APES Ch. 7 Notes ~ Water: Hydrologic Cycle and Human Use

7.1 Notes

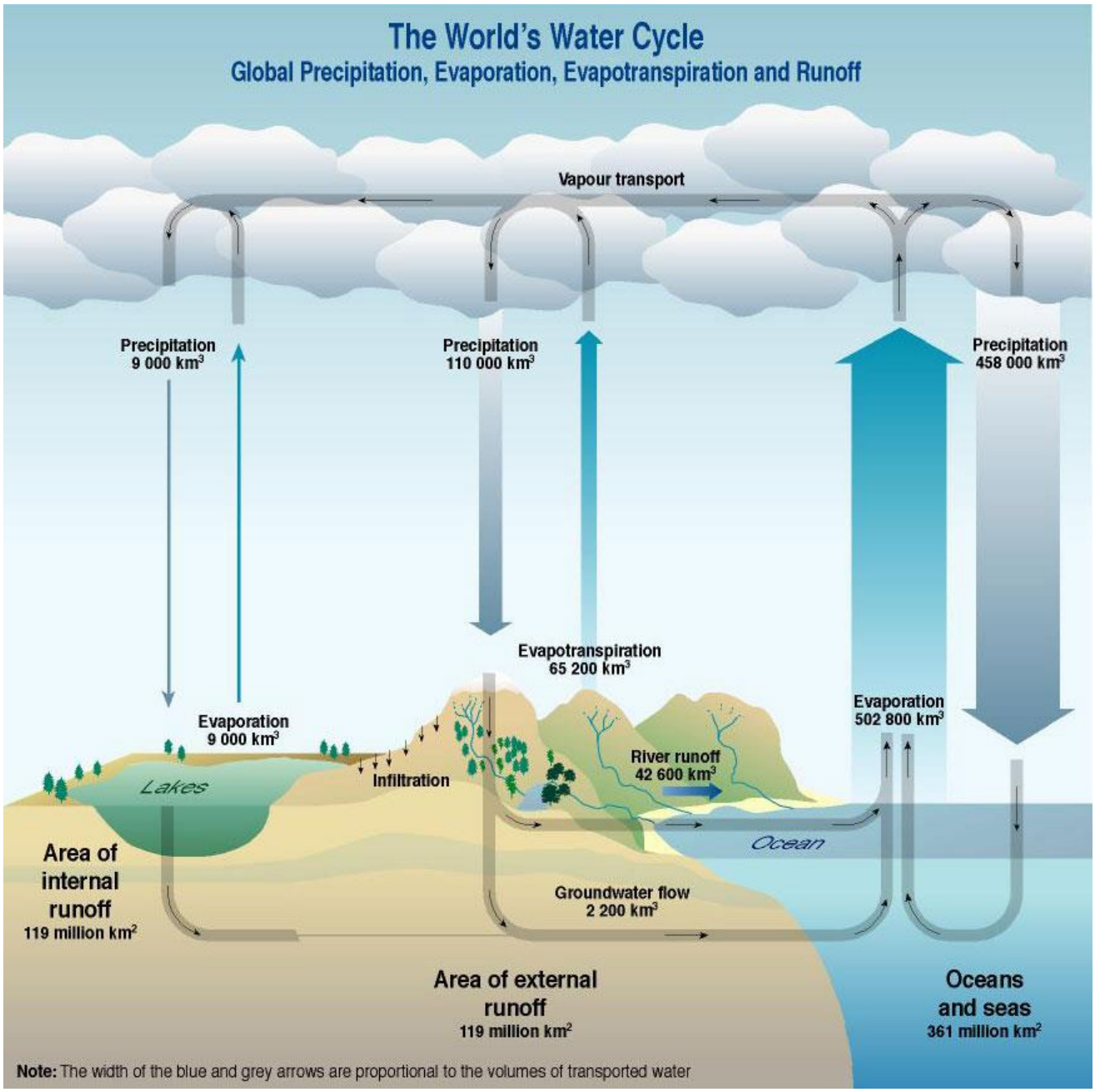
I. Water: A Vital Resource
- A. *water covers 71% of Earth's surface*
- B. *~ 97% of Earth's water is salt water*
- C. from the remaining ~2.5%...
  - 0.76% is groundwater
  - 0.0132% is in lakes and streams
  - 1.74% is in glaciers and icecaps
  - 0.001% is water vapor
- D. **fresh water** = *water containing < 1000 ppm salt content*

7.2 Notes

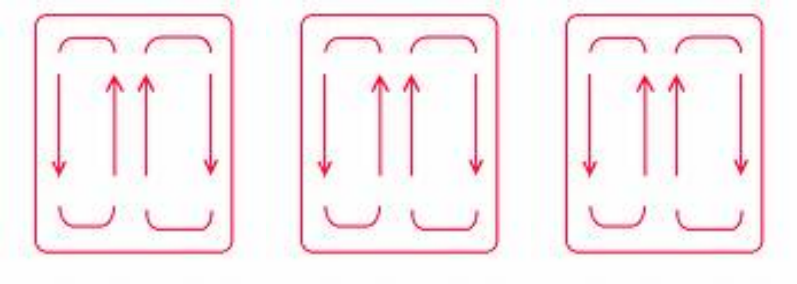
II. The Hydrological Cycle (Water Cycle): Natural Cycle, Human Impacts
(See diagram on page 2)

A. Evaporation, Condensation, and Purification
1) **hydrology**—*the study of Earth's water*
2) **hydrosphere**—*water found on, in, or above the Earth*
3) **evaporation**—*phase change from a liquid to a gas or vapor above Earth*
(review kinetic energy and phase changes)
   a) "vapor" is used to describe a substance when it found as a gas, even though the normal state is not
   b) *water vapor = humidity*
   c) **relative humidity**—*amount of water vapor air can hold at a specific temperature*
4) **condensation**—*phase change from a vapor or gas to a liquid*
   - **aerosols**—*microscopic particles in the air which promote condensation; natural or from pollution*
5) natural water *purification* from the water cycle
   a) *water will evaporate, leaving behind the formerly dissolved materials*
   b) water will condense (with some dissolved pollutants and aerosols)
   c) *evaporation and condensation act as a natural purification process*

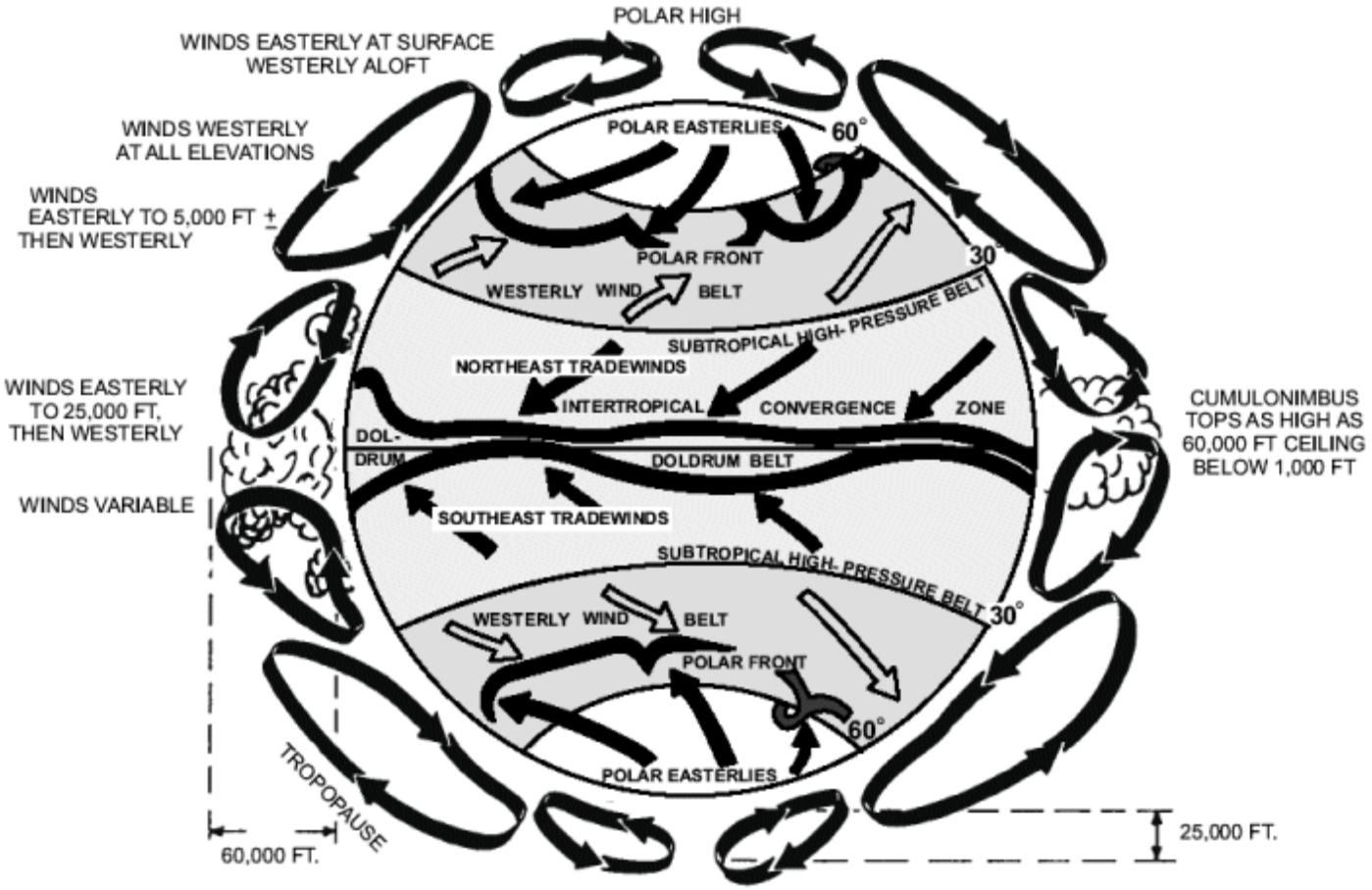
B. Precipitation
1) **precipitation**—*water returning to the earth's surface*; rain, snow, hail, etc.
2) **adiabatic cooling**—*light warm air rises; cools and expands with low pressure*
3) **adiabatic warming**—*cooling air sinks and is warmed by compression due to high pressure*
4) two causes of air currents: convection currents & mountain ranges
   a) **convection currents**—*warm air rising OR cool air sinking*
   (See second diagram on page 3)
      - **Hadley cells**—*"loops"* of warm air rising and cool air sinking
      (See first diagram on page 3)
   b) mountain ranges block air current flow
      - *High precipitation* on the **windward** side
      - *Low precipitation* on the **leeward** side (**rain shadow** effect)


The World's Water Cycle
Global Precipitation, Evaporation, Evapotranspiration and Runoff
Vapour transport
Precipitation
9 000 km3
Precipitation
110 000 km3
Precipitation
458 000 km3
Evapotranspiration
65 200 km3
Evaporation
9 000 km3
Evaporation
502 800 km3
River runoff
42 600 km3
Infiltration
Lakes
Ocean
Area of
internal
runoff
119 million km2
Groundwater flow
2 200 km3
Area of external
runoff
119 million km2
Oceans
and seas
361 million km2
Note: The width of the blue and grey arrows are proportional to the volumes of transported water

HADLEY CELLS



CONVECTION CURRENTS AND GLOBAL WIND BELTS

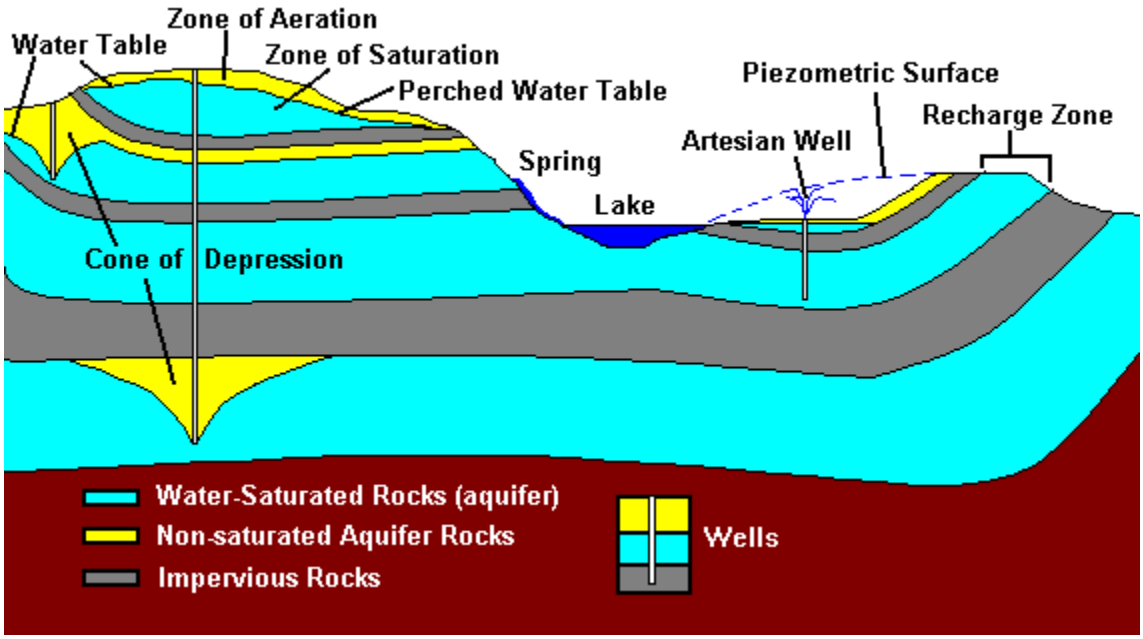


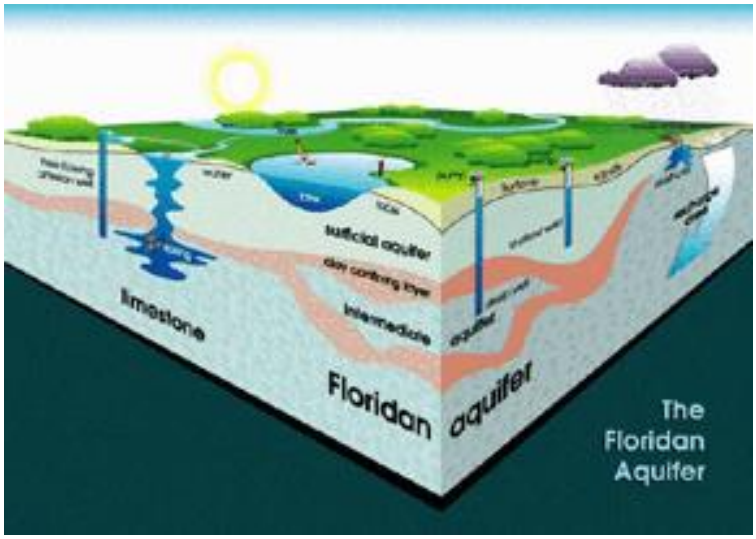
C. Ground water (review porosity vs. permeability)

1) two paths for precipitated water
    a) i**nfiltration**—*water seeping into the surface*
    b) **runoff**—*water flowing over the surface*
2) infiltration-runoff ratio—comparison
3) two paths for infiltrated water
    a) **capillary water**—*water held in the ground*
        - released by *evapotranspiration (green water flow)*
    b) **percolation**—*gravitational water moves downward through pore spaces (blue water flow)*

4) **watershed**—*all land that drains into a body of water*
5) **surface water**—*bodies of water on the surface of Earth* (as opposed to groundwater)
6) **groundwater**—*accumulated water below the surface*
    a) **water table**—*top of the groundwater*
    b) **aquifer**—*layer of porous rock through which water flows* (See diagram below)
    c) **recharge area**—*where water enters an aquifer*
    d) **spring**—*water flowing from a specific opening*
    e) **seep**—*water flowing from a larger, wider area*

A TYPICAL AQUIFER, from www.uwgb.edu





FLORIDA HAS MORE THAN ONE AQUIFER
FROM http://www.ufl.edu

"Florida's aquifers vary in depth, composition, and location, and are divided into two general categories: *Surficial* and *Floridan*. **Surficial aquifers** *are shallow beds of shells and sand that lie less than 100 feet underground.* They are separated from the Floridan aquifer from a confining bed of soil. Some have been contaminated by saltwater, yet they provide most of the public freshwater supply southwest of Lake Okeechobee and along the Atlantic coast north of Palm Beach.

In surficial aquifers, the groundwater continuously moves along the hydraulic gradient from areas of recharge to places of discharge. Surficial aquifers are recharged locally as the water-table fluctuates in response to drought or rainfall. Therefore, the temperature and flow from water-table springs varies.

Important surficial aquifers include:

1) *The Biscayne aquifer is a surficial aquifer located in southeast Florida. It covers over 3,000 square miles, and is the most intensely used water source in Florida,* supplying water to Dade, Broward, Palm Beach, and Monroe counties. The aquifer lies close to the surface and is extremely vulnerable to pollutants that leach through the shallow limestone bedrock. In some areas, it has been contaminated by fuel spills, industrial discharge, landfills, and saltwater.
2) The *sand and gravel aquifer* stretches 2,400 square miles across the Panhandle. Although this surficial aquifer is replenished with rainfall, water levels have dropped due to water-well use (pumping), and it has been contaminated by industrial waste and saltwater instrusion.
3) The *Chokoloskee aquifer* is another surficial aquifer in the state; it covers 3,000 square miles in southwest Florida. It is recharged by rainfall. It is believed that artificial drainage canals have lowered water levels and increased saltwater intrusion.

The **Floridan aquifer***, in contrast to surficial aquifers, is the portion of the principal artesian aquifer that extends into Florida.* The principal artesian aquifer is the largest, oldest, and deepest aquifer in the southeastern U.S. Ranging over 100,000 square miles, it underlies all of Florida and parts of southern Alabama, southeastern Georgia, and southern South Carolina. The Floridan portion developed millions of years ago during the late Paleocene to early Miocene periods, when Florida was underwater. Unlike water in surficial aquifers, groundwater in the Floridan aquifer is contained under pressure by a confining bed of impermeable sediments. When the water pressure is great enough, the groundwater breaks to the surface and a spring flows. Water temperature and flow from a Floridan spring is relatively constant.
The Floridan aquifer supplies fresh water to many cities such as Daytona, Gainesville, Jacksonville, Ocala, St. Petersburg, Tallahasse, and numerous rural communities. In areas where the Floridan contains saltwater, due to saltwater intrusion along the southwest Florida coast, it is injected with sewage and industrial waste.

In addition to the surficial and Floridan aquifers, several **intermediate aquifers** comprised of limestone beds lie between the surficial and Floridan aquifers, and a variety of **undifferentiated aquifers** store approximately ten percent of Florida's groundwater."

D. Summary of the Hydrologic Cycle
   1) four processes
      a) evaporation/transpiration (evapotranspiration)
      b) condensation
      c) precipitation
      d) gravitational flow
   2) "loops"
      a) Evapotranspiration Loop (green water)
      b) Surface Runoff Loop (blue water)

c) Groundwater Loop (blue water)

3) fluxes and pools
   a) *fluxes—exchange of water throughout the cycle*
   b) *pools—areas holding water*

III. Human Impacts on the Hydrologic Cycle

A. Changes to the Surface of Earth

1) contributing factors
   a) *overgrazing*
   b) *improper irrigation*
   c) *deforestation*

2) consequences
   a) flooding
   b) erosion
   c) sediment deposition
   d) less infiltration
   e) less rainfall
   f) depleted groundwater
   g) depleted rivers and streams
   h) less evapotranspiration

B. Climate Change

1) water cycle affected by increasing global temperatures
2) evaporation increases exponentially with increased temperature

from http://www.sustainableenergy.qld.edu.au/

… "The natural rhythm of the water cycle may be being disturbed by global warming because:

It has increased the amount of water vapor in the atmosphere.

It has increased the extent of cloud formation.

It has produced higher rainfall in many areas.

This could lead to even greater warming because water vapor is itself a greenhouse gas, and it is more efficient at absorbing heat energy than carbon dioxide. This increased warming could result in even more water vapor being taken up by the atmosphere, leading to still greater warming. This cycle has been described as a *runaway greenhouse effect*."

C. Atmospheric Pollution from aerosols

1) **anthropogenic (human-made) aerosols** such as sulfates, carbon soot, and dust provide a place for water to condense (*condensation nuclei*)
2) they increase cloud formation but decrease precipitation
3) they remain in the atmosphere longer than usual because the rain does not wash them out
4) aerosols are more a regional concern

from http://earthobservatory.nasa.gov/Features/Aerosols/

"*Aerosols are tiny particles suspended in the air.* Some occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels and the alteration of natural surface cover, also generate aerosols. *Averaged over the globe, aerosols made by human activities currently account for about 10 percent of the total amount of aerosols in our atmosphere.* Most of that 10 percent is concentrated in the Northern Hemisphere, especially downwind of industrial sites, slash-and-burn agricultural regions, and overgrazed grasslands.

Scientists have much to learn about the way aerosols affect regional and global climate. We have yet to accurately quantify the relative impacts on climate of natural aerosols and those of human origin. Moreover, we do not know in what regions of the planet the amount of atmospheric aerosol is increasing, is diminishing, and is remaining roughly constant. Overall, we are even unsure whether aerosols are warming or cooling our planet."

D. Withdrawing Water Supplies
1) Demand is outpacing supply
2) Annual global water withdrawal is expected to rise by 10% each decade

7.3 Notes

IV. Uses and Sources of Fresh Water
A. *quantitative (shortage concerns) vs. qualitative (purity issues)*
B. *U.S. water usage: agricultural (irrigation), industrial, residential*
1) **nonconsumptive**—*the water is still available to use afterward*
2) **consumptive**—*the water is inaccessible afterward*
3) U.S. water use: ~ half comes from groundwater and ~ half from surface water
4) U.S. water use: ~85% of freshwater is used for irrigation
C. worldwide water usage
1) ~70% for irrigation, ~20% for industry, ~10% for human use
2) 1,100,000,000 people do not have regular access to fresh, clean water
3) 80% of diseases in developing countries are from water-borne pathogens

D. water purification and treatment
additional info from www.hawaii.edu, www.corrosion-doctors.org, www.gewater.com, www.howstuffworks.com, and www.excelwater.com

1) **settling**
a) *letting water sit still, and/or adding Al^{3+} from $Al_2(SO_4)_3$ ("alum")*
b) *the Al^{3+} ion promotes precipitation*

2) **filtration**—commonly through a layer of sand
a) *mechanical filters (or microfiltration)*
b) *activated charcoal (carbon) filters*
- **adsorption—**binding and retention of undesired materials

c) *oxidizing filters (***ion exchange***; water softeners)*
- soften hard water by removing minerals that cause hardness
- hard water is pumped through a tank containing an exchange resin or plastic beads
- sodium ion on the resin replaces the hardness minerals
- sodium ion remains in a soluble form in the softened water
- Contaminants Removed: Fe, Mg, Ca, Mn

d) *neutralizing filter—treats acidic water*
e) **reverse osmosis** or **RO –** (*hyperfiltration*)
- *can reject bacteria, salts, sugars, proteins, particles, dyes*
- uses a membrane that is semi-permeable
- usually uses a process known as *crossflow* to allow the membrane to continually clean itself, preventing algae growth
- *requires a driving force (pump) to push the fluid through the membrane*

3) **biological oxidation**--*organic material removed by detritus feeders and decomposers*
4) **distillation**—*evaporating and re-condensing the water*
a) *separation of substances due to boiling point differences*

b) uses substantial amount of energy
c) re-condensed water is pure (left impurities behind)

5) **disinfection**

a) *chlorination*

- elimination of undesirable matter from the water by oxidation
- *permanent protection of the hygienic and sanitary quality of the water throughout the distribution phase*
- *active, immediate disinfection in cases of accidental pollution*
- continuous monitoring (of the chlorine demand) to warn of pollution

b) *pasteurization*

- solar cookers
- flow-through heat exchangers
- solar puddle

c) *ultraviolet light*

d) *boiling*

for a more detailed list, go to
http://www.excelwater.com/eng/b2c/techniques.php?WL_Session=6db91c5fb0a6336e849c2bd48e62649c

V. Overdrawing Water Resources

A. Consequences of Overdrawing Surface Waters

1) Guideline: only 30% or less of a river's flow should be withdrawn yearly.
2) *ecological effects of damming*
   a) *depletes the underlying areas of water*
   b) *affects water table*
   c) *disrupts food chains of area*
   d) *possible drying up of the body of water*
   e) *diminishes fresh water flow to **estuaries**—areas where fresh water flows into salt water*

National Estuary Program

The National Estuary Program (NEP) was established by Congress in 1987, as an amendment to the Clean Water Act, to recognize and protect "estuaries of national significance." The NEP targets a broad range of issues and engages local communities in the process of identifying problems affecting their estuary and coming up with solutions. The program focuses not just on improving water quality, but on maintaining the character of the entire ecosystem.

The NEP is administered by the U.S. Environmental Protection Agency (EPA), which provides money to local communities to study their estuary. Each NEP has a management committee that is made up of representatives from federal, state and local government agencies responsible for managing the estuary's resources, and often include other members of the community: conservation advocates, business leaders, educators and researchers. These stakeholders work together to

- Identify the major threats facing an estuary.
- Develop a comprehensive conservation and management plan (CCMP) as part of a consensus community process that sets forth specific actions to restore and maintain the estuary.
- Encourage implementation of the CCMP.
- Monitor the progress that has been made toward the achievements of the CCMP's goals.

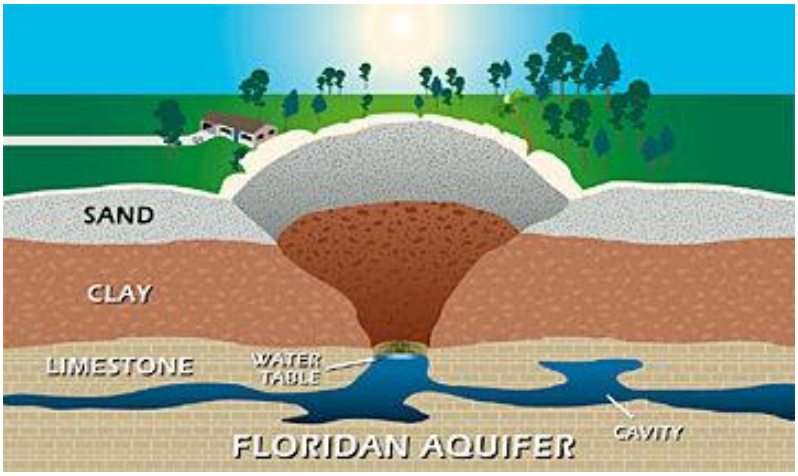
A monitoring review is typically completed every two years following the CCMP's adoption.

Individual estuaries are nominated to participate in the NEP by their respective Governors. The EPA Administrator approves or disapproves the nominee. Of the 28 estuaries in the NEP, four are found in Florida: Charlotte Harbor, Indian River Lagoon, Sarasota Bay and Tampa Bay.

B. Consequences of Overdrawing Groundwater

1) *falling water tables and depletion*
   a) diminished crop harvest
   b) The Ogallala aquifer lends irrigation water to 20% of the irrigated land in this country, in the Great Plains area. It is overdrawn, twice as much as the recharge rate.
2) *diminishing surface water*
   - possible drying up of wetlands, springs, seeps, streams, rivers
3) *saltwater intrusion* caused by aquifer depletion and lowered water table
4) **land subsidence**—*natural settling of the land*
   - can be caused by dropping water levels underground creating a loss of support
3) **sinkhole**—*deep subsidence* (see diagrams below and on page 10)
   a) a common problem in FL due to the reaction of slightly acidic water with limestone
   b) example: $\mathbf{2HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + CO_2 + H_2O}$

SINKHOLE from http://sjr.state.fl.us



7.4 Notes

VI. Obtaining More Water

U.S. Dams http://www.usdams.info/

World Commission on Dams http://www.unep.org/dams/WCD/

1) *dam building – pros*
   a) *irrigation water*
   b) *hydroelectric power (turbines)*
   c) *flood control*
   d) *increased accessible water supply*
2) *dam building – cons*
   a) *can cause damage to ecosystems*
   b) *disrupts natural river systems*
   c) *not a sustainable practice (does not ensure long-term success)*

d) *removing a dam is not easy*

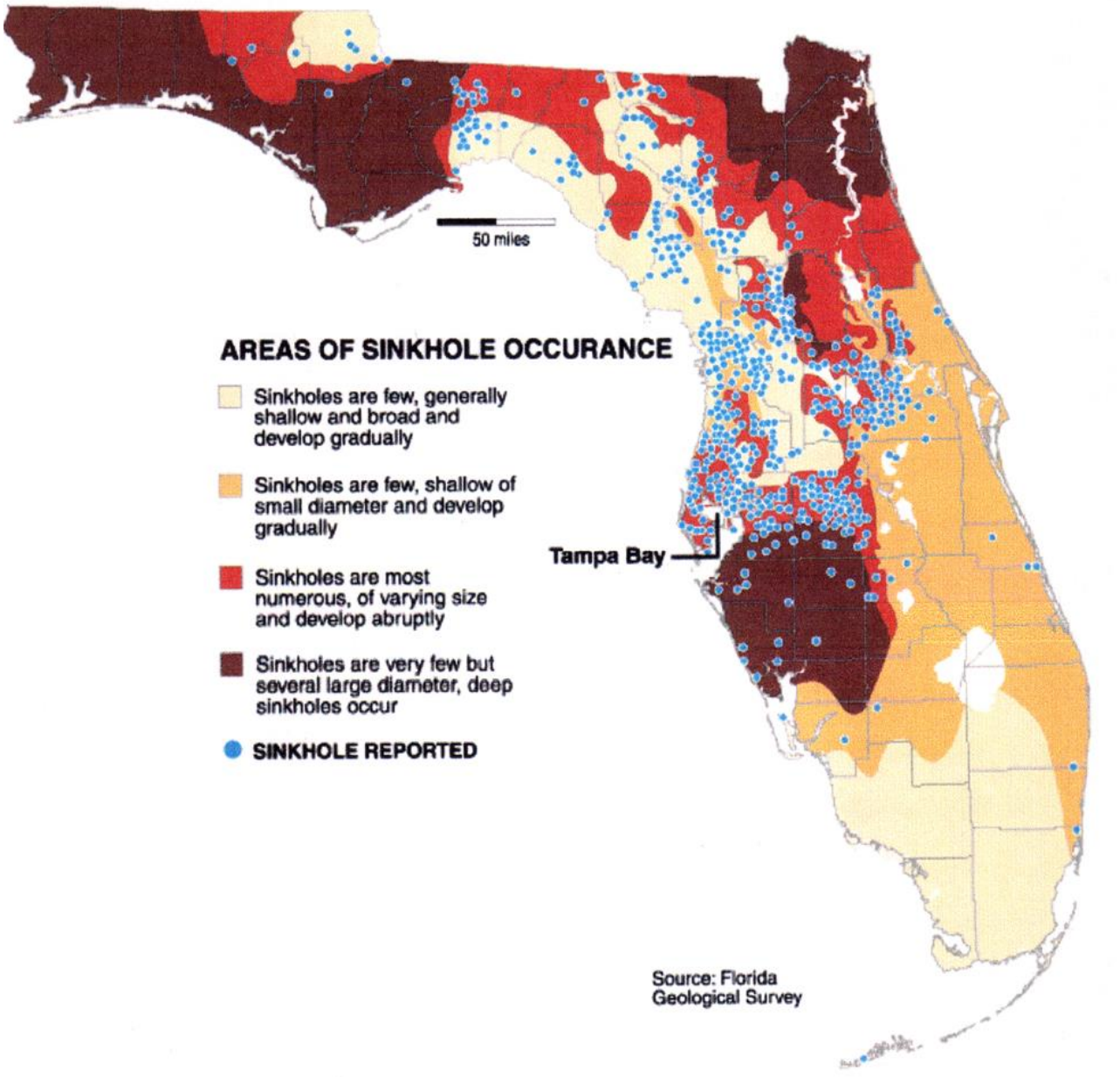
3) Who has the most dams? (from http://www.infoplease.com/askeds/country-most-dams.html)

"A study by the World Commission on Dams placed China's large dam total at over 22,000—the most in the world. Large dams are those roughly four stories or taller. Most of China's were built after 1949. And as the study points out, that translates into one large dam built per day, every day since the emergence of modern China.

Overall, *China is believed to have more than 80,000 dams.* Flood control and irrigation are China's top two purposes for building large dams like the Three Gorges Dam on the Yangtze River and the Xiaolangdi Dam on the Yellow River.

The United States has about 75,000 total dams (over 25 feet high). According to the Association of Dam Safety Officials the average number of dams per state is 1,800. Kansas leads all states with about 9,900 dams."

FLORIDA SINKHOLES



VII. Desalting Sea Water

A. **desalination** ("desal")—*the removal of salts from sea water*

B. main processes (see WATER TREATMENT section for more details)

1) *reverse osmosis*

2) *distillation*

C. Tampa Bay Seawater Desalination Plant

background info: www.water-technology.net/projects/tampa

update: http://www.uimonline.com/index/webapp-stories-action?id=116

… "2.4 million west-central Florida residents are benefiting from a project pioneered by their regional water utility, Tampa Bay Water. The Tampa Bay Seawater Desalination Plant, now fully operational, is providing millions of gallons of clean drinking water from the sea every day. At 25 *million gallons per day (mgd)*, the plant provides about 10 percent of the Tampa Bay region's drinking water supply…

The plant uses about 44 mgd of seawater from a nearby power plant's cooling system. The seawater is pretreated to remove algae and other particles. Then, *reverse osmosis* filters separate 25 mgd of freshwater from the seawater. The unused concentrated seawater is diluted with up to 1.4 billion gallons of cooling water before it is discharged to the bay. That dilution is why environmental studies show no measurable salinity change in Tampa Bay related to plant production. Protecting the environment was a big concern for Tampa Bay Water… The plant was built to meet the stringent U.S. environmental regulations and overcame the challenges they presented…"

WATER USE CALCULATOR:
https://www.swfwmd.state.fl.us/conservation/thepowerof10/

VIII. Using Less Water

A. *Irrigation*

1) *water loss of 30-50% (usual methods: flood and center-pivot)*

*evaporation *percolation *runoff

2) improvements

- **surge flow**—*computerized control over water flow; saves water*
- **drip irrigation**—*plastic pipes with tiny holes through which water seeps*
- **treadle pumps** (like step machines) available in developing countries

3) hindrances

- government subsidies for traditional irrigation: almost free for the farmer
- pipe network installation is costly

B. Municipal Systems

1) Water use in USA http://www.data360.org/dsg.aspx?Data_Set_Group_Id=757

~ 152 gallons per person per day (FL = ~175)

Water use today https://www3.epa.gov/watersense/our_water/water_use_today.html

2) *common uses*

- *showers and baths*
- *washing laundry by hand or machine*
- *washing dishes by hand or dishwasher*
- *swimming pool maintenance*

- *lawn watering*
- *flushing toilets*
    - 1992 National Energy Act

http://www.eoearth.org/article/energy_policy_act_of_1992%2C_united_states

    - 1997: illegal to sell old toilet styles with large tanks
    - 1.6-gal toilet; 1.1-gal or less toilet

3) *recycling of* **gray water** *(slightly dirty water from sinks, showers, washing clothes, etc.)*
4) treatment of wastewater to use for watering lawns
5) **xeriscaping** is encouraged to cut down on water required

IX. Stormwater

A. Mismanagement and Its Consequences

1) flooding
2) streambank erosion
3) soil erosion
4) undercutting of tree roots
5) disruption of stream shape and flow
6) property damage
7) increased pollution from
    a) fertilizer
    b) pesticides
    c) rock salt
    d) fecal bacteria
    e) oil/grease
    f) trash
8) **channelization**—*human intervention, adjustment of stream banks*
    a) merely postpones where the flooding will occur
    b) disrupts natural ecosystem

B. Improving Stormwater Management

1. *large scale*
    - *storm water retention reservoir—a pond holding runoff water*
2. *small scale*
    a) *collecting water in various containers to reuse it*
    b) *gravel trenches, letting water percolate down*
    c) *terracing*

X. Water Stewardship

A. Key points:

- We must realize we have a large impact on the water cycle.
- We must conserve what we can.
- We must take responsibility for our actions.

B. Public Policy Challenges

1) *Water Wars*—water needed for irrigation vs. water needed for drinking
2) **The Clean Water Act (CWA) of 1972**
    a) the cornerstone of surface water quality protection in the U.S.
    b) does not deal directly with ground water or water quantity issues
3) **World Water Council – WWC**

World Water Council (WWC) http://www.worldwatercouncil.org/

"The World Water Council was established in 1996 in response to increasing concern from the global community about world water issues. Its mission is to promote awareness, build political commitment and trigger action on critical water issues at all levels, including the highest decision-making level, to facilitate the efficient management and use of water in all its dimensions and on an environmentally sustainable basis."

4) **World Water Forum - WWF**

Meets every three years in different venues all over the globe

World Water Forum (WWF) http://www.worldwaterforum.org/home/home.asp

"The World Water Forum is an initiative of the World Water Council that has the aim of raising the awareness on water issues all over the world. As the main international event on water, it seeks to enable multi-stakeholder participation and dialogue to influence water policy making at a global level, thus assuring better living standards for people all over the world and a more responsible social behavior towards water issues in-line with the pursuit of sustainable development.

The World Water Forums are built on the knowledge, experience and input of different types of organizations active in the global water polity. It is a venture founded on the principles of collaboration, partnership and innovation."