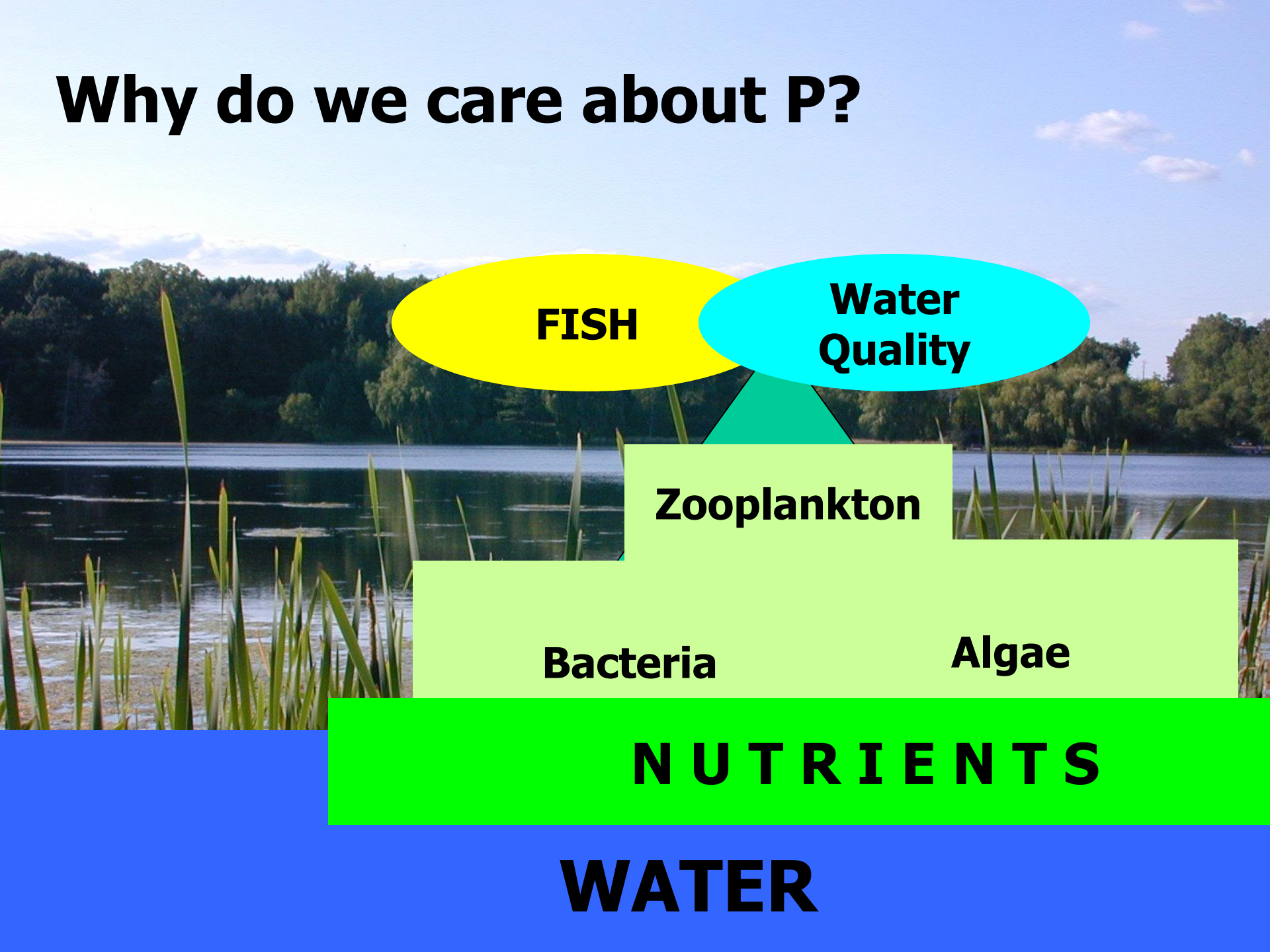

YOU AND PHOSPHORUS
Wisconsin Lake Leaders
2008


Making a Positive Connection Between Land and Lake
Wisconsin Lake Leaders
2008

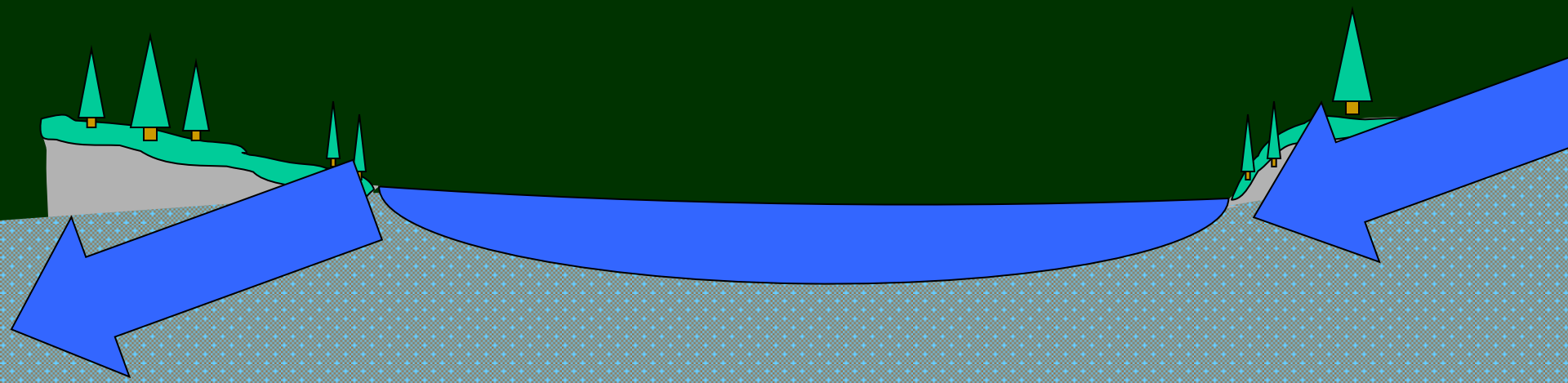
Why do we care about P?



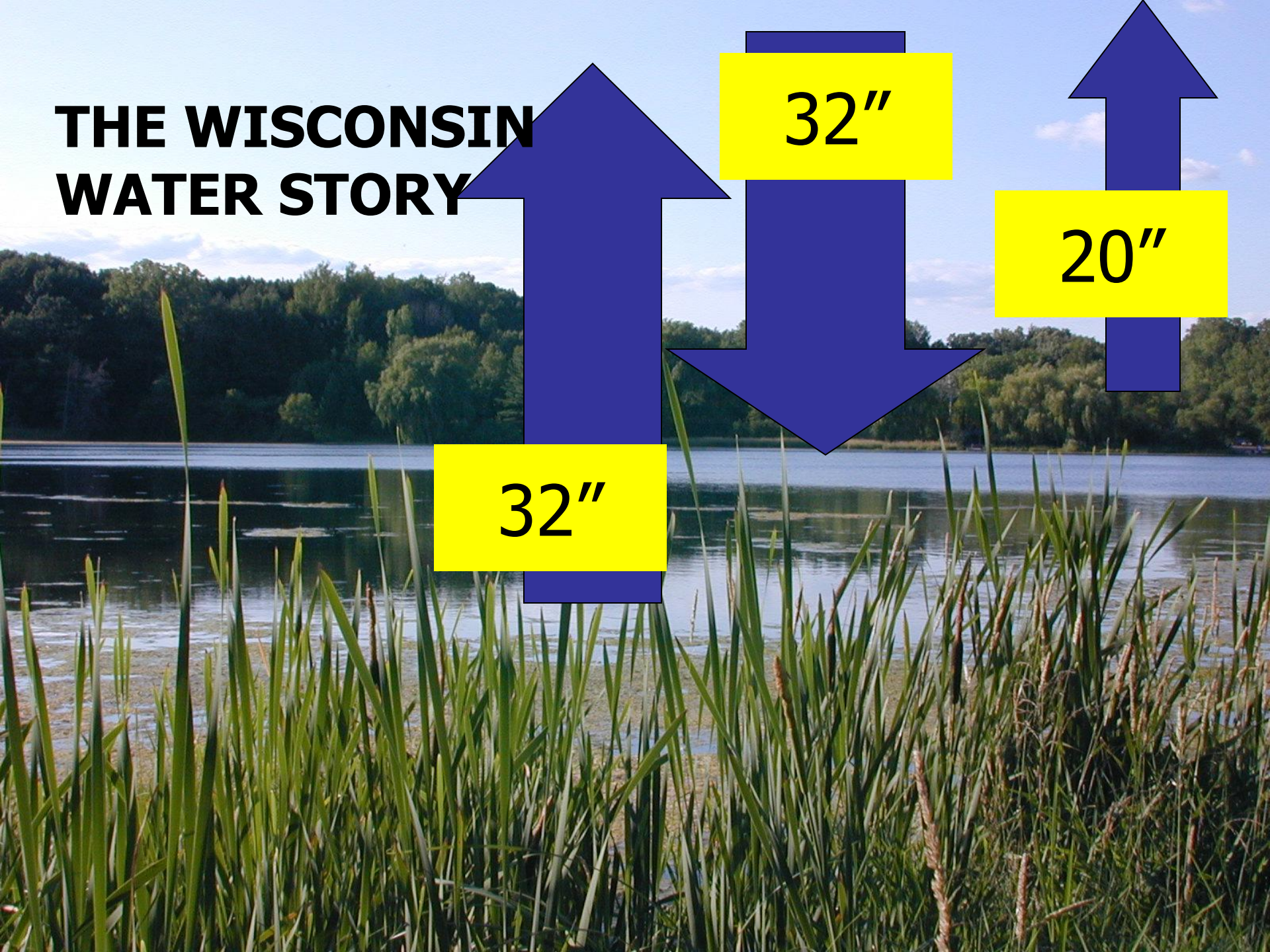
- Add a little extra P to a lake, and you can make a lot of algae…

Phosphorus Concentration (μg/l)	Productivity
10	Low (Oligotrophic)
10-20	Medium (Mesotrophic)
Greater than 20	High (Eutrophic)

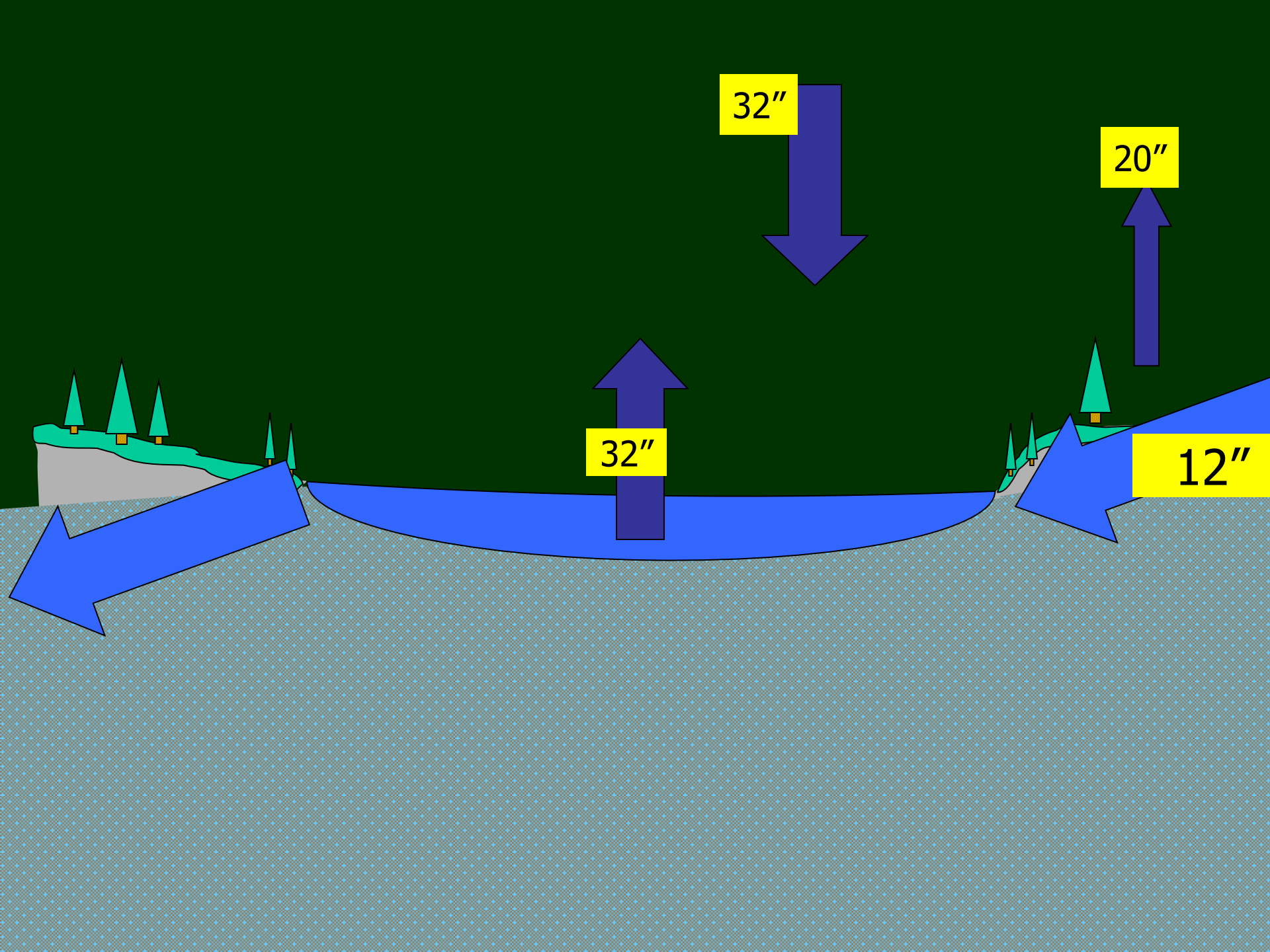
Let’s think about the water!



THE WISCONSIN WATER STORY

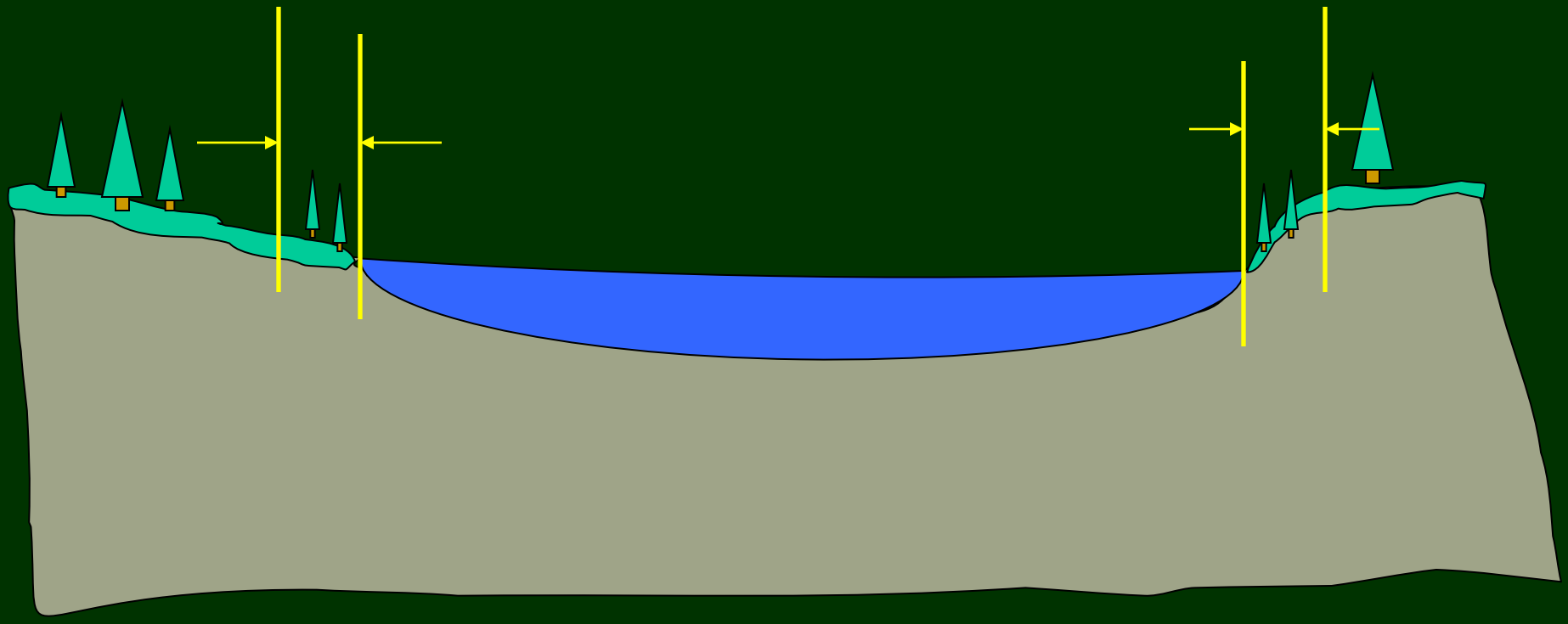



NET
WATER BUDGET
12″


32″
20″
32″
12″


Do you see any
phosphorus here?

Assume a 300’ shoreline zone
And 300 acre lake…

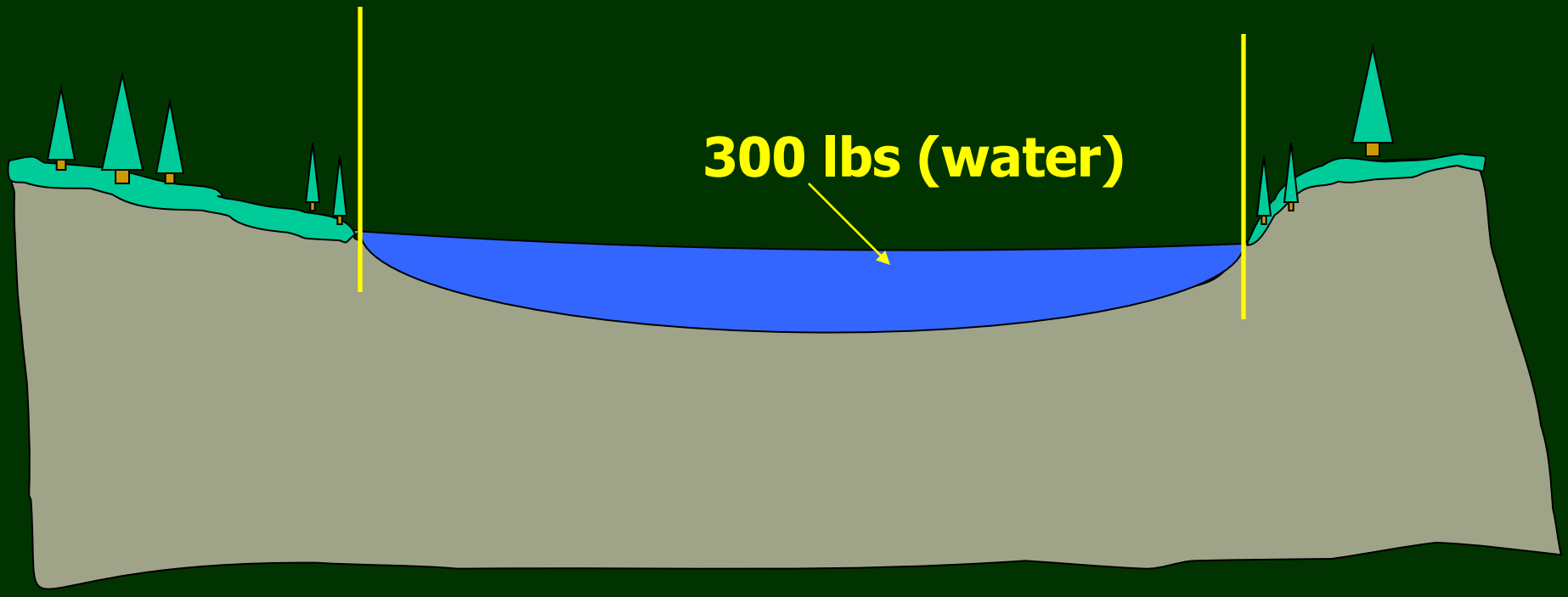


Likens and Bormann, 1995 (Biogeochemistry Of a Forested Ecosystem);
Schlesinger, 1991 (Biogeochemistry);
Wetzel, 2001 (Limnology).

- 300 acre
- 25’ mean depth
- 15 ug/l TP

- 300 acre
- Circular Lake
- 200 mg/kg soil P
- 100 lb/acre P

How much phosphorus in the Lake?



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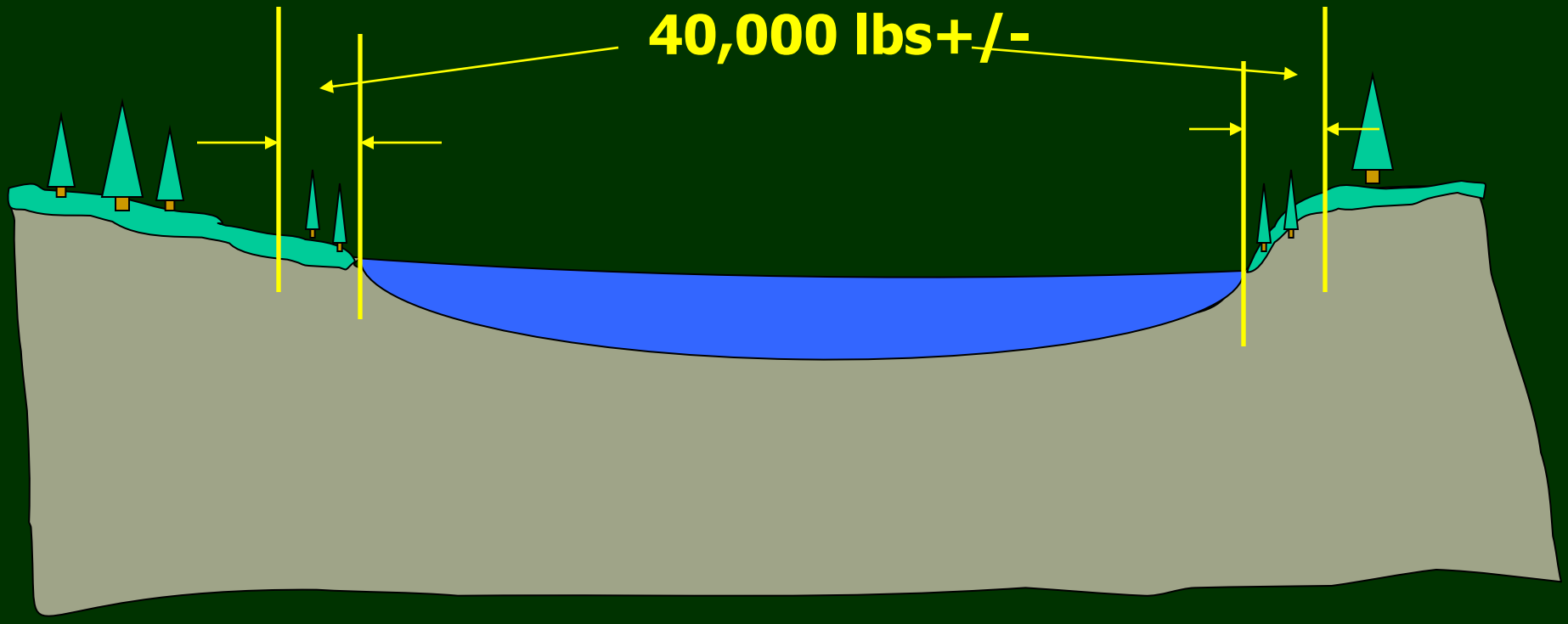
How much phosphorus in the Land?



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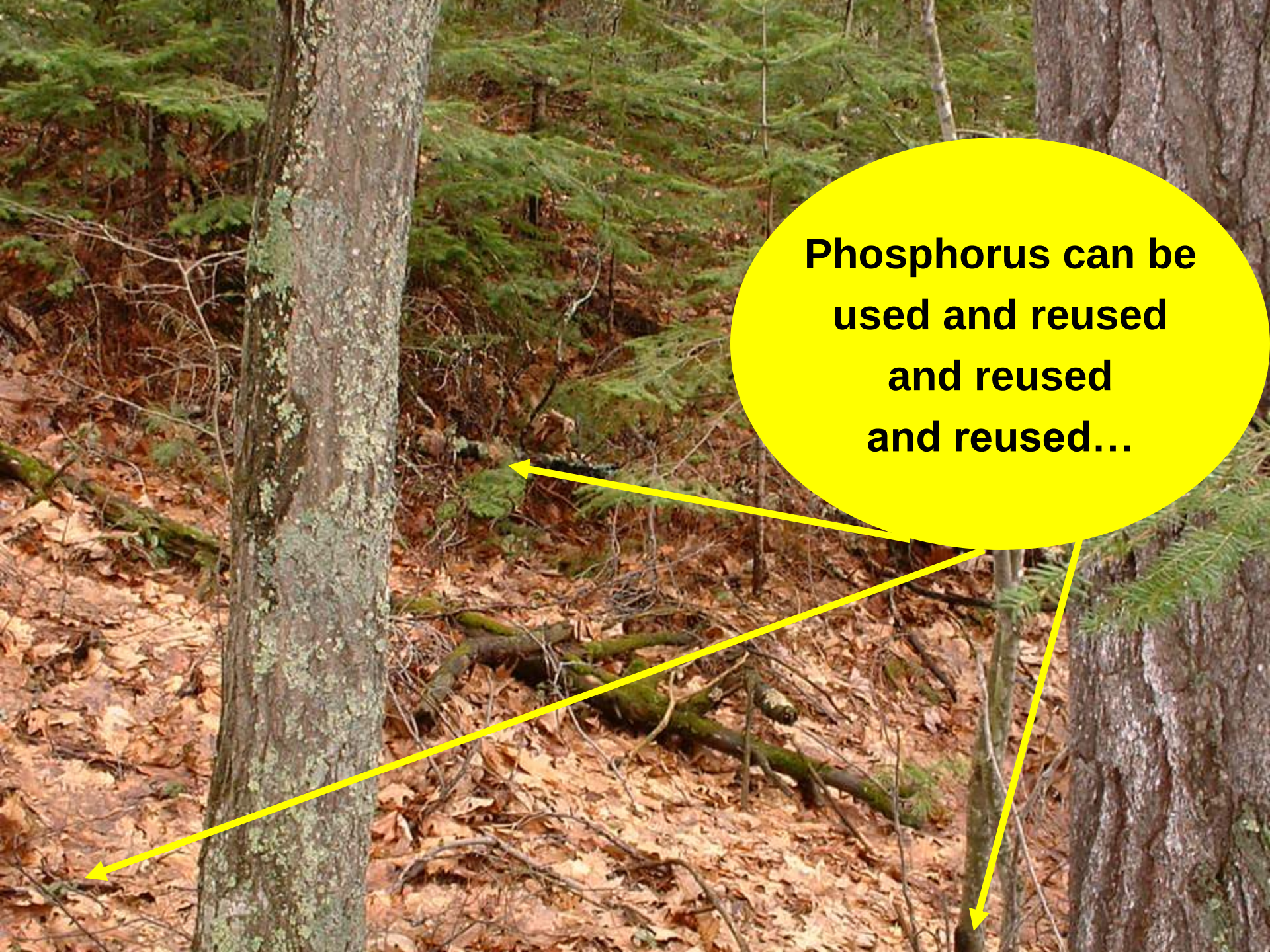
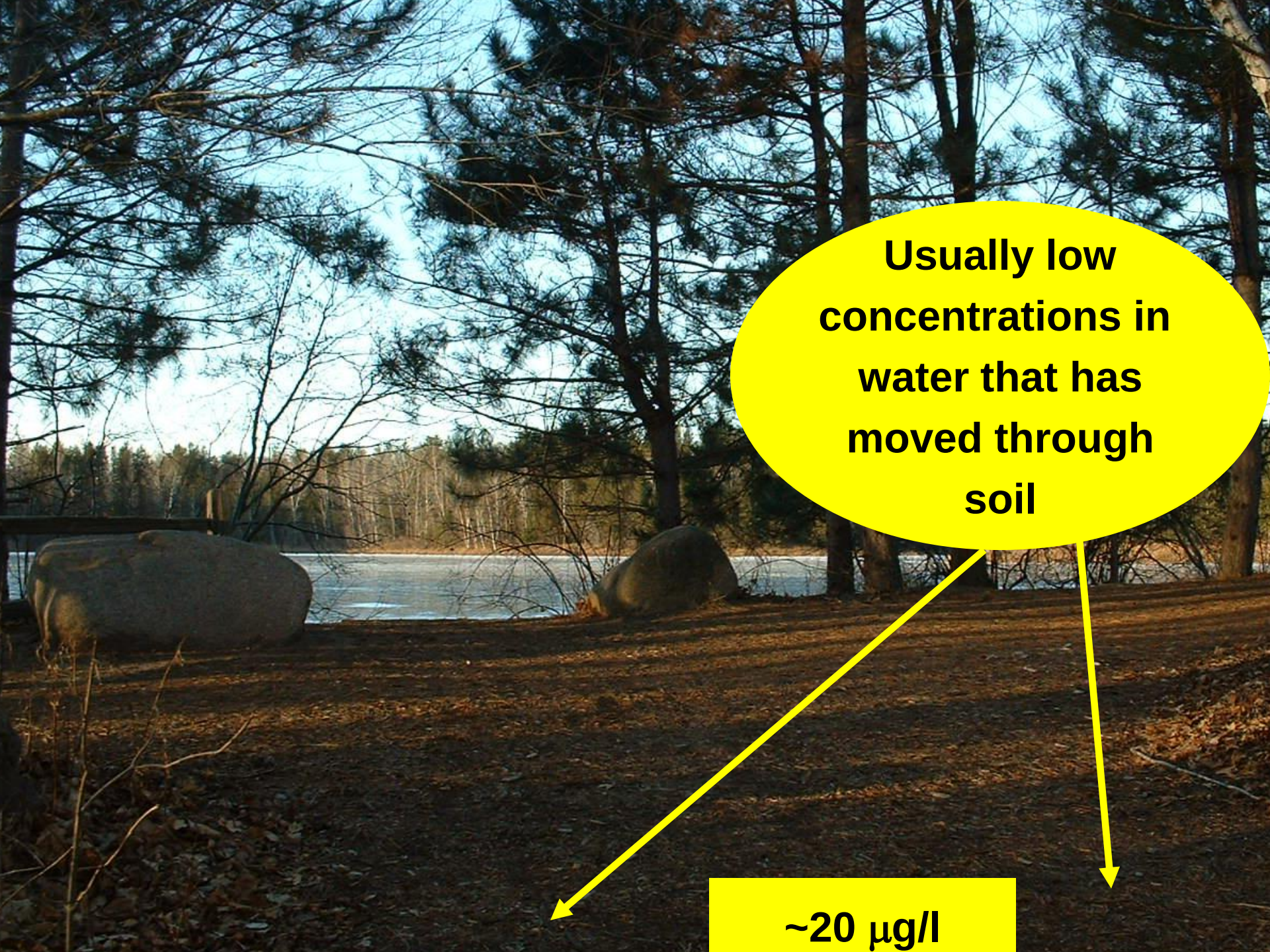

Phosphorus can be
used and reused
and reused
and reused…


Usually low concentrations in water that has moved through soil
~20 µg/l


Water running
Off the land
Has much higher
concentrations
~1000 µg/l

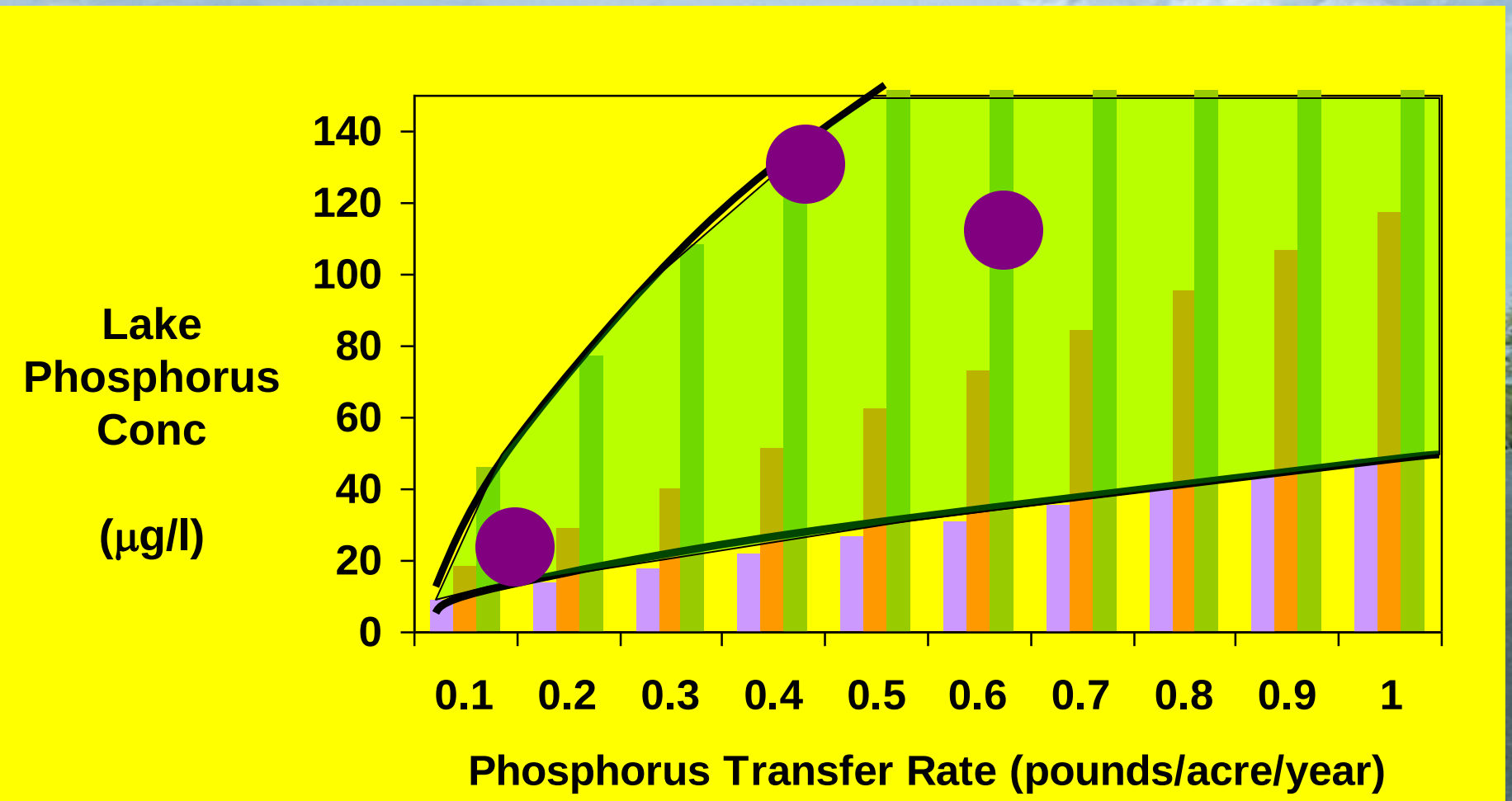
USGS
science for a changing world

In cooperation with the Wisconsin Department of Natural Resources

Hydrology, Nutrient Concentrations, and Nutrient Yields in Nearshore Areas of Four Lakes in Northern Wisconsin, 1999–2001

Water-Resources Investigations Report 03-4144

- **Lots of phosphorus in soils & vegetation**
- **Lots of water moving through land to water**
- **Amount of phosphorus transferred depends on the path the water takes**
  - Direct, surface runoff conveys much more phosphorus than infiltrating water


Lake Phosphorus Conc
(µg/l)
140
120
100
80
60
40
20
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Phosphorus Transfer Rate (pounds/acre/year)

How do we increase P transfer?

- Impervious surfaces
- Compact soil
- Open/bare soil
- Shape to the lake and stream

How do we increase P transfer?

- Impervious surfaces
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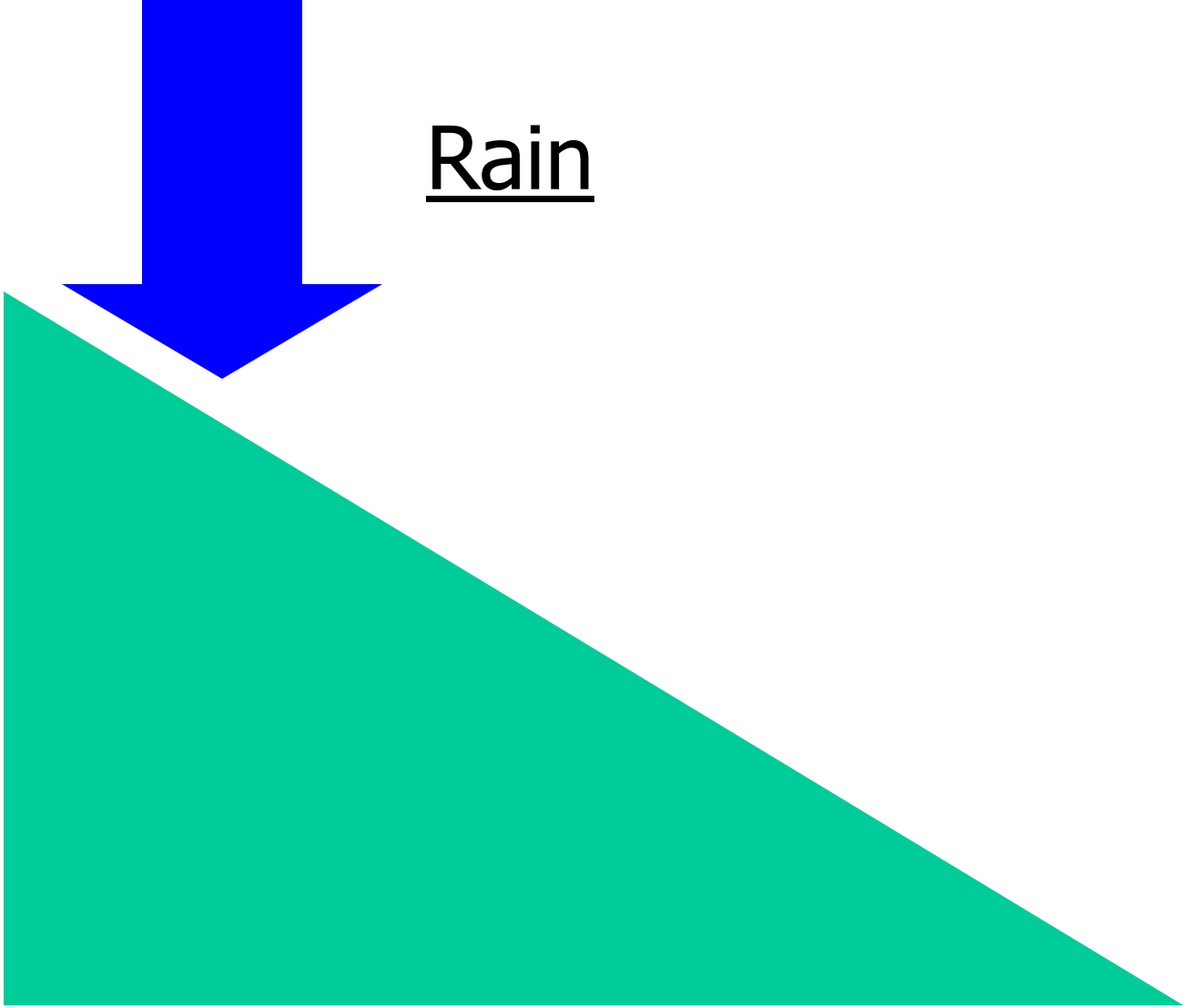
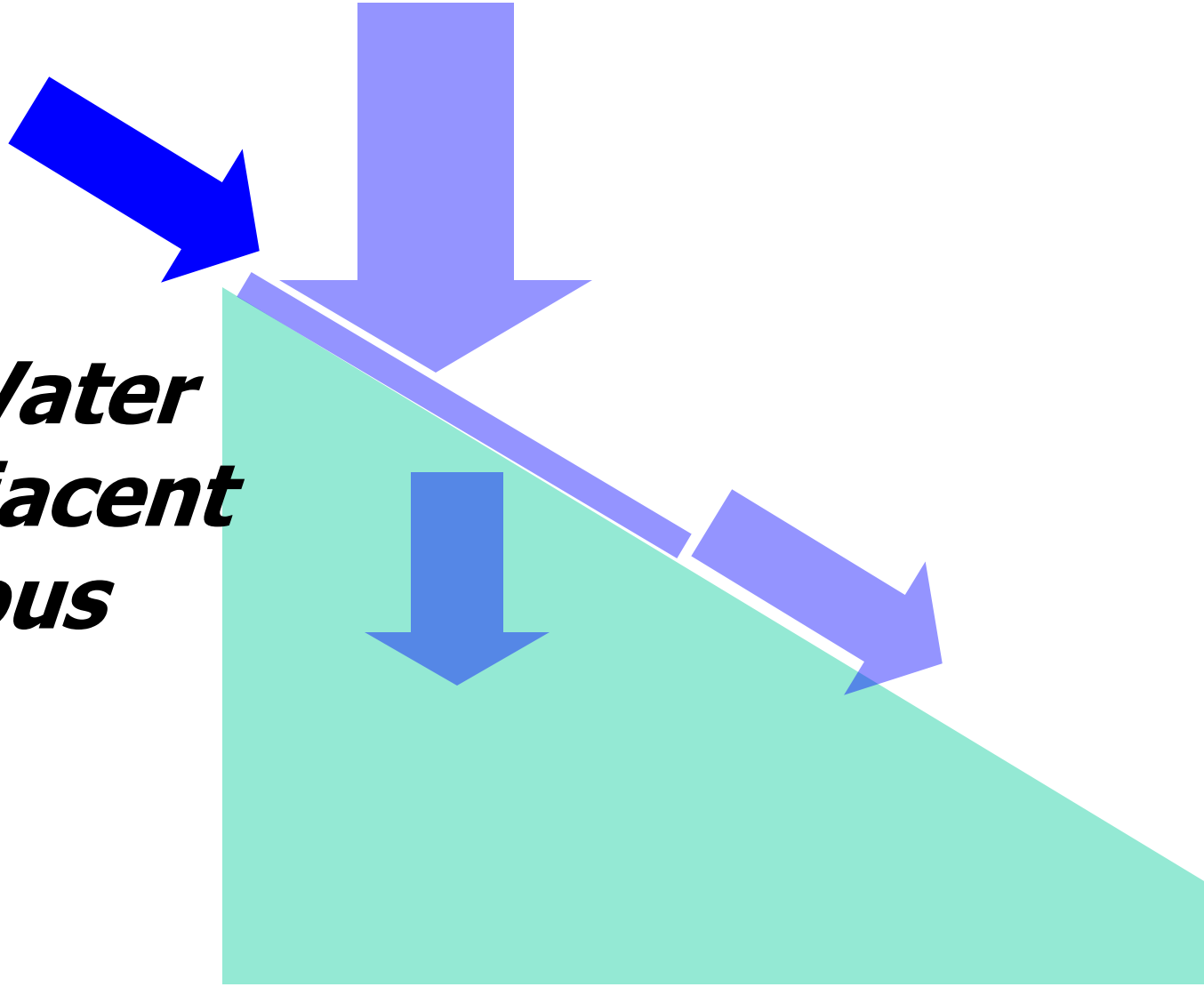
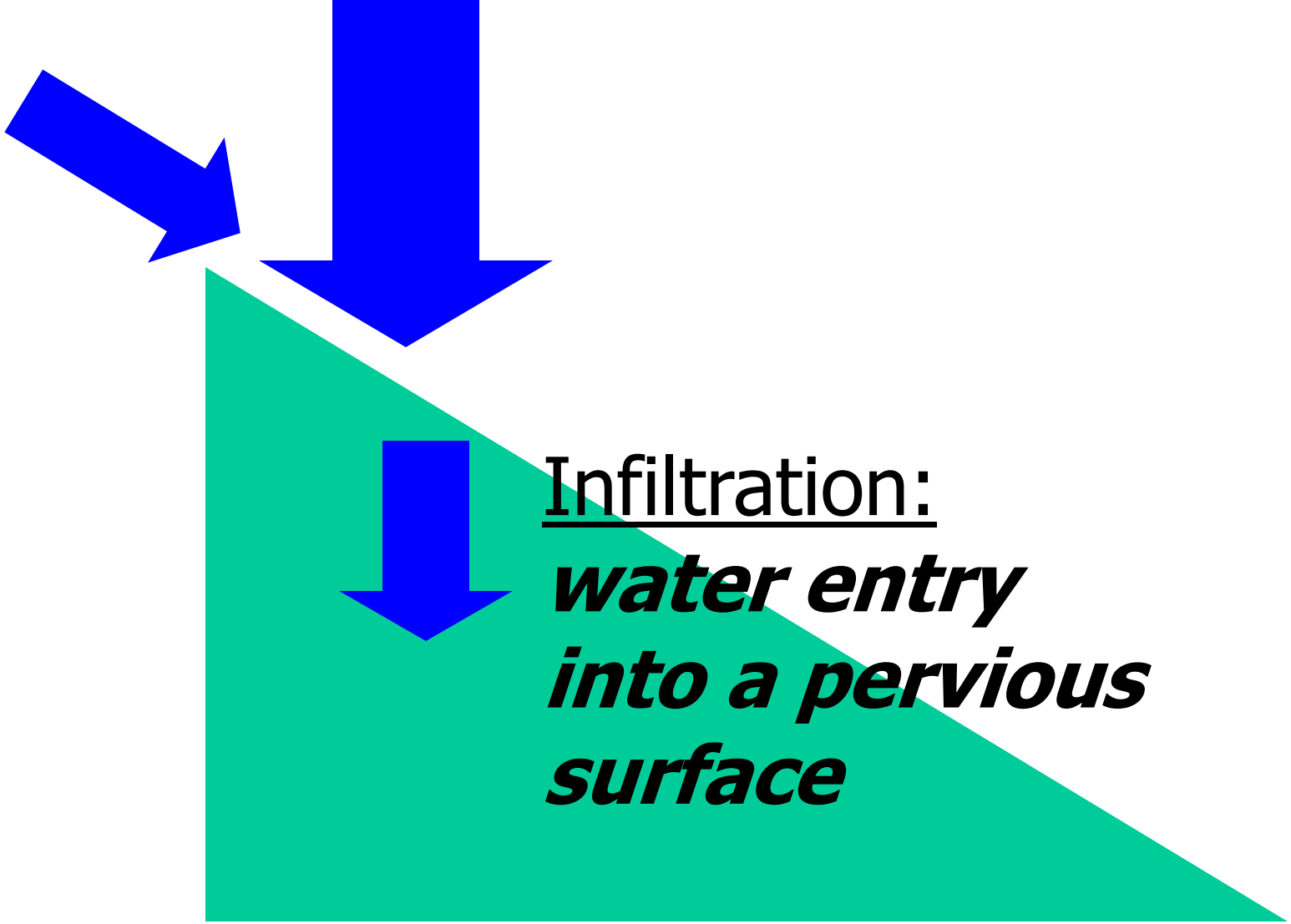
Let's Follow the Water…

Rain



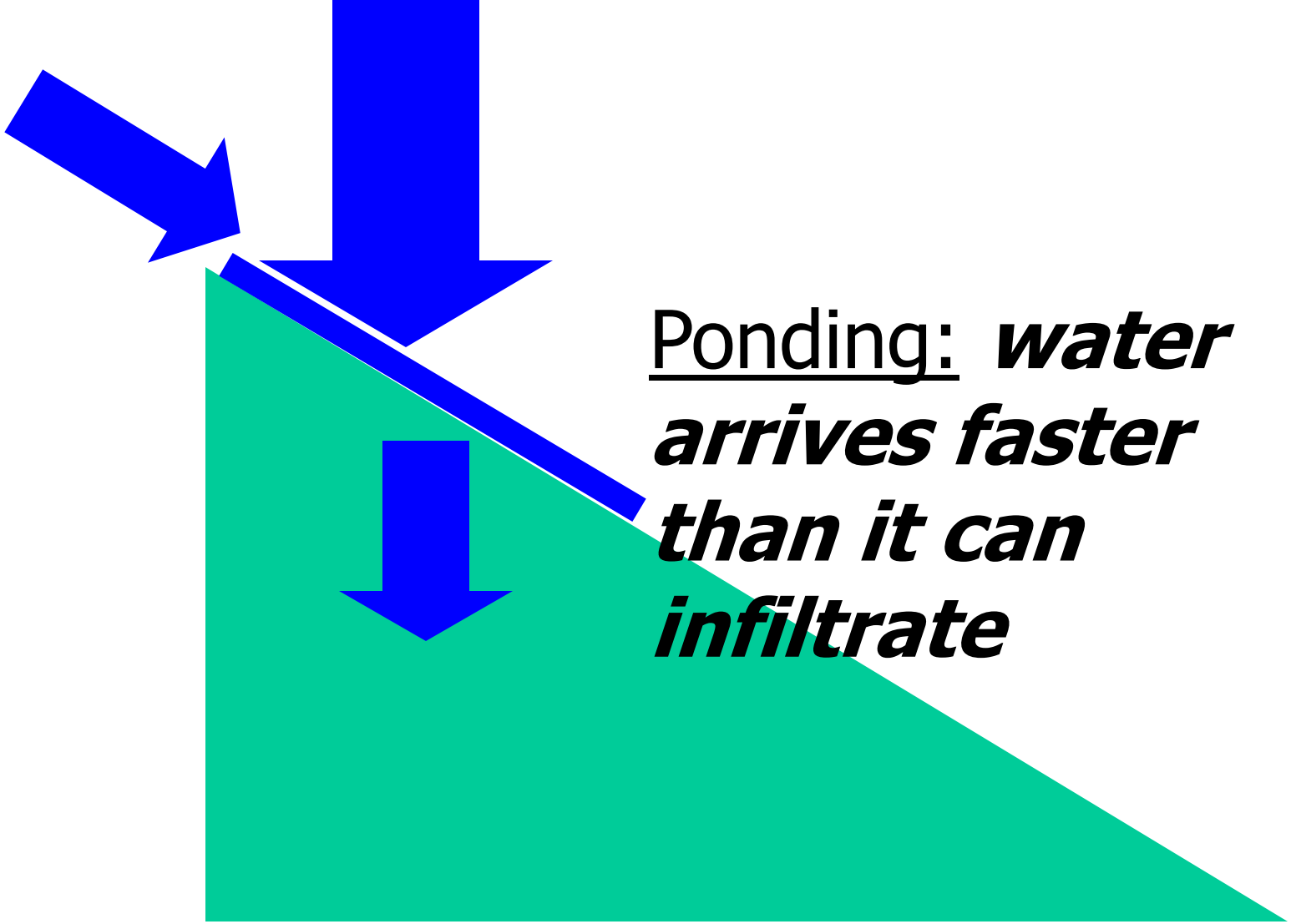
Runon: ***Water from adjacent impervious surfaces***



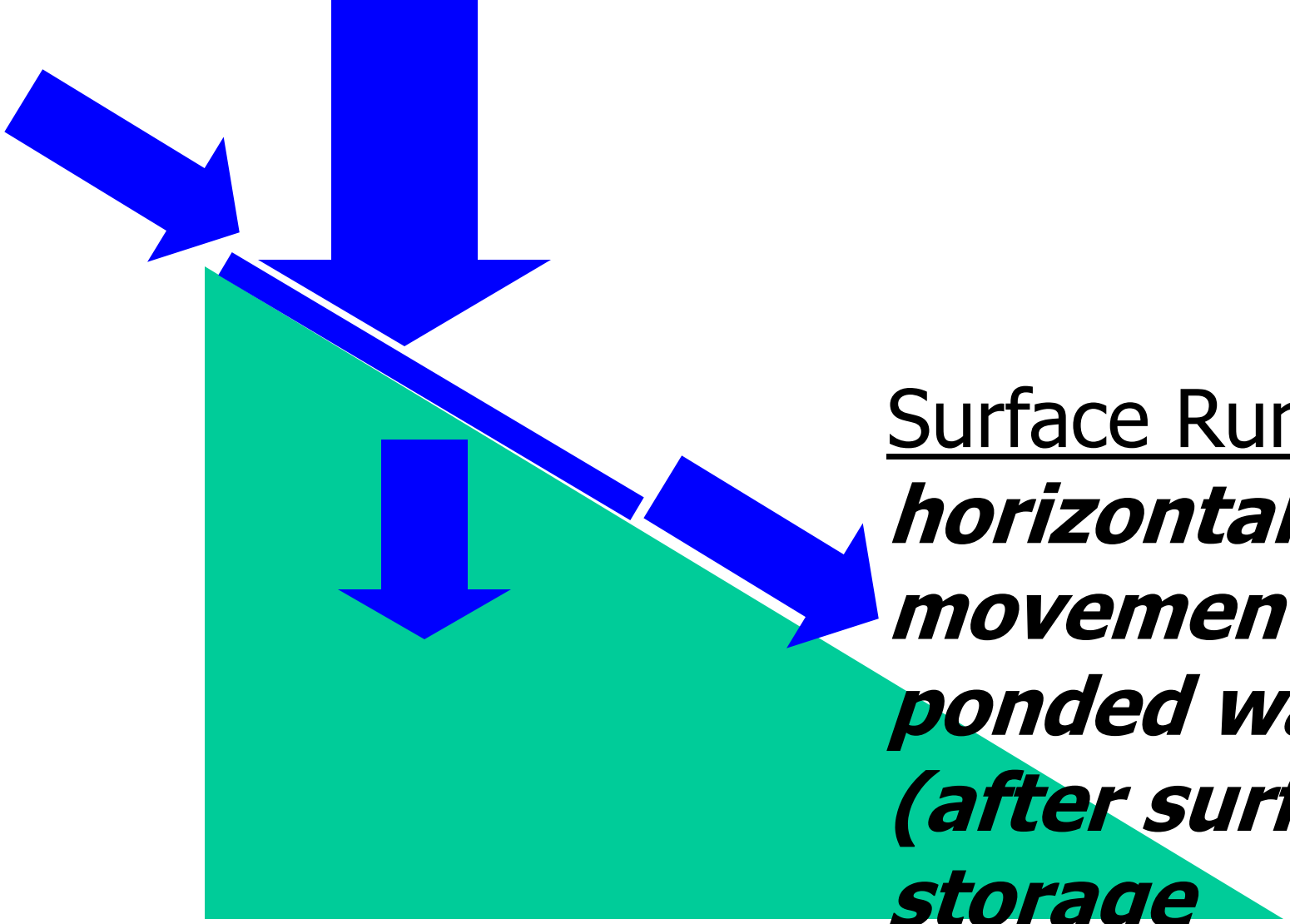


Infiltration:

water entry into a pervious surface



Ponding: ***water arrives faster than it can infiltrate***



Surface Runoff:

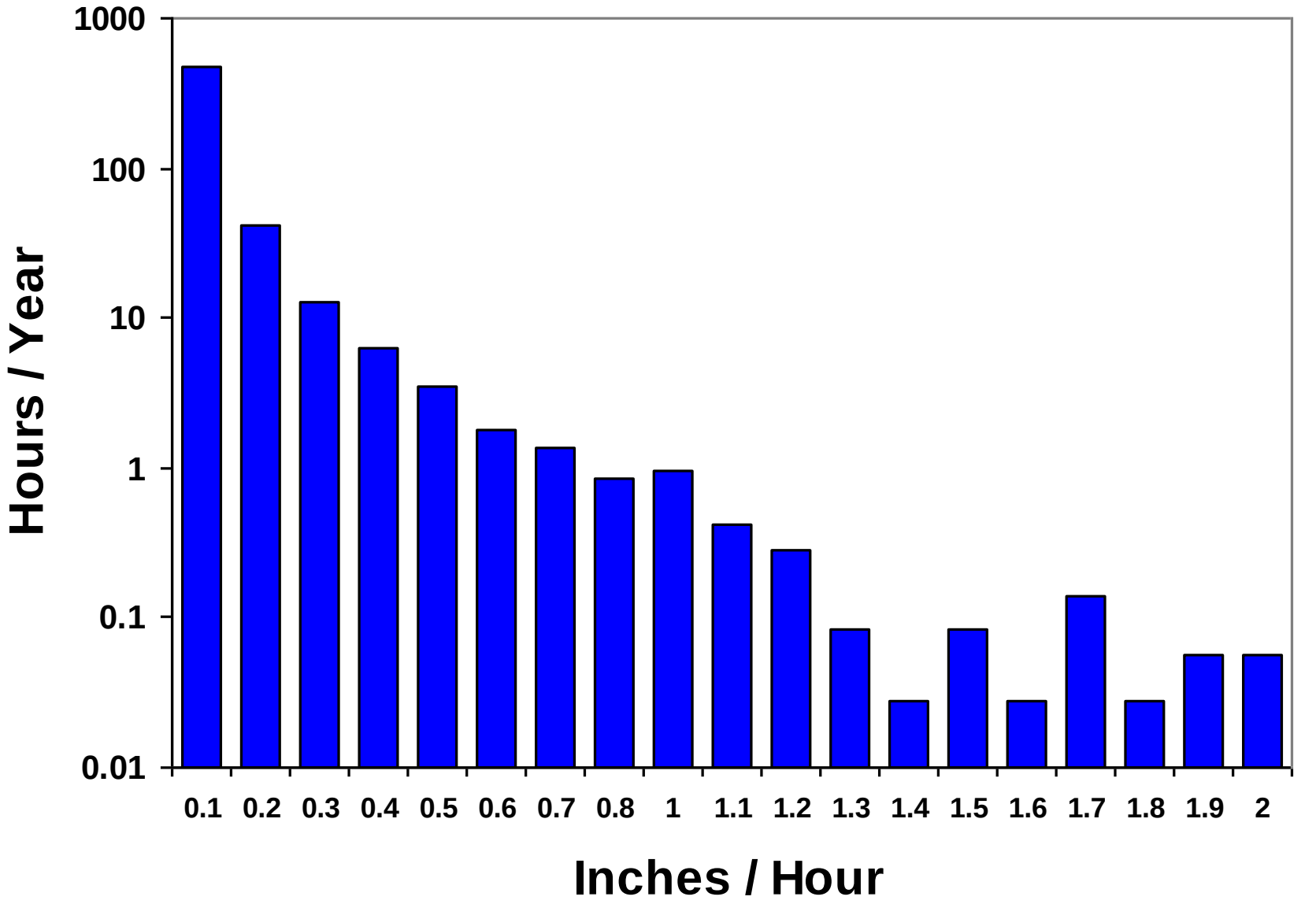
horizontal movement of ponded water (after surface storage satisfied)

The Rain

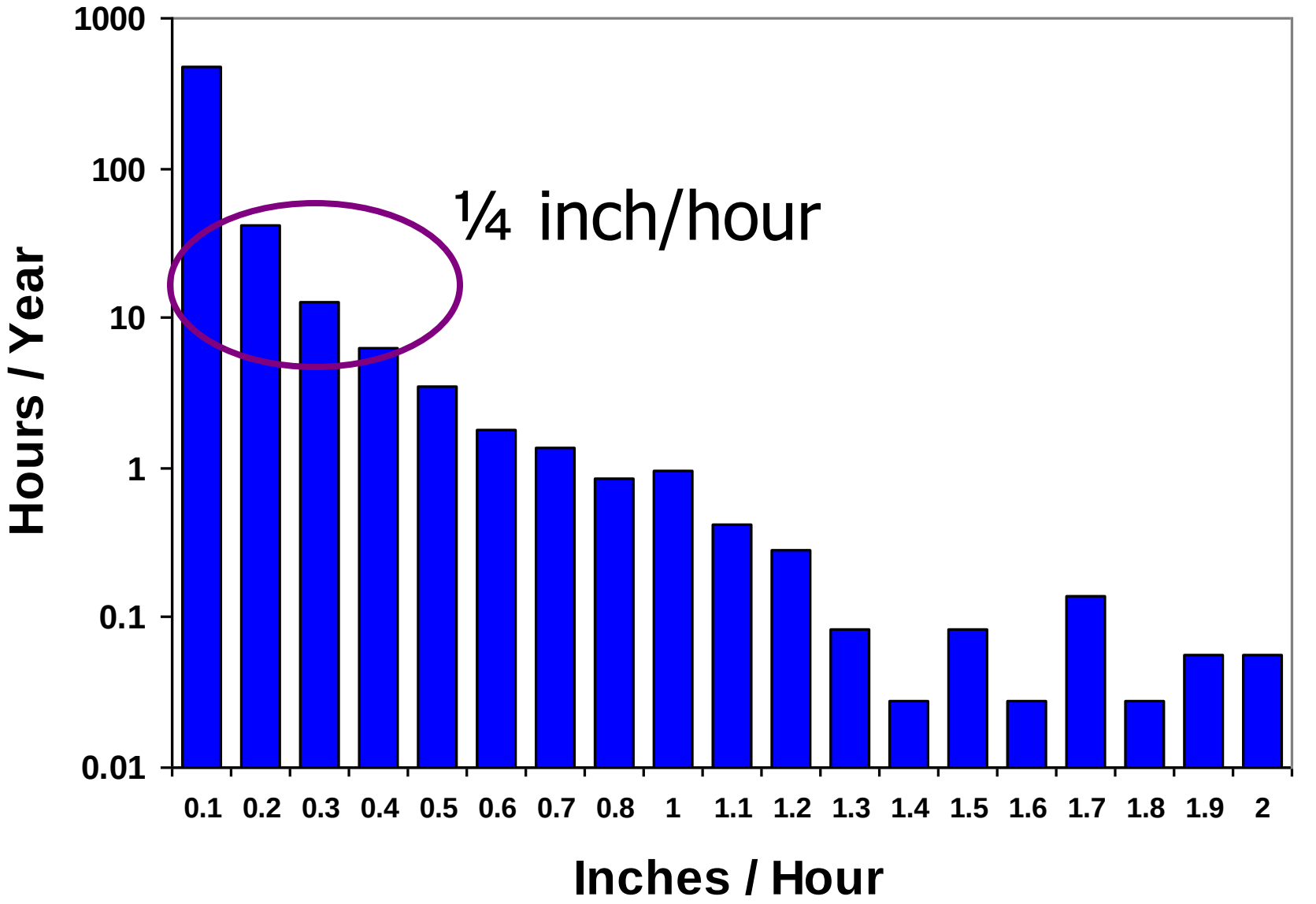
32 Inches per Year +/-

100 storms per year +/-

500 hours of precipitation (>trace) per year +/-



Based on P8 hourly rainfall
File for 36 years, Madison



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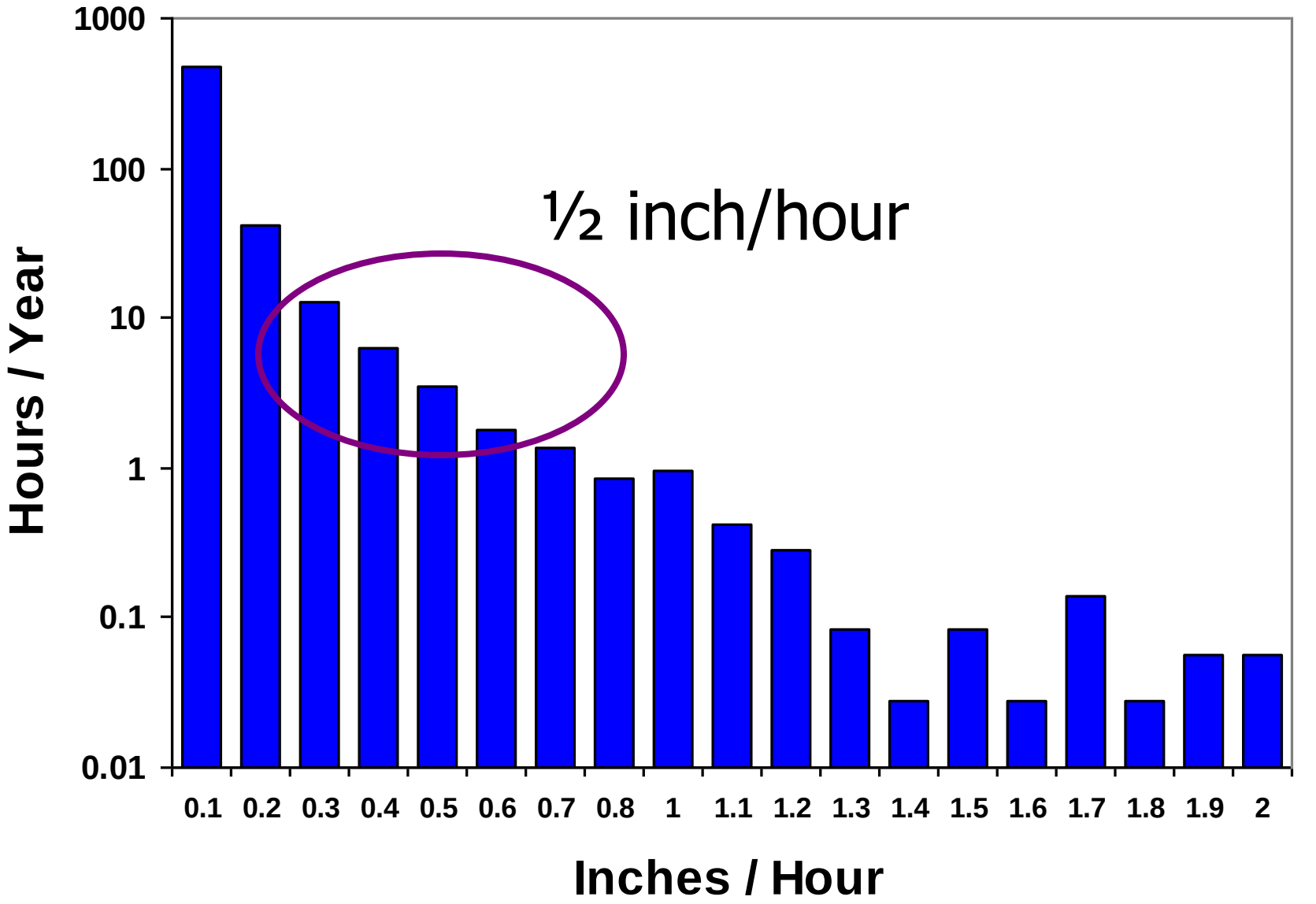

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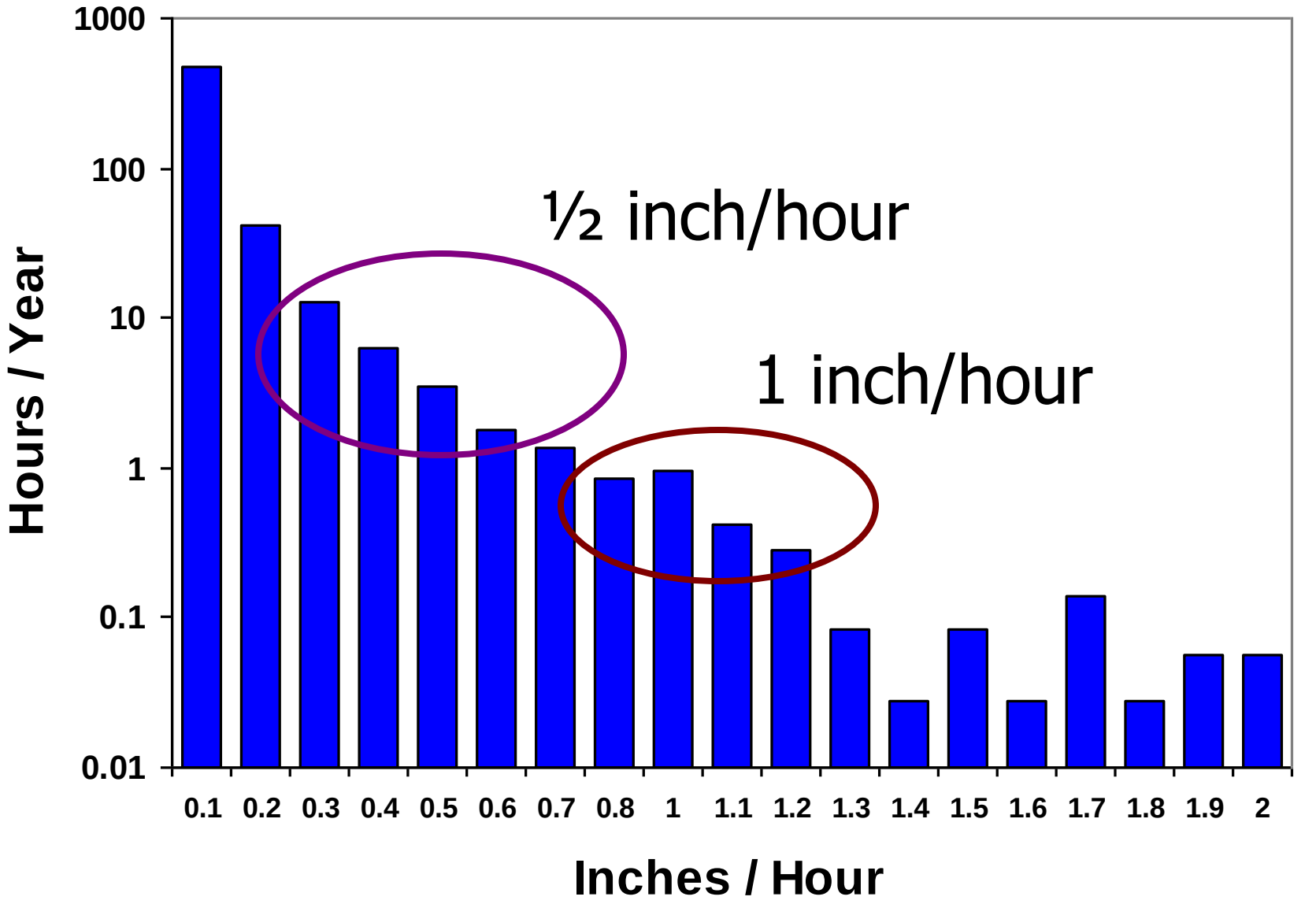

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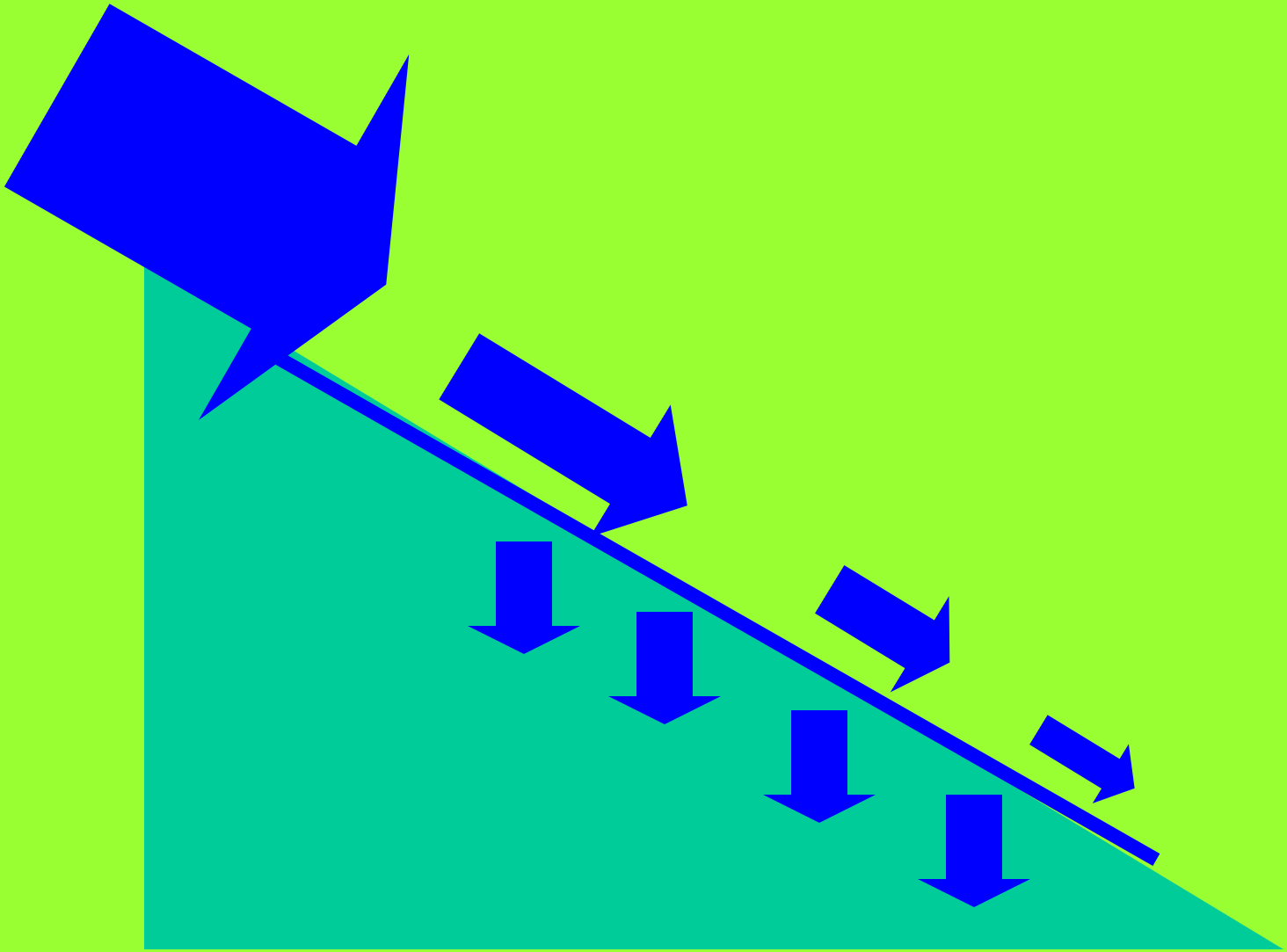
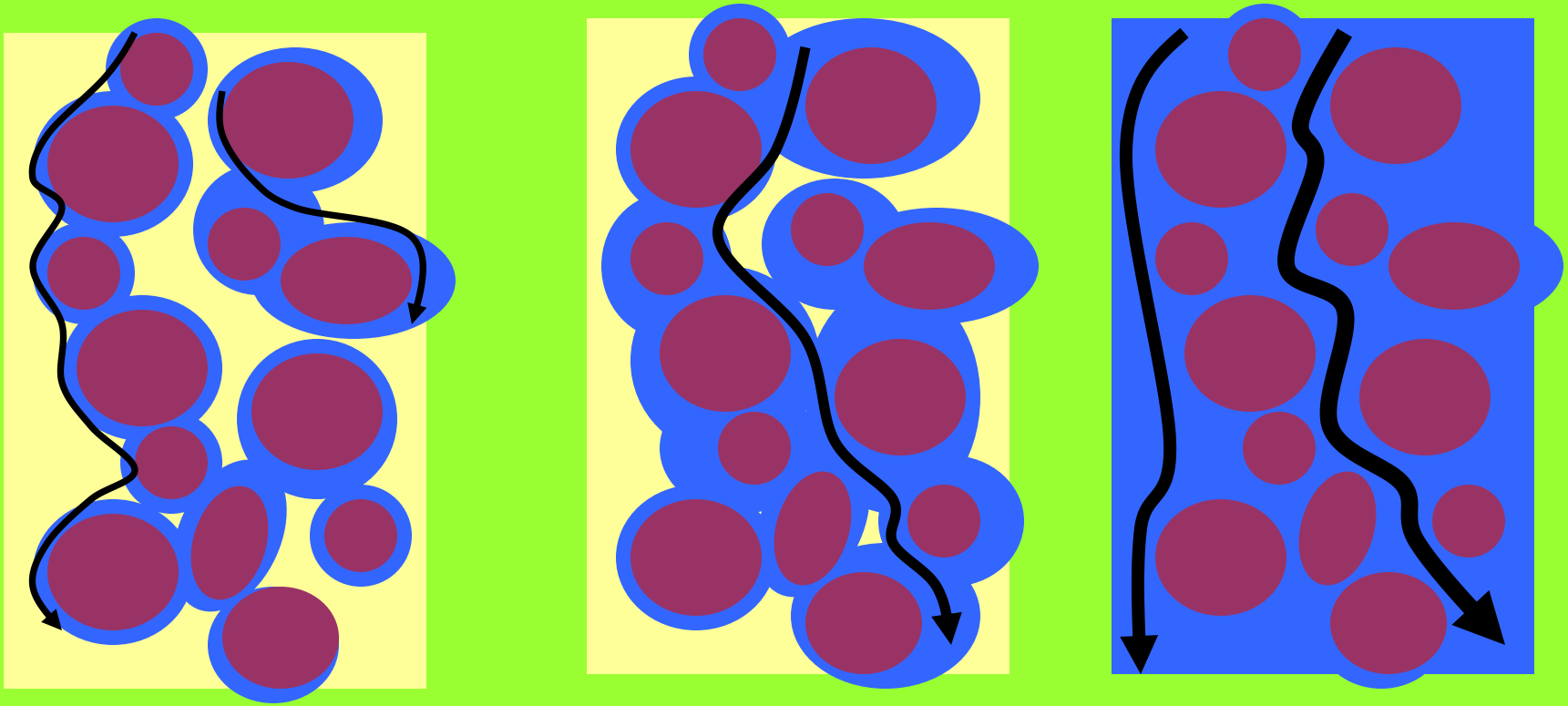


Water Infiltration & Movement

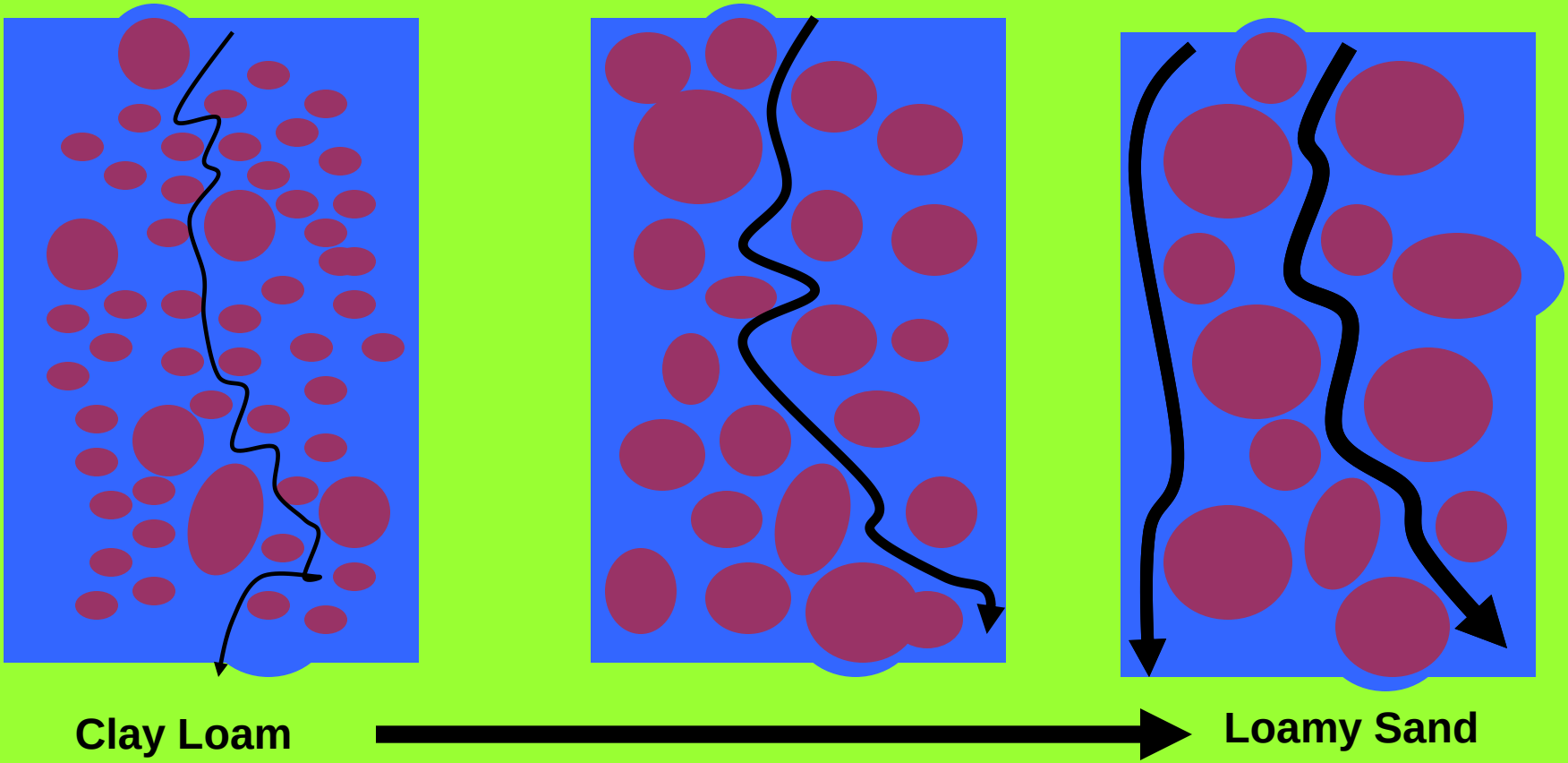
At higher moisture contents, more (..most) of the water is moving in the larger openings (pores)



Low Moisture → High Moisture

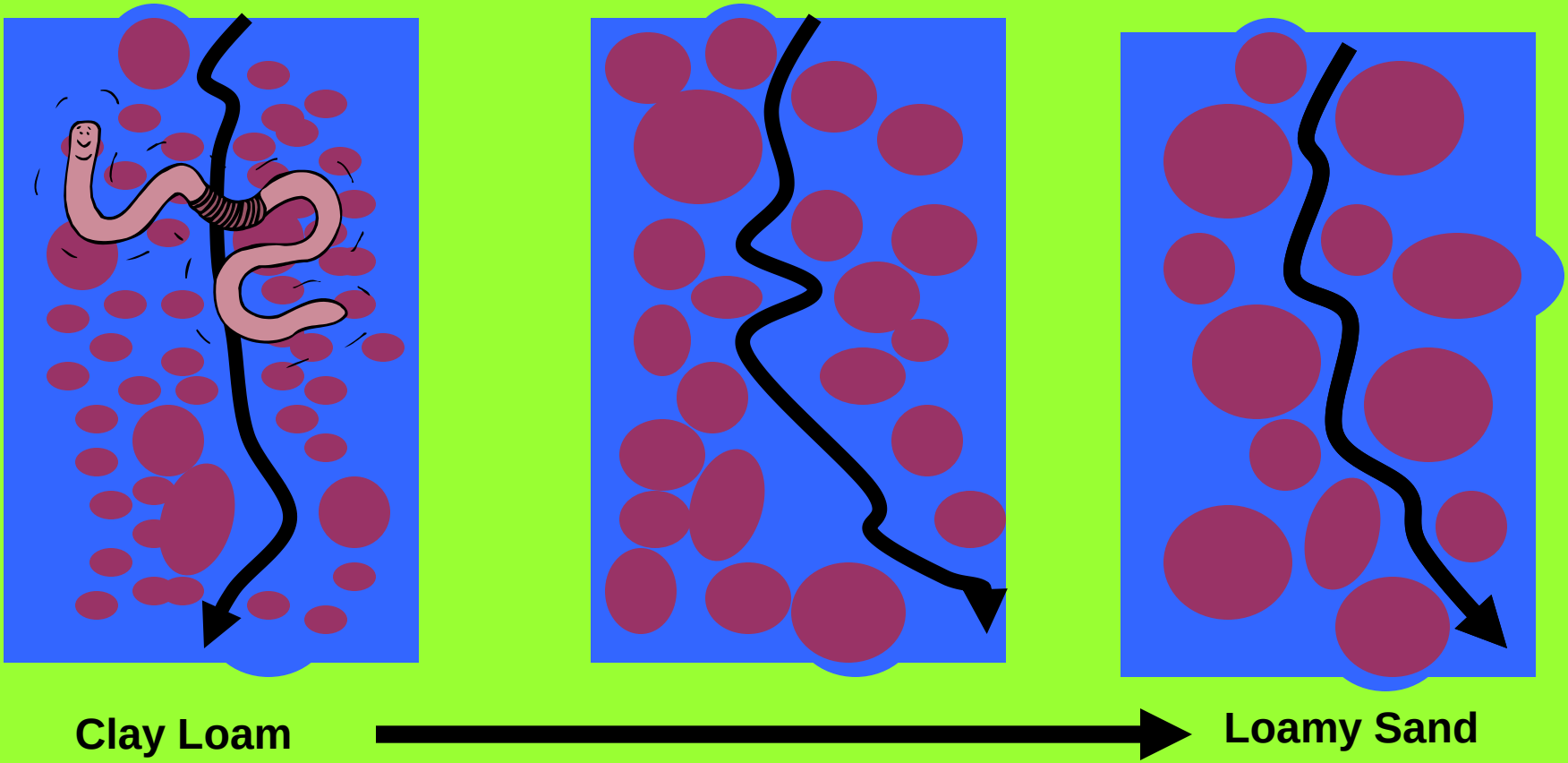
Pore Size and Texture

Coarse soils can have more larger pores



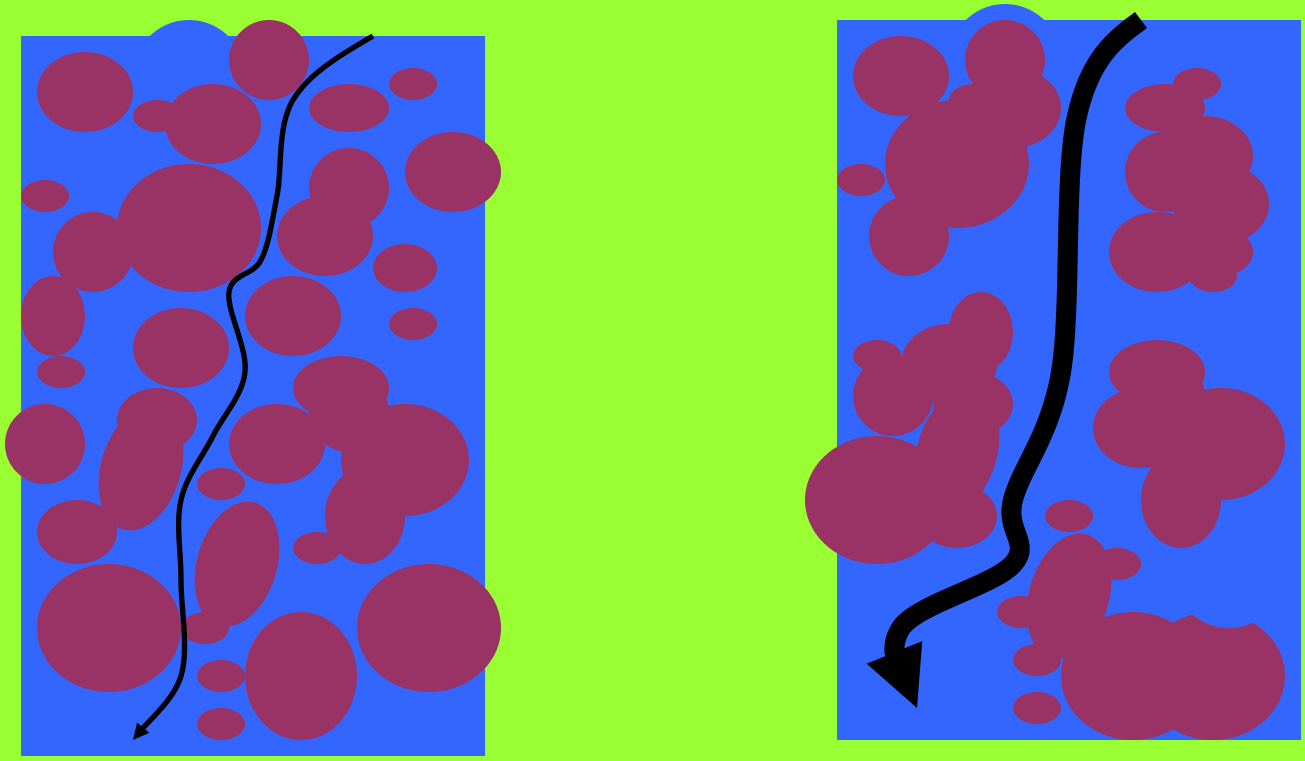
Pore Sizes: Macropores

When very large pores are present (“macropores”),
They can dominate flow at high moisture content



Soil Structure

Aggregations of soil particles with larger openings between



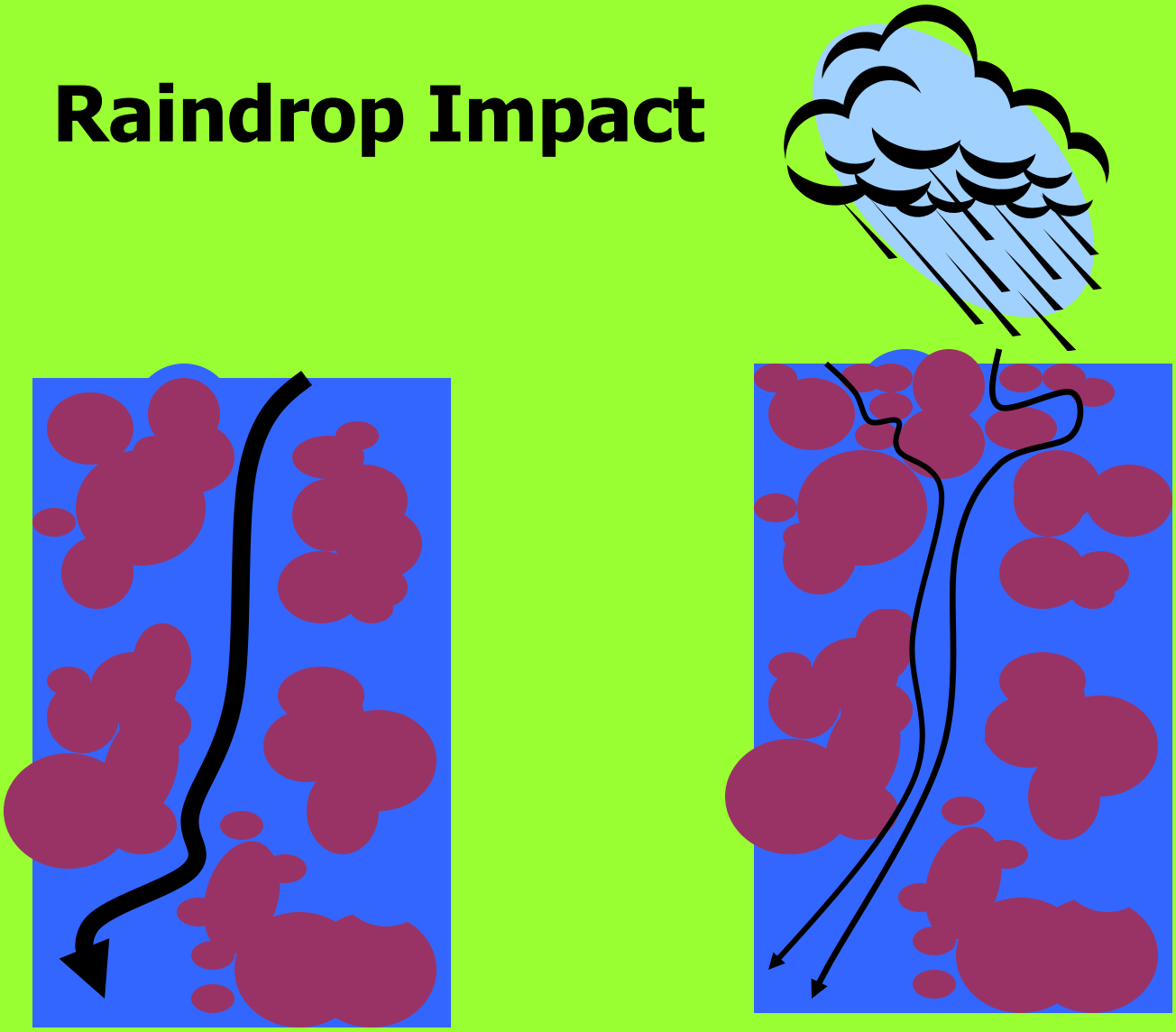
Less Structure → **More Structure**

Example Infiltration Rates

- **Sand**
  - **2 to more than 10 inches/hour**
- **Silt Loam**
  - **0.2 inches/hour to 1 inch/hour**
- **Clay**
  - **0.03 to 0.3 inch/hour**

Reducing Infiltration Rates

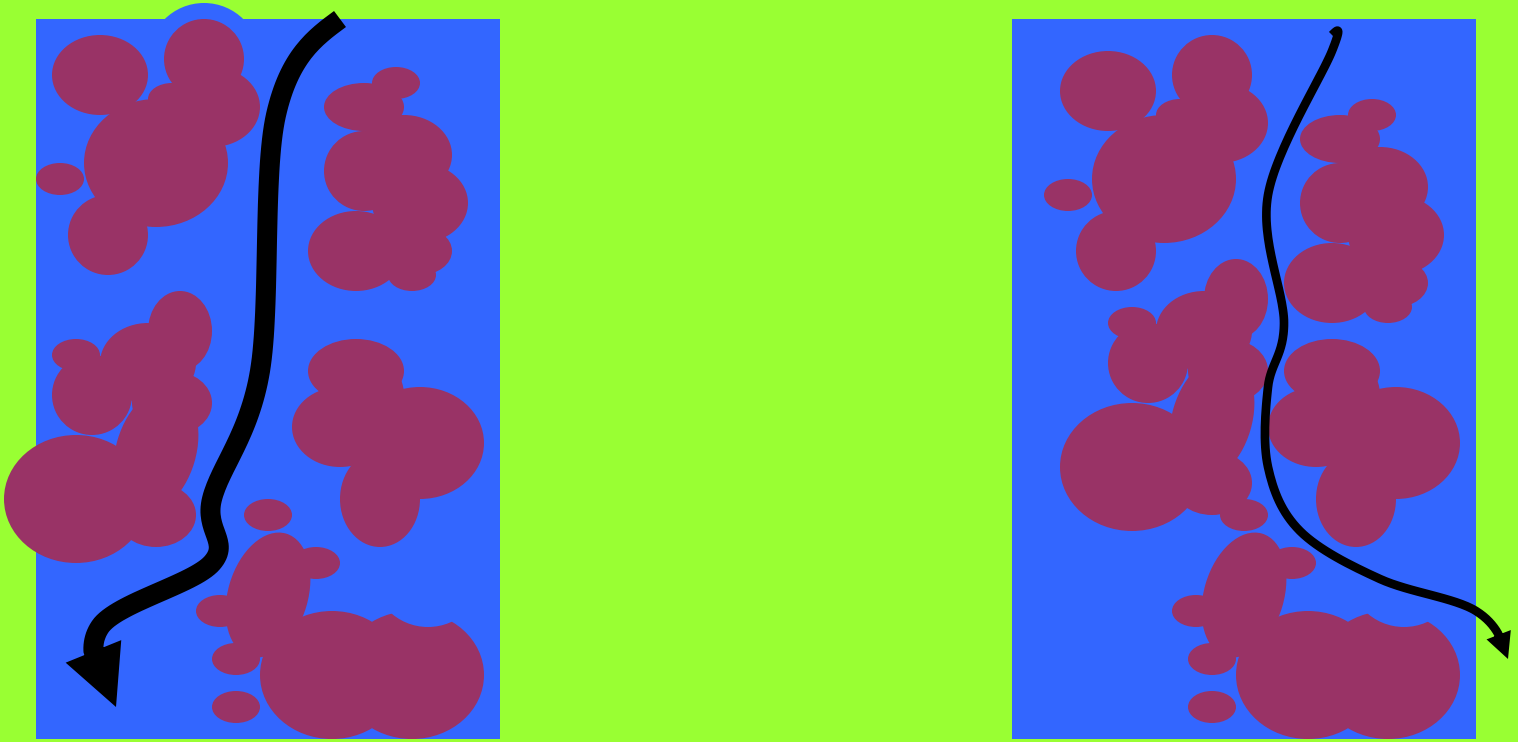
Raindrop Impact



Terminal velocity of 10-30 mph can break up structure. Small particles washed into openings forms “surface seal” and dries to form surface crust

Compaction

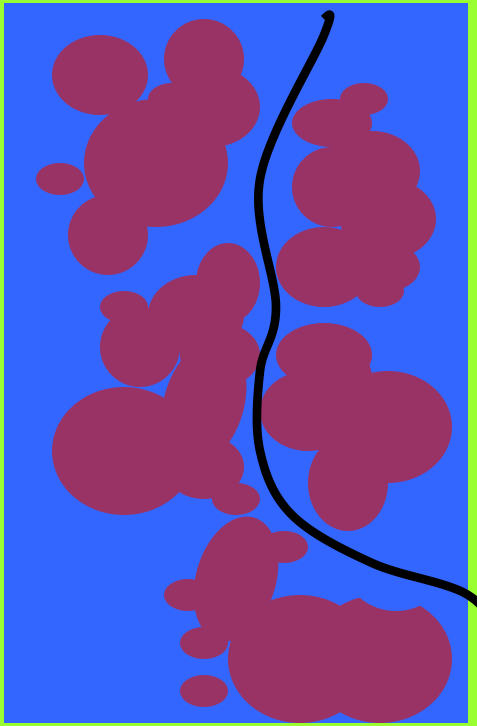
Move aggregates or particles together, reduce porosity – increase bulk density



Uncompacted → **Compacted**

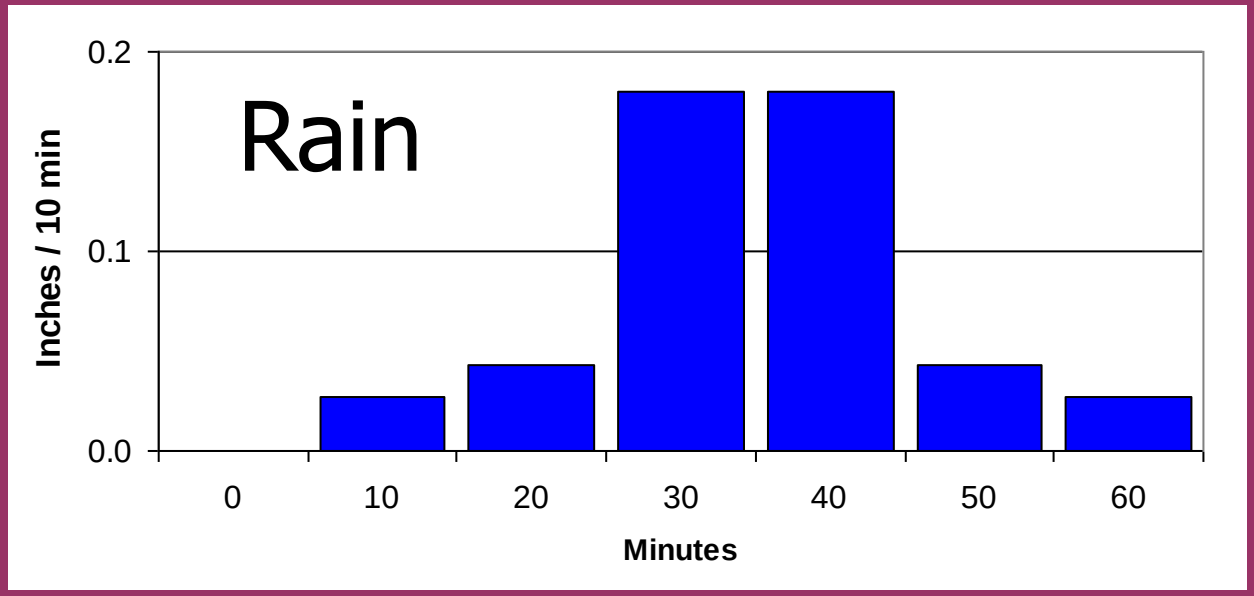
Compaction

Condition	Ponded Infiltration Rate (in/hr)
Vegetated	3.4
Open Soil	0.7
Traffic	0.1

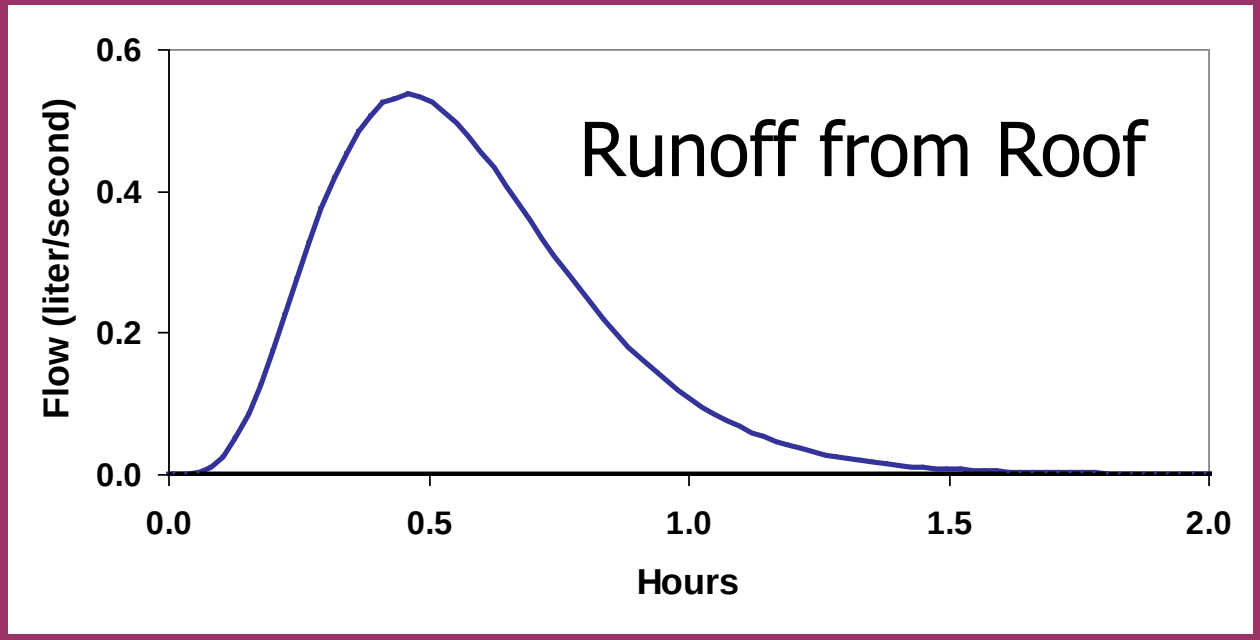


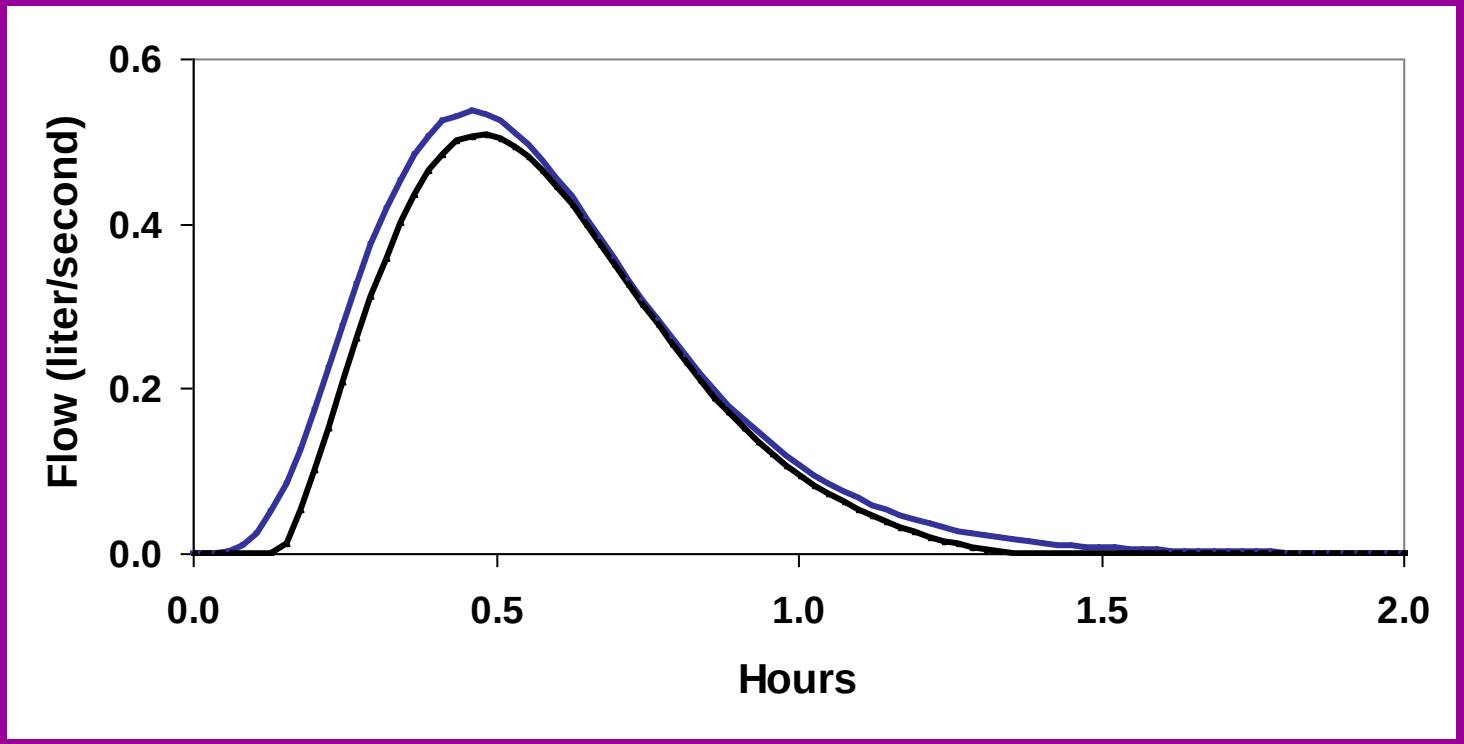
Silt loam soil described by Vervoort, R.W., S.M. Dabney and M.J.M. Romkens. 2001. Tillage and Row Position Effects on Water and Solute Infiltration Characteristics, Soil Science Society of America Journal 65:1227-1234.

Runoff Infiltration Experiments



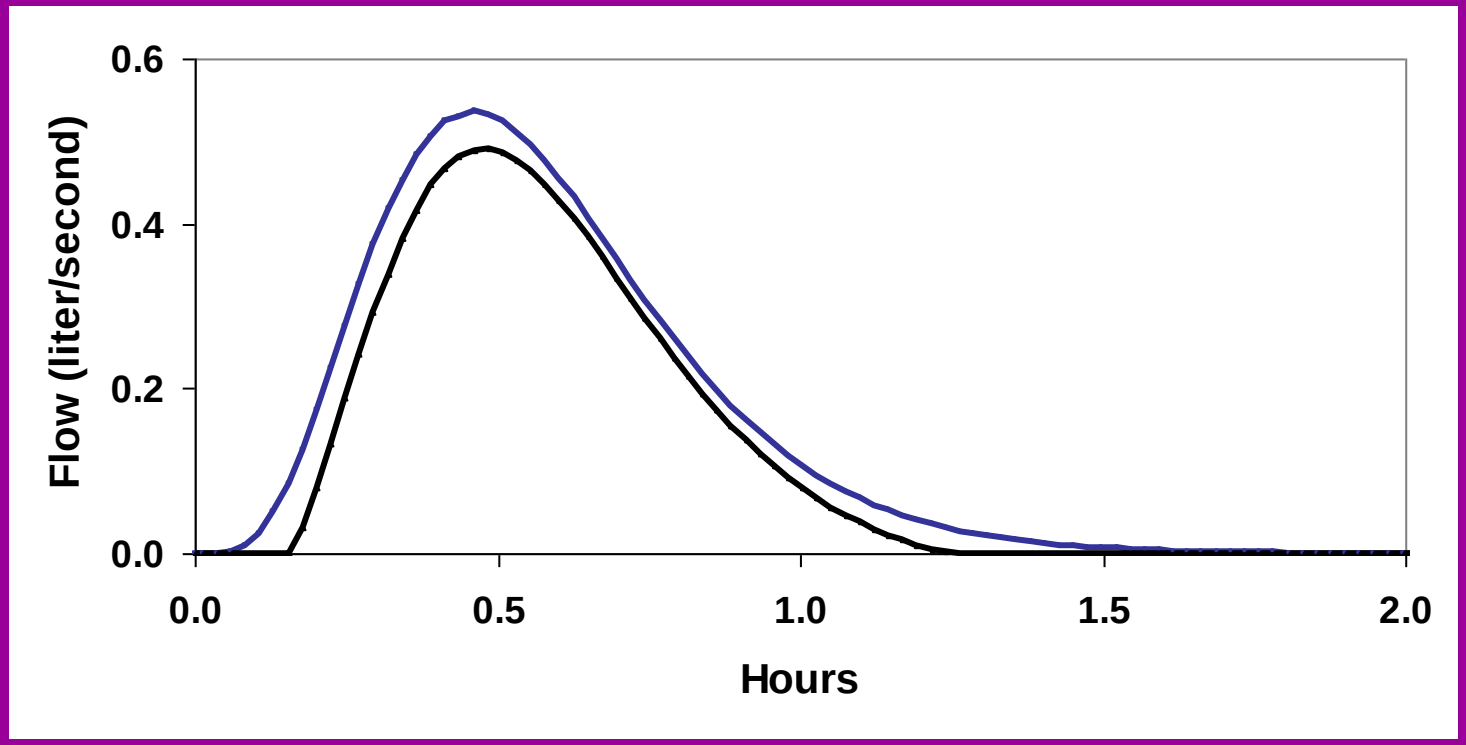
1000 ft^2 roof
1/2 inch rain
in 1 hour





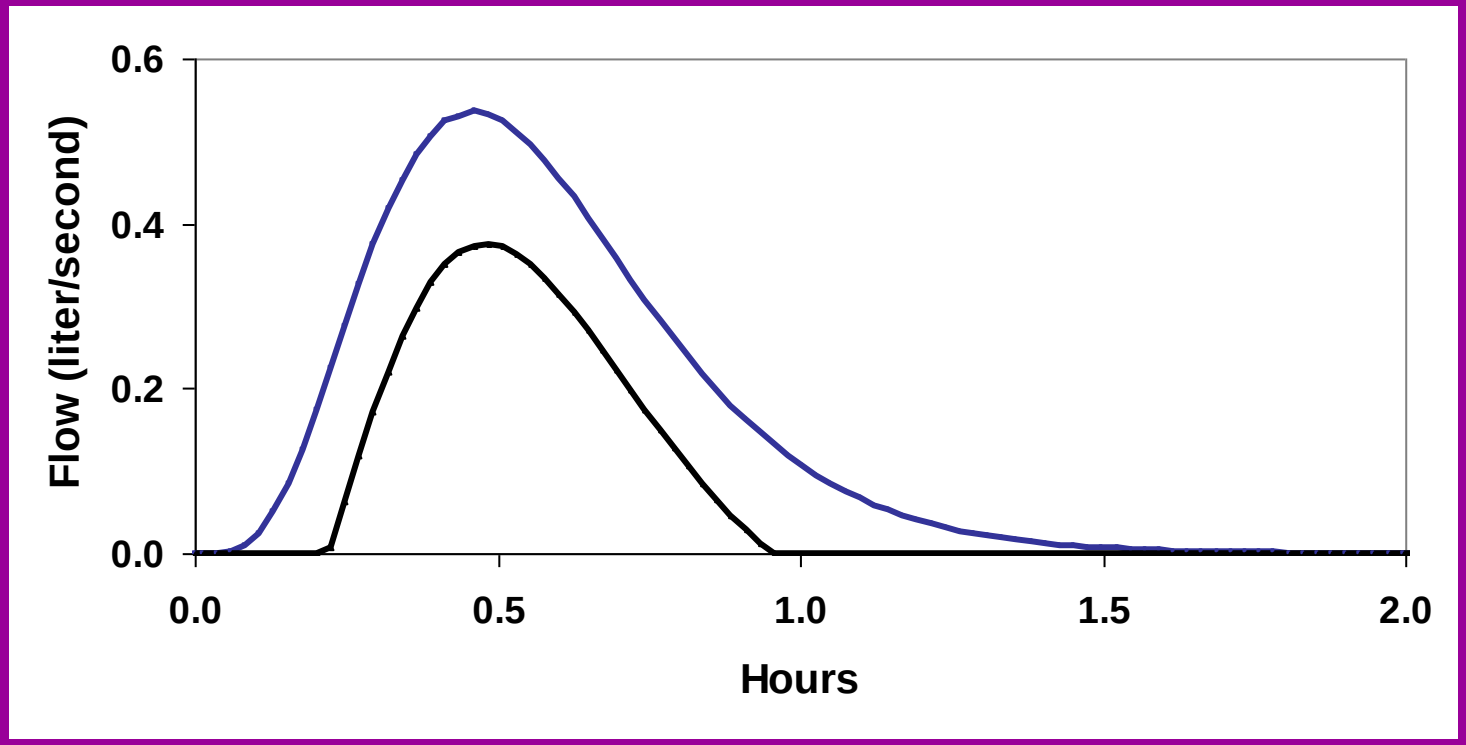
1”/hr

2’ Wide 10’ Long



2”/hr

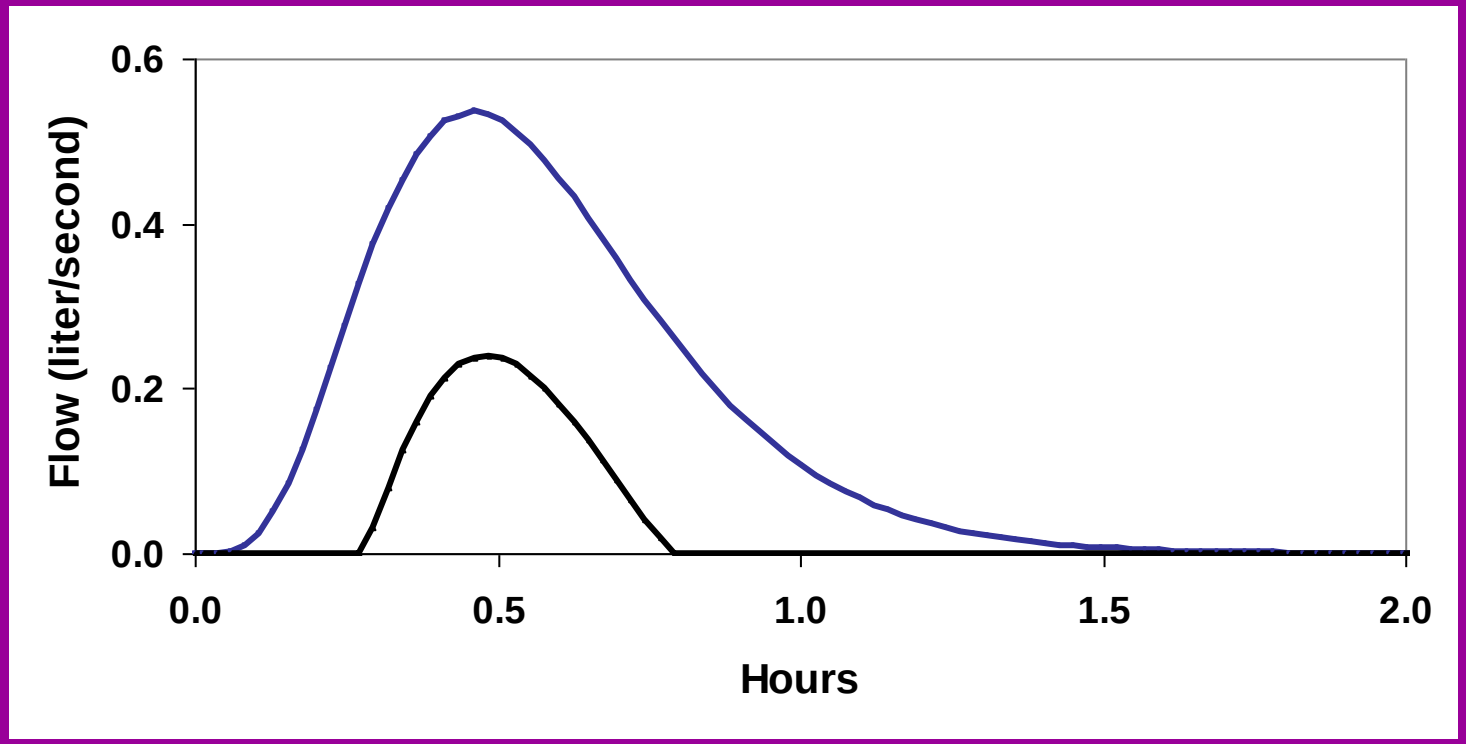
2’ Wide 10’ Long



50% Runoff

10”/hr

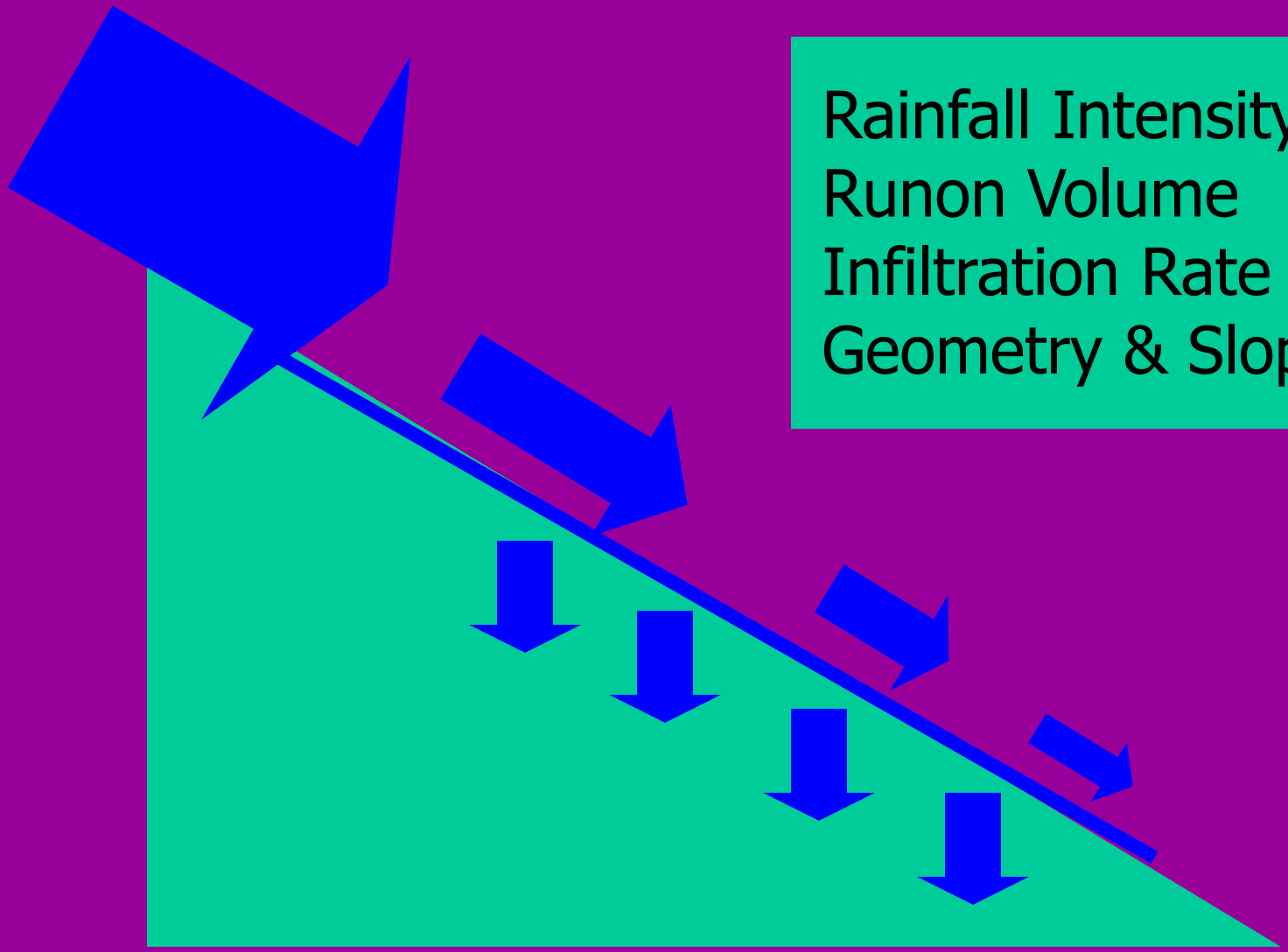
2’ Wide 10’ Long



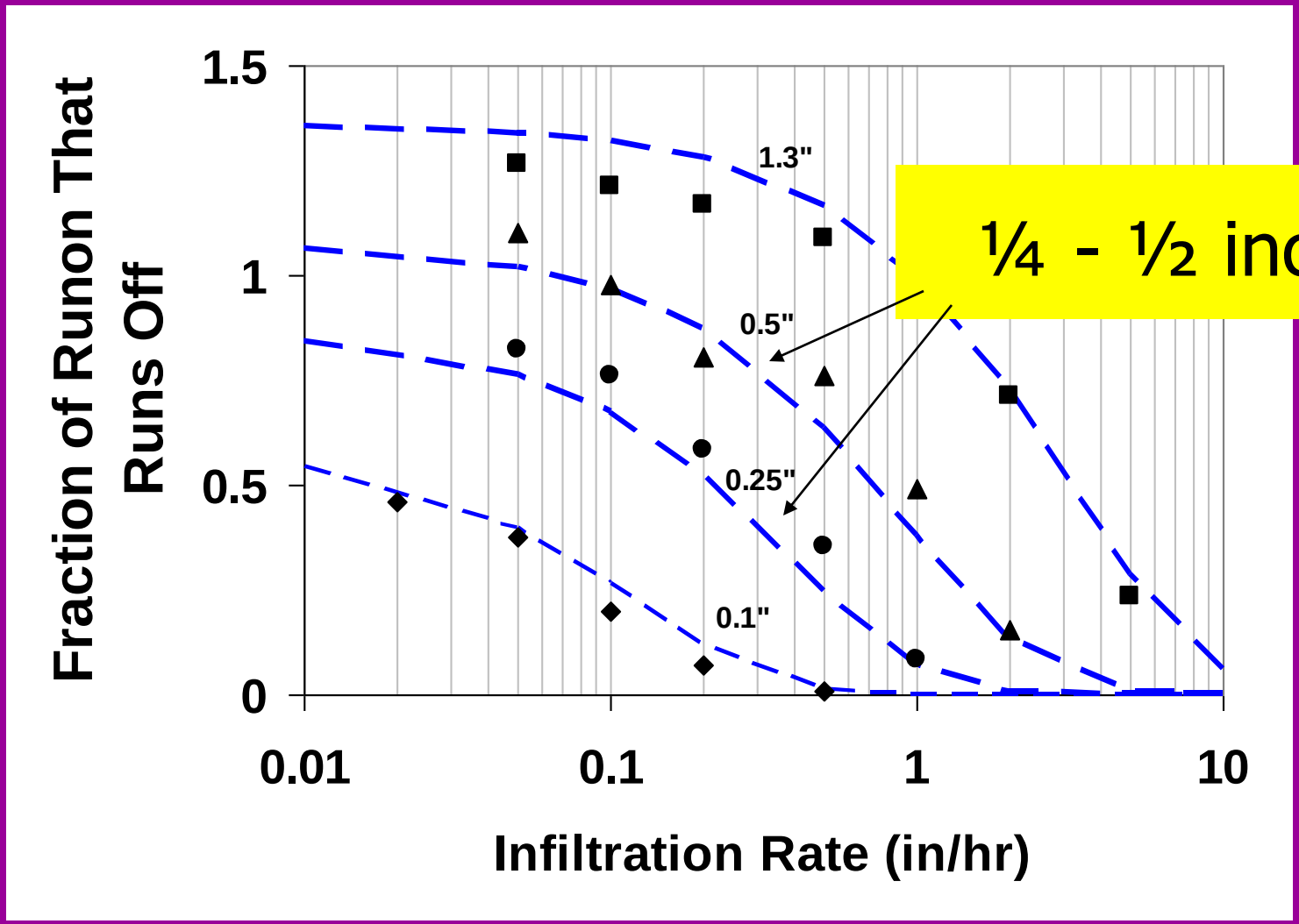
20”/hr

2’ Wide 10’ Long

25% Runoff



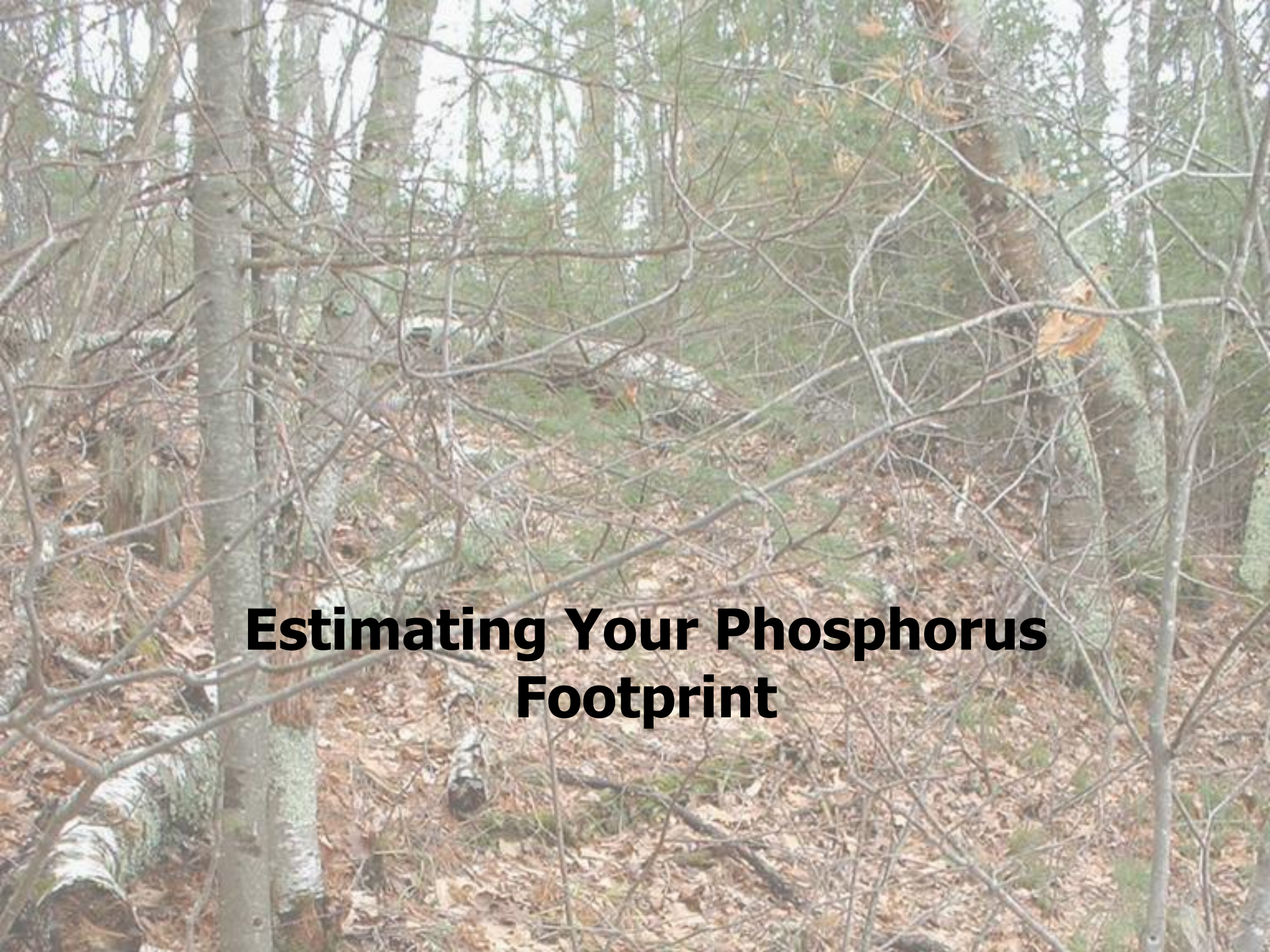
Rainfall Intensity
Runon Volume
Infiltration Rate
Geometry & Slope



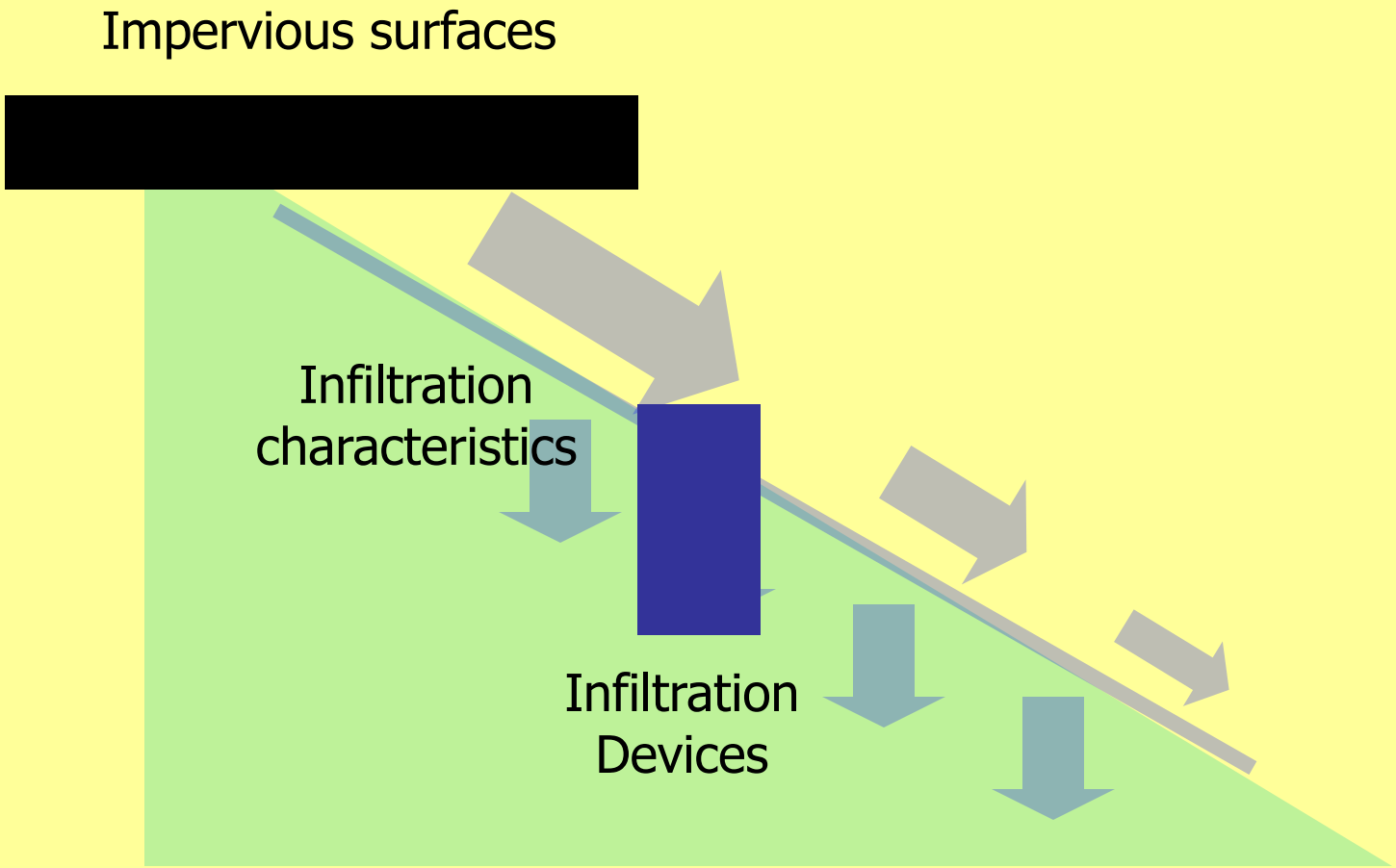
¼ - ½ inch/hour

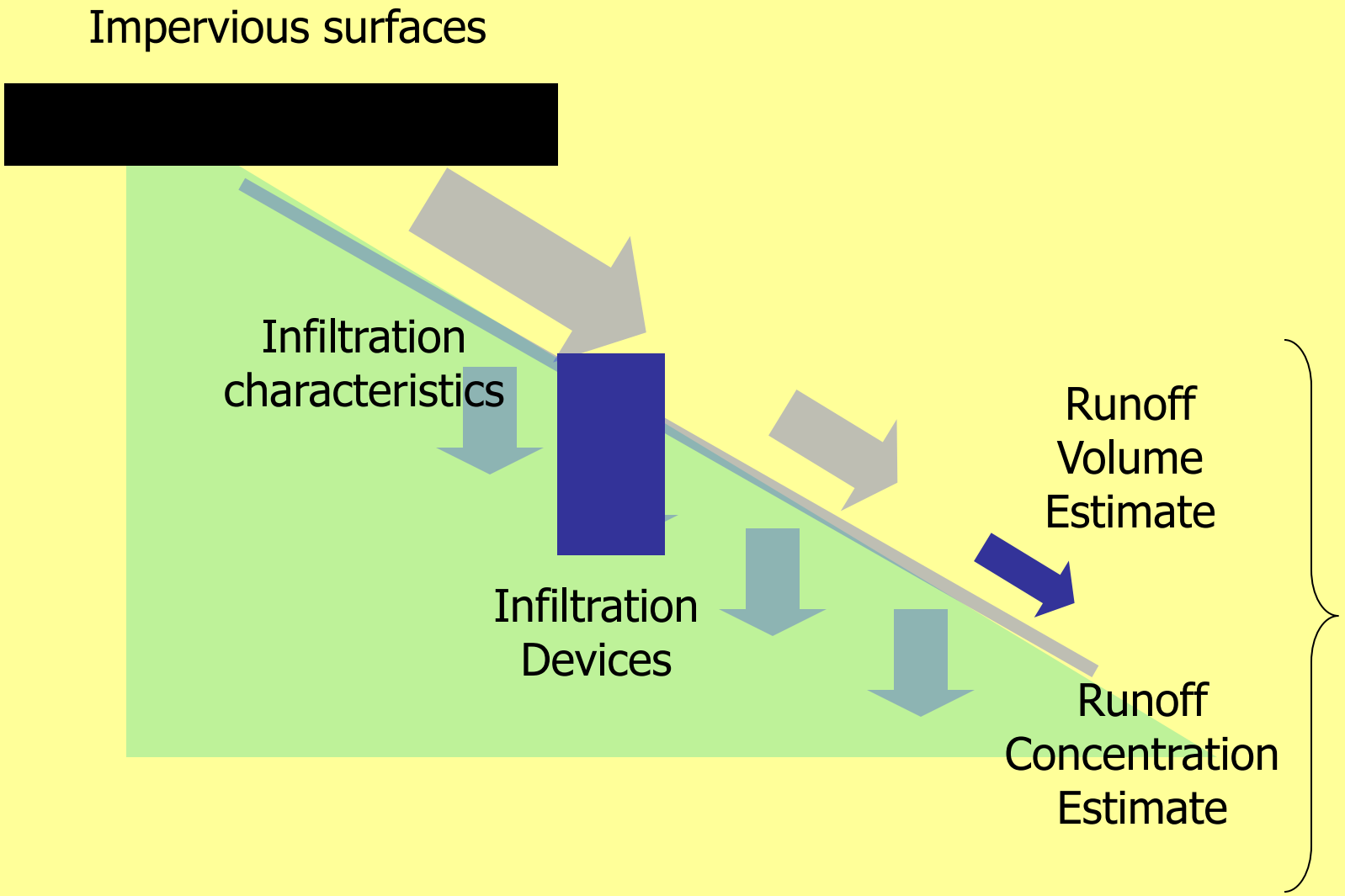
Runon Ratio
500 / 5(w) x 40 (L)

. *The fraction of runon to the secondary buffer that would infiltrate for different storm sizes and infiltration rates (assumes a 500 ft2 impervious area draining to a five foot wide channel, forty feet long and one hour storm of depth shown). Dashed lines show the fitted equation based on soil infiltration rate and storm depth.*



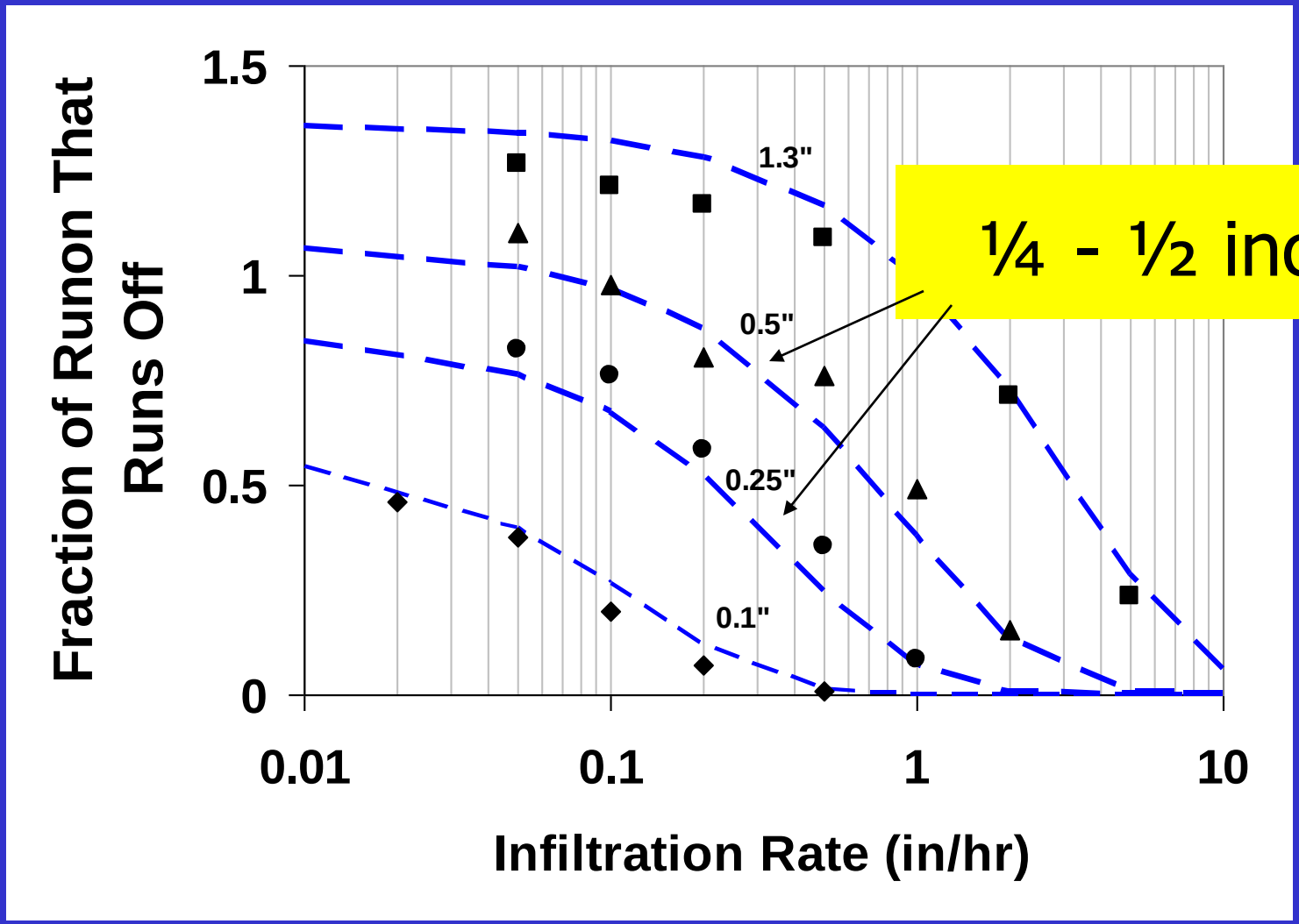
Estimating Your Phosphorus Footprint


Impervious surfaces
Infiltration characteristics
Infiltration Devices


Impervious surfaces
Infiltration characteristics
Infiltration Devices
Runoff Volume Estimate
Runoff Concentration Estimate


Rainfall


Rainfall



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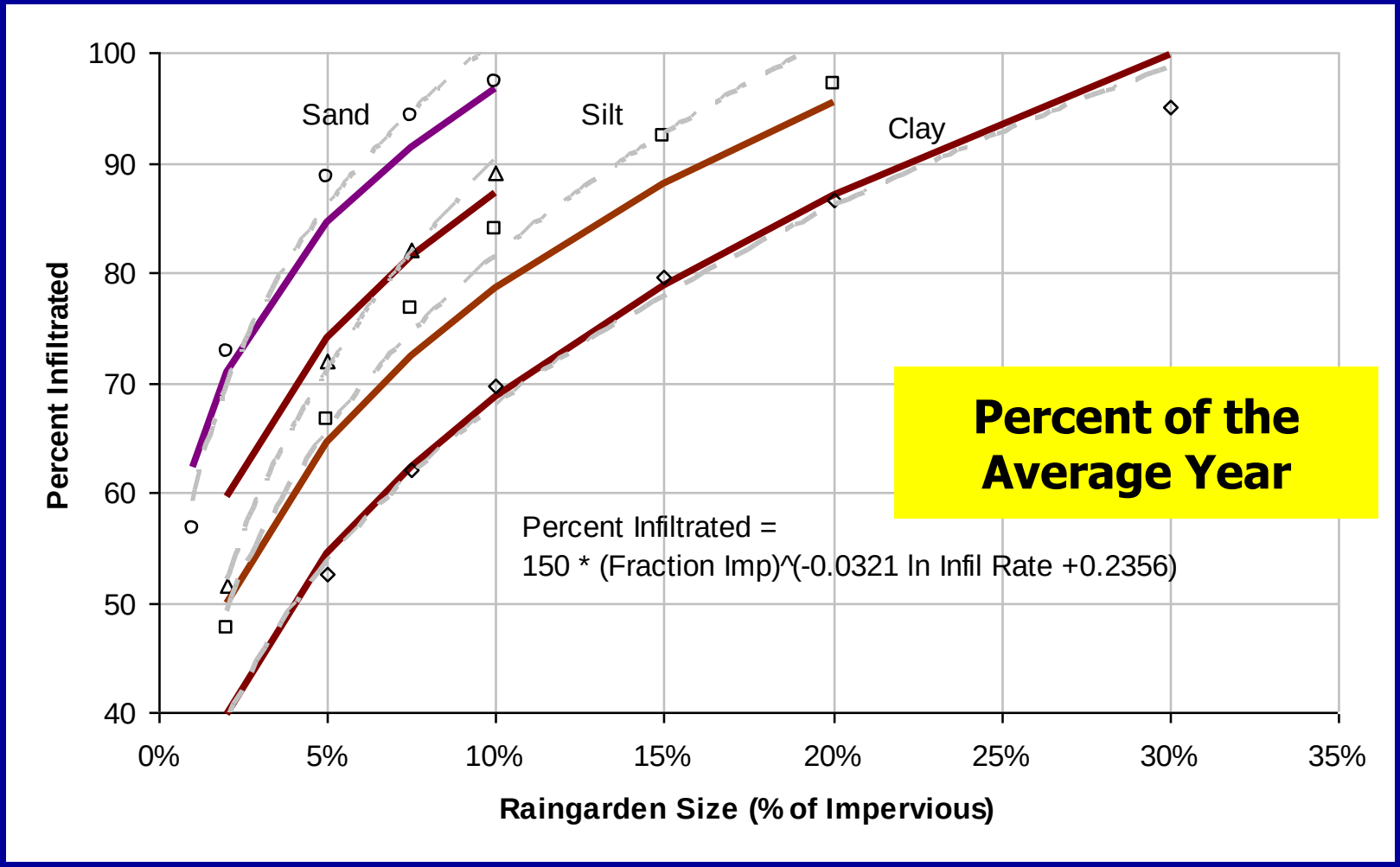
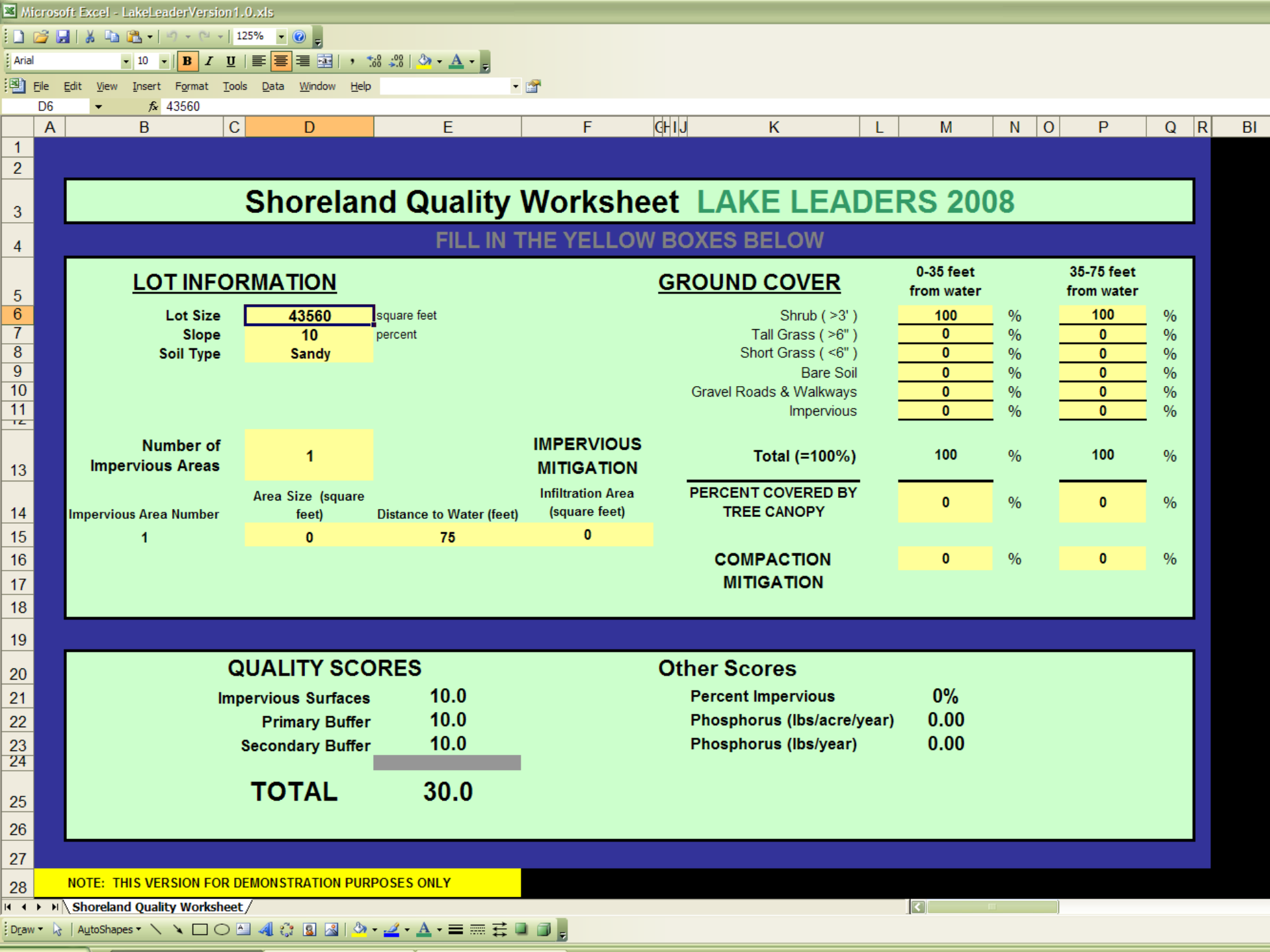
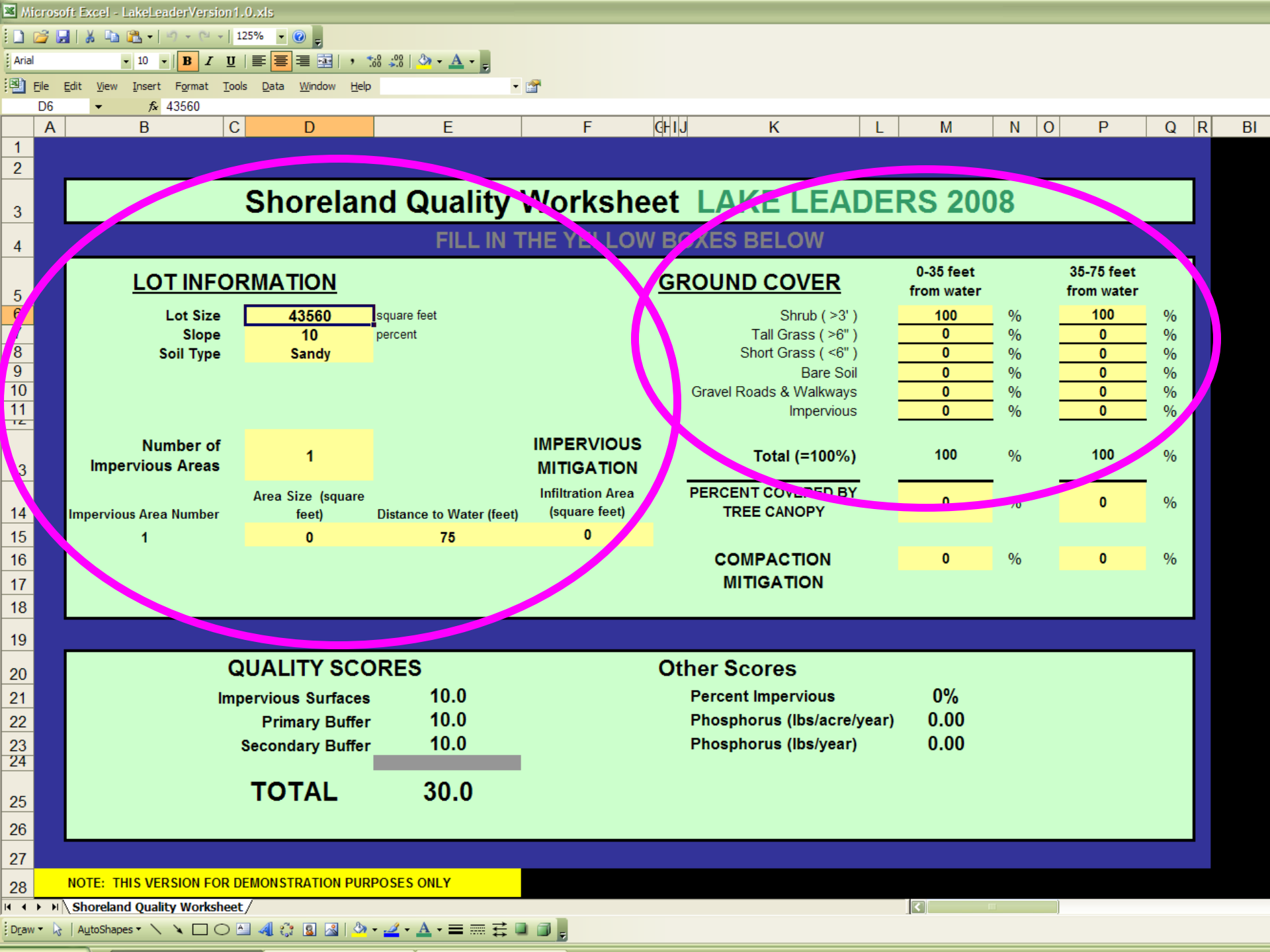


Percentage of the annual average rainfall infiltrated for different infiltration area sizes (shown as a percentage of the impervious area) for sand, fine sand, silt and clay. The symbols show the results of individual RECARGA simulations, the dashed lines show the single-soil best fit, and the solid lines show the single-equation fit (equation shown on the figure)for all textures.


Microsoft Excel - LakeLeaderVersion1.0.xls
File Edit View Insert Format Tools Data Window Help
D6
43560
Shoreland Quality Worksheet LAKE LEADERS 2008
FILL IN THE YELLOW BOXES BELOW
LOT INFORMATION
Lot Size 43560 square feet
Slope 10 percent
Soil Type Sandy
Number of Impervious Areas 1
Impervious Area Number
Area Size (square feet)
Distance to Water (feet)
IMPERVIOUS MITIGATION
Infiltration Area (square feet)
1 0 75 0
GROUND COVER
0-35 feet from water
35-75 feet from water
Shrub (>3') 100 % 100 %
Tall Grass (>6") 0 % 0 %
Short Grass (<6") 0 % 0 %
Bare Soil 0 % 0 %
Gravel Roads & Walkways 0 % 0 %
Impervious 0 % 0 %
Total (=100%) 100 % 100 %
PERCENT COVERED BY TREE CANOPY 0 % 0 %
COMPACTION MITIGATION 0 % 0 %
QUALITY SCORES
Impervious Surfaces 10.0
Primary Buffer 10.0
Secondary Buffer 10.0
TOTAL 30.0
Other Scores
Percent Impervious 0%
Phosphorus (lbs/acre/year) 0.00
Phosphorus (lbs/year) 0.00
NOTE: THIS VERSION FOR DEMONSTRATION PURPOSES ONLY
Shoreland Quality Worksheet
Draw AutoShapes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IMPERVIOUS MITIGATION
Infiltration Area (square feet)
1 0 75 0
GROUND COVER
0-35 feet from water
35-75 feet from water
Shrub (>3') 100 % 100 %
Tall Grass (>6") 0 % 0 %
Short Grass (<6") 0 % 0 %
Bare Soil 0 % 0 %
Gravel Roads & Walkways 0 % 0 %
Impervious 0 % 0 %
Total (=100%) 100 % 100 %
PERCENT COVERED BY TREE CANOPY 0 % 0 %
COMPACTION MITIGATION 0 % 0 %
QUALITY SCORES
Impervious Surfaces 10.0
Primary Buffer 10.0
Secondary Buffer 10.0
TOTAL 30.0
Other Scores
Percent Impervious 0%
Phosphorus (lbs/acre/year) 0.00
Phosphorus (lbs/year) 0.00
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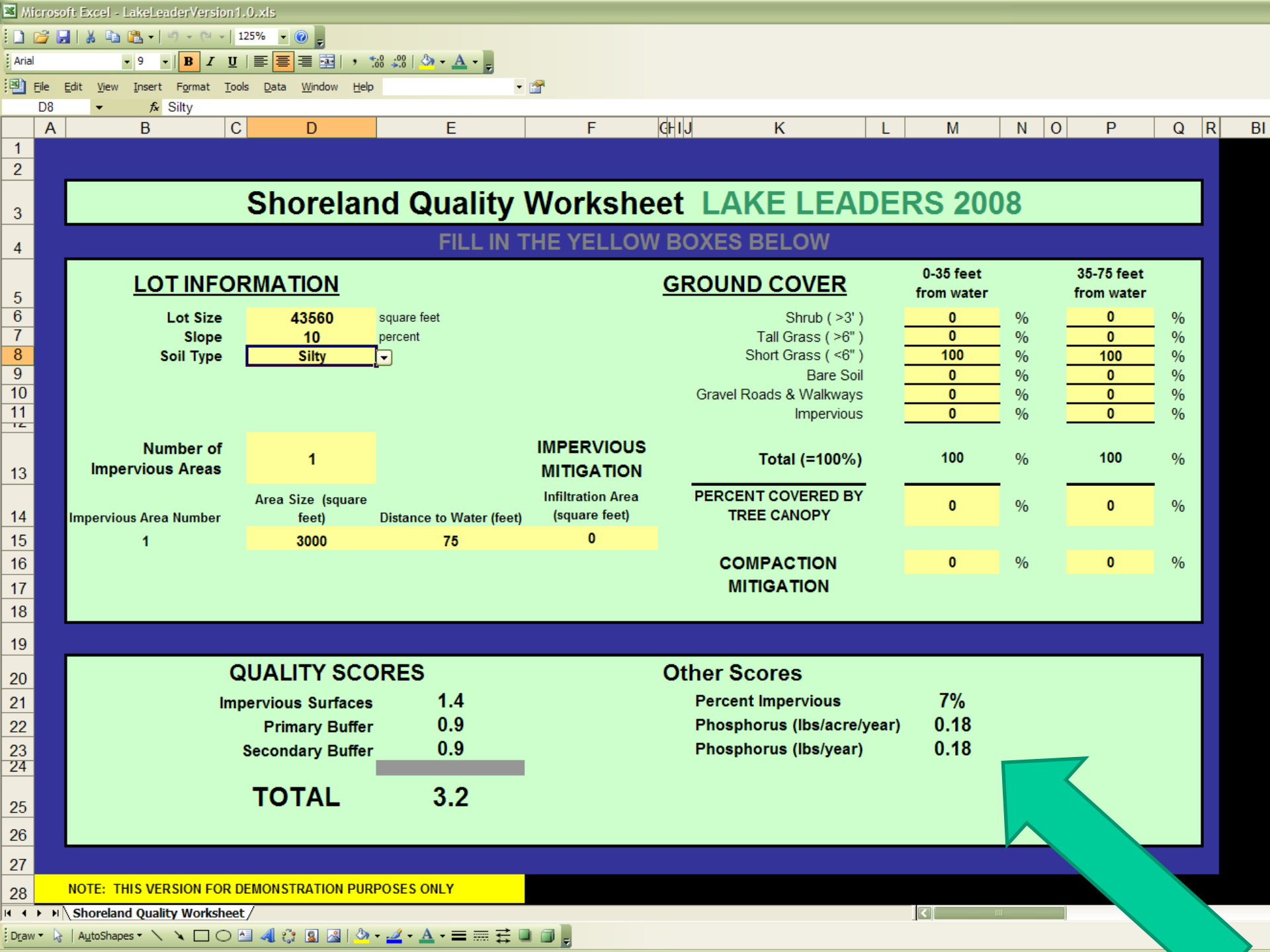
Shoreland Quality Worksheet


Microsoft Excel - LakeLeaderVersion1.0.xls
File Edit View Insert Format Tools Data Window Help
D8 Silty
Shoreland Quality Worksheet LAKE LEADERS 2008
FILL IN THE YELLOW BOXES BELOW
LOT INFORMATION
Lot Size 43560 square feet
Slope 10 percent
Soil Type Silty
Number of Impervious Areas 1
Impervious Area Number
Area Size (square feet)
Distance to Water (feet)
IMPERVIOUS MITIGATION
Infiltration Area (square feet)
1 3000 75 0
GROUND COVER
0-35 feet from water
35-75 feet from water
Shrub (>3') 0 % 0 %
Tall Grass (>6") 0 % 0 %
Short Grass (<6") 100 % 100 %
Bare Soil 0 % 0 %
Gravel Roads & Walkways 0 % 0 %
Impervious 0 % 0 %
Total (=100%) 100 % 100 %
PERCENT COVERED BY TREE CANOPY 0 % 0 %
COMPACTION MITIGATION 0 % 0 %
QUALITY SCORES
Impervious Surfaces 1.4
Primary Buffer 0.9
Secondary Buffer 0.9
TOTAL 3.2
Other Scores
Percent Impervious 7%
Phosphorus (lbs/acre/year) 0.18
Phosphorus (lbs/year) 0.18
NOTE: THIS VERSION FOR DEMONSTRATION PURPOSES ONLY
Shoreland Quality Worksheet

Shoreland Quality Worksheet

FILL IN THE YELLOW BOXES BELOW

LOT INFORMATION

Lot Size	21780	square feet
Slope	20	percent
Soil Type	Sandy	

Number of Impervious Areas	1

Impervious Area Number	Area Size (square feet)	Distance to Water (feet)	IMPERVIOUS MITIGATION Infiltration Area (square feet)
1	2000	75	0

GROUND COVER

	0-35 feet from water		35-75 feet from water	
Shrub (>3')	0	%	0	%
Tall Grass (>6")	100	%	0	%
Short Grass (<6")	0	%	100	%
Bare Soil	0	%	0	%
Gravel Roads & Walkways	0	%	0	%
Impervious	0	%	0	%
Total (=100%)	100	%	100	%
PERCENT COVERED BY TREE CANOPY	0	%	0	%
COMPACTION MITIGATION	0	%	0	%

QUALITY SCORES

Impervious Surfaces	4.1
Primary Buffer	7.4
Secondary Buffer	4.0
TOTAL	15.5

Other Scores

Percent Impervious	9%
Phosphorus (lbs/acre/year)	0.11
Phosphorus (lbs/year)	0.06

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Shoreland Quality Worksheet LAKE LEADERS 2008

FILL IN THE YELLOW BOXES BELOW

LOT INFORMATION

Lot Size	43560	square feet
Slope	10	percent
Soil Type	Silty	

Number of Impervious Areas	1

Impervious Area Number	Area Size (square feet)	Distance to Water (feet)	IMPERVIOUS MITIGATION Infiltration Area (square feet)
1	3000	75	300

GROUND COVER

	0-35 feet from water		35-75 feet from water	
Shrub (>3')	0	%	0	%
Tall Grass (>6")	0	%	0	%
Short Grass (<6")	100	%	100	%
Bare Soil	0	%	0	%
Gravel Roads & Walkways	0	%	0	%
Impervious	0	%	0	%
Total (=100%)	100	%	100	%
PERCENT COVERED BY TREE CANOPY	0	%	0	%
COMPACTION MITIGATION	0	%	0	%

QUALITY SCORES

Impervious Surfaces	8.7
Primary Buffer	0.9
Secondary Buffer	0.9
TOTAL	10.5

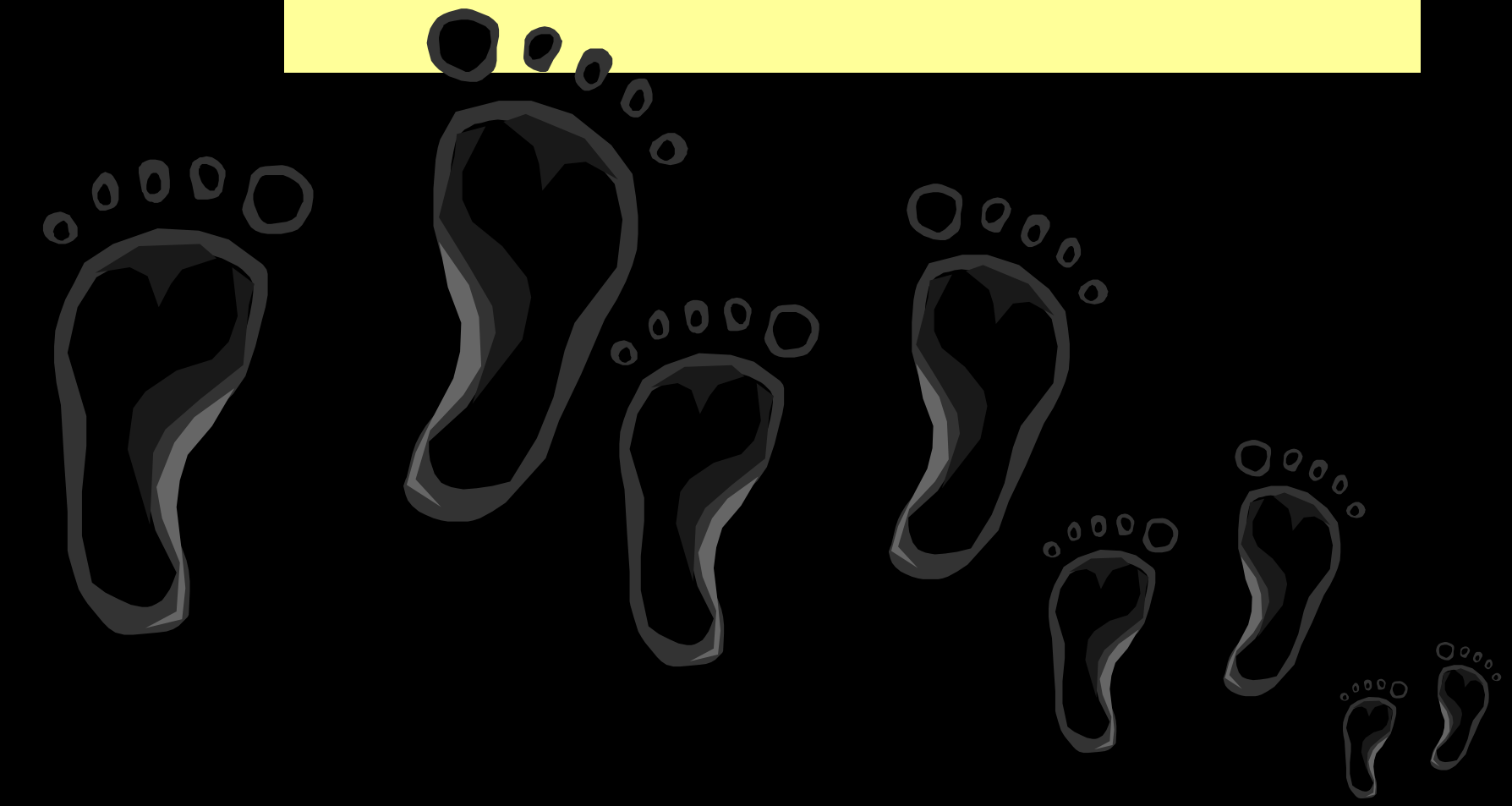
Other Scores

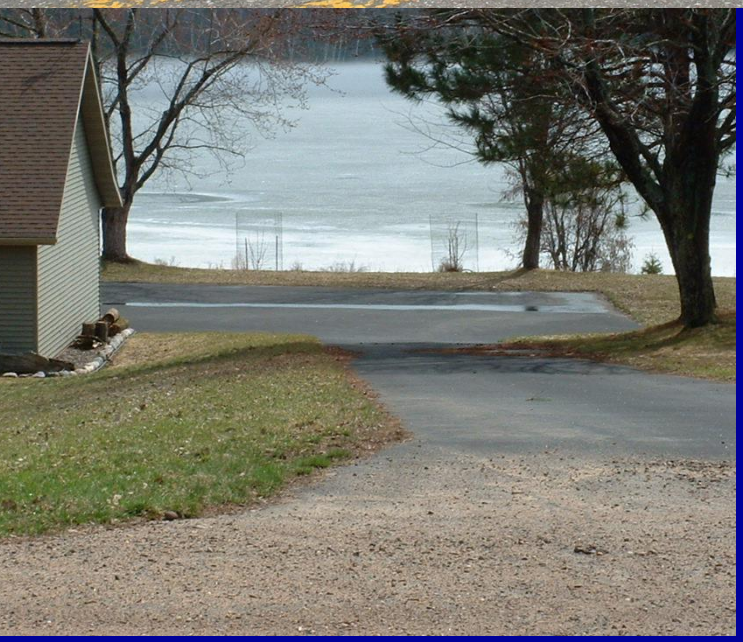
Percent Impervious	7%
Phosphorus (lbs/acre/year)	0.07
Phosphorus (lbs/year)	0.07

Ponding Warning-- Some Infiltration Areas May Remain Wet More Than 24 Hours

NOTE: THIS VERSION FOR DEMONSTRATION PURPOSES ONLY

Shrinking Our Footprint





Reduce Runoff Generation

Reduce Impervious Area

Promote High Infiltration Rates in Pervious Areas

Infiltrate Runoff Generated

Allow water to spread out (take advantage of infiltration geometry and don't channelize)

Impound where possible (raingardens, trenches)

Promote High Infiltration Rates in Pervious Areas

Infiltrate Runoff Generated

Don’t compact

Don’t shape to lake

No bare soil

Don’t make it easy for the water to get to the lake

FUTURE

- Stay-tuned…there is still a lot we don't know…
  - Micro-topography
  - Winter…
  - Other considerations

THANKS

Thanks to
many folks from
the WDNR (Buzz, Tim, Carroll, Steve, Gregg…)
from Lake Groups, Counties, UWExtension &
UWSP (Bob, Patrick, Tiffany, Nancy…),
Graduate Students (Kaylea, Darrin, Adam…)

SUMMARY

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How do we decrease P transfer?

- Vegetation
- Don’t compact
- Don’t channelize
- Don’t shape to the lake
- Direct impervious surface runoff to infiltration areas

12 inches water on 1 square mile
in a year

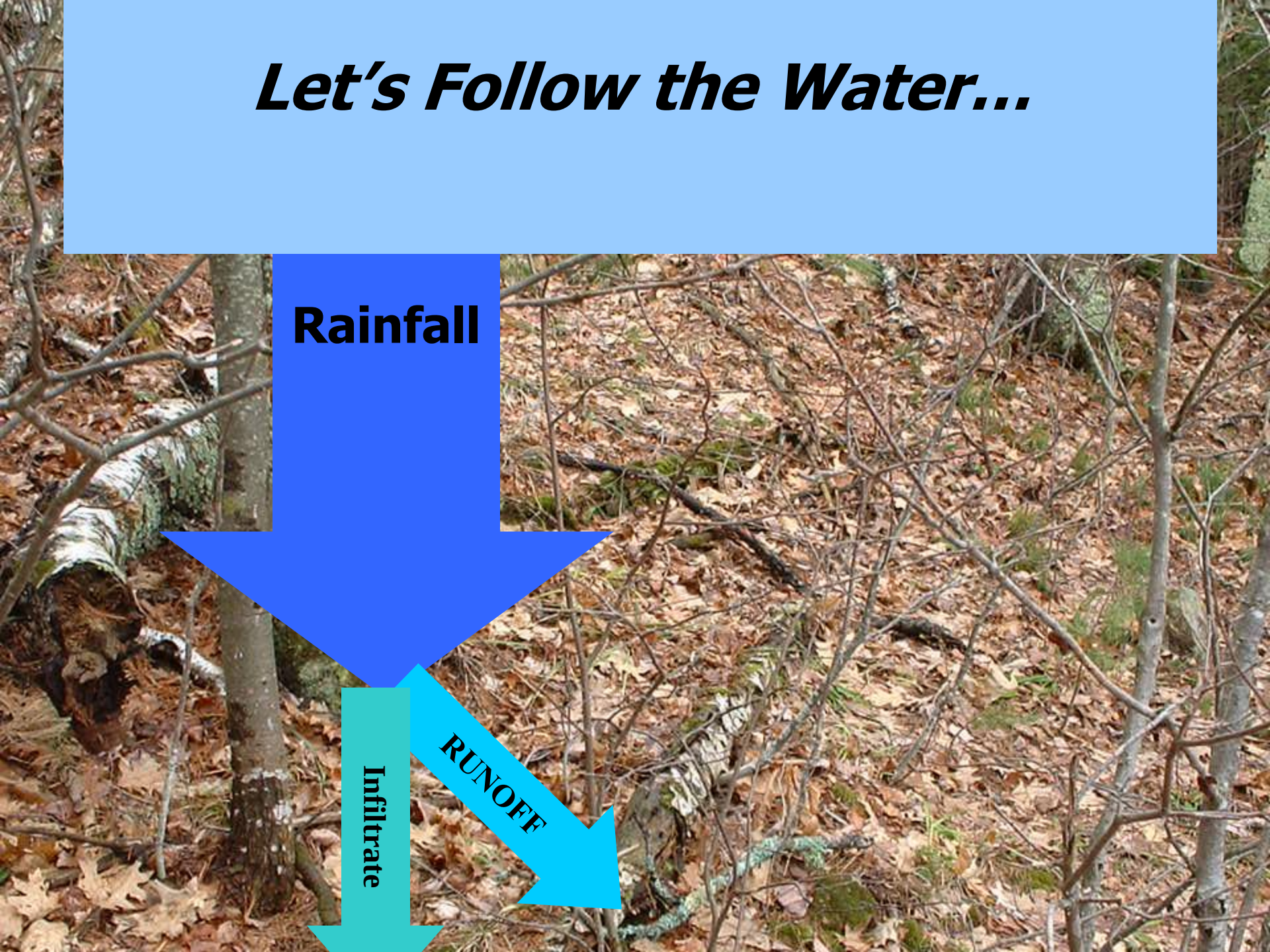
~ 31 million
seconds in
a year

= 28 Million Cubic Feet
Of water each year

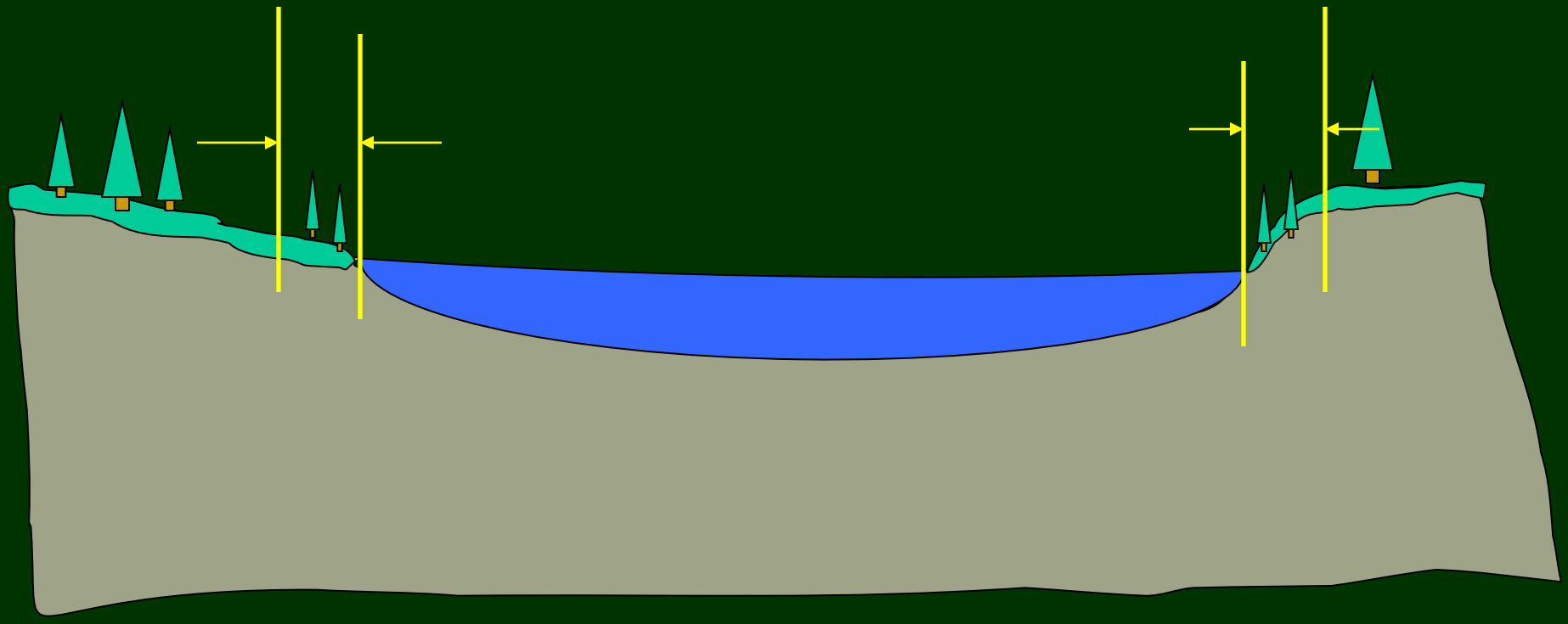
= almost 1 cubic foot
of water
every second -- every square mile!

Summary

Let's Follow the Water…



Assume a 300’ shoreline zone
And 300 acre lake…

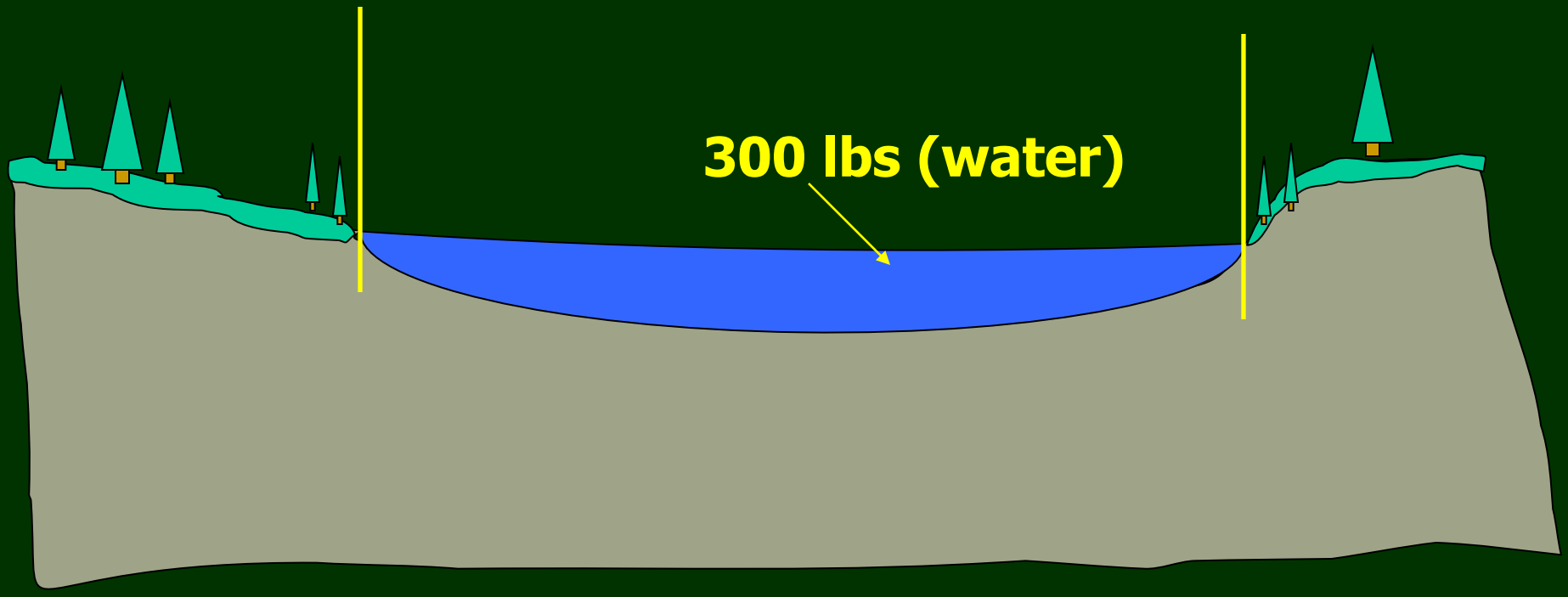


Likens and Bormann, 1995 (Biogeochemistry Of a Forested Ecosystem);
Schlesinger, 1991 (Biogeochemistry);
Wetzel, 2001 (Limnology).

- 300 acre
- 25’ mean depth
- 15 ug/l TP

- 300 acre
- Circular Lake
- 200 mg/kg soil P
- 100 lb/acre P

How much phosphorus in the Lake?



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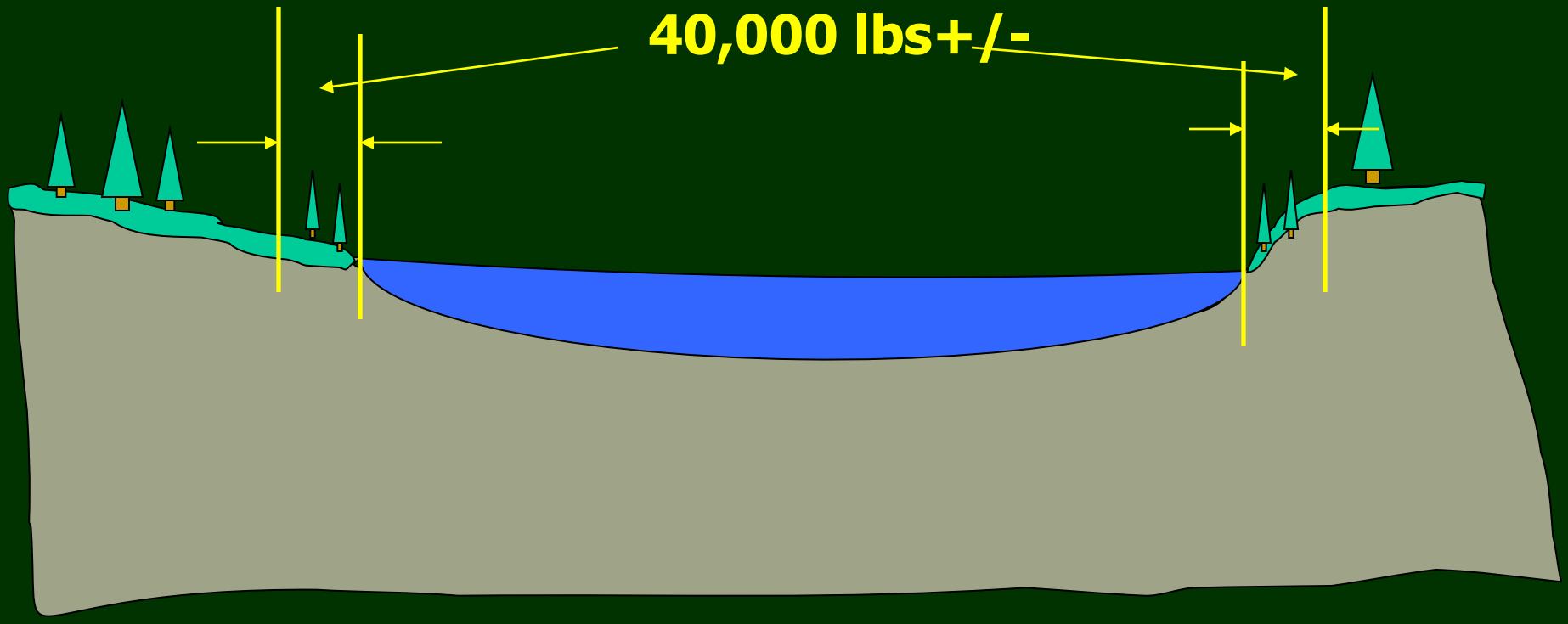
How much phosphorus in the Land?



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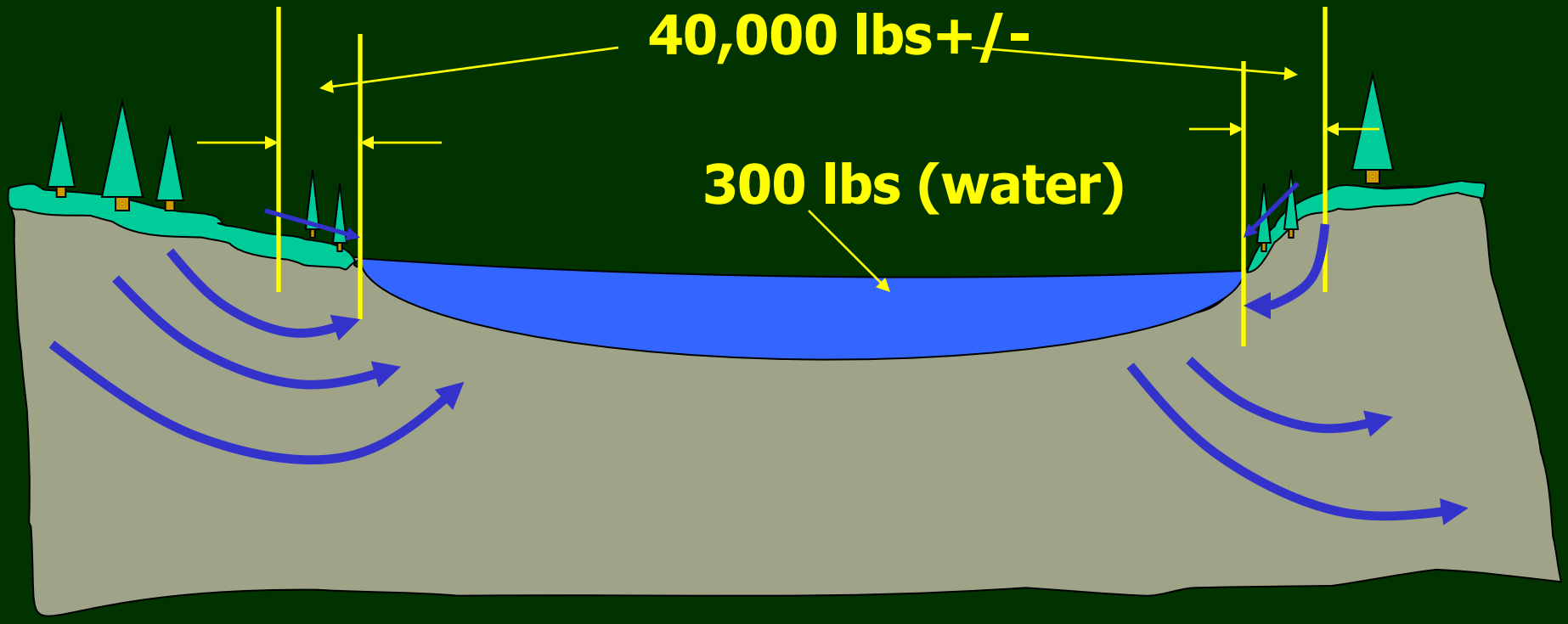
Comparing Lake and Land…



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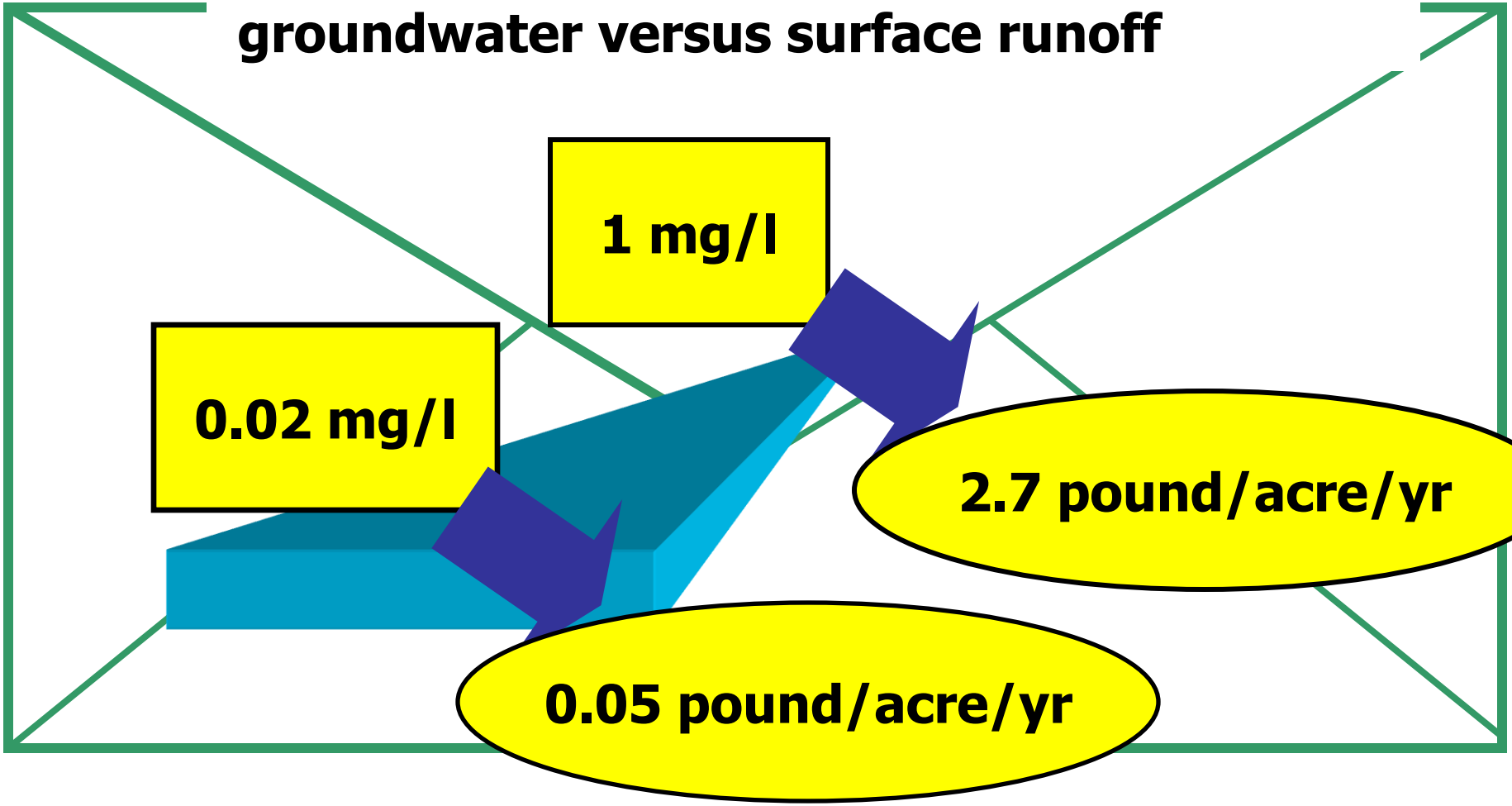
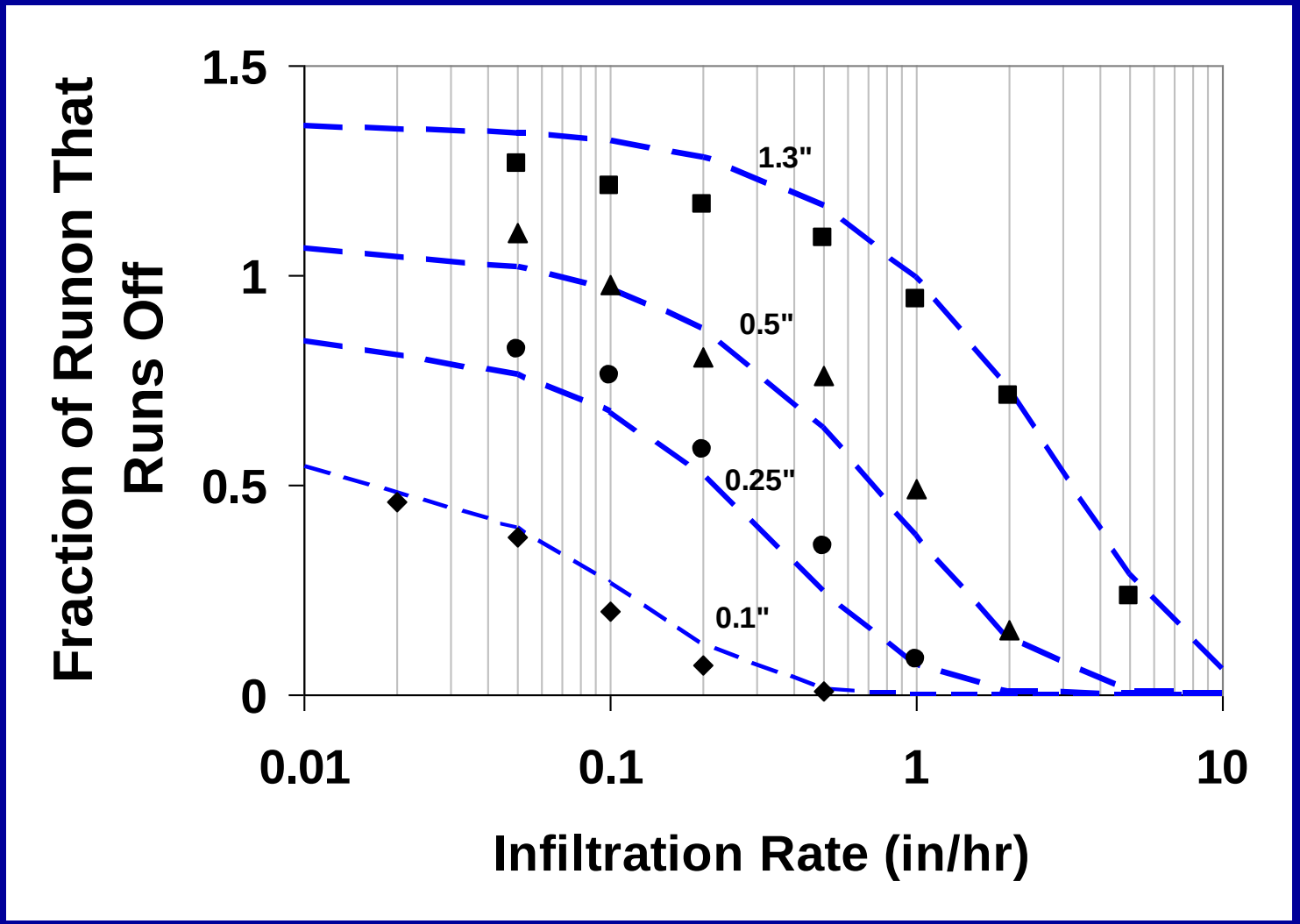
RECALL --- Back of the envelope comparison groundwater versus surface runoff

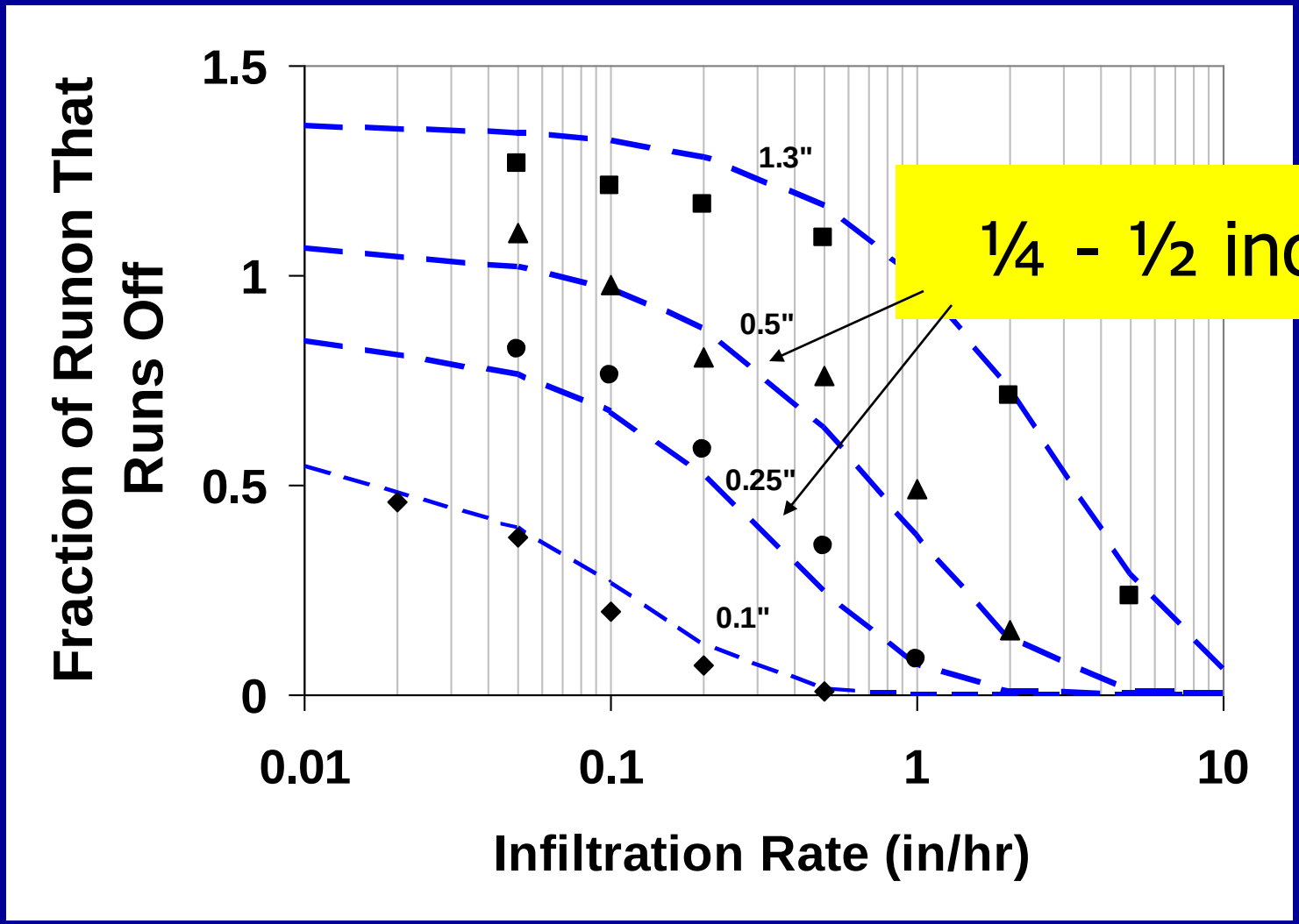


Assumes 12 inches runoff



Runon Ratio
500 / 5(w) x 40 (L)

. The fraction of runon to the secondary buffer that would infiltrate for different storm sizes and infiltration rates (assumes a 500 ft2 impervious area draining to a five foot wide channel, forty feet long and one hour storm of depth shown). Dashed lines show the fitted equation based on soil infiltration rate and storm depth.



¼ - ½ inch/hour

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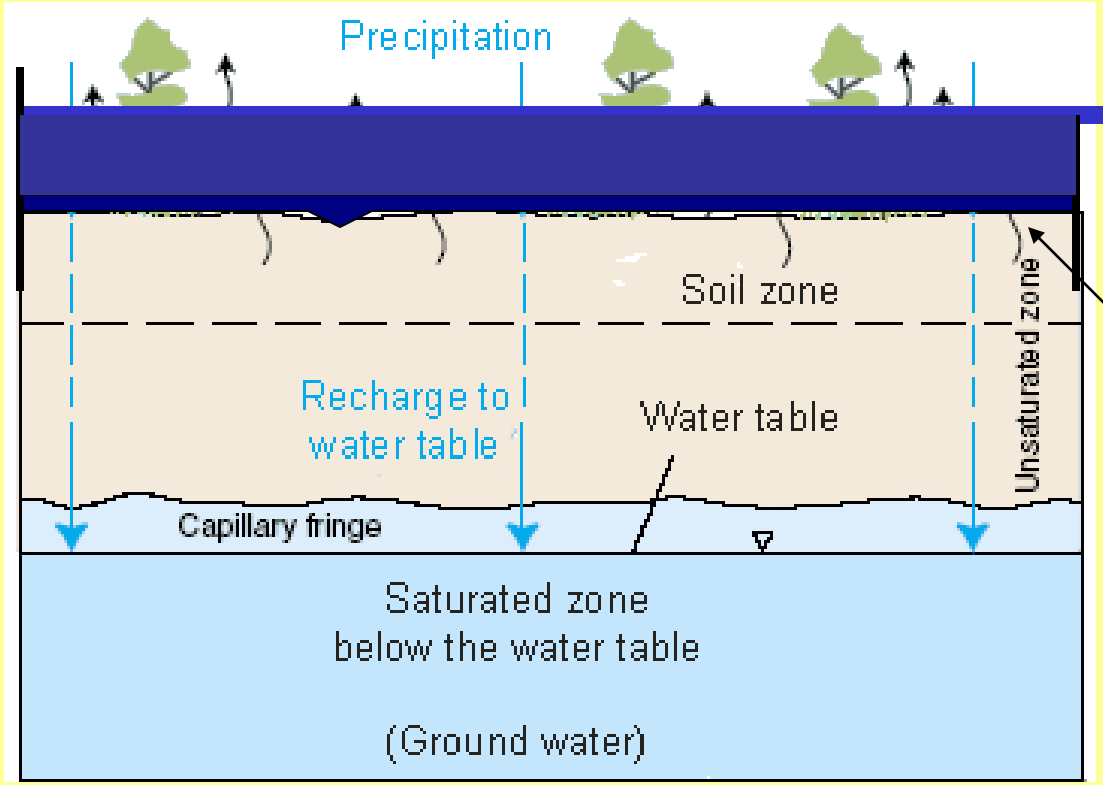
Design Infiltration
Areas

Infiltration Device

- **Designed to facilitate the entry and movement of precipitation or runoff into or through the soil**



Here shown with increased surface storage capacity

- **Make it hard for the water to get to the lake**

SUMMARY

- **Make it hard for the water to get to the lake**

SUMMARY

- No compaction
- No shaping for drainage
- No bare soil

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SUMMARY

- Slow it down &
- Infiltrate

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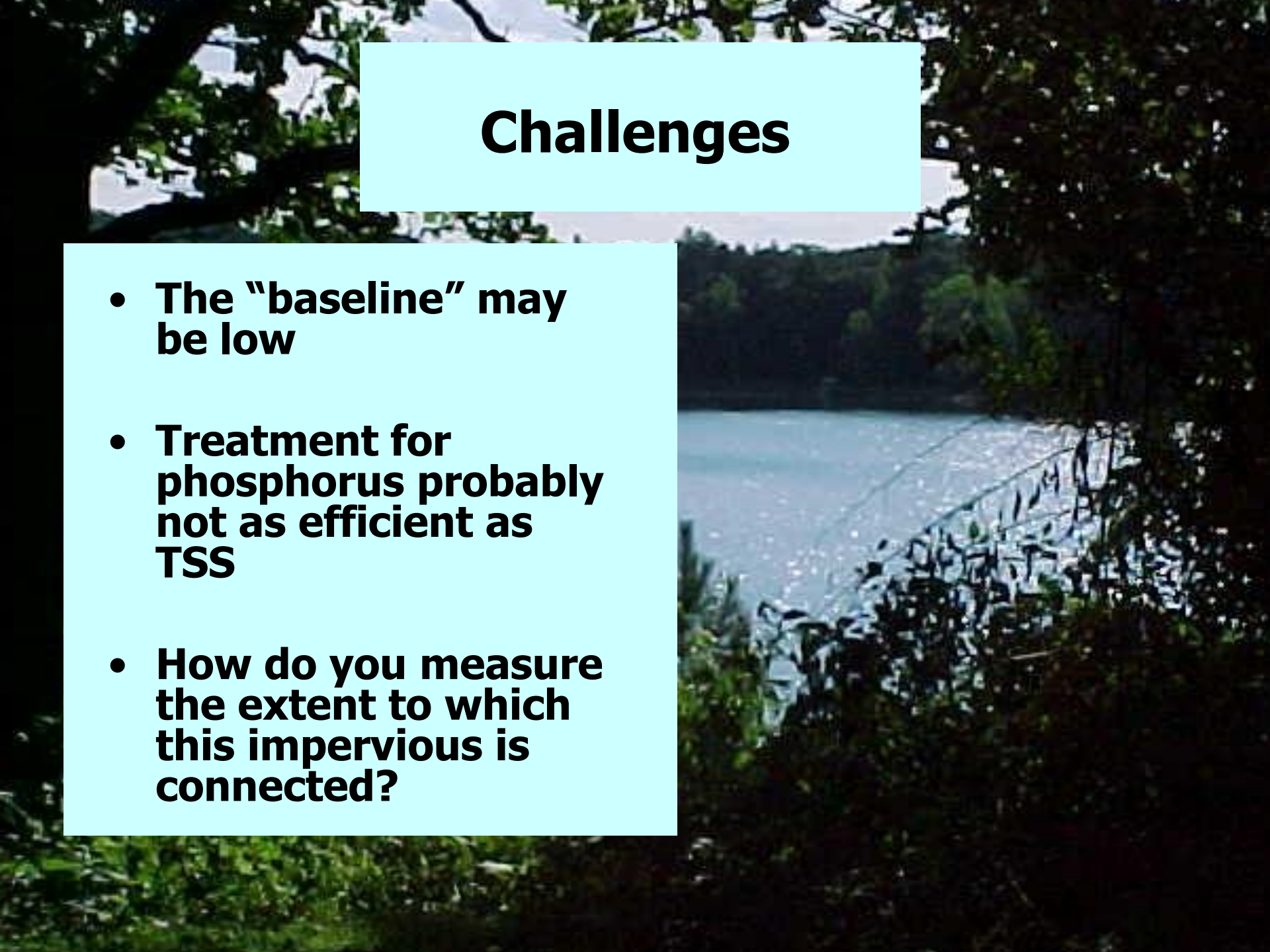
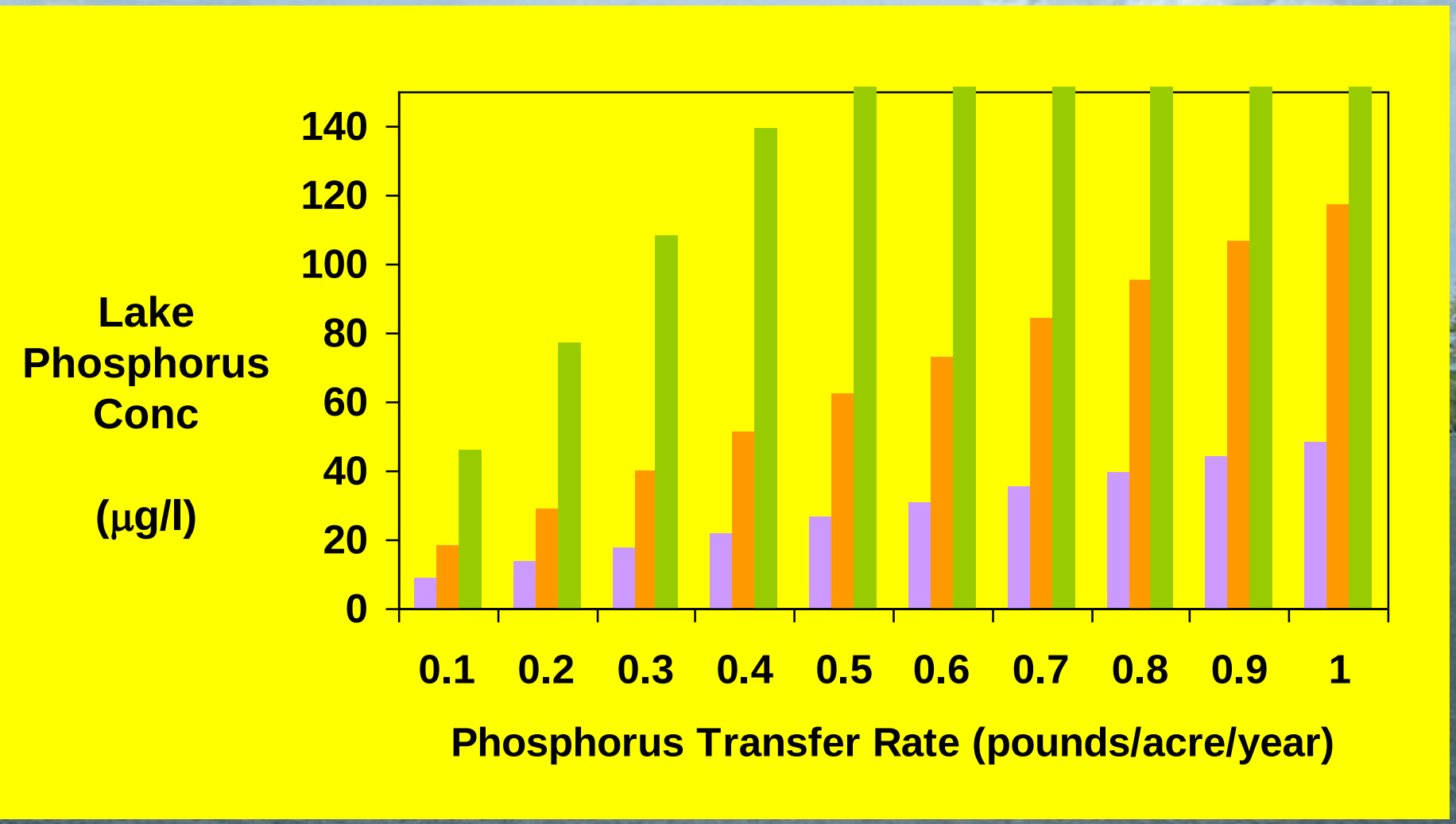
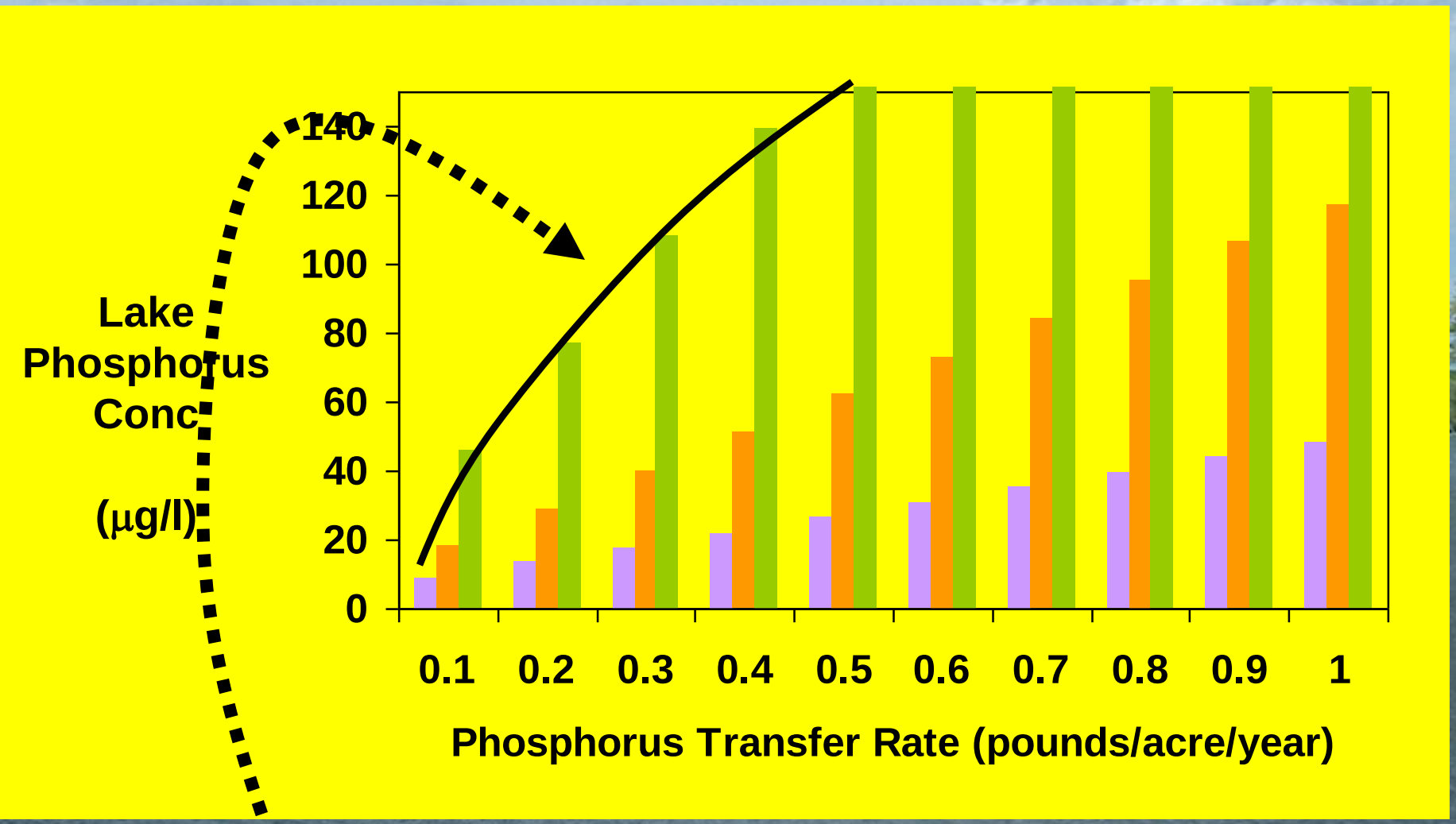


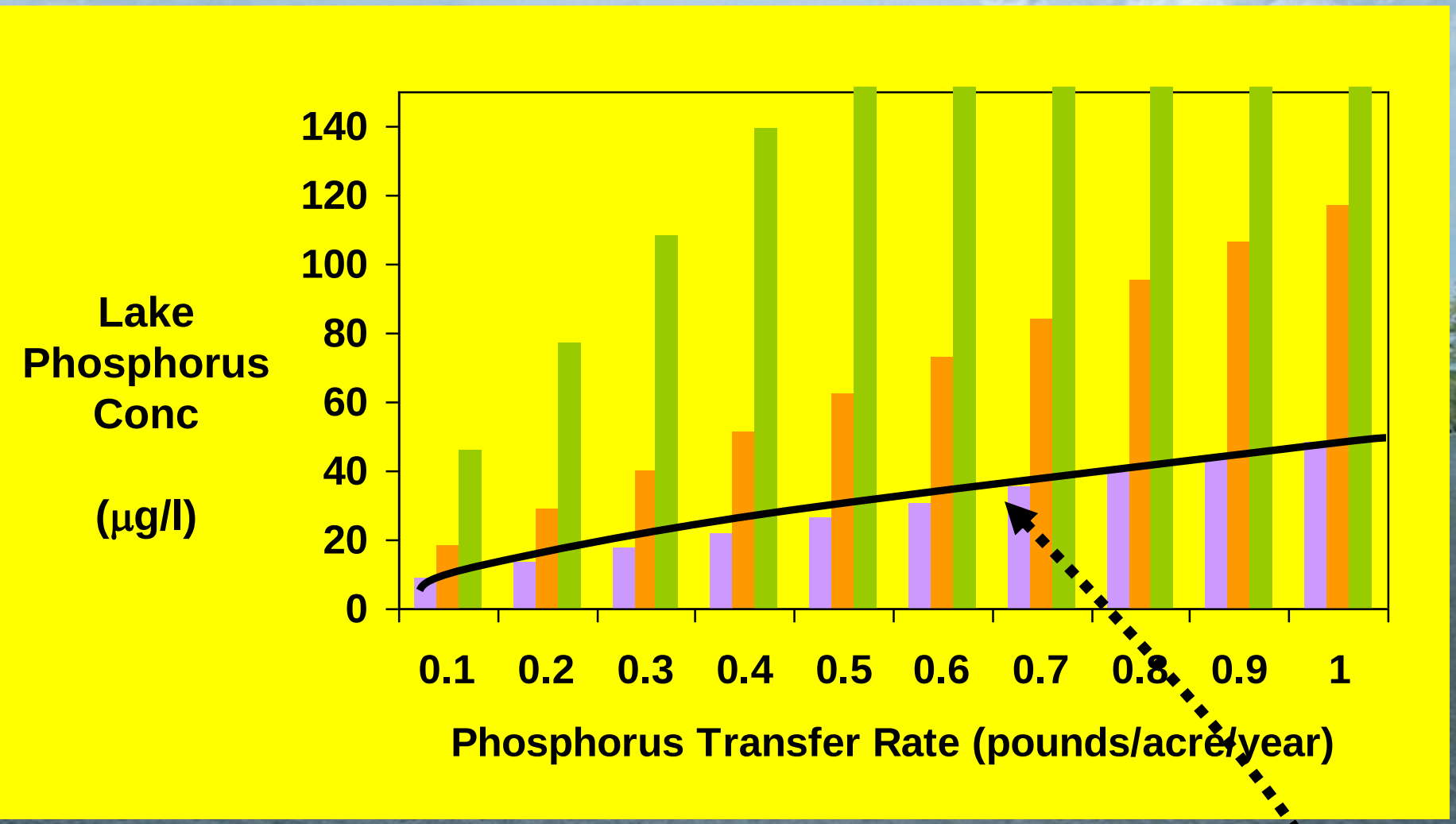
Challenges

- The "baseline" may be low
- Treatment for phosphorus probably not as efficient as TSS
- How do you measure the extent to which this impervious is connected?

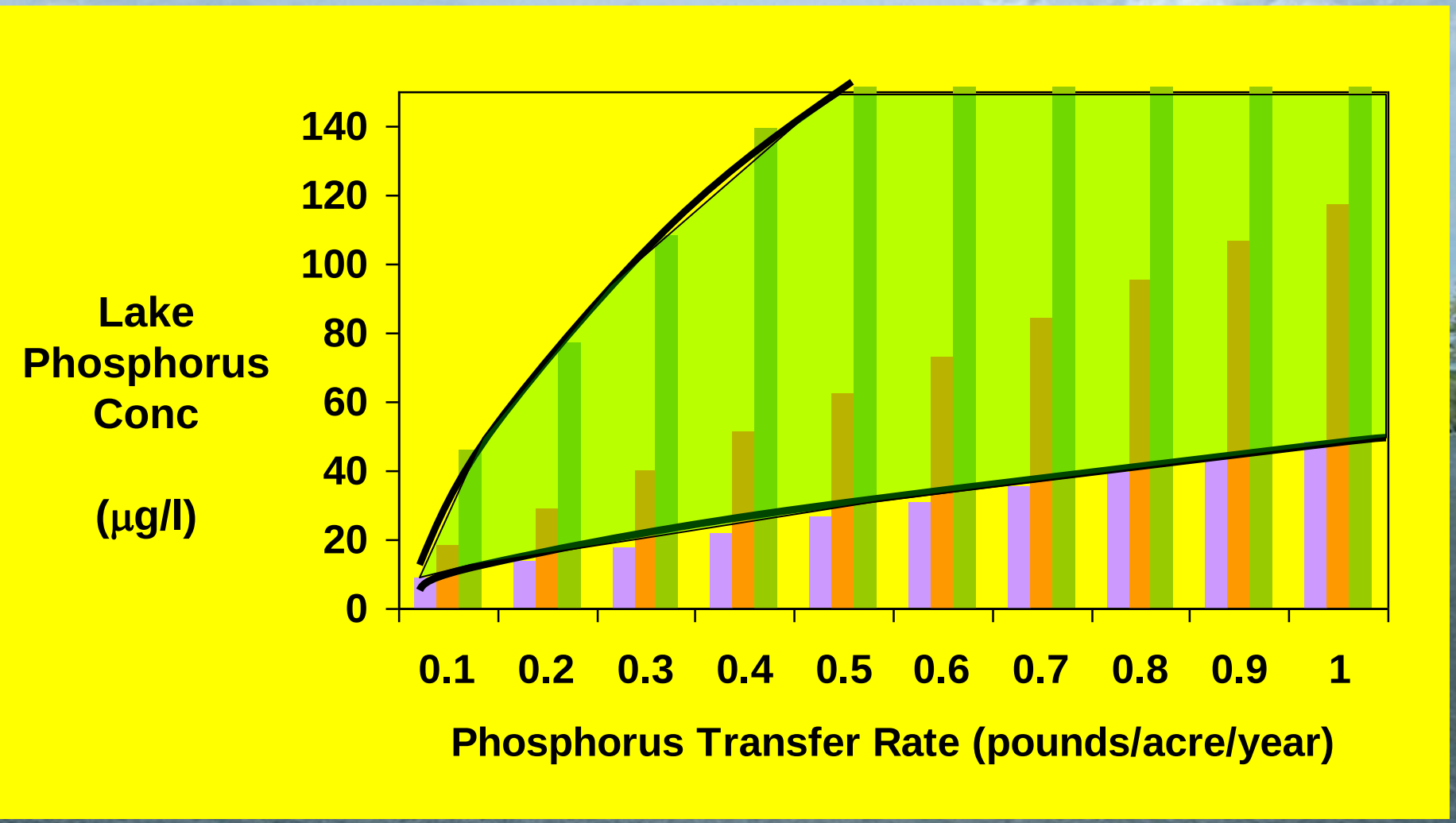

Lake Phosphorus Conc
(µg/l)
140
120
100
80
60
40
20
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Phosphorus Transfer Rate (pounds/acre/year)



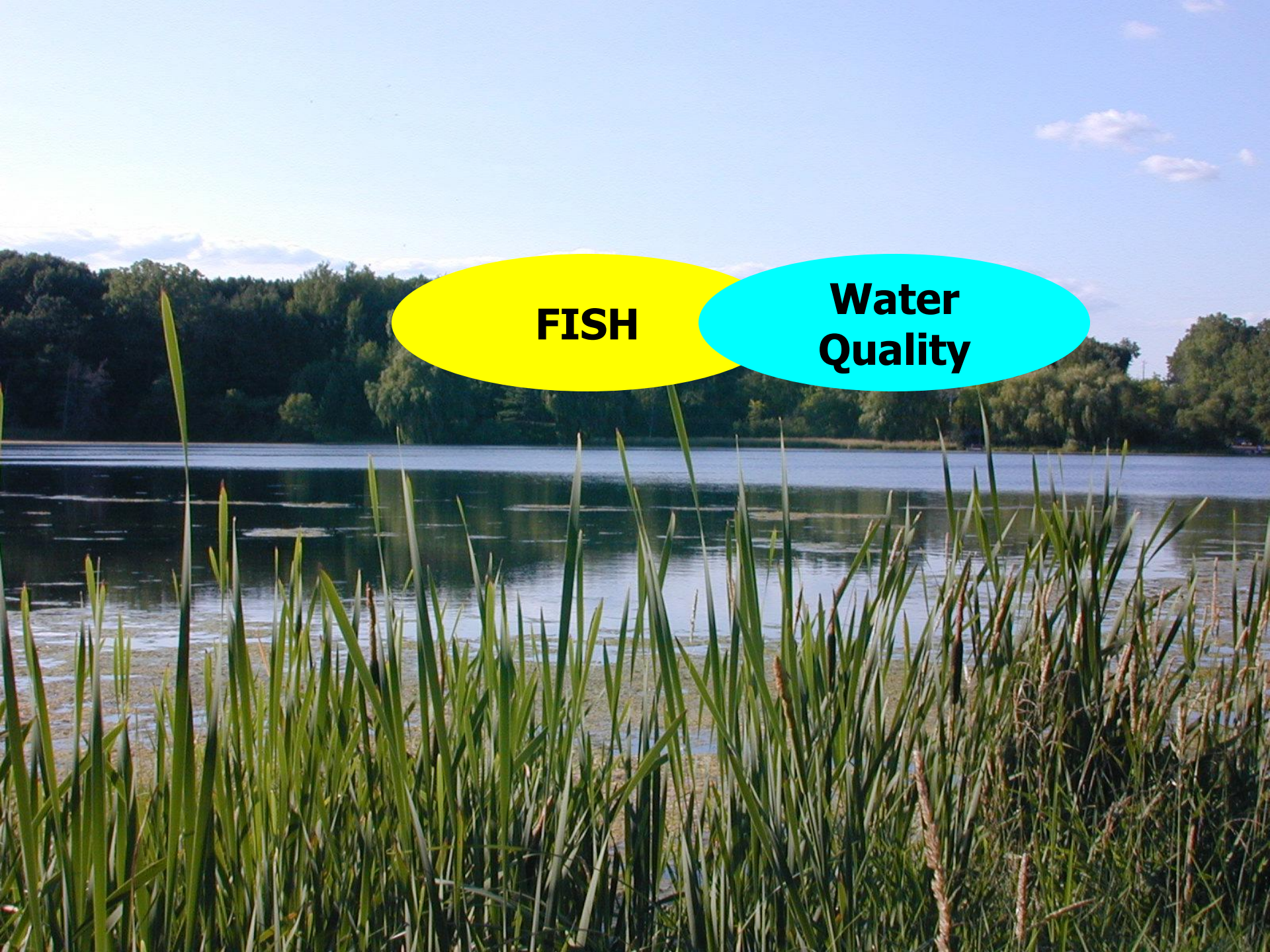
Large Watershed/Lake Ratio



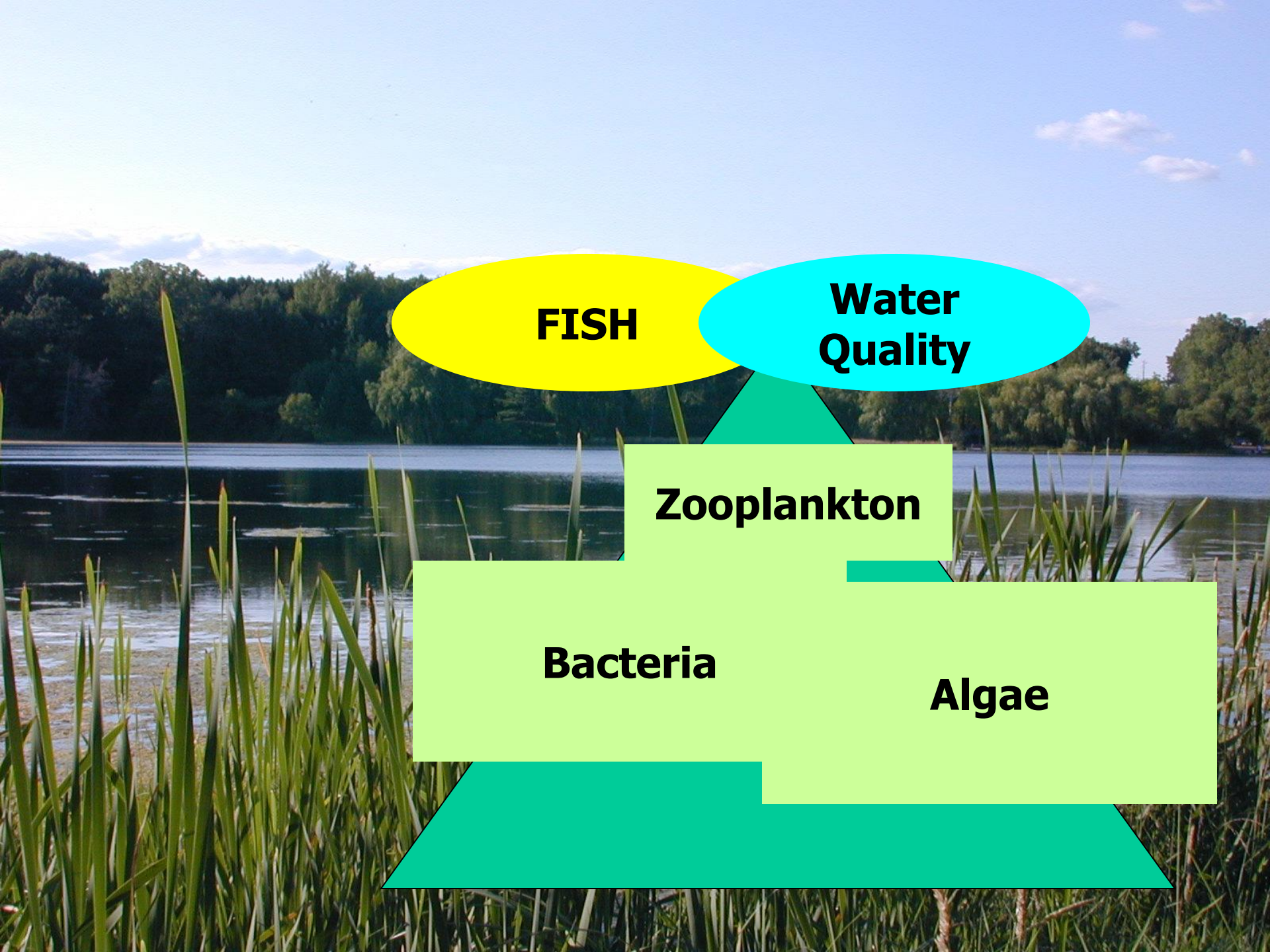
Small Watershed/Lake Ratio

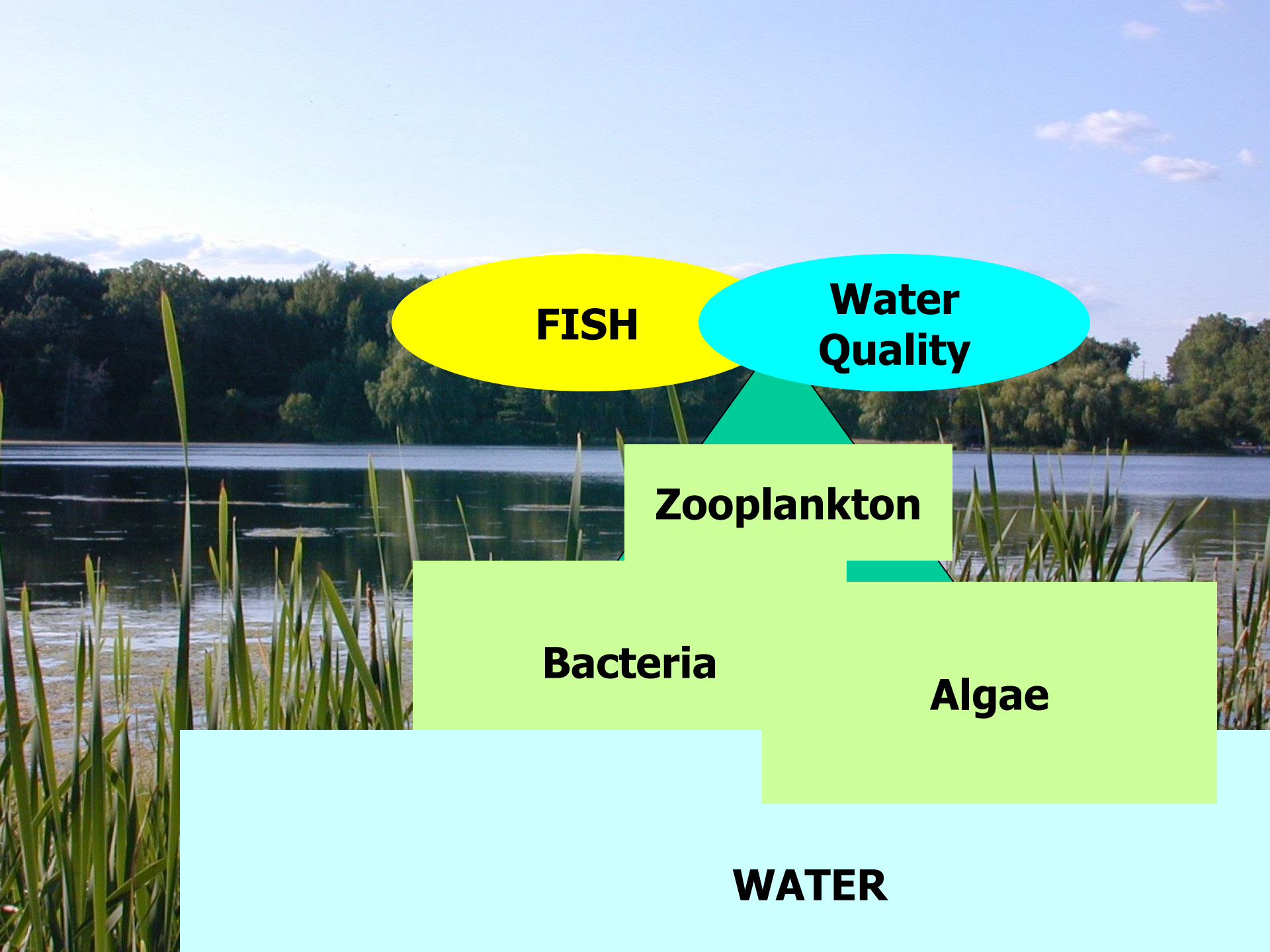

Lake Phosphorus Conc
(µg/l)
140
120
100
80
60
40
20
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Phosphorus Transfer Rate (pounds/acre/year)

Lakes

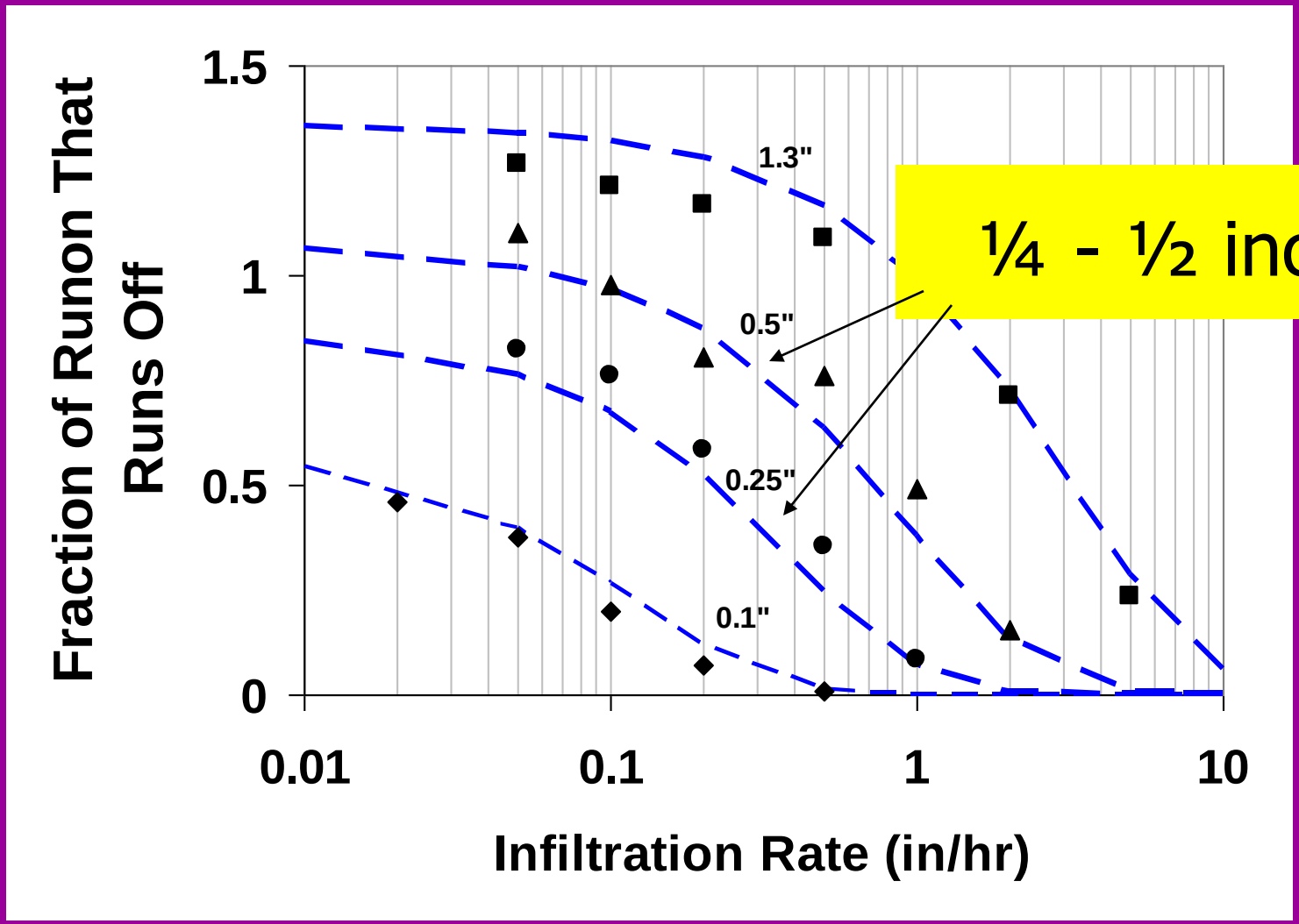

FISH
Water Quality

This water is always moving!


FISH
Water Quality
Zooplankton
Bacteria
Algae


FISH
Water Quality
Zooplankton
Bacteria
Algae
WATER

How do we keep all this water (and nutrients) on the land



¼ - ½ inch/hour

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