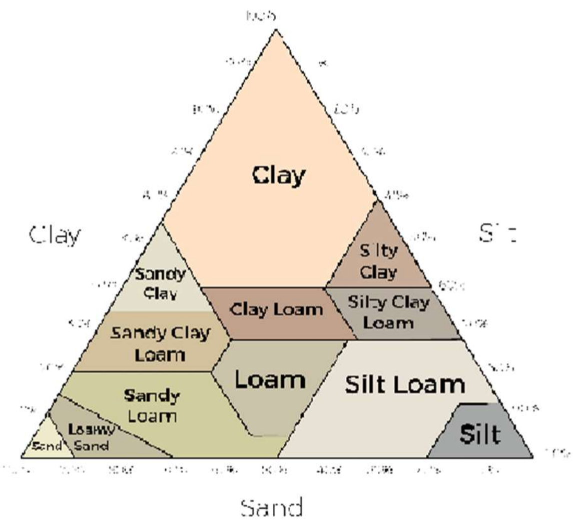
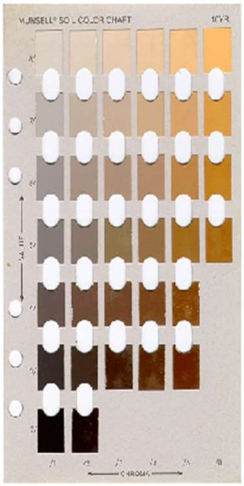
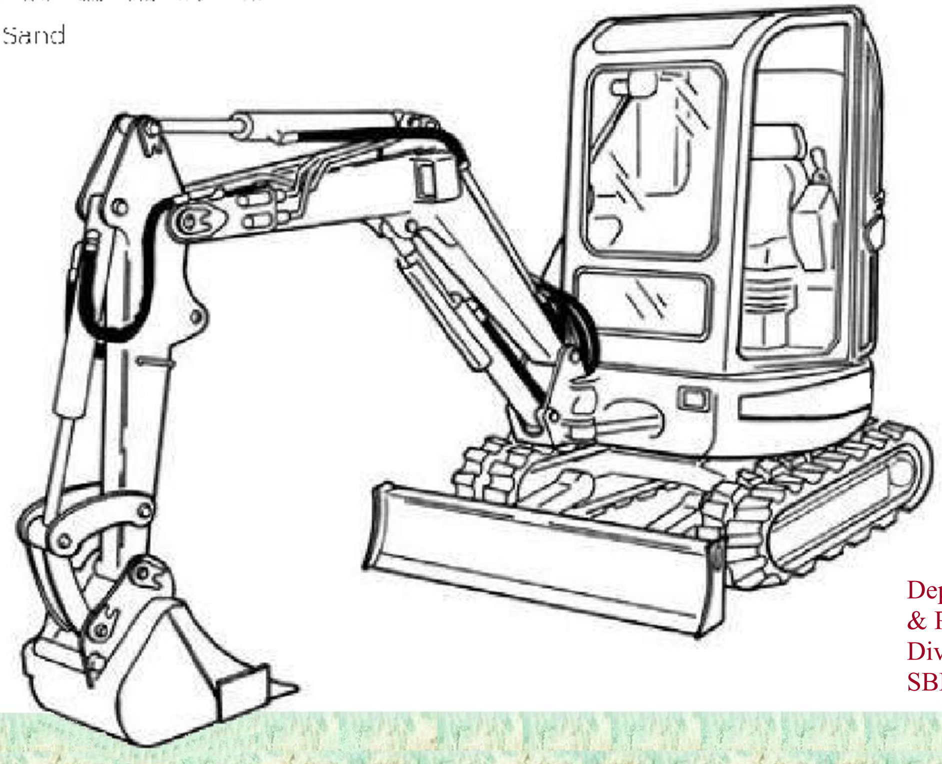
Soil and Site Evaluation Handbook







Department of Safety
& Professional Services,
Division of Industrial Services
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FOREWORD

This soil and site evaluation handbook is intended for use as a study guide and reference for Certified Soil Testers. These individuals conduct onsite evaluations of soils to determine suitability characteristics for the treatment of wastewater, dispersal of treated wastewater, treatment of non-water carried human wastes and subsurface infiltration of stormwater. The Wisconsin Administrative Codes regulating the certification of soil testers, soil & site evaluations, private onsite wastewater treatment systems and stormwater subsurface infiltration plumbing systems are administered by the Wisconsin Department of Safety and Professional Services.

This handbook alone should not be considered as the only reference in preparation for the examination required to be certified as a Soil Tester. Other knowledge that will be needed can be obtained through study of Chapters DSPS 381-387 of the Wisconsin Administrative Code, Chapter 145 Stats., Chapter 3 of the USDA Soil Survey Manual and other soil science texts.

Learning from a more experienced person in the field is essential to becoming a competent soil tester. Such hands-on experience cannot be provided by any book, nor can it be verified by any written exam. Passing the examination and acquiring the CST credential allows one to perform soil evaluations. It also opens the door to the vast and sometimes confusing, world underneath. Some of the most valuable experience is gained by comparing and discussing soil evaluation with others on the job site.

Maintaining the CST Credential also includes a minimum continuing education requirement. Continuing education credits may be obtained from sessions offered by the Division of Extension - University of Wisconsin Madison, Department of Safety and Professional Services, County seminars, private companies, and the meetings of professional organizations such as the Wisconsin Society of Professional Soil Scientists and Wisconsin Onsite Water Recycling Association. All soil testers are urged to take advantage of these opportunities whenever available.

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CHAPTER 1

Basic Principles of Private Onsite Wastewater Treatment Systems

The health of individuals living where public sewers are not available is of major concern in the State of Wisconsin. Domestic wastewaters may contain many substances that are undesirable and potentially harmful to people and the environment such as pathogenic bacteria, infectious viruses, undesirable organic matter, toxic chemicals, and excess nutrients. To protect the public as well as the environment, wastewaters must be treated and dispersed in a safe and effective manner so that:

1) They will not contaminate any drinking water supply.

2) They will not cause a human health hazard by being accessible to insects, rodents or other possible disease carriers (vectors) that may come into contact with food or drinking water.

3) They will not cause a human health hazard by being accessible to people, especially children.

4) They will not violate laws or regulations governing water pollution or sewage disposal.

5) They will not rise to the surface and cause a nuisance due to wetness, odor, or unsightly appearance.

6) They will be adequately purified in the course of their return to the natural ecosystem.

Where the use of a private onsite wastewater treatment system (POWTS) is considered, the basic principles outlined in this manual for conducting site and soil evaluations must be followed to provide a proper soil absorption component for the system.

To design a safe and effective onsite dispersal system, it is necessary to evaluate the physical characteristics of the local environment where treatment and dispersal of the wastewater is to occur. For the purpose of this manual, the soil and other physical characteristics of the site are considered as the local treatment environment. Each site has its own characteristics that determine its potential for onsite wastewater treatment and dispersal.

Soil suitable for the treatment of wastewater is composed of a sufficient depth of porous mineral material containing both air and water. Wastewater treatment occurs in the soil, within very thin films of water on the surfaces on soil particles. This micro-environment must be adjacent to soil air containing oxygen. The movement of wastewater through the soil must be slow enough to allow for the die-off of disease-causing pathogens and for the oxidation of organic compounds by the natural soil microorganisms. However, it must be fast enough to prevent saturation which blocks the vital oxygen provided by air flowing through the larger pores and channels.

Many soils in the state are less than ideal for the treatment of domestic wastewater and thus pose limitations that must be addressed in the design and installation of onsite treatment systems. For example, red clay soils in the northern and eastern part of the state are very slowly permeable, as are soils formed in tight glacial till in the central and southeastern portions of the state. Construction of in-ground gravity soil absorption systems in such soils could result in surface discharge or seepage of inadequately treated wastewater leading to a potential health hazard and/or surface-water contamination. At the opposite extreme, coarse-textured soils over creviced bedrock are too permeable. Here inadequately treated wastewater may contaminate groundwater with disease causing bacteria and viruses due to insufficient retention by the soil. Soils of this type occur in Northeastern and Southwestern Wisconsin. Soils with constant or periodic high groundwater occur locally all over the state. Saturated soil does not provide effective treatment for domestic wastewater. Shallow depth to a zone of soil saturation is one of the most common soil limitations encountered by soil testers.

The Septic Tank Component

The anaerobic treatment tank (septic tank) is used to provide partial treatment of raw domestic wastewater. Its primary purpose is to protect the soil absorption system from becoming clogged by solids suspended in the raw wastewater. The raw wastewater is discharged from the building directly into the tank where it is retained for two or three days. During this time, the large solids settle to the bottom where a sludge blanket develops while the greases, oils, and other floating particles rise to the top to form a scum layer. (See **Figure 1.1**)

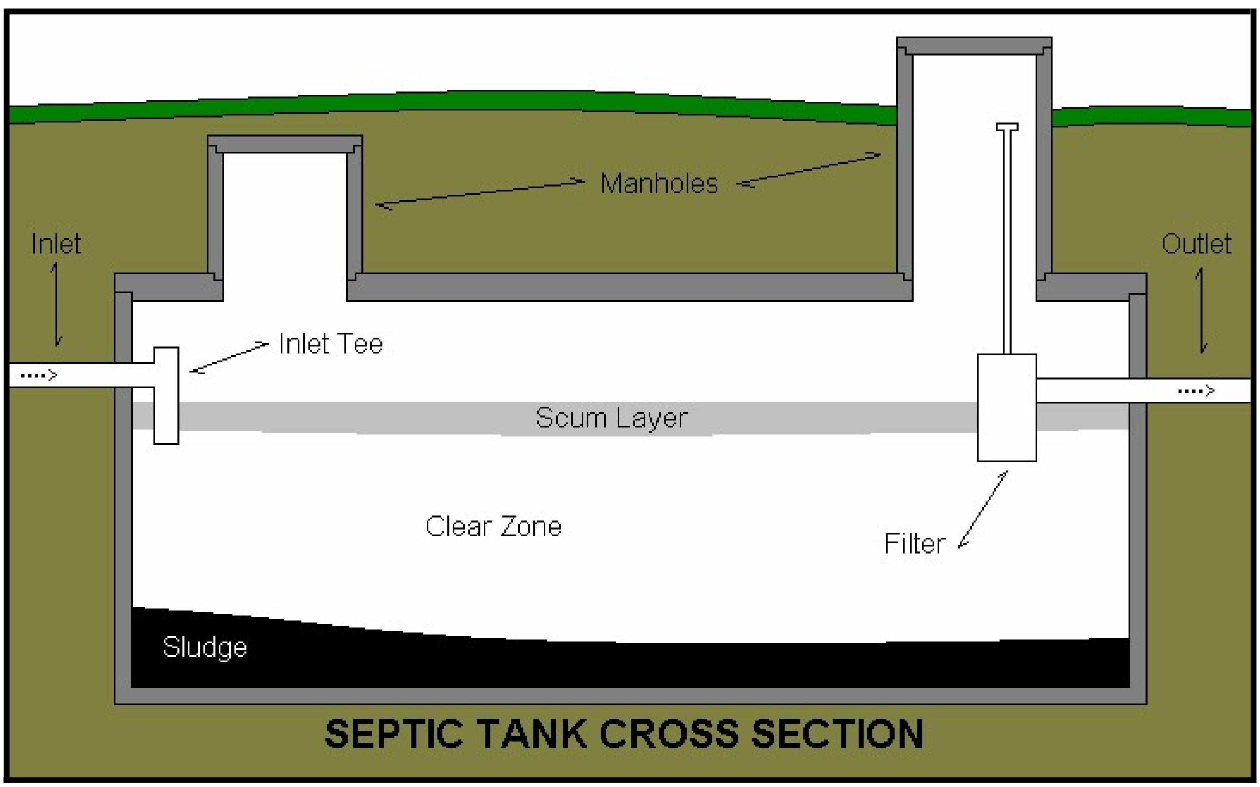


FIGURE 1.1 - Septic tank cross section

In addition to acting as a settling chamber and providing storage for the sludge and scum, the septic tank contains bacteria that digest or break down the waste solids that settle out. Anaerobic bacteria, organisms that live without oxygen, feed on the sludge reducing its volume. In the process, soluble organic matter is released from the sludge into the effluent. Methane and carbon dioxide gases are also produced which are vented from the tank. Only about 40 percent of the sludge volume is reduced by this process and about once every three years it is necessary to pump the tank to remove the accumulated solids. If this is not done, the tank will fill with sludge to a point where the settled solids will be re-suspended and washed out into the soil dispersal cells where they can quickly clog the soil pores, and drastically slow infiltration into the soil.

The clarified liquid (effluent) is conveyed from the septic tank to the soil dispersal component for final treatment and dispersal. It is an odorous liquid high in partially degraded waste constituents, suspended solids, organic material and ammonia nitrogen. Disease-causing bacteria are present in high numbers and viruses are sometimes present. Section SPS 383.44, Wisconsin Administrative Code specifies that influent going into a soil absorption component cannot contain any solid particles exceeding 1/8 inch in diameter. This is usually achieved by means of an effluent filter located at the outlet of the septic tank.

Treatment of Septic Tank Effluent by Soil Absorption

The in-ground gravity soil absorption system has traditionally been the most used system to provide onsite treatment and dispersal of septic tank effluent. Often called the "conventional system" it is an ideal onsite treatment system where soils are deep, permeable, and well-drained. The in-ground gravity soil absorption system is simple, inexpensive and relatively maintenance free. When properly designed, installed and maintained, it is a very satisfactory system. (See **Figure 1.2**).

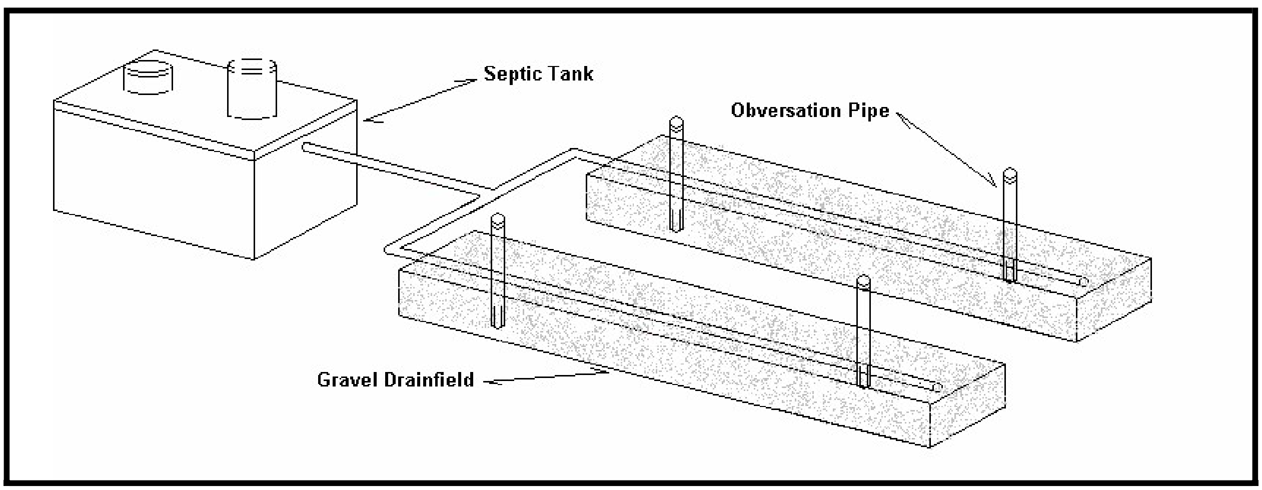


FIGURE 1.2 - Typical in-ground gravity soil absorption system

Distribution of the septic tank effluent into the soil treatment zone is accomplished by passive gravity flow. Traditionally, this was done by means of gravity flow from the tank through a solid-wall pipe to one, or more, 4-inch diameter perforated pipes placed within an excavated cell partially filled with gravel aggregate (See **Figure 1.3**). A variety of prefabricated leaching chambers and synthetic substitutes are now commonly used as an alternative to gravel and pipe.

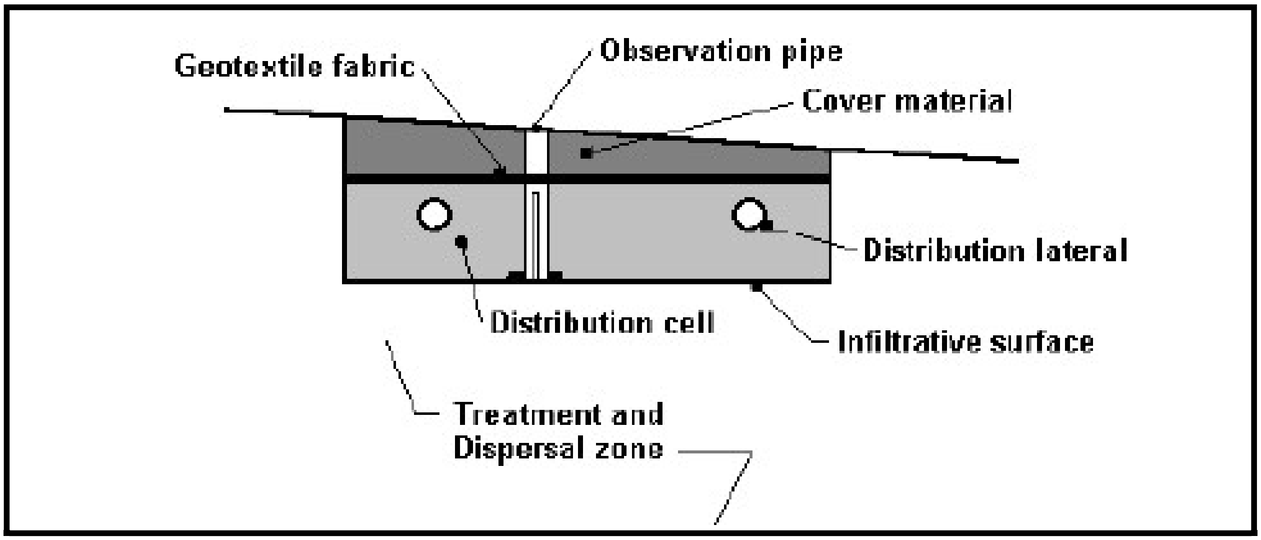


FIGURE 1.3 – Cross section of an In-Ground soil adsorption component with two laterals

In-ground gravity soil absorption components may also be used where gravitational pitch from the tank is lacking. Distribution into the soil is similar, except that the flow is delivered in measured doses as delivered by the periodic activation of the pump to overcome the difference in elevation.

Dosing is also employed in a more highly engineered means of distributing effluent known as pressure distribution. Pressure distribution systems use small diameter laterals in the soil absorption cell with smaller, single holes spaced a specified distance apart. An effluent pump is selected to provide a minimum pressure to the distribution laterals. The pump, which is typically located in a separate tank or chamber, will discharge a calculated volume of effluent to the distribution network. Due to the pressure applied, the effluent will be evenly distributed throughout the absorption field.

Even distribution and control of dose timing and volume, allows pressure distribution systems to compensate somewhat for limitations of a soil to treat wastewater. Pressure distribution provides means to compensate for soil limitations due to both moderately slow permeability of finer textured soils and the moderately rapid permeability of coarse soil materials. Generally, coarse soils need frequent, small doses with closely spaced lateral holes. Soils of moderately slow permeability may be served with larger, less frequent doses.

Soils that have a depth to a zone of seasonal saturation or bedrock that is too shallow to accommodate an in-ground installation may be served by an above grade system. An at-grade soil absorption system typically uses pressure distribution to apply effluent to the original soil surface. A layer of gravel aggregate provides efficient spreading of the dose over an established absorption area downslope from the distribution line. The distribution lines and gravel aggregate are all covered by a cap of vegetated earth fill to provide frost protection and to prevent exposure of wastewater to the surface. The at-grade system has been shown to be a very reliable means of dealing with sites where the entire soil profile is needed to provide the minimum thickness of suitable soil required for treatment. (See **Figure 1.4**).

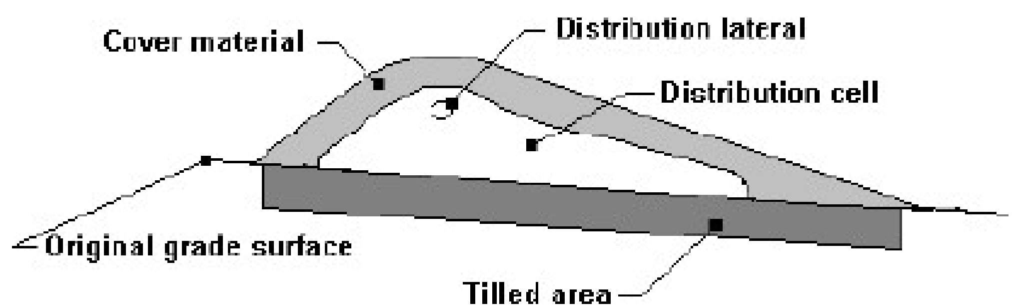


FIGURE 1.4 – At-Grade soil adsorption system cross section

Soils that have permeability and depth limitations too severe for an at-grade soil adsorption system, require additional treatment media to provide enough separation above the soil limitation. The mound system achieves this by placing a layer of engineered sand (ASTM C33) on the plowed soil surface. The sand thickness is dependent on the depth to the limiting soil condition. A pressure distribution network distributes the effluent into gravel above the sand layer where it undergoes partial treatment prior to infiltration into the surface of the natural soil below. The engineered sand, pressure distribution lines and aggregate are all covered by a cap of vegetated earth fill to provide frost protection.

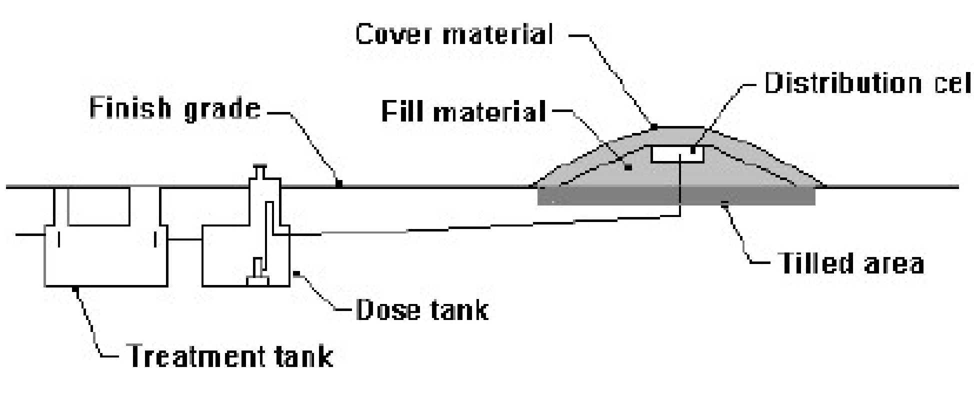


FIGURE 1.5 – Mound system cross section

The objective of a mound designed for slowly permeable soils is to spread the effluent out sufficiently to compensate for the slow downward movement of effluent once it reaches the slowly permeable layer. For soils with shallow depth to seasonal saturation, bedrock or coarse rock fragments the objective is to provide additional sand fill in which treatment can take place prior to effluent reaching the limiting condition. (**See Figure 1.5**).

Dispersal of Pretreated Effluent by Soil Absorption

Raw sewage and septic tank effluent can be pretreated by a variety of devices that greatly reduce contaminant in the wastewater. These pretreated effluents still contain low concentrations of pathogenic microorganisms and other contaminants and cannot be discharged to surface waters, groundwater or to the ground surface. Soil absorption systems provide final treatment and short-term backup treatment capacity if the pretreatment device were ever to malfunction.

Generally, the soil treatment zone required to achieve performance goals for pretreated effluent is smaller than that needed for treating residential septic tank effluent. The Wisconsin Administrative Code allows lesser minimum vertical separation as well as higher soil application rates per square foot of absorption area for several approved pretreatment units. The justification for the reduced vertical separation is based upon the lower biological hazard present in the pretreated effluent. Higher soil application rates can be used since organic clogging of the soil pores at the infiltrative surface is greatly reduced.

The principle types of soil absorption components used for treatment of septic tank effluent are also applicable to dispersal of pretreated effluent. The minimum depth (thickness) of suitable soil and the minimum absorption area may be significantly different, but the structure and function of the various components are essentially the same. The soil test report must provide a complete set of information from which both septic tank and pretreatment soil absorption options could be designed. A fundamental knowledge of POWTS system requirements and specifications is necessary to guide the Certified Soil Tester as he, or she, performs the soil and site evaluation.

Soil and Site Factors

State regulations covering private onsite wastewater treatment systems recognize several soil and site factors that are applied as parameters in locating and designing systems. The Certified Soil Tester must identify these factors in the field evaluation and present them in a format that the department approves. In this case the Soil and Site Evaluation Report form.

Soil Saturation - Soils horizons affected by seasonal or periodic saturation are unsuitable for wastewater treatment. Failure to identify this condition can result in system failure by sewage backup, surface discharge of effluent or contamination of groundwater, wells and surface waters. It is essential that the proper vertical separation be provided between the bottom of the soil absorption system and a zone of soil saturation. Preliminary information concerning high groundwater can be obtained from detailed soil surveys. An on-site investigation is always needed to establish the extent of seasonal soil saturation using the criteria established by the

National Cooperative Soil Survey which is provided in the USDA Soil Survey Manual, 2017.

Bedrock – The ability to treat wastewater is severely limited in shallow soils over bedrock. Consolidated bedrock restricts vertical movement of liquids and can result in sewage backup or surface discharge of effluent. Creviced bedrock, such as limestone, can result in rapid vertical movement of inadequately treated effluent into groundwater and contaminate wells. It is essential that a sufficient volume of suitable soil be provided between the bottom of the soil absorption system and any type of bedrock.

Soil Permeability - The success of a soil absorption system is based on the ability of soil to remove harmful substances and transmit liquids. Very rapid passage of effluent may contribute to pollution of groundwater while extremely slow movement can result in saturation of the soil and ponding of effluent on the ground surface. Between these extremes are the soils suitable for treating wastewater provided that the appropriate application rates are used. The maximum application rates are specified by s. SPS 383.44, Wisconsin Administrative Code. Application rates are determined by the soil properties of texture, structure, and consistence in reference to Table 383.44-2. The minimum depth (thickness) of unsaturated soil required for effective treatment is determined by the properties of texture and rock fragment content in reference to Table 383.44-3.

Setbacks - Soil absorption systems must be located to provide for adequate separating distances between the system components and certain other objects and encumbrances. These are bodies of water, buildings, water service lines, swimming pools, lot lines and water supply wells. The minimum setback separation distances are provided in Table 383.43-1 of chapter SPS 383, Wisconsin Administrative Code. The setbacks for wells are determined by the Department of Natural Resources, found in chapters NR 811 & NR 812 Wisconsin Administrative Code and are incorporated into chapter SPS 383 by reference.

Flood Hazard – POWTS system installation in a floodplain is addressed in several portions of chapter SPS 383, Wisconsin Administrative Code. POWTS systems cannot be installed in a floodway except as provided in chapter NR 116, Wisconsin Administrative Code. The regional flood elevation (RFE) is required on the Soil and Site Evaluation Report. County Planning & Zoning Departments and the Wisconsin DNR are sources for existing RFE and floodplain location determinations.

Land Slopes – Land slope can limit or prevent the installation and proper functioning of soil absorption systems. Land slope information must be obtained and reported as part of the site evaluation. Because different types of soil absorption components are affected differently by the shape and degree of land slope, the Certified Soil Tester needs to be aware of the slope limitations for each of the various types of components. Methods of measuring and depicting topographic contours and land slope are discussed later in this handbook.

Applicable Regulations

Chapter 145 of the Wisconsin Statutes is the state law that authorizes the Department of Safety and Professional Services to administer rules known as the Uniform State Plumbing Code, which includes Chapters SPS 381–387 & 391, Wisconsin Administrative Code.

Chapter SPS 381 Wisconsin Administrative Code contains all definitions and referenced standards used within chapters SPS 382-387 & 391 Wisconsin Administrative Code.

Chapter SPS 383 Wisconsin Administrative Code establishes minimum standards and criteria for the design, installation, inspection and management of a private onsite wastewater treatment system (POWTS). Some of these standards and criteria are derived directly from the reported results of the Soil and Site Evaluation. Other criteria of this code such as setback separation distances are addressed by the soil and site evaluation.

Chapter SPS 385 Wisconsin Administrative Code establishes the minimum requirements for evaluating and reporting soil and site characteristics that may affect treatment or dispersal of wastewater, treated wastewater, final effluent or non-water carried human wastes. This code relates most closely to the Certified Soil Testers activities.

Chapters SPS 383 and SPS 385 Wisconsin Administrative Code are closely linked, one serving the other. Clearly, a prospective Certified Soil Tester must be intimately familiar with SPS 385. However, a general understanding of SPS 383 and a thorough understanding of pertinent sections is also essential to the satisfactory performance of soil and site evaluations.

References to highly specific items in other Wisconsin Administrative Codes are sited occasionally within the SPS 381-387 Wisconsin Administrative Codes. These items are usually provided as text footnotes or are in an appendix.

Chapter SPS 391 Wisconsin Administrative Code is a sanitation code that establishes minimum standards and criteria for the design, installation and maintenance of sanitation systems and devices which are alternatives to water-carried waste plumbing fixtures and drain systems. This code contains information on non-plumbing sanitation devices such as privies, that may utilize an earthen pit and thus be subject to soil and site evaluation considerations.

Sanitary regulations in the form of county, local, and/or sanitary district ordinances may determine potential treatment options and therefore affect how a soil and site evaluation is best conducted. Since the Soil and Site Evaluation Reports are reviewed and recorded by the county, the prospective Certified Soil Tester can expect to be working closely with the county POWTS program staff. They act as agents for the Department of Safety and Professional Services in managing specific aspects of the POWTS program at the local level.

The POWTS program in Wisconsin is a team effort that includes the property owner, Certified Soil Tester, POWTS designer, installer, plus state and local regulators. Working with this team, the property owner can be assured that the POWTS system that is selected for their site will provide a long-lasting, cost effective method of wastewater treatment and dispersal that is protective of everyone’s health and environment.

CHAPTER 2

Basic Soils

Soil, as used in this manual, is the collection of natural bodies on the Earth's surface, in places modified or even made by people of earthy materials, containing living matter and supporting or capable of supporting plants out-of-doors. Its upper limit is air or shallow water, but its lower limit is perhaps the most difficult to define. Soil, as defined in soil science, includes the horizons near the Earth's surface that differ from the underlying material as a result of interactions of time, climate, living organisms, parent materials and relief. For purposes of this manual, the definition of soil includes all lower layers extending to bedrock that influence the movement and content of water and air.

Two definitions in chapter SPS 381 Wisconsin Administrative Code present soil as a material, rather than a three-dimensional body. These definitions are:

SPS 381 (222) "Soil" means the naturally occurring pedogenically developed and undeveloped regolith overlying bedrock.

SPS 381 (135) "In situ soil" means soil naturally formed or deposited in its present location or position and includes soil material that has been plowed using normal tillage implements and depositional material resulting from erosion or flooding.

Soils, as defined in soil science, are conceived to be independent bodies, each with a unique morphology resulting from a unique combination of the soil forming factors. Those five factors are climate, living matter, parent material, relief and time. The morphology of each soil is expressed by a vertical section (profile) through the differing horizons (layers) which reflects the combined effects of the factors responsible for its development. The layers, approximately parallel to the surface of the land are distinguishable from adjacent layers by a distinctive set of properties produced by the soil forming process.

A soil is a dynamic three-dimensional piece of landscape that blends into other soils as part of a continuum on the land surface. Each has depth and occupies space. Many thousand soils exist in the world; as many as there are significant combinations of the soil forming factors.

Parent Material

Parent Material refers to the great variety of unconsolidated organic and mineral material of which soils form. Parent materials generally fall into two major groups: weathered in place and transported material. However, transported material can be further described as being influenced by water, glacial processes or gravity.

Much of the mineral matter in which soils form is derived in one way or another from hard rocks such as granite. Glaciers may grind the granite into rock fragments or earthy materials and deposit a mixture of granite particles as glacial till. Such material could be identified as "glacial till derived from granite." In contrast, granite may be weathered with great chemical and physical changes but not moved from its place or origin. This altered material is called "residuum from granite."

The parent material of a modern mineral soil is not necessarily residuum from the bedrock that is directly below. Movement of soil material downslope is an important process and can be appreciable even on gentle slopes, especially on very old landscapes. Also, soils can form directly from different layers of sedimentary rocks. The material that developed into a modern soil may be unrelated to the underlying bedrock.

Seldom is there absolute certainty that a highly weathered material was formed in place. The term "residuum" is used when the properties of the soil indicate that it has been derived from rock like that which underlies it and when evidence is lacking that it has been modified by movement. In sloping soils, a rock fragment distribution that decreases in amount with increasing depth, indicates that soil material probably has been transported downslope. Stone lines, especially if the stones have a different lithology than the underlying bedrock, provide evidence that the soil did not form entirely in residuum. In some soils, transported material overlies residuum and the discontinuity can be readily seen between the contrasting materials. A certain degree of landscape stability is inferred for residual soils and to a lesser degree is inferred for soils that developed in transported material.

MATERIAL DERIVED BY WEATHERING IN PLACE

Weathered in place material is produced by weathering of rock close to the original location of the native rock. These soils form in the weathered material itself which may have undergone various changes from the original rock. This includes changes in volume and loss of easily weathered minerals, such as plagioclase feldspar. Under some conditions, rocks may lose minerals without any change in volume or in the original rock structure. The point where rock weathering ends and soil formation begins is not always clear. These processes may be consecutive and even overlapping.

Quite different soils may result from similar or even identical rock under different soil forming conditions. Texture, color, consistence and other important characteristics of the parent material should be described. As much useful information as can be obtained about the mineralogical composition, hardness and structure of the parent rock itself should be noted to help in understanding the changes from parent rock to weathered material.

<u>Igneous rocks</u> form by the solidification of molten materials that originate within or on the surface of the earth. Examples of igneous rocks that weather into important soil material are granite, syenite, basalt, andesite, diabase and rhyolite.

<u>Sedimentary rocks</u> form from sediments laid down during previous geologic ages. The major broad groups of sedimentary rocks are limestone, dolomite, sandstone, shale, and conglomerate. All of which have varying degrees of hardness. There are many varieties of these broad classes of sedimentary rocks and many types intermediaries between them, such as calcareous sandstone

and limestone. Chalk and marl are soft varieties of limestone. Also included are deposits of diatomaceous earth, which formed from the siliceous remains of primitive plants, called diatoms.

Metamorphic rocks result from profound alteration of igneous and sedimentary rocks by heat and pressure deep within the earth. General classes of metamorphic rocks, important as sources of parent material, are gneiss, schist, slate, marble, quartzite, and phyllite.

About three-quarters of the land area of the world is underlain by sedimentary rocks and one-quarter by igneous and metamorphic rocks.

TRANSPORTED MATERIAL

The most extensive group of parent materials in the world is the very broad group of materials that have been moved from the place of their origin and deposited elsewhere. Principle groups of transported materials are usually named according to the main force responsible for their transport and deposition. In most places sufficient evidence is available to make a clear determination. Elsewhere their precise origins are uncertain.

In soil morphology and classification, it is exceedingly important that the characteristics of the material itself be observed and described. It is not enough simply to identify the parent material as alluvium, loess, or glacial till. Such names supplement the descriptions of the material and any doubt of the correctness of the identification should be mentioned. For example, it is often impossible to be sure whether certain silty deposits are alluvium, loess, or residuum. Certain mud flows are indistinguishable from glacial till and some sandy glacial till is nearly identical to sandy outwash. However, such difficult distinctions may not be significant if the properties of the parent material are well documented.

MATERIALS MOVED AND DEPOSITED BY WATER

Alluvium -- Alluvium consists of sediment deposited by moving water: streams and rivers. The deposited material usually ranges from fine sand to coarse gravel. The moving water tends to sort the material into uniform particle size within individual layers or beds. High and low flow events create various layers having different size particles. Alluvium may occur on terraces well above present streams or in the flooded bottom land of existing streams. Remnants of very old stream terraces may be found in dissected country far from any present stream. Along many old established streams lie a whole series of alluvial deposits in terraces: young deposits in the immediate flood plain to very old deposits on the highest stream terraces. In some places recent alluvium covers older terraces. In glaciated regions of Wisconsin, the rivers and streams are relatively young and undeveloped. Here the stream terraces tend to be low and close to the floodplain.

Lacustrine Deposits -- These deposits consist of material that has settled out of still water found in lakes. Deposits laid down in freshwater lakes associated with glaciers are commonly identified as glacial drift material (defined below). Besides these, there are other lake deposits, including some of Pleistocene age, not associated with the continental glaciers. Very thin alternating strata of silt and clay may be seen in this material. These alternating strata are thought to be the result of seasonal flooding that muddied the water of the source lake. Glacial lacustrine deposits usually occur on broad, nearly level plains but there can be exceptions.

Marine Sediments -- These sediments settled out of the sea and were reworked by currents and tides. Later they were exposed either naturally or following the construction of dikes and drainage canals. They vary widely in composition and may resemble lacustrine deposits.

Beach Deposits -- Beach deposits mark the present or former shorelines of seas or lakes. These deposits are low ridges of sorted material and are commonly sandy, gravelly, cobbly or stony. Deposits on the beaches of former glacial lakes are usually identified as glacial drift.

Wind Blown Material can be divided into groups based on particle size and origin. Volcanic ash and cinders are examples of materials classed by both particle size and origin. Nearly all textures intermediate between silt and sand can be found in windblown deposits. Two windblown materials are commonly found in Wisconsin.

Loess deposits typically are very silty but may contain significant amounts of clay and very fine sand, calcareous in nature. Most loess deposits are pale brown to brown, although gray and red colors are seen. The thick deposits are generally massive and have some gross vertical cracking. The walls of road cuts in thick loess can stand nearly vertical for years. Other silty deposits that formed in other ways may also have some or all of these characteristics. Windblown silt can be leached and strongly weathered so that it is acidic and rich in clay whereas young deposits are mainly silt and are exceedingly low in clay. In Wisconsin, loess deposits are thicker near the Mississippi River in the west and are thinner to the north and east.

Eolian Sand deposits are another type of windblown material that is primarily fine sand. Eolian sand is commonly but not always found in dunes. This uncommon parent material may be hard to distinguish from beach and glacial deposits.

MATERIALS MOVED AND DEPOSITED BY GLACIAL PROCESSES

Glacial drift consists of all the material picked up, mixed, disintegrated, transported and deposited by glacial ice or water from melting glaciers. In many places glacial drift is covered by a mantle of loess. Deep mantles of loess are usually easily recognized but very thin mantles may be so altered by soil-building forces that they can scarcely be differentiated from the underlying modified drift.

Glacial Till is that part of the glacial drift material that had been deposited directly by the ice with little or no transportation by water. It is generally an unstratified, unconsolidated, heterogeneous mixture of clay, silt, sand, gravel, cobbles, and sometimes boulders. Some material settled out as the ice melted with very little washing by water and some was overridden by the glacier and is densely compacted. Till may be found in various types of moraines: ground, terminal, medial and lateral. In many places it is important to differentiate between the various tills. Tills may underlie one another and can be separated by other deposits or old weathered surfaces. Many deposits of glacial till were later washed by lakes but without important additions. The upper part of such wave-cut till is rich in coarse fragments as a result of the wave action in glacial lakes. Drumlins are long, low, cigar-shaped hills of glacial till with a smooth skyline; the long axis lies parallel to the direction of movement of the ice.

Till varies widely in texture, chemical composition and the degree of weathering following its deposition. Most till is calcareous but some can be non-calcareous because no calcite or dolomite bearing rocks contributed to the material or because subsequent leaching and chemical weathering have removed the carbonates.

Glaciofluvial Deposits are material produced by glaciers and carried, sorted and deposited by moving water that originated from melting glacial ice.

The most important kind of glaciofluvial deposit is glacial outwash. Outwash is made up of complex beds of sand and gravel deposited by the running water from melting glaciers and may be far from the nearest present-day stream. This broad term includes all the material swept out, sorted and deposited beyond the glacial ice front by streams of melt water. Commonly, this outwash is in the form of plains, valley trains or deltas in old glacial lakes. The valley trains of outwash may extend far beyond the farthest advance of the ice. Especially near moraines, poorly sorted glaciofluvial material may form kames, eskers and crevasse fills. There are also vast areas covered by alluvial deposits known as outwash plains. They are commonly found on broad, nearly level landscapes but also as pitted outwash in areas with many lakes. The central sands region of Wisconsin is one such outwash plain.

Glacial Beach Deposits consist of gravel & sand and mark the beach lines of former glacial lakes. Depending on the character of the original drift, beach deposits may be sandy, gravelly, cobbly or stony.

Glaciolacustrine Deposits range from fine clay to sand. They are derived from glaciers but were reworked and laid down in glacial lakes. Many of them are stratified or laminated. Alternating strata exposed in a section of glaciolacustrine clay, each related to one year's deposition and one season's glacial ice melt, are called varves.

Good examples of all the glacial materials and forms described in the preceding paragraphs can be found in Wisconsin. In many places, however, it is not easy to distinguish among the kinds of drift based on mode of origin and landform. For example, pitted outwash plains can scarcely be distinguished from sandy till in terminal moraines. Distinguishing between wave-cut till and lacustrine material is often difficult. The names themselves suggest only a little about the actual characteristics of the parent material. Certainly, origin of the parent material is not a sufficient basis, by itself, for distinguishing soils because similar parent materials may have different origins.

MATERIALS MOVED AND DEPOSITED BY GRAVITY

Colluvium is an incoherent mass of soil material or rock fragments at the base of slopes. It is largely material that has rolled, slid or fallen down the slope under the influence of gravity. An accumulation of rock fragments is called talus (Devil’s Lake near Baraboo, has large talus deposits). The rock fragments in colluvium are usually angular, in contrast to the rounded, waterworn cobbles and stones in alluvium and glacial outwash. "Colluvium" is used generally for that part of the poorly sorted debris that has accumulated at the base of slopes, in depressions, or along tiny streams through gravity, soil creep and local wash.

The Soil Profile: Horizons and Layers

The first requirement of performing a soil profile evaluation is to conduct a horizon by horizon examination. Every horizon or layer is described separately and objectively in respect to depth, color, texture, structure, consistence and porosity. Differences in these soil properties signify a separate horizon. Each of these properties will be discussed later in this chapter.

The term horizon is used where the differences in soil properties are due to the effects of soil formation upon a parent material. Soils vary widely in the degree to which horizons are expressed. Relatively fresh geologic formations such as sand dunes may have no recognizable horizons, although they may have distinct layers that reflect the mode of deposition.

Some of the designations that would be appropriate for use in identifying properties important and relative to subsurface disposal of effluent are included in this manual. Designations are provided for layers that have been changed by soil formation and for those that have not. Each horizon designation indicates that the original material has been changed in certain ways. The designation is assigned after comparison of the observed properties of the layer with properties inferred for the material before it was affected by soil formation. The processes that have caused the change need not be known; properties of soils relative to those of an estimated parent material are the criteria for judgment. For transported material, such as alluvium or loess, the parent material is inferred for the horizon in question, not necessarily the material below. For soils developed directly from underlying bedrock or a thick uniform deposit such as glacial till, the inferred parent material is very similar to or the same as the unaltered material below.

Layers in soil need not be identified by symbols for a good description of the soil. Yet the usefulness of soil descriptions is greatly enhanced by the proper use of designations. The designations show the investigator's interpretations of genetic relationships among the layers within a soil body.

These Horizon designations are not substitutes for descriptions. A designation tells little about the properties of the horizon or layer, but if both designations and adequate descriptions of a soil are provided, the reader has the interpretation made by the person who described the soil and also the evidence on which the interpretation was based. Additional studies and investigations may indicate the need for a change in designations.

Three kinds of symbols are used in various combinations to designate horizons and layers. These are capital letters, lower case letters, and Arabic numerals. Capital letters are used to designate the master horizons and layers; lower case letters are used as suffixes to indicate specific characteristics of the master horizon and layer; and Arabic numerals are used both as suffixes to indicate vertical subdivisions within a horizon or layer and as prefixes to indicate discontinuities.

MASTER HORIZONS AND LAYERS

The capital letters O, A, E, B, and C and R represent the master horizons and layers of soils. These capital letters are the base symbols to which other characters are added to complete the designation. Most horizons and layers are given a single capital letter symbol; however, transitional horizons require two.

O Horizon: Layers dominated by fresh or partially decomposed organic material. Some are saturated with water for long periods or were once saturated but are now artificially drained; others have never been saturated. Some O layers consist of undecomposed or partially decomposed litter, such as leaves, needles, twigs and moss that have been deposited on the surface. They may be on top of either mineral or organic soils. Typically, most reports do not include any O horizon and start with mineral soils.

A Horizon: Mineral horizon that formed at the surface or below an O horizon and is characterized by an accumulation of humified organic matter intimately mixed with the mineral fraction. An A horizon that resulted from mixing due to plowing is designated as an Ap horizon.

E Horizon: Mineral horizon in which the main feature is loss of clay, iron, aluminum or some combination of these, leaving a concentration of sand and silt particles or other resistant minerals. The loss is due to the process of leaching as water moves downward. The E horizon is usually lighter in color than the underlying horizon that accumulated the leached material. The E horizon is commonly below an A or O horizon and above a B horizon. Although possibly once present, agricultural practices can obliterate evidence of an E horizon.

B Horizon: Horizons that form below an A, E or O horizon and are dominated by accumulations of clay, iron, aluminum, humus or carbonates or show development of soil structure. B horizons are also known as subsoil horizons.

C Horizon: Horizons or layers, excluding bedrock, that have been little affected by the soil forming factors (pedogenic processes). The material in C horizons may be either like or unlike that from which the solum (A, B and/or E horizons) presumably formed.

R Layers (Bedrock): Granite, limestone, sandstone and quartzite are examples of bedrock that are designated R. The bedrock of an R layer is sufficiently coherent to make hand digging with a spade-impractical, although it may be chipped or scraped with a spade. For purposes of this manual, granite, platy sandstone or limestone bedrock is encountered where greater than 50 percent of the material is consolidated. Monolithic sandstone bedrock is encountered where there is resistance to penetration of a knife blade or auger.

DEPTH AND THICKNESS OF HORIZON

A description of a profile includes the thickness and the depth limits of each horizon or layer. Depths are measured from the soil surface. For soils with an O horizon that has never been saturated for prolonged periods, the soil surface is the top of the part of the O horizon that has decomposed so much that most of the original material cannot be recognized with the naked eye.

If the uppermost layer is an O horizon that is or has been saturated for prolonged periods, the soil surface is at the top of that horizon. Otherwise the soil surface is the top of the mineral soil.

BOUNDARIES OF HORIZONS

A boundary is a surface or transitional layer between two adjoining horizons or layers. It is roughly parallel to the soil surface. Most boundaries are zones of transition rather than sharp lines of division. Boundaries are determined in the field at the bottom of the described horizon and are described according to distinctness and topography.
Distinctness refers to the thickness of the zone within which the boundary can be located. The distinctness of a boundary depends partly on the degree of contrast between the adjacent layers and partly on the thickness of the transitional zone between them. Distinctness is defined in terms of thickness of the transitional zone:

Abrupt:	Less than 2 cm thick Clear: 2 to 5 cm thick
Gradual:	5 to 15 cm thick
Diffuse:	More than 15 cm thick

Topography refers to the irregularities of the surface that divides the horizons. Even though soil layers are commonly seen in vertical section, they are three-dimensional. Topography of boundaries is described with the following terms:

Smooth:	Boundary is a plane with few or no irregularities.
Wavy:	Boundary has undulations where depressions are wider than they are deep.
Irregular:	Boundary has pockets that are deeper than they are wide.
Broken:	One or both the horizons or layers separated by the boundary are discontinuous and the boundary is interrupted.

Soil Material and Rock Fragments

This section discusses the sizes of mineral particles in soils and conventions for expressing combinations of particles of the various sizes using the USDA system of classification. The finer sizes are called fine earth, as distinct from rock fragments (pebbles, cobbles, stones, and boulders). The fine earth fraction is that part of the mineral material, excluding organic matter, composed of particles smaller than 2 mm in diameter.

It is necessary to treat soil material smaller than 2 mm separately from rock fragments. Particle-size distribution of material smaller than 2 mm is determined in the field mainly by feel (hand texturing). The content of particles much coarser than 2 mm cannot be determined by manipulating a sample of soil in the hand; therefore, the composition of the fine earth is determined by feel and the content of coarser particles is determined using sieves or by estimating the proportion of the soil volume that they occupy.

SOIL SEPARATES

Soil separates are the individual size groups of mineral particles. Different disciplines and different groups of workers within some disciplines use different size limits for separating particles into classes. The choice of limits is arbitrary within some range around various points on the scale but relationships between several properties and particle size do suggest some critical limits. Much depends on the purposes for which the data are to be used and the other properties of the soil.

Because the processes of wastewater treatment tend to depend upon some of the same physical phenomena important for the growth of plants, the United States Department of Agriculture (USDA) particle size classification is quite applicable to wastewater treatment interpretations.

The United States Department of Agriculture and the National Cooperative Soil Survey uses the following classes of soil separates for fine earth:

Very coarse sand	2.0-1.0 mm
Coarse sand	1.0-0.5 mm
Medium sand	0.5-0.25 mm
Fine sand	0.25-0.10 mm
Very fine sand	0.10-0.05 mm
Silt	0.05-0.002 mm
Clay	Smaller than 0.002 mm

SOIL TEXTURE

Soil texture refers to the physical composition of soil defined in terms of the relative proportions by weight of each soil separate. It is important to note that sand textures are defined as mixtures of the various soil separates, even though some of the sand textures use the same names as some of the sand separates defined above. For example, the texture “coarse sand” may be a mixture of very coarse sand, coarse sand and smaller proportions of the finer separates. The texture classes are defined in terms of particle-size distribution of the material finer than 2 mm as determined in the laboratory but are based on the distribution determined for a large number of soil samples that many soil scientists had placed in the texture classes on the basis of field techniques.

Field criteria for estimating soil texture must be chosen to fit the soils in the individual area. Sand particles can be seen individually with the naked eye and have a gritty feel to the fingers. Many sand soils are loose, but some are not. Silt particles cannot be seen individually without magnification; they have a smooth feel to the fingers when dry or wet. In most places in Wisconsin, clay soils are sticky, however, some are not. Soils dominated by montmorillonite clays, for example, feel perceptibly different from soils that contain similar amounts of micaceous or kaolinitic clay. Even locally, the relationships that are useful for judging texture of one type of soil may not apply as well to another type.

The late Professor C. F. Shaw developed the following definitions of the basic soil textural classes in terms of field experience and feel. They are included here as an example of the kind of field criteria that can be used locally:

<u>Sand:</u> Sand is loose and single grained. The individual grains can readily be seen or felt. Squeezed in the hand when dry it will fall apart when the pressure is released. Squeezed when moist, it will form a cast but will crumble when touched.

<u>Sandy loam:</u> A sandy loam is a soil containing much sand but which has enough silt and clay to make it somewhat coherent. The individual sand grains can readily be seen and felt. Squeezed when dry, it will form a cast which will readily fall apart but if squeezed when moist a cast can be formed that will bear careful handling without breaking.

<u>Loam:</u> A loam is a soil having a relatively even mixture of different grades of sand, silt and clay. It is mellow with a somewhat gritty feel, yet fairly smooth and slightly plastic. Squeezed when dry, it will form a cast that will bear careful handling, while the cast formed by squeezing the moist soil can be handled quite freely without breaking.

<u>Silt loam:</u> Silt loam is a soil having a moderate amount of the fine grades of sand and only a small amount of clay, with over half of the particles being of the size called "silt." When dry it may appear clod-like but the lumps can be readily broken and when pulverized it feels soft and flour-like. When wet the soil readily runs together and puddles. Either dry or moist it will form casts that can be freely handled without breaking but when moistened and squeezed between thumb and finger it will not produce a "ribbon" longer than 2.5 cm but will give a broken appearance.

<u>Clay loam:</u> Clay loam is a fine textured soil which usually breaks into clods or lumps that are hard when dry. When the moist soil is pinched between the thumb and finger it will form a thin "ribbon" which will break readily, barely sustaining its own weight. The moist soil is plastic and will form a cast that will bear much handling. When kneaded in the hand it does not crumble readily but tends to work into a heavy compact mass.

<u>C1ay:</u> Clay is a fine textured soil that usually forms very hard lumps or clods when dry and is quite plastic and usually sticky when wet. When the moist soil is pinched out between the thumb and fingers it will form a long, flexible "ribbon."

Field estimates are subject to error. They need to be checked against laboratory determinations of particle-size distribution and the field criteria should be adjusted as necessary. The soil scientist should not attempt to estimate texture with greater precision than is justified by the reliability of field estimates. For most soils, for example, attempting to distinguish loam from silt loam is futile if the textures of the samples are near the boundary between the classes.

A texture not included in Shaw's definitions is loamy sand. It is between the sand and sandy loam. Loamy sand has enough cohesion to form a golf ball sized cast when moist that can be gently tossed from hand to hand. It will retain a thumb indentation when moist but will not form a "ribbon" (see **Figure 2.2**).

A flow diagram for estimating soil texture by feel (see **Figure 2.2**) is included in this chapter as a guide for field determinations.

Definitions of the basic textural classes are set forth in graphic form (see **Figure 2.1)** in terms of percent sand (2.0 to 0.05mm), percent silt (0.05 to 0.002mm) and percent clay (less than 0.002mm).

There are 12 basic textural classes. When the individual subclasses sands, loamy sands and sandy loams are included, there are 21 soil texture classes.

DEFINITIONS OF SOIL TEXTURE CLASSES

Sands – More than 85% sand, the percentage of silt plus 1.5 times the percentage of clay is less than 15.

Coarse sand A total of 25% or more very coarse and coarse sand and less than 50% any other single grade of sand.

Sand A total of 25% or more very coarse, coarse, and medium sand, a total of less than 25 percent very coarse and coarse sand and less than 50 percent fine sand and less than 50 percent very fine sand.

Fine sand 50% or more fine sand or a total of less than 25 percent very coarse, coarse and medium sand and less than 50 percent very fine sand.

Very fine sand 50% or more very fine sand.

Loamy sands – Between 70 and 91% sand and the percentage of silt plus 1.5 times the percentage of clay is 15 or more; and the percentage of silt plus twice the percentage of clay is less than 30.

Loamy coarse sand A total of 25% or more very coarse and coarse sand and less than 50 percent any other single grade of sand.

Loamy sand A total of 25% or more very coarse, coarse, and medium sand and a total of less than 25 percent very coarse and coarse sand and less than 50 percent fine sand and less than 50 percent very fine sand.

Loamy fine sand 50 percent or more fine sand; or less than 50 percent very fine sand and a total of less than 25 percent very coarse, coarse, and medium sand.

Loamy very fine sand 50 percent or more very fine sand.

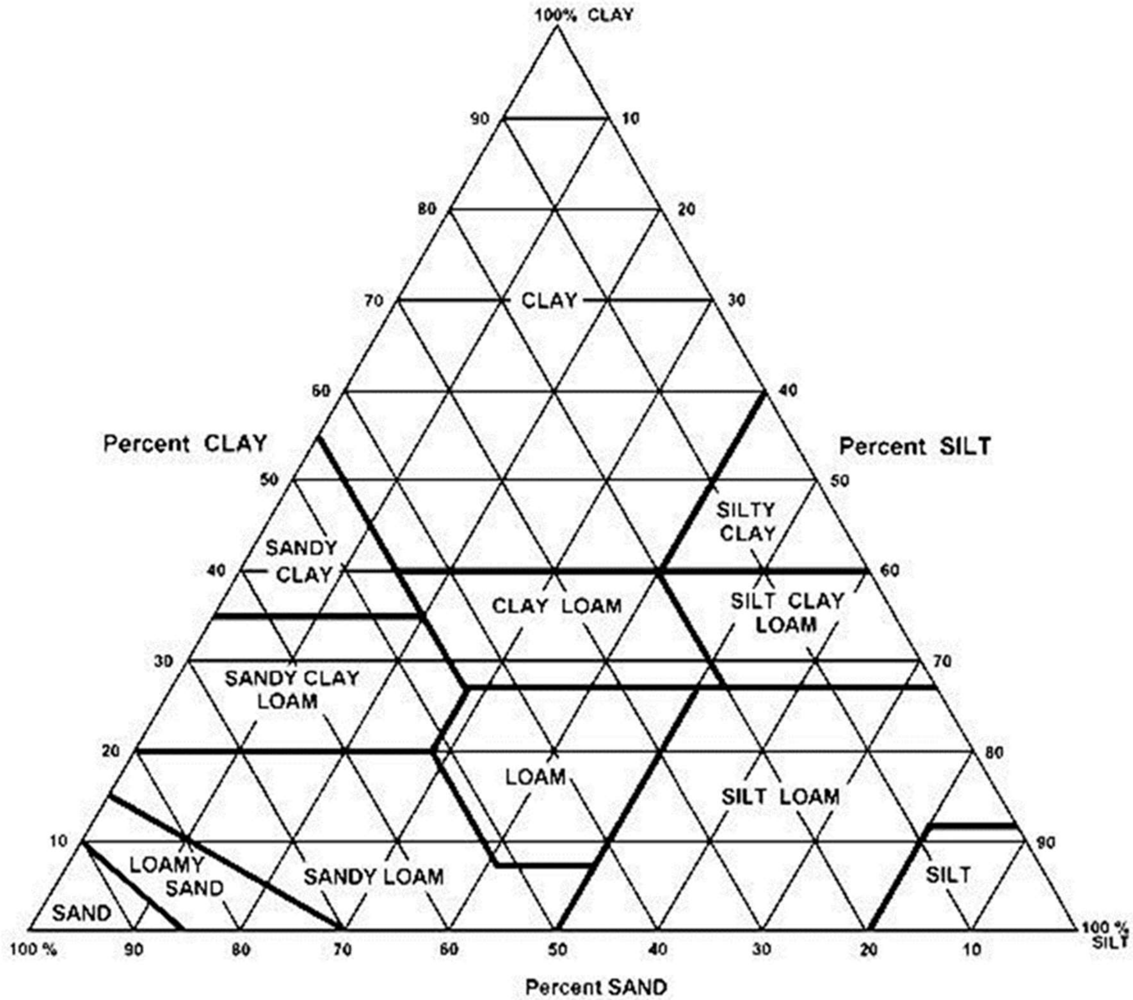


FIGURE 2.1 – Percentages of sand, silt and clay comprising the basic textural classes

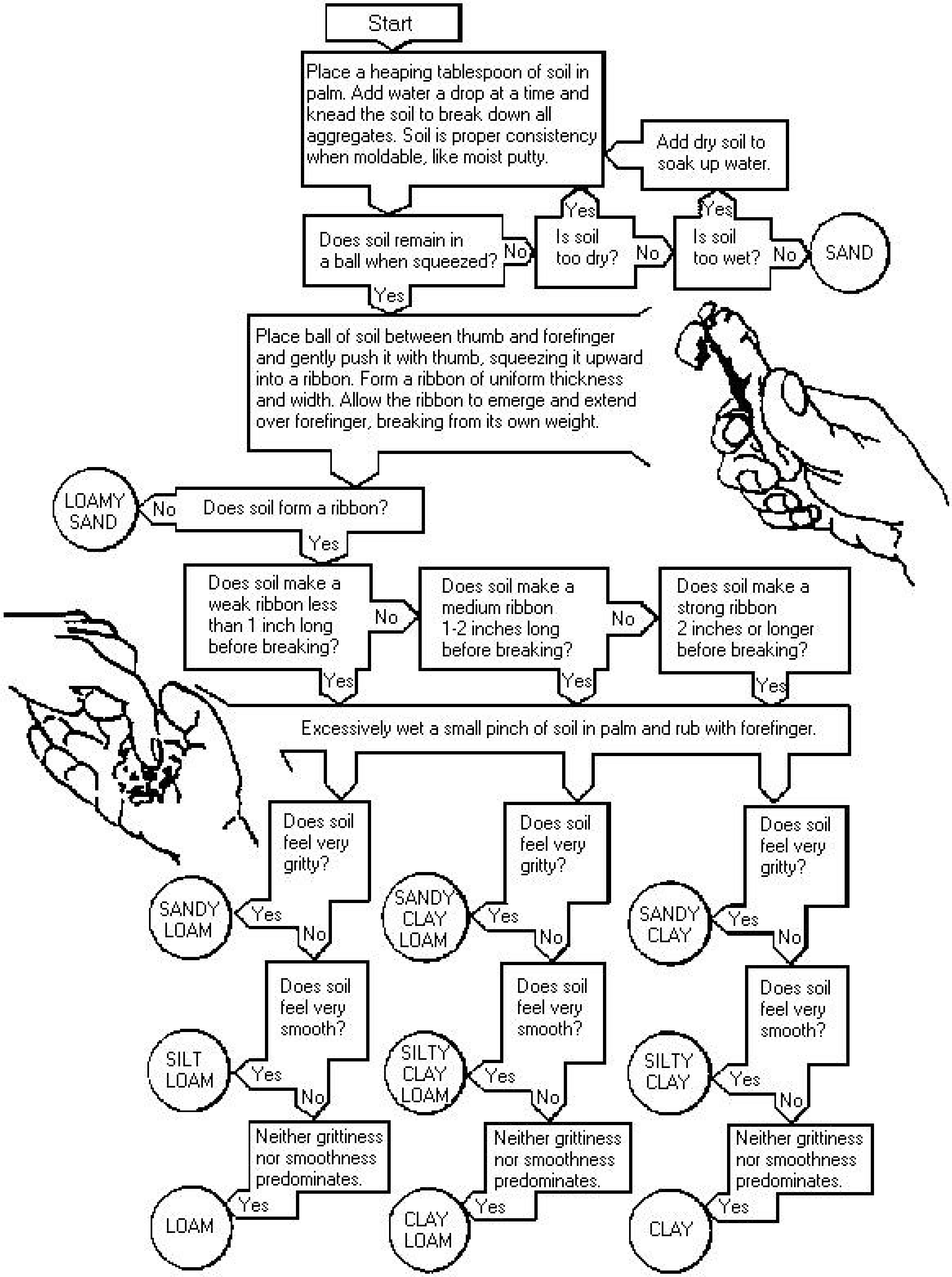


FIGURE 2.2 – Flow diagram for estimating soil texture by feel

Sandy Loams – 7 to 20% clay, more than 52 percent sand and the percentage of silt plus twice the percentage of clay is 30 or more; or less than 7 percent clay, less than 50 percent silt and more than 43 percent sand.

Coarse sandy loam A total of 25% or more very coarse sand and coarse sand and less than 50 percent any other single grade of sand.

Sandy loam A total of 30% or more very coarse, coarse and medium sand but a total of less than 25 percent very coarse and coarse sand and less than 30 percent fine sand and less than 30 percent very fine sand; or a total of 15 percent or less very coarse, coarse, and medium sand, less than 30 percent fine sand and less than 30 percent very fine sand with a total of 40 percent or less fine and very fine sand.

Fine sandy loam 30% or more fine sand and less than 30 percent very fine sand; or a total of 15 to 30 percent very coarse, coarse and medium sand; or a total of more than 40 percent fine and very fine sand, one half or more of which is fine sand and a total of 15 percent or less very coarse, coarse and medium sand.
Very fine sandy loam 30% or more very fine sand and a total of less than 15 percent very coarse, coarse and medium sand; or more than 40 percent fine sand and a total of less than 15 percent very coarse, coarse and medium sand.

Loam - 7 to 27% clay, 28 to 50 percent silt and 52 percent or less sand.

Silt loam – 50% or more silt and 12 to 27 percent clay or 50 to 80 percent silt and less than 12 percent clay.

Silt – 80% or more silt and less than 12 percent clay.

Sandy clay loam - 20 to 35% clay, less than 28 percent silt and more than 45 percent sand.

Clay loam - 27 to 40% clay and more than 20 to 46 percent sand

Silty clay loam - 27 to 40% clay and 20 percent or less sand.

Sandy clay – 35% or more clay and 45 percent or more sand.

Silty clay – 40% or more clay and 40 percent or more silt.

Clay – 40% or more clay, 45 percent or less sand and less than 40 percent silt.

The textural triangle (**Figure 2.1**) is used to resolve problems when applying lab results to the word definitions for the 12 basic soil textural classes. The four distinctions in the sandy loam group provides refinement greater than can be consistently determined by field techniques. The eight subclasses of sands and loamy sands can usually be determined in the field.

ROCK FRAGMENTS

Rock fragments are unattached pieces of rock 2.0 mm in diameter or larger. Terms describing size and shape are presented in **Table 2.3.** The adjective is used in the soil texture name as a modifier: example - "gravelly loam".

TABLE 2.3 - Terms for rock fragments

Shape	**Size**	**Noun**	**Adjective**
Spherical, cube like	2-75 mm diameter	Pebbles	Gravelly
or equiaxial	2-5 mm diameter	Fine	Fine Gravelly
	5-20 mm diameter	Medium	Medium Gravelly
	20-75 mm diameter	Coarse	Coarse Gravelly
	75-250 mm diameter	Cobbles	Cobbly
	250-600 mm diameter	Stones	Stony
	>600 mm diameter	Boulders	Bouldery
Flat			
	2-150 mm long	Channers	Channery
	150-380 mm long	Flagstones	Flaggy
	380-600mm long	Stones	Stony
	>600 mm long	Boulders	Bouldery

Four classes are used as modifiers to the soil texture name to denote relative percentages of rock fragments in the total soil volume as follows:

Less than 15%: No modifying terms are used: "loam".

15 to 35%: The size/shape adjective is used as a modifier to the texture name: gravelly loam, "channery loam," "cobbly loam".

35 to 60%: The size/shape adjective is used with the word "very" as a modifier to the texture name: "very gravelly loam", "very channery loam," "very cobbly loam".

More than 60%: The size/shape adjective is used with the word "extremely" as a modifier to the texture name: "extremely gravelly loam", "extremely channery loam," "extremely cobbly loam". Where rock fragments occupy greater than 90 percent of the volume (less than 10 percent fine earth), the texture of the fine earth is dropped leaving the rock fragment term to stand alone: "pebbles", "channers", "cobbles".

Soil Color

Color is the most obvious of soil properties and it is easily determined. Except for the effect of color on absorption of heat at the surface, it has little known *direct* influence on the functioning of the soil. Still, color is one of the most useful properties for soil identification and appraisal, mainly because other, more important characteristics that are not so easily and accurately observed can be inferred from it.

SIGNIFICANCE OF COLOR

Within a limited area, color can be reliably associated with important soil properties. Color of the surface layer, for example, may be used to judge the content of organic matter. Color is a clue to wetness or droughtiness in some areas. It may be a mark of the effects of past vegetation or of use or misuse of the soil. Some soils exhibit color directly inherited from the parent rock. These and other relationships are clues for identifying soils and appraising their properties. Yet, when attempts are made to relate soil color to specific properties, any relationship considered universal has so many exceptions and such complicated qualifications that the generalization itself becomes obscure. Many local relationships are known only empirically.

The importance of soil color is greatest within a local set of microenvironments. Some common relationships of color to other soil properties can serve as a basis for interpreting color. Relationships of color that are observed repeatedly are noted. The exceptions to common relationships are learned for the local area. The reasons for relationships of soil color to other properties or for the exceptions may or may not be known but they are associated with specific materials or specific environments. In this perspective, soil color is important. When applying local relationships, the fact that the same color means different things in different places outside the area is not of special concern. But the possibility of exceptions should be kept in mind.

Commonly, dark colors suggest more organic matter than light colors. The relationships may be quite good locally but exceptions must be understood. Humified organic material is commonly dark; however, raw organic material such as peat is not necessarily dark. Where mean annual temperature is high, soils that are high in organic matter are commonly less dark than soils in cool regions having similar amounts of organic matter. Yet in places in warm regions, black or nearly black clay soils have less than 2 percent organic matter, and these may be next to much lighter colored soils that have two or three times as much organic matter. Some soils are nearly black because of organic coatings on peds, and when the soil is crushed it appears significantly lighter. In other soils, the organic matter is disseminated throughout the peds. In some soils organic material moved by eluviation is light colored.

Color is one of the most useful criteria for recognizing coatings or the lack of them, on peds. If clay coats differ in color from interiors of peds, they are easily recognized, though proof that the coatings are clay depends on other properties. Most E horizons lack coatings and therefore have the color of the residual minerals, such as quartz. Some E horizons are difficult to detect because they are not light colored.

Many bodies of segregated material have colors that make them easy to see. Bodies in which iron is segregated commonly are brown, reddish, or yellowish but some are nearly black. Manganese segregations are nearly black in most soils. Coatings of compounds of iron and manganese on peds are dark and can be mistaken for organic matter. Segregated materials such as carbonates or more soluble salts may be obvious because of their light color.

Gray, greenish-gray or bluish-gray colors in soils commonly indicate chemically reducing conditions caused by prolonged periods of saturation. Greenish and bluish hues (gley) are strong evidence of the presence of reduced iron (reduced matrix) (gley). A gray soil color is commonly the result of primary mineral grains being stripped of iron when the iron was in the reduced state (depletion). Gray or grayish soil colors are generally recognized as indicating prolonged saturation but not without significant exceptions. Some light gray E horizons are depleted of iron by organic compounds leached from an overlying A or O horizon, not by chemical reduction due to saturation. Some parent materials that are of very low iron content may be gray even under oxidizing conditions.

Usually, blotches or spots (mottles) of yellowish or reddish colors were indicate the alternating oxidizing and reducing conditions and are recognized as redoximorphic iron concentrations. They indicate a soil horizon subjected to a fluctuating seasonal water table. Yellowish and reddish mottles are concentrations of material of which oxidized iron is one of the most important components. These concentrations of oxidized iron are formed by repeated cycles of chemical reduction and mobilization during saturation, followed by oxidation and precipitation during dry periods. Multiple soil colors are not necessarily always the result of reduction and oxidation in association with a fluctuating water table. Mixed soil colors can result from different original color or differential weathering of the parent material instead of impeded drainage; such soils are usually described as "variegated." In materials of recent geological origin such as glacial deposits, iron concentrations can sometimes be found associated with rock fragments containing weatherable iron minerals.

Reddish and yellowish colors can be attributed to iron in its various forms. The relationship between color and iron in soil is fairly complex. Color depends on the compound or mineral thickness of the coatings, age and other factors. No correlation relating color to specific compounds of iron applies everywhere but among similar soils within a local area, inferences from reddish and yellowish colors can be valuable in determining the physical and chemical conditions prevalent within a soil horizon.

The number of soil properties that are indicated by color or that are easily distinguished because of color differences within the soil is large. Many of the relationships are based on empirical correlations, most of which are most useful when applied within the perspective of soils and environments in a small area, such as a county or part of a county. One of the most critical applications of soil color is in the recognition of the redoximorphic features used to interpret zones of periodic saturation within the soil profile. Look to the USDA Soil Survey Manual, Chapter III for identification and interpretation of redoximorphic features.

DETERMINING SOIL COLOR

Soil color is measured by comparison with a standard color chart. The most commonly used chart is taken from the Munsell color system and includes only that part needed for soil colors, about one fifth of the entire range of hue. The standard Munsell chart for soil color consists of about 175 different colored chips, systematically arranged according to their Munsell notations, on seven cards (pages) that are assembled in a loose-leaf notebook. Three additional pages, two for the reddest hues of soils and one for the bluish and greenish hues of gleyed soils, are also available.

The Munsell color system uses three elements of color: hue, value and chroma, to make up a specific color notation. The notation is recorded in the form: hue, value/chroma -- for example, 5Y 6/3. The three attributes of color are arranged in the system in orderly scales of equal visual steps, which are used to measure and describe color accurately under standard conditions of illumination.

Hue identifies the quality of color registered by the eye as related to the wavelength of the visible light reaching the eye. The Munsell system is based on five principal hues: red (R), yellow (Y), green (G), blue (B), and purple (P). Five intermediate hues representing midpoints between each pair of principal hues complete the 10 major hue names used to describe the notation. The intermediate hues are yellow-red (YR), green-yellow (GY), blue-green (BG), purple-blue (PB), and red-purple (RP). For use, each of the 10 major hues is divided into four segments of equal visual steps, which are designated by numerical values applied as prefixes to the symbol for hue name. Four equally spaced visual steps of the adjacent yellow-red (YR) hue are identified as 2.5YR, 5YR, 7.5YR, and 10YR. Each of these classes of hue has a narrow range of the wavelength of light. The standard chart for soil has pages from 10R through 5Y hue, a total of seven pages plus a composite page for gley.

Value indicates the degree of lightness or darkness of a color. On a neutral gray (achromatic) scale, value extends from pure black (0/) to pure white (10/). Whereas hue is a measure of the chromatic composition of light that reaches the eye, the value notation is a measure of the amount of light that reaches the eye. Gray is perceived as about halfway between black and white, and has a value notation of 5/. (The actual amount of light that reaches the eye is related logarithmically to color value.) Lighter colors have values between 5/ and 10/; darker colors have values from 5/ to 0/. These values may be designated for either achromatic or chromatic conditions. Thus, a page of the color chart for soil has a series of chips arranged vertically to show equal steps from the lightest to the darkest shades of that hue.

Chroma is the relative purity or strength of the spectral color (hue). Chroma indicates the degree of dilution of the hue by neutral gray of the same value. The scales of chroma for soils extend from /0 for neutral gray, to a chroma of /8 as the strongest expression of color used for soils. High chroma colors may be seen as strong, or bright, whereas low chroma colors are grayish.

Brownish yellow, for example, is designated as 10YR 6/6 and light brownish gray is 10YR 6/2. Very dark brown is designated 10YR 2/2. All of the colors on the chart have hue of 10YR. The darkest shades of that hue are at the bottom of the page and the lightest shades are at the top. The lowest chroma, which is the weakest expression of hue and the grayest color, is at the left. The highest chroma and the strongest expression of hue, is at the right.

At the extreme left of some pages are symbols such as N 2/. These are colors of zero chroma which are totally achromatic--neutral color. They have no hue and no chroma but range in value from pure black (N 0/) to pure white (N 10/). The color chips for neutral colors are the same on cards of different hue because they have no hue. An example of a notation for a neutral (achromatic) color is N 5/**,** called gray. The color 10YR 5/1 is also called "gray," for the hue is hardly perceptible at such low chroma.

CONDITIONS FOR MEASURING COLOR

The quality and intensity of the light falling on a sample of soil affect the amount and quality of the light reflected from the sample to the eye. The moisture content of the sample and the roughness or smoothness of its surface also affect the amount and quality of the light reflected. The visual impression of color from the standard color chips is accurate only under standard conditions of light intensity and quality. As the color standards are used in the field, it is important that the light be white enough that the sample reflects its true color and that the amount of light be adequate for visual distinction between chips.

Color determination may be inaccurate early in the morning or late in the evening and from late September through mid-March. When the sun is low in the sky or the atmosphere is hazy, the light reaching the sample is somewhat red and the light reflected from the sample is redder than at midday. Even though the same kind of light reaches the color standard and the sample, the reading of the sample color at these times is commonly one or more intervals of hue redder than at midday. Colors also appear different in the subdued light of a cloudy day than in bright sunlight. If artificial light is used, as for color determinations in an office, the light source used must be as near the white light of midday as possible. With practice, compensation can be made for the differences unless the light is so subdued that the distinctions between color chips are not apparent. Intensity of the incident light is especially critical when matching soil to chips of low chroma and low value or evaluating faint redoximorphic features.

RELIABILITY OF COLOR MEASUREMENTS

Under field conditions, measurements of color are reproducible by different individuals within 2.5 units of hue (one page) and 1 unit of value and chroma. Most soil colors do not precisely match a color chip and notations are made to the nearest whole unit of value and chroma. Colors are determined and reported for moist soil unless specifically noted as dry soil color.

SOIL COLOR NAMES

The left page of the Munsell color contain a table of soil color names, such as “yellowish brown” that correspond to the hue-value-chroma notations on the opposite page. Some soil color names include more than one Munsell color notation and some names are used applied to more than one hue. The Munsell notations are therefore usually more precise than color names alone. Use hue-value-chroma notations when recording soil color in the field and on standardized report forms. In narrative soil descriptions and correspondence, it is appropriate to use the soil color name followed by its specific Munsell notation in parentheses: yellowish brown (10YR 5/6). On some of the color chart pages, certain chips fall on the boundary between two color names. The name that better describes the color is assigned. Expressions such as "brown to dark brown" are not used.

COLOR PATTERNS

The color of each soil horizon or layer is recorded in soil descriptions. The aggregate of descriptions of each individual horizon describes the color pattern of the whole soil.

The single layer may be uniform in color or it may be streaked, spotted, variegated or otherwise heterogeneous in color. Accumulations of carbonates, organic matter, iron, manganese, and other substances commonly differ in color from the surrounding soil. Soils that have impeded drainage commonly are marked by a mixture of gray, brown, and yellowish red colors. In some soils, coatings are present on primary particles or peds in one part of a layer but not in another, creating a mixture of colors. These kinds of color patterns within layers are recorded, and are part of the color pattern of the whole soil.

Some soil color patterns are patches of one color within another. Others are colors intermingled in such a way that no one color is clearly continuous throughout the layer. In the first kind, the continuous color can occupy a small part of the total surface observed, as in layers that have a network of thin bands of one color along parting planes between peds. This threadlike network encloses another color within the peds. In another soil, the continuous color can occupy almost the entire observed surface, as where a few small spots of color are found in an otherwise uniformly colored layer. In patterns of intermingled colors, one color can be most abundant, though not necessarily continuous. Some layers have intermingled colors in which no single color is most abundant.

Color patterns within soil layers are discussed under three headings: (1) dominant color, (2) mottling, and (3) color patterns related to physical organization. These are elements of the internal color pattern of a layer, which is seen when the soil is broken, revealing the natural physical organization of the soil in section. A broken section passes through peds and other unit bodies if they can be broken with the soil as a whole. A broken section commonly exposes only the faces of strong granules, fine blocks, and plates, but these should not be accepted in determining color; the colors of the interior of peds are also recorded. Some small peds must be crushed in order to reveal the interior color.

<u>Dominant color</u> is the color that occupies the greatest volume of the layer. It is judged based on colors of broken sections that represent the volume. For only two colors, the dominant color occupies more than 50 percent of the volume. For three or more colors, the dominant color occupies more of the volume of the layer than any other color, but it may occupy less than 50 percent. In some layers, no single color is dominant. Dominant color (or colors) is always given first among those of a multicolored layer. The expression "brown with yellowish brown and grayish brown" signifies that brown is the dominant color. It may or may not occupy more than 50 percent of the layer. The expression "brown and yellowish brown with grayish brown" indicates that brown and yellowish brown are about equal and are co-dominant. If the colors are described as "brown, yellowish brown, and grayish brown," the three colors occupy nearly equal parts of the layer.

If the description makes it obvious that some colors occupy a very small percentage of the total, the percentage of the dominant color need not be given, although recording the proportion helps to avoid mistakes. By conventions given below, the word "few" signifies less than 2 percent of the layer. If yellowish brown and strong brown mottles in a grayish brown layer were each "few," the approximate percentage of grayish brown is obvious. Of course, if the percentage is used, there can be no question about the writer's meaning.

Mottling means marked with spots of different colors but the application of the term to soils is not as simple as the dictionary definition. Soil mottles specific to seasonal or periodic saturation will be discussed as redoximorphic features in further detail in Chapter III of this manual. The following example will illustrate some of the complications in observing mottling.

A section of soil broken through the peds, which may be strong very coarse prisms parting to weak medium blocks, might include the following distinctive colors: (1) a dominant color inside the blocky peds, (2) spots of different color within the peds and not associated with any discrete structural unit or body, (3) spots of still different color marking exposed surfaces of nodules within the peds, (4) a thin band, perhaps 1 mm wide, of yet another color in a discontinuous network marking interrupted boundaries between the weak blocks, (5) a thicker continuous band of color, perhaps 2 mm wide, marking the outer rim of the very coarse prisms, and (6) spots of still different color on the surfaces of pebbles. These are all "spots of color" and a soil description distinguishes them but not all of them are called "mottles."

The dominant color (or colors) is given first. Mottles are then described as details of the color pattern. Some of the associated colors may be related to specific locations or discrete bodies and that kind of relationship is recorded. The colors of concretions, nodules, coats of peds, fillings in burrows of animals and the like are commonly described as properties of identifiable bodies or surfaces and are usually not called "mottles" in the description.

Mottles are described in terms of quantity, size, contrast, and color, in that order. Other properties, including shape, location and character of boundaries of mottles are recorded as needed. Color of mottles is recorded according to the conventions described in the preceding section. Quantity, size and contrast of mottles are described using the conventions that follow.

Quantity is indicated as one of three general classes based on the percentage of the observed surface that is occupied by mottles of a given kind:

Few --------------------- Less than 2 percent
Common --------------- 2 to 20 percent
Many ------------------- More than 20 percent

The conventions for quantity are used to describe mottling on surfaces, such as faces of peds, as well as within the body of the soil. A card having sections showing spots of different sizes in different proportions is commonly available and it provides standards for visual impressions of quantity.

The words used to name quantity classes may imply to some that the mottles are spots on a background of another color. This is not always true. If the mottling is a continuous network of different color, the term threadlike may be added: "few threadlike... mottles." Estimated percentages may be used instead of class terms: "one percent threadlike... mottles."

When describing multicolored materials, the notations must clearly indicate to which colors the terms for quantity apply. For example, "common grayish brown and yellowish brown mottles" could mean that *each* occupies 2 to 20 percent of the layer. By convention, the example is interpreted to mean that the quantity of the two colors *together* is between 2 and 20 percent. If each color occupies between 2 and 20 percent, the description should read "common grayish brown and common yellowish brown mottles."

<u>Size</u> refers to the approximate dimensions of the mottles as seen on a plane surface. If the length of a mottle is not more than two or three times the width, the dimension recorded is the greater of the two. If the mottle is long and narrow, as a band of color at the periphery of a ped, the dimension recorded is the smaller of the two and the shape and location are also described. Three size classes are used:

Fine----------------------Smaller than 5 mm
Medium-----------------5 to 15 mm
Coarse-------------------Larger than 15 mm

Size of mottles, like quantity, must be carefully identified in terms of the kinds of mottles to which the terms apply. A card having spots of various shapes in sizes that correspond to size classes is helpful for field use.

<u>Contrast</u> refers to the degree of visual distinction that is evident between associated colors. Contrast is described as <u>faint</u>, <u>distinct</u> or <u>prominent:</u>

<u>Faint</u>: Evident only on close examination. Faint mottles commonly have the same hue as the color to which they are compared and differ by no more than one unit of chroma or two units of value. Some faint mottles of similar but low chroma and value differ by 2.5 units (one page) of hue.

<u>Distinct</u>: Readily seen but contrast only moderately with the color to which they are compared. Distinct mottles commonly have the same hue as the color to which they are compared but differ by two to four units of chroma or three to four units of value; or differ from the color to which they are compared by 2.5 units (one page) of hue but by no more than one unit of chroma or two units of value.

<u>Prominent:</u> Contrast strongly with the color to which they are compared. Prominent mottles are commonly the most obvious color feature of the section described. Prominent mottles that have medium chroma and value commonly differ from the color to which they are compared by at least five units (two pages) of hue if chroma and value are the same; at least four units of value or chroma if the hue is the same; or at least one unit of chroma or two units of value if hue differs by 2.5 units (one page).

If colors of mottles and of the background are recorded by Munsell notations, the degree of contrast is evident from the notations. For readers who do not use the Munsell color system regularly, however, the notations do not create a clear impression of color or contrast. The connotative terms for contrast are usually used, even though color notations are given. A judgment of degree of contrast at the time the soil is described is useful, since the contrast is often not a simple comparison of one color with another but is a visual impression of the prominence of one color against a background commonly involving several colors. The guides provided in the definitions of contrast classes, therefore, are used with appropriate judgment of the visual impression of the layer. The description shows whether the contrast term compares only two colors or is a visual impression of contrast of color against a multicolored background.

Shape of some mottles is significant and is often described by common words like streaks, bands, tongues, tubes and spots. Commonly, the location and shape of mottles is related to structure of the soil. Such relationships are described. The nature of boundaries of mottles is important in some soils and can be described as sharp (like a knife edge), clear (color grades over less than 2 mm) or diffuse (color grades over more than 2 mm). These and other attributes of mottling are described as necessary to record features that may be significant in identifying redoximorphic features. No special conventions are provided for these attributes because of their diversity. Generally, more useful records are obtained by tailoring the description to the special features observed rather than by depending on conventions that are likely to be inadequate.

The elements of mottling are conventionally described after the dominant color in the order (1) quantity, (2) size, (3) contrast, (4) color, (5) other attributes: "few, medium, distinct, yellowish brown (10YR 5/4), diffuse, streak like mottles." Color is recorded by Munsell notation in detailed field descriptions. In non-technical descriptions the color group name may be used alone, but if the description is for technical use as well, the Munsell notation is given in parentheses.

Mottling is described following the dominant color. The quantity, size and contrast of mottles and the name and Munsell notation of the color are recorded. Moisture state and physical state of the dominant color are presumed to apply to the mottles unless the description states otherwise. An example, for which a standard moist broken state of the sample has been specified, might read "dark brown (10YR 4/3); many medium distinct yellowish brown (10YR 5/6) mottles. Such a description implies no special relationship of mottling to structure.

PHYSICAL COLOR PATTERNS

Color, including mottling, is described separately for any physical feature that merits separate description as a unique part of the soil. The colors, including internal color patterns, are described for such bodies as structural peds, concretions, nodules, cemented bodies, pore linings, filled animal burrows and the like.

Colors are given for coatings on faces of peds as well as for faces of peds that do not have identifiable coatings. Extensions of material from another soil layer are usually described as unique attributes of the soil and the descriptions of them include color. The conventions for describing the color of the soil are used for descriptions of unique bodies and surfaces.

Commonly, the colors of unique bodies and surfaces have significant relationships to location on or in the feature described. Some are products of the boundary between the interior and the exterior of a discrete body. Some soils, for example, have colors that record past chemical phenomena adjacent to roots that once occupied existing channels or tubules. Different colors between the surfaces and interiors of structural peds may reflect water movement into and out of the peds and the resulting oxidation-reduction relationships of the two physical-chemical environments. In addition to unique features, color patterns that are consistently associated with specific locations are described in relation to location. If color differences are related to differences in other properties, such as texture or structure, that relationship is also noted.

In general, any color pattern that exhibits order requires explanation because order implies a cause and affects relationship. Much of our present understanding of soil originated from such observations. Accurate and thorough soil descriptions are the means whereby soil morphological information and interpretations are communicated.

RECORDING COLOR

The Munsell system provides the essential means for recording the visual property of soil color. The means of describing the objects of color found in soils has been described in the preceding section. These methods of reporting complex visual observations have been used for decades in recording the color characteristics of many thousands of soils classified in the United States. Conforming to the basic conventions of recording color is essential in making an effective soil description. However, one must not allow an overly strict adherence to convention to result in a report that fails to record what was observed in the field. The objective of an acceptable soil description should be that a colleague could read the report, go to the same soil pit and not be at all surprised.

Physical Organization in Soil

Soils differ in the organization of the individual soil particles and in the numbers, sizes and kinds of soil pores. Although some soils have little organization, in most soils the particles are organized in varying degrees into units of various sizes, shapes and compositions. These units and their special arrangements are described in this section. The units themselves are named according to kind, such as "peds", "nodules," "clay coats."

Peds make up the structural framework of most soils. Soil structure is the combination or arrangement of primary soil particles into larger, secondary units called peds. In addition, many soils have other organized morphological elements. Some are associated with ped surfaces. Others are discrete separate and independent bodies within peds or in structureless soils. Elements on ped faces, pore walls and other surfaces are described below as "Surface Features." They include coatings of clay, silt, sand, organic material, sesquioxides, carbonates and the like. Discrete, separate, independent bodies, such as nodules and concretions are described later as "Concentrations within the Soil." Pores are voids within and between ped structural units and are the consequences of the combination of primary soil particles into ped organization.

SOIL STRUCTURE

Soil structure refers to the natural organization of primary soil particles into larger, secondary units called peds. The cohesion within these units is greater than the adhesion among units. As a consequence, when under stress, the soil mass tends to rupture along pre-existing planes, or surfaces, of weakness. It is these surfaces that form the boundary between adjacent units. The surfaces persist in place through multiple cycles of wetting-drying and freeze-thaw. Peds range in size from a few millimeters to over 10 cm and are of several distinct shapes.

Structural peds are distinguished from:

clods, which are caused by disturbances, such as plowing, that mold the soil into temporary bodies.

soil fragments, which form when the soil cracks or is broken along a momentary zone of weakness that did not exist as a boundary prior to the stress.

concretions or nodules, which are local concentrations of chemical compounds, such as calcium carbonate or iron oxide, in the form of discrete separate, independent units within the soil. These kinds of bodies are described in other parts of this section.

The persistent surfaces of peds can often be distinguished from the fracture surfaces of soil fragments as pre-existing surfaces tend to be smoother and may have coatings or other surface features. Identification of structure in some soil requires careful examination to detect clearly defined parting planes repeated over fairly consistent distances and careful examination of the surfaces of units when they are removed. In other soils, the tendency to rupture into distinct peds may be the most noticeable physical characteristic of the soil.

Some soils lack structure. Some have simple structure, each ped being an entity without component smaller peds within the larger. Other soils have compound structure, in which large peds are composed of smaller peds separated by persistent planes of weakness.

Soil Layers that lacks structure are structureless. In structureless soils, no peds are observable in place or after the soil has been gently disturbed, as by prying loose a section with a spade or knife. When structureless soils are disturbed, soil fragments and single mineral grains can be identified. The soil fragments may be strongly coherent or they may be easily broken or crushed. Evidence of pre-existing surfaces cannot be found.

For soils that have structure, the properties of grade (distinctness), size and shape of the peds are described using the established convention presented below:

Shape: Several basic shapes of peds are recognized in soils. Supplemental statements about the variations in shape of individual peds are needed in detailed descriptions of some soils. The following terms describe the basic shapes and related arrangement of peds:

Platy: The peds are flat and plate-like. They are generally oriented horizontally and stacked, like pages in a book.

Prismatic: The individual peds are bounded by flat or slightly rounded vertical faces. Peds are distinctly longer vertically and the faces are typically casts or molds of adjoining peds. Vertices are angular or sub-rounded; the tops of the prisms are somewhat indistinct and normally flat.

Columnar: The peds are similar to prisms and are bounded by flat or slightly rounded vertical faces. However, the tops of columns, in contrast to those of prisms, are very distinct and normally rounded.

Blocky: The peds are block-like or polyhedral. The peds are bounded by flat or slightly rounded surfaces that are casts of the faces of surrounding peds. Blocky peds are nearly equidimensional. The structure is further described as angular blocky if the faces intersect at relatively sharp angles and as sub-angular blocky if the faces are a mixture of rounded and plane faces and the angles are mostly rounded.

Granular: The peds are approximately spherical or polyhedral and are bounded by curved or very irregular faces that are not casts of adjoining peds. Formally sometimes called crumb, the peds do tend to resemble bread crumbs.

Size. Five classes describe the size of peds: very fine, fine, medium, coarse and very coarse. The size limits of the classes differ according to the shape of the peds. The size limits refer to measurements in the smallest dimension of plates, prisms, and columns and to the largest of the nearly equal dimensions of blocks and granules.

TABLE 2.4 – Size Classes of Soil Structure

Size Class	**Shape**			
	Prismatic & Platy*	Columnar	Blocky	Granular
	------------------------ mm ---------------------------			
Very fine	<1	<10	<5	<1
Fine	1-2	10-20	5-10	1-2
Medium	2-5	20-50	10-20	2-5
Coarse	5-10	50-100	20-50	5-10
Very coarse	>10	>100	>50	>10

* In describing plates, “thin” is used instead of “fine” and “thick” instead of “coarse.”

In some horizons the peds are very much larger than the minimum size given for the very coarse class. If the peds are more than twice the minimum size of very coarse, the actual size is given: "Prisms 30 to 40 cm across "

Grade describes the distinctness of peds and the relationship of cohesion within peds and adhesion between peds. Basically, it is how well the structure is expressed. The determination of grade of structure in the field depends on the relative ease with which the soil separates into discrete peds and also on the proportion of peds that hold together when the soil is handled. Three classes are used:

Weak peds are barely observable when in place. When gently disturbed, the soil material parts into a mixture of entire and broken peds and there is much material that exhibits no ped faces. Pre-existing surfaces (ped faces) are evident if the soil is handled carefully. Distinguishing structureless from weak structure is sometimes difficult. In virtually all material that has structure, the surface of individual peds will differ in some way from the interiors of the peds.

Moderate peds are well formed and evident in undisturbed soil. When disturbed, the soil material parts into a mixture of many entire peds, some broken peds and little material that is not in peds. The peds part from adjoining peds to reveal nearly entire faces that have properties distinct from those of fracture surfaces.

Strong peds are distinct in undisturbed soil. They separate cleanly when the soil is disturbed. When removed, the soil material separates mainly into entire peds. Generally, faces of peds have distinctive properties that distinguish them from fracture surfaces.

The distinctness of individual peds and the relationship of cohesion within peds to adhesion between peds determine grade of structure. The relationship of adhesion to cohesion is relative to the soil material being evaluated: individual peds in a sandy loam A horizon may have strong structure yet be less durable than individual peds in a silty clay loam B horizon of weak structure. The degree of disturbance required to evaluate structure grade depends largely on moisture content and percentage and kind of clay. Therefore the effort needed to separate peds is not a uniform indicator of structure grade. This is particularly true in light of the changing effects of soil moisture and clay content. Only a slight disturbance may be necessary to separate peds of a moist sandy loam having strong granular structure, while considerable effort may be required to separate peds of a moist clay loam having strong blocky structure.

Structure may be altered in soil exposures such as old road cuts exposed to variations of temperature and moisture. Soil profiles that have been exposed for a length of time are not suitable places to determine the grade of structure. A fresh face should be exposed to adequately judge soil properties.

The terms for the three properties of soil structure are combined in the order grade, size and shape to create the structure name. "Strong fine granular structure" describes a soil horizon that separates almost entirely into discrete units that are loosely packed, roughly spherical and mostly between 1 and 2 mm in diameter. The designation of structure by grade, size and shape can be modified with other appropriate terms when necessary to describe other characteristics of the peds. Surface characteristics of peds are described separately.

COMPOUND STRUCTURE

In many soil horizons one or more sets of small peds are held together to form discrete bodies recognizable as larger peds. Both orders of peds, as well as the relationship of one to the other, are described. Grade, size, and shape are given for both. The relationship of one set of structural units to the other is important and is shown: "strong medium blocks within moderate coarse prisms," or "moderate coarse prismatic structure parting to strong medium blocky." The word "parting," not "breaking," is used. The term "breaking" is applied when the soil is fractured along planes other than natural places of weakness.

A description of peds within peds implies primary and secondary parting planes and voids associated with them. It commonly also suggests differing degrees of continuity of the parting planes and associated voids.

STRUCTURELESS SOIL MATERIALS

Soil structure is usually limited to the A and B horizons within several feet of the surface. Material in the C horizon usually has no developed soil structure. Some soils may have soil structure only in the A horizon. Soil material that does not exhibit any structure is described as either massive or single grain.

Massive is the structureless condition of soil materials that have enough cohesion so that the primary particles stick together in a mass. If enough force is used, any body of cohesive soil material can be broken into smaller pieces. The pieces are peds if their form and size are related to persistent planes of weakness. Aggregations of soil material that do not have orderly shape and size or evidence of pre-existing surfaces are not peds but are massive structureless units that can be divided into two types:

Clods are bodies of soil material that form when the soil is subjected to shearing, as during plowing or digging. There is some rearrangement of primary particles, at least next to the surfaces formed. Clods are created by a disturbance event that molds, or fuses soil material into unit. The pre-disturbed soil could have been structured or structureless. If the soil material had structure prior to the event that created the clod, then some of the peds may remain within the clod. The grade, size, and shape of clods should be described.

Soil fragments include (1) units of undisturbed soil that are separated by planes of weakness or planar voids at the time they are observed but that do not persist through cycles of wetting and drying and (2) pieces formed independently of planes of weakness by outside pressures, as when massive soil material or a ped is broken during examination of the soil. Fragments formed when a soil contracts upon drying are examples of the first kind. They form without manipulation and have size, shape and arrangement governed by forces within the soil; but the same fracture planes might not form during another wetting and drying cycle. The sizes and shapes of pieces of soil material formed by outside pressures during manipulation depend on the pressure applied. The term "soil fragments" is used to avoid confusion with rock fragments.

Single-grain is the structureless condition of soil materials that have very little cohesion and the primary particles behave independently rather than sticking together in a mass. Clean beach sand is an example of a single-grain material.

SURFACE FEATURES

Surface features include (1) coats of a variety of substances unlike the adjacent soil material and covering part or all of surfaces, (2) material concentrated on surfaces by the removal of other material and (3) stress formations in which thin layers at the surfaces have undergone reorientation or packing. All differ from the adjacent material in composition, orientation or packing.

Descriptions of surface features may include kind, location, amount, continuity, distinctness and thickness of the features. In addition, color, texture and other characteristics that apply may be described, especially if they contrast with the characteristics of the adjacent material.

Surface features are distinguished by differences in texture, color, packing, orientation of particles or reaction to various tests. If a feature is distinctly different from the adjacent material but the specific kind cannot be determined, it is described. Some of the more common kinds of surface features are:

Clay skins (synonymous with clay films) are thin layers of oriented translocated clay.

Sand or silt coats are sand or silt grains adhering to a surface. Some sand and silt coats are concentrations of the sand and silt originally in the horizon from which finer particles have been removed. Some are material that has been moved from horizons above and deposited on surfaces. In some coats, the grains are almost free of finer material; in others, the grains themselves are coated. If known, the origin of the coat is noted. Sand or silt coats are commonly high in quartz but may consist of other materials.

Other coatings may consist of iron oxides, manganese oxides, carbonates or organic matter.

CONCENTRATIONS

The features discussed here are identifiable bodies embedded in the soil. Some of these bodies are thin and sheet-like; some are nearly equidimensional; others have irregular shapes. They may contrast sharply with the surrounding material in strength, composition or internal organization. Concentrations are not dissimilar fragments originating from the parent material, they formed in the soil.

Masses are non-cemented concentrations of substances that cannot be removed from the soil as a discrete unit. Most accumulations consist of calcium carbonate or oxides of manganese and iron. Masses of iron and manganese oxides are redoximorphic features that will be discussed in Chapter III of this handbook. Masses are usually detected by a difference in color from the soil matrix and are thus commonly reported as mottles.

Nodules and concretions are discrete bodies strong enough and distinct enough to be removed from the soil intact. They are commonly cemented but include uncemented but coherent units that separate from the surrounding soil along clearly defined boundaries. They range in composition from material dominantly like that of the soil to concentrations of nearly pure chemical compounds. Nodules are distinguished from concretions on the basis of internal organization. Concretions appear to be constructed of concentric layers like an onion, whereas nodules show no such form. Stable oxides of manganese and iron are common constituents of nodules and concretions. Colors due to these compounds range from black to dark reddish brown, respectively. Nodules and concretions of iron and manganese oxides are redoximorphic features that will be discussed in Chapter 3 of this handbook.

CONSISTENCE

Soil consistence in the general sense refers to "attributes of soil material as expressed in degree of cohesion and adhesion or in resistance to deformation on rupture." These include:

(1) resistance of the soil material to rupture
(2) resistance to penetration
(3) plasticity, toughness, and stickiness of kneaded moist material
(4) the manner in which the soil material behaves when subjected to compression

For the purpose of this handbook, the classes for determining resistance to rupture and plasticity are provided in **Table 2.5** and **Table 2.6**. Rupture resistance tests are applied to intact cohesive units, such as peds, clods, or soil fragments.

TABLE 2.5 - Rupture Resistance Classes for Block-like Specimens

	Classes		**Test Description**
Dry	**Moist**	**Air dried, Submerged**	
Loose	Loose	Not Applicable	Not Applicable (non-cohesive, single grain)
Soft slowly	Very Friable	Non-Cemented	Fails under very slight force applied between thumb and forefinger
Slightly Hard	Friable	Extremely Weakly Cemented	Fails under slight force applied slowly between thumb and forefinger
Moderately Hard	Firm	Very Weakly Cemented	Fails under moderate force applied slowly between thumb and forefinger
Hard	Very Firm	Weakly Cemented	Fails under strong force applied slowly Between thumb and forefinger
Very Hard	Extremely Firm	Moderately Cemented	Cannot be failed between thumb and forefinger, but can be between both hands or by gentle pressure under foot

Extremely Hard	Slightly Rigid	Strongly Cemented	Cannot be failed in hands but can be underfoot by full body weight
Rigid	Rigid	Very Strongly	Cannot be failed underfoot by body weight

SOURCE: Soil Survey Manual, USDA Handbook No. 18, 1993.

PLASTICITY

Plasticity is determined for a very moist sample that has been manipulated and kneaded by hand. The sample used for soil texture can be used to determine plasticity.

Practical use of soil plasticity is when determining if a mound site can be plowed prior to construction. If the soil can form a ¼" (6mm) ribbon when rolled between the hands it is at its plastic limit. Therefore, smearing will occur, and it is too wet to plow.

TABLE 2.6 – Plasticity Classes

Classes	Test Description
Non-Plastic	A roll 4 cm long and 6 mm thick that supports its own weight held on end cannot be formed
Slightly Plastic	A roll 4 cm long and 6 mm thick can be formed and, if held on end, will support its own weight. A roll 4 mm thick will not support its own weight.
Moderately Plastic	A roll 4 cm long and 4 mm thick can be formed and, if held on end, will support its own weight, but a roll 2 mm thick will not support its own weight.
Very Plastic	A roll 4 cm long and 2 mm thick can be formed and, if held on end, will support its own weight

SOURCE: Soil Survey Manual, USDA Handbook No. 18, 1993.

Summary

The goal of recording field observations of soil characteristics is to create an instrument of communication. This requires tools of observation, measurement, classification and terminology unique to the morphology of soils. When properly applied, these tools allow direct observations of complex soil morphology to be represented on a sheet of paper or electronic record.

A soil description or field report must be purely objective. Interpretation of what the morphological observations may mean is a separate phase of the evaluation. One does not allow interpretive judgments to influence the reporting of soil characteristics. This definitely does not mean that we should not be thinking about what story these characteristics tell us while we are making and recording our observations.

Indeed, we should be very reluctant to climb out of the pit until we know that we have collected enough information to definitively answer our questions. In a way, a soil description is like a photograph in that it stands as an indelible record of fact. An interpretation, such as depth of seasonal saturation or permeability class, is derived from the basic facts of the soil description.

CHAPTER 3

Interpreting Soil Characteristics for Treatment of Domestic Wastewater

Interpretations are predictions of soil behavior for specified uses. This chapter emphasizes determining soil suitability for treatment of septic tank effluent, predicting where the water will go and ensuring it will be properly treated prior to reaching the groundwater or surface waters.

One of the five limiting factors which determine suitability and system design parameters for subsurface treatment of domestic wastewater is depth to groundwater. This includes depth to seasonally or periodically saturated zones in the soil that are wet for a week or more during the year.

Soil morphology (mainly soil color patterns) have been used by the Soil Survey to infer moisture conditions in a soil for over half a century. It is well recognized that depth and duration of saturation can be related to the quantity, nature and pattern of certain soil characteristics and features. More recently, a system and terminology has been developed to re-define "aquic conditions" based upon identification and interpretation of specific "redoximorphic features" of soil morphology. This approach concentrates on the circumstances responsible for the origin of specific features as a basis in using them to define conditions of periodic soil saturation.

When the soil temperature is above 40°F (4°C), two basic types of bacteria in the soil decompose or oxidize organic matter. When soil pores contain air (oxygen), aerobic bacteria are the primary agents in the decomposition process. When the soil is saturated, air and free oxygen are excluded and anaerobic bacteria become the primary decomposers. Anaerobic bacteria utilize insoluble iron (Fe) and manganese (Mn) compounds instead of oxygen in the decomposition process.

Brown colors in soil are due mainly to the presence of iron oxides. When anerobic decomposition occurs, an oxidation-reduction chemical reaction results. Manganese and iron ions are reduced and liberated from otherwise insoluble oxide or hydroxide compounds during this chemical reaction. Resulting reduced iron ions can migrate within the soil/water solution, causing depletions in some places, leaving gray areas. When the reduced iron is again exposed to oxygen, the iron oxidizes and precipitates out of solution with a reddish, brownish or yellowish color. Movement of iron and manganese as a result of redoximorphic processes in a soil may result in redox features.

Certain redox features occur due to the way in which the ion-carrying water moves through the soil and because of aerated zones in the soil. Characteristic redox color patterns created by these processes are divided into two types: concentrations and depletions. Wherever the iron and manganese is oxidized and precipitated, concentrations form: either soft masses, hard concretions or nodules. However, the reduced iron and manganese ions may be entirely removed from a soil if vertical or lateral movements of water occur. In this case there is no iron or manganese precipitation in that part of the soil profile and the mineral color itself is apparent.

A. Redox Concentrations - zones of apparent accumulation of Fe-Mn oxides, including:

(1) Nodules and concretions, i.e., cemented bodies that can be removed from the soil intact. Concretions are distinguished from nodules on the basis of internal organization. A concretion typically has concentric layers that are visible to the naked eye. Nodules do not have visible organized internal structure. Boundaries commonly are diffuse if formed *in situ* and sharp after pedoturbation.

(2) Masses are non-cemented concentrations of substances within the matrix

(3) Pore linings, i.e., zones of accumulation along pores which may be either coatings on pore surfaces or impregnations from the matrix adjacent to the pores.

B. Redox Depletions - zones of low chroma (2 or less) where either Fe-Mn oxides alone or both Fe-Mn oxides and clay have been stripped out, including:

(1) Iron depletions, i.e., zones which contain low amounts of Fe and Mn oxides but have a clay content similar to that of the adjacent matrix

(2) Clay depletions, i.e., zones which contain low amounts of Fe, Mn, and clay (often referred to as silt coatings or skeletons).

C. Reduced Matrix - a soil matrix which has a low chroma *in situ,* but undergoes a change in hue or chroma within 30 minutes after the soil material has been exposed to air.

Isolated areas of different soil color resulting from saturation**,** sometimes called "drainage mottles", are seen as spots of gray (iron depletions) or reddish-yellowish colors (iron masses) depending on whether the spot resulted from the removal of iron or from the accumulation of oxidized iron. Most soils that have repeated or extended periods of wetness are mottled or dull colored in all or part of the profile. The proportion of grayness implies the thoroughness with which reduced iron has been removed. Where very long periods of wetness occur in a zone where there is movement of soil water, the soil may become entirely depleted of iron and have a uniform gray color. This is the redoximorphic feature known as a depleted matrix.

Another feature created by intense reduction is a layer characterized by a bluish gray color. This is the color of iron in a reduced state. It has not been subjected to air and oxidation has not taken place. A lack of soil water movement has not removed this reduced, dissolved iron. These layers are called "gleyed." Material from this layer commonly changes to reddish brown upon exposure to air. This is the redoximorphic feature known as a reduced matrix.

Not all redoximorphic concentrations of iron and manganese oxides take the form of classical "drainage mottles". Nodules and concretions are exceptions. Others are pore linings. Here, oxide coatings occur on the inside surfaces of the larger pores and channels. They are found in root channels and in the spaces between ped faces. They usually form in zones subjected to extended periods of wetness where brief periods of de-saturation allows air only into the large channels and pores. This exposure to oxygen precipitates iron oxides on the surfaces of these large pores and channels while leaving the ped interiors in a reduced state.

Not all wet soils have morphological properties indicating saturation. Some soils are wet for significant periods but the water contains sufficient oxygen to maintain bright, high-chroma soil colors devoid of redoximorphic features. Many of these soils are of a coarse texture allowing fairly rapid water movement. In addition some of these soils are wet when soil temperatures are so low that organisms have a very slow rate of respiration and chemical reactions virtually stop. Materials located deep below the biological rooting zone may experience periods of saturation, but never develop redoximorphic features due to the lack of microbial activity needed to initiate the chemical reduction of iron.

Soil Texture and Structure Characteristics

Soil wetness can be attributed to a combination of properties of the soil: influence by climate, slope and landscape position as well as by physical characteristics. By determining soil texture we can infer pore size and number. Loose single grained sand would have large pores but fewer of them than a soil made up primarily of smaller sized silt particles. The smaller the particles are, the pores are more numerous but they have smaller pore space. Water generally moves faster through large pores than through smaller pores. However, this generalized statement cannot be taken independently when estimating the water transmitting ability of the soil. The physical organization of the soil particles, particularly structure must also be considered.

An example of using texture, structure and consistence in making some water movement assumptions is as follows: a three foot thick layer of silt loam material overlies a sandy loam glacial till. If texture alone were considered, it could be inferred that the silt loam has many smaller particles with many small pores that hold water under more tension while the sandy loam has fewer but larger pores that allow more rapid movement of water. But, in evaluating the structure it is noted that the silt loam particles are so arranged that it the soil is comprised of many angular blocky peds with large channels between them. The sandy loam is arranged in plates that are layered like pages in a book with small pores between the plates, parallel to the ground surface. In addition, the silt loam has a friable consistency and the sandy loam is very firm. Further examination of the profile revealed redox mottles between the sandy loam plates as well as up into the silt loam material.

It can now be concluded that water moves readily through the silt loam until it reaches the sandy loam. The water movement is slow and retention is long enough for the reduction - oxidation process to develop. Also, the retention time is long enough so that if excess water is added, such as in wet periods, that water stacks up above the sandy loam into the silt loam.

Permeability and Soil Water Movement

Soil permeability is the quality of the soil that enables water or air to move through it. Permeability to water and air are both important functions of a soil, particularly in treating wastewater. Any measure or classification of a soil's ability to transmit water also serves as a reasonably good estimator of its permeability to air.

Water movement in soil is controlled by two factors: 1) the resistance of the soil matrix to water flow and 2) the forces acting on the water to move it. Hydraulic conductivity is the inverse of the resistance to flow or a measure of the ease with which water can move through the soil. The rate of water movement at any time depends on soil properties, which determine the resistance, and the energy potential (sum of forces) acting on the water at that point and time.

Saturated Flow: A distinction is made between saturated flow and unsaturated flow. Saturated flow occurs when soil water pressure is positive which occurs when gravity is the primary driving force. In most soils water pressure is positive when about 95 percent or more of the total pore space is filled with water. If the soil remains saturated for a long time, the proportion of total pore space filled with water may approach 100 percent. Saturated hydraulic conductivity is a function of the arrangement and size distribution of pores. Large, continuous pores have a lower resistance to flow than small or discontinuous pores. It is for this reason that structured soils, with their large channels between peds, can drain much quicker than massive soils having the same texture.

Saturated hydraulic conductivity is expressed by the term (Ksat) as a velocity (distance/time) under the full acceleration of gravity (straight down). Hydraulic gradient is the difference in hydraulic head between two points divided by the distance between those two points. It can be envisioned as a slope. Flows can be calculated by applying mathematics derived from Darcy's Law (described above). Many references exist if one wishes to study this subject beyond the scope of this handbook.

Hydraulic conductivity values are extremely variable. Measured values for a particular soil series can vary by 100 fold or more. Values measured on soil samples taken only centimeters apart may vary by 10 fold or more. Furthermore, laboratory-determined values are generally higher than field-measured values, often by as much as 100-fold. Field methods generally are more reliable than laboratory methods. Because of this variability, a single measured value is a poor indicator of a soil's hydraulic conductivity. An average of several values gives a reliable estimate that can be used to place the soil into a particular hydraulic conductivity class.

Hydraulic conductivity can be given for the soil as a whole or for a particular layer or combination of layers. The layer with the lowest value determines the hydraulic conductivity classification of the soil. If an appreciable thickness of soil above or below the least conductive layer has significantly higher hydraulic conductivity, then the estimates of both parts are usually given.

Since measured values of hydraulic conductivity are available on relatively few soils, estimates are based on soil properties and correlations that have been made between these properties and hydraulic conductivity measurements.

A soil or layer in the high hydraulic conductivity class commonly transmits water downwards so readily that the soil or layer remains wet for no more than a few hours after thorough wetting. Soil in this class is usually composed of largely sand and has little silt and clay. It has large connected voids and many continuous conducting pores that are usually medium to coarse. The size and continuity of pores and voids are the critical factors. Many pores and voids are large enough to be distinguished easily; their continuity and persistence when the soil is wet must be determined. Some medium- and fine-textured soils have strong granular structure and large connecting pores. Others have many large voids, pores or root channels that transmit water rapidly. If the soil cracks when dry, the cracks may not close on wetting.

A soil in the moderate hydraulic conductivity class commonly transmits water downward readily enough that it remains wet for no more than a few days after thorough wetting. Layers may be massive, granular, blocky, prismatic or weakly platy if they contain common continuous pores. If the soil cracks when dry, the cracks may not close on wetting. This class includes many soils considered favorable for rooting and for supplying water to plants. The moderate class can be divided into moderate and moderately low.

Soils in the low hydraulic conductivity class commonly transmits water downward so slowly that it remains wet for a week or more after thorough wetting. Soils in the low class are structureless or have only fine and discontinuous pores (as in some clays, fragipans, or cemented layers). Layers may be massive, blocky or platy. Structural plates or blocks commonly are overlapping so that there are few connecting pores which conduct water when the soil is wet. If the soil cracks when dry, the cracks close completely on wetting. Plant roots are usually few or absent and are localized along the cracks. Slickensides and continuous stress surfaces also indicate low hydraulic conductivity. The low class can be divided into low and very low.

TABLE 3.1 – Conductivity Classes

Hydraulic conductivity class	Saturated hydraulic conductivity		
	µm/s	**m/s**	**in/hr**
Very High	>100	10 –4	14.2
High	10 - 100	10-5 -10-4	1.42 - 14.2
Moderately High	1 - 10	10-6 - 10-5	0.142 - 1.42
Moderately Low	0.1 - 1	10-7 - 10-6	0.014 - 0.142
Low	0.01 - 0.01	10-8 - 10-7	0.001 - 0.014
Very Low	< 0.01	<10-8	<0.001

SOURCE: Soil Survey Manual, USDA Handbook No. 18, 1993.

Hydraulic conductivity may not describe the ability of soils in their natural setting to dispose of water internally. A soil may have very high conductivity yet contain free water because there are restricting layers below the soil or because the soil is in a depression where water from surrounding areas accumulates faster than it can pass through the soil. The water may actually move very slowly despite the soil's high conductivity. Actual rate of water movement is a product of the hydraulic conductivity and the hydraulic gradient. In other words, it must have somewhere down-gradient for it to go to drain effectively. Saturated hydraulic conductivity cannot be used to describe water movement under unsaturated conditions.

Unsaturated Flow: Unsaturated conditions exist when the soil water is under tension (negative pressure). This occurs when adhesion and capillarity are the primary forces acting on the water. Gravity is proportionally less significant. The term tension is synonymous with soil suction, in that soil draws water to itself rather than gravity pulling water through the soil. Force is applied to soil water under tension when a difference in negative pressure exists (pressure gradient). Water moves from zones of lower tension to zones of higher tension. This would mean that water would move from a wetter zone to a dryer zone if all other conditions remained the same. Generally, soil materials having smaller pores hold water at a higher tension than materials having larger pores. As an example, water would tend to move from a sandy loam into a silt loam if both materials contained the same percentage of water. Flow from the sandy loam to the silt loam would proceed until both materials achieved equal negative pressures. At this point, the silt loam would contain a greater percent of water than the sandy loam.

The direction of water flow in soil is governed by the sum of the negative (tension or suction) and the positive (gravity) forces acting on the water. Under saturated flow in soil, the direction is nearly always in the same direction of the hydraulic gradient. However, the direction will be determined by the relative strength of the forces under unsaturated flow. Negative pressure gradients can induce flow in any direction -- up, sideways or down. Gravity will have its influence and will tend to steer a greater portion the unsaturated flow toward the center of the earth. The influence of gravity on the direction of flow increases as the negative pressure approaches zero. At zero (saturated flow), the tension forces due to adhesion and capillarity drop out and soil water will flow in the direction of the gravitational gradient.

The rate of unsaturated flow is determined by the sum of both the negative and positive forces acting on the water and the unsaturated hydraulic conductivity. Unsaturated hydraulic conductivity is not a constant, as is hydraulic conductivity. It is dependent upon soil water content and decreases with decreasing water content. It is also influenced by the different effect of soil water tension on the geometry of flow path patterns for different soil textures. Because of these complexities, there is no table of rates or classes provided for unsaturated hydraulic conductivity. It is always less than saturated hydraulic conductivity for the same material.

Measurement: Saturated hydraulic conductivity measurements are made on cores of natural soil material. A low head of water is maintained on the saturated core and rate of water flow is measured. In many soils, the hydraulic conductivity does not remain constant. It changes with various chemical, physical, and biological processes. It is extremely difficult to saturate a soil with water without trapping some air. Entrapped air bubbles may block pore passages. Temperature changes may cause the flowing water to dissolve or release gas, and will also cause a change in volume of the gas phase, thus affecting conductivity. Furthermore, the hydraulic conductivity is not an exclusive property of the soil. It also depends upon the attributes of the soil solution, that is, its viscosity and fluid density. These properties of the fluid may vary with temperature, pressure, and chemical composition. Since measurements are difficult to make and are available on relatively few soils, estimates are based on soil properties and on correlations between these properties and hydraulic conductivity.

Making estimates of permeability. The soil properties that affect hydraulic conductivity are total porosity, distribution of pore sizes and the tortuousity (flow path of water)--in short, the pore geometry of the soil. Since the pore geometry of a soil is not readily observable or measurable, other properties related to pore geometry are used to make estimates of permeability. These are texture, structure, pore size and density. Color is also an important property because it relates to organic matter and mineralogy which in turn has an effect on structure and porosity.

In making estimates, first evaluate the soil characteristics that exert the greatest control on permeability. For many soils this may be texture. If texture exerts the greatest control, relate permeability with texture and then modify the classes on the basis of other observed properties. **Table 3.2** is a guide for predicting the class of saturated vertical hydraulic conductivity from soil properties.

These general relationships are adjusted up or down depending on structure, pore size, density, organic matter, clay mineralogy and other observations within the profile such as consistence, dry layers in wet season, root mats or absence of roots, and evidence of perched water levels or standing water.

TABLE 3.2 – Guide to predict the class of saturated vertical hydraulic conductivity from soil properties

Class	Soil Properties
Very High	- Fragmental - Sandy with coarse sand or sand texture, and loose consistence - More than 0.5 percent medium or coarser vertical pores with high continuity
High	- Other sandy, sandy-skeletal, or coarse-loamy soil material that is very friable, friable, soft or loose - When very moist or wet, has moderate or strong granular structure or strong blocky structure of any size or prismatic finer than very coarse, and many surface features except stress surfaces or slickensides on vertical surfaces of structural units. - 0.5 to 0.2 percent medium or coarser vertical pores with high continuity.
Moderate	-Sandy in other consistence classes except extremely firm or cemented. - 18 to 35 percent clay with moderate structure except platy or with strong very coarse prismatic and with common surface features except stress surfaces or slickensides on vertical surfaces of structural units - 0.1 to 0.2 percent medium or coarser vertical pores with high continuity
Moderately Low	- Other sandy classes that are extremely firm or cemented - 18 to 35 percent clay with other structures and surface conditions except pressure or stress surfaces

	- Greater than or equal to 35 percent clay and moderate structure except if platy or very coarse prismatic, and with common vertical surface features except stress surfaces or slickensides - Medium or coarser vertical pores with high continuity percent but less than 0.1 percent
Low	- Continuous moderate or weak cementation greater than or equal to 35 percent clay and meets one of the following: weak structure; weak structure with few or no vertical surface features; platy structure; common or many stress surfaces or slickensides
Very Low	- Continuously indurated or strongly cemented and less than common roots - Greater than 35 percent clay and massive or exhibits horizontal depositional strata and less than common roots

Soil-Water States

Soil-water relations are important in evaluating plant response and engineering behavior and in understanding soil development. Because of precipitation, plant rooting habits, temperature gradients, and evaporation and transpiration, the soil water conditions are constantly changing. They may change significantly in a few hours or days or only over a season of a year or longer. Soil water conditions may change so slowly that they appear to be constant.

Soil-water state describes the moisture condition of a layer of soil. Three soil-water states-- dry, moist and wet --can be estimated in the field.

When a soil is described, the soil-water states throughout the soil are recorded in order to relate them to soil properties. Ideally, the soil-water states should be observed for each soil periodically to determine the annual pattern.

Soil is dry when the water is held at a tension of 1,500 kPa (15 bars) or more. Most plants cannot extract enough water at these high tensions to stay alive. The term "air-dry" means that the soil is in equilibrium with the air. The amount of water in the soil when “air-dry” varies with the humidity of the air. When soil is “air-dry”, the water is held at a tension much greater than 1,500 kPa.

Soil is moist when the water is held at a tension between 1 kPa and 1,500 kPa. The use of 1 kPa tension to separate the moist and wet states is arbitrary, but at tensions less than 1 kPa all, or most all of the total pore space in most soils is completely filled with water. Soil properties change appreciably with varying water content within the moist state. For some purposes it may be useful to divide the moist class into slightly moist and very moist using 33 kPa as the division point. Tension of 33 kPa approximates "field moisture capacity" which has been measured on a great number of soils.

Soil is wet when it contains water, including free water, at a tension of 1 kPa or less. Free water is at a tension of 0 kPa or less. Depth to free water is defined as the depth to water standing in a freshly dug uncased borehole after adequate time has elapsed (about 1 day) for the water level to adjust to the surrounding soil. The lower boundary of a zone of free water is established by sinking two or more bore holes cased to different depths. In practice, the depth to and thickness of zones of free water are estimated and bore holes are generally not used.

Zones of free water range greatly in thickness and continuity. Free water may be restricted to a single thin zone near the surface. In soils having a fragipan, free water is often above the fragipan but not immediately below it. Two or more layers containing free water may be separated by a zone without free water, as in soils that formed in stratified alluvium that is mostly clayey but contains loamy and sandy bands. In many soils, free water is continuous from its highest level to below the depth normally observed during a soil survey.

Several kinds of field clues can be used to determine the soil-water state. In wet soil, water films on sand grains and peds are visible without magnification. Excavation through a wet layer causes water to flow down the exposed face, though flow may be very slow and confined to large pores and cracks. Free water may not be evident where there are no large pores that hold water at very low tension and the hydraulic head on the free water is slight. Many layers of high bulk density contain very little pore space that drain under 1 kPa tension and therefore, although wet, do not exhibit evidence of free water.

Features of the Landscape and the Soil Surface

The setting of a soil (i.e., its position in the landscape) and the surface features of the soil itself deserve emphasis. Landscape features strongly influence the distribution of soils. From the landscape, the properties of the soil and the location of soil boundaries can be deduced. Features of the soil surface, when considered along with internal properties of the soil, are important in making predictions about soil use, management and behavior. The kind of landform or the part of it that a particular soil occupies should be described so that the reader will know how that soil fits into the landscape.

Surface features other than rock fragments are discussed in this section. Rock fragments, both on top of the soil and within it, are covered in the section **"Soil material and rock fragments"** in Chapter 2.

To list all of the terms used to characterize landforms is beyond the scope of this manual. The literature of soil science, geology and geomorphology guides the choice and definition of terms.

Relief refers to the elevations or differences in elevation considered collectively, of a land surface on a broad scale.

Micro-relief refers to differences in relief measured over distances of feet or yards. In areas of similar relief, the surface may be nearly uniform or it may be interrupted by mounds, swales, or pits that contrast sharply with the broad pattern of relief. Examples include the cradle-knoll micro-relief created when trees are blown over; consisting of the knoll left by the earth that clung to the roots of the tree when it was uprooted and the depression from which it came.

Descriptions of micro-relief should indicate whether the mounds or depressions are closed, form a network or are in a linear pattern. If mounds rest on a smooth surface, their size and spacing should be described. At a specific site within an area having micro-relief, it is important to note whether a described soil is at a high point, on a slope, in a depression or at some combination of these places. Internal soil properties in mounds may be quite different from the properties in depressions.

To some, the term "topography" means the same thing as "relief," but is commonly used for features disclosed on a contour map. It should be avoided in describing soils, and the more specific terms: relief, landform or slope, used instead.

Soil Slope

The slope of the soil surface has several distinct properties: gradient, complexity, configuration, length and aspect. In soil science, slope is considered a property of the soil, not a landform like a ridge or a valley side.

Slope influences the retention and movement of water, transfer of heat, movement of soil material, rate and amount of runoff, potential for soil slippage and accelerated erosion, ease with which machinery can be used, soil-water state and perhaps other factors. None of these, however, is a function of slope alone. Evaluation of the significance of the slope of a soil must be made in relation to the other properties of the soil and to the environment.

Surface configuration has two components. One is in a direction roughly parallel to the contours of the landform; that is, the shape seen by looking at the landform (or the contour lines on a map) from directly overhead. The other component of configuration is in a direction perpendicular to the contours; that is, the shape of the slope as seen from the side. The shape parallel to the contours is less commonly consistent for a soil than is the shape perpendicular to the contours.

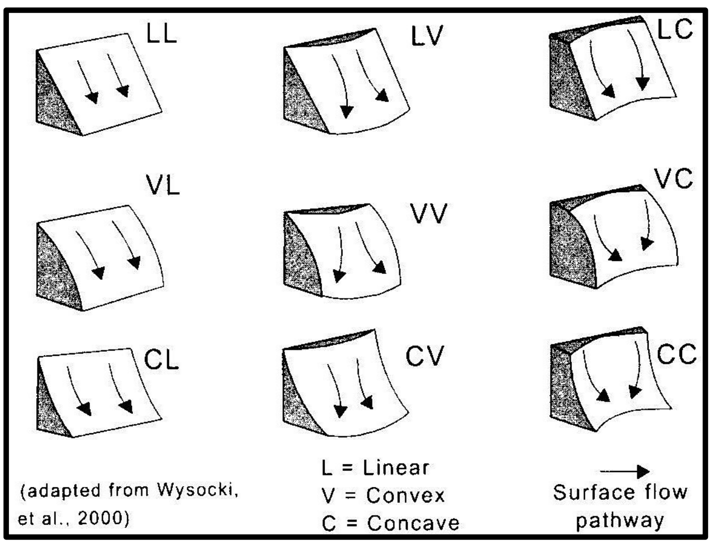
The shape parallel to the contours (across the slope) can be described by the shape of the contours. The shape is linear if contours are substantially a straight line, as on the side of a moraine. An alluvial fan has a convex contour, as does a spur of the upland projecting into a valley. Coves on a hillside and a cirque in a glaciated landscape have concave contours. Where the contour is convex, runoff water tends to spread laterally as it moves down the slope. Where the contour is concave, runoff water tends to be concentrated toward the middle of the landform.

The shape of the surface at right angles to the contours (up and down the slope) may also be described as linear, convex, or concave. Shape in this dimension is usually identified simply as slope shape in contrast to slope contour in the other dimension. The surface of a linear slope is substantially a straight line when seen in profile at right angles to the contours. The gradient neither increases nor decreases significantly with distance. On a concave slope, gradient decreases down the slope, as on foot slopes.

Runoff water tends to decelerate as it moves down the slope, and if it is loaded with sediment, the water tends to deposit the sediment on the lower parts of the slope. The soil on the lower part of the slope also tends to dispose of water less rapidly than the soil above it. On a convex slope such as the shoulder of a ridge, gradient increases down the slope and runoff tends to accelerate as it flows down the slope. Soil on the lower part of the slope tends to dispose of water by runoff more rapidly than the soil above it. The soil on the lower part of a convex slope also is subject to greater erosion than the higher-lying soil.

The configuration of the surface of a soil may be described in terms of both the shape of the contour and the shape of the slope. For example, a surface can be described as having a convex contour and a convex slope (an alluvial fan) or a linear contour and a concave slope (the base of a moraine). See **FIGURE 3.3**

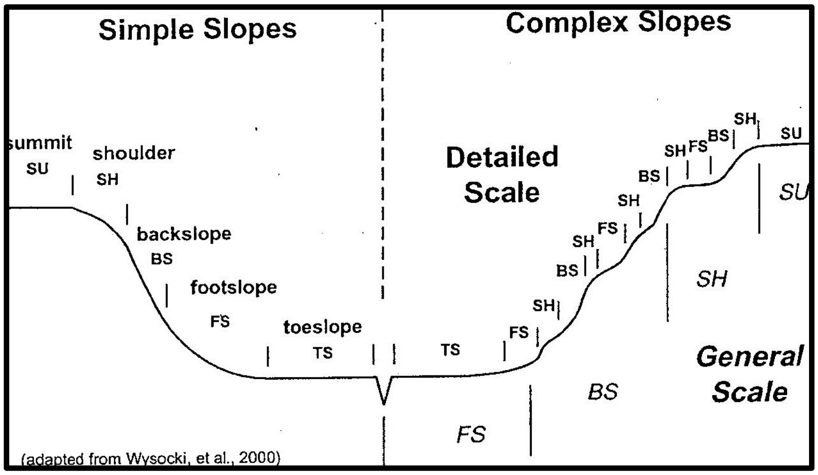
The position on a hill is described by identifying the landform. A landform is a three-dimensional part of the land surface, but a hill can be sliced into a two-dimensional profile for the purpose of reporting position. See **FIGURE 3.4**



Down Slope (Vertical)	**Across Slope (Horizontal)**	Code
concave	concave	CC
concave	convex	CV
concave	linear	CL
convex	concave	VC
convex	convex	VV
convex	linear	VL
linear	concave	LC
linear	convex	LV
linear	linear	LL

Figure 3.3 - Slope shape is described in two directions: 1) up and down slope (vertical), and 2) across slope (horizontal).

To illustrate how landscape position can affect and indicate the development of a soil, the silt loam over sandy loam till example that was cited previously can be used again. On the high gentle convex slopes, runoff of excessive precipitation is not restricted, and no runoff is received from above. Consequently, the silt loam should not be eroded and should not be wet enough to have retarded soil development. The surface layer should be thick and dark colored but not black unless forested, the subsoil texture should show clay enrichment, soil structure should be well developed, silt coatings may occur on some ped faces and redoximorphic features should not be apparent until the dense slowly permeable till is encountered.



Position	**Code**
summit	SU
shoulder	SH
backslope	BS
footslope	FS
toeslope	TS

Figure 3.4 - Hillslope Profile Position: Two-dimensional descriptors of parts of line segments (slope position) along a transect that runs up and down the slope.

On the steep side slopes, erosion may have stripped off all or most of the silt loam, with more soil formation occurring in the sandy loam till. The surface layer will be thinner, less gray and have more sand and stones. The subsoil layer will be thinner, have more sand and stones but less clay enrichment. Soil structure will not extend as deep, and the upper part of the glacial till will be darker, less dense, more friable and without redoximorphic features mottles.

On the concave foot slopes, erosion from above may have deposited and stratified materials on the till before the silt loam was blown in. On-going erosion continues to deposit soil particles from above. Where erosion from above is severe, the resulting structure will be weak and thin or medium throughout. Dark colored topsoil materials may extend quite deep and be intermixed with other eroded materials. Redoximorphic indicators of soil saturation may appear shallow in the subsoil or surface layer and as wetness is prolonged, the surface layer becomes blacker from organic material that is less decomposed. Where water ponds on the surface for extended periods, peat and muck soils form from the organic material that is deposited faster than it can be decomposed by anaerobic bacteria. Integration of these examples illustrates how different soils blend together to form a continuum on the landscape, through gradual transition from one soil's range of characteristics to another.

Contrasting material. (Banding and stratification) Contrasting layers of unconsolidated material affect soils and soil patterns in several ways. The material may differ in pore-size distribution, particle-size distribution, color, mineralogy, density or other properties. Some of the differences may not be obvious. Some deposits are clearly stratified, such as some lake sediments and glacial outwash where the discontinuities may be sharply defined. Banded sandy soils are readily identified by color differences but not easily interpreted.

The most important effect of banding and stratification that is described in this manual is that of altering water movement. A layer of coarse sand and gravel over a layer of fine sand will tend to transmit water vertically through large pores until it reaches the fine sand. The fine sand because of pore size, cannot accept the water as fast as it is added and the water will begin horizontal movement in the coarser material as well as build up over the fine sand. Many times the horizontal flow will exceed the vertical flow, especially on sloping sites.

Textural differences are not so readily determined in the field. Often a band will feel texturally, the same as the material over or below it. In these instances careful determination should be made as to differences in structure or consistency of the band. As an example, in most instances darker colored bands in a lighter colored sandy soil will be found to be more dense and firm. The restrictive nature of bands in some cases is not usually supported by the presence of soil mottles. Water reaches the band rapidly, moves through the band at a slower rate and out horizontally. Oxygen is never totally removed from the band and reduction does not take place.

Where conditions of stratification or banding are encountered, the hydraulic conductivity of a total soil profile should be based on the characteristics that most restrict the water movement.

Bedrock Condition

Bedrock is discussed in this section under three general headings: granite and other igneous bedrock, limestone bedrock and sandstone/shale bedrock. Each of these has been defined in Chapter II and will be only briefly expanded in regard to how they relate to water movement and of domestic wastewater.

Two major questions must be addressed when interpreting near surface bedrock conditions: when is material considered bedrock and what is the nature of the bedrock?

Nature of the bedrock refers to the degree it is cracked or fractured. All bedrock has a degree of cracking or fractures; however, limestone is by far the most severe. Those fractures usually are such that water can find its way directly to groundwater that is moving through the limestone in passageways. Where insufficient natural soil overlies bedrock, complete treatment of wastewater may not take place before it reaches the groundwater.

Definitions of the bedrock condition are provided in Chapter SPS 381, Wis. Adm. Code. Interpretation of when granite, limestone or platy sandstone bedrock is encountered is based on the volume of soil material (fine earth less than 2 mm) present in a soil horizon versus the volume of consolidated material. At least 50 percent of the soil horizon must be made up of soil material. Any less than 50 percent is considered insufficient for filtration and purification of effluent.

Monolithic sandstone often grades from a weakly cemented state to hard with depth. The weakly cemented sandstone has very low porosity, does not transmit water well and therefore is treated the same as hard sandstone. The accepted means of determining the upper limit of sandstone bedrock is to identify where resistance to penetration by a knife blade is encountered.

Vegetation

Vegetation observed in the field, can be of great help in interpreting soil conditions. The growth of native vegetation as well as cultivated crops can aid in recognizing certain soil conditions. Relationships between soil and plants must be interpreted with caution. However, certain key indicator plants can infer soil condition.

Wetness or prolonged water retention is generally observed by the presence of plants that require or can tolerate long periods of wetness (hydrophytes). The presence of alders or sedges should alert the observer to a condition of slow soil permeability. The presence of wetland plants on a side-slope usually indicates water is being discharged to the surface as a result of an impermeable horizon within the soil profile. The tolerance of various plant species to soil wetness has been extensively studied and vegetation composition is used in identifying jurisdictional wetland boundaries. Vegetation, alone, should never take the place of a profile examination. However, its presence should not be overlooked either.

CHAPTER 4

Use of Soil Survey Information

Changes in the kinds of use and intensity of soil utilization are a part of the story of civilization. From earliest time we searched for lands that supported the plants and animals we gathered for food. With domestication of plants and animals we searched for lands that were suitable for agricultural production. This search was generally on a hit-or-miss basis with no written record of soil features and qualities to aid in its selection. There was no organized body of knowledge that we have come to know as soil science. This is not to say that nothing was known about soils. Early settlers in this country used tree growth as a guide to soil productivity and used position in the landscape for siting cemeteries to avoid having to dig graves in sites that were often wet. Indeed we had learned a great deal through experience over the centuries.

With the application of chemistry, physics, biology and other sciences to soils, it became possible to establish various means of classifying soils so as to identify one soil from another. At the turn of the century there was an increasing awareness of the bonds between land and society. In an attempt to find the underlying causes of some agricultural problems and in an effort to build a solid foundation for future research, the U.S. Department of Agriculture, in cooperation with the various state experiment stations, began at that time a systematic investigation of our soil resources. This investigation assumed the form of a national inventory and survey and involved classifying and mapping of soils.

Soil Classification

A classification is an ordering or arrangement of objects in the mind and distribution of them into compartments. Soils are classified and placed into compartments (categories) according to profile characteristics as influenced by the five soil forming factors (time, parent material, climate, relief or slope and plant and animal life) that influence soil formation and the resulting properties of the soil.

In the past there have been a number of classification systems ranging from general to complex. General systems are based on single soil characteristics such as texture, color, landscape position or mode of (parent material) origin. Some of these characteristics are as follows:

1) Soil by texture: sandy, clayey, loamy, and organic soils.
2) Soil by color: red, brown, yellow and black soils.
3) Soils by landscape position: upland, slopes, terrace, flood plain and bog.
4) Soils by origin
   a) Alluvial - transported and deposited by water in recent geologic time.
   b) Glacial till - transported and deposited by ice during a glacial period.
   c) Aeolian - transported and deposited by wind (loess or silt).
   d) Residual - weathered in place, near or directly above bedrock.
   e) Lacustrine - deposited in lakes or generally quiet backwaters of glacial periods.
   f) Outwash - water transported and deposited during glacial periods by post glacial

streams (or moving water).

The present classification system used by soil scientists of the Natural Resource Conservation Service of the U.S. Department of Agriculture (National Cooperative Soil Survey) was developed over many years and is flexible in that it can change as additional knowledge is gained. The system provides the means to place boundaries between soil bodies at a place where there has been or is now a significant difference in one or more soil features that are caused by differences in the soil forming factors: climate; parent materials; living organisms including people; age of the landform; and relief, primarily through its influence on the soil moisture conditions. The soil series and phase are the lowest categories in this classification system and are the units delineated on soil maps, and are of the greatest importance to most people. These units are explained as follows:

Soil Series - a soil series is a named group of soils (e.g. Plainfield) having soil horizons (layers) similar in differentiating characteristics (color, texture, structure, consistence, organic matter content, etc.) and arrangements in the soil profile, except for texture of the surface soil. Soils of the same series, having similar surface textures, are included in a single soil (e.g. Plainfield Loamy Sand). Soil types now have little significance in detailed mapping. Series names are usually the names of a town or geographic feature near the place where the series was first observed.

Soil Phase - a phase of a soil is a unit of classification used in detailed mapping, designed with our use in mind. For example, "Plainfield, Gravelly Variant" indicates a soil with a slightly different substratum. A county having 30 soil series may have 150-200 map units, most of which are phases.

Soil Complex - a soil complex consists of two or more soil series that occur in such an intricate pattern that it is not possible to map them out at the scale used.

Map Units on the detailed soil maps in a published soil survey represent areas on the landscape and consist of one or more soils for which the unit is named. Most map units include small scattered areas of soils other than those for which the unit is named, called inclusions. Some of these included soils have properties that differ substantially from those of the major soil or soils. Such differences could significantly affect use of the soils in the map unit.

Soil Maps and Their Use

Soil maps are classified into two general types: reconnaissance and detailed. Reconnaissance maps are generally of a scale of one inch to the mile or less and are made in the field by studying soils at wide intervals. Map units consist usually of soil associations (several geographically associated soils) and land types; e.g. wet marsh, stony or steep land. Reconnaissance maps are useful for general planning purposes.

Detailed maps are usually prepared on air photos at a scale of 3.17 inches to one mile. Soil scientists, who are usually graduates of an agricultural or natural resources college, make soil surveys and the resultant maps. To make a detailed soil survey, the soil scientists walk over the land carrying an auger, spade, hand level, air photo field sheet and other equipment essential to a detailed study of the soil. They observe the landscape and soil profile (horizon) characteristics at various intervals and delineate areas (map units which would be the soil type, phase or complex) on the field sheet.

Periodically, soil scientists examine soil profiles and record their observations by means of a detailed description. Soils typical of an area (map unit) mapped are described in detail and notes are made regarding their site characteristics and their use and behavior when used for various purposes. Each soil is also compared with similar soils in other areas so that the results of research and experience with a particular kind of soil can be used to predict its behavior wherever it may occur in a process called soil correlation.

Soil maps are very good tools for preliminary investigations when understood and used properly. A good example would be using a detailed soil survey to study a proposed POWTS area prior to doing any field investigation. Such a study would provide expected site conditions such as the possibility of high groundwater, bedrock, steep slopes or impermeable soils and the extent of obviously suitable soils as well as obviously unsuitable areas. Expected conditions certainly help in determining equipment and time requirements for conducting a field investigation. The soil map can also be helpful in eliminating tracts of land that have severe limitations for subsurface disposal of effluent from septic systems and in locating areas that may be more suitable. The use of the Soil Survey is a planning tool for, not a replacement of field investigation.

Preliminary Soil Reports

During the survey, as small areas or blocks are completed, copies of the field sheets along with interpretative materials are available for use. Interim reports are compiled for some townships and counties for use until the final soil survey report is published. Ten northwestern Wisconsin counties are currently in the process of publishing an original Soil Survey. During this interim period, copies of the field sheets and interpretations are generally provided in a single sheet format for each soil. It should be remembered that those single sheet interpretations are for the model or central concept of the soil series and should only be used as a guide for what to expect prior to doing on-site evaluations. Unpublished field sheets and interim soil survey information can be used in lieu of the published report until it is available. The county office of the Natural Resource Conservation Service can be contacted for availability of soil information.

Published Soil Surveys

The final document, the published soil survey (either on paper or in digital format), contains all the soil maps of the survey area, detailed descriptions of the soils and interpretative sections for the use and management of the soils. Major sections are included for cropland, woodland, engineering, wildlife and recreation. The engineering section will include sample test data, a table of the estimated soil properties and many contain ratings indicating the degree and type of limitations for POWTS. However, these limitations cannot be used alone for siting soil absorption systems as they do not necessarily reflect the requirements of the current Wisconsin Administrative Code. As published surveys are updated, revised tables more closely reflecting the administrative code will be included.

Limitations of Soil Maps

In order to properly use a soil map, one must definitely know and understand the very important limitations it has. To disregard or be unaware of the limitations often results in costly losses of time and money. Remember, the soil survey is not the "final word" but a beginning tool for on-site waste disposal planning. Some of the limitations are:

- Early soil surveys were completed prior to the present and ever-expanding knowledge of soils and do not reflect current concepts and interpretations.
- In some counties certain soils are not separated as to those well drained versus those moderately well drained.
- Because of scale limitations, areas of two to three acres or less are seldom shown on a soil map and are described as an inclusion in a mapping unit. The soil survey mapping unit description must be checked to determine any significantly different inclusions. Usually, significantly different smaller areas such as sand, erosion, wetness and rocks are shown by spot symbols which are identified in soil survey legends.
- Soil scientists do permit some inclusion of other soils in the defined map units. As a rule, these inclusions do not exceed 15 percent. These may be differences in slope class, depth range, drainage class or some other characteristic. These inclusions are necessary because they do, in fact, occur in nature.
- Soils are a continuum on the landscape. That is, one soil blends into an adjacent soil and seldom is the boundary between soils absolute. Thus, we can expect a small range of characteristics throughout a mapping unit.
- Soil scientists observe road cuts and deep excavations whenever possible, but most observations do not exceed a depth of five feet. Many soils can be classified by observing the soil to a depth of 40 inches.

Because of the above factors, final decisions concerning the acceptability of a small parcel of land for a specific use should not be made without conducting a site investigation. Certainly a lot or a soil absorption site is very small and on-site investigations must be made.

Procedure for Using a Published Soil Survey

The following is a brief outline of a procedure to follow in gathering soil and other information about a tract of land on which a soil survey was completed. Published soil survey reports are available for many counties from the local Land Conservation or USDA-Natural Resources Conservation Service office, which are often located together. Local libraries may also maintain reference copies of soil survey reports. Contact information for local NRCS offices is available in the phonebook or on the internet at: www.nrcs.usda.gov

Locating a hard copy of a county Soil Survey has become increasingly difficult as they are no longer being produced. All Soil Surveys for Wisconsin are now available digitally online. The Web Soil Survey shows soil boundaries overlaid on an air-photo background, where soil interpretive maps and detailed soils information can be generated or viewed online. It can be found on-line at: *https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm*

Specific instructions on how to use a soil survey are found at the very beginning of each published survey or in the case of the Web Soil Survey, online.

1) Locate the proper tract of land.

   a) Legal land description-township, range and section are used.
   b) Locate the tract on the photo index map. This index will provide the number of the map sheet on which the tract is shown.
   c) The tract can then be located on the proper map sheet by reference to the location of the section and section corners, roads, railroads, streams, buildings, and other features shown. (On the Web Soil Survey, zoom in to the area until you can locate the tract by features shown on the air photo base. Select an Area of Interest or "AOI".)

2) List the mapping unit code symbols and other information such as wet spots, escarpments, and sand spots.

3) Obtain the soil name from the Guide to Mapping Units Section. You now have the mapping unit name. (On the Web Soil Survey, once an "AOI" has been selected, reports including map unit name and other properties can be generated by clicking on the "Soil Map" and "Soil Data Explorer" tabs respectively.)

4) With the mapping unit name you can go to that portion of the report containing the written description. The first thing noted is that the soil series is described followed by each mapping unit within the series. Read the series description first and then that of the specific mapping unit. Be sure to check for any inclusions and then having the inclusion name, read the descriptions for any inclusions. It is important that the description of any inclusion be examined to determine the drainage class of the soil.

Soil drainage classes

Seven drainage classes are recognized. The first two, excessively drained and somewhat excessively drained, describe soils that are dry longer than is typical for the dominant soils of an area. Well drained soils are neither unusually dry nor unusually wet. Increasing degrees of wetness limit use of moderately well drained, somewhat poorly drained, poorly drained, and very poorly drained soils.

The seven classes are:

1) Excessively drained: These are soils that have very high and high hydraulic conductivity and low water holding capacity. They are not suited for crop production unless irrigated. Seasonal or periodic saturation is at greater than five feet.

2) Somewhat excessively drained: These soils have high hydraulic conductivity and low water holding capacity. Without irrigation only a narrow range of crops can be grown and yields are low. Seasonal or periodic saturation is at greater than five feet.

3) Well drained: These soils have intermediate water holding capacity. They retain optimum amounts of moisture, but they are not wet close enough to the surface or long enough during the growing season to adversely affect yields. Seasonal or periodic saturation is at greater than five feet.

4) Moderately well drained: These soils are wet close enough to the surface for long enough that planting or harvesting operations or yields of some field crops are adversely affected unless artificial drainage is provided. Moderately well drained soils commonly have a layer with low hydraulic conductivity, a wet state relatively high in the profile, additions of water by seepage, or some combination of these conditions. Seasonal or periodic saturation is at three to five feet.

5) Somewhat poorly drained: These soils are wet close enough to the surface or long enough that planting or harvesting operations or crop growth is markedly restricted unless artificial drainage is provided. Somewhat poorly drained soils commonly have a layer with low hydraulic conductivity, a wet state high in the profile, additions of water through seepage, or a combination of these conditions. Seasonal or periodic saturation is at one to three feet.

6) Poorly drained: These soils commonly are wet at or near the surface during a considerable part of the year, so that field crops cannot be grown under natural conditions. Poorly drained conditions are caused by a saturated zone, a layer with low hydraulic conductivity, seepage, or a combination of these conditions. Seasonal or periodic saturated is at less than one foot.

7) Very poorly drained: These soils are wet to the surface most of the time. These soils are wet enough to prevent the growth of important crops (except rice) unless artificially drained. Seasonal or periodic saturation is at less than one foot.

Site Investigation

During the first surface observation of a site, some preliminary observations should be made. A view of the topography and vegetation may indicate the location of unsuitable conditions such as wet soils, bedrock outcropping and steep slope areas. Some other factors to be considered in site selection are the location of lakes, streams, wells, buildings and property lines. These factors and other aspects of site investigations are described in more detail in Chapter 6.

CHAPTER 5

Legal Land Descriptions of Wisconsin Real Estate

The familiar checkerboard pattern of the fields in Wisconsin is the result of the Public Land Survey System, referred to as PLS or PLSS, which is the basis for the original description of all land in Wisconsin and surrounding states. In Wisconsin, the PLS was conducted by land surveyors on the ground during the years 1833 to 1856 and represents the technology and surveying practices of that time. Anyone working with Wisconsin real estate should have knowledge of the methods employed in making the original survey and the meaning of present descriptions based on that survey.

The method employed in making the survey in Wisconsin was to run parallel east—west lines across the state at six mile intervals, starting with the southern boundary of the state, which is called the base line. Parallel north—south lines were also run across the state at six mile intervals, thus dividing the state into six mile squares known as public land survey or congressional townships. While it is possible to run continuously parallel east—west lines across the state, it is impossible to do the same with north—south lines, as all north—south lines meet at the north and south poles. Accordingly, guide meridians have been established running north and south.

Do not confuse townships (T4N, T5N, etc.) with civil towns. In Wisconsin the word town refers to a politically defined area of land, sometimes called a civil town. A congressional township's boundaries cannot he changed (except by an act of Congress), whereas town boundaries are frequently changed. Towns in Wisconsin are unincorporated (usually rural) areas outside villages and cities.

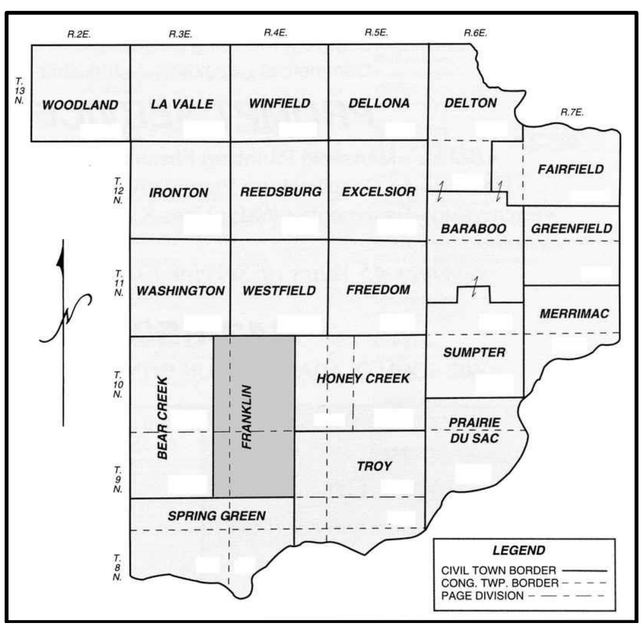


FIGURE 5.1 – Political Township vs. Congressional Township

This terminology tends to cause a great deal of confusion. Many incorrectly refer to towns as "civil or political townships" because in many other states (such as Illinois and Michigan), such political units are also called townships. A (civil) town may be larger or smaller than a township. As cities grow in size, land may be annexed from part of the surrounding town or towns. Boundaries of adjacent towns may also be changed over time. As an example, in Sauk County, the civil Township of Franklin includes T9N & T10N and R3E & R4E, while civil Township of Excelsior is the same as congressional township of T12N R5E (**Figure 5.1**).

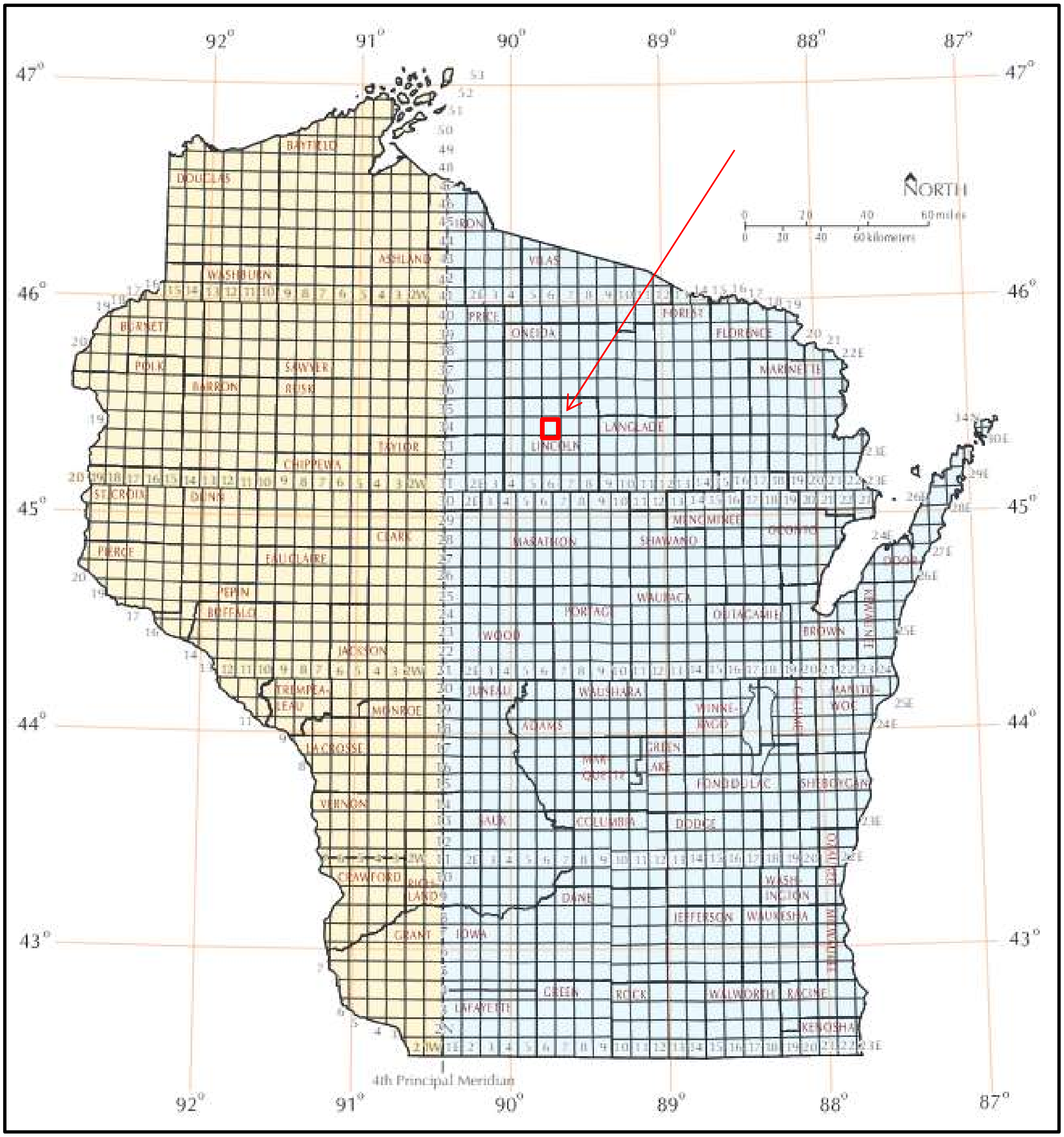


FIGURE 5.2 – Township numbering in the State of Wisconsin

The townships in Wisconsin are numbered north from the base line (Wisconsin-Illinois border) and east or west of the fourth Principal Meridian, a north-south line which runs about 50 miles west of Madison. Measurement east or west of the principal meridian is referred to as range, while the measurement north of the base line is referred to as township. **Figure 5.2** shows the numbering of townships in Wisconsin.

Townships are divided by parallel north—south line and parallel east—west lines at one-mile intervals. This is intended to create 36 squares, measuring one mile on each side and containing one square mile of 640 acres each, these squares are called sections. They are always numbered in the same pattern, starting in the northeast corner of the township, in a serpentine pattern as follows: see **Figure 5.3** numbering of sections.

Unfortunately, due in part to the curvature of the earth and the resulting bending of the north-south lines and due in part to the frontier conditions under which the original survey had to be made, the desired uniformity in the size of sections was often not achieved. There are many sections in Wisconsin that contain either a great deal more or a great deal less than 640 acres and that have boundaries which enclose an area that has little resemblance to a square. In addition, several adjustments were needed in the south-central portion of the state because a mistake was made in marking the south boundary of the state. The boundary does not extend correctly due east, as it is about one-half mile too far north on the Mississippi River and a similar distance too far south on Lake Michigan.

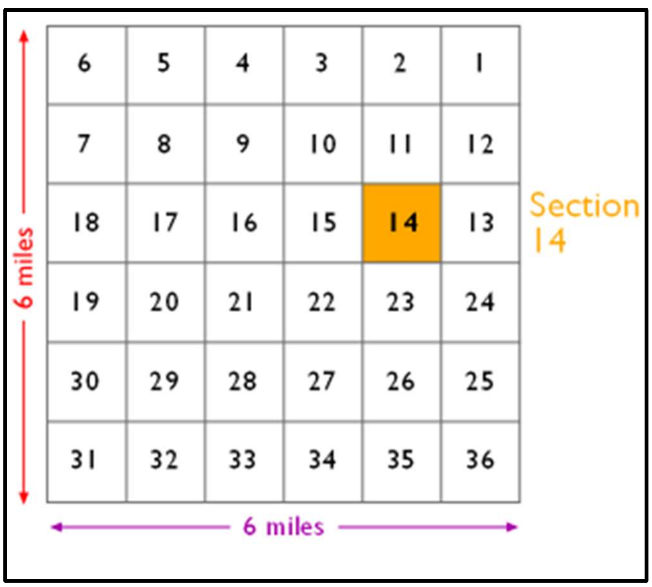


FIGURE 5.3 - Section numbering in a Township

The surveyors marked on the ground and described in their official notes the location of the corners and quarter corners of each section and these are the points from which we measure today. A surveyor who is employed to survey a particular section in a particular township today does not attempt to lay out a perfect square mile; the job is to locate the corners and boundaries of the section in the same place that they were located in the original government survey. Rural land is typically described as a fractional part of a section. A diagram depicting this method is shown below (**Figure 5.4)**.

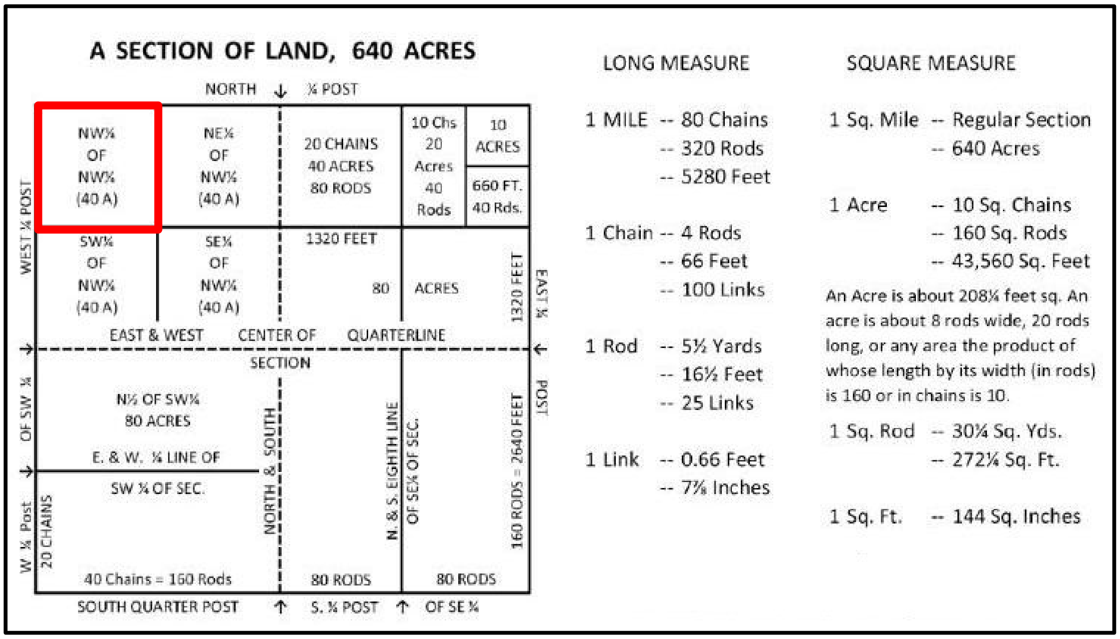


FIGURE 5.4 - Fractional parts of a section.

Assuming the section above is section 14, township 34 north and range 6 east; the parcel highlighted in **FIGURES 5.2, 5.3 and 5.4** would be described as the northwest quarter of the northwest quarter of section 14, T34N, R6E or more simply: NW NW 14-34-6. This, if the name of the county and state is added, is a complete legal description of the parcel. Wisconsin has only one base line and one principle meridian, therefore no other ~40 acre property can have the same description as NW NW S14 T34N R6E in the state. However, because of the variation in the size of sections, there is no certainty that the parcel contains 40 acres.

This example illustrates that when writing descriptions, start with the smallest unit and end with the largest unit. When given a parcel description to locate on a map, start with the large unit and end with the smallest. Locate the county, then the township, then section, the quarter section, etc.

If a township included a lake or river, there were parcels of land along the shore which were not large enough to be considered sections. These partial sections were called government lots and were usually identified by number. Where surveying left odd parcels of land along a township boundary, they were also designated as government lots. A typical description would be "Government Lot 3, Section 12, T7N, R9E, Dane County, Wisconsin."

Some parcels in Wisconsin, which were not included in the township and range system, occur along the Fox River near Green Bay and along the Mississippi River at Prairie du Chien, where earlier claims had been made and were already occupied when the government survey was conducted. An exception to the section numbering also occurs within the Stockbridge Indian Reservation boundaries in Calumet County, where lot numbers are used instead. In Wisconsin these older systems are known by a variety of different names: river frontage long lots, French land claims, Private Claims, Farm Lots, or French Long Lots (all of which were based on French land grants) and Indian reservation lots. In **Figure 5.5**, note the long parcels originating at the Fox River crossing the East River compared to the square sections on the right side of the map.

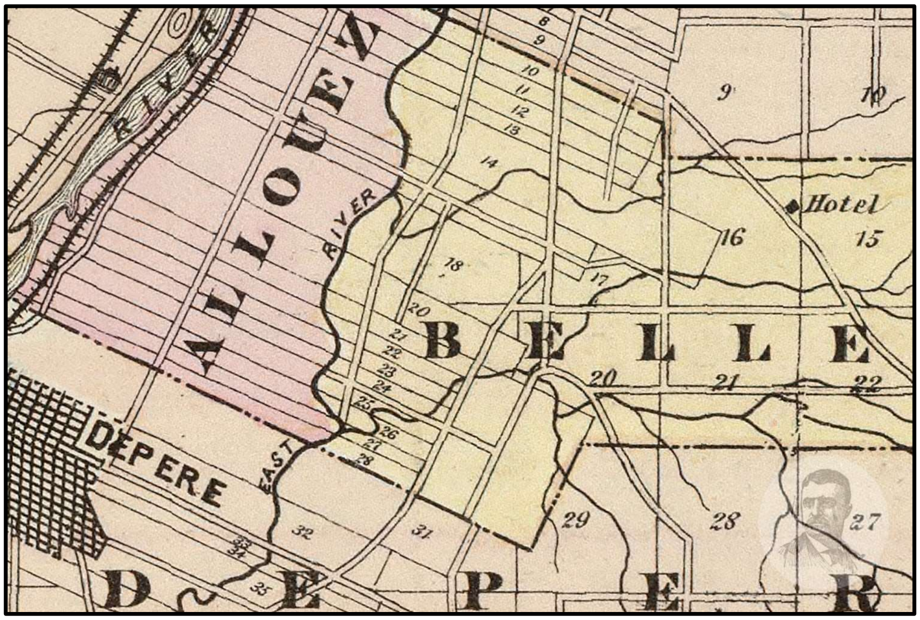


FIGURE 5.5 – Pre-survey Lots

Metes and Bounds

Any land description which starts from a known point and then follows the outside boundaries of the parcel, giving the direction and length of each side, is a "metes and bounds" description. A known point is any point which has a definite location that can be found. The typical known points in rural land are section corners or quarter corners. The typical known points in platted land are lot corners. Sometimes street or road intersections are used as known points, but if the road is later moved or the intersection altered, difficulty with the description is almost sure to follow.

Metes and bounds descriptions can be very complicated when a parcel has irregular or curved boundaries or when it abuts a body of water. Drafting of such descriptions requires specialized training and they are ordinarily made only by a registered land surveyor. People drafting descriptions today usually show distances in feet. Older descriptions will sometimes be seen however, in which distances are given in chains, links, rods or furlongs. Conversions for these can be found in survey manuals and **Figure 5.4**.

From the point of beginning, the metes and bounds description recites the course or direction and the length of each succeeding boundary line. The course is stated by giving the bearing of the line. The bearing of a line is its angular deviation generally measured in degrees, minutes and seconds from a true north and south line. **Figure 5.6** shows a circle, whose circumference contains 360 degrees, with each degree composed of 60 minutes and each minute composed of 60 seconds. The circle is divided into four (4) equal parts by a line running north and south and a line running east and west through the center.

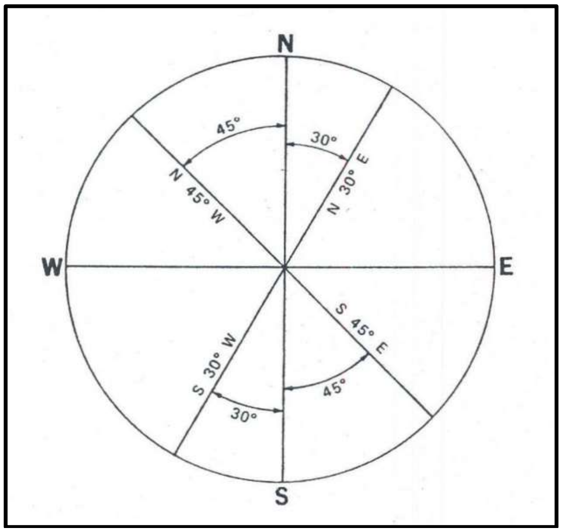


FIGURE 5.6 – Bearings of lines

The north and south line has a bearing of zero degrees, the east and west line bears 90 degrees. With the point of beginning at the intersection of the two lines, the bearing of the line is described by measuring easterly or westerly from the north and south line to a maximum of 89^0 59' 59". Thus, if the direction of a line measures 30 degrees from north toward east, the bearing of the line is stated as North 30 degrees East or simply N 30^0 E. If the angular deviation is greater than 90 degrees, the measurement is not given, for example, as 135 degrees but as 45 degrees east of south or S45^0 E.

The length of the line whose bearing has been given is then added and this completes the description for that particular line. This is repeated for each new line until the point of beginning is again reached and the enclosed area is described.

Wisconsin Coordinate System

Over many years the United States Coast and Geodetic Survey has been surveying the entire country by a system of triangulation and has mapped many known points and marked them on the ground. In 1935 it established a plane coordinate system for the various states based on these mapped and marked points. In 1963 the Wisconsin Legislature recognized the system and authorized its use. Thus it is possible to describe the starting point in a land description by its distance and direction from a point in the Wisconsin coordinate System. This approach has seldom been used in private land descriptions in Wisconsin.

Plats

When a parcel of land is platted, it is surveyed and divided into lots and blocks, each of which is given a number. The corners of each lot are marked on the ground and a detailed map is made giving all necessary metes and bounds descriptions for locating the boundaries of each lot. This map is called a plat and is recorded in the office of the Register of Deeds in the county where the land is located. Thereafter, the lot and block numbers are a sufficient description, as anyone needing the detailed description can secure it in the office of the Register of Deeds or from a copy of the recorded document. In some plats, the blocks are not numbered and the lot number is then sufficient. A typical description would be “Lot Six (6), Block Ten (10), Jones Addition to the City of Madison, Dane County, Wisconsin.”

The division of land within a period of five years into five or more parcels of 1½ acres each or less is a “subdivision” as defined in Chapter 236 of the Wisconsin Statutes: “Any subdivider or the subdivision’s agent who offers or contracts to convey, or conveys, any subdivision ... or lot or parcel which lies in a subdivision ... knowing that the final plat thereof has not been recorded may be fined not more than $500 or imprisoned not more than six months or both....” The platting of land is a complex procedure which usually requires the services of both an attorney and a registered land surveyor.

Parts of platted lots may be described either by metes and bounds or as a fractional portion of the lot such as “the South one-half (S 1/2) of Lot Six (6), Block Ten (10), Jones Addition to the City of Madison, Dane County, Wisconsin.” Be aware that it is illegal to divide any lot of any state level plat for the purpose of sale or building development if the resulting parcels do not conform to the requirements of chapter 236 Statutes and applicable local governmental unit regulations. Any person making or causing such an illegal division to be made is subject to forfeit not less than $100 nor more than $500.

Any local governmental unit, for convenience in assessment and taxation, may make an “assessor’s plat.” This includes recording in the office of the Register of Deeds of the county where the land is located a detailed map of the area giving complete metes and bounds descriptions of all parcels of land within the area. Thereafter, any parcel within the assessor’s plat may be adequately described by using its designation on the plat.

Recorded Certified Survey Maps

A certified survey map of not more than four parcels of land may be recorded Register of Deeds in the county in which such land is located. These are not subject to state level review but chapter 236 of the statutes establishes minimum standards concerning preparation and recording.

Only registered surveyors can perform the survey and prepare the map. After recording, the parcels on the map can be described by reference to the name of the county, number of the survey and the volume and page where recorded. However, in order for others to locate sites that are tested, the government survey descriptions must also be given.

Following is a list of common maps which may be useful.

Maps In Common Use

1. State Division of Highways County Maps	varies about 1:316800	varies about 1" = 26400'
2. County Plat Book Maps	1:62500	1" = 5280' (mi.)
3. Floodplain - Shoreland Maps	varies	varies
4. USGS, 7.5 Minute Topographic	1:24000	1" = 2000'
5. Detailed Soil Maps	1:15840 1:24000 1:20000	1" = 1320' 1" = 2000' 1" = 1667'
6. Topographic Groundwater	varies	varies

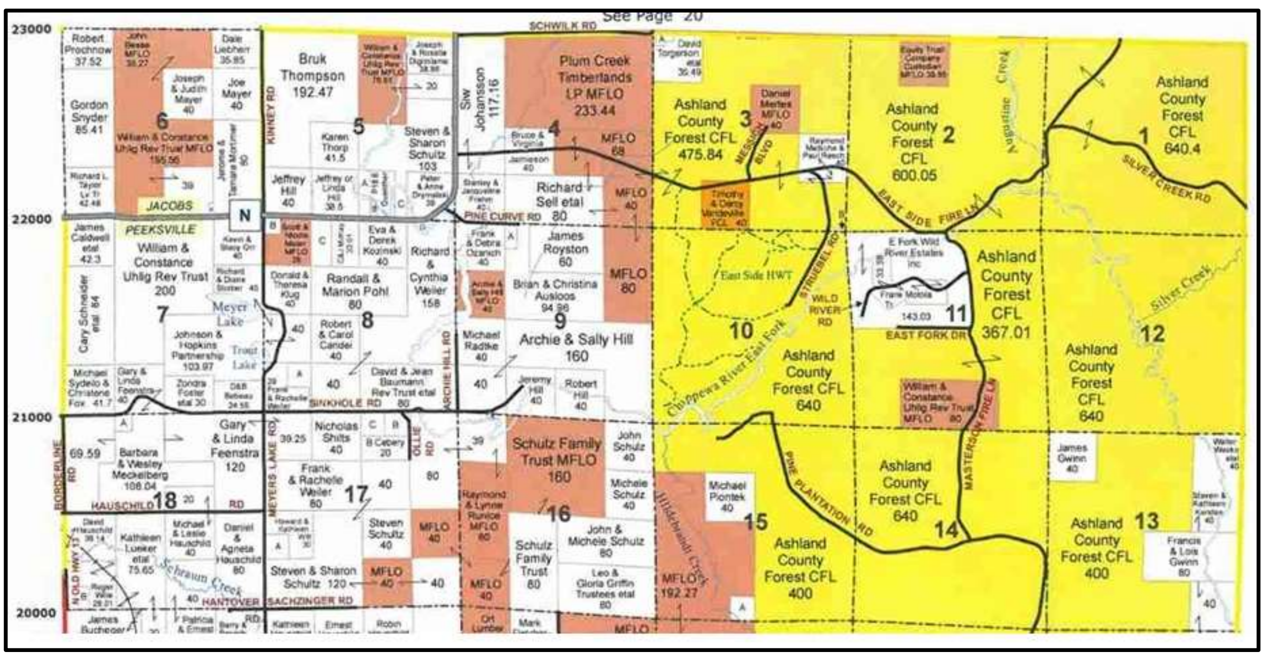


Figure 5.7 – Representative sample plat map

CHAPTER 6

Simple Site Surveying

This chapter explains how to gather data properly utilizing a builder's level and determine contour lines. Basic steps will be outlined to determine elevations at a site. Collection of elevation data is essential for accurately showing contours and completing the plot plan. It is critical that careful and accurate data is obtained as this data directly affects many aspects of POWTS design.

Builder's Level Equipment

There are two types of builder's levels: optical and laser. Either type is suitable for collecting data. Lasers predominate as optical levels have fallen out of favor because they are difficult to use single-handedly. In either case, the basics of taking readings and gathering data is essentially the same. The laser or optical level sits upon a tripod where a level plane is established across the site. A staff with graduated marks in either decimal or fractional format is the target of the laser beam or optical tube. A calculation is then made between the known height of the level and the point on which the staff is resting. When referenced back to a known point, elevations for the site can be obtained.

SETTING UP

The optical sight tube or laser is placed upon the tripod in an area where there is a line of sight to all areas under investigation. It is best if the builder's level is placed near the highest area, for reasons explained later. All is not lost if these cannot be accomplished due to terrain, buildings, or other obstacles. However, extra steps will be needed to obtain elevation data.

The tripod must be firmly set on the ground and the instrument must be leveled prior to taking any readings. Failure to do so will result in erroneous data. Most lasers are self-leveling if set reasonably close to level at the start. If not or if it is an optical instrument, set screws are used for adjustment. This is accomplished by turning the screws to elevate or declinate the instrument as guided by a bubble gauge. Your instrument manufacturer should have directions to assist you in assuring it is level.

READING THE STAFF

Surveying staff can be found in two formats: decimal or fractional. Decimal staffs have measurements in feet divided by tenths and hundredths of a foot. Fractional staffs are in feet divided by inches and eighth inch fractions. Either can be used effectively but decimals are easier to use in calculations, as inch fractions need to be converted. See **FIGURE 6.1** for a table to convert inches to a decimal. It is suggested that a decimal staff is used if at all available.

Regardless of the type of level, reading the staff is similar. A crosshair is visible through the tube on the optical level. A reading is taken where the horizontal crosshair line meets is superimposed on the staff (**FIGURE 6.2**). Laser levels have a receiver which reads the laser beam and indicates if the receiver needs to be moved up, down or is level with the beam. This is usually done with either visible and/or audible indicators on the receiver. Once the receiver indicates it is level with the laser beam, the staff can be read as shown by an indicator on the receiver. See **FIGURE 6.3**

Foot increments on the decimal staff are marked in red numerals while the tenths are marked in black numerals. Hundredths of a foot are indicated by graduated black lines between the black tenth numerals. The fractional staff is similar with feet in red and inches in black, and eighths of an inch are indicated by graduated black lines between the black inch numerals.

Inches	Decimal	Inches	Decimal	Inches	Decimal	Inches	Decimal
1/8	0.01	3 1/8	0.26	6 1/8	0.51	9 1/8	0.76
1/4	0.02	3 1/4	0.27	6 1/4	0.52	9 1/4	0.77
3/8	0.03	3 3/8	0.28	6 3/8	0.53	9 3/8	0.78
1/2	0.04	3 1/2	0.29	6 1/2	0.54	9 1/2	0.79
5/8	0.05	3 5/8	0.30	6 5/8	0.55	9 5/8	0.80
3/4	0.06	3 3/4	0.31	6 3/4	0.56	9 3/4	0.81
7/8	0.07	3 7/8	0.32	6 7/8	0.57	9 7/8	0.82
1	0.08	4	0.33	7	0.58	10	0.83
1 1/8	0.09	4 1/8	0.34	7 1/8	0.59	10 1/8	0.84
1 1/4	0.10	4 1/4	0.35	7 1/4	0.60	10 1/4	0.85
1 3/8	0.11	4 3/8	0.36	7 3/8	0.61	10 3/8	0.86
1 1/2	0.13	4 1/2	0.38	7 1/2	0.63	10 1/2	0.88
1 5/8	0.14	4 5/8	0.39	7 5/8	0.64	10 5/8	0.89
1 3/4	0.15	4 3/4	0.40	7 3/4	0.65	10 3/4	0.90
1 7/8	0.16	4 7/8	0.41	7 7/8	0.66	10 7/8	0.91
2	0.17	5	0.42	8	0.67	11	0.92
2 1/8	0.18	5 1/8	0.43	8 1/8	0.68	11 1/8	0.93
2 1/4	0.19	5 1/4	0.44	8 1/4	0.69	11 1/4	0.94
2 3/8	0.20	5 3/8	0.45	8 3/8	0.70	11 3/8	0.95
2 1/2	0.21	5 1/2	0.46	8 1/2	0.71	11 1/2	0.96
2 5/8	0.22	5 5/8	0.47	8 5/8	0.72	11 5/8	0.97
2 3/4	0.23	5 3/4	0.48	8 3/4	0.73	11 3/4	0.98
2 7/8	0.24	5 7/8	0.49	8 7/8	0.74	11 7/8	0.99
3	0.25	6	0.50	9	0.75	12	1.00

FIGURE 6.1 – Inch fractions to decimal.

Foot increments on the decimal staff are marked in red numerals while the tenths are marked in black numerals. Hundredths of a foot are indicated by graduated black lines between the black tenth numerals. The fractional staff is similar with feet in red and inches in black, and eighths of an inch are indicated by graduated black lines between the black inch numerals.

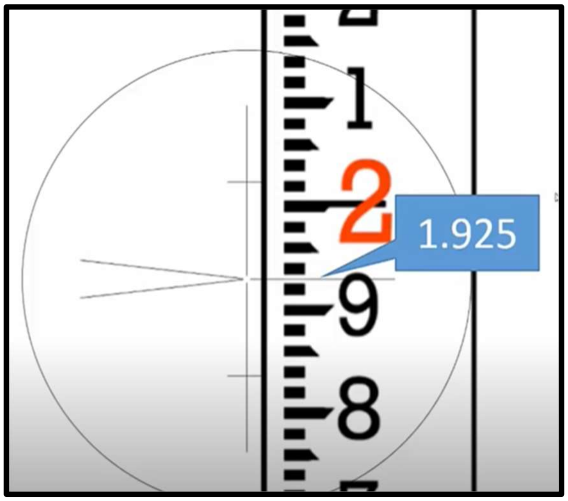


FIGURE 6.2 – Optical instrument view

FIGURE 6.3 – Laser receiver

Using the horizontal crosshair on the optical level or the indicator on the laser receiver, the plane from the level can be measured where it intersects the vertical staff. A calculation can be made to determine the difference in height and therefore, relative elevations established. The figure below shows a close-up of a decimal staff. The red number 2 and black numbers 3 & 4 indicate that we are looking at 2.4 to 2.3 on the staff. The top and bottom edge of each graduated mark indicates a difference of 1/100th of a foot (**FIGURE 6.4**).

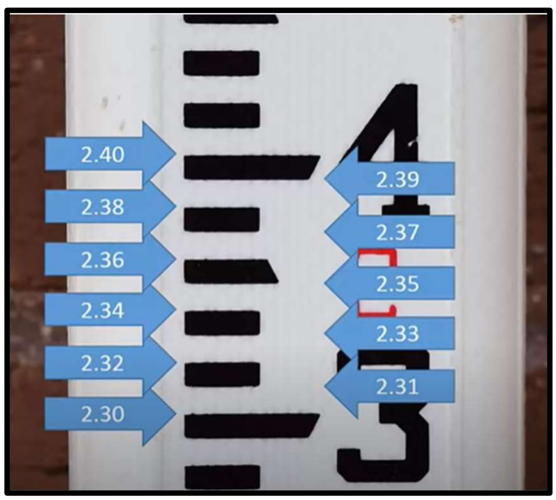


FIGURE 6.4 – 1/100ths marks on staff

Obtaining Elevation Data

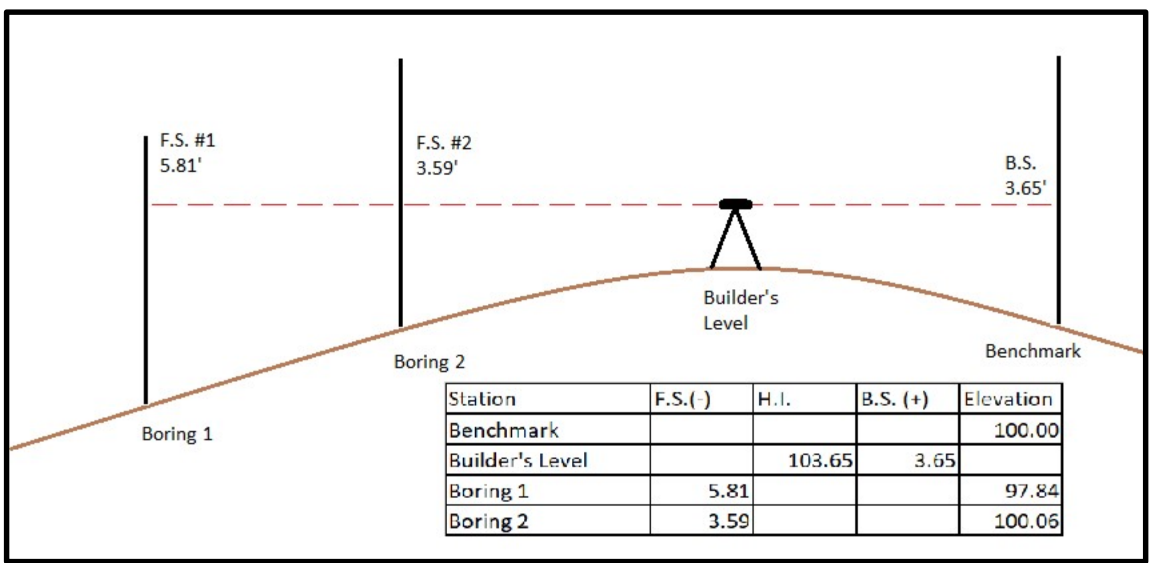
After setting up the tripod and level as instructed above, one can begin to obtain site elevation data. First, the height of the instrument must be established. This can be done by determining the difference between the instrument and a known vertical reference point (object with pre-established elevation) or by setting a new reference point or benchmark, for the site.

Benchmarks are commonly used as most sites do not have pre-established vertical reference points. Care should be taken in selecting a good benchmark as it will be used to set system elevations by the designer and plumber. A benchmark should be steady, easily locatable, and easily determined. It should be something such as: top of utility pedestal, flagged nail in tree, SE corner of garage slab, metal rod or lot stake, etc., not ground surface, center of roadway, unflagged nail in tree, base of tree, etc. It may be of benefit to place a second benchmark in a different area on a site. This is especially true if the site is undeveloped and significant clearing or disturbance will take place.

CALCULATING DATA

Once a benchmark (reference point) is established, a reading is taken at that location. This is called a "backsight". A staff reading to a backsight is always added to the benchmark to determine the height of instrument. When taking a reading at an unknown point, this is called a foresight. A staff reading at a foresight is always subtracted from the height of instrument. Recording data in this manner, one can take any number of foresights, all correlated back to the benchmark.

In **FIGURE 6.5**, a benchmark is established and assumed to be at 100.0'elevation. A backsight to the benchmark is 3.65' (higher than the benchmark), so this reading would be added to the 100.0' as the height of instrument is calculated at 103.65'. Foresights reading #1 (5.81') and #2 are subtracted from the height of instrument to show elevations of 97.84' and 100.6' respectively.

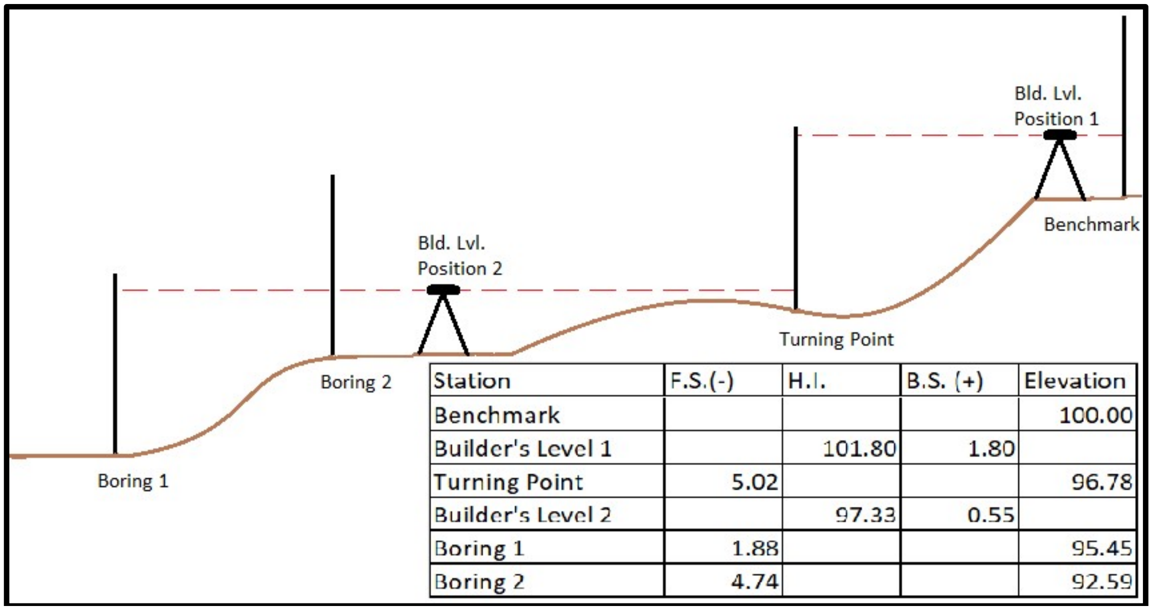


Station	F.S.(-)	H.I.	B.S. (+)	Elevation
Benchmark				100.00
Builder's Level		103.65	3.65	
Boring 1	5.81			97.84
Boring 2	3.59			100.06

FIGURE 6.5 – Elevation Diagram

If there is a line-of-sight obstruction or extreme elevation change beyond the reach of the staff, a turning point can be utilized. To start, turning points are measured as any other foresight. A turning point should be in such a location as to be seen and measured from the existing instrument location and a proposed instrument location. Once the measurement is taken, the instrument is moved and placed in a new location. Here a new height of instrument must be calculated by taking a backsight the turning point.

Now, all measurements are a foresight to this new height of instrument. In this manner, any number of turning points can be established and therefore an infinite number of data point collected; all tied back to the original benchmark. See **FIGURE 6.6**



Station	F.S.(-)	H.I.	B.S. (+)	Elevation
Benchmark				100.00
Builder's Level 1		101.80	1.80	
Turning Point	5.02			96.78
Builder's Level 2		97.33	0.55	
Boring 1	1.88			95.45
Boring 2	4.74			92.59

FIGURE 6.6 – Turning Point Diagram

Contour Lines

A contour line is a line on a map representing an imaginary line on the land surface, on which all points are at the same elevation. Visual interpretation of contour lines on a map can quickly give insight as to the landscape found on a site.

Here are some helpful rules concerning contour lines. Since they are the same elevation, lines can never cross. Close contour lines indicate a steep slope while far apart lines indicate flatter areas. Lines in concentric circles indicate a hill (or possibly a depression). Lines that take the form of a "V" indicate a valley with the upslope towards the point of the "V". Contour lines should be indicated at whole numbers and at an interval suitable to the site. One- or two-foot contours work best for most sites.

DETERMINING CONTOURS

Mapping contours can be accomplished by a couple different methods. The first method involves interpolation of data between points. Elevation data is obtained in either a grid pattern or random points. Although both require the same calculations, the grid method is easier to locate on the plot plan. The second method plots each contour separately.

The interpolation requires the collection of many data points across the area. Using a grid, data points are easily mapped on the plot plan. In **FIGURE 6.7** below, elevations are collected at points which are 25 feet apart. Based on the data, we will be mapping one-foot contours. Data shows some points fall exactly on a contour (i.e., 99.0') and lines can be drawn connecting those points. Locations of contour lines passing between data points can interpolated.

Note the two center bottom data points (98.5' and 95.5') in **FIGURE 6.7**. Contour lines 98.0', 97.0' and 96.0' must pass between them. Interpolation is just a fractional representation of the difference between a data point and the contour line, divided by the difference between data points. In the case of the 96.0' contour, it is 0.5' different from the right data point and in between two data points that differ by 3.0'. So, mathematically, it would be 0.5/3.0 or 17% of the distance from the 95.5' data point and conversely, 83% of the distance from the 98.5' data point. In this manner, every contour can be plotted accurately.

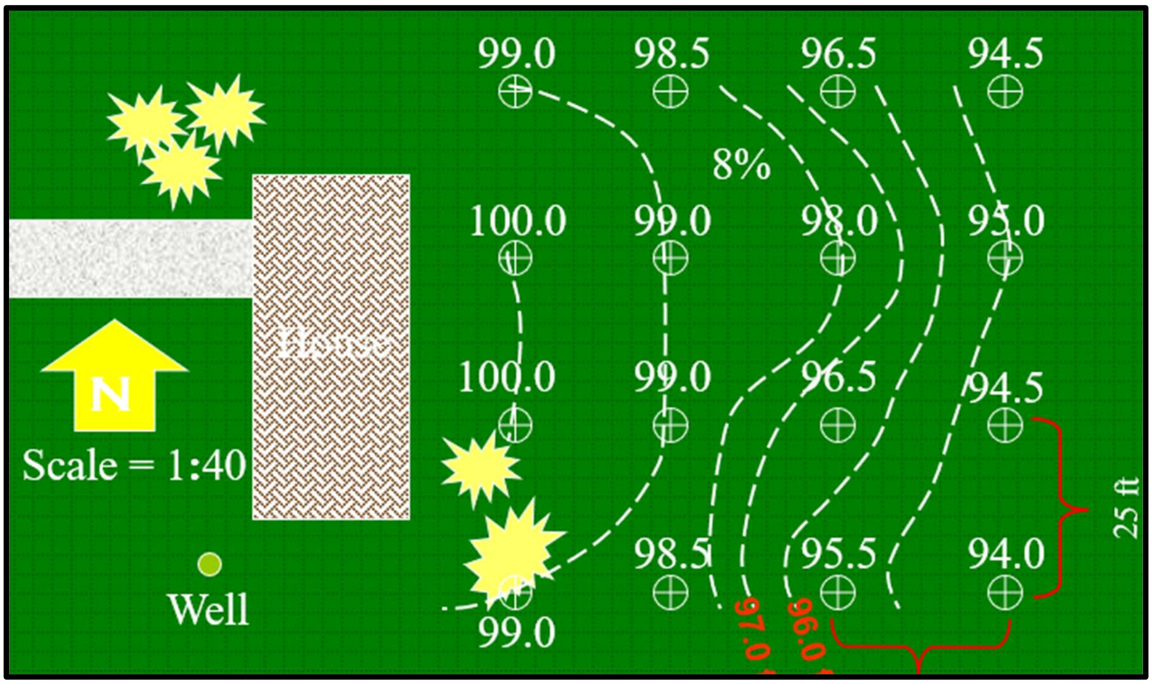


FIGURE 6.7 – Interpolation Method

An alternate method of determining contours, plotting, is most easily done with a laser level. There are two slightly different way to do this. One uses a fixed reading on the staff (98' for instance), while moving up and down slope at various points. Wherever the staff reading indicates the ground is at 98', a surveying flag is placed. As the contour is plotted, measurements are made to each flag to accurately plot the contour on the plot plan. A second way is to again move up or down the slope, but this time marking each contour with a flag as it is crossed. Multiple colored flags corresponding to the elevations are sometimes used to identify contour lines more easily.

CHAPTER 7

Site Investigation Procedures

This chapter explains how to evaluate a property for a private sewage system. It outlines the basic steps to follow when conducting and documenting an onsite investigation in such a way that system designers, installers and regulatory personnel are furnished with complete, reliable information about site and soil limitations on the property. Furthermore, adherence to this procedure should save the soil tester time and effort. If properly executed, an onsite investigation contributes significantly toward providing the property owner with a functioning and environmentally compatible soil treatment facility.

Initial Work

When first contacted by a prospective client, request/gather the following information:

1) the owner's name, address, and phone number;

2) a legal description of the property;

3) a map sketch, if available, showing property boundary locations and dimensions (you may have to wait until you visit the property to obtain this information);

4) a description of the structure to be serviced (proposed or existing) and its use to determine the maximum daily flow estimate of effluent to be treated.

5) If an existing site, contact the county office for copies of what work has already been performed on the property. This would include previous soil tests and location(s) of old systems.

Also inform the client that an onsite investigation does not guarantee that the property in question will be suitable for the intended use. Local zoning or other land use ordinances may significantly impact the use of a proposed building site. The client must understand that the soil tester's responsibility is to complete an accurate evaluation of the site. A written contract between the client and the CST is a convenient way to document that understanding.

Supplemental Maps

Once the location of the property is known, review published maps that delineate natural and cultural features of the area in question. Begin with a detailed county soil survey or an online county GIS map if one is available. Published soil surveys can be obtained at no charge from the Natural Resource Conservation Service, USDA or through their website. Consulting a soil survey prior to performing field work could save time, especially if the parcel is large; areas that are likely to be suitable for a private sewage system can be identified on the soil map. (Caution: do not assume that an area described as suitable for a system on a soil map is in fact acceptable. Examination of soil profiles at the site is still required.) Instructions for using soil surveys are included in Chapter 4 of this handbook.

Other maps that may aid site evaluation are USGS topographic maps, shoreland—floodplain maps and county plat maps. Most counties have GIS databases of several of the above maps, including soils. You may be able to access these online or through the county land information office.

Preparing a Map Sketch

Begin the field work portion of the investigation by preparing a scaled map sketch of the property if one has not already been provided by the client. Along with the locations and dimensions of property boundaries, show other features which affect private sewage system siting, including those encumbrances which may occur on adjacent lots. Possible Items to locate and identify on the map sketch are existing buildings, driveways or lanes, POWTS systems, wells, steep slopes, open water, drainage swales, concave depressions, floodplains, bedrock outcrops, disturbed or filled areas and areas with hydrophytic vegetation (i.e., cattails, sedges, willows, tamaracks, tag alders, etc.). Remember to indicate which direction is north on the map.

If the parcel is undeveloped, it is best to first choose a site for the private sewage system before deciding where to place other constructed improvements; otherwise show the proposed locations of planned improvements (i.e. house, garage, etc.) on the map sketch.

As mentioned previously, an air photo copy to use as a base map may facilitate the task of preparing a map sketch for large parcels. Do not forget to note features on near-by properties which will influence the location of a system on the property being evaluated. An accurate map sketch showing all pertinent features relative to private sewage system siting and design greatly enhances the collection and analysis of other required observations at the site. The sketch will also be the basis of the finished plot plan discussed later in this chapter.

Choosing a Site

After the map sketch is complete, use it as a tool for identifying possible sites on the property to consider for further evaluation. If the map sketch is drawn to scale, it is a simple matter to delineate on the map any area to eliminate from consideration due to the minimum location requirements in SPS 383 Wisconsin Administrative Code.

Other areas to eliminate would be drainage swales, concave depressions, floodplains, steep slopes, disturbed or filled areas, bedrock outcrops and areas with hydrophytic vegetation. When a site without sufficient area for a system exists after deleting all unsuitable areas, discontinue the investigation and report that the property has no suitable area for a septic system other than a holding tank. If, sufficient area can be identified, proceed with the investigation.

Continuing the investigation at this point does not imply that the site is necessarily acceptable, just that there is enough area to continue. Soil or slope limitations may still disqualify the sites suitability for a private sewage system.

Before You Dig

Before any excavating (including hand tools) is started at the site, Diggers Hotline should be contacted at (800) 242-8511, or by dialing 811, or on the web at www.diggershotline.com. State law requires that all contractors call at least 3 working days prior to any excavation. There is no charge or fee for this service.

Diggers Hotline was created in 1976 as a one-call center to increase worker and public safety, prevent damage to underground and overhead facilities, protect the environment and to help ensure continuity of utility and communication services. It is comprised of transmission utilities such as municipalities, state agencies, sewer districts, local and long distance telephone, petroleum transmission companies, electric and natural gas providers, cable television and others.

Some counties may require that onsites be conducted by county personnel. It is suggested that before scheduling a soil test in the field, the county should be contacted. This will facilitate county coordination and may reduce the need for subsequent visits to the site. In addition, the county personnel are a primary source for assistance and a valuable asset when problems arise.

Weather and time of day must be considered when performing a soil test. Light conditions within 2 hours of sunrise or sunset and most of the winter are not conducive to determining soil color. A predominance of red wavelength light can make it hard to perceive color and distinguish mottles. In addition, winter poses other issues such as frozen soil (can't be textured) and snow cover (light sensitivity and slope determination issues). Although the code does not set limits on soil testing weather conditions, it is the soil tester's responsibility to assure that an accurate test is conducted. The county and /or the state may refuse to perform a soil onsite if the inspector feels weather conditions are not appropriate.

Locating and Preparing Soil Observation Pits

The next step, once a potential area has been identified, is to describe soil profiles at the site. When multiple sites are available, begin descriptions on the site closest to the structure (proposed or existing) to be served by the system unless circumstances or cost considerations dictate otherwise. It is useful at this time to set up the laser/level to determine slopes and grades; don't rely on "eyeballing" the site. Correctly orienting the system parallel to the slope will aid in properly locating the pits/borings.

A minimum of three soil profiles must be described on the site for an accurate evaluation. One of which must be it while the other two can be an auger boring (provided the soils are uniform and similar). However, additional pits may be necessary if the soils vary, unsuitable areas are identified or the uniqueness of the design/system requires it.

Select positions for profile descriptions which would best describe the site. Do not describe areas with anomalies such as rodent burrows, tree up-rooting, etc. But do include areas with importance to system operation such as filled areas, old foundations, compacted areas etc. Locate the excavations around the outside perimeter to limit disturbance in the proposed absorption area. Also include at least one description from a position downslope of the proposed system area.

Excavations should preferably be dug with a backhoe although hand dug pits are ok. Dig pits large enough to occupy while making observations and deep enough to extend at least three feet below the proposed system elevation. Try to orient the pits so that one sidewall is exposed to full sunlight. Pick away smeared parts of the sidewall with a shovel or small hand tool to reveal the natural structure of the soil. Moisten the exposed surface with a spray bottle if the soil is dry. This will aid in obtaining accurate descriptions.

Refer to Federal OSHA standards for excavating and trenching, as outlined in 29 CFR 1926, part P. The Federal register contains specific safety requirements and regulations concerning the construction and occupation of soil pits. Do not enter any pit or excavation if you are not familiar with the above rule, see unstable pit walls, and/or deem it unsafe.

Completing the Soil Description Form

This phase of the investigation involves documenting soil characteristics which influence water movement, and which indicate the depth to periodic or permanent saturation by groundwater. Inferences made from these observations are used to decide if a private sewage system will function in soil on the site without contaminating groundwater or without discharging effluent to the soil surface. If the soil is suitable for an absorption system, information from the profile descriptions, combined with the daily flow estimate, is used to determine the geometry, elevation and size of the proposed system.

TOOLS

It is helpful if you assemble the following tools and materials before beginning profile observations: laser/level, tape measure, knife, tile spade or shovel, water bottle, Munsell color charts, clip board and Soil Description Forms, SBD-8330 (**Figure 7.3**). Other helpful but optional items are horizon markers, dilute solution of hydrochloric acid, hand lens, 2mm sieve.

STANDARD DESCRIPTION ABBREVIATIONS

Use the Soil Description Form SBD-8330 as a guide for organizing your profile observations in the field even though its use is not mandatory for recording field notes. All profile description notes, however, must eventually be transcribed to this form using the standard NRCS-USDA abbreviations in order to be an acceptable report submission to the county or state. The appropriate abbreviations for each soil characteristic are summarized in **Figure 7.4**. These abbreviations and only these may be used for submitted reports. Any report not using the standard terminology will be returned to the CST for correction. A standardized reporting system is necessary to facilitate communication about soil properties.

HORIZON BOUNDARIES

Begin the profile description by identifying major soil horizon boundaries. Any change with depth in at least one soil property listed on the form constitutes a different horizon. For instance, if mottles start at 28 inches but other properties have not varied at that depth, then mark the beginning of a new horizon at 28 inches. The most conspicuous changes, which usually have significant effects on water movement through soil, are changes in parent materials; learn to distinguish different parent materials (see chapter 2 of this manual). Other changes are often more subtle but could likely be as critical in their effect on water movement. Hand texture frequently and periodically penetrate or vertically slice the profile with a knife to detect variations in texture, consistency and bulk density which are not immediately visible.

Delineate horizon boundaries by either scoring the face of the profile with a knife or by inserting markers (i.e., nails, tongue depressors, etc.). Then note the thickness of each horizon by sequentially recording the lower boundary depths or range in inches as illustrated below (**Table 7.1**). Do not describe horizons beyond what is observed; the last horizon's lower boundary will be the depth of the pit or boring.

Horizon	Depth (inches) Lower Boundary	Range
#1	10	0-10
#2	16	10-16
#3	28	16-28
#4	45	28-45
#5	62	45-62

TABLE 7.1 – Example recording of horizon depths

Next, sequentially number each horizon or if able to do so, assign a horizon designation to each layer using the system explained on page 18 of this handbook. Assigning horizon designations may have to wait until the profile is completely described and genetic relationships within the profile are apparent. It is important that if you do not completely understand master horizon (and sub-horizon) letters – **do not use them**. Each has a specific meaning to Soil Scientists and may incorrectly indicate features which are not present in the profile. Finally, record the distinctness and the topography of each horizon boundary.

After being delineated in the profile, each horizon can be described in detail. Suggestions for observing and characterizing each soil feature listed on the description form follow.

MATRIX COLORS

The matrix color of a horizon is the color that occupies the greatest volume in the layer. To determine the matrix color, remove a moist sample (only moist colors are acceptable) from the horizon and find the closest match between the dominant sample color and a chip on one of the Munsell hue charts; interpolate when necessary. Do not rub or smear the sample unless it is from a surface horizon; by convention, only surface horizon colors are estimated in a rubbed state. If the horizon has developed structure, the matrix color is the dominant interior color, not the surface color, of the peds. Therefore, break peds to expose their interiors when determining matrix colors.

Evaluate colors in the best available light. Occasional adjustment of the color chips in relation to your line of vision may be required to minimize glare. Do not place soil sample on top of the Munsell page or color chips. This can contaminate the color chips and skew future color determinations. Record the matrix color for each horizon in Munsell notation as instructed on page 30 of this handbook.

MOTTLES

Mottles, when present, are spots of color in soil which are contrast with the dominant matrix color. Do not confuse mottles with coherent structural elements of different colors such as coatings, nodules and concretions. Describe mottles when soil is in a moist state and light intensity and quality are adequate. In addition to Munsell color notations, record the relative quantity, size and contrast of mottles as specified on page 33 of this handbook.

TEXTURE

Texture refers to the particle size distribution by weight of mineral soil material sma1ler than two millimeters. It is the relative proportion of sand, silt and clay in a soil sample. Texture not only influences the infiltration and permeability of water in soil, but also affects the degree of aeration and the amount of active surface area available for the treatment of septic effluent in soil.

Estimate soil texture in the field by feel. Use **Figures 2.1 & 2.2** on pages 22 & 23 of this handbook as a guide for estimating textures in the field. Be sure to distinguish among coarse, medium, fine and very fine sands; carry standard samples of these sand sizes if necessary. Remember that textural classes form a continuum. If the texture is on the border between two classes, choose the texture class which fits most closely with respect to water movement. Do not make estimates beyond the precision of the method you use.

Also, determine the approximate volume of rock fragments larger than two millimeters in each horizon. This can be done with a visual estimate or by calculating the percent by weight of material retained from a sample on a #10 sieve and then converting the percent by weight to percent by volume by dividing the percent by weight by the dry bulk density of the coarse fragment fraction.

Use textural modifiers as necessary according to directions on page 27 of this handbook.

STRUCTURE

Structure results from the organized aggregation of mineral particles into discrete units. These units are called peds and retain their integrity through multiple wetting and drying cycles. Because structure is maintained by electro-chemical forces associated with clay minerals and by plant root interactions, the degree of structural expression is usually related to texture and to root density. Structural expression in a profile increases with increasing clay content and with increasing plant root activity.

Two structureless conditions can also occur in soil: single-grained and massive. In a single grained state, the individual mineral particles are not coherent. Sand textures are single grained due to the inability of sand grains to form aggregating bonds. The mineral particles are coherent in a massive state but discrete aggregates are not visible and planar voids are lacking. Massive conditions normally coincide with sandy loam or finer textures combined with an absence of plant roots. C horizons are usually single grained or massive depending on their texture.

Describe the grade size and shape of structural elements as specified on page 38 of this handbook and **Table 2.4**. Do not confuse depositional organization (i.e., layering or banding) inherited from parent materials with soil structure.

CONSISTENCE

Soil consistency refers to the relative ease with which soil can be deformed; dependent on soil moisture content. Evaluate consistency for a moist state in terms of soil strength and note any cemented horizons as explained on page 42 of this handbook and **Table 2.5**.

ROOTS

Describe the distribution of root size and frequency in each profile. Quantity of roots can be described as (1) for few or <1%, (2) common or 1-5% and (3) many or >5%. Root size is categorized as (vf) for very fine or <1mm, (f) fine or 1-2mm, (m) medium or 2-5mm and (co) coarse >5mm. Note the relationship of root distribution to other soil features that either influence or indicate spatial and temporal patterns of water movement in soil.

REMARKS

In the "Remarks" column on the description form, record other pertinent observations which may aid another person reading the form to interpret the soil profile described. Included might be ped coatings, concretions, nodules, bands, lamellae, burrows, free carbonates, bulk density estimates, evidence of disturbance or compaction, etc.

DESIGN LOADING RATE

Refer to Table 383.44-2 in SPS 383, Wisconsin Admin. Code to determine the proper loading rate from textural, structural and effluent concentrations. Assign a proper loading rate for each horizon. NOTE: Residential strength wastewater meets parameters of Effluent #1 (left column): >30 ≤220mg/L BOD_5 and >30 ≤150 mg/L TSS. Testing and/or some type of pretreatment would be required to meet Effluent #2 (right column): <30 mg/L BOD_5 and <30 mg/L TSS.

MISCELLANEOUS INFORMATION

Finish the description form by describing the vegetation, land use and parent materials at the site. If available, provide the Soil Survey map unit name(s) for the site. Recommend the type of system and any soil parameters that the designer should take into account. Finally, make any notes which would clarify the description or in any way influence how it may be interpreted. Remember that the purpose of the description form is to effectively communicate observations of soil and site characteristics which will affect the design of a proposed private sewage system.

SPS 385.40 contains additional information which must be included as part of a soil test submittal to the county / governmental unit. Please refer to this code section for a definitive list of evaluation report contents.

Contact the county / governmental unit that has jurisdiction for the parcel tested to obtain instructions regarding filing procedures and fees. Also see "Before You Dig" page 80, for information about county onsites.

Additional Plot Plan Information

The original sketch drawn earlier will serve as a basis for the finished plot plan. All valid soil tests require both the soils data on form SBD-8330 **Figure 7.3** and a plot plan see **Figure 7.2**. Most soil testers use the parcel map, CSM or their own map (hand drawn or computer generated) as a base. Do not use an air photo or satellite image as a base map. The map should be at or drawn to a useful scale such as 1"=40' to show detail. If not already shown, add precisely the location of any property lines, utilities, buildings, drives, wells, bodies of water and any other features which may impact the installation of the system.

Identify the bench mark used to set elevations by describing verbally and assigning an elevation. Then locate the bench mark on the plot plan. Also, remember to include a reference to map orientation, i.e. north arrow.

CONTOURS AND SLOPE

Record data concerning the gradient, shape and aspect of the slopes in the system area by placing contour lines on the plot sketch. Contours should be at an interval which will convey the complexities of the direction and topography of the slope, yet not clutter the plot plan. Contours at one or two foot intervals are usually sufficient.

Include any notable micro-relief observed such as hummocks or cradle-knoll topography.

Contours should be based on actual elevation data gathered from the site. Do not guess as to the direction and degree of slope and do not extend contours beyond the area measured.

BORING ELEVATIONS

Each observed pit and boring location must be accurately located on the plot plan and have an assigned elevation. Determine and record the elevations on both the SBD-8330 form and the plot plan.

Elevations

B-1 = 115.8’

B-2 = 118.5’

B-3 = 115.7’

B-4 = 113.5’

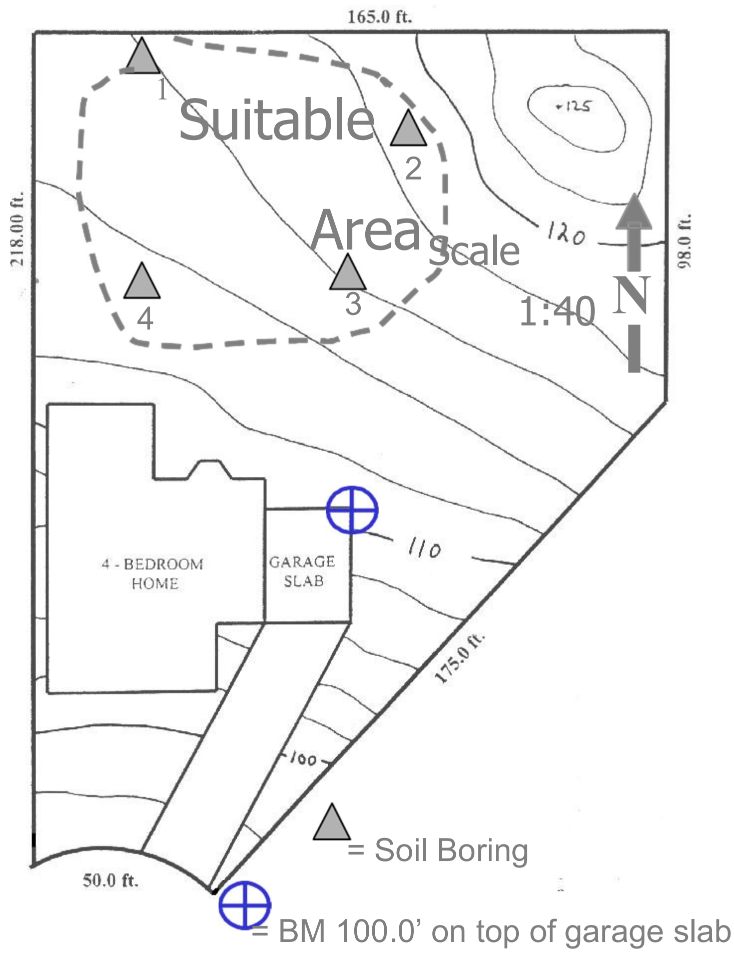


FIGURE 7.2 – Sample Plot Plan

Wisconsin Department of Safety and Professional Services
Division of Industry Services

Page_____of_____

SOIL EVALUATION REPORT

In accordance with SPS 385, Wis. Adm. Code

Attach complete site plan on paper not less than 8 1/2 x 11 inches in size. Plan must include, but not limited to: vertical and horizontal reference point (BM), direction and percent slope, scale or dimensions, north arrow, and location and distance to nearest road.

Please print all information.

Personal information you provide may be used for secondary purposes (Privacy Law, s. 15.04(1)(m)).

County	
Parcel I.D.	
Reviewed by	Date

Property Owner	Property Location Govt. Lot ¼ ¼ S T N R ☐ E (or) ☐ W
Property Owner's Mailing Address	Site Address or CSM and Lot #:
City / State / Zip Code / Phone Number ( )	☐ City ☐ Village ☐ Town / Nearest Road

☐ **New Construction** **Use:** ☐ **Residential / Number of bedrooms** ___________ **Code derived design flow rate** ______ **GPD**

☐ Replacement ☐ Public or commercial – Describe: ___________ Flood Plan elevation if applicable______ ft.

Parent material______________________

General comments and recommendations:

☐ Boring # ☐ Boring ☐ Pit Ground surface elev.______ft. Depth to limiting factor______in. / elev.______ft.

Horizon	Depth in.	Dominant Color Munsell	Redox Description Qu. Az. Cont. Color	Texture	Structure Gr. Sz. Sh.	Consistence	Boundary	Roots	Soil Application Rate GPD/Ft² *Eff#1	*Eff#2

☐ Boring # ☐ Boring ☐ Pit Ground surface elev.______ft. Depth to limiting factor______in. / elev.______ft.

Horizon	Depth in.	Dominant Color Munsell	Redox Description Qu. Az. Cont. Color	Texture	Structure Gr. Sz. Sh.	Consistence	Boundary	Roots	Soil Application Rate GPD/Ft² *Eff#1	*Eff#2

CST Name (Please Print)	Signature	CST Number
Address	Date Evaluation Conducted	Telephone Number

* Effluent #1 = BOD > 30 ≤ 220 mg/L and TSS > 30 ≤ 150 mg/L * Effluent #2 = BOD, ≤ 30 mg/L and TSS ≤ 30 mg/L

SBD-8330 (R04/21)

FIGURE 3.2 – Soil Evaluation Report Form SBD-8330

HORIZON
Use A, E, B, C and subscripts, or number 1, 2, 3

DEPTH
Inches, decimal feet or centimeters.

COLOR (Munsell Notation) is described using HUE, VALUE and CHROMA. For example, a gray color, 10YR 5/1, has a hue of 10YR, a value of 5 and a chroma of 1.

Dominant Color occupies the greatest volume of the horizon.

MOTTLING
spots of different color, is described by color, quantity, size, contrast and shape.

Quantity
few (f) < 2%
common (c) 2–20%
many (m) > 20%

Size
fine (1) < 1 mm
medium (2) 5–15 mm

Contrast
faint (f) difficult to see
distinct (d) readily seen
prominent (p) conspicuous

Shape
streaks, bands, spots, etc.

CONSISTENCE
describes particle cohesion and adhesion.

Moist Soil
loose (ml)
very friable (mvfr)
friable (mfr)
firm (mfi)
very firm (mvfi)
extremely firm (mefi)

Dry Soil
loose (dl)
soft (ds)
slight hard (dsh)
hard (dh)
very hard (dvh)
extremely hard (deh)

ROOTS

Quantity
few (1) < 1%
common (2) 1–5%
many (3) > 5%

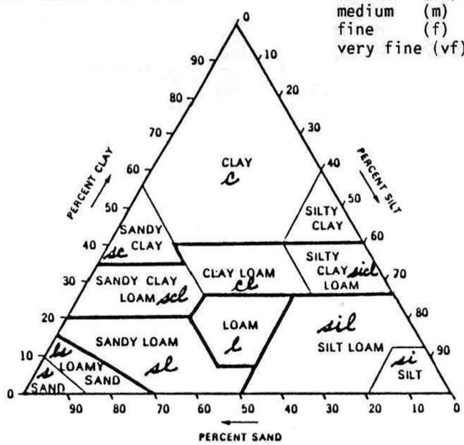
Size
very fine (vf) < 1 mm
fine (f) 1–2 mm
medium (m) 2–5 mm
coarse (co) > 5 mm

BOUNDARY is the transition between horizons.

Distinctness
abrupt (a) < 25 mm
clear (c) 25–65 mm
gradual (g) 65–130 mm
diffuse (d) > 130 mm

Topography
smooth (s) nearly a plane
wavy (w) w/width > depth
irregular (i) w/depth < width
broken (b) discontinuous

TEXTURE
USDA twelve divisions.



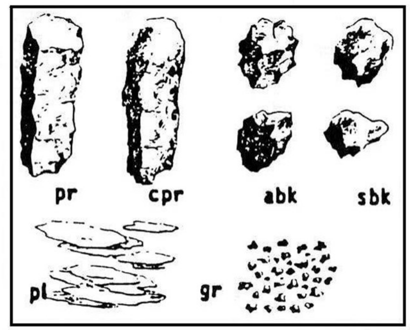
Texture triangle describing size distribution or particles less than than 2 mm.

Prefixes for Sand Sizes
coarse (co)
medium (m)
fine (f)
very fine (vf)

STRUCTURE describes units that separate at surfaces of weakness.

Grade
structureless (0) no aggregation
weak (1) barely observable
moderate (2) distinct peds
strong (3) durable peds

Type
platy (pl)
prismatic (pr)
– columnar (cpr)
blocky (bk)
– angular (abk)
– subangular (sbk)
granular (gr)
– crumb (cr)
single grain (sg)
massive (m)



Size		Granular, Crumb, Platy*	Angular, Subangular Blocky	Prismatic columnar
very fine	(vf)	< 1 mm	< 5 mm	< 10 mm
fine	(f)	1–2 mm	5–10 mm	10–20 mm
medium	(m)	2–5 mm	10–20 mm	20–50 mm
coarse	(c)	5–10 mm	20–50 mm	50–100 mm
very coarse	(vc)	> 10 mm	> 50 mm	> 100 mm

*For platy structure, use "thin" for fine and "thick" for coarse.

FIGURE 7.4 – Soil Abbreviations