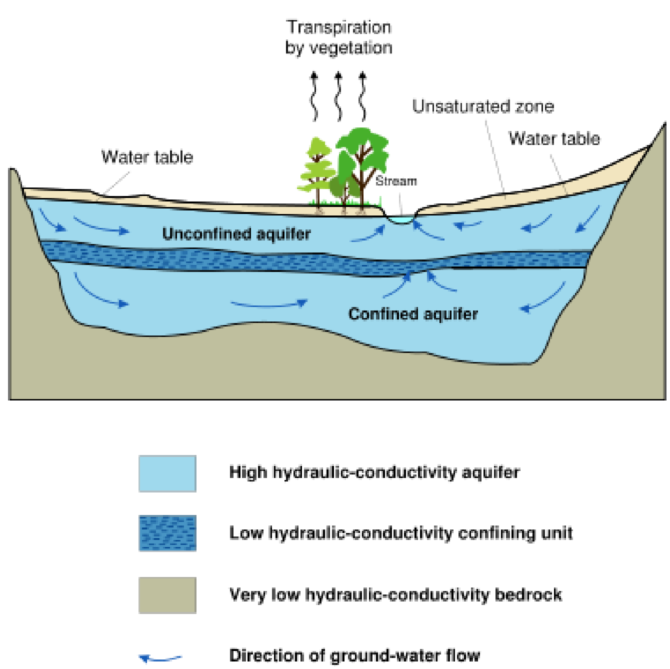
Aquifer

An **aquifer** is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be usefully extracted using a water well. The study of water flow in aquifers and the characterization of aquifers is called hydrogeology.

Shallow aquifers

Aquifers can occur at various depths. Those closer to the surface are not only more likely to be exploited for water supply and irrigation, but are also more likely to be topped up by the local rainfall. Many desert areas have limestone hills or mountains within them or close to them which can be exploited as groundwater resources. Parts of the Atlas Mountains in North Africa, the Lebanon and Anti-Lebanon ranges of Syria, Israel and Lebanon, the Djebel Akhdar in Oman, parts of the Sierra Nevada and neighbouring ranges in the United State's South West, have shallow aquifers which are exploited for their water. Over exploitation can lead to the exceeding of the practical sustained yield, i.e. more water is taken out than can be replenished. Along the coastlines of certain countries, such as Libya and Israel, population growth has led to over-population which has caused the lowering of water table and the subsequent contamination of the groundwater with saltwater from the sea (saline intrusions).

Classification



Typical aquifer cross-section

This diagram indicates typical flow directions in a cross-sectional view of a simple confined/unconfined aquifer system (two aquifers with one aquitard, also known as a confining or impermeable layer, between them, surrounded by the bedrock aquiclude) which is in contact with a gaining stream (typical in humid regions). The water table and unsaturated zone are also illustrated.

An *aquitard* is a zone within the earth that restricts the flow of groundwater from one aquifer to another. An aquitard can sometimes, if completely impermeable, be called an *aquiclude* or *aquifuge*. Aquitards are composed of layers of either clay or non-porous rock with low hydraulic conductivity.

Saturated versus unsaturated

Groundwater can be found at nearly every point in the earth's shallow subsurface, to some degree; although aquifers do not necessarily contain fresh water. The earth's crust can be divided into two regions: the *saturated zone* or *phreatic zone* (e.g., aquifers, aquitards, etc.), where all available spaces are filled with water, and the *unsaturated zone* (also called the aeration), where there are still pockets of air with some water that can be replaced by water.

Saturated means the pressure head of the water is greater than atmospheric pressure (it has a gauge pressure > 0). The definition of the water table is surface where the pressure head is equal to atmospheric pressure (where gauge pressure = 0). **Unsaturated** conditions occur above the water table where the pressure head is negative (absolute pressure can never be negative, but gauge pressure can) and the water which incompletely fills the pores of the aquifer material is under suction. The water content in the unsaturated zone is held in place by surface adhesive forces and it rises above the water table (the zero gauge pressure isobar) by capillary action to saturate a small zone above the phreatic surface (the capillary fringe) at less than atmospheric pressure. This is termed tension saturation and is not the same as saturation on a water content basis. Water content in a capillary fringe decreases with increasing distance from the phreatic surface. The capillary head depends on soil pore size. In sandy soils with larger pores the head will be less than in clay soils with very small pores. The normal capillary rise in a clayey soil is less than 1.80 m (six feet) but can range between 0.3 and 10 m (1 and 30 feet).

The capillary rise of water in a small diameter tube is this same physical process. The water table is the level to which water will rise in a large diameter pipe (e.g. a well) which goes down into the aquifer and is open to the atmosphere.

Aquifers versus aquitards

Aquifers are typically saturated regions of the subsurface which produce an economically feasible quantity of water to a well or spring (e.g., sand and gravel or fractured bedrock often make good aquifer materials). An **aquitard** is a zone within the earth that restricts the flow of groundwater from one aquifer to another. An aquitard can sometimes, if completely impermeable, be called an **aquiclude** or **aquifuge**. Aquitards comprise layers of either clay or non-porous rock with low hydraulic conductivity. *Economically feasible* is a relative term; for example, an aquifer that is quite adequate for local domestic use, as in a rural area, might be considered an inadequate *aquitard* for industrial use, mining, or urban water supply.

In non-mountainous areas (or near rivers in mountainous areas), the main aquifers are typically unconsolidated alluvium. They are typically composed of mostly horizontal layers of materials deposited by water processes (rivers and streams), which in cross-section (looking at a two-dimensional slice of the aquifer) appear to be layers of alternating coarse and fine materials. Coarse materials, because of the high energy needed to move them, tend to be found nearer the source (mountain fronts or rivers), while the fine-grained material will make it farther from the source (to the flatter parts of the basin or overbank areas - sometimes called the pressure area). Since there are less fine-grained deposits near the source, this is a place where aquifers are often unconfined (sometimes called the forebay area), or in hydraulic communication with the land surface.

Confined versus unconfined

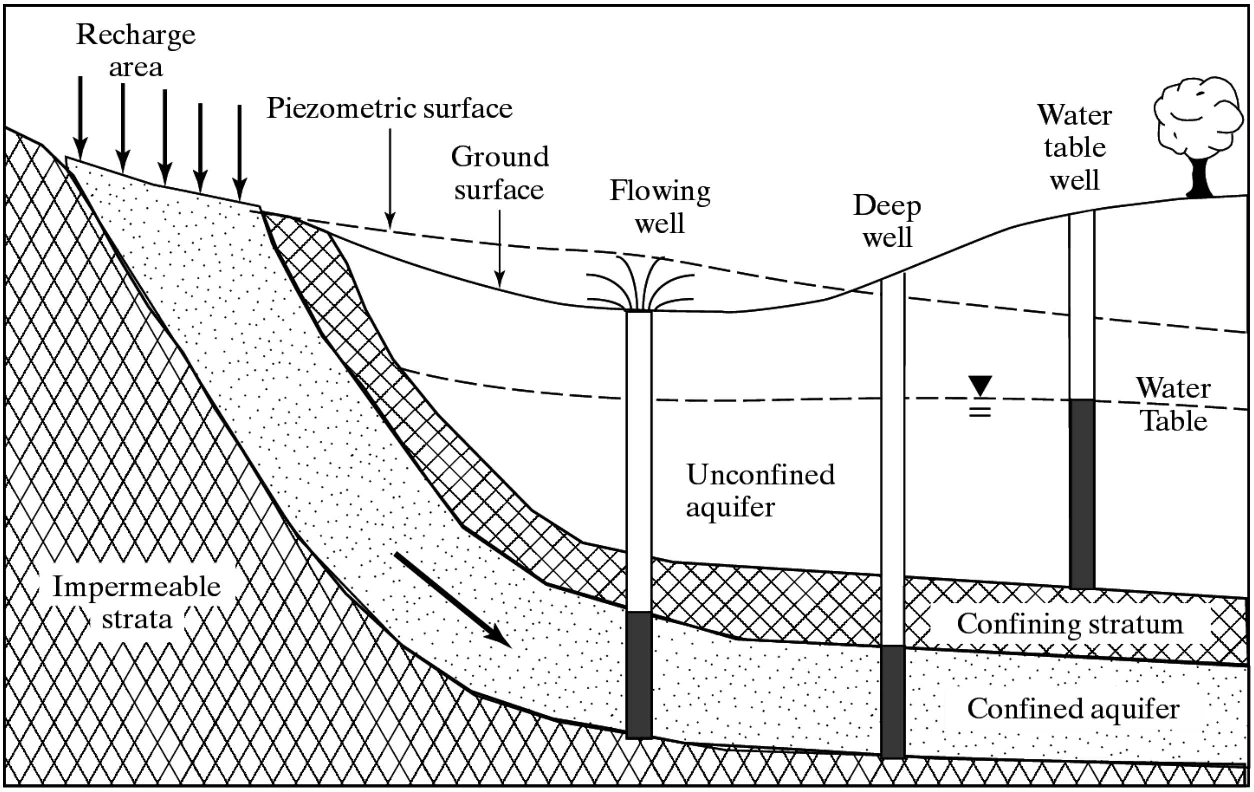


Figure 8.6

Schematic cross section illustrating unconfined and confined aquifers.

There are two end members in the spectrum of types of aquifers; *confined* and *unconfined* (with semi-confined being in between). **Unconfined** aquifers are sometimes also called *water table* or *phreatic* aquifers, because their upper boundary is the water table or phreatic surface. Typically (but not always) the shallowest aquifer at a given location is unconfined, meaning it does not have a confining layer (an aquitard or aquiclude) between it and the surface. Unconfined aquifers usually receive recharge water directly from the surface, from precipitation or from a body of surface water (e.g., a river, stream, or lake) which is in hydraulic connection with it. **Confined** aquifers have the water table above their upper boundary (an aquitard or aquiclude), and are typically found below unconfined aquifers. The term "perched" refers to ground water accumulating above a low-permeability unit or strata, such as a clay layer. This term is generally used to refer to a small local area of ground water that occurs at an elevation higher than a regionally-extensive aquifer. The difference between perched and unconfined aquifers is their size (perched is smaller).

If the distinction between confined and unconfined is not clear geologically (i.e., if it is not known if a clear confining layer exists, or if the geology is more complex, e.g., a fractured bedrock aquifer), the value of storativity returned from an aquifer test can be used to determine it (although aquifer tests in unconfined aquifers should be interpreted differently than confined ones). Confined aquifers have very low storativity values (much less than 0.01, and as little as 10^{-5}), which means that the aquifer is storing water using the mechanisms of aquifer matrix expansion and the compressibility of water, which typically are both quite small quantities. Unconfined aquifers have storativities (typically then called specific yield) greater than 0.01 (1% of bulk volume); they release water from storage by the mechanism of actually draining the pores of the aquifer, releasing relatively large amounts of water (up to the drainable porosity of the aquifer material, or the minimum volumetric water content).

Misconception

A common misconception is that groundwater exists in *underground rivers* (e.g. caves where water flows freely underground). This is only sometimes true in eroded limestone areas known as karst topography which make up only a small percentage of Earth's area. More usual is that the pore spaces of rocks in the subsurface are simply saturated with water — like a kitchen sponge — which can be pumped out and used for agricultural, industrial or municipal uses.

The beach provides a model to help visualize an actual aquifer. If a hole is dug into the sand, very wet or saturated sand will be located at a shallow depth. This hole is a crude well, the wet sand represents an aquifer, and the level to which the water rises in this hole represents the water table.

Human dependence on groundwater

Most land areas on Earth have some form of aquifer underlying them, sometimes at significant depths. Fresh water aquifers, especially those with limited recharge by meteoric water, can be over-exploited and, depending on the local hydrogeology, may draw in non-potable water or saltwater (saltwater intrusion) from hydraulically connected aquifers or surface water bodies. This can be a serious problem especially in coastal areas and other areas where aquifer pumping is excessive.

Aquifers are critically important in human habitation and agriculture. Deep aquifers in arid areas have long been water sources for irrigation (see Ogallala below). Many villages and even large cities draw their water supply from wells in aquifers.

Municipal, irrigation, and industrial water supplies are provided through large wells. Multiple wells for one water supply source are termed "wellfields" which may withdraw water from confined or unconfined aquifers. Using ground water from deep, confined aquifers provides more protection from surface water contamination. Some wells, termed "collector wells," are specifically designed to induce infiltration of surface (usually river) water.

Aquifers that provide sustainable fresh groundwater to urban areas and for agricultural irrigation are typically close to the ground surface (within a couple of hundred meters) and have some recharge by fresh water. This recharge is typically from rivers or meteoric water (precipitation) that percolates into the aquifer through overlying unsaturated materials.

Subsidence

In unconsolidated aquifers, groundwater is produced from pore spaces between particles of gravel, sand, and silt. If the aquifer is confined by low-permeability layers, the reduced water pressure in the sand and gravel causes slow drainage of water from the adjoining confining layers. If these confining layers are composed of compressible silt or clay, the loss of water to the aquifer reduces the water pressure in the confining layer, causing it to compress from the weight of overlying geologic materials. In severe cases, this compression can be observed on the ground surface as subsidence. Unfortunately, much of the subsidence from groundwater extraction is permanent (elastic rebound is small). Thus the subsidence is not only permanent, but the compressed aquifer has a permanently-reduced capacity to hold water.

Saltwater Intrusion

Aquifers near the coast have a lens of freshwater near the surface and denser seawater under freshwater. Seawater penetrates the aquifer diffusing in from the ocean and is more dense than freshwater. For porous (i.e. sandy) aquifers near the coast, the thickness of freshwater atop saltwater is about 40 feet for every 1 ft of freshwater head above sea level. This relationship is called the Ghyben-Herzberg equation. If too much ground water is pumped near the coast, salt-water may intrude into freshwater aquifers causing contamination of potable freshwater supplies. Many coastal aquifers, such as the Biscayne Aquifer near Miami and the New Jersey Coastal Plain aquifer, have problems with saltwater intrusion as a result of overpumping.

Examples

An example of a significant and sustainable **carbonate** aquifer is the **Edwards Aquifer** in central Texas. This carbonate aquifer has historically been providing high-quality water for nearly 2 million people and, even today, is completely full because of tremendous recharge from a number of area streams, rivers and lakes. The primary risk to this resource is human development over the recharge areas.

One of the largest aquifers in the world is the Guarani Aquifer, with 1.2 million km² of area, from central Brazil to northern Argentina.

Aquifer depletion is a problem in some areas, and is especially critical in northern Africa; see the Great Manmade River project of Libya for an example. However, new methods of groundwater management such as artificial recharge and injection of surface waters during seasonal wet periods has extended the life of many freshwater aquifers, especially in the United States.

- The Great Artesian Basin is one of the largest groundwater aquifers in the world. It plays a large part in water supplies for remote parts of South Australia.

North America

- Canada - Oak Ridges Moraine, north of the city of Toronto.
- United States - The Ogallala Aquifer of the central United States is one of the world's great aquifers, but in places it is being rapidly depleted by growing municipal use, and continuing agricultural use. This huge aquifer, which underlies portions of eight states, contains primarily fossil water from the time of the last glaciation. Annual recharge, in the more arid portions of the aquifer, is estimated to total only about ten percent of annual withdrawals.
- United States - The Kirkwood-Cohansey Aquifer, located under the Pine Barrens of Southern New Jersey, contains 17 trillion US gallons (64 km^3) of some of the purest water in the United States.
- United States - The Mahomet Aquifer supplies water to some 800,000 people in central Illinois and contains approximately four trillion US gallons (15 km^3) of water. The **Mahomet Aquifer Consortium** [3] was formed in 1998 to study the aquifer with hopes of ensuring the water supply and reducing potential user conflicts.

INDIA

THE ALLUVIAL BELTS

- Thick Accumulation of porous unconsolidated sediments.
- Includes the areas like Indo Gangetic plain,Plains of Brahmaputra, Mahanadi, Godavari, kaveri,Narmada,Mahi, Sabarmati.
- Characterised by Large Lensoid and locally interfingering aquifers.
- Thickness of aquifer varies from less than 20m to as much as 330 m in the Ganga basin.
- The Kosi alluvial megafans are also important sources of Groundwater resources.

The Himalayan Regions

- The siwalik ranges are finged on the southern side by an apron of coalescing fans of colluvial and fluvial debris.
- This piedment belt is known as “Bhabhar”where mountain river loose theirwater and recharge the unconfined aquifers which extands down to a depth of 90 to 150m.
- It is fringed to the south by a line of countless no. of perennial springs and seepages making the whole belt very wet. This is know as” Tarai”belt.
- in the vertical column of 300m there can be as many as 3 to 4 different confined aquifers under varying artesian condition.

PREPARED BY

KUNWAR BIJENDRA PRATAP RAHI

GUEST FACULTY, P.G. DEPT. OF GEOLOGY

PATNA UNIVERSITY, PATNA