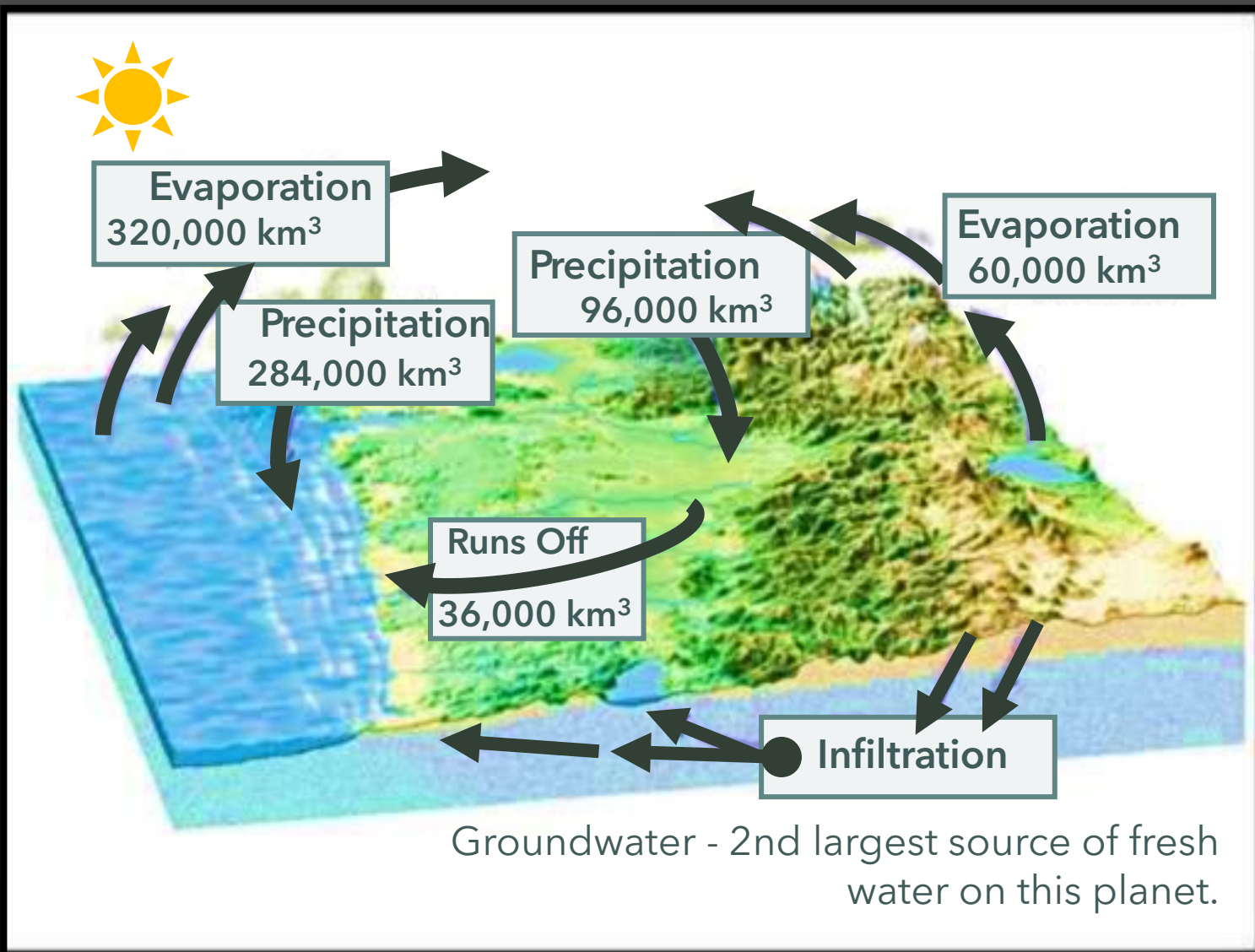


GROUNDWATER

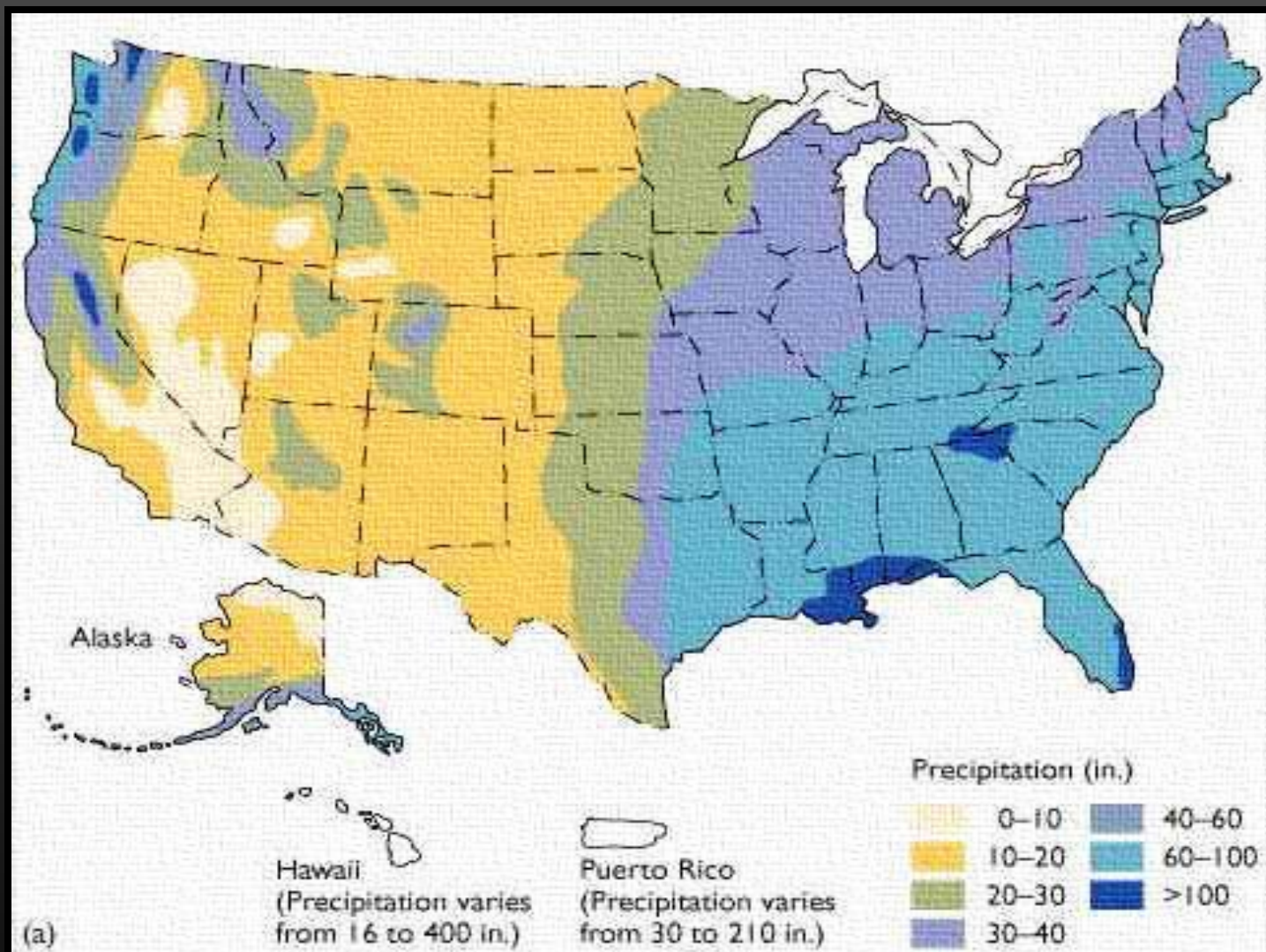
The Flow of Water Through the
Subsurface



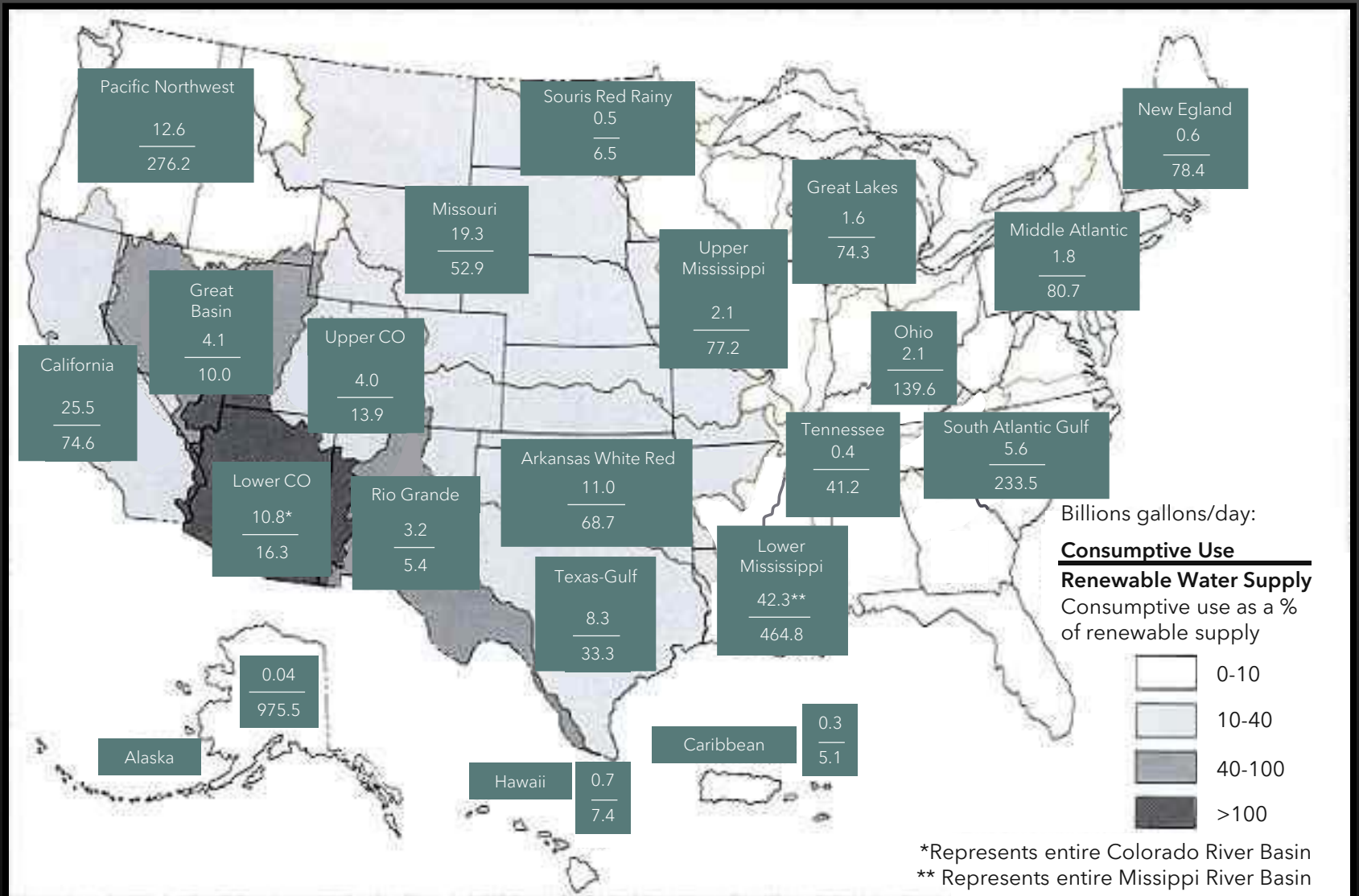
Where's the Water?

Parts of the Hydrosphere	Volume of Freshwater (km ⁵)	Share of Total Volume of Freshwater (%)
Ice Sheets and Glaciers	24,000,000	84.945%
Groundwater	4,000,000	14.158%
Lakes and Reservoirs	155,000	0.549%
Soil Moisture	83,000	0.294%
Water Vapor in the Atmosphere	14,000	0.049%
River Water	1,200	0.004%
Total	28,253,200	100%

Where's the Rainfall?



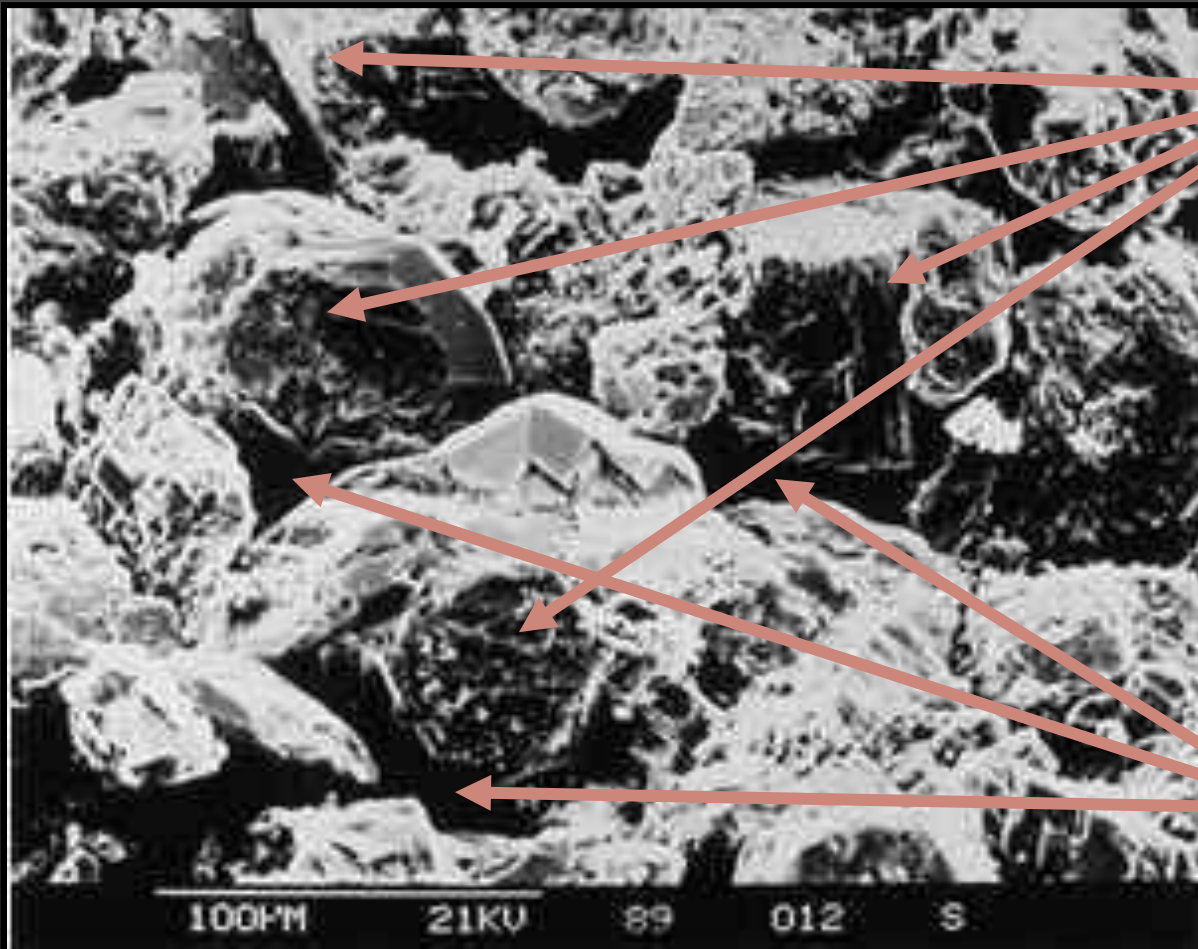
Water Consumption



Rainfall vs. Consumption

- Consumption exceeds renewable water sources in the Southwest.
- This is also true in Southern California since about 1900
- Also, some places locally in the Midwest
- Necessitates the use of groundwater to meet human needs.

Its All About Porosity...



Sand Grains

the individual particles of sand

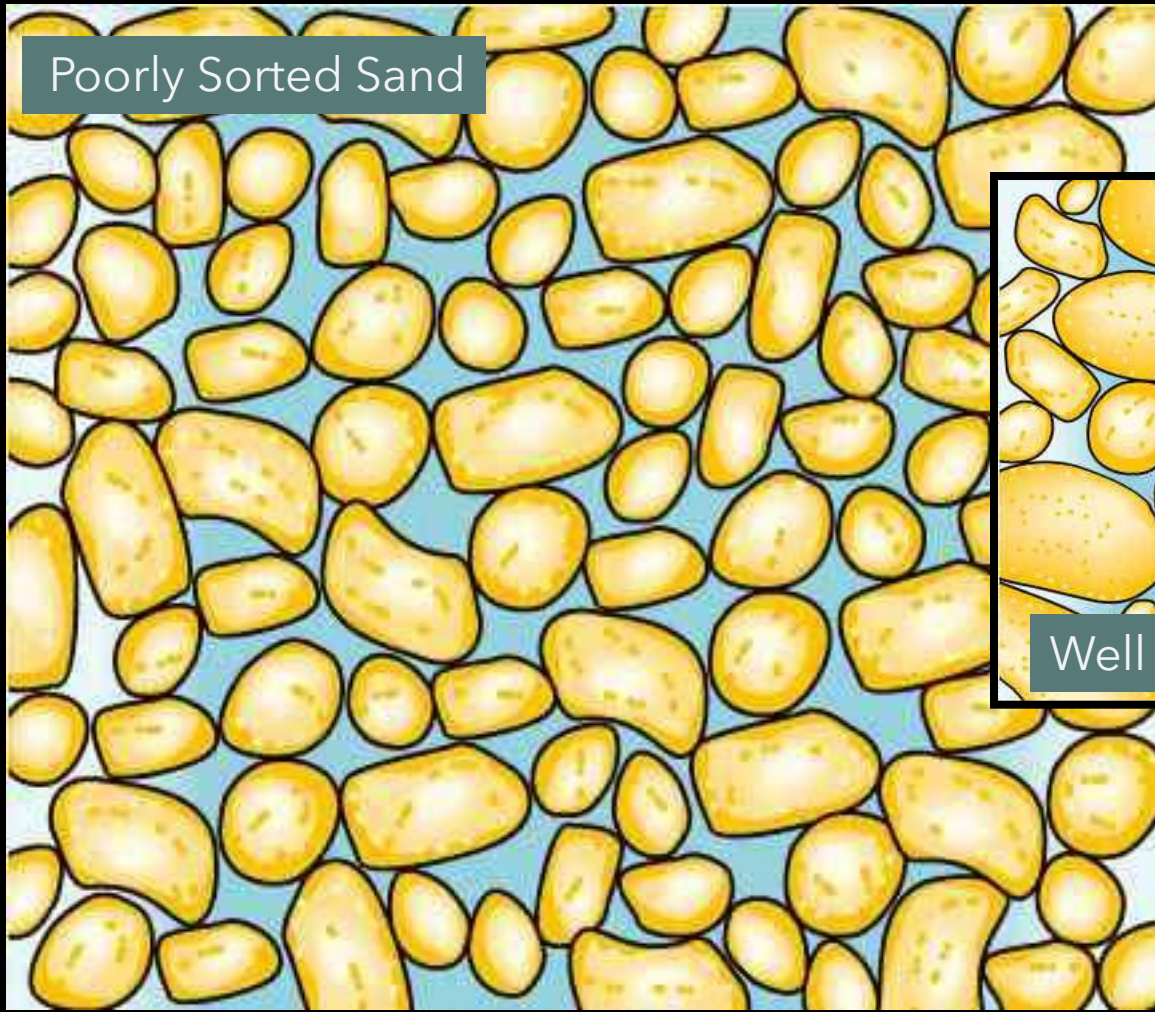
Porosity

Amount of empty space that is between particles

Sediment Sorting and Porosity

Which has greater porosity?

Poorly Sorted Sand

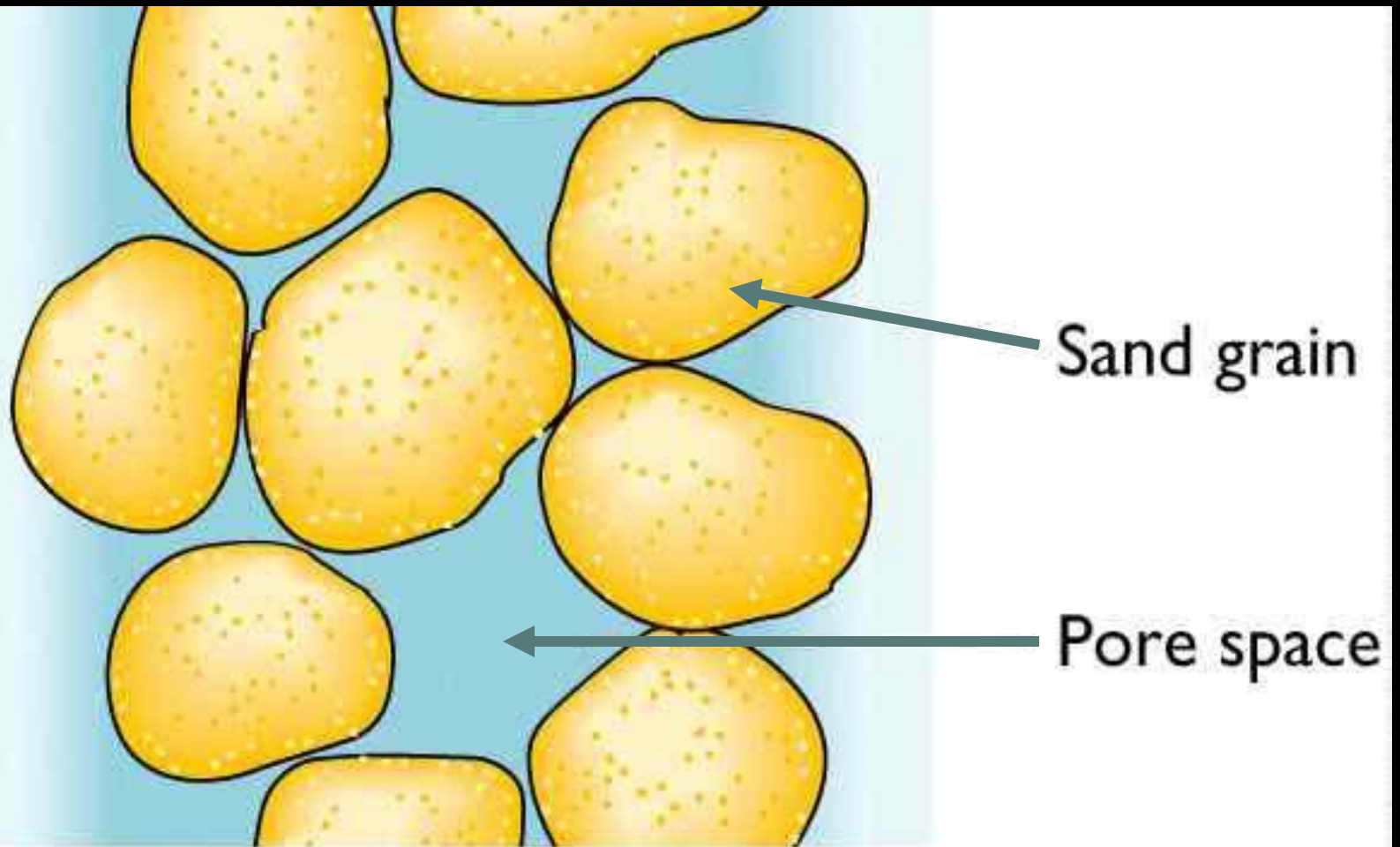


Well Sorted Sand



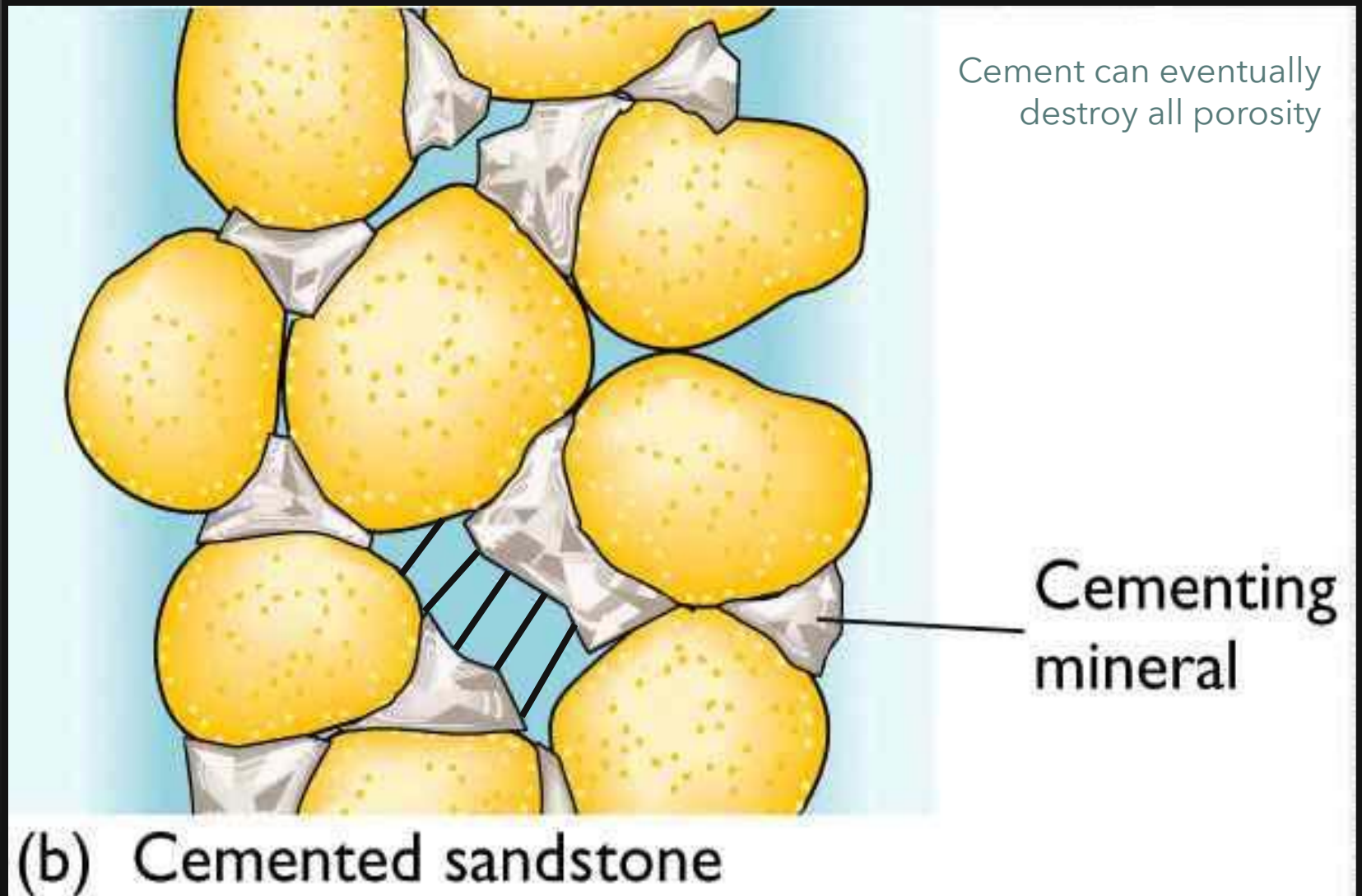
The sand with more space in between particles has the higher porosity meaning the poorly sorted sand

Intragranular Porosity



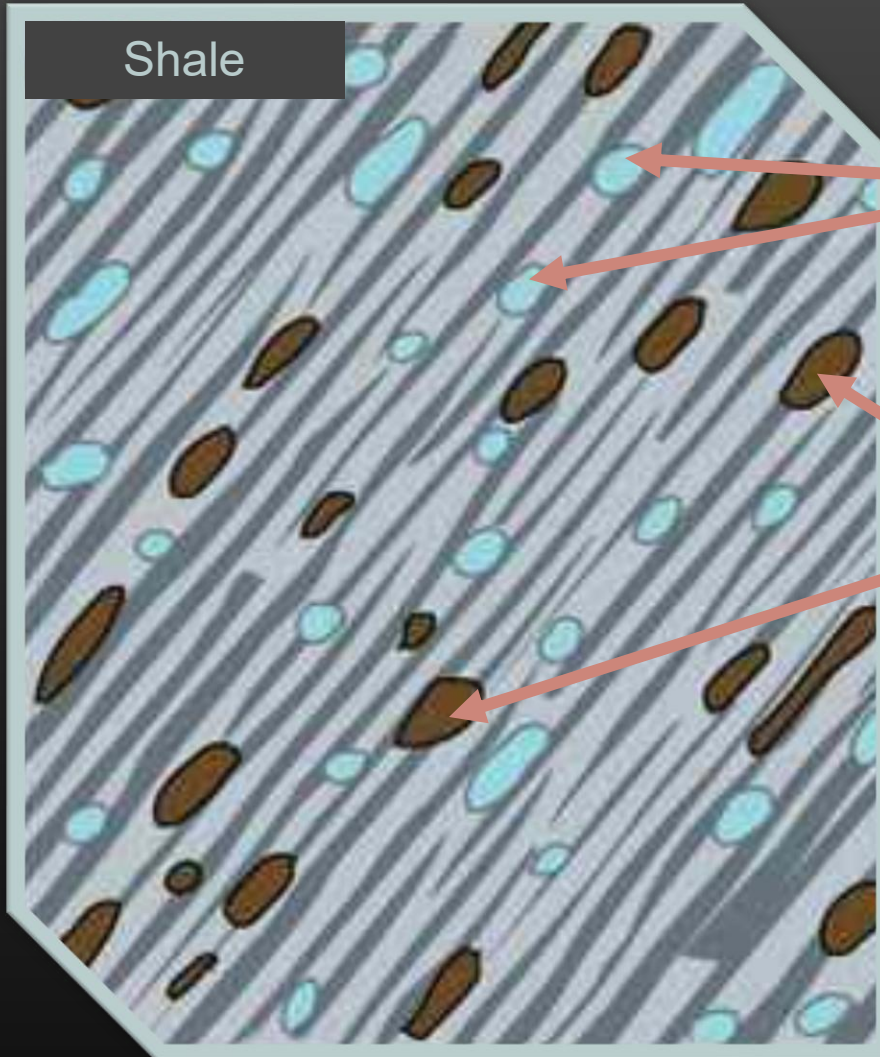
(a) Porous sandstone

Intragranular Cement and Porosity



Porosity in Shale

Higher or lower than a typical sandstone?



Shale

Clay Grains

the individual particles of clay that composes Shale

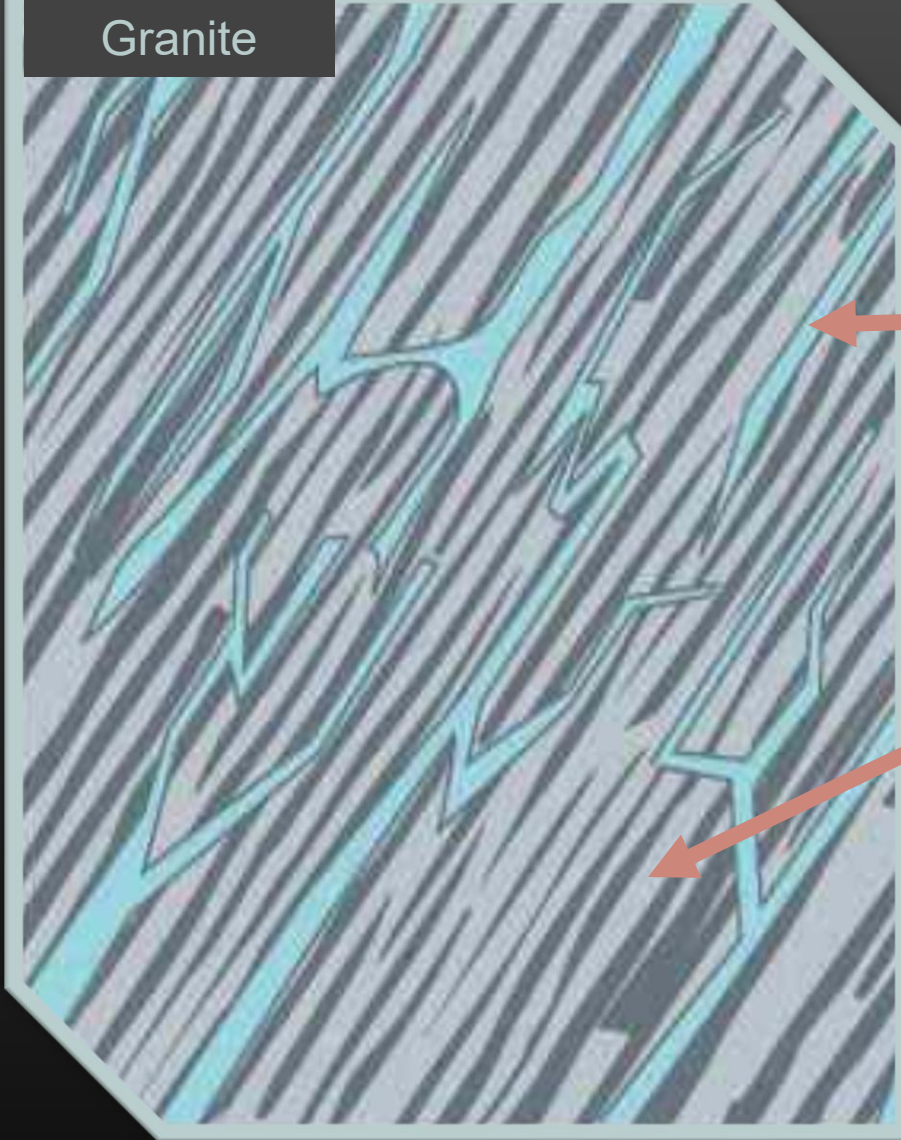
Silt Grains

the individual particles of Silt that composes Shale

There is very small amounts of pore space between the particles giving Shale a low porosity

Fracture Porosity

Granite



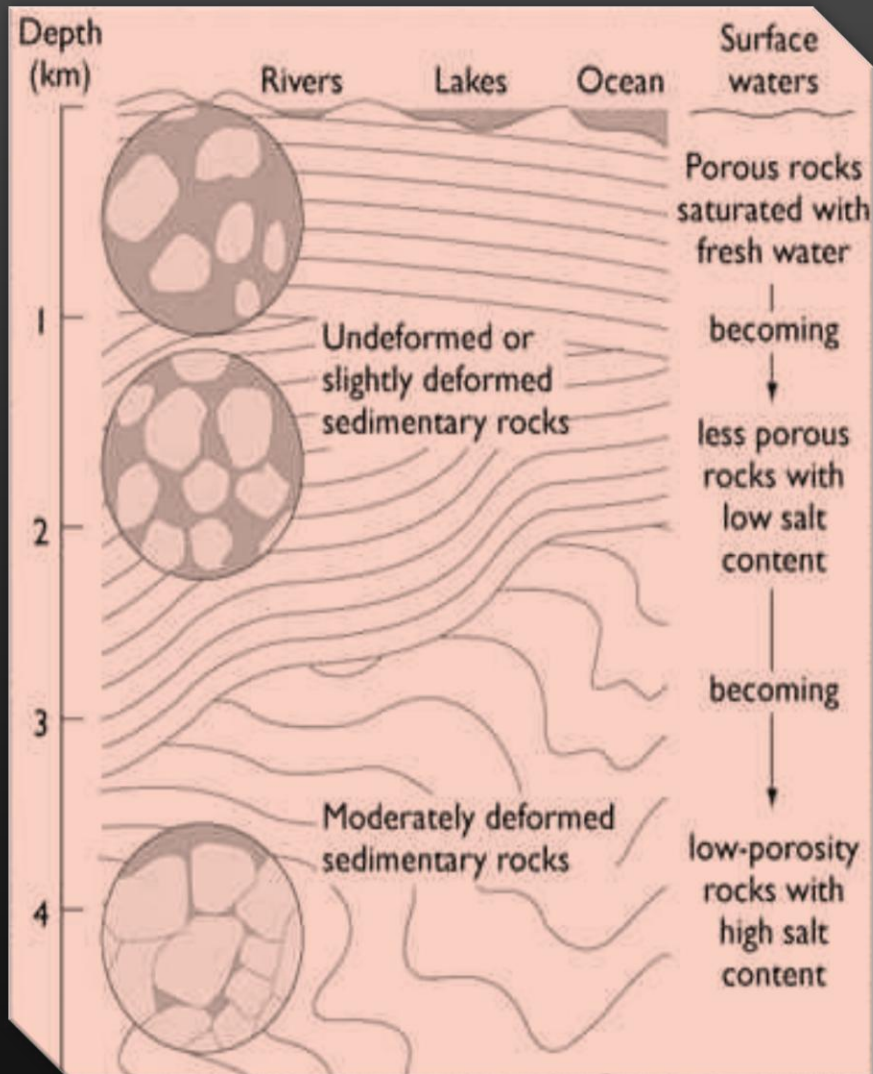
Fractures

Cracks in the rock where small amounts of pore space is created

Impermeable Rock

Solid rock with zero permeability such as granite

Porosity and Burial



Porous Rocks Saturated with Fresh Water

Loose, unconsolidated sediment

Less Porous with Low Salt

Consolidated sediment that is partly cemented

Low Porosity with High Salt

Well compacted and cemented with sediments

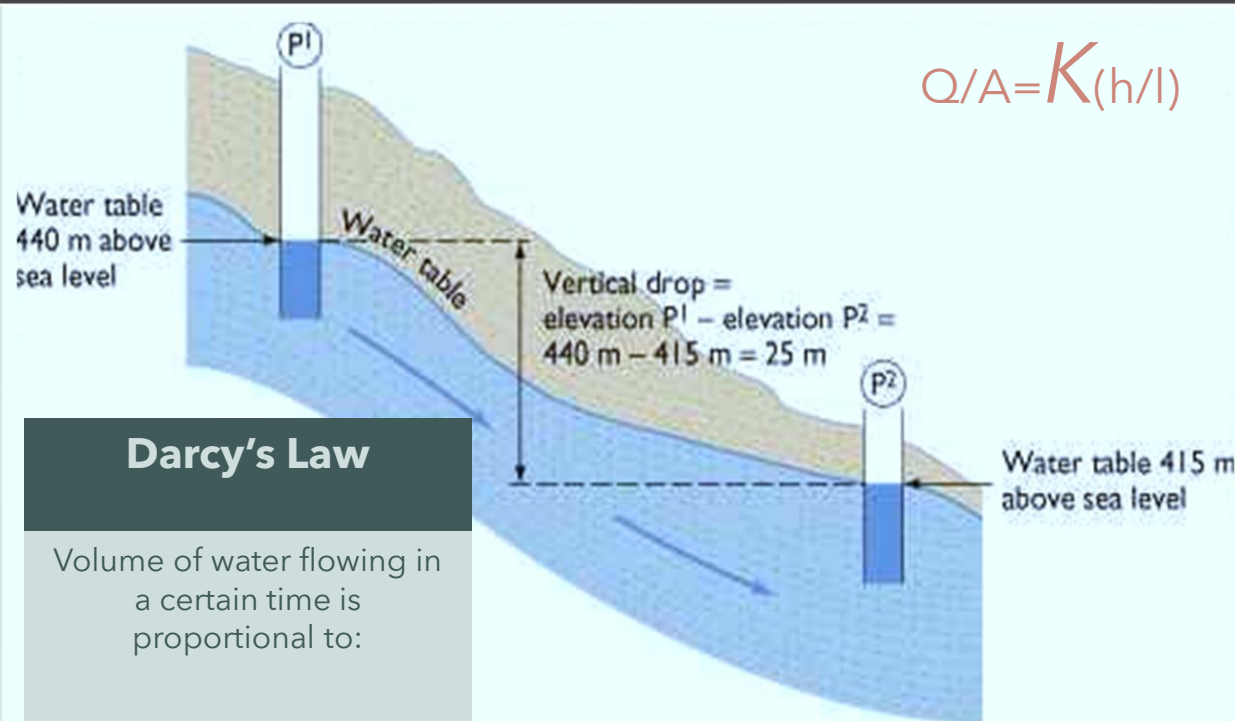
Porosity is important but...

...it isn't the whole story!

Permeability

- ❖ **Permeability** - How well connected are the open spaces (porosity)
- ❖ **Hydraulic Conductivity (k)** - measures how easily a fluid (like water) moves through spaces in soil or rock.
 - High means water passes through fast like sand
 - Low means slow like clay
- ❖ Both **porosity** and **permeability** control the rate of groundwater flow along with...(Hint: What's the driving force?)
 - **GRAVITY** - The force that pulls object of mass toward other objects of mass like water towards the Earth

Darcy's Law



Darcy's Law

Volume of water flowing in a certain time is proportional to:

Vertical drop ÷ flow distance

or

$$\frac{Q}{A} = K \times \frac{h}{l}$$

Q = Volume of water flowing in a given time

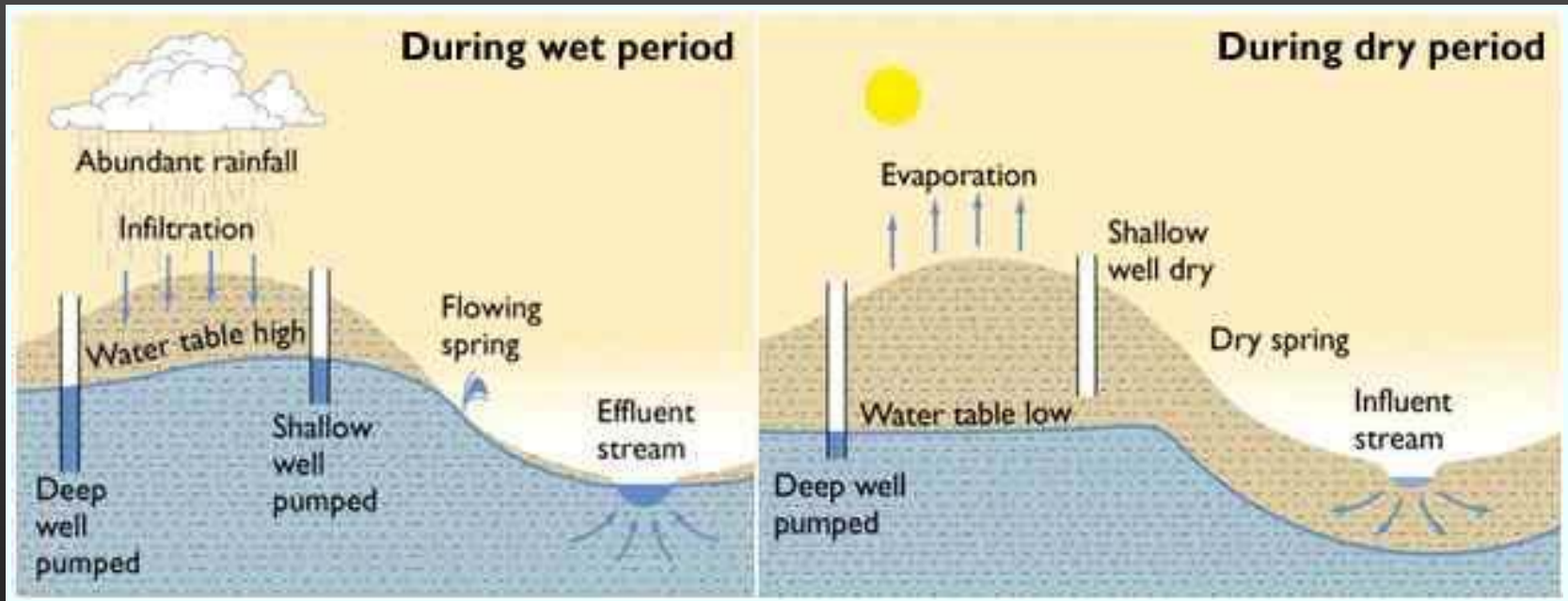
A = Cross-sectional area through which water flows

K = hydraulic conductivity

h = height difference
(vertical drop between two points)

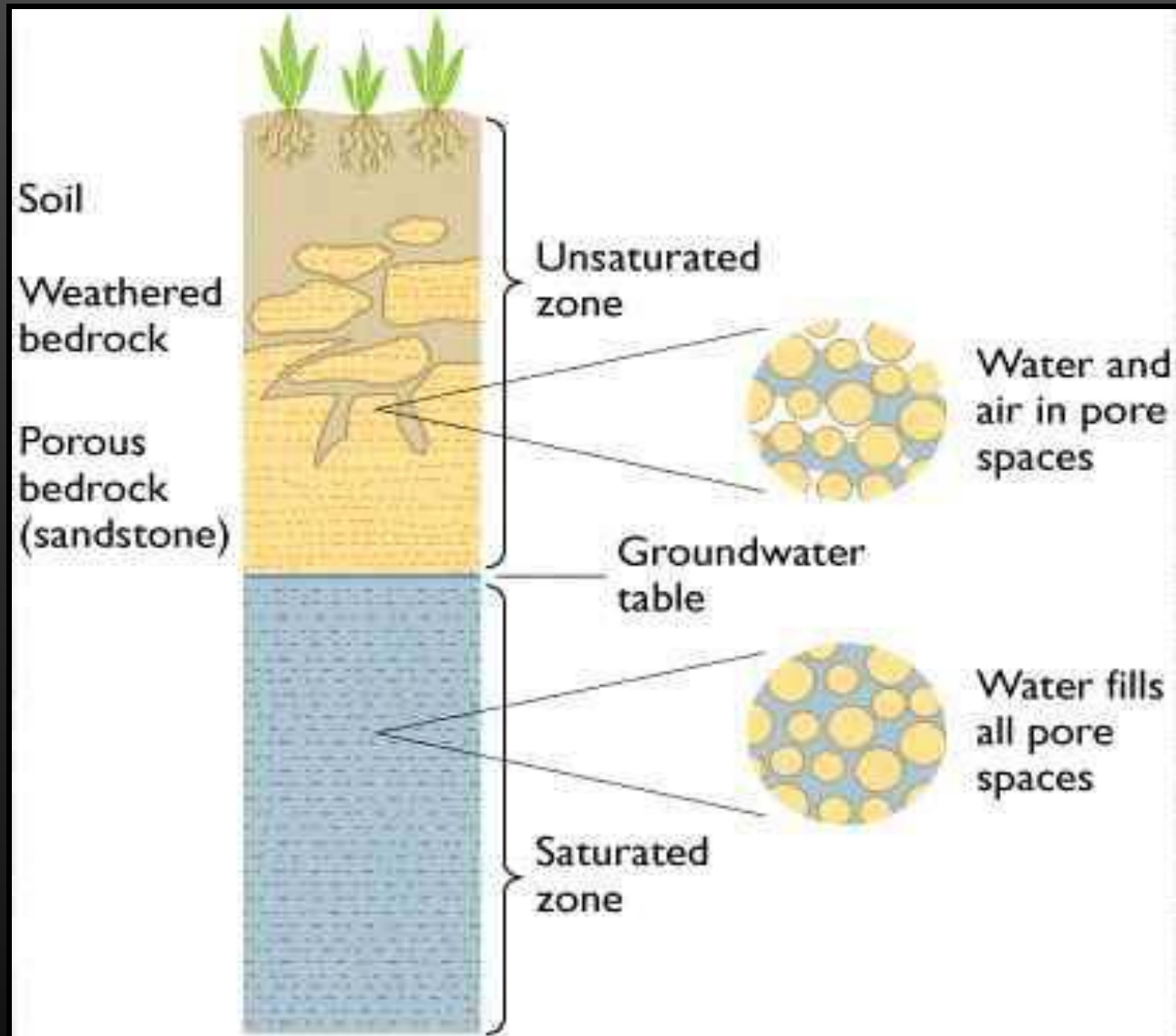
l = Distance the flow travels

The Water Table

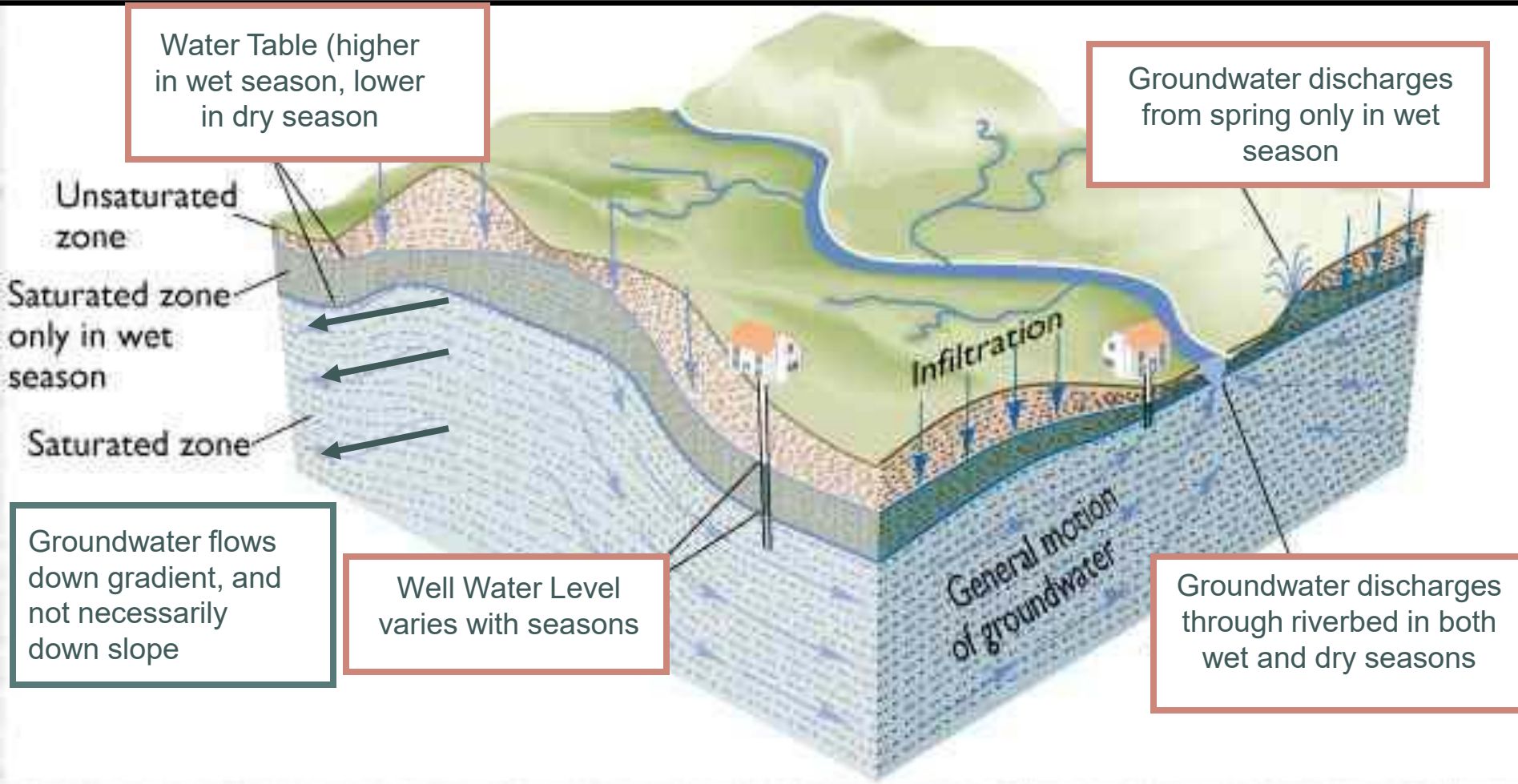


- Downward infiltration from surface
- Percolation from influent streams
- Pore space completely filled = saturation
- Zone of saturation below water table.

Water Table



Water Table Characteristics

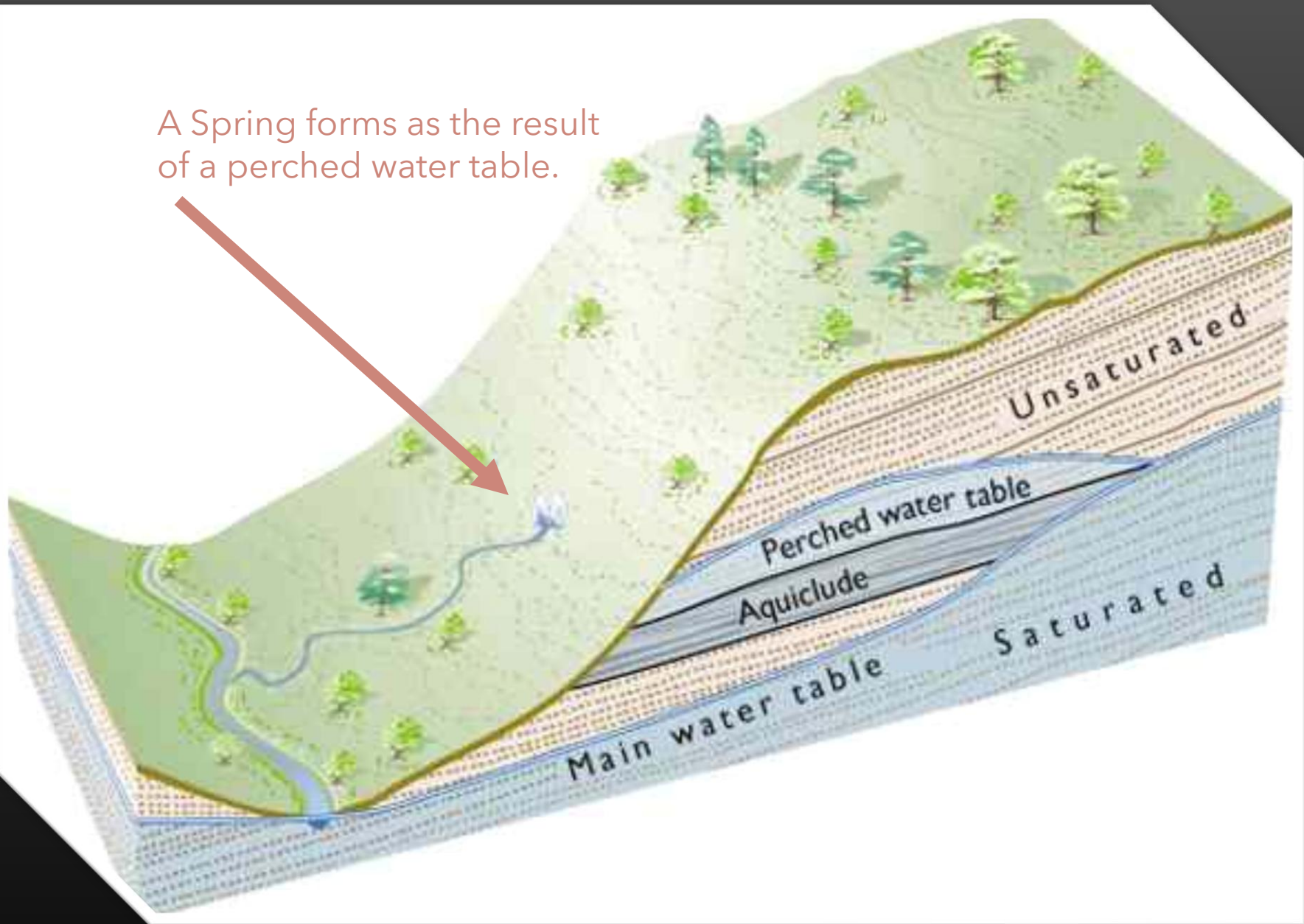




- ❖ **Aquifer** - has high porosity and permeability therefore allowing the transmission of water
- ❖ **Aquitard** - retards the flow of water through the sub surface
- ❖ **Aquiclude** - prohibits the flow of water through the subsurface

Springs often occur when groundwater is forced to the surface by an aquitard.

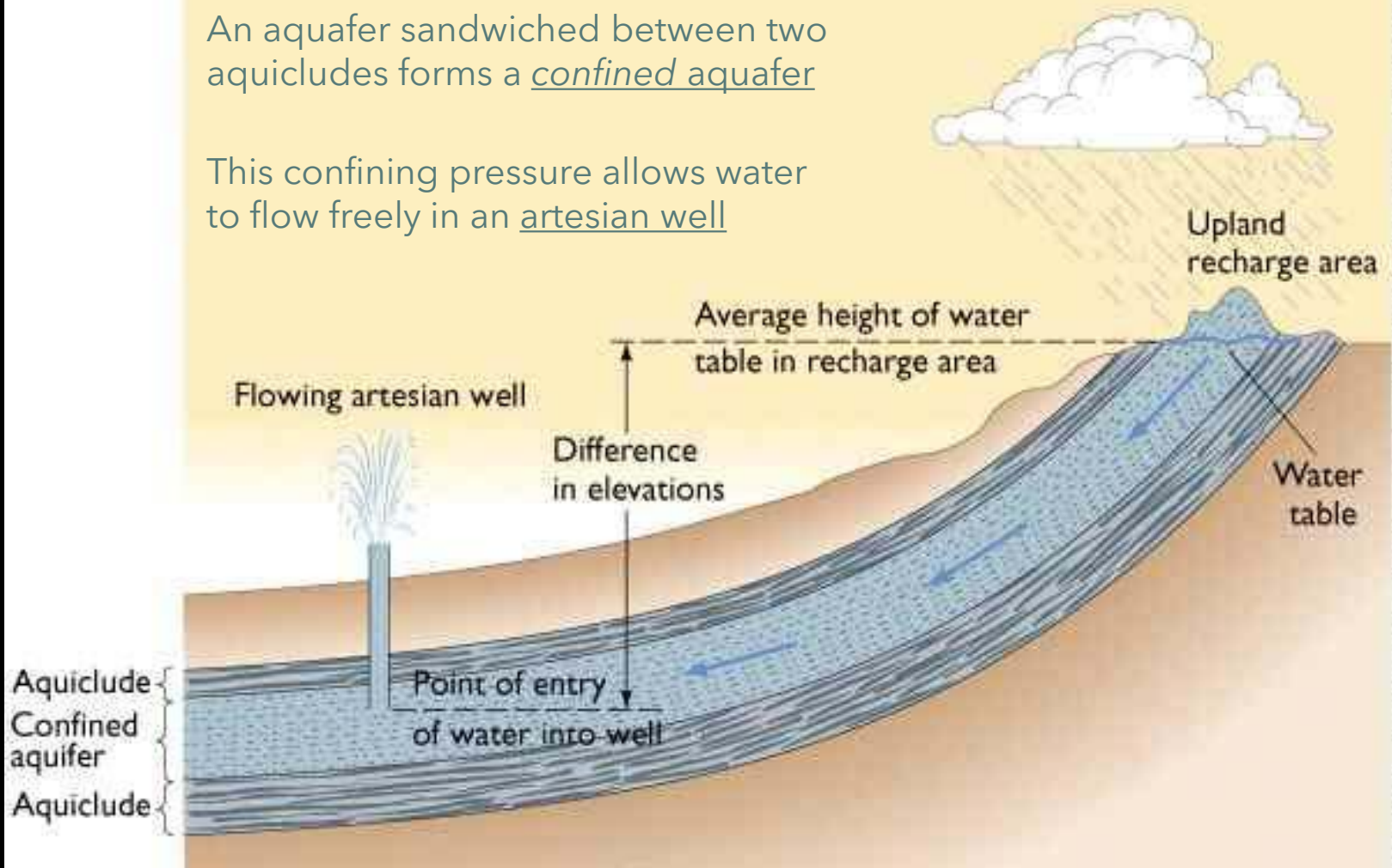
A Spring forms as the result of a perched water table.



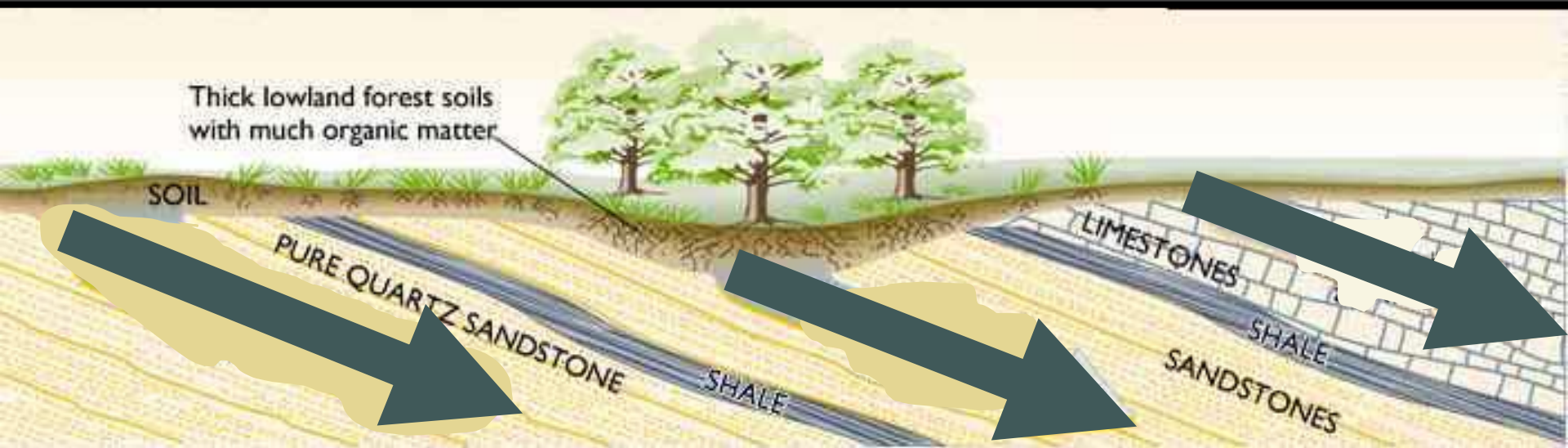
Artesian Groundwater Systems

An aquifer sandwiched between two aquicludes forms a confined aquifer

This confining pressure allows water to flow freely in an artesian well



Water Quality Issues - Source Area

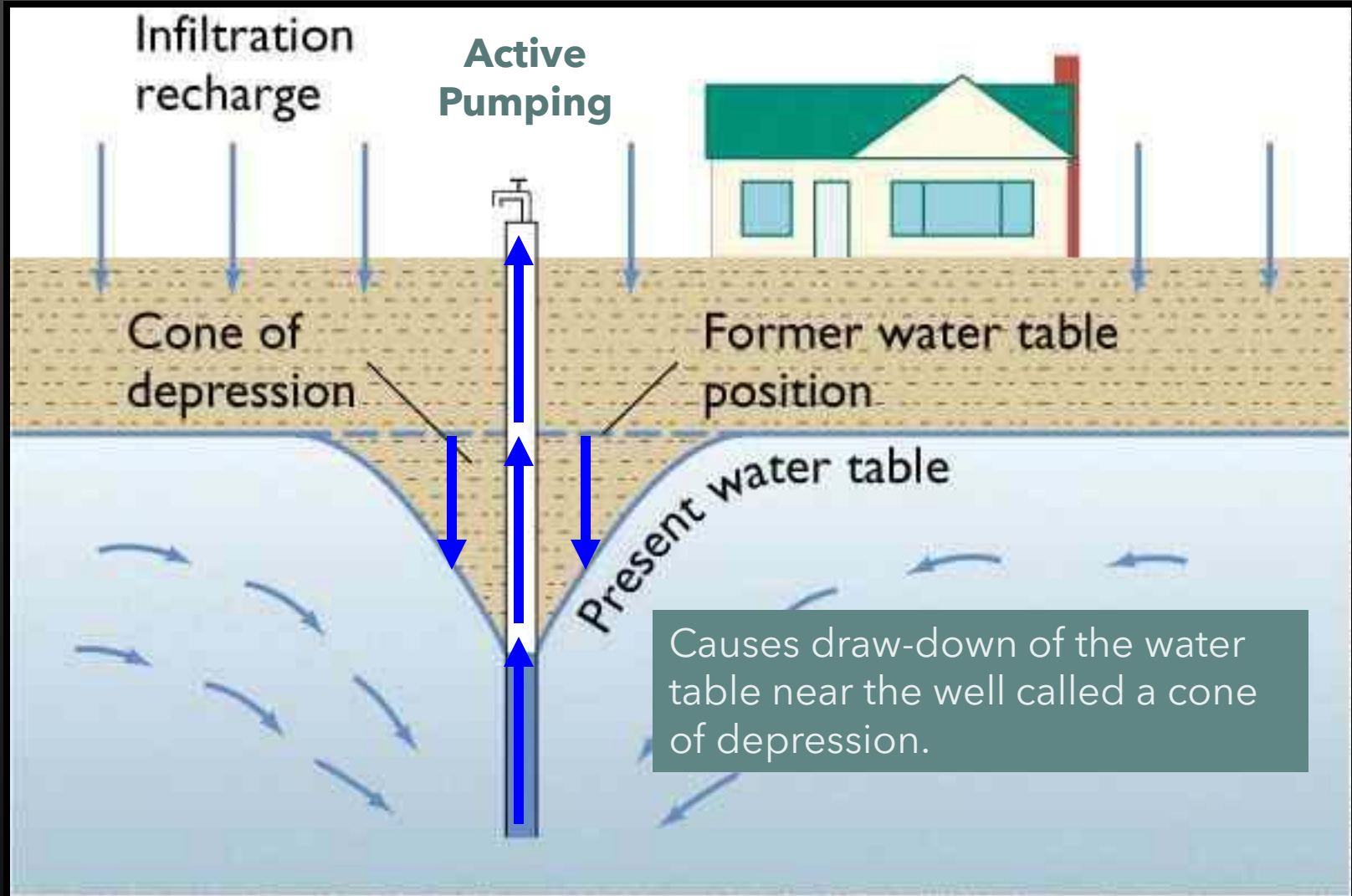


Sandstone - Good pure water

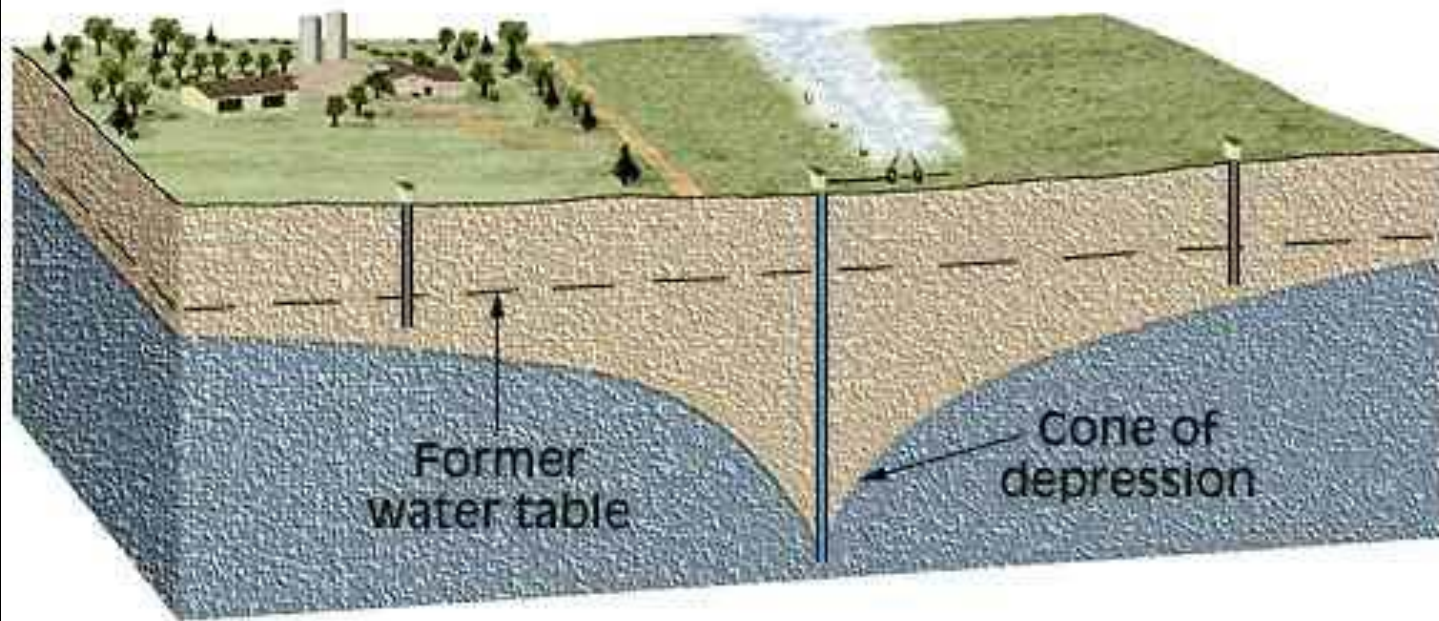
Swampy source - Lots of organics

Limestone - High in calcium carbonate

Cone of Depression



Over pumping can produce a large cone of depression causing shallow wells to go dry.



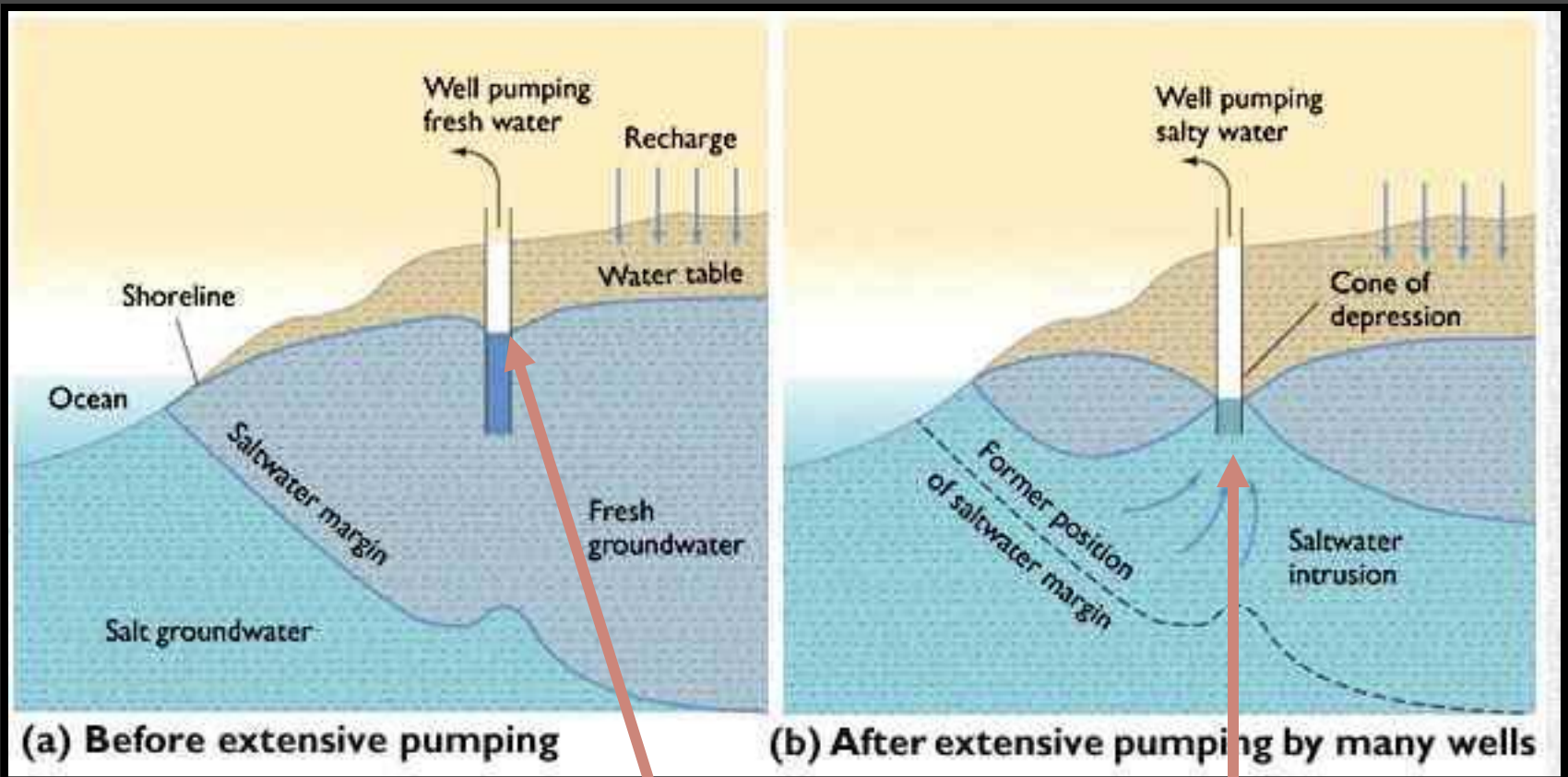
If heavy pumping lowers the water table, the shallow wells may be left dry.

Over Pumping Continued

In the San Joaquin Valley of California, over-pumping has not only depleted aquifers but caused the ground to subside drastically.



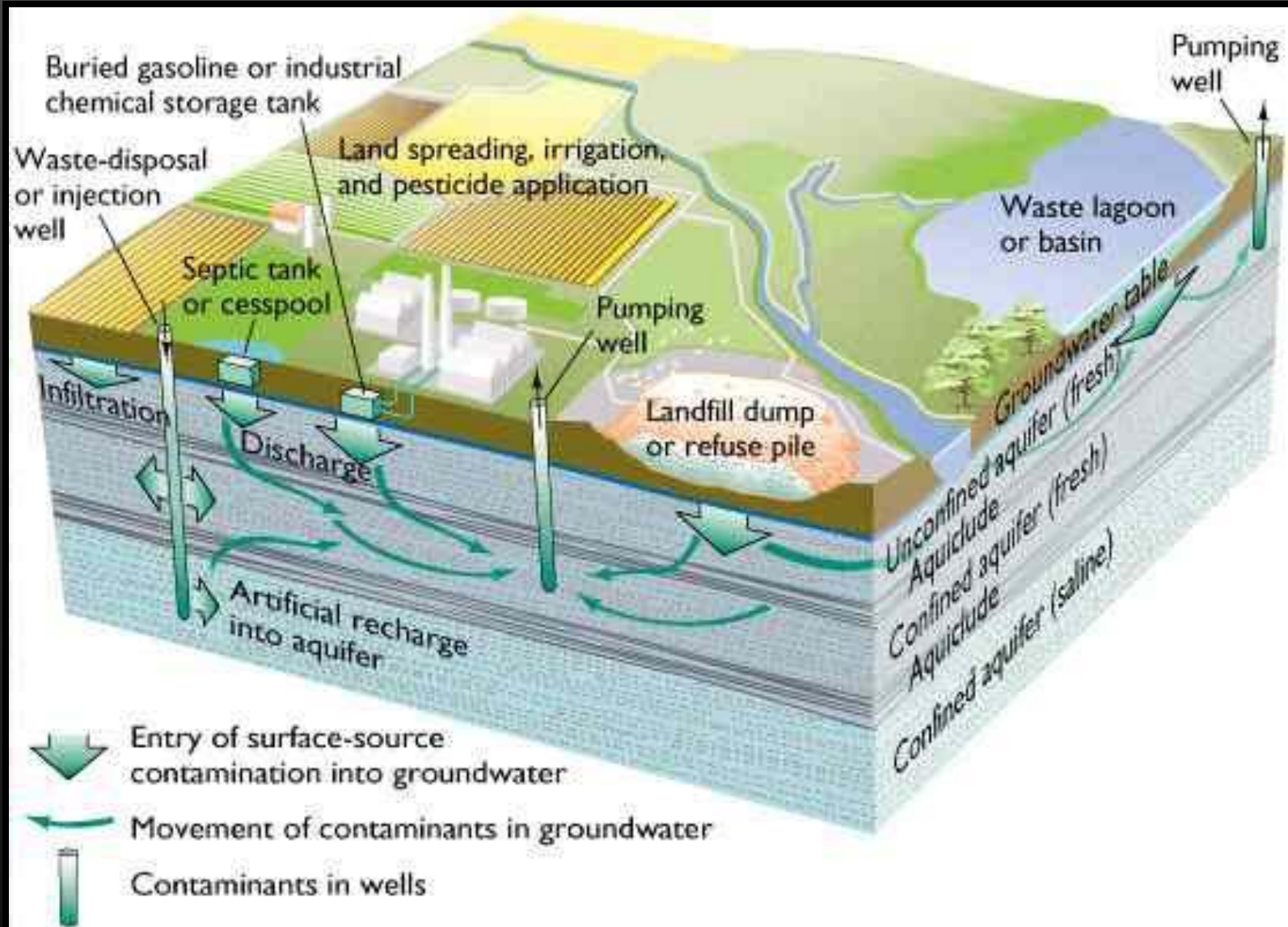
Saltwater Intrusion



Pumping causes a cone of depression and...

...draws the salt water upwards into the well.

Effects on Water Quality



Groundwater - Some Main Points

- Part of the hydrologic system
- Subsurface flow of water
- Porosity *and* Permeability
- Fluid flow (Darcy's Law)
- Water table - Zone of saturation
- Aquifers, Aquicludes, Aquitards
- Confined aquifers
- Effects of over pumping
- Effects on water quality.