Soil Water Retention

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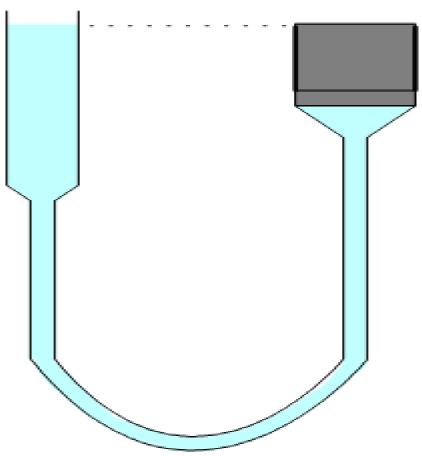
SOIL SUCTION

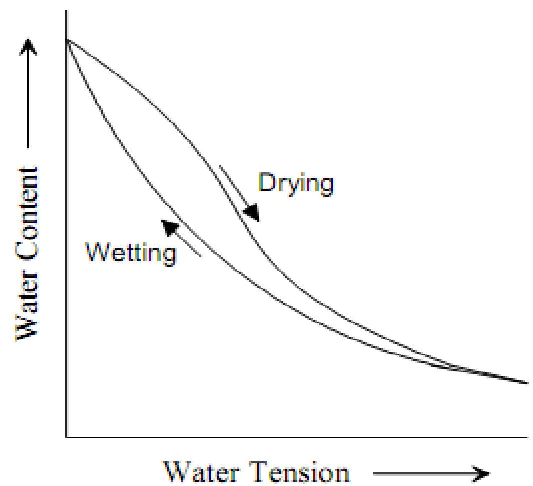
Consider a soil sample in contact with a porous ceramic membrane that allows the passage of the soil solution but not the soil particles. This plate is connected to a burette with a flexible water filled tube, and the height of the burette is adjusted so that the water level is at the same level as the soil surface. In this state, the soil will be saturated under equilibrium conditions.



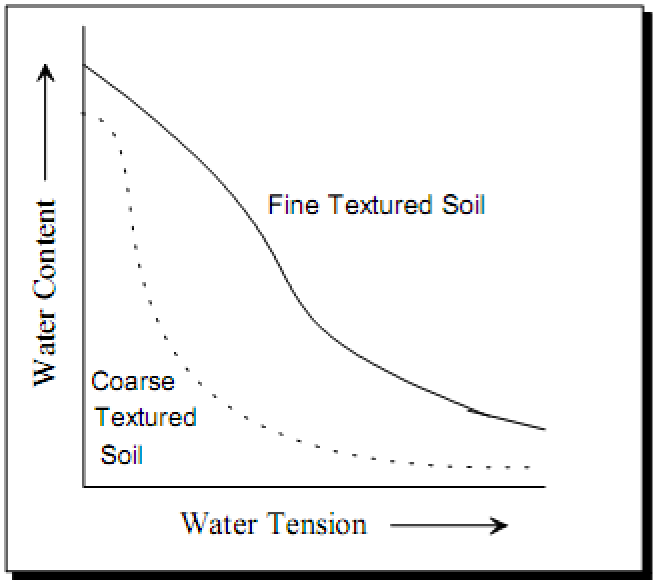
What happens if the burette is raised?

What happens if the burette is lowered?

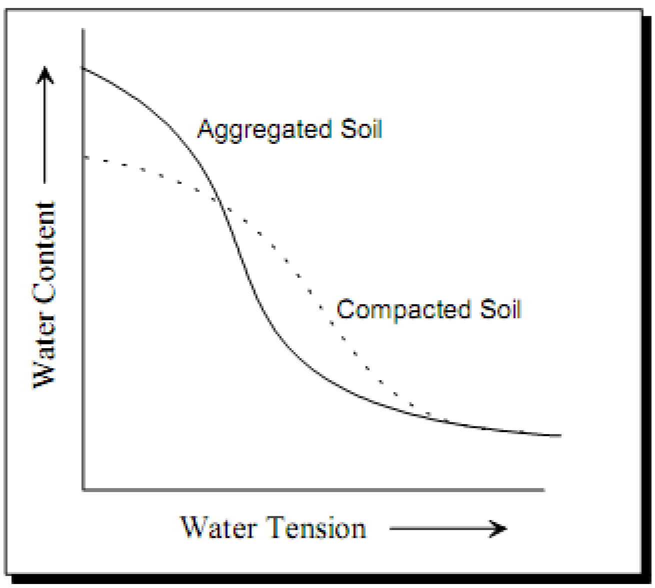
The amount of water remaining in the soil is a function of the soil water tension. The curve showing the relationship between soil water suction and soil water content for a soil is called the characteristic curve or the retention curve. This curve exhibits hysteresis due to contact angle effects, entrapped air, swelling and shrinking, and inkbottle effects. However, this phenomenon can usually be ignored for cases where water is the only liquid in the soil. Spatial variations in soil properties dominate over hysteresis effects.



Effect of texture on soil water retention



Effect of structure on soil water retention



PARAMETRIC FORMS OF THE WATER RETENTION CURVE

To evaluate drainage volumes and for use in numerical models, it is convenient if the soil water tension curve can be expressed in some simple parametric forms. The two most frequently used forms are presented below.

BROOKS-COREY MODEL

$$\bar{S} = \begin{cases} \left[\frac{h_d}{h}\right]^{\lambda} & ; \; h > h_d \\ 1 & ; \; h \leq h_d \end{cases}$$

VAN GENUCHTEN MODEL

$$\bar{S} = \begin{cases} [1 + (\alpha h)^n]^m & ; \; h > 0 \\ 1 & ; \; h \leq 0 \end{cases}$$

$$m = 1 - \frac{1}{n}$$

IN BOTH MODELS;

$$\bar{S} = \frac{S - S_m}{1 - S_m}$$

Where S_m is an apparent minimum water saturation. In actuality, S_m is a purely empirical parameter with no physical significance since the water saturation theoretically decreases to zero. Including this as an adjustable parameter, however, enhances the ability of the model to fit a wide variety of soils. The shape of the water saturation curve reflects an underlying pore size distribution. This fact can be Utilized in developing an unsaturated hydraulic conductivity curve.

HYDRAULIC CONDUCTIVITY IN UNSATURATED SOILS

As soils dry out the cross-sectional area for water transport decreases. Thus the rate at which water moves through the soil also decreases. The relative permeability or the unsaturated hydraulic conductivity may be expressed as a function of the mean water-filled pore radius as

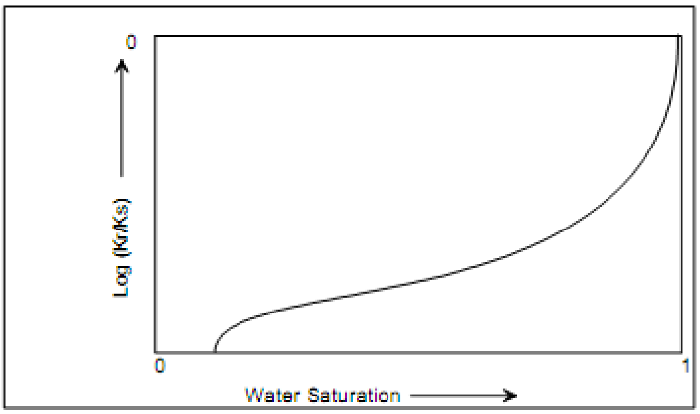
$$K_r = K_s \tau \frac{\bar{R}_{S_w}}{\bar{R}_1}$$

where R S_w is the mean water filled pore radius at a water saturation of S_w, and τ is the tortuosity of the travel paths in the soil. Under the assumptions that R S_w is inversely proportional to the soil water tension, and that

$\tau = \bar{S}^{\frac{5}{2}}$ the unsaturated hydraulic conductivity is given by

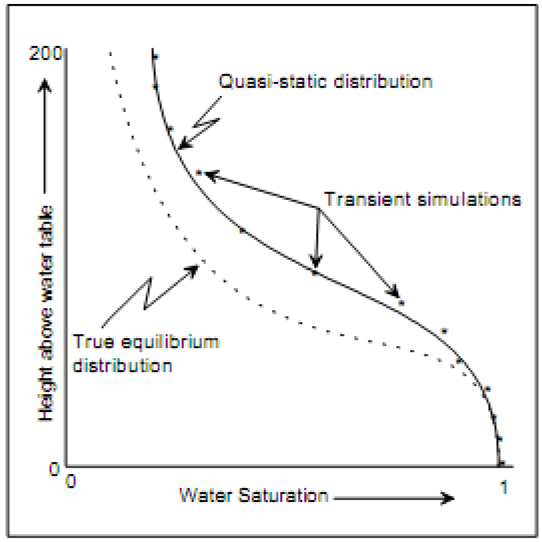
$$\text{(BC)} \qquad K_r = K_s\left[\bar{S}_w\right]^{\frac{2+3\lambda}{\lambda}}$$

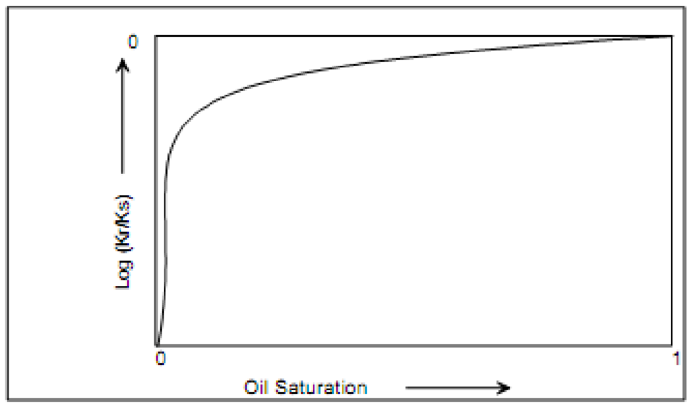
$$\text{(VG)} \qquad K_r = K_s\bar{S}_w^{\frac{1}{2}}\left[1-\left(1-\bar{S}_w^{\frac{1}{m}}\right)^m\right]^2$$



A 10% decrease in water saturation may cause an order of magnitude reduction in Kr. These low values make it practically impossible pump water from unsaturated soils.

In practice, the water saturation distribution is rarely the true equilibrium saturation. A quasi-static distribution may be fitted by setting the minimum saturation as the saturation at field capacity (200 cm tension). If this pressure distribution is used in simulations, the results are closer to reality than if the true equilibrium distribution is used.





Typical soil properties for various soil types.

Soil Type	K_s (m/d)	ϕ -	S_m -	α m^{-1}	n -
Sand	7.1	0.43	0.09	14.5	2.7
Loamy sand	3.5	0.41	0.15	12.4	2.3
Sandy loam	1.06	0.41	0.15	7.5	1.9
Sandy clay loam	0.31	0.39	0.26	5.9	1.5
Loam	0.25	0.43	0.19	3.6	1.6
Silty loam	0.11	0.45	0.16	2.0	1.4
Clay loam	0.062	0.41	0.22	1.9	1.3
Silt	0.06	0.43	0.07	1.6	1.4
Sandy clay	0.03	0.38	0.26	2.7	1.2
Silty clay loam	0.017	0.43	0.21	1.0	1.2
Silty clay	0.005	0.36	0.19	0.5	1.1