Engineers and Soil Scientists

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Site Visit Summary Report
Town of Mount Olive – Wastewater Irrigation System

Wayne County
(NC DEQ-DWR Permit# WQ0029169)

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Agri-Waste Technology, Inc. (AWT) performed two site visits to the recently modified Town of Mount Olive Wastewater Irrigation system by request of WithersRavenel, Inc. (WR). The site visits were performed on April 4, 2023, and May 25, 2023. The purpose of these visits was to evaluate and troubleshoot issues identified by the town staff regarding infiltration and runoff from the irrigation fields.

Background:

Previously the site was served by a drip irrigation system with trees planted for agronomic and hydraulic/evapotranspiration benefit. The drip system was removed, and many of the same fields were re-purposed with spray irrigation. AWT's involvement in the project came at the conclusion of the drip field removal and tree clearing/grubbing services. The majority of AWT's site testing took place prior to the construction of the irrigation system network.

Soils on the site are primarily Norfolk and Ruston series with other similar soils of the upper coastal plain also observed around the site. Surface horizons are generally sandy (Loamy Sand and Sandy Loam) in areas that were not excavated or disturbed by machinery; however, much of the sand composition is comprised of fine sands. This distinction can be important when other factors come into play. The previously established infiltration rate of 0.4 inches per hour was considered to remain appropriate for the re-purposed fields. Slopes range from 0-8% with most areas less than 6%.

Observed Conditions Summary:

During the two site visits, the following items were noted as points of discussion:

- Runoff was observed due to both point source concerns and overland flow concerns in several of the fields. This seems to be occurring across several fields scattered through the entire site with no discernable pattern. Fields with steeper slopes likely begin to show evidence of runoff earlier in the dose cycle than fields with slight slopes.
- During the first site visit the winter cover Ryegrass was near the end of the growth cycle but was relatively sparse in thickness/ground cover. In areas with tall Ryegrass, runoff was generally not observed at that time. Areas which had been cut to stubble were more likely to contribute runoff.
- During the second site visit the Ryegrass had been cut and removed, and the Bermudagrass was starting to mature. The Bermudagrass is newly seeded as of 2022. The ground cover was noticeably thin, and exposed soil was present in large patches across several fields.
- The fields appeared to have been mostly bare with no vegetative residue or organic matter left during the period of construction.
- There are access roads and construction areas with subsoil showing at the surface (red or reddish-orange shaded soils). These areas also show evidence of compaction. Runoff is occurring instantaneously when there is irrigation occurring on unvegetated roads or areas which were mechanically compacted.
- There is evidence of surface "crusting" in many areas. Crusting typically occurs when precipitation falls on bare soil aggregates and breaks down the soil structure. This can be exacerbated when fine sands are present, and there is no vegetative residue or roots remaining on a field.
- Subsoils generally contained minimal moisture, indicating the full soil profile is not saturated. Saturated soils could also lead to runoff, but there is no evidence of this based on borings performed by AWT during these visits.
- Irrigation system calibration, uniformity, and distribution are critical pieces of any soil-based treatment system.

Recommendations:

A literature review was conducted along with a review of the design and soil parameters. Attached is supporting documentation related to several of the observed conditions noted above. This information is provided as part of the NC Surface Irrigation Operator Training Program. In an effort to address improving the infiltration capacity of the site, the following suggestions are offered:

- Surface crusting will persist until there is significant vegetative cover to improve aeration through root growth and organic matter accumulation. Time and careful farming management practices will be the biggest contributor allowing these factors to thrive.
- Improving the vegetative cover condition will help dissipate the velocity of precipitation and allow more time for infiltration. Bare soil will continue to cause runoff unless there is protective cover.
- Aeration/"breaking" of the crusting conditions should allow increased infiltration capacity as long as a dense vegetative cover remains. It will be critical not to destroy the actively growing grass but also be necessary to allow for deeper aeration practices than normal so that the crusting can be truly fractured and not simply "perforated".

- Areas with subsoils showing and very thin vegetation will likely need to be disked and covered immediately with an erosion prevention cover material in order to facilitate new growth. The addition of sandy soil and incorporation via tillage may be necessary to improve surface infiltration in these areas.
- Providing surface water diversions, check dams, or other preventative measures along roads may help slow down the velocity of runoff in areas which will always be prone to greatly reduced infiltration.

Sincerely,

Christopher McGee, LSS

Summary of Attachments

Attachment 1: Supporting Documentation

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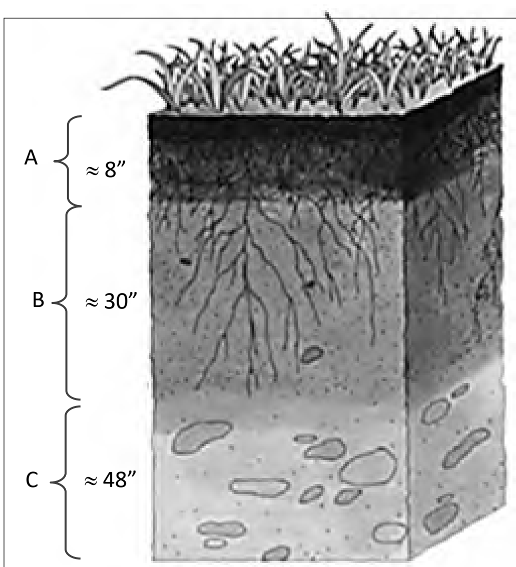
What is a Soil Profile, a Soil Horizon, and a Soil Series?

To understand soil and how one soil differs from another, soil scientists name or "classify" soils by evaluating their physical, biological, and chemical properties. This classification is based on a three-dimensional volume or unit of soil called a soil profile. A ***soil profile*** is a vertical section of soil from the ground surface to the parent material (the original material the soil formed from). Each profile consists of a series of layers, called ***soil horizons***, whose properties differ from the layers above and beneath.

Soils that have very similar profiles are classified as the same ***soil series.*** Soils in the same series have major horizons that are similar in thickness, arrangement, and other important properties. A soil series name generally comes from a town or landmark in or near the area where the soil series was first recognized. The properties of the soil series that exist at a proposed site determines if the site is suitable for irrigation of wastewater.

Each soil series has at least one, and usually three or four, horizons. Additional horizons can also be present, depending upon soil forming factors and soil age. Under disturbed conditions -- heavy agriculture or severe erosion -- not all horizons will be present. For our purposes, we are mainly concerned with the A and B horizons (Figure 3-2).



A horizon	Surface horizon or "topsoil". It is usually darker than lower layers, loose, and crumbly with varying amounts of organic matter mixed with mineral particles. Properties may reflect plowing, pasturing or similar activities. Zone of maximum ***biological*** activity in a soil.
B horizon	"Subsoil". Usually contains more clay and less organic matter than the A horizon. Zone of maximum ***chemical*** activity in a soil.
C horizon	Consists of slightly broken-up bedrock or other parent material (the original material the soil formed from). Very little organic material is present and plant roots do not penetrate this layer.

Figure 3-2. Simplified profile of a soil in the NC Piedmont region.

Soil Properties

Soils vary greatly over short distances. A field at a land application site often contains several soil series, each with its unique properties. Some of these properties are inherent – they are permanent and do not change. Other properties are dynamic and change depending on management.

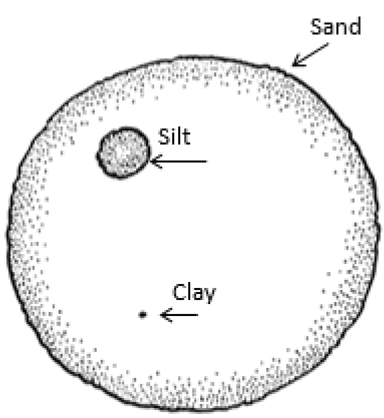
A working knowledge of soil properties and processes will help you, as an operator, understand the limitations imposed by inherent soil properties and the challenges posed by dynamic soil properties. The goal is to manage your site(s) in a manner that maintains, and possibly improves, the treatment capacity of the soil(s).

Soil properties that influence wastewater irrigation include:

- soil texture
- soil structure
- infiltration
- percolation and permeability
- soil depth and restrictive horizons
- seasonal high water table
- topography
- soil pH
- cation exchange capacity

Soil Texture

The mineral particles in the soil come in three sizes: sand-sized particles are the largest, silt-sized particles are medium-sized, clay-sized particles are the smallest (Figure 3-3). Every soil contains some of each particle size, but not every soil contains the same amounts. The percentage of each particle size in a particular soil determines the soil's texture.



Particle Size	General Characteristics
Sand	Individual grains visible to the eye, gritty when soil is rubbed between the thumb and fingers.
Silt	Smooth and baby-powder feel when rubbed between the thumb and fingers. Not plastic or sticky when moist.
Clay	Can't be seen with the naked eye. Smooth, sticky and plastic feel when moist. Forms very hard clods when dry. Particles may remain suspended in water for extended periods of time.

Figure 3-3. The three particle sizes (not to scale) and their general characteristics. If a sand particle is the size of a basketball, a silt particle would be the size of a golf ball, and a clay particle the size of a dot made by chalk.

The four major soil textural classes take their names from the three particle size categories. Sand is made up of mostly sand-sized particles, silt is mostly made up of silt-sized particles, and clay is mostly made up of clay-sized particles. The fourth major textural class is called loam. ***Loam*** is not another particle size, but is a balanced mix of sand, silt, and clay-sized particles (Figure 3-4).

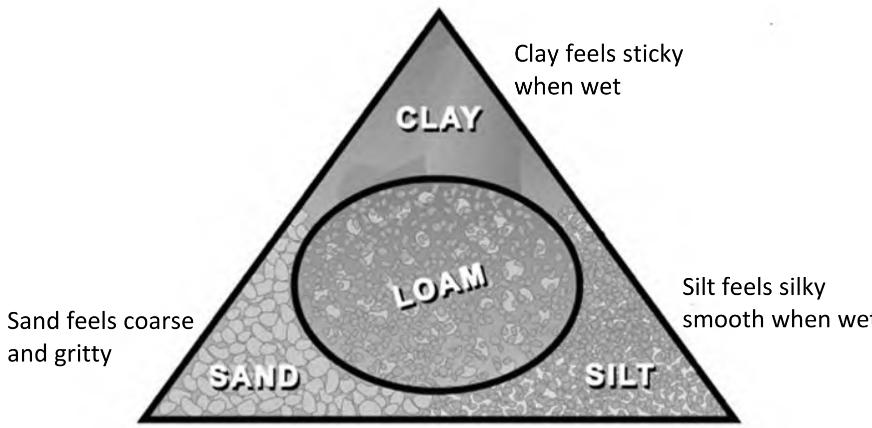


Figure 3-4. The 4 major textural classes: sand, silt, clay, and loam.

There are a total of 12 soil textural classes (Table 3-1) that can be lumped into three general categories: coarsely-textured (sandy soils), medium-textured (loamy soils), and finely-textured (clay soils).

Table 3-1. The 12 soil textural classes.

General Terms	Textural Class
Sandy soils (coarsely-textured)	Sand Loamy sand
Loamy soils (medium-textured)	Sandy loam Loam Silt loam Silt Clay loam Sandy clay loam Silty clay loam
Clayey soils (finely-textured)	Sandy clay Silty clay Clay

Texture influences soil suitability for wastewater irrigation in many ways. Texture is related to the size and shape of soil pores, which affects water movement into and through the soil. Texture influences the balance between water-filled pores and air-filled pores, creating different soil environments for root growth and microorganism activity.

Coarsely-textured soils have large spaces (***macropores***) between their soil particles. Water and air pass through these macropores rapidly. Consequently, coarsely-textured soils are usually well-aerated and well-drained.

However, water often passes through these soils too quickly for significant treatment to occur. In addition, these soils may not hold enough water and nutrients to support healthy vegetation. A poor vegetative cover results in reduced uptake of water, nutrients, and pollutants and an increased potential for soil erosion.

Clayey soils have smaller spaces (***micropores***) between soil particles. Due to cohesive and adhesive forces, micropores hold water, nutrients, and pollutants more tightly than macropores. Consequently, water tends to move into and through finely-textured soils more slowly.

Loamy or medium-textured soils have a range of pore sizes. Water can flow through the smaller pores while air can move through the larger pores. Medium-textured soils provide favorable environments for root growth, store large amounts of water for plant use, and have good nutrient-supplying power.

Texture is an inherent soil property. Because texture is the relative proportion of sand-, silt-, and clay-sized particles, it can be modified only through the addition of one of these particle sizes. This may be feasible when working in greenhouses or small garden plots but changing soil texture on a large scale is not practical, so soil texture is considered an inherent property.

Soil Structure

Soil structure is the arrangement of individual sand, silt, and clay particles into clusters of particles called soil *aggregates*. Aggregates occur in different shapes and patterns, resulting in different kinds of soil structure. Examples include granular, blocky, platy, prismatic, structureless–single grained, and structureless–massive (Figure 3-5).

Soil structure is important because it modifies some of the undesirable effects of certain textures on water and air movement. Structure creates relatively large pores between the aggregates, which are much larger than those between individual soil particles. Water, air, and plant roots move more readily through the macropores between aggregates than through the micropores inside the aggregates. Good structure means good aeration and a favorable balance between air and water containing pores.

The ideal structure for agriculture and wastewater irrigation is granular structure in the topsoil and blocky structure in the subsoil. Water movement in soils with platy, prismatic, or massive structure is slow and restricted (Table 3-2).

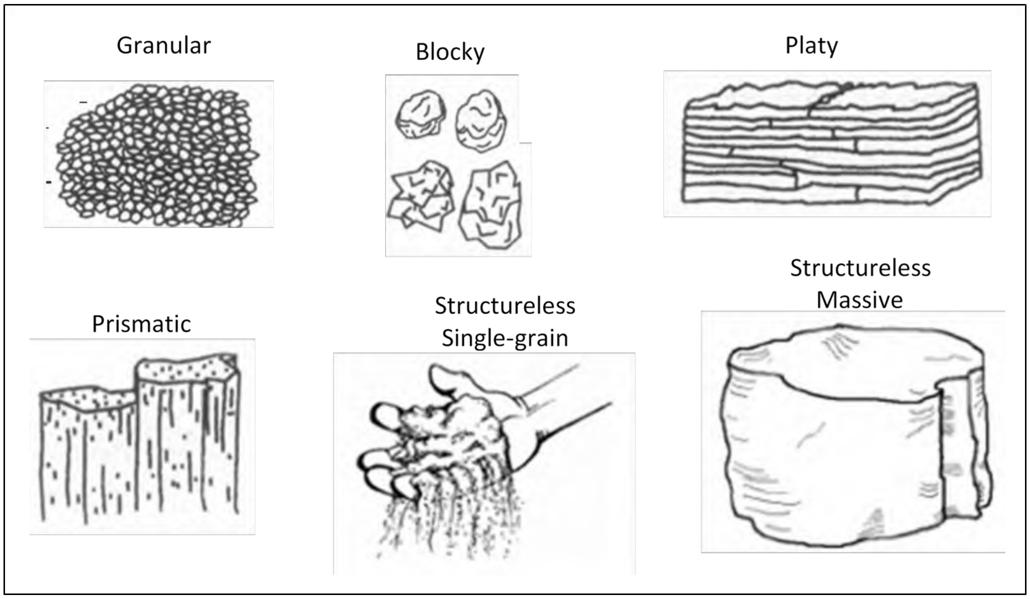


Figure 3-5. Examples of soil structure.

Table 3-2. Descriptions of soil structure types and rate of water movement.

Type	**Description**	**Water Movement**
Granular	Small, rounded aggregates, resembling cookie crumbs that separate easily from each other. Usually found at the soil surface in the A horizon where there is more organic matter and biological activity.	Rapid
Blocky	Irregular block-like aggregates that can have angled or rounded sides. Blocky structure is most common in the B horizon where clay content is higher.	Moderate
Platy	Overlapping plates or sheets piled horizontally on one another. Platy structure can be found in the surface or subsoil.	Slow
Prismatic	Vertical columns or pillars separated by miniature, but definite, vertical cracks. It is commonly found in the B-horizon where clay has accumulated.	Slow
Structureless – single grain	There is no structure, only individual soil particles that are not aggregated into any other soil structure. Beach sand is a good example.	Very rapid
Structureless - massive	There is no structure. The soil does not naturally separate into structural units because there are none. This is common in C horizons or in very sticky clay soils.	Very slow

Soil structure is a dynamic soil property. Unlike texture, structure is easily altered by management practices. Maintaining strong, stable aggregates is important in any good soil management strategy. Wastewater is a valuable soil amendment because it adds organic matter which encourages the formation and maintenance of good soil structure. In addition, application stimulates root growth which tends to bind particles together.

On the other hand, driving heavy equipment on wet soil (especially clayey soil) breaks down soil aggregates. The breakdown of soil structure is called ***soil compaction***. Soil particles are pressed closely together and macropores disappear. Compaction can change granular or blocky structure into platy or massive structure (Figure 3-6). ***Subsurface compaction*** (traffic pans and plow pans) are compacted layers that can develop beneath the topsoil as a result of driving heavy equipment or tilling soil when wet (Figure 3-7).

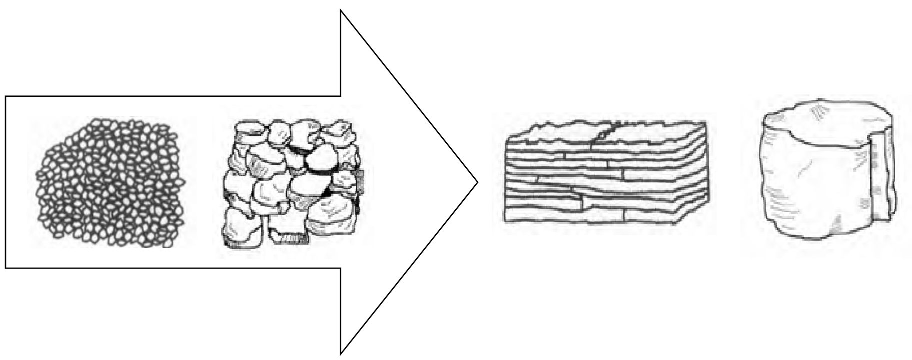


Figure 3-6. Compaction can turn granular or blocky structure into platy or massive structure.

Compaction of topsoil can also occur. ***Surface crusting*** is a form of compaction that happens when the impact from water falling on or flowing over bare soil breaks down soil aggregates. Individual soil particles become suspended in water, flow together, and then dry into a hard crust.

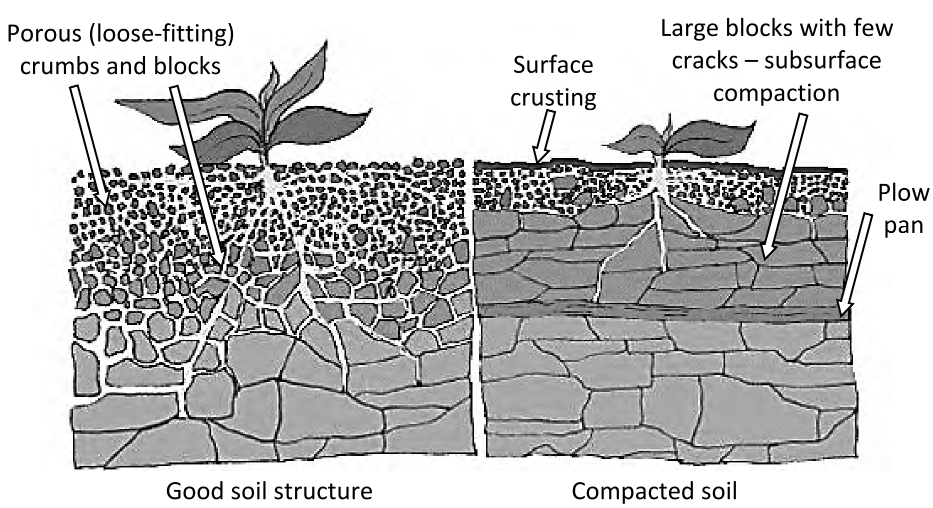


Figure 3-7. Example of good soil structure and compacted soil.

Soil compaction reduces:

- water and air movement into and through the soil
- seedling germination and emergence
- root penetration
- nutrient and water uptake by crops
- treatment capacity of the soil

Soil compaction should be avoided. Limiting operations on wet soils, reducing load weight when possible, and using flotation tire, doubles, or tracks will go a long way toward limiting compaction and maintaining soil productivity. Maintaining a healthy crop and crop rotations that include deep-rooted plants like alfalfa will help protect soil structure.

Tilling can break up compaction in the topsoil, although no-till fields and fields with perennial forages are a problem. Subsoiling, a process of deep tilling with a disk chisel, subsoiler (disk ripper), or ripper, penetrates soil below normal tillage depths (usually 12-18" deep) and breaks up deeper compaction. Low-disturbance subsoiling equipment can break up deep soil while leaving the surface virtually untouched. Subsoiling works well on Coastal Plains soils but is not effective in very clayey or rocky soils.

Infiltration

Infiltration is the movement of water *into* the soil. ***Infiltration rate*** (expressed in inches per hour) is the maximum rate at which water enters the soil. A moderate to rapid infiltration rate is desirable for plant growth and the environment. Infiltration rate is a function of surface texture and structure, vegetative cover, slope, and soil moisture.

- ***Surface texture and structure.*** We have already discussed the effects of texture and structure on water movement. A surface soil with medium to course texture and good structure will have a rapid infiltration rate. Infiltration rates can be near zero for very clayey and compacted surface soil.

- ***Vegetation.*** A healthy vegetative cover or crop protects soil structure and increases infiltration rates. Without the protective benefits of vegetative, water falling on or flowing over the soil destroys surface structure and results in surface crusting.

- ***Slope.*** On flat or gently sloping land, water has more time to soak into the soil surface. On steeper slopes, water moves over the surface more rapidly and the amount of time for infiltration is reduced. Soils tend to be thinner on steep slopes, limiting storage of water. Where bedrock is exposed, little infiltration can occur, except through large cracks which is unacceptable. We will discuss slope in more detail later in this section.

- ***Soil moisture.*** **I**nfiltration rates are higher when the soil is dry than when it is wet. As the soil becomes wet, the infiltration rate decreases. If all soil pores are filled with water the soil is said to be ***saturated***. Water must move downward through the soil profile before more water can enter at the surface. When the surface soil is completely saturated, the infiltration rate will be quite low.
  When the surface soil is temporarily saturated and more water is added through rainfall or wastewater irrigation, the water must go somewhere. It either ponds on the soil surface or moves downslope as runoff.

  In most cases, the surface soil does not stay saturated for long periods. Water that isn't taken up by plants or lost through evaporation moves downward through the larger pores. This process is called ***percolation***.

Table 3-3 shows the influence of texture, slope, vegetation, and surface conditions on infiltration rates. A dry sandy soil on a gentle slope with a good vegetative cover will have a much higher infiltration rate than a wet finely-textured surface soil on a sparsely covered steep slope.

Table 3-3. Influence of texture, slope, vegetation, and surface conditions on infiltration rates.

	Slope		
	0 to 3%	3% to 9%	>9%
	Inches per hour		
Sand	>1.00	>0.70	>0.50
Loamy sand	0.70 to 1.00	0.50 to 1.00	0.40 to 0.70
Sandy loam and fine sandy loam	0.50 to 1.00	0.40 to 0.70	0.30 to 0.50
Loam and silt loam	0.30 to 0.70	0.20 to 0.50	0.15 to 0.30
Sandy clay loam and silty clay Loam	0.20 to 0.40	0.15 to 0.25	0.10 to 0.15
Clay, sandy clay, and silty clay	0.10 to 0.20	0.10 to 0.15	<0.10
For poor vegetative cover or surface soil conditions, actual rates may be as much as 50% less than shown.			

Source: Sprinkler Irrigation Association Journal

Percolation and Permeability

Percolation is the movement of water *through* the soil once it infiltrates into the soil. ***Permeability*** is how *fast* (inches per hour) water moves through the soil. Permeability is largely determined by soil texture and structure. Sandy soils have very rapid permeability, and clayey soils have very slow permeability. But, as we have discussed, the rate that water moves through the soil also depends on soil structure. Good soil structure enhances permeability by providing stable aggregates that have large pores between them.

Soils that are well suited for wastewater irrigation have moderate or moderately slow permeability. If water moves through the soil too slowly, soil will become waterlogged and saturated. If water moves through the soil too rapidly, nutrients and contaminants can leach to groundwater before they are adequately treated.

Soil Depth and Restrictive Horizons

Soil depth is the distance from the soil surface to bedrock or other restrictive horizons. A ***restrictive horizon*** is a layer in a soil profile that roots, water, and air cannot penetrate. In addition to bedrock, examples of restrictive horizons include:

- bedrock
- natural hardpans (soil cemented by iron, lime, gypsum, silica, etc.)
- densely compacted soil (traffic pan or plow pan)
- seasonal high water table (discussed later in this section)

Soil depth determines how much water can infiltrate and be held by the soil and how much space plant roots can occupy. Deep soils hold more plant nutrients and water than shallow soils and provide more treatment opportunities for contaminants.

Shallow soils limit the volume of soil available for treatment of contaminants and increase the risk of groundwater contamination. Areas where bedrock is close to the soil surface make particularly poor surface irrigation sites. Fractures or cracks in bedrock can act as direct conduits for contamination of groundwater. Shallow soils also limit the types of crops that can be grown and the yield of those crops.

For these reasons, surface irrigation permits do not allow wastewater irrigation where (or when) the vertical separation between bedrock or the seasonal high-water table and the soil surface is less than one foot.

Seasonal High Water Table

A soil's seasonal high-water table (SHWT) is one of the restrictive horizons just mentioned. Before we define and discuss the seasonal high-water table, we need to define and discuss some other terms.

Some of the water that infiltrates into the soil is used by plants or evaporates. The remaining water percolates downward through the ***unsaturated zone*** (pores are filled with air and water). Eventually, it reaches the ***saturated zone***, where all the pores in the soil or bedrock are filled with water. The surface or uppermost level of the saturated zone is called the ***water table***. When water percolates through the soil and reaches the water table, it becomes groundwater. ***Groundwater*** is any water contained in interconnected pores located below the water table.

Water table depths are determined by the restrictive horizons below the soil surface. They may be very deep and cover a large area. A water table that results from such a restrictive horizon is called a ***permanent or apparent water table*** (Figure 3-8).

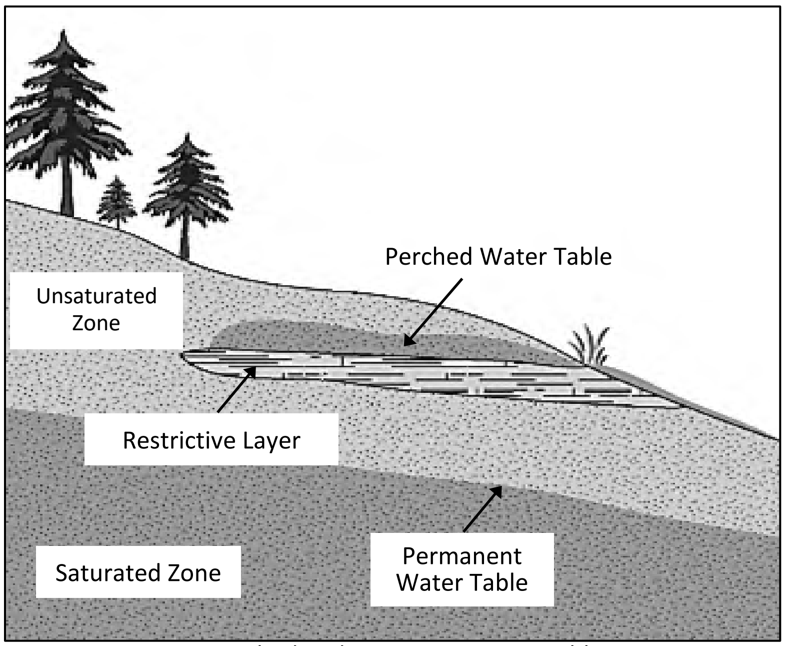


Figure 3-8. Perched and permanent water tables.

A water table may also be caused by a shallow restrictive horizon in the soil that creates saturated conditions above it, while unsaturated conditions exist below it. This type of water table is called a ***perched water table***, and usually occurs over a small area. Perched water table depths are quite variable and are usually of shorter duration than a permanent water table.

The depth of the permanent water table varies from place to place, mainly due to changes in landscape position. At the top of slope, soils are usually (but not always) well-drained, with the water table at some depth. Soils at the bottom of a slope, where water accumulates, are often poorly drained, with the water table near or at the soil surface.

The depth of the water table at a particular location also varies over time, moving up and down in response to weather conditions (Figure 3-9). The fluctuation of the water table occurs seasonally, rising in rainy seasons and dropping during dry periods.

The ***seasonal high water table*** (SHWT) is the highest level to which the soil is saturated during the wettest season of the year. Surface irrigation permits require that there must be at least one foot between the SHWT and the soil surface. Seasonally wet soils may not be suitable for irrigation