Lesson 10: Effects of Soil on Water Movement and Retention

Importance of Water to Plant Growth

Water is a basic natural resource. All plants and animals need it to survive, although the amount needed varies widely. Actively growing plants are composed of up to 90 percent water.

Plants need water to take up soil nutrients. Roots take up soil water and the leaves release water through transpiration. See Figure 10.1. **Transpiration** is the process whereby plant moisture is released in water vapor through the plant pores. Water is necessary for plant transpiration to occur. Wind, temperature, soil fertility, and humidity all can affect the rate of plant transpiration. If transpiration water exceeds the quantity of water entering through the roots, the plant will wilt and may eventually die.

The soil loses water through evaporation and plant use. **Evaporation** in the soil occurs where pores are so interconnected that air circulates to the soil surface. Evaporation usually only affects the surface 2 or 3 inches, but when large cracks are present, it can extend to 2 or 3 feet in depth. Plants use 300–500 lbs of water for every pound of dry weight. For example, an acre of corn requires about .5 million gallons of water for healthy growth. As vital as water is to healthy plant growth, too much water in the soil can be harmful to crops commonly grown for food production. Conversely, the lack of water interferes with the normal growth processes as well as the food-making power of the plant.

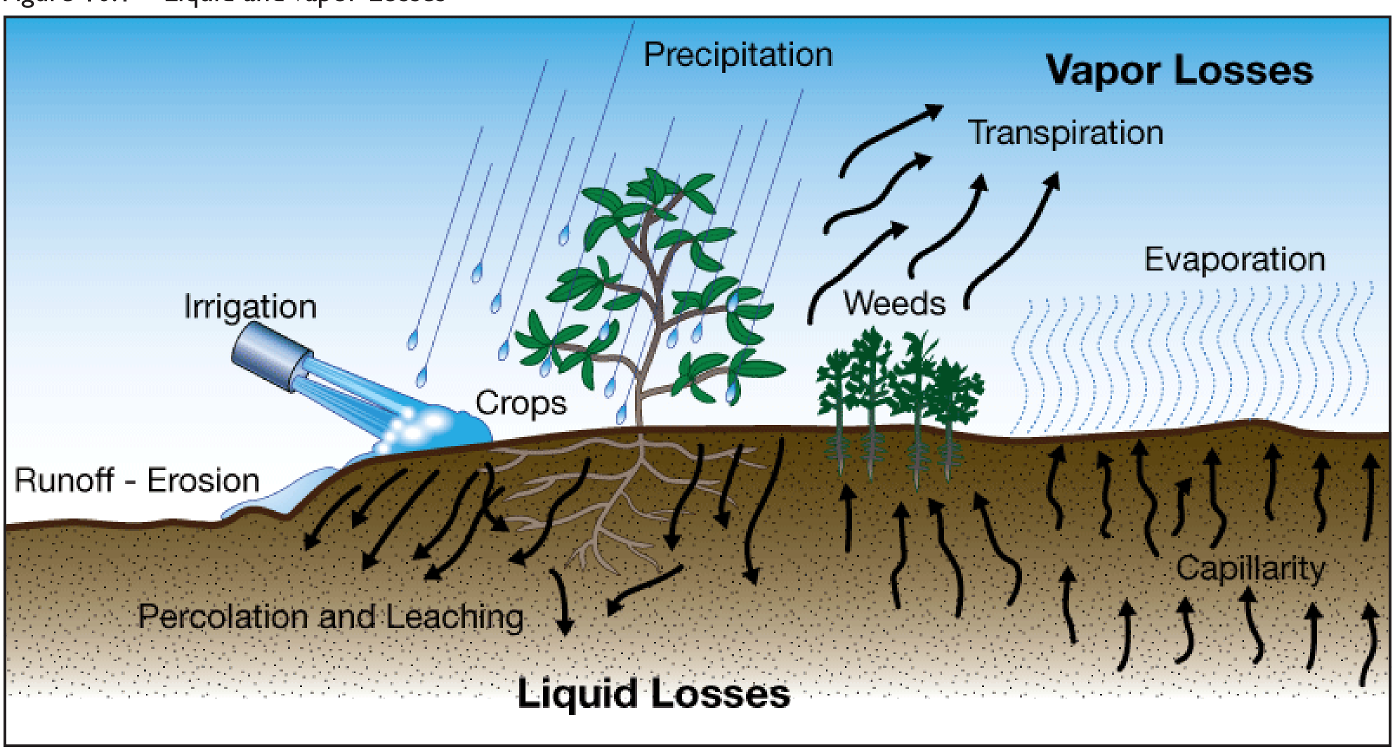
Types of Soil Water

Only part of the water contained in the soil is available to plants. There are three major kinds of soil water: gravitational water, capillary water, and hygroscopic water. See Figure 10.2. Only the available water is useful to plants.

Gravitational water fills large pores when the soil is saturated. It drains away quickly as soon as the water table drops or it stops raining. Plants cannot use gravitational water.

Capillary water is held in smaller soil pores or capillaries against a force of gravity similar to water drops on a glass

Figure 10.1 – Liquid and Vapor Losses



or cohesion (attraction between water molecules). Most of this water is available to plants.

Hygroscopic water is held so tightly in tiny soil pores by adhesion (a strong attraction between soil particles and water molecules) that roots cannot remove it. When a soil is so dry that only this water remains in the soil, plants will wilt and die. Clayey soils contain large amounts of unavailable water that plants cannot use.

Available Water Capacity (AWC)

Adequate water in the soil is vital to plant growth. Plants need water for the physiological actions that take place, for example, photosynthesis and respiration. Water also contains plant nutrients that are readily usable by plants. Water comes mostly from precipitation, but the soil needs good infiltration and storage of the water for use between rains. Water often is the most limiting factor in crop yields.

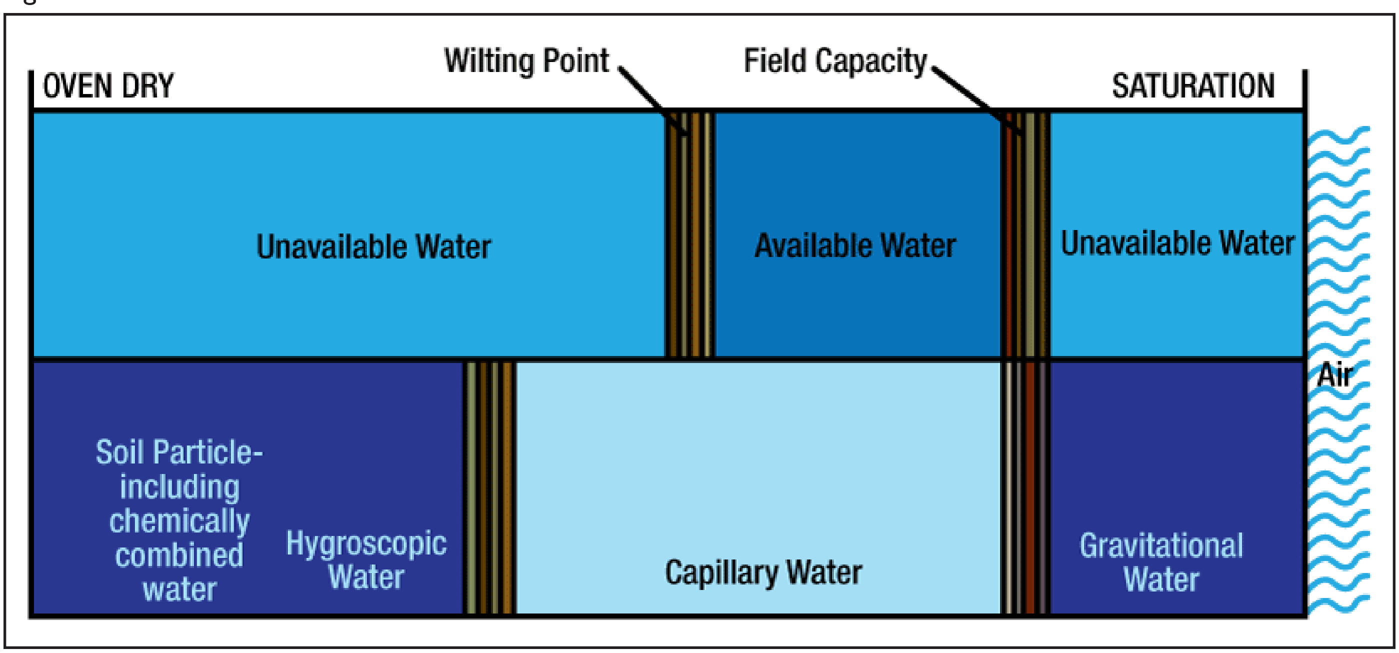
It is possible to make field measurements of water content, rates of water movement, and internal drainage, but they require a great deal of time, skill, and expensive equipment. However, by observing some of the primary properties of soil horizons, such as color, texture, and structure, estimates of the available water capacity (AWC), permeability, internal drainage, and several other properties can be made. These estimates are useful for learning how the soil may respond to use and management.

The **available water capacity** or **AWC**, is the potential of a soil to hold water in a form available to plants, and commonly is defined as the amount of water held between **field capacity** (the point at which the downward movement of water caused by gravity and underlying dry soil has ceased) and the **wilting point** (the point at which all available water is depleted). See Figure 10.2. Since the soil provides the only reservoir of water from which plants can draw, the size (or volume) of the reservoir is one of the most important properties of the soil. Soils that have a high AWC have a greater potential to be productive than soils that have a low AWC.

Water is held on soil particles by surface tension. The force holding water is closely related to the total surface area of the soil particles. Because the volume of small particles has more total surface area than the same volume of large particles, small particles exert a greater holding force than large particles.

Plant roots must overcome the force of surface tension in order to take up water from the soil. This tension can actually be measured and provides valuable information

Figure 10.2 – Kinds of Soil Water

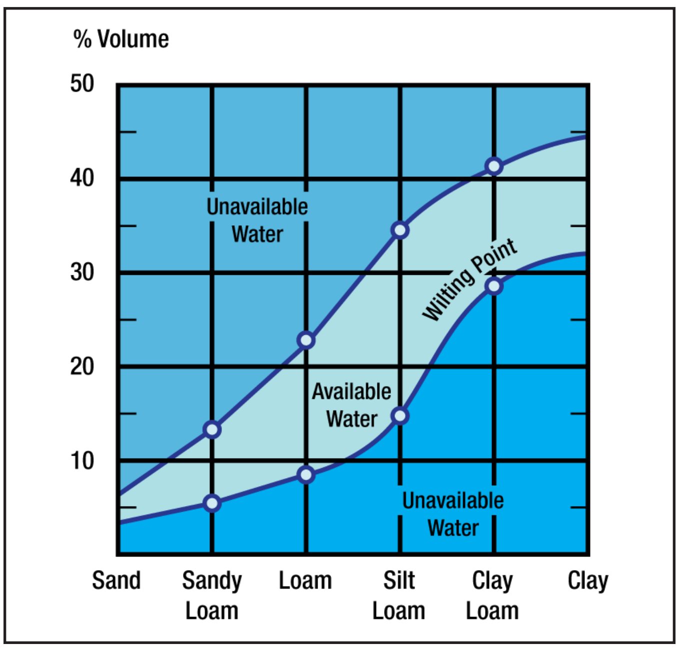


for obtaining the wilting point. Irrigation water should be applied before the wilting point is reached, because wilting may cause enough damage to substantially reduce crop yields.

Field Capacity

The moisture content of the soil, when downward movement of water caused by gravity and the underlying dry soil has ceased, is called **field capacity**. Expressed in another way, field capacity is the maximum amount of water left in the soil after losses to the forces of gravity have ceased and no surface evaporation has occurred. About one-half or more of the water held in the soil at field capacity is held so tightly that it is unavailable to plants. The amount of water at field capacity is reduced either by plants or evaporation and is restored only by another rain, rising water table, irrigation, or flooding. The texture of the different layers is important because more water will move downward if there is a greater attraction for the water in the lower layer. Clayey layers can delay downward movement of water when the soil is saturated, but they also can exert strong tension and can pull water out of silty and loamy layers that are above. This is especially true during dry periods when plants and evaporation have nearly depleted the water from the surface layer. See Figure 10.3.

Figure 10.3 – Available Water



Wilting Point

The **wilting point** occurs when all available water for a particular kind of plant is removed. It is critical in irrigation not to let plants reach the wilting point before irrigation water is applied to the soil. The wilting point will vary with plants and sometimes with atmospheric conditions. Some plants are more tolerant to drought than others. That is why grain sorghum produces better than corn in some areas.

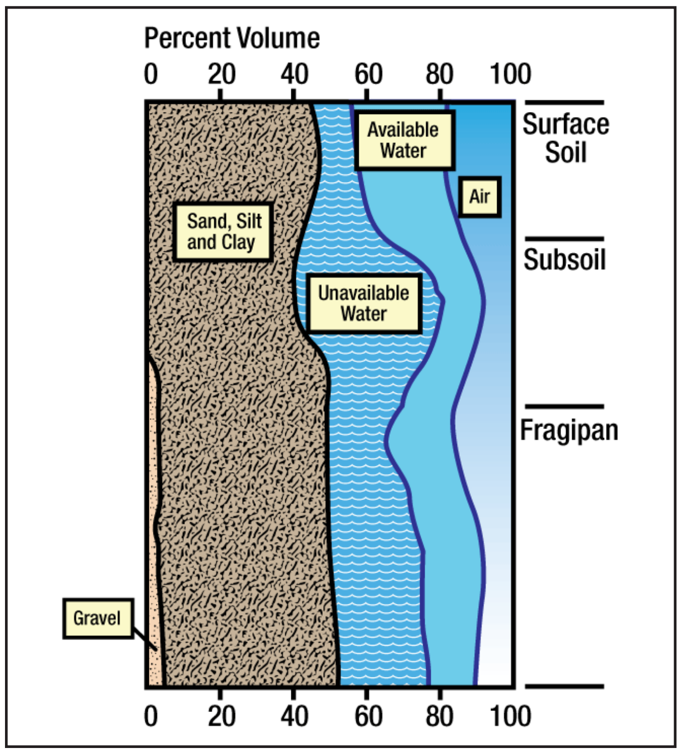
Soil Properties that Affect AWC

Available water capacity depends primarily on texture, effective rooting depth, and rock fragment content. To a lesser extent, AWC depends on structure and organic matter. See Table 10.1 and Figure 10.4.

Table 10.1 – Soil Properties that Affect AWC

AWC depends on...	
Texture	Structure
Effective rooting depth	Organic matter
Rock fragment content	

Figure 10.4 – Volumes of Air, Water, and Solids for Gerald Silt Loams



The **texture** has the greatest effect on the AWC because of the differences in sizes of soil particles. Clay has a tremendous surface area per volume of soil as compared to sand, with silt somewhere in the middle (see Lesson 4). The surface areas have been determined for the different texture classes. As water is held on the surfaces of soil particles, the AWC can be estimated by determining the texture, percentage of rock fragments of each horizon, and the effective rooting depth.

The **effective rooting depth** is simply the distance from the surface to the top of any soil horizon that prevents significant root penetration. Dense layers or horizons, such as fragipans, and extremely gravelly or cobbly layers limit root development. Extended periods of free water (high water table) at high levels in the soil also inhibit root growth. Bedrock completely blocks root penetration, unless it has large cracks filled with soil material. See Plate 1, p. 50-A.

Fragipans are very dense layers with high bulk density (mass of dry soil per unit bulk volume) and very low permeability. Fragipans are hard and brittle, but not cemented. They are so dense and have such poor structure that roots generally cannot penetrate. See Plates 25, 26, 27, and 29, pp. 50-G and 50-H.

Many plants extend roots to depths well beyond 3 feet, provided there is no physical barrier to root growth. Soils that allow deep rooting are potentially very productive because plants that grow in them can use the greatest possible volume of soil in search of water and nutrients.

Soils that have restricted rooting depths are more susceptible to drought because of the lower available water capacity. Crop production will require either more moisture through irrigation or the use of drought tolerant plant species. See Table 10.2.

Table 10.2 – Classes of Effective Rooting Depth

Very deep:	>60 inches (>150 cm)
Deep:	40–60 inches (100–150 cm)
Moderately deep:	20–40 inches (50–100 cm)
Shallow:	10–20 inches (25–50 cm)
Very shallow:	<10 inches (<25 cm)

Rock fragments cannot store water, so horizons that contain rock fragments contain less available water. Soil **structure** and **organic matter** affect the AWC because they influence the size of aggregates. This is most noticeable in the amount of pore spaces between particles. Pore spaces are needed to hold water and for aeration.

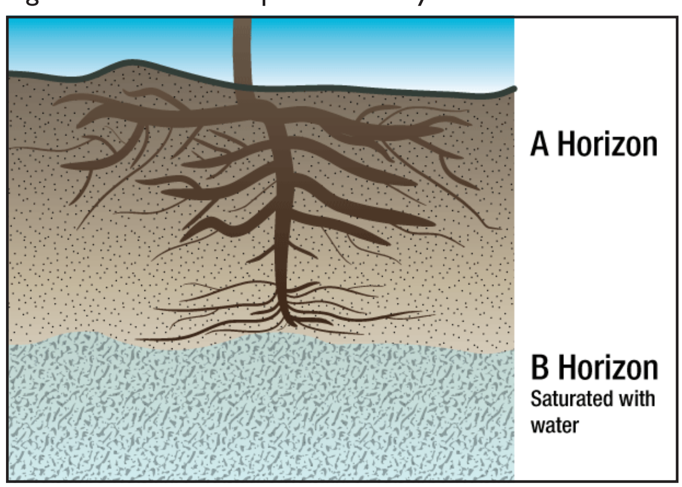
Field Observations for Determining Effective Rooting Depth

Soil color, texture, structure, and density each provide clues for judging the effective rooting depth. Soils that have brown or red colors throughout usually allow deep rooting. These colors indicate good drainage and good aeration, both of which favor deep root penetration.

Gray colors and iron and manganese concretions usually indicate soil wetness. Most roots will not grow in soil that is saturated for long periods of time. See Figure 10.5. But if the water table is not present during the growing season, or if it can be removed with artificial drainage, then gray colors do not necessarily indicate a limitation to root development.

Soil texture limits root growth only where the texture changes abruptly from one horizon to another. Silt loam over clay, or loam over gravelly sand, are common examples of abrupt textures that inhibit root penetration. Textures that are nearly uniform throughout, even in clayey or gravelly soils, are not likely to prevent root

Figure 10.5 – Roots Spread Sideways



growth. However, other factors may be responsible for limiting root growth in these soils.

Structure and density work together to influence rooting depth. Moderate and strong structures always favor root development. Weak structures and massive soil horizons may or may not limit rooting, depending on the density. In fragipans, for example, massive, dense soil restricts rooting.

Determining AWC

The available water capacity has been determined for each class of soil texture. It is expressed in inches of water per inch of soil depth. The AWC can be calculated for any single horizon (within the effective depth of rooting) by multiplying the inches of water per inch of soil (for that texture) by the total thickness of the horizon. For example, if a 6-inch horizon is sandy loam, use Figure 10.6 to find the AWC rate for sandy loam (.12). Next, multiply the given rate by the thickness of the horizon (.12 x 6 inches). This gives the AWC (.72) for this horizon.

To determine the AWC class for the whole soil, repeat the calculation above for each horizon within the effective depth of rooting. The total for the whole soil is the sum of the AWC for each horizon. If some horizons contain rock fragments, determine the percentage of rock fragments. Subtract the percentage of rock fragments from 100 to give the percentage of the fine earth (soil particles) for that horizon. Then multiply the AWC rate by the thickness of the horizon by the percentage of fine earth (AWC rate x thickness x percent fine earth). This will give the AWC. Total the AWCs for all horizons. To find the AWC class, refer to the chart in Figure 10.6.

Figure 10.6 – Determining Available Water Capacity (AWC)

Field Procedure for Estimating AWC

1. Identify the horizons present in the soil profile.
2. Measure the thickness of each horizon.
3. Determine the effective depth of rooting.
4. For each horizon:
   a. Determine the texture and the rock fragment (2 mm – 25 cm) content.
   b. Find the percent fine earth by subtracting:
      100% – percentage rock fragment content = percent fine earth.
   c. Use the AWC rate that corresponds to the texture of each horizon.
   d. Multiply the AWC rate by thickness of horizon by percent fine earth to determine the AWC.
5. Total the AWC for all horizons within the effective rooting depth.
6. Determine the correct AWC class.

Soil Texture	**AWC Rate in Inches of Water/Inch of Soil**
Sand, loamy sand	.06
Sandy loam	.12
Loam, silt loam	.22
Silty clay loam, clay loam	.17
Silty clay, sandy clay	.12
Sandy clay loam	.15
Clay	.09

AWC Class (rates to 60 inches)	
Very low:	<3 inches
Low:	3 – 6 inches
Moderate:	6 – 9 inches
High:	9 – 12 inches
Very high:	>12 inches

Permeability

Permeability refers to water movement through the soil, specifically the rate at which a saturated soil (pores full of water) transmits water. This rate is called the saturated hydraulic conductivity of soil physics. Because water moves through the pores of the soil (the spaces between the grains of sand, silt, and clay), the rate of water movement depends on the amount of total pore space (porosity), the size of the pores, and the connections between the pores.

Properties Affecting Permeability

Pore characteristics cannot be measured directly, although porosity and permeability are closely related to soil texture and structure. Thus, permeability can be estimated in the field by carefully observing the texture, structure, pore size, and density of the soil. Soil color is also important in determining permeability because it relates to organic matter and mineralogy.

For many soils, **texture** is the soil characteristic that exerts the greatest control on permeability. If texture exerts the greatest control, permeability can be related to the texture class and can be modified up or down on the basis of structure, pore size, organic matter, and type of clay. Permeability classes are used to characterize a soil horizon or a soil profile. If applied to a soil horizon, the permeability class describes the potential of that horizon to transmit water. When it is applied to a soil profile, the water-transmitting potential of the least permeable layer is implied.

Soil layers also have other properties that affect permeability. **Tillage pans** (dense layers that are caused by continuous tillage at the same depth) have poor structure and smaller pore space than the Ap horizon above it. See Plate 20, p. 50-E. Water cannot flow through the pan as fast as through the layer above it. That is why, during heavy rainfall or irrigation, all the pores in the upper layer fill with water and any additional water that falls will run off. This tends to increase soil erosion. Subsoil layers with slow permeability could be fragipans (dense horizons) or layers high in clay. Water moves very slowly through these layers because of the small pore space and thus tends to build up and perch on top of the layers. This often causes the water to move horizontally and explains the genesis of E horizons (eluviation-leaching) in some soils.

Because permeability depends on the amount and size of soil pores, and on how interconnected they are, any soil property that increases any of these factors increases permeability. Sandy and gravelly soils have large, well-connected pores and rapid permeability. Clayey soils have tiny pore spaces and slow permeability, unless well-developed structure creates some larger pores. Silt loam and clay loam tend to have moderate permeability, especially if the structure is moderate or strong.

In Missouri, there is an exception to the general rule that horizons with clay texture have slow permeability. Some clays in southern Missouri mainly consist of the kaolinite clay mineral, which absorbs much less water in its inner structure than the montmorillonite clay mineral. Kaolinite generally does not swell when wet and is moderately permeable. In fact, many ponds constructed in red clays will not hold water. See Table 10.3.

Table 10.3 – Permeability Class

Permeability Class	Water Flow in Saturated Soil (inches/hour)
Very rapid	>20.0
Rapid	6.0 – 20.0
Moderately rapid	2.0 – 6.0
Moderate	0.6 – 2.0
Moderately slow	0.2 – 0.6
Slow	0.06 – 0.2
Very slow	0.01 – 0.06
Extremely slow	<0.01

Surface Soil Permeability

The rate of water and air movement through the surface layer of sloping soils directly affects runoff, erosion, and water applied through irrigation. Soils with rapid or moderate infiltration rates are best suited for irrigation and are subject to less erosion than soils with slow infiltration. If water cannot enter into the soil when it rains or during irrigation, it runs off, causing erosion.

Besides causing erosion, runoff wastes water that could be stored in the soil for plant use. Excessive runoff also can increase the hazard of flooding in downstream areas.

One way to maintain good permeability is to incorporate enough crop residues to maintain or increase the amount of organic matter in the surface layer. Minimum tillage or no-till systems help to improve the structure and organic matter content, and enhance the infiltration rate of the surface layer. Minimum tillage leaves more plant residue, and allows for an increase in root growth, organic matter content, and better aeration. Soils that have adequate pore space and permeability also are the best soils for on-site waste disposal and building sites.

Excessive tillage causes compaction and reduces pore space. Without adequate pore space, the soil is not a good place for roots to grow. Driving over wet soils also causes compaction, reduces the total pore space, and destroys the large pores needed for good permeability.

Subsoil Permeability

Water movement through B and C horizons affects soil drainage, leaching of salts and fertilizers, and performance of septic tank absorption fields. Rapidly permeable soils are readily leached. Soluble salts, especially nitrogen fertilizers, are easily lost from the soil without benefitting the crops. Leaching also may contaminate the ground-water if easily soluble components are present. Rapidly permeable soils do not make good waste disposal sites. Effluent (waste water) from the septic tank absorption field is likely to leave the soil too quickly to receive adequate biological treatment. Sanitary landfills placed on these soils increase the hazard of leaching dangerous chemicals and other pollutants into the groundwater.

In slowly permeable soils, water moves so slowly toward the drainage lines and the lines must be so closely spaced in the soil that drainage is not feasible. Slowly permeable soils are also unsuitable for conventional septic tank absorption fields because the soil near the distribution lines is likely to become saturated and cause the septic system to fail.

Because the texture, structure, and porosity may change from horizon to horizon in the subsoil, the permeability of each horizon should be evaluated individually. The overall permeability of the subsoil is that of the least permeable horizon within the subsoil. The Cr and R horizons are not considered. In any case, the permeability of the entire profile can never be greater than the horizon with the slowest permeability.

Guide for Determining the Permeability of Each Horizon

This is a guide for determining the permeability of each horizon by texture and structure and special features (such as fragipans and type of clay). See Table 10.4.

Table 10.4 – Guide for Determining Soil Permeability

Texture	Structure	Permeability (inches of water/hour)
Sand, loamy sand	Single grain	Rapid and very rapid (>6.0 inches/hour)
Sandy loam	Granular	Moderately rapid (2.0–6.0 inches/hour)
Loam, silt loam	Granular	Moderate (0.6–2.0 inches/hour)
Sandy clay loam*	Blocky	Moderately slow (0.2–0.6 inches/hour)
Clay loam, silty clay loam*	Blocky	Moderately slow (0.2–0.6 inches/hour)
Sandy clay*	Blocky	Moderately slow (0.2–0.6 inches/hour)
Silty clay, clay*	Blocky	Very slow and slow (<0.2 inches/hour)
All fragipans will be very slow in permeability	Platy	Very slow (<0.06 inches/hour)

*NOTE: If the horizon is kaolinite/sandy clay loam; clay loam, silty clay loam; sandy clay; or silty clay, clay use the moderately slow permeability to the right.

For subsoil permeability, use permeability of most limiting layer (between the base of the surface layer to a depth of 60 inches excluding the CR and R horizons).

Internal Soil Drainage

When all the pores of a soil are full of water, the soil is **saturated.** The top of a zone of saturated soil is called a **water table**. A **seasonal high water table** (internal free water) is the highest level of a saturated zone in the soil during the wettest season, and is used in reference to undrained soils. It is based on evidence of **reduction**, such as grayish colors or mottles. Generally, the zone of saturation has to last longer than one month for the reduction of iron to occur to produce mottling. The height of the water table and the length of time that the soil remains saturated determine the internal drainage of a soil. Soil drainage is important because it affects the environment of plant root growth. See Figure 10.5. Ideally, about half of the pores in the soil should contain water. The other half should contain air.

Wet Soil Conditions

When the soil is saturated, plant roots quickly become oxygen-starved; prolonged saturation kills many plants. That is why the choice of crop plants is severely limited in poorly-drained or very poorly-drained soils.

Wet soils are also cold soils. Early spring growth is slower because it takes longer for wet soils to warm up. Wet soils cannot be plowed, tilled, or cultivated as early in the year, so planting dates may have to be delayed. Nitrogen fertilizers are not used as efficiently in wet soils, because the wetness causes the loss of some of the nitrogen to the atmosphere. Root rot and other plant diseases are also more serious in soils that are not well drained.

Wet soils are poorly suited for homesites, too. Conventional septic tank absorption fields installed in these soils will not function properly because waste water does not receive adequate treatment. No one wants water in the basement, so special precautions must be taken when houses are constructed on poorly-drained soils.

Soil Properties and Other Factors in Drainage Classification

Many times when soils are studied in the field, the soil surface is dry and the water table is below the bottom of the pit. Rarely is the water table observed as it fluctuates throughout the year. That makes it necessary to determine the drainage class from the permanent properties observed in the soil profile. Color, permeability, horizons (especially restrictive layers), and landscape position all enter into the evaluation of soil drainage.

Color – The most important clues come from color and mottling. Brown, yellowish-brown, and red colors are characteristic of well-oxidized soils. These soils are rarely saturated, and when they are, it is only for very short periods of time. Dark gray or olive-gray colors reflect intense reduction, which can only be caused by long periods of saturation. Poorly-drained and very poorly-drained soils have these colors.

Mottles indicate that a soil undergoes repeated cycles of saturation and oxidation. They often represent the effects of temporary water tables that may be perched above slowly permeable layers. Mottles also are present in moderately well-drained and somewhat poorly-drained soils.

Permeability – Permeability is another clue to internal soil drainage. It is not the same as drainage, though. Some rapidly permeable sandy soils may be poorly drained if they lie in a depression that has a permanently high water table. Some slowly permeable soils may have good drainage if they are on rounded upland hills.

Slow permeability, though, does suggest that excess water cannot escape quickly by moving through the soil. This situation often leads to buildup of temporary high water tables.

Horizons (restrictive layers) – Subsoil permeability is especially important when combined with evidence of restrictive layers like fragipans or clay layers. Because these layers are so slowly permeable, water does tend to build up above them, creating **perched water tables**.

Perched water tables are temporary, and their presence is usually indicated by mottling just above and in the upper part of the restrictive layer. The closer these restrictive layers are to the surface, the more frequent and prolonged is the existence of the perched water table. On the other hand, restrictive layers deep in the soil may have little effect on internal drainage.

Landscape position – Landscape position also provides valuable information on soil drainage. Soils on **convex** (rounded, arching out) uplands tend to lose water both by runoff and by flow within the soil. They generally are well drained.

Soils lower on the slope, or on **concave** (saucer-shaped) footslope positions, tend to receive extra water both as runoff and as seepage from higher soils. Water tables in these landscapes are likely to be periodically close to the surface. If the soils in these positions also contain slowly permeable horizons, they are sure to be somewhat poorly drained or even poorly drained.

Soils in low-lying areas, on broad, level landscapes, or in depressions, may have permanent water tables just a few inches beneath the surface. They may be poorly drained or very poorly drained. Again, slow permeability compounds the problem, although poor drainage conditions can exist by themselves.

Classes of Internal Drainage

The seven classes of internal drainage are defined in Figure 10.7. Soil color and depth to mottles are the primary keys to correct classification. Remember, however, that a few soils may have color patterns or coating on aggregates that are not related to internal drainage. The other factors—landscape, permeability, and restrictive layers—are all used as supporting evidence when determining drainage class.

Seasonal High Water Table

A **seasonal high water table** refers to a zone of saturation at the highest average depth during the wettest season. It is at least 6-inches thick, persists in the soil for more than a few weeks, and is within 6 feet of the soil surface. Soils that have a seasonal high water table are classified according to the depth to the water table, the kind of water table, and the time of year when the water table is highest.

A seasonal high water table is an important criterion in a number of engineering and biological uses of soils. Its depth and duration influence the limitation of soils for such uses as septic tank absorption fields, and the ease of excavation for roadfill and topsoil, building sites, and roads and streets. A high water table during the growing season is detrimental to most crops. There are two kinds of seasonal high water tables: apparent and perched.

Apparent Water Table

An **apparent water table** is the level at which water stands in a freshly dug unlined borehole after adequate time for adjustments in the surrounding soil.

Perched Water Table

A **perched water table** is one that exists in the soil above an unsaturated zone. To prove that a water table is perched, the water levels in boreholes must fall when the borehole is extended.

The depth and duration of a water table can actually be measured with boreholes caused with perforated pipe. Measurements are recorded periodically. However, soil scientists can make close approximations of the depth of a seasonal high water table at any time by observing the depth to gray mottles. Gray mottles that have a chroma of two or less are evidence of a seasonal high water table in most soils. The presence of concretions and uncoated sand grains is also a good indicator of water tables in some soils. A few soils have relict mottles, which do not represent wetness, but are a reflection of the original color of the parent material. See Table 10.5.

Summary

Plants need water to survive, although the amount of water needed varies widely. There are three kinds of soil water: gravitational water, which fills large pores and drains quickly; available water, which is held in small pores that plants can use; and unavailable water, which is held so tightly in tiny soil pores that plant roots cannot remove it.

Available water capacity (AWC) is the capacity of the soil to hold water in a form available to plants, and is determined largely by soil texture. Clayey soils hold large amounts of water in tiny pore spaces, but only a small

Figure 10.7 – Classes of Internal Drainage

1. Excessively drained (E). Water is removed very rapidly. Internal free water (water table) is very rare or very deep. These soils are characterized by bright colors and coarse textures throughout the profile. These soils have sand to sandy loam textures and are often extremely gravelly or cobbly. The permeability is rapid or very rapid. They have the brownish colors of well-oxidized soils, and they are not mottled. They typically have a low or very low AWC and generally are not suitable for crops unless irrigated.

2. Somewhat excessively drained (SE). Water is removed from the soil rapidly. Internal free water (water table) commonly is very rare or very deep. These soils commonly are loamy sand, sandy loam, or extremely gravelly or cobbly. The permeability is rapid or moderately rapid. They have brownish colors of well-oxidized soils, and they are not mottled. They typically have a low AWC and are suited only to crops that are moderately tolerant to drought.

3. Well drained (W). Water is removed from the soil readily but not rapidly. Internal free water (water table) commonly is deep or very deep. Wetness does not inhibit the growth of roots for significant periods during most growing seasons. The soils are free of mottles to a depth of 40 inches. These soils may have any texture, though the most common are silt loam, silty clay loam, loam, clay loam, and sandy loam. Soil colors are various shades of yellowish brown and reddish brown throughout, all indicating well-aerated soil. Well-drained soils generally have moderate subsoil permeability. Occasionally, however, the lower part of the soil may be saturated for a day or two at a time. Thus, the soil below a depth of 40 inches may have a few gray mottles. These soils are not wet close enough to the surface to restrict equipment use.

4. Moderately well drained (MW). Water is removed from the soil somewhat slowly during some periods of the year. Internal free water commonly is moderately deep. The soils are wet for only a short time within the rooting depth during the growing season, but long enough that some crops are affected. These soils may have any texture. Subsoil permeability is usually moderate or slow. There may be a deep, restrictive layer that temporarily perches water. The soil commonly is mottled at depths of 24–42 inches (60–105 cm) below the surface. The mottles may be gray in a brownish matrix, or they may be yellowish brown in a grayish-brown matrix. It only takes a few gray or grayish-brown mottles to indicate enough wetness to drop a soil into a moderately well-drained class. These soils are wet close enough to the surface to restrict equipment use during wet periods of the year, mainly early spring.

5. Somewhat poorly drained (SP). Water is removed slowly so that the soil is wet at a shallow depth for significant periods during the growing season. Internal free water commonly is shallow to moderately deep. The soils are wet for extended periods during the growing season and crop growth is markedly restricted. These soils may have any texture and any permeability. They usually occur on nearly level or low-lying positions and have a seasonal high water table. Some have fragipans or clayey subsoils. Somewhat poorly-drained soils are rarely saturated all the way to the surface for long periods of time. The profile is mottled below the surface layer. The water table is high enough to cause some mottling of the soil somewhere between 12 and 24 inches (30–60 cm). Some soils have a gray E horizon and at increasing depths, the mottling becomes more noticeable. In some somewhat poorly-drained soils, black or very dark grayish-brown colors extend throughout the soil. These either have a gray matrix with yellowish-brown or reddish-brown mottles below 12 inches, or they have a few grayish mottles throughout, starting right below the Ap. Iron and manganese concretions are typical throughout the profile. Equipment usage is markedly restricted unless artificial drainage is provided.

6. Poorly drained (P). Water is removed so slowly that the soil is wet at shallow depths periodically during the growing season or it remains wet for long periods. Internal free water is shallow or very shallow. Free water commonly is at or near the surface long enough that crops cannot be grown unless the soils are drained. They either occupy low-lying or depressional areas that have permanently high water tables, or they have restrictive layers close to the surface, or both. Any texture or permeability can occur, but fine textures and slow permeabilities are most common. Poorly-drained soils are mottled in the lower part of the A horizon and have gray matrix colors and reddish mottles or black concretions in the Ap or A horizon. In a few soils, the black colors (caused by high organic matter content) may completely mask the mottles in the surface horizons. Equipment usage is very restricted unless artificial drainage is provided. Gleyed horizons are common, and are designated by gray colors caused by water saturation. The soil below the A horizon is gray or dark gray and becomes noticeably lighter upon drying. Landscapes are low-lying or in depressions in nearly every case. Water-tolerant plants do best on these soils.

7. Very poorly drained (VP). Water is removed from the soil so slowly that free water remains at or very near the ground surface during much of the growing season. Internal free water is very shallow. Unless drained, most crops cannot be grown. These soils commonly are gray or black throughout the profile, and may have reddish colors only in root channels. Gleyed horizons are common, and are designated by gray colors caused by water saturation. These soils may or may not be mottled. The soil below the A horizon is gray or dark gray and becomes noticeably lighter upon drying. Landscapes are low-lying or in depressions in nearly every case. Equipment usage is severely restricted except where artificial drainage is provided. Water-tolerant plants do best on these soils.

Table 10.5 – Guide for Internal Drainage and Depth to Water Table

Drainage Class	Subsoil Color	Mottles	Depth to Water Table
Excessive (E)*/Somewhat excessive (SE)*	Brown, red	No gray colors or mottles within 72 inches	>6 feet
Well (W)	Brown, red	Gray mottles below a depth of 42 inches	3.5–6 feet
Moderately well (MW)	Brown, red	Gray mottles at depths of 24–42 inches	2–3.5 feet
Somewhat poorly (SP)	Grayish brown, gray	Gray mottles below the A horizon at depths of 12–24 inches	1–2 feet
Poorly (P)	Gray, black	Gray mottles in and below the A horizon or at a depth of less than 12 inches	0–1 foot
Very poorly (VP)	Gray, black	Gleyed colors or gray mottles to the surface, depressional areas, and evidence of long periods of ponding above the surface	0–1 foot

*These soils commonly are loamy sand, sandy loam, or extremely gravelly or cobbly.

amount of this water is available to plants. Silty or loamy soils hold smaller amounts of water than clayey soils, but more is available for plant use.

Effective rooting depth of plants is restricted by bedrock, very dense horizons, extremely gravelly or cobbly layers, or extended periods of high water tables. Soils with restricted rooting depths are more susceptible to drought because of the lower AWC.

Rock fragments cannot store water, so horizons that contain rock fragments contain less available water. Other properties that affect AWC are structure and organic matter. The AWC can be estimated by determining the soil texture, percentage of rock fragments, and effective rooting depth for each horizon.

Permeability refers to water movement through the soil, specifically the rate at which a saturated soil transmits water. This rate depends on the soil texture, structure, and color as they relate to the amount of total pore space, size of the pores, and connections between the pores. The permeability of the subsoil is determined by the least permeable horizon within the subsoil. Factors that affect the internal drainage of soil are the height of the water table and the length of time that the soil remains saturated.

A seasonal high water table is the highest average depth of a saturated zone during the wettest season. It is based on evidence of reduction, such as gleyed colors or gray mottles. There are two kinds of seasonal high water tables: apparent and perched.

Credits

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