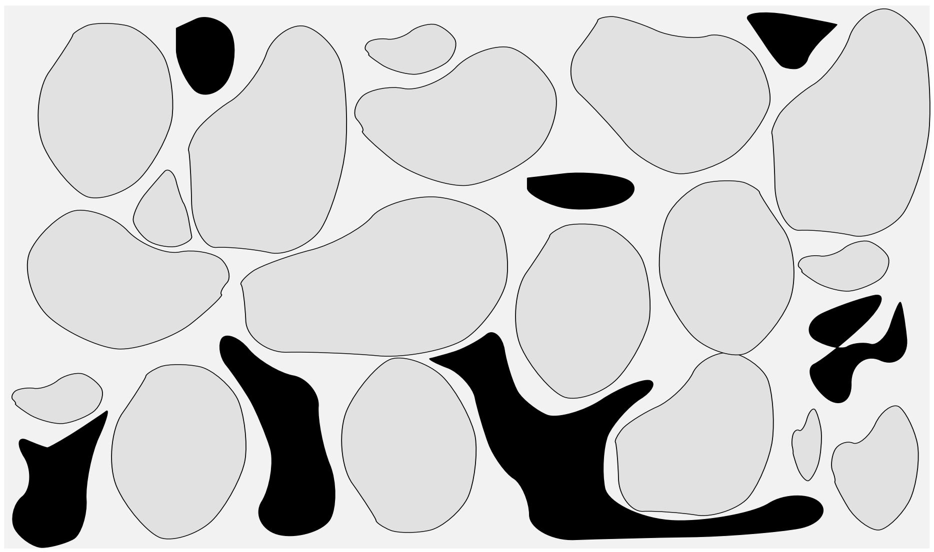
Water Related Soil Properties

Water is essential for plant growth. Plants extract mineral laden water from the soil. For effective irrigation and drainage it is important that the processes governing soil water storage and soil water movement be understood.



- In a ***saturated*** soil all the pore space is occupied by water. Under field conditions full saturation is hardly ever achieved, as there is almost always some air trapped in the soil. The approximate saturation achieved in practice is referred to as *Field Saturation*.

- As the soil drains, air occupies the biggest pores in the soil. As more and more water is removed from the soil, smaller and smaller pores are drained.

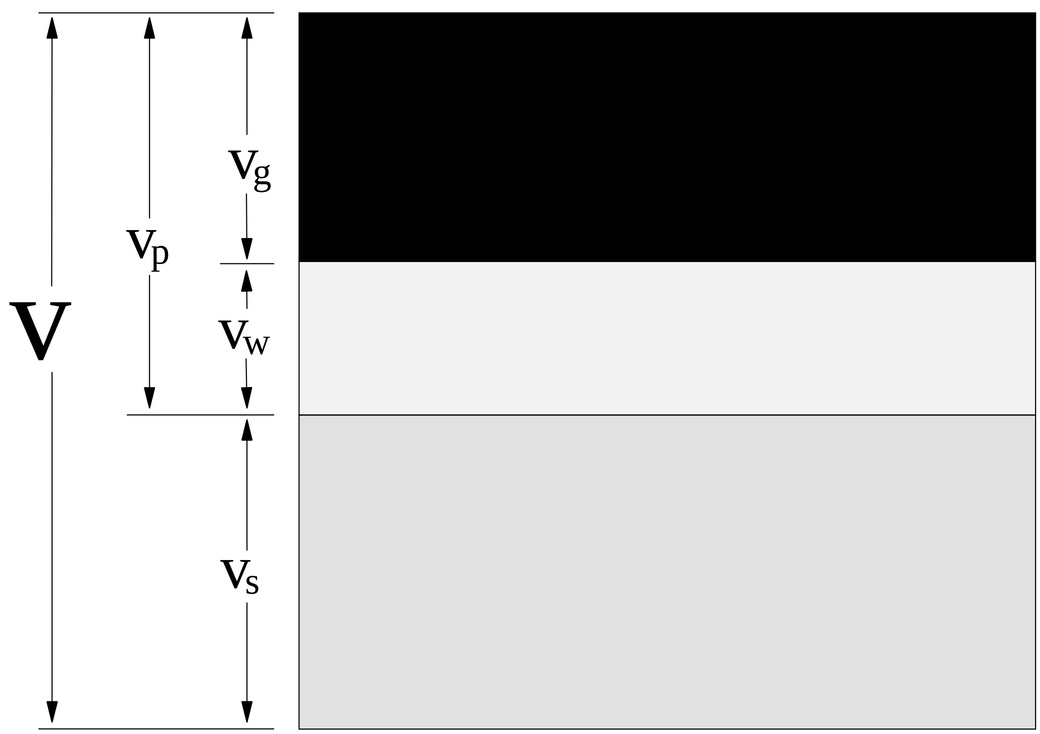
- ***Field Capacity*** is defined as the soil water content when the gravity filled pores are drained. This occurs one day after field saturation in a sandy soil and three days after field saturation in a clay soil. Field capacity is also defined as the water content when the suction on the soil is 1/3 bar.

- Below field capacity, for all intents and purposes, no more gravity drainage occurs. Water is removed from the soil by evaporation at the soil surface or through uptake by plants.

- ***Permanent Wilting Point*** is defined as the soil water content below which plants cannot extract any water from the soil. Water is then held in very small pores or chemically bound to the soil particles. Permanent wilting point corresponds to a suction of 15 bars.

- In irrigation and drainage, the main objective is to maintain the soil water content between field capacity and permanent wilting point.

Several other important soil properties are defined below. These properties can be visualized with the help of the schematic diagram shown below. This diagram shows the soil as a three-phase system. For convenience the phases are separated.



V : Volume of soil
v_g: Volume of gas (soil air)
$v_{w:}$ Volume of water
v_p: Volume of pores
v_s: Volume of soil solids (soil particles)

<u>Porosity</u> (ϕ)

$$\mathit{Porosity}(\Phi) = \frac{\mathit{Volume\ of\ pores}}{\mathit{Volume}\ \text{of soil}} = \frac{v_p}{V}$$

Porosity lies in the range 0.3 - 0.6 (30 - 60%). Coarse-textured soils tend to be less porous than fine-textured soils.

<u>Bulk Density</u> (ρ_b)

$$\mathit{Bulk\ Density}\ (\rho_b) = \frac{\mathit{Mass\ of\ soil\ particles}}{\mathit{Volume}\ \text{of soil}} = \frac{M_s}{V}$$

In sandy soils the bulk density can be as high as 1.6 gm/cm^3, whereas in aggregated loams and in clay soils, it can be as low as 1.1 gm/cm^3. The density of the alumino-silicate particles in the soil is 2.6 gm/cm^3. Thus if a soil has a porosity of 0.5, the bulk density will be 1.3 gm/cm^3. In general

$$\mathit{Porosity} = 1 - \frac{\mathit{Bulk\ Density}}{2.6}$$

<u>Soil Water Content</u> (θ)

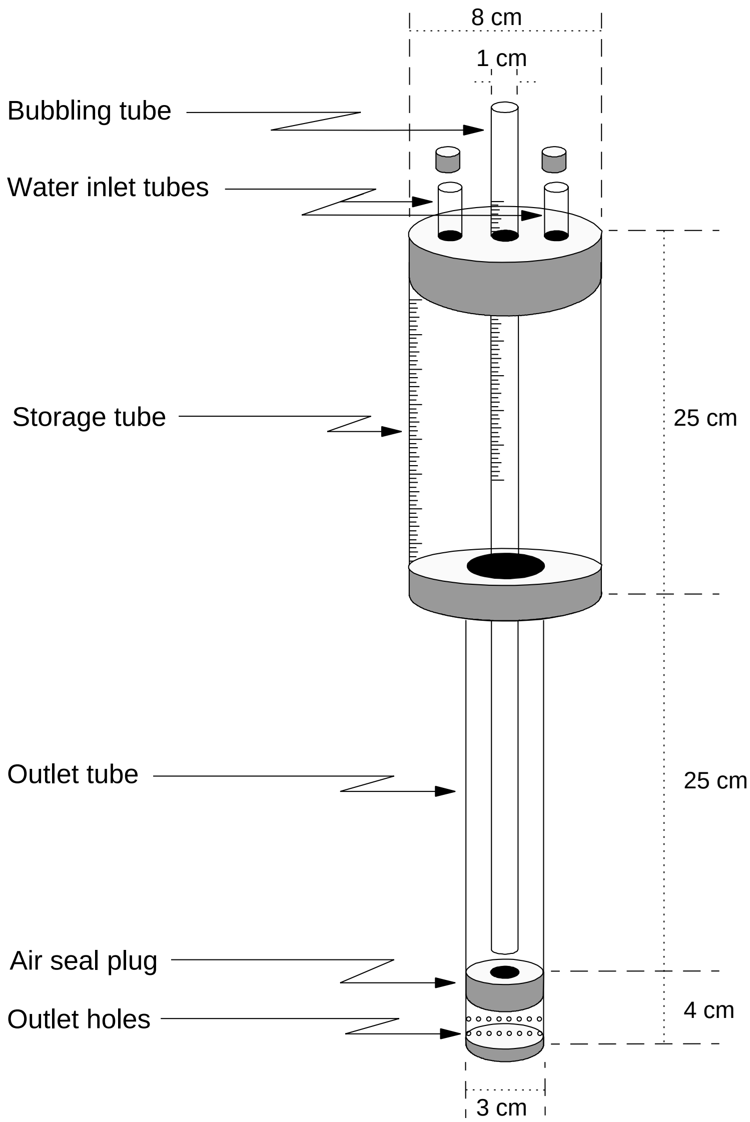
$$\mathit{Soil}\ \text{Water Content}\ (\theta) = \frac{\mathit{Volume\ of\ water}}{\mathit{Volume}\ \text{of soil}} = \frac{v_w}{V}$$

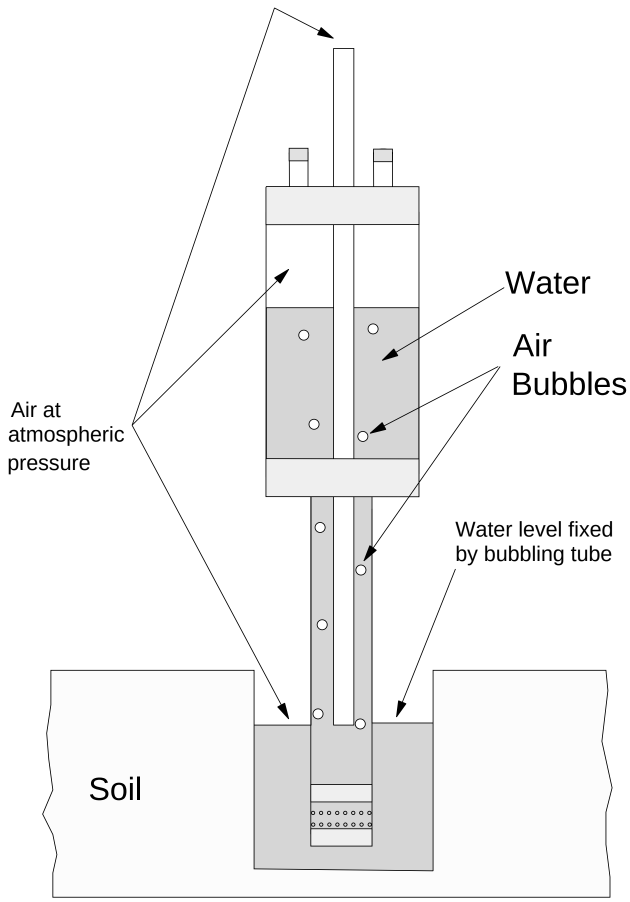
In sandy soils, the value of soil water content at saturation varies from 40 - 50 %. In medium-textured soils it is about 50%, while it may be up to 60% in clayey soils. In swelling clay soils, the volume of water at saturation may be much more than the porosity of the dry soil.

<u>Saturated Hydraulic Conductivity</u> (K_s)

Saturated Hydraulic Conductivity (sometimes referred to as hydraulic conductivity) is the rate at which water moves through saturated soils. It is one of the most used soil property in irrigation and drainage. It is dependent on the total porosity of the soil and also on the arrangement of the pores. It has values of about 1 to 10 cm/hr in sandy soils and 0.0001 - 0.1 cm/hr in clayey soils. It can vary over several orders of magnitude in a single field. While there are methods for measuring K_s in the laboratory, field methods produce more representative values. Two such methods are described below.

Guelph Permeameter





The first step in using the permeameter is to make a hole in the ground. This hole has to be at least 5.0 cm deep, 4.0 cm in diameter, and has to be located so that it does not intersect an animal burrow or a root channel. The permeameter is then placed in the hole with the axis of the bubbling tube in a vertical position. The bubbling tube is then pushed down until it enters the air seal plug, creating a fluid-tight seal. Both water inlet tubes are then open. Flexible tubing is attached to one of the water inlet tubes and water is then siphoned in until both the outlet tube, above the air seal plug, and the storage tube are filled. The water inlet tube that is not connected to the flexible tubing, acts as an air escape duct during filling, to ensure that the water surface in the storage tube is always at atmospheric pressure. Both water inlet tubes are then closed and the bubbling tube is slowly raised to the required level. This fixes the level of water in the hole. Water seeps out of the hole into the soil, the water level in the storage tube falls, creating a partial vacuum in the space between the bottom of the upper stopper and the water surface. In response to the pressure differential with the atmosphere, air passes through the bubbling tube and into this space, increasing the pressure back up to atmospheric pressure. While all this is happening, the water level in the hole remains constant. Steady-state conditions are achieved when the rate at which the water level in the storage tube falls, becomes constant. This constant rate, along with the geometry of the hole, is used in the determination of infiltration rate.

Cylinder Infiltrometers

In general, cylinder infiltrometers consist of metal cylinders, partially driven into the ground, filled with water, with the hydraulic conductivity being the rate at which the water level falls. There is usually some lateral seepage below the bottom of the cylinder. This shortcoming is usually eliminated by using two concentric cylinders, with the outer cylinder acting as a buffer. Since there is some difficulty in maintaining the same water level in both cylinders under falling head conditions, modern double cylinder (ring) infiltrometers use Mariotte bottles to maintain a constant level of water in both cylinders. Under these conditions the infiltration rate is a function of the rate of change of the water level in the Mariotte bottle that empties into the inner cylinder, and the diameters of this bottle and the inner cylinder. The major limitation of these devices is that they take up a lot of room and require more than 150 liters of water per measurement.