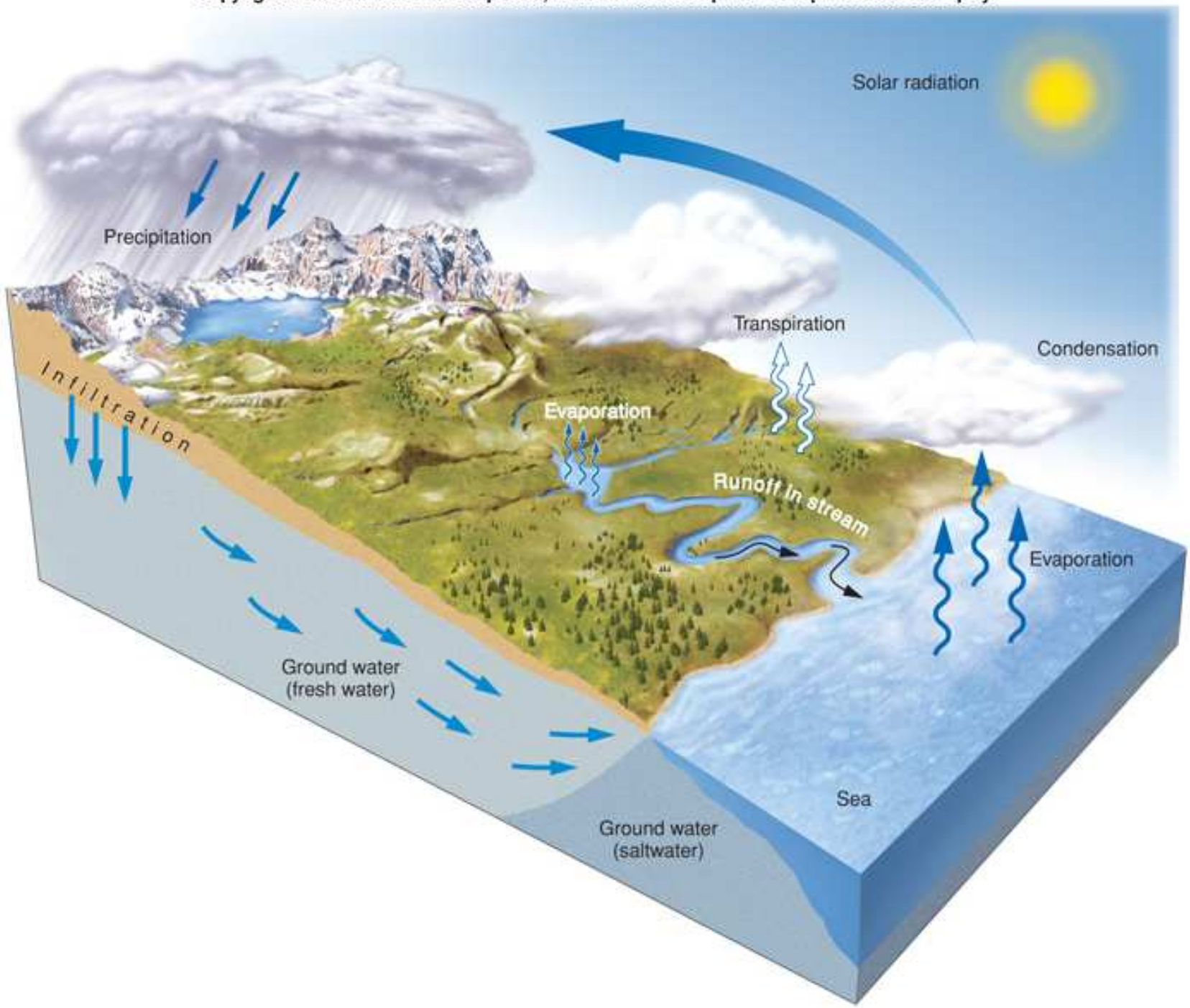
Ground Water

Chapter 17

Ground Water

- *Ground Water* lies beneath the ground surface, filling pores in sediments and sedimentary rocks and fractures in other rock types
- Represents *0.6%* of the hydrosphere (35x the water in all lakes and rivers combined)
  - Resupplied by slow *infiltration of precipitation*
  - Generally cleaner than surface water
  - Accessed by *wells*



Porosity and Permeability

- *Porosity* - the percentage of rock or sediment that consists of voids or openings
  - Measurement of a rock's ability to hold water
  - Loose sand has ~30-50% porosity
  - Compacted sandstone may have only 10-20% porosity

- *Permeability* - the capacity of a rock to transmit fluid through pores and fractures
  - Interconnectedness of pore spaces
  - Most sandstones and conglomerates are porous *and* permeable
  - Granites, schists, unfractured limestones are *impermeable*

Porosity

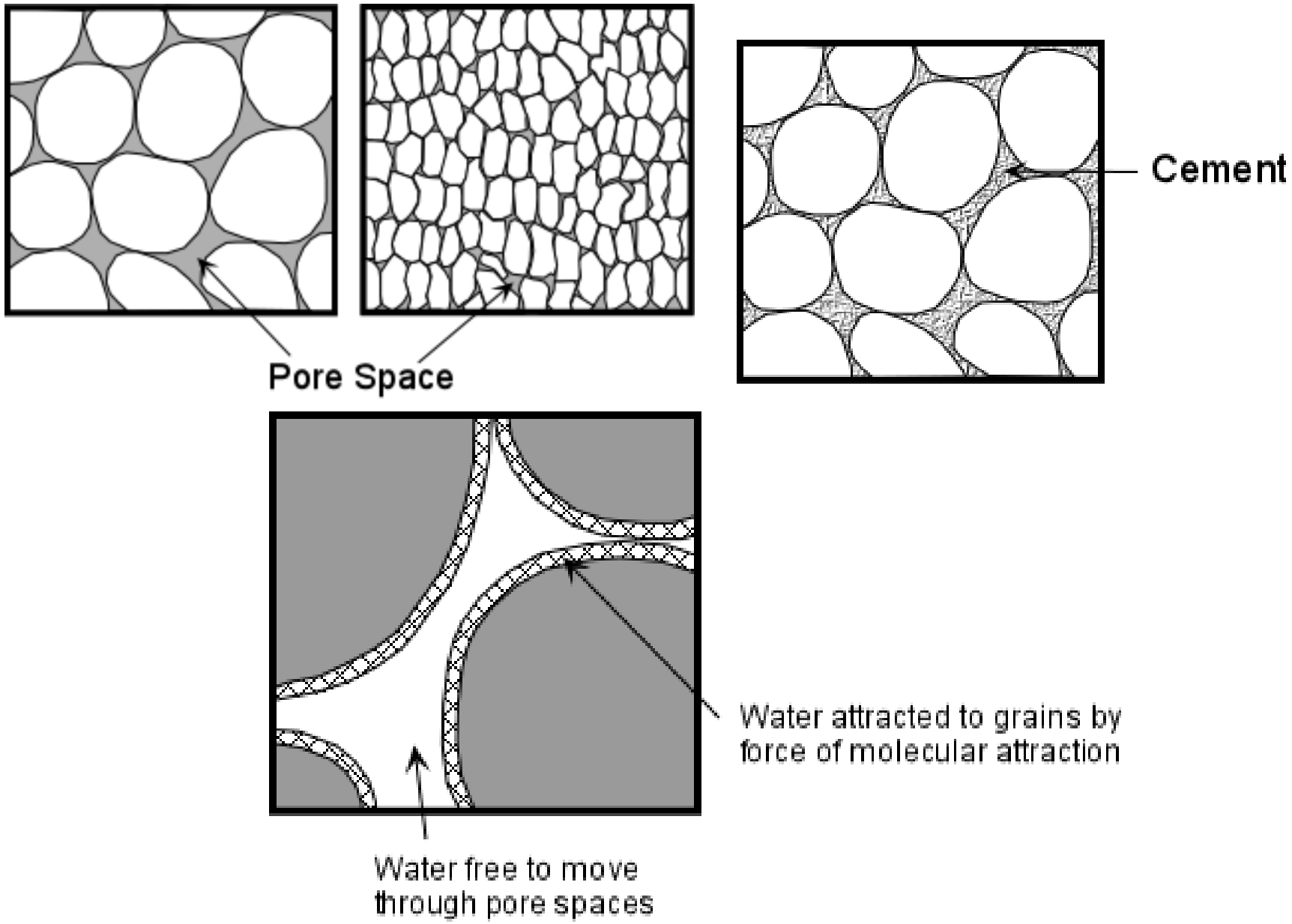
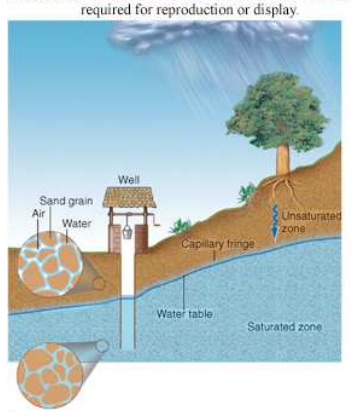

Pore Space
Cement
Water attracted to grains by force of molecular attraction
Water free to move through pore spaces

TABLE 17.1 Porosity and Permeability of Sediments and Rocks

Sediment	Porosity (%)	Permeability
Gravel	25 to 40	Excellent
Sand (clean)	30 to 50	Good to excellent
Silt	35 to 50	Moderate
Clay	35 to 80	Poor
Glacial till	10 to 20	Poor to moderate
Rock		
Conglomerate	10 to 30	Moderate to excellent
Sandstone		
Well-sorted, little cement	20 to 30	Good to very good
Average	10 to 20	Moderate to good
Poorly sorted, well-cemented	0 to 10	Poor to moderate
Shale	0 to 30	Very poor to poor
Limestone, dolomite	0 to 20	Poor to good
Cavernous limestone	up to 50	Excellent
Crystalline rock		
Unfractured	0 to 5	Very poor
Fractured	5 to 10	Poor
Volcanic rocks	0 to 50	Poor to excellent

The Water Table

- Subsurface zone in which all rock openings are filled with water is the *saturated zone*
- Top of the saturated zone is the *water table*
  - Water level at surface of most lakes and rivers corresponds to local water table
- Above the water table is an unsaturated region called the *vadose zone*
- A *perched water table* is above and separated from main water table by an unsaturated zone
  - Commonly produced by thin lenses of impermeable rock (e.g., shales or clays) within permeable ones



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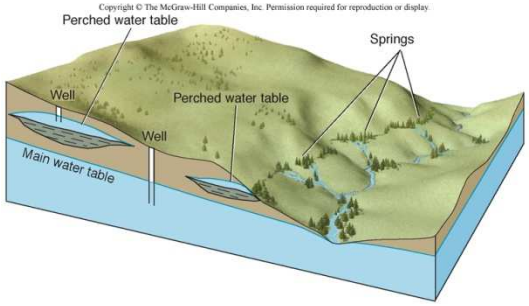
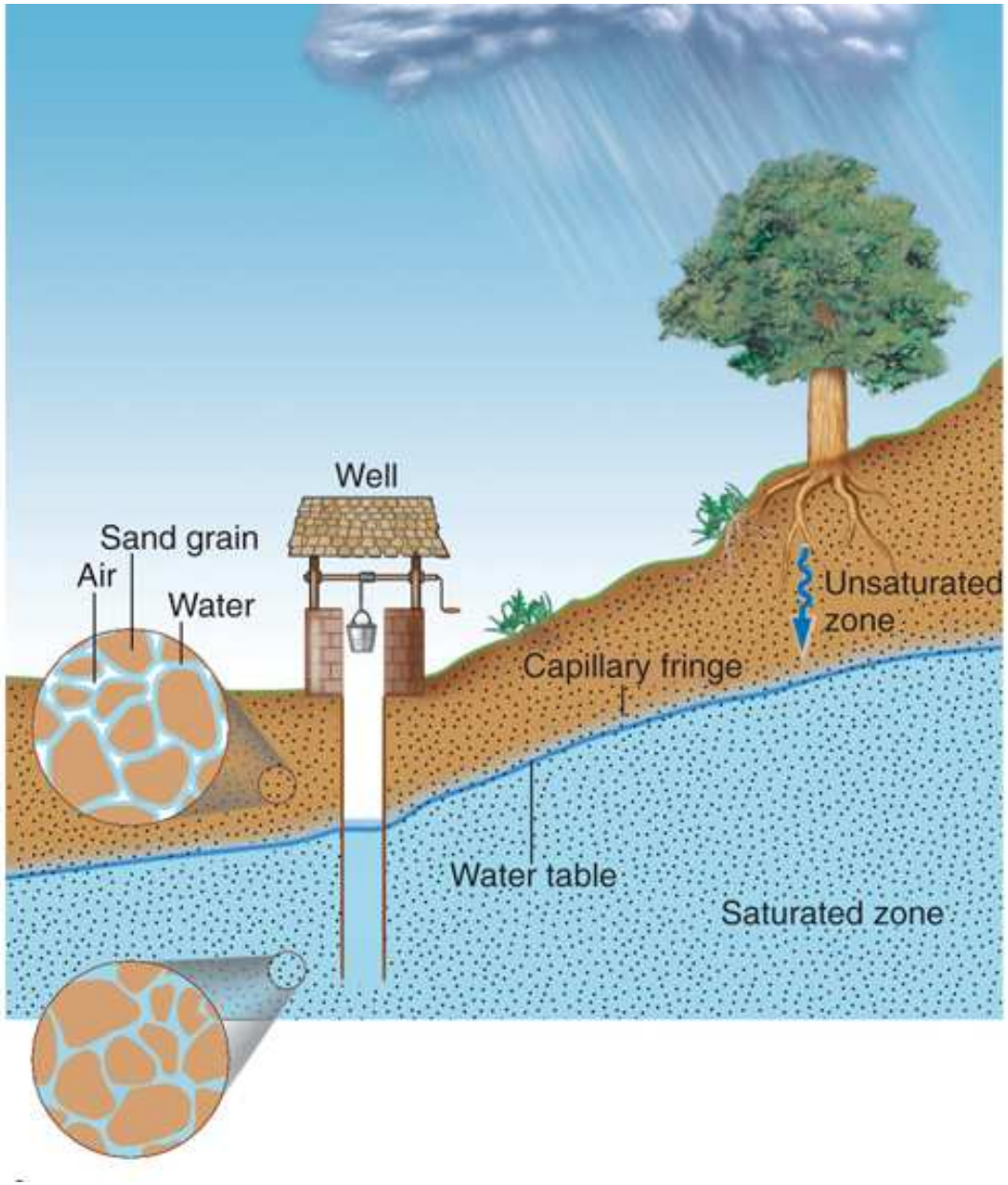
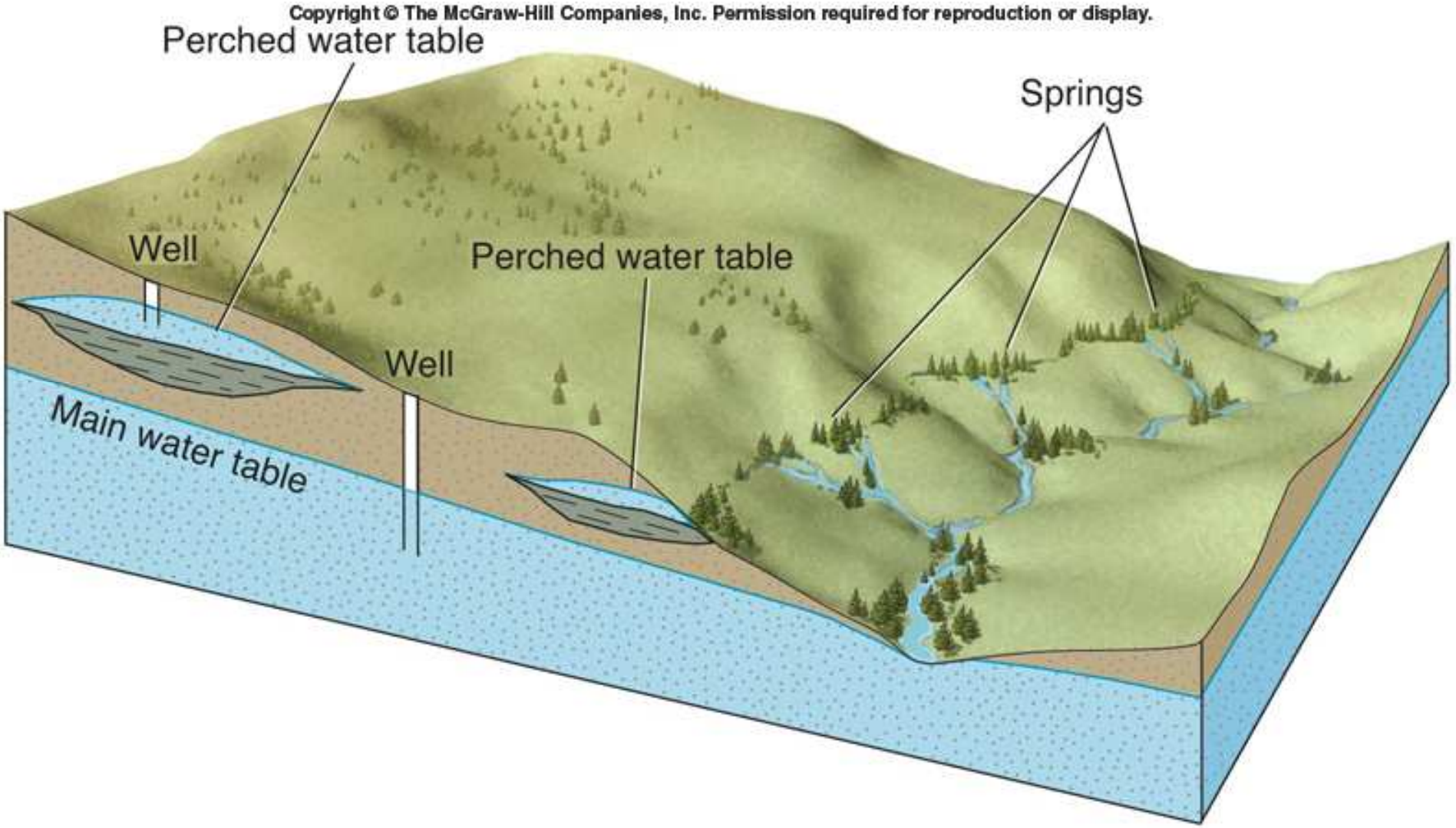


Water Table


Well
Sand grain
Air
Water
Unsaturated zone
Capillary fringe
Water table
Saturated zone

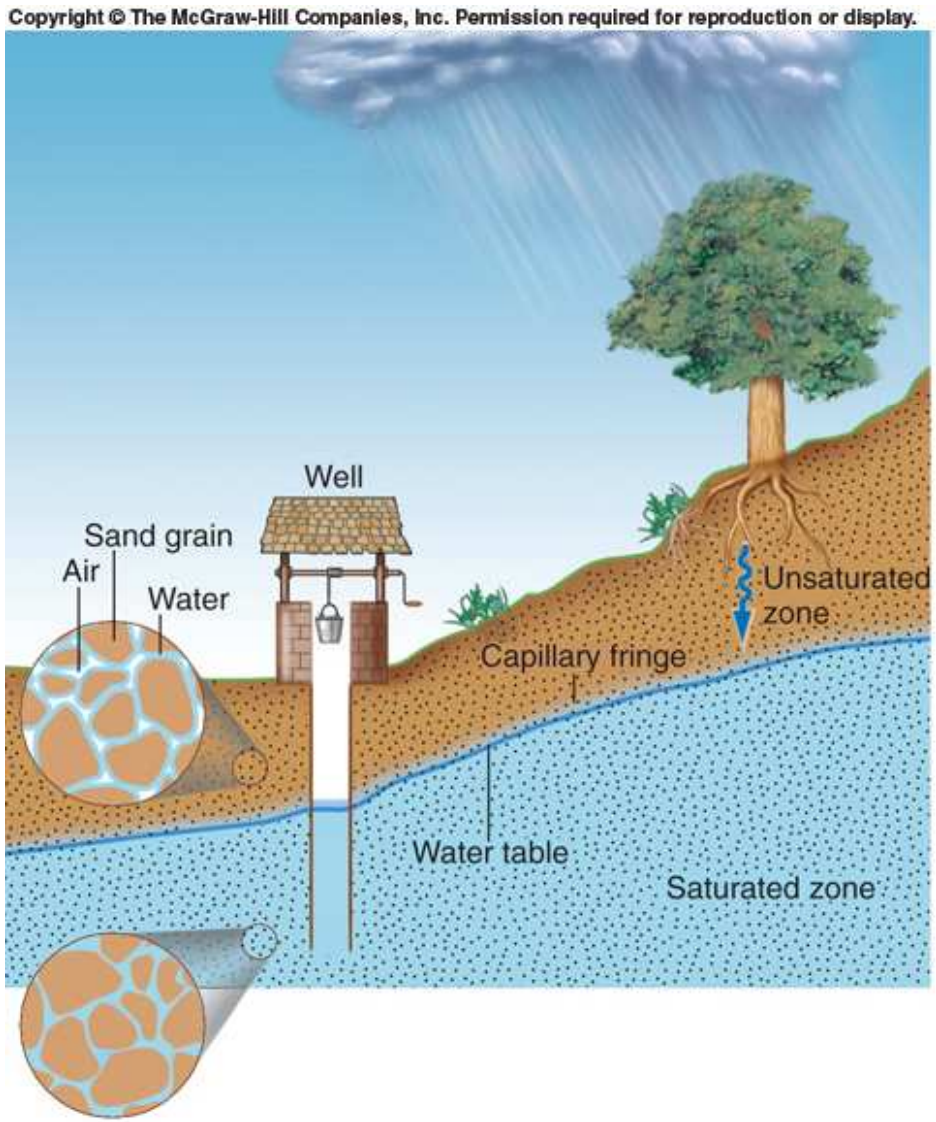
Perched Water Table



Perched water tables above lenses of less permeable shale within a large body of sandstone. Downward percolation of water is impeded by the less permeable shale.

Water Table

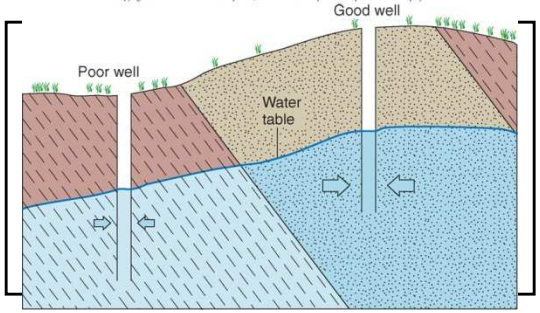
- Unsaturated/Vadose Zone
- Saturated Zone
- Location of Water table is dynamic – changes seasonally and with topography

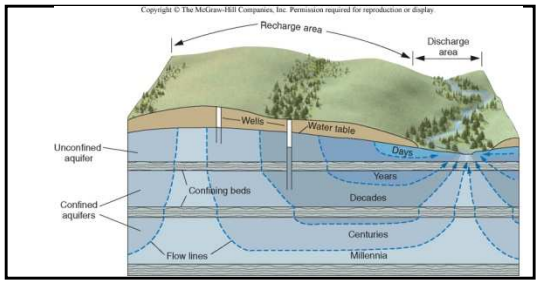


Ground Water Movement

- Movement of ground water through pores and fractures is *relatively slow* (cms to meters/day) compared to flow of water in surface streams
  - Flow velocities in cavernous limestone can be much higher (kms/day)

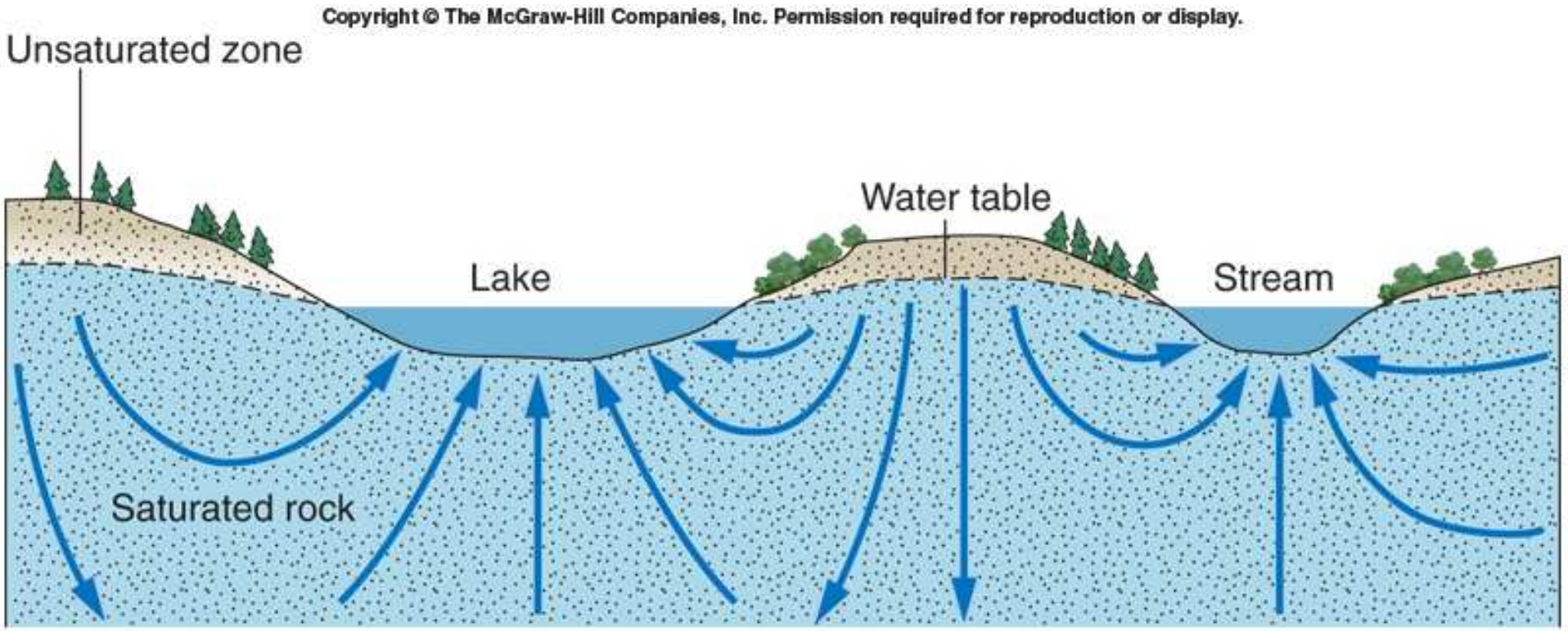
- Flow velocity depends upon:
  - *Slope* of the water table
  - *Permeability* of the rock or sediment



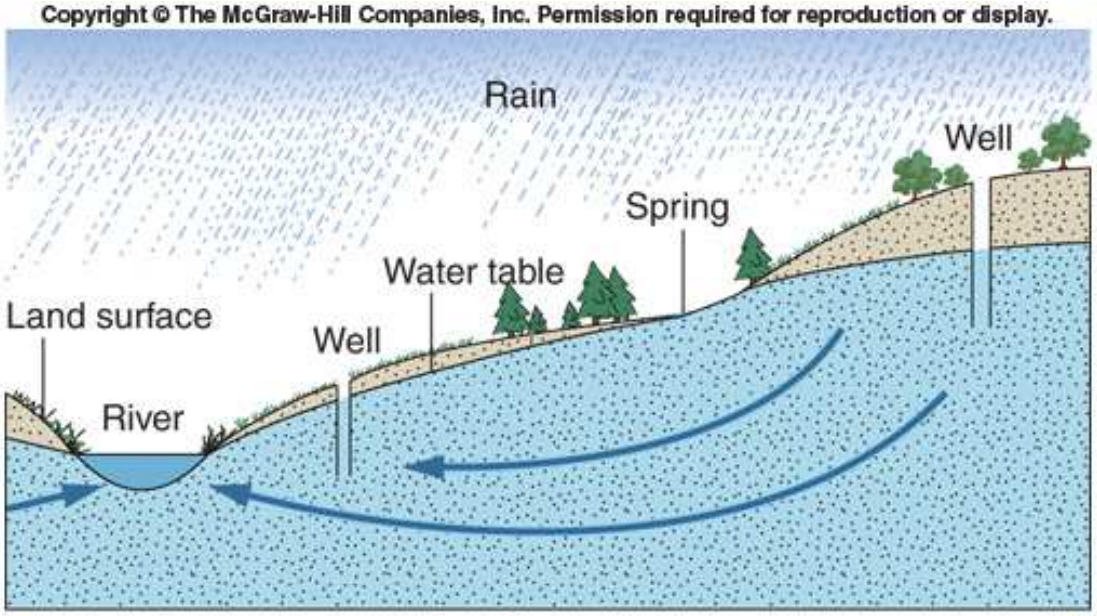


Movement of Ground Water

- Recharge vs. Discharge



Seasonal Variations in Water Table



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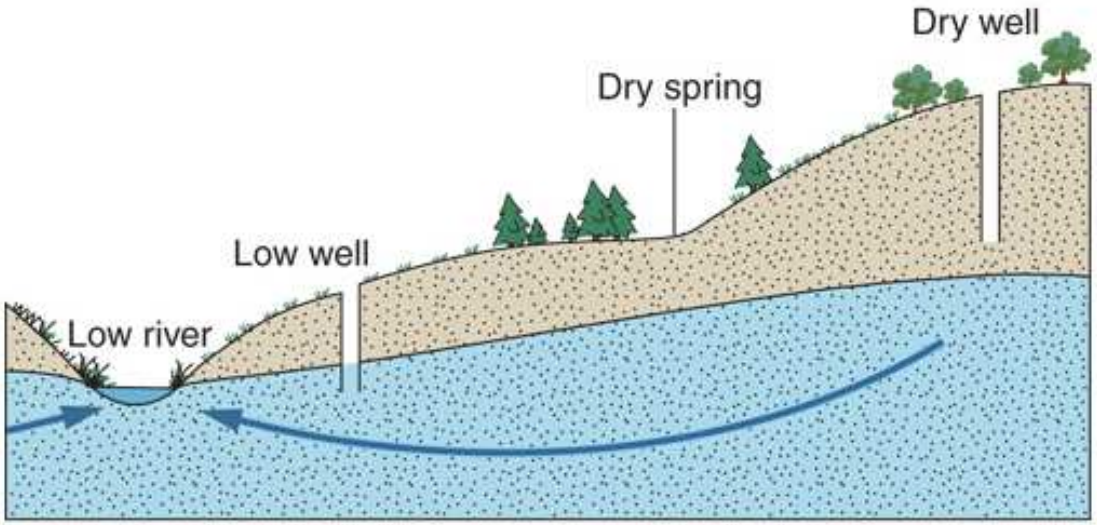
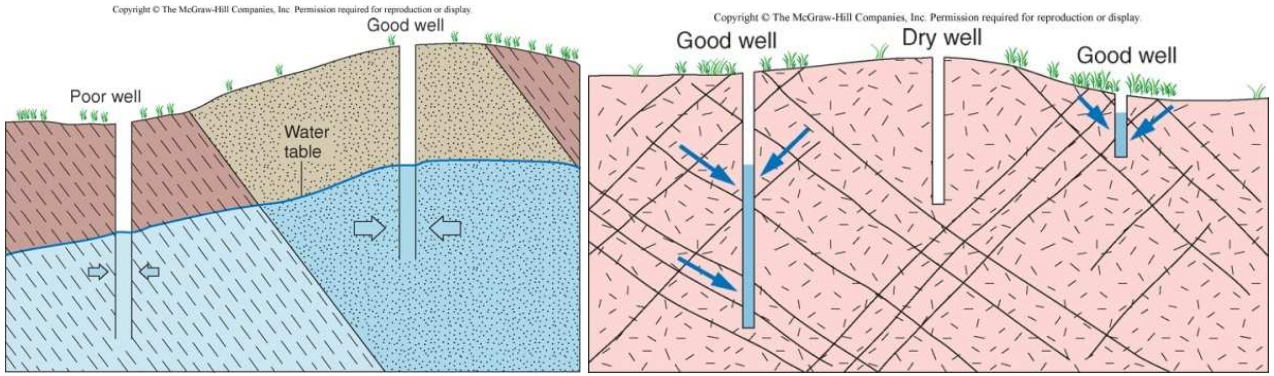


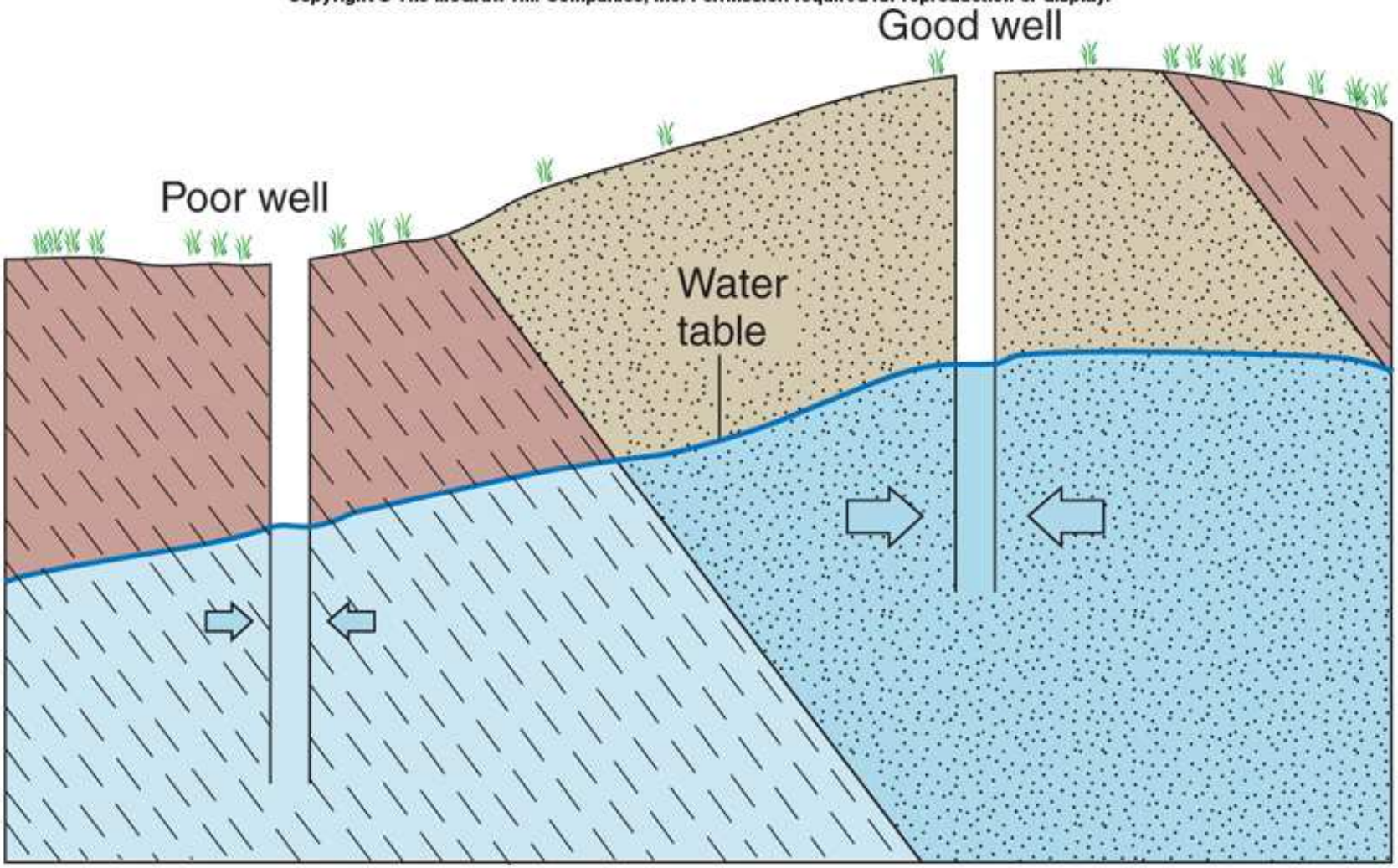
B

Aquifers and Aquitards

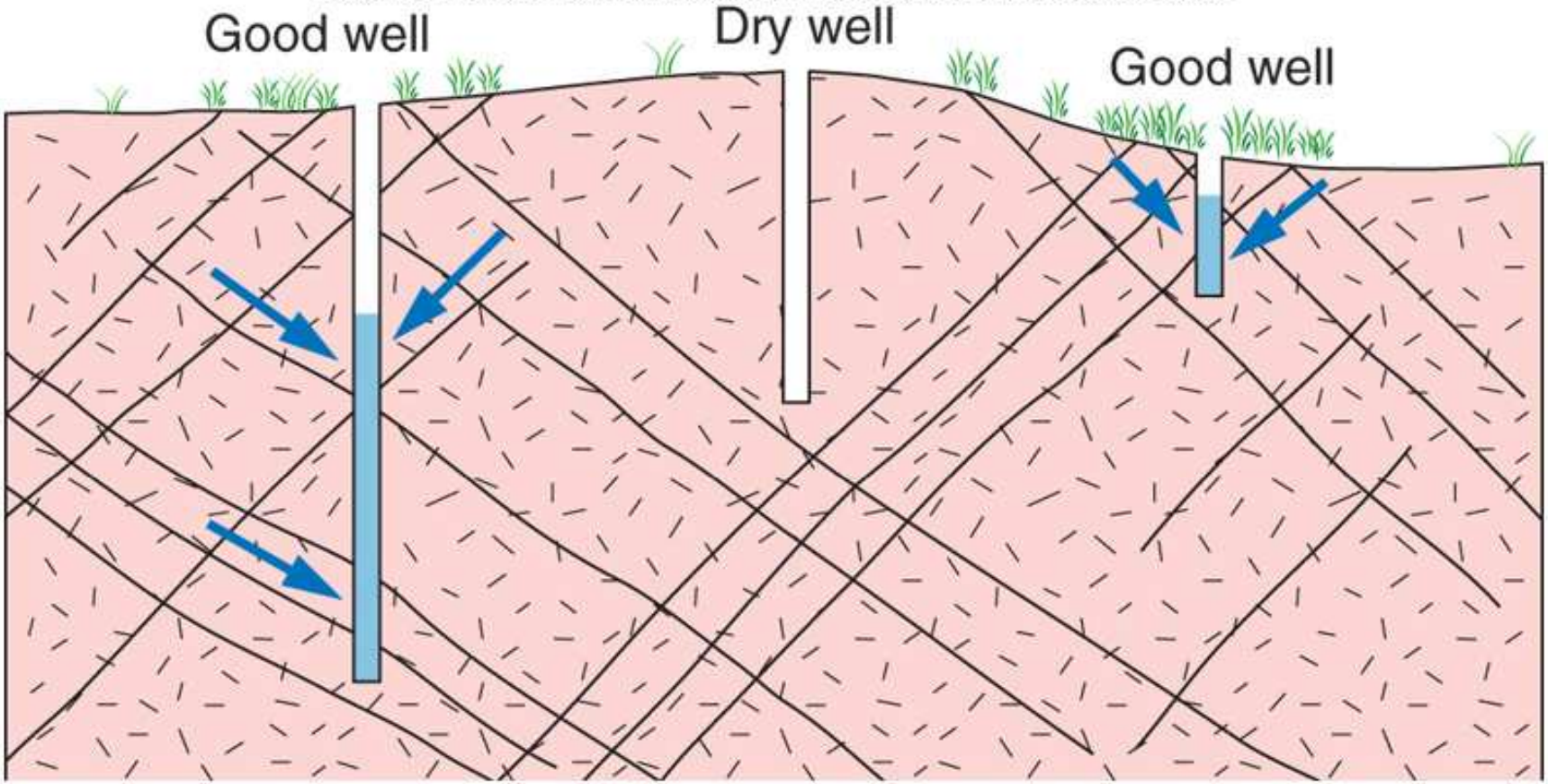
- *Aquifer* - body of saturated rock or sediment through which water can move easily
  - Sandstone
  - Conglomerate
  - Well-jointed limestone
  - Sand and gravel
  - Highly fractured rocks



- *Aquitard* - rock/sediment that retards ground water flow due to low porosity and/or permeability
  - Shale, clay, unfractured crystalline rocks



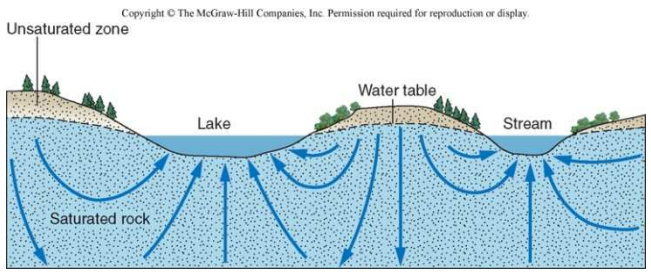
A well must be installed in an aquifer to obtain water. The saturated part of the highly permeable sandstone is an aquifer, but the less permeable shale is not. Although shale is saturated, it will not readily transmit water.



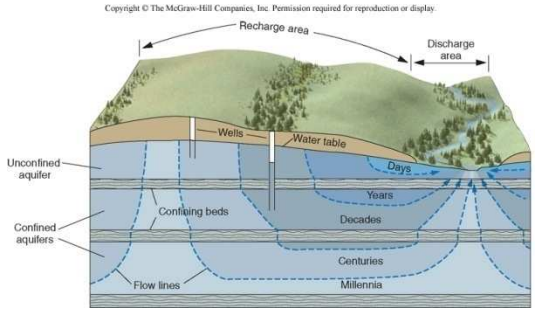
Wells can obtain some water from fractures in crystalline rock. Well must intersect fractures to obtain water.

Unconfined vs. Confined Aquifers

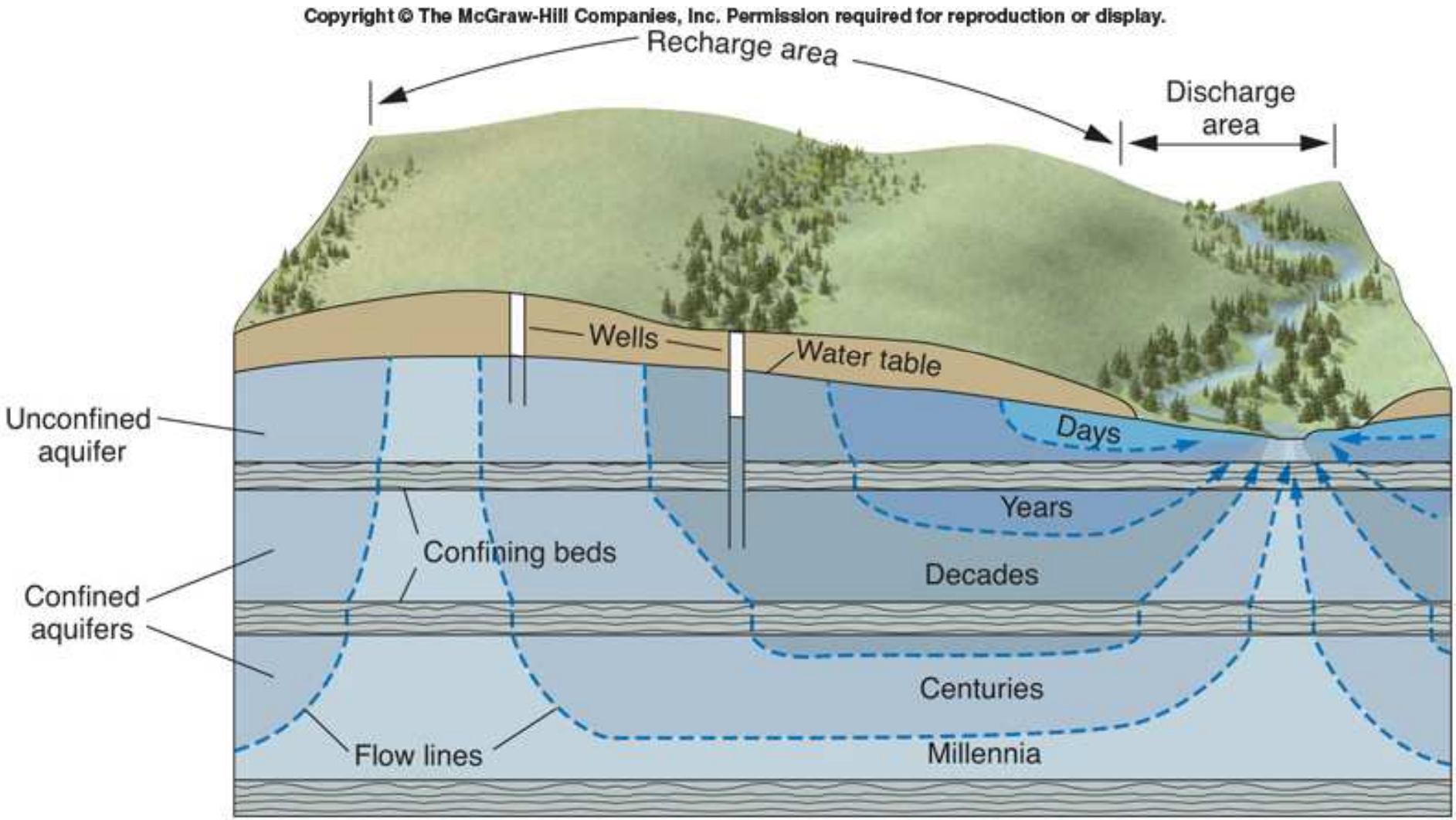
- *Unconfined Aquifer*
  - Has a water table, and is only partly filled with water
  - Rapidly *recharged* by precipitation infiltrating down to the saturated zone



- *Confined Aquifer*
  - Completely filled with water under pressure
  - Separated from surface by impermeable *confining layer/aquitard*
  - *Very slowly* recharged

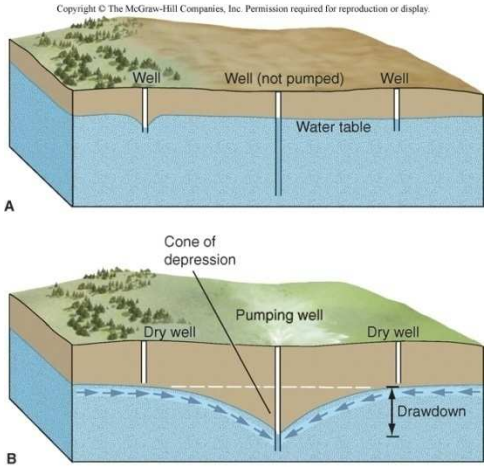


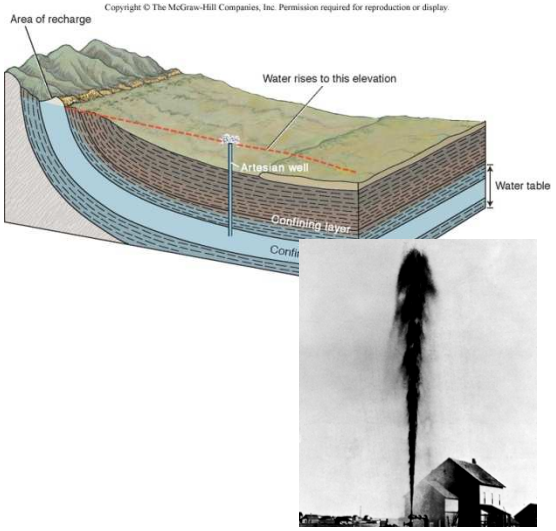
Unconfined vs. Confined Aquifers

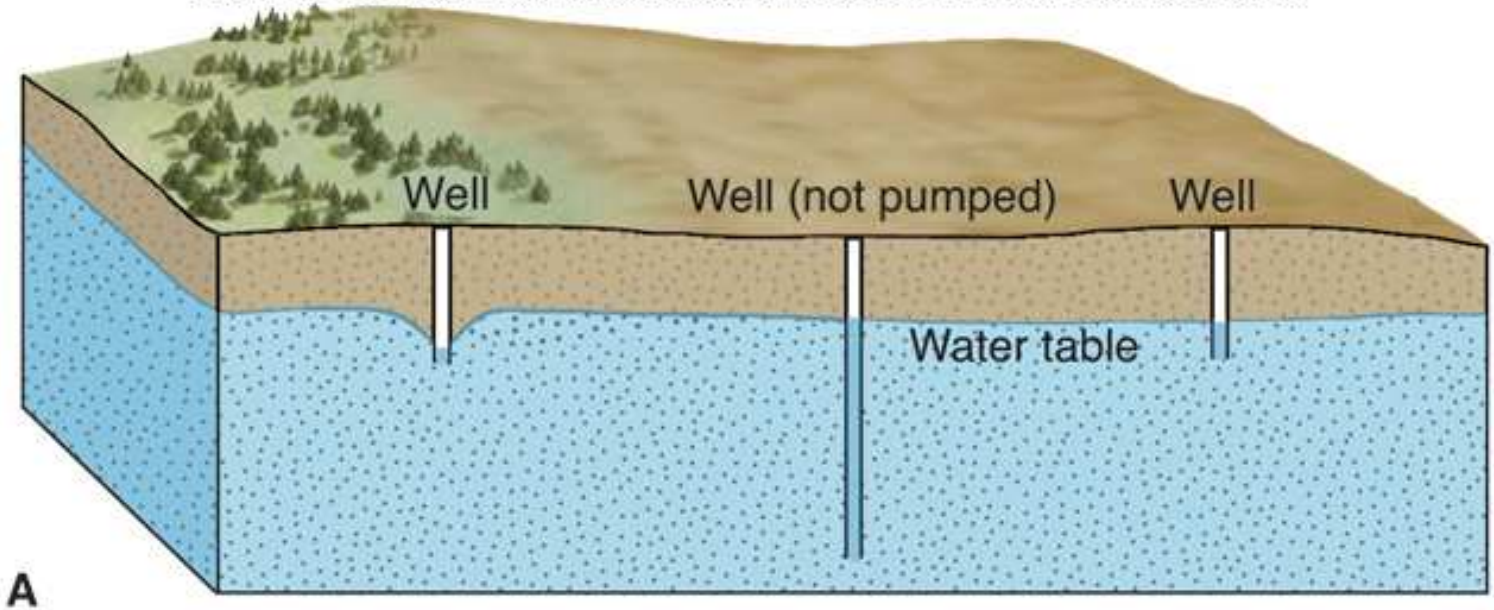


Wells

- *Well* - a deep hole dug or drilled into the ground to obtain water from an aquifer
  - For wells in unconfined aquifers, water level before pumping is the water table
  - Water enters well from pore spaces within the surrounding aquifer
  - Water table can be lowered by pumping, a process known as *drawdown*
  - Water may rise to a level above the top of a confined aquifer, producing an *artesian well*







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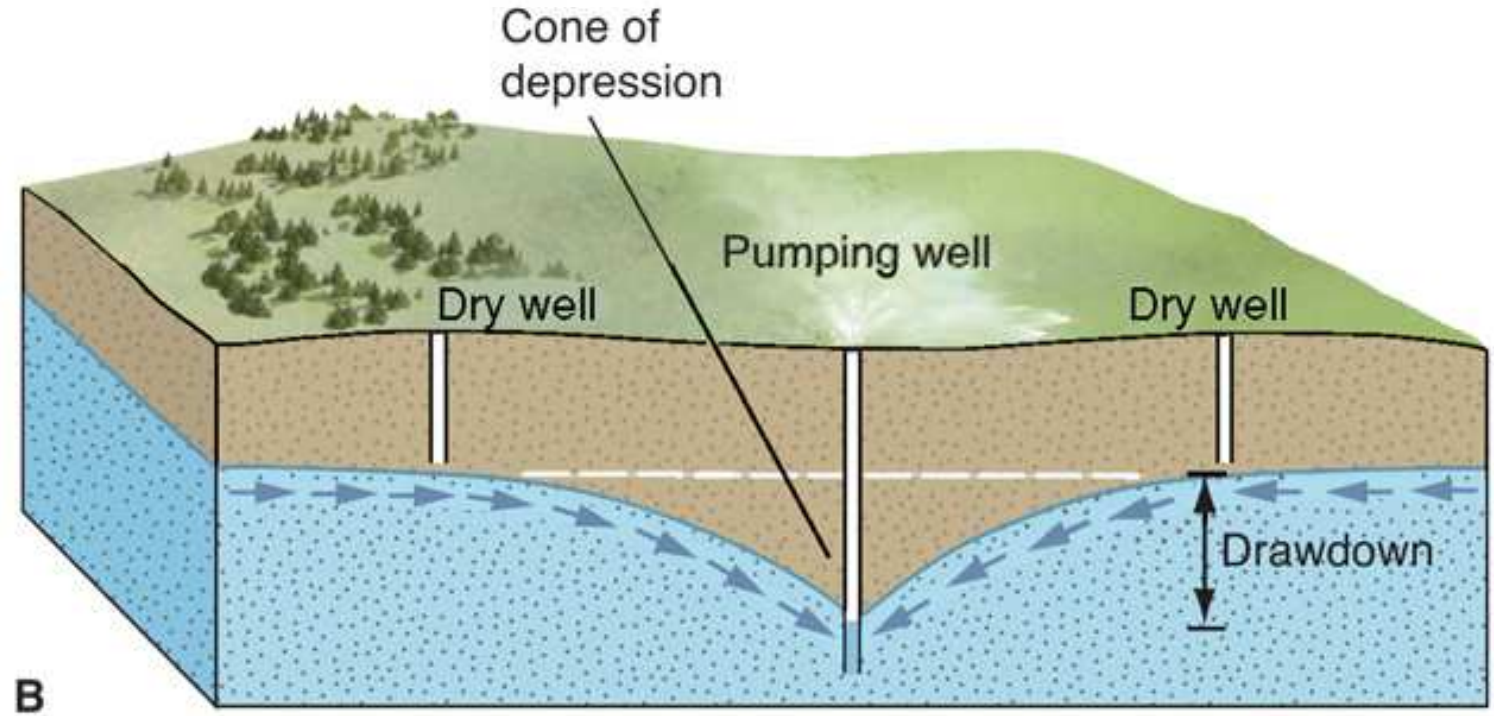

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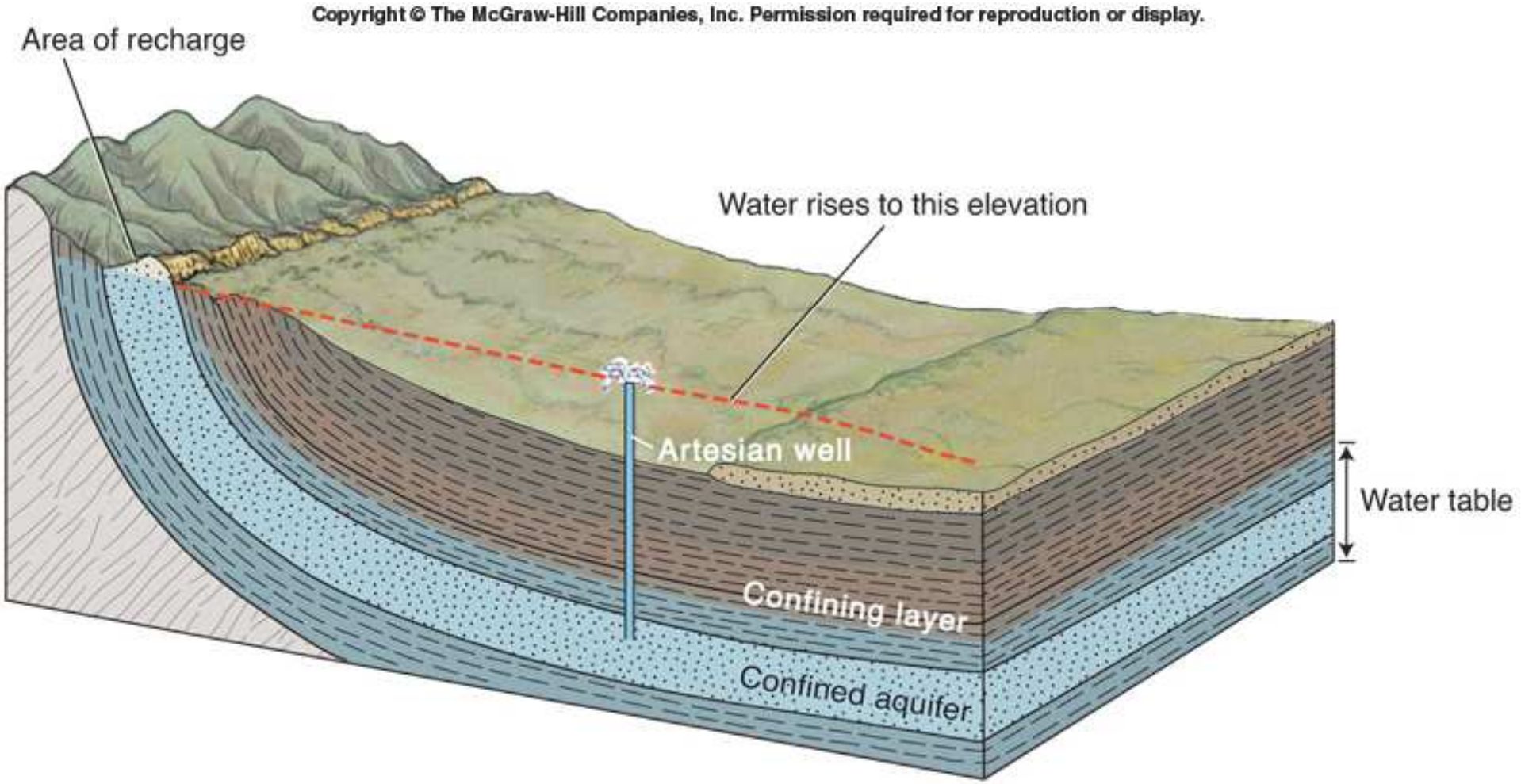
Artesian Well



N.H. Darton, U.S. Geological Survey

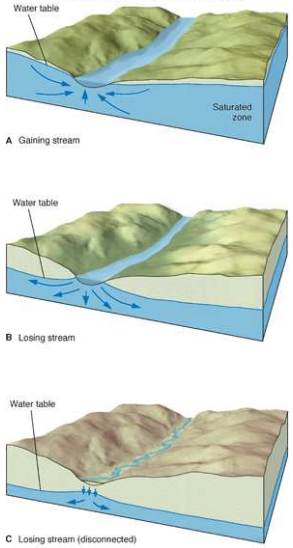
Springs and Streams

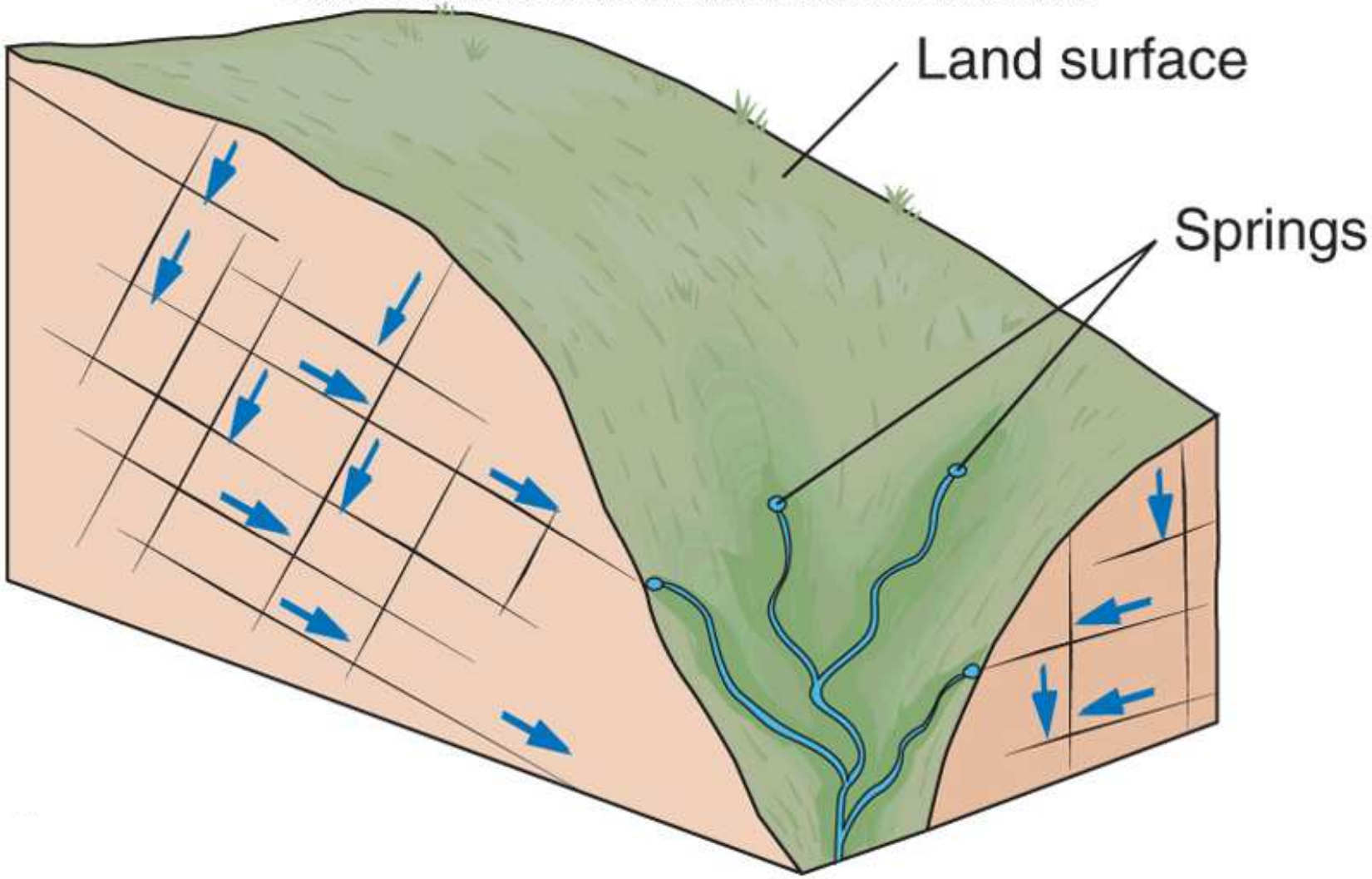
- *Spring* - a place where water flows naturally from rock or sediment onto the ground surface

- *Gaining streams* - receive water from the saturated zone
  - Gaining stream surface is local water table

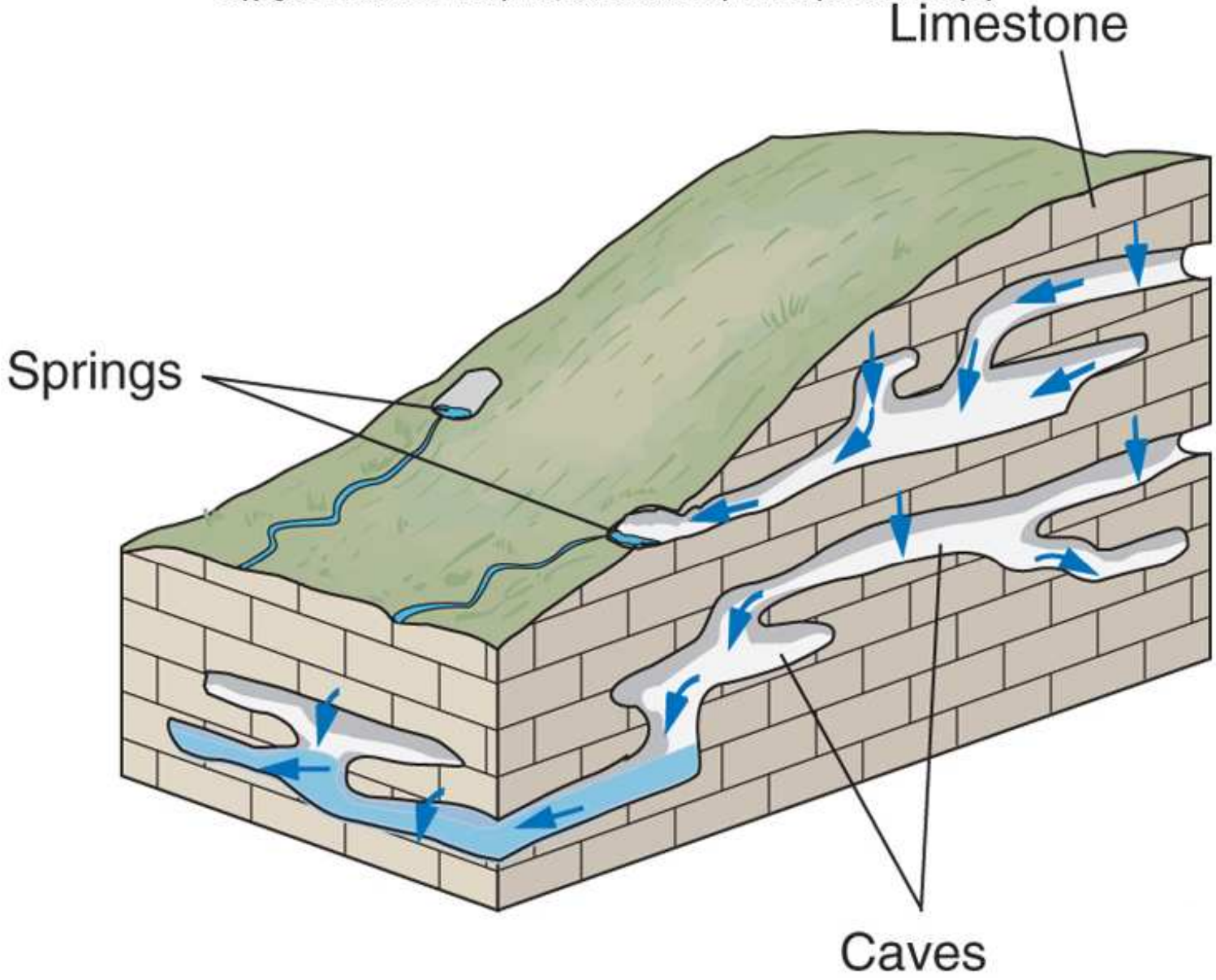
- *Losing streams* - lose water to the saturated zone
  - Stream beds lie above the water table
  - Maximum *infiltration* occurs through streambed, producing permanent “mound” in the water table beneath dry channel

Photo © Alissa Crandall/Corbis Images

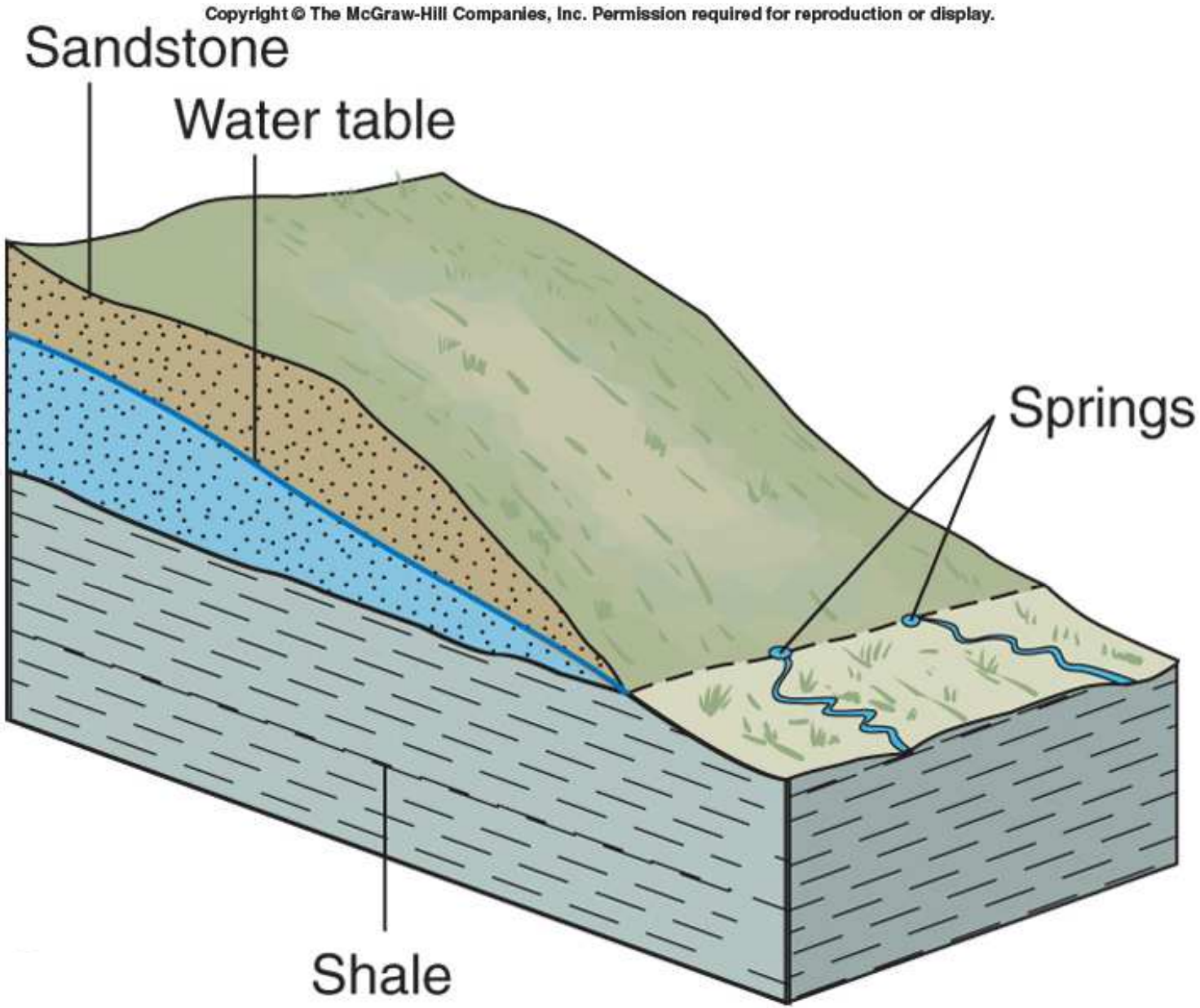




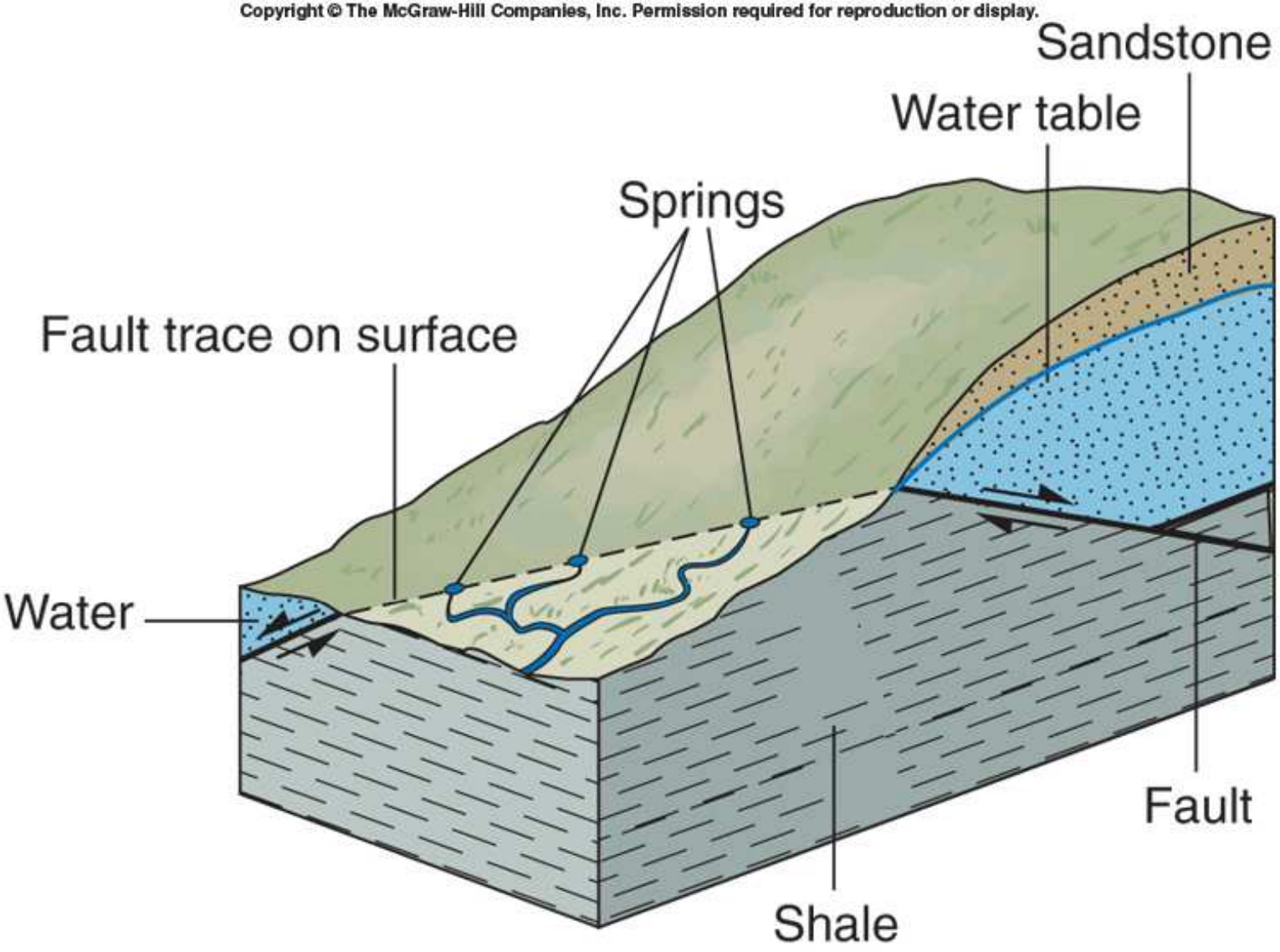
Water moves along fractures in crystalline rock and forms springs where the fractures intersect the land surface.



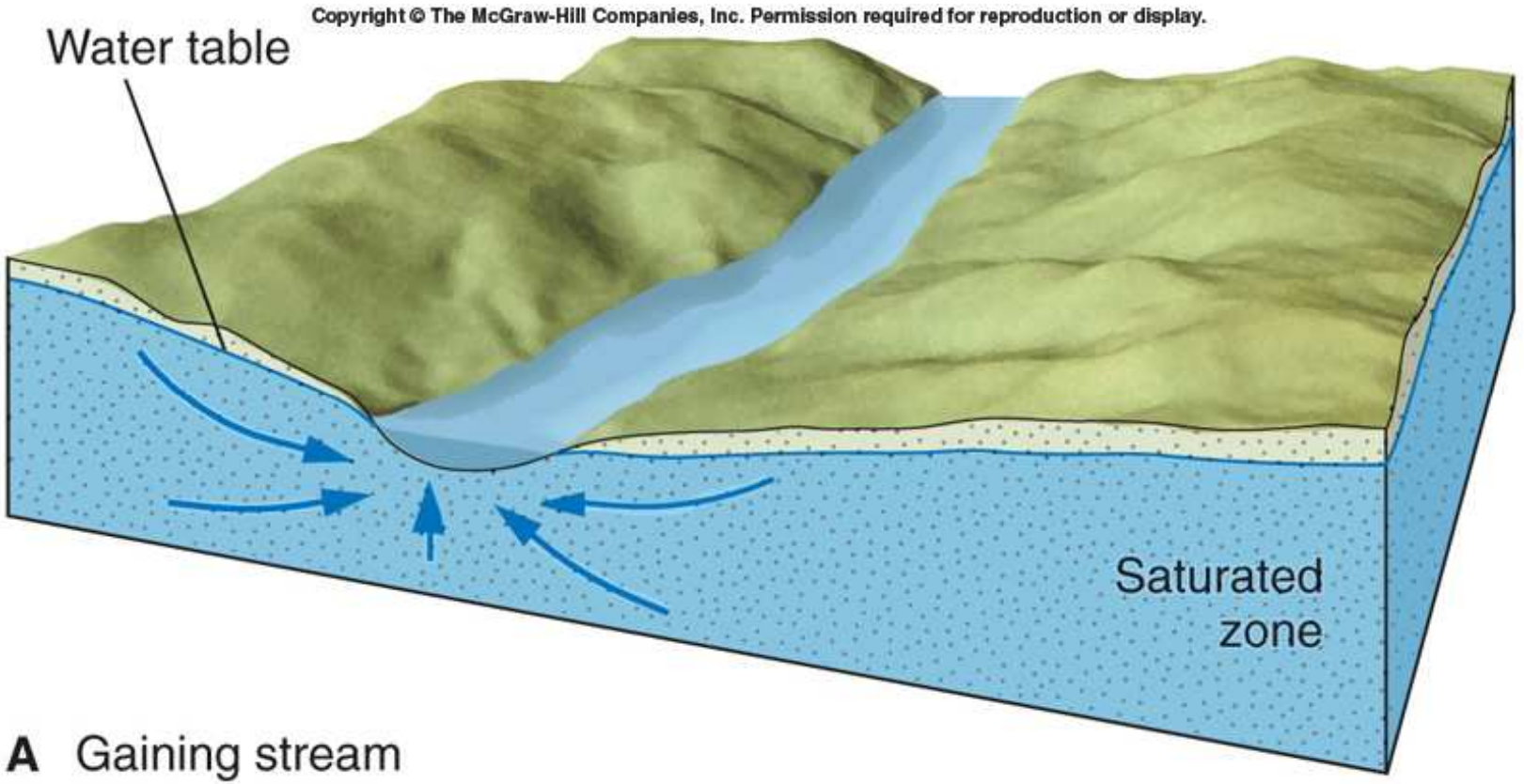
Water enters caves along joints in limestone and exit as springs at the mouth of the caves.



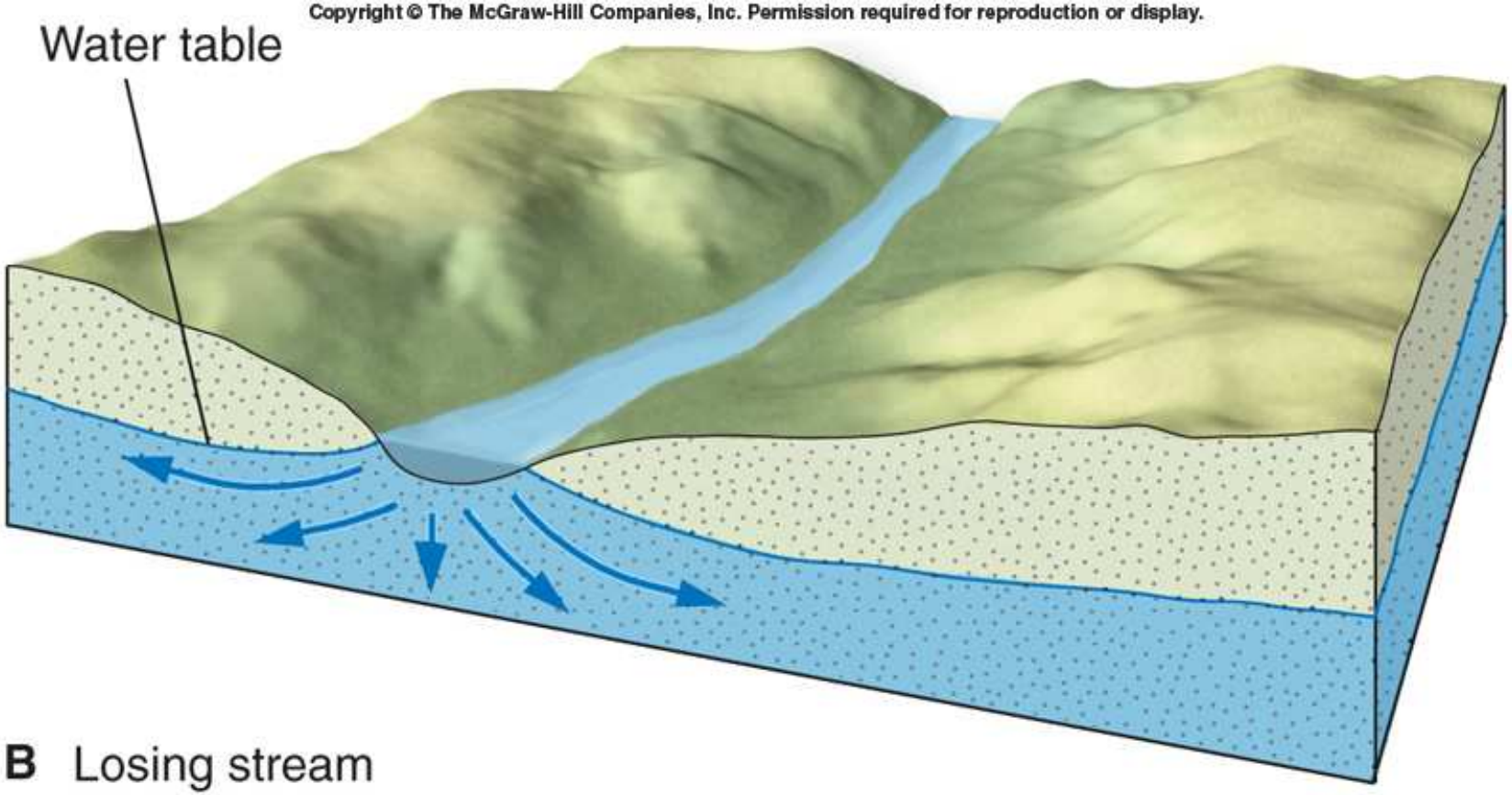
Spring form at the contact between a permeable rock such as sandstone and an underlying less permeable rock such as shale



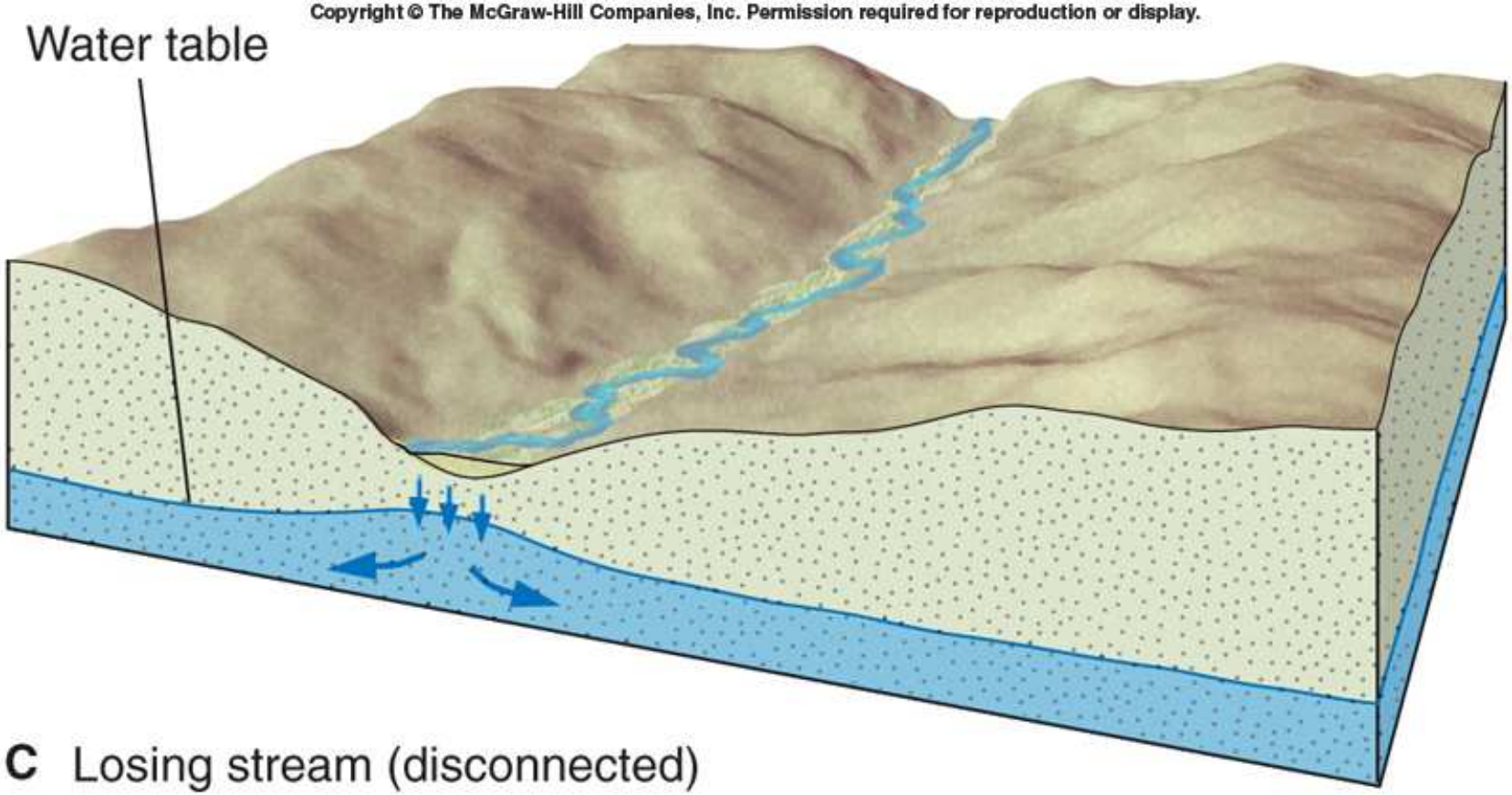
Spring can form along faults when permeable rock has been moved against less permeable rock.



A Gaining stream



B Losing stream

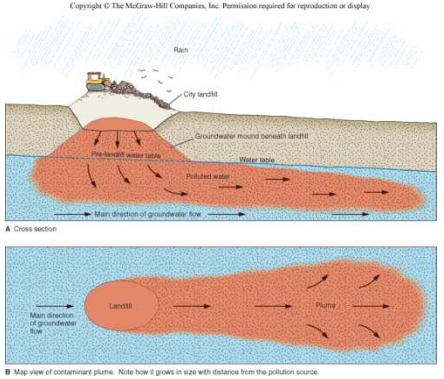


C Losing stream (disconnected)

Ground Water Contamination

- *Infiltrating* water may bring contaminants down to the *water table*, including (but not limited to):
  - Pesticides/herbicides
  - Fertilizers
  - Landfill pollutants
  - Heavy metals
  - Bacteria, viruses and parasites from sewage
  - Industrial chemicals
  - Acid mine drainage
  - Radioactive waste
  - Oil and gasoline

Photo by Doug Wilson, USDA Photography Center



- *Contaminated ground water* can be *extremely difficult and expensive* to clean up

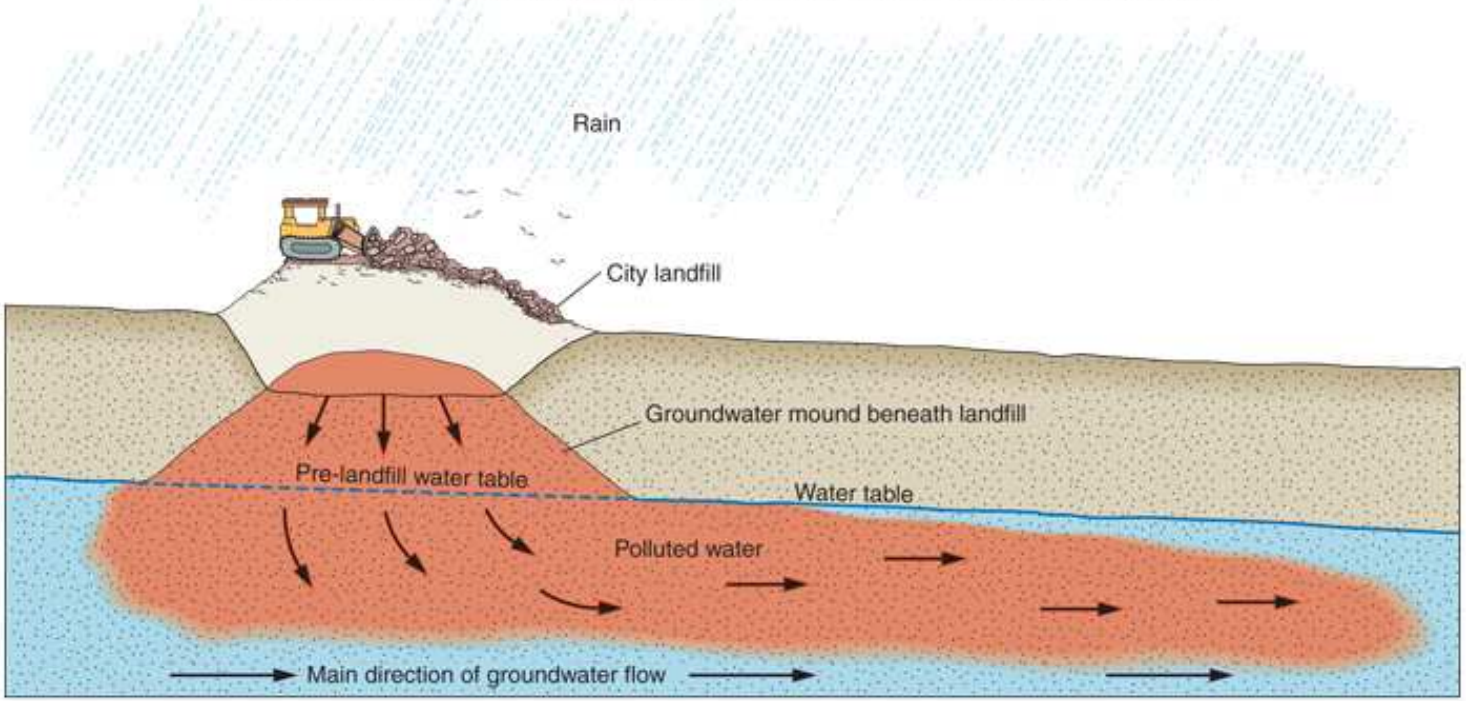
A

B

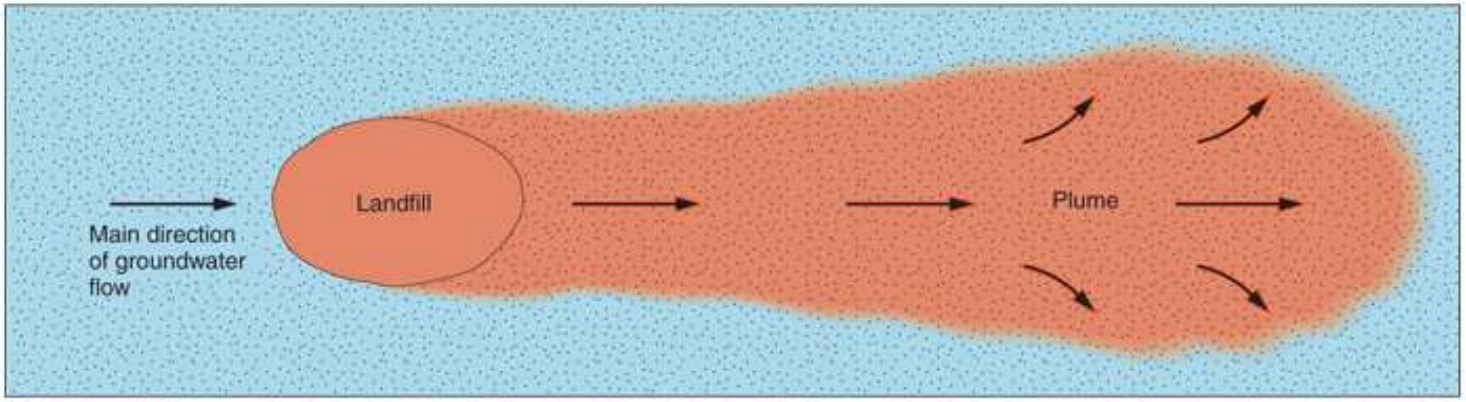
C

D

A by Doug Wilson, USDA Photography Center; B by Frank M. Hanna; C and D by U.S. Department of Agriculture Soil Conservation Service

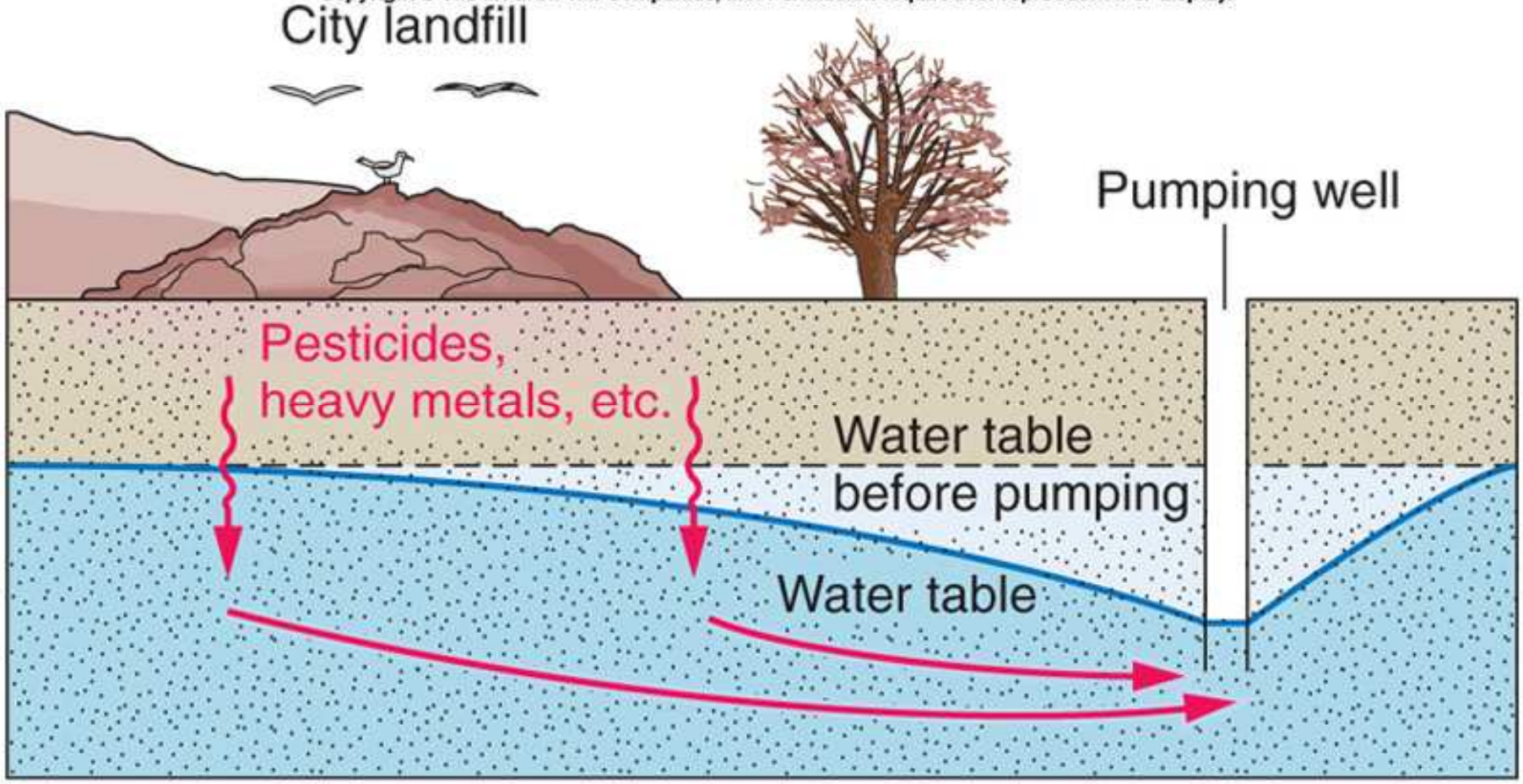


A Cross section



B Map view of contaminant plume. Note how it grows in size with distance from the pollution source.

Rain leaches pollutants into the saturated zone. A plume of contaminated water will spread out in the direction of groundwater flow.



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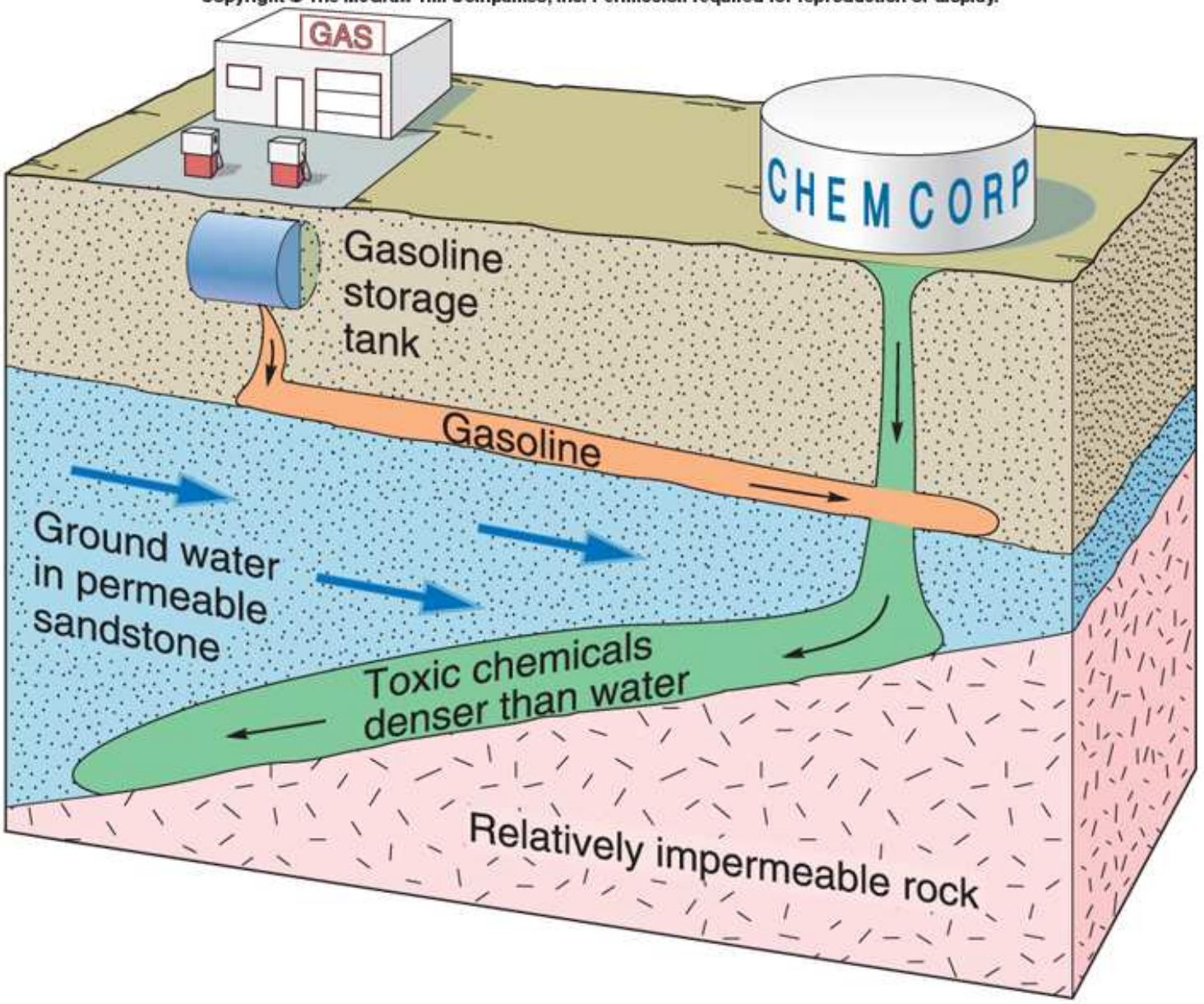

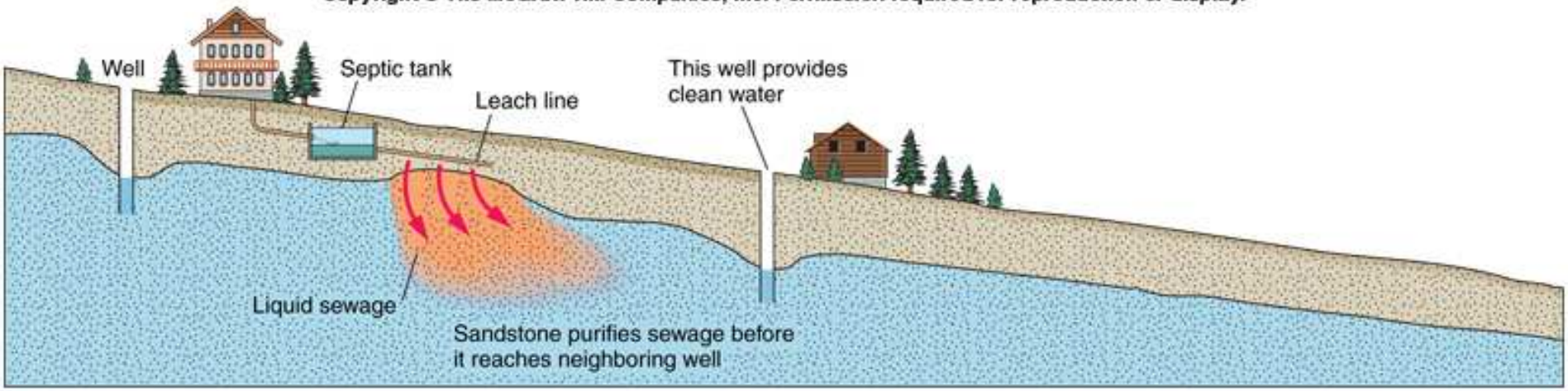

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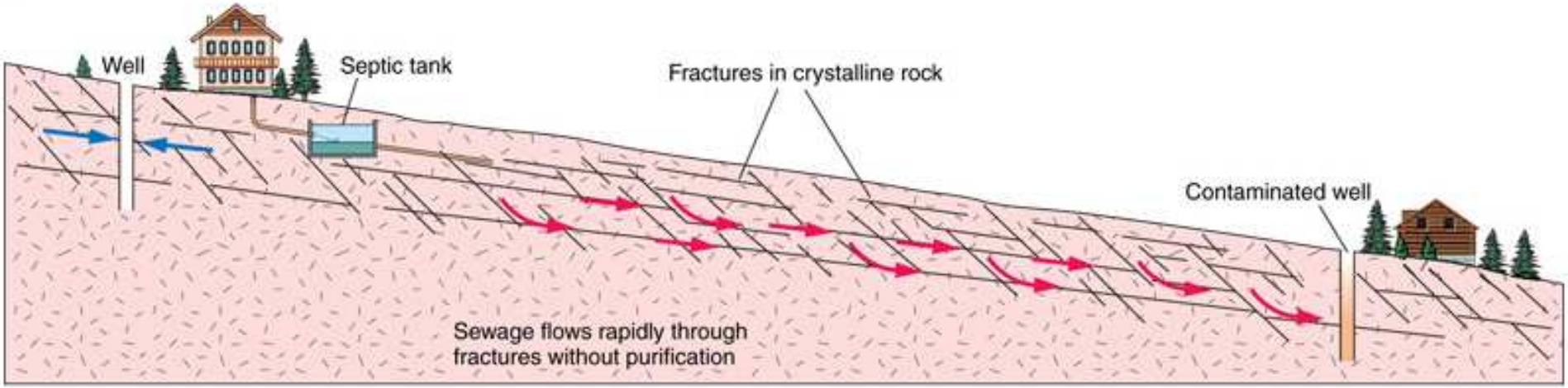
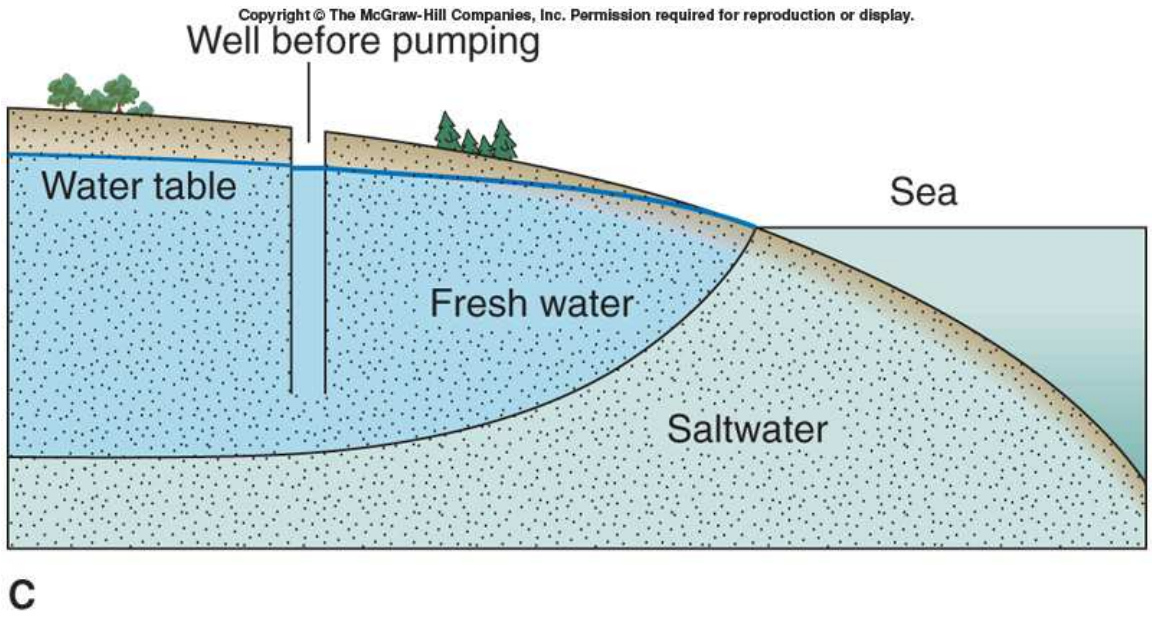


B

Groundwater Contamination - Salt

- Baton Rouge Aquifers



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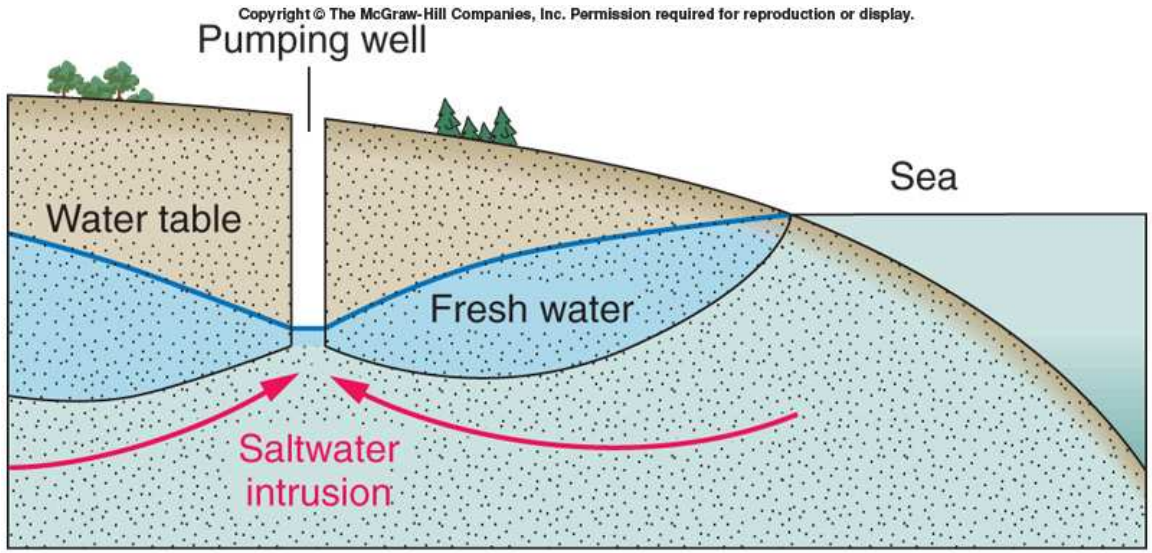
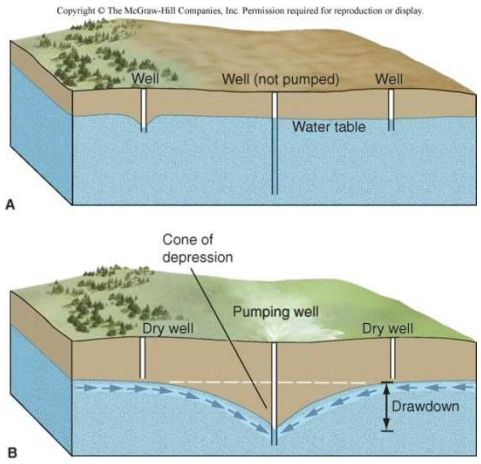


D

Balancing Withdrawal and Recharge

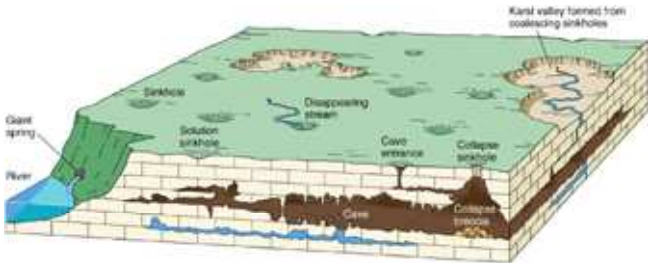
- If ground water is withdrawn more rapidly than it is recharged, the *water table* will drop
  - Dropping water table can lead to ground *subsidence*
    - surface of the ground drops as buoyancy from ground water is removed, allowing rock or sediment to compact and sink
  - Subsidence can crack foundations, roads and pipelines
  - Areas of extremely high *ground water pumping* (such as for crop irrigation in dry regions) have subsided 7-9 meters



Richard O.Ireland, U.S. Geological Survey

Caves, Sinkholes, and Karst

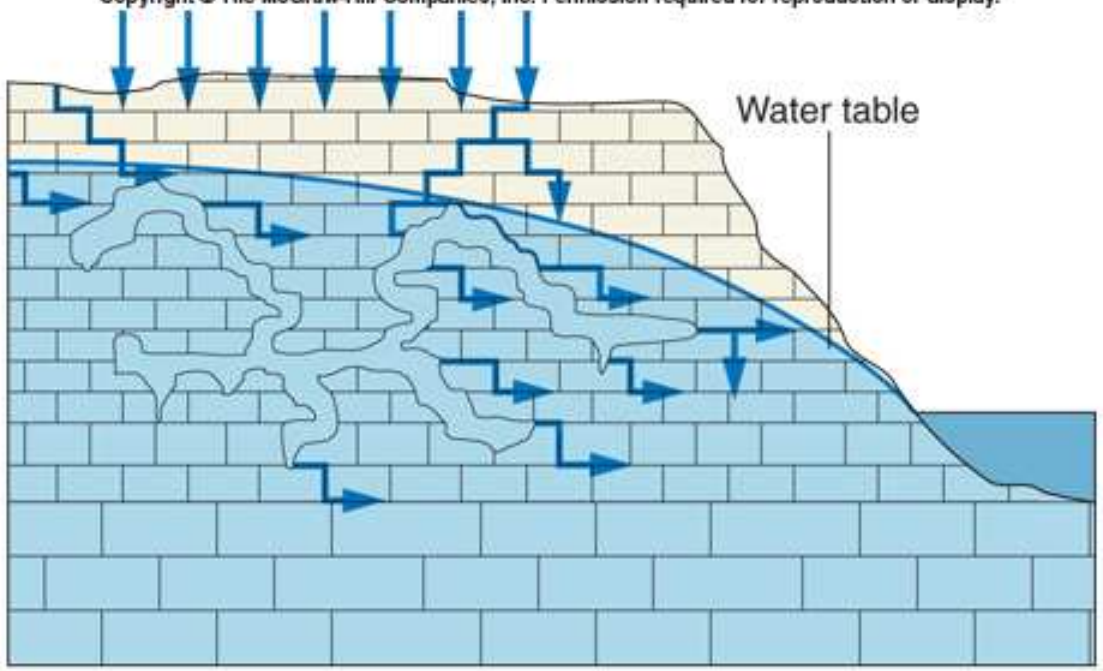
- *Caves (Caverns)* - naturally-formed underground chambers
  - Acidic ground water dissolves limestone along joints and bedding planes



- Caves near the surface may collapse and produce *sinkholes*

- Rolling hills, disappearing streams, and sinkholes are common in areas with *karst topography*

Cave Formation



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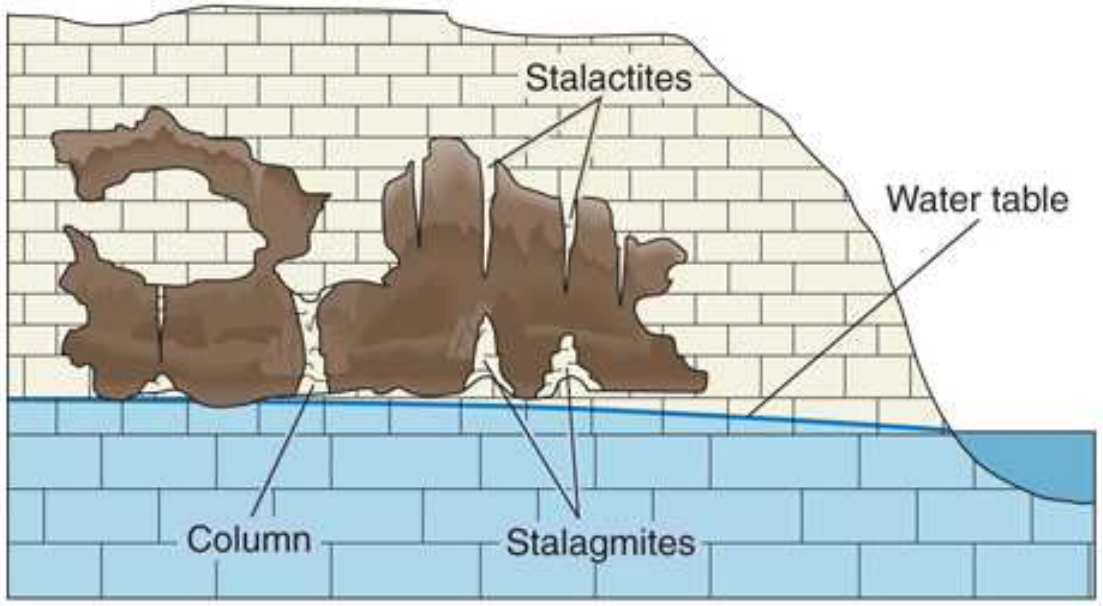

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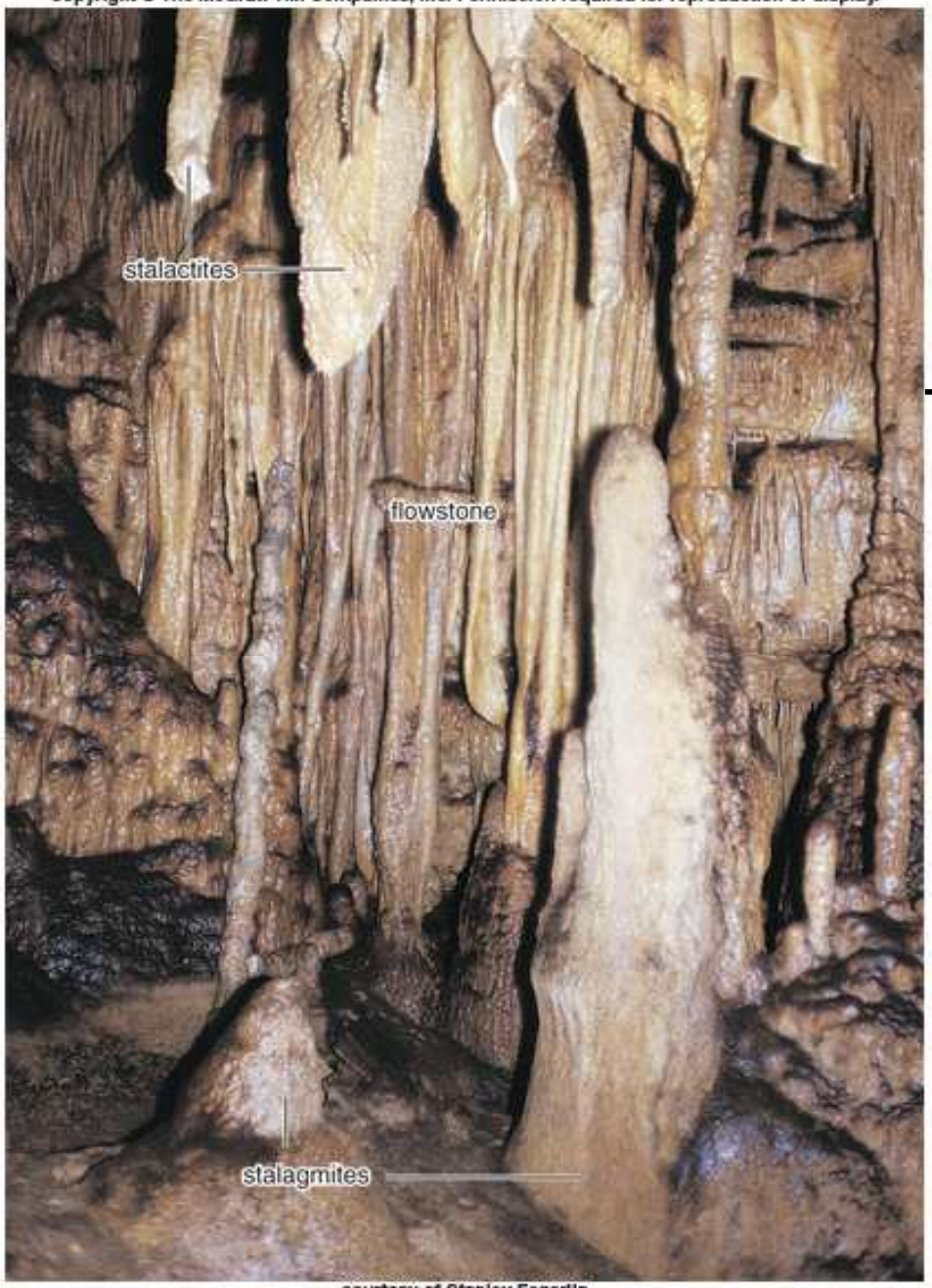


courtesy of Stanley Fagerlin

Stalactites : hanging from cave ceiling

Stalagmites : formed on the cave floor

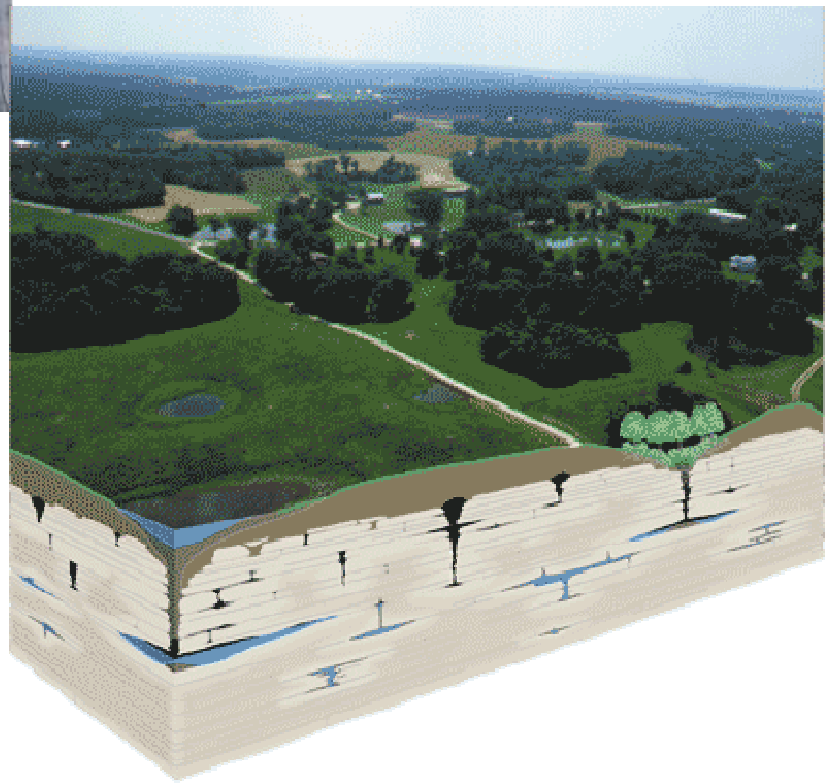
Together they are called as

Dripstone

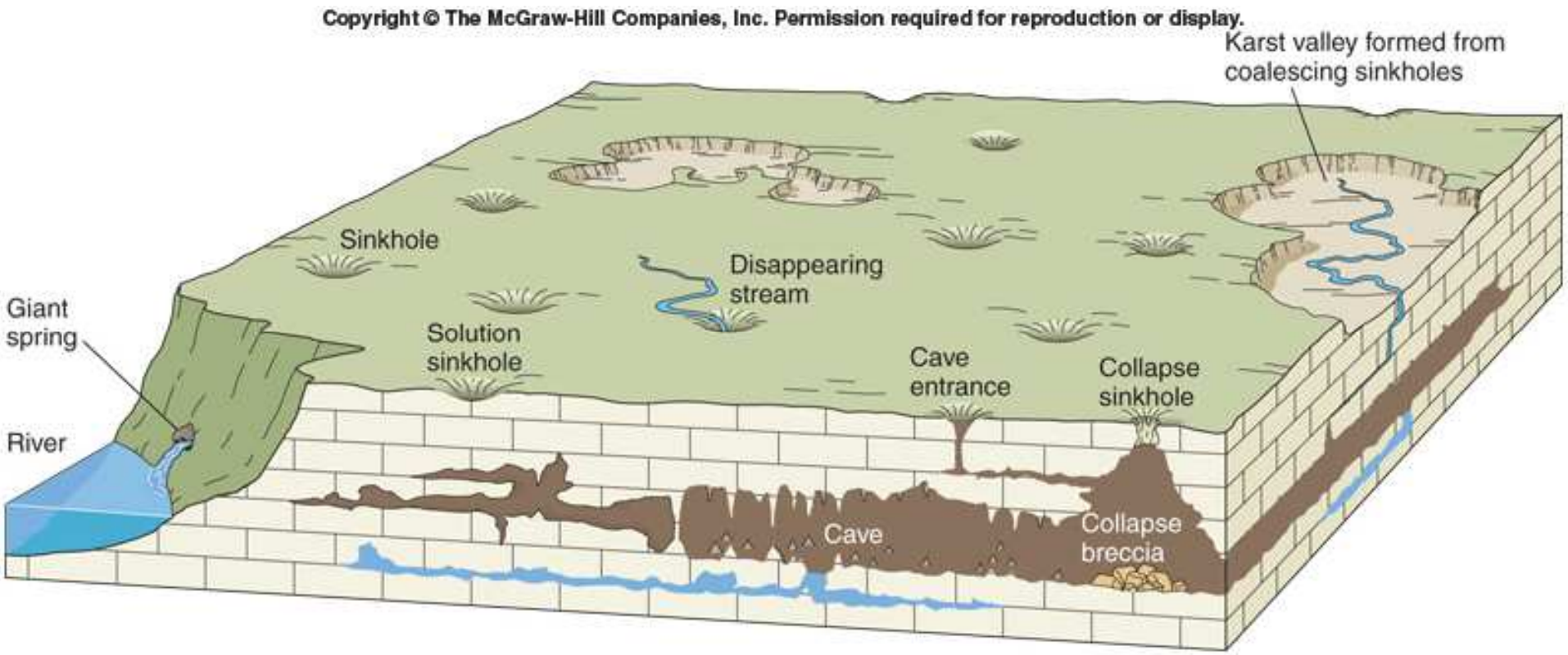
or

Speleothems

Sinkholes :
Collapse of the cave roof



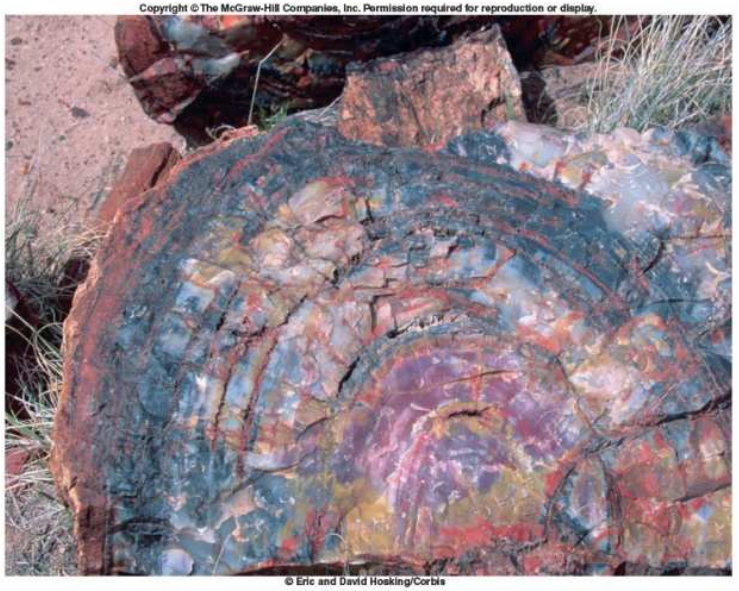
Karst Topography



Other Effects

- **Petrified Wood** – inorganic silica carried by ground water replaces or fills in pores in the wood

- **Travertine** – surface deposits of calcite resulting from degassing of CO_2



Hot Water Underground

- *Hot springs* - springs in which the water is warmer than human body temperature
  - Ground water heated by nearby magma bodies or circulation to unusually deep (and warm) levels within the crust
  - Hot water is less dense than cool water and thus rises back to the surface on its own

- *Geysers* - hot springs that periodically erupt hot water and steam
  - Minerals often precipitate around geysers as hot water cools rapidly in the air

Geothermal Energy

- *Geothermal energy* is produced using natural steam or superheated water
  - No CO_2 or acid rain are produced (*clean* energy source)
  - Some toxic gases given off (e.g., sulfur compounds)
  - Can be used directly to heat buildings

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End of Chapter 17