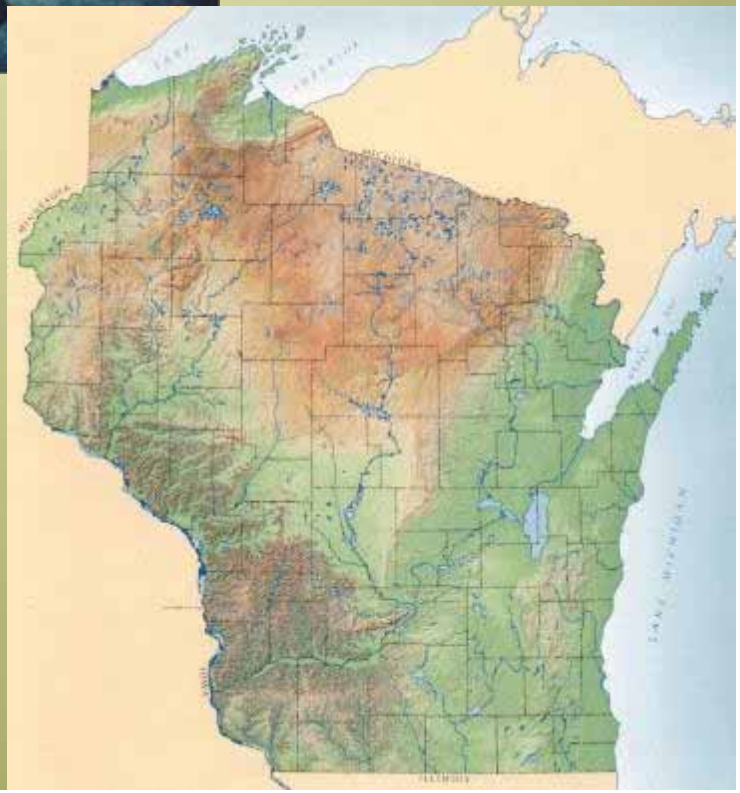
LAKE HEALTH

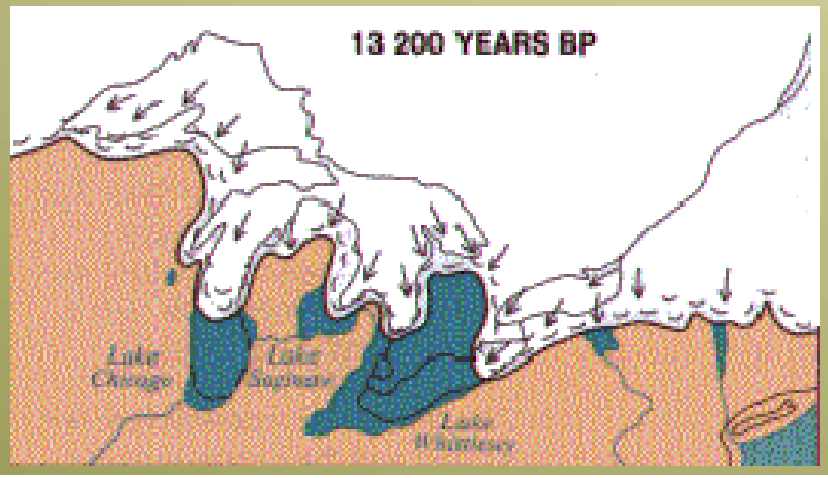
Courtesy of Lake Partnerships

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

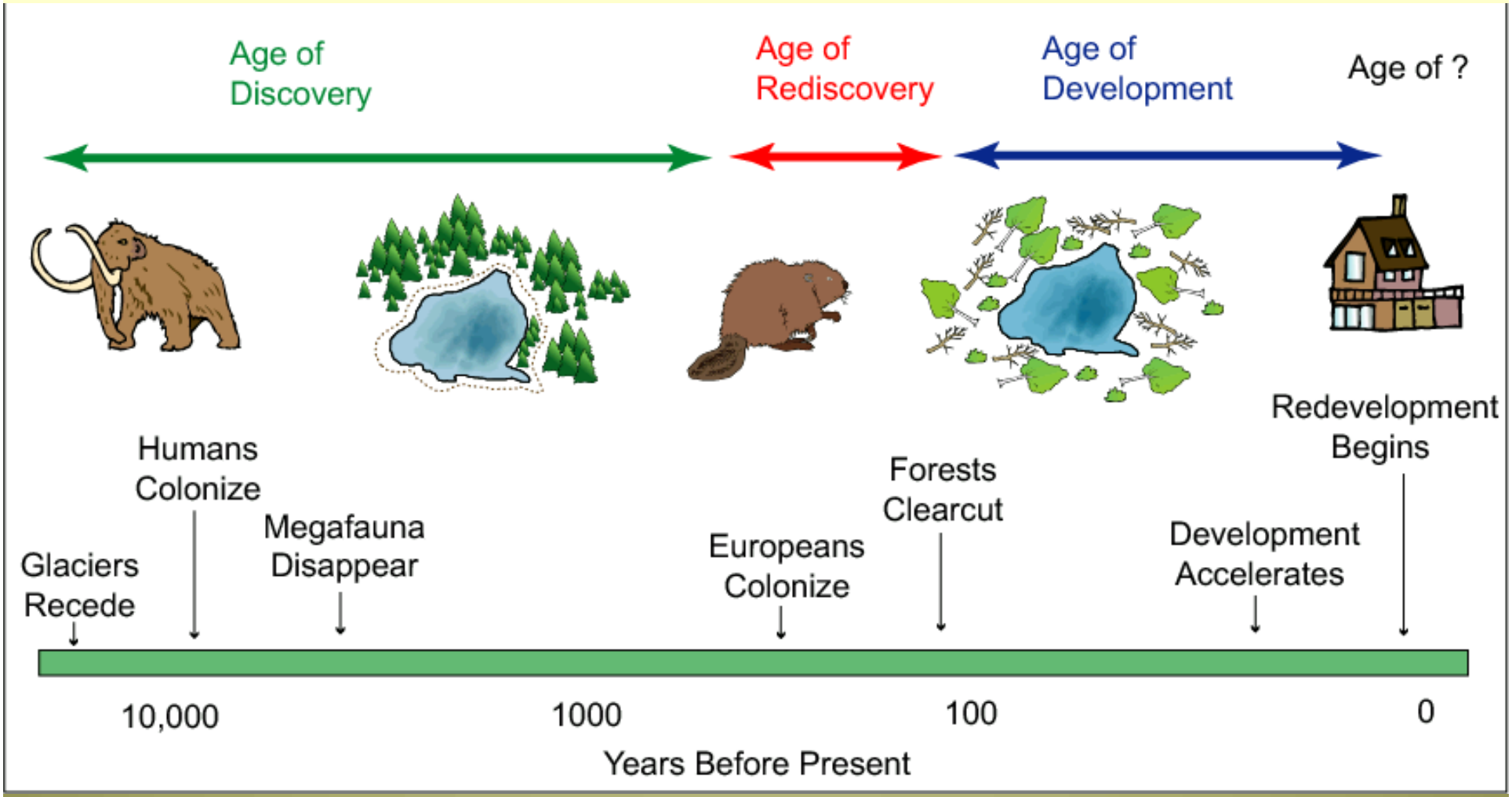
Definitions & Background

Wisconsin's Glacial Legacy





Recent History of Wisconsin's Lakes



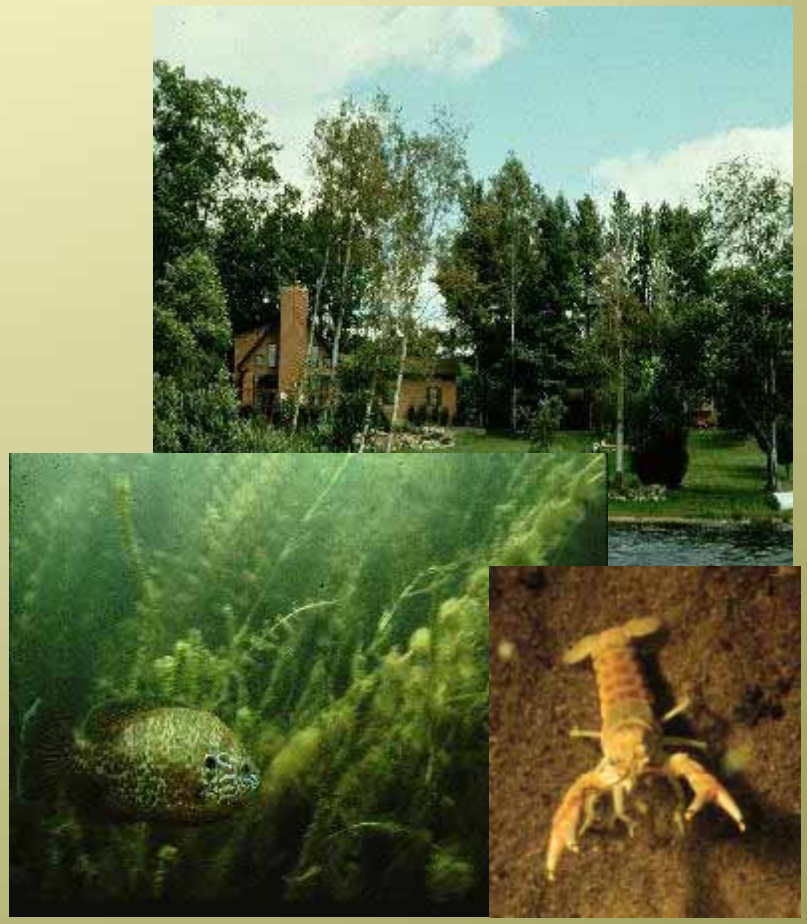

Lakes Provide Services
Ecosystem
Cultural
Societal
07/08/2004
Sara Schmidt
Sara Schmidt

Wisconsin's Lakes are Changing Faster than Ever:

Algae blooms
(phosphorus pollution)

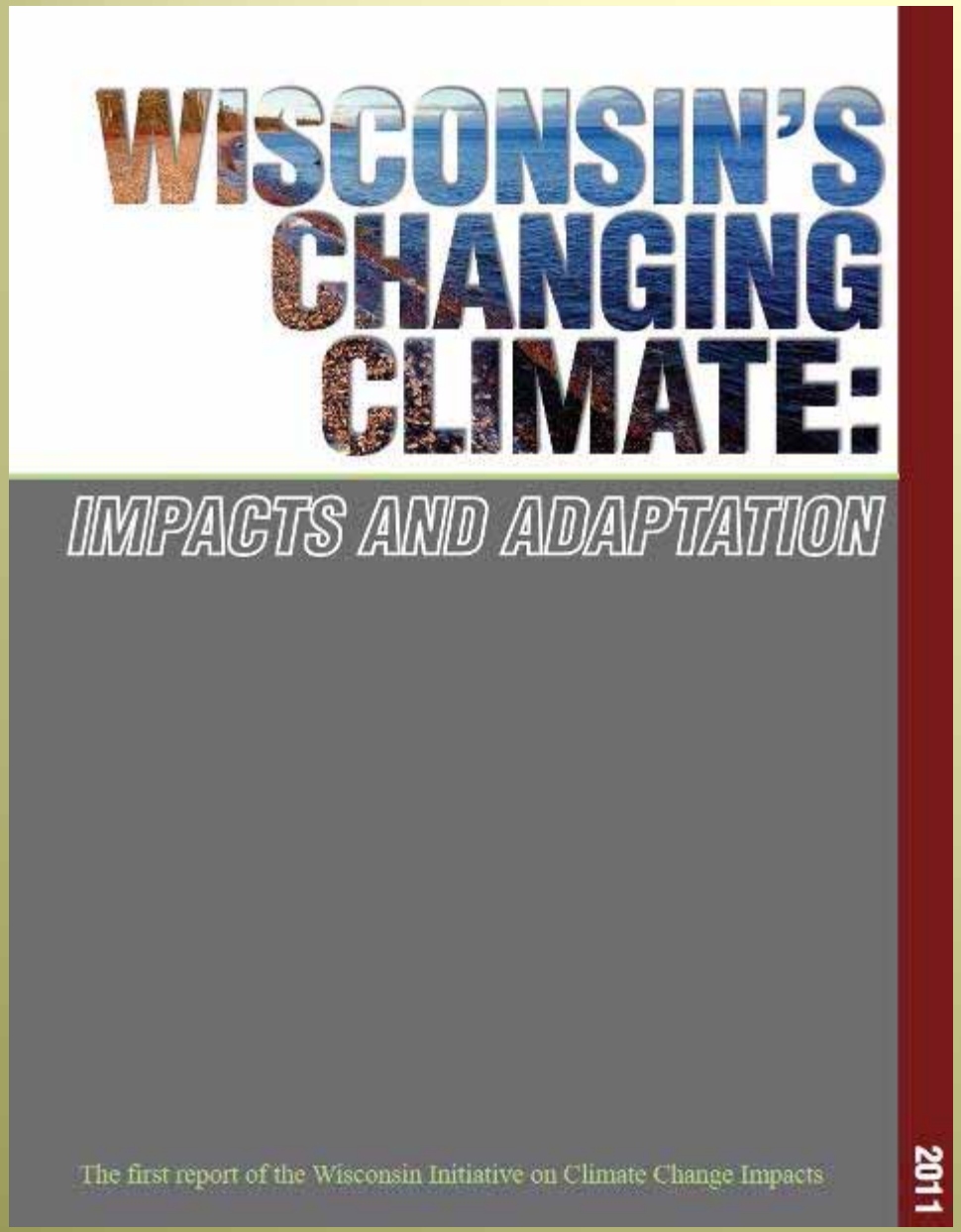
Destruction of
shoreline habitat

Invading plants and
animals



Steve Carpenter

WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS



WICCI's First Adaptive Assessment Report - released Feb 2011

30+ Authors

10 Editorial Team Members

22 Science Council Members

22 Chairs/Co-Chairs of 15 Working Groups

Major Drivers of Climate Change Impacts on Water Resources

- Thermal Impacts (Increased air and water temps, longer ice-free period, more ET)
- Changing rainfall patterns (seasonal and spatial variability, + or – water, less precip in the form of snow)
- Increased storm intensity (more frequent large precipitation events)

WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

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***

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

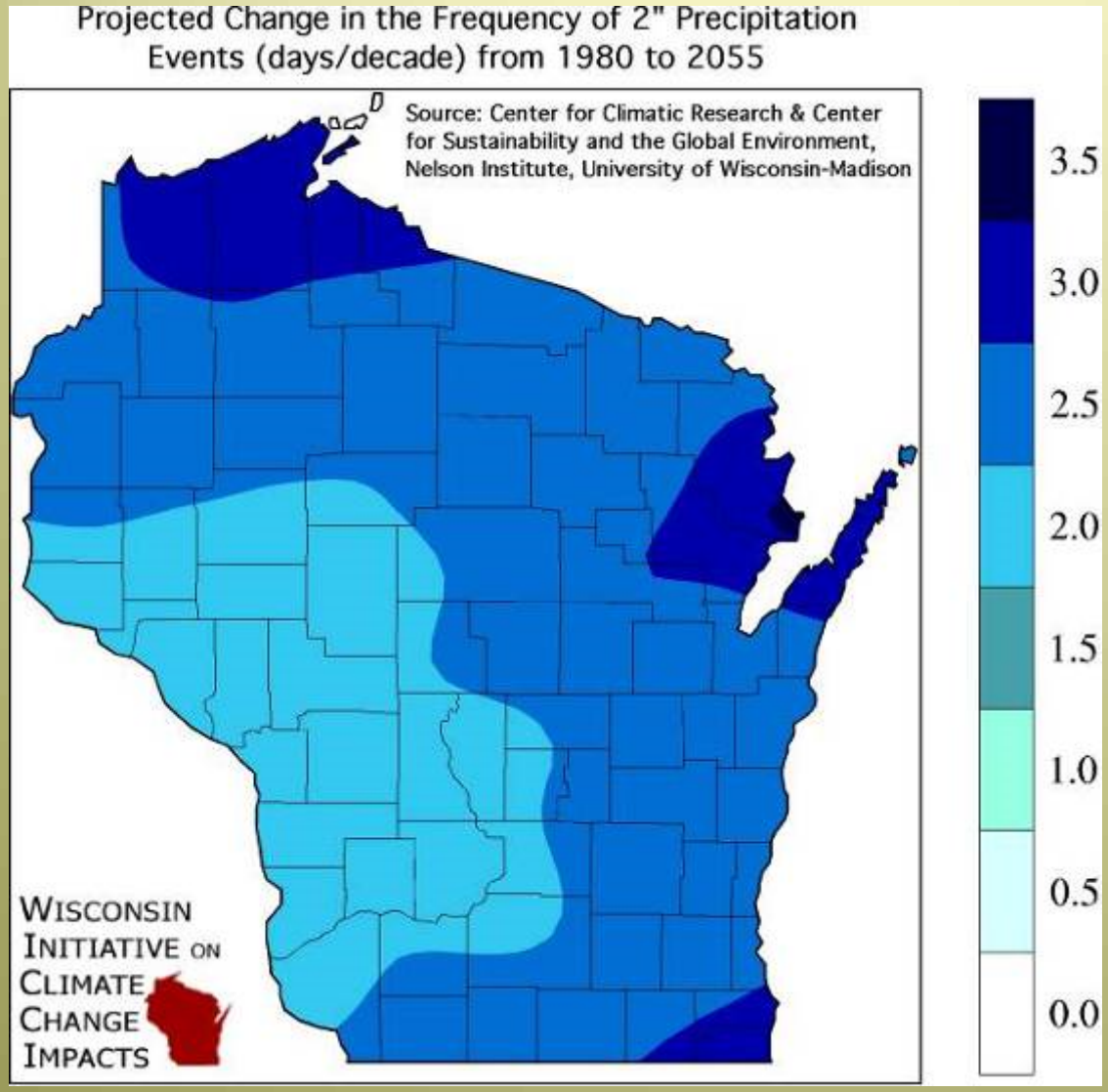
Photo: R. Lathrop

Photo: R. Lathrop

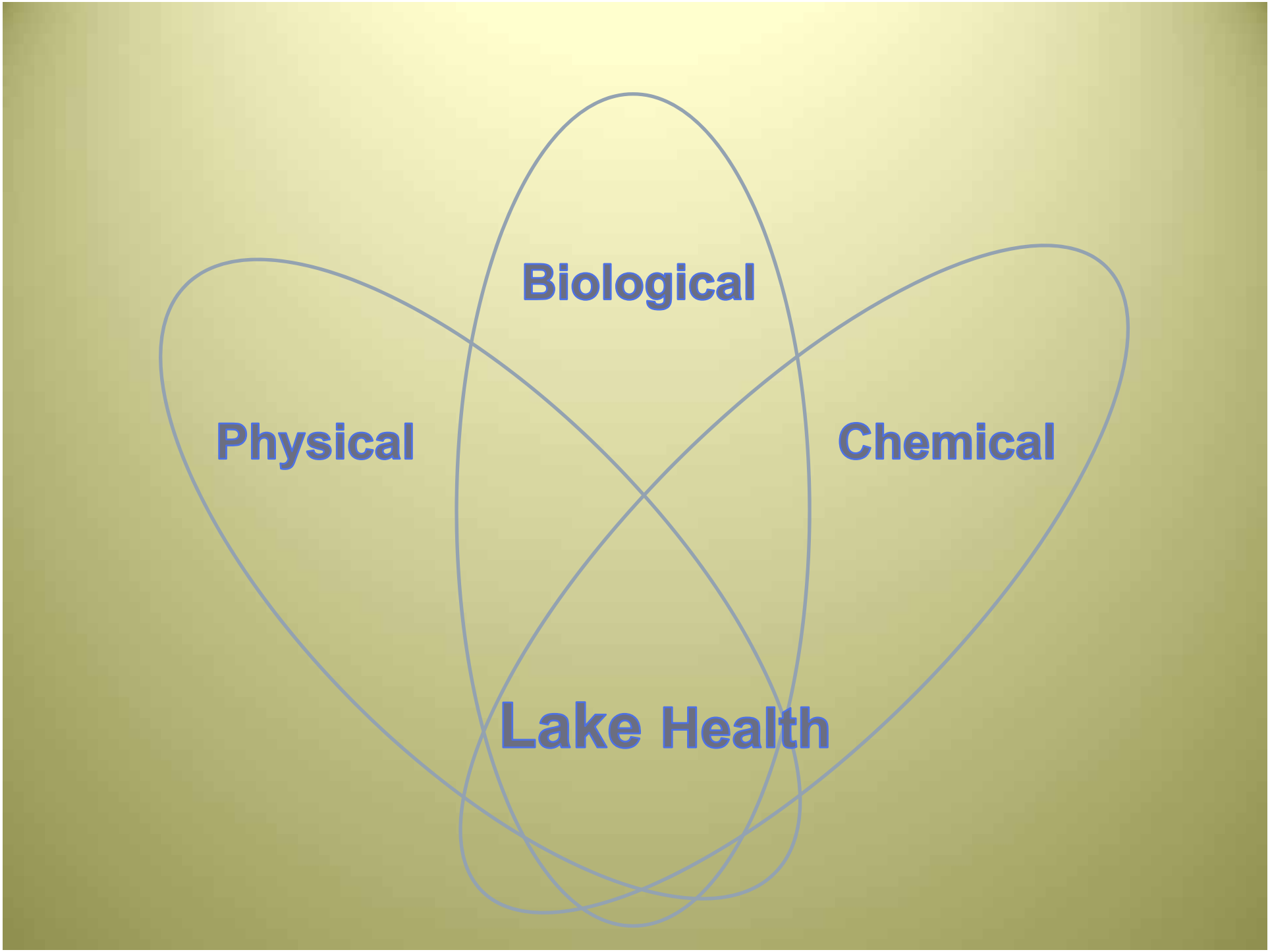
Warmer temperatures and increased runoff from large storm events causes water quality problems, blue-green toxins, eutrophication, etc

Photo: Melvin McCartney, Lake Monona, June 2006

Number of days with intense precipitation is projected to increase across Wisconsin in 21st century.

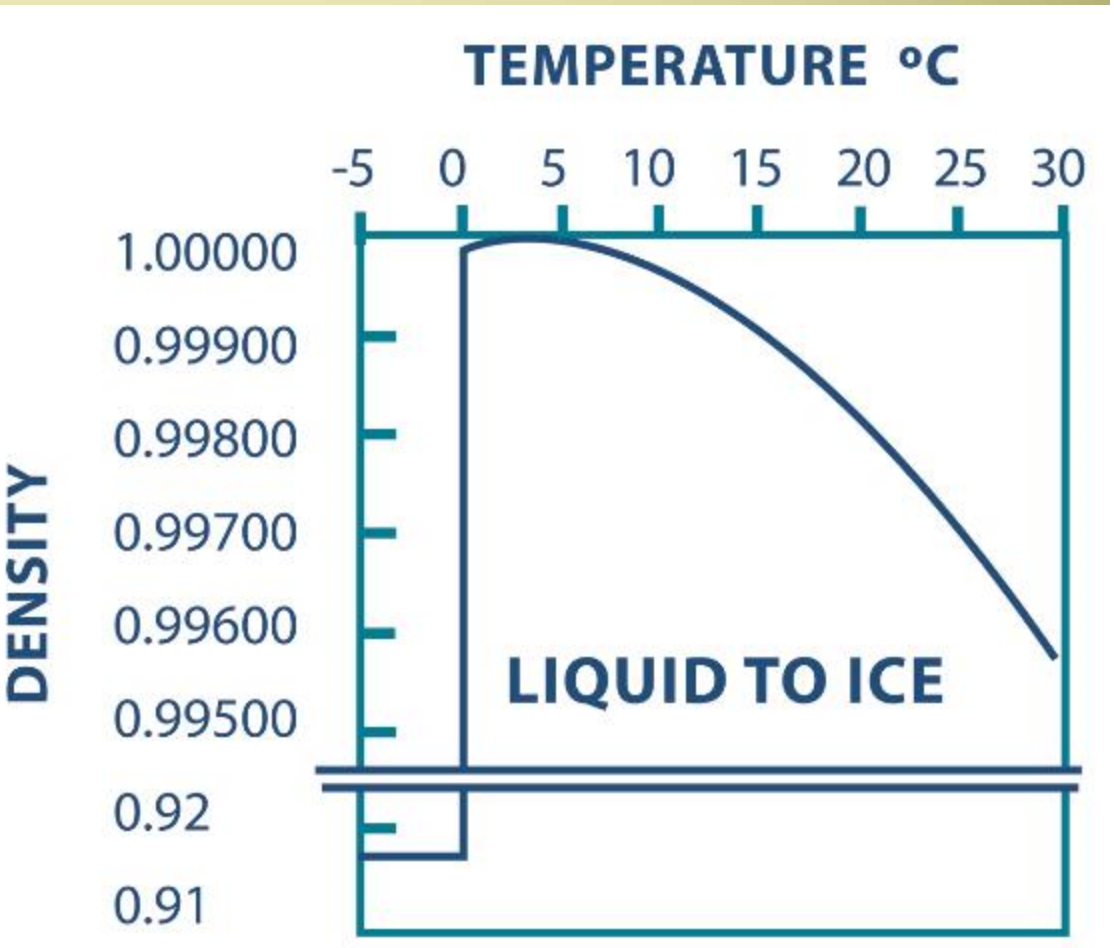


- Roughly a 25% increase in frequency.
- Recurrence intervals decrease from once every 10 months to once every 8 months in southern Wisconsin


Biological
Physical
Chemical
Lake Health

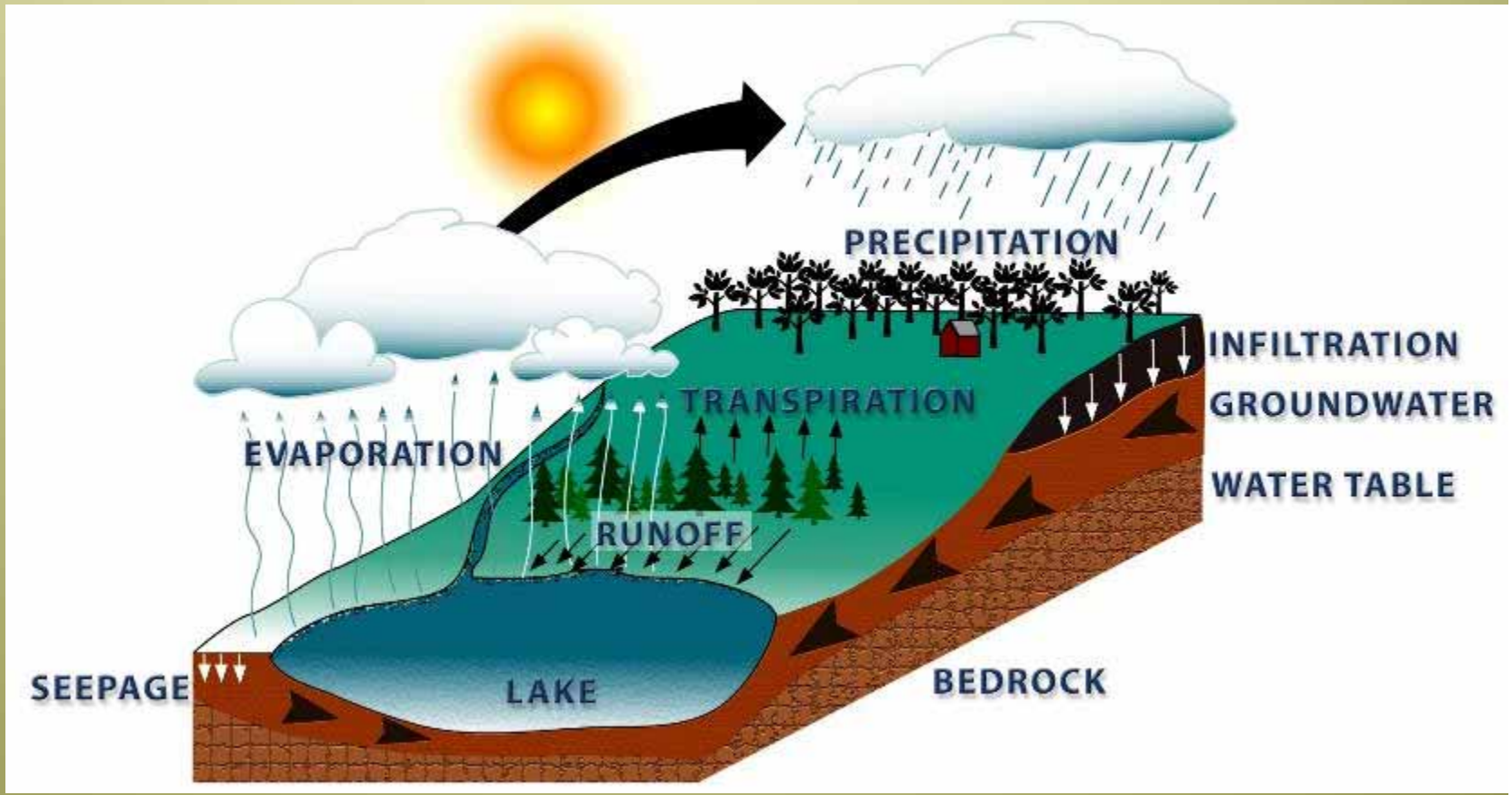
UNIQUE PROPERTIES OF WATER

- Physical Properties
- 71% Earth's Surface Covered by Water
- <1% Water on Earth is Freshwater
- .009% water on Earth is Freshwater Lakes




THE WISCONSIN WATER STORY
32”
20”
32”

HYDROLOGIC CYCLE

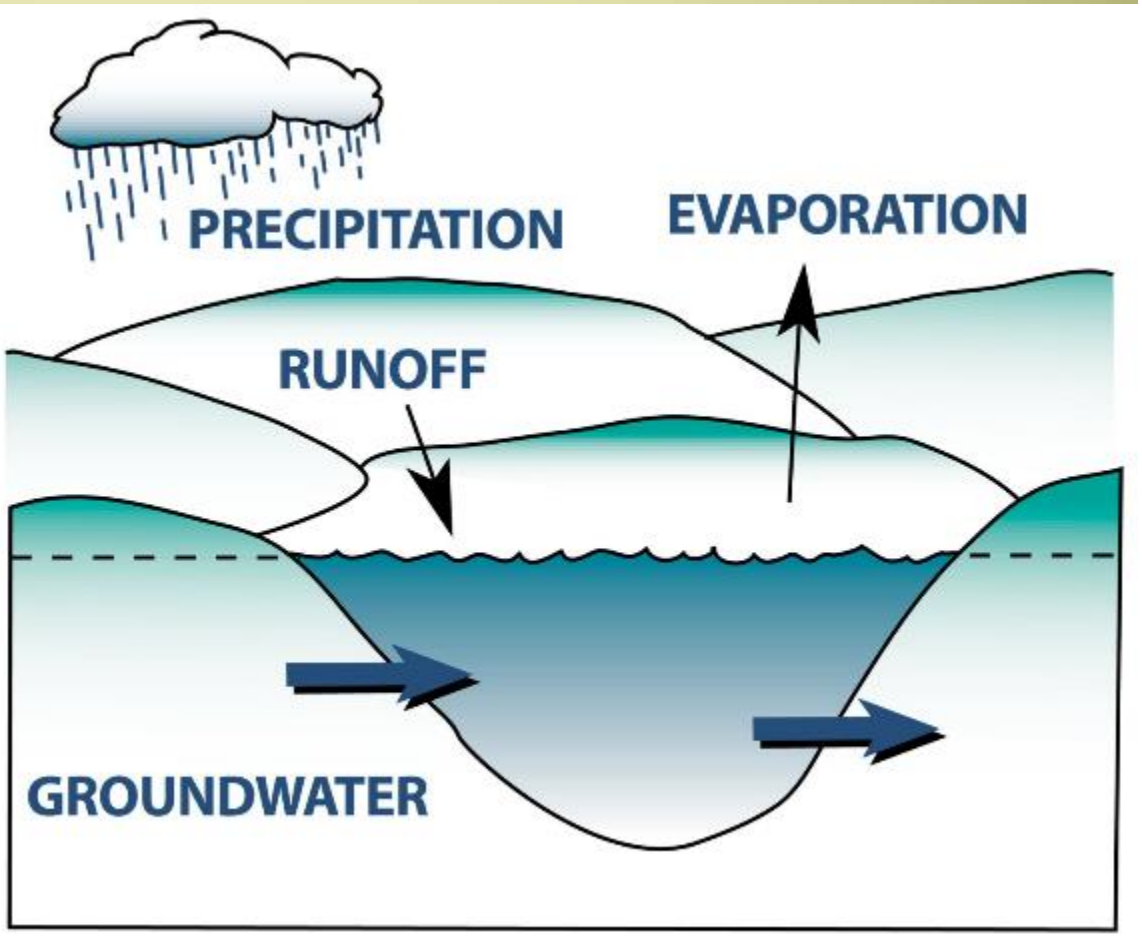


LAKE TYPES

- Seepage
- Groundwater Drainage
- Drainage
- Impoundments
- Oxbow

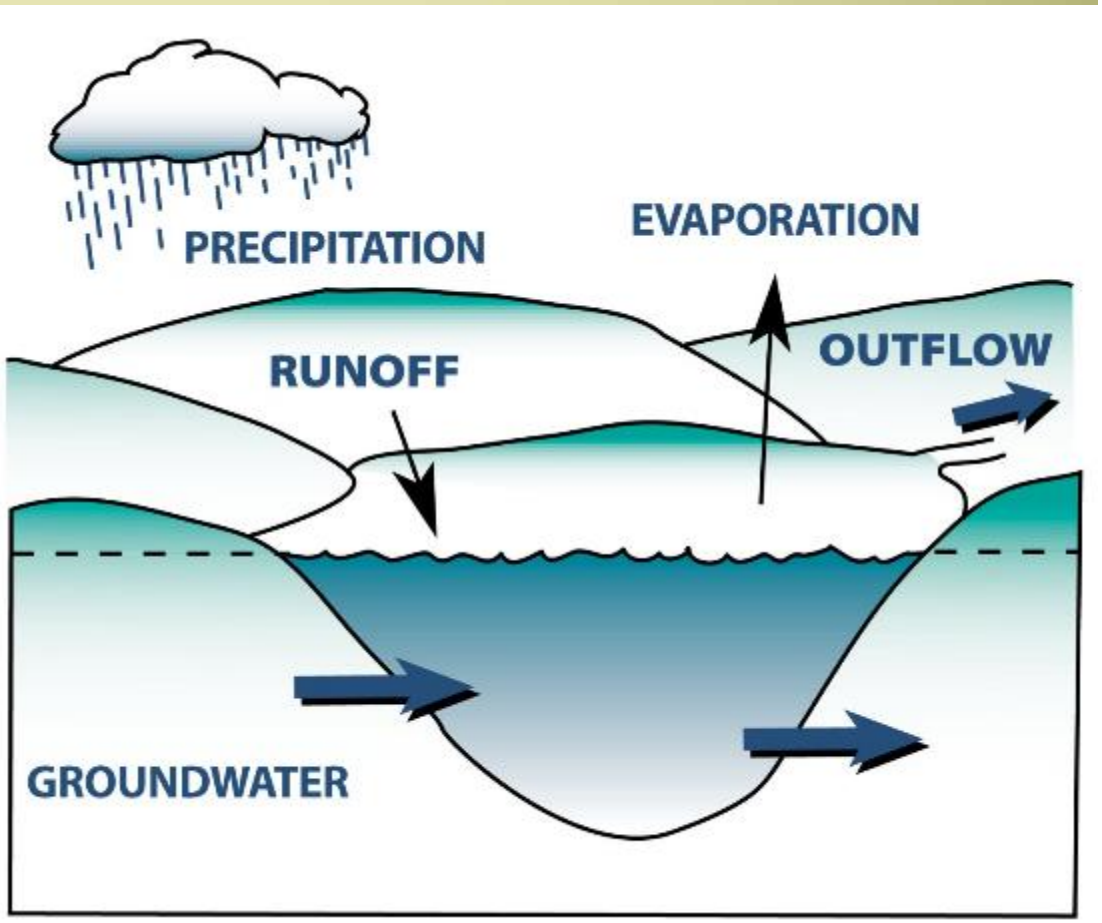
SEEPAGE LAKE

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



GROUNDWATER DRAINAGE

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

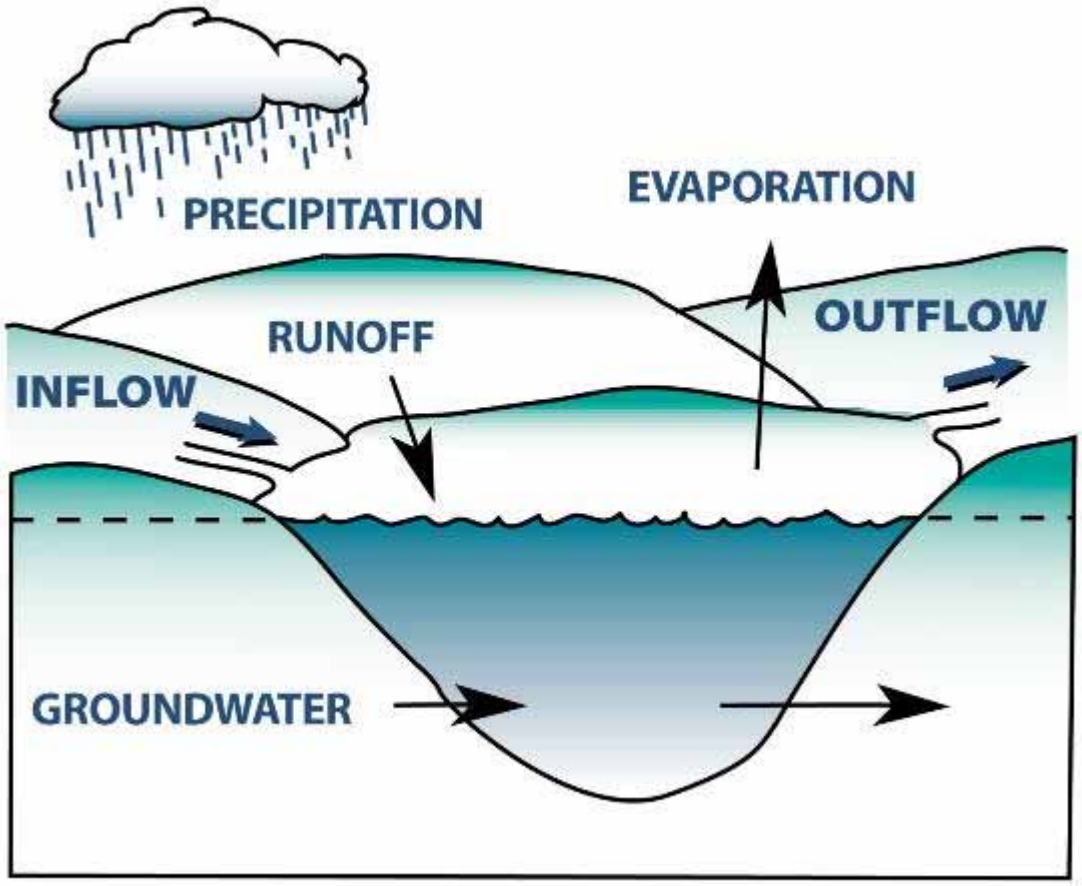


GROUNDWATER DRAINAGE LAKE

- Sand Lake, Chippewa County

DRAINAGE LAKE

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

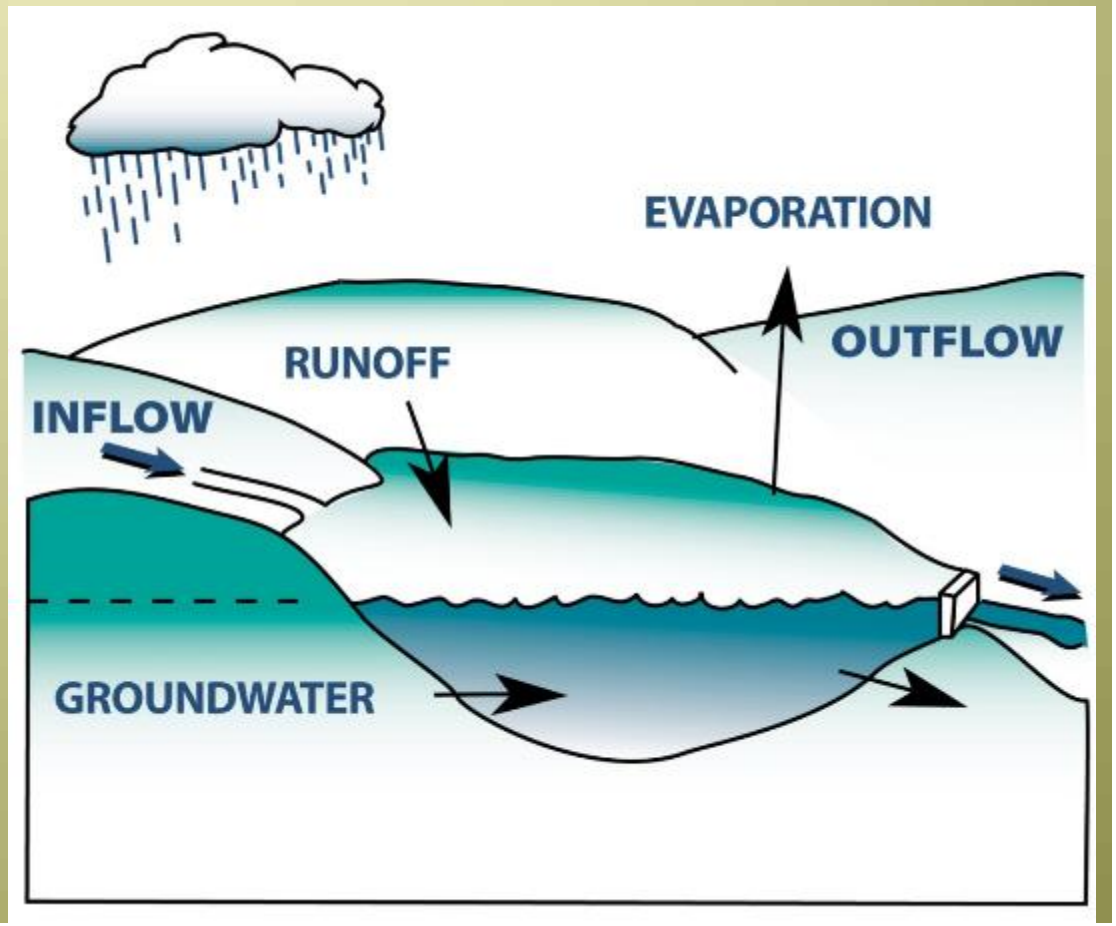


DRAINAGE LAKE

- Long Lake, Chippewa County

IMPOUNDMENT

- A manmade lake
- Dammed River or Stream

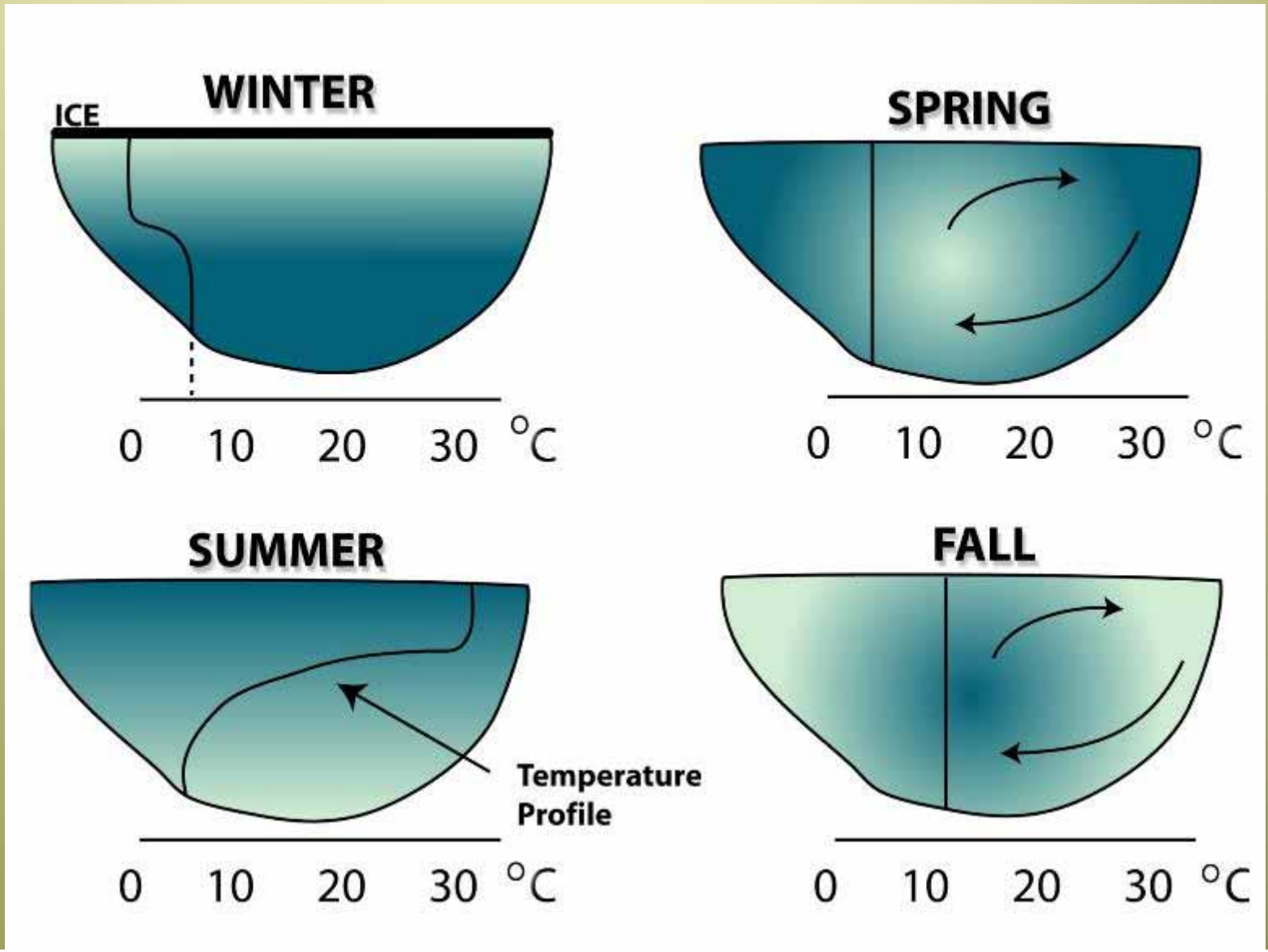


- Lake Hallie, Chippewa County

PHYSICAL CHARACTERISTICS

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

MIXING/ STRATIFICATION



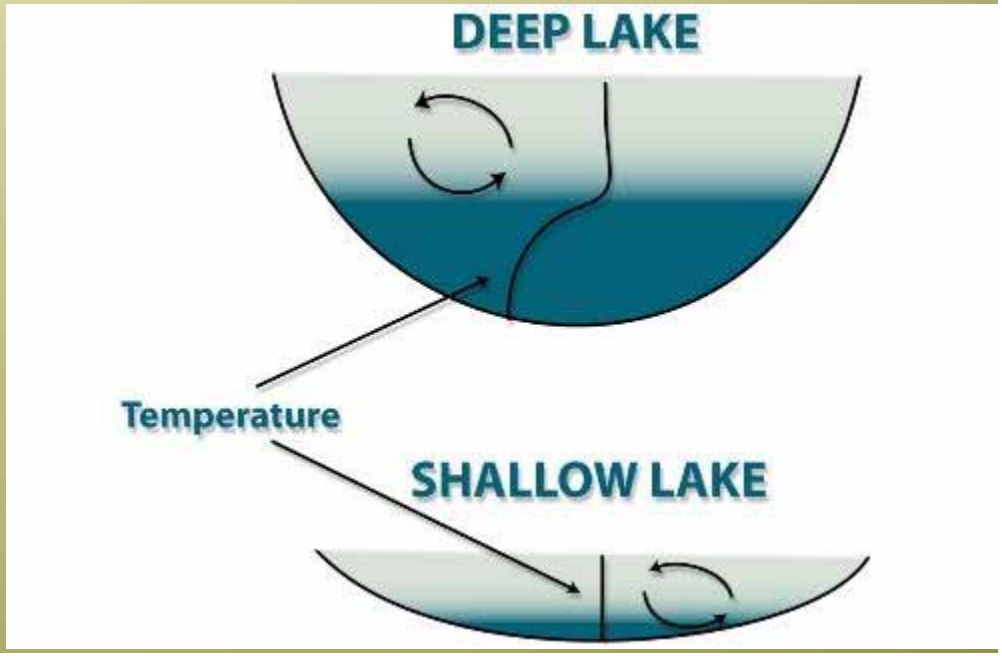
LAKE DEPTH MATTERS

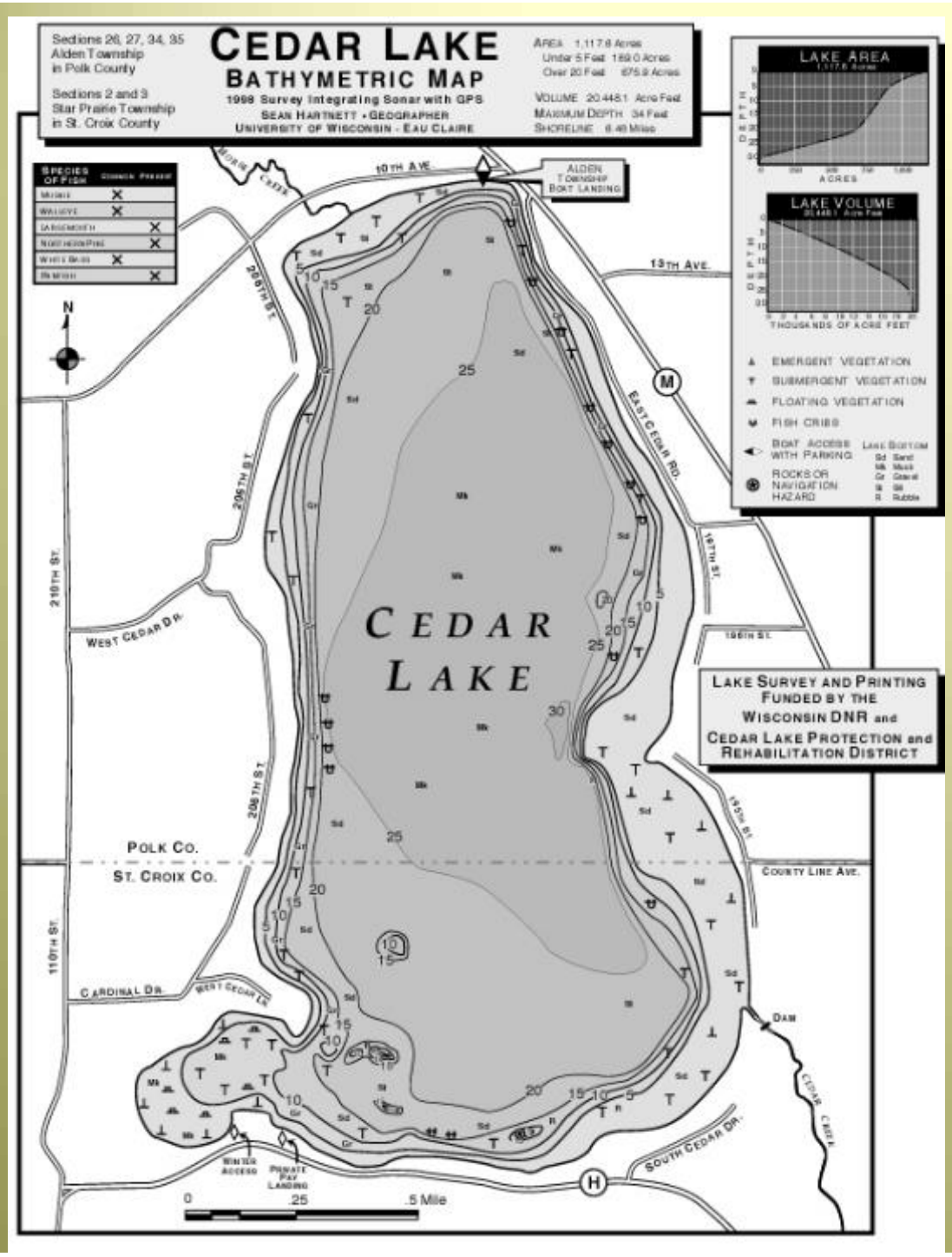
- **Deep Lakes**

  Stratify

- **Shallow Lakes**

  Continuous Nutrient Recycling





20448/1117.6=18

Precip – ***ET*** – *Runoff*

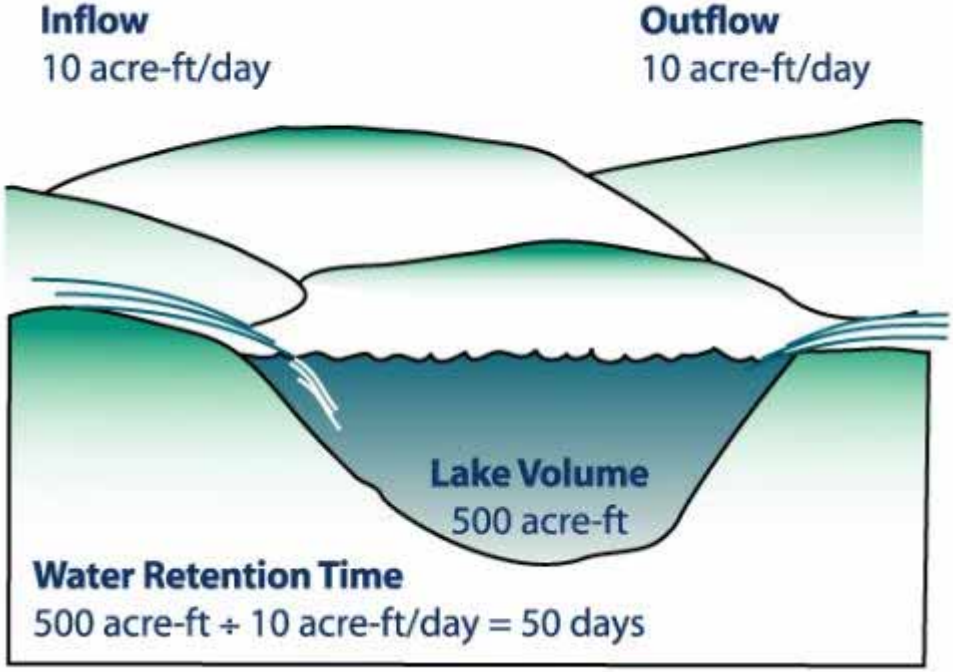
Change in water table (also lakes and wetlands)

Water In – Water Out = ± Storage

Discharge to streams

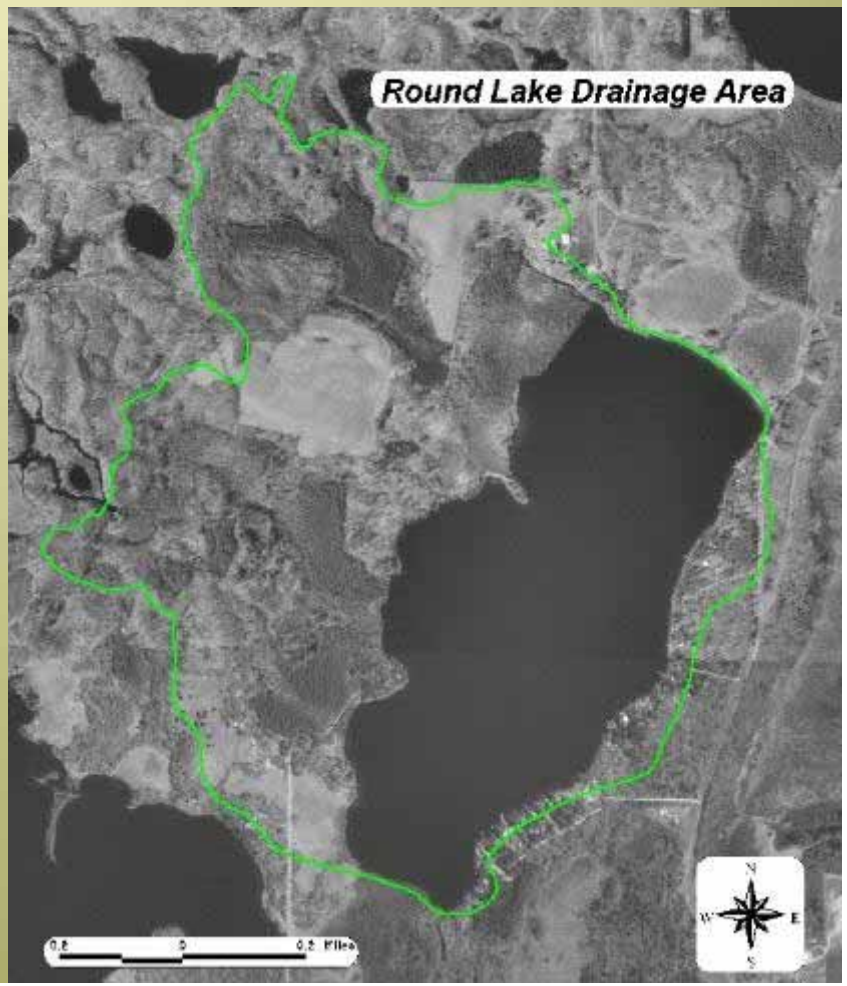
RETENTION TIME/ FLUSHING RATE

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

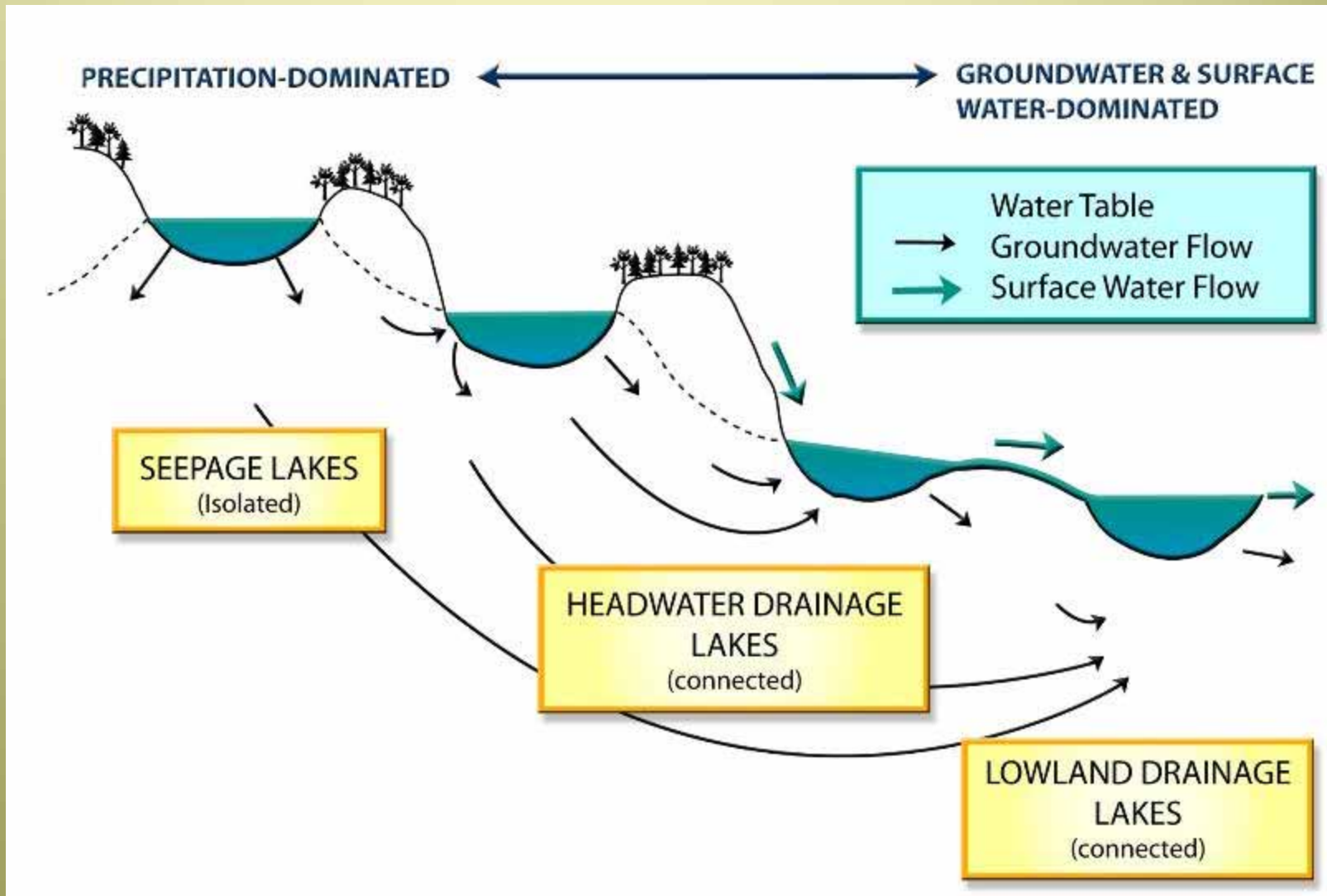


DRAINAGE BASIN/ LAKE AREA RATIO

- Seepage Lake- small
- Drainage Lake- large watershed
  - Seepage Lake w/ drainage area mapped Round Lake



LANDSCAPE POSITION



CHEMICAL CHARACTERISTICS

- Nutrients
  - P
  - N
- pH
- Hardness/ Alkalinity
- Dissolved Oxygen (optimum 5 ppm)

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

Phactoids: 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***
- **A little P goes a long way**
  - 1 lb of P can produce 500 lb of algae, and that P can be recycled many times
- **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 nearly always the principal limiting nutrient***

LIMITING NUTRIENT PRINCIPLE

…That Nutrient in Least Supply
Relative to Plant Needs

N:P Ratio in plant Tissue 10:1

If the Ratio of N:P in Water is

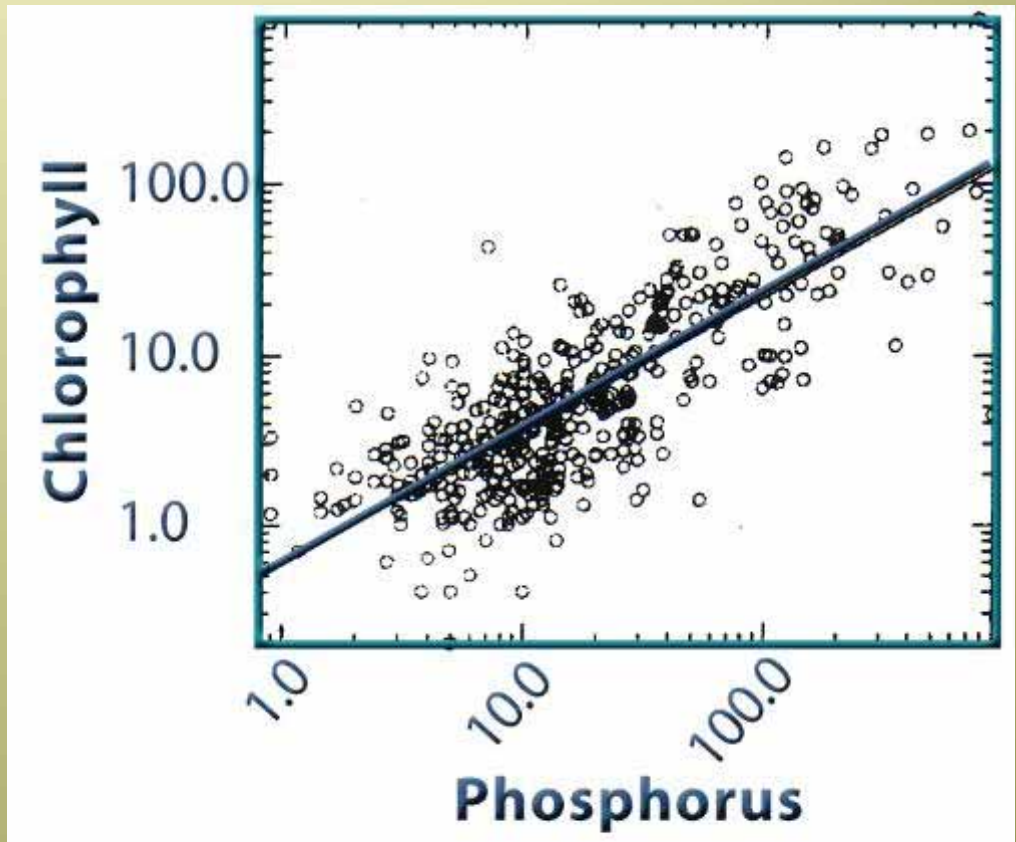
<10:1 Nitrogen Limited

>15:1 Phosphorus Limited

PHOSPHORUS LIMITATION LAKE 227

TOTAL PHOSPHORUS/ CHLOROPHYLL a RELATIONSHIP

- Phosphorus causes algae to grow



Why Develop the Criteria?

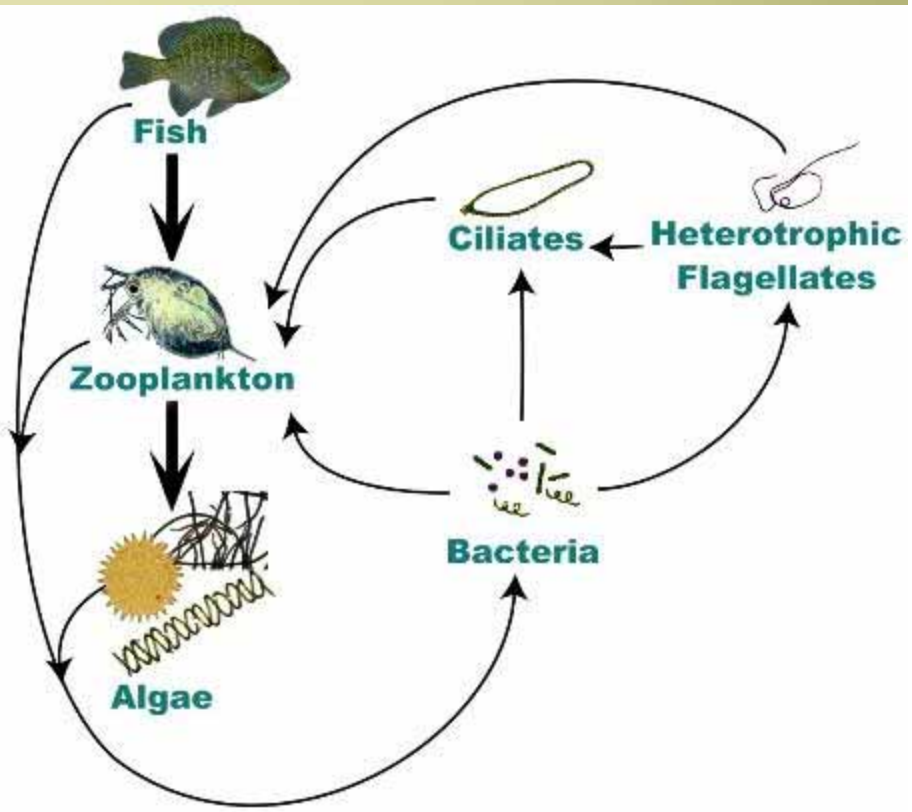
- Obvious water quality problems in state caused by excess nutrient loading
- Numeric goals for protecting or restoring Recreational and Fish and Aquatic Life Uses
- EPA requirement

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

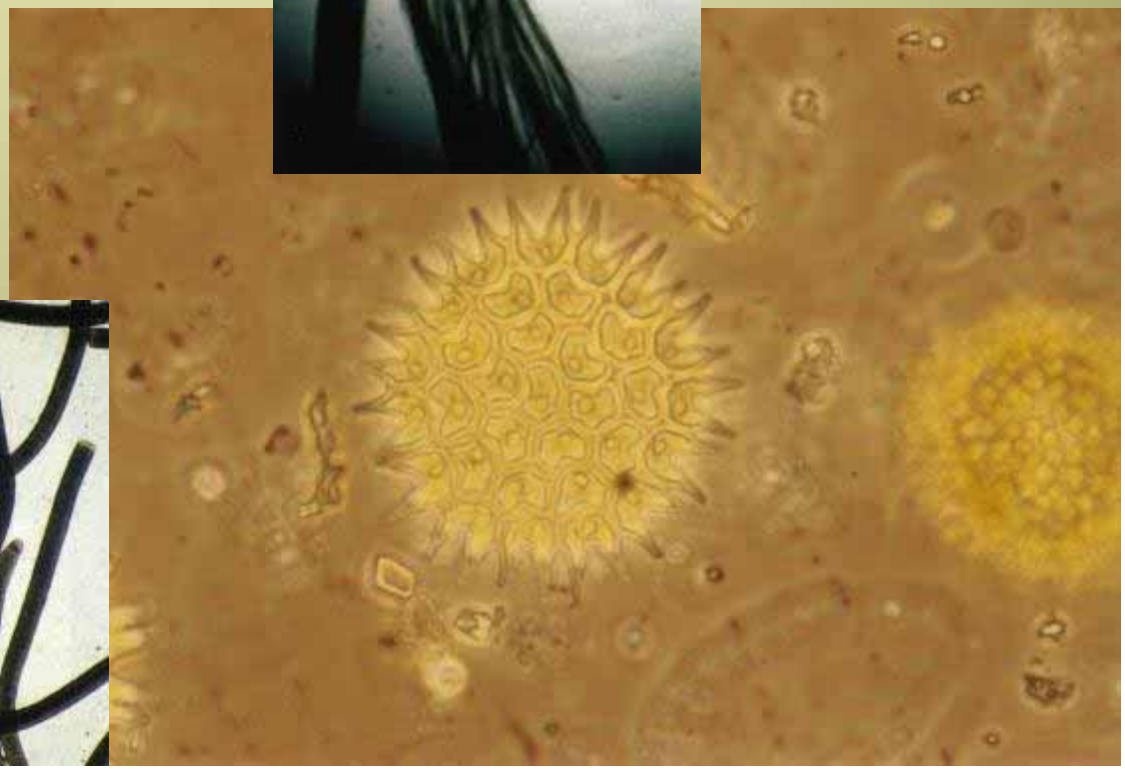
BIOLOGICAL CHARACTERISTICS

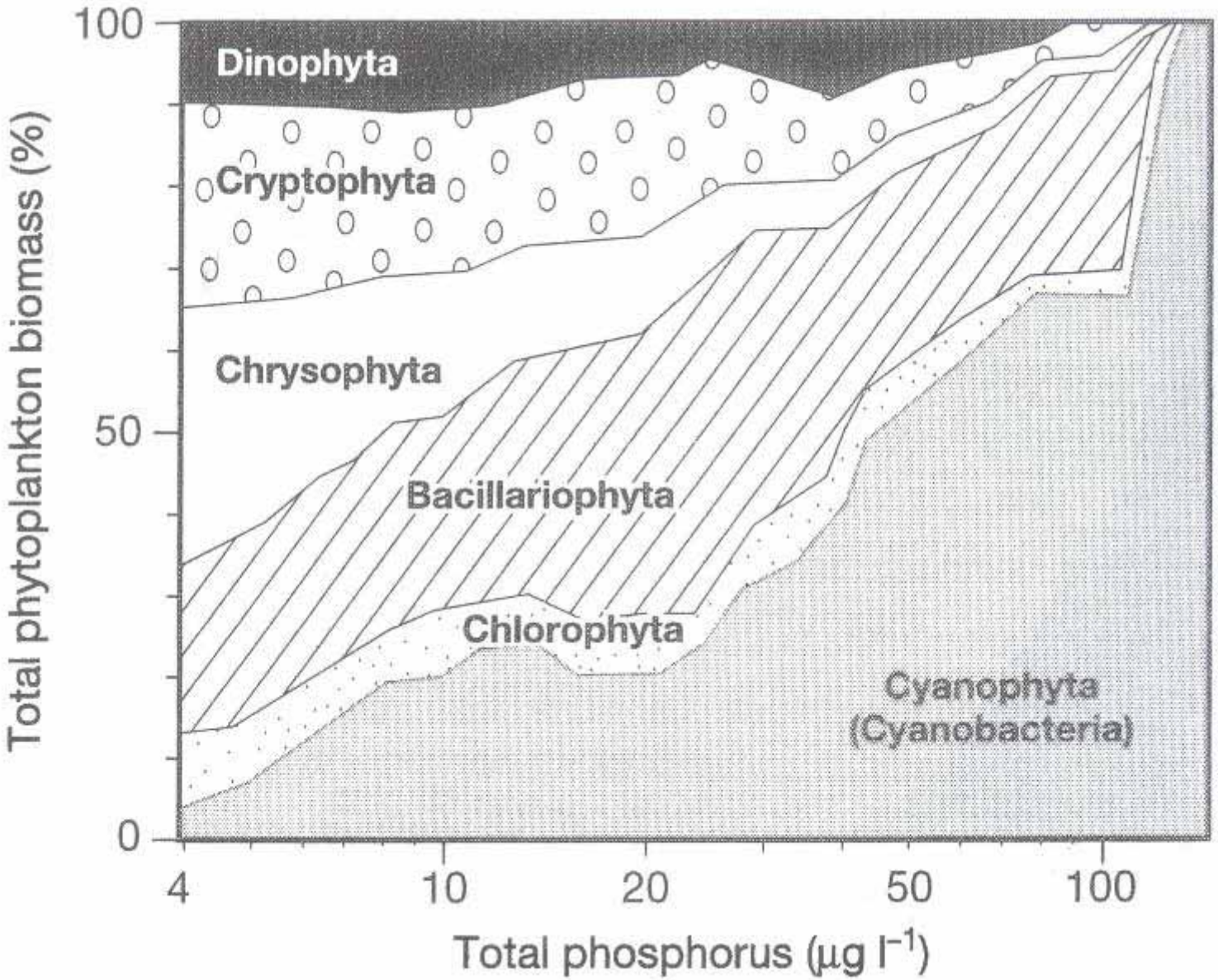
- Viruses/ Bacteria/ Fungi
- Primary - Producers Algae/ Macrophyte
- Zooplankton/ Inverts
- Fish



ALGAE

- Primary Energy Source for Invertebrates
- Can be Nuisance and Human Health Issue
- Produce O_2

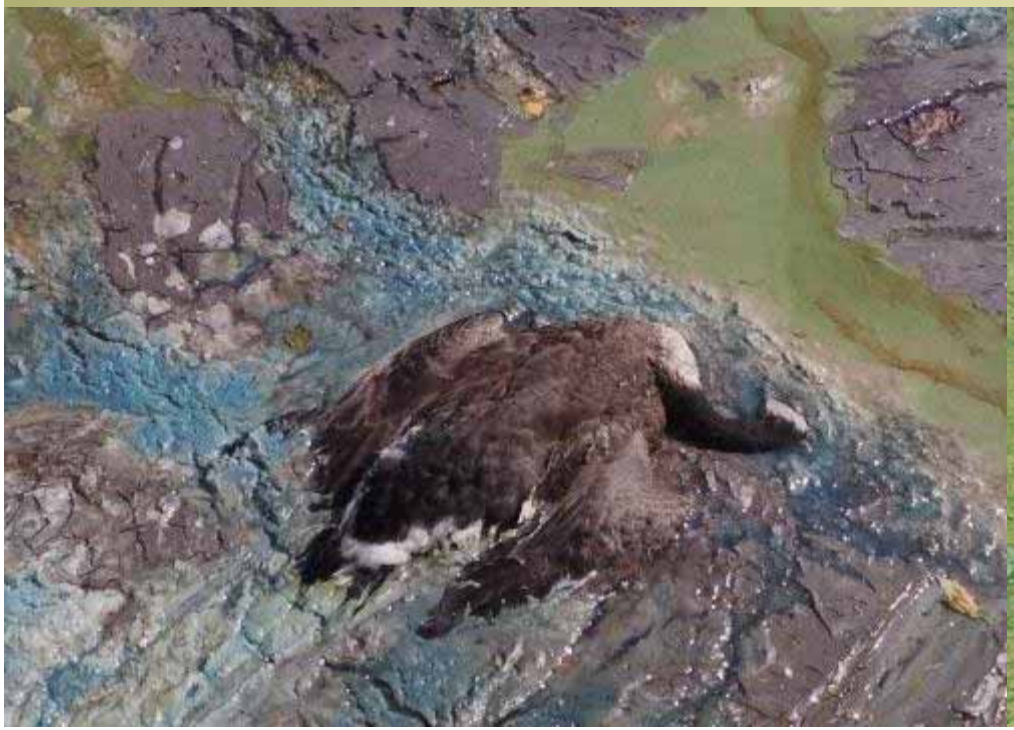




Watson SB, McCauley E, Downing JA. 1997. Patterns in phytoplankton taxonomic composition Across temperate lakes of differing nutrient status. Limnol Oceanog 42:487-495

Human Health Concerns

- **Toxic algae**



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

ZOOPLANKTON & AQUATIC INVERTEBRATES

Zooplankton

Dragonfly

AQUATIC PLANTS

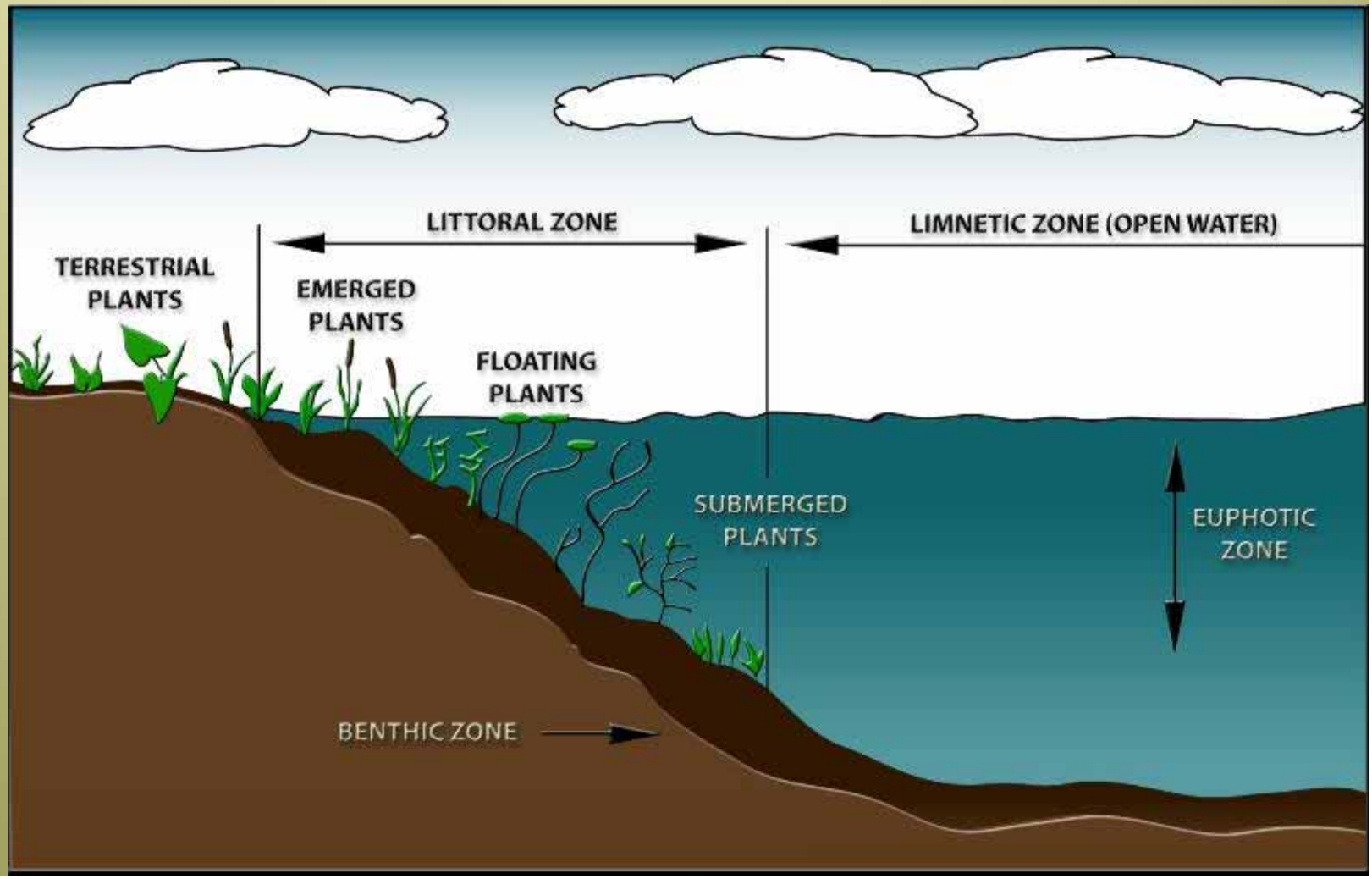
- Habitat
- Energy Dissipation
- O_2 Producers

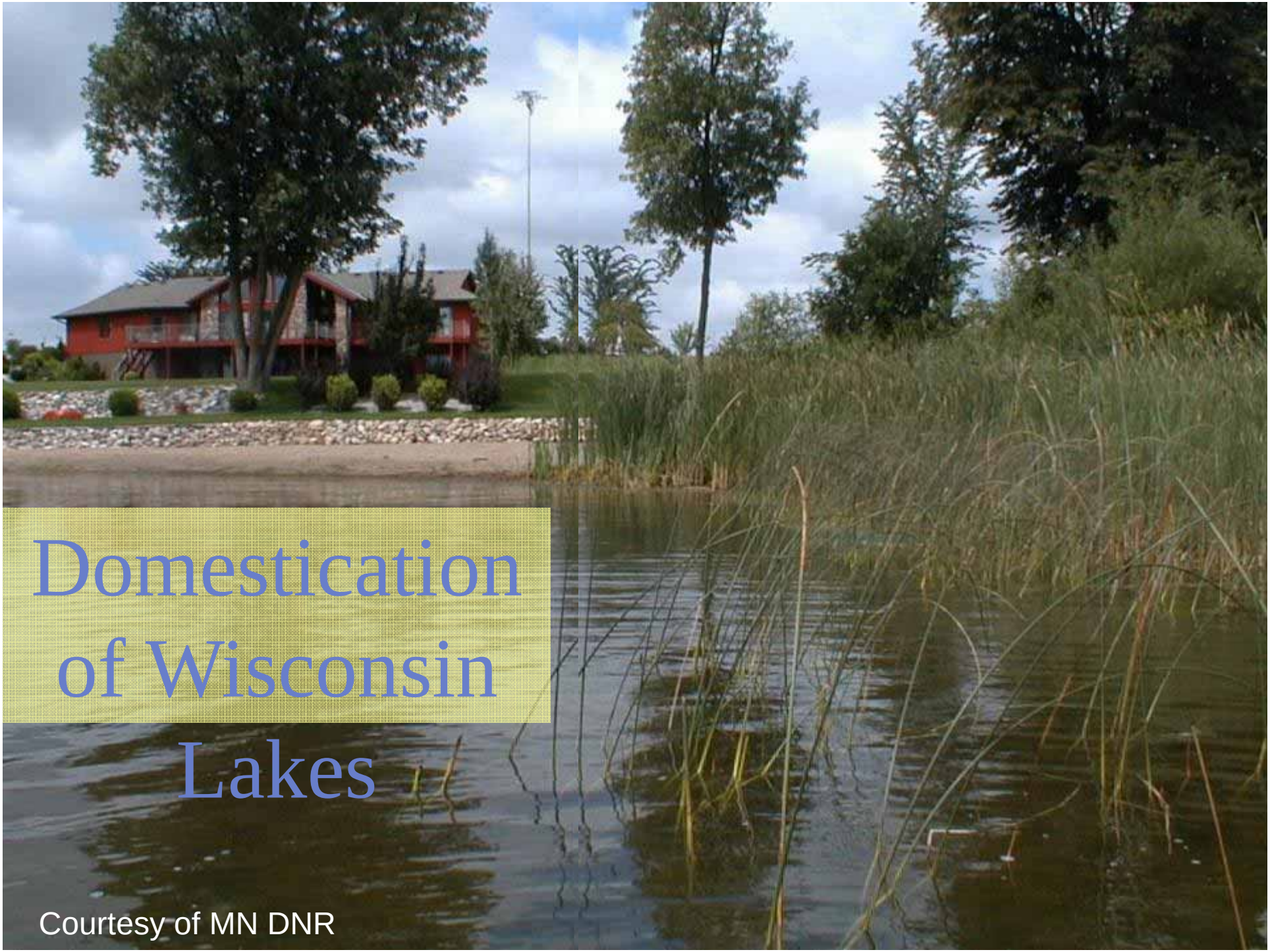
FISH

- Planktivore
- Piscivore
- Benthivore

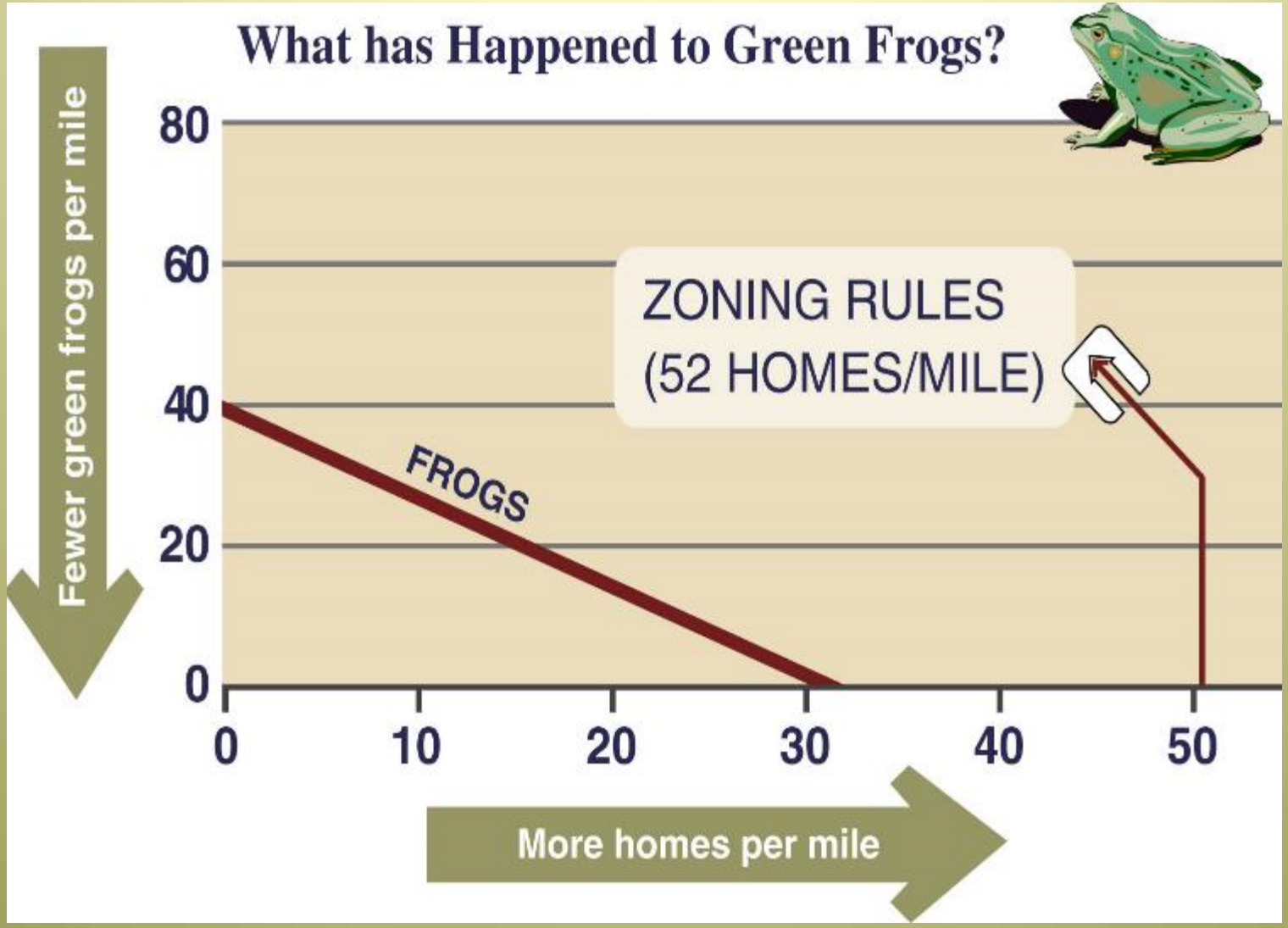
Without habitat, they are gone

LAKE HABITAT ZONES



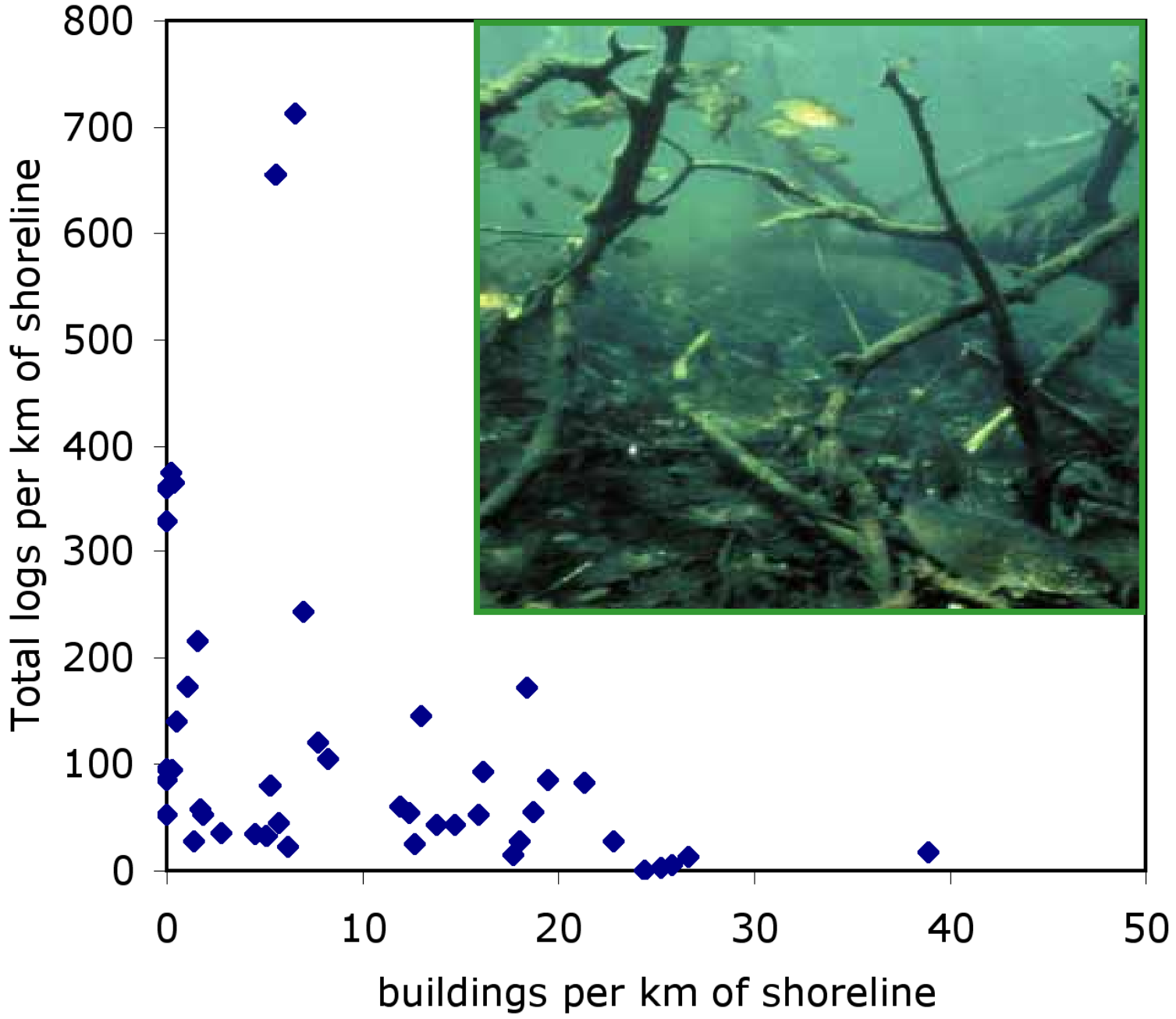

Domestication of Wisconsin Lakes
Courtesy of MN DNR

Shoreland green frog trends



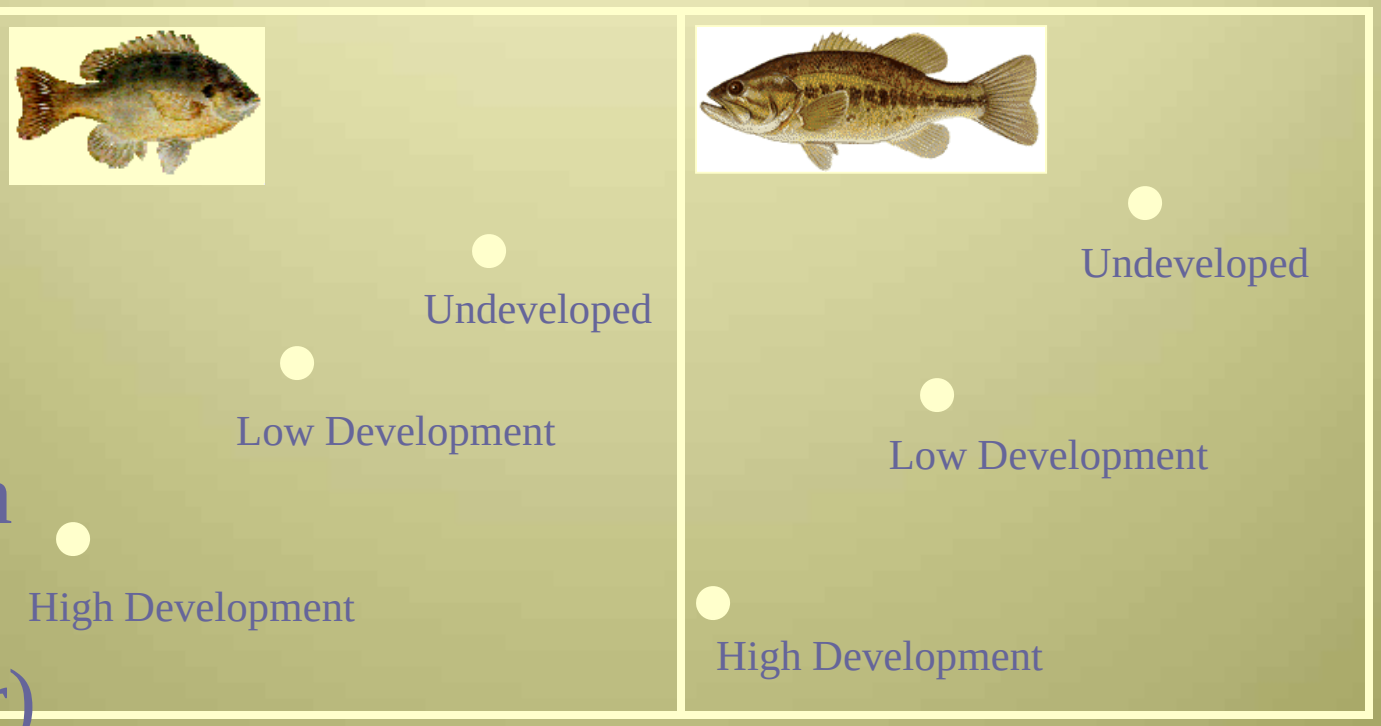
Source: Wisconsin Dept. of Natural Resources

The Wisconsin Lakes Partnership



Data: U.W. BioComplexity project

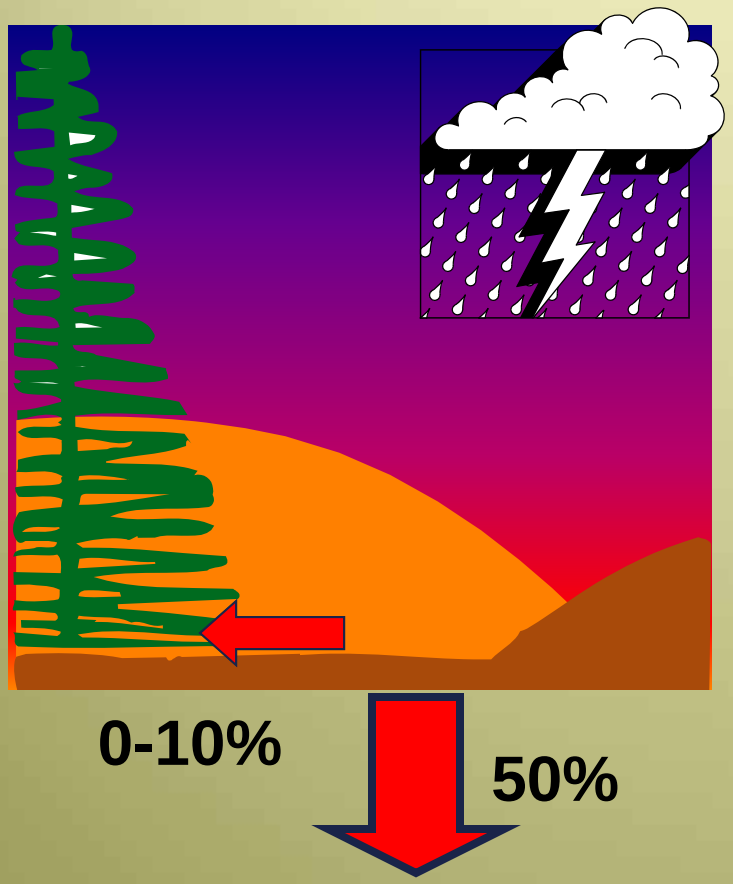
Fish grow ~3X faster in lakes with lots of woody habitat

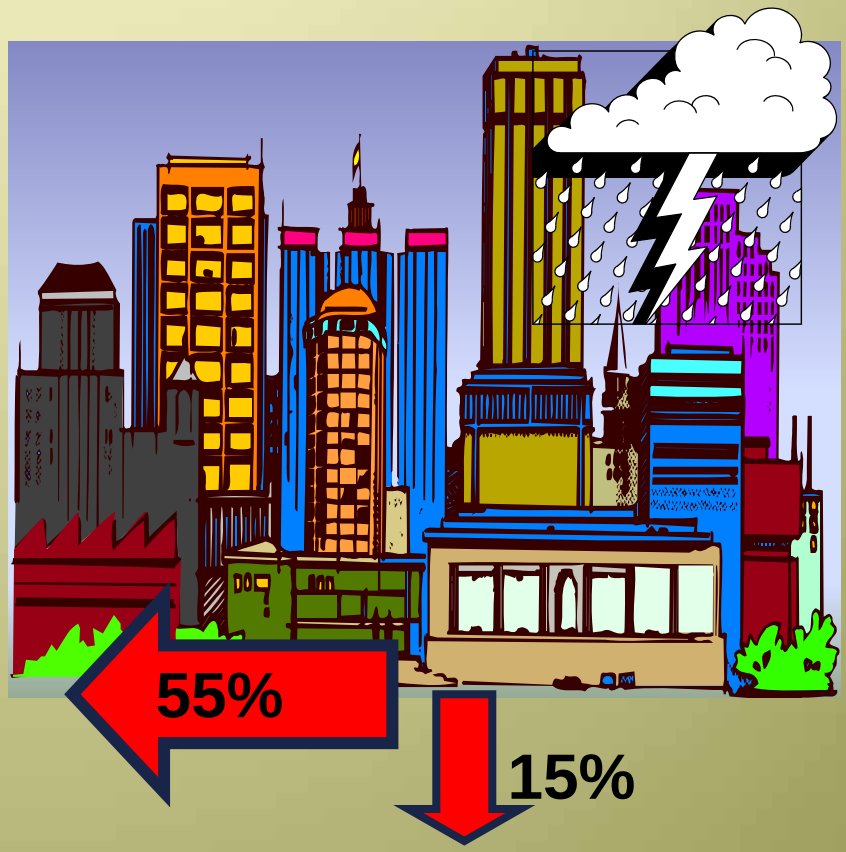


From Schindler et al. 2000

LAND USE AND WATERSHED IMPACTS

Land Use Impacts on the Water Cycle





How do you make this…

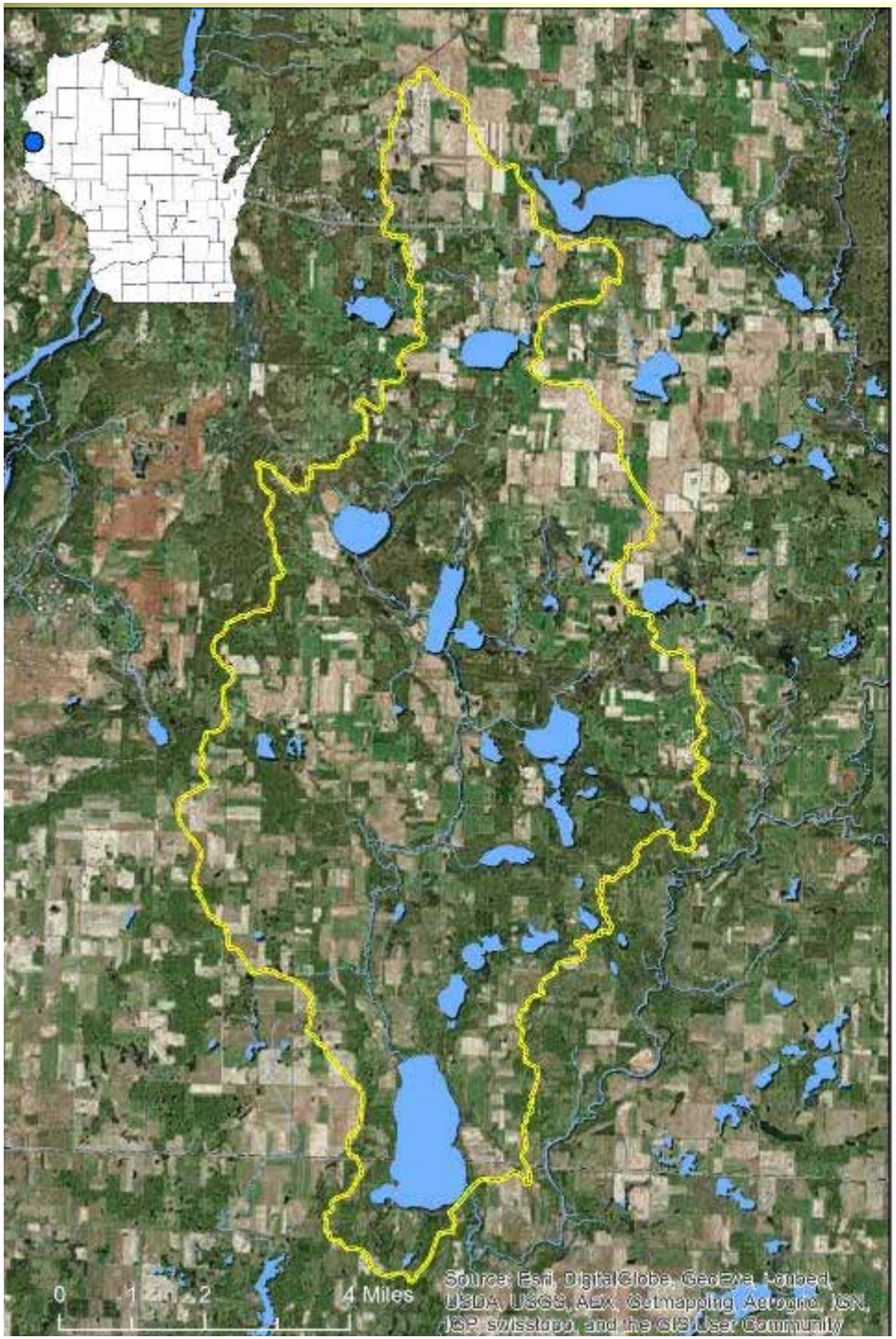
function like this?

Empirical Watershed Models

Phosphorus export coefficients - developed based using monitoring data.

WISCONSIN VALUES

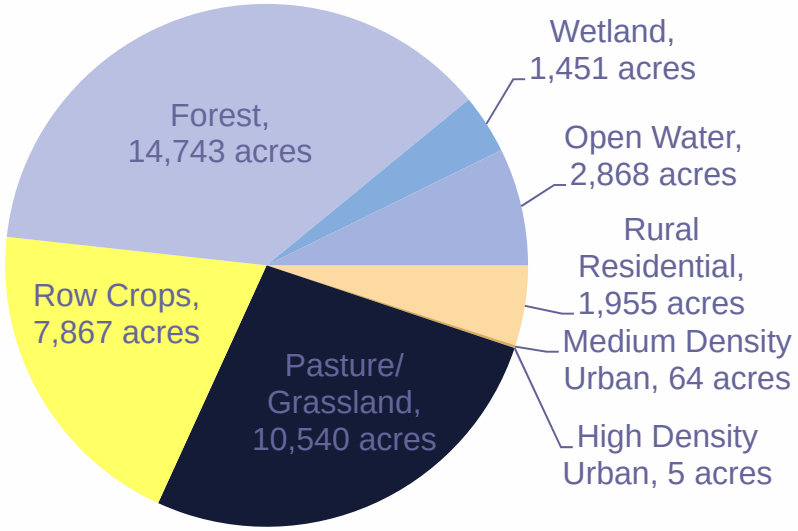
Land Cover	TP Export kg/ha/yr
High Density Urban	1.5
Row Crop Agriculture	1.0
Mixed Agriculture	0.8
Grass / Pasture	0.3
Medium Density Urban	0.5
Low Density Urban	0.1
Forested	0.09



Cedar Lake

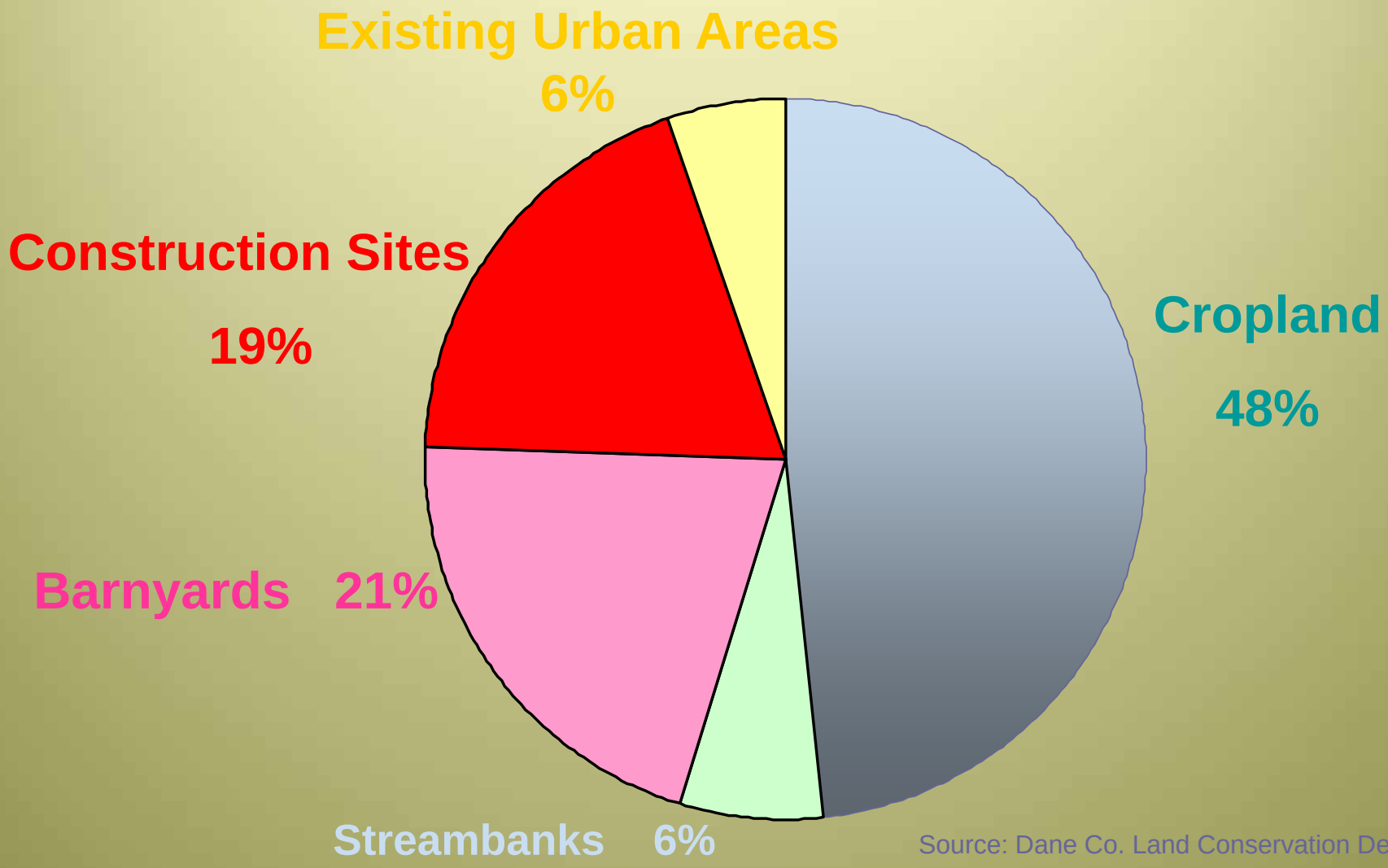
Polk County

WBIC	2615100
Surface area	1,120 acres
Max depth	32 ft
Mean outflow	33.7 cfs
Summer water residence time	280 days
Drainage area	39,495 acres
Phosphorus load (most likely)	13,600 lb/yr
Phosphorus load (range)	6,300 - 35,000 lb/yr



AGRICULTURE IMPACTS

P Loading Sources to Lake Mendota



Source: Dane Co. Land Conservation Dept.

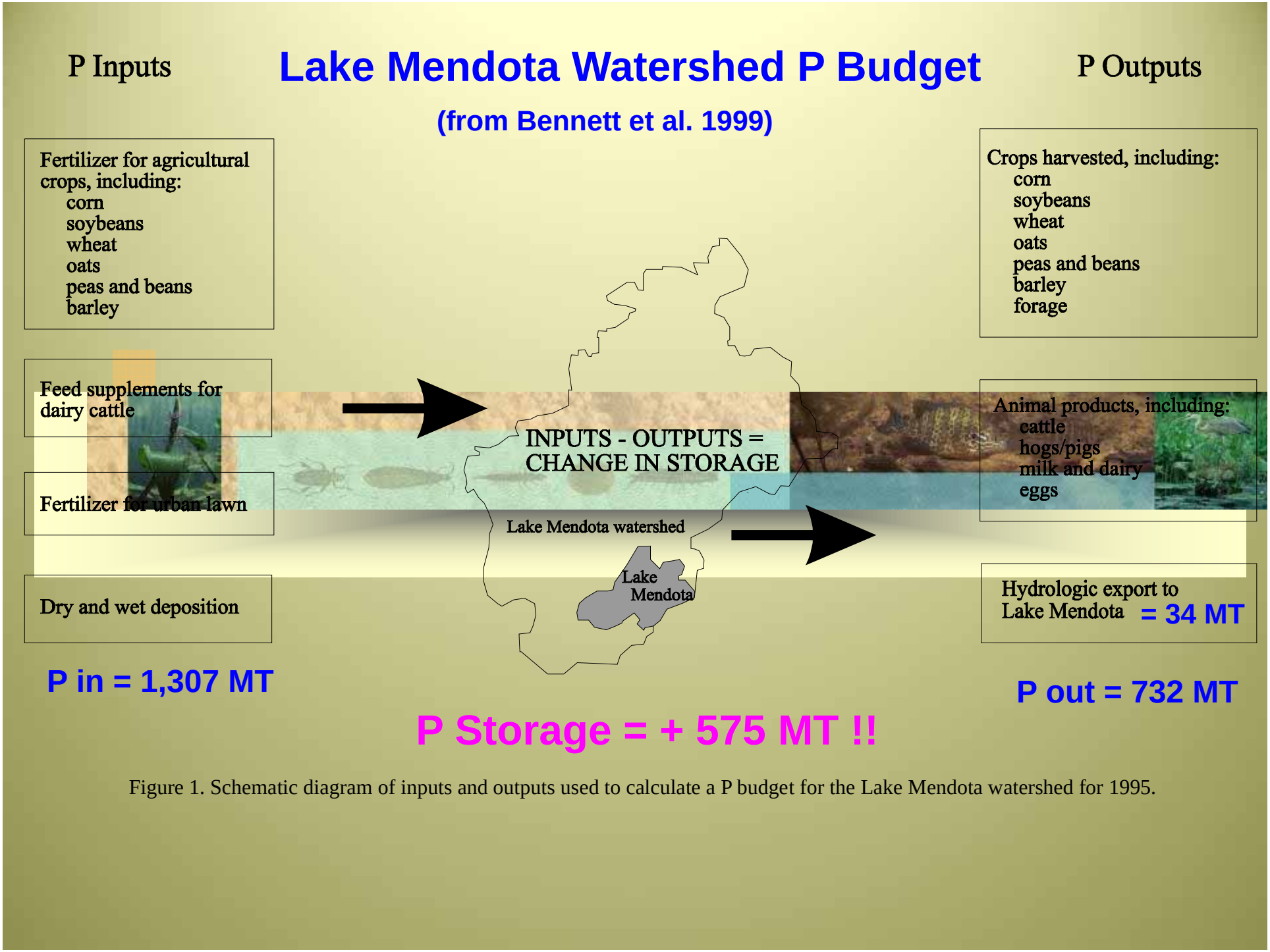
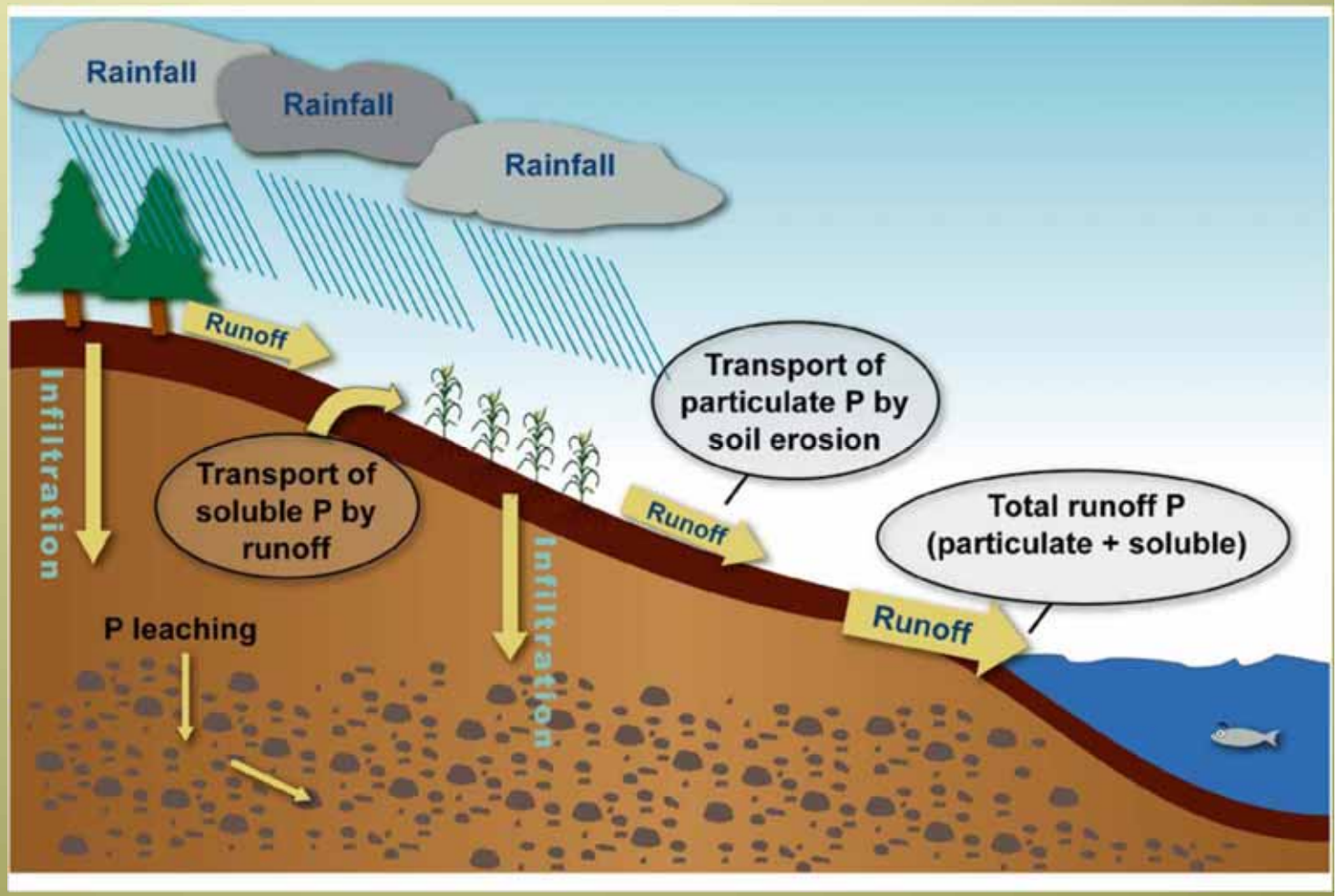


Figure 1. Schematic diagram of inputs and outputs used to calculate a P budget for the Lake Mendota watershed for 1995.

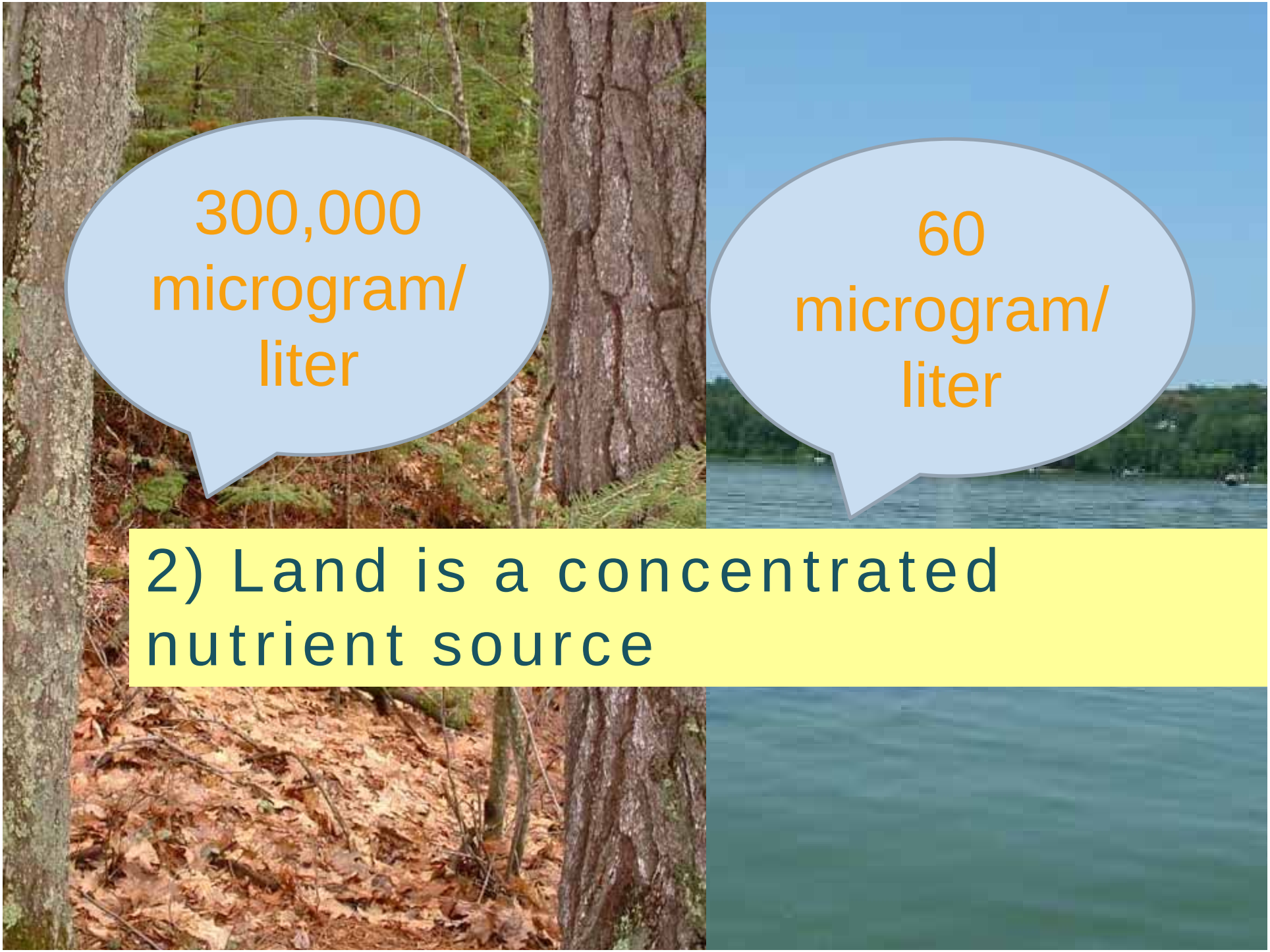
Phosphorus transport

-- P is transported by runoff in both (1) dissolved [DP] and (2) particulate forms [PP].

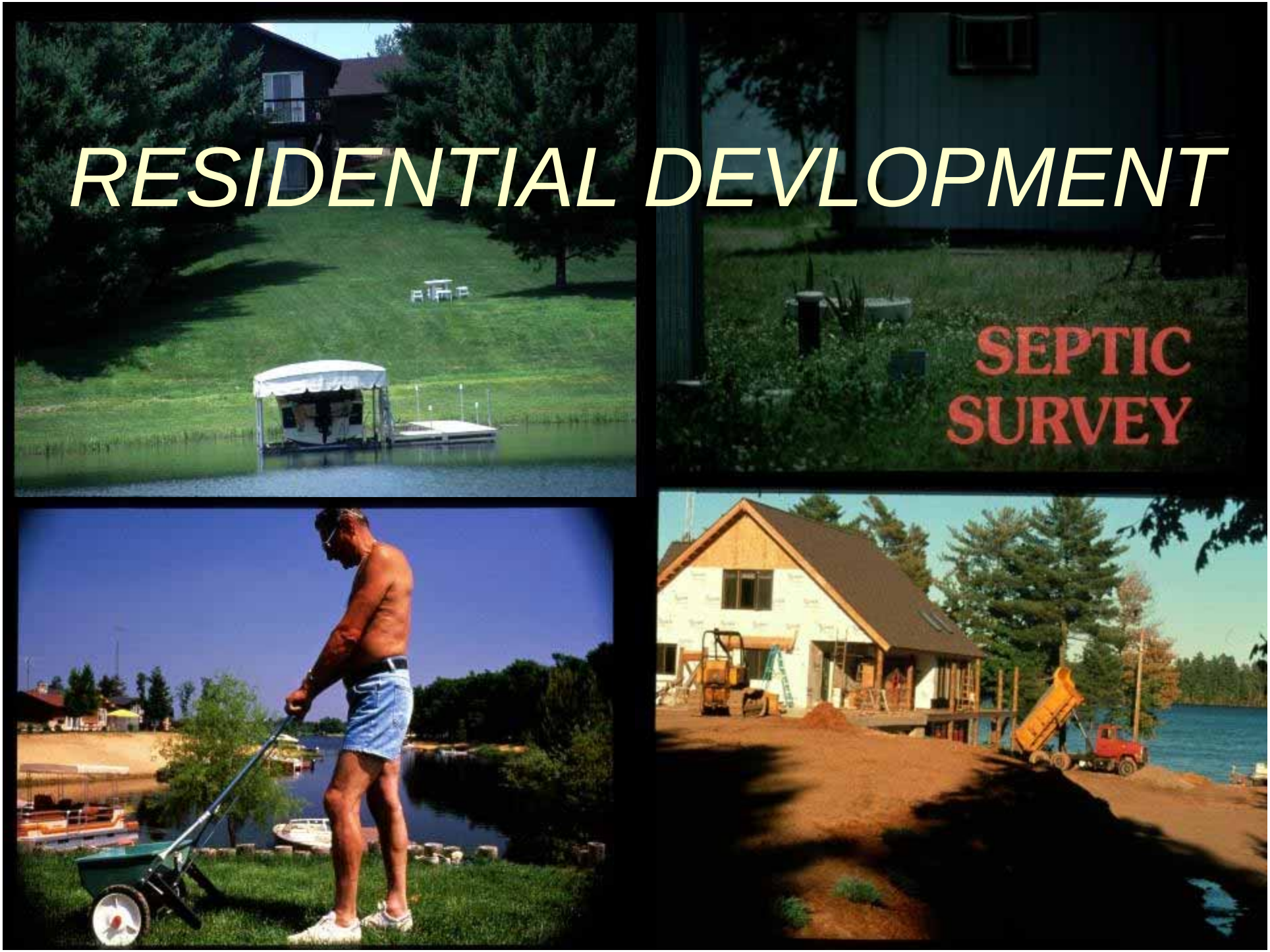
-- GW-P is usually low, ~10-15 ppb



from Sturgul & Bundy 2004; UW-Madison & UW-Extension, Dept. of Nutrient & Pest Mgt.

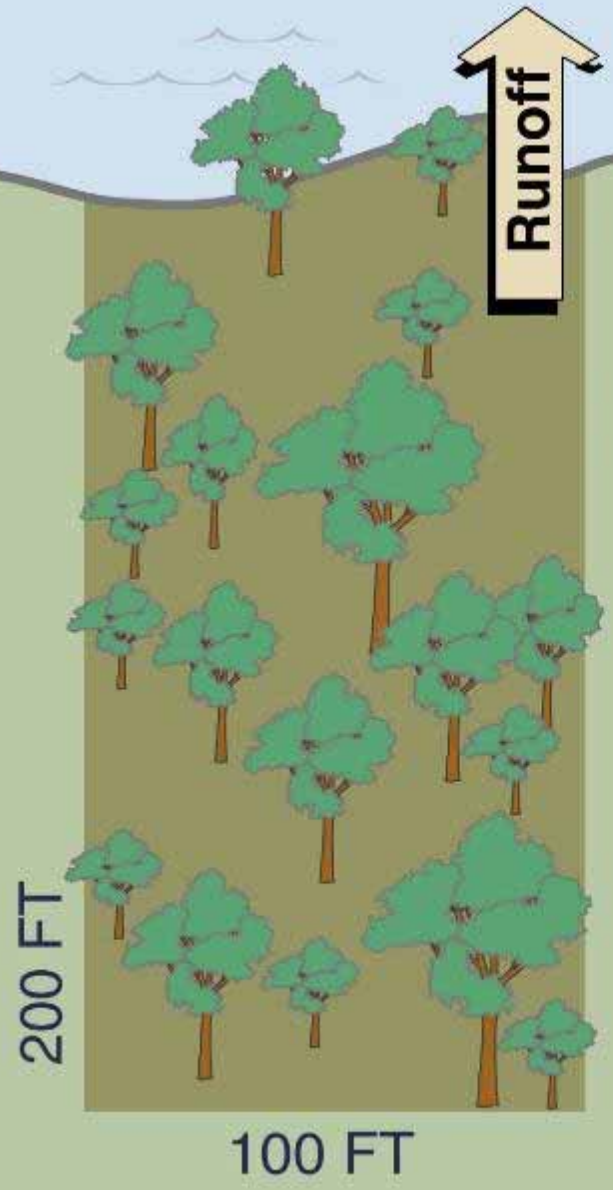


2) Land is a concentrated nutrient source


RESIDENTIAL DEVLOPMENT
SEPTIC
SURVEY

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

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



IMPACT ON LAKE
(April - Oct.)

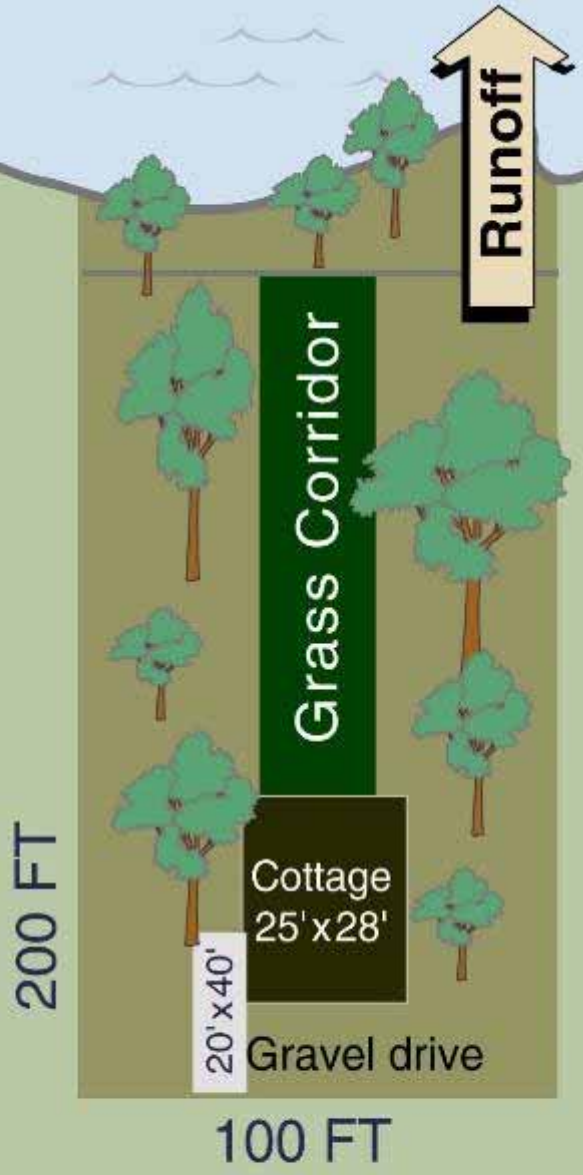
- 1,000 ft^3 runoff to lake
- 0.03 lbs. phos. to lake
- 5 lbs. sediment to lake

Source: Wisconsin Dept. of Natural Resources

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

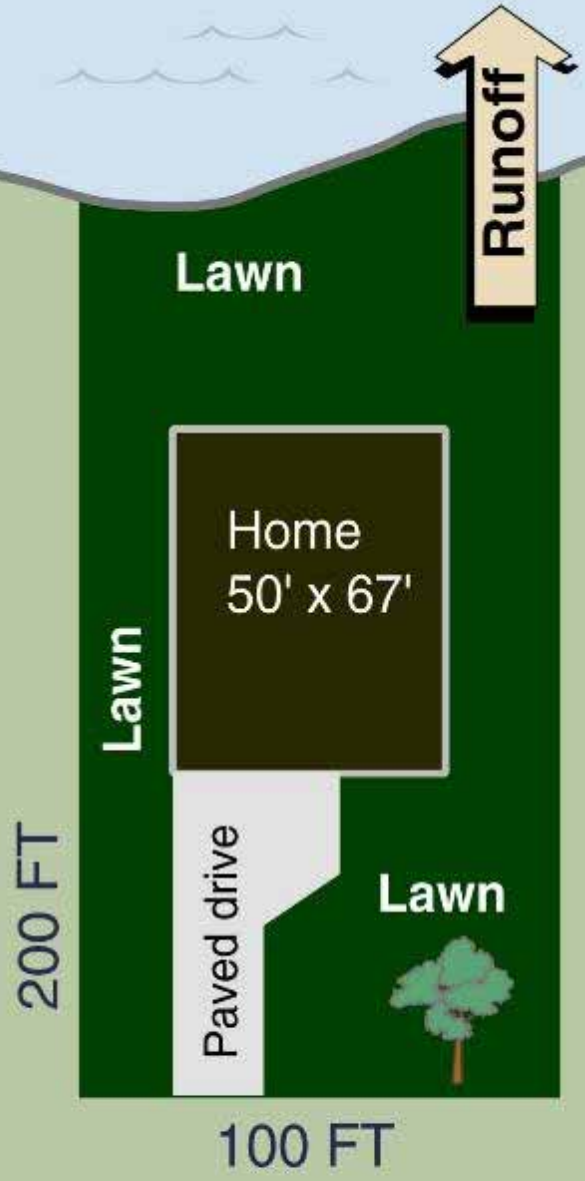
Source: Wisconsin Dept. of Natural Resources

The Wisconsin Lakes Partnership


Redevelopment Long Lake Chippewa County
4 26 '04

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

- maintained lawn, soil graded
- 6% slope to lake
- home 3,350 ft² perimeter
- paved drive 770 ft²



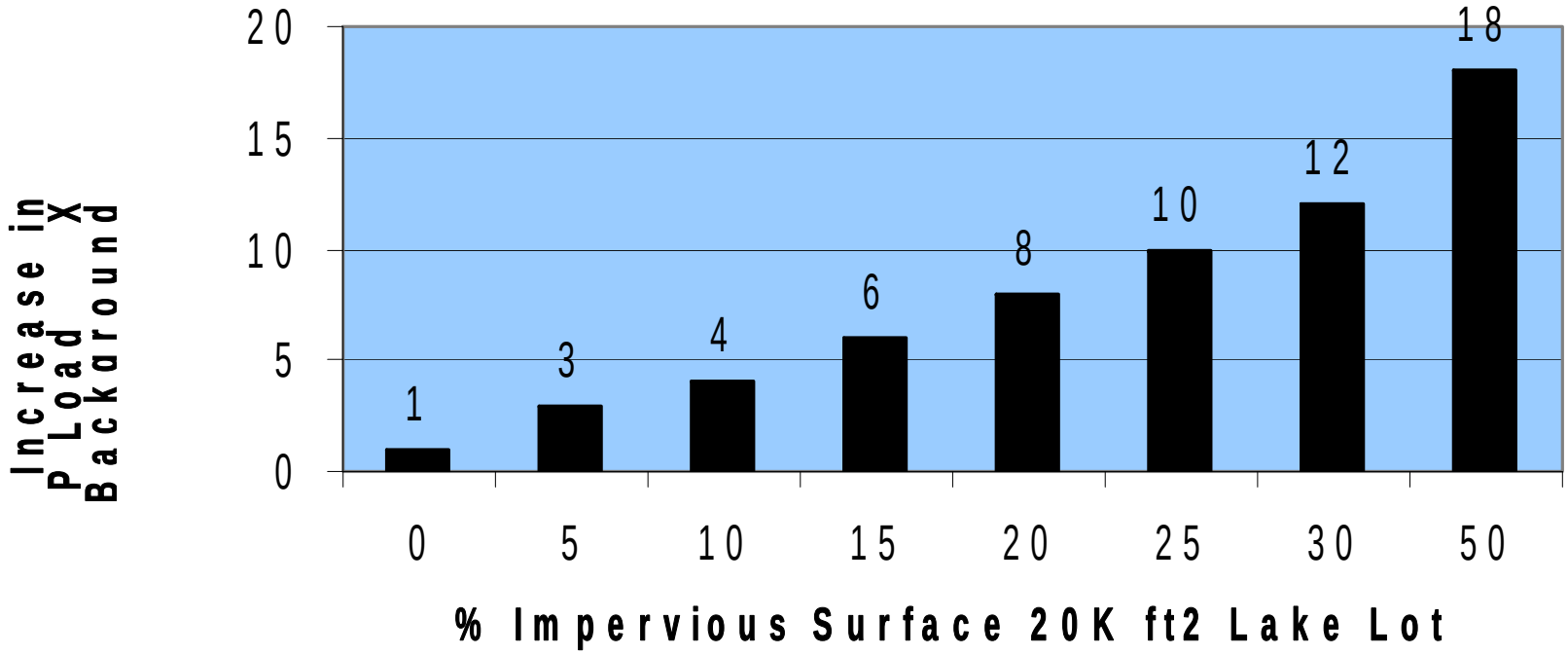
IMPACT ON LAKE
(April - Oct.)

- 5,000 ft³ runoff to lake
- 0.20 lbs. phos. to lake
- 90 lbs. sediment to lake

Source: Wisconsin Dept. of Natural Resources

The Wisconsin Lakes Partnership

Impacts from Impervious Surfaces on Phosphorous Loading



LEAVING A LEGACY

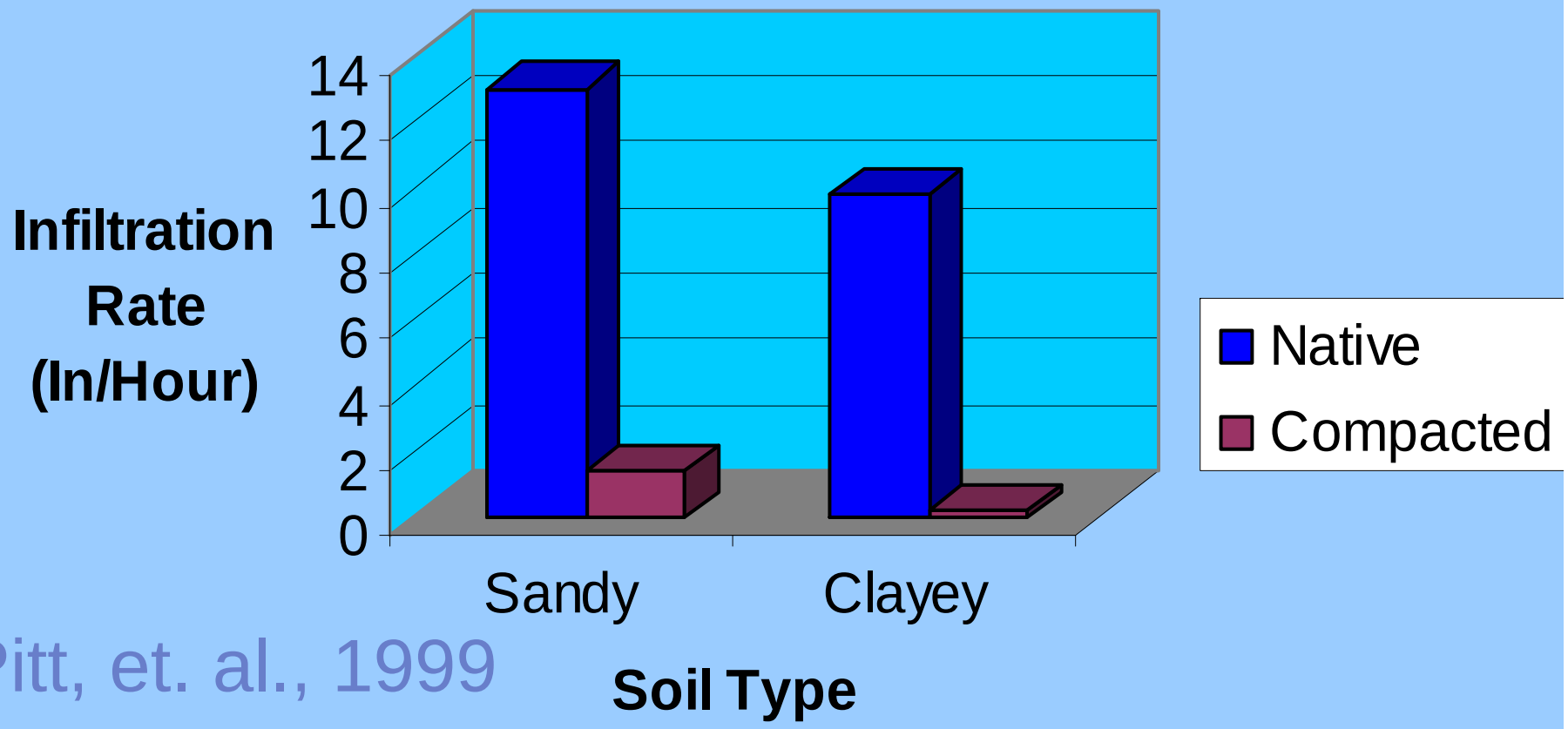
Help Protect Wisconsin's…

LAKE HEALTH.

Soil Compaction is increased during building construction

- Spoil from basements placed on adjacent soils
- Building crews and material suppliers drive on soils

Effect of Compaction on Infiltration Rate



Pitt, et. al., 1999

Reducing Soil Compaction

- Avoid during construction - compaction is fore

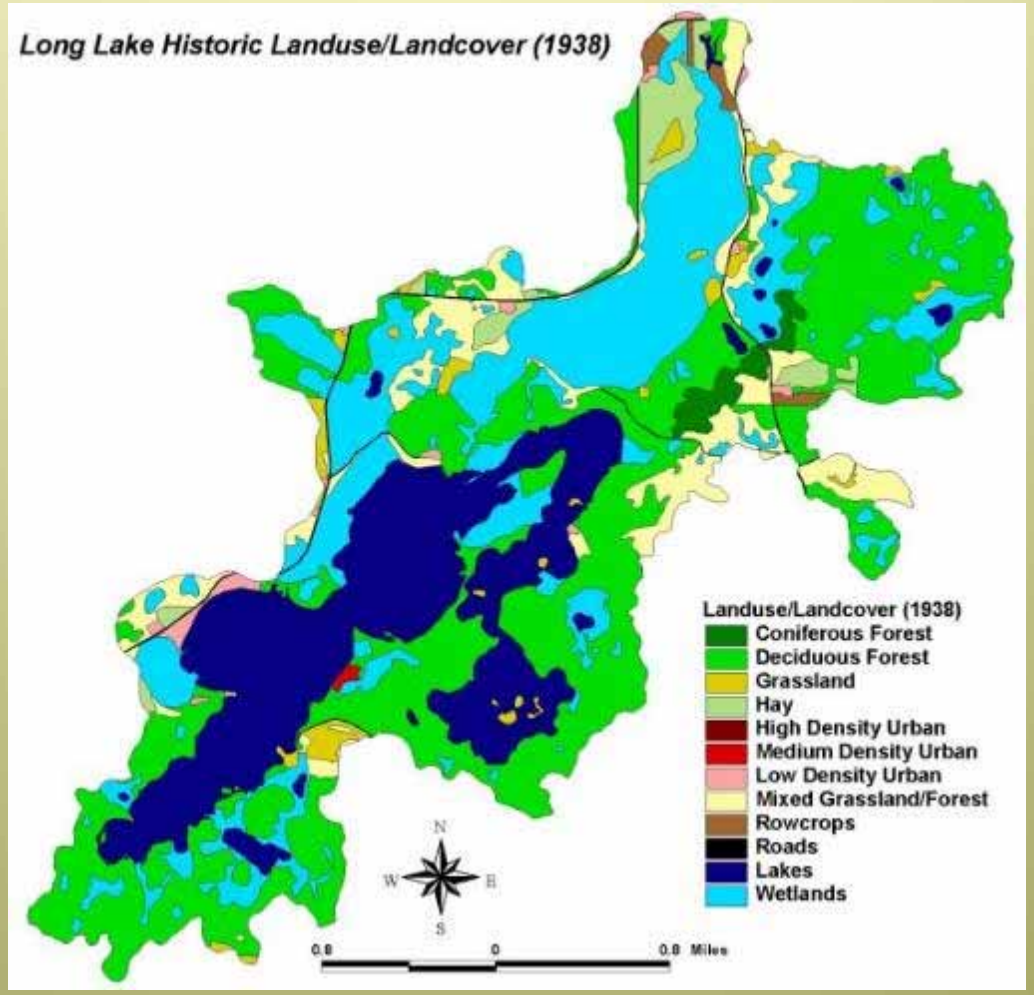
- Till compacted areas around buildings

- Apply adequate topsoil prior to seeding

- Add organic matter - minimum of 5%

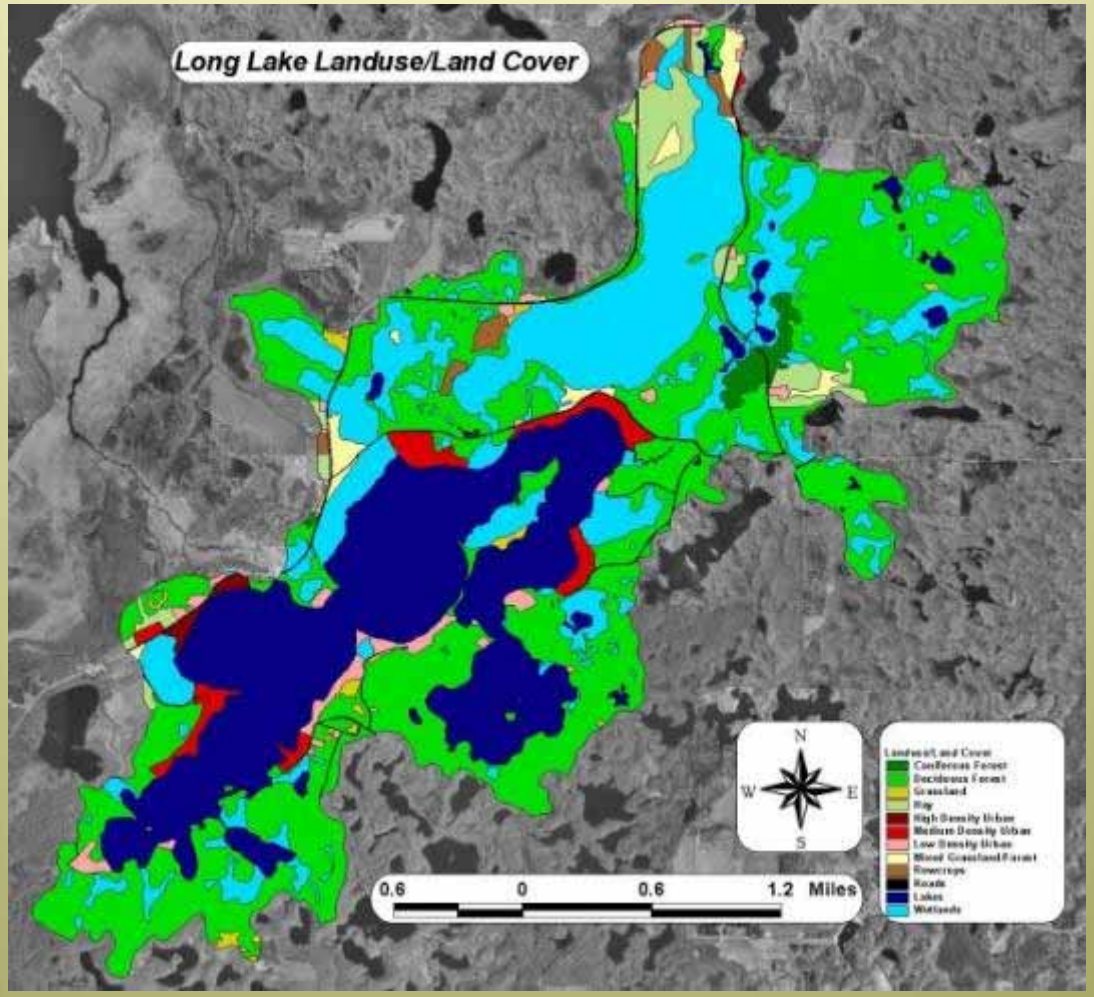
- Aerate turf areas annually

Watershed Landuse 1938



Applied Data Consultants, Inc.

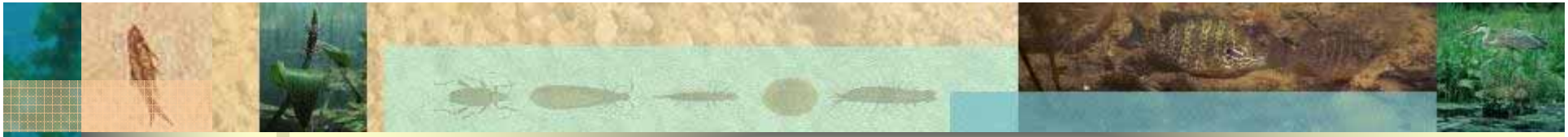
Watershed Landuse 2001



Applied Data Consultants, Inc.

Watershed Landuse 2001

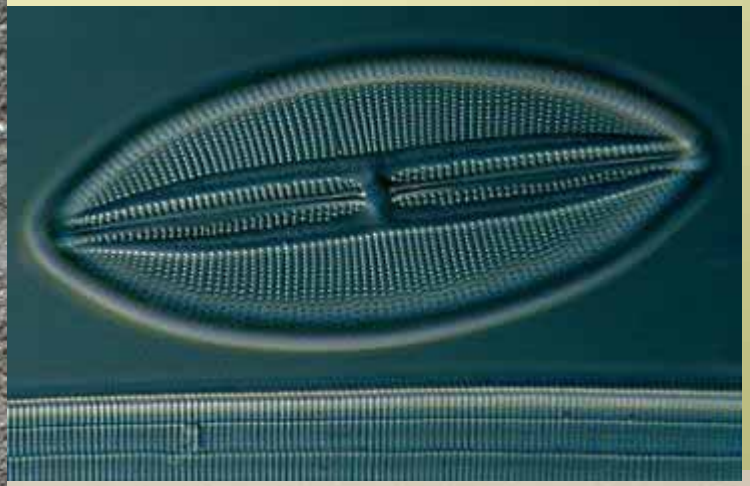
	Historic	Current
Coniferous Forest	59.99	43.17
Deciduous Forest	1875.29	1983.04
Grassland	98.21	32.37
Hay	136.01	147.08
High Density Urban	**----**	**14.32**
Moderate Density Urban	**5.19**	**104.36**
Low Density Urban	39.05	84.01
Mixed Grassland/Forest	383.46	63.12
Roadways	30.92	41.49
Rowcrops	27.61	39.27
Water	1041.81	1193.75
Wetlands	1193.18	1[illegible]

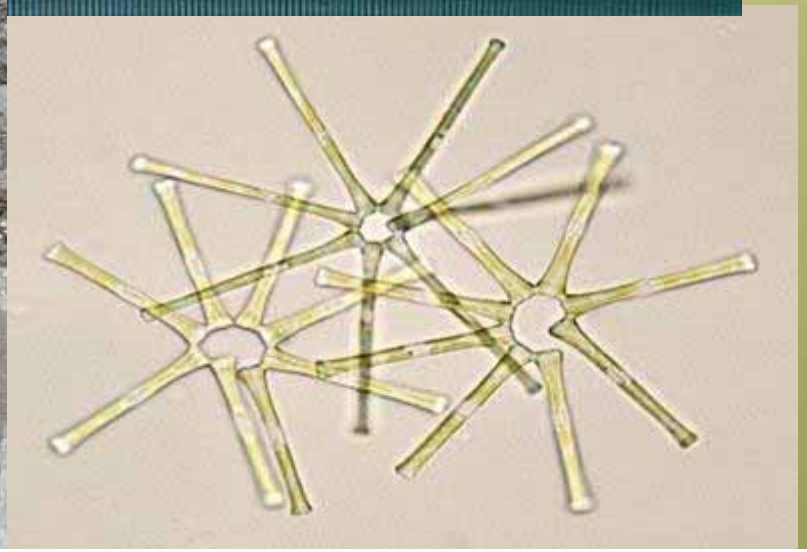


Landuse Nutrient Loads 2006

Landuse	Acres	Kg/Year	Lbs/Year
High Density Urban	17.3	11	24.3
Medium Density Urban	125.7	25	55.1
Rural Residential	101.2	4	8.8
Pasture/Grass	218.7	27	59.5
Wetlands	1144.7	46	101.4
Forest	2089.4	76	167.6
Atmosphere	1052	128	282.2
Septics		6.25	13.8
Total		323.25	712.7

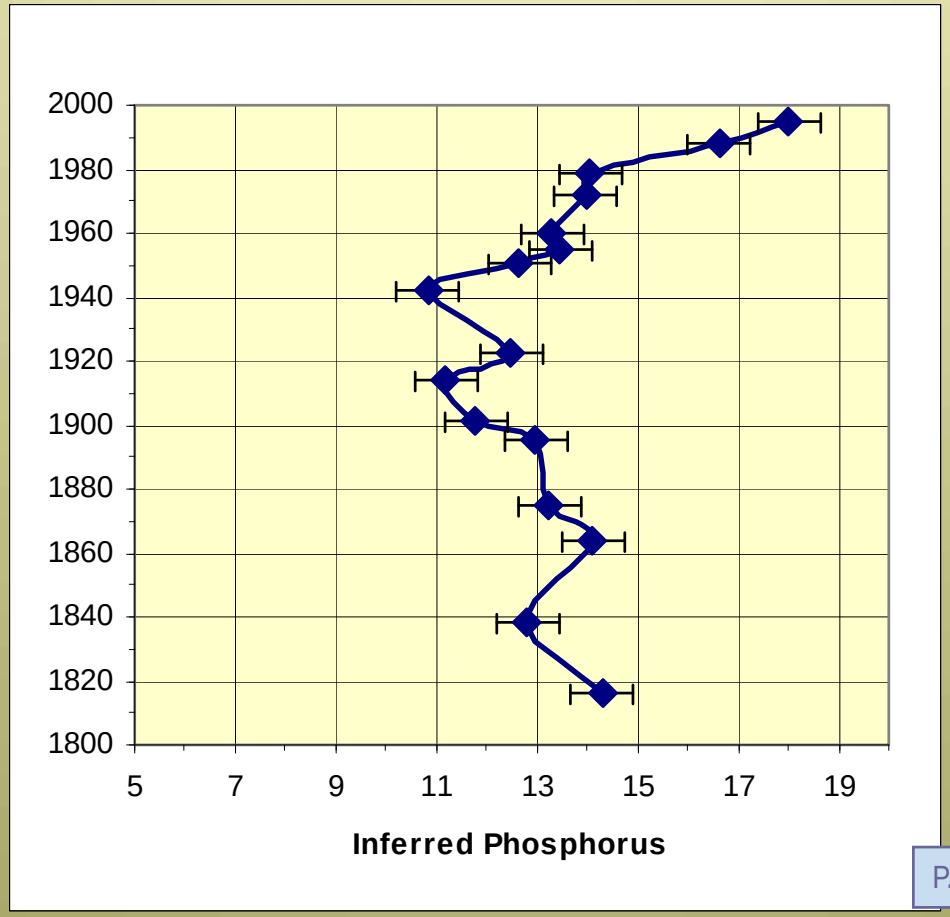
PALEOLIMNOLGY





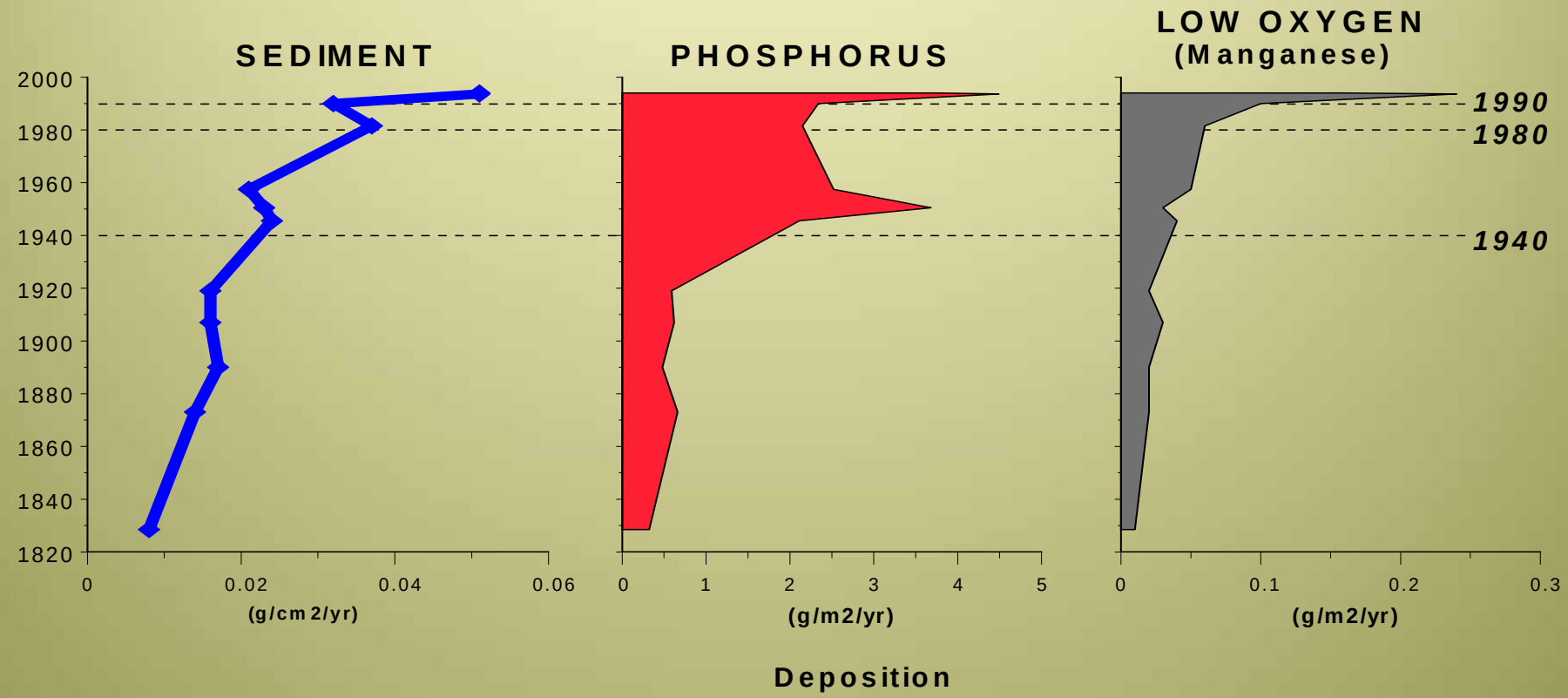
L0NG LAKE

Chippewa County



P. Garrison, 1995

LONG LAKE
Chippewa County



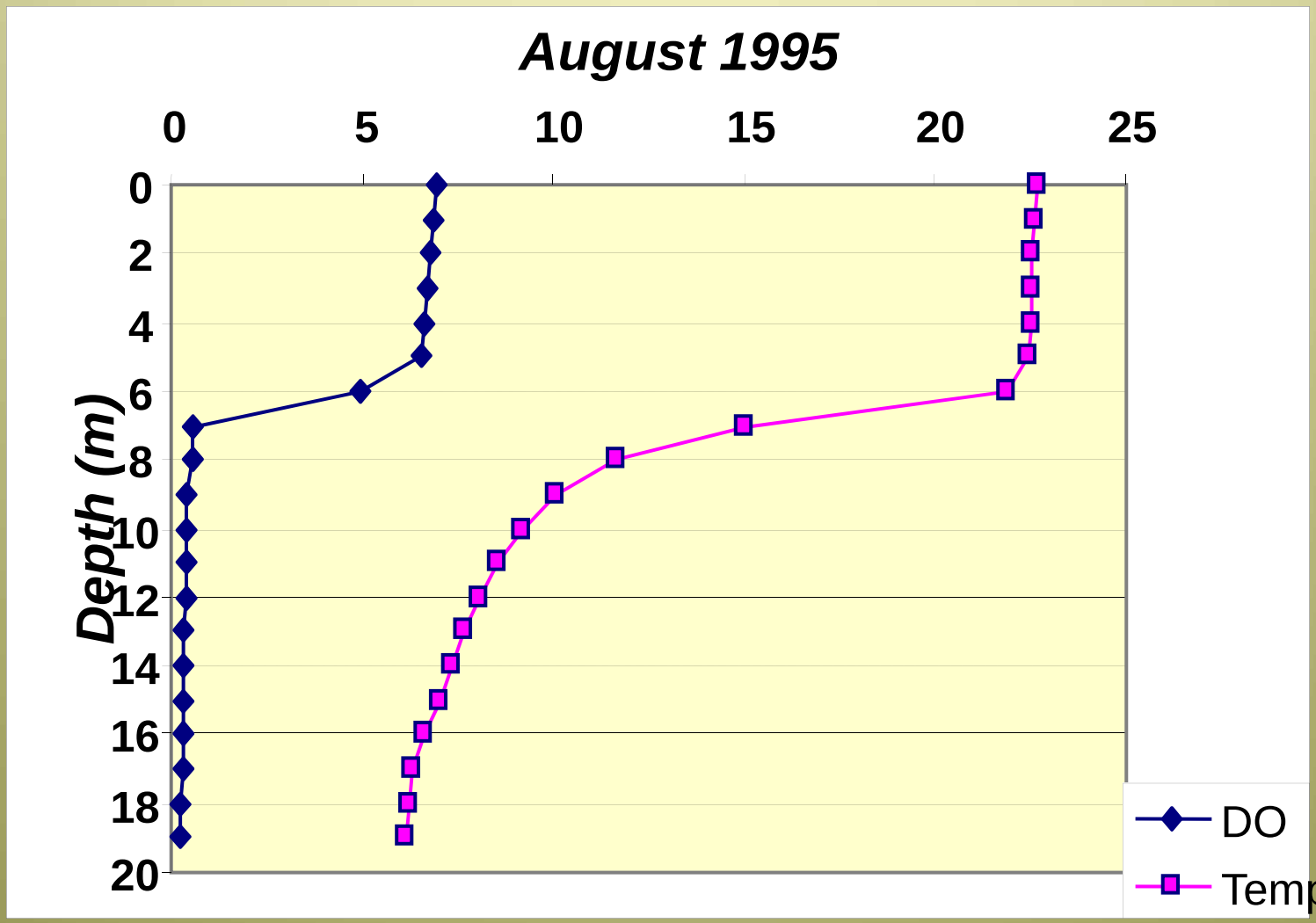
SUMMARY

- Development during the early twentieth century had a small impact on the lakes.
- Development during the last 30 years has degraded water quality.
- In Long Lake recent development has increased sediment infilling, phosphorus levels in the surface waters, phosphorus loving diatoms, and decreased oxygen levels in the bottom waters.

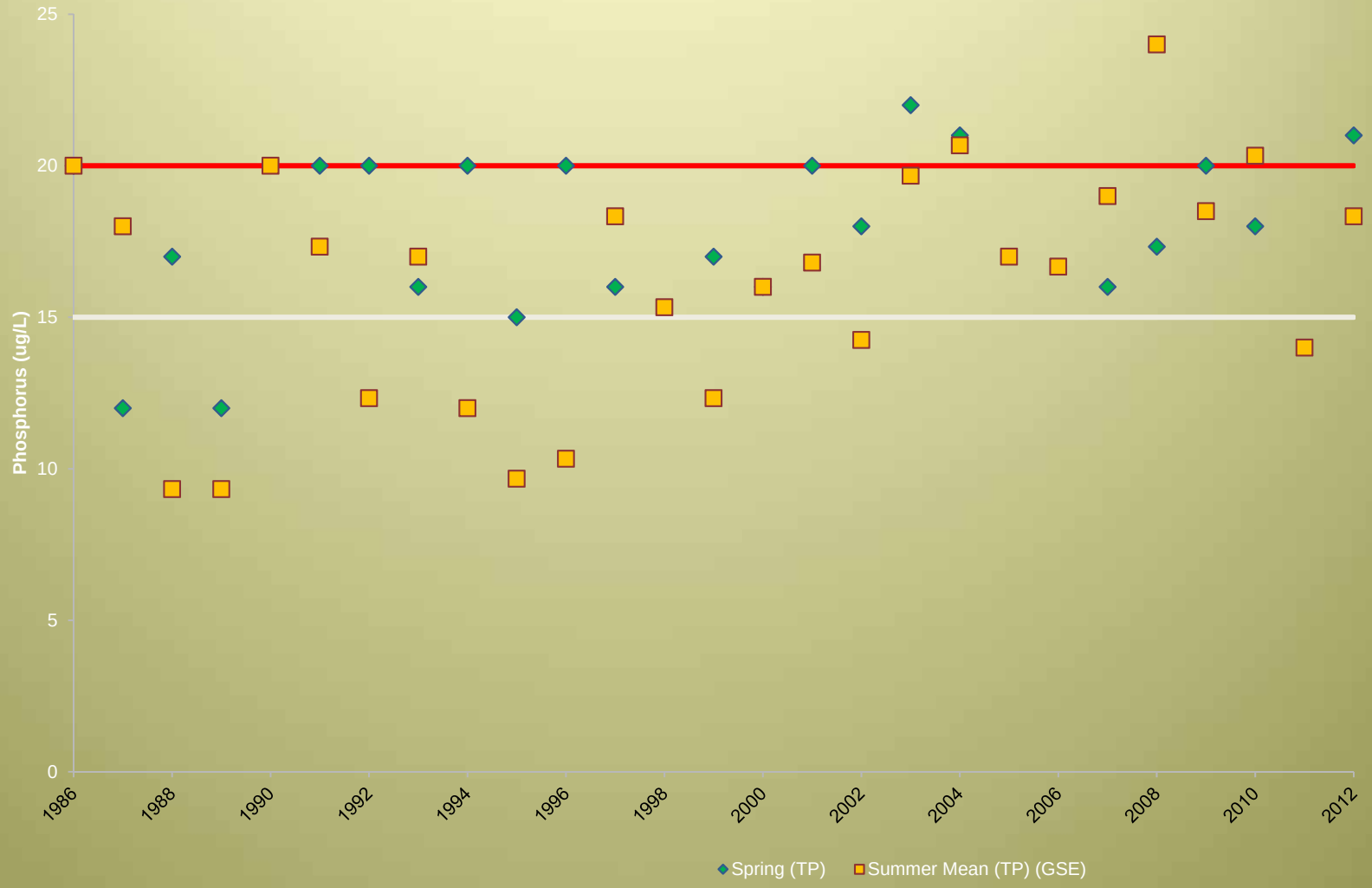
P. Garrison, 1995

Wisconsin Department of Natural Resources

Dissolved Oxygen Depletion



Long Lake
Spring vs. Summer Mean Total Phosphorus
1986-2012



Goal I. Protect water clarity, prevent the occurrence of algae blooms and reduce nutrient levels in Long Lake.

- **The families and individuals, particularly our children, deserve to have a lake with clean water to use and enjoy. Protecting water quality will be achieved by reducing the spring turnover total phosphorus concentration to 16-18 ug/l and summer surface total phosphorus concentration to 14-15 ug/l.**

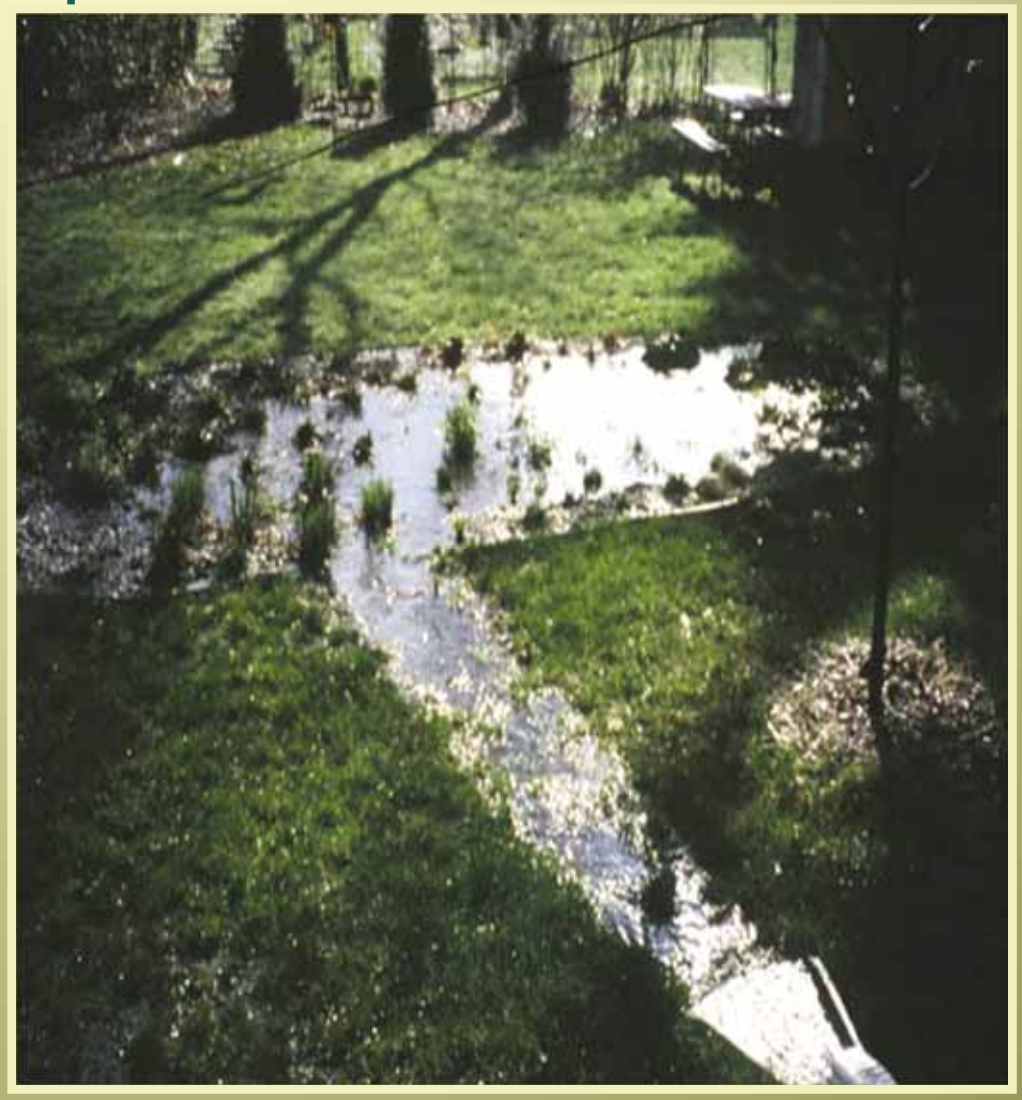
Semi Shade –
Polk County, WI

One year later...

Rain Garden Depth & Size

Balance between:

- drainage area
- slope
- soil
- desired garden size



LEAVING A LEGACY

Help Protect Wisconsin's…

WATER RESOURCES.