Hydrogeology
GLI 101

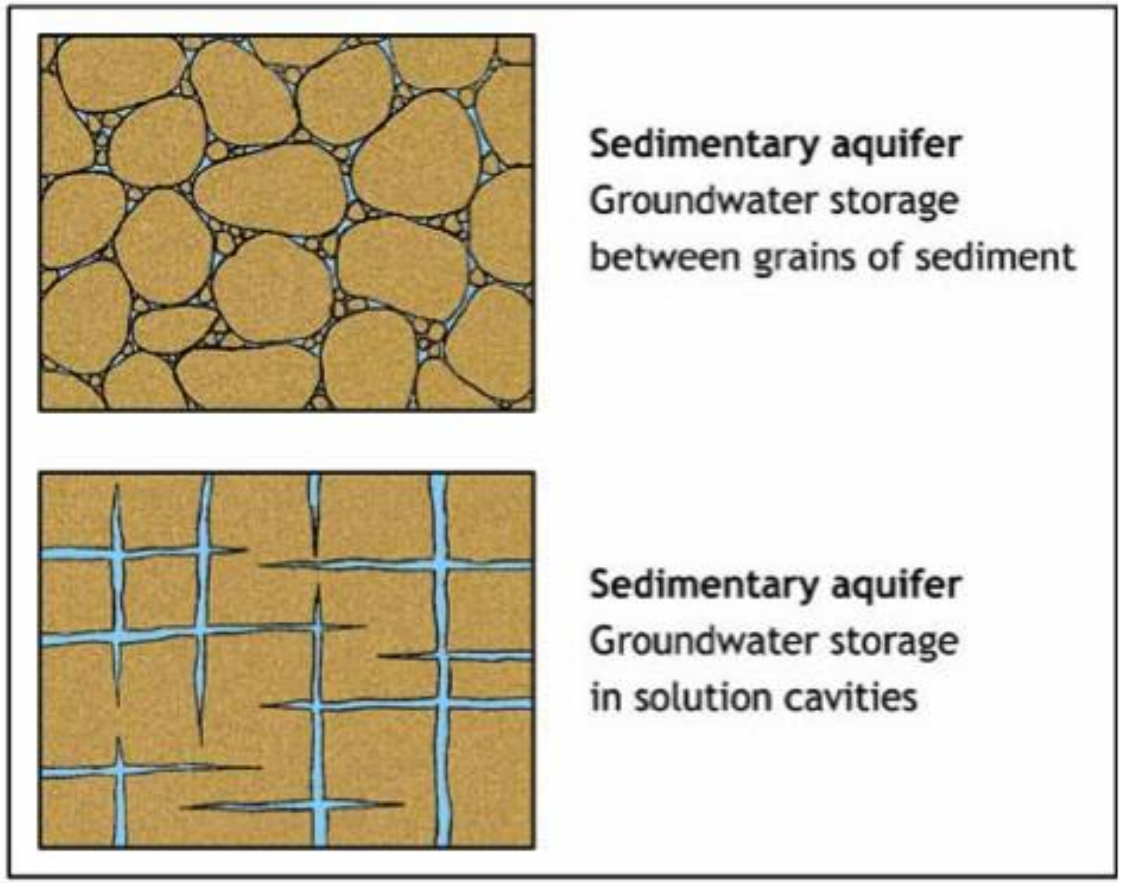
Lecture 2

Occurrence of Groundwater

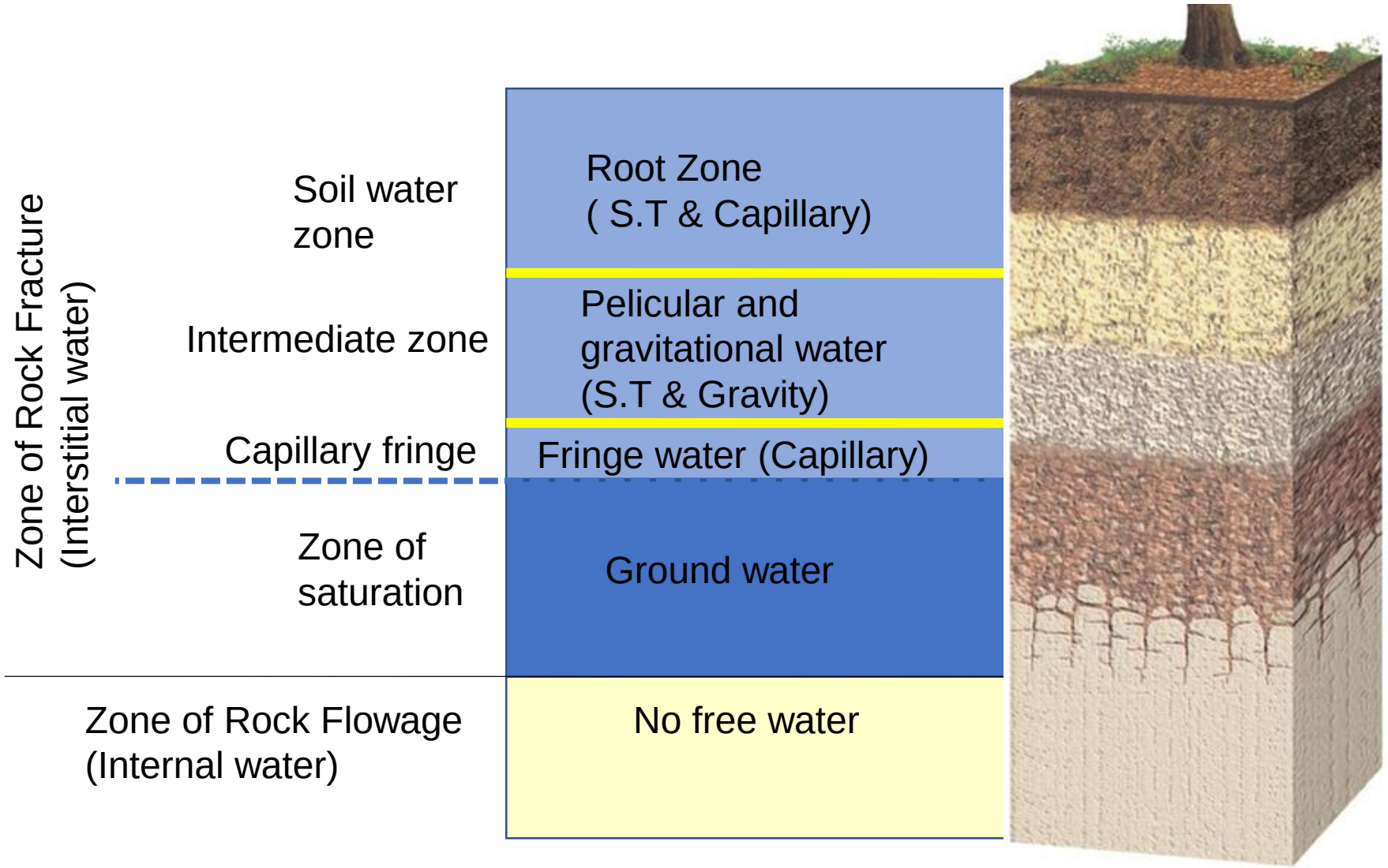
- To describe the occurrence of groundwater necessitates a review of where and how groundwater exists; subsurface distribution, in both vertical and areal extents, needs to be considered.
- **Subsurface water** occurs in the void spaces of earth materials that range from consolidated rocks (Igneous, Metamorphic and Sedimentary rocks) to unconsolidated materials (ranging in size from fractions of a millimeter (clay size) to several meters (boulders).
- Groundwater can be found in all three classes of rocks, but in general, the sedimentary rocks contain by far the greatest amounts of water due to their greater porosity.

Subsurface Openings

- Primary Openings
  - **Syngenetic voids** are called primary openings.
  - Example: voids between sand particles in sandstones and other unconsolidated material
- Secondary Openings
  - Voids induced by fracturing or solution effect **after the formation of the rock** are called secondary openings
  - Example: dissolution cavity in limestones, fractures in granites



Vertical Distribution of Groundwater

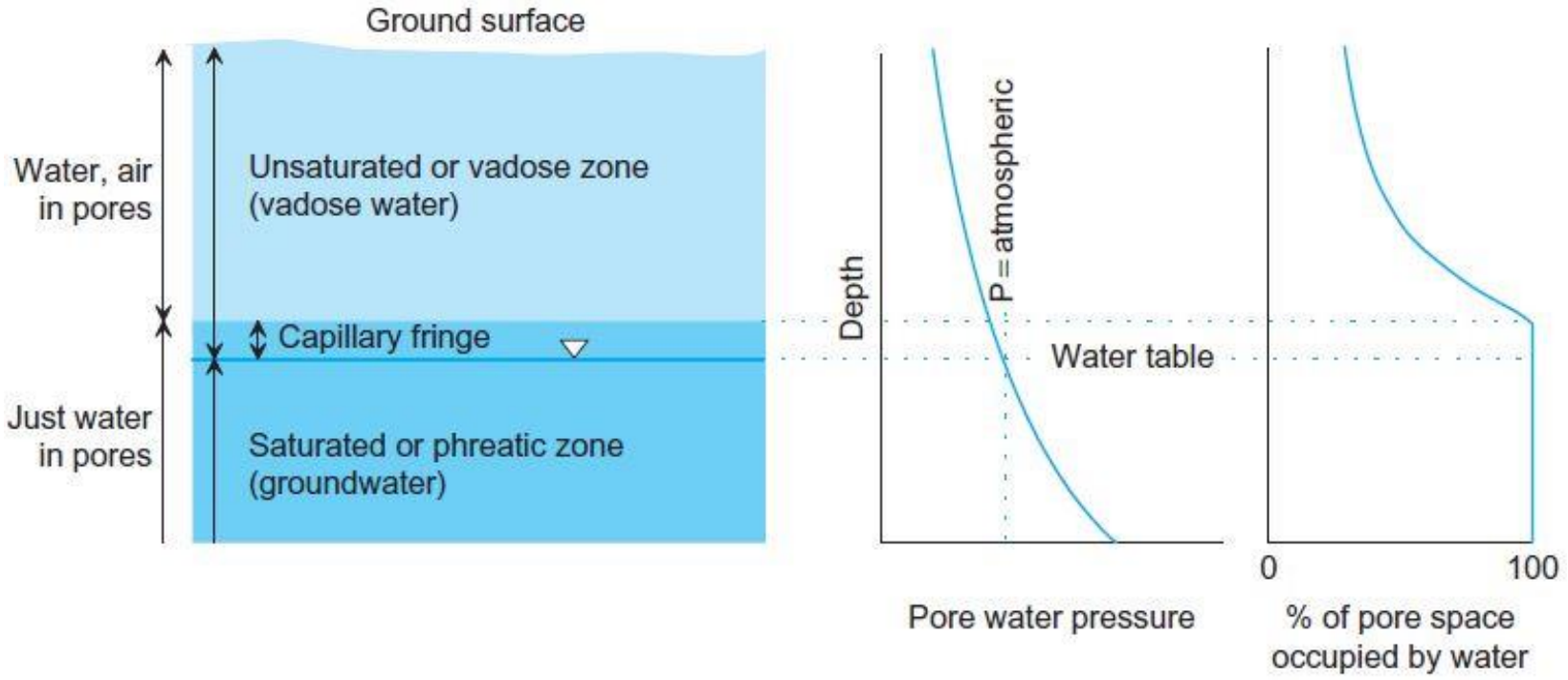


Vertical Distribution of Groundwater

- The ***zone of rock fracture,*** which includes the regolith , is the zone where rocks are under stresses less than those required to close voids by internal deformation.
- The ***zone of rock flowage*** is below the zone of rock fracture where all rocks are under stresses exceeding their elastic limits .In this zone voids are absent or insignificant.
- In the zone of rock fracture subsurface water exists in two broad zones--the ***zone of saturation*** and the ***zone of aeration*** separated by the **water table**.

Vertical Distribution of Groundwater

- The ***water table*** can be technically defined as the surface on which the pore water pressure equals the atmospheric pressure.
- If a shallow well is installed so it is open just below the water table, the water level in the well will stabilize at the level of the water table.



Vertical Distribution of Groundwater

- Water table characteristics
  - In the absence of groundwater flow, water table will be flat
  - A sloping water table indicates that groundwater is flowing
  - Groundwater discharge zones are topographically low areas
  - In the case of lack of water table depth information, water table is assumed to have the same general shape as the surface topography

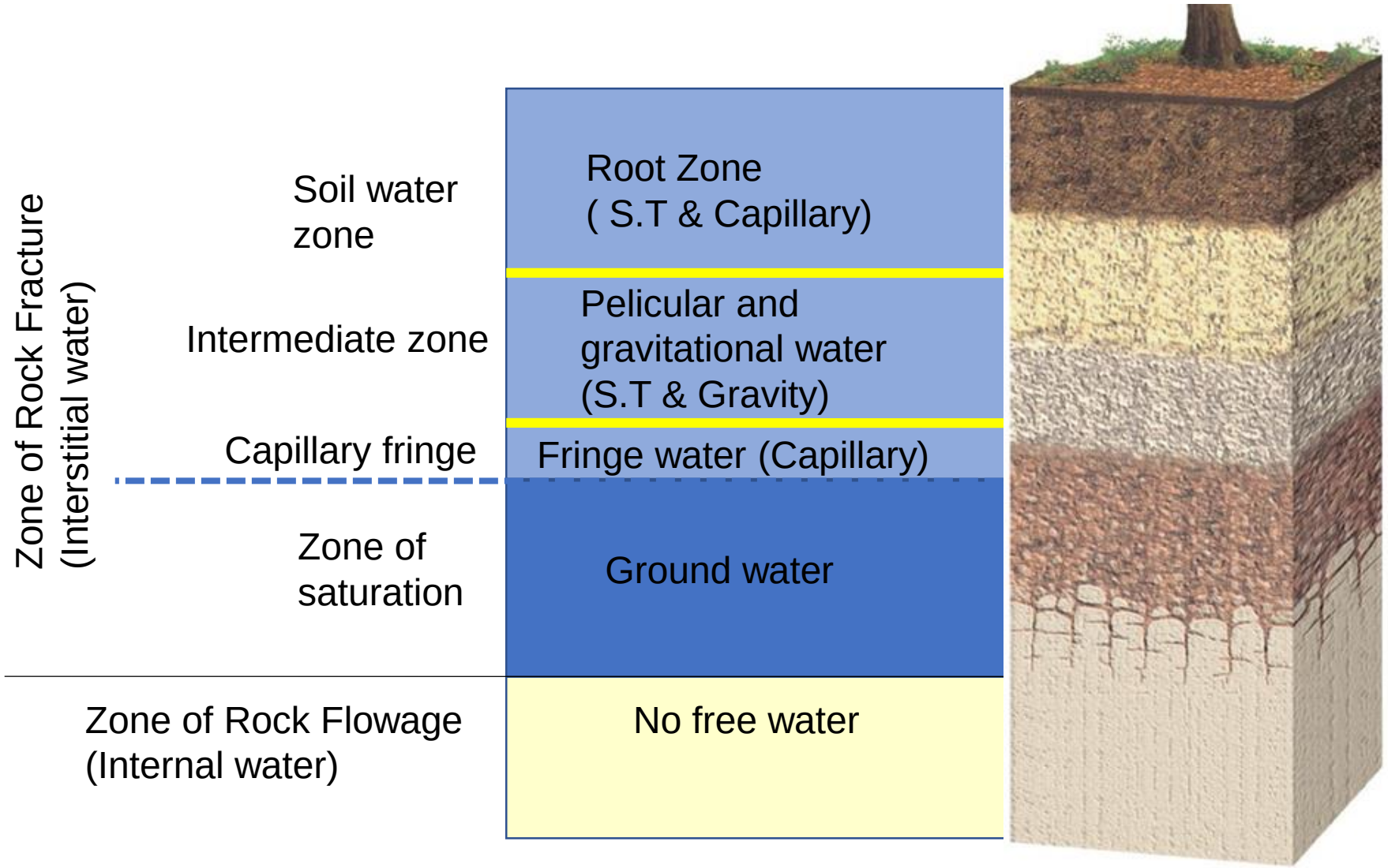
Vertical Distribution of Groundwater

- In the ***zone of saturation*** all communicating voids are filled with water under *hydrostatic pressure*. Water in the zone of saturation is called ***ground water*** or ***phreatic water****.*
- In the zone of aeration, *Capillary forces* attract water to the grain surfaces, causing water pressures to be less than atmospheric.
- In the ***zone of aeration***, voids in permeable materials are empty, partially filled, or filled with water either moving downward under the force of gravity or being held by capillary action.

Vertical Distribution of Groundwater

- The zone of aeration is divided into three sub-zones. These are the *zone of* ***soil water, intermediate zone,*** and the ***capillary fringe****.*
- The soil-water zone extends from the earth surface to slightly below the depth of root penetration. Water in this zone is available for transpiration by plants or for direct evaporation. The soil-water zone is not saturated except temporarily when excess water is applied
- ***Water is held by surface tension & is moved by capillary action and gravity*** in the soil-water zone.
- Water which has penetrated to a depth from which it cannot be returned to the root zone by capillary action is lost from the zone of soil water.

Vertical Distribution of Groundwater

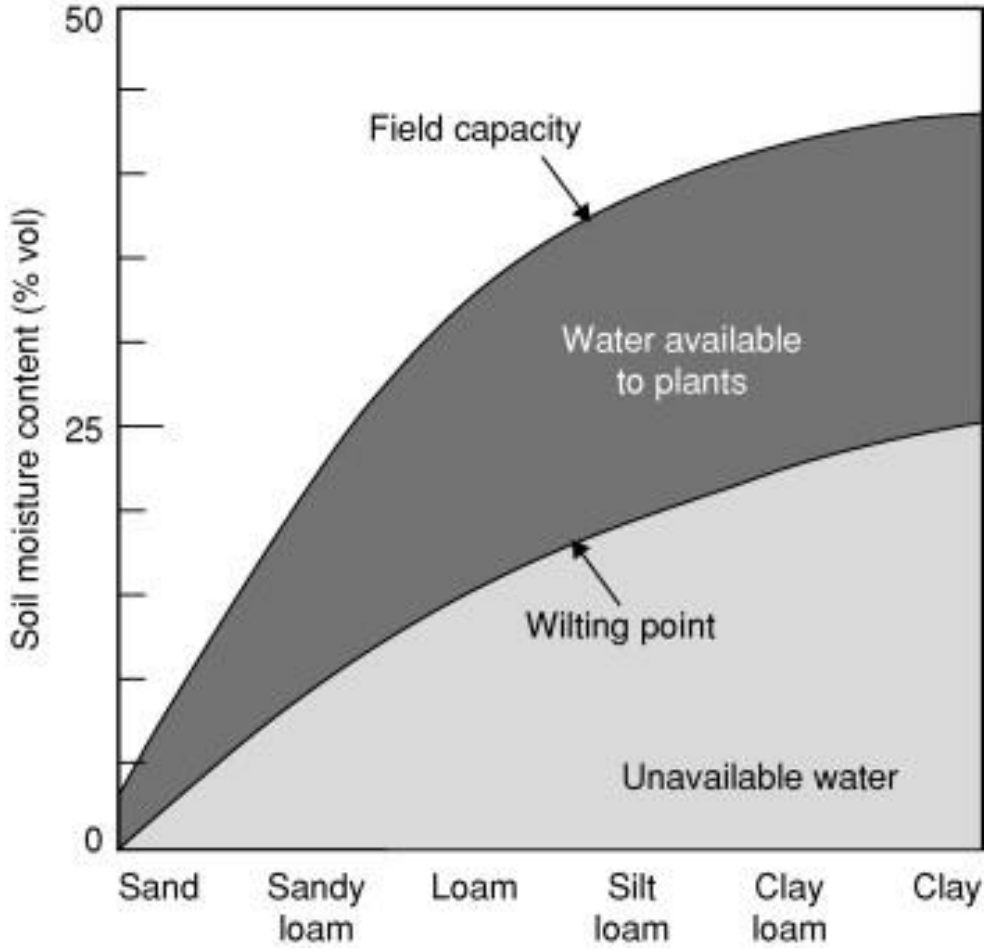


Vertical Distribution of Groundwater

- Water in the **intermediate zone** cannot be brought back to the soil-water zone by capillary action, but it has not yet reached the capillary fringe. It is held in place by ***surface tension*** or is moving downward under the ***force of gravity***.
- The amount of stationary or *pelicular* water in the intermediate zone is dependent upon the nature of the soil or rock and is equivalent to the ***field capacity*** of the same materials in the soil-water zone.
- The stationary water in the intermediate zone is held in-place by hygroscopic and capillary forces.

Vertical Distribution of Groundwater

- Soils absorb and retain water, which may be withdrawn by plants during periods between rainfall or irrigations. This water-holding capacity is called as the *available water.*
- Available water ranges from the ***field capacity*** of the soil to the wilting point.
- Field capacity is defined as the water content of a soil after thorough saturation followed by *gravity drainage* until negligible amount of drainage is observed.

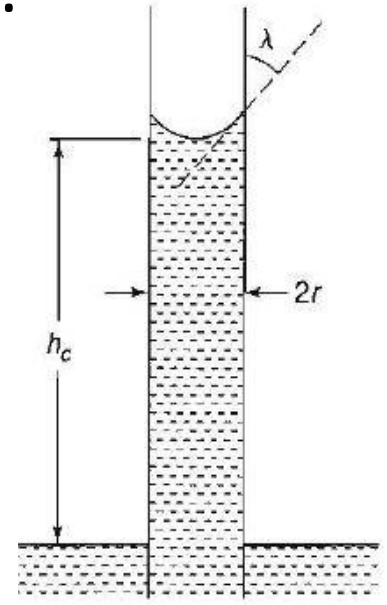


Vertical Distribution of Groundwater

- The **capillary fringe** is a zone that is saturated with water, but above the water table.
- The height of capillary rise (h_c) is a result of the competitive effects of *surface tension* of water and the *weight of water* raised.

$$h_c = \frac{2\tau}{r\gamma}\cos\lambda$$

Where, τ is surface tension (g/cm), γ is the specific weight of water (g/cc), r is the tube radius (cm), and λ is the angle of contact between the meniscus and the wall of the tube



Vertical Distribution of Groundwater

- Since the height to which water is held by capillarity is ***inversely proportional*** *to the diameter* of the interstitial space, the thickness of the capillary fringe will vary with the texture of the rock or soil.
- In finer-grained materials, there is more surface area and the greater overall surface attraction forces result in a thicker capillary fringe.
- In a silt or clay, the capillary fringe can be more than a meter thick, while the capillary fringe in a coarse gravel would be less than a millimetre thick.
- At equilibrium, any water reaching the capillary fringe from above by gravity flow will cause the immediate discharge of an equivalent amount of water to the zone of saturation.