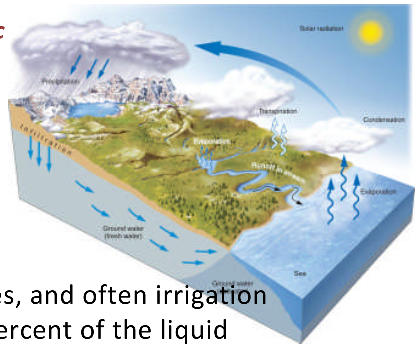
The Hydrologic Cycle



Chapter Outlines

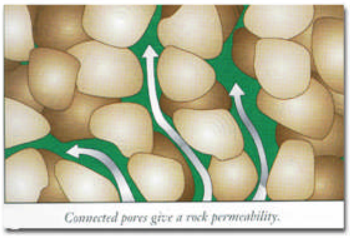
NOTE: This is intended to help students 'organize' their understanding of each topic. It is <u>not</u> a comprehensive study guide for quizzes or midterms, i.e. <u>study your text!</u>

Groundwater

Groundwater is extremely important to our way of life. Most drinking water supplies, and often irrigation water for agricultural needs, are drawn from underground sources. More than 90 percent of the liquid fresh water available on or near the earth's surface is groundwater. Hot groundwater can also be a source of energy. Groundwater is derived from rain and melting snow that percolate downward from the surface; it collects in the open pore spaces between soil particles or in cracks, fissures, or pore spaces in bedrock. The process of percolation is called **infiltration.**

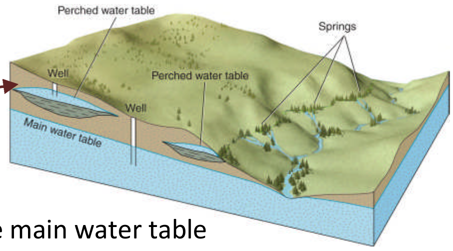
This rock has high permeability

(Magnification)

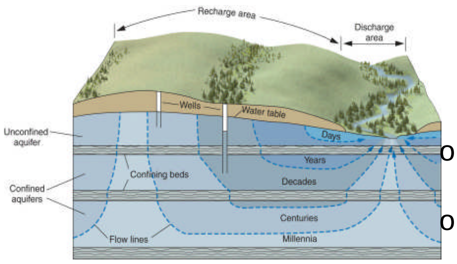


- **Porosity and permeability**
  - **Porosity** – the percentage of void space in a rock.
  - **Permeability** – how well water can flow through a rock. When pores are well connected permeability is high.
  - Both are necessary for an aquifer to be very productive.
    - Coarse sandstone is often high in both porosity and permeability.
    - Granite *(and similar rock)* is usually low in both porosity and permeability.
- **Water table**
  - The **water table** lies at the top of the saturated zone. It can also be defined as the water level in a well *(in an unconfined aquifer).*
  - Above the water table is the **unsaturated zone** *(**vadose zone**).*
  - Below the water table is the **saturated zone** where all rock openings are filled with water.
  - A **perched water table** is a saturated area separated from, and above, the main water table

A perched aquifer



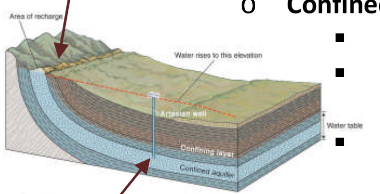
- **Movement of ground water** – *Darcy's Law*
  - Henri Darcy, a French engineer, cleaned-up the sewers and improved the water system of Paris in the 1850's, and then found the mathematical solution for how water travels through permeable materials. Groundwater velocity is a function of water 'head' pressure *(differences in water table elevation), the* cross sectional area of an aquifer, and the permeability of the host rock.
  - Groundwater will move from areas of higher '**head pressure**' to lower head pressure as a result of the 'hydraulic gradient'.
  - Head pressure can be determined over a large area by drilling many monitoring wells and finding the water table level in each. This well water level is the head pressure expressed as distance above sea level.
  - Unless it is caught in a geologic 'basin', groundwater will travel until it flows from the ground into a spring, river, lake, or the ocean.



The flow of groundwater from areas of recharge to areas of discharge

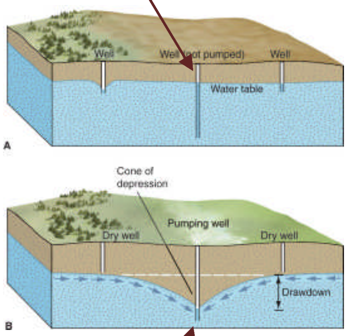
- **Aquifers and aquitards**
  - An **aquife**r is a strata of subsurface material *(bed)* that can supply 'a useful amount of water'. Sand, gravel, jointed, and fractured rock make good aquifers.
  - **Unconfined aquifer *(water table aquifer)***
    - Has permeable materials up to the surface.
    - Receives its water replenishment directly from percolation of the ground surface above.
  - **Confined aquifer *(deeper…below an impermeable layer)***
    - A layer of permeable material with impermeable layers of rock below and above it.
    - Receives its water replenishment from percolation somewhere else where there is no barrier to the ground surface. Replenishment is usually very slow.
    - The water is under pressure. The water level in a well drilled into a confined aquifer will rise in the well, sometimes to near the ground surface (**artesian well**).
  - A bed of material that will not transmit useful amounts of water is called an **aquatard**. Shale, clay, and unfractured crystalline rocks are normally aquitards.

This confined aquifer's recharge area



Well drilled into confined aquifer

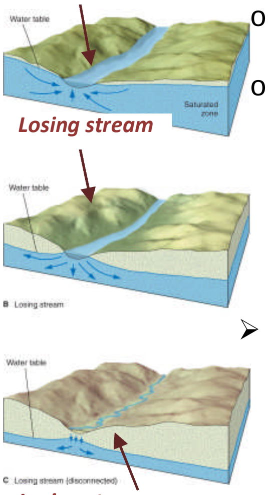
Pump is not running



Pumping well is creating a 'cone of depression'

➢ **Wells**
- A hole drilled shallow or deep vertically down into the Earth – hopefully reaching the saturated zone so it will fill with water.
- The rock extracted during drilling is closely examined in order to understand exactly where *(what depth)* the good aquifer strata is likely to be.
- A pipe liner is inserted into the drilled hole, and perforations are cut into the pipe at only the depth good water is expected to be found.
- A compact submersible *(waterproof)* pump is lowered into the well with a discharge pipe extending up and out of the well.
- Affects of pumping from a well:
  - When the pump is in operation, the groundwater surface *(water table)* will normally dip down *(be 'drawn' down)* at the well. This is called a '**cone of depression**'.
  - If water is extracted faster than it is recharged by rain, the water table will drop. Eventually it can drop so low that it becomes impractical to pump water.
  - When over-extraction of ground water occurs over a long period, the entire ground surface over a wide area may subside…possibly as much as several meters.

Gaining stream



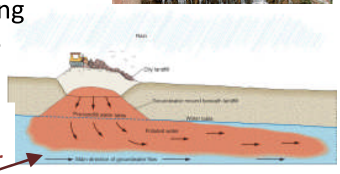
Losing stream

Losing stream

➢ **Springs and Streams**
- Where an aquifer is exposed at Earth's surface *(often on a hillside)* water will run freely from the ground's surface. This is a **spring**.
- A flowing stream can be either a **gaining stream** or a **losing stream**:
  - **Graining streams** – are just slightly below the water table, and therefore water is seeping out of the stream banks and bed, into the stream, and adding to the volume of water in the stream.
  - **Losing streams** – are above the water table, and therefore some water is being lost from the stream, through the stream bed, and percolating down into the ground, helping to fill an aquifer.

Springs (groundwater leaving the ground)

➢ **Ground water contamination** – *not common*
- In most instances, ground water becomes purified by simply traveling through the underground rock.
- Whenever a liquid is spilled onto the ground, it will soak into the ground and percolate downward and eventually combine with the groundwater. If it is high enough concentration or toxic enough material, it may contaminate the groundwater for some distance. In such instances, testing must be done to determine when well water is safe.



Toxic materials percolating into the groundwater

➢ **Ground water budgeting** – *running out of groundwater?*
- Monitoring is done in monitoring wells to watch long term rise or fall of the water table.
- If lowering of a water table from over-pumping becomes a problem (***drawdown***), then pumping of water can be reduced, or efforts can be made to **recharge the aquifer**.
- Recharging of an aquifer can be done during times of surplus surface water:
  - by pumping water under pressure back into a well *(use not widespread yet).*
  - by the use of settling ponds to recharge an aquifer by gravity percolation.

➢ **Affects of ground water action**. Dissolution of limestone bedrock can create:
- Caves – good for exploring
- Sinkholes – can cause surface damage
- Karst topography – multiple sinkholes

A collapsed cavern – now a sinkhole

➢ **Geothermal energy** *(hot water underground)*
- In area where magma is within a couple kilometers of Earth's surface, there is enough heat to raise ground water to very high temperatures. This hot water can be harnessed to generate electricity or to provide heat for buildings. To maximize the amount of energy retrievable, surface water can be pumped into the ground, become heated by the Earth's hot interior, then be extracted to generate electricity.
- **Old Faithful Geyser in Yellowstone** is an example of water heated in the ground by the presence of a shallow body of magma.

'The Geysers' geothermal power plant in N. California