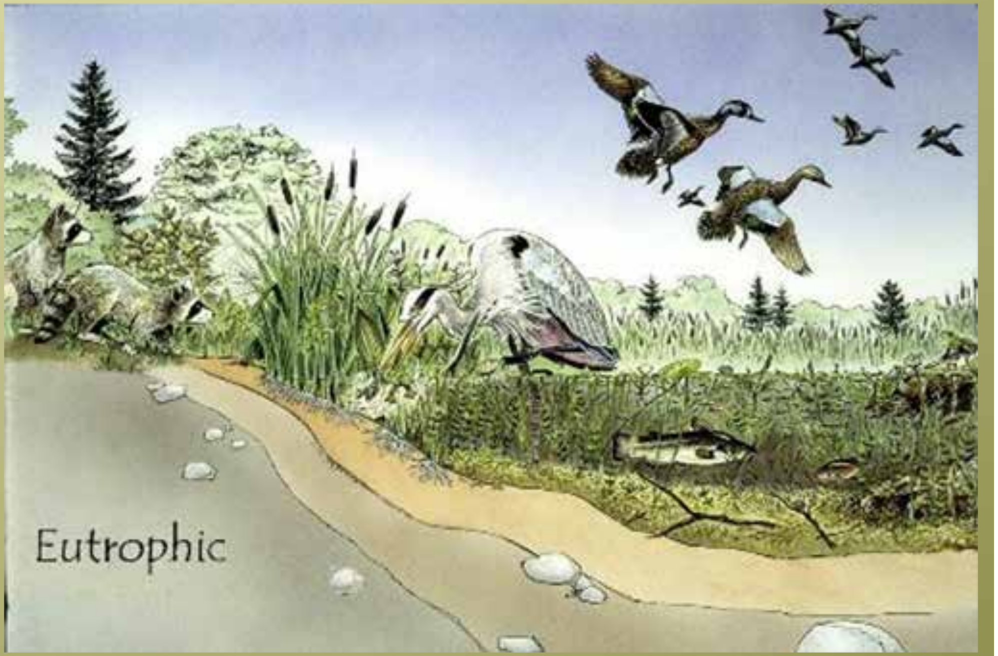


Trophic States

What differences do you see between the states?







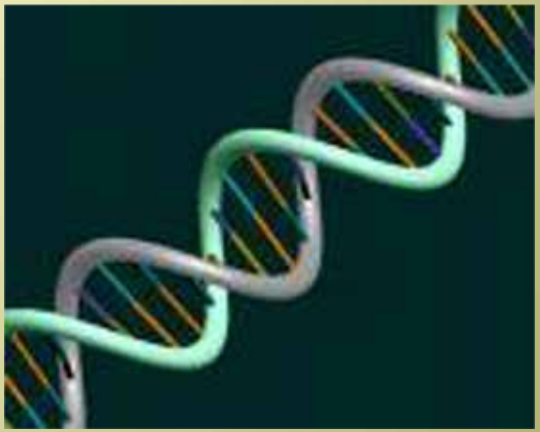
CHEMICAL CHARACTERISTICS

- Nutrients
  - Phosphorus (P or TP for total phosphorus)
  - Nitrogen
- pH
- Hardness/ Alkalinity
- Dissolved Oxygen
- Chloride

NUTRIENT FUNCTIONS

ELEMENT	AVAILABILITY	DEMAND	AVAILABILITY DEMAND	FUNCTION
Na	32	0.5	64	Cell membrane
Mg	22	1.4	16	Chlorophyll, energy transfer
Si	268	0.7	383	Cell wall (diatoms)
P	1	1	1	DNA, RNA, ATP, enzymes
K	20	6	3	Enzyme activator
Ca	40	8	5	Cell membrane
Mn	0.9	0.3	3	Photosynthesis, enzymes
Fe	54	0.06	900	Enzymes
Co	0.02	0.0002	100	Vitamin B12
Cu	0.05	0.006	8	Enzymes
Zn	0.07	0.04	2	Enzyme activator
Mo	0.001	0.0004	3	Enzymes

IMPORTANCE OF P TO ORGANISMS



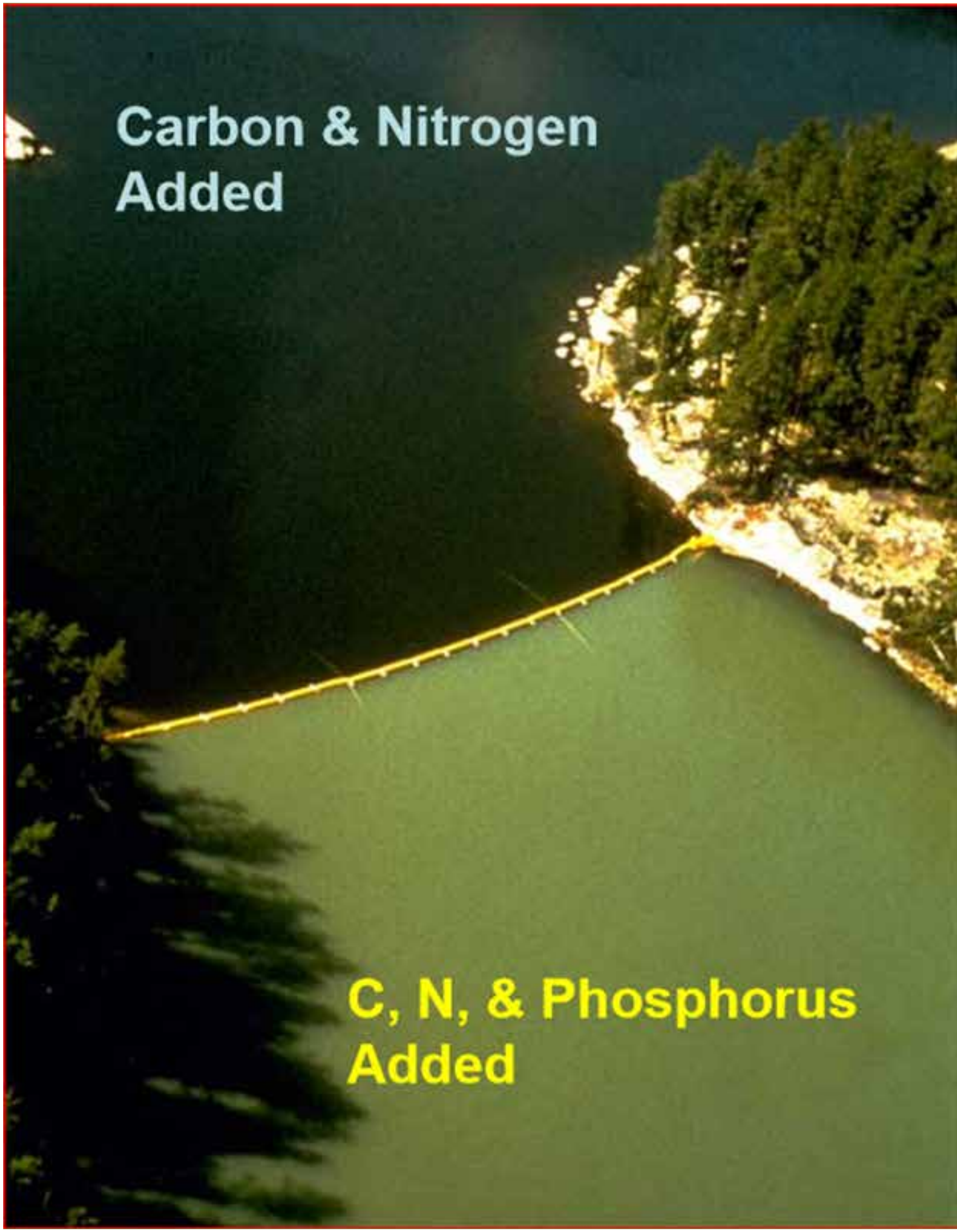
- **Phosphorus is a critical nutrient**
  - Genetic molecules: DNA, RNA
  - Structural molecules: phospholipids in cell walls
  - Energy metabolism: ATP
  - ***Every living organism needs phosphorus***
- **Phosphorus is less abundant than most other nutrients**
  - Both N and P tend to be high in demand by organisms, relative to their supply in the environment
  - N is often the limiting nutrient in terrestrial and marine ecosystems (with P close behind...)
  - ***But in lakes, P is usually the principal limiting nutrient***

LIMITING NUTRIENT PRINCIPLE

…That Nutrient in Least Supply
Relative to Plant Needs

N:P Ratio in plant Tissue 10:1 - 15:1

If the Ratio of N:P in Water is
<10:1 Nitrogen Limited
>15:1 Phosphorus Limited



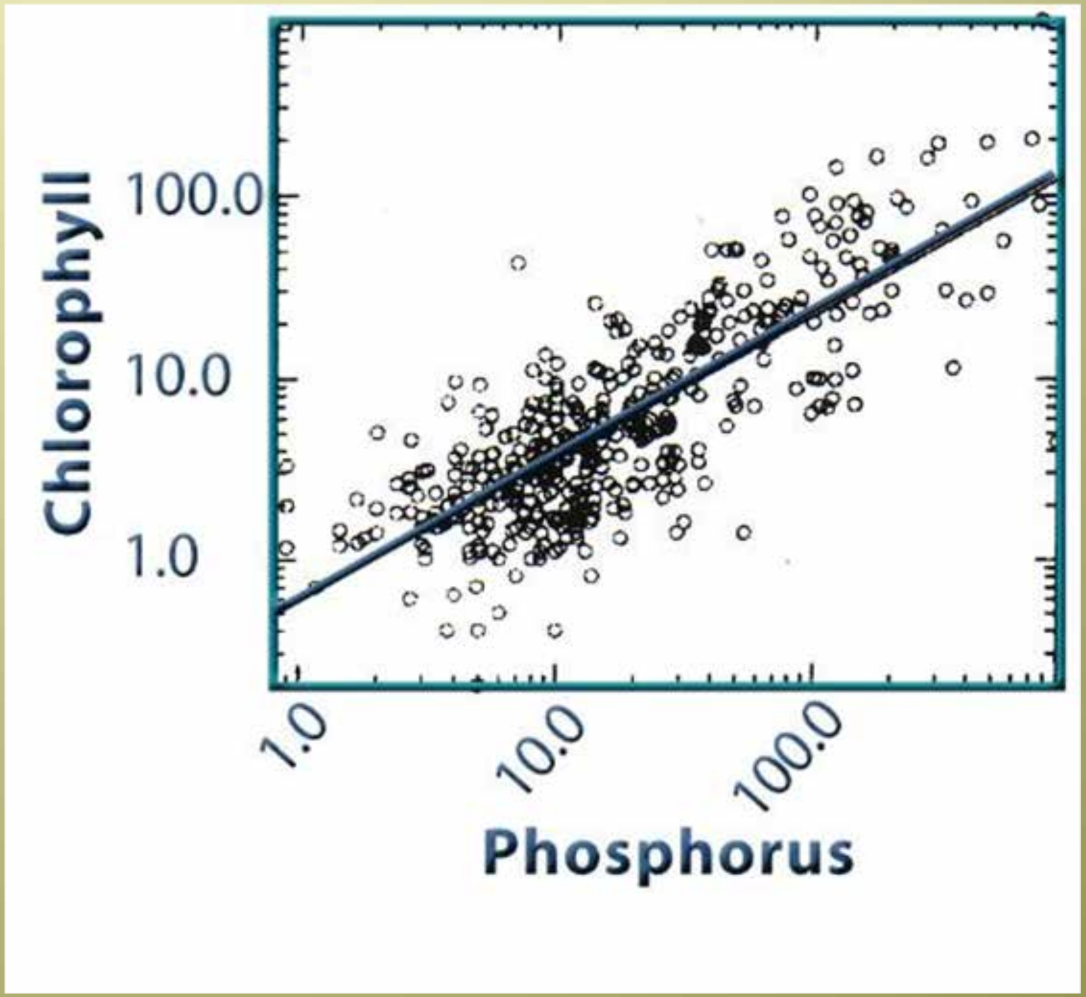
Why do we care about controlling phosphorus (P) in lakes?

Nutrient addition experiments in NW Ontario's Experimental Lakes Area <u>proved</u> that phosphorus was the nutrient responsible for most algal blooms in lakes and was the principle cause of lake eutrophication!

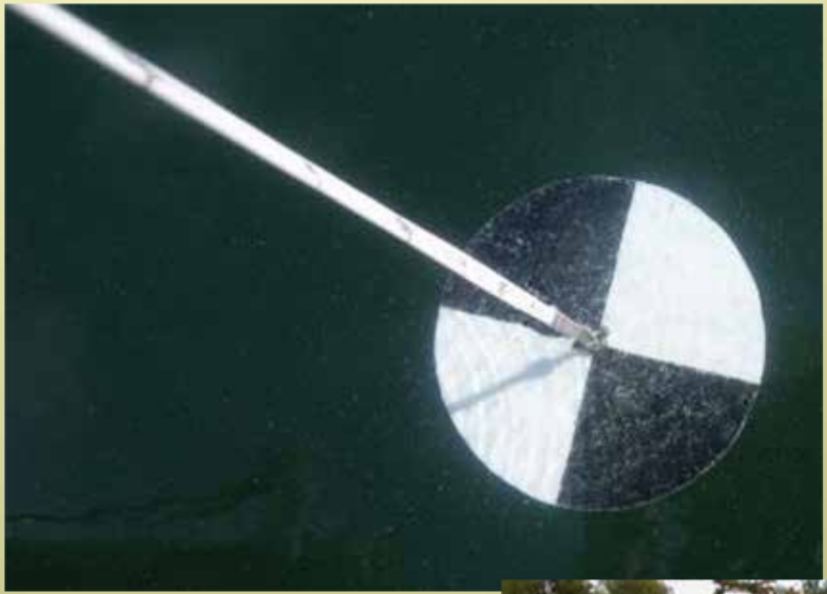
http://www.umanitoba.ca/institutes/fisheries/eutro.html

TOTAL PHOSPHORUS/ CHLOROPHYLL a RELATIONSHIP

- What is chlorophyll a?
- Phosphorus causes algae to grow
- 1 lb P is enough to grow 500 lbs algae
- That P can be recycled within the lake, used again and again.

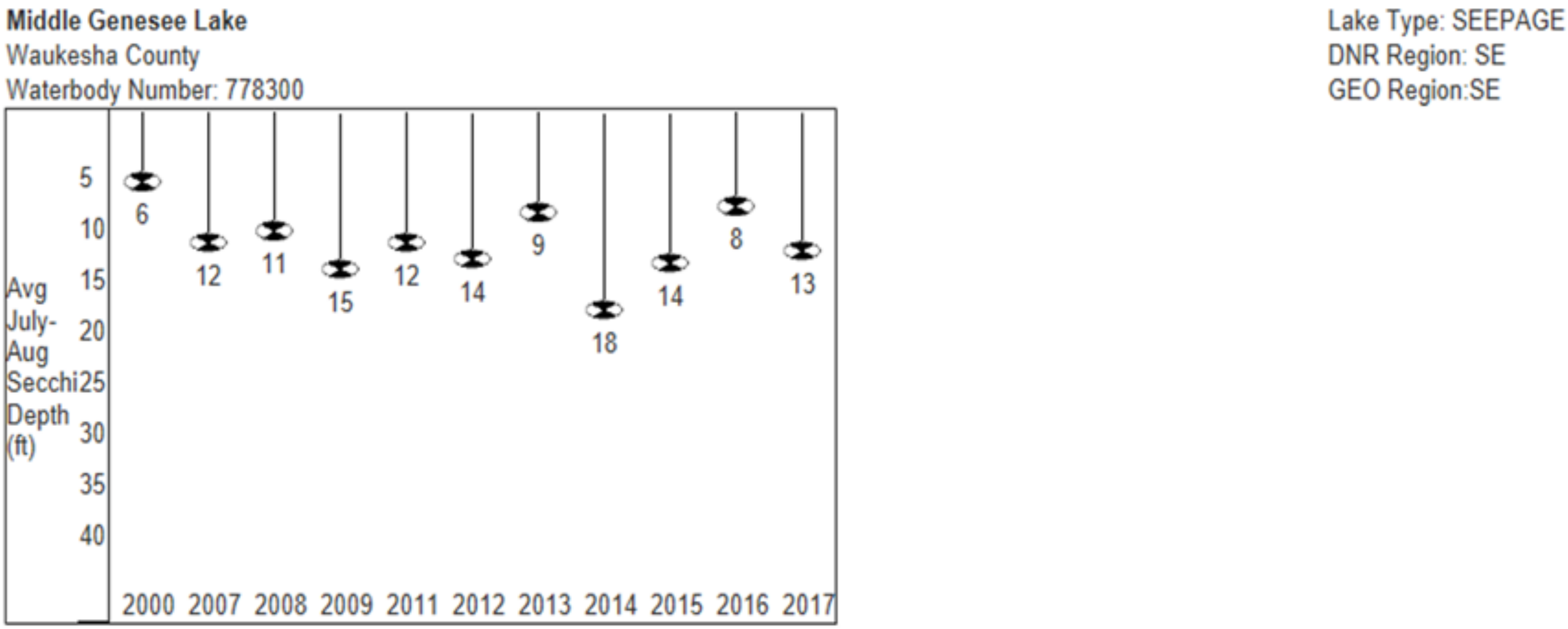


WATER CLARITY
MEASURED USING A SECCHI DISK

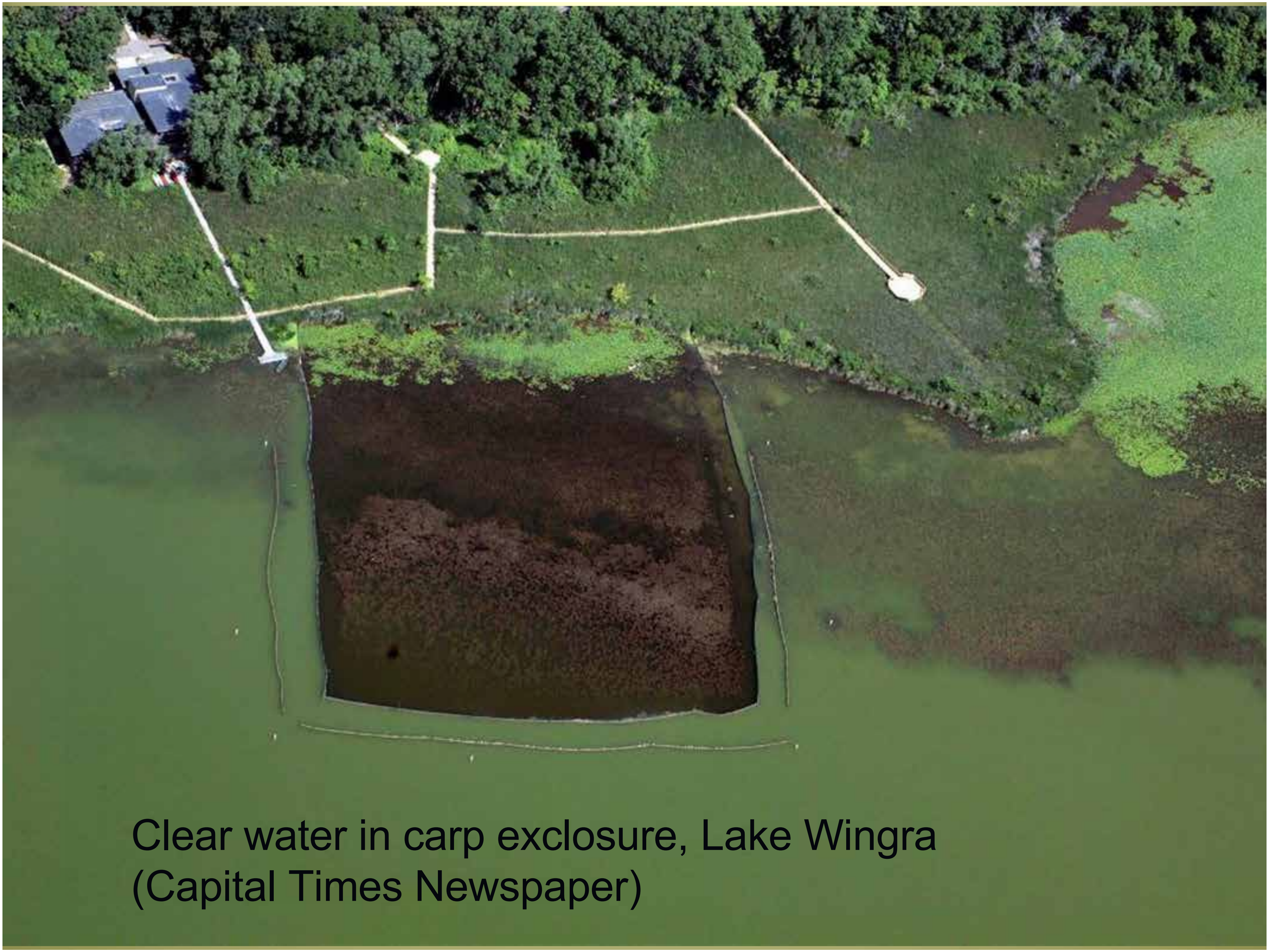


Scott Provost

TYPICAL GRAPH OF WATER CLARITY (SECCHI DEPTH)

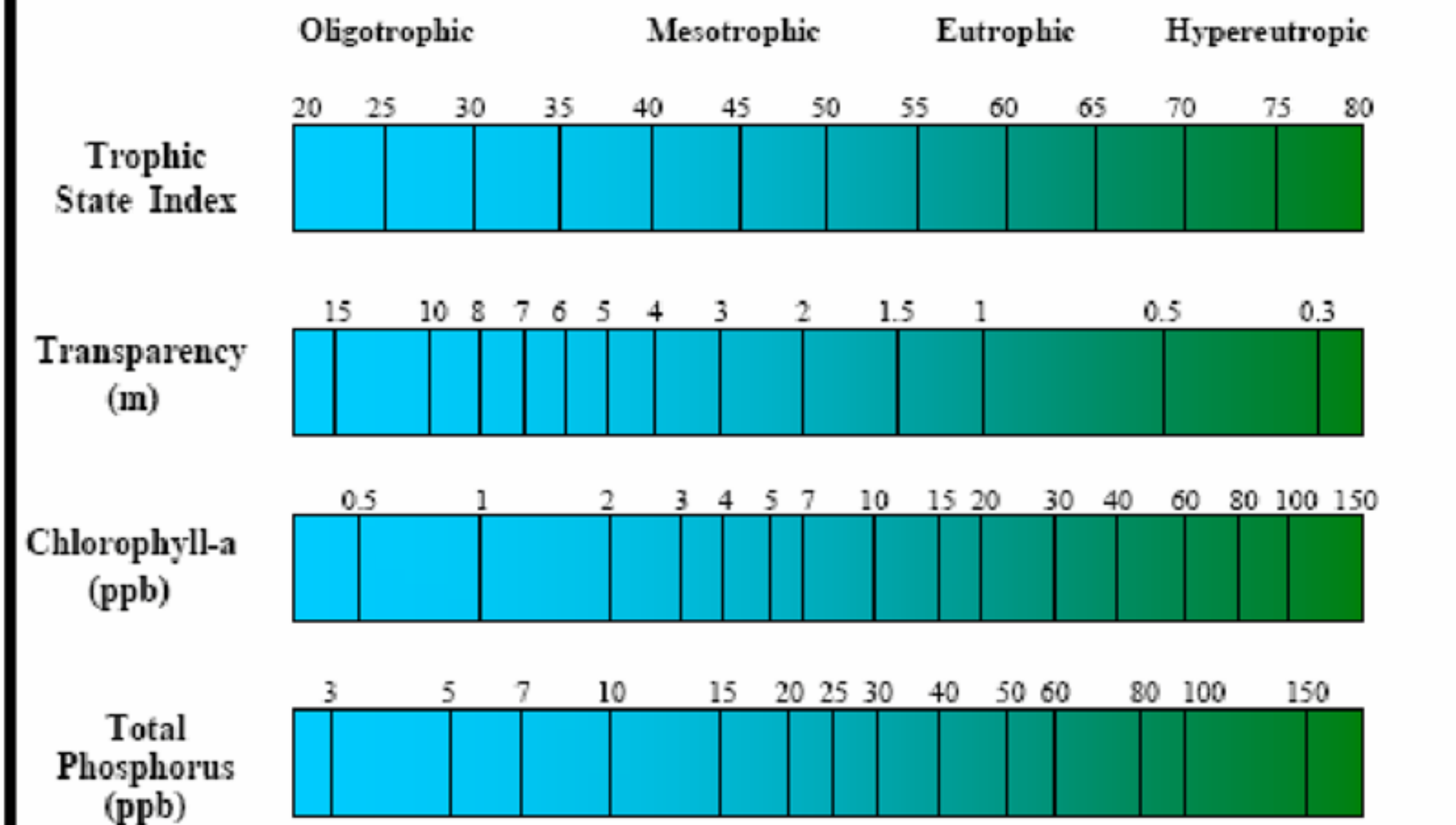


Past secchi averages in feet (July and August only).



Clear water in carp exclosure, Lake Wingra
(Capital Times Newspaper)

Trophic State Index (TSI)



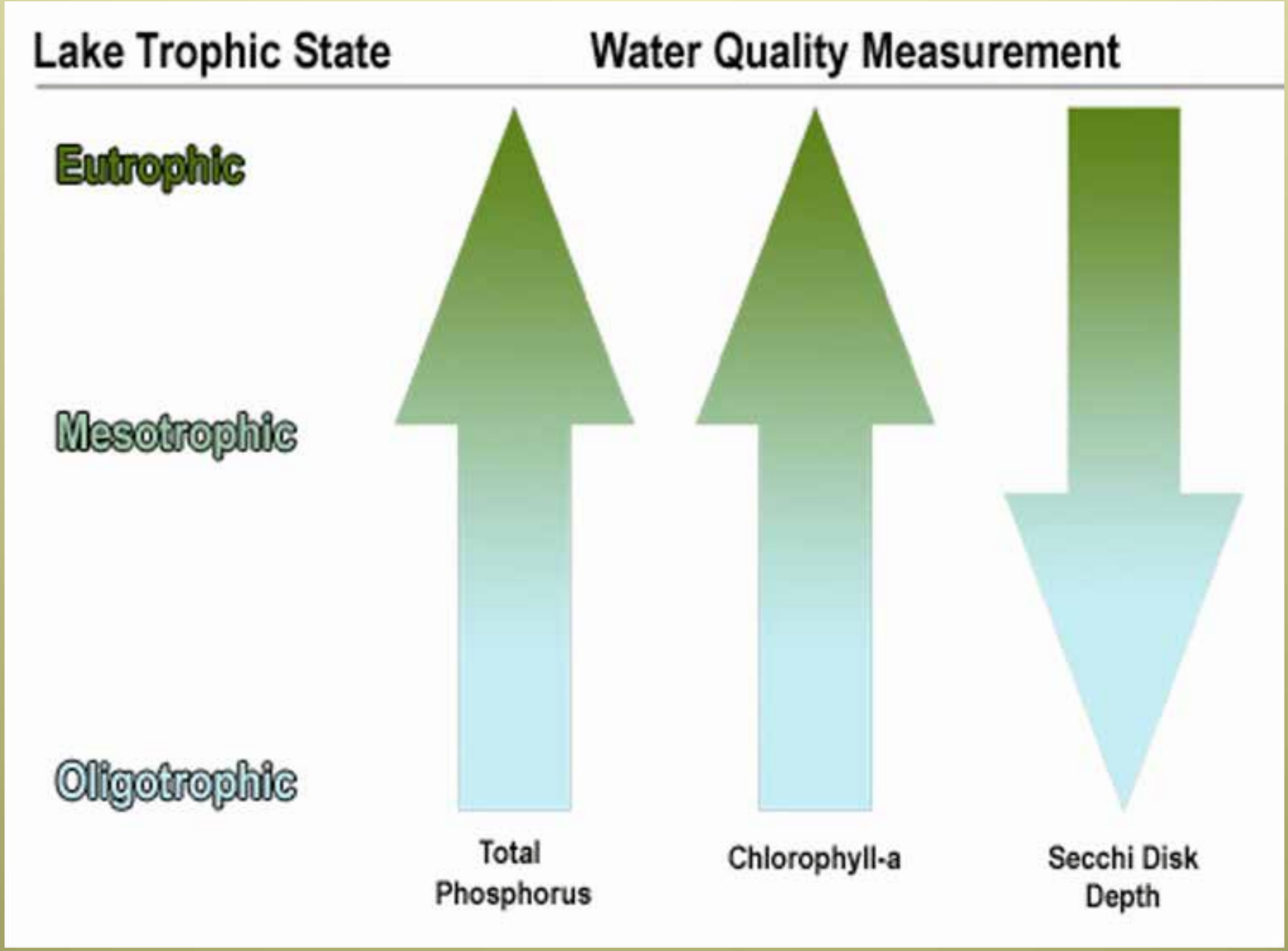
After Moore, 1. And K. Thornton, [Ed.]1988. Lake and Reservoir Restoration Guidance Manual. USEPA>EPA 440/5-88-002.

ANOTHER VIEW OF TSI

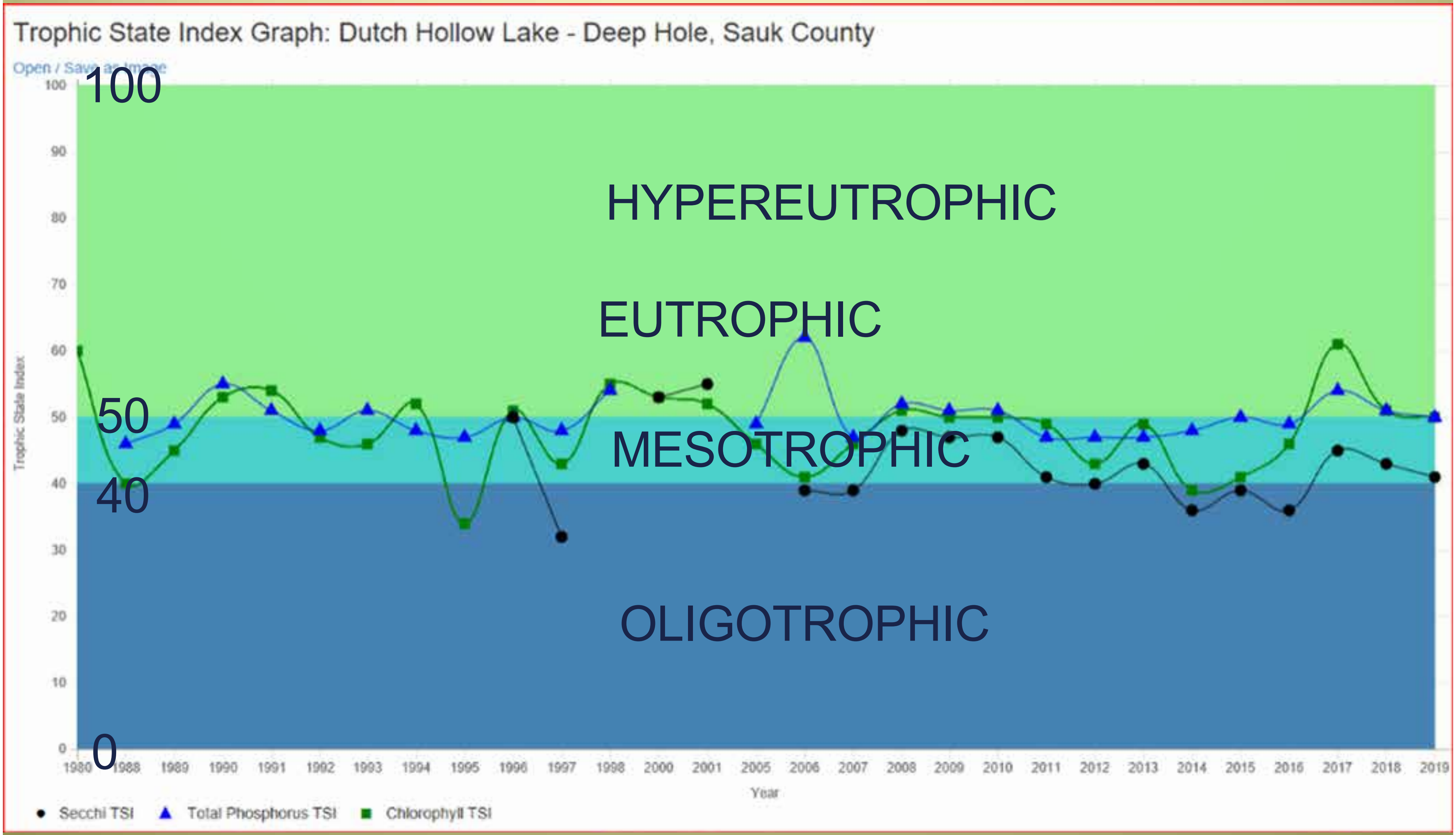
Relationships between Trophic State Index (TSI), chlorophyll (Chl), phosphorus (P, both micrograms per litre), Secchi depth (SD, metres), and Trophic Class (after Carlson 1996)[4]

TSI	Chl	P	SD	Trophic Class
< 30—40	0—2.6	0—12	> 8—4	Oligotrophic
40—50	2.6—20	12—24	4—2	Mesotrophic
50—70	20—56	24—96	2—0.5	Eutrophic
70—100+	56—155+	96—384+	0.5— < 0.25	Hypereutrophic

Relationship of trophic state to water quality parameters

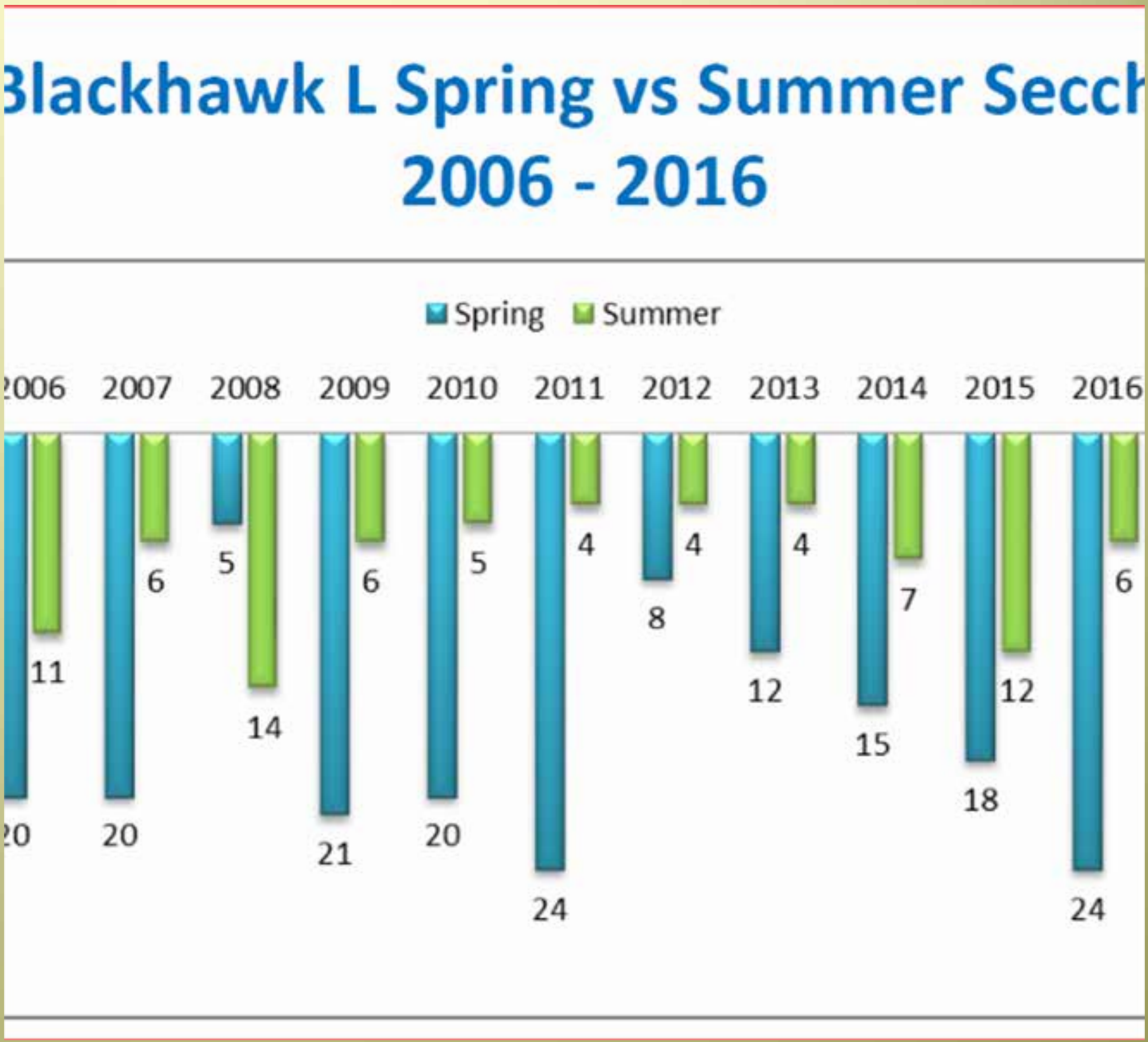


TROPHIC STATE INDEX GRAPH



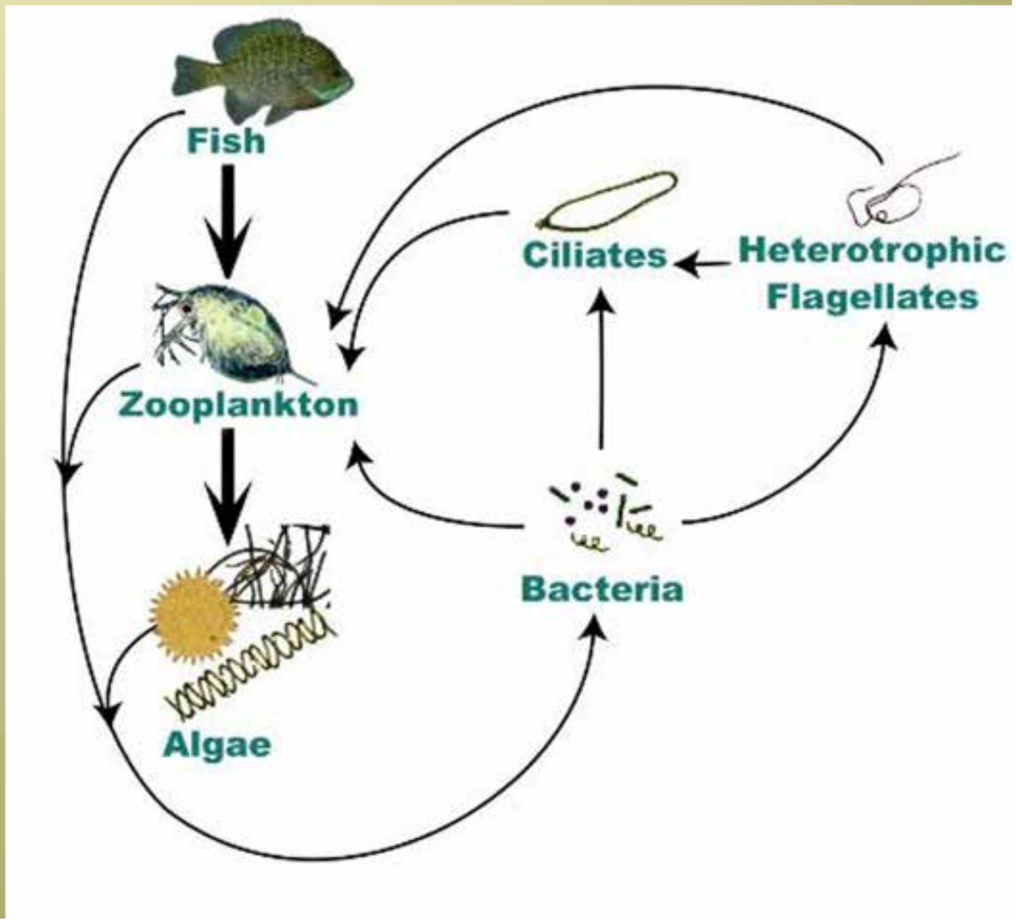
Water quality varies

- Water clarity of a lake varies seasonally and between years.
- Some years have worse water quality than others, but a bad year doesn't necessarily mean there's a trend. The long term record reveals no trend on this lake.
- Eutrophication: the process of a lake becoming more nutrient rich.



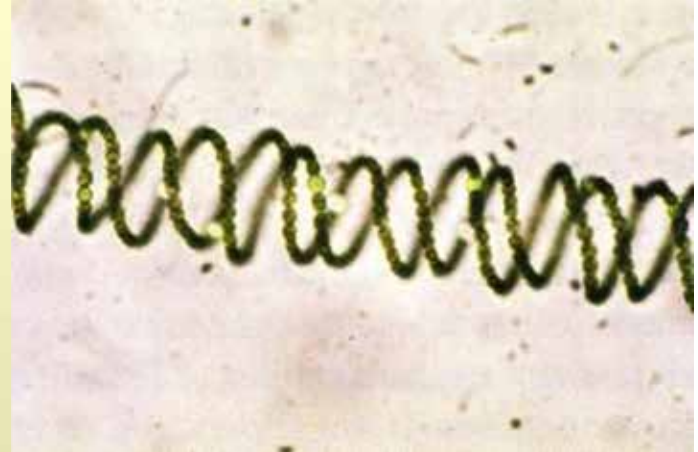
BIOLOGICAL CHARACTERISTICS

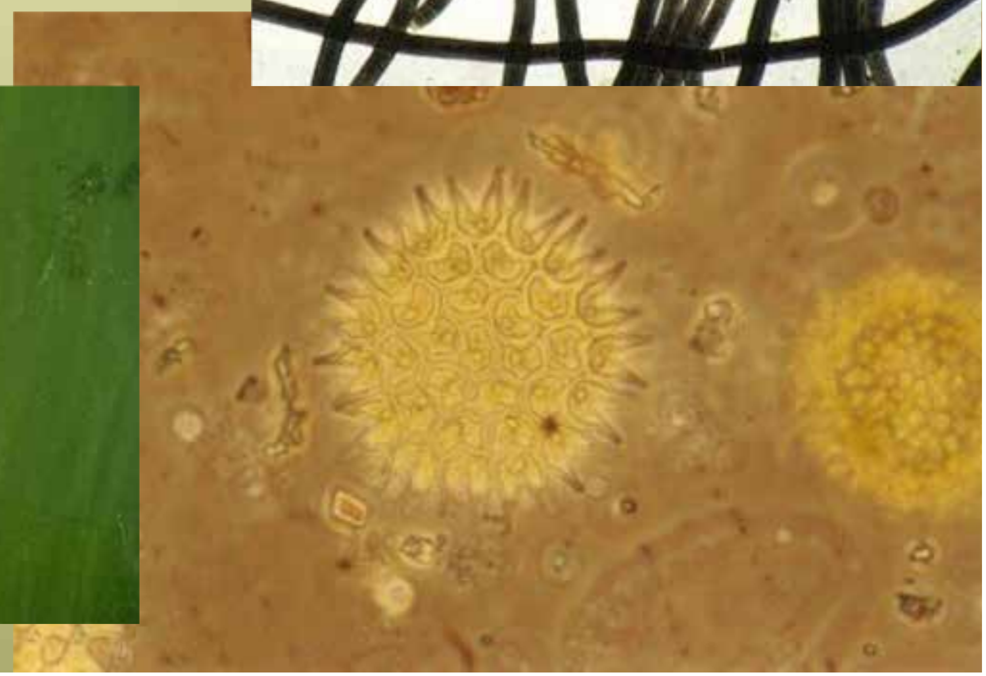
- Viruses/ Bacteria/ Fungi
- Primary - Producers Algae & Plants
- Zooplankton & Invertebrates
- Fish
- Birds
- Mammals



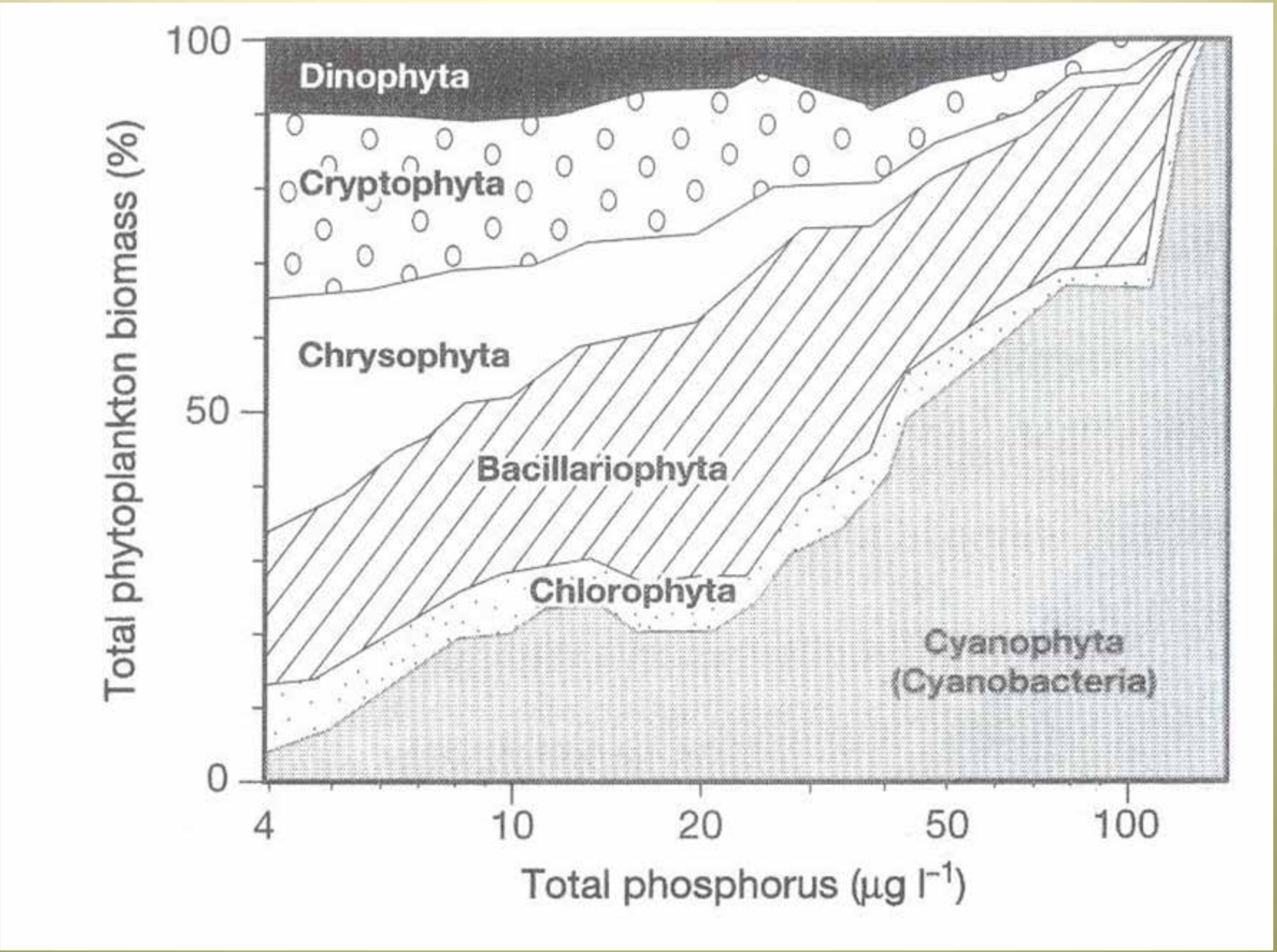
ALGAE

- Primary Energy Source for Invertebrates
- Planktonic vs Filamentous
- Produce O_2
- Algae = phytoplankton





FILAMENTOUS ALGAE



Watson SB, McCauley E, Downing JA. 1997. Patterns in phytoplankton taxonomic composition Across temperate lakes of differing nutrient status. Limnol Oceanog 42:487-495

Human Health Concerns

- Cyanobacteria = Bluegreen algae = BGA
- At times, BGA can produce toxins
- The bigger the bloom, the higher the risk that toxins are present

Common *human* symptoms associated with blue-green algae exposure include:		
Respiratory	**Dermatologic**	**Other**
Sore throat Congestion Cough Wheezing Difficulty breathing Eye irritation	Itchy skin Red skin Blistering Hives Other Rash	Earache Agitation Headache Abdominal pain Diarrhea Vomiting Vertigo

Common *animal* symptoms associated with blue-green algae exposure:
Lethargy Vomiting Diarrhea Convulsions Difficulty breathing General weakness

http://dhs.wisconsin.gov/eh/bluegreenalgae/#NewProg

AQUATIC PLANTS

- Submersed
- Floating
- Emergent

BENEFITS:

Stabilize sediment

Dampen wave energy

Reduce shoreline erosion

Hosts algae and bacteria, tiny bugs and snails (fish food)

Hiding places for fish

Spawning surfaces for fish

Homes for frogs

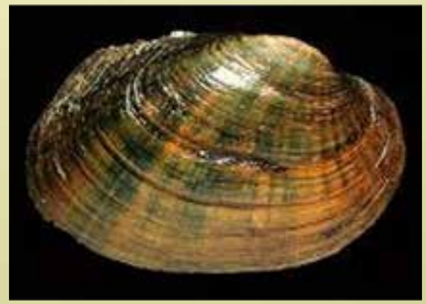
Homes for birds and insects

Keep water cool on hot days

Suppress algae thru multiple pathways

ZOOPLANKTON & AQUATIC INVERTEBRATES

- Zooplankton
- Dragonfly
- Snails
- Tiny worms
- Clams



FISH

Planktivore

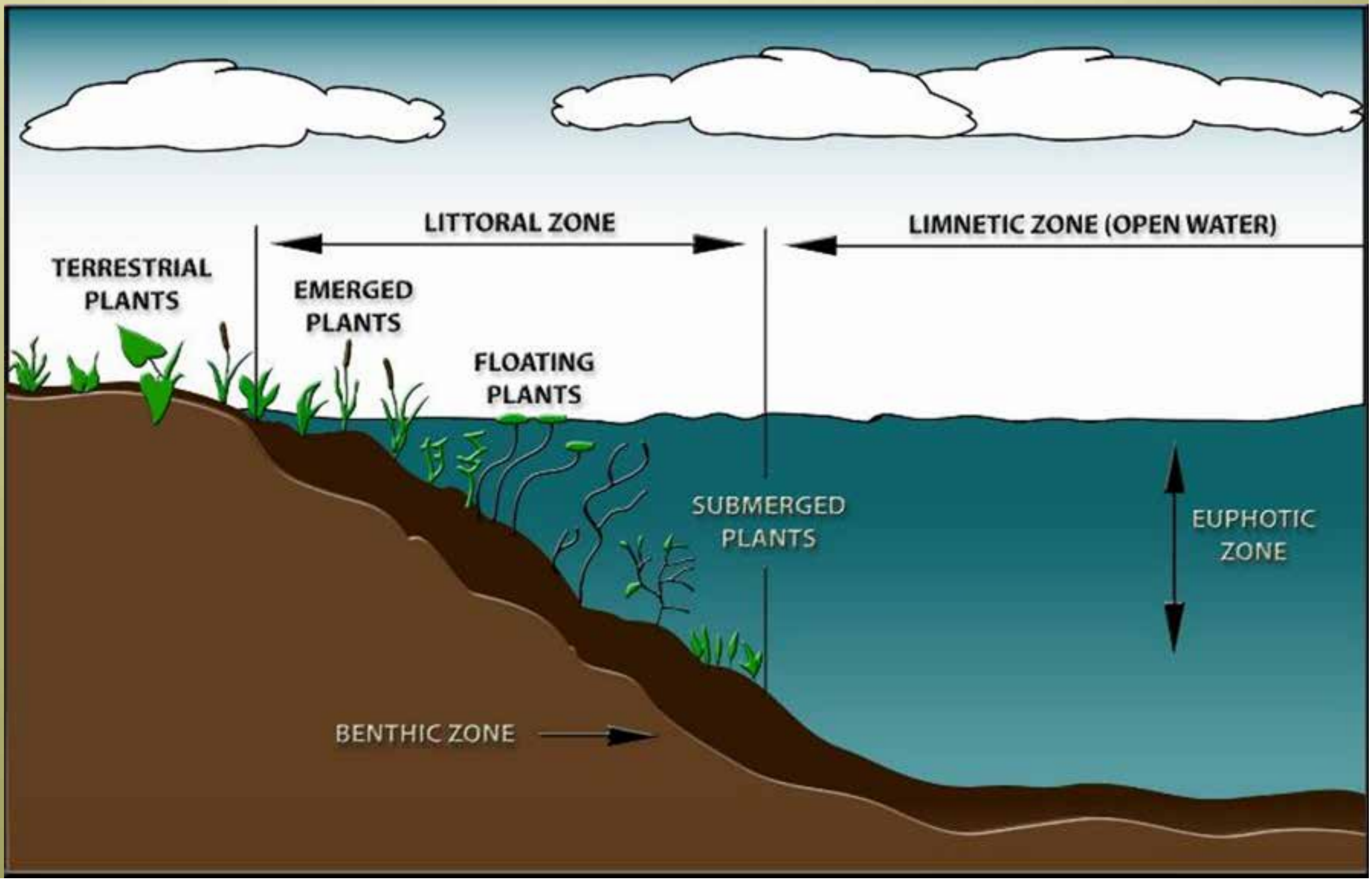
Piscivore

Benthivore

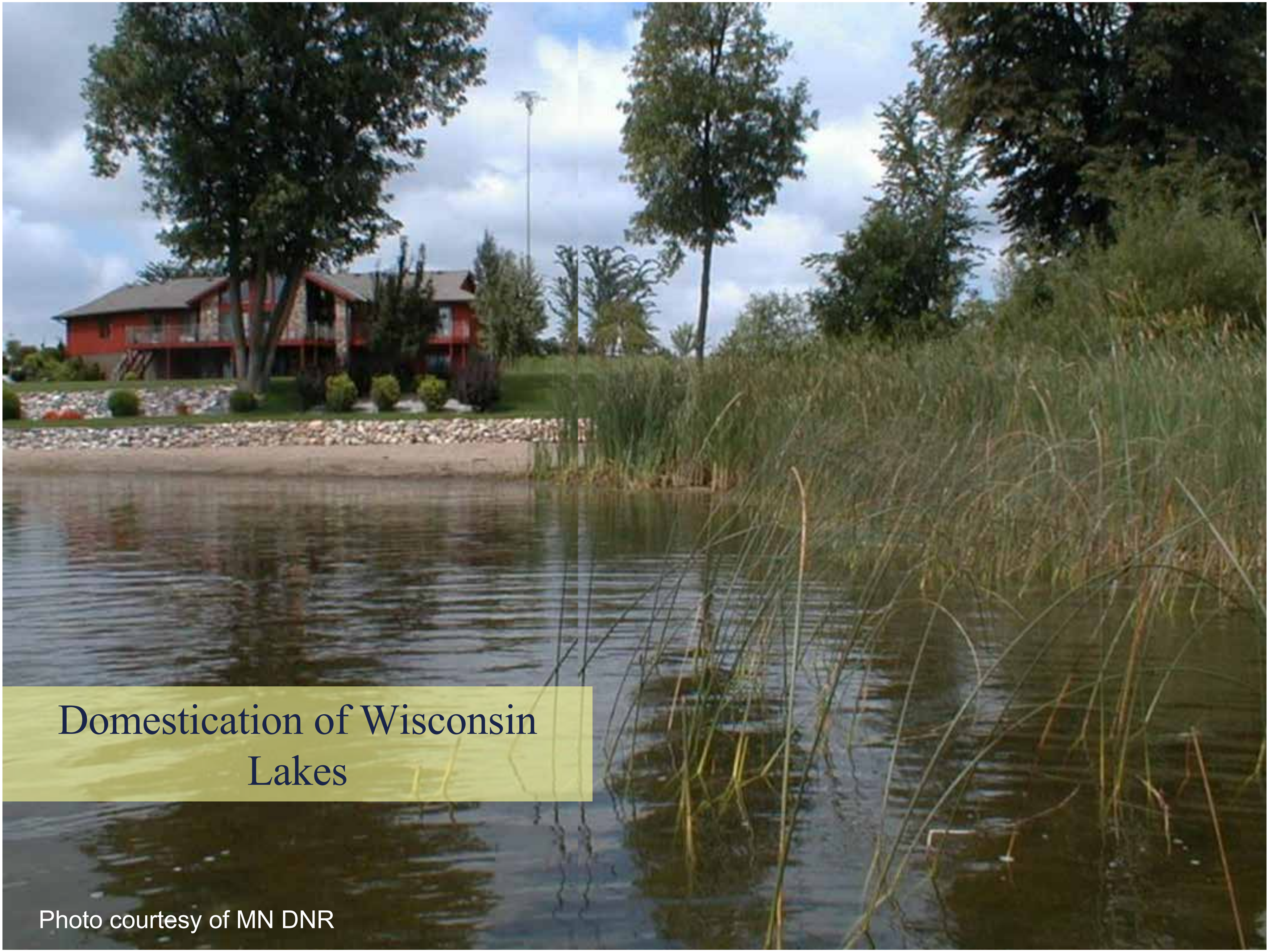
BIRDS

MAMMALS

LAKE HABITAT ZONES



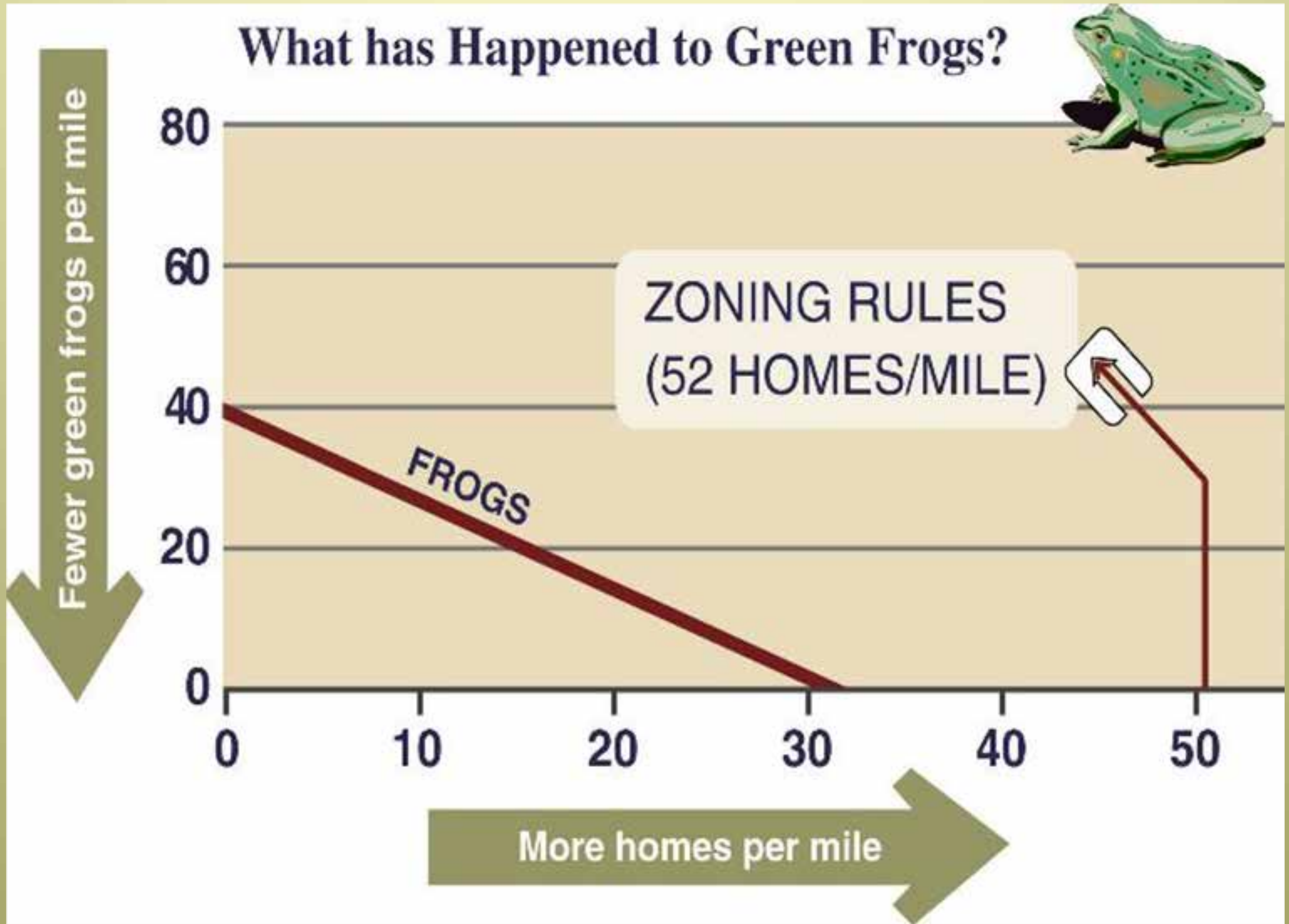
Loss of habitat: Without habitat, they are gone



Domestication of Wisconsin Lakes

Photo courtesy of MN DNR

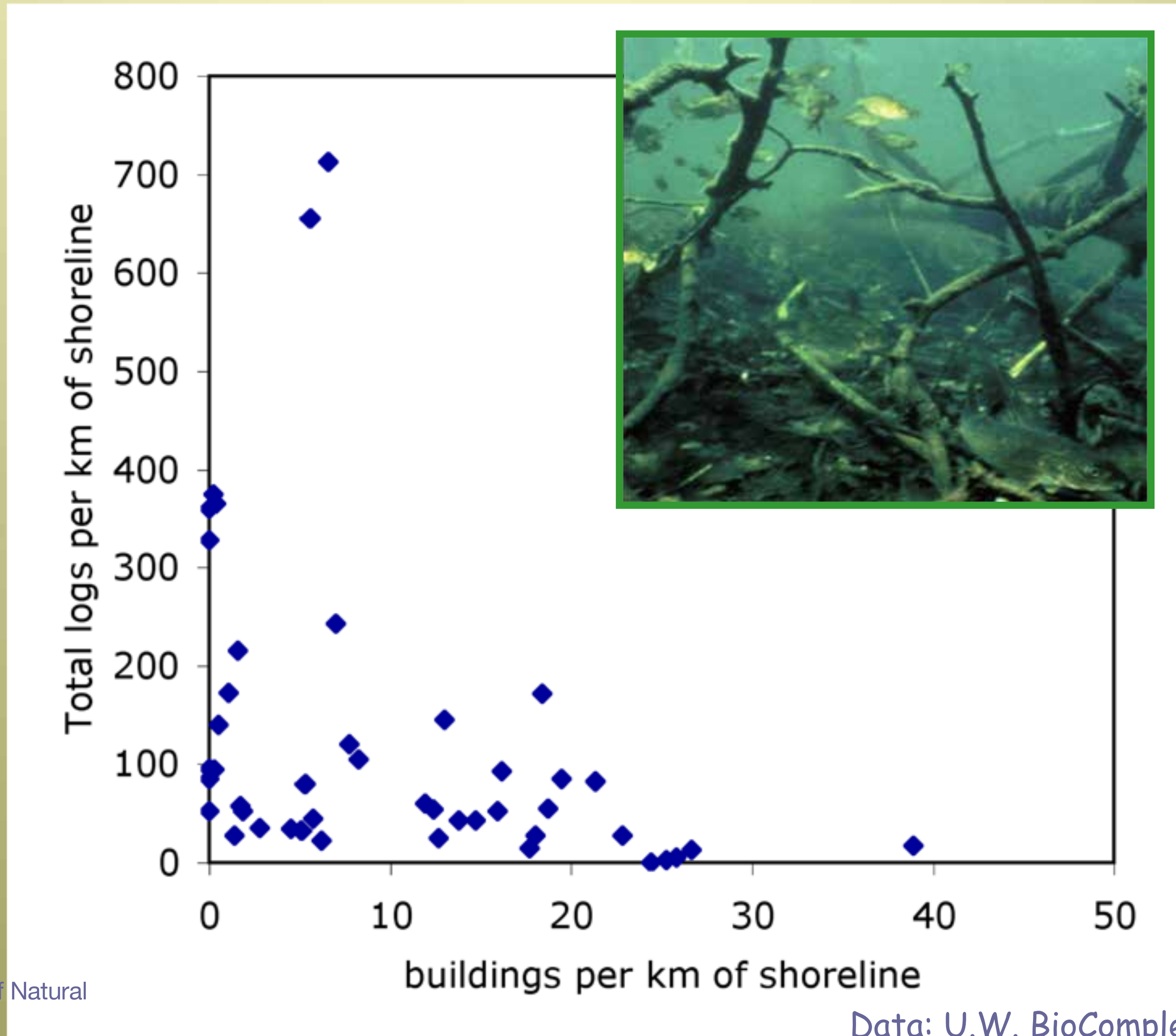
Increase in homes Loss of green frogs



Source: Woodford and Meyer

The Wisconsin Lakes Partnership

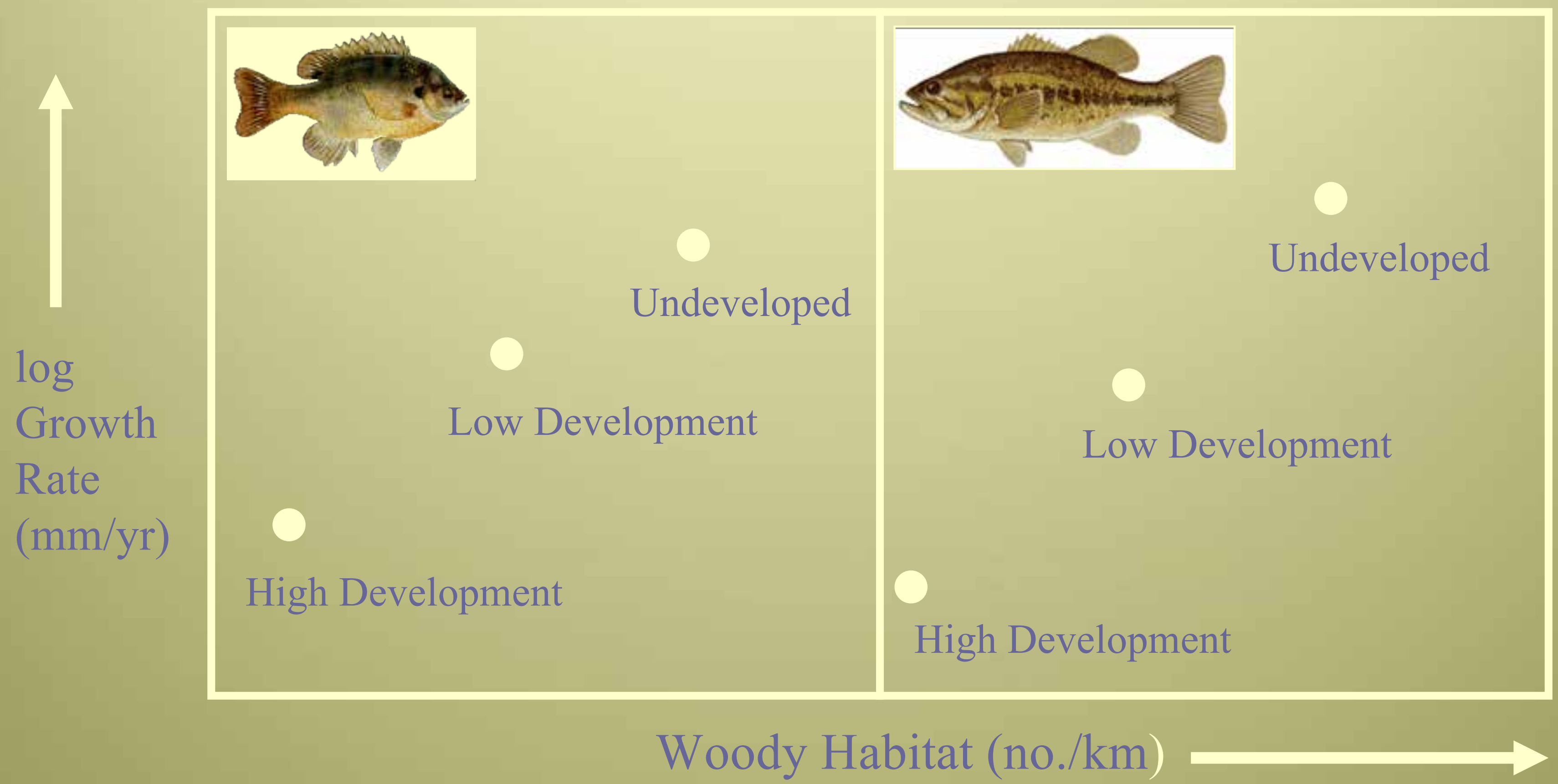
Increase in homes □ Loss of woody habitat



Source: Wisconsin Dept. of Natural Resources

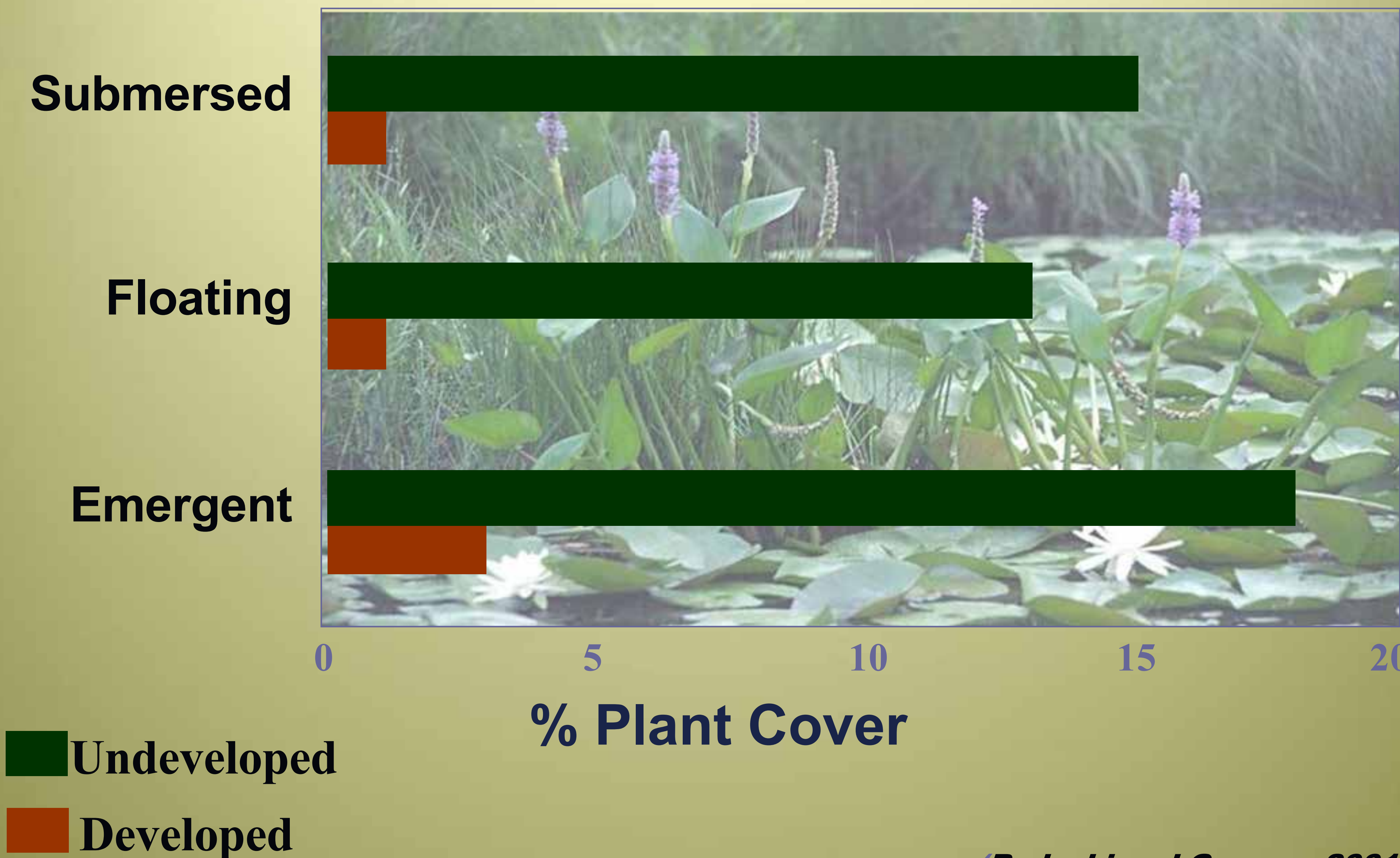
Data: U.W. BioComplexity project

Fish grow ~3X faster in lakes with lots of woody habitat



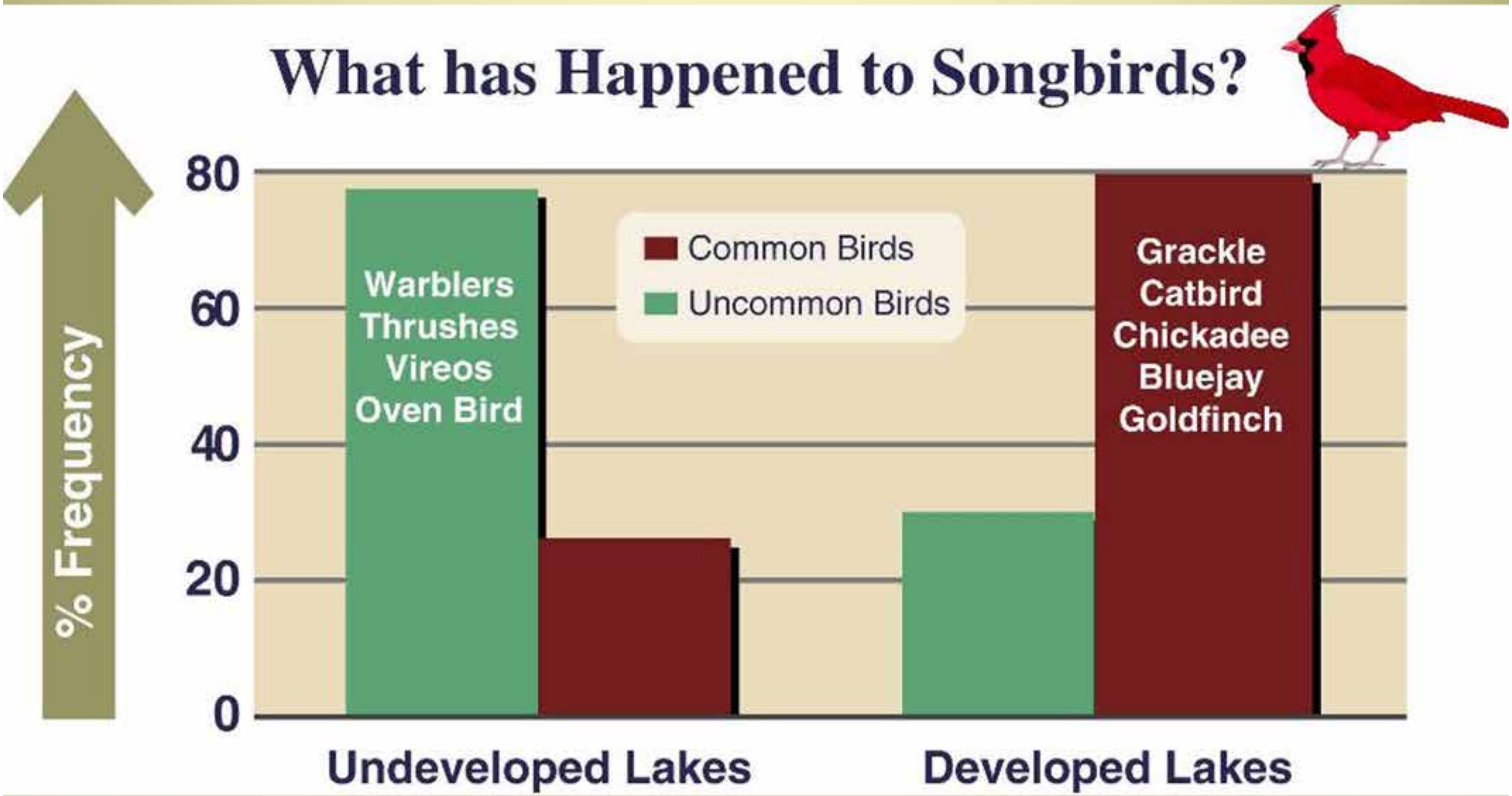
From Schindler et al. 2000

Increase in homes □ Loss of aquatic plants



(Radoski and Goeman 2001

Increase in homes Loss of rural species of birds



LAND USE AND WATERSHED IMPACTS

Lakes react differently to development and land uses. Why? Because of differences in their physical, chemical and biological characteristics.

Non-point P load reduction problems

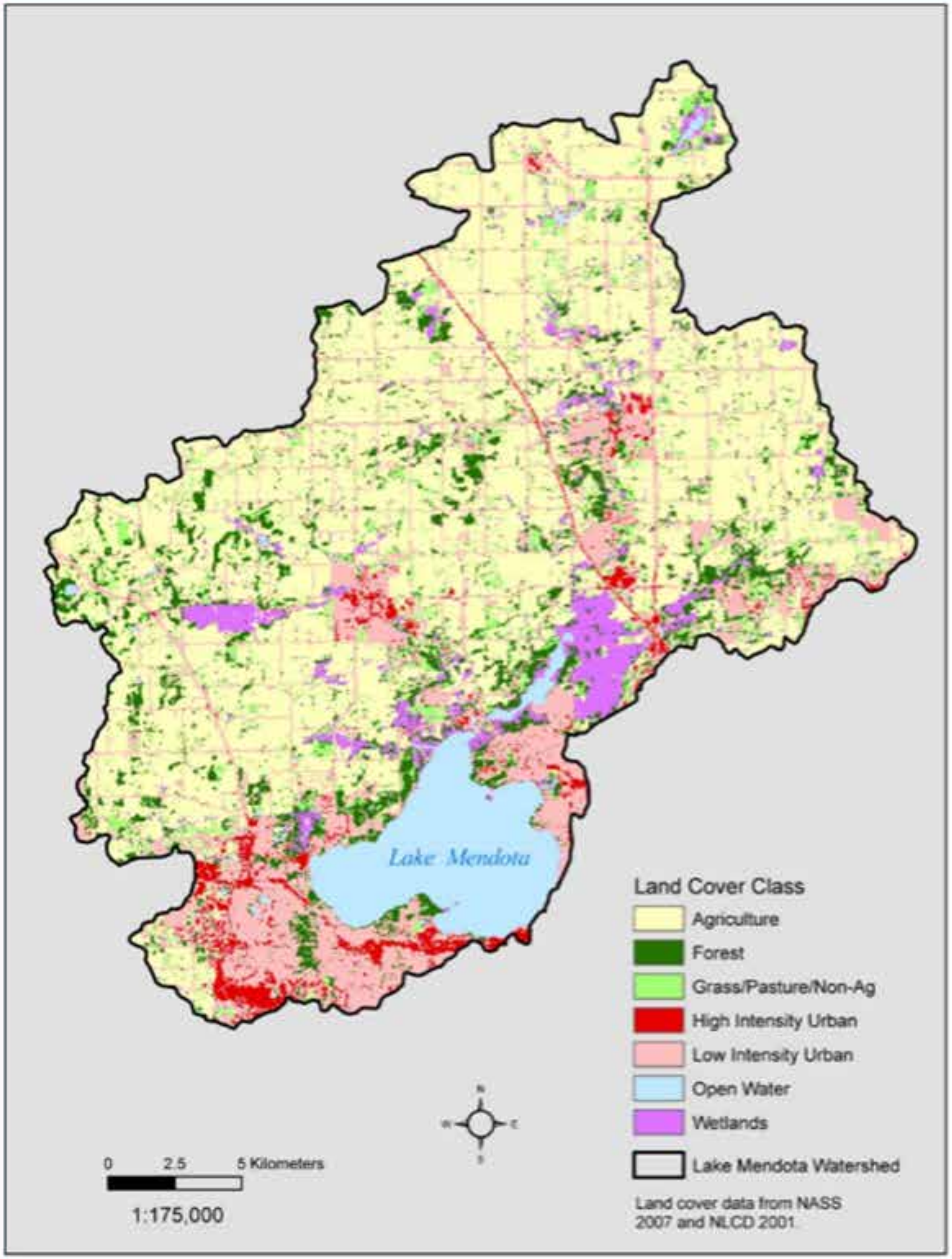
Barnyards

Streambanks

Uplands

Urban construction sites

Photos: Dane Co. Land & Water Resources Dept.



Lake Mendota

Lake Area = 40.0 km^2

Max depth = 25.3 m

Mean depth = 12.7 m

Water residence time = 4.7 yr

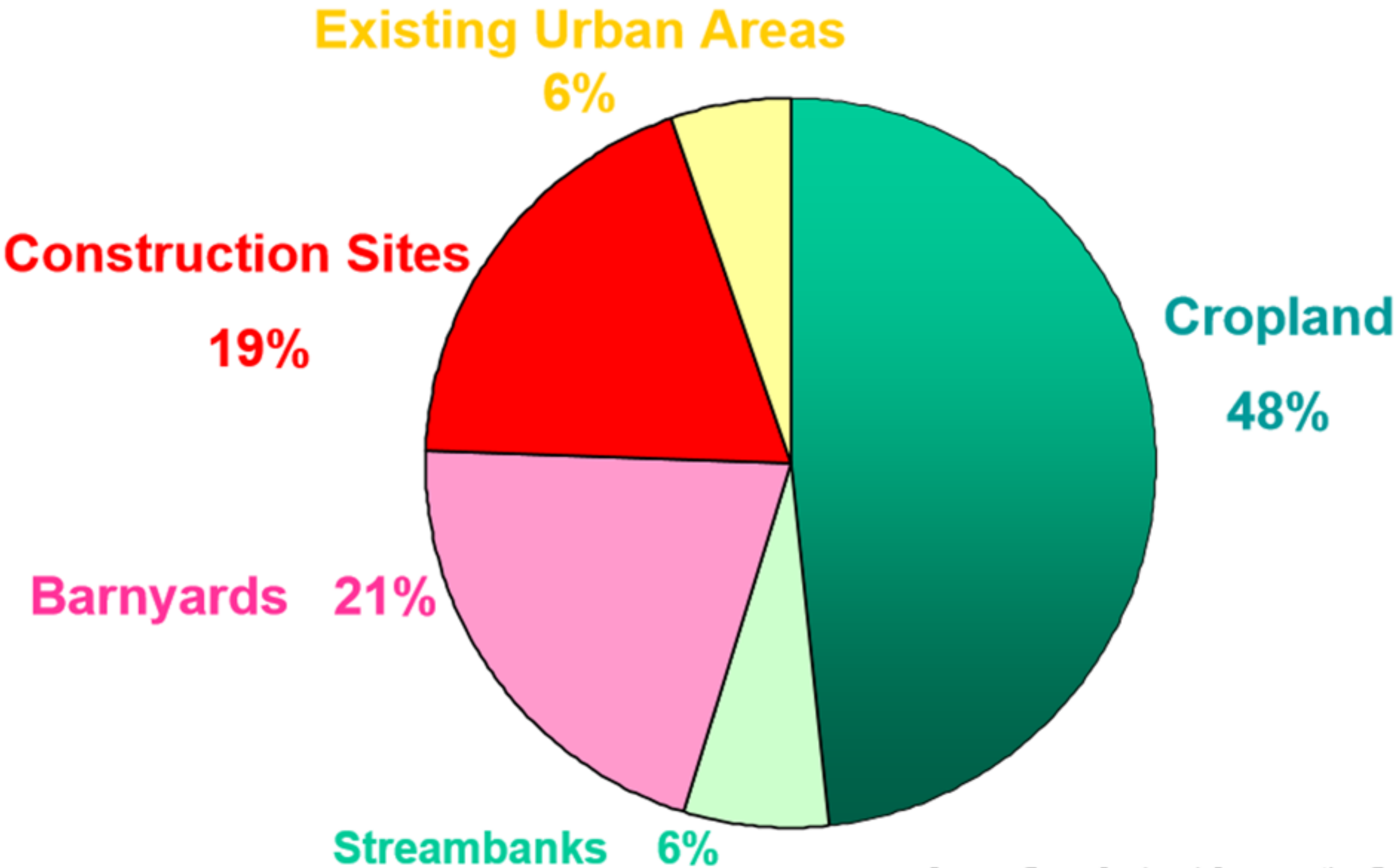
Map: Tom Simmons, WDNR

Watershed Models

Phosphorus export coefficients - developed from monitoring data.

Land Cover	WISCONSIN VALUES TP Export kg/ha/yr
High Density Urban	1.5
Row Crop Agriculture	1.0
Mixed Agriculture	0.8
Grass / Pasture	0.3
Medium Density Urban	0.5
Low Density Urban	0.1
Forested	0.09

Inventory of P Loading Sources to Lake Mendota, mid-1990's



Source: Dane Co. Land Conservation Dept.

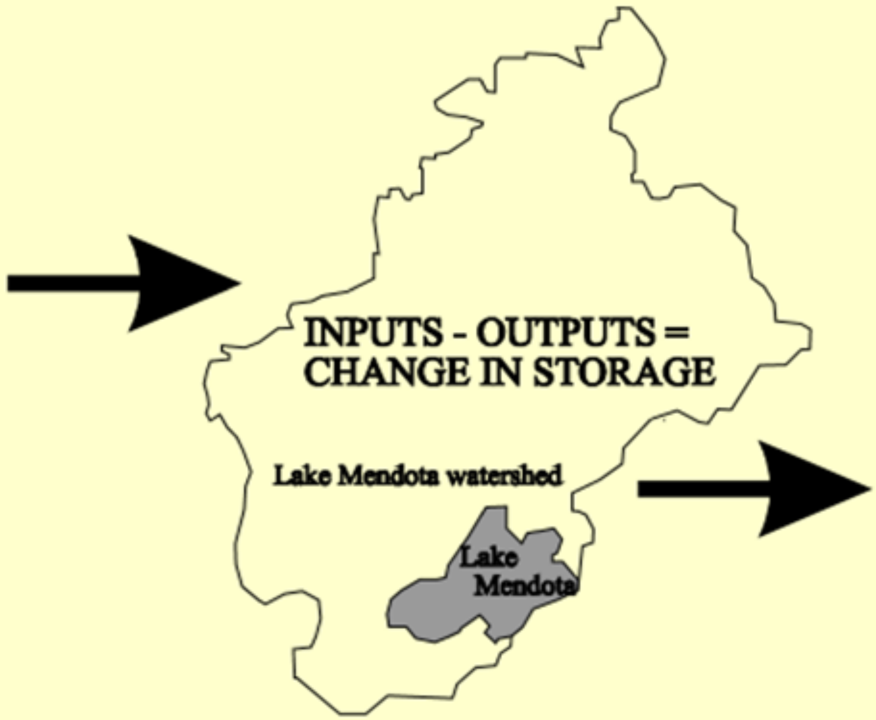
Lake Mendota Watershed P Budget

(from Bennett et al. 1999)

P Inputs

- Fertilizer for agricultural crops, including:
  - corn
  - soybeans
  - wheat
  - oats
  - peas and beans
  - barley
- Feed supplements for dairy cattle
- Fertilizer for urban lawn
- Dry and wet deposition

P in = 1,307 MT



P Outputs

- Crops harvested, including:
  - corn
  - soybeans
  - wheat
  - oats
  - peas and beans
  - barley
  - forage
- Animal products, including:
  - cattle
  - hogs/pigs
  - milk and dairy
  - eggs
- Hydrologic export to Lake Mendota **= 34 MT**

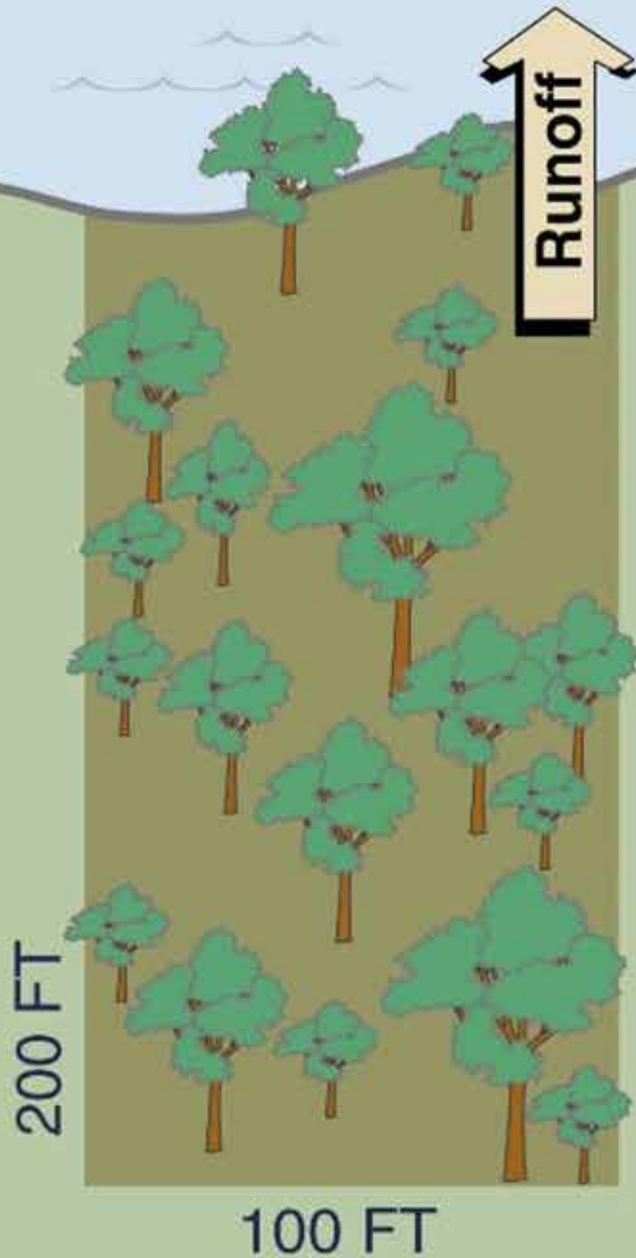
P out = 732 MT

P Storage = + 575 MT !!

Figure 1. Schematic diagram of inputs and outputs used to calculate a P budget for the Lake Mendota watershed for 1995.

Undeveloped – Apr.-Oct. phosphorus/sediment runoff model

- maple-beech forest
- 6% slope to lake
- sandy loam soil



IMPACT ON LAKE
(April - Oct.)

- 1,000 ft^3 runoff to lake
- 0.03 lbs. phos. to lake
- 5 lbs. sediment to lake

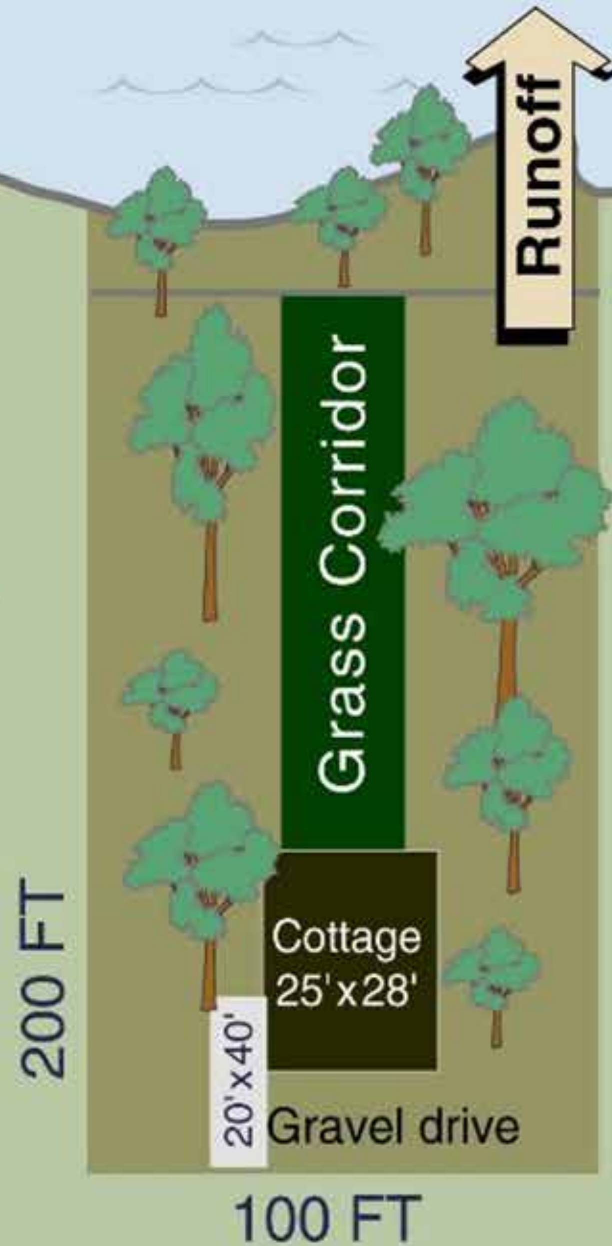
Source: Wisconsin Dept. of Natural Resources

The Wisconsin Lakes Partnership

Laine Cabin, Long Lake Chippewa County

1940s development – Apr.-Oct. phosphorus/sediment runoff model

- maple-beech forest
- 6% slope to lake
- grass corridor 20'-wide
- cottage 700 ft^2 perimeter
- gravel drive 800 ft^2
- 35'-wide buffer strip



IMPACT ON LAKE
(April - Oct.)

- 1,000 ft^3 runoff to lake
- 0.03 lbs. phos. to lake
- 20 lbs. sediment to lake

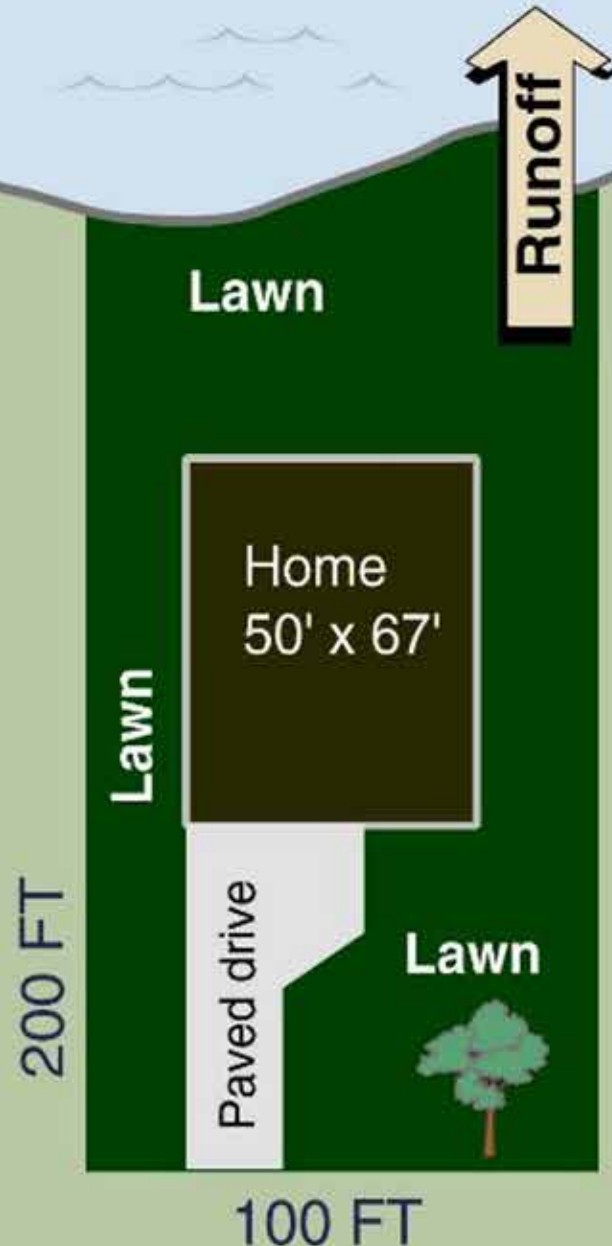
Source: Wisconsin Dept. of Natural Resources

The Wisconsin Lakes Partnership

Redevelopment Long Lake Chippewa County

1990s development – Apr.-Oct. P/sediment runoff model

- maintained lawn, soil graded
- 6% slope to lake
- home 3,350 ft^2 perimeter
- paved drive 770 ft^2



IMPACT ON LAKE
(April - Oct.)

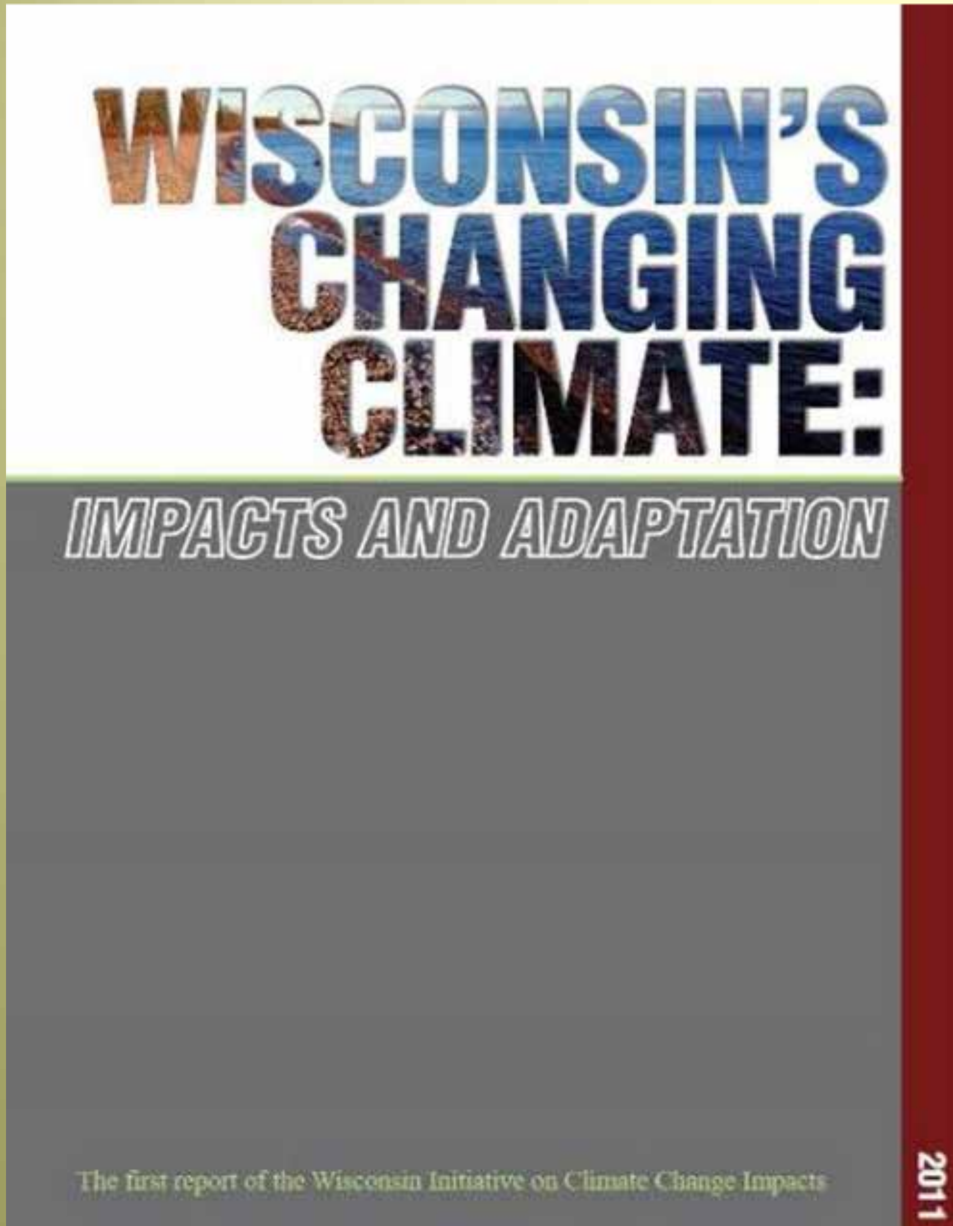
- 5,000 ft^3 runoff to lake
- 0.20 lbs. phos. to lake
- 90 lbs. sediment to lake

Source: Wisconsin Dept. of Natural Resources

The Wisconsin Lakes Partnership

AQUATIC INVASIVE SPECIES

Wisconsin Initiative on Climate Change Impacts



WICCI's First Adaptive Assessment Report - released Feb 2011

Key Water Resource Impacts

- *Increased flooding*
- *Increased frequency of harmful blue-green algal blooms*
- *Conflicting water use concerns*
- *Changes in water levels*
- *Increased sediment and nutrient loading*
- *Increased spread of aquatic invasive species*

http://wicci.wisc.edu


Photo: http://photogallery.nrcs.usda.gov/


Photo: R. Lathrop


Photo: R. Lathrop

Warmer temperatures and increased runoff from large storm events causes water quality problems, blue-green algae blooms, eutrophication, etc


Photo: Melvin McCartney, Lake Monona, June 2006

Protection & Restoration can take place in the watershed, shoreline, and in the lake.

FURTHER READING etc

- Your existing lake management plan
- UW Extension, Wisconsin Lakes & DNR websites
- Understanding Lake Data
- Laketides newsletter
- Lake Leader Training
- Aquatic plant identification training
- UW Madison Limnology
- Google (ie Bluegreen algae, or WICCI)

Do what you can, with what you have, where you are.
– Theodore Roosevelt

LEAVING A LEGACY

Help Protect Wisconsin's…

LAKE HEALTH

Thank you.

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