Central Ground Water Board, North Western Himalayan Region Jammu

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OCCURRENCE, DISTRIBUTION AND MOVEMENT OF GROUND WATER

HYDROGEOLOGY

Groundwater Science

Study of rocks Which refers to the Occurrence, distribution & movement of water below ground (earth) surface

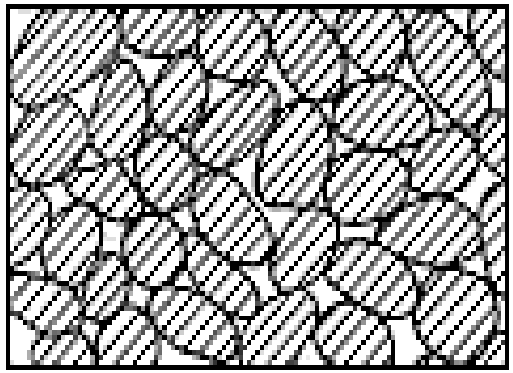
HYDROGEOLOGY

1. Occurrence of ground water in any region is determined by the geology of that region.
2. Rocks in the outer crust of the earth are not solid but have numerous openings, called voids or interstices.
3. The number, size, and shape of these openings depend upon the matrix of rocks.

HYDROGEOLOGY

1. Ground water occurs in material constituting the sub-surface strata.
   - Porous and permeable enough to transmit the water and
   - Rate of percolation depends on permeability and porosity of rocks

1. Interstices or voids in rocks range in size from microscopic openings in clay to huge caverns in limestone.
2. Openings generally are connected which makes water to move from one void to another, but
3. In some rocks, voids are isolated so that there is little or no movement of the water.



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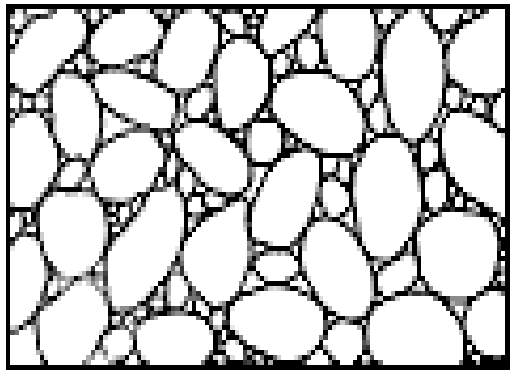

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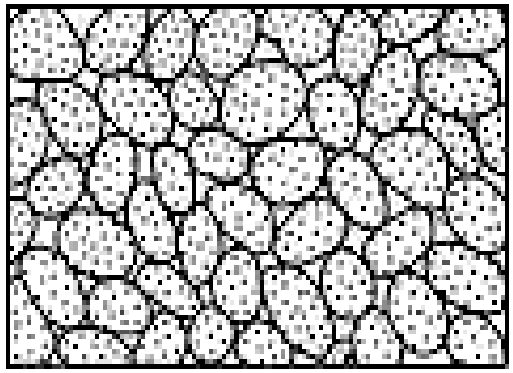

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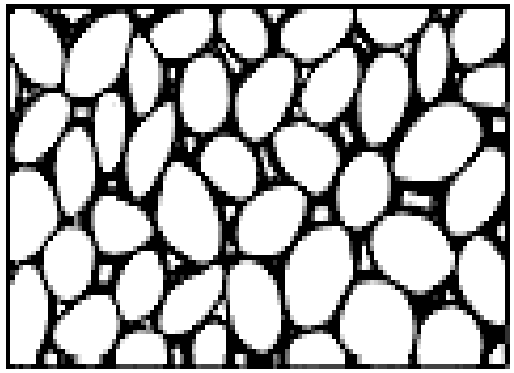

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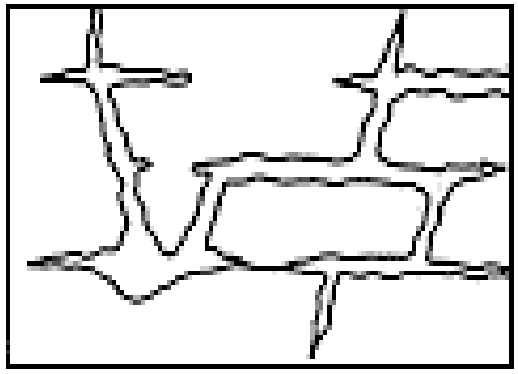

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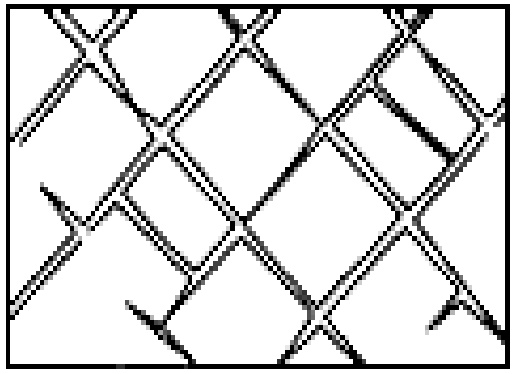

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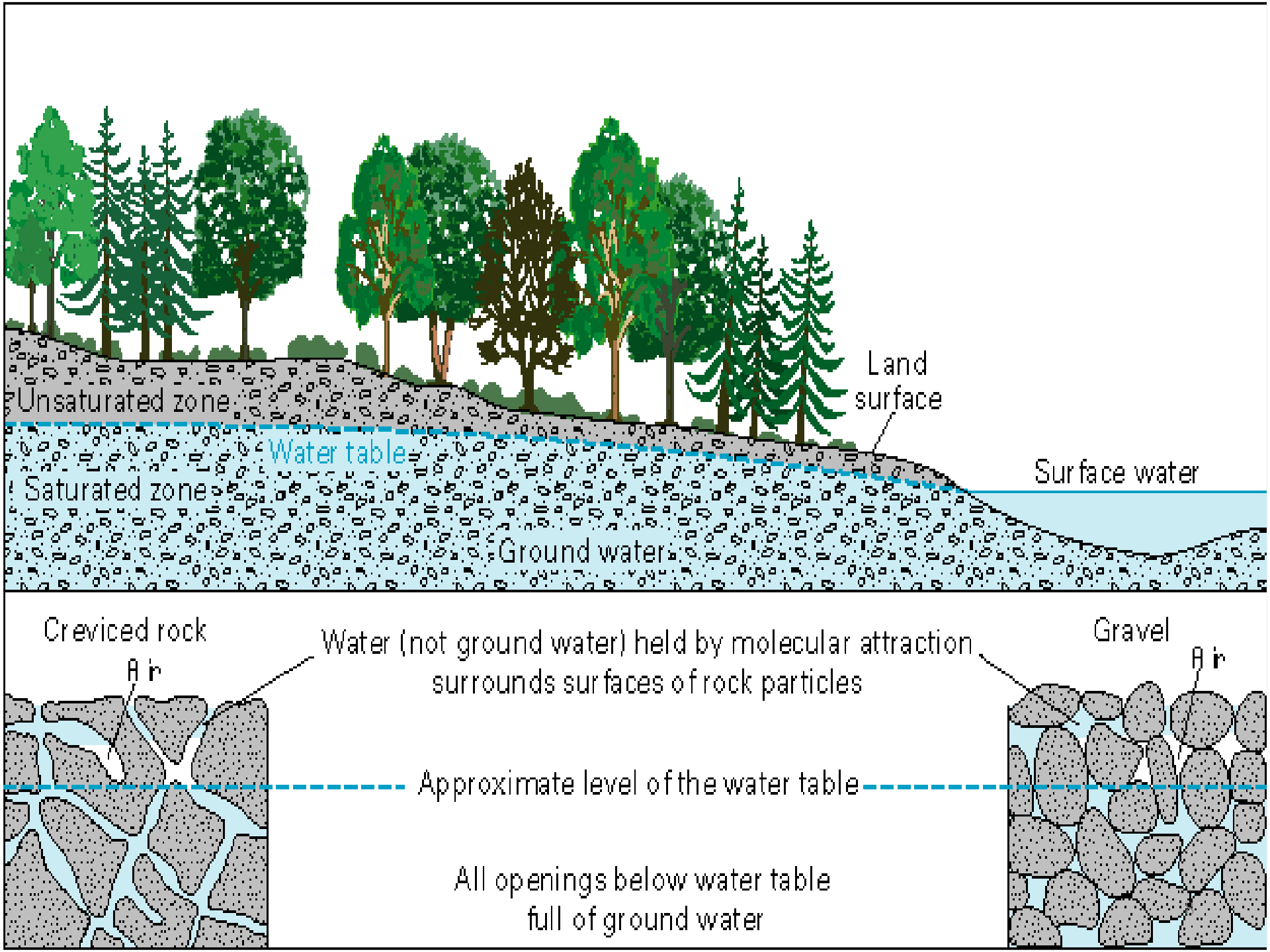

Land surface
Unsaturated zone
Water table
Saturated zone
Surface water
Ground water
Creviced rock
Air
Water (not ground water) held by molecular attraction surrounds surfaces of rock particles
Gravel
Air
Approximate level of the water table
All openings below water table full of ground water

Porosity

1. Porosity of a sediment / rock is a measure of its interstitial space
   i. Expressed quantitatively as the percentage of total volume of the rock occupied by interstices.
   ii. Porosity greater than 20% is considered large and less that 5% is considered small.

Porosity.

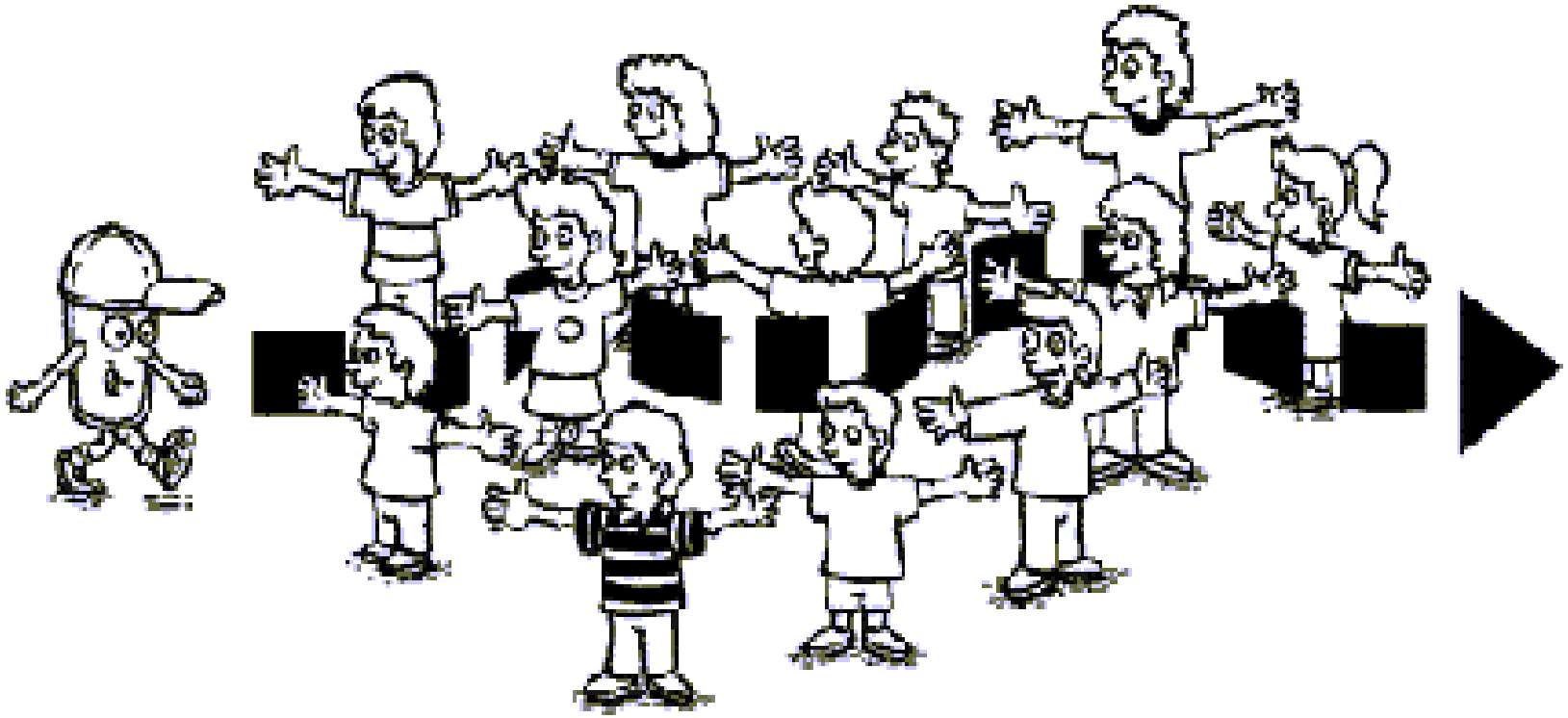
1. It depends on the shape and arrangement of the constituent particles, the degree of assortment of its particles,
2. Cementation and compacting to which it has been subjected since its deposition,
3. Removal of mineral matter through solution by percolating water and
4. Fracturing of the rocks resulting in joints and other interstices.

Porosity.

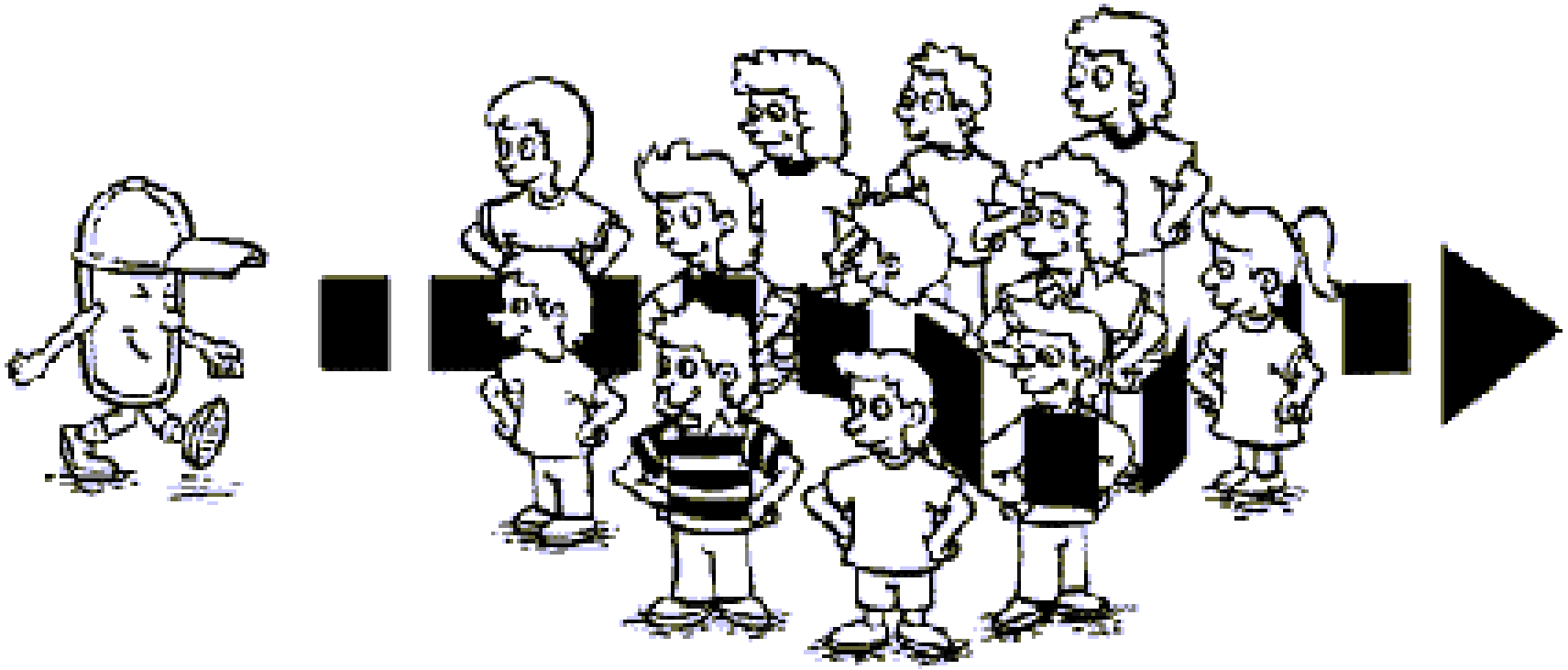
1. Primary Porosity: refers to the porosity developed during deposition and
2. Secondary Porosity: designates the porosity developed subsequently due to various activities

Permeability

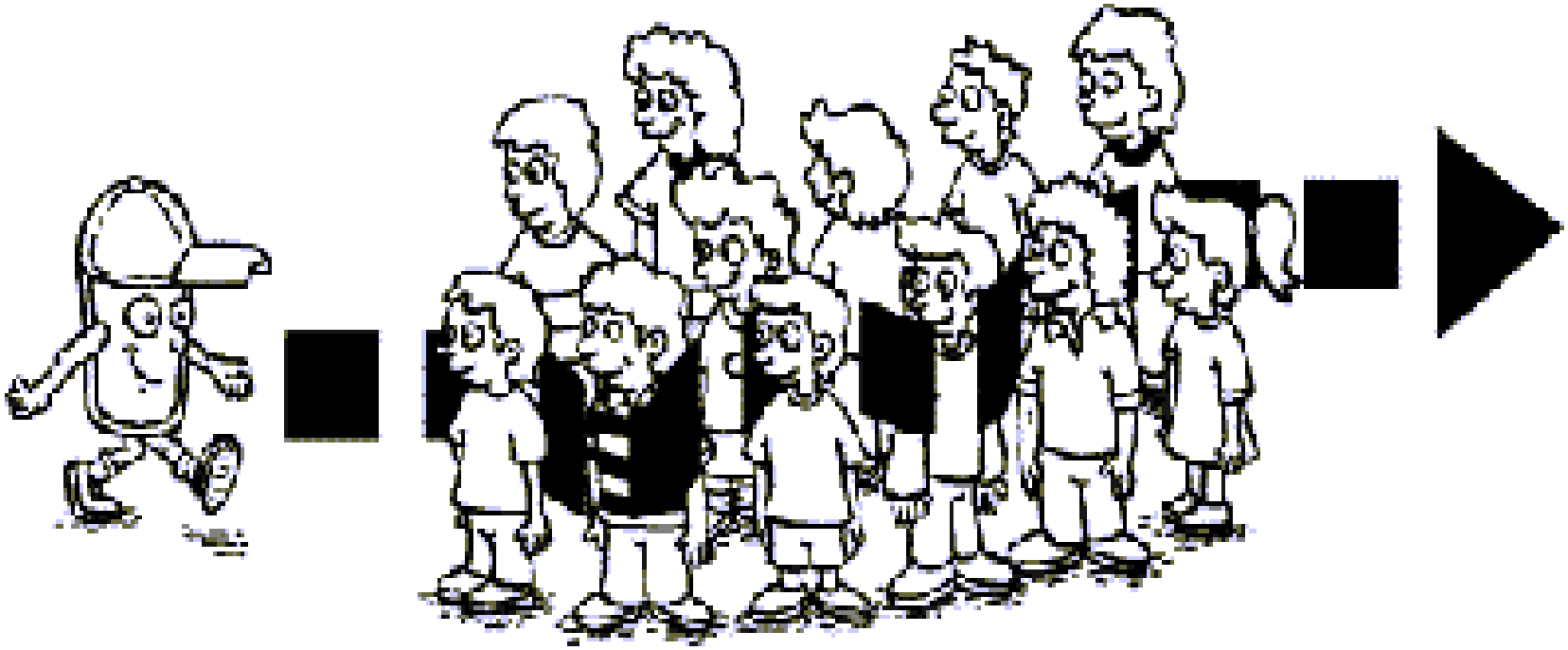
1. Permeability is the measure of the ease with which movement of ground water through aquifers takes place.
2. It is different from hydraulic conductivity in the sense that it does not take into account, the properties of the fluid passing through it.
3. The coefficient of permeability can be defined as the rate of flow per unit cross sectional area of the formation,



Ground Water Movement through Gravel



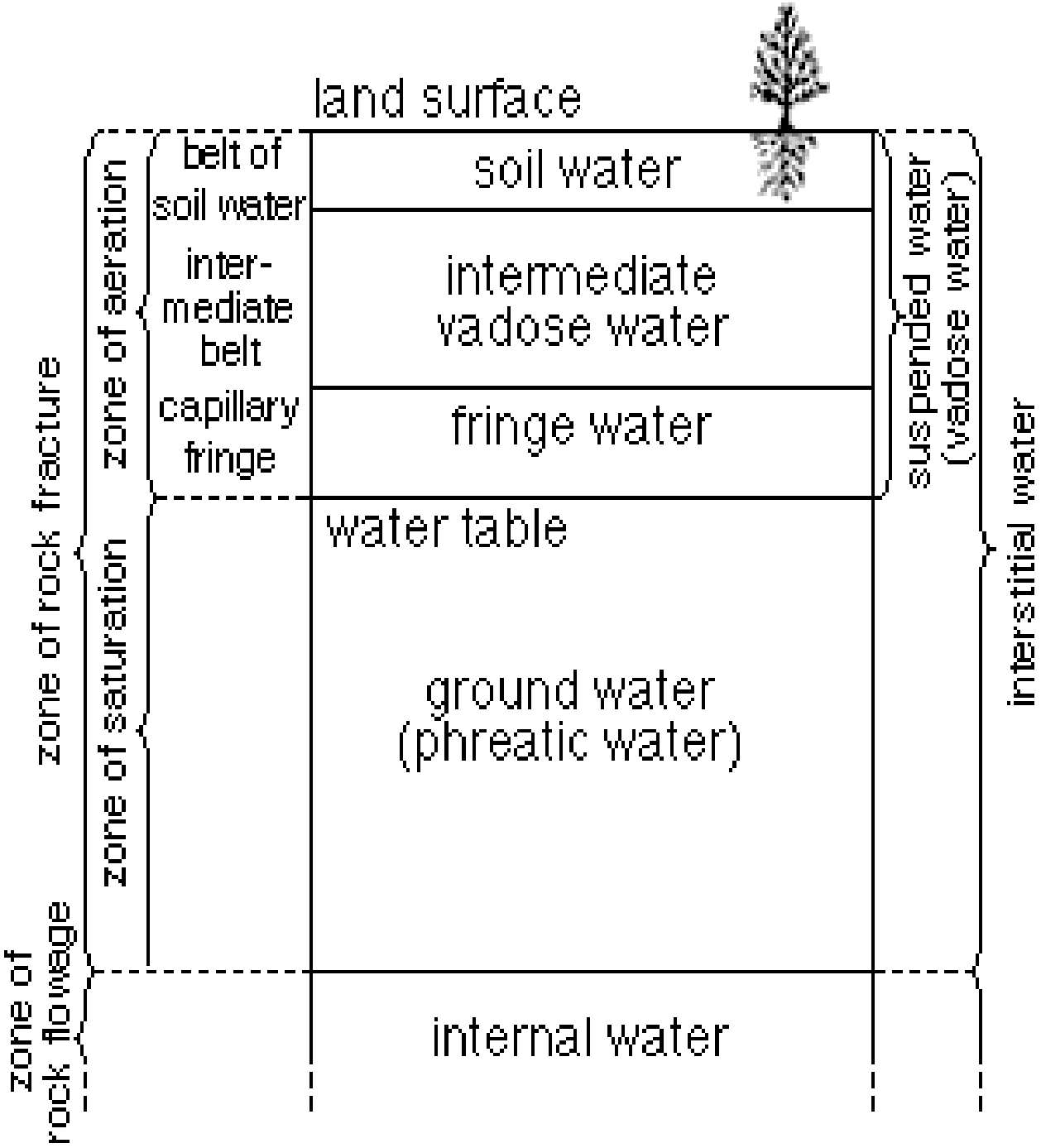
Ground Water Movement through Sand

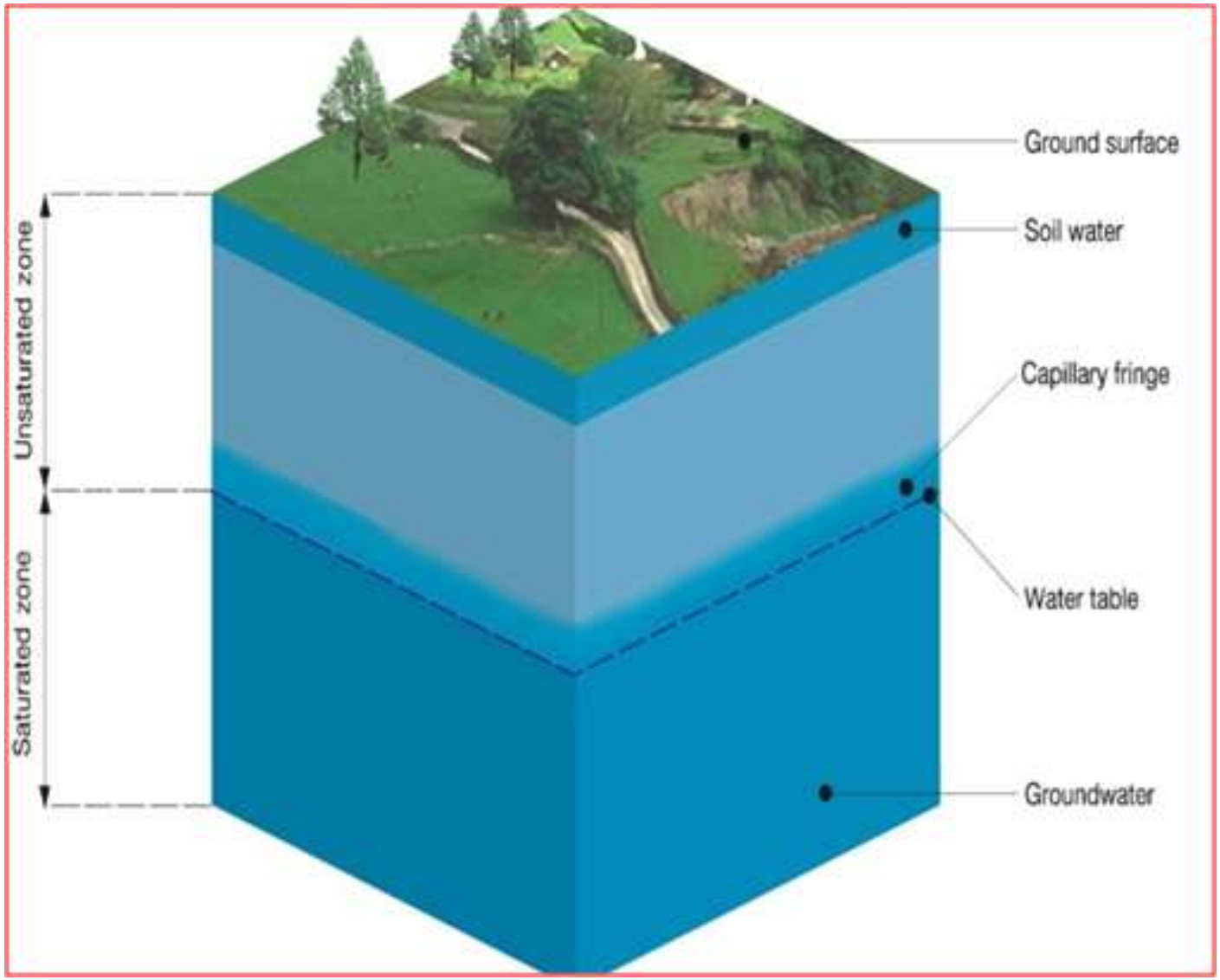


Ground Water Movement through Clay

Vertical Distribution of Ground Water

The occurrence of sub surface water may be divided into zones of aeration and saturation. The zone of aeration consists of interstices occupied partially by air and partially by water, the water contained in it is known as vadoze water.


land surface
belt of soil water
inter-mediate belt
capillary fringe
soil water
intermediate vadose water
fringe water
water table
ground water (phreatic water)
internal water
zone of aeration
zone of saturation
zone of rock fracture
zone of rock flowage
suspended water (vadose water)
interstitial water


Ground surface
Soil water
Capillary fringe
Water table
Groundwater
Unsaturated zone
Saturated zone

AQUIFER

1. An aquifer is a saturated geologic formation which yields sufficient quantity of water to springs and wells as a source of supply.
2. The principal requirement of a geologic formation to be designated as an aquifer is its ability to store water in its interstices (pores) and to transport the water from the recharge area, where it receives the water.
3. Aquifer serves as a storage reservoir and transmission conduit.

AQUICLUDE

Aquiclude is a saturated formation

Yields inappreciable quantities of water to wells as there is inappreciable movement of water through them .

Example: clay etc.

AQUITARD

1. It is a saturated formation, which yields inappreciable quantities of water to wells etc. compared to an aquifer, but
   i. through which appreciable leakage of water is possible. Example: Silt, clay with admixture of fine sand.

AQUIFUGE

1. Geologic formation, with no interconnected pores
   i. Can neither absorb nor
   ii. transmit water. Example massive basalt, granite etc.

1-Static Water level:

Static level is the level of water in a well when no water is being taken from the well by pumps It is usually expressed as the distance in feet or meters from the ground surface to the water level.

2-Pumping Water level:

Pumping level is the level of water in the well during pumping. This, too, is usually expressed as the distance in feet or meters from the ground surface to the water level.

3-Drawdown:

Drawdown is the drop in level of water in a well when water is being pumped. Drawdown is difference between the static level and the pumping level.

4-Well yield

Well yield is the volume of water per unit of time that is produced from the well by pumping.

5-Well recovery

The recovery time of a well is the time required for the aquifer to stabilize at the static water level once pumping has stopped. The rate of well's recovery determines how long you should wait before finding the static level.

Geologic formation as aquifers

Alluvial deposits

1. Unconsolidated deposits of sand and gravel are the most important aquifers where they have high permeability, they provide large ground water supplies.
2. The aquifers are recharged chiefly in areas, accessible to downward percolation of water from precipitation.

Volcanic Rocks

1. Volcanic rocks such as basalt, constitute aquifers.
2. Type of opening include, interstitial space at the top of flows,
   i. Shrinkage cracks, gas vesicles and fissures & resulting from cracking
   ii. Faulting after cooling in massive basalts.

Lime stones & Dolomites

1. The aquifers in which secondary solution openings occur.
2. Ground Water dissolves the rocks, and create larger openings, ultimate development of which is Karst region, with features like sink holes, sub surface drainage etc.

Igneous & Metamorphic Rocks

1. Impermeable and do not constitute aquifers.
   i. They undergo weathering and form a porous and permeable zones near the top, developed by small wells for limited water supply.
2. Fractures and joints developed in the rocks, known as secondary porosity, constitute at places good aquifers.

Types of Aquifers

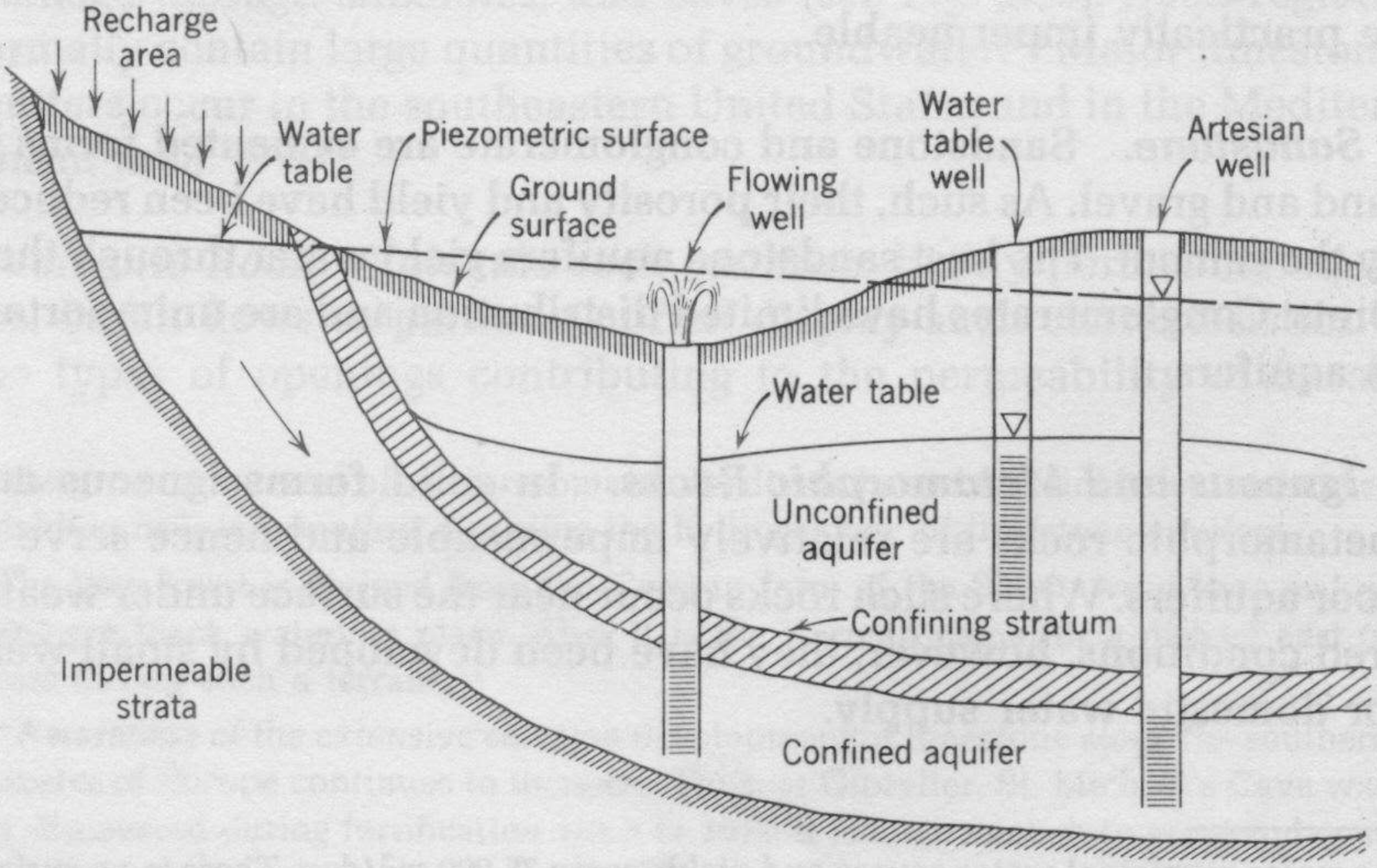


Fig. 2.11 Schematic cross section illustrating unconfined and confined aquifers.

Unconfined aquifer

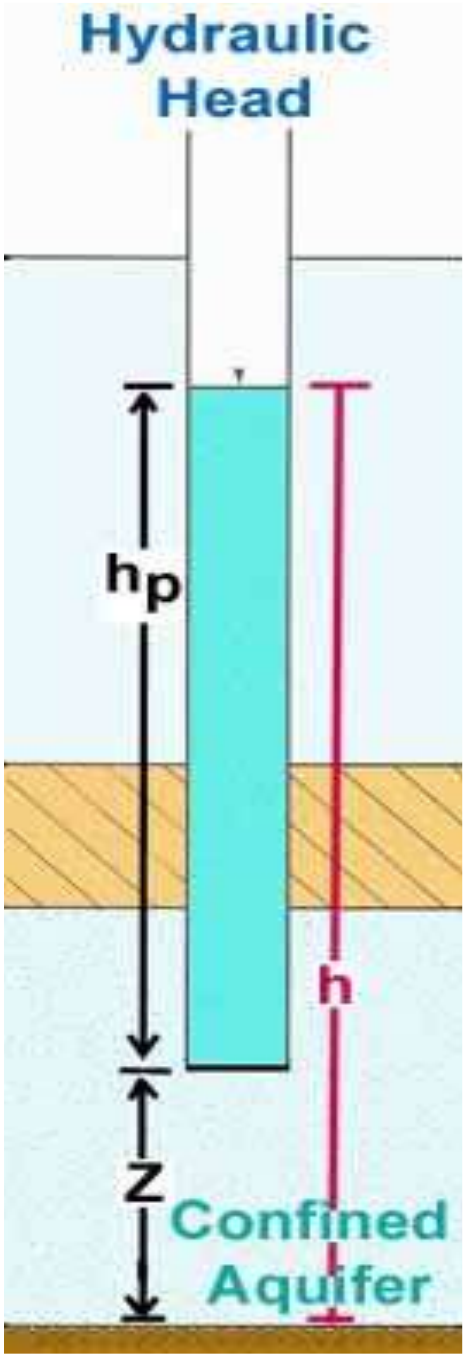
1. An unconfined aquifer is under atmospheric pressure.
2. In unconfined aquifer water table or the upper surface of the zone of saturation, varies
   i. In undulating form and in slope, depending upon areas of recharge and discharge
   ii. Pumping and permeability of the aquifer.
   iii. Rise and fall in water level correspond to changes in the volume of water in storage.

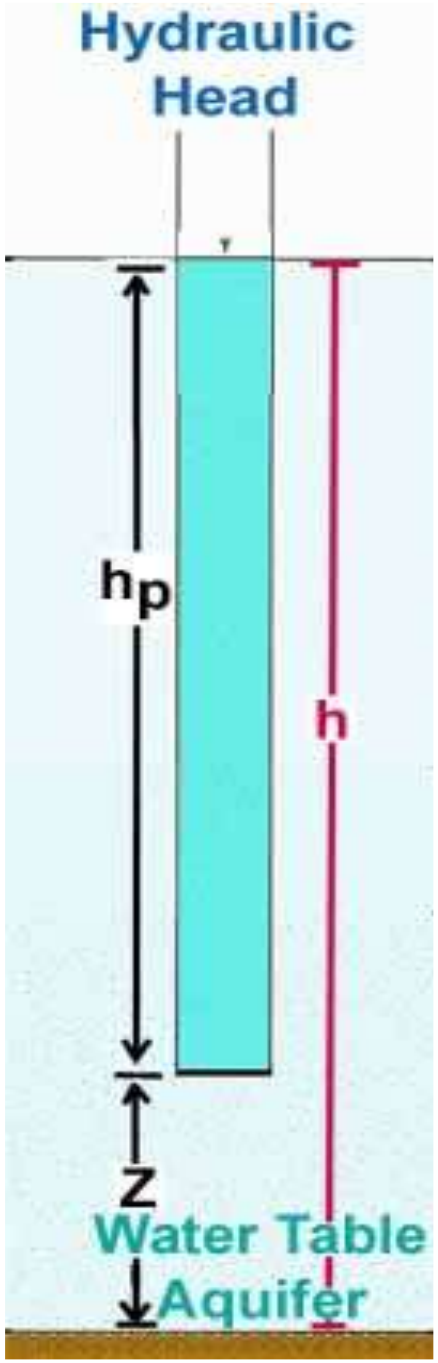
CONFINED AQUIFER

- Confined aquifers may also be referred to as artesian aquifers.
- A confined aquifer is sandwiched between confining beds Because of the confining beds, ground water in these aquifers is under high pressure, because of compaction of rock and expansion of water.
- The water level in a well will rise to a level higher than the water level at the top of the aquifer. The water level in the well is referred to as the potentiometric surface or pressure surface.

CONFINED AQUIFER

1. When a well is drilled through the confining unit, usually far from the recharge zone,
2. the water in this well will rise to the level of the water at the recharge zone.
3. In some instances this may be above the surface of the ground, in which case the well is called a flowing/ artesian well.
4. In some situation, where the level of the water at the recharge zone is above the base of the confining unit, leads to the appearance of springs or seeps where the confining unit is penetrated by a hillside.


Hydraulic
Head
hp
h
Z
Confined
Aquifer


Hydraulic
Head
hp
h
Z
Water Table
Aquifer

Movement of water in Confined aquifer

1. Water pumped from a confined aquifer moves by three principal processes.
   i. Leakage into the aquifer,
   ii. expansion of water within the aquifer because of pressure head reduction, and
   iii. compaction of the aquifer much like squeezing a sponge.
      i. The amount of water yielded by each process depends on the degree to which the aquifer is confined and the compressibility of the aquifer.
      ii. Voids or pore spaces in confined aquifers remain saturated. **If they are dewatered the aquifer becomes unconfined.**

Leakage

The rate of leakage into the confined aquifer is determined by

1. Composition,
2. Thickness,
3. Fracturing,
4. Geometry Of The Confining Material.

If there is fair hydraulic interconnection with other aquifers, leakage will soon equal water being pumped and additional lowering of the well level will stop. The original source of leakage is infiltrating precipitation.

Expansion

Pumping lowers the pressure head in an aquifer. Since water in a confined aquifer may be slightly compressed, a reduction of pressure head means the water will expand.

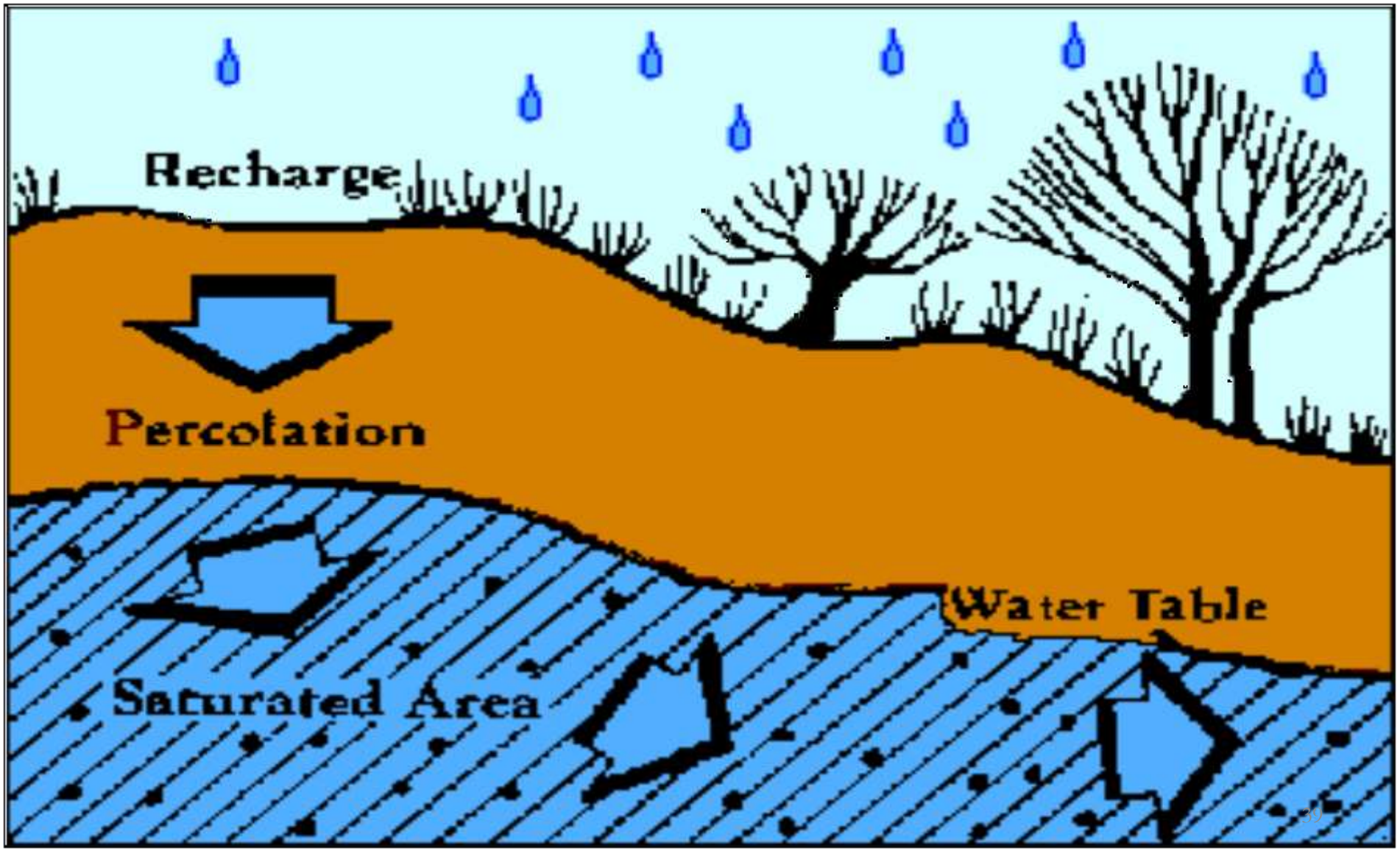
1. This increase in volume then replaces the water that was removed by pumping. It should again be noted that no pore spaces (voids) are dewatered.
2. A large pressure head drop is needed to create significant expansion of water. As a result, the drawdowns in confined aquifers are much greater than in unconfined aquifers.

Compaction

A drop in pressure head means

1. Less hydraulic pressure is exerted against the confining layer overlying the aquifer and more of the weight of the earth above the aquifer must be borne by the solid material of the aquifer.
2. Under these conditions the aquifer itself may compact, leaving less pore space for water storage. The degree of compaction would depend on the strength and composition of the materials in the aquifer.

Recharge of Confined Aquifers



Ground Water Recharge

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.

Leaky Aquifers

Aquifers that are completely confined or unconfined occur less frequently.

1. The hydrogeological conditions, where a permeable stratum is overlain by a semi-pervious aquitard or a semi confining layer.
2. The permeable stratum is known as leaky aquifer or semi confined aquifer. Lumping from a leaky aquifer induces vertical flow from the aquitard into the aquifer.

Aquifer Characteristics

Specific Yield

Expressed quantitatively as the percentage of the total volume of the formation occupied by the ultimate volume of water that can be released or added to storage in a water table aquifer, per unit area of the aquifer and per unit decline or rise of the water table.

Values of specific yield depend on grain size, shape and distribution of pores, compaction of the stratum.

1. Fine grained aquifer yield less water as compared to the coarse grained one.
2. In general, the specific yield values range between 7-15%, because of mixture of grain size present.

Specific Yield

1. The specific yield of a formation is needed to estimate the quantity of water available to wells and
2. To estimate the quantity of water represented by a rise or decline in the water table during periods of recharge or discharge.

Specific Retention

The specific retention is water retaining capacity of the formation, it will retain after desaturation against the force of gravity, to its own volume.

$$Sr = Wr/v$$

Where Sr= Specific retention, Wr= Volume occupied by retained water

V = Bulk volume of the formation.

Transmissivity-T

1. Co-efficient of transmissibility is widely used in ground water hydraulics.
   i. Transmissibility indicates the capacity of an aquifer to transmit water through its entire thickness
   ii. Equal to the coefficient of permeability multiplied by the saturated thickness of the aquifer i.e.
   T= Kb = m2/day

   Where b is the saturated thickness of the aquifer in meter

Storage Coefficients-S

The coefficient of storage of an aquifer has been defined as the volume of water that

1. An aquifer releases from or takes into storage per unit surface area of the aquifer per unit decline or rise of head normal to that surface.
2. In unconfined Aquifers, it is equal to specific yield.
3. A dimension less quantity, involving a volume of water per unit volume of aquifer.
4. Can be determined from pumping tests of well. Its value range between $5*10^{-5}$ and $5*10^{-3}$

Depth To Water Level Maps

Maps are prepared from observations of depth to water level in Ground Water Observation Wells.

1. These maps help in ascertaining the general ground water condition
2. Change in depth to water level indicates the change in ground water storage.

Water Table Contour Maps

Maps are prepared from observations of altitude of water levels above mean Sea level in Ground Water Observation Wells.

These maps indicate the

i. Hydraulic gradient
ii. Direction of ground water flow,
iii. Can be used to determine the quantity of ground water moving from one area over to the other.

THANKS