

CHAPTER 10

WATER AS A RESOURCE

Important Concepts

1. Water can be considered a renewable resource; however, there is relatively little fresh liquid water in the hydrosphere. Most of the fresh water exists as ice, mainly in the polar ice caps.
2. *Subsurface water* is all the water occupying pore spaces in soils and rocks below the ground surface. *Ground water* is subsurface water that exists below the *water table* within the *zone of saturation*; *soil moisture* is the subsurface water contained in unsaturated soil layers.
3. *Recharge* is the process of infiltration and migration through which groundwater is replenished. Urbanization and the filling in of wetlands can reduce groundwater recharge.
4. An *aquifer* is a rock unit that is sufficiently porous and permeable to be useful as a source of water. *Porosity* is the proportion of void space in rocks or soils; *permeability* is a measure of how readily fluids flow through interconnected pores and cracks in the material.
5. An *unconfined aquifer* is an aquifer directly overlain by permeable rocks and soil. A confined aquifer is bounded above and below by impermeable layers (*aquitards* or *aquicludes*). *Artesian* conditions exist when water in a confined aquifer rises above the apparent water table because of hydrostatic pressure. In an artesian system, the *potentiometric surface* represents the height to which the hydrostatic pressure would raise the water if the water were unconfined.
6. The consequences of ground water withdrawal include lowering of the water table, compaction of aquifer rocks, ground subsidence, *sinkhole* formation, and saltwater intrusion.
7. Commonly used indicators of water quality are the concentrations of a dissolved chemical species (commonly expressed as parts per million, ppm, or parts per billion, ppb), concentration of total dissolved solids (TDS), pH (a measure of acidity), hardness, identification of impurities, and presence of naturally occurring radioactive elements.
8. Americans divert about 400 billion gallons of water from the hydrosphere each day. About 100 billion gallons of this total are consumed (not returned to the hydrosphere as wastewater). Most consumed water is lost to evaporation. Agriculture, by diverting water for irrigation use, is the largest consumer of water.
9. Methods of extending the water supply include conservation, interbasin water transfer, and desalination. Interbasin water transfer is politically sensitive, and both this method and desalination are expensive and pose environmental problems.

Key Terms

aquifer	porosity
aquitard	potentiometric surface
artesian system	recharge
cone of depression	saltwater intrusion
confined aquifer	sinkhole
desalination	soil moisture
ground water	unconfined aquifer
hard water	vadose zone
karst topography	water table
permeability	zone of aeration (vadose zone)
phreatic zone	zone of saturation (phreatic zone)

Multiple Choice

1. Excluding the oceans, the largest reservoir of water in the hydrosphere is
 - a. ground water.
 - b. lakes and streams.
 - c. the atmosphere.
 - d. ice.
2. The largest reservoir of unfrozen fresh water is
 - a. ground water.
 - b. lakes.
 - c. streams.
 - d. the atmosphere.
3. Which one of the following rocks would most likely have both high porosity and high permeability?
 - a. shale
 - b. slate
 - c. granite
 - d. sandstone
4. Soil moisture is found
 - a. within the zone of saturation.
 - b. within the vadose zone.
 - c. within the phreatic zone.
 - d. below the water table.
5. In an unconfined aquifer, the top of the zone of saturation is called the
 - a. potentiometric surface.
 - b. water table.
 - c. saturation limit.
 - d. water level.

6. If a 50-foot well is drilled into an unconfined aquifer where the water table is 30 feet below the surface, how many feet of water will be in the well?
- 10 feet
 - 20 feet
 - 30 feet
 - 50 feet
7. Lenses of low-permeability rocks within permeable ones may result in the formation of
- an artesian system.
 - a confined aquifer.
 - an aquiclude.
 - a perched water table.
8. In an artesian well, the water rises to the height of the
- water table.
 - ground surface.
 - potentiometric surface.
 - top of the aquifer.
9. The lowering of the water table around a pumped well in an unconfined aquifer is called a
- sinkhole.
 - cone of depression.
 - depleted freshwater lens.
 - recharge zone.
10. Excessive ground water withdrawal in the Chicago metropolitan area has resulted in
- a significant lowering of the potentiometric surface.
 - extensive surface subsidence.
 - sinkhole formation.
 - saltwater intrusion.
11. The "mining" of ground water with withdrawal rates exceeding recharge is occurring in all of the following western states except (figure 10.8, p. 231)
- Colorado.
 - Arizona.
 - Kansas.
 - South Dakota.
12. Lowering of the water table can result in all of the following except
- sinkhole formation.
 - surface subsidence.
 - compaction of aquifer rocks.
 - "hardening" of the water.
13. Karst topography is predominantly associated with
- limestone.
 - granite.
 - slate.
 - shale.

14. All of the following are commonly associated with karst terrains except
- caves.
 - sinkholes.
 - surface streams.
 - solution channels.
15. A sample of water having a pH of 7 would be
- acidic.
 - alkaline.
 - neither acidic nor alkaline (i.e., neutral pH).
 - “soft.”
16. Hard water contains substantial amounts of dissolved
- sodium chloride.
 - zeolites.
 - hydrous silicate minerals.
 - calcium and magnesium.
17. Which one of the following states has the highest average annual precipitation?
- Michigan
 - North Dakota
 - Alabama
 - Iowa
18. On a daily basis, the greatest consumer of water is
- agriculture.
 - industry.
 - hydropower generation.
 - municipalities.
19. In which one of the following water-resource regions of the United States does the withdrawal of fresh ground water exceed the withdrawal of fresh surface water?
- Texas-Gulf Region
 - Ohio Region
 - Missouri Region
 - Lower Colorado Region
20. The major problem facing users of the Ogallala aquifer system is
- saltwater intrusion.
 - depletion of ground water.
 - ground water pollution.
 - loss of water pressure.

Fill In the Blanks

- _____ is the proportion of void space in a geologic material (rocks, sediments, soils); _____ is a measure of how readily fluids pass through a geological material.
- The _____, or zone of saturation, is that region of rock or soil in which water fills all the pore spaces.

3. The _____, or zone of aeration, is that partially saturated region of rock or soil above the water table.
4. _____ is the water in the zone of saturation.
5. _____ is the process of infiltration and migration by which ground water is replenished.
6. An _____ is a rock unit that is porous and permeable enough to be useful as a source of water.
7. An _____ aquifer is directly overlain by permeable rocks and soil, whereas a _____ aquifer is bounded above and below by rocks of low permeability.
8. In an _____, ground water can rise above its aquifer because of hydrostatic pressure.
9. The _____ represents the height that water within a confined aquifer would rise due to hydrostatic pressure if the water were unconfined.
10. _____ can occur in coastal regions where ground water withdrawal exceeds recharge, resulting in the replacement of fresh ground water with saline ground water.

True or False

Indicate whether the following statements are true or false. If false, correct the statement to make it true.

- _____ 1. Ground water extends no more than a few kilometers into the earth's crust.
- _____ 2. Springs and lakes may indicate where the water table intersects the land surface.
- _____ 3. The water table below ground tends to mimic the contours of the surface topography.
- _____ 4. Coarse, clastic sedimentary rocks, such as sandstone, make excellent aquifers.
- _____ 5. Artesian water is better-tasting than other ground water because of its purity.
- _____ 6. When withdrawal rates exceed recharge in a confined aquifer, the height of the potentiometric surface rises.
- _____ 7. A sample of water having a concentration of 6 ppm salt contains six grams of salt for every gram of water.
- _____ 8. The per capita use of water in the United States is about one gallon per day.

- _____ 9. Of the total amount of water consumed in the United States, most is lost to evaporation.
- _____ 10. As surface and ground water supplies decline, desalination is probably the best hope of providing sufficient water for irrigation use.

Review Questions

1. How important is ground water as a source of water in the United States?
2. Explain, using sketches as necessary, the difference between:
 - (a) porosity and permeability.
 - (b) aquifer and aquitard.
 - (c) confined aquifer and unconfined aquifer.
3. What are the potential consequences if the ground water withdrawal significantly exceeds the recharge in a given area?
4. What measures can be taken to ensure the continued supply of ground water in a given region?
5. Suppose you want to make sure that your tap water is safe for drinking. What tests should you run to check the water quality?

Surfing the Net

Water resources information with many links (U.S. Geological Survey):

<<http://water.usgs.gov/>>

Information for the public by the National Water-Use Information Program (U.S. Geological Survey):

<<http://water.usgs.gov/public/watuse/wufactsheet.html>>

Water resources information provided by the World Resources Institute:

<<http://www.wri.org/>>

Comprehensive Assessment of the Freshwater Resources of the World (United Nations):

<<http://www.un.org/esa/sustdev/freshwat.htm>>

CHAPTER 10 ANSWER KEY

Multiple Choice

- | | | | |
|-------------------|--------------------|---------------------|----------------------|
| 1. d (table 10.1) | 6. b (figure 10.4) | 11. d (figure 10.9) | 16. c |
| 2. a (table 10.1) | 7. d | 12. d | 17. c (figure 10.19) |
| 3. d | 8. c (figure 10.5) | 13. a | 18. a |
| 4. b | 9. b | 14. c | 19. d (figure 10.23) |
| 5. b | 10. a | 15. c | 20. b |

Fill In the Blanks

- | | |
|---------------------------|--|
| 1. Porosity, permeability | 6. aquifer |
| 2. phreatic zone | 7. unconfined, confined |
| 3. vadose zone | 8. artesian system |
| 4. Ground water | 9. potentiometric surface |
| 5. Recharge | 10. saltwater intrusion (figure 10.12) |

True or False

1. True
2. True
3. True
4. True
5. False. There is no difference chemically between artesian water and other ground water. It is no purer or better tasting.
6. False. When withdrawal rates exceed recharge in a confined aquifer, the height of the potentiometric surface may be lowered.
7. False. A sample of water having a concentration of 6 ppm salt contains six grams of salt for every million grams of water.
8. False. The per capita use of water in the United States is about 1800 gallons per day.
9. True
10. False. Using existing technology, desalination is too costly a method in most areas to provide water for irrigation use.