Engineering Geology

Lecture-10

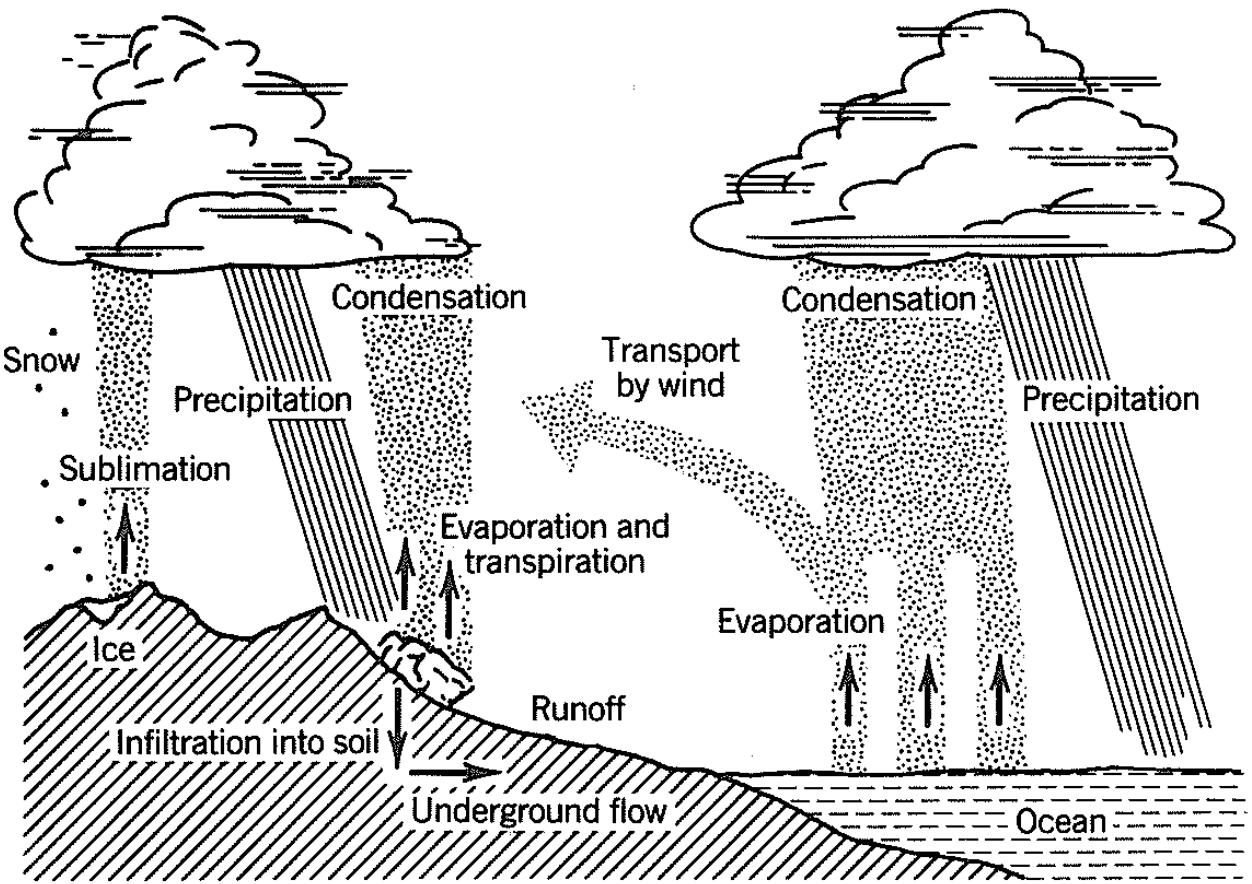
Hydrogeology

- Hydrogeology examines the relationships of geologic materials and flowing water

Hydrologic Cycle

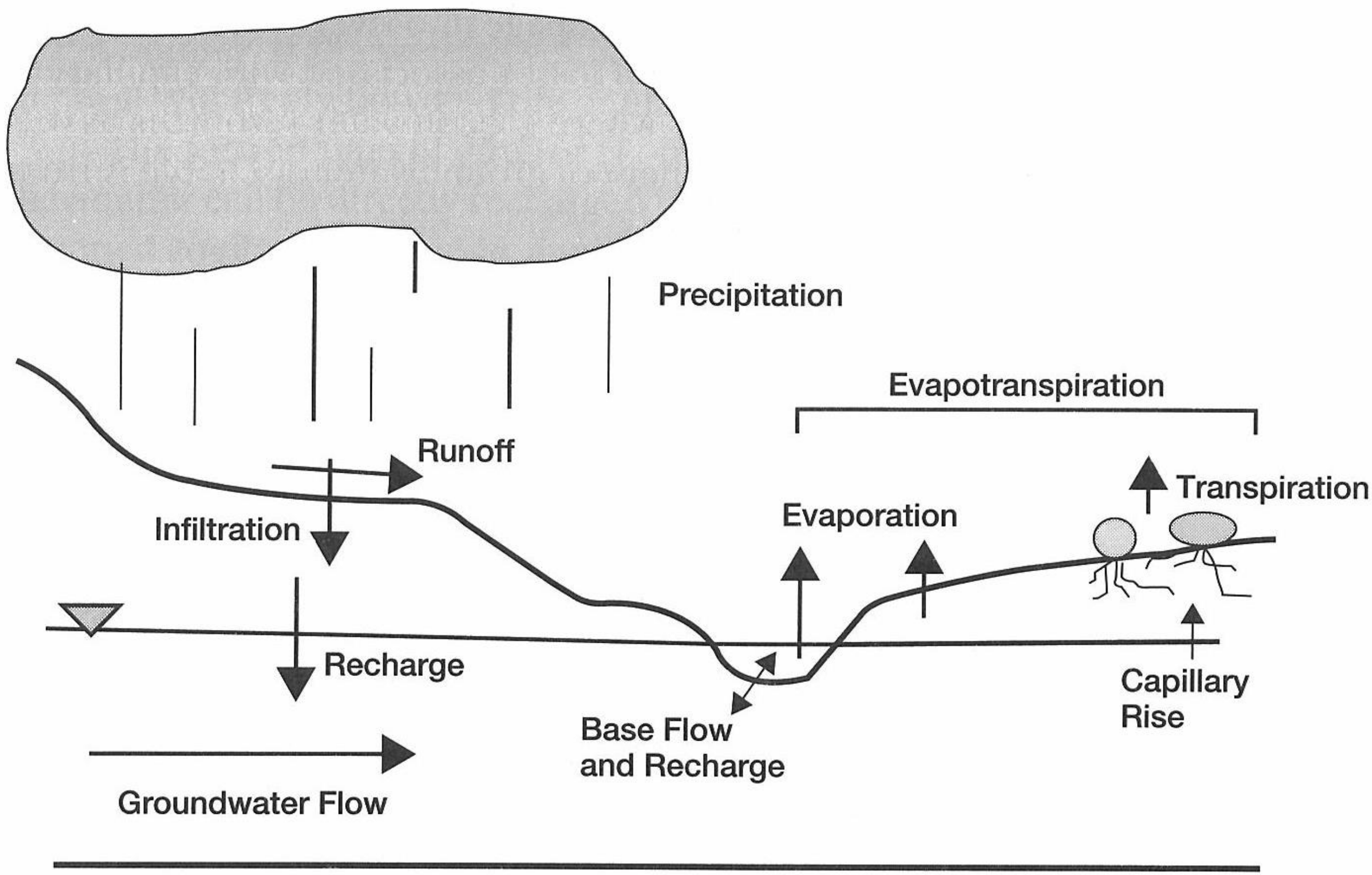
- Hydrologic cycle – circulation of water in the environment
- Surface water evaporates by energy of the sun. The water vapor then forms clouds in the sky. Depending on the temperature and weather conditions, the water vapor condenses and falls to the earth as different types of precipitation (rain, snow, sleet, hail). Some precipitation moves from high areas to low areas on the earth's surface and into surface water bodies. This is known as surface runoff. Other precipitation seeps into the ground and is stored as groundwater.

Hydrologic Cycle



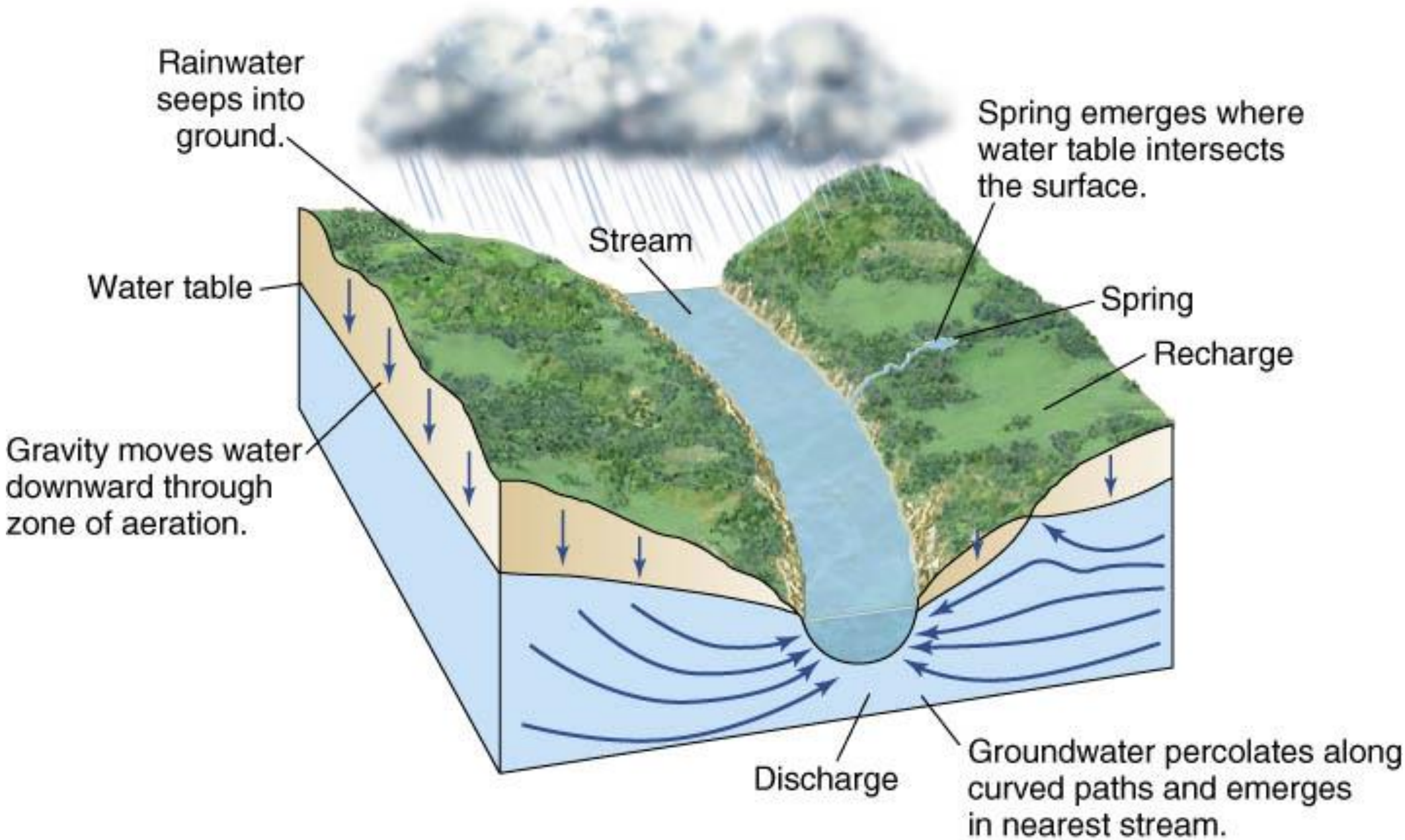
Schematic representation of the hydrologic cycle.

Hydrologic Cycle

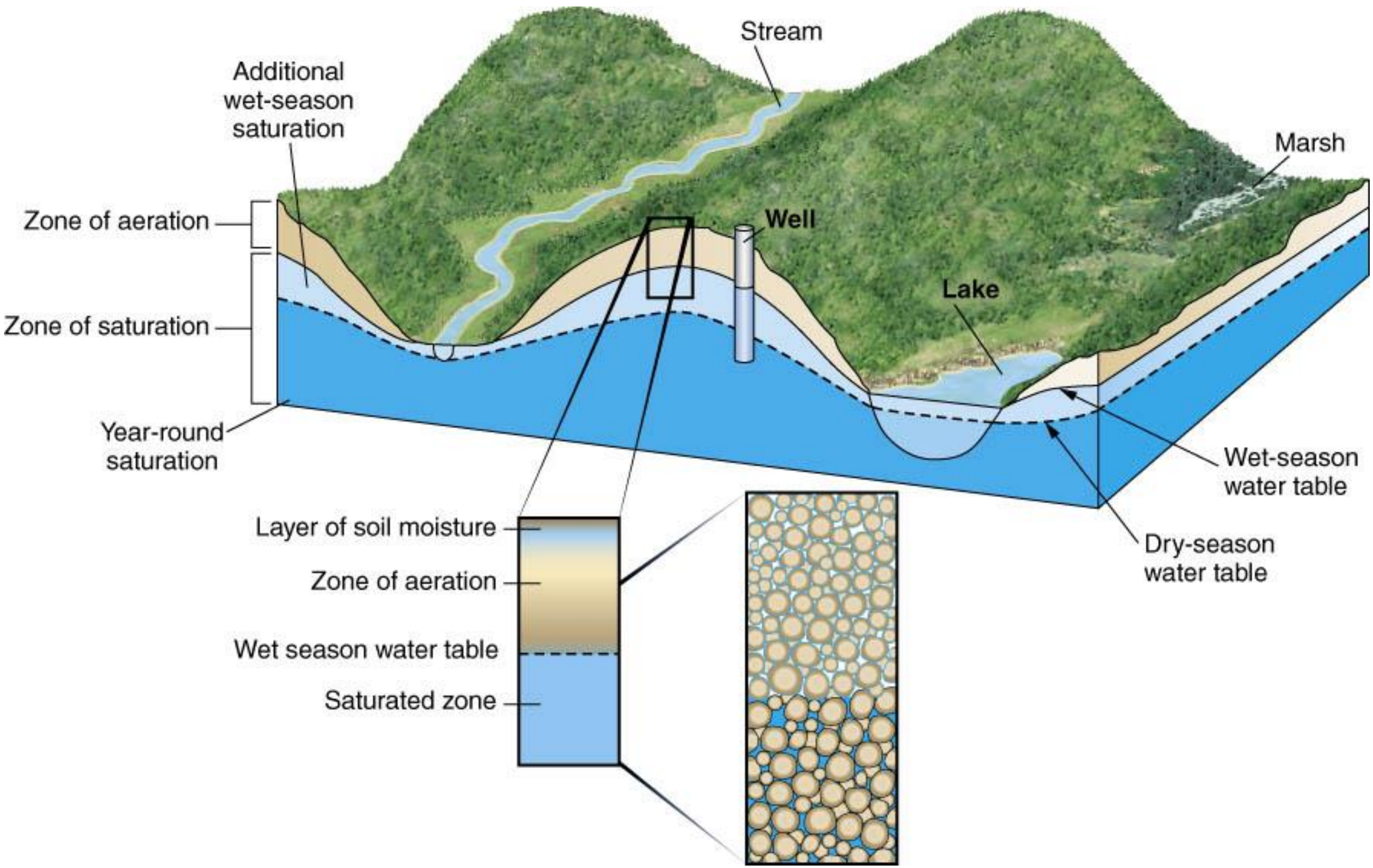


Schematic view of the hydrologic cycle

Hydrologic Cycle

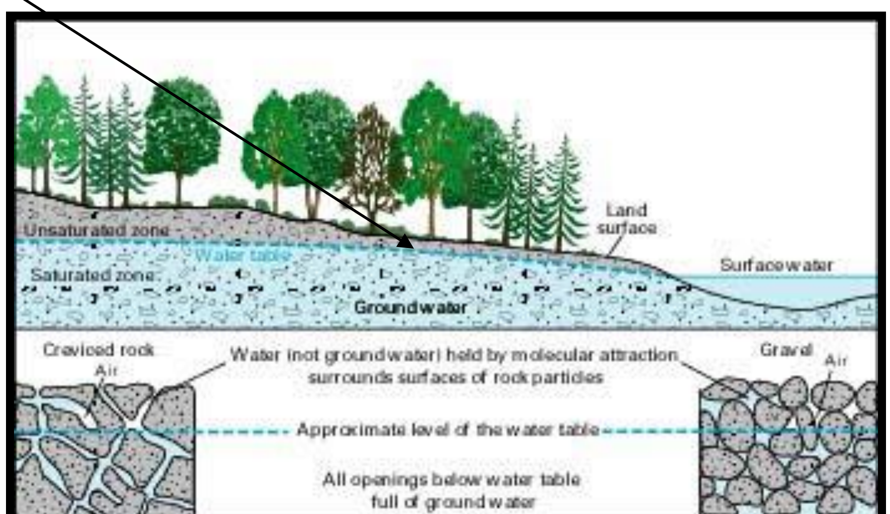


Groundwater



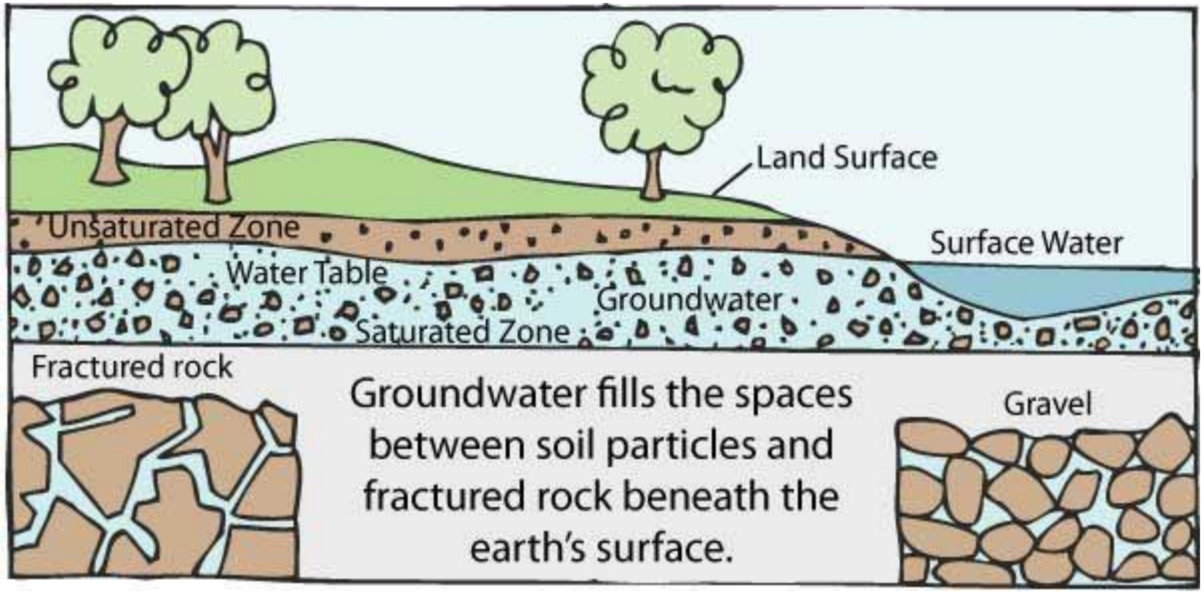
Groundwater

- **Groundwater** is the water found underground in the cracks and spaces in soil, sand and rock. It is stored in and moves slowly through geologic formations of soil, sand and rocks called aquifers.
- Ground water occurs when water recharges the subsurface through cracks and pores in soil and rock
- Shallow water level is called the water table



Groundwater

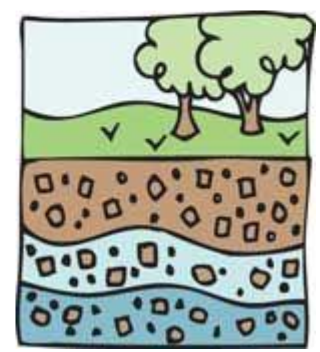
- **Aquifer**: An aquifer is a body of porous rock or sediment saturated with groundwater. Groundwater enters an aquifer as precipitation seeps through the soil. It can move through the aquifer and resurface through springs and wells.
- There are two general types of aquifers: **confined** and **unconfined**. Confined aquifers have a layer of impenetrable rock or clay above them, while unconfined aquifers lie below a permeable layer of soil.
- Many different types of sediments and rocks can form aquifers, including gravel, sandstone, conglomerates, and fractured limestone. Aquifers are sometimes categorized according to the type of rock or sediments of which they are composed.
- The replenishment of aquifers by precipitation is called **recharging**.



The area where water fills the aquifer is called the saturated zone (or saturation zone). The top of this zone is called the water table. The water table may be located only a foot below the ground's surface or it can sit hundreds of feet down.

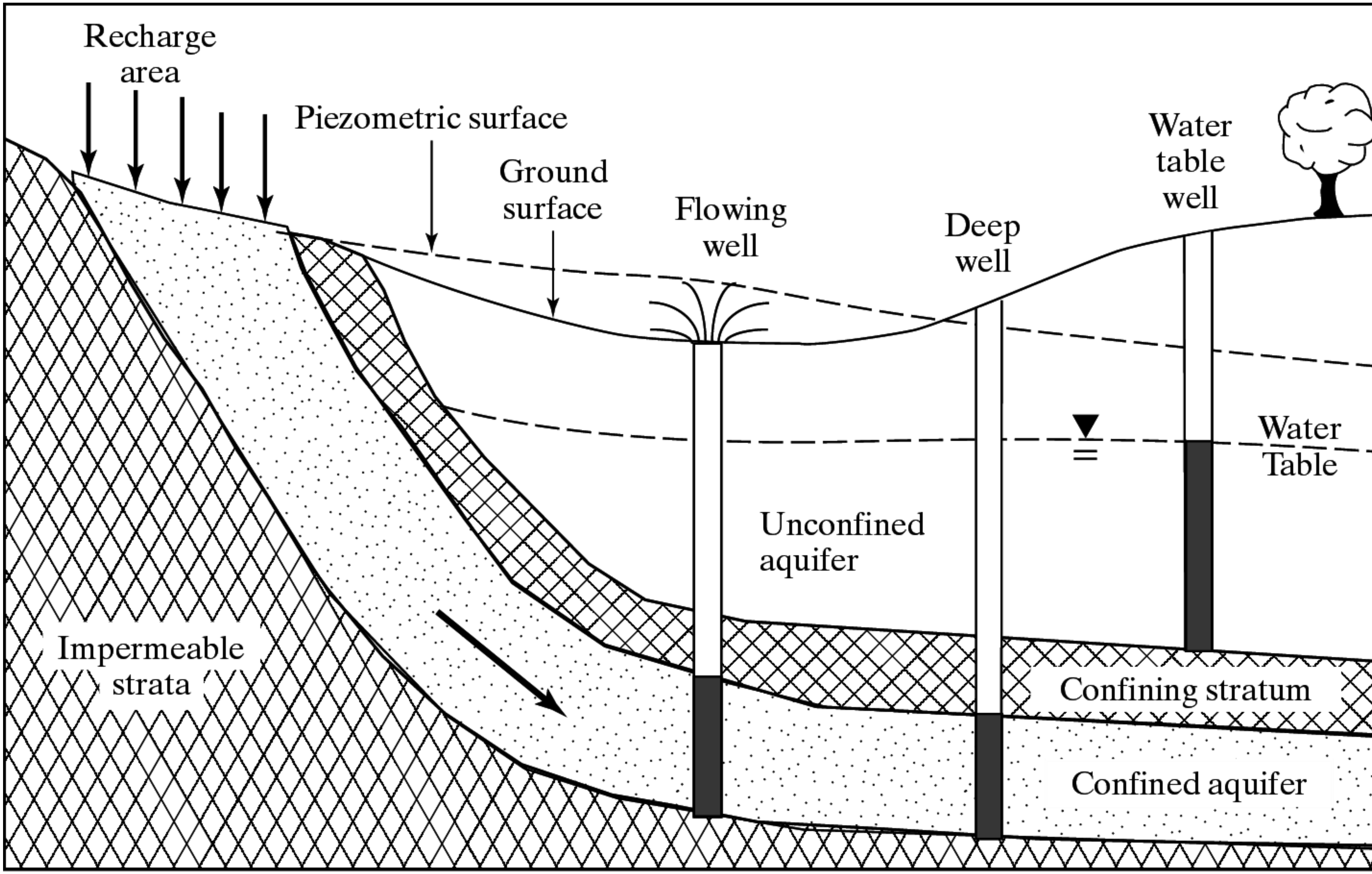
Aquifers are typically made up of gravel, sand, sandstone, or fractured rock, like limestone. Water can move through these materials because they have large connected spaces that make them permeable. The speed at which groundwater flows depends on the size of the spaces in the soil or rock and how well the spaces are connected.

Groundwater can be found almost everywhere. The water table may be deep or shallow; and may rise or fall depending on many factors. Heavy rains or melting snow may cause the water table to rise, or heavy pumping of groundwater supplies may cause the water table to fall.



Groundwater

- A common misconception about aquifers is that they are underground rivers or lakes. While groundwater can seep into or out of aquifers due to their porous nature, it cannot move fast enough to flow like a river. The rate at which groundwater moves through an aquifer varies depending on the rock's permeability
- Aquifers naturally filter groundwater by forcing it to pass through small pores and between sediments, which helps to remove substances from the water. This natural filtration process, however, may not be enough to remove all of the contaminants
- Much of the water we use for domestic, industrial, or agricultural purposes is **groundwater**. Most groundwater, including a significant amount of our drinking water, comes from aquifers. In order to access this water, a well must be created by drilling a hole that reaches the aquifer. While **wells** are **manmade points of discharge for aquifers**, they also **discharge naturally at springs** and in wetlands.


Recharge area
Piezometric surface
Ground surface
Flowing well
Deep well
Water table well
Water Table
Unconfined aquifer
Impermeable strata
Confining stratum
Confined aquifer

Wells

Basically, a well is a hole drilled into the ground to access water contained in an aquifer. A pipe and a pump are used to pull water out of the ground, and a screen filters out unwanted particles that could clog the pipe. Wells come in different shapes and sizes, depending on the type of material the well is drilled into and how much water is being pumped out.

Well Construction

All private well construction is based on establishing the right location for the well, sizing the system correctly and choosing the proper construction techniques. Only professional water well contractors should install wells. They are familiar with the hydrology in an area and all local codes and regulations. Proper well construction is key to operating and maintaining a well.

A well is composed of many components. The most important materials used include:

Casing is used to maintain an open access in the earth while not allowing any entrance or leakage into the well from the surrounding formations. The most popular materials used for casing are steel, PVC pipe and concrete pipe.

Grout is a sealant that is used to fill in the spaces around the outside of the well. It protects the well against the intrusion of contaminants. A grout mixture can be made of cement, bentonite, or concrete (each used separately).

Screen keeps sand and gravel out of the well while allowing groundwater and water from formations to enter into the well. Screen is available in many materials, the most popular being stainless steel and slotted PVC pipe. Screen is used when wells are drilled into unconsolidated materials.

Gravel pack is placed around the outside of the screen to prevent sand from entering the well or clogging the screen and to stabilize the well assembly.

Well Construction

- For understanding of well drilling process using rotary drilling:
- https://www.youtube.com/watch?v=0-KLWEnwiaY

Types of Wells

Three basic types of wells

Bored or shallow wells are usually bored into an unconfined water source, generally found at depths of 100 feet or less.

Consolidated or rock wells are drilled into a formation consisting entirely of a natural rock formation that contains no soil and does not collapse. Their average depth is about 250 feet.

Unconsolidated or sand wells are drilled into a formation consisting of soil, sand, gravel or clay material that collapses upon itself.

Springs

A spring is a place where water moving underground finds an opening to the land surface and emerges, sometimes as just a trickle, maybe only after a rain, and sometimes in a continuous flow. Spring water can also emerge from heated rock underground, giving rise to hot springs.

A spring is a water resource formed when the side of a hill, a valley bottom or other excavation intersects a flowing body of groundwater at or below the local water table, below which the subsurface material is saturated with water. A spring is the result of an aquifer being filled to the point that the water overflows onto the land surface. They range in size from intermittent seeps, which flow only after much rain, to huge pools flowing hundreds of millions of gallons daily.

Springs are not limited to the Earth's surface, though. Recently, scientists have discovered hot springs at depths of up to 2.5 kilometers in the oceans, generally along mid-ocean rifts (spreading ridges). The hot water (over 300 degrees Celsius) coming from these springs is also rich in minerals and sulfur, which results in a unique ecosystem where unusual and exotic sea life seems to thrive.

Streams

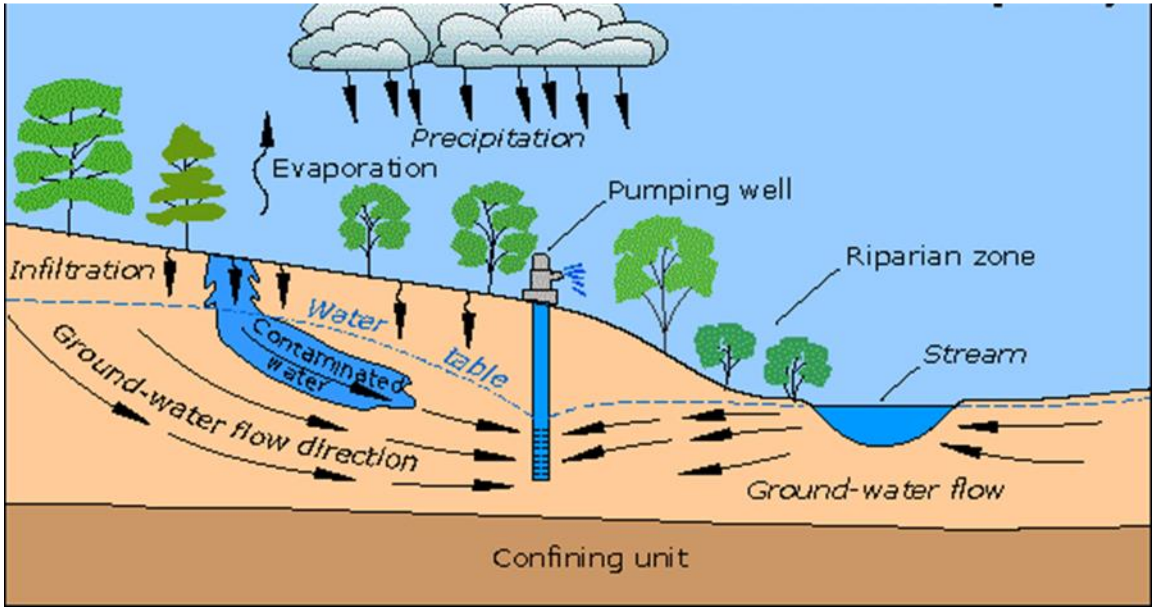
A stream is a body of water with surface water flowing within the bed and banks of a channel. The flow of a stream is controlled by three inputs – surface water, subsurface water and groundwater. The surface and subsurface water are highly variable between periods of rainfall. Groundwater, on the other hand, has a relatively constant input and is controlled more by long-term patterns of precipitation.

Depending on its location or certain characteristics, a stream may be referred to by a variety of local or regional names. Long large streams are usually called **rivers**.

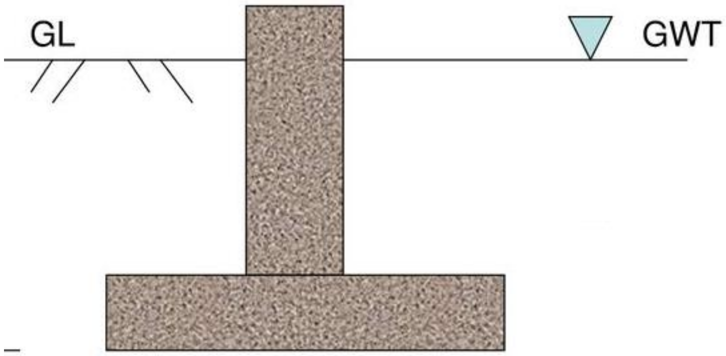
Streams are important as conduits in the water cycle, instruments in groundwater recharge, and corridors for fish and wildlife migration. The biological habitat in the immediate vicinity of a stream is called a riparian zone. The study of streams and waterways in general is known as surface hydrology and is a core element of environmental geography.

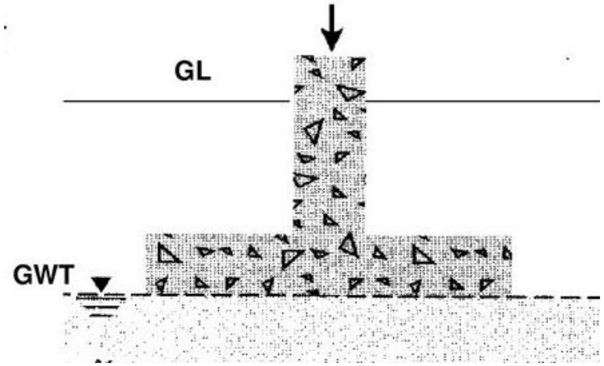
Streams

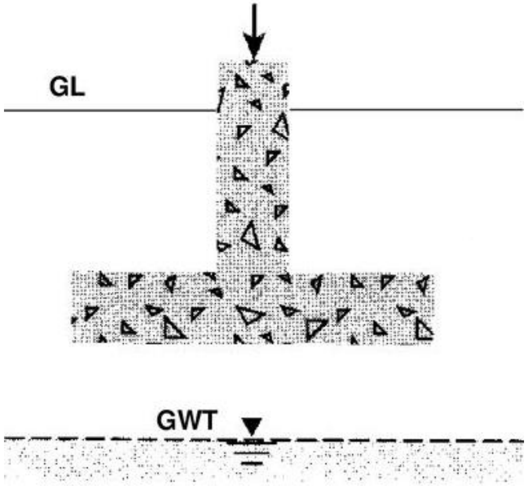
Streams, including those that don't flow all of the time, could be a drizzle of snowmelt that runs down a mountainside crease, a small spring-fed pond, or a depression in the ground that fills with water after every rain and overflows into the creek below. These water sources, which scientists refer to as headwater streams, are often unnamed and rarely appear on maps. Yet the health of small streams is critical to the health of the entire river network and downstream communities. These small streams often appear insignificant, but in fact are very important, as they feed into and create our big rivers.

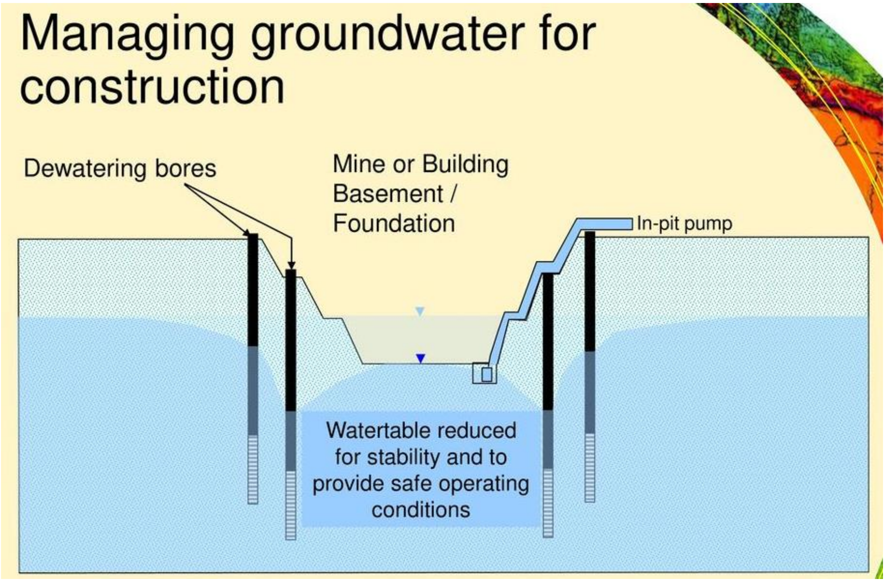


Ground Water Conditions









Glaciers

Glaciers are made up of fallen snow that, over many years, compresses into large, thickened ice masses. Glaciers form when snow remains in one location long enough to transform into ice. What makes glaciers unique is their ability to flow. Due to sheer mass, glaciers flow like very slow rivers. Some glaciers are as small as football fields, while others grow to be dozens or even hundreds of kilometers long.

Presently, glaciers occupy about 10 percent of the world's total land area, with most located in polar regions like Antarctica, Greenland, and the Canadian Arctic. Glaciers can be thought of as remnants from the last Ice Age, when ice covered nearly 32 percent of the land, and 30 percent of the oceans. Most glaciers lie within mountain ranges.

An ice cap is a dome-shaped glacier mass flowing in all directions, such as the ice cap on Ellesmere Island in the Canadian Arctic. An ice sheet is a dome-shaped glacier mass exceeding 50,000 square kilometers. The world's ice sheets are confined to Greenland and Antarctica.

Glaciers

Glaciers begin to form when snow remains in the same area year-round, where enough snow accumulates to transform into ice. Each year, new layers of snow bury and compress the previous layers. This compression forces the snow to re-crystallize, forming grains similar in size and shape to grains of sugar. Gradually the grains grow larger and the air pockets between the grains get smaller, causing the snow to slowly compact and increase in density. After about a year, the snow turns into firn—an intermediate state between snow and glacier ice. At this point, it is about two-thirds as dense as water. Over time, larger ice crystals become so compressed that any air pockets between them are very tiny. In very old glacier ice, crystals can reach several inches in length. For most glaciers, this process takes more than a hundred years.

For further information:

https://www.swisseduc.ch/glaciers/earth_icy_planet/glaciers03-en.html

Major Types of Glaciers

Glaciers fall into two groups:

- Alpine Glaciers and
- Ice Sheets

Alpine glaciers form on mountainsides and move downward through valleys. Sometimes, alpine glaciers create or deepen valleys by pushing dirt, soil, and other materials out of their way. Alpine glaciers are found in high mountains of every continent except Australia. Alpine glaciers are also called valley glaciers or mountain glaciers.

Ice sheets, unlike alpine glaciers, are not limited to mountainous areas. They form broad domes and spread out from their centers in all directions. As ice sheets spread, they cover everything around them with a thick blanket of ice, including valleys, plains, and even entire mountains. The largest ice sheets, called continental glaciers, spread over vast areas. Today, continental glaciers cover most of Antarctica and the island of Greenland.

Movement of Glaciers

- The sheer weight of a thick layer of ice, or the force of gravity on the ice mass, causes glaciers to flow very slowly. Ice is a soft material, in comparison to rock, and is much more easily deformed by this relentless pressure of its own weight. Ice may flow down mountain valleys, fan out across plains, or in some locations, spread out onto the sea. Movement along the underside of a glacier is slower than movement at the top due to the friction with the underlying ground's surface. Where the base of the glacier is very cold, the movement at the bottom can be a tiny fraction of the speed of flow at the surface.
- Sometimes a glacier slides over a thin water layer at the glacier's base. The water may result from glacial melt driven by pressure of the overlying ice, or from water working its way through glacier cracks to the base. Glaciers can also slide on a soft, watery sediment bed. This basal sliding may account for most of the movement of thin, cold glaciers on steep slopes. Warm, thick glaciers on gentle slopes owe less of their movement to basal sliding.

Movement of Glaciers

- Glaciers periodically **retreat** or **advance**, depending on the amount of snow accumulation or melt that occurs. This retreat and advance refers only to the position of the terminus, or snout (the end of a glacier, usually the lowest end), of the glacier. Even as it retreats, the glacier still deforms and moves downslope, like a conveyor belt. In other words, a retreating glacier does not flow uphill; it simply melts faster than it flows.
- Alternatively, glaciers may **surge**, racing forward several meters per day for weeks or even months. In 1986, the Hubbard Glacier in Alaska surged at the rate of 10 meters (32 feet) per day across the mouth of Russell Fjord. In only two months, the glacier had dammed water in the fjord and created a lake.

Types of Glaciers

- **Mountain/Alpine glaciers**

These glaciers develop in high mountainous regions, often flowing out of icefields that span several peaks or even a mountain range. The largest mountain glaciers are found in Arctic Canada, Alaska, the Andes in South America, and the Himalaya in Asia.

- **Valley glaciers**

Commonly originating from mountain glaciers or icefields, these glaciers spill down valleys, looking much like giant tongues. Valley glaciers may be very long, often flowing down beyond the snow line, sometimes reaching sea level.

- **Tidewater glaciers**

As the name implies, these are valley glaciers that flow far enough to reach out into the sea. In some locations, tidewater glaciers provide breeding habitats for seals. Tidewater glaciers are responsible for calving numerous small icebergs, which although not as imposing as Antarctic icebergs, can still pose problems for shipping lanes.

Mountain/Alpine glaciers

Tidewater glaciers

Valley glaciers

Types of Glaciers

- **Cirque glaciers**

A cirque glacier is formed in a cirque, a bowl-shaped depression on the side of or near mountains. Snow and ice accumulation in corries often occurs as the result of avalanching from higher surrounding slopes. If a cirque glacier advances far enough, it may become a valley glacier. Additionally, if a valley glacier retreats enough that it is within the cirque, it becomes a cirque glacier again.

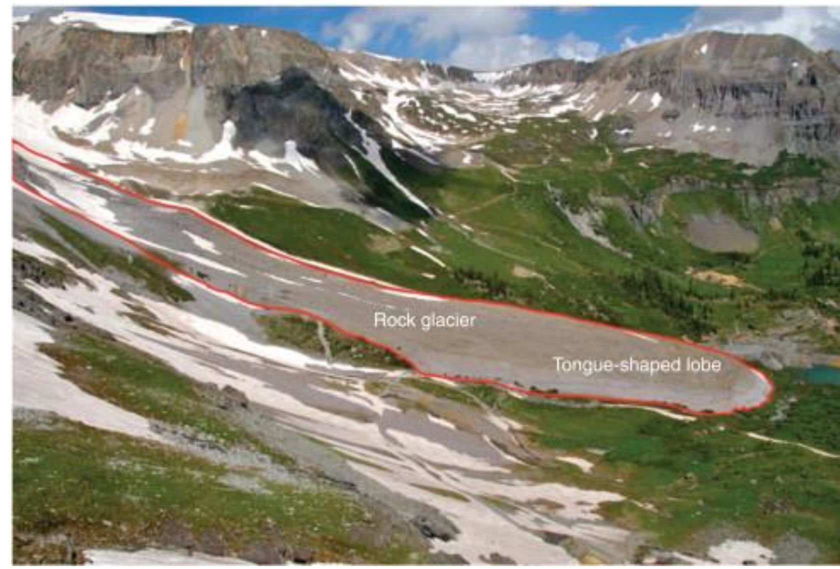
- **Ice aprons**

These small, steep glaciers cling to high mountainsides. Like cirque glaciers, they are often wider than they are long. Ice aprons are common in the Alps and in New Zealand, where they often cause avalanches due to the steep inclines they occupy.

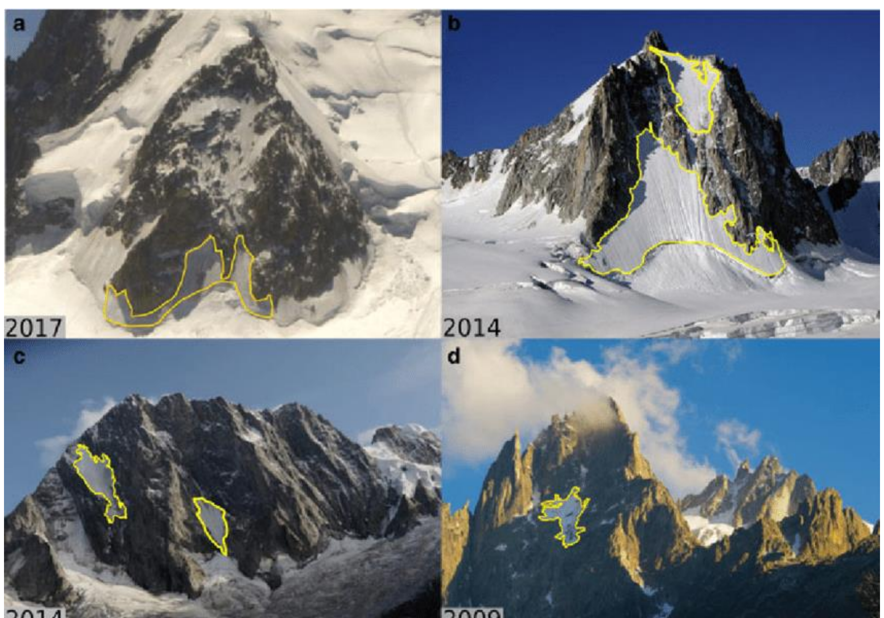
- **Rock glaciers**

Rock glaciers are combinations of ice and rock. Although these glaciers have similar shapes and movements as regular glaciers, their ice may be confined to the glacier core, or may simply fill spaces between rocks. Rock glaciers may form when frozen ground creeps downslope. They may also accumulate ice, snow, and rocks through avalanches or landslides.

Cirque glaciers



Rock glaciers



Ice aprons

Types of Glaciers

- **Ice sheets**

Found now only in Antarctica and Greenland, ice sheets are enormous continental masses of glacial ice and snow expanding over 50,000 square kilometers. The ice sheet on Antarctica is over 4.7 kilometers (3 miles) thick in some areas, covering nearly all of the land features except the Transantarctic Mountains, which protrude above the ice. Another example is the Greenland Ice Sheet. In the past ice ages, huge ice sheets also covered most of Canada and Scandinavia (the Scandinavian Ice Sheet), but these have now disappeared, leaving only a few ice caps and mountain glaciers behind.

- **Ice caps**

Ice caps are miniature ice sheets, covering less than 50,000 square kilometers They form primarily in polar and sub-polar regions and are smaller than continental-scale ice sheets.

- **Ice fields**

Icefields are similar to ice caps, except that their flow is influenced by the underlying topography, and they are typically smaller than ice caps.

Ice Sheets

Ice field

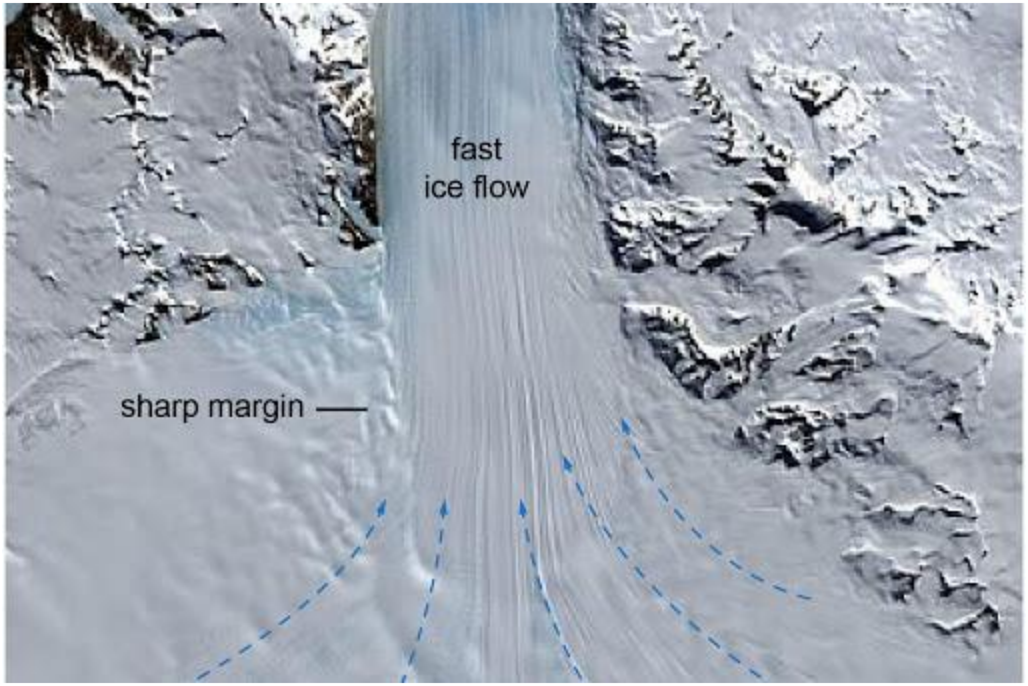
Types of Glaciers

- **Ice streams**

Ice streams are large ribbon-like glaciers set within an ice sheet—they are bordered by ice that is flowing more slowly, rather than by rock outcrop or mountain ranges. These huge masses of flowing ice are often very sensitive to changes such as the loss of ice shelves at their terminus or changing amounts of water flowing beneath them. The Antarctic ice sheet has many ice streams.

- **Ice shelves**

Ice shelves occur when ice sheets extend over the sea and float on the water. They range from a few hundred meters to over 1 kilometer (0.62 mile) in thickness. Ice shelves surround most of the Antarctic continent.



Ice streams

Ice shelves