Chapter 13

Ground Water

Introduction

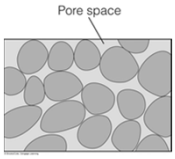
- Groundwater is all subsurface water trapped in the pores and other open spaces in rocks, sediments, and soil.
- It is an important source of freshwater (22% of total)
- Groundwater is also responsible for forming beautiful caverns

Groundwater and the Hydrologic Cycle

- Groundwater is part of the hydrologic cycle and an important natural resource.
- As the world's population and industrial development expand, the demand for water, particularly groundwater, will increase.
- Most groundwater in the United States is used for irrigation and public drinking water supplies

Porosity and Permeability

- Groundwater is stored in open spaces in rocks called pores.
  - Porosity is the percentage of a material's total volume that is pore space.
  - Permeability is the capacity to transmit fluids. This is necessary if we are to produce water from rocks.
  - *Permeability is dependent on porosity, but also on the size of the pores and their interconnections.*



Porosity and Permeability

- Types of Pores – some rock types have more porosity than others

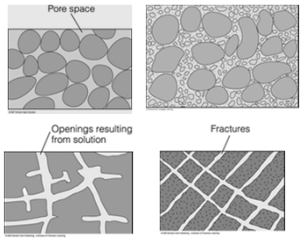
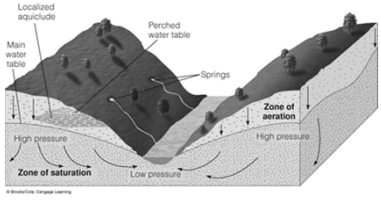


TABLE 13.1 Porosity Values for Different Materials

Material	Percentage Porosity
Unconsolidated sediment	
Soil	55
Gravel	20–40
Sand	25–50
Silt	35–50
Clay	50–70
Rocks	
Sandstone	5–30
Shale	0–10
Solution activity in limestone, dolostone	10–30
Fractured basalt	5–40
Fractured granite	10

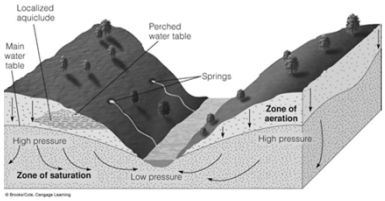
Aquifers

- An aquifer is a region of the subsurface that has sufficient porosity and permeability to store and transmit water.
- Sandstone, sand and gravel make good aquifers.



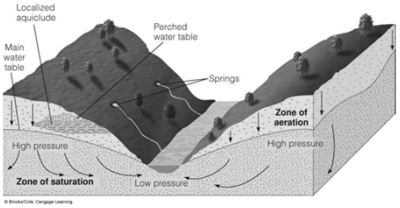
Aquifers

- An aquiclude is a region of the subsurface that has low permeability and will not transmit water easily.
- Shale or clay make good aquicludes.



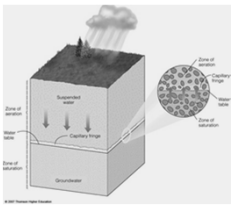
Aquifers

- Aquifers can be confined (aquifer material trapped between aquicludes) or unconfined (upper surface at ground level).



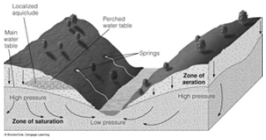
The Water Table

- Unconfined aquifers feature a water table, which is the top of the zone beneath the surface in which the pores are filled with water.
  - The zone of aeration or vadose zone - when water initially infiltrates the ground, most of the pores are filled with air.
  - The zone of saturation or phreatic zone –a zone in which the pores are filled with water or saturated.
  - The capillary fringe is in the vadose zone.



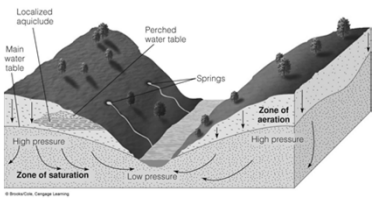
The Water Table

- The water table is typically not flat like a table; it will rise and fall with local topography in humid regions (like here).
- In more arid regions, the water table is more flat and much deeper.



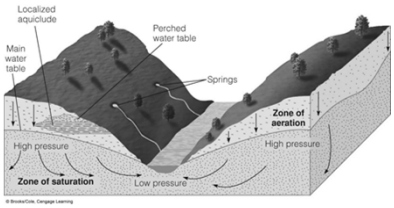
Groundwater Movement

- Groundwater moves slowly downward (from higher to lower elevations) under the influence of gravity through the zone of aeration to the zone of saturation.



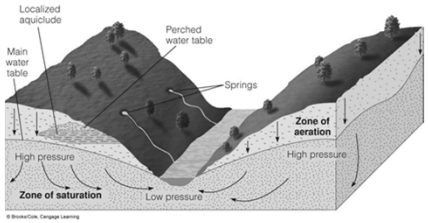
Groundwater Movement

- Aquifers with water tables are unconfined.
- Perched aquifers are a type of unconfined aquifer.



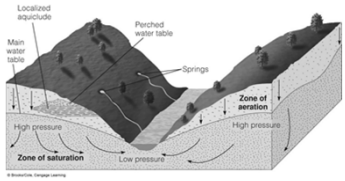
Groundwater Movement

- Some of it moves along the surface of the water table, and the rest moves from areas of high pressure to areas of low pressure.



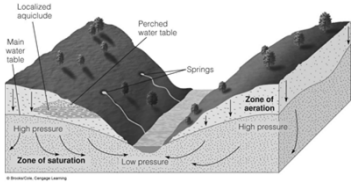
Groundwater Movement

- Groundwater also moves from areas of abundant infiltration to drier areas.
- Groundwater also moves from areas of little use to areas of heavier use.



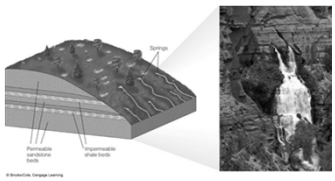
Groundwater Movement

- Groundwater velocity varies greatly and depends on various factors. Generally, the *average velocity of groundwater is a few centimeters per day*.



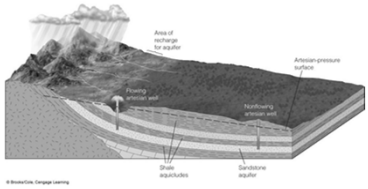
Springs, Water Wells, and Artesian Systems

- ***Springs*** are found wherever the water table intersects the surface.
- When percolating water reaches the water table or an impermeable layer, it flows laterally, and if this flow intersects the surface, water is discharged as a spring.



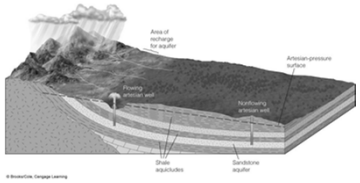
Springs, Water Wells, and Artesian Systems

- ***Water wells*** are openings made by digging or drilling down into the zone of saturation.
- When the zone of saturation has been penetrated, water percolates into the well filling it to the level of the water table.



Springs, Water Wells, and Artesian Systems

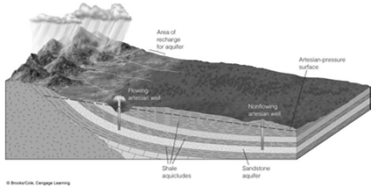
- ***Artesian systems***
  - In an artesian system, confined groundwater builds up high hydrostatic pressure, creating an artesian pressure surface.



Springs, Water Wells, and Artesian Systems

For an artesian system to develop, three geologic conditions must be met:

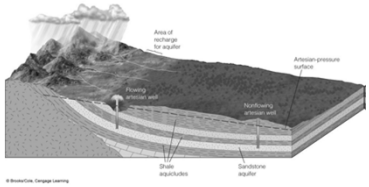
- The aquifer must be confined above and below by aquicludes
- There is enough artesian pressure to raise the water above the aquifer's surface
- precipitation must be sufficient to keep the aquifer recharged



Springs, Water Wells, and Artesian Systems

Artesian systems and Artesian Pressure

- The dashed line defines the highest level the water can rise, the artesian pressure surface.
- If the artesian pressure surface is above ground level, then the well is a flowing artesian well.
- If it does not rise all the way to the surface, it must be pumped out.



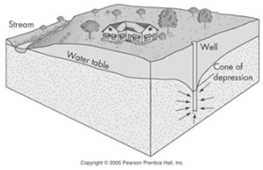
Drilling a Well

- Drilling a well results in one of three things:
- You find drinkable, fresh water
- You find undrinkable water, either because it contains too many dissolve solids, or too much iron or calcium, or perhaps too much salt
- You find polluted water

Even if you find good water, the amount and extent of the resource could be limited. And since recharge typically takes many 10's of years, groundwater is considered to be a nonrenewable resource.

Drilling a Well

- Pumping a well results in a cone of depression, which is a lowering of the water table surrounding the well.
- Excess removal can result in subsidence and other issues.



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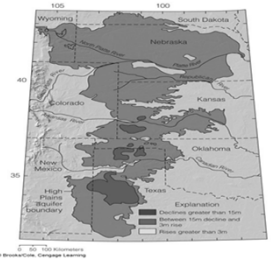
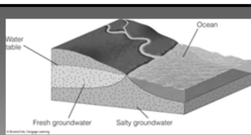
Modifications of the Groundwater System And Their Effects

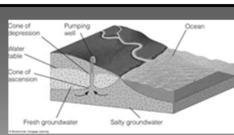
- Groundwater is a valuable natural resource that is being exploited rapidly.
  - Modifications to the groundwater system can cause serious problems such as:
    - Lowering of the water table
    - Saltwater incursion
    - Subsidence
    - Contamination.

Modifications of the Groundwater System And Their Effects

- Overuse has lowered the High Plains aquifer by a significant amount.

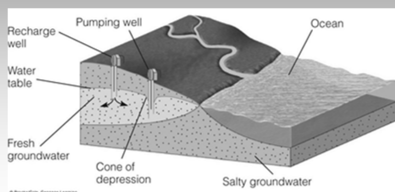






Saltwater Incursion

A problem in coastal areas

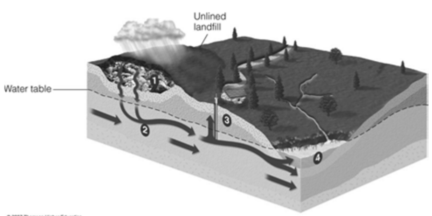


Subsidence

- When withdrawal from wells exceeds the rate of recharge, ground subsidence may result.

Modifications of the Groundwater System And Their Effects

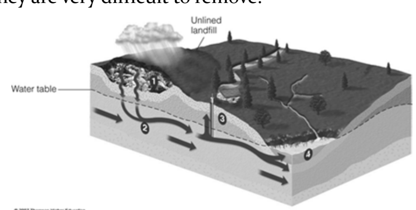
- ***Groundwater Contamination*** by humans from landfills, septic systems, toxic waste sites, and industrial effluents is becoming a serious problem.



Modifications of the Groundwater System And Their Effects

Groundwater Contamination

- Once contaminants get into the groundwater system, they are very difficult to remove.



Modifications of the Groundwater System And Their Effects

Cleaning up Groundwater Contamination

- Since the Clean Water Act in the early 1970s, the amount of industrial pollutants entering the water system has decreased dramatically
- Bans on certain pesticides, herbicides and other chemicals have prevented large amounts of pollution
- Engineering solutions for removing pollutants – such as "pump-and-treat", air sparging, bioremediation, and "permeable reactive barriers", and an enhanced understanding of groundwater flow have improved clean up methods

Modifications of the Groundwater System And Their Effects

Groundwater Quality

- Groundwater quality is mostly a function of
  - the kinds of materials that make up an aquifer
  - the residence time of water in an aquifer
  - the solubility of rocks and minerals.
- These factors account for the amount of dissolved materials in groundwater and are responsible for such undesirable effects as hard water and iron staining.

Modifications of the Groundwater System And Their Effects

- ***The greatest threat to our water supply is overuse!***

What can be done?

- Conserve where water is rare
- Transfer water from wetter to drier areas
- Use desalination in coastal regions

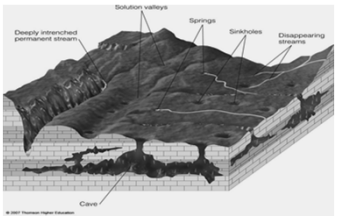
Groundwater Erosion and Deposition

Sinkholes and Karst Topography

- Sinkholes are depressions in the ground formed by the dissolution of the underlying soluble rocks or the collapse of a cave roof.

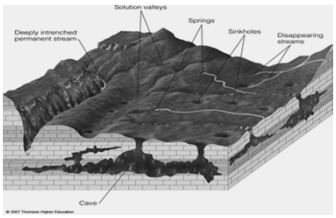
Groundwater Erosion and Deposition

- Karst topography largely develops by groundwater erosion in many areas underlain by soluble rocks, most commonly limestone.



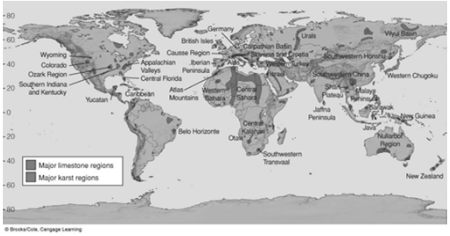
Groundwater Erosion and Deposition

- Features of karst topography include:
- Sinkholes
- Springs
- Solution valleys
- Disappearing streams
- Caves and Caverns



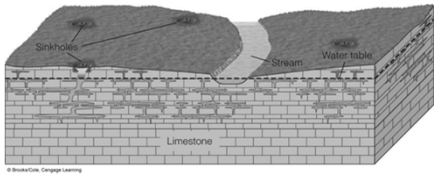
Groundwater Erosion and Deposition

- Areas of the world exhibiting karst topography. Karst develops largely by solution of limestone.



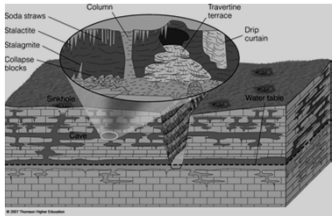
Groundwater Erosion and Deposition

- ***Caves and Cave Deposits*** form when groundwater dissolves the soluble rock layers and they collapse.



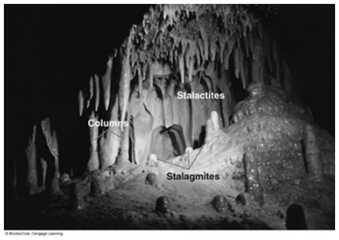
Groundwater Erosion and Deposition

- Common cave deposits include:
  - Stalactites
  - Stalagmites
  - Columns
  - Drip Curtains
  - Travertine



Groundwater Erosion and Deposition

- The precipitation of calcite within caves creates a variety of interesting features.



Hydrothermal Activity

- Hydrothermal refers to hot water, typically heated by magma but also resulting from Earth's geothermal gradient as it circulates deeply beneath the surface.

- Fumaroles, hot springs, and geysers are all hydrothermal features.

Hydrothermal Activity

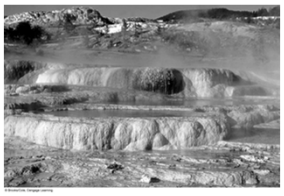
- Geysers and hot springs develop where groundwater is heated by hot subsurface rocks or the geothermal gradient.
  - ***Hot springs*** - springs where the water temperature is higher than 37°C

Hydrothermal Activity

- Waters from hot springs have a lot of dissolved minerals in them, and are thought to have medicinal benefits.

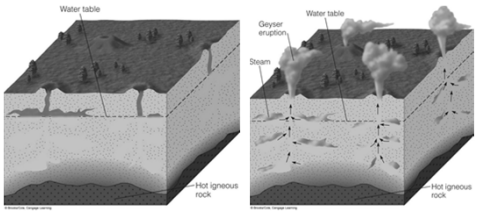
Hydrothermal Activity

- Travertine and tufa - Precipitation of calcite from supersaturated hot spring water



Hydrothermal Activity

- ***Geysers*** are hot springs which periodically eject hot water and steam with tremendous force.



Hydrothermal Activity

Geothermal Energy

- Geothermal energy is energy produced from Earth's internal heat
- Comes from the steam and hot water trapped within Earth's crust
- Derived mostly at convergent zones and hot spots
- It is a relatively clean form of energy that is used as a source of heat and to generate electricity
- 1-2% of the world's energy needs could be met with geothermal energy

End of Chapter 13