



# How Groundwater Interacts with Lakes and Streams

Ken Bradbury

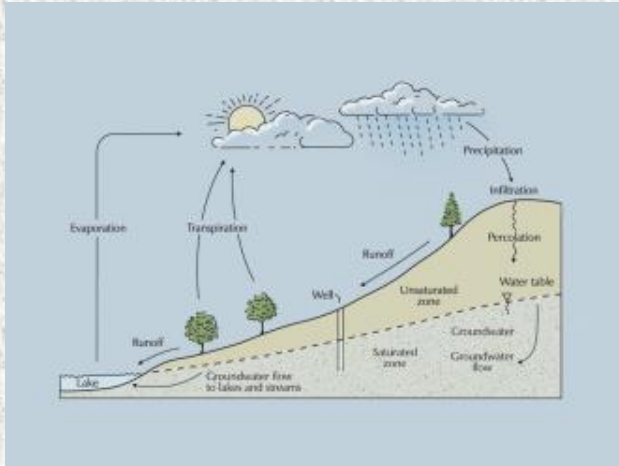
Wisconsin Geological and Natural History Survey  
University of Wisconsin-Extension

AGI Critical Issues Webinar  
July 13, 2015

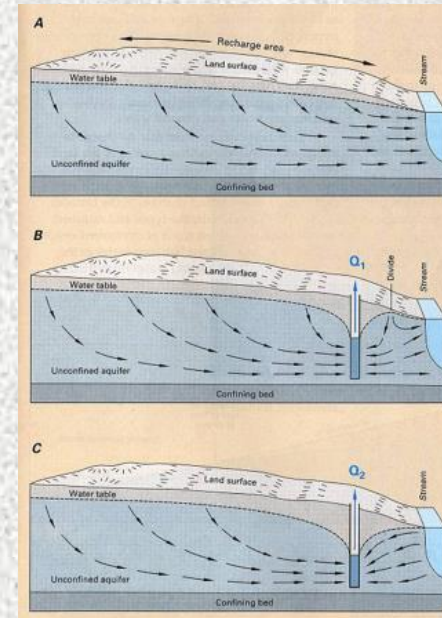


# This talk is about...

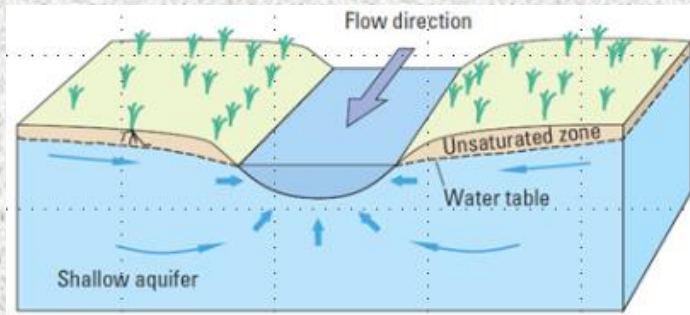
## Groundwater basics

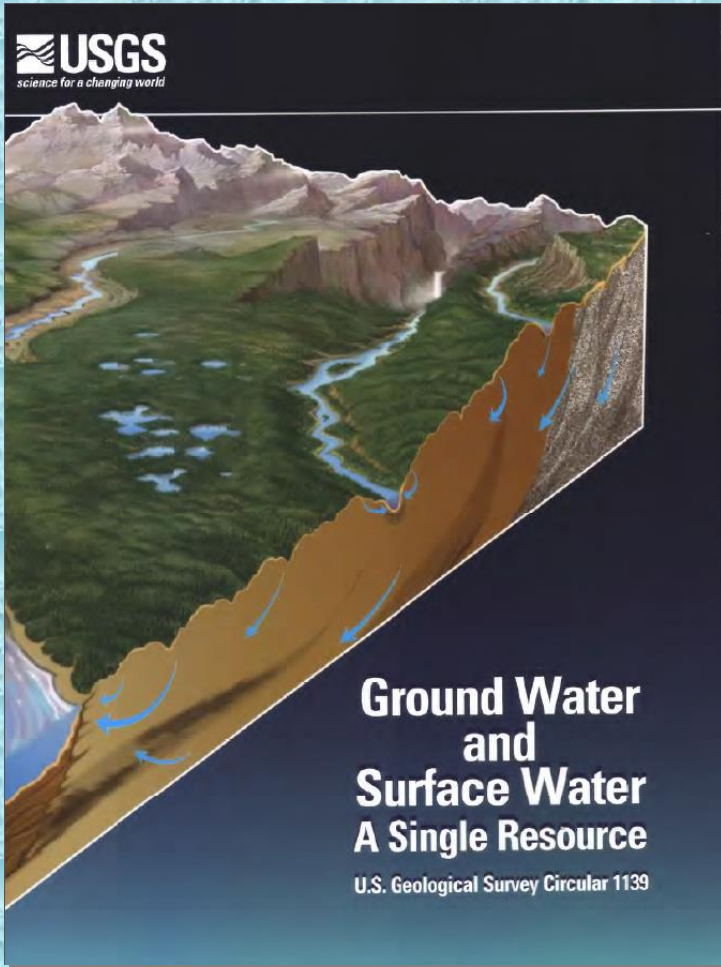


## How pumping wells affect streams



## Stream hydrogeology





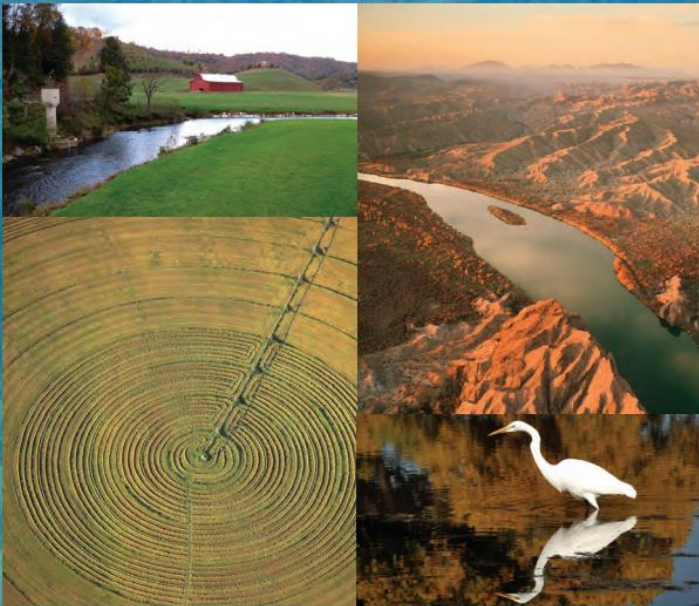
# A single resource...

Groundwater and surface water are intimately related and should be understood and managed as a single resource

<http://pubs.usgs.gov/circ/circ1139/index.html>



## Streamflow Depletion by Wells—Understanding and Managing the Effects of Groundwater Pumping on Streamflow



Circular 1376

U.S. Department of the Interior  
U.S. Geological Survey

Recommended reference

Barlow and Leake, USGS  
Circular 1376, 2012

# What is groundwater?

- Groundwater is water filling pores, cracks, fractures, and other voids in geologic materials beneath the earth's surface.

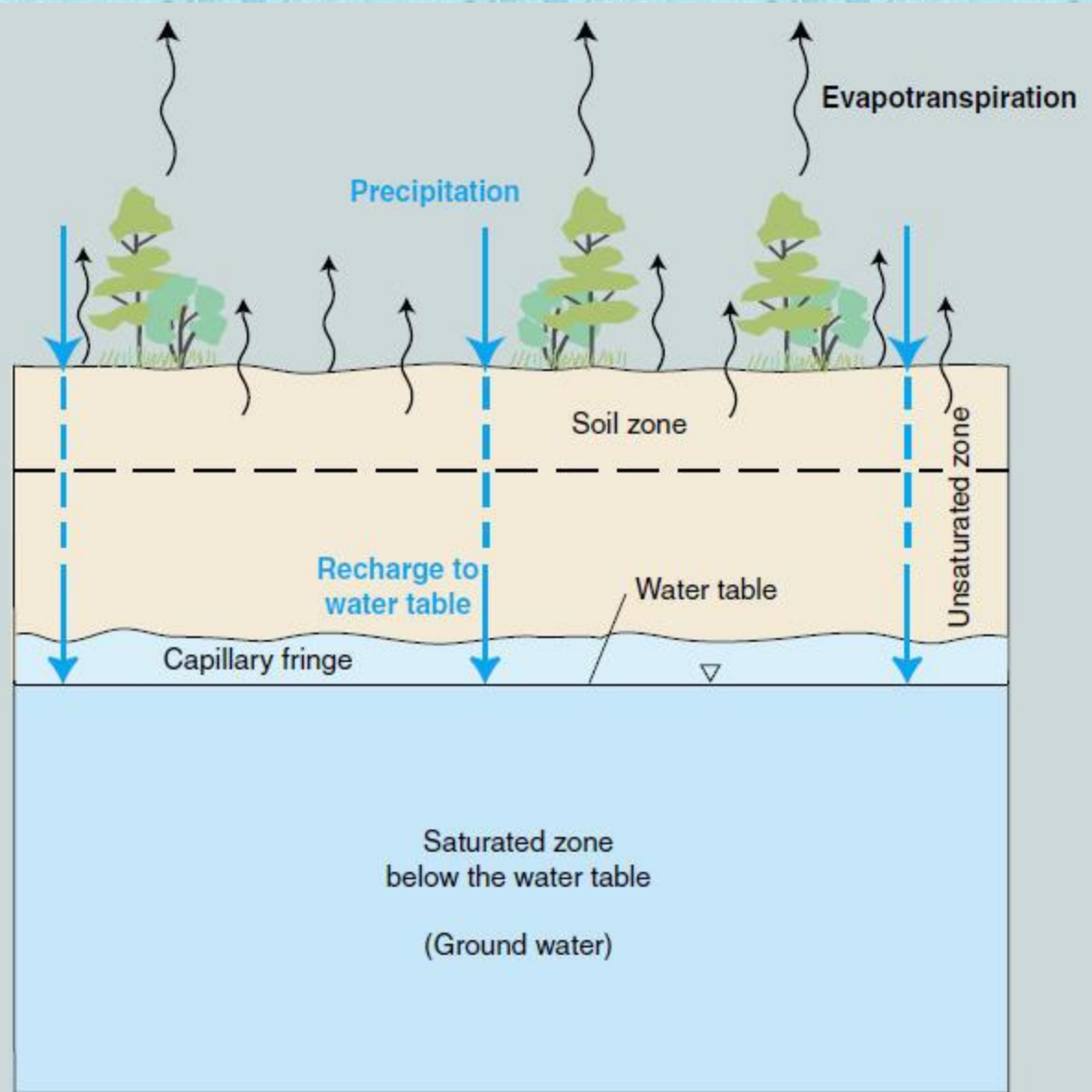
Culver springs, Dane County, WI



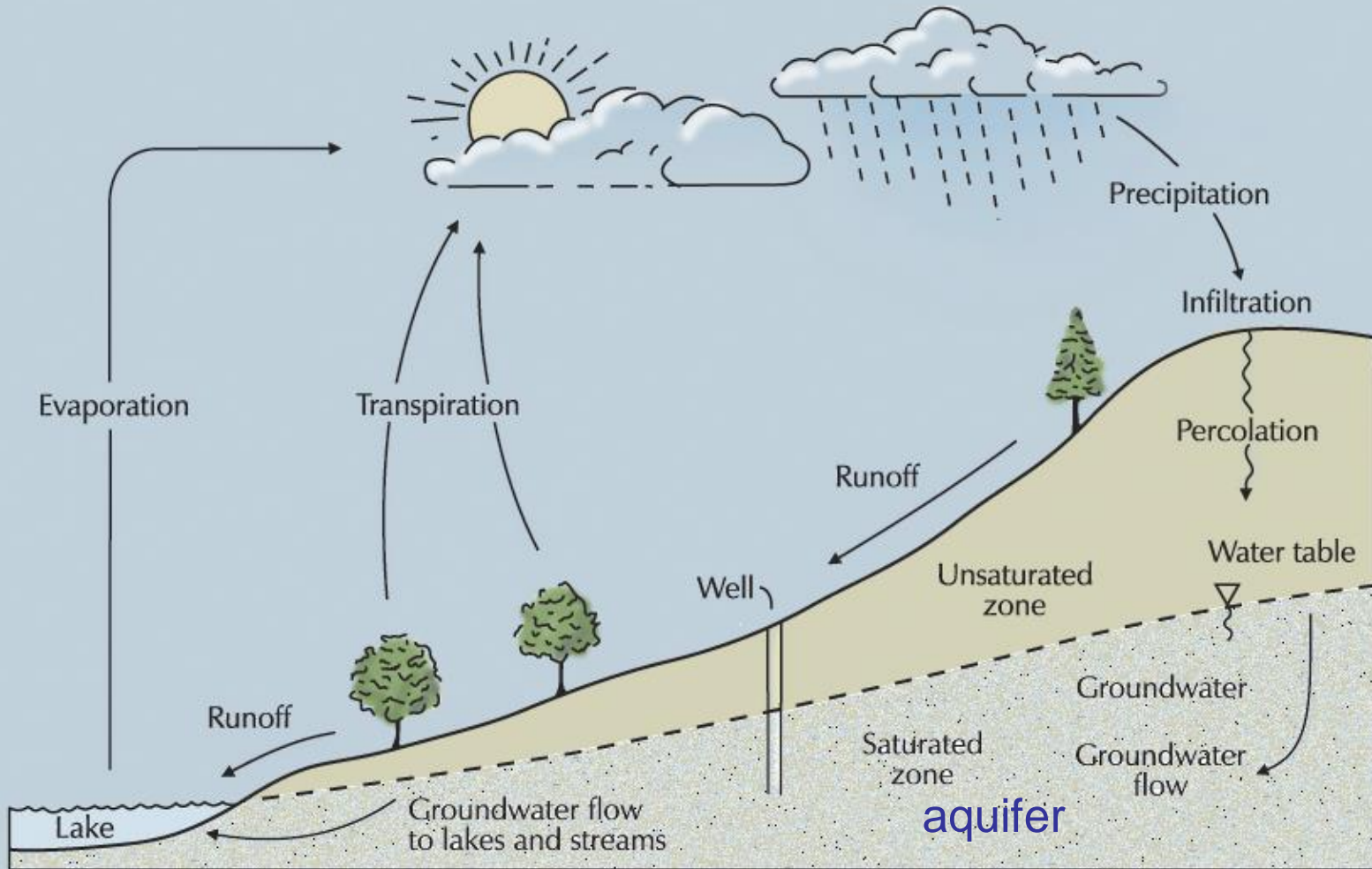


The *water table* is the top of the saturated zone. Below the water table all pores are completely filled with water.

Above the water table, in the *unsaturated zone*, pores are partly or completely filled with air.

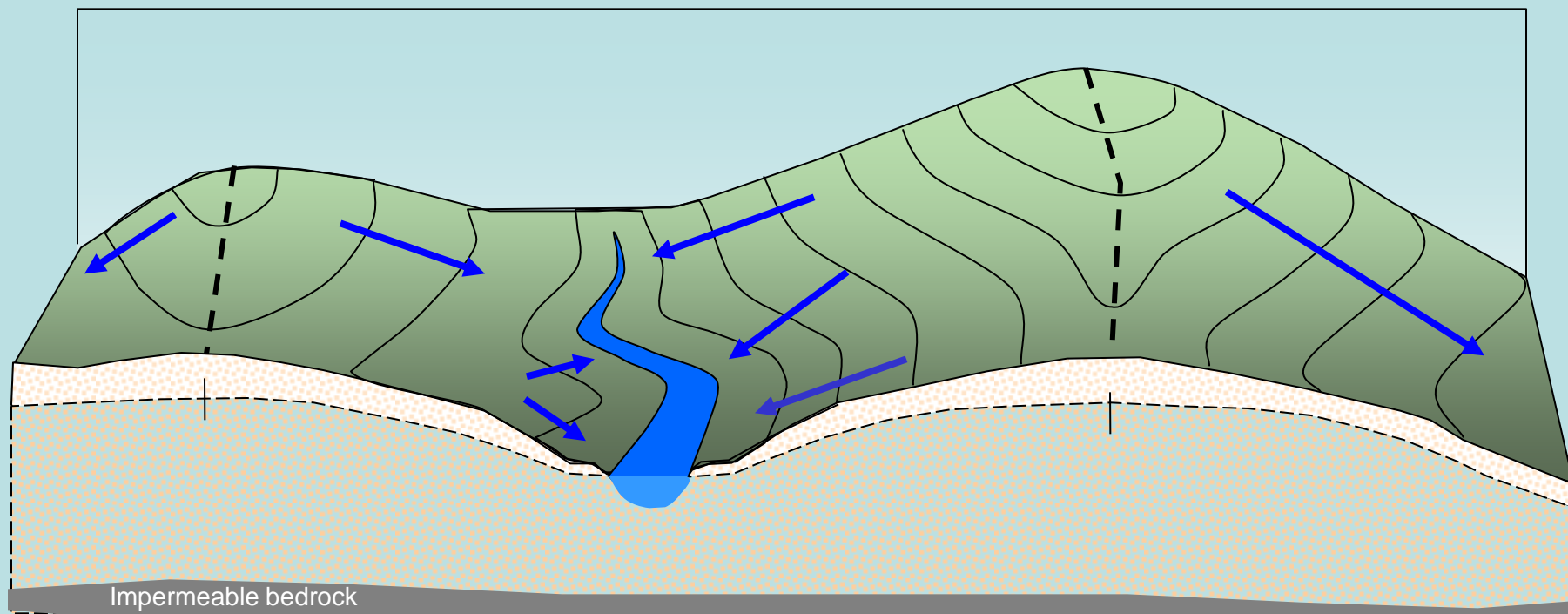


# All water is part of the water cycle...



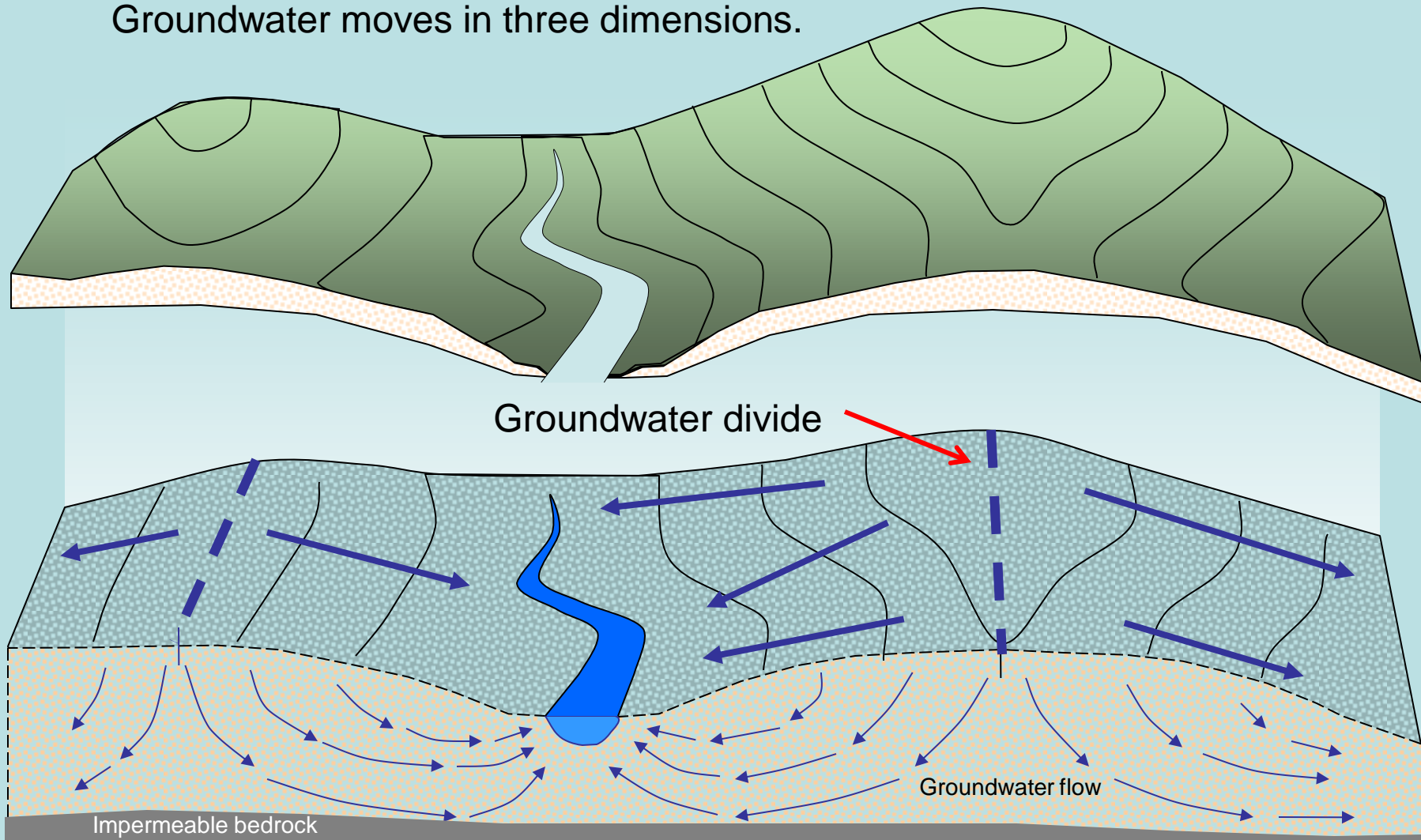
Aquifers are geologic units (sand and gravel, sandstone, etc) that can store and transmit significant quantities of groundwater

Groundwater moves in three dimensions.

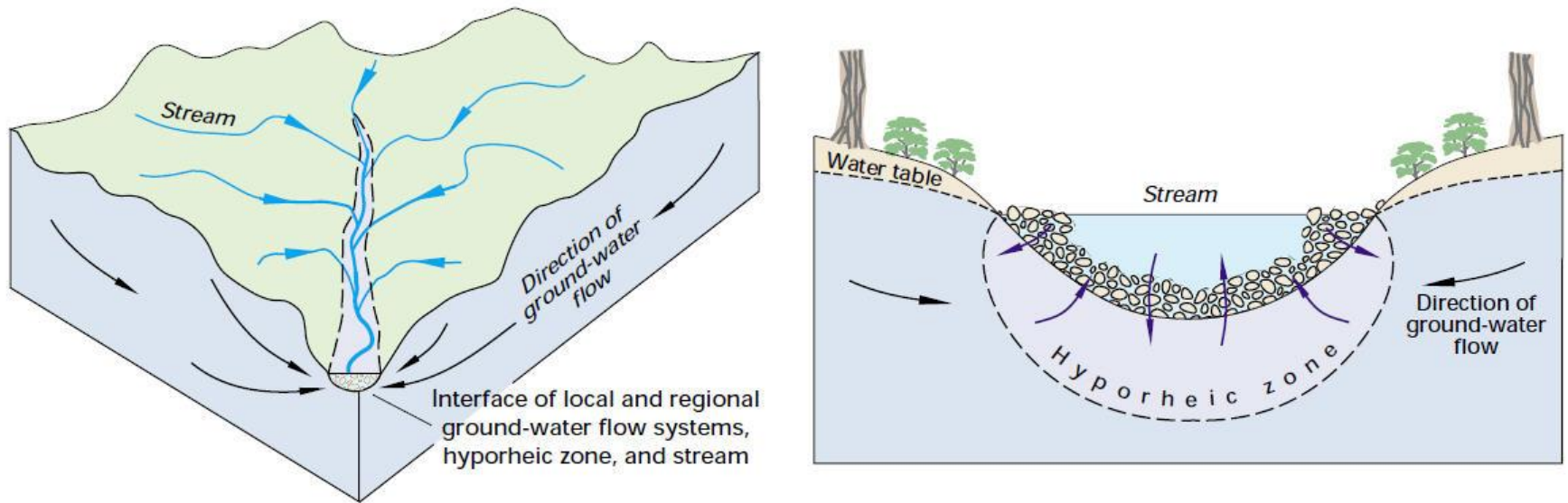




Groundwater moves in three dimensions.



# Groundwater sustains streams, springs, and wetlands

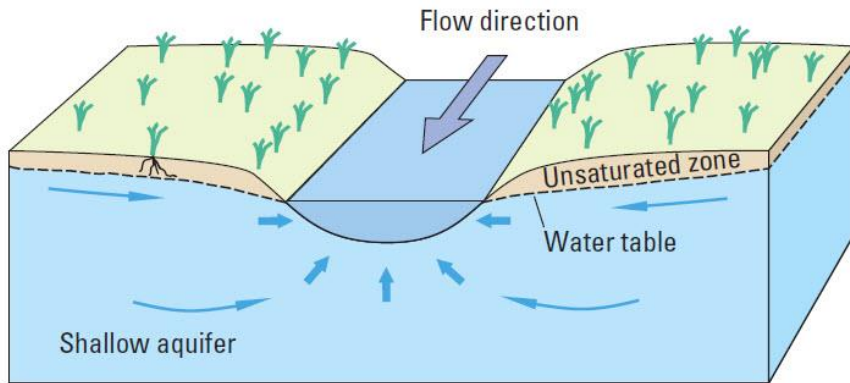


*Figure 15. Streambeds and banks are unique environments because they are where ground water that drains much of the subsurface of landscapes interacts with surface water that drains much of the surface of landscapes.*

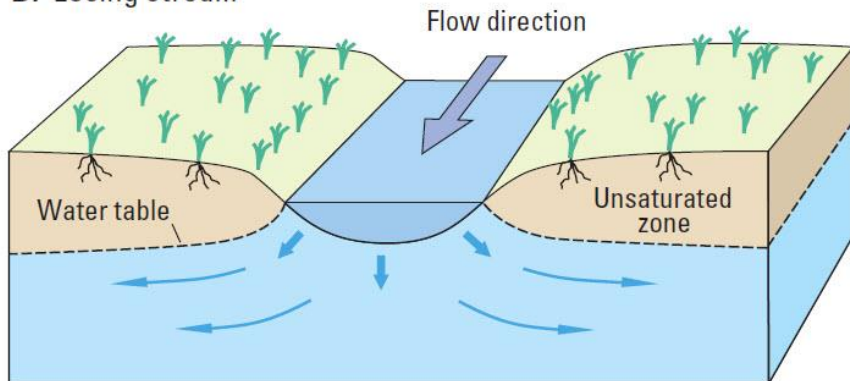


# Gaining and losing streams

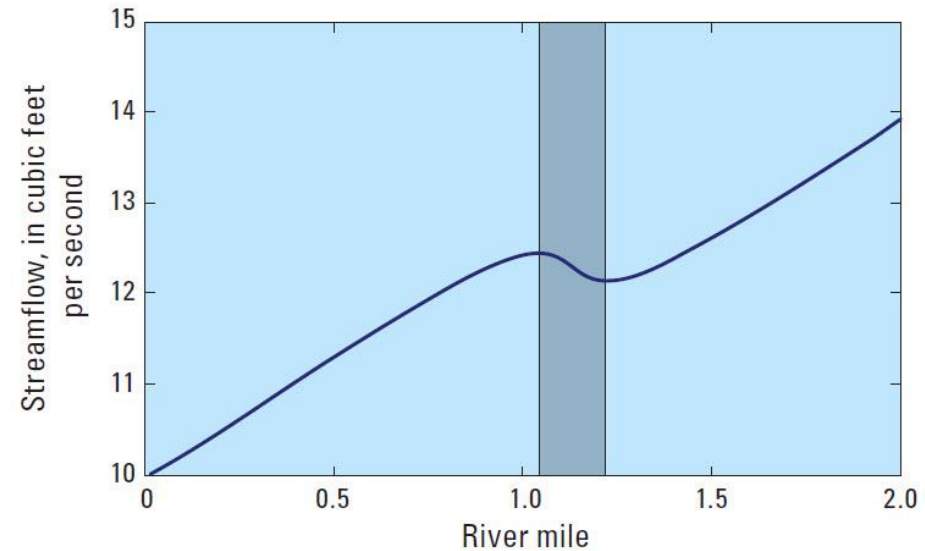
A. Gaining stream



B. Losing stream



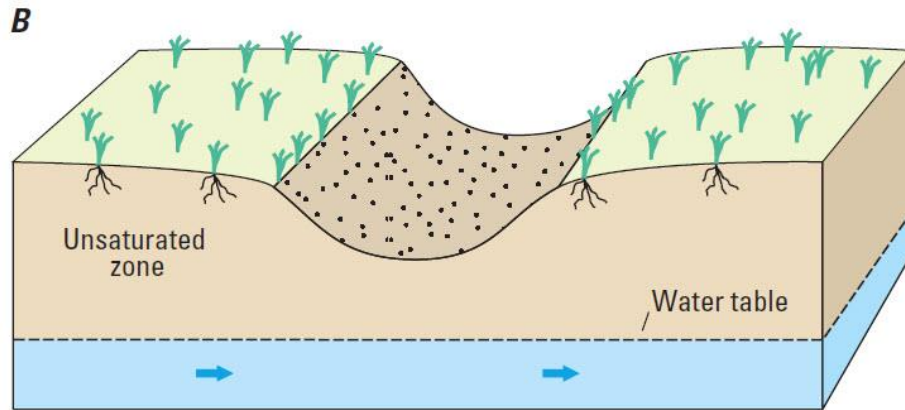
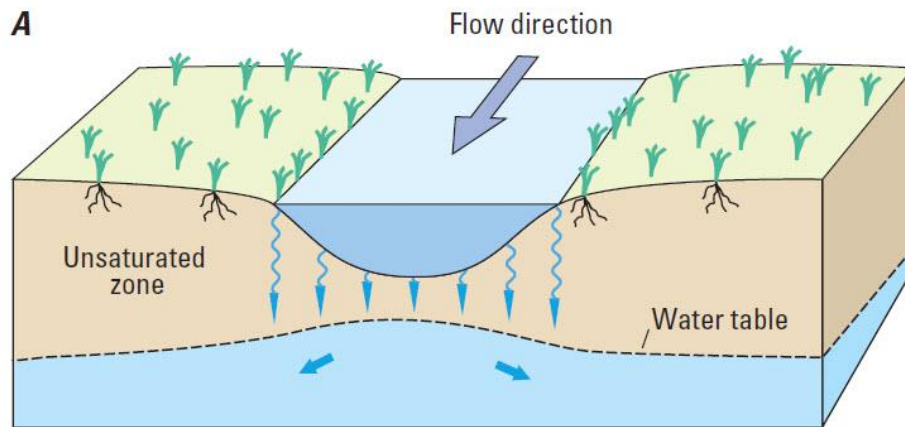
C. Gaining and losing reaches



## EXPLANATION

-  Gaining reach
-  Losing reach

**Figure 4.** A, Gaining stream reaches receive water from the groundwater system, whereas, B, losing reaches lose water to the groundwater system. C, Streamflow increases along the gaining reaches of a river and streamflow decreases along the losing reaches of a river when there is no direct surface-water runoff to the river (parts A and B modified from Winter and others, 1998).



**Figure 5.** Disconnected stream reaches are separated from the groundwater system by an unsaturated zone. In *A*, streamflow is a source of recharge to the underlying groundwater system, but in *B*, streamflow and groundwater recharge have ceased (modified from Winter and others, 1998).

# Disconnected stream



Lakes usually represent “outcrops” of the water table.

Depending on their position in the landscape, and on groundwater conditions, lakes can receive groundwater, lose water to groundwater, or both.

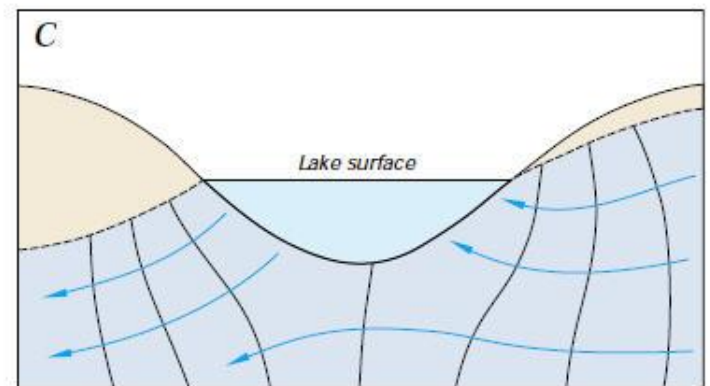
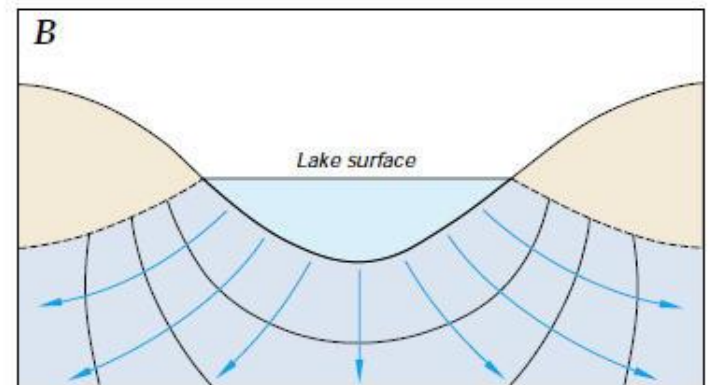
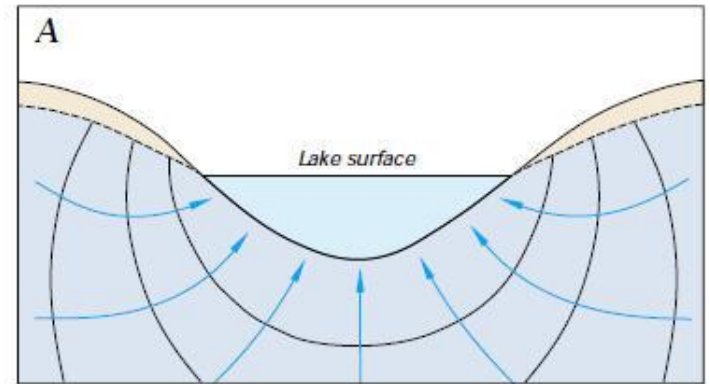
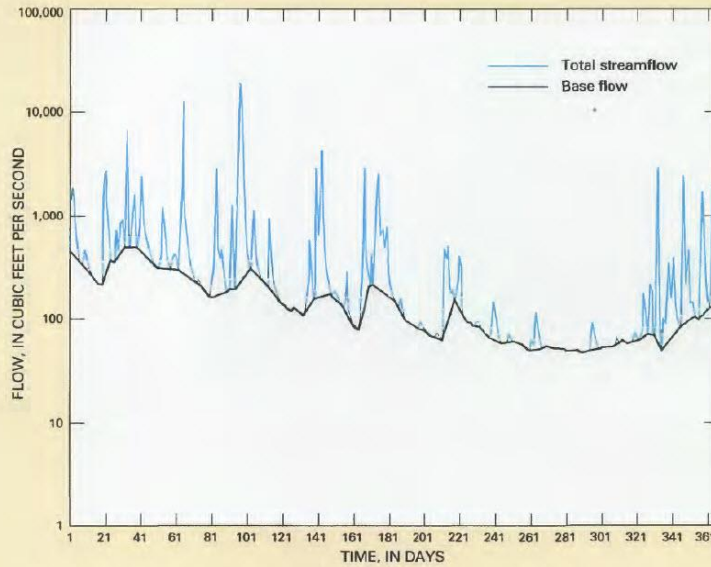


Figure 16. Lakes can receive ground-water inflow (A), lose water as seepage to ground water (B), or both

**Figure B-1.** The ground-water component of streamflow was estimated from a streamflow hydrograph for the Homochitto River in Mississippi, using a method developed by the Institute of Hydrology, United Kingdom. (Institute of Hydrology, 1980, Low flow studies: Wallingford, Oxon, United Kingdom, Research Report No. 1.)

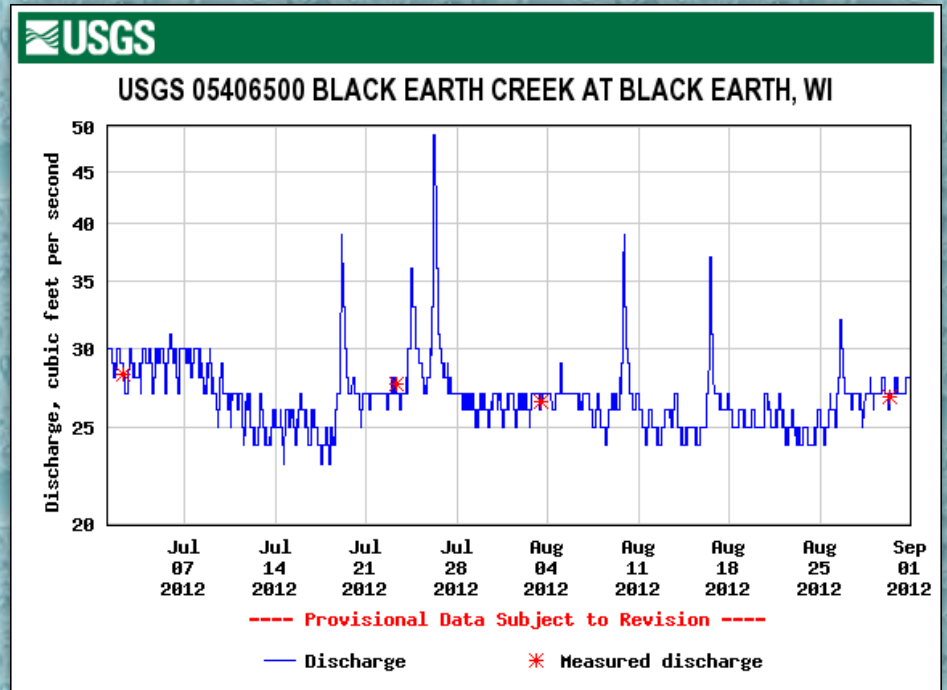


Groundwater discharge sustains streams.

This flow is called *baseflow*, or the *groundwater component of streamflow*

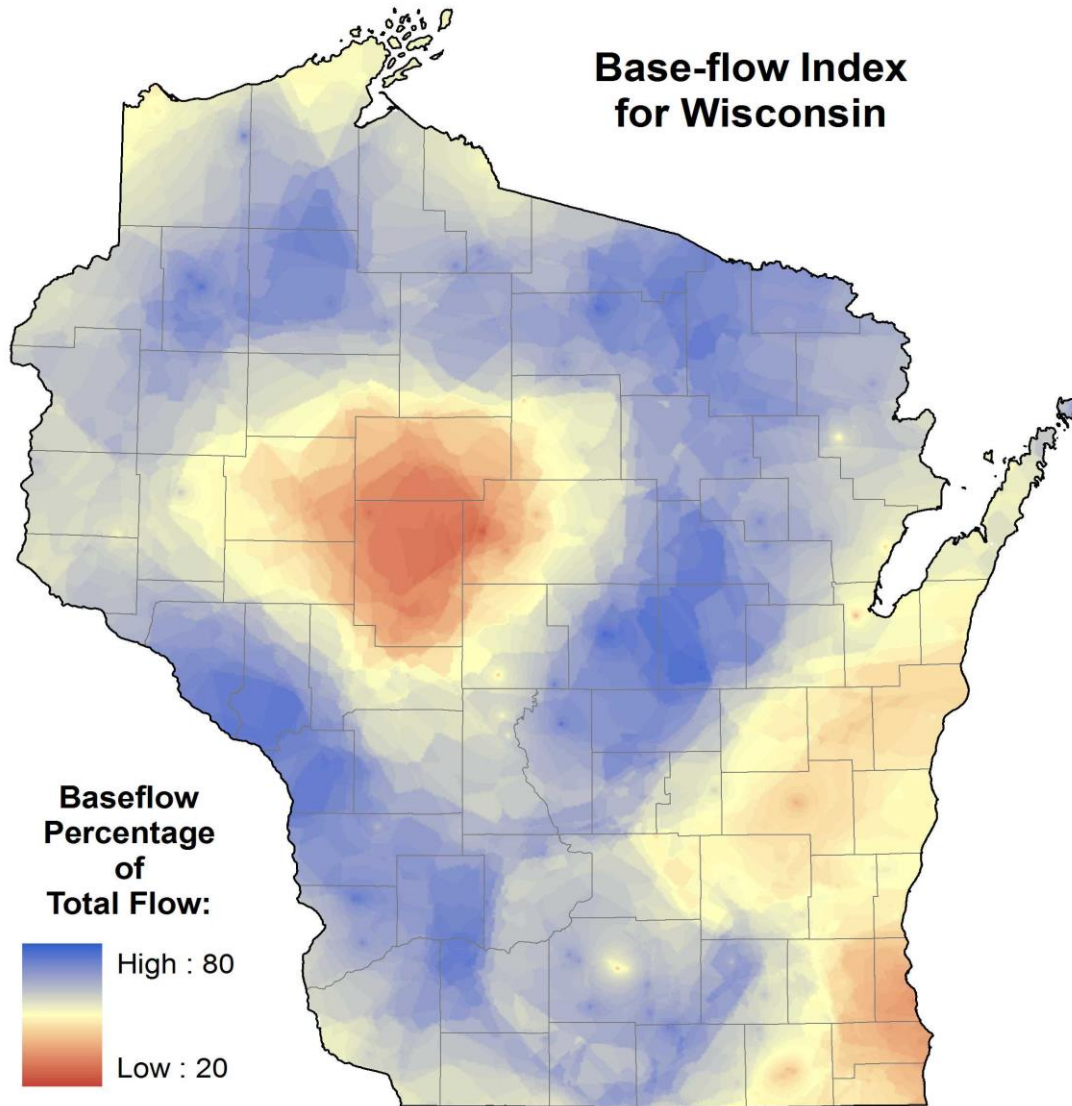


Source: Natural Heritage Land Trust

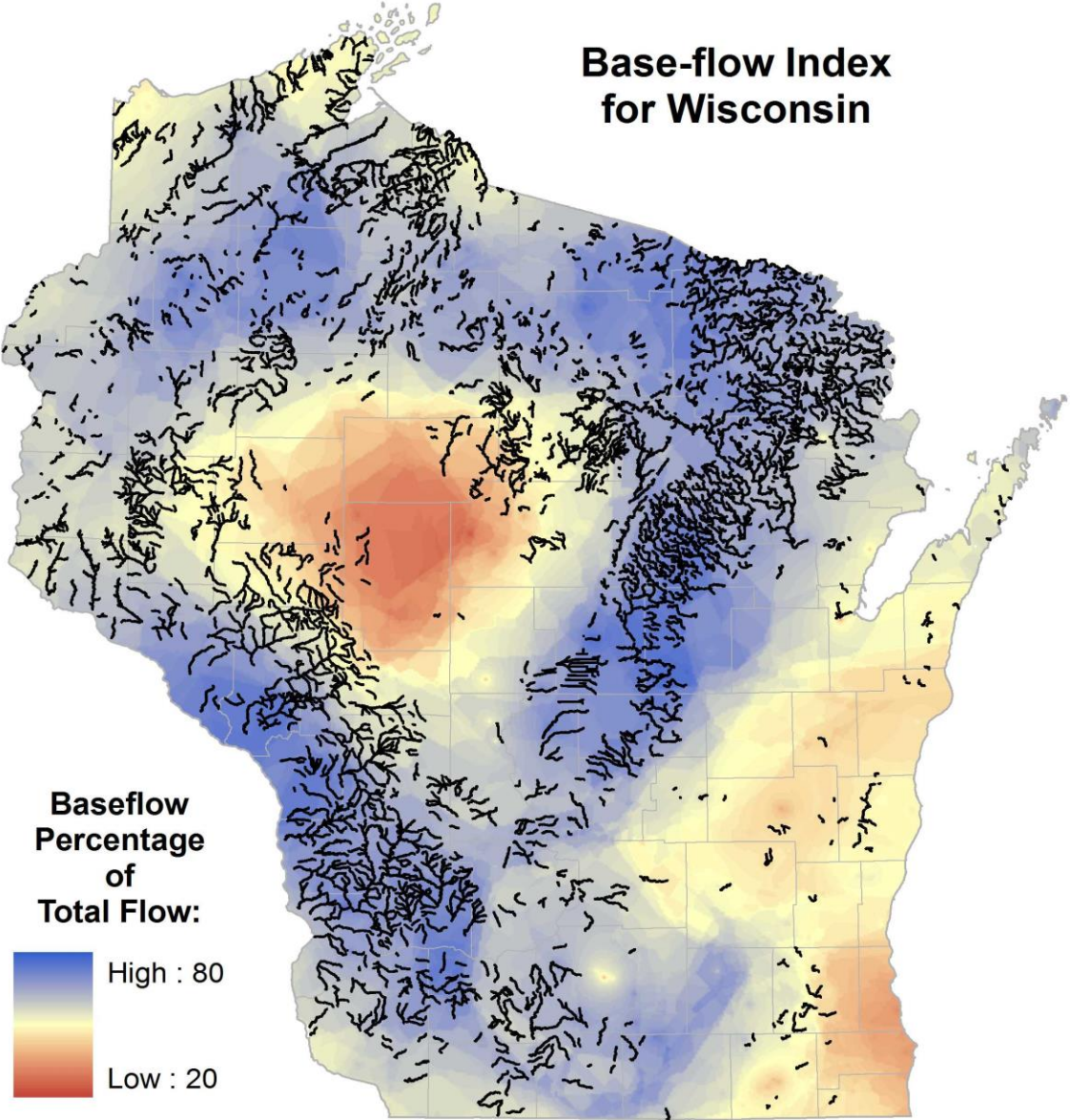




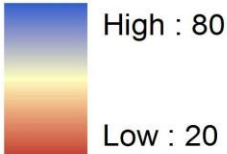
## Base-flow Index for Wisconsin



# Base-flow Index for Wisconsin



**Baseflow  
Percentage  
of  
Total Flow:**



 **Trout Stream**



# Impacts of pumping wells

A center pivot irrigation system is shown in operation over a lush green field. The system consists of a long metal wheelline supported by a series of truss-like structures. Multiple riser pipes are spaced along the wheelline, each with a nozzle that is spraying water in a fan pattern. The background features a dense line of green trees under a bright, slightly cloudy sky. The overall scene is a typical agricultural setting during a growing season.

Pumping can cause two things:

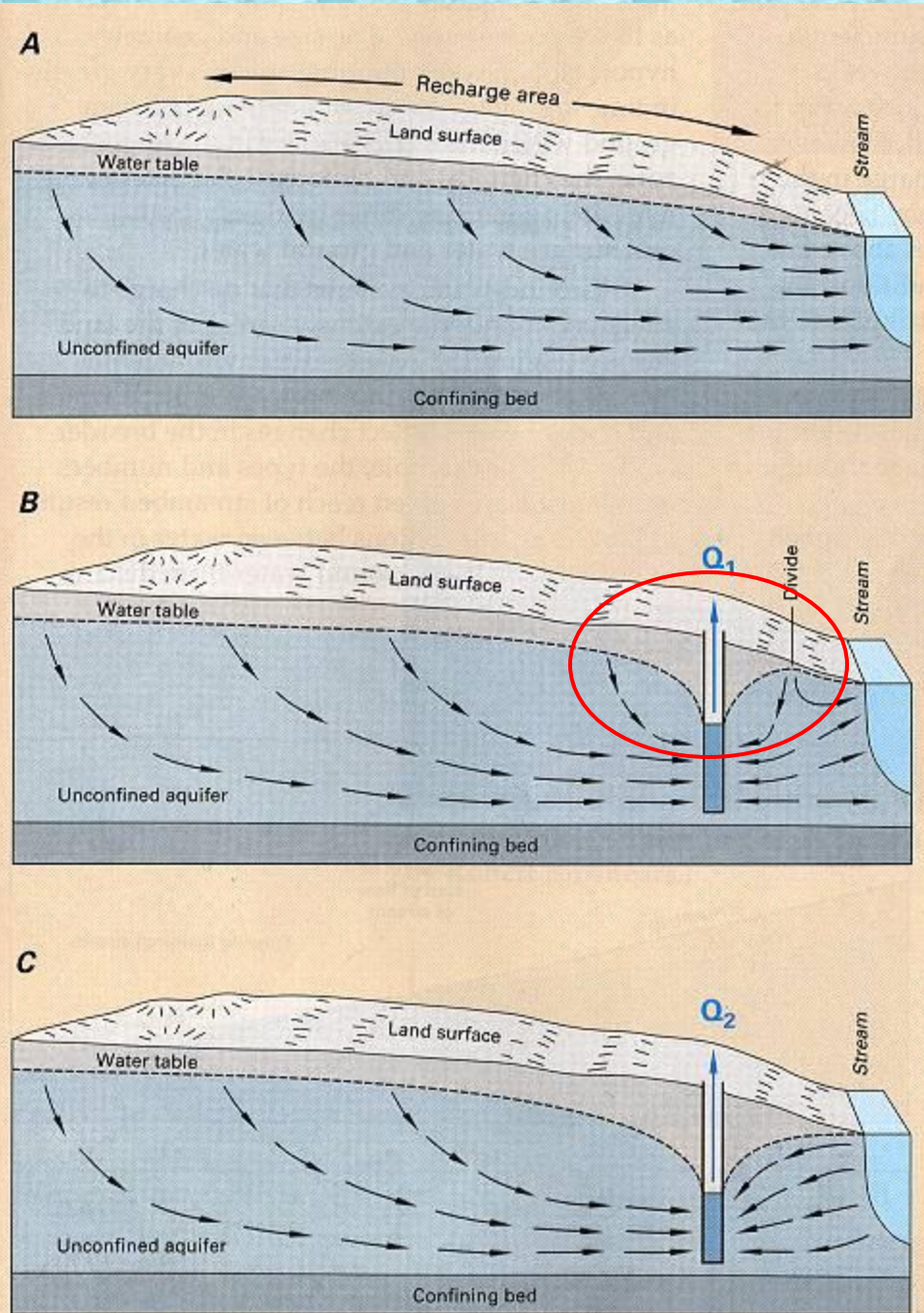
1. Drawdown, or lowering of groundwater levels near the well.
2. Reduction of groundwater flow to nearby surface water features (a reduction of natural groundwater discharge).



# Pumping wells affect groundwater movement

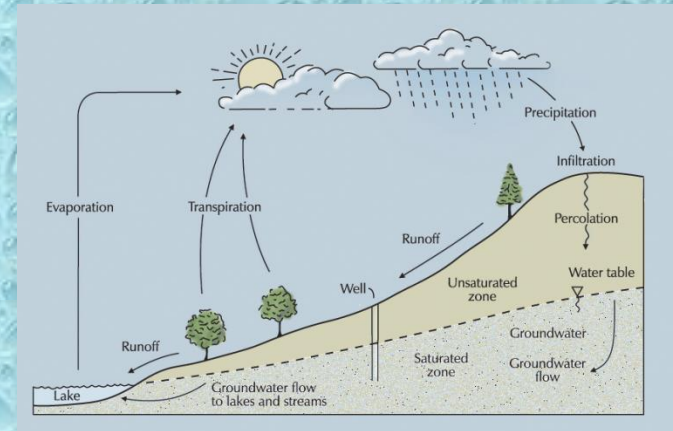
The well causes a cone of depression

Well pumping can reduce flow to surface water





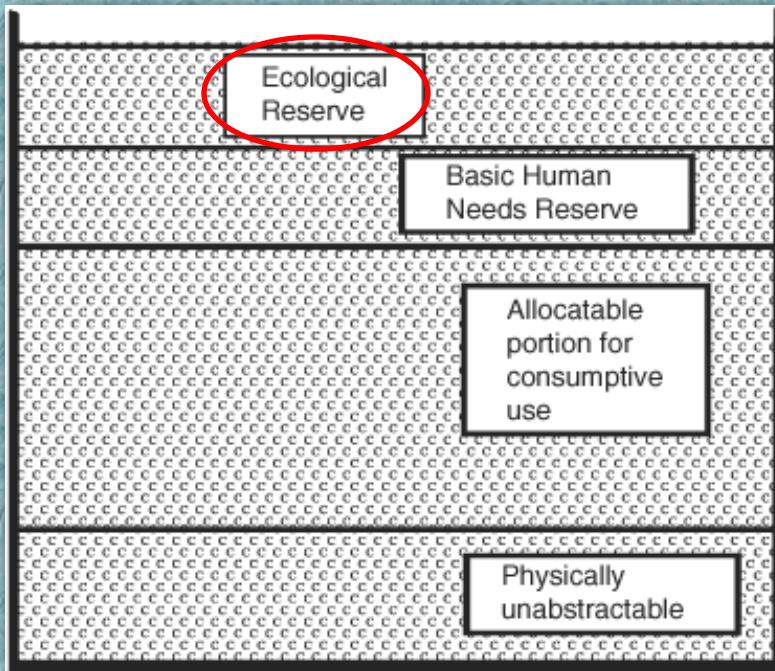
# Water budget basics



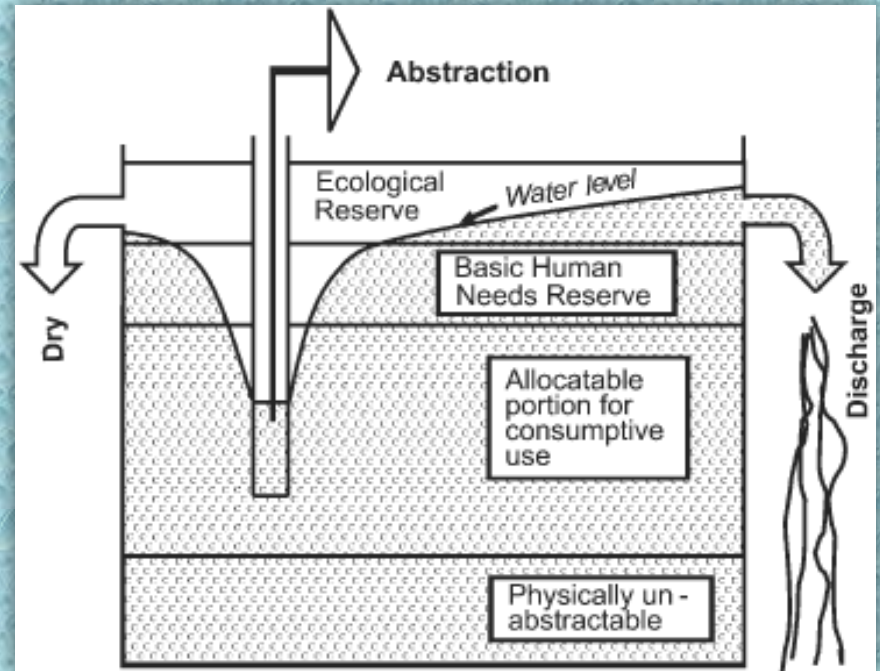
- Like a bank balance, a water budget includes *all* inflows and outflows of water
- Models inherently provide this water budget accounting
- In many areas, the most obvious evidence of “deficit” in the water budget is decreased baseflow to streams, springs, lakes, and wetlands

# The impact on streams can be significant even if drawdown is small.

The “ecological reserve” refers to groundwater that discharges to and sustains streams, lakes, and wetlands. This is the first water to be “lost” from surface water features in areas of intense pumping.



The groundwater “bucket” – allocating water



Effect of pumping on the ecological reserve



# Misconceptions about streamflow depletion

Misconception 1. Total development of groundwater resources from an aquifer system is “safe” or “sustainable” at rates up to the average rate of recharge.

Misconception 2. Depletion is dependent on the rate and direction of water movement in the aquifer.

Misconception 3. Depletion stops when pumping ceases.

Misconception 4. Pumping groundwater exclusively below a confining layer will eliminate the possibility of depletion of surface water connected to the overlying groundwater system.

From: Barlow and Leake, USGS Circular 1376, 2012

[http://pubs.usgs.gov/circ/1376/pdf/circ1376\\_barlow\\_report\\_508.pdf](http://pubs.usgs.gov/circ/1376/pdf/circ1376_barlow_report_508.pdf)



# Ending up...

- Groundwater and surface water are intimately connected and should be thought of as a *single resource*
- All water comes from somewhere — understanding the *water balance* is critical for management decisions
- Groundwater discharge becomes baseflow and sustains the flow in streams
- Pumping from high-capacity wells near streams can reduce streamflow; these impacts depend on pumping rates and the local hydrogeologic setting.