Freshwater Resources

21st Century conflict could be about water with our increasing population.

Water is involved in just about every process of human life – it is our most valuable resource.

Water as a Resource

- ⇒ Occurs as a solid, liquid and gas
- ⇒ It is renewable within the hydrologic cycle

In total 97% of the world's water is in the ocean as salt water (not drinkable), only 3% is fresh water and of that only 0.6% is available for us to drink.

The "shun" words abound in the water cycle: Evaporation, precipitation, condensation and:
Evapotranspiration: Return of the water to the atmosphere by evaporation and evaporation (transpiration) of plants.

- ⇒ Average annual rainfall = 75cm (30"), 55cm of that gets back to the atmosphere via evapotranspiration
- ⇒ River runoff and ground infiltration the accounts for the other 20cm

Fresh Water at the Earth's Surface

1) Rivers
   - ⇒ Usually are dammed and supply is controlled
     a) Instream use- all uses in the channel itself
     - hydroelectric power and navigation

     b) Offstream use- diversion of water from a stream to a place of use outside, like ones home.
     - OU = total flow – instream purposes and maintenance of water quality.

     c) Consumptive use- water that evaporates transpires or infiltrates and cannot be used again immediately.
     - 44% here and 90% of the 44 is for agriculture.

     d) Non-consumptive use- water that is returned to streams with/without treatment so that it can be used downstream.
     - Household water

Western US: consumption exceeds local water supplies, so it needs to be pumped from somewhere.

- ⇒ 75% of CA water comes from sources 200 miles + away.

California: 3 Aqueducts

- ⇒ East of Sierras, west of Sierras and the Colorado
- ⇒ Largest consumer of water (more than #2-Texas- and #3-Illinois- combined)

World Consumption

- ⇒ 2400 km^3/yr or 1.7 trillion gallons/day, 82% of which is agriculture
- ⇒ By 2050: 20,000 km^3/yr (12.5 trillion gallons/day) which is beyond the carrying capacity of the world's rivers.

So, water will limit human population growth this century, one way or another.

2) Lakes
   - ⇒ Bodies of water in land locked basins
   - ⇒ Geologic genesis: glaciers, calderas, faulted basins
   - ⇒ Provides less than 0.4% of all continental freshwater
   - ⇒ 80% of all lake water is held in less than 40 lakes.
   - ⇒ If P+R = E+O, fresh water lake
     If P+R = E, no outflow (salt lake)
     If P+R < E+O, playa lake (seasonal)

where
P= precipitation
R= runoff
E= evaporation
O= outflow

Overturn- process that keeps bottom waters in lakes from becoming stagnant.
- ⇒ See figure
- ⇒ Thermocline is more pronounced in summer
- ⇒ Water's max density occurs @ 4ºC, more dense water sinks (spring and fall)

Nourishment Classification of Lakes
1) Oligotrophic- deep, low nutrient, clear lake
   - ⇒ Good drinking water and pretty
2) Eutrophic- well fed, shallow, many plants, trash fish population, low oxygen content
3) Mesotrophic- well balanced input/output

⇒ Good fish, plankton, vegetation

Freshwater Underground

Groundwater- infiltrated and valuable

Dowser or divining rods- find water

Hydrogeologist- water geologist
- ⇒ Lucrative field

Groundwater Supply
- ⇒ 34 of 100 largest cities in the US depend entirely on groundwater
  - ■ Miami Beach, San Antonio, Memphis, Honolulu and Tucson
- ⇒ 80% use is agricultural, so agricultural states are the highest users (CA, TX, Idaho, Nebraska)

Location and Distribution

Soil Zone

Infiltration
Zone of Aeration (soil and rock contains air and water film)

Water Table Capillary Fringe
Zone of Saturation (water fills voids)

Aquifers- rocks that can hold and yield water

- ⇒ Porosity: volume of open space
- ⇒ Permeability: ease of which water flows
  Hydraulic Conductivity is what hydrologists prefer.

Aquiclude- rocks that do not transmit water

Perched Water Table- lenses of water preclude on aquicludes.

Static Water Table

Unconfined Aquifers: formations that are exposed to atmospheric pressure changes and that can provide water to wells by draining adjacent saturated rock and soil.

Cone of Depression: lowering of water table produced by pumping

Drawdown: the difference between the bottom of the cone of depression and the top of the static water table.

Single family well= 11 liters/minute or 3,700 gallons/day, with many families only using 1350gallons/day.

Losing Streams: streams abate water table

Gaining Streams: streams that intersect water table

- ⇒ Three types of springs:
  1) Limestone Bedrock with high water table
  2) Fault- groundwater follows fault
  3) Perched water table

Confined Aquifers: where water table is located between two aquicludes.

Artesian Wells: pressurized water rises naturally due to its confined nature.

- ⇒ Artesian- pressure surface- level to which water will rise in a well at a given point
- ⇒ Water moves from areas of high pressure to low, just like air

Groundwater Storage and Management

Management of underground water is determined by:

1) Quantity of water stored in the basin
2) Sustained Yield- amount of water the aquifers in the basin can yield on a day-to-day basis over a long period of time.

Recharge Area- places where water goes back into the aquifer

Specific Yield (SY) - the ratio of the volume of water an aquifer will give up by gravity flow to the total volume of material, expressed as a percentage.

- ⇒ Saturated clay: may have a porosity of 25%, but may have a yield of only 3%.

Specific Retention (SR) - water held by rock or soil layer

Porosity = SY+SR

Thus, the total water storage capacity can be calculated by multiplying the SY by the volume of the aquifer (determined by well-water-data).

Groundwater Mining

- ⇒ Overdraft condition where we withdraw too much water from an aquifer.
- ⇒ High Plains Aquifer
  - Main rock- Ogallala Sandstone (80%)
  - Overdrafts around 65% in Texas, and as high as 95%
  - 1980s- LEPA (low energy precision application) irrigation nozzles helped situation.
  - Ogallala name- Sioux Nation
- ⇒ Groundwater mining can eventually dry up a well
  - Tucson area now imports water
- ⇒ Other overdrafts
  - Santa Clara Valley of Central CA (San Jose down 9 feet)
  - Alabama- some areas below sea level 80 miles inland

Groundwater – Saltwater Interaction

- ⇒ "Brackish"- saline water from mixing
- ⇒ Seawater is 2.5% heavier than freshwater
- ⇒ Ghybon- Herzberg Lens- lens of freshwater that can float on seawater due to the density difference.

Saltwater Encroachment- drainage to aquifer by saltwater in a coastal area due to pumping.

Water spreading- recharging an aquifer artificially with injection of freshwater.

Groundwater – Surface Water Interaction and Usage Trends

- ⇒ Need to understand the characteristics of both water bodies in question.
- ⇒ Water used in power stations is generally less polluted than irrigation water.
- ⇒ Between 1950-1980, usage increased
- ⇒ But between 1980-1995, usage decreased even though the population increased by 37 million.
  - Efficient irrigation, conservation, water recycling, down turn in farm economies.

Geologic Work by Underground Water

Karst Terrain- produced by the dissolution of limestone or gypsum underground, leads to the formation of caves, caverns, disappearing streams, and prolific underground aquifers.

- ⇒ Named after the Kars limestone of NW Yugoslavia

Classic Case- Winter Park, Florida

- ⇒ Huge sinkhole- figure

Carbonate Rocks are usually the culprit: Limestone ($CaCO_3$), Dolomite (CaMg), Marble (CO_3)

⇒ Other noncarbonated evaporites: Gypsum ($CaSO_4$), Rock salt (NaCl)

⇒ Ionically bonded salts

Water Quality

1) Dissolved substances
   - ⇒ US Public Health Service established potable (drinkable) water standards
     - Less than 550 ppm (parts per million) of total dissolved solids (tds)
   - ⇒ Persistent Pollutant- one that builds up in the human body
     - Arsenic and Lead
   - ⇒ Hard Water- Ca^{+2} and Mg^{+2}
     - prevalent in areas underlain by carbonates
     - water softeners use sodium to exchange
   - ⇒ Fluoride (1-1.5ppm) allows teeth to be harder and resistant to decay
     - Rare naturally except in Colorado Springs

Ground Water Pollutants

⇒ Introduction of chemical, physical or biological material that could affect its future use.

Residence Time- length of time a substance remains

⇒ Rivers- days, Lakes- decades, shallow aquifers- days, deep aquifers- thousands or hundreds of thousands of years.

Most pollution is due to careless disposal

⇒ Some is due to leaching of toxic materials from mines

⇒ Sewer systems, chemical waste, animal fecal runoff, inorganic fertilizers

⇒ Gasoline storage tanks- "Yank a Tank"

Bioremediation- soil cleaning by bacteria

Density Differences can help or hurt:

Help- Gas and hydrocarbons less dense, float

Hurt- salt veins denser sink

Conservation and Alternative Sources

⇒ Southwest is conventional

⇒ Remedies

1) Desalination of seawater
2) Recycling
3) Iceberg tug

⇒ 6 Billion folks intercept 54% of freshwater

⇒ By 2025, 70%

Case Studies

8.1 Who Shrunk the Aral Sea?

- ⇒ Lost 74% of its area since 1960
- ⇒ Now too saline
- ⇒ No fishing industry anymore
- ⇒ Dust, and respiratory diseases

8.2 Fluid Flow in Porous Rocks: Darcy's Law

Q=KIA, where K is hydraulic conductivity (measure of the permeability), I is hydraulic gradient or slope of water table, and A is the cross-sectional area

8.3 Groundwater Law

Riparian Doctrine: landowners have absolute rights to the water

Reasonable-use Doctrine: restricts a landowner's right to reasonable use, and does not deprive neighboring landowners reasonable use

Prior-appropriation Doctrine: earliest water users have the firmest rights

Correlative-rights Doctrine: landowners own shares to the water beneath a collective property that are proportional to the land that they own.

8.4 The Edwards Aquifer

Central Texas, serving San Antonio, TX

8.5 Long Island, NY