Chapter 21

WATER SUPPLY, USE, AND MANAGEMENT

21.1 WATER

Case Study: What is the Value of Clean Water to New York City?

The water supply for NYC originates in the Catskill Mountains within a basin that is only 8% owned by the city. In the 1990s the city opened a waste water treatment plant in the Catsills to protect its water supply, and the city provides financial incentives to farmers and homeowners living in the basin to maintain best management practices. Thus, the city has chosen to protect its watershed to produce clean water rather than constructing and maintaining expensive drinking water treatment plants.

- Properties:
  High heat capacity – can modify climate
  Universal solvent – will dissolve salts and minerals
  Has a high surface tension – a property that plants rely on (transpiration)

One of the few substances that is lighter as a solid than as a liquid (ice floats), which has consequences for the origin and evolution of life.

- Review the hydrologic cycle (see Fig 5.6, Fig. 21.2 and Table 21.1).
- Standing stocks: 97% of all water is in the ocean, 2% (and the largest freshwater pool) is in glacial ice. Water moves back and forth slowly between the glacial pool and the ocean as the climate changes. Currently glaciers are melting. There is a net movement of water globally from the ocean to the atmosphere (as evaporation) and to the land (as precipitation), and back to the ocean in runoff. Only a small fraction (less than 1%) of the water in the hydrologic cycle is of practical use by people.
- Use of water increases with population; consumption worldwide is about 6,000 km^3/yr, which is a significant fraction of the available fresh water. Consider that the volume of water in rivers is only 1,200 km^3, but the average turnover is on the order of 2 weeks. So, roughly, people use about 10 weeks of supply, which is significant. The U.S. Water Resources Council estimates that water use in the U.S. by 2020 may exceed surface water resources by 13%. Thus, wise management of water is quite important.
- Ground water refers to the water below the **water table** in the saturated zone. Ground water drains slowly, eventually toward the sea, and seeps out from **discharge zones**. New water enters the saturated zone from **recharge areas**. An **aquifer** is a body of ground water from which water can be withdrawn mechanically or under pressure (as from an **artesian well**).
- Streams are classified as **effluent** (when flow is maintained by base flow) or **influent** (when flow is above the water table and is dependent on surface runoff). Effluent streams may be **perennial**, while influent streams are **ephemeral**.
- Surface water and ground water interact because they are connected by flow paths.

21.2 WATER SUPPLY IN THE U.S.

- Water approximately obeys a mass balance and, neglecting consumption due to photosynthesis and production due to respiration, the balance is: Precipitation = Runoff + Evapotranspiration + Infiltration. Infiltration may or may not be important, depending on the location and spatial scale. See Table 21.2 for continental scale water budgets. The continental U.S. receives about 16,0000 million m^3/yr of precipitation. 65% of that is returned to the atmosphere via ET. Roughly 35% runs off into the ocean, most of it (68% of runoff and subsurface flow) drains into the Atlantic Ocean (see Fig. 21.5).
- Precipitation and runoff often vary greatly over time, with season, drought cycles, etc. The amount of sustainable water supply to people is normally less than the time-averaged runoff rate.
- Droughts can occur anywhere; long range forecasting is not yet possible, but they can be predicted to occur with some frequency, depending on the region.
- Groundwater accounts for 20% of all water used in the U.S. There are areas in the U.S. where the recharge rate is much slower than the rate of withdrawal. The Ogallala aquifer in the mid-west is important for agriculture and is being depleted. In regions along the coast, where withdrawals exceed recharge, a cone of depression develops, which causes salt intrusion.
- Desalination, a process of removing salt from water, is used in a number of areas (largely islands and coastal regions), but is about 10x more expensive than surface, freshwater. The process is energetically expensive and has environmental impacts (brine is a byproduct).

21.3 WATER USE

- Water use is classified as off-stream (withdrawals, removed from the source) or in-stream (incl. navigation, hydroelectric generation, etc.). Off-stream use includes consumptive uses, which are water withdrawals that are not returned to the source, e.g. irrigation, some industrial uses, etc.). Off-stream and in-stream uses present their own unique environmental problems. E.g. how much water can be consumptively removed, or how much of a river's flow can be held behind a dam before the river ecosystem is damaged.
- Water is often transported from areas of surplus to areas of deficit. This has been practiced by multiple civilizations for several 1000 years. Major cities like NYC import water through a series of pipes from reservoirs in the region. Southern California is a spectacular example of a megalopolis that runs entirely on water imported through a series of canals from northern California and the Colorado River. The Colorado River is now almost completely consumed within the United States; only a trickle enters Mexico.
- Trends: the major uses of water are for irrigation and thermoelectric power (cooling). Water use of agriculture leveled off beginning about 1980; thermoelectric uses have declined slightly since 1980; use of water for public and rural supplied are relatively small, but are increasing due most likely to population growth (See Fig. 21.10).

21.4 CONSERVATION

- Improved irrigation could reduce agricultural withdrawals by 20-30%, which would have a large impact. Conservation could be encouraged by modifying the price structure of water, lining canals to reduce seepage and evaporation, optimizing the transport and irrigation times, using improved irrigation systems (e.g. drip), etc.
- Domestic use is only about 10% of the total national water withdrawals. However, urban consumption is regionally significant as in the SW. Conservation could be achieved by xeriscaping, using more efficient toilet fixtures and appliances (e.g. toilets are available with two flush modes for #1 and #2!), and common sense measures. Use of grey water for irrigation should be encouraged.

A closer look 21.1: Water Supplies in Trouble

- Southern California is growing rapidly, and its water needs are exceeding capacity. San Diego is negotiating with farmers in the Imperial Valley to purchase their water. Other problems areas include Denver, Chicago, Tampa, Atlanta and New York. The legal issues involving water rights are complex, and states are heading to court as they compete for control. Thus, regional scale water resource problems are appearing.
- Improvements in water use efficiency by industry are possible, e.g. by using cooling towers for steam generating electric power plants instead of water.
- Public perception of water conservation is important. If water is cheap and inexpensive, there is little incentive to conserve.

21.5 SUSTAINABILITY AND MANAGEMENT

- Sustained use of water can be defined as use of water resources in a way that allows society to flourish into the future without degrading the hydrologic cycle or the ecological systems that depend on it.
- Groundwater sustainability involves balancing the rates of withdrawal and recharge. Ground water consumption in some areas is not sustainable.
- Water management is more difficult in areas where the need for management is greatest. Where water is limited, management will need to encompass a multidimensional approach, termed a variable-water-source approach.
- A master management plan would include contingencies for drought years, such as rationing and reuse of waste water. Surface water should be used preferentially over ground water. Manipulations of the hydrologic cycle should minimize environmental impacts.

21.6 WETLANDS

- Wetlands are areas where the surface soil is permanently or periodically flooded, which gives the soils unique chemical properties. Wetlands are classified as such on the basis of their unique soils and vegetation.
- Wetlands constitute a small amount of land area, but are quite important for the ecological functions that they provide, and they are threatened, primarily by draining and filling. Wetlands absorb water in times of flood; they are often areas of recharge or

discharge; they harbor many threatened and endangered species; they are important nursery areas; they filter and cleanse water; they are productive; they are carbon sinks; and some (coastal wetlands) protect human infrastructure against the force of destructive storms. There are different kinds of wetlands depending on the local hydrogeomorphology. One large wetland area of particular concern is at the mouth of the Mississippi River (MR), and wetlands there are disappearing at a rapid rate due to a combination of factors, including the construction of levees along the MR to control flooding. The wetlands require periodic flooding to supply the sediment they need to keep pace with sea level rise and subsidence. In addition to the numerous biological resources supported by these wetlands, they also protect the city of New Orleans, which is well below mean sea level, from hurricanes.

- Wetlands can be restored and even created, thought there is still controversy about the equivalency of ecological functions afforded by natural and created wetlands. One of the largest wetland restoration projects is focused on the Everglades where decades of modifications to the hydrologic cycle and agricultural runoff have greatly impacted its structure and function. Wetlands also have been created specifically to treat waste water, as well as urban and agricultural runoff. Wetland waste water treatment is quite common in Europe.

21.7 DAMS AND THE ENVIRONMENT

- Dams are constructed to control flooding, to hold back water in times of surplus for later use, and for hydroelectric power. Flood control is accomplished by drawing down the reservoir in anticipation of a period of higher than normal precipitation. There are significant environmental impacts including the loss of land, cultural, and biological resources. Dams also trap sediment. This had led to a decline in the coastal fisheries in some areas (e.g. Nile delta). The presence of a dam also, by design, greatly alters the hydroperiod of the river.
- Canals are constructed for navigation or for transporting water.
- There is a trend in the U.S. now to remove dams that are economically marginal because of the damage they do to river ecosystems.

A CLOSER LOOK 21.2: THREE GORGES

Constructed on the Yangtze River, this is the world's largest dam. It was constructed to produce 18,000 MW of electricity, in spite of displacement of 2 million people, drowned archeological sites and expected negative environmental effects.

21.8 CHANNELIZATION

- Many streams and rivers have been channelized in order to improve navigation and for flood control. Channelization was done in the past without regard to the effects on river and floodplain ecology (see Fig. 21.18), and in some areas (Kissimme River FL) the rivers are being restored.

21.9 THE COLORADO RIVER

● The CR is the major river of the SW US (Fig. 21.22). It is one of the most regulated rivers in the world. Its flow was divided among competing interests (seven U.S. states and Mexico) by the Colorado Compact of 1922. The legal entitlements actually exceed the average flow (Table 21.2). The CR is almost completely consumed. Little flow ever reaches the Gulf of California. Most water is held behind dams and distributed through canals and aqueducts to the major cities and agriculture.

21.10 GLOBAL WATER SHORTAGE AND THE FOOD SUPPLY

● Groundwater and surface water supplies are being strained. Groundwater in the U.S., China, India and Pakistan is being mined and depleted (e.g. Ogallala). Large lakes are drying up (e.g. Aral Sea, Fig. 21.9), large rivers are now entirely consumed. Much of the world's food supply depends on irrigation. In the fertile and productive Imperial Valley, CA, the city is competing for water with agriculture.

CRITICAL THINKING ISSUES

● How wet is a wetland?

Wetlands often occupy transition zones between aquatic and terrestrial environments. Ecological transition zones are referred to as ecotones. The point is that wetlands occupy a continuum. We want to protect wetlands, and alterations of wetlands that occur along navigational waters are regulated. Permits are required by US Army Corps of Engineers, called section 404 permits. This permitting process helps to protect wetlands. However, where along the continuum does one draw the line? Where does the wetland stop and the terrestrial environment begin?

● Should isolated wetlands be protected? How?

Background: Before 2001, the U.S. Army Corps of Engineers used a patchwork of statutes and rules, including the Clean Water Act, the Rivers and Harbors Act and the Commerce Clause of the Constitution to claim regulatory authority over all U.S. wetlands. The Commerce Clause of the Constitution gives Congress the right to pass legislation that regulates activities that may affect interstate commerce. In 1986, the Solid Waste Agency of Northern Cook County (SWANCC), a coalition of municipalities northwest of Chicago, contacted the Corps to determine if depressions on a former strip mine now filled with water were wetlands. If the Corps determined that these filled depressions met the definition of navigable waters, then SWANCC would have to acquire a section 404 permit. The Corps has authority over navigable waters (and that authority has been extended to the wetlands adjacent to navigable waters) granted by virtue of the commerce clause in the U.S. Constitution. In 1987, the Corps was informed by the Illinois Nature Preserve Commission (a state agency) that "a number of migratory bird species had been observed [on the land]." After this observation, the Corps revisited the issue and determined that SWANCC would need a section 404 permit because "all of the waters in the site were in fact used as habitat by migratory birds." This resulted in what is known as the "migratory bird rule" which said that, because birds traveling between states and nations use isolated ponds, the Corps has authority to regulate those wetlands under the Commerce Clause. The logic that links migratory birds, navigable waters, and the commerce clause is quite convoluted, and on January 9, 2001, the U.S. Supreme

Court struck down the migratory bird rule, and the Federal Government lost its authority to protect/regulate isolated wetlands. One important message here is that all regulation at the Federal level must be authorized by our Constitution.

Should a local municipality be allowed to divert water from agricultural areas if that reduces food production? The example of this, introduced above, is the competition for water between the urban population of S.W. California and agriculture in the Imperial Valley. Without irrigation, the IV is a desert. With irrigation it is fertile ground in a climate favorable for winter vegetables and fruit. Much of the produce in our grocery stores, including winter produce, is from the IM.

Web Resources

http://water.usgs.gov/ This is the home page of the USGS Water Resources Division with links to everything you need to know about water resources in the United States, including water use statistics, flow statistics, and water quality information.

http://www.nwrc.usgs.gov/ The homepage of the USGS National Wetlands Research Center. This site has some great resources, including much information about wetlands loss issues in coastal Louisiana.