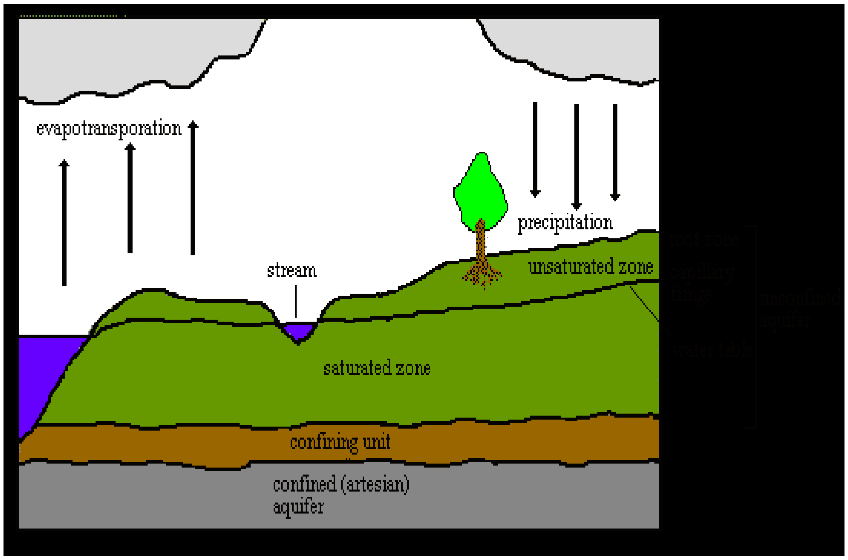
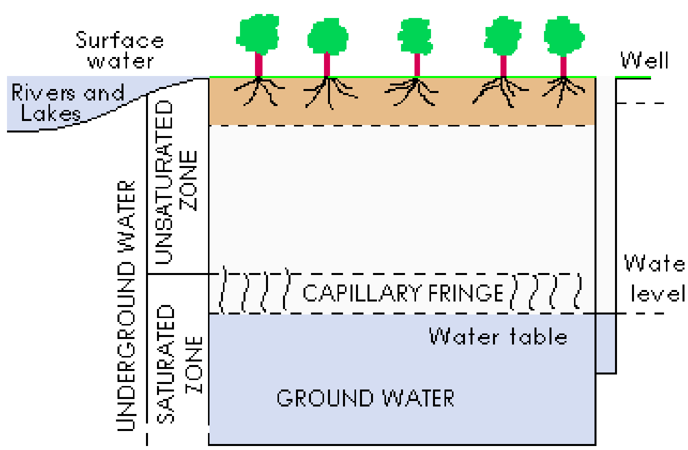
GROUNDWATER

Groundwater Part 1



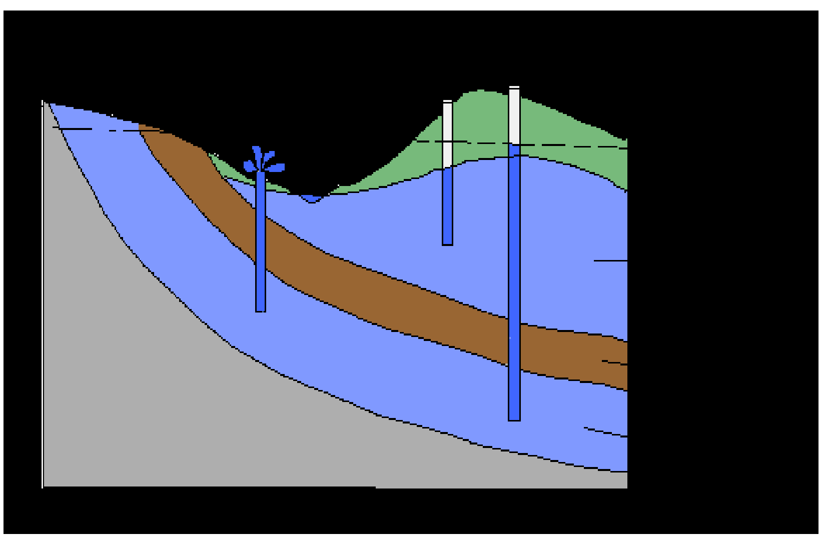
Groundwater is water held within the interconnected openings of saturated rock beneath the land surface.

The hydrologic cycle shows that when rain falls to the ground, some water flows along the land surface to streams or lakes, some water evaporates into the atmosphere, some is taken up by plants, and some seeps into the ground. As water begins to seep into the ground, it



enters a zone that contains both water and air, referred to as the unsaturated zone or vadose zone. The upper part of this zone, known as the root zone or soil zone, supports plant growth and is crisscrossed by living roots, holes left by decayed roots, and animal and worm burrows. Below lies an intermediate zone, followed by a saturated capillary fringe, which results from the attraction between water and rocks. As a result of this attraction, water clings as a film on the surface of rock particles.

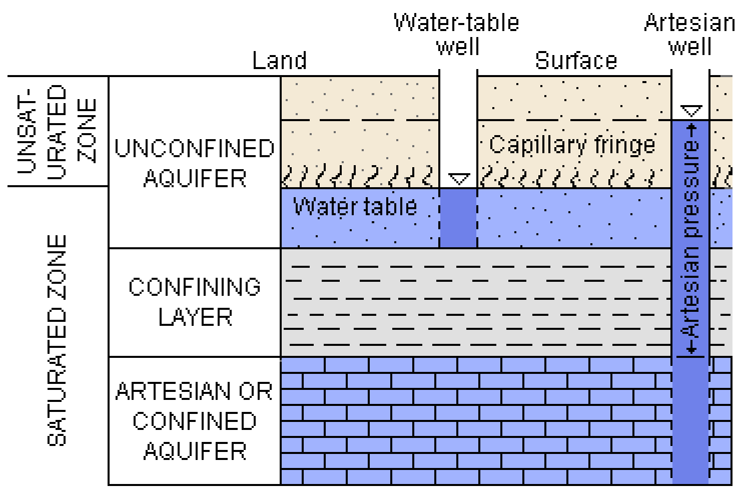
Water moves through the unsaturated zone into the saturated zone, where all the interconnected openings between rock particles are filled with water. It is within this saturated zone that the term "ground water" is correctly applied. Ground water is held in aquifers, which are discussed in the following sections.



Aquifer is the term given to a rock unit that will yield water in usable quantities to wells or springs. An aquifer can be visualized as a giant underground sponge which holds water and which, under certain conditions, will allow water to move through it.

Depending on the type, the aquifer may contain both saturated and unsaturated zones or just the saturated zone.

The water-bearing rocks that compose aquifers consist either of unconsolidated (soil-like) deposits or consolidated rocks. Most consolidated rocks (otherwise known as bedrock) consist of rock and mineral particles of different sizes and shapes that have been welded together by heat and pressure or chemical reaction into a rock mass. Aquifers of this type are commonly composed of one or more of the following rocks: sandstone, limestone, granite, or lava. Water flows through these rocks through fractures, gas pores, and other openings in the rock.



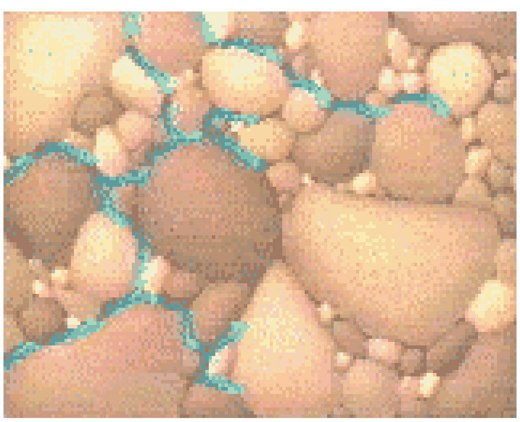
Most unconsolidated materials consist of material derived from the disintegration of consolidated rocks. Unconsolidated deposits include, in different types of unconsolidated deposits, some or all of the following materials in varying combinations: soil-like materials, gravel, sand, silt, clay, and the fragments of shells of marine organisms. Sand dunes and gravel piles are examples of unconsolidated material. Water flows through these materials through the natural openings between particles.

The physical properties of aquifer materials and of the aquifers themselves (i.e., thickness, depth) are important in determining how quickly ground water will move and what routes it will take as it moves through an aquifer. This knowledge helps decide how best to get water out of the ground for drinking water, irrigation, and other uses. These same properties are important in defining how contaminants originating on the surface will flow in the aquifer and in determining an appropriate cleanup remedy if the aquifer becomes contaminated.

Aquifers are generally classified as one of the following:

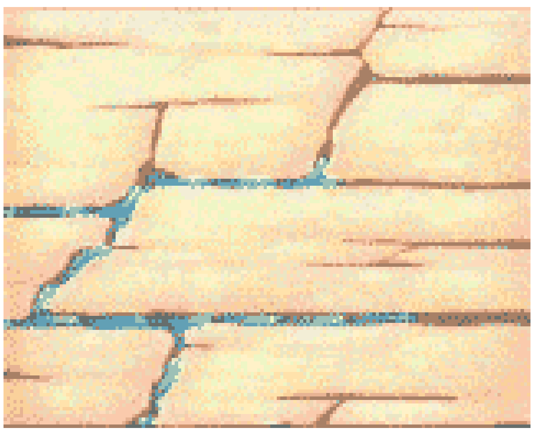
Unconfined Aquifers

Confined Aquifers



While aquifers can be thought of simply as unconfined or confined for educational purposes, in nature, most of the world's ground water occurs in far more complex hydrogeological systems that can radically impact the movement of ground water. These systems might contain multiple overlying confined and unconfined aquifers, partially permeable or laterally incomplete confining beds, perched water tables, intersecting lakes and streams, intrusions of rock such as granitic domes, faulting, etc. Understanding these complexities is critical to designing adequate drinking water supplies and selecting appropriate remedies for cleaning up contamination.

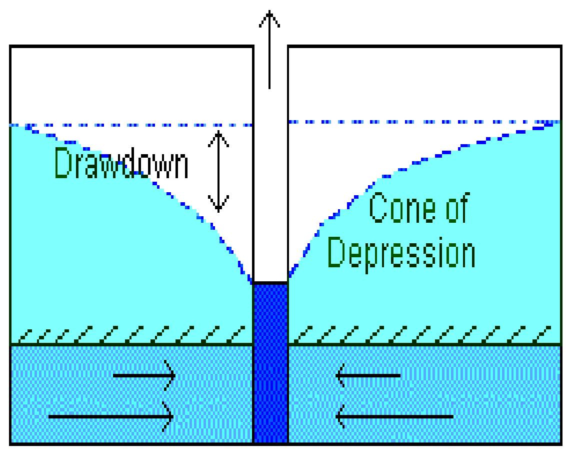
It is a common misconception that ground water is found in underground rivers, like those that form limestone caverns. In fact, ground water is more like the



water in a sponge, held within the tiny pores of the surrounding aquifer material. Much like the flow of water in a river, however, the flow of ground water is subject to gravity and is almost always in motion, flowing from areas of higher elevation to areas of lower elevation. (In the case of ground water in confined aquifers, it is pressure rather than gravity that makes water move. In this case, water flows from areas of high pressure to areas of low pressure.) Just like what happens when a sponge soaked with water is tilted, gravity forces water to flow from one pore space or fracture to another. The steeper the gradient or slope, the faster the ground water will flow. It is important to note that the rate of ground water flow, especially in confined systems, is very slow compared to the flow of water on the surface. It is typically in the range of several inches per year to several feet per year.

For water to move freely through a rock, the pores and/or fractures must be large enough and connected enough so that the friction from the water moving past the rock particle does not impede the flow. The degree of an aquifer's porosity and permeability is key to the movement of ground water through an aquifer.

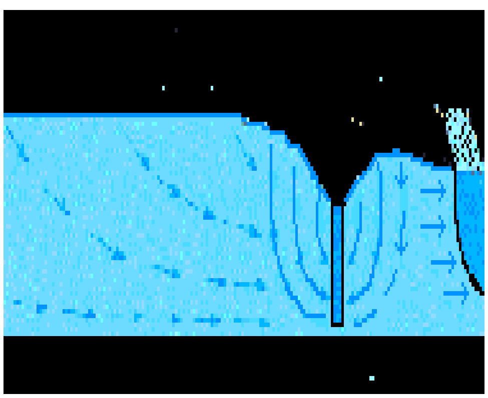
Ground water can move through pores or fractures.



Ground water is withdrawn from wells to provide water for everything from drinking water for the home and business, to water to irrigate crops, to industrial processing water. When water is pumped from the ground, the dynamics of ground water flow change in response to this withdrawal.

When a well is installed in an unconfined aquifer, water moves from the aquifer into the well through small holes or slits in the well casing or in some types of wells, through the open bottom of the well. The level of the water in the well is the same as the water level in the aquifer. Ground water continues to flow through and around the well in one direction in response to gravity.

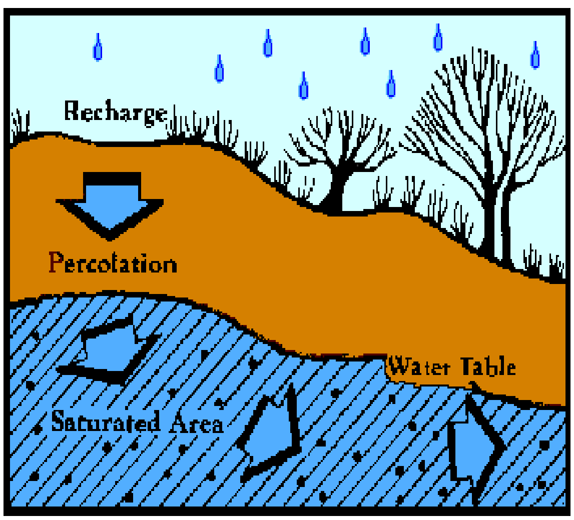
When pumping begins, water begins to flow towards the well, in contrast to the natural direction of ground water movement. In response, the water level in the well falls below the water table, in the surrounding aquifer. As a result, water begins to move from the aquifer into the well. As pumping continues, the water level in the well continues to increase until the rate of flow into the well equals the rate of withdrawal from pumping. The movement of water from an aquifer into a well results in the formation of a cone of depression. The cone of depression describes a three dimensional inverted cone surrounding the well that represents the volume of water removed as a result of pumping. Drawdown is the vertical drop in the height between the water level in the well prior to pumping, and the water level in the well during pumping.



This information is used in a number of ways:

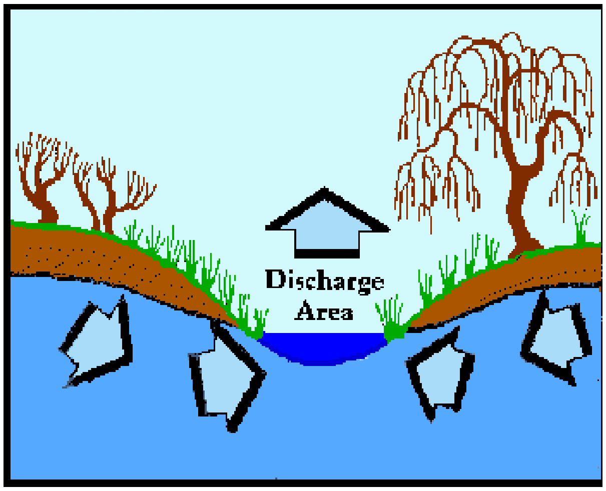
The knowledge of natural ground water flow and the impact of pumping on flow is important in the strategic placement of wells (geographically and vertically) and the design of appropriate pumping rates and frequencies. This is important for a number of reasons:

- to ensure the specific source of water is known, be it a specific aquifer or a nearby surface water body,
- to pump out contaminated ground water so that it can be treated on the surface, such as by an air stripper. An air stripper remediates ground water contaminated by volatile organic compounds (VOCs). The illustration on the right shows water being treated using an air stripper.



- to manipulate local ground water flow so that contaminated ground water flows away from a drinking water source.

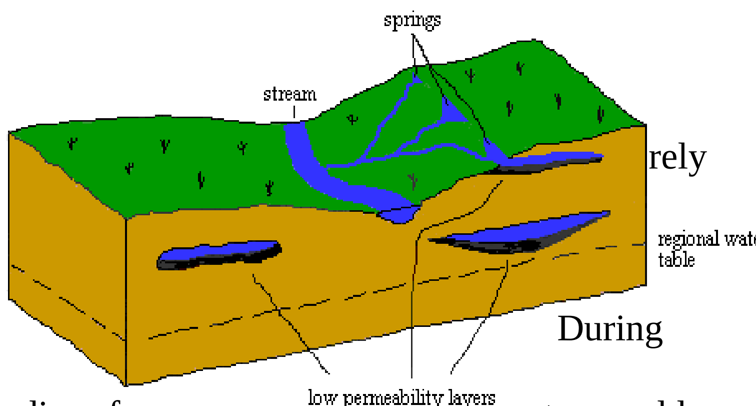
Recharge is the process by which aquifers are replenished with water from the surface. This process occurs naturally as part of the hydrologic cycle as infiltration when rainfall infiltrates the land surface and as percolation of water into underlying aquifers. A number of factors influence the rate of recharge including physical characteristics of the soil, plant cover, slope, water content of surface materials, rainfall intensity, and the presence and depth of confining layers and aquifers.



Surface water bodies may also recharge ground water. This occurs most often in arid areas. Lakes and dry creek beds may fill up with water during heavy rains. If the water table is low in underlying aquifers, water may seep from the sides of these water bodies and percolate into the ground water.

In some places, artificial recharge is used to replenish aquifers. This is accomplished through the pumping, or injection, of water into wells where it replenishes the aquifer directly or through the spreading of water over the land surface where it can seep into the ground. Artificial recharge is done to replenish the ground water supply when rains are heavy in order to preserve water for later use or, in the case of injection wells, to dilute or control the flow of contaminated ground water.

Gravity is the dominant driving force in ground water movement in unconfined aquifers. As such, under natural conditions, ground water moves "downhill" until it reaches the land surface at a spring or through a seep in the side or bottom of a river bed, lake, wetland, or other surface water body. Ground water can also leave the aquifer via the pumping of a well. The process of ground water outflowing into a surface water body or leaving the aquifer through pumping is called discharge..



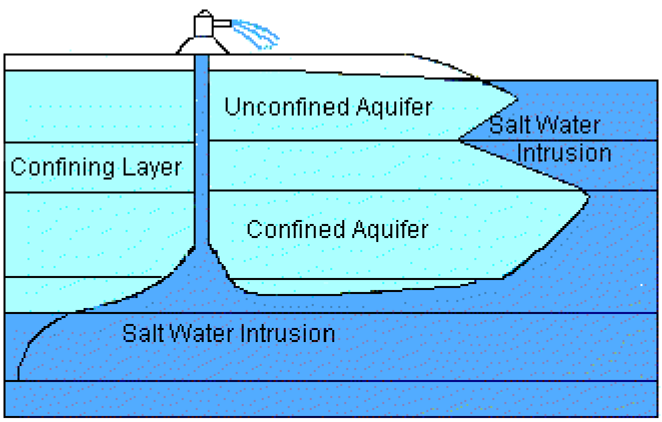
Many rivers, lakes, and wetlands rely heavily on ground water discharge as a source of water. During times of low precipitation, these bodies of water would not contain any water at all if it were not for ground water discharge.

It is important to note that because of discharge, contaminants in ground water can flow into surface water bodies. This process can make the removal of contamination very complex.

Discharge from confined aquifers occurs in much the same way except that pressure, rather than gravity, is the driving force in moving ground water to the surface. When the intersection between the aquifer and the land's surface is natural, the pathway is called a spring. If discharge occurs through a well, that well is a flowing artesian well.

When the withdrawal of ground water in an aquifer exceeds the recharge rate over a period of time, the aquifer is overwithdrawal. There are two possible effects from the overwithdrawal of water from an aquifer.

First, when the amount of fresh water being pumped out of an aquifer in a coastal area can not be replaced as fast as it is being withdrawn, salt water migrates towards the point of withdrawal. This movement of salt water into zones previously occupied by fresh water is called salt water intrusion. Salt water intrusion can also occur in inland areas where briney water underlies fresh water.



Secondly, in some areas over withdrawal can make the ground sink because ground water pressure helps to support the weight of the land. This is called subsidence. Sinkholes are an example of this effect.