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Introduction to Hydrology

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Hydrology is the study of the movement, distribution, and quality of water throughout an area

Arizona – arid and semi-arid hydrology

- Low precipitation
- High evaporation and transpiration (plants)
- Few perennial streams
- Water is primarily stored in the subsurface

This talk will focus on aquifers

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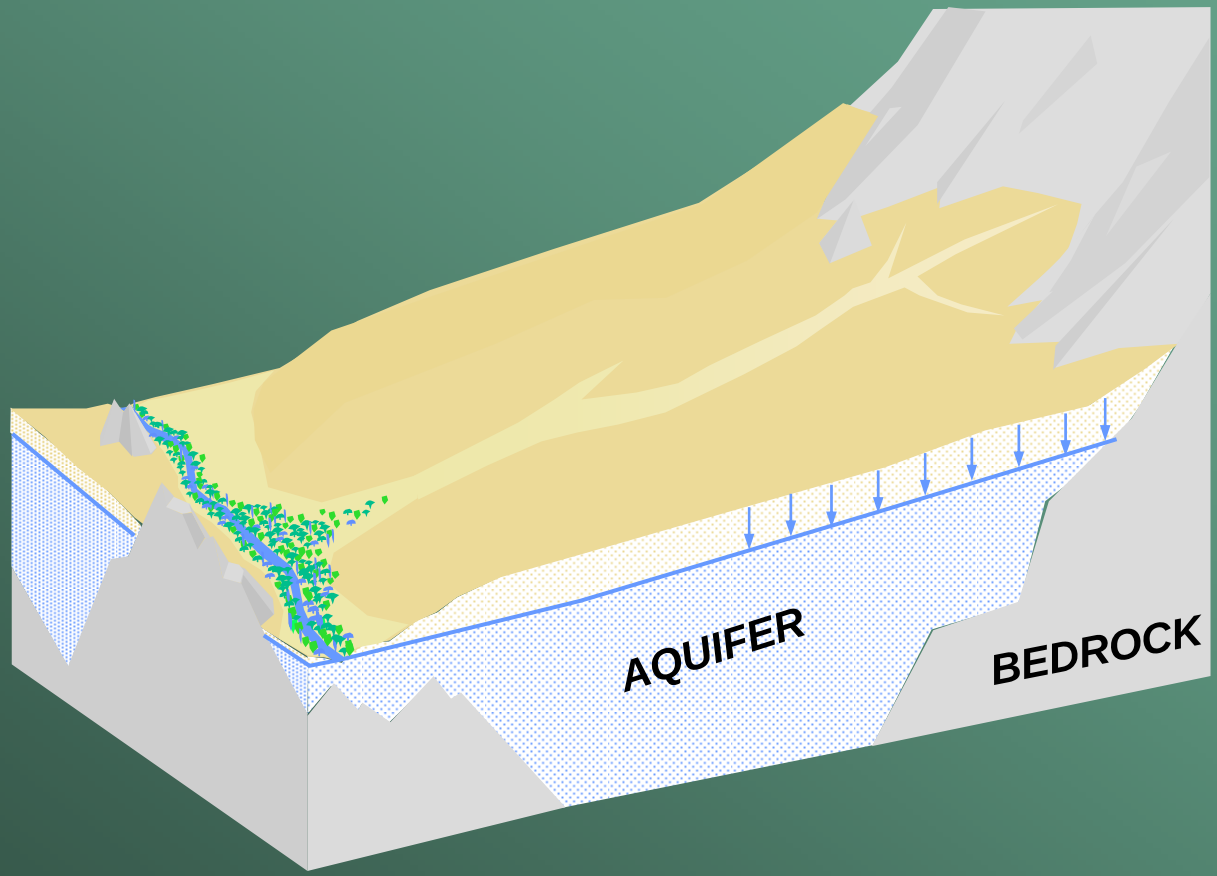
What is an aquifer?

A rock or sedimentary unit that is fully saturated (all pore spaces are filled with water) and sufficiently permeable to transmit economic quantities of water to wells and springs

Basin Aquifer



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What is a Water Budget?

A water budget is an accounting of water entering and leaving a specified volume over a given time period

A specified area can be

- Global
- Watershed
- Aquifer
- Lake

The time period can be

- Seasonal
- Annual
- An average of annual values

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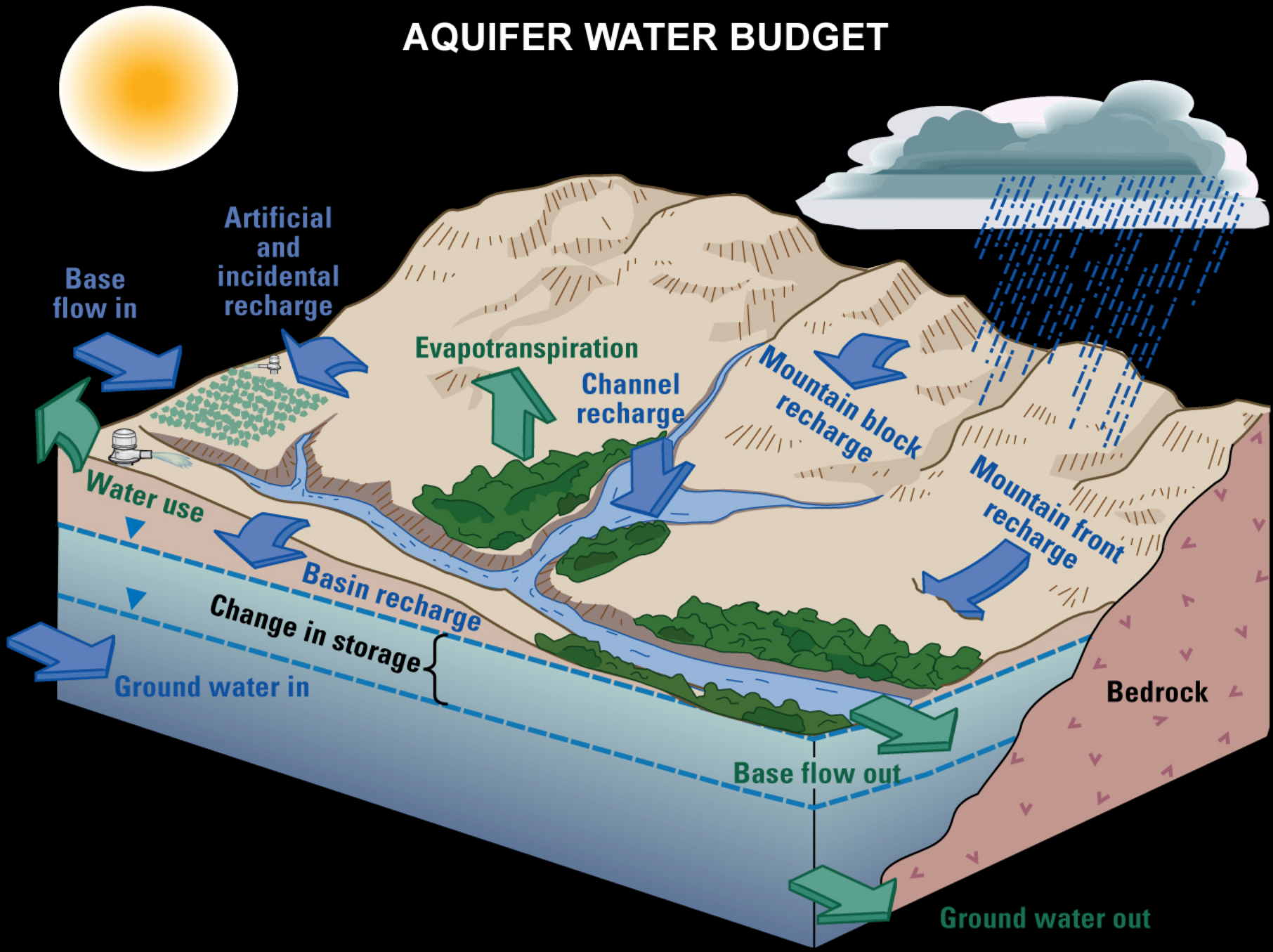
AQUIFER WATER BUDGET
Base flow in
Artificial and incidental recharge
Evapotranspiration
Channel recharge
Mountain block recharge
Mountain front recharge
Water use
Basin recharge
Change in storage
Ground water in
Bedrock
Base flow out
Ground water out

What is a Water Balance Equation?

A water balance equation is a mathematical expression of water entering and leaving a specified volume over a given time period

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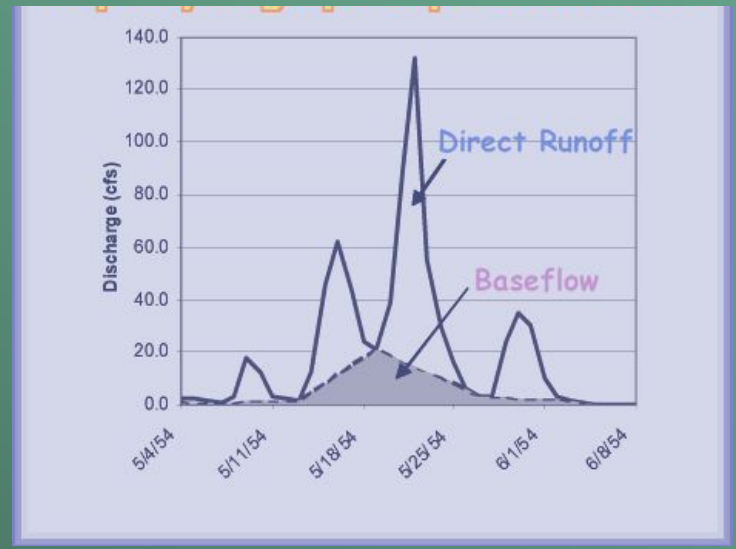
Aquifer water balance equation

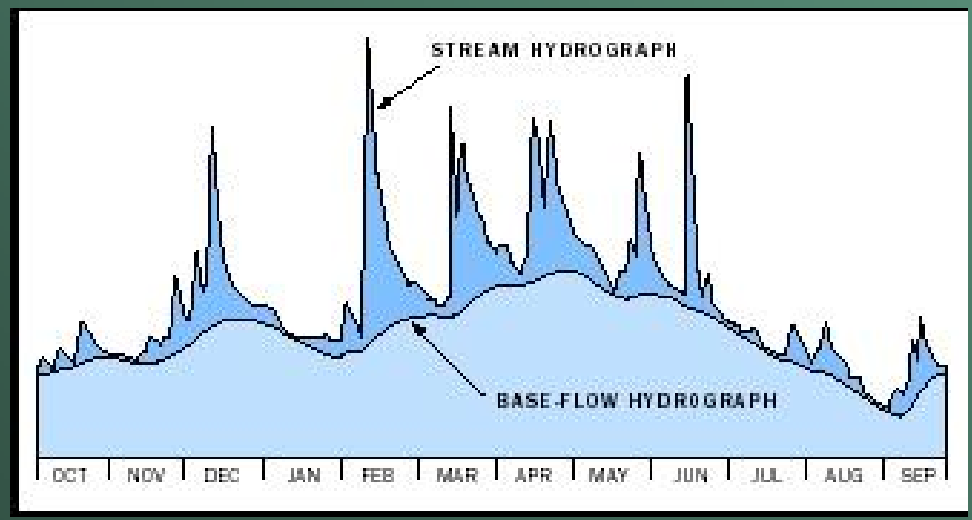
$$R + IR + GW_{in} + BF_{in} - ET - GW_{out} - BF_{out} - WU = \Delta S$$

R	Natural Recharge
IR	Incidental and Artificial Recharge
GW_{in}	Ground-water in
BF_{in}	Base-flow in
ET	Evapotranspiration
GW_{out}	Ground-water out
BF_{out}	Base-flow out
WU	Water use
ΔS	Change in storage

What is base flow?

-The discharge of water from an aquifer to a stream





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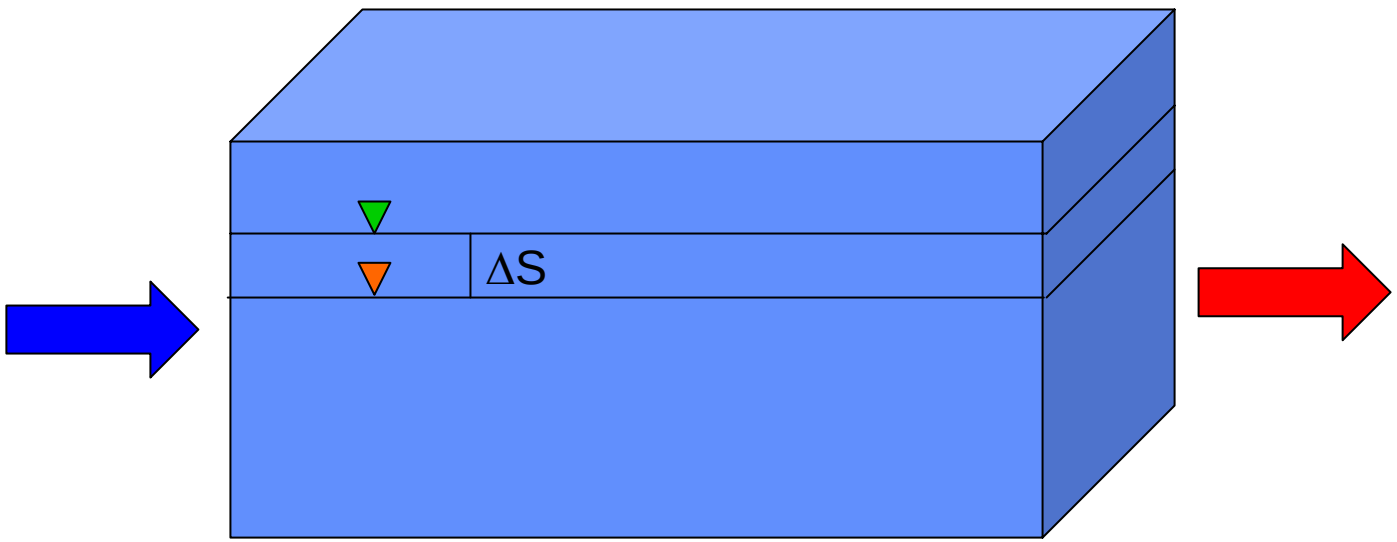
Inflow – Outflow = Change in Storage (ΔS)

ΔS = Water Level After – Water Level Before



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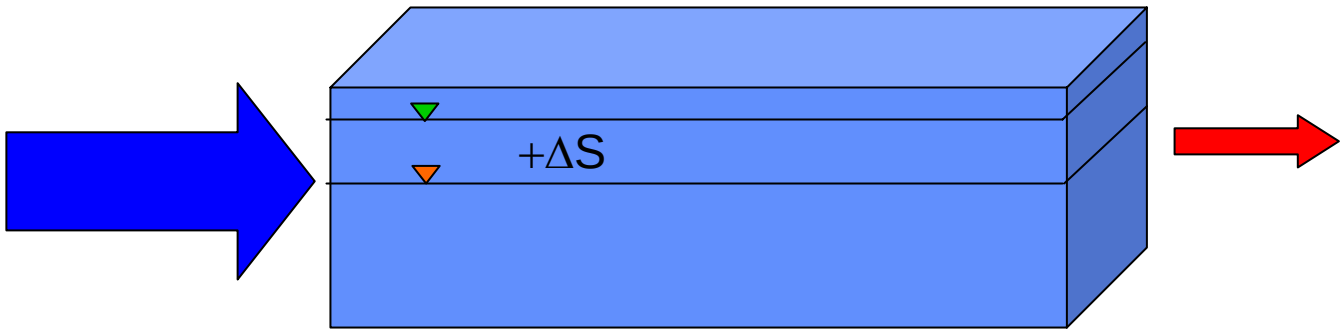
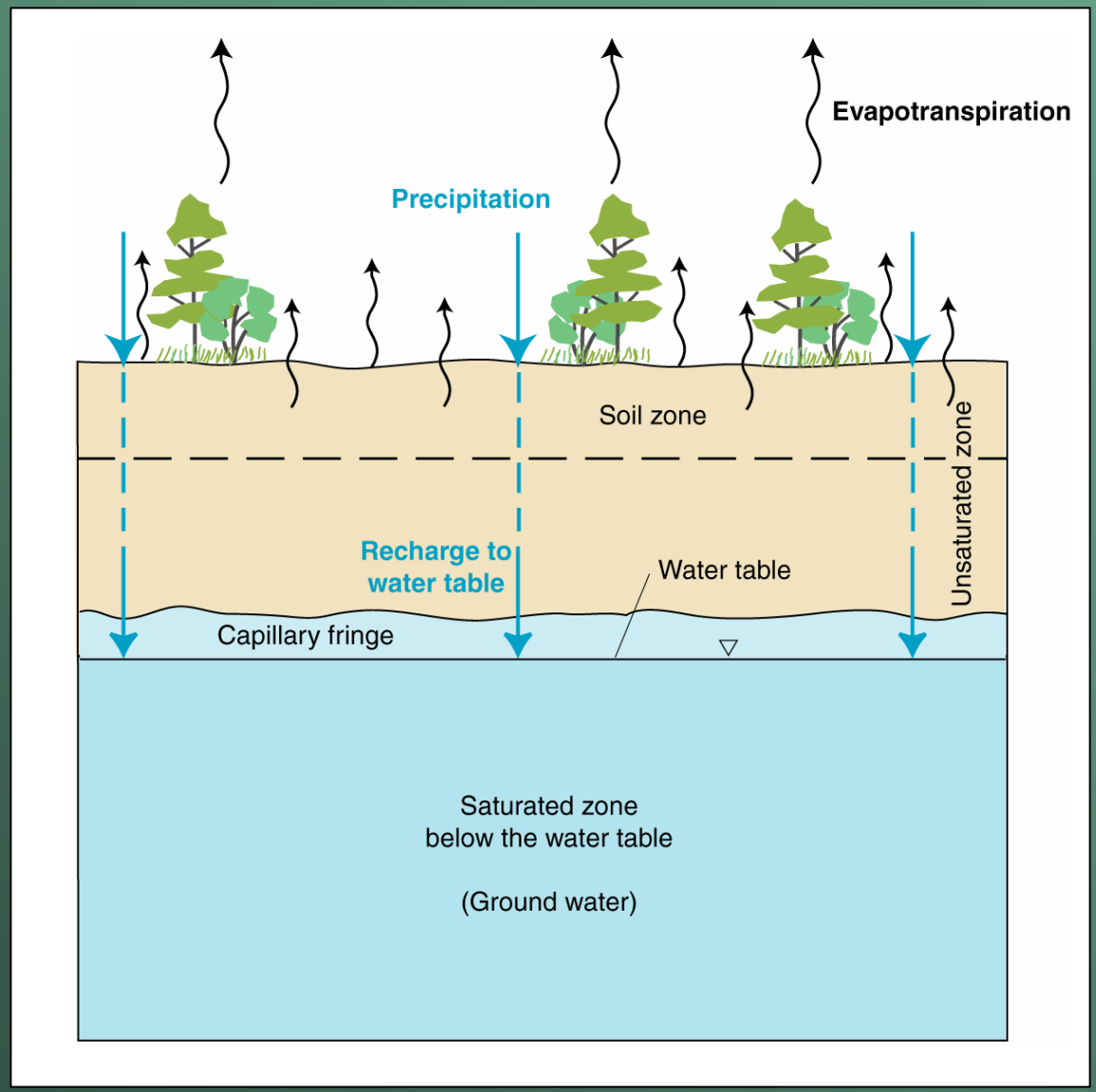
If inflow = outflow then ΔS is zero

If inflow > outflow then ΔS is positive



If inflow < outflow then ΔS is negative

The unsaturated zone is the soil zone above the aquifer



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What makes ground water move?

- Differences in hydraulic head (the height to which water will rise in an open pipe)

- How fast it moves depends on:
  - How easily water can move through the aquifer (hydraulic conductivity)
  - The area available for water to move through

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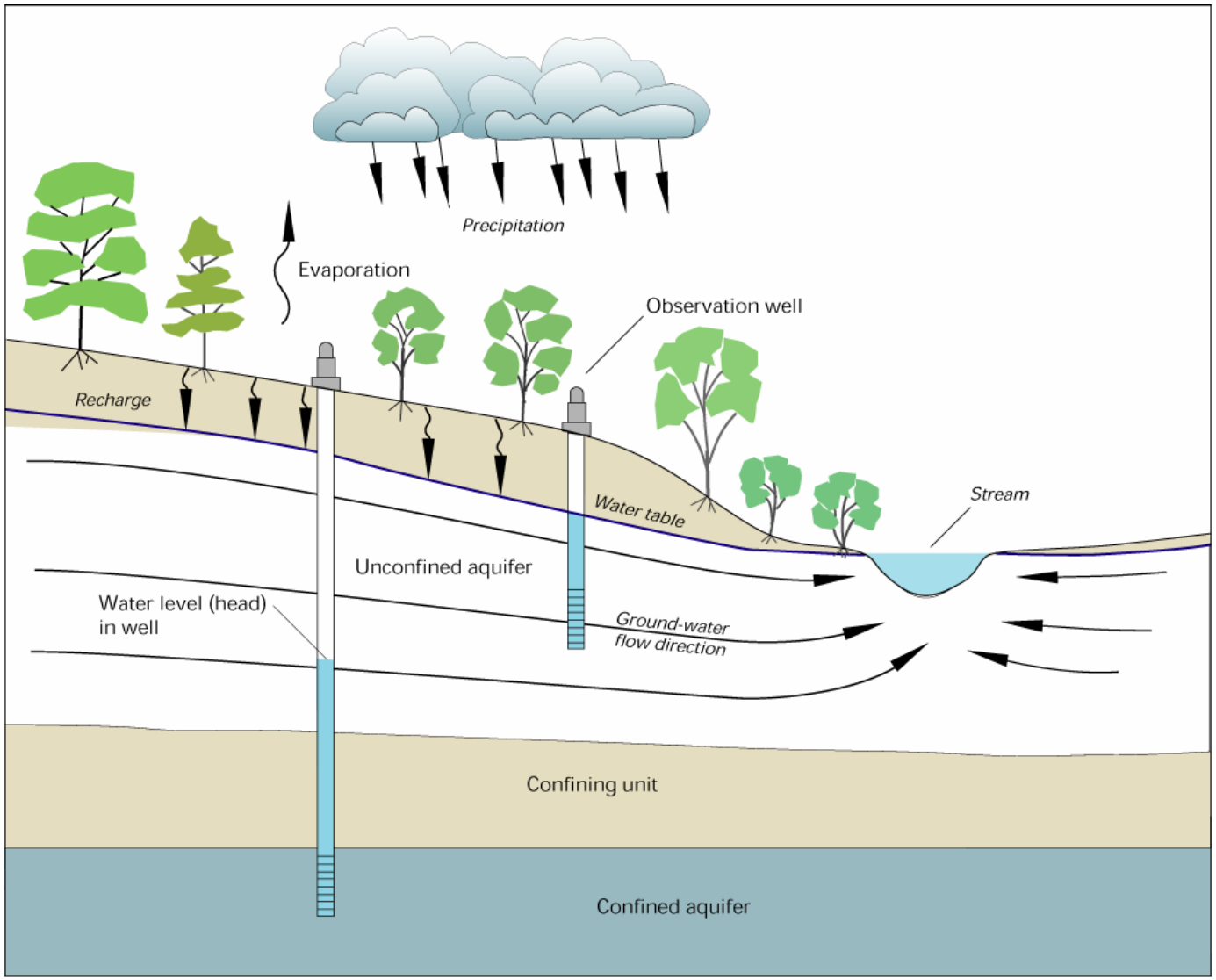
Water Level Measurements



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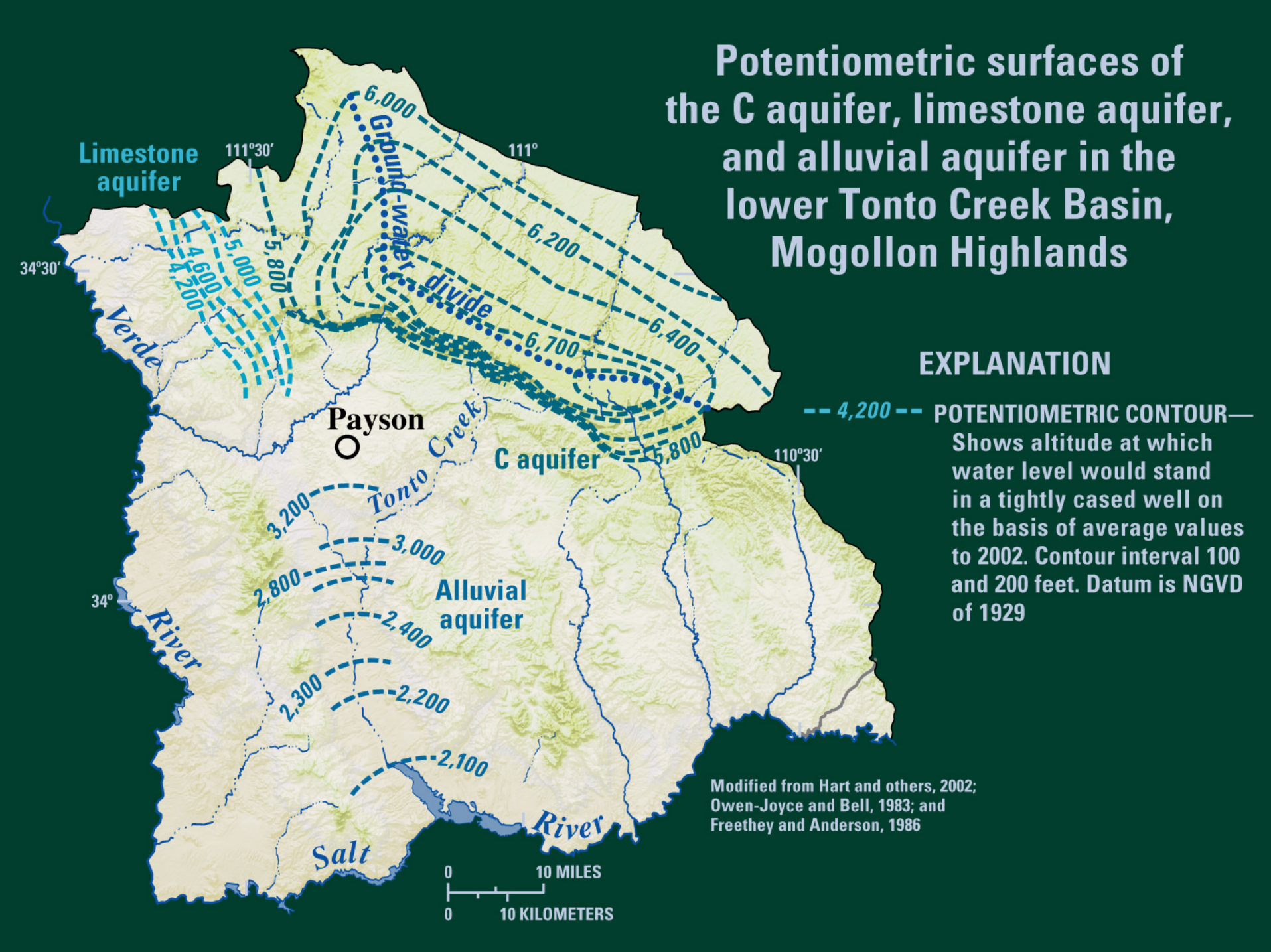
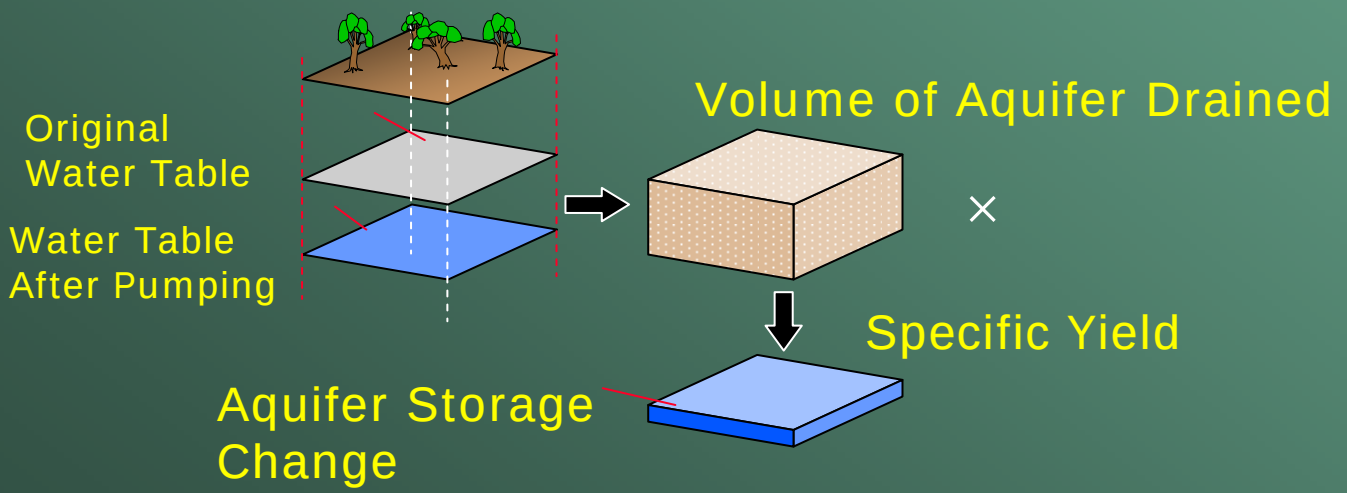

Potentiometric surfaces of the C aquifer, limestone aquifer, and alluvial aquifer in the lower Tonto Creek Basin, Mogollon Highlands
Limestone aquifer
111°30′
111°
34°30′
6,000
Ground-water divide
6,200
6,400
6,700
5,800
5,000
4,600
4,200
Verde
Payson
Tonto Creek
C aquifer
110°30′
3,200
3,000
2,800
Alluvial aquifer
34°
2,400
2,300
2,200
2,100
River
Salt
River
EXPLANATION
4,200
POTENTIOMETRIC CONTOUR—Shows altitude at which water level would stand in a tightly cased well on the basis of average values to 2002. Contour interval 100 and 200 feet. Datum is NGVD of 1929
Modified from Hart and others, 2002; Owen-Joyce and Bell, 1983; and Freethey and Anderson, 1986
0
10 MILES
0
10 KILOMETERS

Ground-water storage

- **Product of the area, saturated thickness, and specific yield (effective porosity or available water in soil matrix)**

Aquifer Storage Change



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What happens when ground water is pumped?

- Depends on:
  - Pumping rate
  - Hydraulic conductivity (transmissivity) of the aquifer
  - Extent of the aquifer

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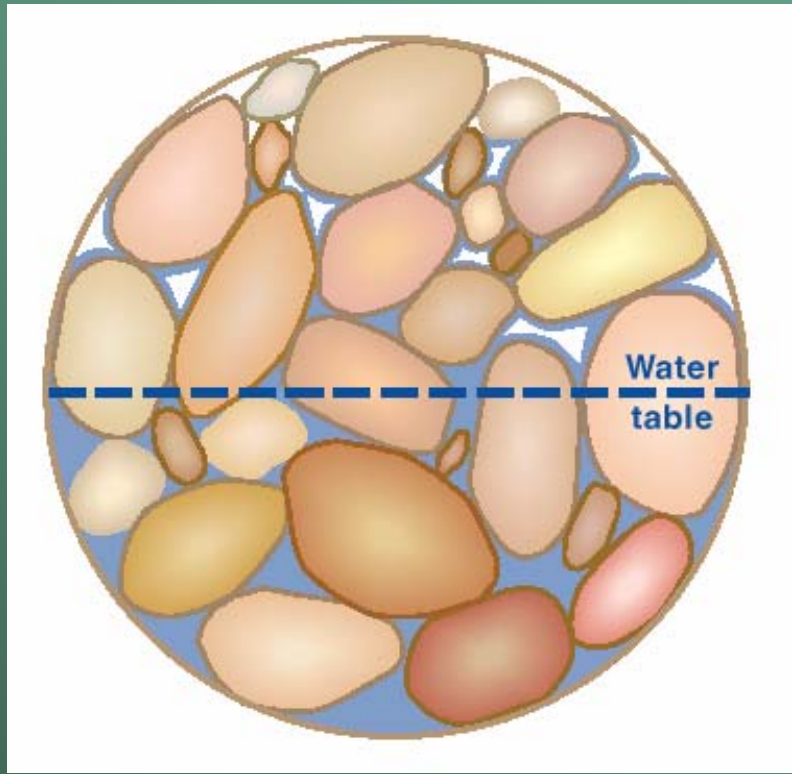
Hydraulic Conductivity (K)

- K is the capacity of a rock or formation to transmit water.
- K values are high for sand and gravel, low for clay and most rocks.
- K is primarily a function of
  - Grain sizes
  - Shape of grains
  - Packing
  - Fracture network.



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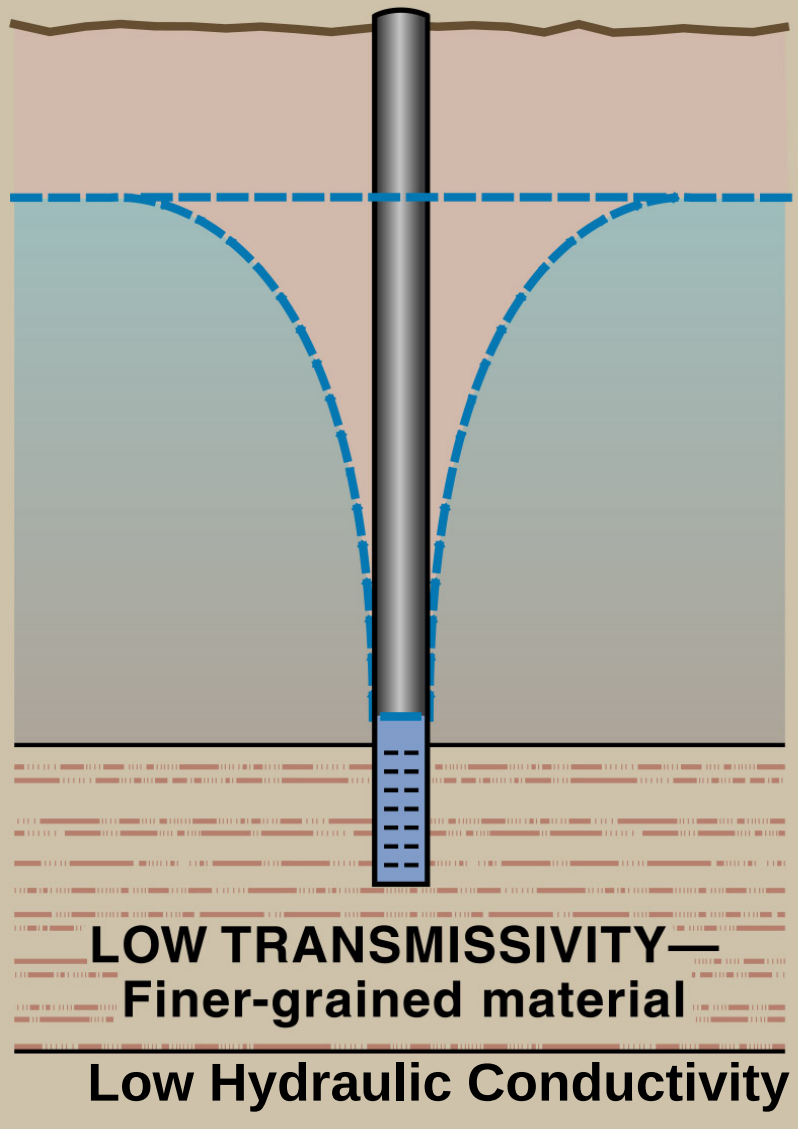
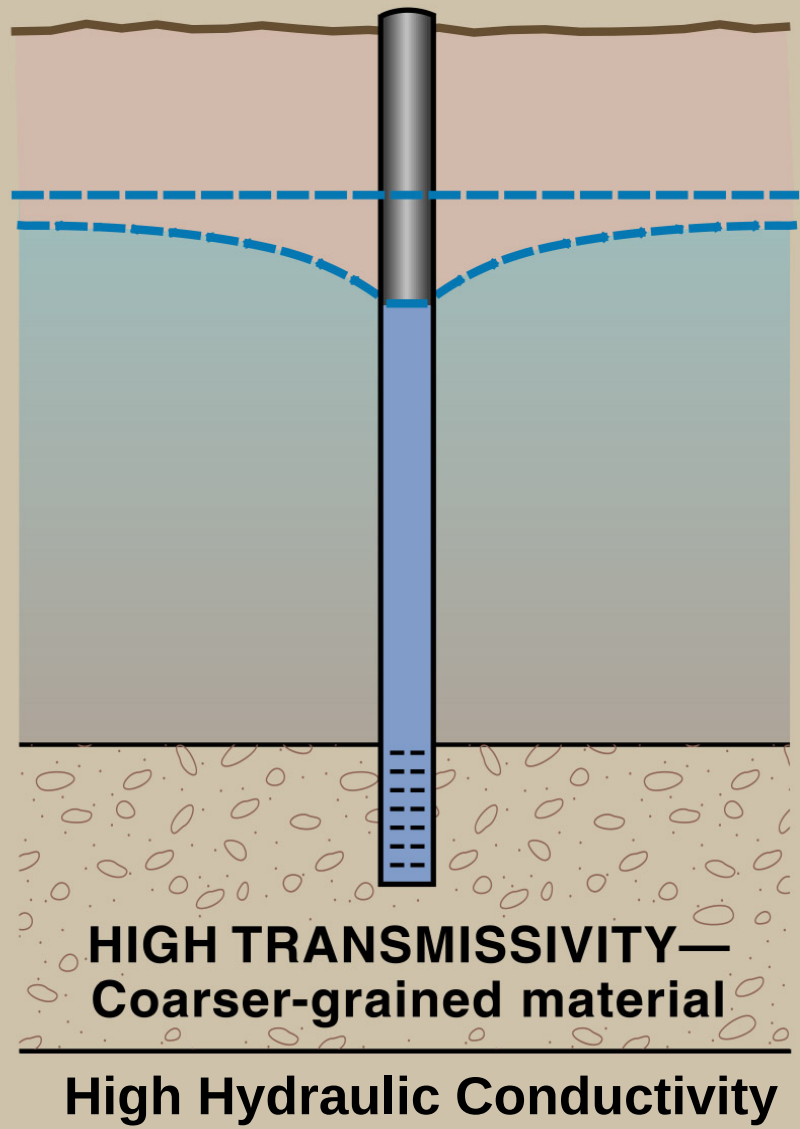
Drawdown Comparison





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Sources of water to wells
(responsiveness of surface water to ground-water pumping)

Two Views of Ground-Water Systems

1. Aquifers as “containers”— Water occurs in underground containers (aquifers) and can be removed from containers at rates up to the amounts flowing in. (Safe Yield Concept)

2. Aquifers as “containers that have water moving through them”— Water underground moves under the force of gravity. Removal of water will result in reduced “downstream” flow. Reduced downstream flow is also referred to as capture. (Sustainability Concept)

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Questions?