



Chapter 14

Water



“It’s A Small World After All”

Outline

Water’s Importance, Availability, and Renewal

- A. Water keeps us alive, moderates climate, sculpts the land, removes and dilutes wastes and pollutants, and moves continually through the hydrologic cycle.
 - 1. It covers about 71% of the earth’s surface; most organisms cells contain about 60%.
 - 2. Water is an amazing molecule with unique properties that affect life on earth.
 - 3. Water is one of our most poorly managed resources.
 - 4. Access to water is a global issue, a children’s issue, a women’s issue, and an environmental issue.
- B. Only about 0.024% of the earth’s water supply is available to us as liquid freshwater in accessible groundwater deposits and in lakes, rivers, and streams. The hydrologic cycle collects, purifies, recycles, and distributes the world’s freshwater supply. Some countries have more water than they need; some countries have far less.
- C. Some precipitation infiltrates the ground and percolates downward through spaces in the soil, gravel, and rock. This water is known as groundwater, an important fresh water source.
 - 1. In the zone of saturation, the spaces in the ground are filled with water.
 - 3. The water table is located at the top of the zone of saturation.
 - 3. An aquifer is deeper down in the geologic layers and is like an elongated sponge with watertight layers of rock or clay below the aquifer to keep water from seeping out.
 - 4. A natural recharge replenishes an aquifer through the precipitation that percolates down through soil and rock. This recharge occurs extremely slowly.
 - 5. Lateral recharge is replenished from the side of nearby streams.
 - 6. Water mining withdraws water from deep underground, ancient deposits of water that are not generally recharged.
- D. Water that does not sink into the ground or evaporate into the air runs off into bodies of water. This is known as surface water.
 - 1. Water that flows across the earth and empties into rivers, streams, lakes, etc., and so does not infiltrate the ground or evaporate into the atmosphere is called surface runoff.
 - 2. A watershed/drainage basin is that region from which surface water drains into a body of water.
 - 3. There is a hydrological connection between surface water and groundwater as shown in Figure 14-3.
- E. We currently use more than half (54%) of the world’s reliable runoff of surface water and could be using 70-90% by 2025.
 - 1. Two-thirds of the annual surface runoff is not available for human use; the remaining one-third is reliable runoff that is stable and that we count on from year to year.
 - 2. As a result of increased population and withdrawal rates, we now withdraw about 34% of the world’s reliable runoff. We also use another 20% of this runoff for other purposes.
- F. About 70% of the water we withdraw from rivers, lakes, and aquifers is not returned to these sources.
 - 1. Most freshwater use is consumptive use and does not return water to its original sources, mostly because of losses such as evaporation, seepage into the ground, transport to another area, or contamination.
- G. Irrigation is the biggest user of water (70%), followed by industries (20%) and cities and residences (10%).
 - 1. 70% of the water we withdraw from surface water/aquifers is to irrigate crops, which account for 40% of the world’s food
 - 2. About 85% of this water is consumed, not returned to its water basin.
- H. The United States has plenty of freshwater, but supplies vary in different areas depending on climate.
 - 1. This unequal distribution of water can be seen in Figure 14-4.
 - 2. There are water hot spots in 17 western states (Figure 14-5), that could trigger intense conflict in the next 20 years.

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- A. Almost 41% of the world’s population lives in river basins that do not have enough freshwater.
 - 1. More than 30 countries face water scarcity. This figure could reach 60 countries by 2050.
 - 2. A United Nations study found that one of six people do not have access to adequate, affordable, and clean water.
 - 3. The volumes of water in some of the world’s largest lakes have shrunk because of water diversion and periods of prolonged drought.
 - 4. Poor people live in hydrological poverty; more than two-thirds of the world’s households do not have access to clean water at a reasonable cost.
 - 5. People in developed countries live near water supplies, but people in developing countries must make do with what is available.
 - 6. Sanitation levels decline when the daily supply of water decreases. Diseases caused by drinking unsanitary water kill at least 3 million people a year.
- B. There is controversy over whether water supplies should be owned and managed by governments or by private corporations. Most people believe that everyone has a right to clean water.
 - 1. Most water resources are owned by governments and managed as publicly owned resources, but a number of governments hiring private companies to manage them. There have been mixed results and the lesson learned is that governments need to maintain strict oversight of these contracts.
 - 2. Currently, 85% of Americans get their water from publicly owned companies.
 - 3. Two possible problems with a totally privatized water system are: First, private companies have an incentive to seal as much water as possible rather than conserve it; second, the poor will continue to be left out because they can’t pay for the water.
- C. Cities are outbidding farmers for water supplies from rivers and aquifers; countries are importing grain as a way to reduce their water use; and more crops are being used to produce biofuels.
- D. We can get more water from aquifers and rivers, desalinate ocean water, and waste much less water.

Withdrawing Groundwater to Increase Supplies

- A. Most aquifers are renewable resources unless water is removed faster than it is replenished or the aquifers are contaminated. Aquifers provide almost one-fourth of the world’s water.
- B. In many parts of the world, aquifers are being depleted faster than they are renewed.
 - 1. Water tables are falling in many areas of the world because the rate of pumping out water (mostly to irrigate crops) exceeds the rate of natural recharge from precipitation.
 - 2. The widespread drilling of inexpensive tube wells by small farmers, especially in Asia, has accelerated aquifer over pumping.
 - 3. In the United States, groundwater is being withdrawn four times faster than it is being replenished.
 - 4. Government subsidies to farmers have increased depletion of the Ogallala aquifer.
 - 5. Saudi Arabia gets 70% of its water from the world’s largest desalination complex.
- C. Groundwater over pumping can increase the gap between the rich and the poor, cause land to sink, and contaminate freshwater aquifers near coastal areas with saltwater.
- D. Sustainable use of aquifer water requires controlling the rate of water removal, identifying and protecting aquifer recharge zones from development, wasting less water, and slowing population growth.

Using Dams and Reservoirs to Supply More Water

- A. Large dams and reservoirs can produce cheap electricity, reduce downstream flooding, and provide year-round water for irrigating cropland, but they also displace people and disrupt aquatic systems.
 - 1. Dams and reservoirs capture and store runoff water. The water is released to control floods, generate electricity, and to irrigate. Reservoirs also provide for swimming, fishing, and boating.
 - 2. Figure 14-13 shows both the benefits and drawbacks to dams and reservoirs.
- B. The Colorado River has so many dams and withdrawals that it often does not reach the ocean.
 - 1. The Colorado River is 1,400 miles long and has been altered by 14 major dams and reservoirs to the point that water rarely reaches the Gulf of California now. This endangers many species

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that spawn in the river system and has led to increased salt contamination of aquifers near the coast.

- a. The dams and reservoirs make it possible to grow crops, have recreation, raise livestock, generate electric power, and increase the population of rather arid areas.
 - b. The pacts that were drawn for water allocations to the U.S. and Mexico did not consider environmental needs.
 - c. Water was supplied to farmers at a low price, leading to inefficient use of irrigation water to grow crops such as rice, cotton and alfalfa that need a lot of water in watershort areas.
 - d. Other problems include evaporation, leakage, and siltation from large reservoirs.
- C. There is debate over whether the advantages of the world’s largest dam and reservoir will outweigh its disadvantages.
1. When completed the Three Gorges Dam on the Yangtze River (in China) will be the largest hydroelectric dam and reservoir in the world.
 - a. 1.2 million people are being relocated on some land that will not grow much food.
 - b. The dam will reduce China’s dependence on coal and hold back the Yangtze’s floodwaters.
 - c. Large cargo-carrying ships will be able to go into China’s interior and, thus, reduce current transportation costs.
 - d. The dam is built over a seismic fault and there is worry that millions of people will be killed should the dam collapse.
- D. Some dams are being removed for ecological reasons and because they have outlived their usefulness.

Transferring Water from One Place to Another

- A. Transferring water can make unproductive areas more productive but can cause environmental harm.
- B. A massive transfer of water from water-rich northern California to water-poor southern California has brought many benefits, but remains controversial.
1. Tunnels, aqueducts, and underground pipes can transfer stream runoff.
 2. The California Water Project is one of the worlds’ largest water transfer projects.
 3. Southern California is heavily populated while being used for agriculture.
 4. Water is used inefficiently and for water thirsty crops in southern California.
 5. Opponents to sending more water south state that this would degrade the Sacramento River, disrupt the fisheries and reduce the flushing action that helps to clean San Francisco Bay of pollutants.
 6. Figure 14-16 gives an overview of the project.
- C. Diverting water from the Aral Sea and its two feeder rivers mostly for irrigation has created a major ecological, economic, and health disaster.
1. This activity has tripled the salinity of the sea since 1961, the surface area has decreased, and 90% of its water volume has been lost.
 2. About 85% of the area’s wetlands have been eliminated; roughly half the birds and mammal species have disappeared.
 3. Huge areas of the lake bottom are now white salt desert that appears to have caused the extinction of 20 of the 24 native fish species.
 4. The fishing industry has disappeared; salty dust from the exposed seabed blows onto fields as much as 190 miles away. Chemicals used to raise crop yields are poisoning the groundwater.
 5. The reduction in the size of the sea has changed the area’s climate for the worse.
 6. Health problems from the toxic dust, salt, and contaminated water plague the people.
 7. Crop yields have decreased by 20-50% on almost a third of the area’s cropland.
 8. Since 1999, the UN and the World Bank have spent about \$600 million to purify drinking water, upgrade irrigation efficiency, and flush salts from croplands.
 9. Some artificial wetlands and lakes have been constructed to help restore aquatic vegetation, wildlife, and fisheries. With the various improvements, the water volume in the Aral Sea has stabilized.

Desalting Seawater, Seeding Clouds, and Towing Icebergs and Giant Baggies

- A. Removing salt from seawater by current methods is expensive and produces large amounts of salty

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wastewater that must be disposed of properly. The process is known as desalination.

1. One desalination method is distillation, which heats salt water until it evaporates and condenses as fresh water; the salts are left behind as solids.
 - a. Desalination is very expensive because of the amount of energy used.
 - b. Desalination produces large amounts of wastewater, which must be disposed of.
 2. Another method of desalination is to use reverse osmosis, a method of pumping salt water under high pressure through a thin membrane.
 3. Desalination is currently only feasible for rich, coastal areas due to its high cost.
 4. Scientists are working to develop new membranes for reverse osmosis that can separate water from salt more efficiently and under less pressure.
- B. Seeding clouds with tiny particles of chemicals to increase rainfall or towing icebergs or huge bags filled with freshwater to dry coastal areas are unlikely to provide significant amounts of freshwater. Cloud seeding has been tried by 10 U.S. states and 24 countries. Dry ice or some other particles are seeded into clouds to act as a nucleus for raindrops.
1. This does not work well in very dry areas because there are few clouds in these regions.
 2. This method introduces large amounts of the chemicals used into soil and water systems and may harm people and wildlife.
 3. Seeding has led to legal disputes over the ownership of cloud water.
 4. Some analysts proposed towing icebergs or huge bags of water to arid coastal areas from the Arctic or Antarctica, but there is no technology to do this and the expense would be too great.
 5. A company has also suggested collecting spring runoff water from northern California in large plastic bags and having tugboats tow them to southern California.

Increasing Water Supplies by Wasting Less Water

- A. We waste about two-thirds of the water we use, but we could cut this waste to 15%.
1. 65-70% of water that we now use is wasted through evaporation, leaks, and other losses.
 2. Being more careful of water use will provide water for the foreseeable future.
 3. Reasons for water being wasted are that it is under priced and we do not reward conservation.
 4. Government subsidies should be for improving the efficiency of water use, not to support farmers’ energy costs for obtaining water.
 5. Lifeline water pricing is a means of giving each household an amount of water for basic needs, excess usage means higher prices.
- B. Sixty percent of the world’s irrigation water is currently wasted, but with improved irrigation techniques could cut this waste to 5-20%.
1. Use center-pivot low-pressure sprinkler irrigation, which sprays water directly on a crop rather than flood irrigation, which provides water flowing in ditches in crop fields.
 2. Low-energy precision application (LEPA) sprinklers spray water closer to the ground than the center-pivot low-pressure sprinkler, using less energy and less water.
 3. Use soil moisture detectors to water crops only when they need it.
 4. Drip irrigation/microirrigation systems are the most efficient ways to move small amounts of water to crops. Small holes in a network of perforated plastic tubing deliver drops of water at a slow and steady pace to plant roots.
 - a. It is very efficient with water input reaching crops.
 - b. New types of drip systems cost 1/10th as much per hectare as conventional drip systems.
- C. Many poor farmers in developing countries use low-tech methods to pump groundwater and make more efficient use of rainfall.
- D. Industries can recycle much of the water they use; and homeowners can use water-saving toilets, appliances, and showerheads, fix leaks, use drip irrigation and yard plants that need little water (xeriscaping), save and reuse rainwater, and reuse wastewater for some purposes.
- E. We can reduce water use and waste by raising the price of water while providing low lifeline rates for the poor.
1. Use water meters to monitor use.
 2. Introduce a tiered water pricing system.
- F. We can mimic the way nature deals with wastes instead of using large amounts of high-quality water to wash away and dilute industrial and animal wastes.
1. In current waste treatment systems, we use large amounts of drinkable water to flush and dilute

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wastes.

2. We could mimic nature and return nutrient-rich sludge from conventional waste treatment plants to the soil as fertilizer.
3. Rely more on waterless composting toilets rather than conventional ones.

Too Much Water

- A. Heavy rainfall, rapid snowmelt, removal of vegetation, and destruction of wetlands cause flooding.
 1. A flood happens when water in a stream overflows its normal channel and spills into the adjacent area, called a floodplain.
 2. People settle on floodplains because of fertile soil, ample water, nearby rivers for transportation and recreation, flat land for crops, buildings, highways and railroads.
 3. To allow people to live in floodplains, rivers have been straightened (channelized), equipped with protective levees and walls, and dammed to create reservoirs that store and release water as needed.
 4. Natural benefits include a regular supplement of nutrient-rich silt after a flood and a recharge of the groundwater and wetlands areas
 5. Floods also kill thousands of people and cause great losses by property damage.
 6. Floods are usually considered natural disasters, but since the 1960’s several types of human activities have contributed to a sharp rise in deaths and damages.
 7. Removal of water-absorbing vegetation contributes to greater flooding
 8. Draining wetlands removes a needed “sponge” to absorb floodwaters and reduce the severity of floods.
 9. Paving and building on floodplains also increases the chance of more severe floods.
 10. When Hurricane Katrina struck the Gulf Coast of the United States in August 2005 and flooded much of New Orleans, the damage was intensified because of the earlier degradation of an important ecosystem service: the buffering of storm surges by coastal wetlands.
- B. Bangladesh has experienced increased flooding because of upstream deforestation of Himalayan mountain slopes and the clearing of mangrove forests on its coastal floodplains.
 1. Bangladesh is one of the world’s most densely populated countries, and is very flat.
 2. The people of Bangladesh depend on the moderate annual flooding to maintain soil fertility.
 3. Great floods used to occur about every 50 years or so, but since the 1970’s they now occur about every 4 years.
 4. Cutting of forests in the Himalayan foothills increased runoff and carried away vital topsoil.
 5. Floods and cyclones have destroyed many crops and have killed thousands of people and left many others homeless.
 6. Poor families have cleared many mangrove swamps for fuelwood, farming, and aquaculture ponds for raising shrimp, which ultimately led to greater flooding with the loss of those wetlands.
- C. We can reduce flooding risks by controlling river water flows, protecting mountainside forests, preserving and restoring wetlands, identifying and managing flood-prone areas, and, if possible, choosing not to live in such areas. Ways to prevent and control flooding include:
 1. Channelization reduces upstream flooding, but increases stream velocity and removes bank vegetation.
 2. Levees or floodwalls can be built along the sides of streams. This method contains/accelerates the stream flow increases possibility for damage downstream.
 3. Building dams can also reduce the threat of flooding by storing water in a reservoir for later slow release.
 4. Preserve existing wetlands and restore degraded wetlands to take advantage of natural flood control.
 5. Identify and manage flood-prone areas.
 6. Think carefully about where we choose to live.

Solutions: Using Water More Sustainably

- A. We can use water more sustainably by cutting waste, raising water prices, preserving forests and wetlands in water basins, and slowing population growth. A blue revolution to conserve water would include a mix of several components:

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1. Expand and improve monitoring of river flows.
2. Overhaul water policy to protect forests etc.
3. Regulate withdrawals to prevent aquifer depletion.
4. Leave enough water in rivers to protect wildlife.
5. Remove government subsidies that cause water to be under priced.
6. Switch to waste-treatment systems that accept only nontoxic wastes.
7. Get very serious about slowing global warming.
8. Slow population growth.

Summary

1. Approximately 0.024% of the earth’s water supply is available as liquid freshwater. Management of the world’s water supply is a huge, 21st century challenge.
2. Freshwater shortages are caused by dry climate, droughts, desiccation, and water stress. Solutions for this problem include building dams and reservoirs, transport of freshwater between locations, withdrawing of groundwater, and desalination.
3. Advantages of dams and reservoirs include cheap electricity, reduction of downstream flooding, and year-round water for irrigation. Disadvantages include displacement of people and disruption of aquatic systems, and the hydrological cycle.
4. Transferring large amounts of water from one area to another can give stream runoff from water-rich areas to water-poor areas and aid in irrigation of farmland. It can also cause ecological, economical, and health disasters.
5. The advantages of withdrawing groundwater include water for drinking and irrigation, availability and locality, low cost, no evaporation losses, and it is renewable. Disadvantages include aquifer depletion from over pumping, subsidence, pollution, saltwater intrusion, and reduced water flow. Desalination increases the supply of fresh water but is expensive and produces large quantities of wastewater.
6. We can waste less water by lining canals, leveling fields, irrigating at night or using new irrigation techniques, polyculture or organic farming, seasonal farming, irrigating with treated waste water, and importing water-intensive crops and meat.
7. Flooding is caused by heavy rain or melting of snow within a short time. To reduce flood damage or the risk of flooding we must avoid building on floodplains, removing water-absorbing vegetation, or draining wetlands.
8. Methods for achieving more sustainable use of the earth’s water include not depleting aquifers, preserving aquatic systems and water quality, integrated watershed management, agreements among regions and countries sharing surface water resources, outside party mediation of water disputes nations, marketing of water rights, raising water prices, wasting less water, decreasing government subsidies for reducing water waste, and slowing population growth.

Objectives

1. Briefly describe earth's water supply. Compare amounts of salt water and fresh water. Compare amounts of frozen fresh water and water available for human use. Define *watershed* and *groundwater*.
2. Summarize water use in the United States and the world.
3. List four causes of water scarcity. Describe the factors that play into a positive feedback loop creating water stress. Assess the significance of water resources for international relations.

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4. List five ways to increase the water supply. List advantages and disadvantages of each strategy. Summarize a key lesson learned from the following case studies: the Colorado River; Egypt's Aswan High Dam; the California Water Project; the James Bay project; the Aral Sea disaster.
5. Describe the role of groundwater in supplying fresh water. Assess our current use of groundwater: is it sustainable use? Determine which principles are best illustrated by the Ogallala Aquifer experience. Distinguish between *riparian rights* and *prior appropriation* as to regulate water use.
6. State the percentage of water wasted throughout the world. Briefly describe measures that can be taken to reduce water losses through irrigation, industry, and home use.
7. Describe the history of the development of the Columbia River Basin. Summarize the lessons learned from the problems that were generated and the plans to address those problems.
8. List three ways that humans contribute to flooding. List four strategies humans employ to minimize the risks of flooding. Analyze the water problems of Bangladesh. What key principles are illustrated by this case study?
9. List and describe four ways humans use to control flooding. Evaluate which of these strategies is likely to have the best long-term results.
10. Describe the pieces that contribute to a picture of sustainable water use.

Key Terms (Terms are listed in the same font style as they appear in the text.)

<p>Aral Sea (p. 321) aquifers (p. 307) <i>California Water Project</i> (p. 320) <i>center-pivot low-pressure sprinklers</i> (p. 325) <i>channelization</i> (p. 331) <i>consumptive water use</i> (p. 308) Desalination (p. 322) <i>distillation</i> (p. 323) drainage basin (p. 307) <i>drip irrigation systems</i> (p. 325) <i>flood irrigation</i> (p. 324) natural recharge (p. 307) <i>nonconsumptive use</i> (p. 309) Ogallala aquifer (p. 307) <i>rainwater harvesting</i> (p. 326) reliable runoff (p. 308) <i>reverse osmosis</i> (p. 323) <i>sinkholes</i> (p. 314) <i>soil moisture detectors</i> (p. 326) surface runoff (p. 307) surface water (p. 307)</p>	<p>floodplain (p. 329) <i>gray water</i> (p. 328) groundwater (p. 307) <i>hydrologic cycle</i> (p. 306) <i>hydrological connection</i> (p. 307) <i>hydrological poverty</i> (p. 305) <i>land subsidence</i> (p. 314) <i>lateral recharge</i> (p. 307) <i>low-energy precision application (LEPA)</i> <i>sprinklers</i> (p. 325) <i>microirrigation systems</i> (p. 325) Three Gorges Dam (p. 319) <i>tiered water-pricing system</i> (p. 328) <i>user-pays approach</i> (p. 324) <i>water hot spots</i> (p. 310) water table (p. 307) watershed (p. 307) <i>withdrawal</i> (p. 308) <i>xeriscaping</i> (p. 328) zone of saturation (p. 307)</p>
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