WATER POLLUTION

GROUNDWATER AND STREAMS

Groundwater usually refers to the water below the water table,

where saturated conditions exist.

The upper surface of the groundwater is called **the water table**.

Rain falls on the land evaporates, runs off the surface, or moves below the surface and is transported underground. Locations where surface waters move into (infiltrate) the ground are known as **recharge zones**. Places where groundwater flows or seeps out at the surface, such as springs, are known as **discharge zones or discharge points.**

Water that moves into the ground from the surface first seeps through pore spaces in the soil and rock known as the **vadose zone.** The water then enters the groundwater system, which is saturated. An **aquifer** is an underground zone or body of earth material from which groundwater can be obtained (from a well) at a useful rate.

Streams may be classified as **effluent** or **influent**.

In an **effluent** stream, the flow is maintained during the dry season by groundwater seepage into the stream channel from the subsurface. A stream that flows all year is called a **perennial** stream.

An **influent** stream is entirely above the water table and flows only in direct response to precipitation. Water from an influent stream seeps down into the subsurface. An influent stream is called an **ephemeral** stream because it doesn't flow all year.

Interactions between Surface Water and Groundwater

Some Trends in Water Use

1. The major uses of water were for **irrigation** and the **thermoelectric** industry. Excluding thermoelectric use, agriculture accounted for 65% of total withdrawals in 2005.

2. The use of water for irrigation by agriculture increased about 68% from 1950 to 1980. It decreased and leveled off from about 1985 to 2005, due in part to better irrigation efficiency, crop type, and higher energy costs.

3. Water use by the thermoelectric industry decreased slightly, beginning in 1980, and has stabilized since 1985 due to recirculating water for cooling in closed-loop systems. During the same period, electrical generation from power plants increased by more than 10 times.

4. Use of water for public and rural supplies continued to increase through the period 1950-2005 presumably due to the increase in human population.

Water Conservation

Water conservation is the careful use and protection of water resources, it involves both the quantity of water used and its quality.

Agricultural Use: improved irrigation could reduce agricultural withdrawals by 20 to 30 % because agriculture is the biggest water user, this would be a huge savings.

Public Supply and Domestic Use: Domestic use of water accounts for only about 12% of total national water withdrawals. However, because public supply water use is concentrated in urban areas, it may pose major local problems in areas where water is periodically or often in short supply.

Industry and Manufacturing Use: Water conservation by industry can be improved. For instance, water use for steam generation of electricity could be reduced 25 to 30% by using cooling towers that require less or no water.

Sustainability and Water Management

Because water is essential to sustain life and maintain ecological systems necessary for human survival, it plays important roles in ecosystem support, economic development, cultural values, and community well-being. Managing water use for sustainability is thus important in many ways.

Sustainable Water Use: use of water resources in a way that allows society to develop and flourish in an indefinite future without degrading the various components of the hydrologic cycle or the ecological systems that depend on it.

Groundwater Sustainability: effective management for sustainability requires an even longer time frame than for other renewable resources. The effects of pumping groundwater faster than it is being replenished—drying up of springs, weaker stream flow—may not be noticed until years after pumping begins. The long-term approach to sustainability with respect to groundwater is basically not to take out more than is going in; to keep monitoring input and adjusting output accordingly.

Water Management

Maintaining a water supply is a complex issue that will become more difficult as demand for water increases in the coming years. Options for minimizing problems include finding alternative water supplies and managing existing supplies better. In some areas, finding new supplies is so unlikely that people are seriously considering some literally far-fetched water sources, such as towing icebergs to coastal regions where freshwater is needed.

A Master Plan for Water Management:

In wet years, there is plenty of surface water, and the near-surface groundwater is replenished. But we must have specific plans to supply water on an emergency basis to minimize hardships in dry years, which we must expect even though we can't accurately predict them.

Another possible emergency plan might involve the treatment of wastewater. Its reuse on a regular basis is expensive, but advance planning to reuse treated wastewater during emergencies is a wise decision.

Finally, we should develop plans to use surface water when available, and not be afraid to use groundwater as needed in dry years. During wet years, natural recharge as well as artificial recharge will replenish the groundwater.

Water Management and the Environment

Many agricultural and urban areas depend on water delivered from nearby (and in some cases not-so-nearby) sources. Delivering the water requires a system for water storage and routing by way of canals and aqueducts from reservoirs. As a result, dams are built, wetlands may be modified, and rivers may be channelized to help control flooding—all of which usually generates a good deal of controversy.

Virtual Water

The amount of water necessary to produce a product, such as an automobile, or a crop such as rice. The virtual water content is measured at the place where the product is produced or the crop grown. It is called “**virtual**” because the water content in the product or crop is very small compared with the amount of water used to produce it.

How much water is necessary to produce a cup of coffee requires knowing how much water is necessary to produce the coffee berries (that contain the bean) and the roasted coffee. Much of the water in coffee-growing areas is free; it comes from rain. However, that doesn’t mean the water has no value. People are usually surprised to learn that **it takes about 140 liters** (40 gallons) **of water to produce one cup of coffee**.

Water Footprint

The water footprint is the total volume of freshwater used to produce the products and services used by an individual, community, country, or region. The footprint is generally expressed as the volume of water used per year and is divided into three components:

Green water, defined as precipitation that contributes to water stored in soils. This is the water consumed by crops (consumptive use) that evaporates or transpires from plants we cultivate.

Blue water, defined as surface and groundwater. This is used to produce our goods and services.

Gray water, defined as water polluted by the production of goods and services and rendered not available for other uses. The volume of gray water use has been estimated by calculating the amount of water required to dilute pollutants to the point that the water quality is acceptable and consistent with water quality standards.

Wetlands

Wetlands is a landforms such as salt marshes, swamps, bogs, prairie potholes, and vernal pools (shallow depressions that seasonally hold water). Their common feature is that they are wet at least part of the year and, as a result, have a particular type of vegetation and soil.

Wetlands may be defined as areas inundated by water or saturated to a depth of a few centimeters for at least a few days per year. Three major characteristics in identifying wetlands are hydrology, or wetness; type of vegetation; and type of soil.

Natural Service Functions of Wetlands

Freshwater wetlands are a natural sponge for water. During high river flow, they store water, reducing downstream flooding. Following a flood, they slowly release the stored water, nourishing low flows.

Many freshwater wetlands are important as areas of groundwater recharge

Wetlands are one of the primary nursery grounds for fish, shellfish, aquatic birds, and other animals.

Wetlands are natural filters that help purify water; plants in wetlands trap sediment and toxins.

Wetlands are often highly productive and are places where many nutrients and chemicals are naturally cycled.

Coastal wetlands buffer inland areas from storms and high waves.

Wetlands are an important storage site for organic carbon; carbon is stored in living plants, animals, and rich organic soils.

Wetlands are aesthetically pleasing to people.

Dams and the Environment

Dams and their reservoirs generally are designed to be multifunctional: used for recreational activities and for generating electricity, as well as providing flood control and ensuring a more stable water supply.

The environmental effects of dams are considerable and include the following:

Loss of land, cultural resources, and biological resources in the reservoir area.

Potential serious flood hazard, should larger dams and reservoirs fail.

Storage behind the dam of sediment that would otherwise move downstream to coastal areas, where it would supply sand to beaches. The trapped sediment also reduces water storage capacity, limiting the life of the reservoir.

Downstream changes in hydrology and in sediment transport that change the entire river environment and the organisms that live there.

Fragmentation of ecosystems above and below a dam.

Restricted movement upstream and downstream of organic material, nutrients, and aquatic organisms.

Water Pollution and Treatment

Water pollution refers to degradation of water quality.

How far the water departs from the norm, its effects on public health, or its ecological impacts.

A pollutant is any biological, physical, or chemical substance that, in an identifiable excess, is known to be harmful to desirable living organisms.

Water pollutants include heavy metals, sediment, certain radioactive isotopes, heat, fecal coliform bacteria, phosphorus, nitrogen, sodium, and other useful (even necessary) elements, as well as certain pathogenic bacteria and viruses. In some instances, a material may be considered a pollutant to a particular segment of the population, although it is not harmful to other segments. For example, excessive sodium as a salt is not generally harmful, but it may be harmful to people who must restrict salt intake for medical reasons.

Biochemical oxygen demand (BOD).

Dead organic matter in streams decays. Bacteria carrying out this decay use oxygen. if there is enough bacterial activity, the oxygen in the water available to fish and other organisms can be reduced to the point where they may die. A stream with low oxygen content is a poor environment for fish and most other organisms. A stream with an inadequate oxygen level is considered polluted for organisms that require dissolved oxygen above the existing level. **The amount of oxygen required for biochemical decomposition processes** is called the biological or biochemical oxygen demand (BOD). BOD is commonly used in water-quality management.

1. A pollution zone, where a high BOD exists. As waste decomposes, microorganisms use the oxygen, decreasing the dissolved oxygen content of the water.

2. An active decomposition zone, where the dissolved oxygen reaches a minimum owing to rapid biochemical decomposition by microorganisms as the organic waste is transported downstream.

3. A recovery zone, where dissolved oxygen increases and BOD is reduced because most of the oxygen-demanding organic waste from the input of sewage has decomposed and natural stream processes are replenishing the water's dissolved oxygen. For example, in quickly moving water, the water at the surface mixes with air, and oxygen enters the water.

Waterborne Disease: the primary water-pollution problem in the world today is the lack of clean drinking water.

Fecal Coliform Bacteria: The presence of fecal coliform bacteria in water indicates that fecal material from mammals or birds is present, so organisms that cause waterborne diseases may be present as well.

Nutrients:

Two important nutrients that cause water-pollution problems are phosphorus and nitrogen, and both are released from sources related to land use.

Eutrophication is the process by which a body of water develops a high concentration of nutrients, such as nitrogen and phosphorus (in the forms of nitrates and phosphates).

A lake that has a naturally high concentration of the chemical elements required for life is called a **eutrophic lake**. A lake with a relatively low concentration of chemical elements required by life is called an **oligotrophic lake**. The water in oligotrophic has a relatively low abundance of life. Eutrophic lakes have an abundance of life, often with mats of algae and bacteria and murky, unpleasant water.

Oil

Oil discharged into surface water—usually in the ocean but also on land and in rivers—has caused major pollution problems. Several large oil spills from underwater oil drilling have occurred in recent years. However, although spills make headlines, normal shipping activities probably release more oil over a period of years than is released by the occasional spill. The cumulative impacts of these releases are not well known.

Sediment

Sediment consisting of rock and mineral fragments can produce a sediment pollution problem. In fact, by volume and mass, sediment is our greatest water pollutant. In many areas, it chokes streams; fills lakes, reservoirs, ponds, canals, drainage ditches, and harbors; buries vegetation; and generally creates a nuisance that is difficult to remove. Sediment pollution is a twofold problem: It results from erosion, which depletes a land resource (soil) at its site of origin, and it reduces the quality of the water resource it enters.

Acid Mine Drainage

Acid mine drainage is water with a high concentration of sulfuric acid that drains from mines—mostly coal mines but also metal mines (copper, lead, and zinc). Coal and the rocks containing coal are often associated with a mineral known as fool's gold or pyrite, which is iron sulfide. When the pyrite comes into contact with oxygen and water, it weathers. A product of the chemical weathering is sulfuric acid. The acid is produced when surface water or shallow groundwater runs through or moves into and out of mines. If the acidic water runs off to a natural stream, pond, or lake, significant pollution and ecological damage may result. The acidic water is toxic to the plants and animals of an aquatic ecosystem; it damages biological productivity, and fish and other aquatic life may die. Acidic water can also seep into and pollute groundwater.

Surface-Water Pollution

Pollution of surface water occurs when too much of an undesirable or harmful substance flows into a body of water, exceeding that body of water's natural ability to remove it, dilute it to a harmless concentration, or convert it to a harmless form. Water pollutants, like other pollutants, are categorized as being emitted from point or nonpoint sources. **Point sources** are distinct and confined, such as pipes from industrial and municipal sites that empty into streams or rivers. In general, point source pollutants from industries are controlled through on-site treatment or disposal and are regulated by permit.

Nonpoint sources, such as runoff, are diffused and intermittent and are influenced by factors such as land use, climate, hydrology, topography, native vegetation, and geology. Common urban nonpoint sources include runoff from streets or fields; such runoff contains all sorts of pollutants, from heavy metals to chemicals and sediment. Rural sources of nonpoint pollution are generally associated with agriculture, mining, or forestry. Nonpoint sources are difficult to monitor and control.

Reducing Surface-Water Pollution

From an environmental view, two approaches to dealing with surface-water pollution are

(1) to reduce the sources and

(2) to treat the water to remove pollutants or convert them to forms that can be disposed of safely.

Which option is used depends on the specific circumstances of the pollution problem.

Groundwater pollution

In general it is believed that pure and safe to drink. In fact, however, groundwater can be easily polluted by any one of several sources, and the pollutants, though very toxic, may be difficult to recognize.

Groundwater pollution differs in several ways from surface-water pollution. Groundwater often lacks oxygen, a situation that kills aerobic types of microorganisms but may provide a happy home for anaerobic varieties. The breakdown of pollutants that occurs in the soil and in material a meter or so below the surface does not occur readily in groundwater. Furthermore, the channels through which groundwater moves are often very small and variable. Thus, the rate of movement is low in most cases, and the opportunity for dispersion and dilution of pollutants is limited.

Wastewater Treatment

Water used for industrial and municipal purposes is often degraded during use by the addition of suspended solids, salts, nutrients, bacteria, and oxygen-demanding material. Wastewater treatment—sewage treatment—costs about $20 billion per year in the United States, and the cost keeps rising.

Septic-Tank Disposal Systems: In many rural areas, no central sewage systems or wastewater treatment facilities are available. As a result, individual septic-tank disposal systems, not connected to sewer systems, continue to be an important method of sewage disposal in rural areas as well as outlying areas of cities.

Wastewater Treatment Plants: In urban areas, wastewater is treated at specially designed plants that accept municipal sewage from homes, businesses, and industrial sites. The raw sewage is delivered to the plant through a network of sewer pipes. Following treatment, the wastewater is discharged into the surface-water environment (river, lake, or ocean) or, in some limited cases, used for another purpose, such as crop irrigation. The main purpose of standard treatment plants is to break down and reduce the BOD and kill bacteria with chlorine.

Water Reuse

Water reuse can be inadvertent, indirect, or direct. Inadvertent water reuse results when water is withdrawn, treated, used, treated, and returned to the environment, followed by further withdrawals and use. Inadvertent water reuse is very common and a fact of life for millions of people who live along large rivers. Many sewage treatment plants are located along rivers and discharge treated water into the rivers. Downstream, other communities withdraw, treat, and consume the water.

Several risks are associated with inadvertent reuse: **1. Inadequate treatment facilities may deliver contaminated or poor-quality water to downstream users. 2. Because the fate of all disease-causing viruses during and after treatment is not completely known, the health hazards of treated water remain uncertain. 3. Every year, new and potentially hazardous chemicals are introduced into the environment**. Harmful chemicals are often difficult to detect in the water; and if they are ingested in low concentrations over many years, their effects on people may be difficult to evaluate.