What is Groundwater and How Does Geology Impact Groundwater Quality?

Groundwater in the Catskills: Challenges and Solutions

Presentation for The Catskill Water Discovery Center

June 7, 2024

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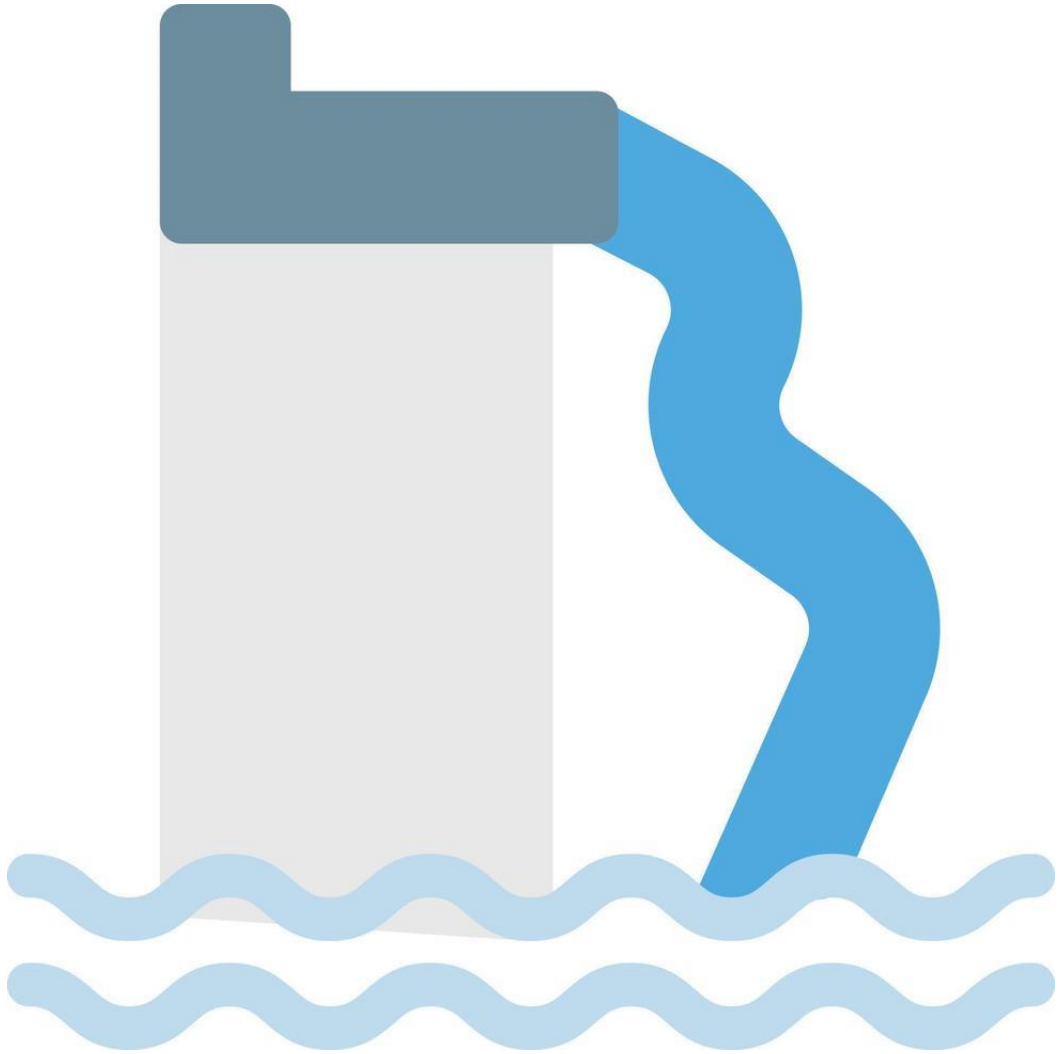
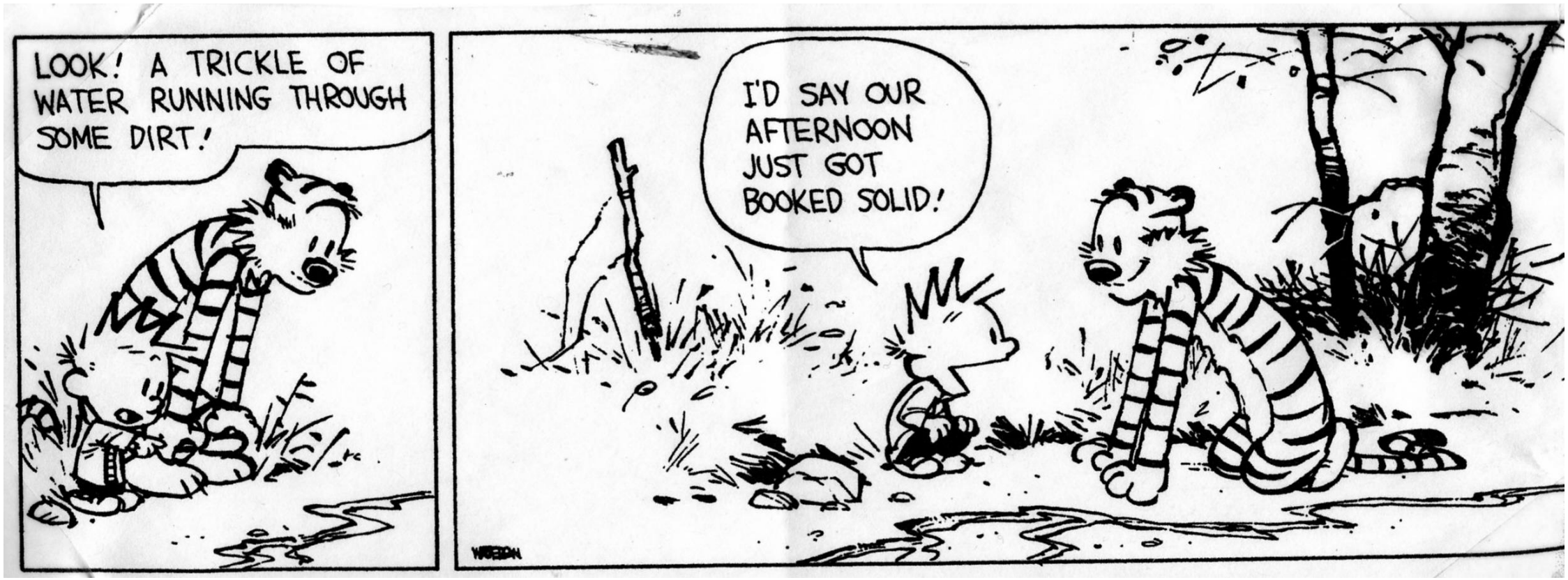
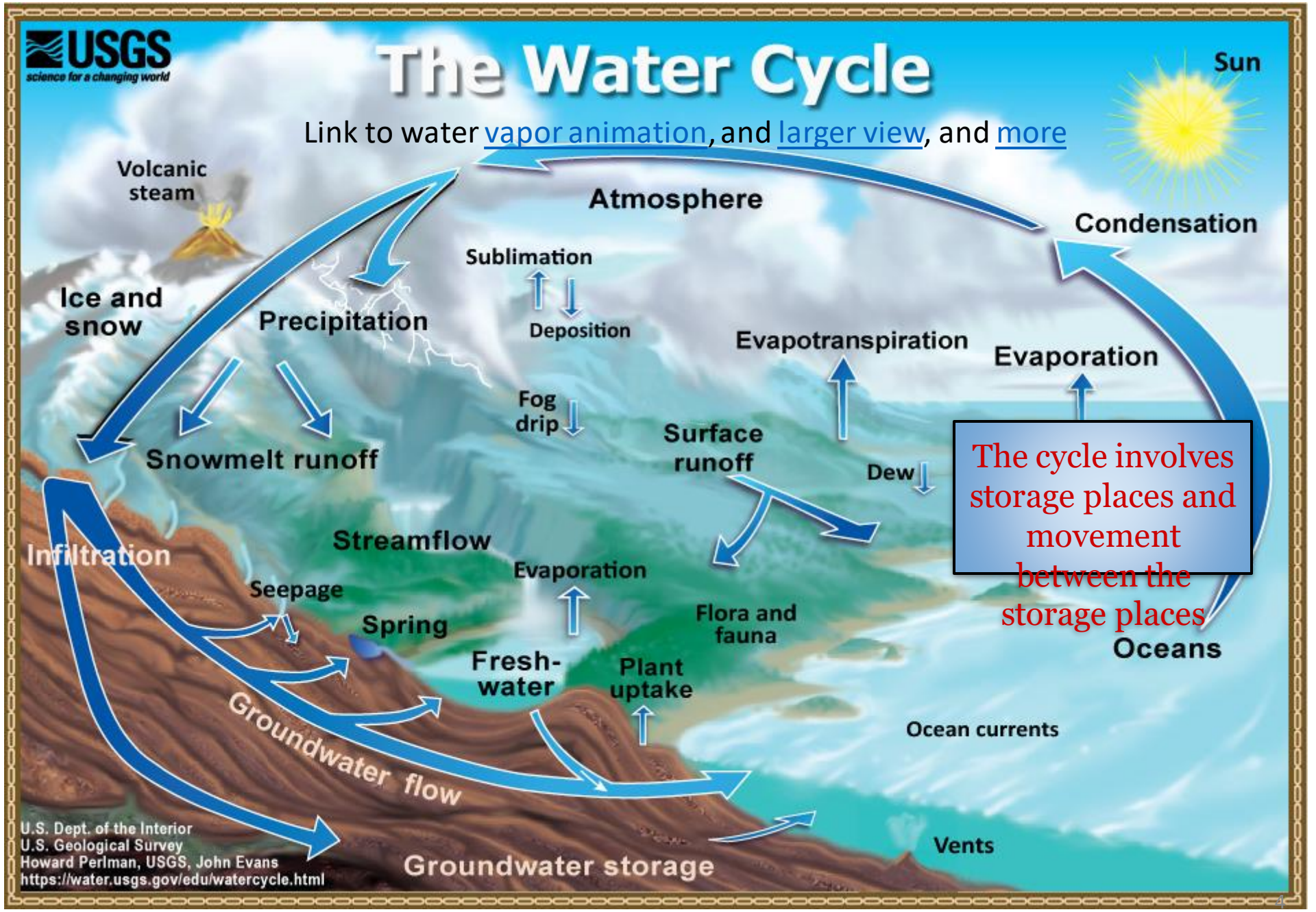
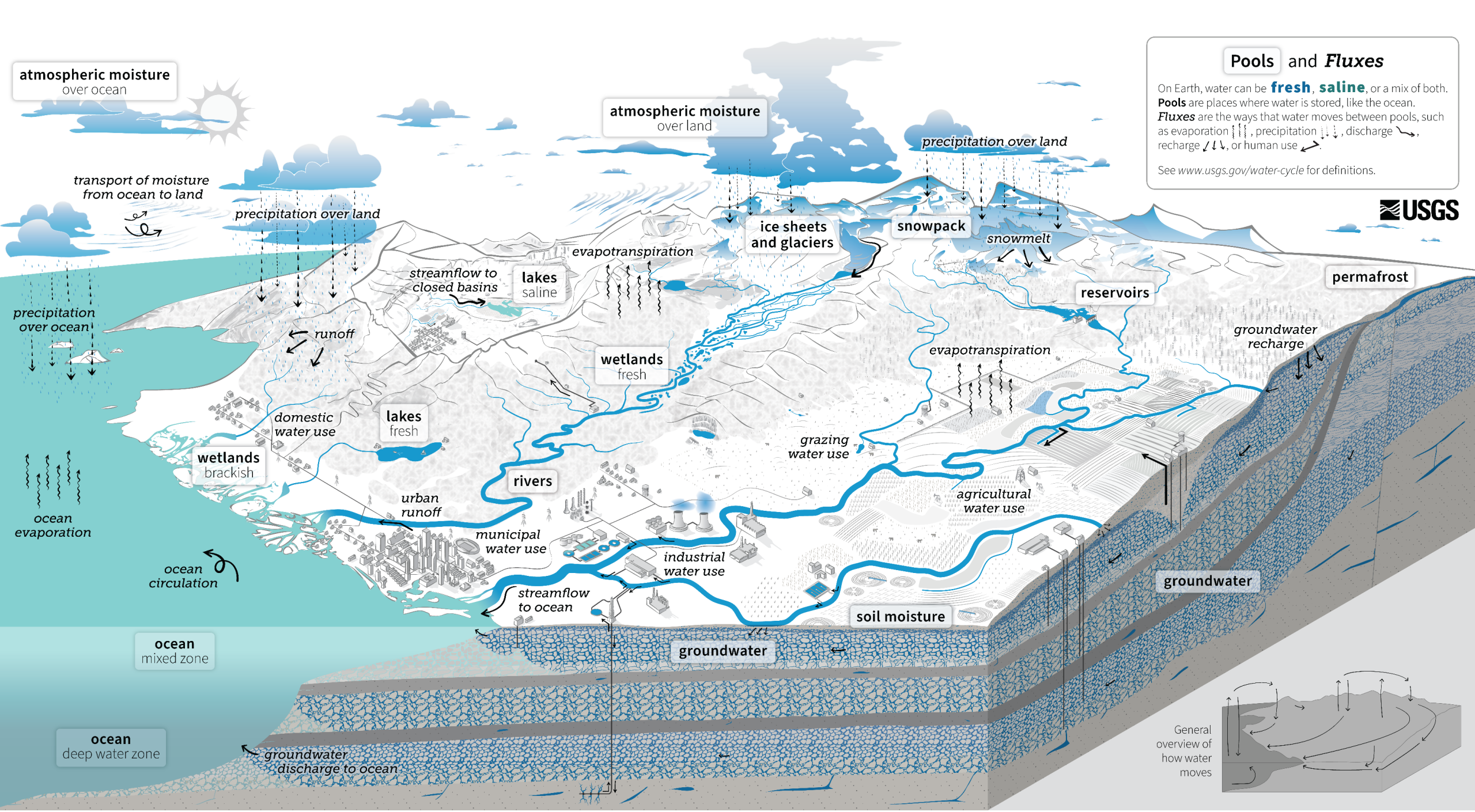
SUNY Oneonta

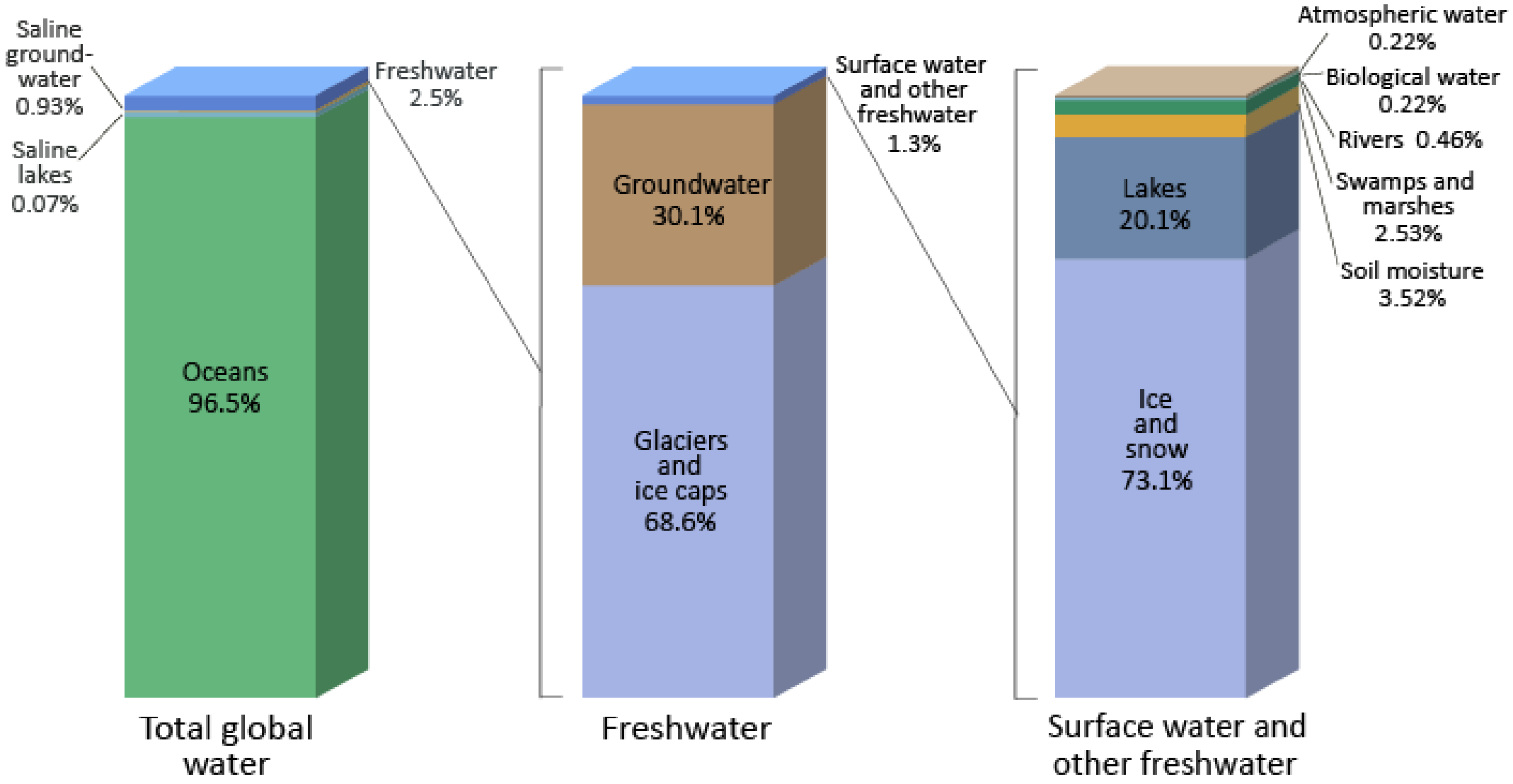



LOOK! A TRICKLE OF WATER RUNNING THROUGH SOME DIRT!
I'D SAY OUR AFTERNOON JUST GOT BOOKED SOLID!


USGS
science for a changing world
The Water Cycle
Link to water vapor animation, and larger view, and more
Sun
Volcanic steam
Atmosphere
Condensation
Sublimation
Deposition
Ice and snow
Precipitation
Evapotranspiration
Evaporation
Fog drip
Surface runoff
Dew
Snowmelt runoff
The cycle involves storage places and movement between the storage places
Infiltration
Streamflow
Evaporation
Seepage
Spring
Flora and fauna
Oceans
Fresh-water
Plant uptake
Groundwater flow
Ocean currents
Vents
Groundwater storage
U.S. Dept. of the Interior
U.S. Geological Survey
Howard Perlman, USGS, John Evans
https://water.usgs.gov/edu/watercycle.html


Pools and Fluxes
On Earth, water can be fresh, saline, or a mix of both.
Pools are places where water is stored, like the ocean.
Fluxes are the ways that water moves between pools, such as evaporation, precipitation, discharge, recharge, or human use.
See www.usgs.gov/water-cycle for definitions.
USGS
atmospheric moisture over ocean
atmospheric moisture over land
transport of moisture from ocean to land
precipitation over land
precipitation over ocean
ice sheets and glaciers
snowpack
snowmelt
permafrost
reservoirs
evapotranspiration
streamflow to closed basins
lakes saline
runoff
wetlands fresh
groundwater recharge
domestic water use
lakes fresh
wetlands brackish
grazing water use
rivers
urban runoff
agricultural water use
ocean evaporation
municipal water use
industrial water use
ocean circulation
streamflow to ocean
groundwater
soil moisture
ocean mixed zone
groundwater discharge to ocean
ocean deep water zone
General overview of how water moves

Distribution of Earth's Water



Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources.

Groundwater

Groundwater - ~30% of Earth's freshwater exists as groundwater.

Water held underground within the soil or rock. Typically, this is thought of as water in the saturated zone.

It can be a renewable or a non-renewable resource.

Groundwater

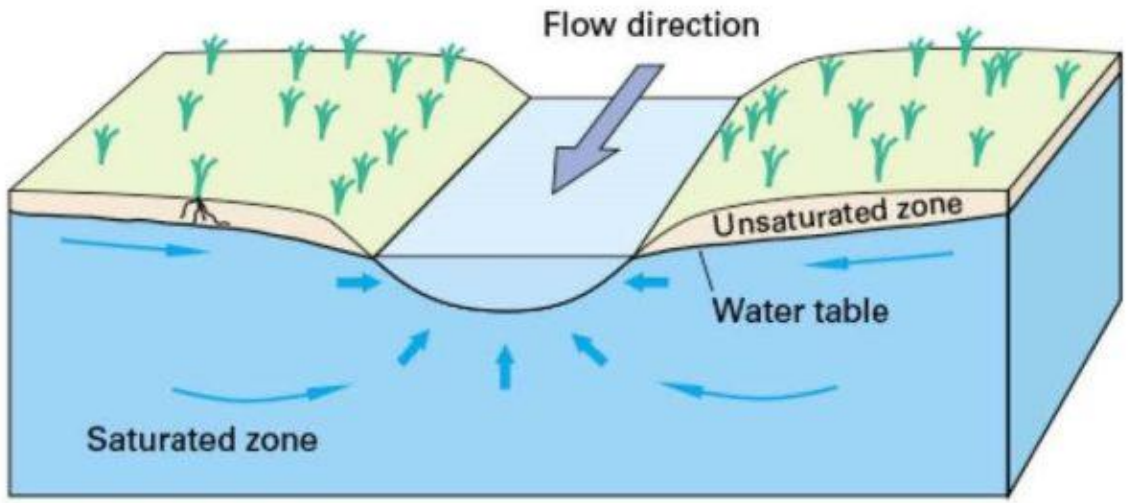
USES

Groundwater is used for drinking water by more than 50% of the people in the United States, including most who live in rural areas.

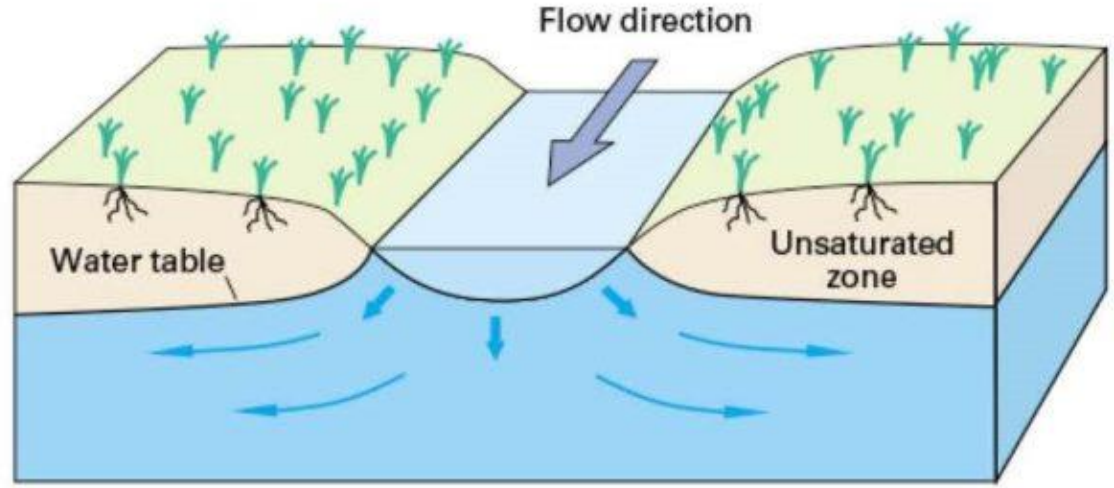
The largest use for groundwater is to irrigate crops.

New Yorkers use almost 900 million gallons per day of groundwater

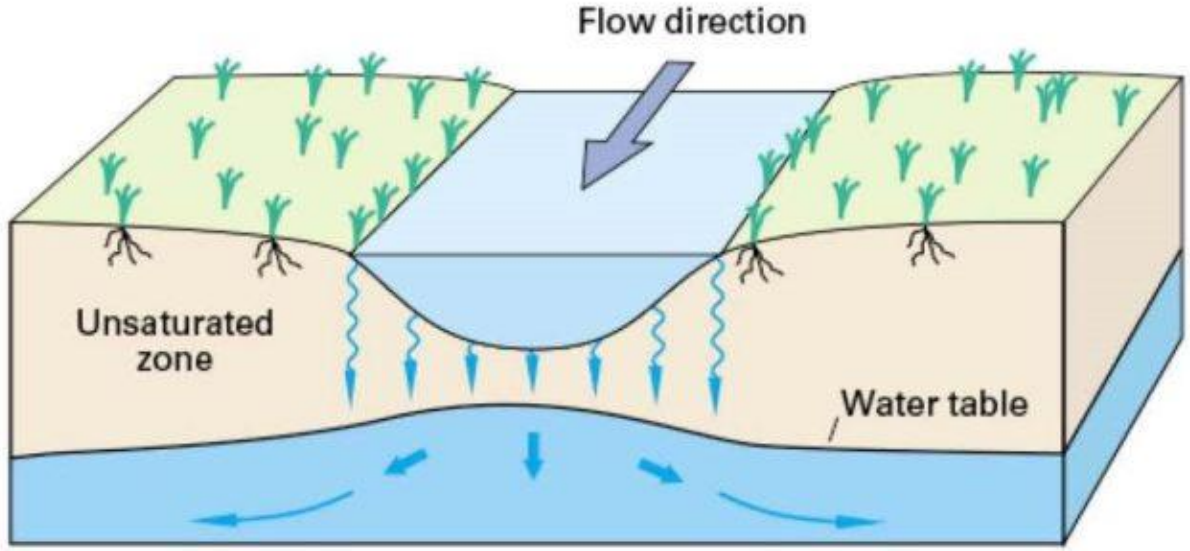
GAINING STREAM



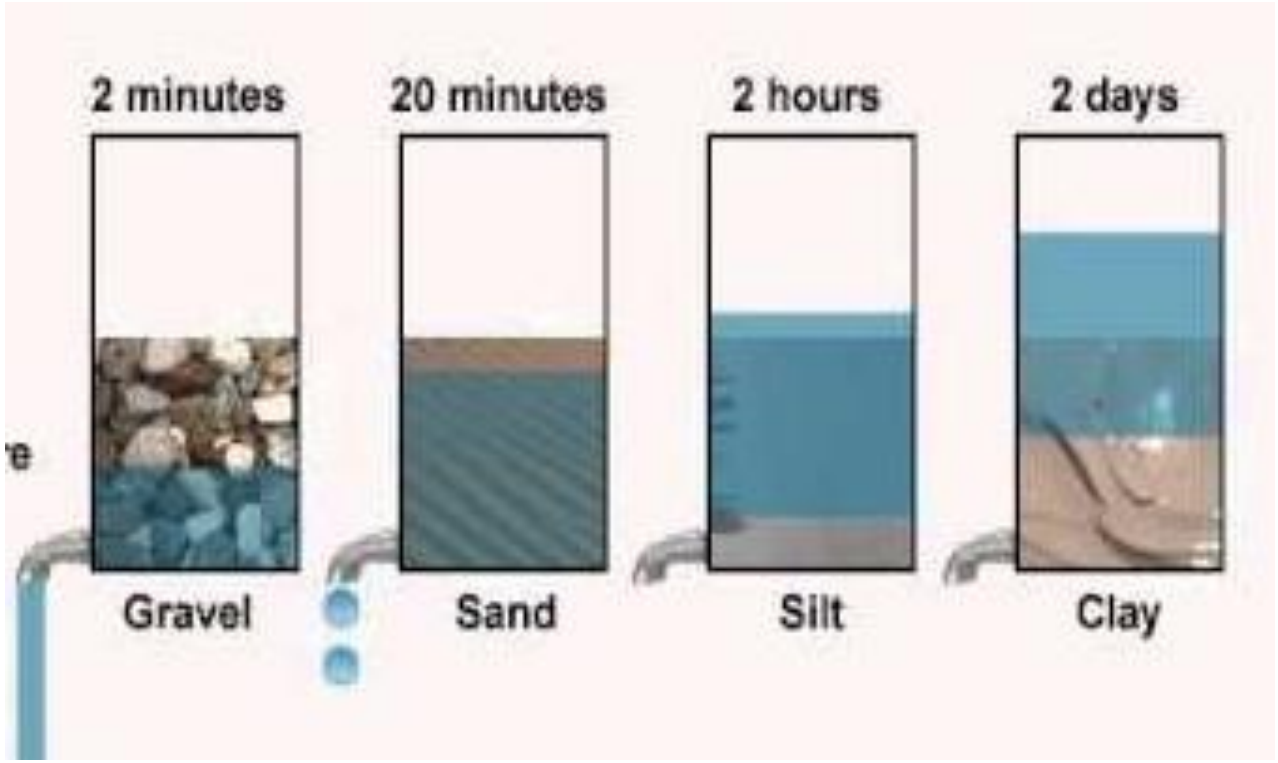
LOSING STREAM

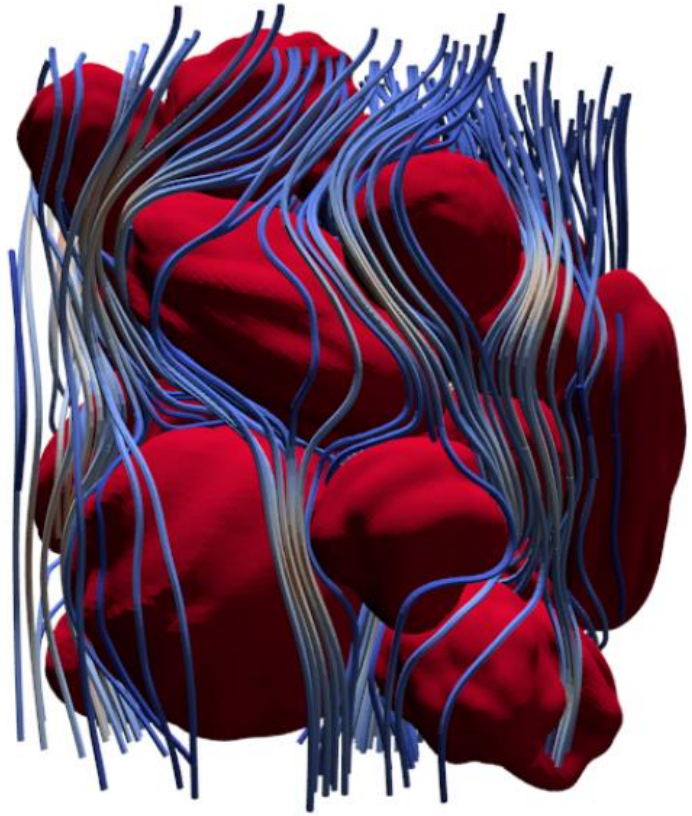


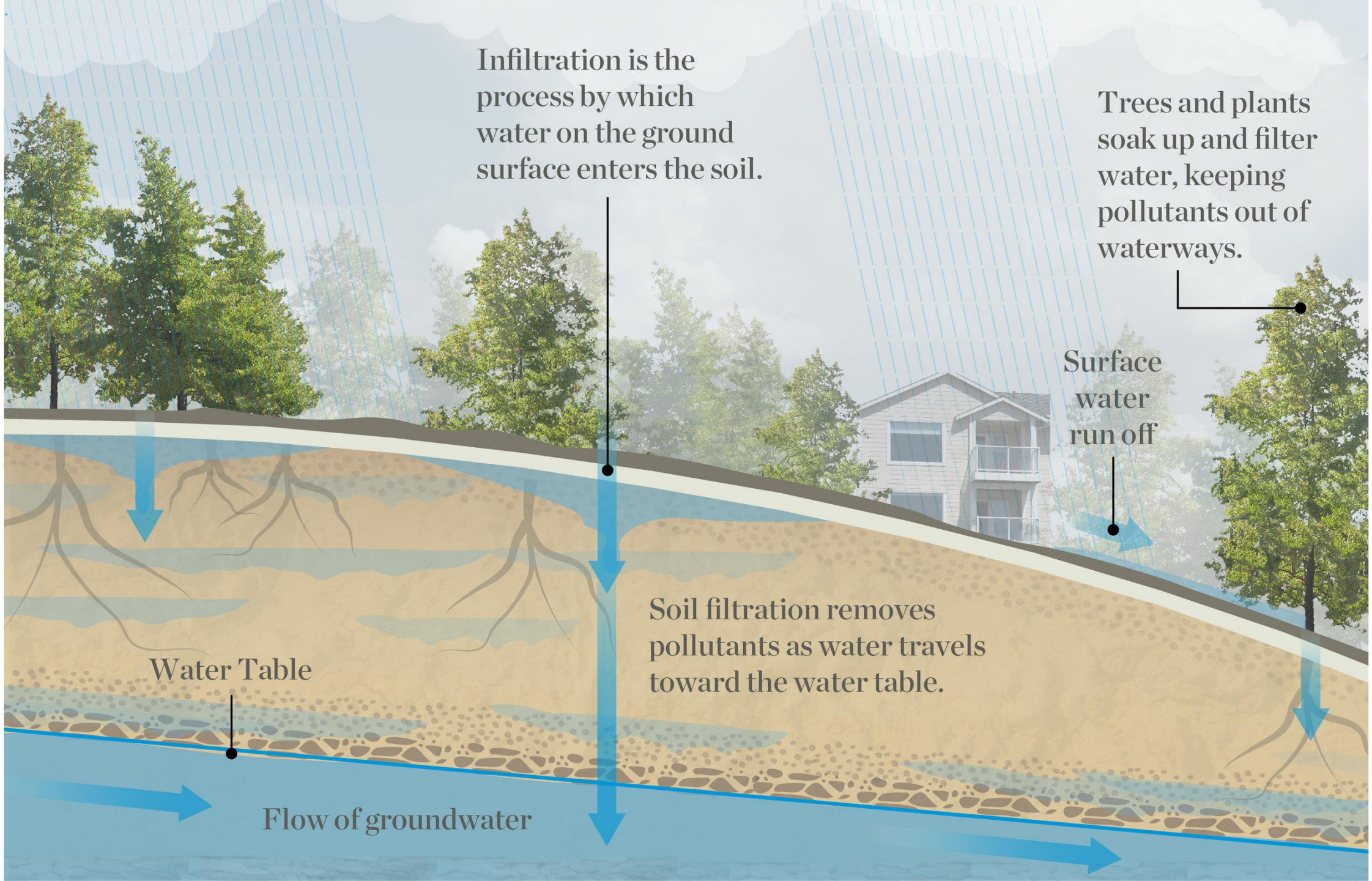
LOSING STREAM THAT IS DISCONNECTED FROM THE WATER TABLE



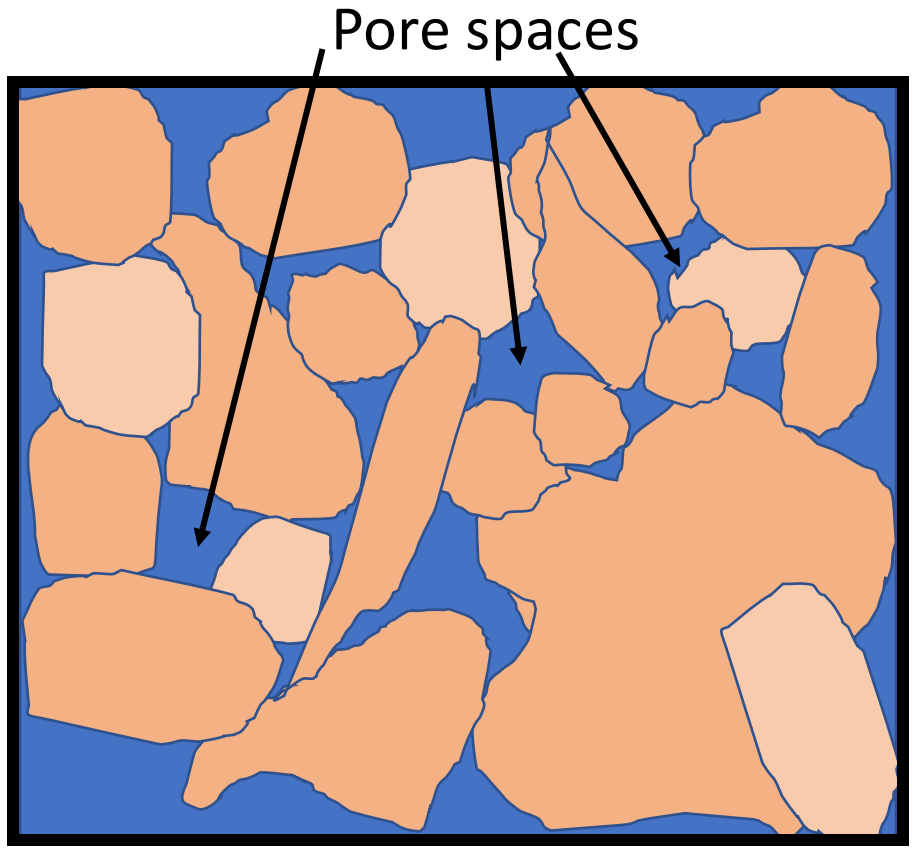
Water Infiltration Recharges Groundwater





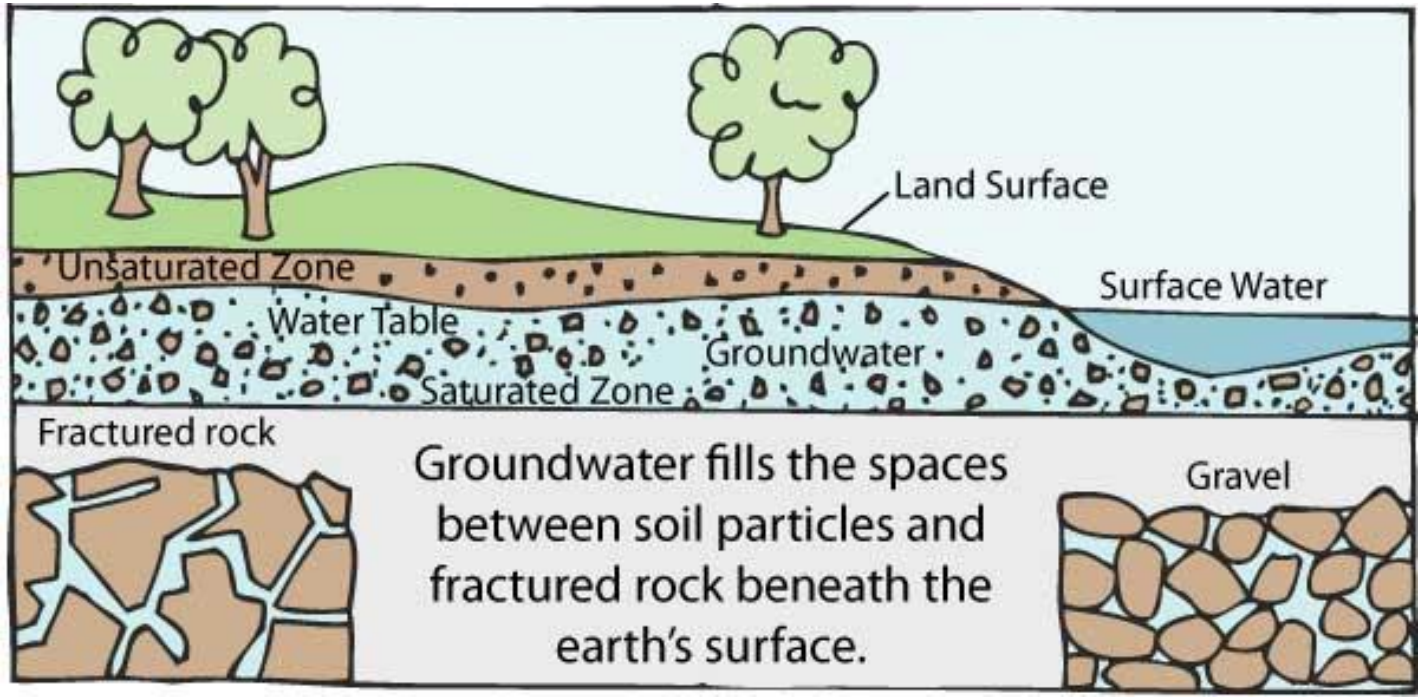

Infiltration is the process by which water on the ground surface enters the soil.
Trees and plants soak up and filter water, keeping pollutants out of waterways.
Surface water run off
Soil filtration removes pollutants as water travels toward the water table.
Water Table
Flow of groundwater

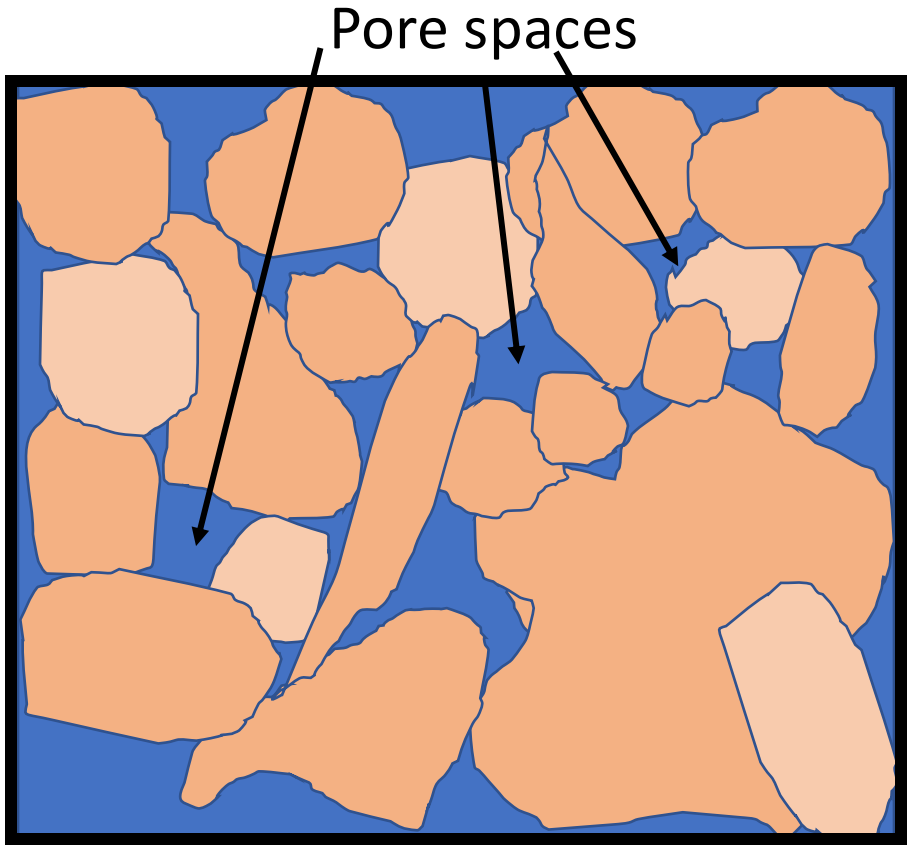
Groundwater



<u>Porosity (empty space)</u> (%) = Pore Volume : Total Volume

Groundwater

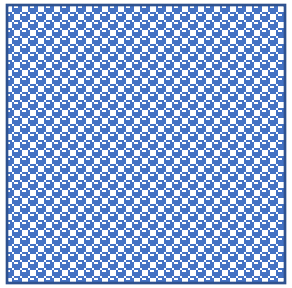


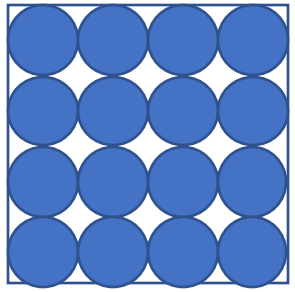


<u>Porosity (empty space)</u> (%) = Pore Volume : Rock Volume

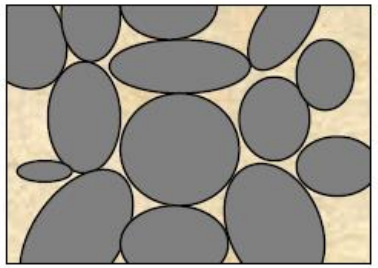
Porosity

- Variety of grain shapes impacts porosity
- Porosity is independent of scale

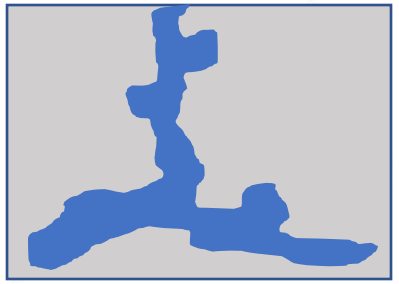




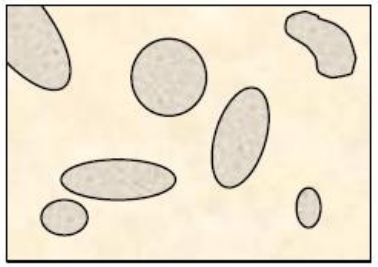
Same pore volume!



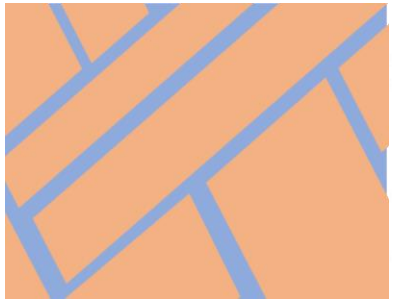
Well Sorted



Dissolution

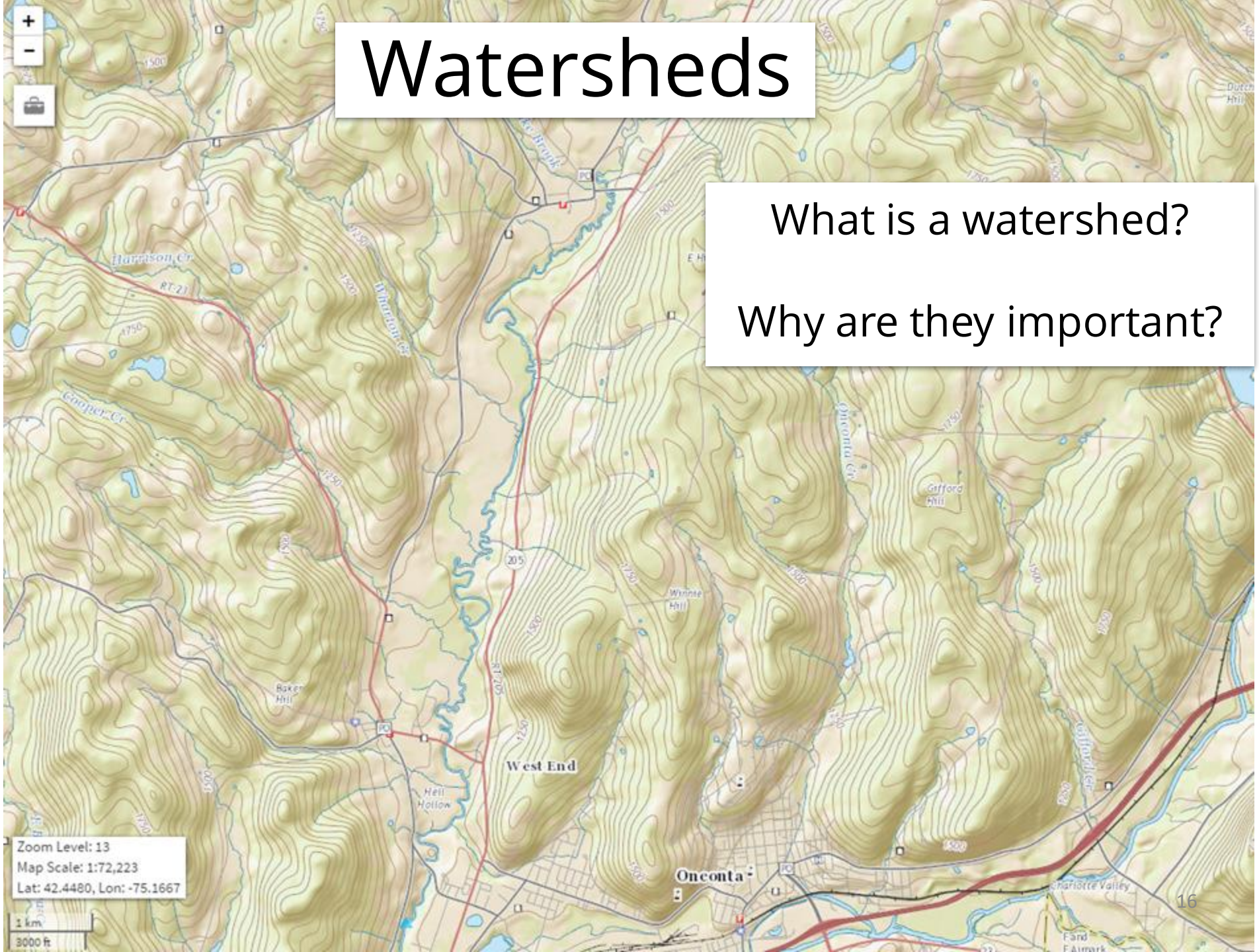


Poorly Sorted



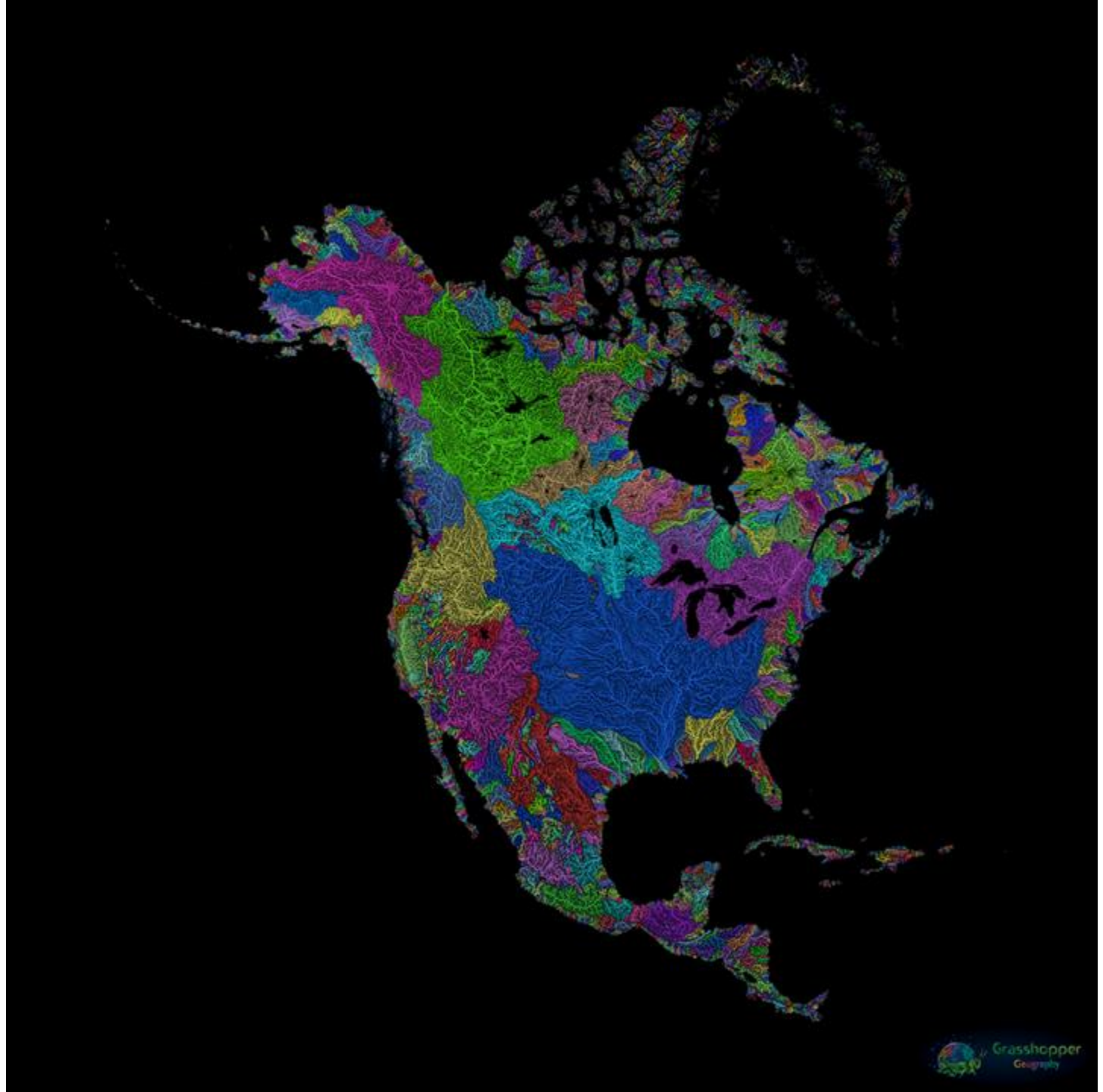
Fracture

Watersheds



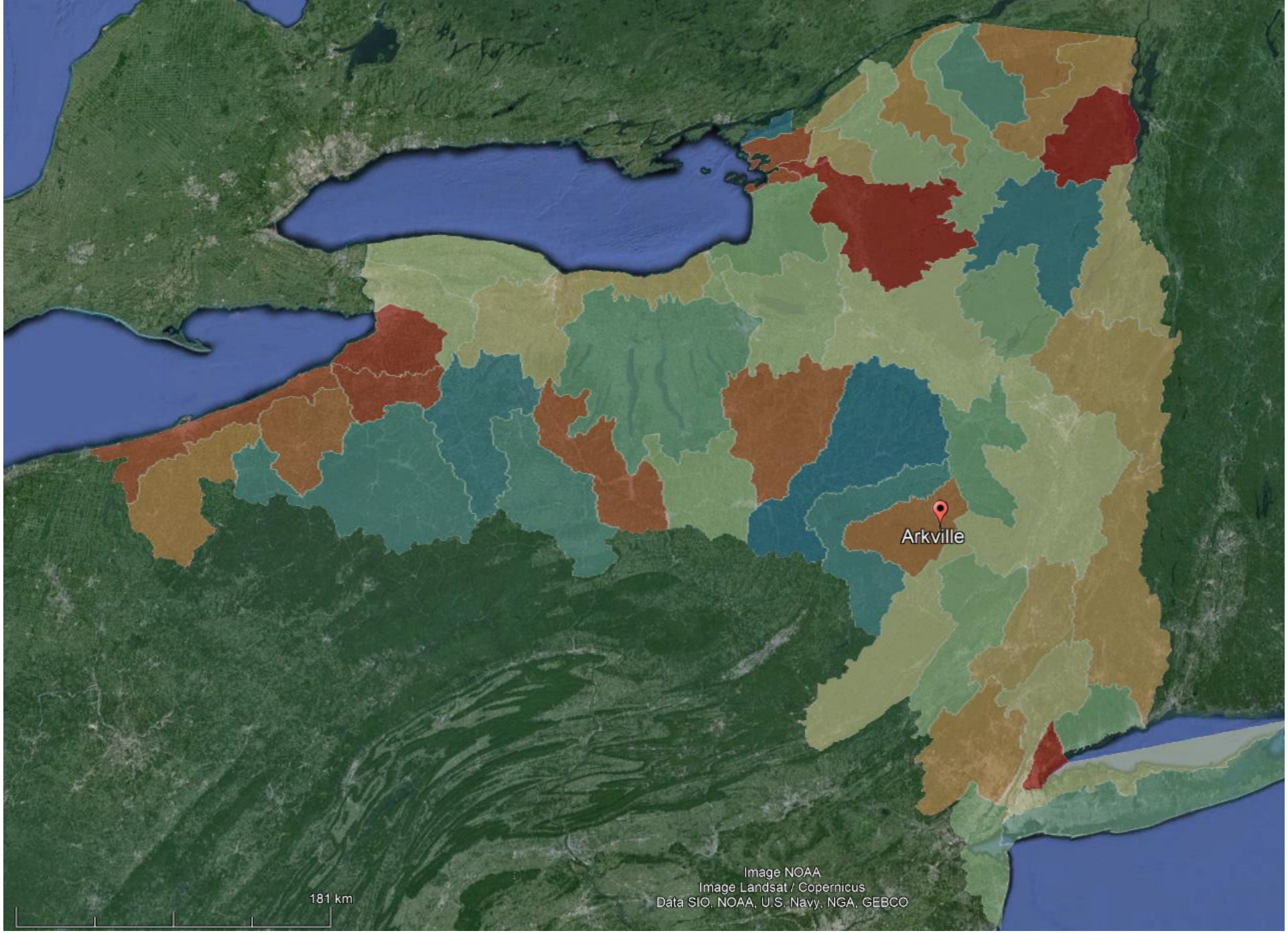
What is a watershed?

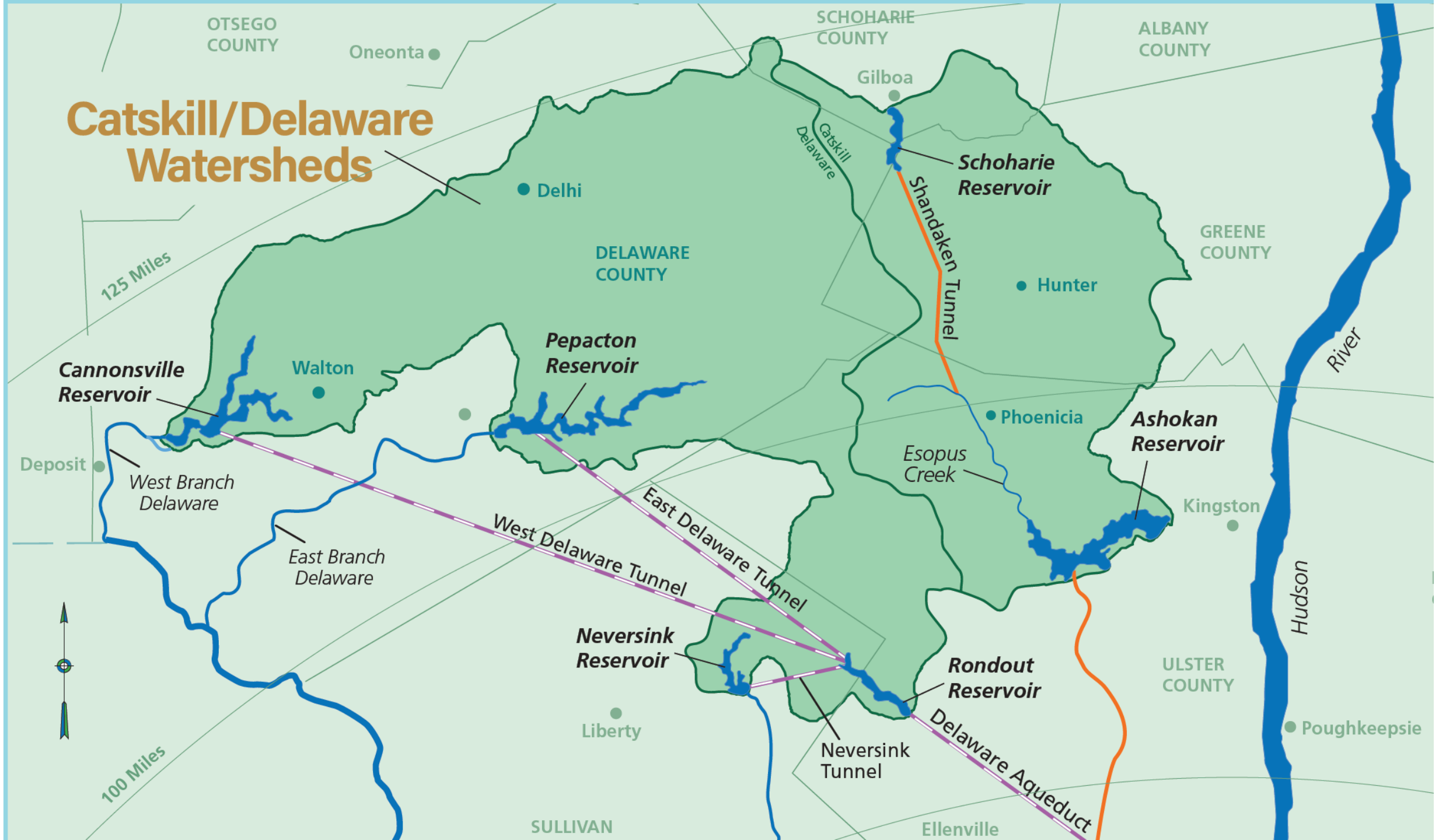
Why are they important?


Grasshopper
Geography

Sourc
e

Can you identify: Hudson, Delaware, Susquehanna, Ohio, Mississippi, Missouri, Rio Grande, Colorado, Snake, Columbia, Sacramento river watersheds?
Can you find watersheds that don't drain to the ocean?


Arkville
181 km
Image NOAA
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO


Catskill/Delaware Watersheds
OTSEGO COUNTY
Oneonta
SCHOHARIE COUNTY
ALBANY COUNTY
Gilboa
Schoharie Reservoir
Catskill
Delaware
Shandaken Tunnel
Delhi
DELAWARE COUNTY
GREENE COUNTY
Hunter
125 Miles
Pepacton Reservoir
Cannonsville Reservoir
Walton
Phoenicia
Ashokan Reservoir
Esopus Creek
Deposit
West Branch Delaware
East Branch Delaware
West Delaware Tunnel
East Delaware Tunnel
Kingston
Hudson River
Neversink Reservoir
Rondout Reservoir
ULSTER COUNTY
Liberty
Neversink Tunnel
Delaware Aqueduct
Poughkeepsie
100 Miles
SULLIVAN
Ellenville

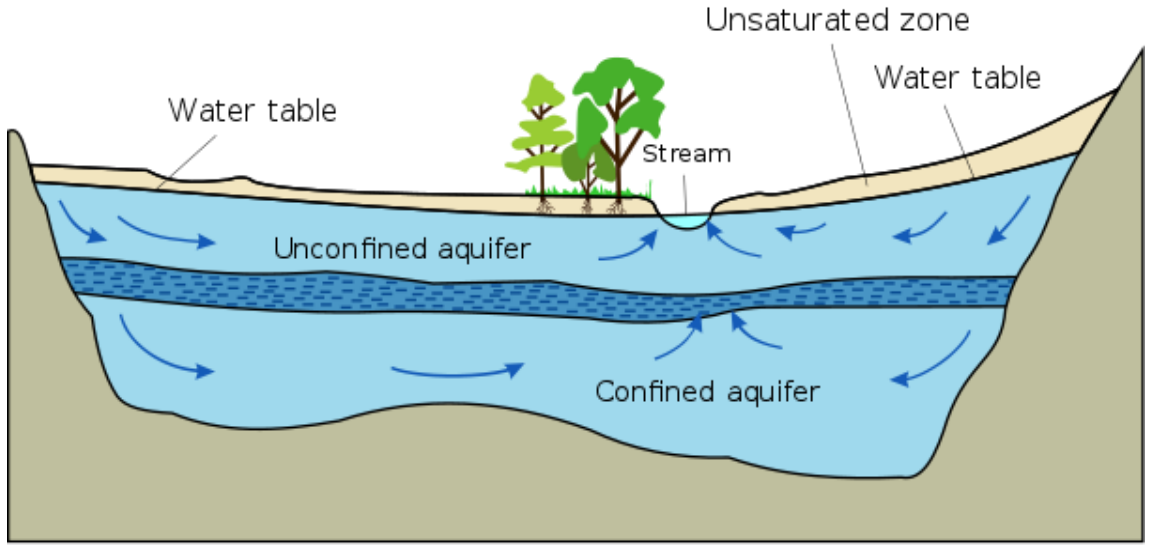
Groundwater and Geology

Aquifers: Saturated and permeable units that can transmits groundwater.

Aquitard: Restrictive of groundwater flow. A less permeable subsurface region.

Aquiclude: Completely restrictive of groundwater flow.

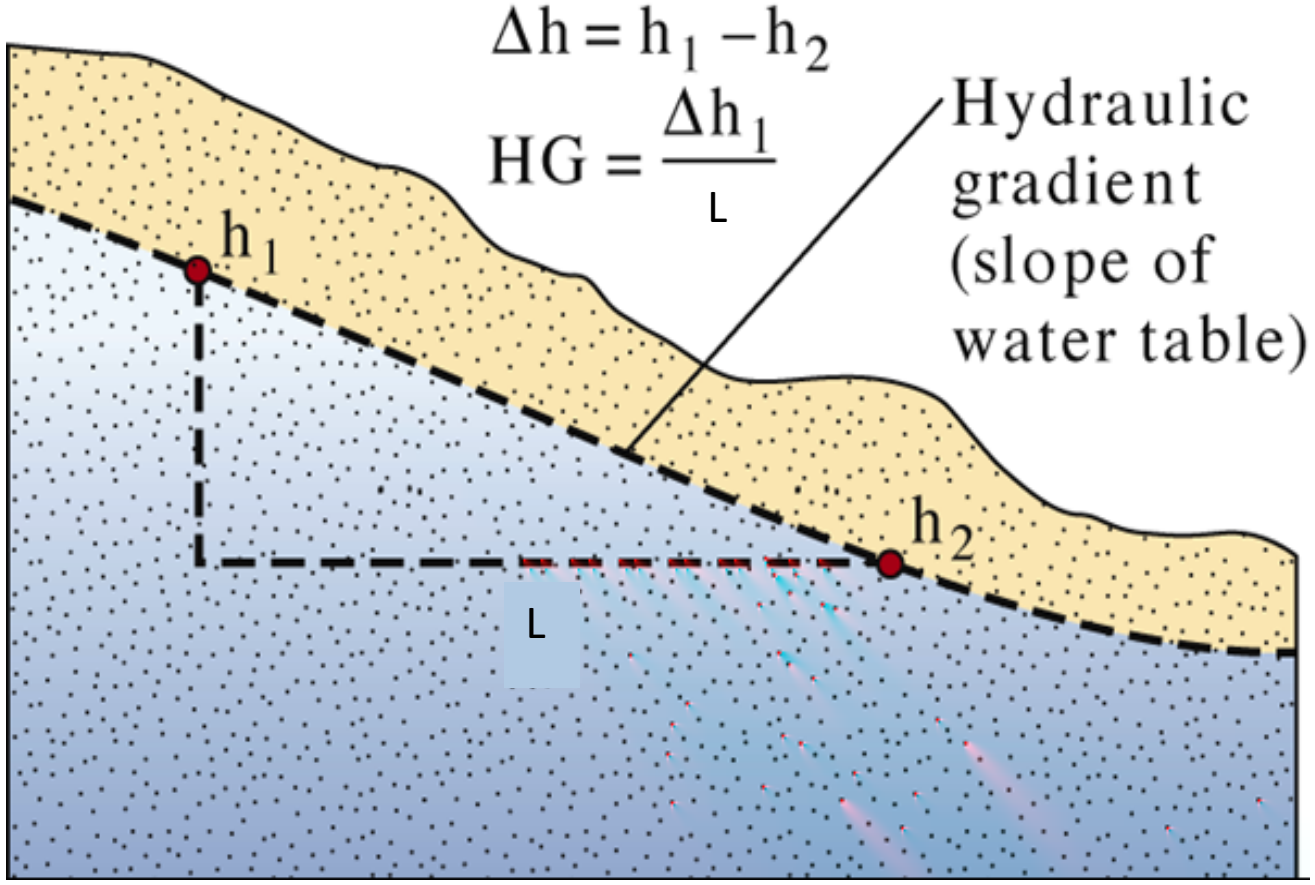
What is permeability?
A measure of transmission. The state of how well water moves through a rock.

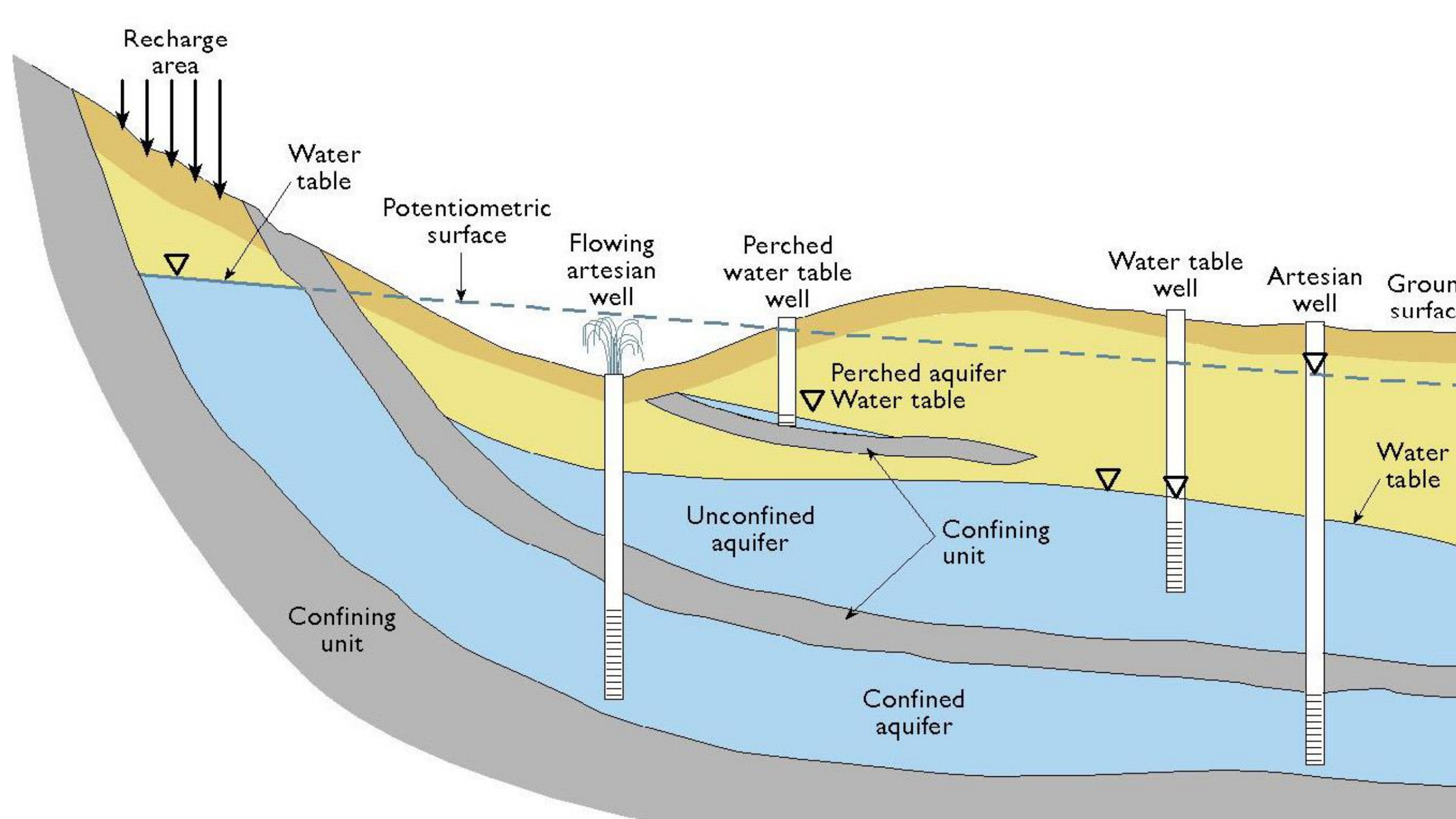


What drives groundwater flow?

Hydraulic gradient

- Pressure differences drive fluid flow
- Pressure changes with the slope of the water table




Recharge area
Water table
Potentiometric surface
Flowing artesian well
Perched water table well
Water table well
Artesian well
Ground surface
Perched aquifer
Water table
Unconfined aquifer
Confining unit
Water table
Confining unit
Confined aquifer

How can geology affect water quality?

Smelly Water

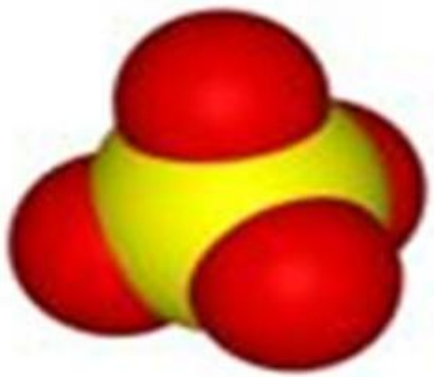
“Hard” Water

Contaminated Water

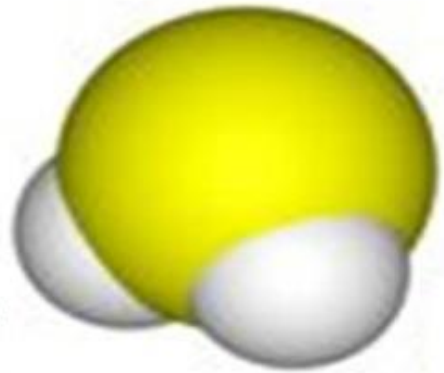
What does Yellowstone National Park have in common with Broccoli?

Sulfate → Sulfide

Sulfate is a naturally occurring in many rocks and sediments (and broccoli!)



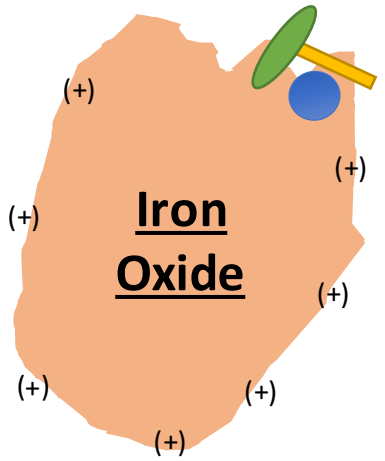
anaerobic sulfate
Reducing bacteria



Sulfate
(SO_4^{2-})

Sulfide
(H_2S)

Bacteria Dissolve Iron in Anaerobic Groundwater



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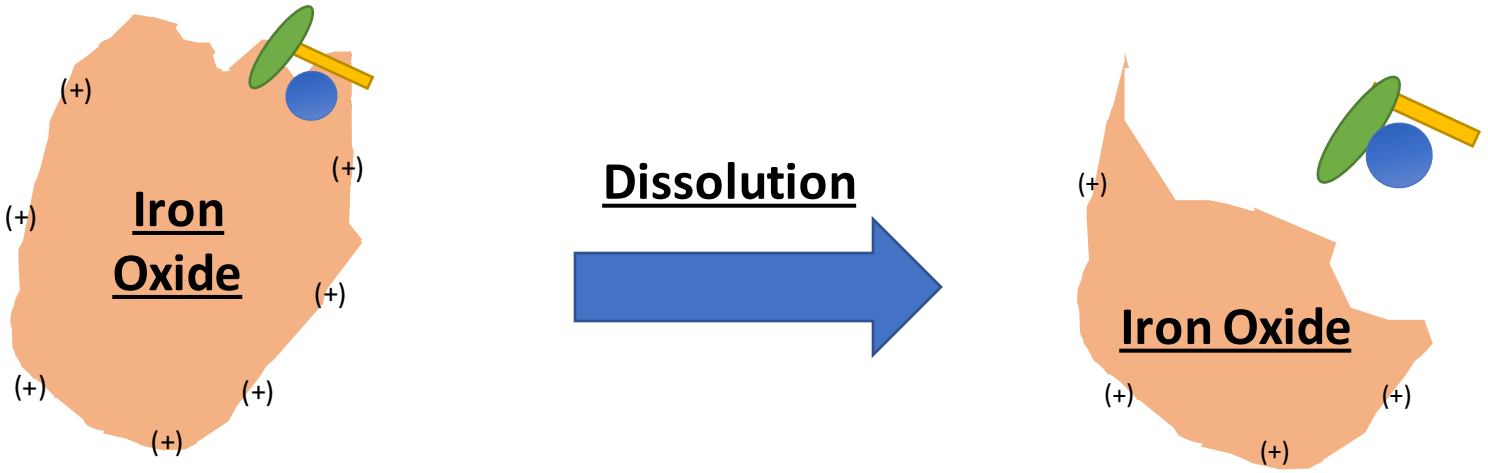

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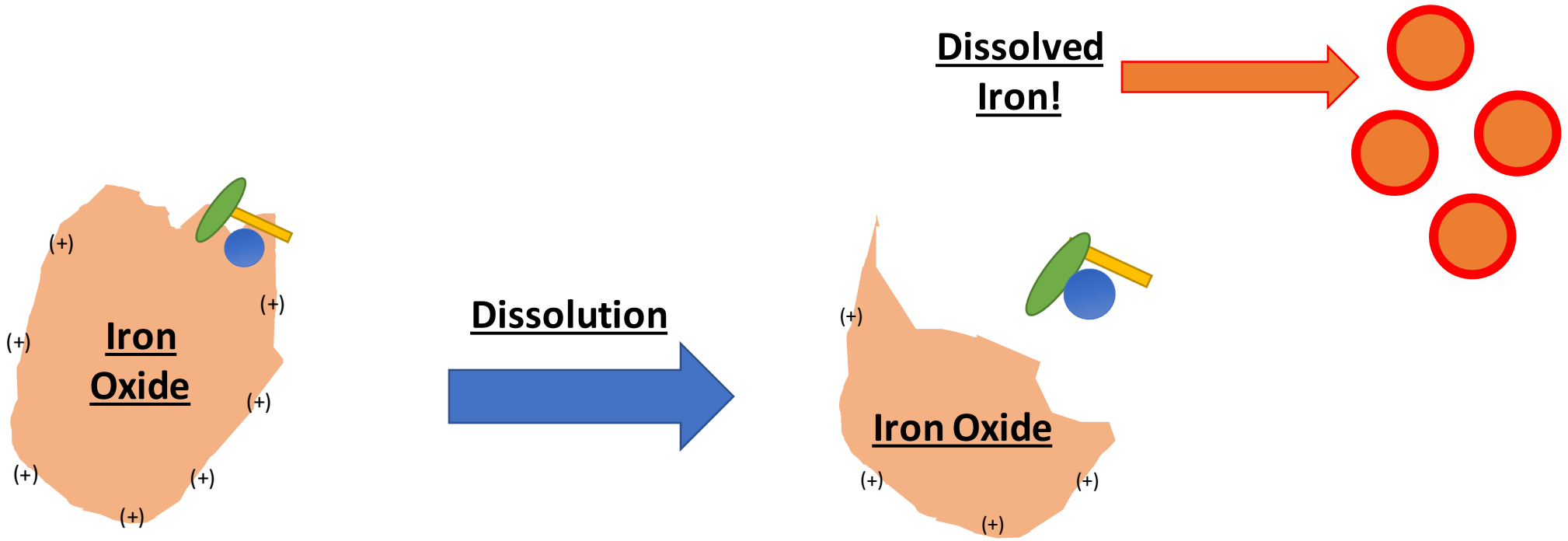

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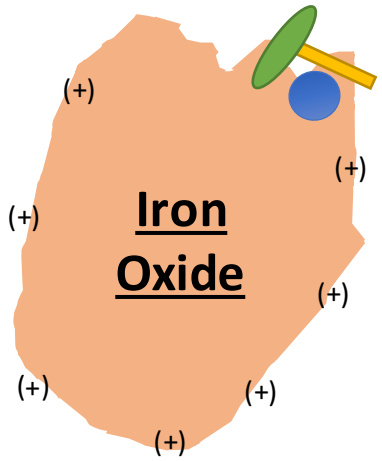
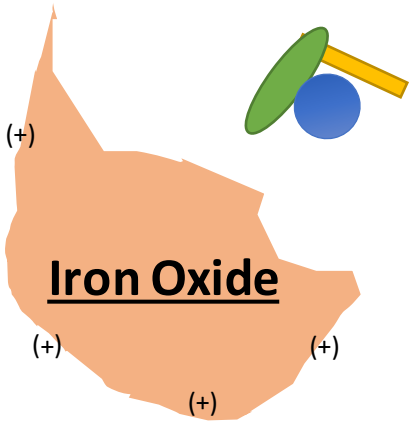
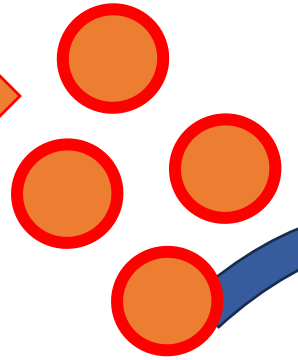


Dissolution

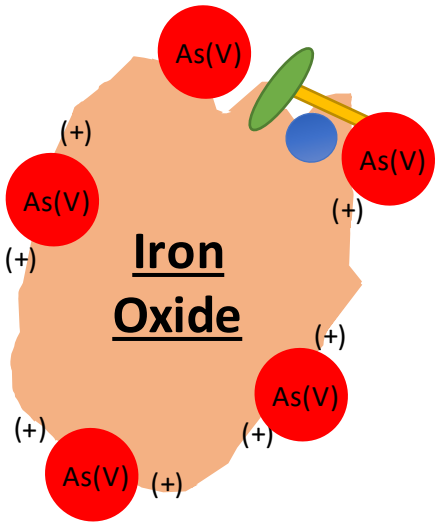


Dissolved Iron!

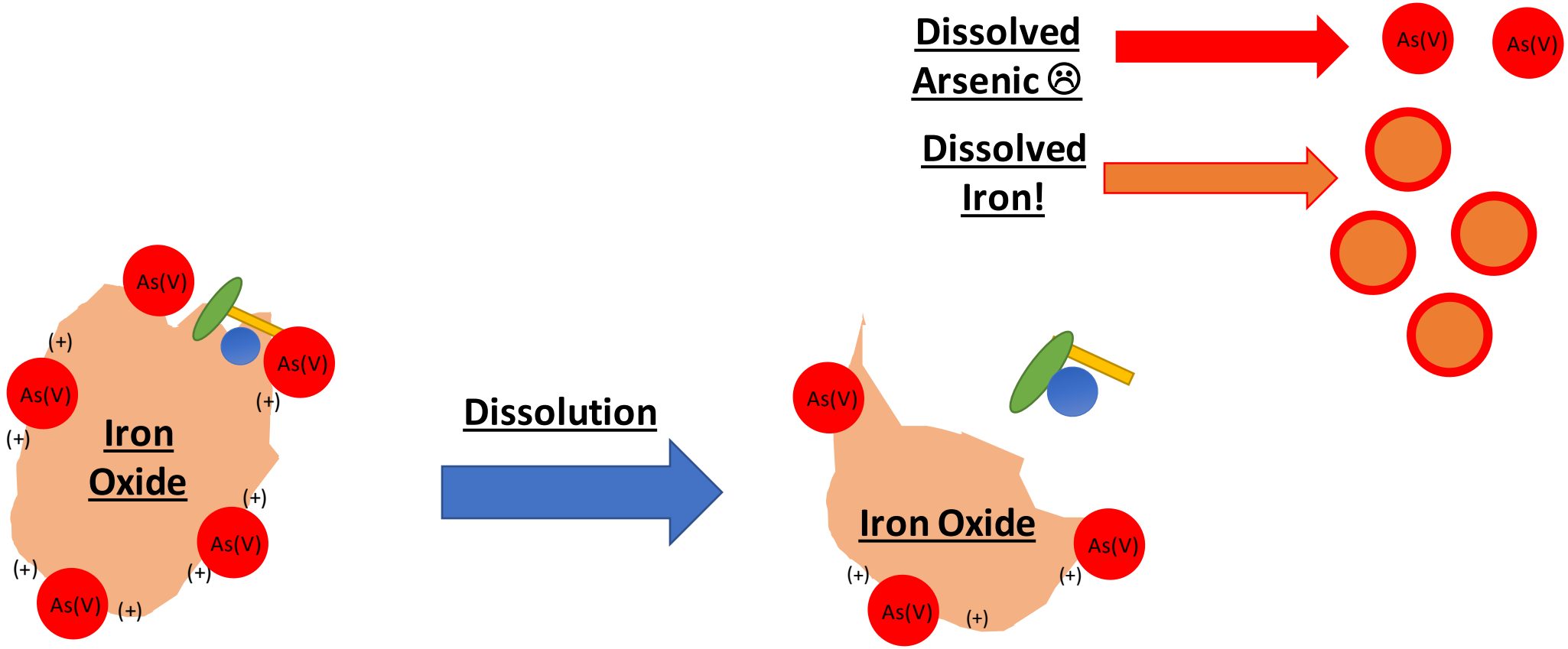


Add Oxygen and you get rust!

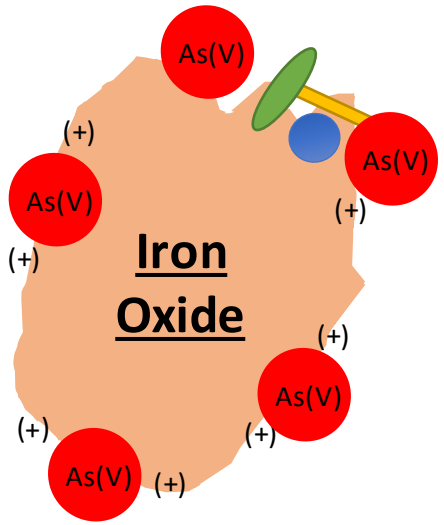
Bacteria Dissolve Iron in Anaerobic Groundwater



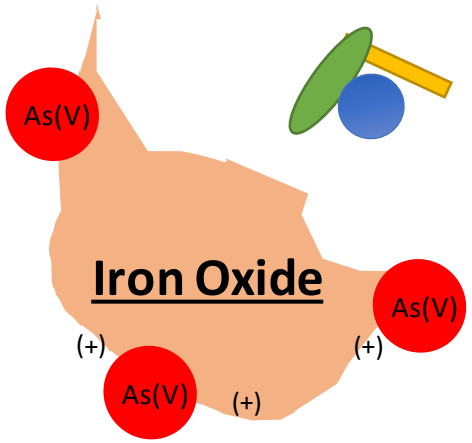
Bacteria Dissolve Iron in Anaerobic Groundwater



Bacteria Dissolve Iron in Anaerobic Groundwater

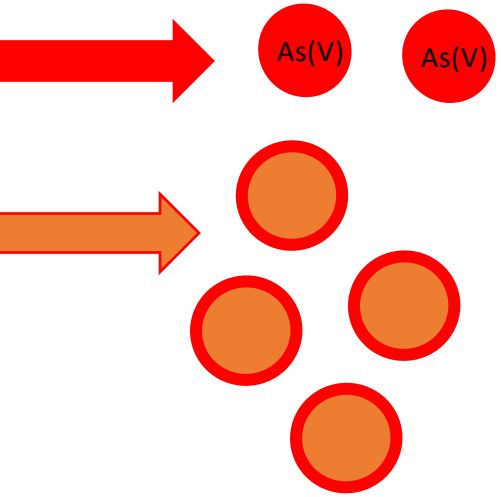


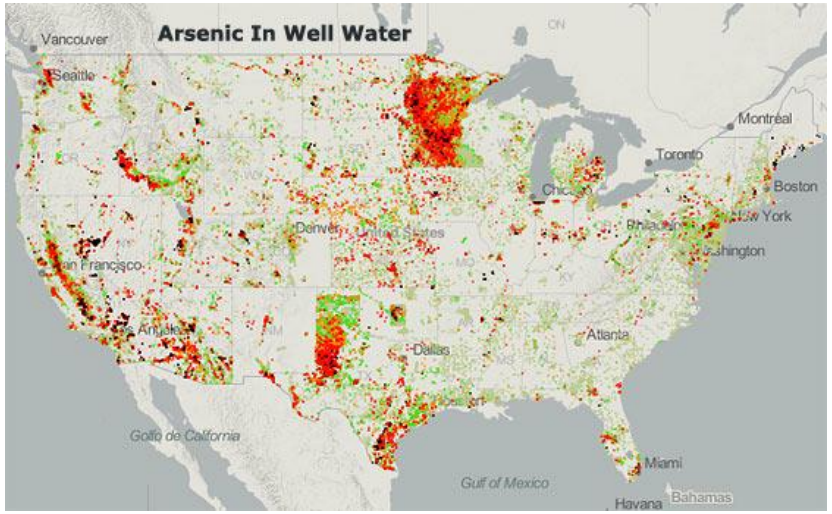
Dissolution

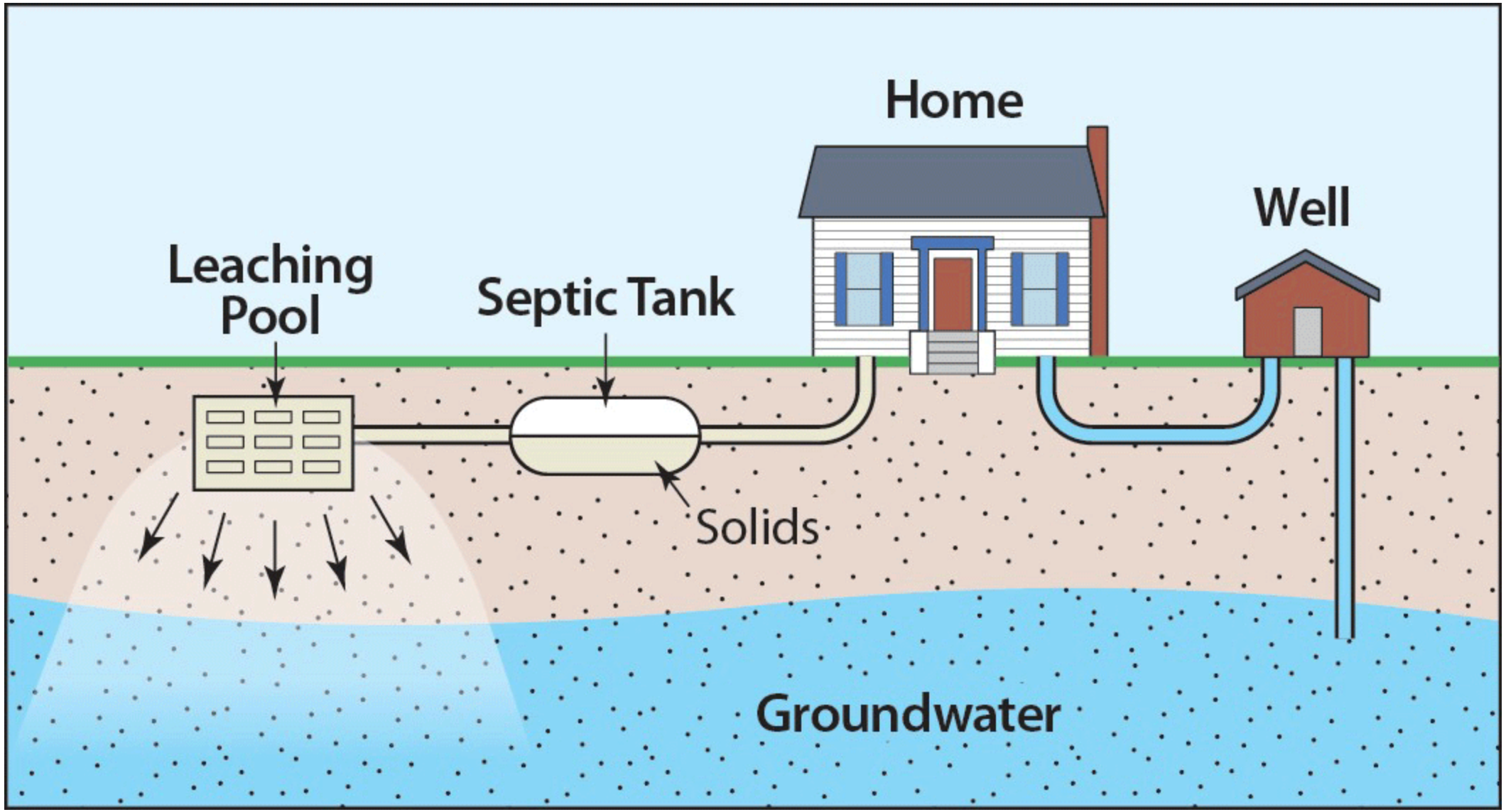


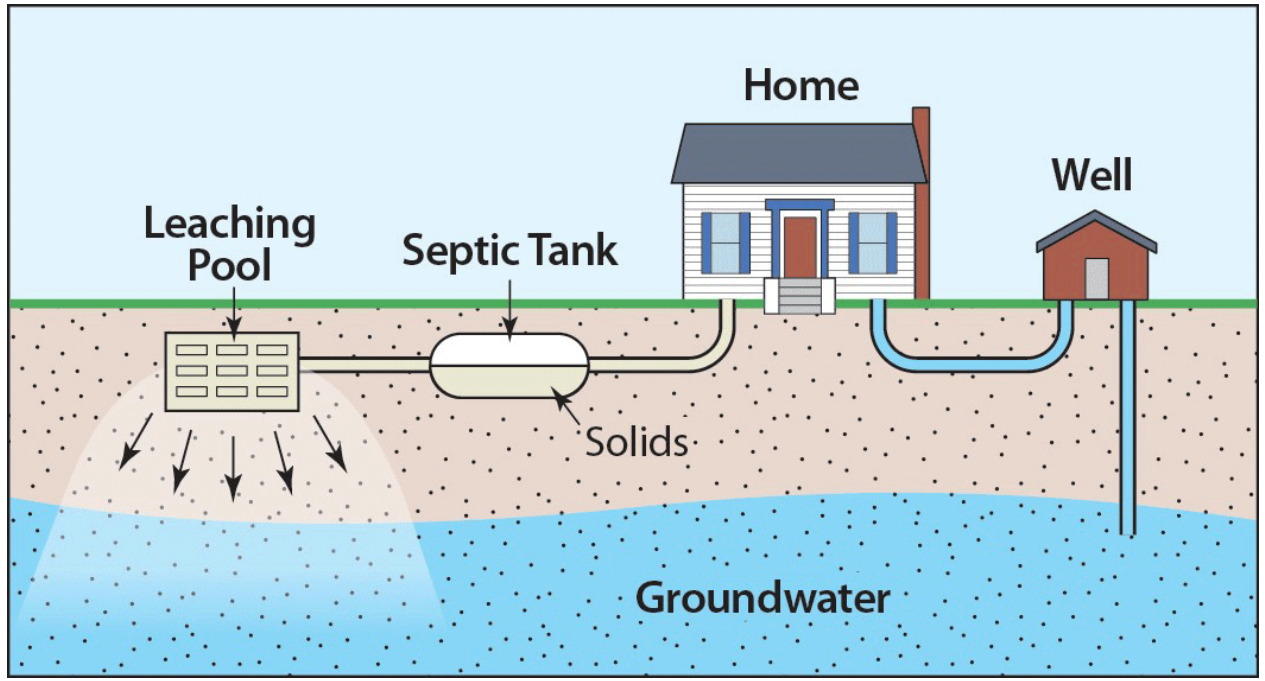
Dissolved Arsenic ☹

Dissolved Iron!






Home
Well
Leaching Pool
Septic Tank
Solids
Groundwater



Pathogens:

- Bacteria (e.g., Escherichia coli, Salmonella)
- Viruses (e.g., Hepatitis A, Norovirus)
- Parasites (e.g., Giardia, Cryptosporidium)

Nutrients:

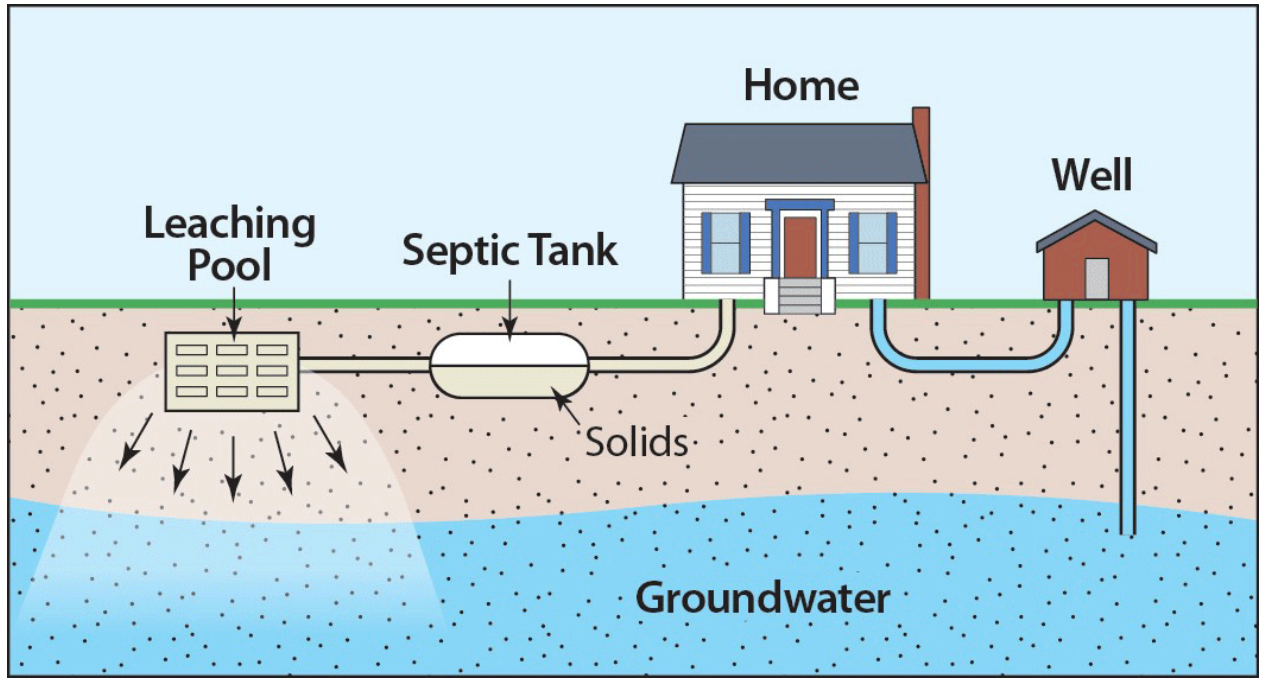
- Nitrogen (primarily as nitrate and ammonia)
- Phosphorus

Organic Chemicals:

- Pharmaceuticals and personal care products (PPCPs)
- Household chemicals (e.g., cleaning agents)
- Volatile organic compounds (VOCs)

Inorganic Chemicals:

- Chloride
- Sulfate
- Heavy metals (e.g., lead, mercury, cadmium, zinc)

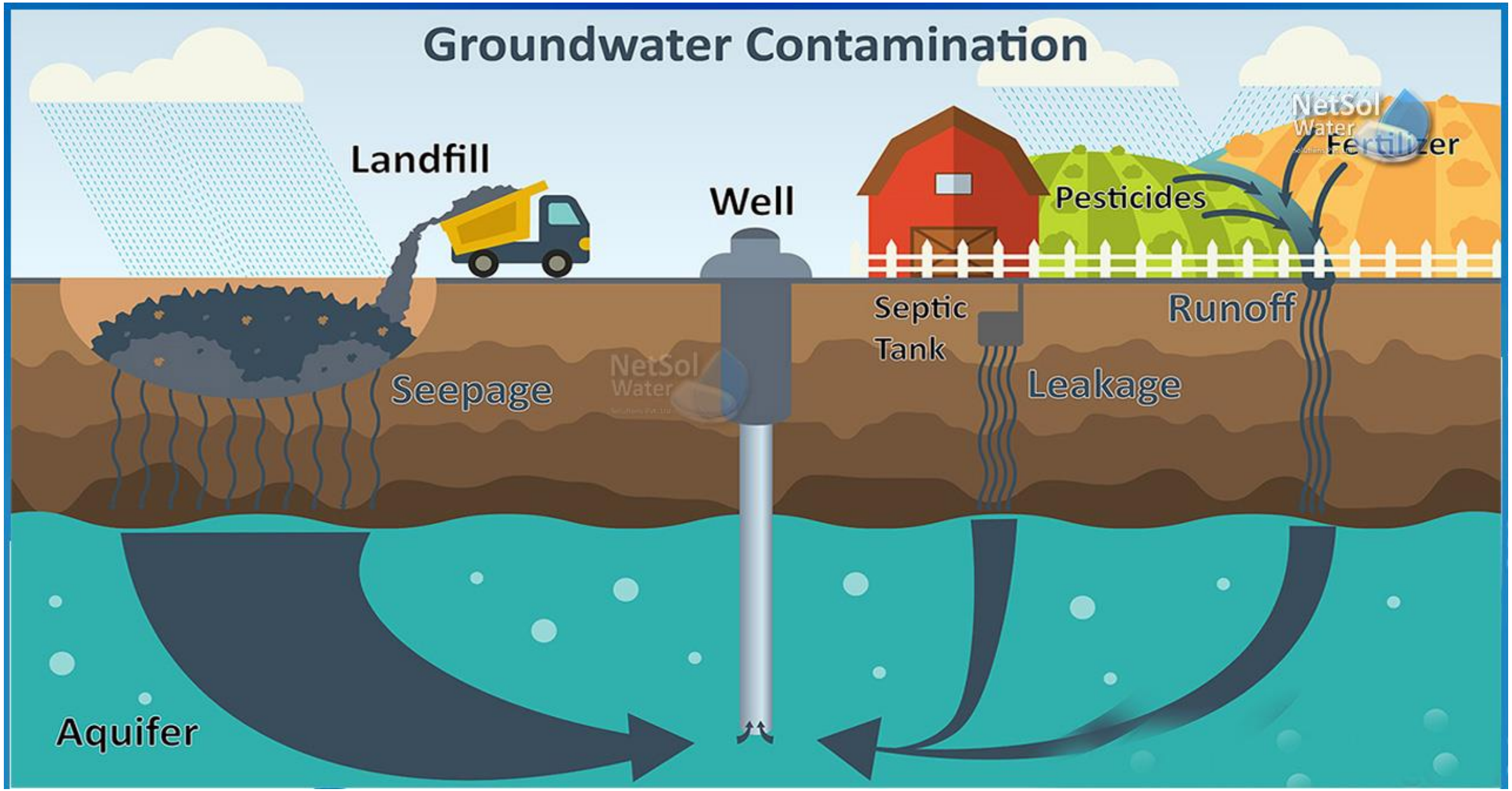


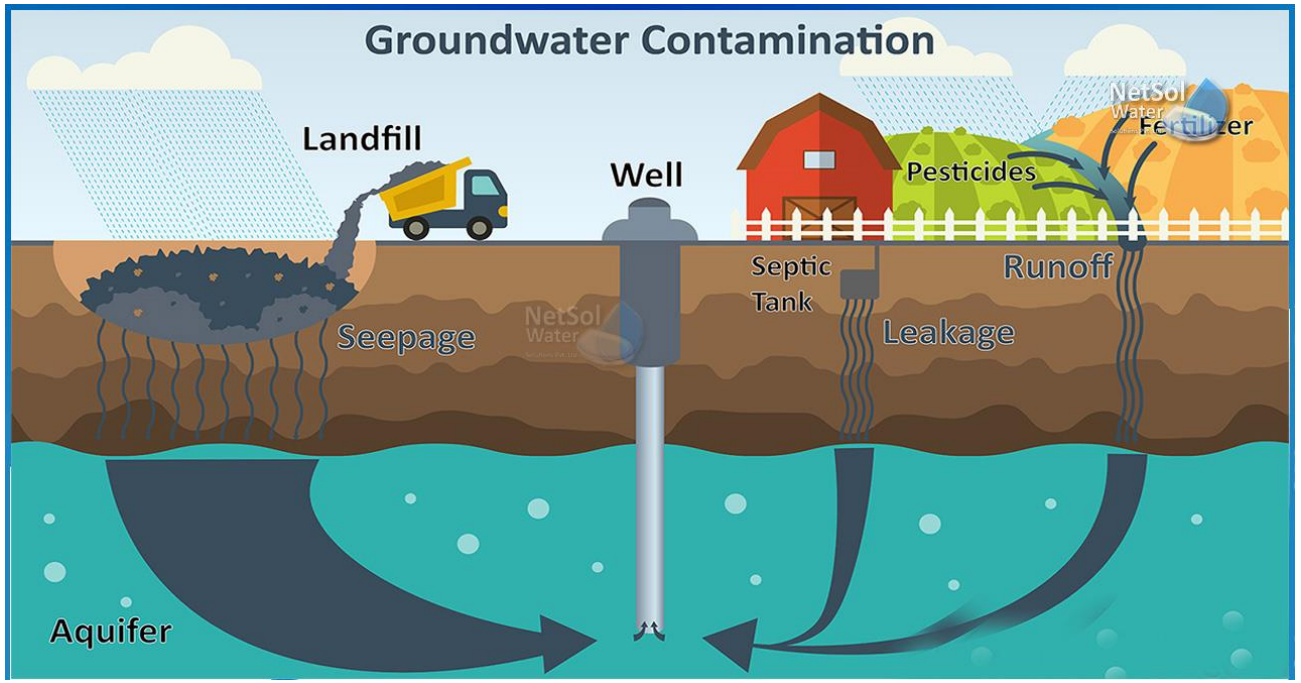
Emerging Contaminants:

- Endocrine-disrupting compounds (EDCs)
- Synthetic organic chemicals (e.g., pesticides, plasticizers)

Biochemical Oxygen Demand (BOD):

- A measure of the amount of oxygen that bacteria will consume while decomposing organic matter.


Groundwater Contamination
Landfill
Well
Pesticides
Fertilizer
Septic
Tank
Runoff
Seepage
Leakage
Aquifer



Phthalates:

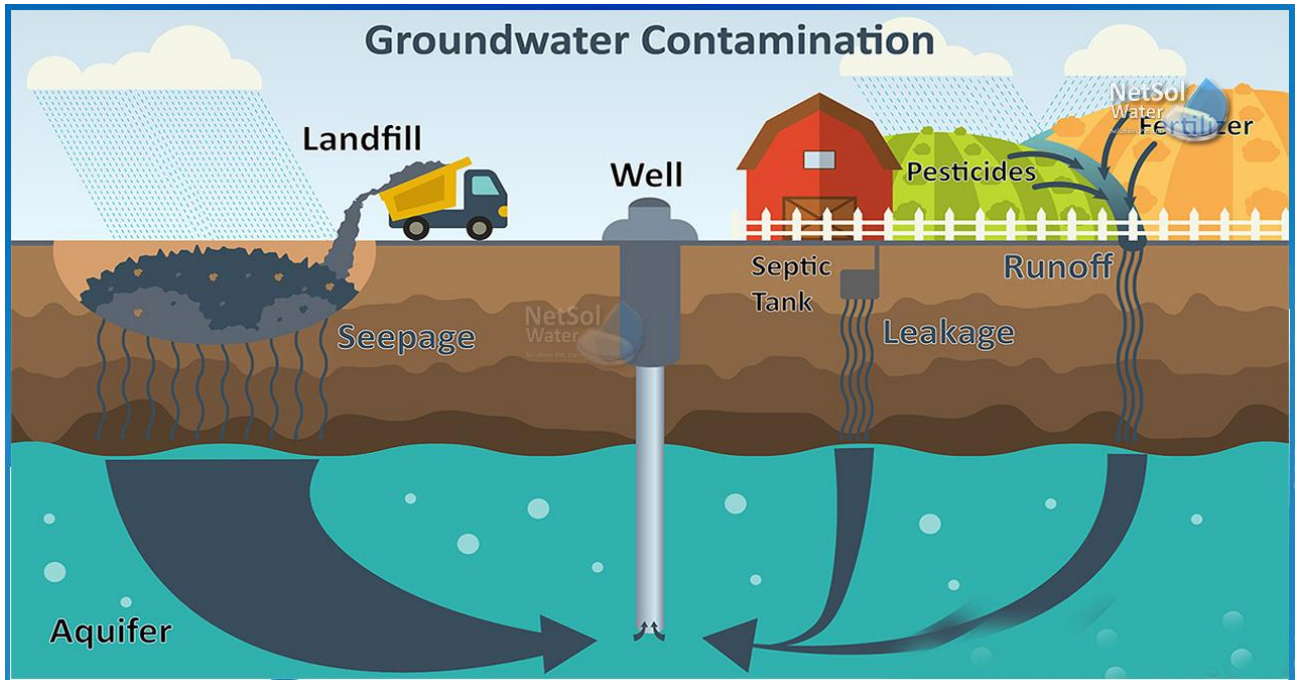
- These are a group of chemicals used to make plastics more durable. They are found in numerous household products and can leach into groundwater from septic systems.

Per- and Polyfluoroalkyl Substances (PFAS):

- These are synthetic chemicals used in various industrial and consumer products for their water- and grease-resistant properties. PFAS are highly persistent in the environment and can contaminate groundwater through septic systems.

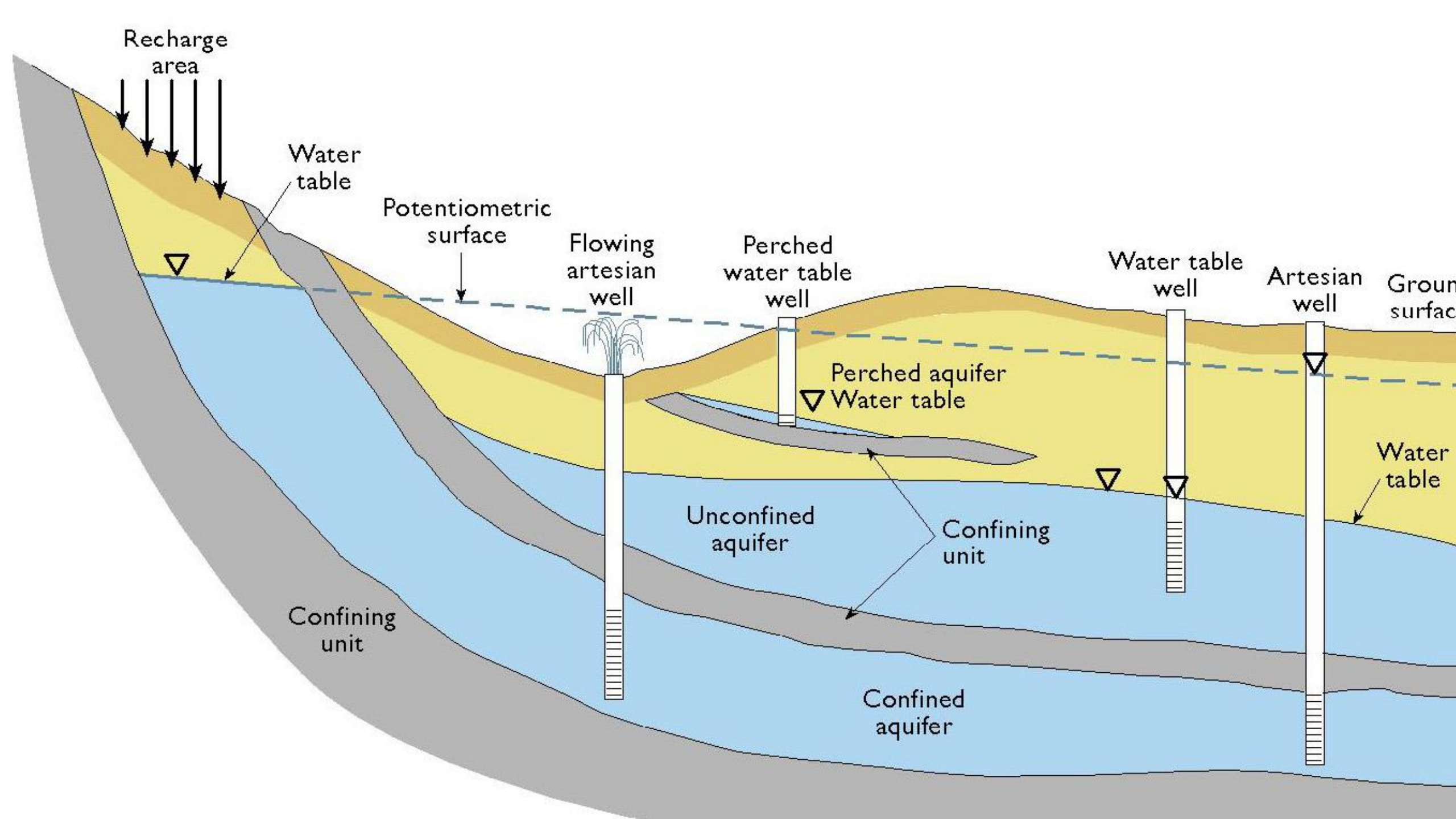
Microplastics:

- Tiny plastic particles resulting from the breakdown of larger plastic debris or from products like synthetic fibers from clothing. Microplastics can enter septic systems and eventually leach into groundwater.



Gases

- **Methane (CH_4)**: Produced during the anaerobic digestion of organic matter in septic systems. Methane is a potent greenhouse gas and can migrate into groundwater.
- **Carbon Dioxide (CO_2)**: Also produced from the decomposition of organic matter. High levels of CO_2 can affect groundwater pH and contribute to acidification.


Recharge area
Water table
Potentiometric surface
Flowing artesian well
Perched water table well
Water table well
Artesian well
Ground surface
Perched aquifer
Water table
Unconfined aquifer
Confining unit
Water table
Confining unit
Confined aquifer


Thank you for your attention
Questions?