

The McGraw-Hill Companies

Environmental Science A Study of Interrelationships

Twelfth Edition

Enger & Smith

Chapter 15

Water Management

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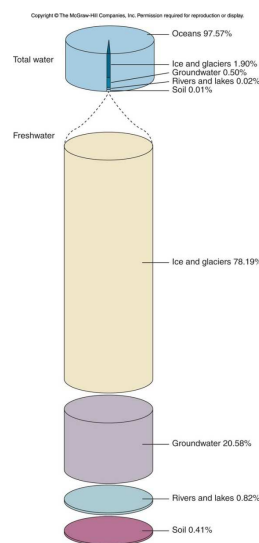
The Water Issue

- Water is the material that makes life possible on Earth.
- Water has remarkable physical properties:
 - Water molecules are polar: one part of the molecule is slightly positive, and the other is slightly negative.
 - Molecules tend to stick together.
 - They also can separate other molecules from each other (solvent).
 - It stores heat.

The Water Issue

- Water quality is as important as its quantity.
- 70% of Earth's surface is covered by water in the form of oceans, representing 97% of all the Earth's water.
- Of Earth's freshwater (3% of total), only a tiny fraction is available for use.
- **Potable water** is unpolluted fresh water, suitable for drinking.
- Shortages can be directly attributed to human-induced water pollution.

The Water Issue

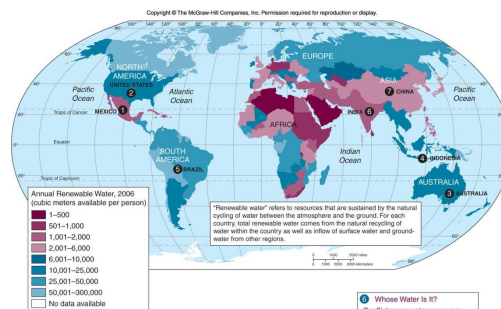


Freshwater resources

The Water Issue

- ✚ The World Health Organization estimates 25% of the world's population does not have access to safe drinking water.
- ✚ According to the U.N. Environment Program, between 5-10 million deaths occur each year from water-related diseases, including cholera, malaria, dengue fever, and dysentery.
 - These illnesses have been increasing over the past decade and without economic investments in safe drinking water supplies, the rate of increase will continue.

The Water Issue



- 1 Antiquated Systems**
 Mexico City, with a population of 20 million people, suffers from water shortages. Aging water pipes also waste millions of liters of water every year.
- 2 Industrial Needs**
 Nearly half of Indonesia's 232 million citizens lack sufficient water because of pollution and poor water storage. Competition for available water is severe between domestic and industrial users.
- 3 Whose Water is It?**
 Conflicts over water resources impact many countries. For example India and Bangladesh have bitterly disagreed over the water resources of the Ganges River for decades.
- 4 Population Pressures**
 Inadequate freshwater supply is a major problem facing China. While the south of China has adequate supplies, the north suffers from frequent shortages. It is the northern part of China that has many of its agricultural and population centers. It is also estimated that 200 million Chinese do not have adequate clean drinking water.
- 5 Depletion of Resources**
 Ninety five percent of the freshwater in the United States is underground in aquifers. Today many aquifers are being depleted faster than they can be replenished.
- 6 Scarcity Where Water Seems Abundant**
 While parts of Brazil have abundant freshwater resources, because of the Amazon River, other parts of the country suffer water shortages. Pollution also severely impacts the country's freshwater supplies.
- 7 Mismanagement**
 Australia is the world's driest inhabited continent. Lack of proper management of water and the effects of global climate change have caused critical water supply problems in parts of Australia.

Source: United Nations, Population Division, UNDP and AQUASTAT/FAO Population Reference Bureau.

Areas of the world experiencing water shortage

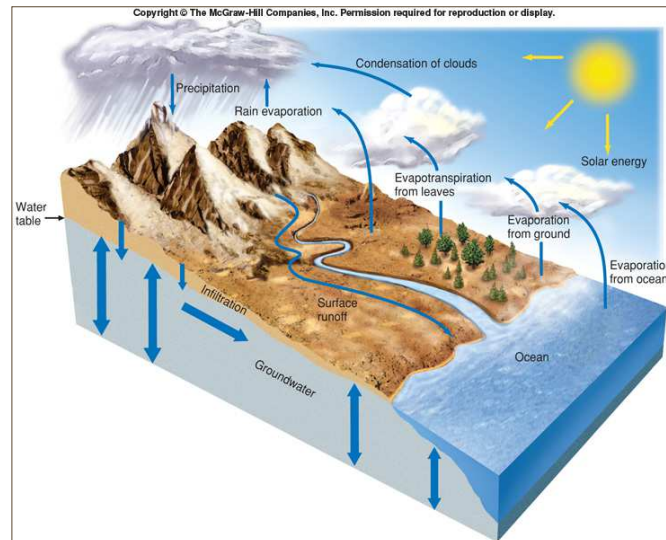
The Hydrologic Cycle

- All water is locked into a constant recycling process called the **hydrologic cycle**.
 - Solar energy evaporates water.
 - **Evapotranspiration** is the process of plants giving off water.
 - Warm, moist air rises, cools, condenses, and falls as precipitation.
 - Some precipitation remains on the surface and evaporates, while most sinks into the soil or returns to the oceans.

The Hydrologic Cycle

- **Runoff** is surface water that moves across the surface of the land and enters streams and rivers.
- **Groundwater** is water that fills spaces in the substrate.
- Water entering the soil is either taken up by plant roots or moves downward until it reaches an impervious layer of rock, and accumulates in porous strata called an **aquifer**.

The Hydrologic Cycle



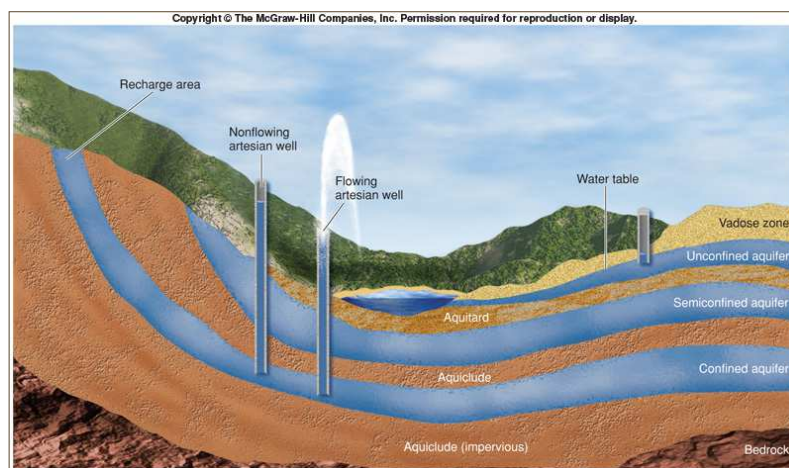
The Hydrologic Cycle

- ✿ An **unconfined aquifer** is usually near land's surface.
 - The top layer saturated with water is called the **water table**.
 - The lower boundary is impermeable layer of clay or rock.
 - Vadose zone (**zone of aeration**) is the area above the water table unsaturated with water.
 - The water in these aquifers is at atmospheric pressure and is recharged by rainfall and percolation.

The Hydrologic Cycle

- A **confined aquifer** is bounded on top and bottom by layers impermeable to water.
 - Water in these aquifers is stored under high pressure and recharged by rain and surface water from a geologic recharge zone.
 - **Porosity** is a measure of the size and number of spaces in the substrate.

The Hydrologic Cycle



Aquifers and groundwater

Human Influences on the Hydrologic Cycle

- Runoff and the infiltration rate are greatly influenced by human activity.
- A major concern in many urban areas is transportation of storm water.
 - Water withdrawals are measurements of the amount of water taken from a source.
 - Water incorporated into a product, or lost to the atmosphere through evaporation or **evapotranspiration**, cannot be reused in the same geographic area and is said to be **consumed**.

Kinds of Water Use

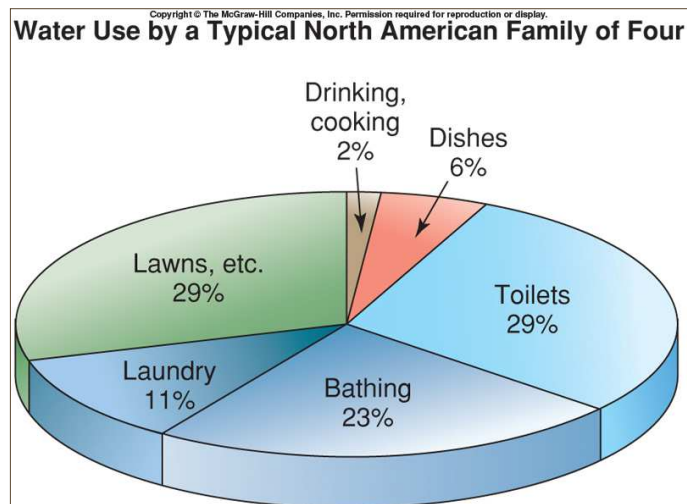
- Freshwater and conservation of aquatic resources are key to human well-being.
- The quality and quantity of water and life supporting ecosystem services are being jeopardized by population growth, rural to urban migration, rising wealth and resource consumption, and climate change.
- If trends continue 1.8 billion people will have a water scarcity by 2025, and 2/3 of the world's populations could suffer water stress.

Kinds of Water Use

Domestic water use

- Over 90% of water used for domestic purposes in North America is supplied by municipal water systems.
- The average person in a North American home uses approximately 400 liters (100 gallons) of domestic water per day.
 - 69% used as solvent to carry wastes (bathing, laundry, toilets, and washing dishes).
 - 29% used for lawn and garden (consumptive use).
 - 2% used for drinking or cooking.

Kinds of Water Use



In Florida, irrigation is often >50% of residential water use.

Kinds of Water Use

- Natural processes cannot cope with highly concentrated urban wastes.
 - It must be treated before release.
 - Some of this water is re-introduced into the surface waters of an area, but in some cases treated wastewater is sent out to the ocean or deep in the ground away from drinking aquifers (hence “lost” from the local system)
- In North America, more than 36 states expect a water crisis in the next ten years.
 - Fast-growing western cities are especially vulnerable.

Kinds of Water Use

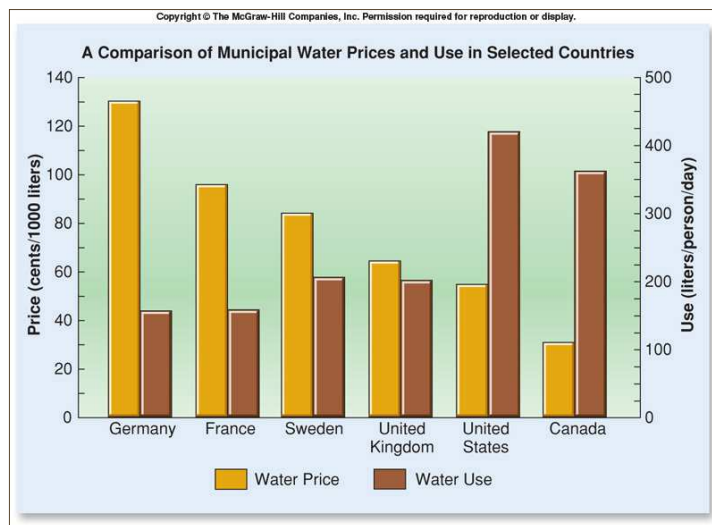
- Shortages of water and increasing purification costs have raised the price of domestic water in many parts of the world, and increased costs do tend to reduce use.
 - Many cities in China are setting quotas on water use that are enforced by higher prices for larger users.
 - In the coastal city of Dalian, a family that uses more than 8000 liters (2113 gallons) per month will pay four times more than a family that conserves water.

Kinds of Water Use

- Public attitude is a major cause of water loss.
 - As long as water is a considered limitless, inexpensive resource, few conservation measures will be taken.
- St. Johns County has a tiered rate structure

Single Family:	Current Rates	New Rates
<u>WATER</u>		
Monthly Rate	\$10.75 Base	\$11.50 Base
Block 1 (0 - 5,000 gallons)	\$2.73 per 1,000	\$2.92 per 1,000
Block 2 (5,001 - 10,000 gallons)	\$3.41 per 1,000	\$3.65 per 1,000
Block 3 (10,001 - 20,000 gallons)	\$5.75 per 1,000	\$6.15 per 1,000
Block 4 (20,001 gallons and over)	\$8.34 per 1,000	\$8.92 per 1,000
<u>WASTEWATER</u>		
Monthly Rate	\$10.31 Base	\$11.03 Base
Usage Charge	\$3.25 per 1,000	\$3.48 per 1,000
<i>The volume charge for single-family users shall not exceed 10,000 gallons per dwelling unit.</i>		

Kinds of Water Use



Water use trends

Kinds of Water Use

- At the federal level, the U.S. Environmental Protection Agency (EPA) is promoting WaterSense, a national consumer labeling program of water-efficient products modeled after its highly successful Energy STAR program.
- Consumers can visit <http://www.epa.gov/watersense/> to find water-efficient products



Kinds of Water Use

- In addition to encouraging the public to conserve water, municipalities can limit losses that occur within the distribution system.
- Leaking water pipes and mains account for significant losses of water.
 - Even in the developed world, losses may be as high as 20%.
 - Poorer countries may lose over 50% of water to leaks.

Kinds of Water Use

🌾 Agricultural Water Use

- In North America, groundwater accounts for about 37% of water used in agriculture and surface water accounts for about 63%.
- Irrigation is the major **consumptive use** of water in most parts of the world (i.e., the water is removed from the local system by evaporation or incorporation into plant tissue) (cf. **non-consumptive use** where the water re-enters the local system).
 - It accounts for about 80% of all water consumed in North America.

Kinds of Water Use

- Costs for irrigation water have traditionally been low since many dams and canals were built with federal assistance (another subsidy).
 - Competition for scarce water resources is prompting communities to raise water rates for irrigation, prompting farmers to conserve.
 - Demand for irrigation water can also be reduced by reducing the quantity of water-demanding crops grown in dry areas.

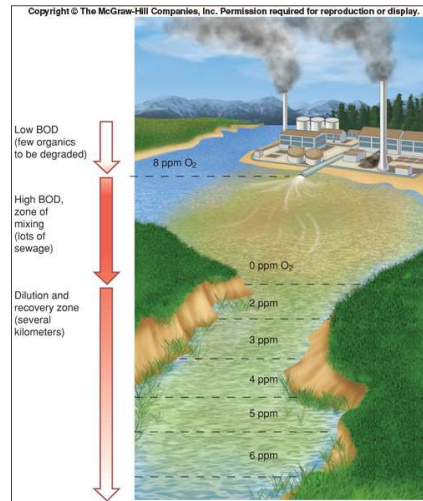
Kinds of Water Use

- The Clean Water Act (1972) seeks to protect U.S. waters from pollution.
 - It specifically regulates pollutant discharges into navigable waters by implementing two concepts:
 - Setting water quality standards for surface water.
 - Limiting effluent discharges into the water.
- Requires states to identify impaired waters
 - FL impaired water list (303(d) list):
 - <http://www.dep.state.fl.us/water/watersheds/assessment/303dmap.htm>

Kinds and Sources of Water Pollution

- Dissolved organic matter is a significant water pollution problem because it decays in the water.
- **Biochemical oxygen demand (BOD)** is the amount of oxygen required to decay a certain amount of organic matter.
 - If too much organic matter is added, all available oxygen will be used up.
 - Anaerobic bacteria begins to break down waste, producing a foul odor.

Kinds and Sources of Water Pollution



Effect of organic wastes on dissolved oxygen.

Kinds and Sources of Water Pollution

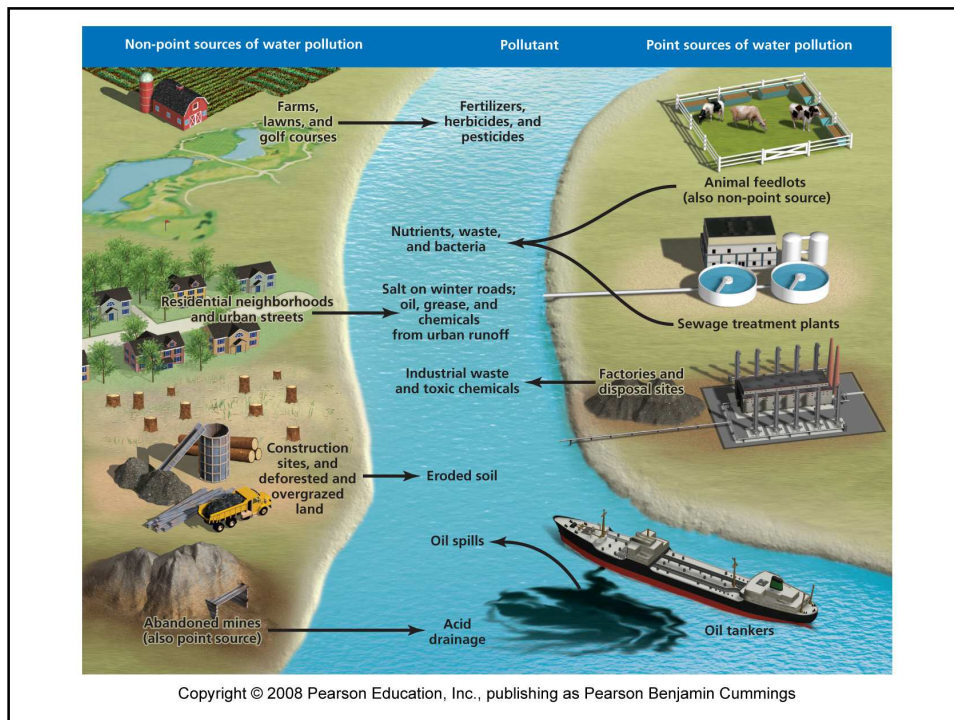
- ❖ Disease-causing organisms are a very important pollution problem in most of the world.
- ❖ Untreated or inadequately treated human or domesticated animal waste is most often the source of these organisms.
- ❖ In the developed world, sewage treatment and drinking-water treatment plants greatly reduce this public health problem.

Kinds and Sources of Water Pollution

- Nutrients can also be a pollution problem.
 - **Eutrophication** is excessive growth of algae and aquatic plants due to added nutrients.
 - Particulate matter can also affect quality.
 - Particles alter the clarity of the water.
 - They cover spawning sites.
 - They act as abrasives that injure organisms.
 - They carry toxic materials.

Kinds and Sources of Water Pollution

- A **point source** is a source of pollution readily located and identified.
 - Municipal and industrial waste discharge pipes.
- **Nonpoint sources** are more difficult to identify and control.
 - Diffuse pollutants from agricultural land and urban paved surfaces come from nonpoint sources.
 - Acid rain



Kinds and Sources of Water Pollution

Individuals can protect surface and ground waters from nonpoint pollution:

- Use less toxic or nontoxic alternatives to commonly used home chemicals.
- Buy chemicals only in the amount you intend to use, and apply them only as directed. More is not better.
- Take unwanted household chemicals to hazardous waste collection centers. Do not pour them down the drain.

Kinds and Sources of Water Pollution

- Never pour unwanted chemicals on the ground.
- Use water-based products whenever possible.
- When landscaping your yard, select (preferably native) plants that have low requirements for water, fertilizers, and pesticides.
- Test your soil before applying fertilizers.

Kinds and Sources of Water Pollution

Municipal Water Pollution

- Waste from homes consists primarily of organic matter from garbage, food preparation, cleaning of clothes and dishes, and human waste.
 - Fecal coliform bacteria is a generic term for bacteria found in the intestines of warm-blooded animals, such as *Escherichia coli* and *Streptococcus faecalis*.
 - Numbers and types of bacteria present in water are directly related to amount of fecal matter entering the system.

Kinds and Sources of Water Pollution

- Wastewater from cleaning dishes and clothing contains some organic material along with soap or detergent.
- Many detergents contain phosphates, which contribute to eutrophication.
- Pharmaceuticals, hormones, detergent metabolites, insecticides, fire retardants, and plasticizers, among other chemicals, also found in municipal water discharge.

Kinds and Sources of Water Pollution

- In a study of 139 streams throughout the United States, the U.S. Geological Survey (USGS) found one or more of these synthetic chemicals in 80% of sampled streams.
 - These chemicals largely escape regulation and are not targeted by municipal wastewater treatment.

Kinds and Sources of Water Pollution

- Agricultural activities are the primary cause of water pollution (pesticides, herbicides, fertilizer).
- Excessive fertilizer use may lead to eutrophication in many aquatic habitats.
 - Runoff from animal feedlots carries nutrients, organic matter, and bacteria.
- Agricultural runoff from large, open expanses is a major source of water pollution, but can be controlled:
 - Leave conservation buffer.
 - Keep soil covered with crop.
 - Control amount and timing of fertilizer application.

Kinds and Sources of Water Pollution

- Factories and industrial complexes frequently dispose of waste in municipal sewage systems.
 - These wastes may require special wastewater treatment.
- Mining is a special source of industrial water pollution.
 - Chemical run-off is released into streams.
 - Water draining from mines is highly acidic.

Kinds and Sources of Water Pollution

- ✿ Marine pollution has many sources, including accidents.
- ✿ The *Exxon Valdez* ran aground in Prince William Sound, Alaska, in 1989 and spilled 42 million liters (11 million gallons) of oil.
 - This affected nearly 930 miles of coastline.
 - Economic impact on the local economy was severe.

Kinds and Sources of Water Pollution

- ✿ A U.S. National Oceanic and Atmospheric Administration study determined:
 - 50% of the spilled oil biodegraded on beaches or in the water
 - 20% evaporated
 - 14% recovered
 - 12% is on sea bottom
 - 3% lies on shorelines
 - <1% still adrift

Kinds and Sources of Water Pollution

- Tanker accidents are spectacular, but more oil is released as a result of small, regular releases from other sources.
 - Two-thirds of all human-caused marine oil is from:
 - Street runoff
 - Improper disposal of lubricating oil
 - Intentional oil discharges during tanker loading and unloading
- An international agreement was reached in 1992 that declared new oil tankers must be double-hulled.
 - Currently 25% of all tankers double-hulled.

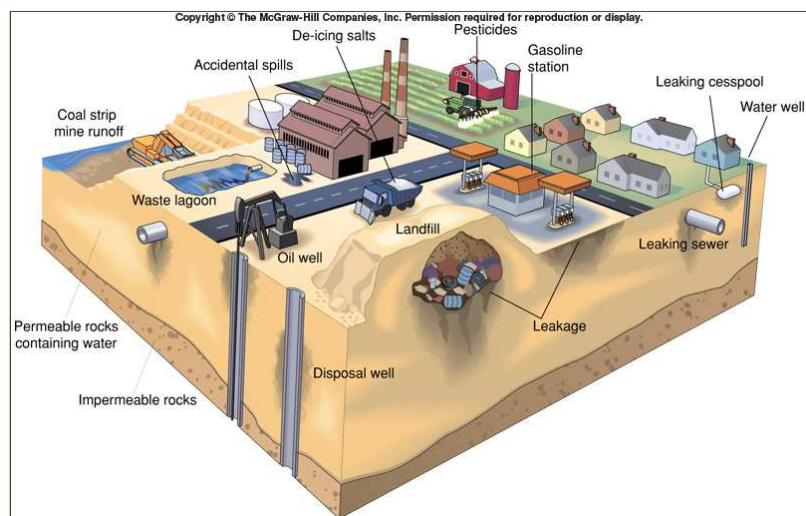
Kinds and Sources of Water Pollution

- Major sources of groundwater pollution include:
 - Agricultural products
 - Pesticides
 - Underground storage tanks
 - Leakage
 - Landfills
 - Approximately 90% of North American landfills have no liners to stop leakage.
 - 96% do not have systems to collect leachate that seeps from the landfill.

Kinds and Sources of Water Pollution

- Septic tanks
 - There are over 20 million septic tanks in U.S.; about one-third are operating improperly.
- Surface impoundments
 - About 71% are unlined
 - 1% use a plastic or other synthetic, non-soil liner
 - 99% have no leak-detection system
 - 73% have no restriction on the waste placed in the impoundment.

Kinds and Sources of Water Pollution



Sources of groundwater contamination

Water-Use Planning Issues

- Historically, wastes were discharged into waterways with little regard for costs imposed on other users by the resulting decrease in water quality.
- The population has grown dramatically, and thus domestic water use has intensified. There has not been enough water to satisfy everyone's needs.

Water-Use Planning Issues

- Metropolitan areas must deal with and provide three basic services:
 - Water supply for human and industrial needs.
 - Wastewater collection and treatment.
 - Storm water collection and management.

Water-Use Planning Issues

- Urban areas are paved, thus little water can be absorbed into the ground, so managing storm water is a problem.
- The Water Quality Act of 1987 requires that municipalities obtain permits for discharges of storm water runoff so that nonpoint pollution sources are controlled.
- Many cities have separated storm sewers from sanitary sewers to avoid contamination in time of flooding and heavy storm water runoff.

Water-Use Planning Issues

- Future issues will have to be addressed:
 - Increased demand will generate pressure to divert water to high-use areas (e.g., from North FL to South FL).
 - There will be increased demand for wastewater treatment and reuse of existing water supplies.
 - Groundwater over-pumping will cause water tables to be lowered.
 - Seawater intrusion in coastal aquifers will ruin water supplies.
 - There will be increased demand for water-based recreation, which demands high water quality.

Water-Use Planning Issues

- **Primary sewage treatment** removes large particles via filtration and then pumps remaining water into settling ponds and lakes.
- After settling, water is drawn off the top, and although devoid of large particulate matter, it still has a heavy load of organic matter, dissolved salts, bacteria, and microorganisms.

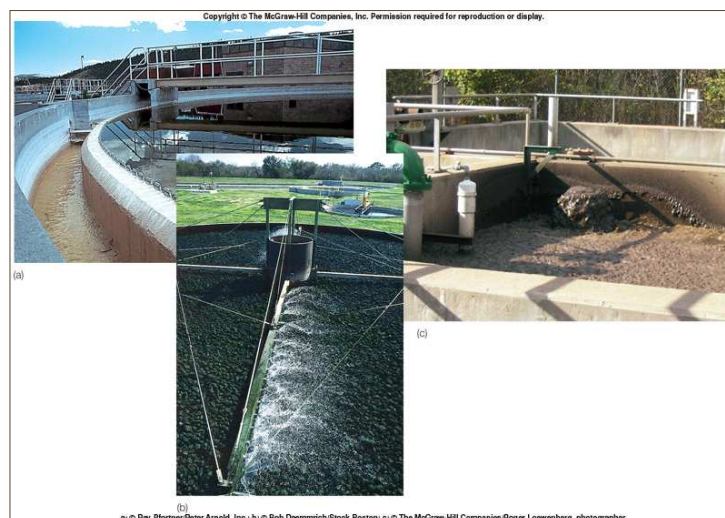
Water-Use Planning Issues

- **Secondary sewage treatment** is a biological process that usually follows primary treatment.
 - Such facilities are designed to promote bacterial and other microorganism growth, which will degrade the organic matter.
 - Wastewater is mixed with large quantities of highly-oxygenated water to encourage this growth.
 - In a **trickling filtering system**, wastewater is sprayed over a surface of rock or other substrate to increase the amount of dissolved oxygen.

Water-Use Planning Issues

- **Sewage sludge** is a mixture of organisms and other particulate matter that have settled out during the treatment process.
- Activated-sludge sewage treatment plants hold wastewater in settling tanks with air continuously bubbled through it, and water and sludge eventually separate out.

Water-Use Planning Issues



Primary and secondary wastewater treatment

Water-Use Planning Issues

- **Tertiary sewage treatment** is an additional stage used to remove inorganic nutrients such as phosphorous and nitrogen left after primary and secondary treatments.
 - This process is costly because it requires specific chemical treatment of the water.
 - Some municipalities use natural or constructed wetlands to serve this stage.
 - Some areas use effluent to irrigate golf courses, roadside vegetation, or cropland. The vegetation takes up the nutrients and prevents them from being released into streams and lakes.

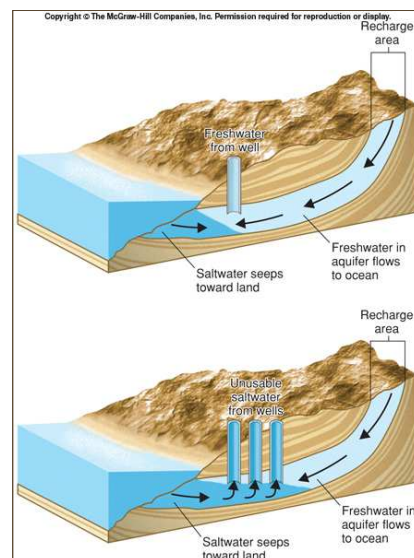
Water-Use Planning Issues

- **Salinization** is an increase in salinity caused by growing salt concentrations in soil.
- As plants extract water from the ground, the salts present in all natural waters become concentrated.
- Irrigation of arid farmland can make salinization more acute due to increased evaporation rates.
 - Primarily a problem in areas under irrigation for several decades.

Water-Use Planning Issues

- **Groundwater mining** is removing water from an aquifer faster than it can be replenished.
 - Extended periods of mining can lead to:
 - Land settling (sinkholes in karst areas like FL).
 - Lowering of the water table.
 - Saltwater intrusion into wells near coastal areas.

Water-Use Planning Issues



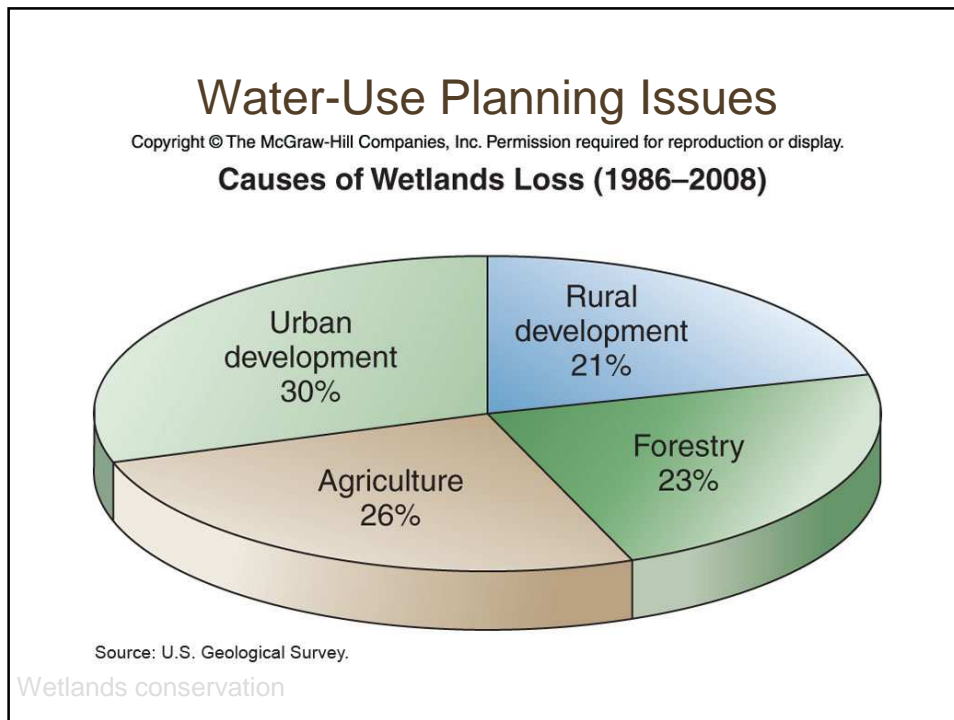
Saltwater intrusion

Water-Use Planning Issues

- An average of 85 billion gallons of groundwater are withdrawn daily in the U.S.
- Management strategies include:
 - Shift from groundwater to surface water, import water from outside the local water-system boundaries.
 - Control pumping with guidelines, policies, taxes, or regulations.
 - Conservation practices, techniques, and technologies
 - Reuse wastewater (grey water) and treated wastewater (reclaimed water) for non-potable purposes.
 - Desalination of brackish groundwater

Water-Use Planning Issues

- Historically, poorly drained areas were considered worthless, and were filled or drained and used as building sites.
 - Less than half the original wetland acreage remains.
 - In the U.S., 95% of the remaining 20 million hectares (221 million acres) of wetlands are inland freshwater wetlands (as compared to coastal brackish wetlands).



Water-Use Planning Issues

- Only recently has the natural and economic importance of wetlands been recognized.
- Wetlands provide:
 - Wildlife spawning and breeding habitats
 - Natural water filtration systems
 - Slow floodwaters, permitting nutrient settling
 - Floodwater control
- We have a national policy of “no net loss” of wetlands, but the implementation is flawed and we continue to lose wetland habitat each year