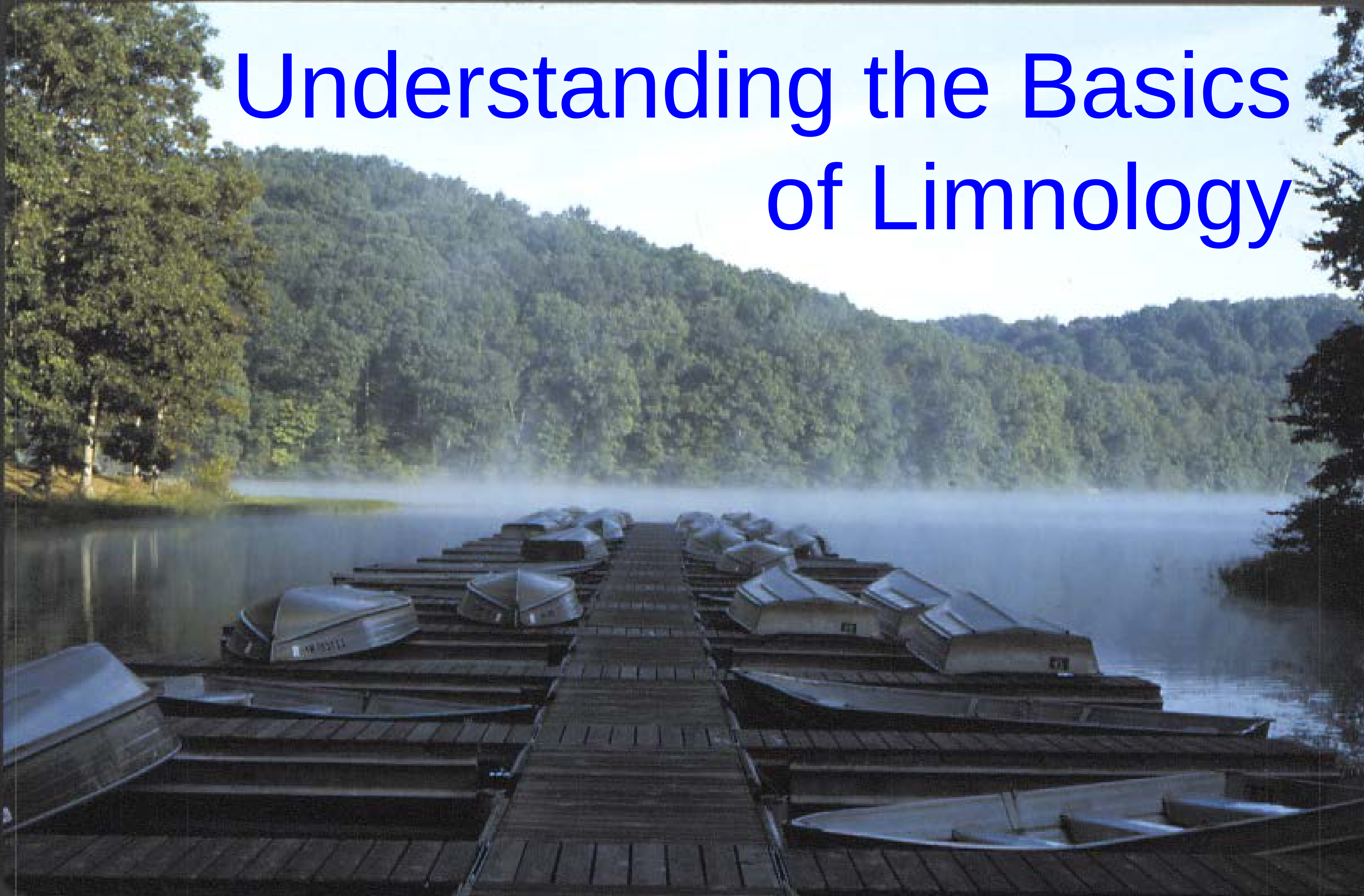
# Understanding the Basics of Limnology



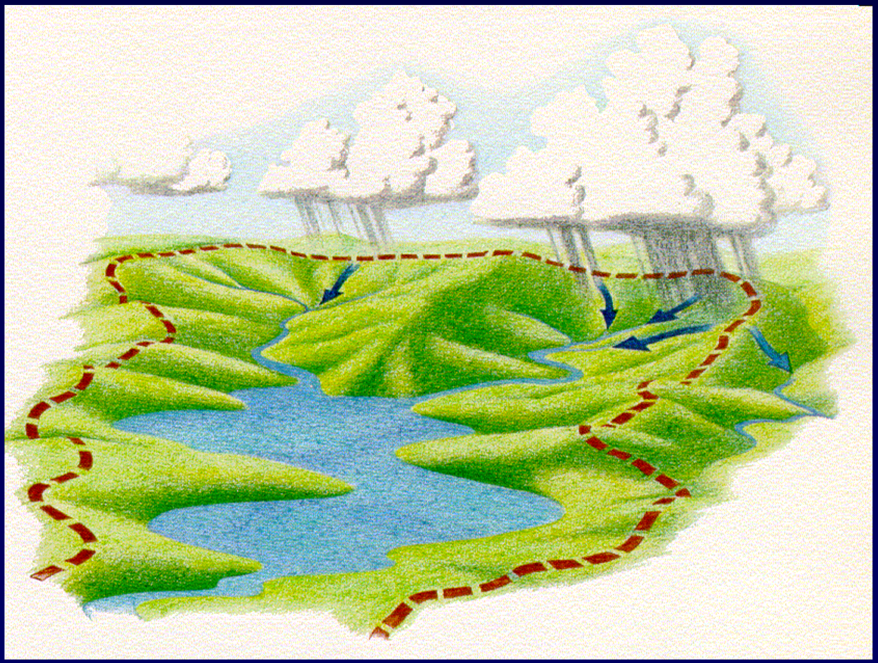
# Outline

- Watershed Processes
- Lake Formation
- Physical Features of Lakes
- Lake Processes
- Lake Chemistry
- Lake Biology
- Lake Management

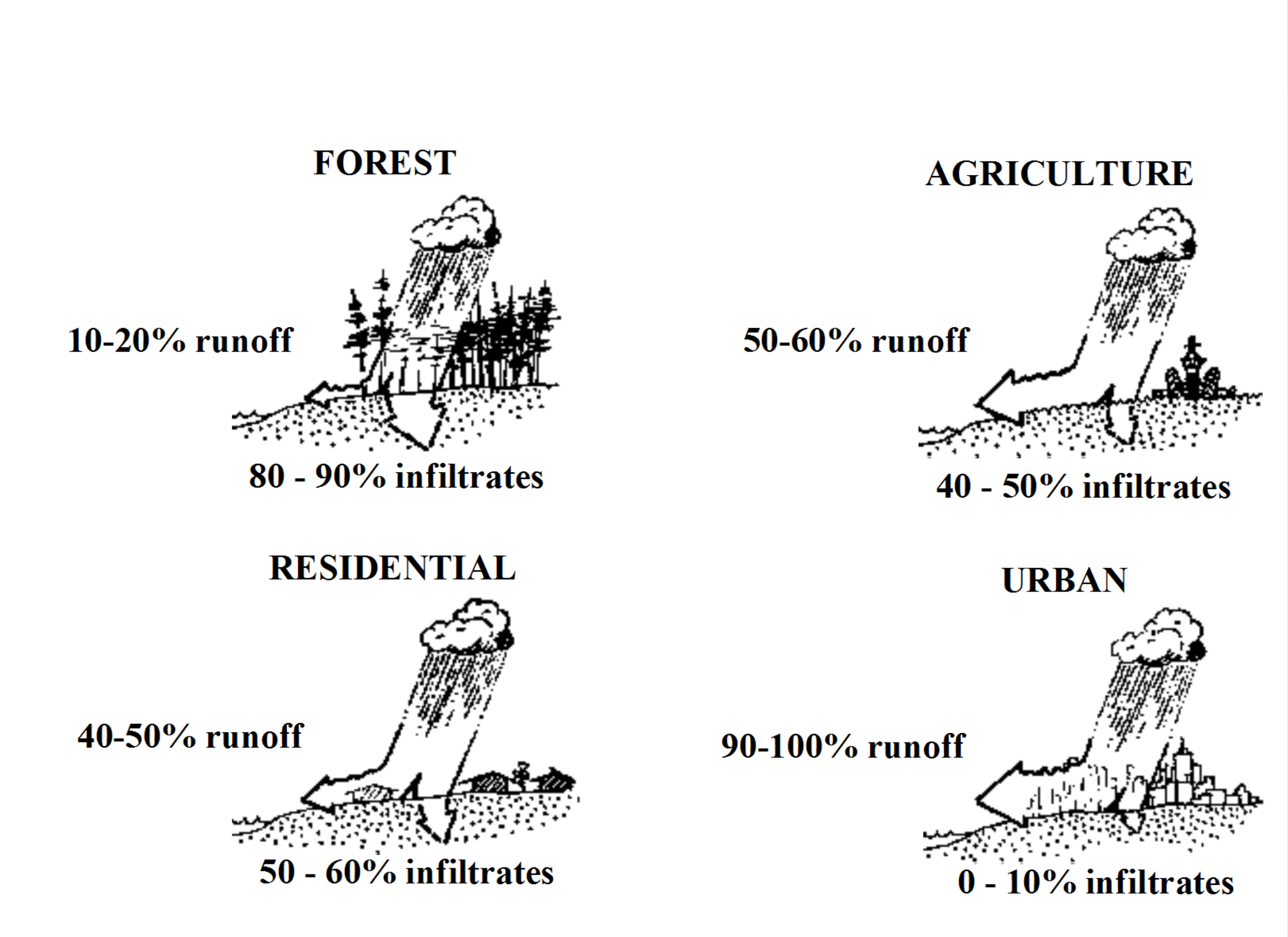
# WATERSHED PROCESSES

# A Lake is a *Reflection* of its Watershed:

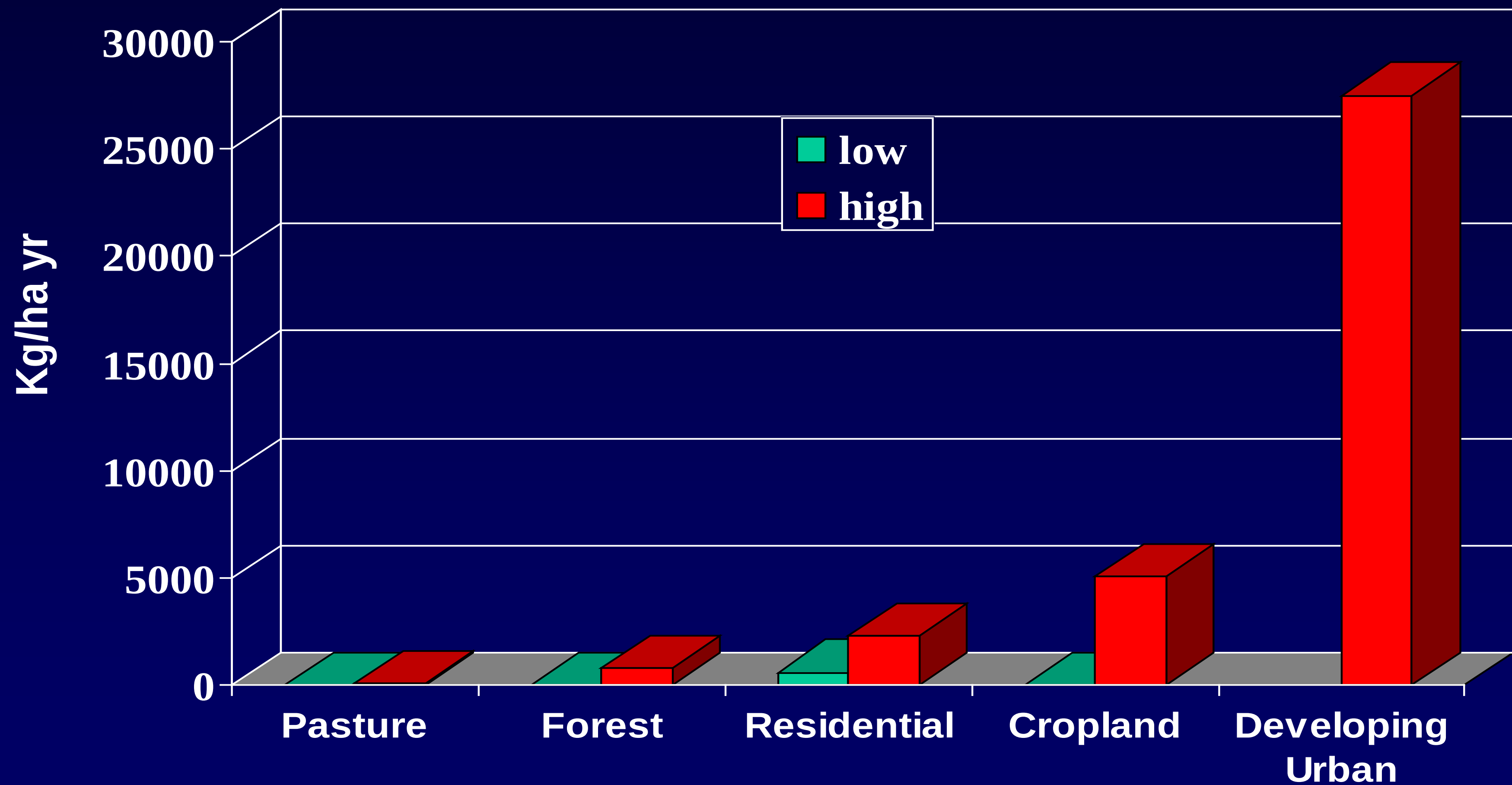
- Rainfall collects within the lake basin
- Water runs down hill
- Runoff carries nutrients, soil and pollutants with it
- Watershed slope, geology and soils affect runoff
- Human land uses influence the amount and quality of runoff water.



# Watershed Features Affect the Amount of Runoff

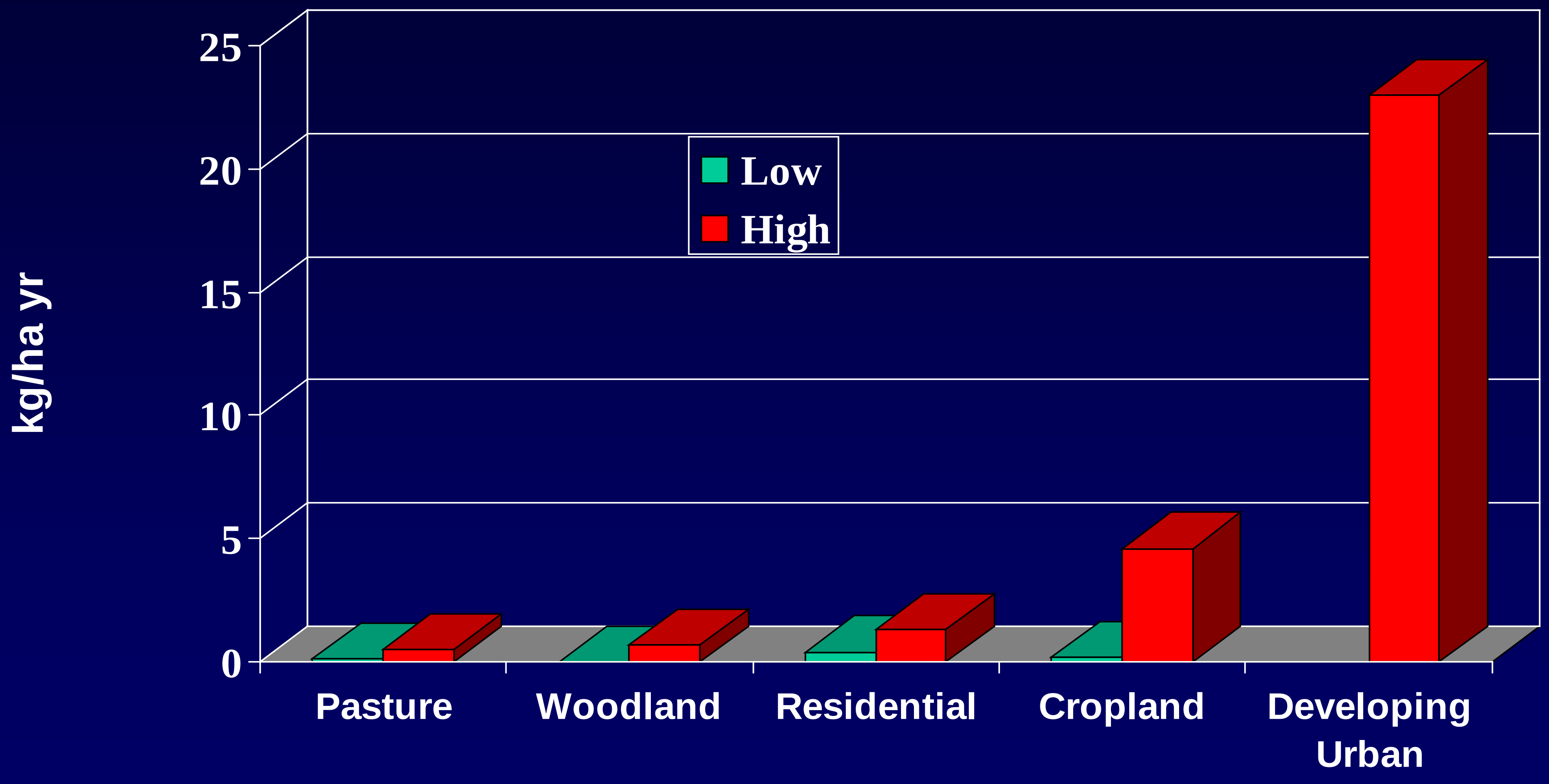


# Nonpoint Source Suspended Solids Loss From Various Land Uses




Source: Sonzogni et al. (1980)

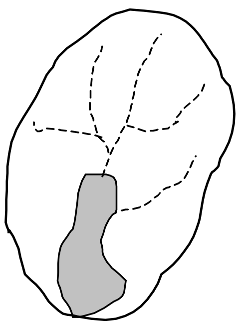
# Nonpoint Total Phosphorus Loss from Various Land Uses




Source: Sonzogni et al. (1980)

# Watershed size and its effect on lakes

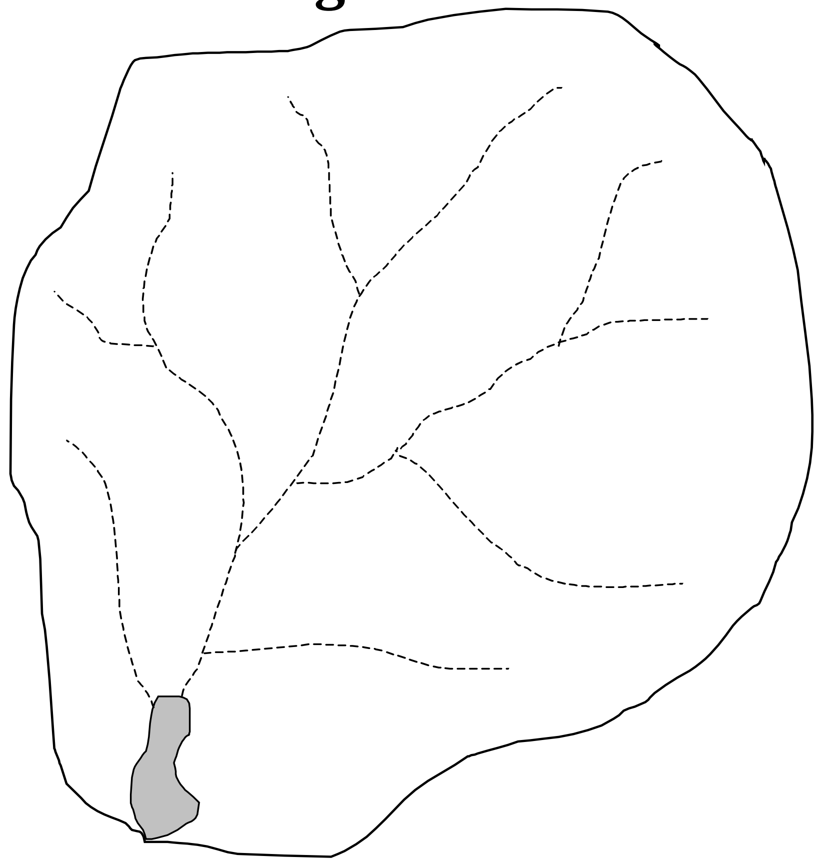
**Small Watershed**



**Lake Surface Area = 100 acres**

**<runoff**
**<sediment and nutrient loading**
**>hydraulic residence time**

**Large Watershed**



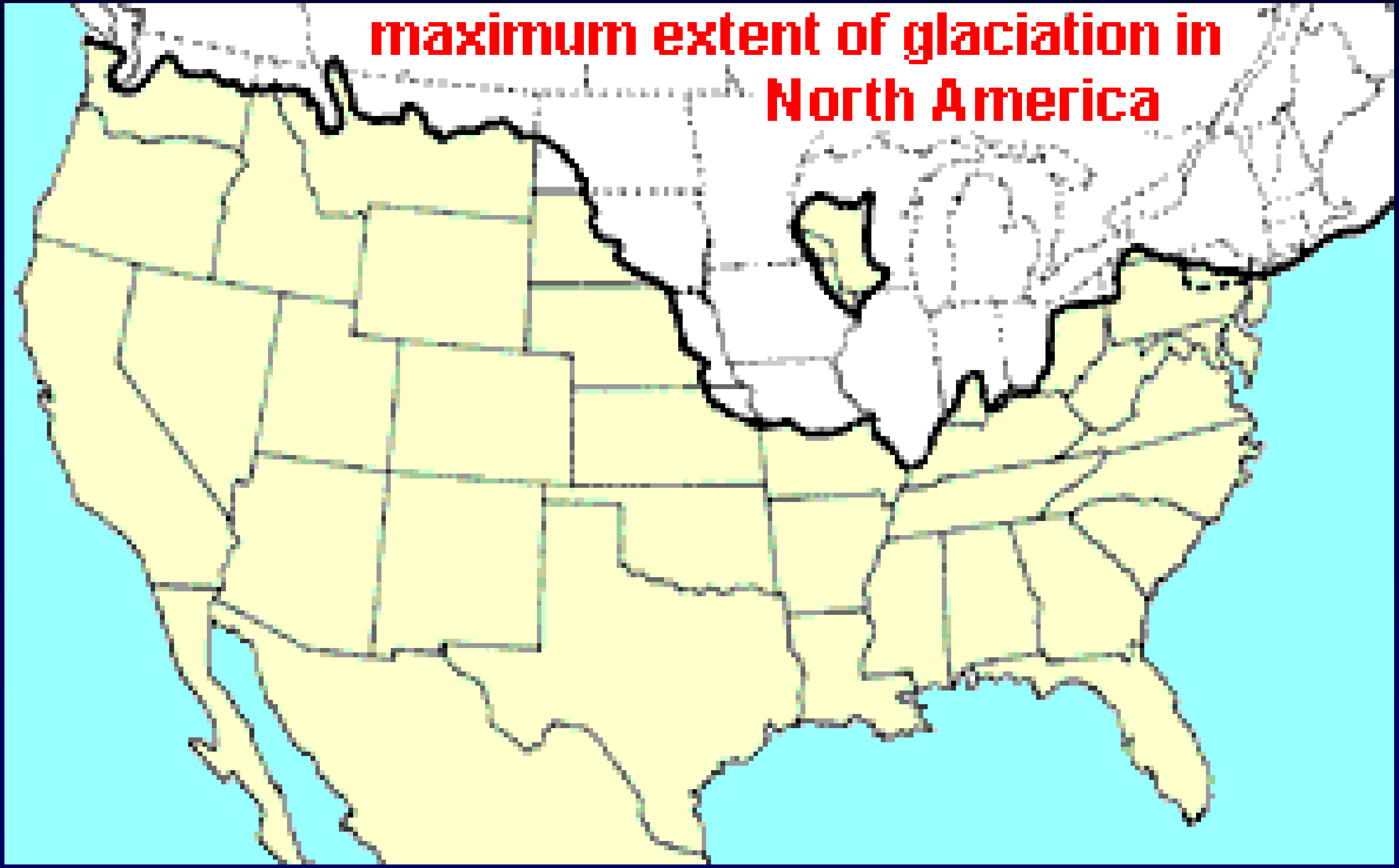
**Lake Surface Area = 100 acres**

**>runoff**
**>sediment and nutrient loading**
**<hydraulic residence time**

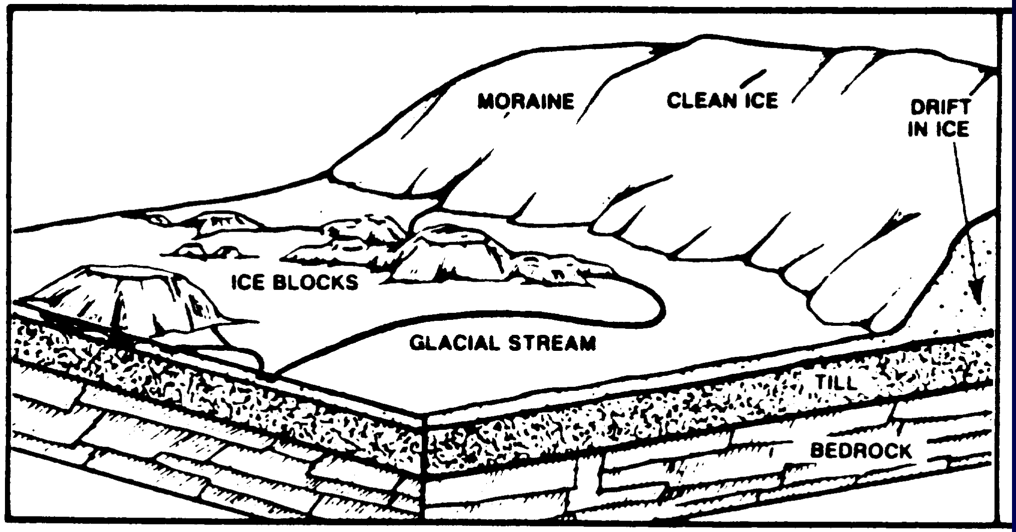
# LAKE FORMATION

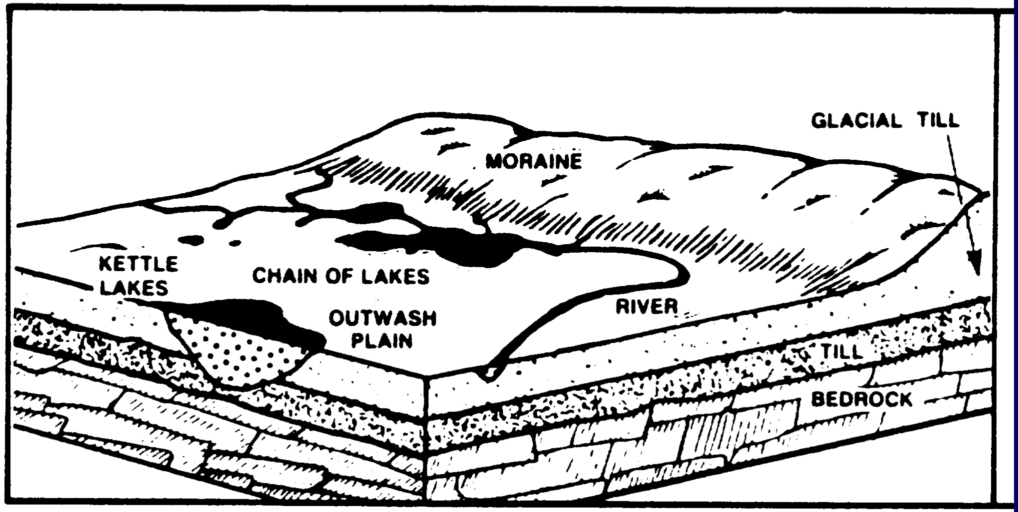
# LAKE FORMATION

- G.E. Hutchinson identified 76 ways lakes may form
- Include: earthquakes, volcanoes, oxbows, faults in the Earth’s crust and glaciers
- Lake formation affects lake size, shape and depth and watershed characteristics


maximum extent of glaciation in
North America

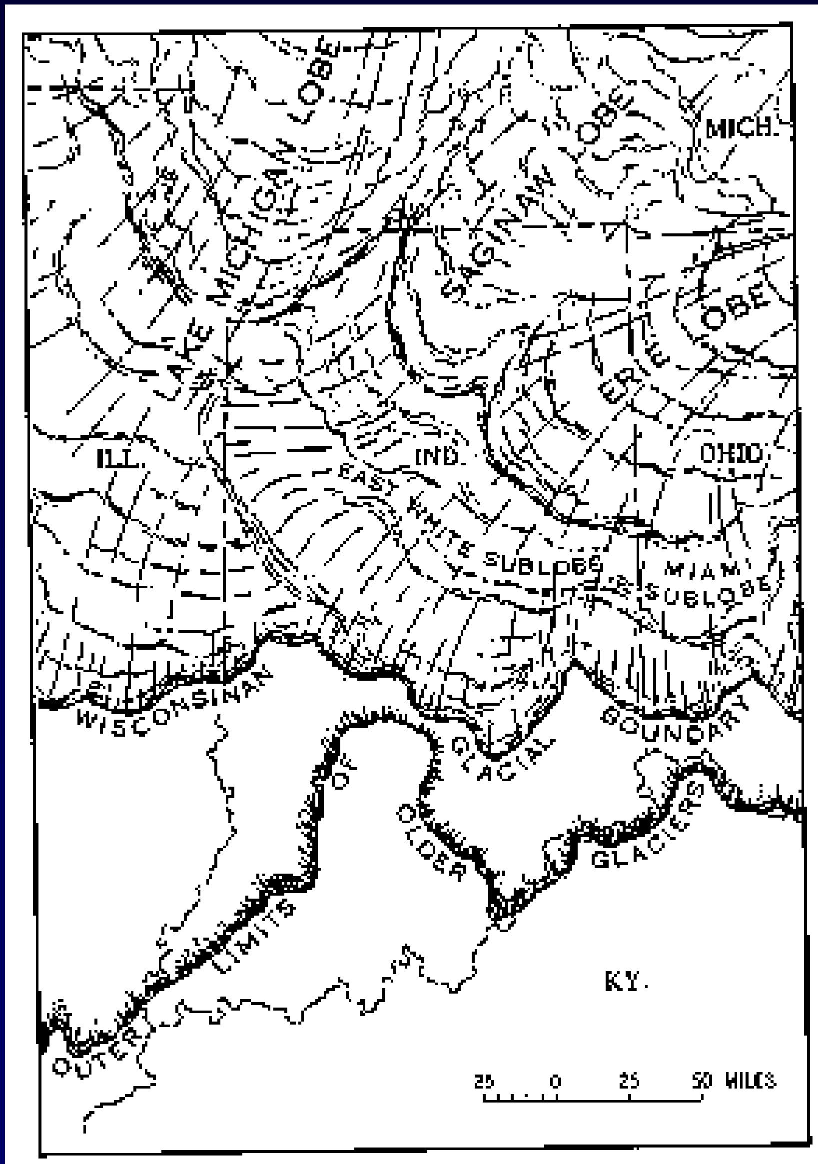
# Lake Formation



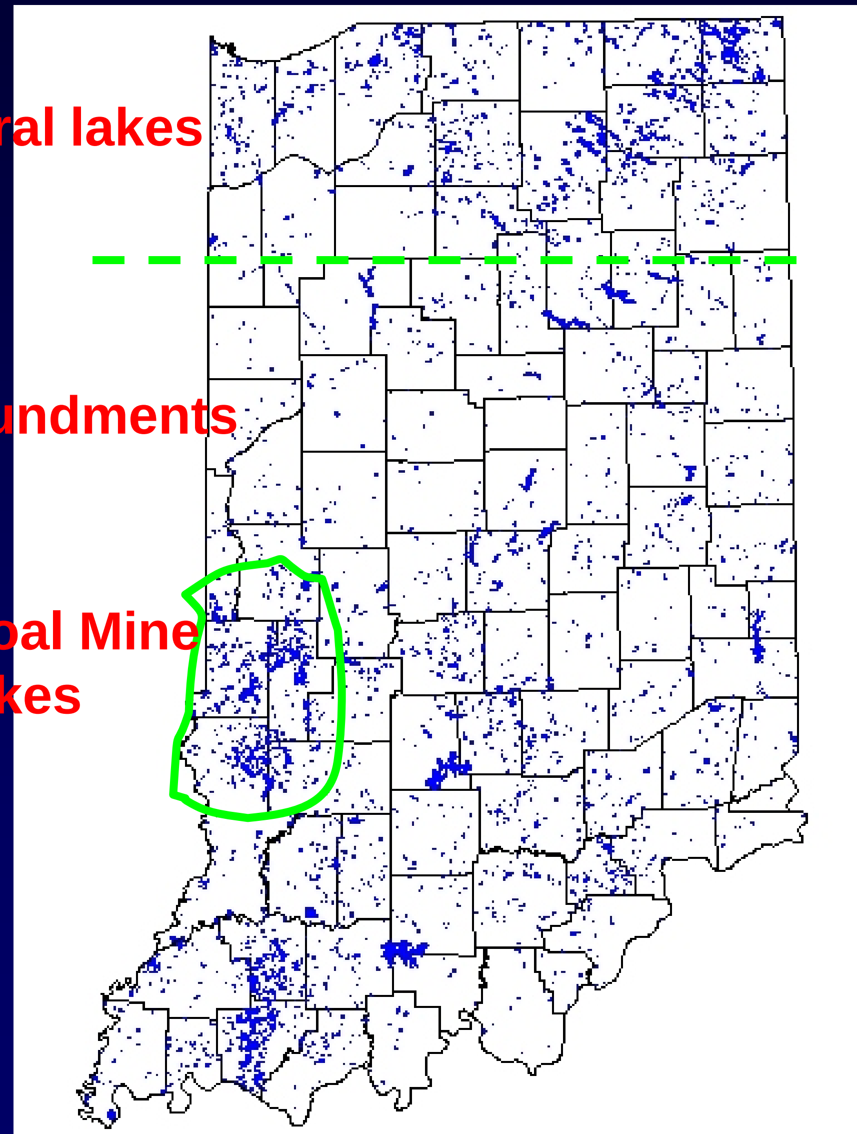




- Most natural Midwestern lakes were formed by glaciers >10,000 yrs ago
- Glaciers scoured out lake basins
- Ice blocks formed depressions that filled and became lakes (*kettle* or *ice block* lakes)

# Coverage of last glacial episode
# ~ 10,000 years before present




# Lake Distribution

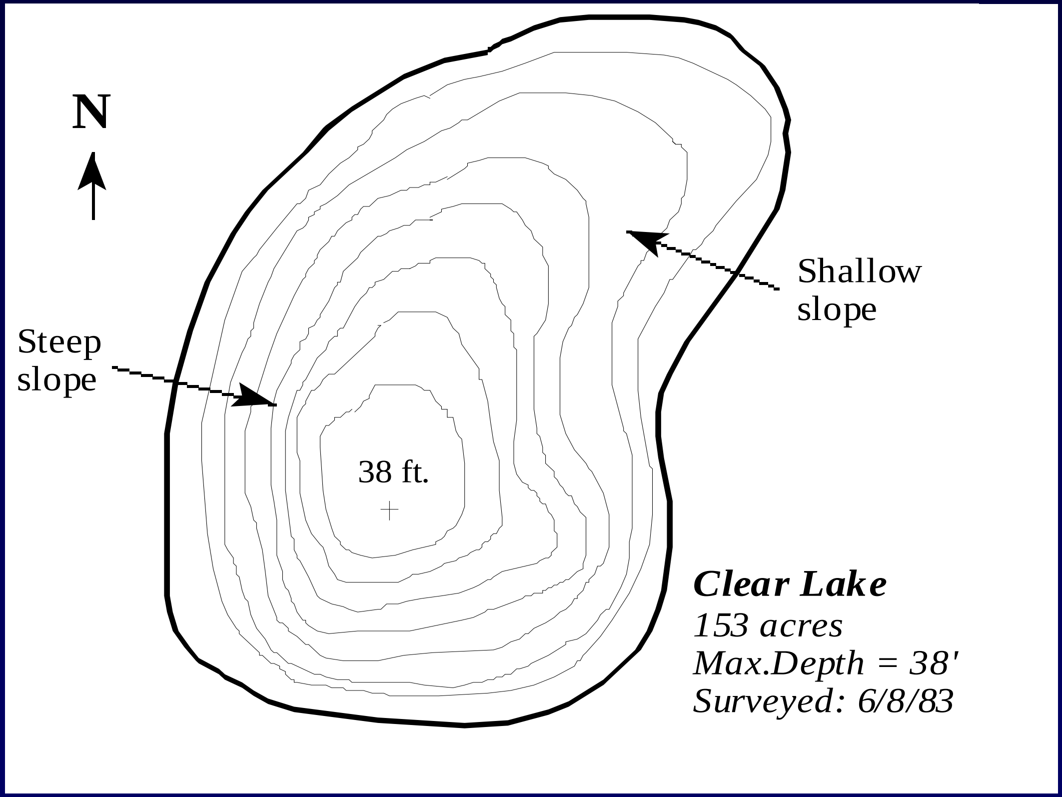


# PHYSICAL FEATURES

# Bathymetric maps are a great source of lake *morphometry* information!

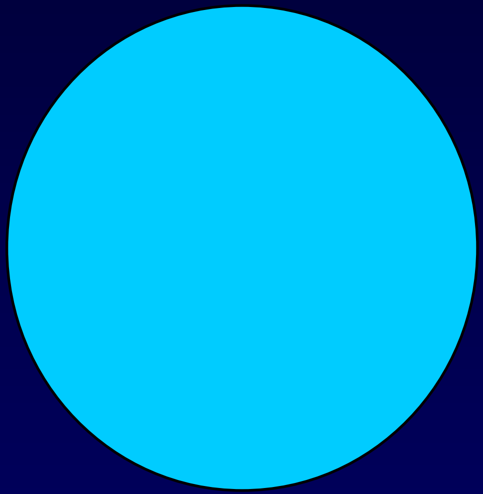
- Lake area ($A_o$)
- Maximum depth ($Z_{max}$)
- Mean depth ($\bar{Z}$)
- Shoreline Length (L)
- Deep holes
- Shallow areas
- Volume (V) can be calculated from this map.

  ($V = A_o * \bar{Z}$)



# Lake Shape and Shoreline Length

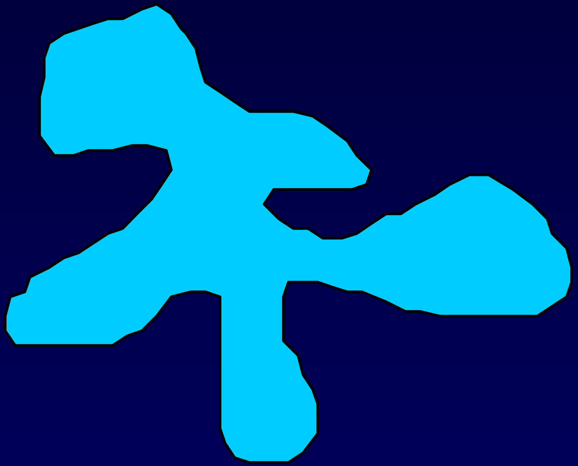
**Round Lake**



**Area = 100 acres**

**Shoreline = 7,400 feet**

**Crooked Lake**



**Area = 100 acres**

**Shoreline = 12,000 feet**

# Lake Shape & Orientation and Wind Fetch

**Wind Direction**

- **long fetch = more internal mixing**

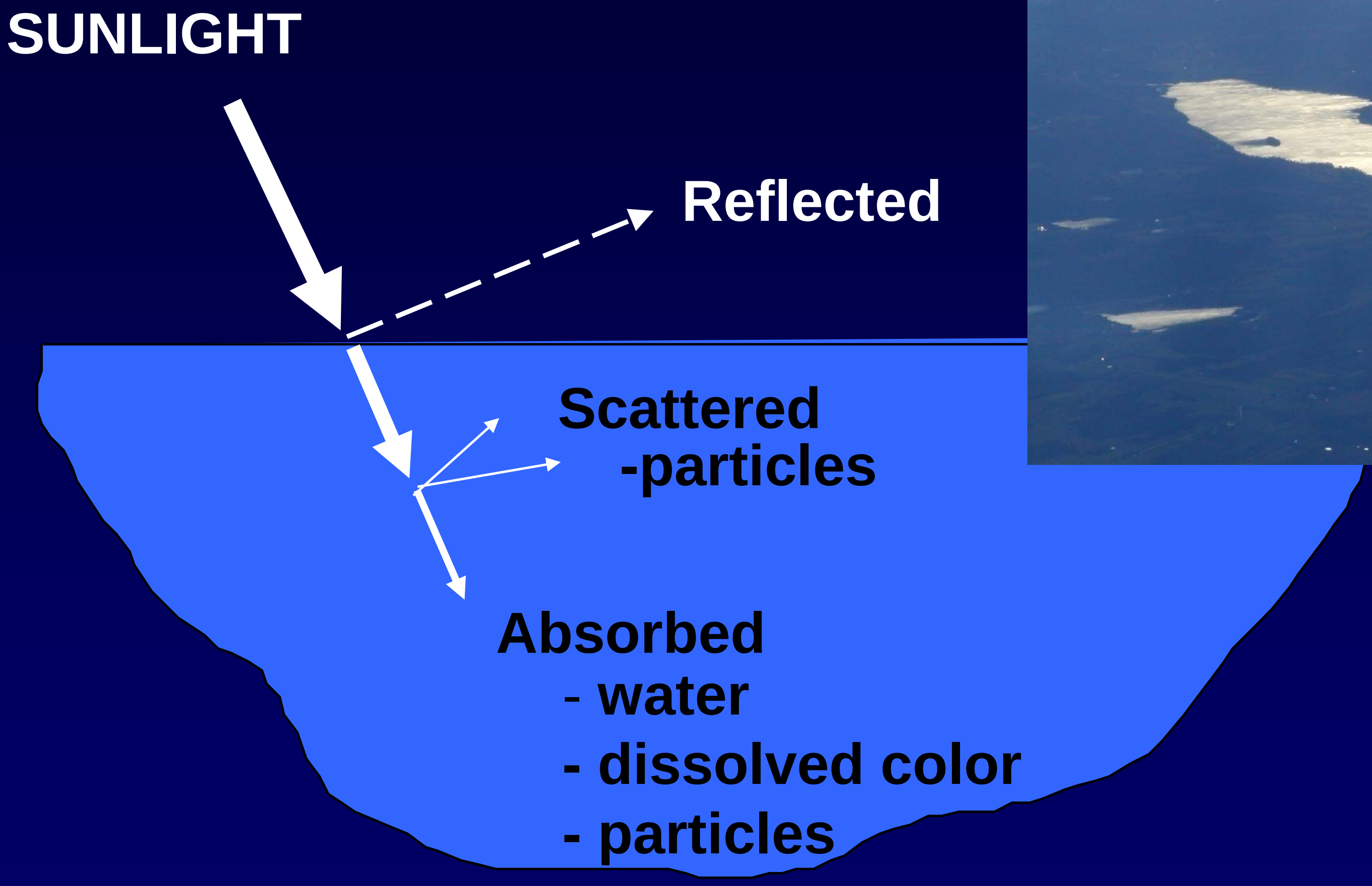
**Wind Direction**

- **short fetch = less internal mixing**

# LAKE PROCESSES

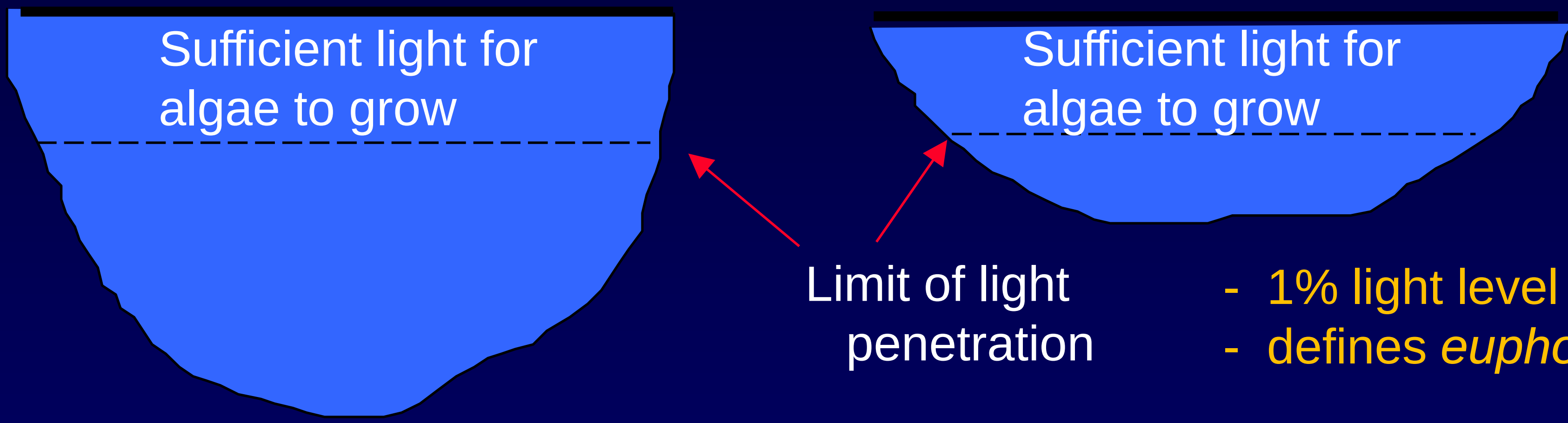
# Solar Energy – the engine that <u>powers</u> lake ecosystems!

# Light Attenuation



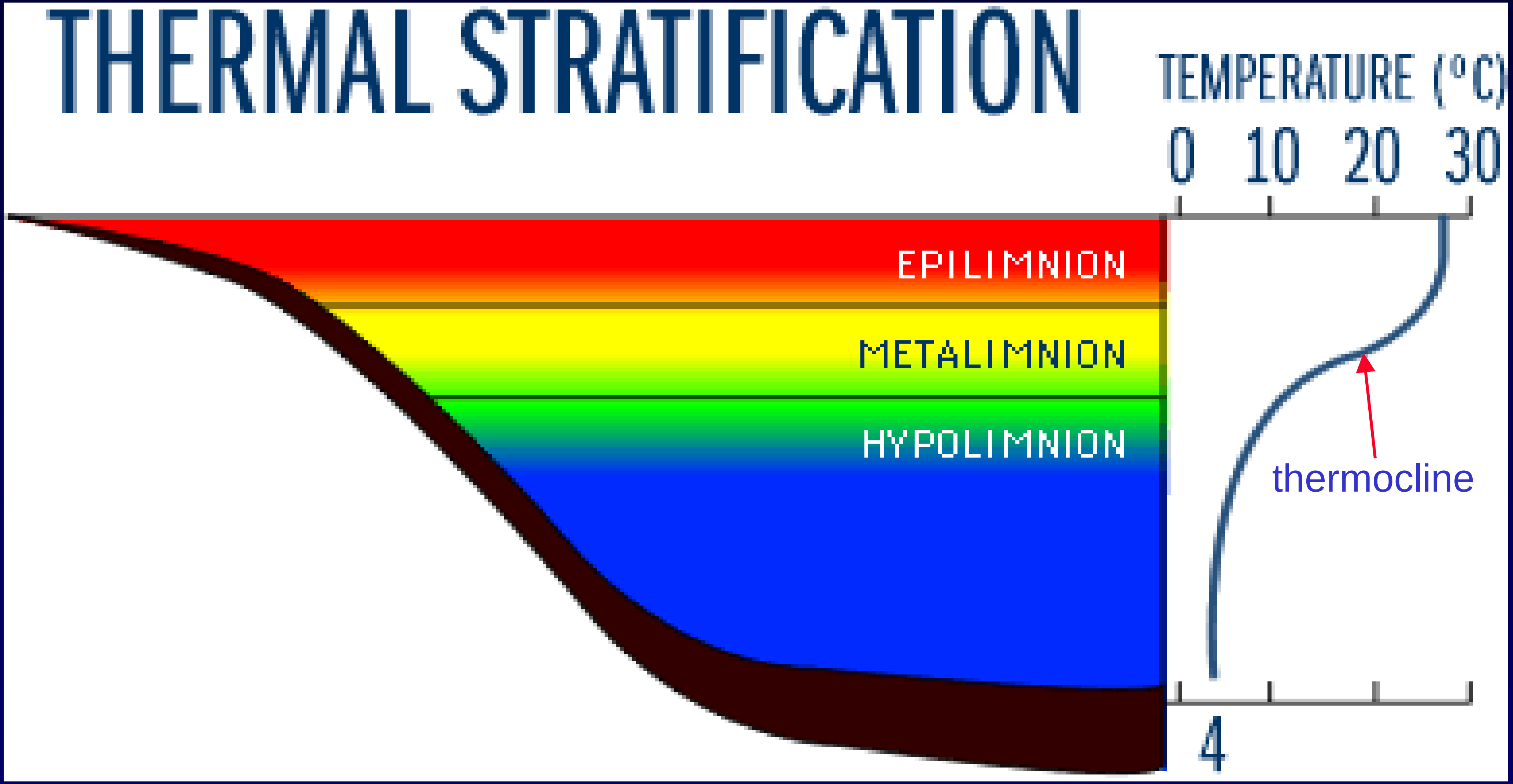

# Lake Depth and Productivity

**Deep Lake** | **Shallow Lake**

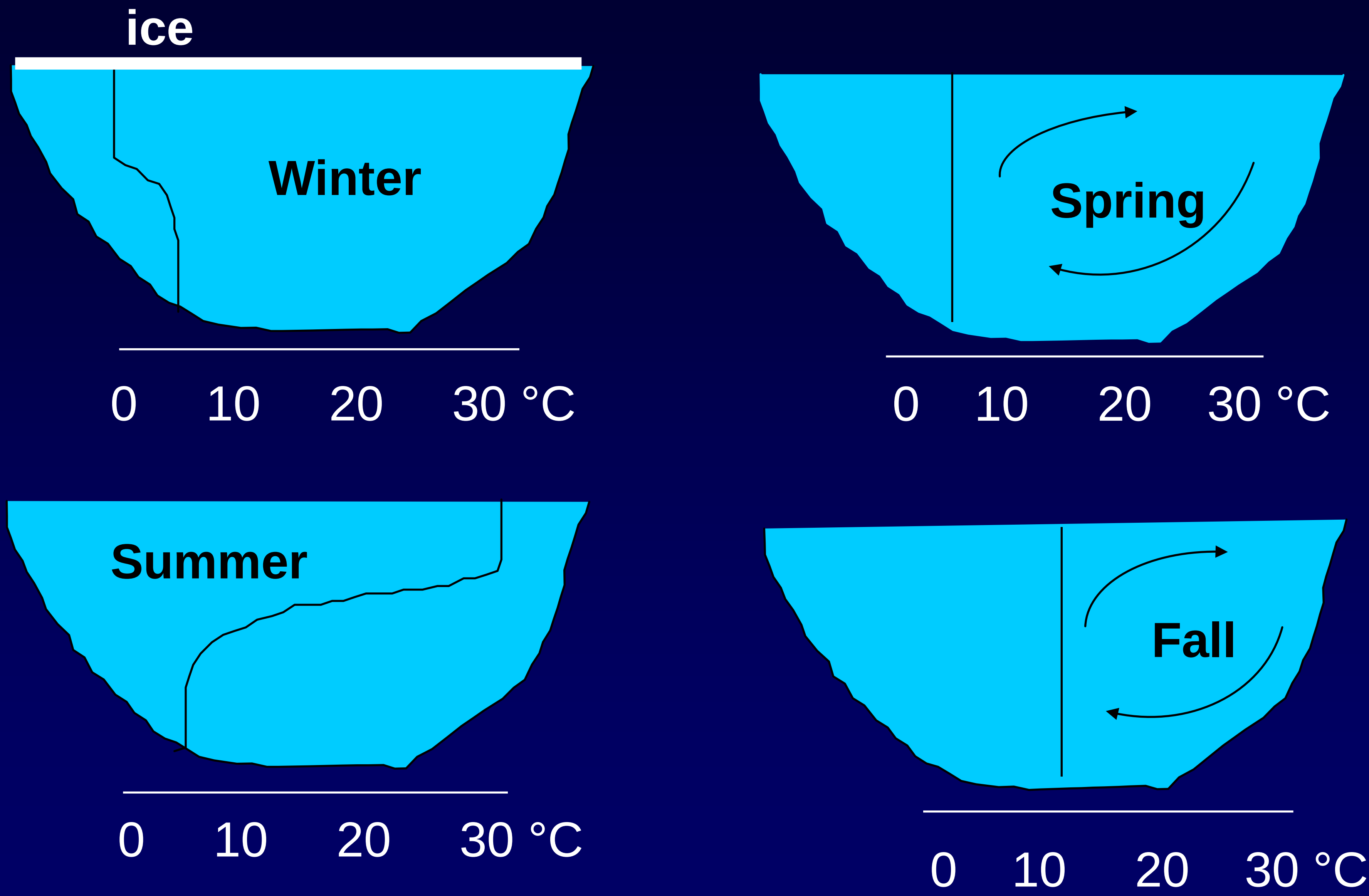



- 1% light level
- defines *euphotic zone*

- Small % of lake volume can support algae.
- Most of lake volume can support algae.


THERMAL STRATIFICATION
TEMPERATURE (°C)
0 10 20 30
EPILIMNION
METALIMNION
HYPOLIMNION
thermocline
4

# Thermal Stratification



# Physical Features Summary

- Lake Shape (morphometry)
  - wind fetch
  - shoreline length
- Lake Volume
  - productivity
- Lake Depth
  - stratification

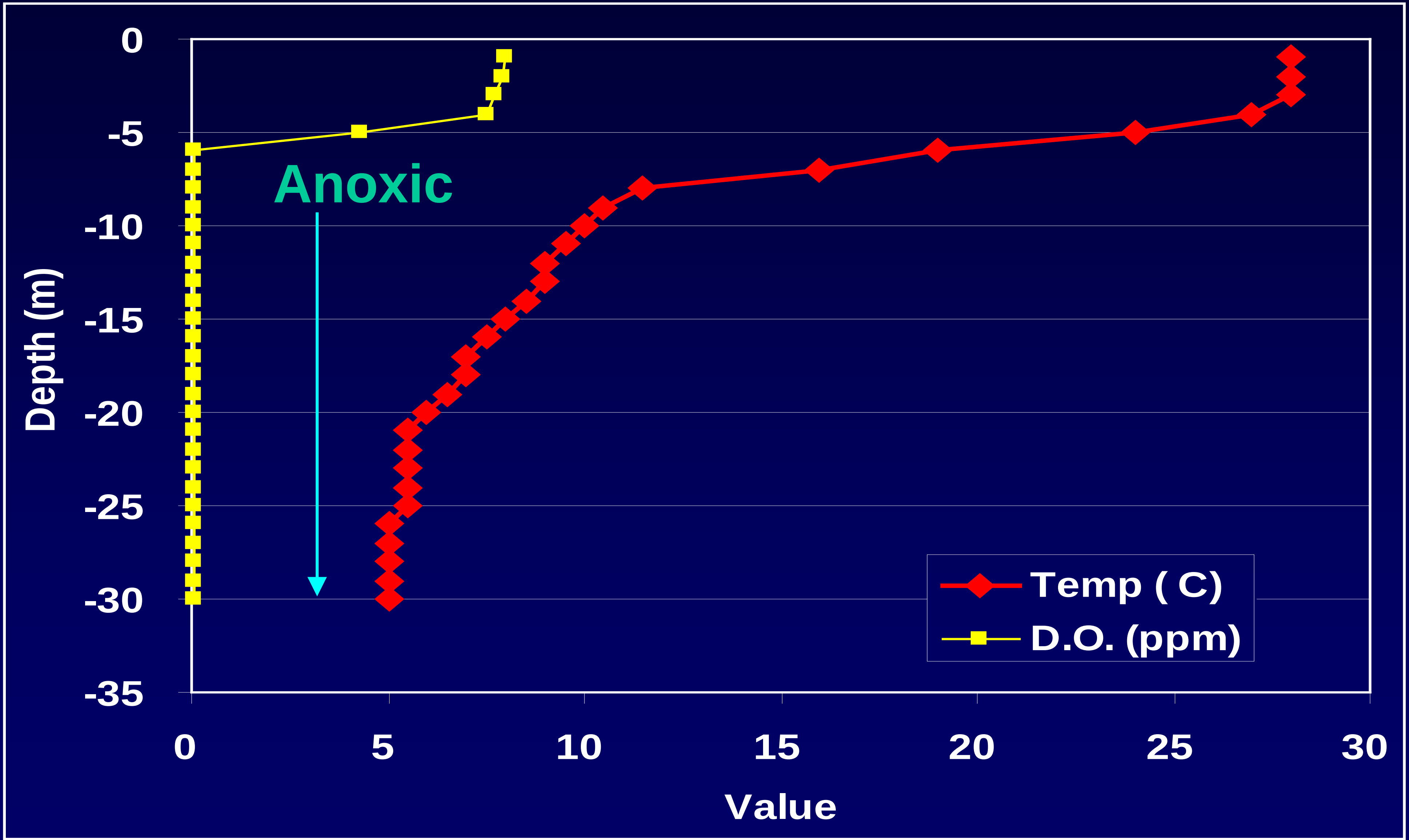
# Photosynthesis

carbon dioxide + water + nutrients + light → glucose + oxygen

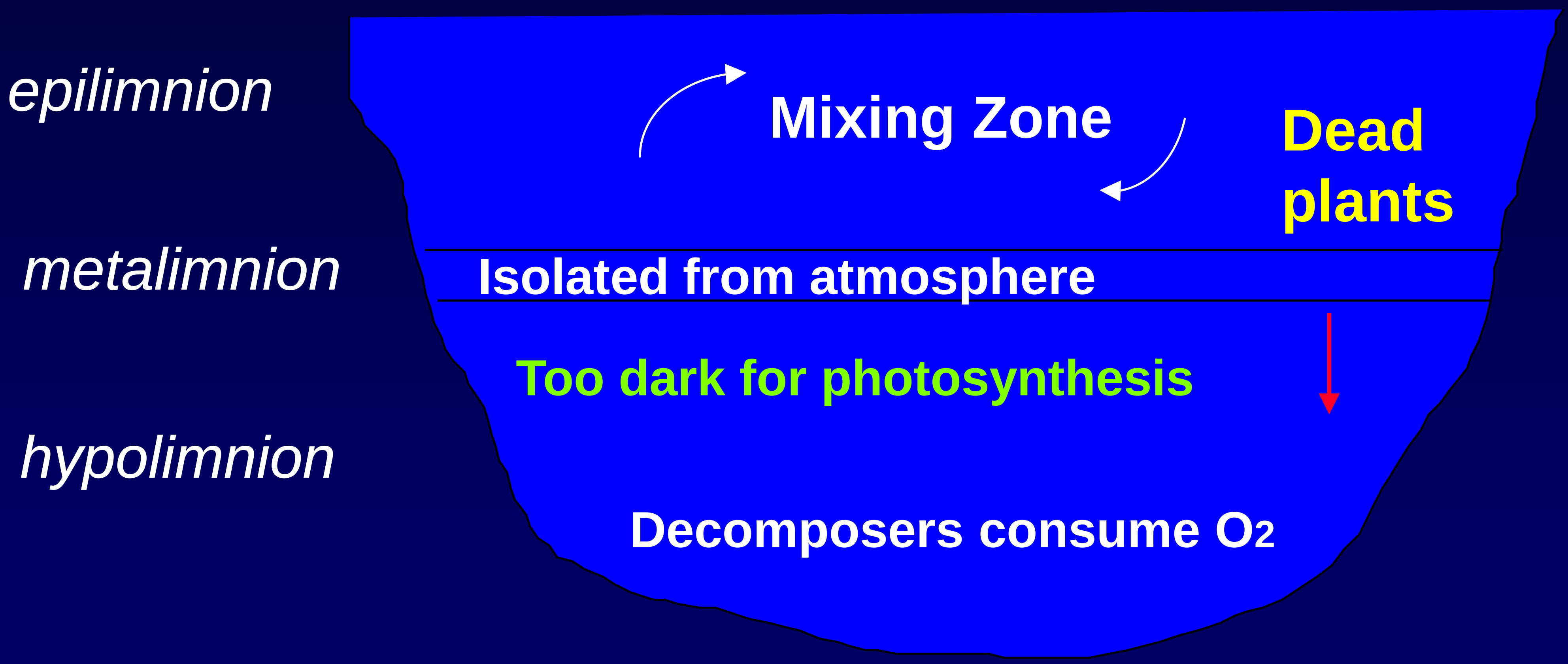
# Respiration

glucose + oxygen → carbon dioxide + water + ENERGY

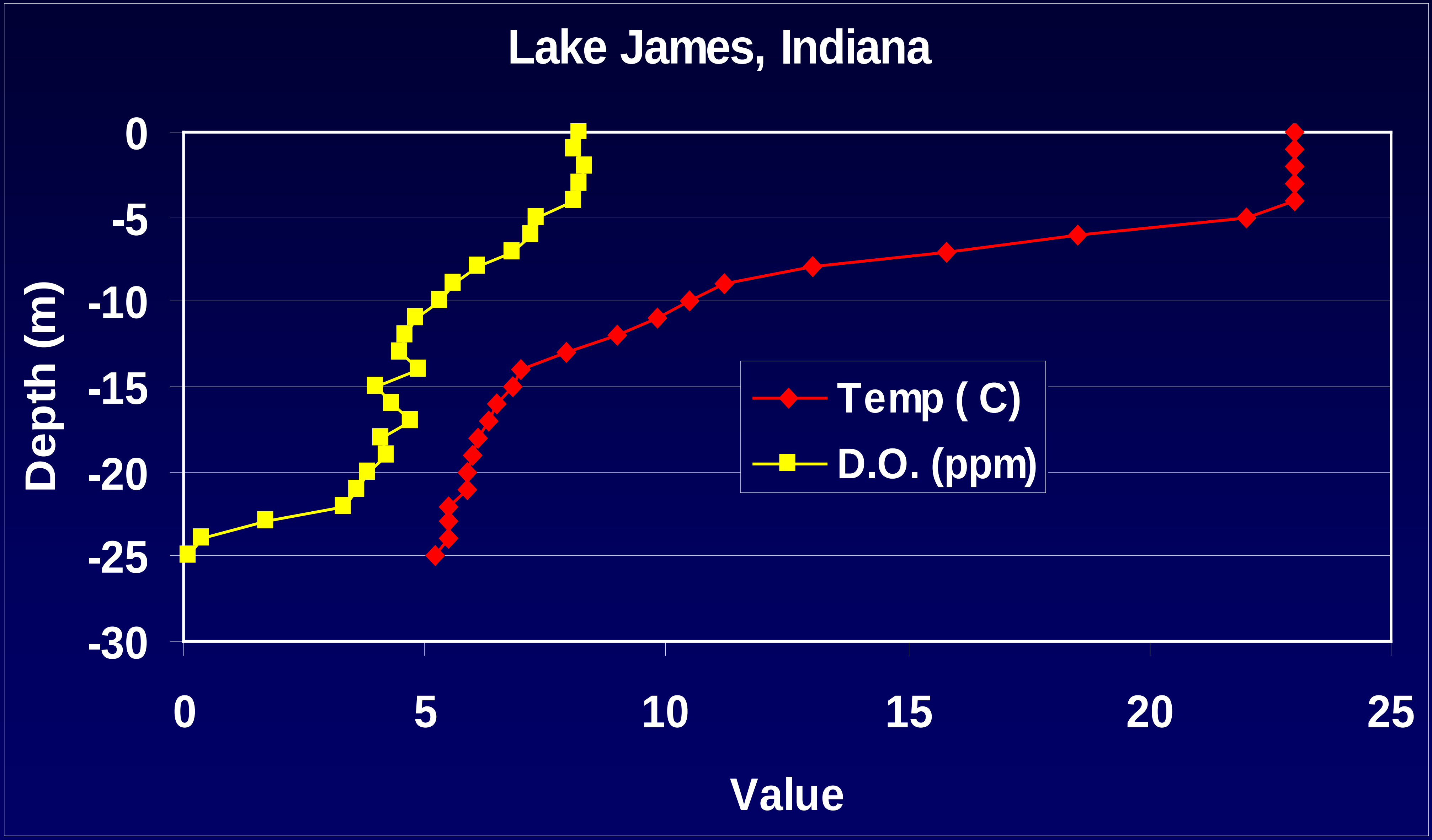
# Dallas Lake – Temp. & D.O.



# Oxygen is Often Low in the Hypolimnion



# Not all deep lakes are *anoxic*

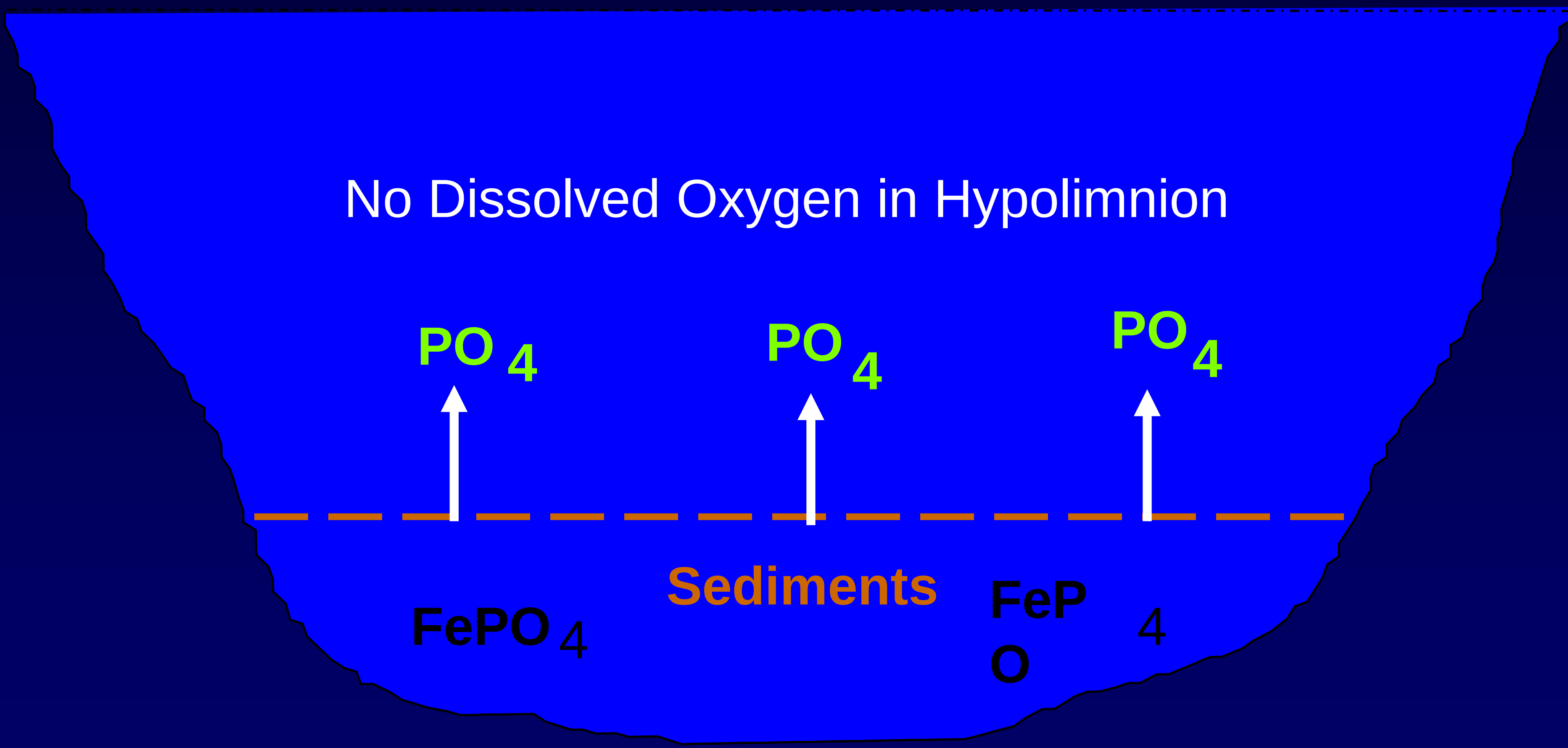


# LAKE CHEMISTRY

# Water Chemistry

- Nutrients
  - Nitrogen
  - Phosphorus
  - Carbon
- Suspended sediments
- Trace metals
  - Mercury
- Organic contaminants
  - Pesticides
  - Algal toxins

# Phosphorus Release from Sediments (Internal Loading)



# Internal Phosphorus Cycling

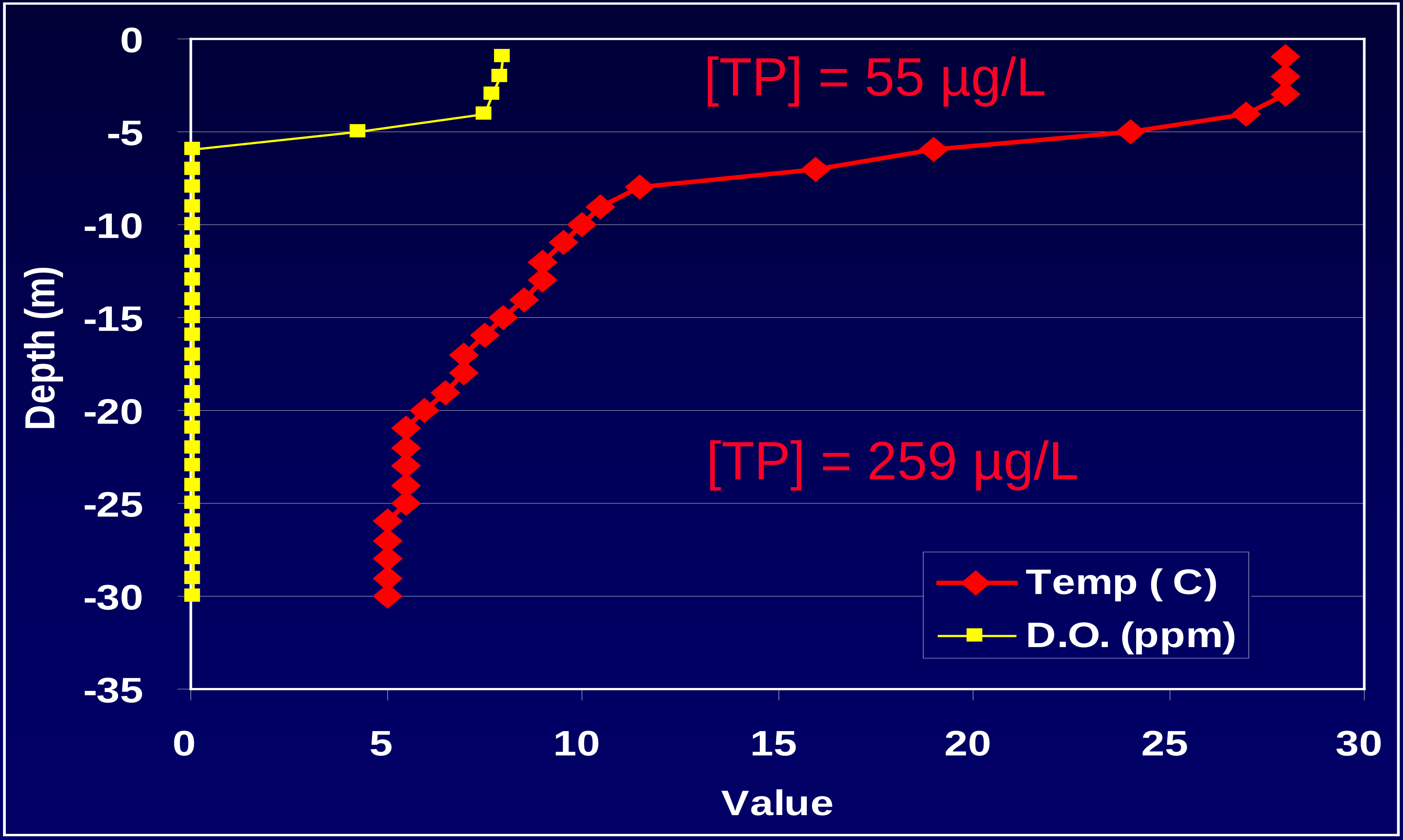
Dead plants settle down to the sediments

Bacteria decompose the plant materials

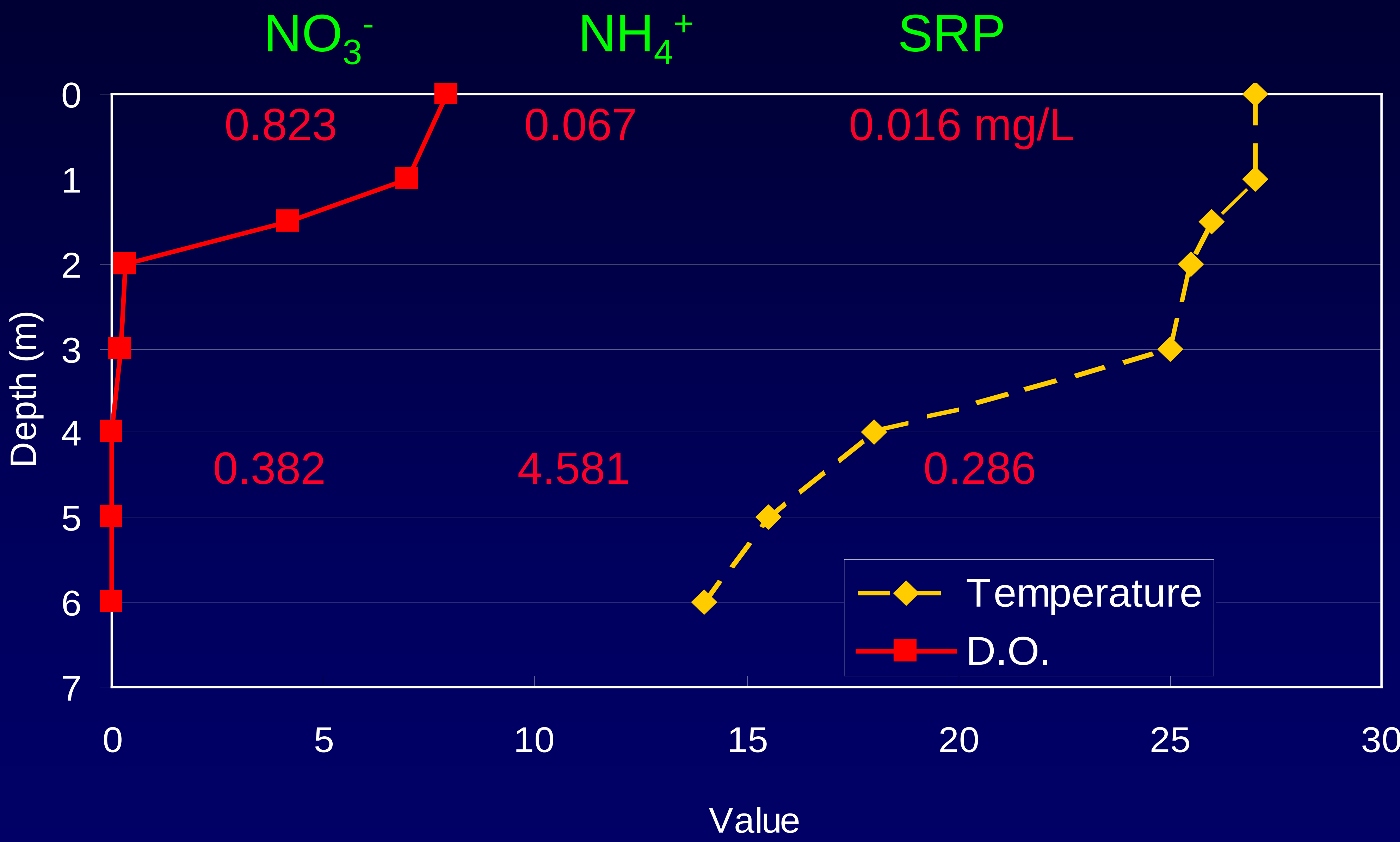
Oxygen is consumed by the bacteria during decomposition

Phosphorus is released from the sediments back into the water where it encourages the growth of more plants

# Sediment P Release – Dallas Lake

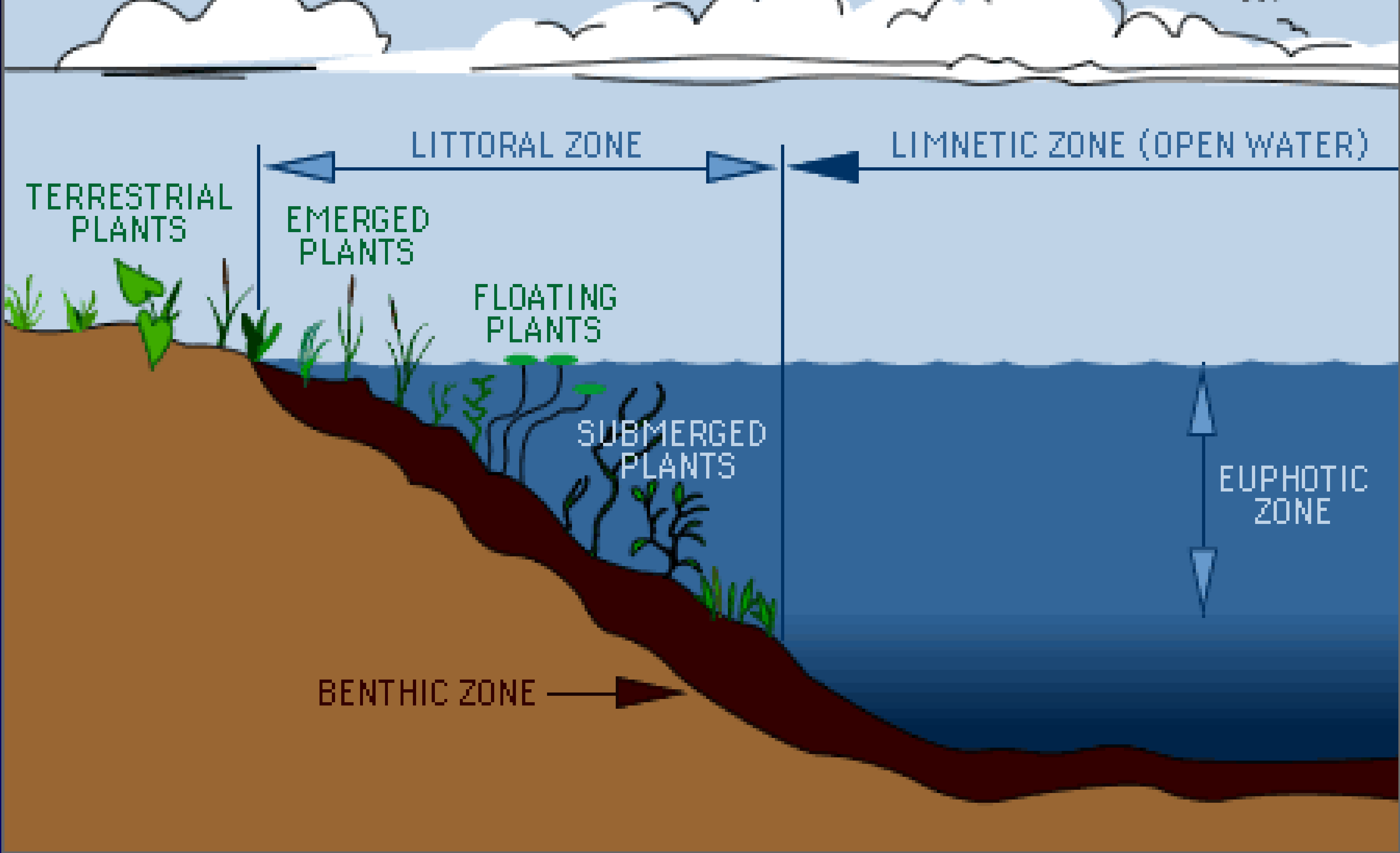


# Redox Changes in Lake Shakamak

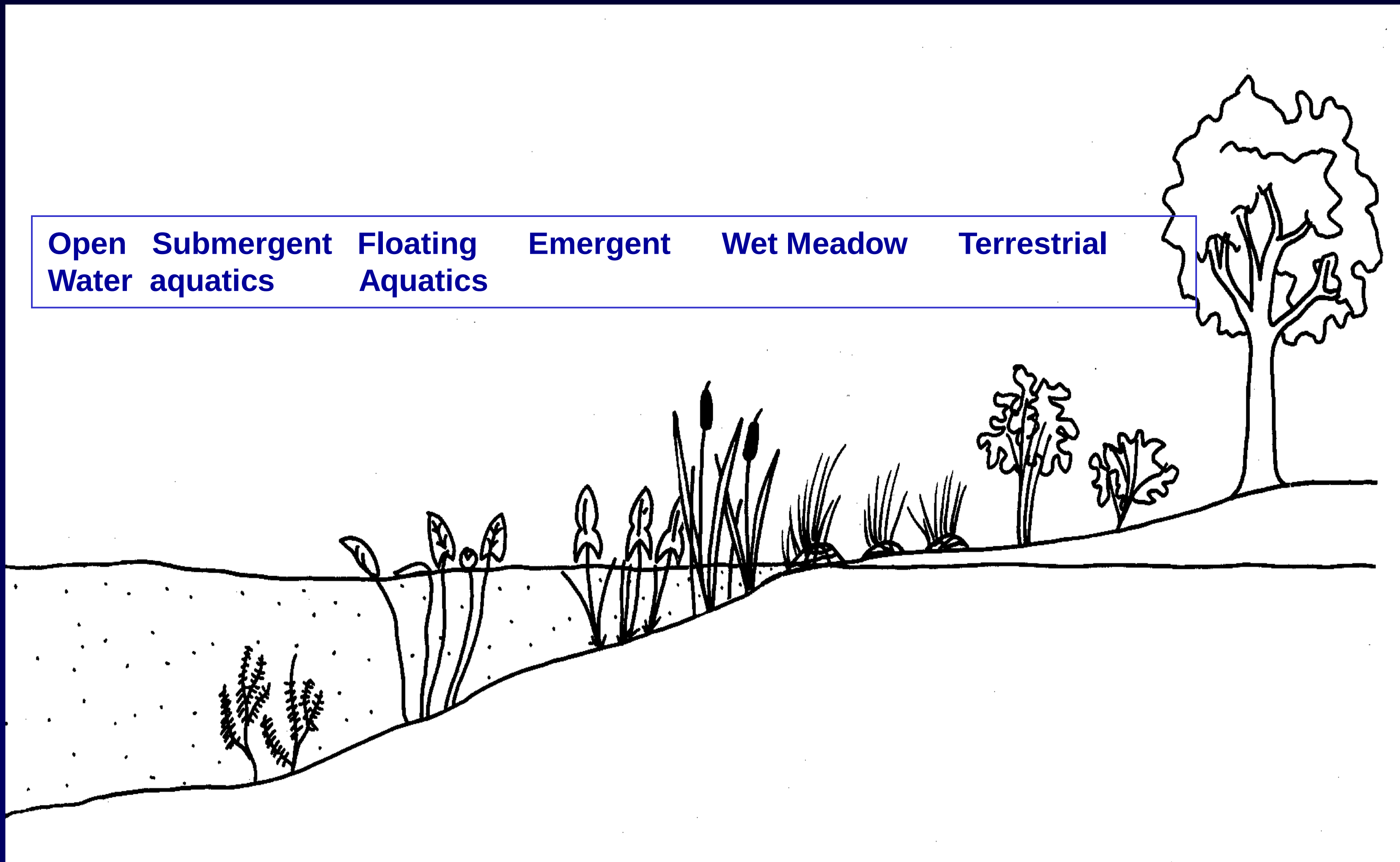


# LAKE BIOLOGY

# Lake Communities



# Aquatic plants are *primary producers*

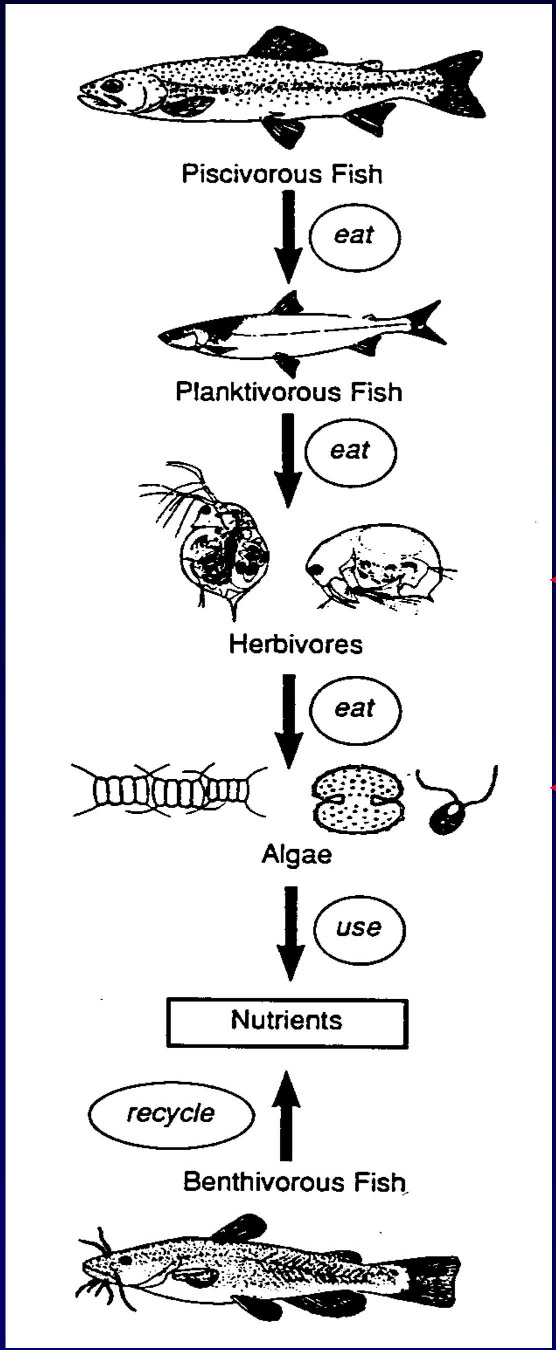



| | | | | | |
|---|---|---|---|---|---|
| e.g. algae | watermilfoil<br>pondweeds | pond lily<br>spatterdock | arrowhead<br>cattail | sedges | shrubs<br>trees |

# Aquatic macrophytes have many positive attributes

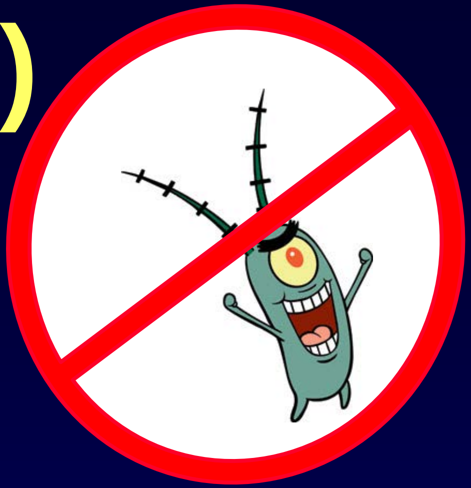
- Help protect shorelines from erosive waves
- Stabilize littoral sediments
- Help block out lake sounds
- Provide visual screen for privacy
- Are important habitat for fish and other aquatic life
- Many are aesthetically pleasing

# The Aquatic Food Web




- bass, pike, walleye
- minnows, YOY sunfish
- aquatic equivalent to <u>cows</u>
- primary producers also include macrophytes
- stir up sediments and nutrients from bottom sediments

# Phytoplankton (aka: Algae)

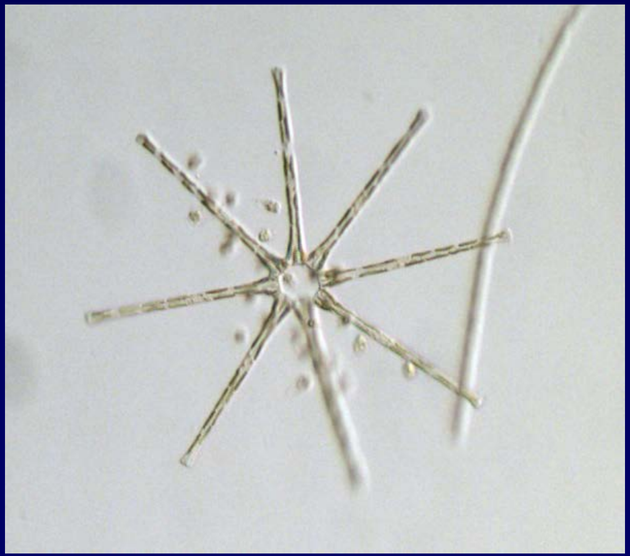


- Microscopic plants
- Are primary producers
- Produce oxygen during photosynthesis
- Are important at the base of the food chain
- Chlorophyll pigment gives green color
- Groups are often differentiated by color
- Too many may cause problems

# Types of Algae

## Diatoms

- Have hard shells made from silica
- Shells remain in sediments 1,000s of years
- Often abundant in spring



Asterionella

## Green Algae

- Bright green chlorophyll
- Are generally considered "good" algae
- Important food for zooplankton
- Often abundant in early summer

Dinobryon
(a yellow-brown alga)

# The Amazing Blue-Greens

- Often become a nuisance when excess phosphorus is available
- Dominate during the warm summer months
- Can out-compete other "desirable" algae

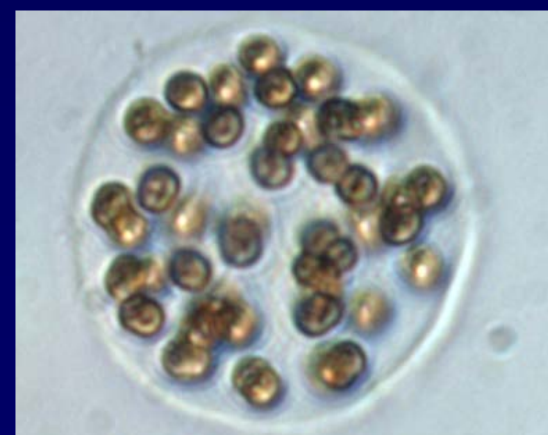
Competitive Advantages

- Buoyancy regulation
- Nitrogen fixation
- Gelatinous sheath
- Large size
- Some produce toxins
- Unpalatable

Anabaena

Heterocyst

Coelosphaerium

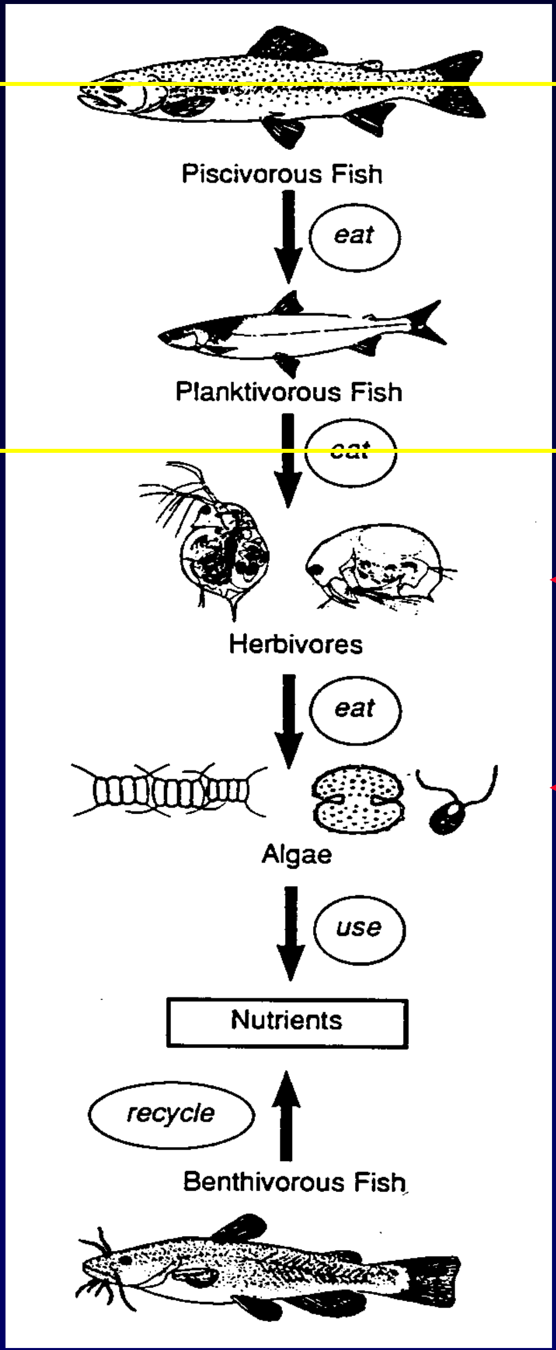


# Zooplankton

**Daphnia ~ 2.5mm**

**Bosmina ~ 0.5 mm**

# The Aquatic Food Web




bass, pike, walleye

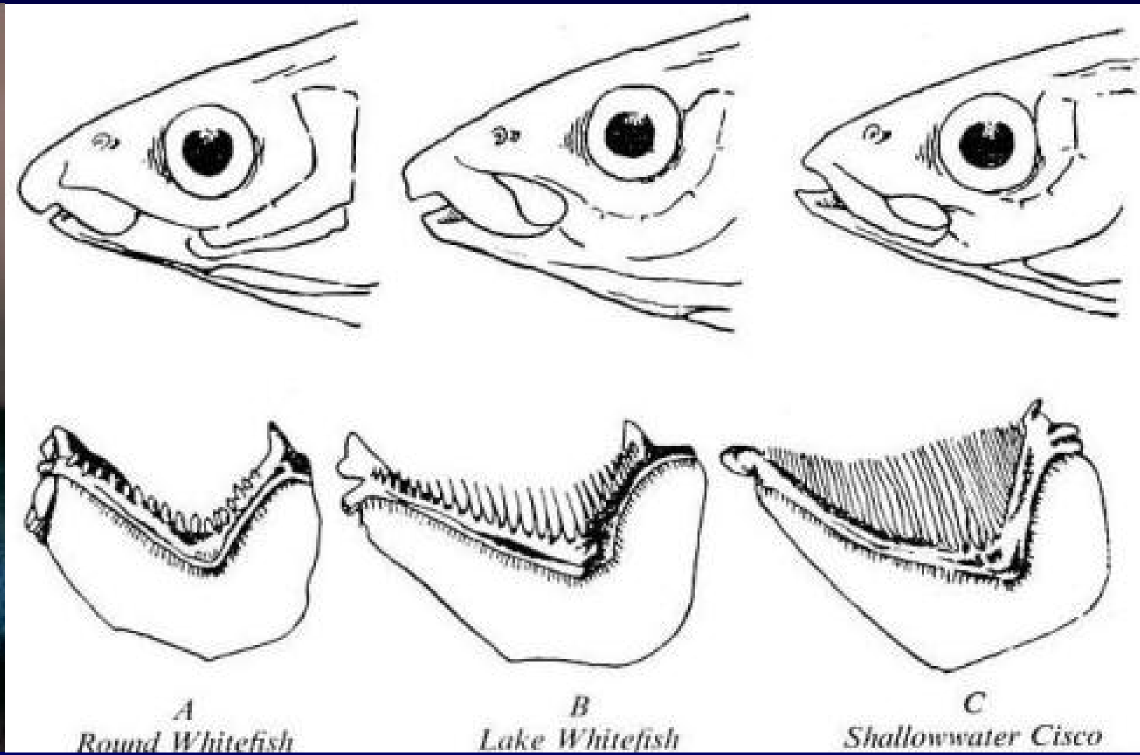
minnows, YOY sunfish

aquatic equivalent to <u>cows</u>

primary producers also include macrophytes

stir up sediments and nutrients from bottom sediments

# Planktivores

# LAKE MANAGEMENT

# Eutrophication

Process of excessive addition of:

1. Inorganic nutrients
2. Organic matter, and
3. Silt

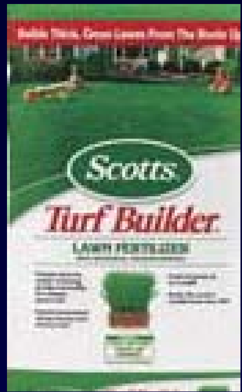
to lakes leading to increased biological production and a decrease in lake volume.

# Nitrogen

- Atmospheric nitrogen ($N_2$) isn't usable by plants
- Most blue-green algae can "fix" atmospheric nitrogen
- Ammonia ($NH_4$) is formed as a product of decomposition
- $NH_4$ and $NO_3$ are both used by algae
- Sources include: fertilizer, sewage waste, animal waste, atmosphere

# Phosphorus

- No atmospheric gaseous phase
- Sources: fertilizer, animal and human wastes, detergents, natural rocks
- Found in runoff and precipitation
- Is the primary plant nutrient of algae

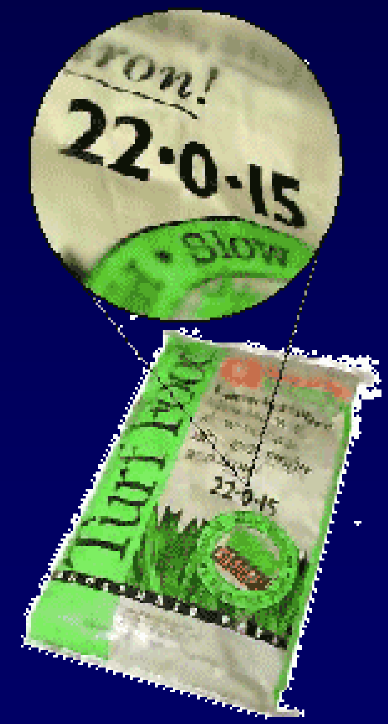



## Lawn Fertilizer

- 29-3-4 on label means
- 29 parts N : 3 parts P : 4 parts K

Most lawns have plenty of available phosphorus!

Phosphorus-free lawn fertilizers are becoming widely available.



# Limiting Nutrient Concept

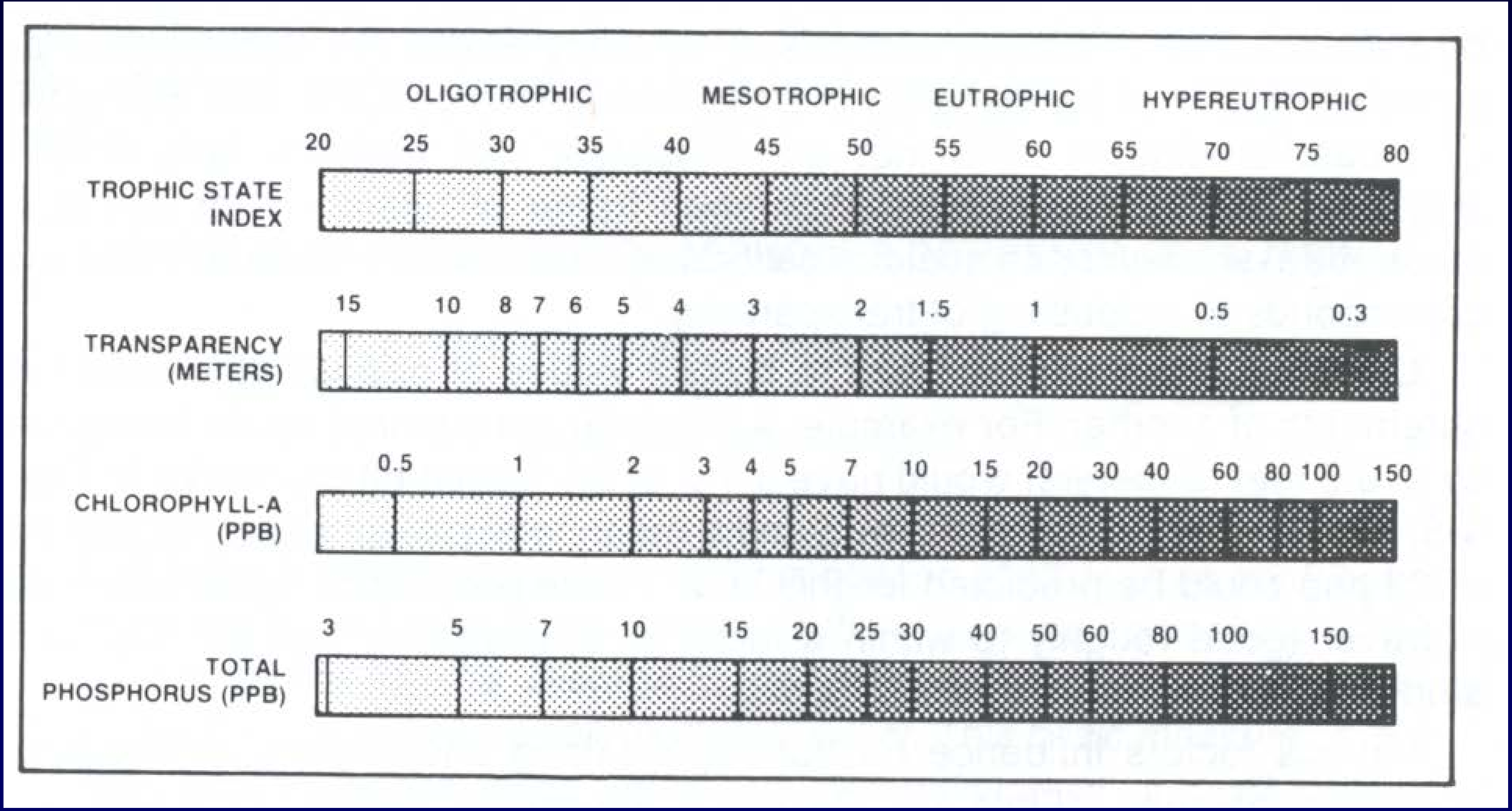
- Definition: that essential material that is in least supply and limits the growth of the plant.
- Phosphorus is often the limiting nutrient to algae.
- Other limiting factors = temperature, light.

# Trophic Classification

EUTROPHICATION

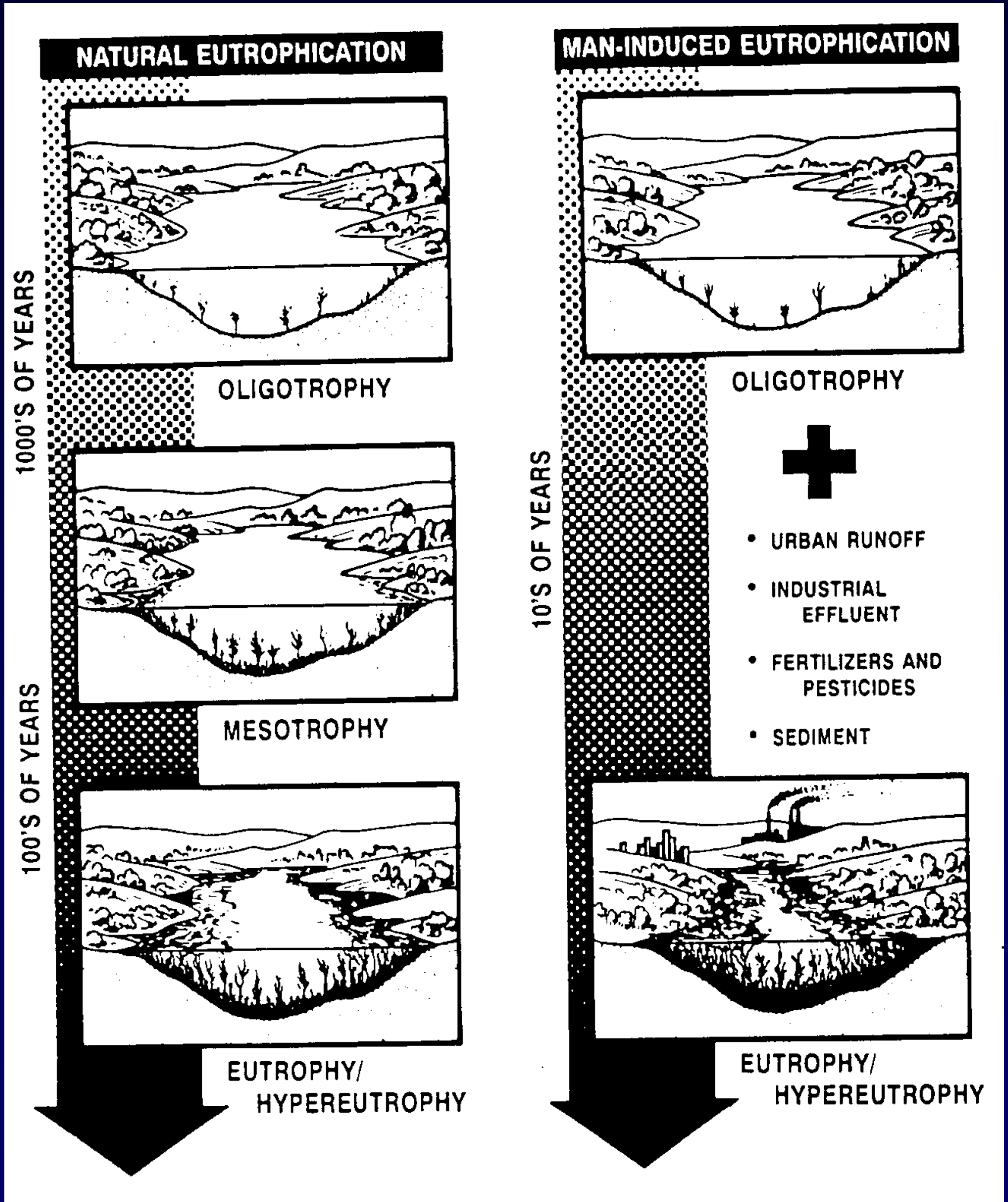
| Classification | Transparency | Nutrients | Algae | D.O. | Fish |
|---|---|---|---|---|---|
| ***Oligotrophic*** | clear | Low<br>TP < 6 µg/L | few algae | Hypo has D.O. | can support salmonids (trout and salmon) |
| ***Mesotrophic*** | Less clear | Moderate<br>TP 10-30 µg/L | healthy populations of algae | Less D.O. in hypo | lack of salmonids |
| ***Eutrophic*** | transparency <2 meters | High<br>TP > 35 µg/L | abundant algae and weeds | No D.O. in the hypo during the summer | |
| ***Hypereutrophic*** | transparency <1 meter | extremely high<br>TP > 80 µg/L | thick algal scum<br>Dense weeds | No D.O. in the hypo during the summer | |

# Carlson's Trophic State Index (TSI)

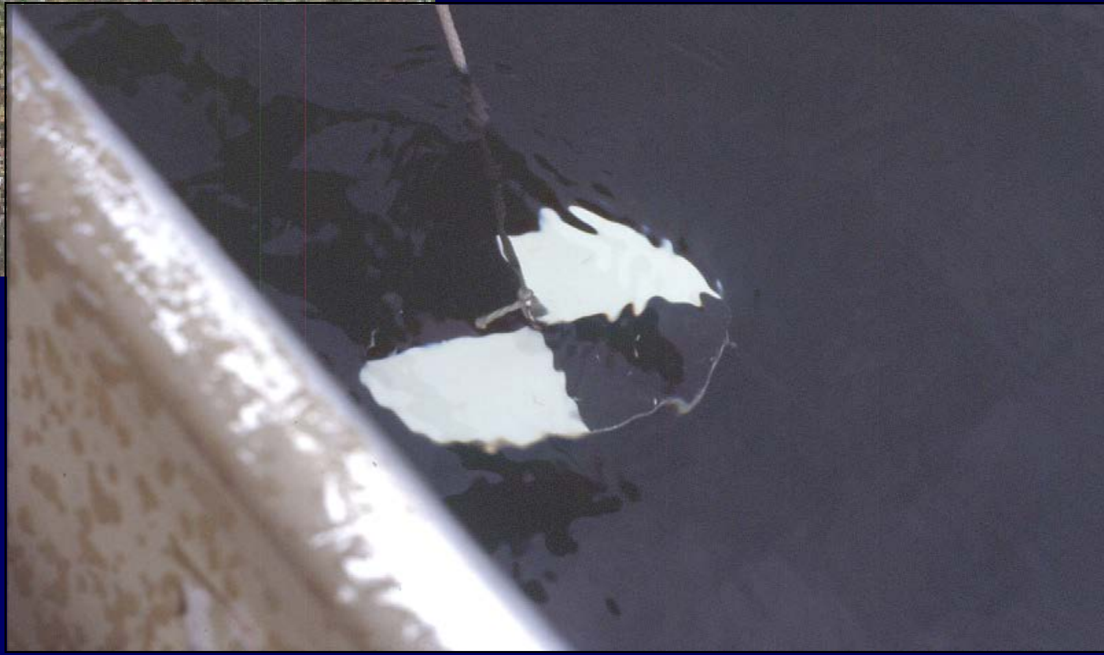


# Cultural Eutrophication

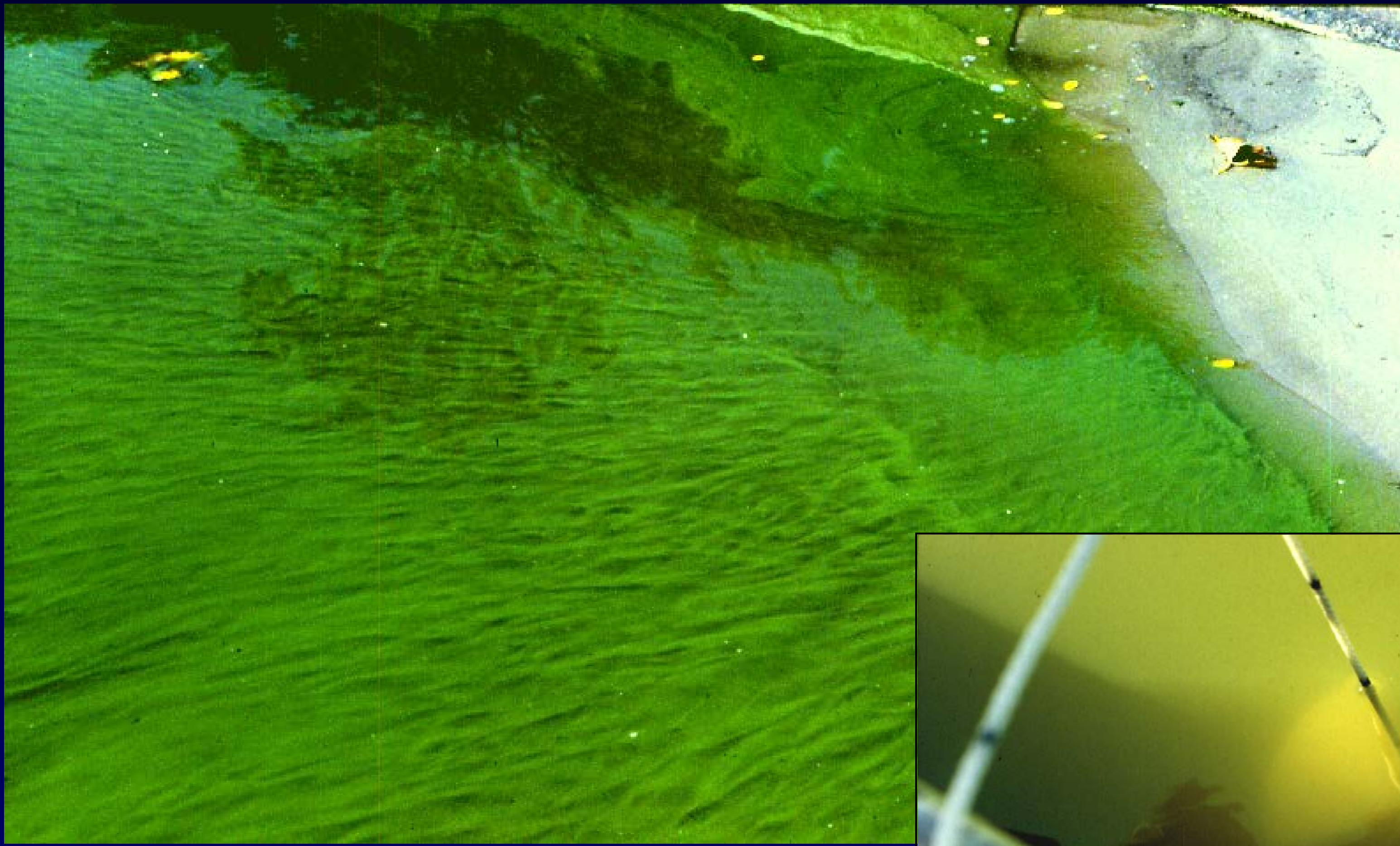
- May take only decades
- Rapid decline caused by human activities

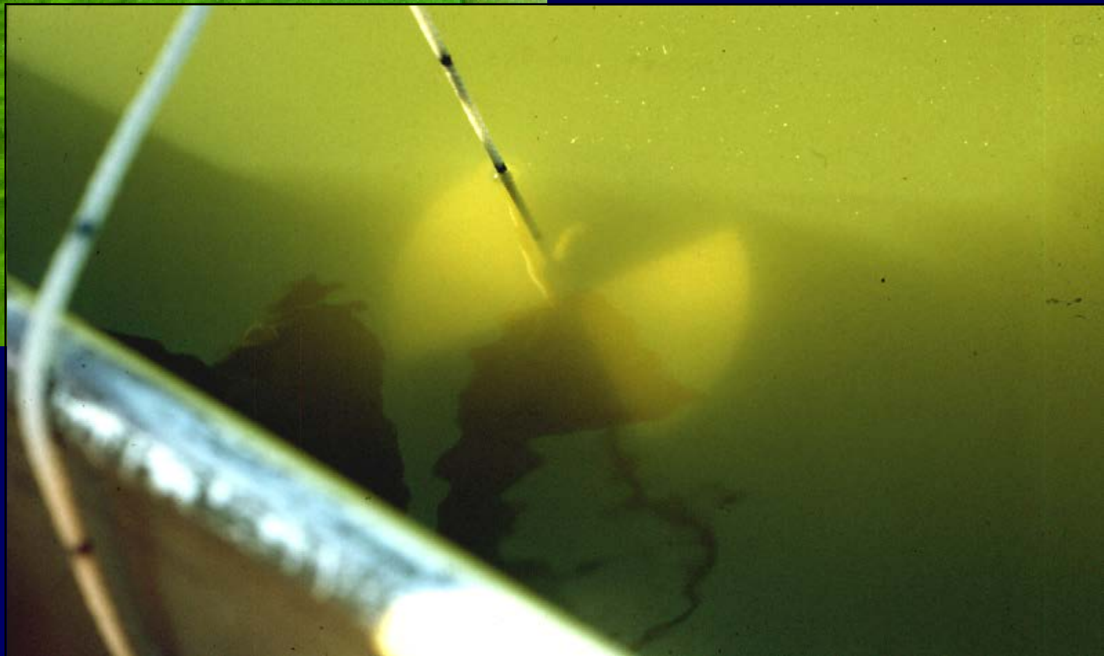


# Plant-dominated lake



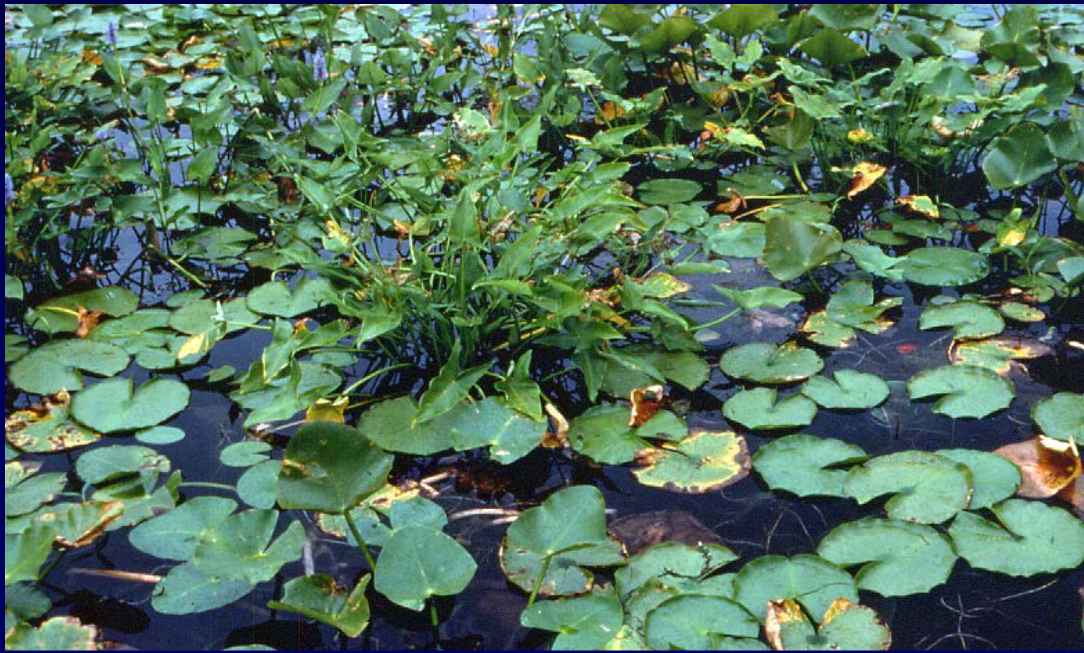
# Algae-dominated lake





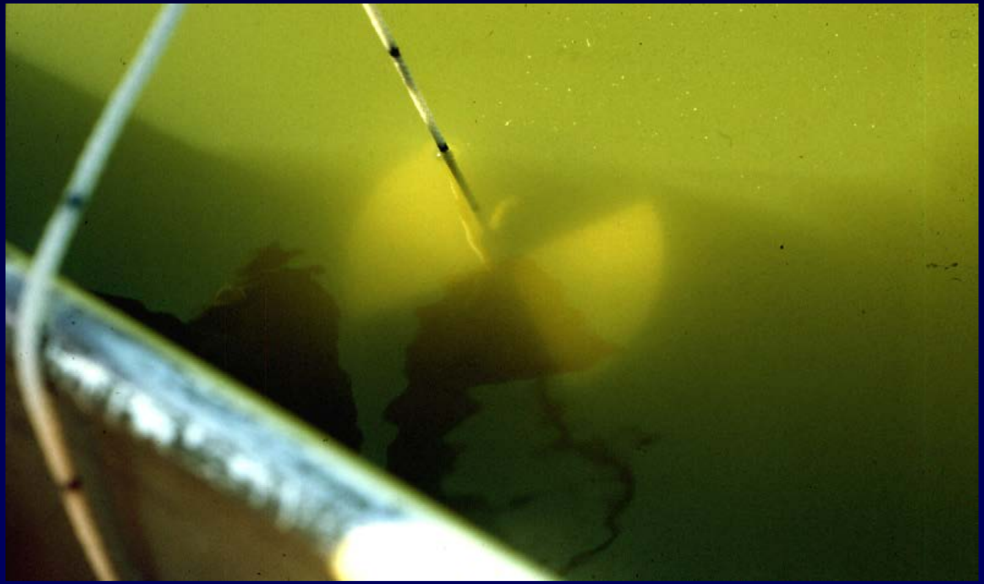
# Why does the ‘plant phase’ persist?

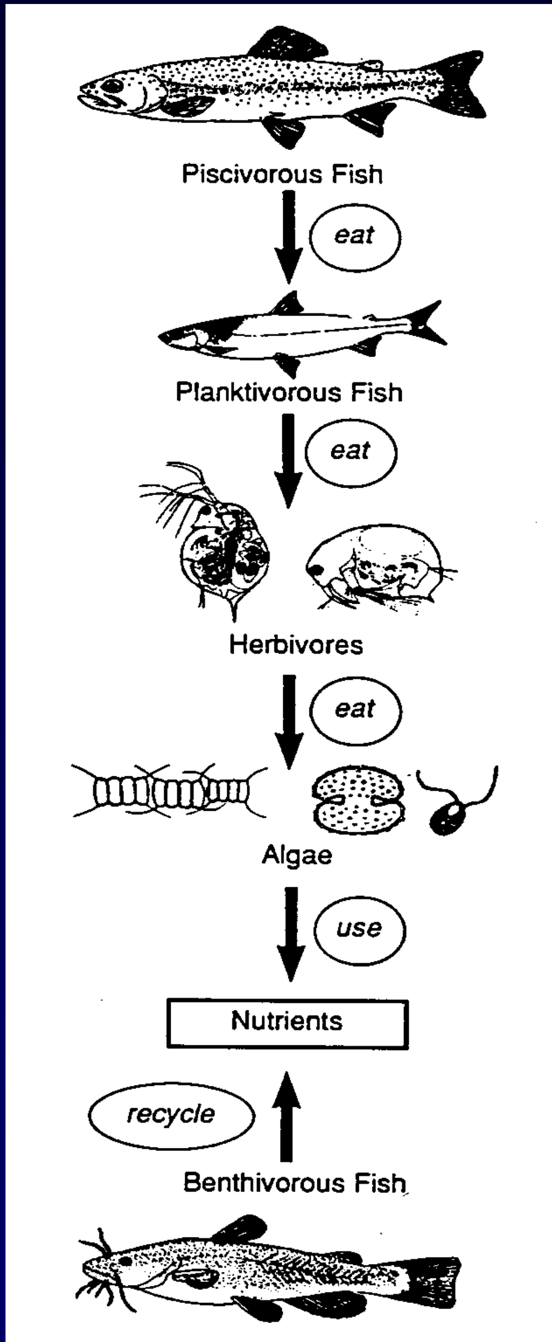
- Tall or emergent plants reach for the light
- Some plants secrete algae inhibitors
- Zooplankton grazers of algae find refuge within the rooted plants
- Rooted plants stabilize the sediments – preventing sediment-disturbing waves
- Few boats operate within the rooted plants



# Why does the algae stage persist?

- Algae shade out rooted plants
- Begin growth earlier in the spring
- Uptake $CO_2$ more efficiently
- Without plants, algal grazers are eaten by fish
- Rough fish such as carp keep water turbid and nutrient-rich






# Lake Management Goal

- Maintaining a healthy ecological balance in our lakes

Depends on:
- physical,
- chemical, and
- biological factors

# Major Demands (Stressors) on Indiana Lakes

- Eutrophication
- Shoreline Development (and Re-development)
- Over Use
- Exotic Species

# Indiana Clean Lakes Program

- Sponsored by Indiana Department of Environmental Management (IDEM)
- Administered by I.U. School of Public and Environmental Affairs (SPEA)
- Created in 1989