# 8.2: The Hydrosphere

Water, chemical formula $H_2O$, comprises the hydrosphere (Figure 8.1). As discussed in more detail in Chapter 9, although it has a simple chemical formula, water is actually a very complex substance largely because of the water molecule's polarity and ability to form hydrogen bonds. Water participates in one of the great natural cycles of matter, the **hydrologic cycle** illustrated in Figure 8.1. Basically the hydrologic cycle is powered by solar energy that evaporates water as atmospheric water vapor from the oceans and bodies of fresh water from where it may be

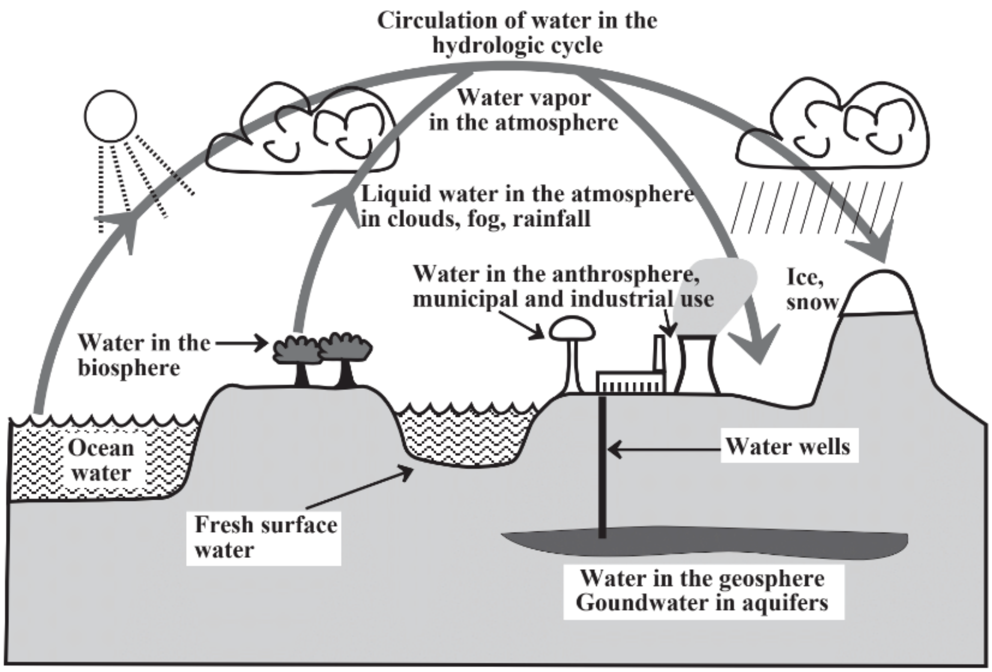


Figure 8.1. The hydrosphere overlaps strongly with all the other environmental spheres. This illustration shows water in bodies of water, underground as groundwater, in snow pack, in plants in the biosphere, as droplets and vapor in the atmosphere, and in water distribution systems and cooling towers in the anthrosphere. Water's cycle in the environment is the hydrologic cycle shown here in which solar energy evaporates water from the oceans, surface bodies of water, soil, and plants (transpiration) and the water in the atmosphere is carried for a distance (sometimes thousands of kilometers), falls back to Earth as precipitation, infiltrates in part into groundwater, moves on Earth's surface in rivers, back in part to the oceans, then evaporates to renew the cycle.

carried by wind currents through the atmosphere to fall as rain, snow, or other forms of precipitation in areas far from the source. In addition to carrying water, the hydrologic cycle conveys energy absorbed as latent heat when water is evaporated by solar energy and released as heat when the water condenses to form precipitation.

The hydrosphere is shown in Figure 8.1, which also illustrates its relationship to the other environmental spheres. A remarkable 97.5% of Earth's water is saltwater in the oceans. Of the remaining fresh water, 1.7% of Earth's total water is in polar ice and the Greenland icecap. This leaves only about 0.77% of Earth's water as fresh water for other than ocean-dwelling organisms and for use by humans. This fresh water occurs in natural lakes, rivers, impoundments made by humans, and underground as groundwater. At any given time a miniscule, but very important fraction is contained in the anthrosphere, such as in water distribution systems.

Water is the most widely used substance by organisms in the anthrosphere. Humans use water in their households for drinking, food preparation, cleaning, and disposal of wastes, drawing water from rivers, from impoundments made by damming rivers, and by pumping from underground aquifers. Moving water is one of the oldest forms of power harnessed by humans. Water wheels date back more than 2000 years and hydroelectric power is still the leading source of renewable energy. Hot water vapor (steam) is widely used for heat transfer in industry and in buildings and is the largest means of electrical power generation through the mechanism of steam turbines coupled to electrical generators.

Sustainability demands consideration of the water resource, shortages of which resulting from climate-induced droughts have caused severe problems for many organisms and declines of major civilizations. Devastating floods displace and even kill large numbers of people throughout the world and destroy homes and other structures. Severe droughts curtail plant productivity resulting in food shortages for humans and animals in natural ecosystems and often necessitating slaughter of farm animals. It is feared that both drought and the severity of occasional flooding will become much worse as the result of global warming brought on by rising carbon dioxide levels in the atmosphere (see Chapter 10, Section 10.6).

The maintenance of healthy and prosperous human populations requires consideration of both water quality and quantity. Waterborne diseases including cholera and typhoid have killed millions of people and these and others, especially dysentery, are problems in less developed areas lacking proper sanitation. The prevention of water pollution has been a major objective of the environmental movement and avoiding discharge of harmful water pollutant chemicals is one of the main objectives of the practice of green technology. Water supplies are a concern with respect to terrorism because of their potential for deliberate contamination with biological or chemical agents.

Since ancient times humans have built water reservoirs for water storage and dikes and dams for flood control. Such water management measures have enabled development of large populations in arid regions and in areas vulnerable to flooding. However, unusually severe, prolonged droughts do occur and in past times entire civilizations have been wiped out as a result. The effects of severe droughts are exacerbated by the fact that control of water supplies has enabled excessive growth in water-deficient areas. The Las Vegas metropolitan region of the U.S.and Mexico City in Mexico are examples of metropolitan regions that have outgrown the natural water capital available to them.

Floods cause hundreds of millions of dollars in damage to communities where construction of river dikes and impoundments have enabled agricultural and other developments in flood-prone areas that become overwhelmed by “hundred-year” flood events. Such an incident took place along the Missouri River in 1993 when a 500-year flood overwhelmed most of the protective structures. Failure of the protective systems caused much greater devastation than would otherwise have been the case when Hurricane Katrina destroyed much of New Orleans in 2005. Following the 1993 Missouri River flood, sensible actions were taken in some areas where farm property along the Missouri river was purchased by government agencies and allowed to revert to wildlife habitat in its natural state, which included periodic flooding. It would have been sensible for the future of New Orleans to move areas located below sea level and flooded by levee failure in 2005 to higher ground and to avoid trying to thwart the natural tendency of water to seek lower levels where humans may try to live.

Problems with water supply are discussed in Chapter 9. Figure 9.2 showing rainfall patterns in the continental U.S. reveals that the eastern continental U.S. receives generally adequate rainfall, although damaging droughts may still occur in that region. However, except for northern coastal regions, the western half of the continental U.S. is water-deficient. Water-deficient areas of theU.S. including southern California, Arizona, Nevada, and Colorado have exhibited some of the most rapid population growth in recent decades putting increasing pressure on limited water supplies and making the region vulnerable to prolonged severe droughts. Even much more severe water supply problems exist in other parts of the world, such as sections of Africa and the Middle East including the area of Palestine and Israel.

## Damage to the Hydrosphere

Earth could have lost most of its water by now except for one very fortunate atmospheric feature, the very cold tropopause boundary at the upper part of the atmospheric troposphere. At a temperature well below the freezing point of water, this region converts water vapor to ice that remains in the troposphere and participates in the hydrologic cycle. Were this not the case, the water vapor would infiltrate the next higher atmospheric layer, the stratosphere, where highly energetic solar ultraviolet radiation would split H atoms off the $H_2O$ molecules. These very light atoms and $H_2$ molecules formed from them would have diffused into space, leaving Earth with an arid Martian landscape. In fact, there is probably a net influx of water into Earth’s atmosphere from meteorites that are largely composed of water.

Although water is not destroyed on Earth, the hydrosphere certainly can suffer damage by human activities. One of the main ones of these is excessive utilization of water in arid regions. Withdrawal of irrigation water from rivers in arid regions has reduced some once mighty rivers to trickles by the time they reach the ocean. The water is not destroyed, but it evaporates and in some cases infiltrates to below ground.

Mexico City manifests one of the most serious problems of water over-use, the depletion of groundwater. This highly populous city was built on an old lake bed, and excessive pumping of ground water has caused land subsidence and damage to surface structures. In the U.S. wasteful use of groundwater is illustrated by the depletion of the High Plains Aquifer (Figure 8.2) commonly called the Ogallala aquifer. Largely composed of fossil water remaining from the last

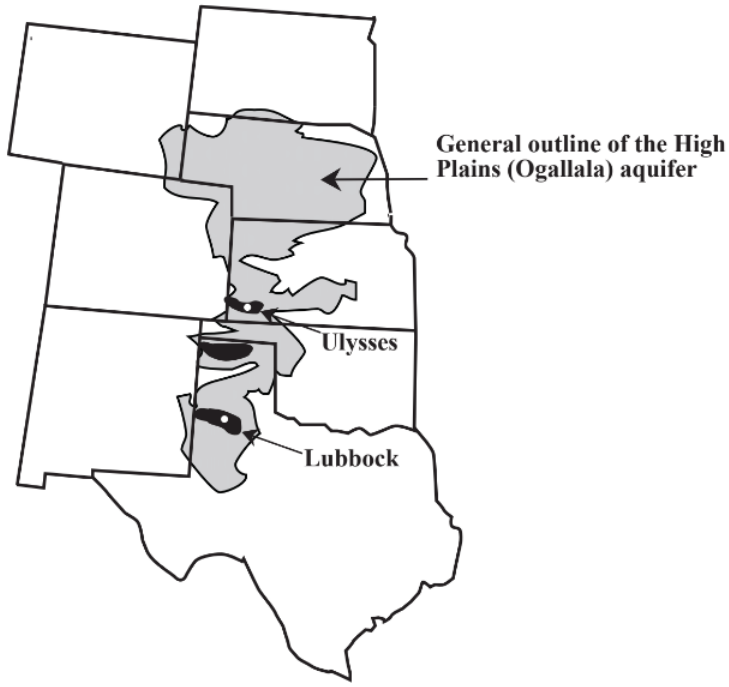


Figure 8.2. The water of the vast Ogallala aquifer, a precious resource remaining from the last Ice Age, has been recklessly exploited and depleted to grow water-intensive crops in semi-arid regions that do not normally support such crops. Areas outlined in black are those in southwestern Kansas and the Texas Panhandle where depletion has been especially severe.

Ice Age, the Ogallala aquifer lies beneath much of Nebraska, western Kansas, the Oklahoma and Texas panhandles, and small sections of eastern Wyoming, Colorado, and New Mexico. Although it is recharged from surface water in parts of Nebraska, it is largely composed of fossil water from the last Ice Age. It contains an astounding amount of water, enough to cover the entire United States to a depth of around 1.5 meters!

Since the 1940s, huge quantities of water pumped from the Ogallala aquifer have been used to irrigate corn and other crops not normally adapted to the High Plains region. As a result, the water table (level reached by water in a well drilled into an aquifer, Figure 8.3) has dropped dramatically, exceeding 50 meters in some areas, In the single decade beginning in 1995, the water level dropped by 6 meters in the middle of Kansas' irrigated corn belt around Ulysses, Kansas. Such unsustainable water depletion will force a shift from thirsty crops, such as corn, to those that require less water, such as milo.

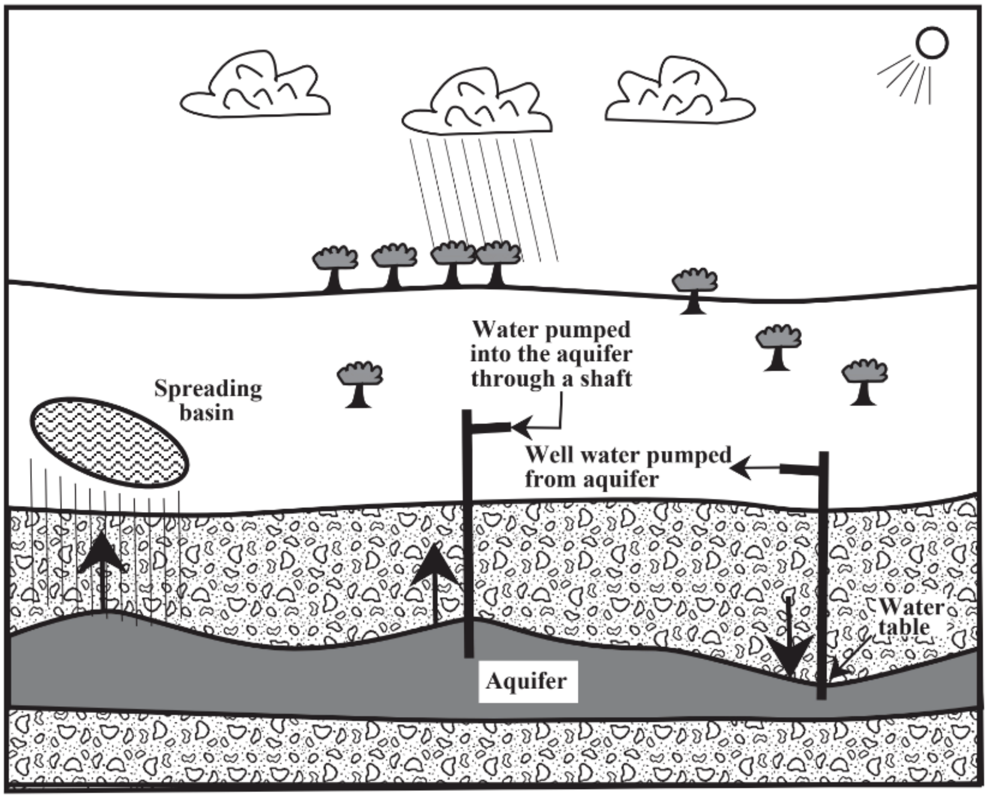


Figure 8.3. Water levels in an aquifer can be directly influenced by human activities. Water levels are lowered by withdrawal of water from wells. The recharge of aquifers can be aided by water infiltrating from spreading basins on the surface or by direct injection of water

The depletion of water supplies has numerous implications for sustainability. Clearly, the U.S. can meet its food demands without exploiting the Ogalla aquifer and other diminishing sources of water. A major thrust of the U.S. energy plan — such as it is — has been increased production of biofuels — ethanol from fermentation of glucose sugar derived from corn and biodiesel fuel from soybeans. The voracious consumption of irrigation water required to grow enough of these crops to make a significant difference in fuel resources is not sustainable. Some underground water supplies should be regarded as depletable resources and reserved for municipal water supplies and manufacturing, which require only a fraction as much water as does irrigation.

## Sustaining the Hydrosphere

Fortunately, the solar-powered hydrologic cycle and the inexhaustible supply of water in Earth's oceans makes water one of nature's most renewable resources. Water is never really consumed or destroyed, although it may become so polluted or dispersed that its reclamation is impractical. Even water infiltrating into the ground may be regarded as recycled water because it renews groundwater sources. Although the thought of so doing has largely prevented efforts to completely recycle water that has been through domestic sewage systems, recycling of this water following purification will have to be practiced in some water-deficient areas in the future. In fact, recycling sewage water has long been the practice where municipalities take their water supplies from rivers into which other municipalities discharge treated wastewater. A very favorable development during the last 30 years is that the trend toward ever increasing water use that prevailed in the U.S. until about 1980 has leveled off due to more efficient irrigation and industrial processes and it appears that total utilization of water will remain relatively constant in the U.S into the future.

As exemplified by the exploitation of the Ogallala aquifer discussed above, human manipulation of the hydrosphere to provide water has often had adverse effects. However, application of the principles of green science and technology can enable supply of water to water-deficient areas without damaging the environment and even with enhancement of water quality. Unlike the over-utilized Colorado and Rio Grande rivers of the southwestern U.S., the enormous flow of the Mississippi River could be tapped for water-deficient areas. One scheme would be to divert a fraction of this flow near the mouth of the Mississippi where it discharges to the Gulf of Mexico and pump the water using abundant wind power to arid regions of the U.S. Southwest and northern Mexico. Mississippi River water retained for some time in constructed wetlands near the point of the diversion could undergo self-purification, collecting sediment that builds up land mass and removing nutrients that are now harmful to water quality in the Gulf of Mexico. Aquatic plants growing in the wetlands and thriving on fertilizer runoff from the upstream Mississippi watershed could remove nutrients that are now harmful to water quality in the Gulf of Mexico.

Groundwater recharge is another key to water sustainability that is being practiced in parts of the world. Most groundwater recharge occurs naturally, although it has been reduced by paving and surface modifications in the anthrosphere. Anthrospheric constructs on the surface can be designed to maximize recharge. For example, some paving surfaces in China have been made of porous materials that allow water to penetrate into the ground below. Two of the more active approaches to groundwater recharge are shown in Figure 8.3. One of these is water pumped into a shaft that extends underground and even to the aquifer itself. Surfaces of these conduits can become clogged with silt, bacterial growths, and other materials suspended in the recharge water and may have to be cleaned periodically. A spreading basin consists of a reservoir of water excavated into porous geospheric material from which water flows into the aquifer. An advantage is the purification of water that occurs through contact with mineral matter, but the process does not work well if aquifers are overlain by poorly pervious layers