Groundwater

What is groundwater?

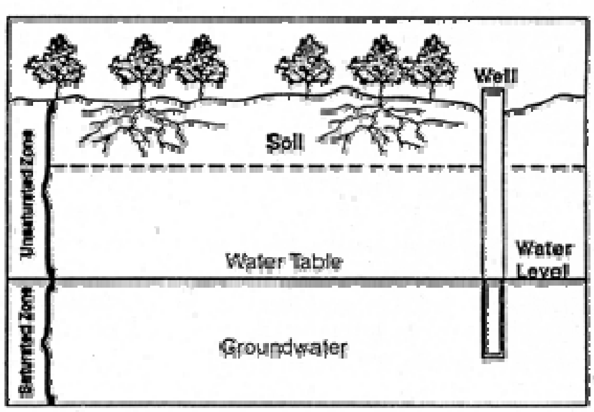
Groundwater is fresh water (from rain or melting ice and snow) that soaks into the soil and is stored in the tiny spaces (pores) between rocks and particles of soil. Groundwater accounts for nearly 95 percent of the nation's fresh water resources. It can stay underground for hundreds of thousands of years, or it can come to the surface and help fill rivers, streams, lakes, ponds, and wetlands. Groundwater can also come to the surface as a spring or be pumped from a well. Both of these are common ways we get groundwater to drink. About 50 percent of our municipal, domestic, and agricultural water supply is groundwater.

How does the ground store water?

Groundwater is stored in the tiny open spaces between rock and sand, soil, and gravel. How well loosely arranged rock (such as sand and gravel) holds water depends on the size of the rock particles. Layers of loosely arranged particles of uniform size (such as sand) tend to hold more water than layers of rock with materials of different sizes. This is because smaller rock materials settle in the spaces between larger rock materials, decreasing the amount of open space that can hold water. Porosity (how well rock material holds water) is also affected by the shape of rock particles. Round particles will pack more tightly than particles with sharp edges. Material with angular-shaped edges has more open space and can hold more water.

Groundwater is found in two zones. The **unsaturated zone**, immediately below the land surface, contains water and air in the open spaces, or pores. The **saturated zone**, a zone in which all the pores and rock fractures are filled with water, underlies the unsaturated zone. The top of the saturated zone is called the **water table** (Diagram 1). The water table may be just below or hundreds of feet below the land surface.

Diagram 1
Groundwater Zones



What is an aquifer?

Where groundwater can move rapidly, such as through gravel and sandy deposits, an **aquifer** can form. In an aquifer, there is enough groundwater that it can be pumped to the surface and used for drinking water, irrigation, industry, or other uses.

For water to move through underground rock, pores or fractures in the rock must be connected. If rocks have good connections between pores or fractures and water can move freely through them, we say that the rock is **permeable**. **Permeability** refers to how well a material transmits water. If the pores or fractures are not connected, the rock material cannot produce water and is therefore not considered an aquifer. The amount of water an aquifer can hold depends on the volume of the underground rock materials and the size and number of pores and fractures that can fill with water.

An aquifer may be a few feet to several thousand feet thick, and less than a square mile or hundreds of thousands of square miles in area. For example, the High Plains Aquifer underlies about 280,000 square miles in 8 states— Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming.

How does water fill an aquifer?

Aquifers get water from precipitation (rain and snow) that filters through the unsaturated zone. Aquifers can also receive water from surface waters like lakes and rivers. When the aquifer is full, and the water table meets the surface of the ground, water stored in the aquifer can appear at the land surface as a spring or seep. **Recharge** areas are where aquifers take in water; **discharge** areas are where groundwater flows to the land surface. Water moves from higher-elevation areas of recharge to lower-elevation areas of discharge through the saturated zone.

How does water circulate?

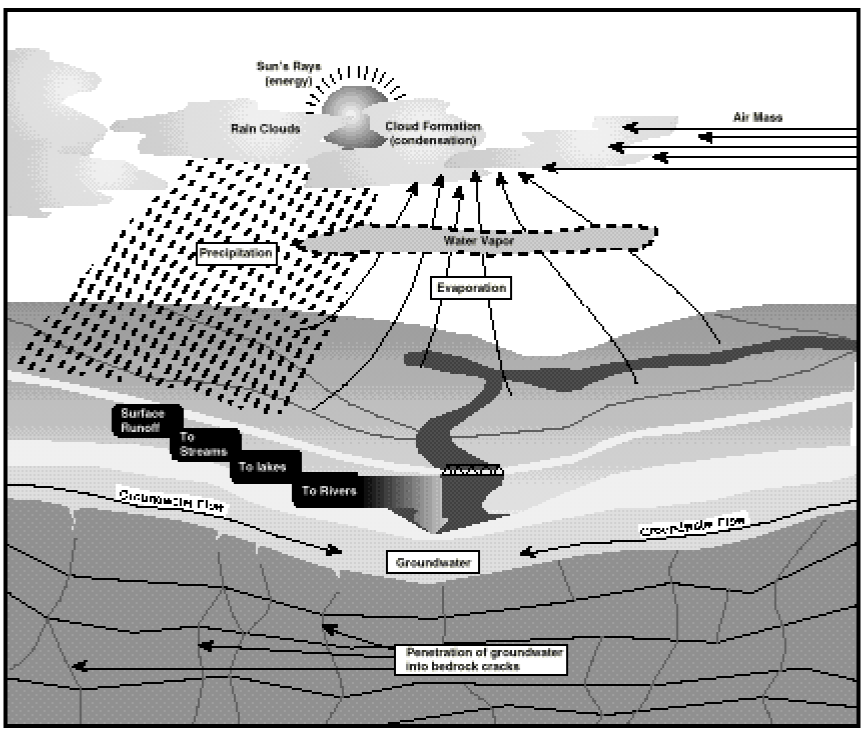
Surface water and groundwater are part of the **hydrologic cycle**, the constant movement of water above, on, and below the earth's surface (Diagram 2). The cycle has no beginning and no end, but you can understand it best by tracing it from precipitation.

Precipitation occurs in several forms, including rain, snow, and hail. Rain, for example, wets the ground surface. As more rain falls, water begins to filter into the ground. How fast water soaks into, or infiltrates the soil depends on soil type, land use, and the intensity and length of the storm. Water infiltrates faster into soils that are mostly sand than into those that are mostly clay or silt. Almost no water filters into paved areas. Rain that cannot be absorbed into the ground collects on the surface, forming **runoff** streams.

When the soil is completely saturated, additional water moves slowly down through the unsaturated zone to the saturated zone, replenishing or recharging the groundwater. Water then moves through the saturated zone to groundwater discharge areas.

Evaporation occurs when water from such surfaces as oceans, rivers, and ice is converted to vapor. Evaporation, together with **transpiration** from plants, rises above the Earth's surface, condenses, and forms clouds. Water from both runoff and from groundwater discharge moves toward streams and rivers and may eventually reach the ocean. Oceans are the largest surface water bodies that contribute to evaporation.

Diagram 2
Hydrologic Cycle



How is groundwater contaminated?

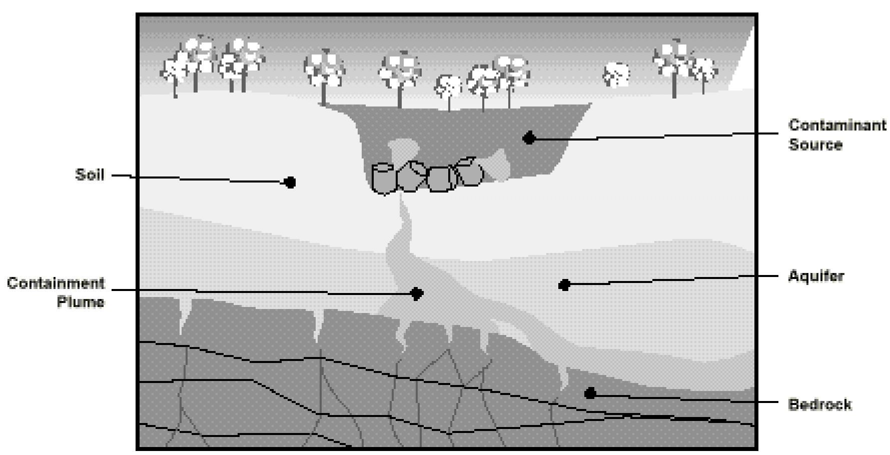
Groundwater can become contaminated in many ways. If surface water that recharges an aquifer is polluted, the groundwater will also become contaminated. Contaminated groundwater can then affect the quality of surface water at discharge areas. Groundwater can also become contaminated when liquid hazardous substances soak down through the soil into groundwater.

Contaminants that can dissolve in groundwater will move along with the water, potentially to wells used for drinking water. If there is a continuous source of contamination entering moving groundwater, an area of contaminated groundwater, called a **plume**, can form (Diagram 3). A combination of moving groundwater and a continuous source of contamination can, therefore, pollute very large volumes and areas of groundwater. Some plumes at Superfund sites are several miles long. More than 88 percent of current Superfund sites have some groundwater contamination.

How do liquids contaminate groundwater?

Some hazardous substances dissolve very slowly in water. When these substances seep into groundwater faster than they can dissolve, some of the contaminants will stay in liquid form. If the liquid is less dense than water, it will float on top of the water table, like oil on water. Pollutants in this form are called **light non-aqueous phase liquids (LNAPLs)**. If the liquid is more dense than water, the pollutants are called **dense non-aqueous phase liquids (DNAPLs)**. DNAPLs sink to form pools at the bottom of an aquifer. These pools continue to contaminate the aquifer as they slowly dissolve and are carried away by moving groundwater. As DNAPLs flow downward through an aquifer, tiny globs of liquid become trapped in the spaces between soil particles. This form of groundwater contamination is called **residual contamination**.

Diagram 3
Contaminated Groundwater



What affects groundwater contamination?

Many processes can affect how contamination spreads and what happens to it in the groundwater, potentially making the contaminant more or less harmful, or toxic. Some of the most important processes affecting hazardous substances in groundwater are advection, sorption, and biological degradation.

- **Advection** occurs when contaminants move with the groundwater. This is the main form of contaminant migration in groundwater.

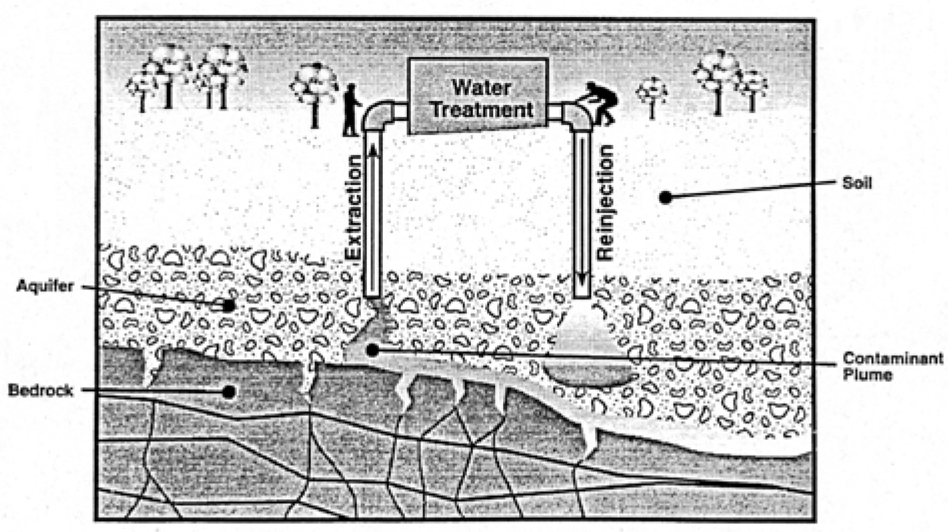
- **Sorption** occurs when contaminants attach themselves to soil particles. Sorption slows the movement of contaminants in groundwater, but also makes it harder to clean up contamination.

- **Biological degradation** happens when microorganisms, such as bacteria and fungi, use hazardous substances as a food and energy source. In the process, contaminants break down and hazardous substances often become less harmful.

Why is cleaning up groundwater so hard?

Cleaning up contaminated groundwater often takes longer than expected because groundwater systems are complicated and the contaminants are invisible to the naked eye. This makes it more difficult to find contaminants and to design a treatment system that either destroys the contaminants in the ground or takes them to the surface for cleanup. Groundwater contamination is the reason for most of Superfund's long-term cleanup actions. Diagram 4 illustrates groundwater treatment in action.

Diagram 4
Pumping and Treating Contaminated Groundwater



For more information on groundwater, visit:

http://www.epa.gov/superfund/students/clas_act/haz-ed/ff_05.htm

http://www.epa.gov/superfund/students/wastsite/grndwatr.htm