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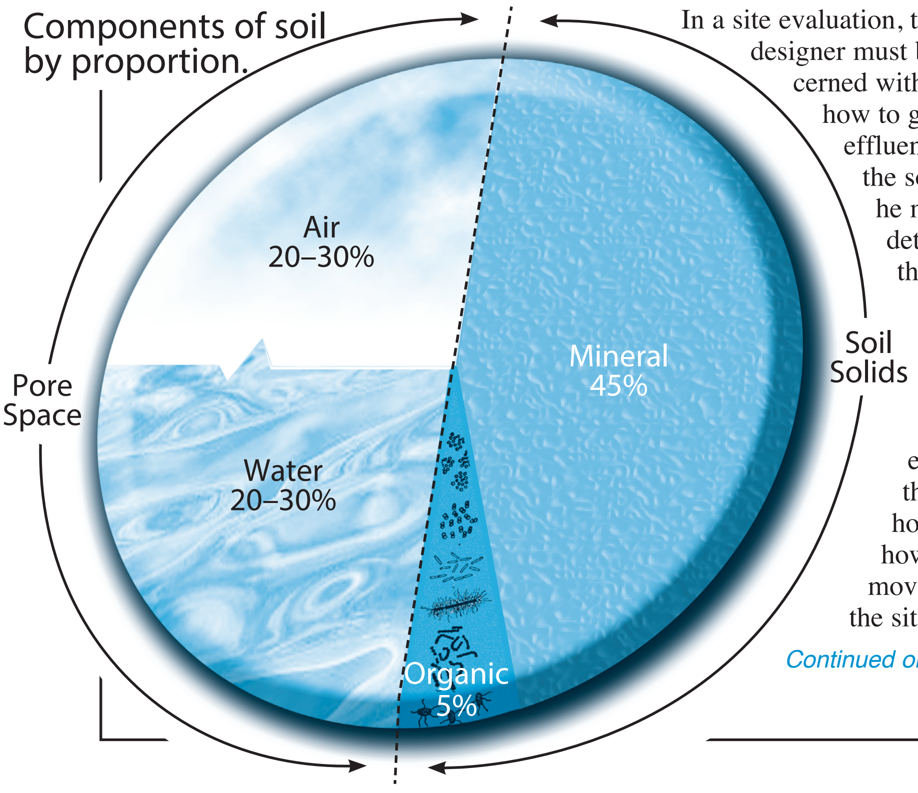
Soil Characteristics – Demystifying Dirt

Soil is the foundation of conventional onsite wastewater treatment. The drainfields used with onsite systems work because the soil around the trenches acts as a filter and removes organic matter, some of the nutrients present in wastewater, bacteria, and other pollutants before the water returns to the groundwater. Every site has unique soil characteristics that are critical in determining the size and type of onsite wastewater treatment system required.

Soil conditions are one of the most important elements in site evaluation and system design. Other restricting site parameters include the topography, separation distances, owner's preferences, existing water sources, depth to any limiting layer, and landscape position. But the ability of the soil to accept and transmit the effluent from the disposal system is the most crucial element.

It is necessary to evaluate the soil to ensure that a drainfield is designed properly and will not fail prematurely. Information about the depth of the soil and how quickly it will absorb water determines the suitability of the dispersal area. Soils that accept water too quickly will not treat wastewater adequately, and soil conditions that do not allow the effluent to move quickly enough into and through the soil also create problems.

Components of soil by proportion.



In a site evaluation, the designer must be concerned with not just how to get the effluent into the soil, but he must also determine the best way to introduce the effluent into the soil horizon, how will it move across the site, and in

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Glossary

Drainfields – an area of perforated piping that carry wastewater from the septic tank to the soil providing both disposal and treatment of the effluent, also referred to as the leachfield or dispersal field

Separation distance – the physical space between the bottom of the trench and the limiting layer

Limiting layer – anything that changes the normal flow of water through the soil profile, such as bedrock or the water table

Effluent – clarified wastewater from the septic tank

Topography- the configuration of a surface in relation to natural and man-made features, described in terms of differences in elevation and slope; in other words, the lay of the land

Nutrients- elements including nitrogen and phosphorus, necessary for plant growth

Percolation rates – indicates how fast the water will move down through the soil

Soil texture – determined by the proportions of the different-sized soil particles

Soil structure – relates to the grouping or arrangement of soil particles

Soil horizons – layers of soil composed of different minerals and amounts of organic matter; each layer exhibits similar color and texture; horizons make up the soil profile as seen in the test pit

Hydraulic conductivity or permeability - the ability of a porous media or soil to conduct water through its pore spaces

Permeameter - an instrument used to measure hydraulic conductivity of soil

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what condition the effluent will be in when (or if) it moves across property lines.

Soil consists of four components in various proportions: mineral particles, organic particles, water, and air. See the figure on Page 1 for a simple pie chart representing these proportions. Note that only about half of the soil volume consists of solid material; the other half consists of pore spaces filled with air or water.

Soil types are a result of the underlying rock types, climate, native vegetation, topography, and weathering. Not much remedial work can be done to change these factors. But, by identifying the soils present, it becomes easier for wastewater professionals to predict which dispersal technology will be most effective and reliable over time.

This issue of *Pipeline* explains how different soil types are classified and how these differences impact onsite wastewater treatment.

Soil characteristics

A site evaluation is the first step toward installing an appropriate wastewater disposal system. Site evaluations determine soil characteristics at the building site and the soil's ability to treat and dispose of wastewater. The Spring 2000 issue of *Pipeline* presents a complete overview of the site evaluation process (See page 8 for more information.) *Small Flows Quarterly*, summer 2002, issue has a discussion on techniques used to determine soil characteristics.

When a landowner applies to have his site evaluated before his onsite wastewater treatment system is approved, a representative from the local health department or permitting agency reviews the soil surveys that the National Resource Conservation Service (formerly known as the U.S. Soil Conservation Service) provides. Table 1 lists the procedures performed by a soil evaluator.

Table 1

Soil evaluation procedures

Describe soil horizons

List soil horizon features:

✓ Depth of horizon, thickness
✓ Moisture content
✓ Color
✓ Volumetric percentage of rock
✓ Size, shape, type of rock
✓ Texture of <2mm fraction of horizon
✓ Presence/absence of mottling
✓ Soil structure by grade
✓ Level of cementation
✓ Presence/absence of carbonates
✓ Soil penetration resistance
✓ Abundance, size,distribution of roots

Determine soil changes in soil profile across proposed site

Interpret results by identifying limiting depths

✓ Check vertical separation distances
✓ Identify mottled layers, concretions
✓ Determine depth to saturation
✓ Measure depth to confining layer
✓ Identify highly permeable layers

Issue site report

Develop system type, size location, and installation recommendations

A soil survey is the systematic examination, description, classification, and mapping of soils in an area. These surveys consist of aerial photographs of the mapped area that note types and distribution of soils. The survey indicates the soil's suitability for subsurface absorption systems, as well as other important engineering properties, such as how far it is to bedrock, if seasonally high water tables are probable, average percolation rates, and drainage potential.

A skilled soil evaluator will be able to estimate the hydraulic conductivity or permeability of the soil horizons by noting the structure and texture of the soil. From this, he or she will be able to determine the layout and format of the drainfield so that it provides adequate dispersion of the effluent into the soil horizons and provide the degree of treatment required to preserve the environment. This is essentially a judgement call based on a thorough examination of soil properties and the evaluator's past experience.

A soil evaluation begins with a simple soil probe or hand auger, to retrieve samples of soil at different depths. To determine if there is enough unsaturated soil below the proposed bottom of the absorption area, the evaluator will then dig a larger test pit within the perimeter of the proposed absorption area.

Some new technologies ,such as a permeameter, are on the horizon that may provide even more precise measurements of soil properties. These techniques and technologies my be faster and more reliable than some of the ones currently in use.

The soil pit should be about three feet deep and about a yard wide to expose the soil layers called horizons. Horizons vary in thickness and have irregular boundaries, but generally parallel the land surface. The vertical section exposing the texture changes in the different layers of soil is termed a soil profile. Road cuts and other open excavations expose soil profiles and serve as a window to the soil.

Horizons begin to differentiate as materials are added to the upper part of the profile and other materials move to deeper zones. Organic matter from decomposed plant leaves and roots tends to accumulate in the uppermost horizons, giving these layers a darker color than the lower ones. These horizons are generally referred to as the topsoil.

The next layers contain less organic matter and are composed of silicate clays, iron and aluminum oxides, gypsum or calcium carbonate accumulated from the horizons above. These lower layers are referred to as subsoil. The characteristics of subsoil greatly influence most land-use activities. Roots can't penetrate impermeable subsoil and water can't move through it. Poor drainage in the subsoil can result in waterlogged conditions in the topsoil.

Limiting layer

A factor known as the "limiting layer" occurs in the subsoil. This limiting layer impedes or interferes with the natural flow of water. It might be a seasonal water table (high in winter and spring then falling in summer and fall), a layer of solid rock, or a gravel bed. The depth between the bottom of the dispersal trench and this limiting layer is important—the greater the depth or distance between them the better it is for effective wastewater treatment. States or regions have various restrictions on this depth. The local permitting authority will have information on restrictions, if any exist.

Where there is a permanently high water table, it is sometimes possible to use subsurface drains to lower the water table and keep it far enough below the trenches so that effluent is treated adequately. Seasonal high water tables may require that loading rates be decreased during wet winter and early spring periods. For septic systems, this means more land area is required for the larger drainfields needed during wet periods, when loading rates need to be reduced. It may also mean that effluent should be diverted to alternate drain lines, so that biological clogging of the soil can be avoided.

Texture

Most of the soil's solid framework consists of mineral particles. These particles in different size ranges and porportions determine the soil texture. The larger soil particles, which include stones, gravel, and coarse sands, are generally different kinds of rock fragments. Most smaller particles are composed of a single mineral. Any soil is made up of particles that vary greatly in both size and composition.

Help your soil be its

- Keep heavy equipment off the soil absorption system area both before and after construction. Soil compaction can result in premature failure of the system.
- Avoid installing the septic tank and soil absorption system when the soil is wet. Construction in wet soil can cause puddling, smearing, and increased soil compaction. This can greatly reduce soil permeability and the life of a system.
- Divert rainwater from building roofs and paved areas away from the soil absorption system. This surface water can increase the amount of water the soil has to absorb and cause premature fail-

Sand grains are the most familiar mineral particles. They are large enough to be seen by the naked eye and feel gritty when rubbed between the fingers. Sand particles do not stick to one another; therefore sands do not feel sticky. Silt particles are somewhat smaller — too small to see without a microscope or to feel individually, so silt feels smooth but not sticky, even when wet. The smallest class of mineral particles are the clays, which form a sticky mass when wet and hard clods when dry.

Terms such as sandy loam, silty clay, and clay loam are used to identify the texture. See Table 2 on Page 4 for a complete list of textures and how they react when wet and dry.

As effluent from a drainfield passes through a silty soil, particulates are filtered out in a relatively short distance. Most bacteria, viruses, or other potential disease-causing organisms cannot pass through long distances of dry soil; they remain within the first few feet. In saturated soils, organisms may travel greater distances. Water moves very slowly through soils with a high clay content, and consequent-

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ly, clay soils require a large areas in order to treat the effluent.

When effluent enters gravel with little or no fine material (silt and clay particles), it will pass through the empty spaces in the soil unfiltered so quickly that pathogens can travel hundreds of feet. Slower travel gives opportunity for good contact between soil particles and effluent, thus providing more effective purification of the water.

Soil structure

Soil structure refers to how soil particles are arranged relative to each other. Soil particles tend to group themselves into blocks or clusters called "peds." If these peds have a characteristic shape, the soil is said to have structure. The space between these peds and how they are aligned influence how water moves within the soil. Structure is considered more important than texture for determining water movement in soils.

Soil structure can be adversely altered if compressed or compacted by heavy equipment during construction. Homeowners need to protect the proposed drainfield site from this type of damage.

Soil color

Color and color patterns may provide clues that help estimate how well a soil will absorb and transmit water. Much of soil color is due to the presence of iron. When there is no air in the soil, as in waterlogged soil, iron is lost from the soil and the soil becomes grayish. When the soil drains well,

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Table 2

Textural properties of mineral soils – feeling and appearance

Soil Class	Dry	Moist
Sandy gravel	Loose stones and single grains that feel gritty. Squeezed in the hand, the soil mass falls apart when the pressure is released.	Squeezed in the hand, it forms a cast that crumbles when touched. Does not form a ribbon when rubbed between thumb and forefinger.
Silty sand	Aggregates easily crushed; very faint velvety feeling initially, but with continued rubbing, the gritty feeling of sand soon	dominates. Forms a cast that bears careful handling without breaking. Does not form a ribbon
Sandy silt	Aggregates are crushed under moderate pressure; clods can be quite firm. When pulverized, soil has velvety feel continued rubbing. Casts bear careful handling.	Casts can be handled quite freely without breaking. Very slight tendency to ribbon between the thumb and forefinger. Rubbed surface is rough.
Clayey silt	Aggregates are firm but may be crushed under moderate pressure. Clods are firm to hard. Smooth, flour-like feel dominates when soil is pulverized.	Cast can be freely handled without breaking. Slight tendency to ribbon between thumb and forefinger. Rubbed surface has a broken or rippled appearance.
Silty	clay Very firm aggregates and hard clods that strongly resist crushing by hand. When pulverized, the soil takes on a somewhat gritty feeling due to the harshness of the	very small aggregates. Cast can bear much handling without breaking. Pinched between the thumb and forefinger, it forms a ribbon whose surface tends to feel slightly gritty when dampened and rubbed. Soil is plastic,
Clay	Aggregates are hard; clods are extremely hard and strongly resist crushing by hand. When pulverized, it has a grit-like texture due to the harshness of numerous very small aggregates which persist.	Casts can bear considerable handling without breaking. Forms a flexible ribbon between thumb and forefinger and retains its plasticity when elongated. Rubbed surface has a very smooth, satin feeling. Sticky when wet and easily puddled.

Table 3

Selection of Dispersal Methods Under Various Site Constraints

	Soil Permeability			Depth to Bedrock			Depth to Water Table	
	Very Rapid	Rapid-Moderate	Slow-Very Slow	Shallow and Porous	Shallow and Non-Porous	Deep	Shallow	Deep
Trenches		◆	◆			◆		◆
Beds		◆				◆		◆
Pressure/Low-Pressure Pipe System		◆	◆		◆	◆	◆	
◆								
Contour Trench		◆	◆	◆	◆	◆	◆	◆
Drip Irrigation	◆	◆	◆	◆	◆	◆	◆	◆
Spray Irrigation		◆		◆	◆	◆	◆	
◆								
Gravelless/Chamber System		◆				◆		◆
Mound System	◆	◆	◆	◆	◆	◆	◆	
◆								

Source: Table adapted and updated from EPA, 1980, table 2-1.

allowing air to enter, the iron oxidizes to brown, yellow, or red. Dark colors generally indicate higher organic content. Interpreting color helps to identify conditions where soils drain well or where soils remain saturated.

The soil in the pit should be examined in bright daylight and compared to the Munsell® color system, the universally accepted standard for identifying soil color. While soil color is easily seen and an excellent indicator of the soil's aeration status, temperature, mineral content, vegetation, and position in the soil profile can modify color. Soil color must be used in conjunction with the other soil features to form a complete analysis.

Typically, well-drained soils are red or brown in color, and poorly drained soils are a splotchy gray. A mottled appearance, where spots of color intermingle with the gray, usually indicates seasonally saturated soils.

Density

A soil's bulk density relates to the volume of mass of dry soil plus its air spaces. Soils with high bulk density are less porous and less permeable. For instance, clay soils have high bulk density. Their particles are tightly packed with minimal air spaces between them. Clays that swell when they become wet, seal off soil pores further, and can virtually stop the flow of water.

Approximately half of the volume of the soil consists of different-sized pore spaces. When water enters the soil, it displaces air. If you think of the network of soil pores as the ventilation system connecting airspaces to the atmosphere, it is easy to understand that when the smaller pores fill with water, the ventilation system becomes clogged.

The

What is soil?

The unconsolidated mineral or organic material on the immediate surface of the earth

What determines the soil's ability to treat wastewater?

Texture, structure, depth, color, and density

What determines these properties?

They are a result of underlying materials, climate, native vegetation, topography, and the time of weathering

The right design for the site

The proper onsite wastewater system must be able to handle the projected wastewater volume and composition, work within the design boundaries of the receiving environment, the performance requirements for the environment and the needs and desires of the owner. Table 3 presents a simple chart of site conditions and some alternative dispersal technologies effective under those conditions.

All of the above soil characteristics together with the percolation tests make up the site evaluation, and the site evaluation identifies the critical design boundaries. Soil characteristics are at the basis of this evaluation procedure.

Indiana soils challenge standard designs

"Until you dig that test pit, you never know what is lurking under there,"

says David Pask, engineering scientist, with the National Environmental Services Center.

At the request of the Indiana State Department of Health, Pask was invited to investigate some failing systems built in Wells and Allen Counties, located in the northeastern part of the state. The terrain of this region is gently rolling.

This part of Indiana has been farmed intensely for years and much of the area is artificially drained with ceramic tile lines. Often these artificial drains improve the hydraulic functioning of the soil, but as in this case, it can never be counted on to completely relieve the problem of saturated or impermeable soils or high water tables.

Three sites were examined: two were lots for new construction and the third was a two-acre site with a two-bedroom home. The homeowner reported that effluent had been discharging onto the surface of the drainfield since the system had been installed.

Test pits dug at the three different sites showed subsoils to be essentially impermeable. The soils are essentially clays and silty clays beneath the shallow organic topsoil. Pask noted that the only available route for the dispersion of the effluent is in the nine-inch depth of the topsoil through evapotranspiration.

Photo courtesy of D. Pask

David Pask, engineering scientist, with the National Environmental Services Center, advises evaluators and system designers to look at the whole picture when evaluating a site.

Although this area is not within the traditionally accepted climate where evapotranspiration exceeds precipitation, it appears that evapotranspiration is the principle route of water loss in these soils is rather than filtering down to the watertable. Evidence showed that during rain even these fine textured topsoils absorb the first quarter to half inch of water to create an impervious surface. The remainder of the stormwater stays on the surface and becomes runoff to the nearest drainage channel. This was corroborated by observations that good grain and vegetable crops were dependant on regular (weekly) rainfall.

From these indicators, only the top nine inches of soil is capable of effluent dispersal. Unfortunately, Indiana state code dictates that the trenches lie deeper than this. In the case of the one existing home with the failing drainfield, sandier soils were found at the western boundary of the property and could easily accommodate an additional disposal trench.

Pask is hoping that an improved layout of shallow soil absorption trenches will be able to contain the effluent beneath the surface without breakout, even under storm conditions. This drainfield will be installed initially as an experimental system with the hope that codes allowing for shallow lines may be put in place some time in the future.

Pask advises that evaluators and system designers look at the whole picture when evaluating a site. The characteristics of the soil must be carefully examined and put into the equation with the topography. And there is no quick and dirty recipe for this procedure. Every location is different and regulators and designers must looks at the whole picture when choosing an appropriate technology.