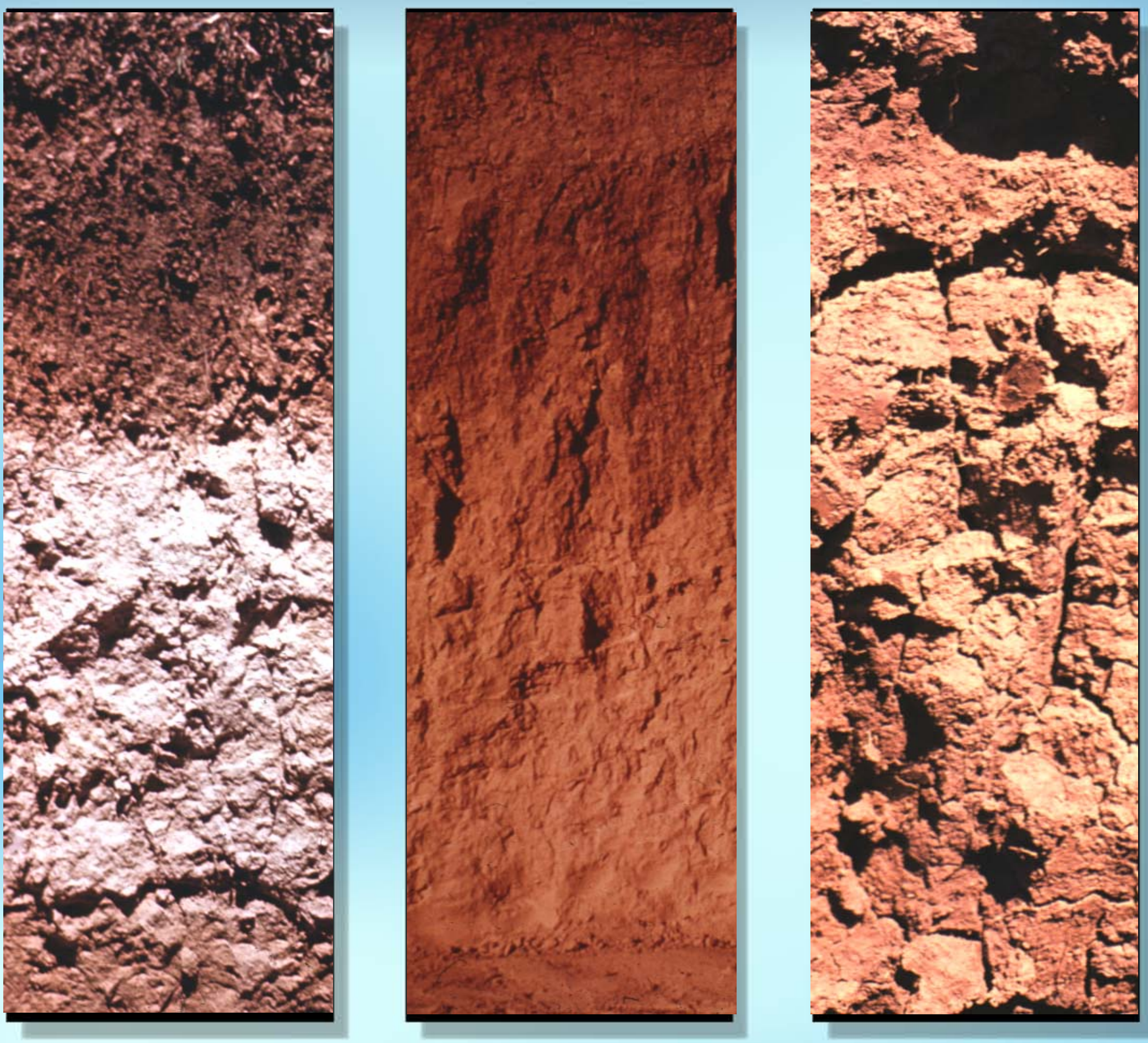
REACCH
www.reacchpna.org
Integrated Secondary Science Curriculum
Readings • Unit 3

Manual 6 • Reprinted September 2007
$12.50

# MANUAL FOR JUDGING OREGON SOILS



Oregon State University Extension Service

# Authors

This publication was prepared by J. Herbert Huddleston, Extension soil science specialist, and Gerald F. Kling, associate professor of soil science, Oregon State University. To simplify information, trade names of products have been used. No endorsement of named products is intended, nor is criticism implied of similar products that are not mentioned.

# Photo and Figure Credits

Plates 5, 8, 9, and 12 are reproduced from *The Marbut Memorial Slides*, slide nos. 5-10, 6-2, 6-16, and 9-1, by permission of the Soil Science Society of America.

Plates 2, 3, 4, 7, 10, and 11 are reproduced from the William M. Johnson slide set illustrating the United States Soil Classification System, by permission of M.A. Fosberg, Department of Plant and Soil Sciences, University of Idaho.

Plates 1, 6, 13, 14, 15, and 16 are from the authors' collections.

Figures 1, 5, 7, 8, and 25 were drawn by Cody Bustamante, OSU Communications Media Center.

Figures 2 and 3 are reproduced from *Soil Microbiology and Biochemistry*, slide nos. 120 and 48, by permission of the Soil Science Society of America.

Figures 4, 6, 17, 18, 19, 20, 21, 22, 23, and 24 are from the authors' collections.

Figures 9, 10, 11, and 12 are by courtesy of Tom Gentle, OSU Extension and Experiment Station Communications.

Figure 13 is reproduced from *The Marbut Memorial Slides*, slide no. 10-4, by permission of the Soil Science Society of America.

Figure 14 is by courtesy of Herb Futter, Natural Resources Conservation Service, Ontario, Oregon.

Figures 15, 29, and 33 are by courtesy of Don Baldwin, Natural Resources Conservation Service, Enterprise, Oregon.

Figure 16 is by courtesy of the Oregon Agricultural Experiment Station.

Figure 26 is by courtesy of Billie Forrest, Natural Resources Conservation Service, Tangent, Oregon.

Figure 27 is by courtesy of OSU Extension and Experiment Station Communications.

Figure 28 is by courtesy of Wilbur Bluhm, OSU Extension Service, Salem, Oregon.

Figures 30 and 31 are by courtesy of Dr. Steve Sharrow, OSU Department of Rangeland Resources.

Figure 32 is by courtesy of Sandy Macnab, OSU Extension Service, The Dalles, Oregon.

Figure 34 is by courtesy of Dr. Robert Paeth, Department of Environmental Quality, Portland, Oregon.



This publication was produced and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. Extension work is a cooperative program of Oregon State University, the U.S. Department of Agriculture, and Oregon counties. Oregon State University Extension Service offers educational programs, activities, and materials without discrimination based on age, color, disability, gender identity or expression, marital status, national origin, race, religion, sex, sexual orientation, or veteran's status. Oregon State University Extension Service is an Equal Opportunity Employer.

Reprinted September 2007

# Contents

# Foreword

Soil judging has been part of the vocational agriculture curriculum in Oregon high schools for more than 40 years. Since 1956, the OSU Extension Service and the Oregon Association of Conservation Districts have worked together to organize and operate the State Soil Judging Contest.

The Extension Service also has provided educational materials for the students and conducted training sessions for the instructors. For many years, Extension Bulletin 769, *Soil Judging from the Ground Up,* was used as the primary text for the program.

As we learned more about Oregon soils, however, and as soil management alternatives became more complicated, we realized that just revising EB 769 would not do the job. Instead a completely new manual was needed.

We began writing a new soil judging manual, and developing a new format for judging soils, in 1978, when we introduced several new ideas to a group of about 20 Vo-Ag instructors. They liked the new format, and their comments were very helpful as we wrote a draft of a new manual. We used this draft for 4 years while we tested new ideas and revised the text.

Publication of this manual would not have been possible without numerous suggestions from many soil scientists and Vo-Ag instructors who have been very closely associated with the soil judging program for a number of years. To each of them, we express our sincere appreciation.

There are several major changes in this new *Manual.*

1. We encourage students to study the whole soil profile and evaluate each of the natural soil horizons present.
2. We stress gathering primary data on just a few important properties that students can determine in the field—color, texture, and structure.
3. We show students how to use these basic properties to discover some important aspects of soil behavior, such as effective depth, water-holding capacity, susceptibility to erosion, and internal drainage class.
4. We explain why soil properties and soil behavior are important to soil management.
5. We develop keys for students to use to relate soil properties to important decisions about irrigation suitability, crop choices, erosion control, and other questions.

We don't expect students to memorize all the factors and interactions that enter into a management decision. We do hope, however, that they will learn how to use the keys to translate their evaluations of profile data into solutions to real problems facing modern agriculturalists and environmental scientists.

Above all, we view soil judging primarily as an educational program. Contests certainly add a dimension of challenge and fun, but they are not the primary objective of the program. Instead, the main objective is to encourage students to investigate this fascinating resource we call soil, to discover how soils are organized into horizons, to learn both how to describe a few key properties of soil horizons and to interpret them in terms of management practices—and to develop a sense of stewardship for the soils that support them.

Nothing would make us happier than for a student to challenge some of the generalized management interpretations we describe in this manual in terms of their relevance to his or her own soil conditions—and for the instructor to seize that opportunity to do some real teaching about the kinds of interactions one must consider when deciding how best to use the soil resources available on a given farm. When this happens, the *Manual for Judging Oregon Soils* will have accomplished its real purpose.

# Why Study Soil?

Soil is an essential natural resource. Without a doubt, that is the most important reason for studying the soil. Nathaniel Shaler put it this way: "Soil, ever slipping away in streams to the sea, is a kind of *placenta* that enables living things to feed upon the earth."

The sketch in Figure 1 illustrates our dependence on the soil. Unlike plant life, we human beings can't manufacture our own food from the four primary resources of soil, air, water, and sunlight. Instead, we depend completely on green plants, which take nutrients and water from the soil and combine them with air and sunlight to provide our food supply.

Some of those plants, such as wheat and corn, we eat directly. Others, such as alfalfa hay and range grasses, we process through livestock first. Even the fish we eat depend on plants that grow in the sea using nutrients that have been washed out of the soil and carried to the sea in rivers and streams.

We study the soil, then, to increase our understanding of this resource that supports us.

Another important reason for studying soil is that soils are different. Oregon alone has nearly 2,000 different kinds of soils, ranging from deep to shallow, clayey to sandy, wet to dry, nearly level to steeply sloping. These differences are important, because different soils require different kinds of management practices.

Wet soils, for example, are essential components of wetland ecosystems. Proper management of wet soils depends on recognizing the imprint of saturated

[1]Shaler, N.S., *Man and the Earth* (Chautauqua, NY: The Chautauqua Press, 1915).

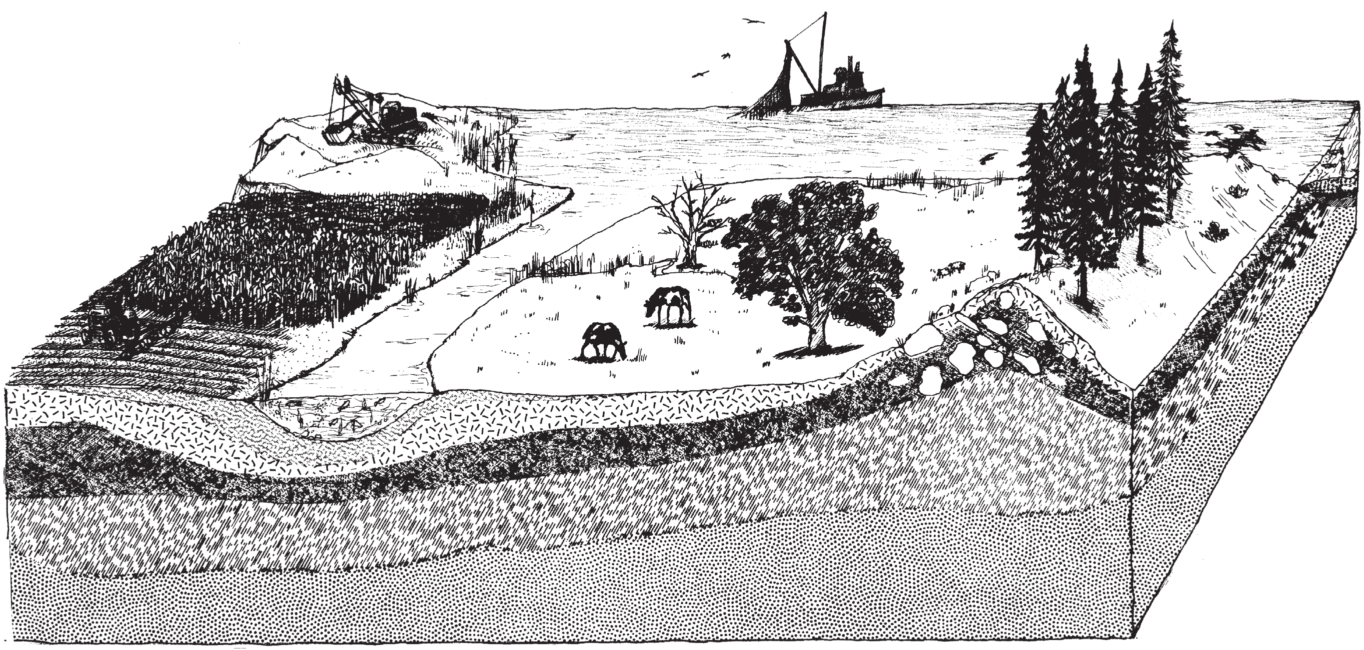


Figure 1.—All of our food resources can be traced directly back to the soil.

conditions on soils and maintaining water tables at desired levels.

Many soils require irrigation for maximum productivity. Both the amount of irrigation water needed and the proper method of applying it depend on a soil's permeability rate and water-holding capacity.

Still other soils have a very serious erosion hazard. The proper choice of conservation practices depends in part on the texture of the surface horizon and the steepness of the slope.

Only by studying soils can we learn how to tailor management practices to the specific needs of each of the many different kinds of soils we depend on.

Some of us study soil because we're just plain curious about this unique and fascinating natural resource. When you dig a hole or scrape off a road cut, you discover right away that there's a whole lot more to the soil than just the top 8 or 10 inches.

Soil scientists, in fact, study the soil to a depth of about 5 feet. They see several different layers, or *horizons,* in the soil. Together, these horizons make a soil *profile.*

We describe the horizons in a soil profile in terms of their properties, or *morphology.* Some properties, such as color and root abundance, can be determined by eye. Others, such as texture and structure, require a keen sense of touch.

You, too, can learn how to determine the important properties of soil horizons. Then you will be able to make a number of important decisions about drainage, irrigation, crop selection, erosion control—and much, much more.

At the beginning of this chapter, we talked about how all human life depends on our soil resources. Knowing that, we must study the soil so that we can learn how to protect it for others to use. There's plenty of good soil on this planet—as long as we take care of it properly. But if we let it erode, or compact it, or mine it, it will fail to support us.

Farmers are the primary stewards of the soil, for they are the tillers of the land. All of us, however, share the responsibility to protect this valuable resource. If we manage our soil properly, it will continue to nourish us for generations to come. If we don't, our very civilization is threatened.

So study the soil, learn about its properties and behavior, manage it wisely, and do your part as a steward of the land.

# The Soil We Study

Soil has been defined by lots of different people in lots of different ways. Here's a very basic definition:

> **SOIL—**the natural medium in which plants grow.

This definition, however, may be a little too simple. Here's a better one:

> **SOIL—**a natural body that develops in profile form from a mixture of minerals and organic matter. It covers the earth in a very thin layer and supplies plants with air, water, nutrients, and mechanical support.

Our definition is, of course, the one we prefer:

> **SOIL—**a *living, dynamic system* at the *interface* between air and rock. Soil forms in response to forces of *climate* and *organisms* that act on *parent material* in a specific *landscape* over a long period of *time.*

We like this definition because each key word says something important about the soil. Why *living?* Because the soil is full of living organisms: roots large and small, animals and insects, millions of microscopic fungi and bacteria.

Equally important are the decaying remains of plants and animals after they die. They form soil organic matter, or *humus,* which is vitally important for good soil tilth and productivity.

*Dynamic* says that the soil changes all the time. Oregon soils change from very wet in the winter to very dry in the summer. Even under irrigation, the amount of water in the soil can vary widely.

Soil organic matter increases when crop residues are worked in, and decreases as fresh plant materials decay. Soil nutrients increase as soil minerals break down. They decrease as water moving through the soil carries them away. Even soil acidity, or pH, changes seasonally.

The word *system* says that all parts of the soil work together to make up the dynamic whole. A change in one part may cause changes in many other parts.

Suppose, for example, we add water until the soil is very wet. That reduces the amount of air available to plant roots. It makes the soil colder, and the activity of roots and soil microbes (very small plants and animals) slows down. The wet soil is stickier and cannot bear as much weight.

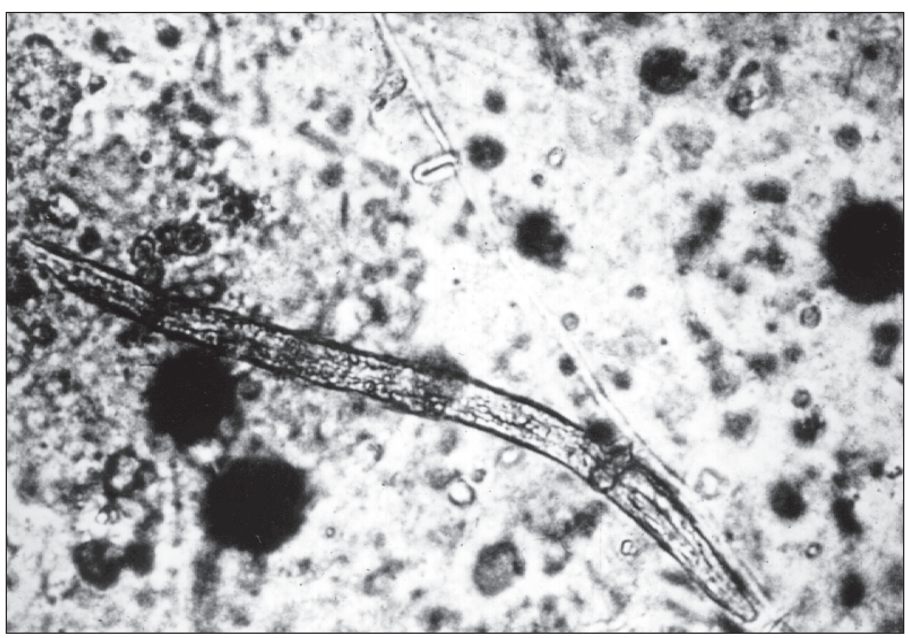


Figure 2.—Living, dynamic soil. The microscopic worm shown is called a nematode. The lower part of the nematode is being attacked and invaded by a fungus.

Now let's remove the excess water. The whole system changes to a warmer and drier soil that is better for plants to grow in and easier for farmers to manage.

The word *interface* stresses the idea that soil is indeed a very thin rind at the earth's surface. When air meets rock, especially if the air is warm and the rock is moist, the rock begins to change. Some changes are physical. They break rocks down into smaller pieces. Other changes are chemical. They destroy some of the original minerals and create new ones.

These physical and chemical changes are called *weathering.* Weathering occurs only within the first few feet of the earth's surface. Plate 5 illustrates a strongly weathered soil. The light-colored parts of the BC horizon are highly weathered bedrock remnants not yet fully changed into soil.

Now consider the size of the earth. The distance from the surface to the center of the earth is about 4,000 miles. Thus, 10 feet of weathered rock out of 4,000 miles is something less than .00005 percent. Soil does indeed occur at the point of contact between earth and atmosphere!

## Factors of Soil Formation

The rest of the key words in our definition of soil tell us something about how soil forms. We think in terms of five *soil-forming factors.* Two of them, climate and organisms, are called *active* factors. They provide the forces that cause soil to form. The other three, parent material, topography, and time, are called *passive* factors. They respond to the forces exerted by climate and organisms.

Together, the interactions between the force factors and the response factors result in a new product, a unique natural resource, which we call soil.

| Five Soil-forming Factors |
|---|
| Climate |
| Organisms |
| Parent Material |
| Topography |
| Time |

### Climate

Climate affects soil most directly through temperature and rainfall. In warm, moist climates, rocks and minerals weather very quickly. The soil that forms often has a reddish color. Most of the red soils in western Oregon are red because they formed when the climate was warmer than it is now.

High rainfall also causes *leaching*—the removal of soil materials by water flowing through the soil. Free lime is completely leached from western Oregon soils. These soils are acid. Free lime is still present in many eastern Oregon soils because there isn't enough rain to leach the soil completely.

Warm, moist climates encourage lots of plant growth, and that means lots of soil organic matter. The opposite is true in hot, dry climates. Soils in the Willamette Valley are dark-colored because they have plenty of organic matter. Soils in the Ontario area are light-colored because they have very little organic matter.

### Organisms

Organisms are of three general types: large plants, tiny plants (microbes), and animals. Roots of large plants help break rocks apart and mix soil particles. Root channels provide pathways for water and air movement through the soil. Aboveground plant parts die and decay, thereby building up the organic matter in the soil.

Microscopic organisms, or microbes, are an extremely important part of the soil. They are the primary decomposers. They change raw plant material into a complex black substance called humus. At the same time they release soil nitrogen, an essential nutrient that plants need in large quantities. Thus, rich, fertile topsoils are rich and fertile because they are well supplied with humus (see Plates 3, 4, and 8). Even the earthy smell of moist, rich, topsoil is caused by a microorganism.

Microbes and the humus they produce also act as a kind of glue to hold soil particles together in aggregates. Well-aggregated soil is ideal for providing the right combination of air and water to plant roots.

Without microbes, therefore, soil would be a virtually inert (lifeless) body. With them, soil is truly a living, dynamic system.

Soil animals include large burrowing animals, small earthworms and insects, and microscopic worms called nematodes. All are important because they help mix soil. Animal mixing carries raw plant debris that lies on the soil surface down into the topsoil. Only then can the microbes do their job of changing plant material to humus.

## Parent material

Parent material is the original geologic material that has been changed into the soil we see today. Parent material is passive because it simply responds to the changes brought about by weathering and biological activity.

Many parent materials are some kind of bedrock, like sandstone or basalt. Others are deposits of sediments carried by water, wind, or ice. Volcanic ash, lake-laid silts, dune sand, and glacial gravels all are examples of transported parent materials.

## Time

Time is the great equalizer. Young soils inherit the properties of their parent materials. They tend to have the same color, texture, and chemical composition as their parent materials. Later on, the influence of parent material is not as evident.

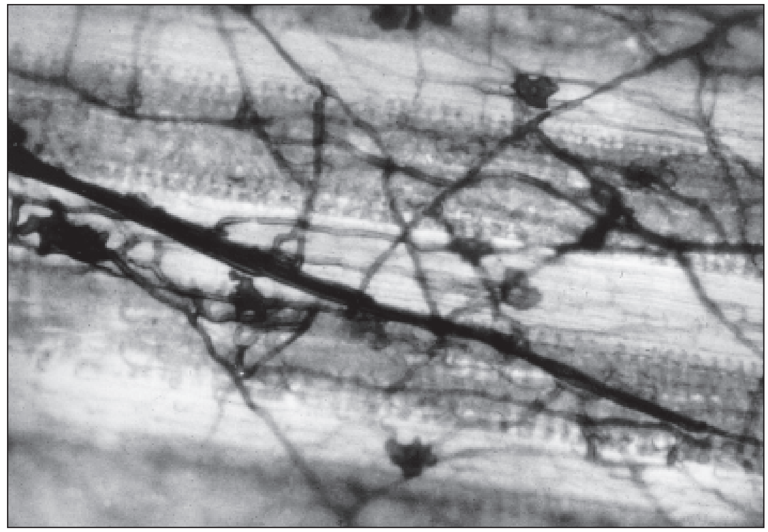


Figure 3.—Humus formation. Strands of fungus surround a freshly clipped blade of grass. Decomposition is beginning and will soon convert the clipping to soil organic matter.

As soils age, many original minerals are destroyed. Many new ones are formed. Soils become more leached, more acid, and more clayey. In short, the soil becomes more strongly developed with the passage of time.

## Topography

Topography, or landscape position, causes localized changes in moisture, temperature, and parent material. When rain falls on a hillslope, for example, water runs away from the top of the hill. Excess water collects at the bottom of the hill. Soils at the top of the hill are relatively dry and often show the effects of erosion on the soil profile. Soils at the bottom of the hill not only are wetter but often are formed in materials transported down slope and deposited in lower landscape positions.

Another effect of topography is due to the direction that a slope faces. Soils on north-facing slopes, for example, tend to be cooler and wetter than soils on south-facing slopes.

## Processes of Soil Formation

Our definition of soil has identified *five factors* of soil formation. We also can think in terms of four major *processes* that change parent material into life-sustaining soil. They are additions, losses, translocations, and transformations.

| Processes of Soil Formation |
|---|
| Additions |
| Losses |
| Translocations |
| Transformations |

### Additions

The most obvious addition is organic matter. As soon as plant life begins to grow in fresh parent material, organic matter begins to accumulate. Organic matter gives a black or dark brown color to surface soils. This is why even very young soils usually have a dark-colored surface layer.

Other additions come with rainfall. On the average, rainfall adds about five pounds of nitrogen each year to every acre of soil. Rainfall also can be acid, especially downwind from industrial areas. Acid rain may change the rate of some soil processes. Rainfall, by causing rivers to flood, is indirectly responsible for the addition of new sediments to the soil on a river's floodplain.

### Losses

Most losses occur by leaching. Water moving through the soil dissolves certain minerals and carries them out of the soil. Some minerals, especially salt and lime, are readily soluble. They are removed very early in the history of a soil's formation. That's why soils in humid regions don't contain free lime.

Many fertilizers, especially nitrogen fertilizers, also are quite soluble. They, too, are readily lost by leaching, either by natural rainfall or by irrigation water.

Other minerals, such as iron oxides and sand grains, dissolve very slowly. They remain in the soil until it is very old and highly weathered.

Losses also occur as gases or solids. Oxygen and water vapor are lost from soil as fresh organic matter decays. And when soils are very wet, nitrogen can be changed to a gas and lost to the atmosphere. Solids are lost by erosion, which removes both mineral and organic soil particles. Such losses are very serious, for the soil lost by erosion usually is the most productive part of the soil profile.

### Translocations

Translocation means movement from one place to another. Usually we think of movement out of a horizon near the soil surface and into another horizon that is deeper in the soil.

In low rainfall areas, leaching often is incomplete. Water starts moving down through the soil, dissolving soluble minerals as it goes. But there isn't enough water to move all the way through the soil. When the water stops moving, then evaporates, the salts are left behind. That's how subsoil accumulations of free lime are formed (Plate 9). Many hardpans in soils of dry areas form this way, too (Plate 10).

Upward translocation also is possible. Even in the dry areas of eastern Oregon, there are some wet soils that have high water tables. Evaporation at the surface causes water to move upward continuously. Salts are dissolved on the way, and left behind as the water evaporates (Figure 4). Salty soils are difficult to manage, and they are not very productive.

Another kind of translocation involves very thin clay particles. Water moving through the soil can carry these particles from one horizon to another, or from place to place within a horizon. When the water stops moving, clay particles are deposited on the surface of soil aggregates. We call these coatings *clay skins,* and they have a dark, waxy appearance (Plate 15).

### Transformations

These are changes that take place in the soil. Microorganisms that live in the soil feed on fresh organic matter and change it into humus. Chemical weathering changes the original minerals of parent materials. Some minerals are destroyed completely. Others are changed into new minerals. Many of the clay particles in soils are actually new minerals that form during soil development.

Still other transformations change the form of certain elements. Iron oxide usually gives soils a yellowish-brown or reddish-brown color. In waterlogged soils, however, iron oxide changes to a different form that we call *reduced.* Reduced iron oxide is lost quite easily from the soil by leaching. After the iron is gone, the soil has a gray or white color.

Repeated cycles of wetting and drying create *mottled* soil (Plates 7 and 16). Part of the soil is gray because of loss of iron, and part is yellow-brown where the iron oxides have accumulated in localized areas.

Figure 4.—Upward translocation. The white areas, called slick spots, are accumulations of salts left on the soil surface after water moving up through the soil evaporated at the surface.

## From Rock to Soil

How do all these processes work together to form soil? Let's start with a fresh parent material. Climate starts acting on it immediately. Weathering begins to change minerals. Leaching removes salts, then free lime.

As soon as plants begin growing, they add organic matter to the soil. Biological activity increases, and humus forms. Soon a dark-colored surface horizon is present.

Weathering and leaching continue to change soil minerals and remove soluble components. More horizons develop beneath the surface. The soil becomes more acid. Clay minerals begin to form. Clay is translocated and clay skins become visible.

As the amount of clay in subsoil horizons increases, the rate of water movement through the soil decreases. Weathering continues, but leaching isn't as rapid. After a while, further change is very slow, and the whole soil-plant-landscape system is in a kind of steady state.

How do we know that all this has happened? First, we dug a hole to reveal a soil profile. Next, we studied the soil carefully, located the horizons, and determined their properties. Then we interpreted the information from the profile in terms of the factors and processes of soil formation.

You, too, can learn how to describe and interpret soil profiles. That's what the rest of this *Manual* is all about.

# Kinds of Soil Horizons

A soil horizon is a layer of soil parallel to the earth's surface. It has a unique set of physical, chemical, and biological properties. The properties of soil horizons are the results of soil-forming processes, and they distinguish each horizon from other horizons above and below.

Soil horizons are named using combinations of letters and numbers. Six general kinds of horizons may occur in soil profiles (Figure 5), and they are named with capital letters: O, A, E, B, C, R. These are called *master horizons.*

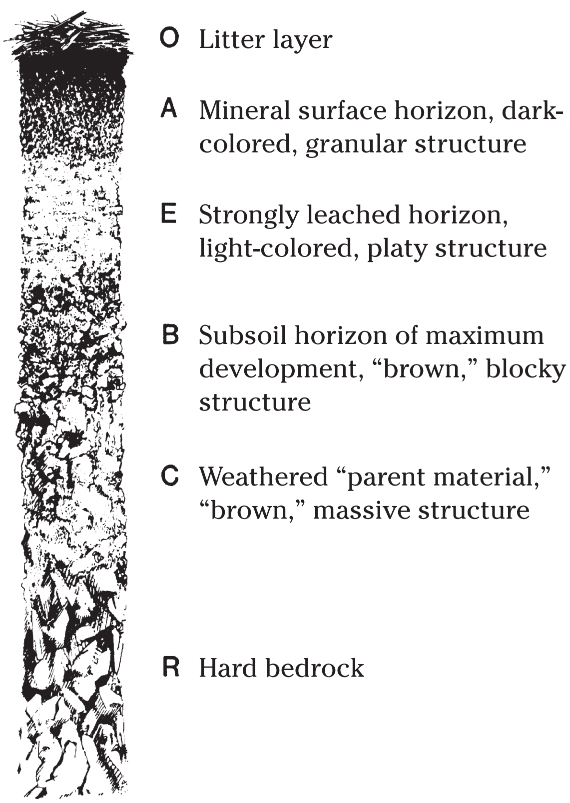



Figure 5.—Generalized soil profile. Each master horizon is shown in the relative position in which it occurs in a soil profile. All six master horizons are shown, even though any one soil usually has only three or four.

Gradual changes from one master horizon to another give rise to *transition horizons.* These are named with two letters, for example, AB, BA, BC. Special kinds of master horizons are named by adding lower case letters—for example Ap, Bt, Cr. Thick horizons may be subdivided using Arabic numbers, as in Al, A2, or Bw1, Bw2, Bw3.

A single soil profile never has all the horizons that are possible. Most Oregon soils have A, B, C, and one or two transition horizons. Other Oregon soils may have an A horizon resting directly on a C horizon, or an A-E-B-C horizon sequence, or even an O-E-B-C sequence.

Because all six master horizons occur somewhere in Oregon, we need to know what each one is and how it differs from the others.

## Master Horizons

Each master horizon has a distinct set of properties.

### O horizon

The O stands for organic. O horizons don't have to be 100 percent organic material, but most are nearly so. Forest soils usually have thin organic horizons at the surface. They consist of leaves and twigs in various stages of decay (Plate 1).

Wet soils in bogs or drained swamps often have O horizons of peat or muck. Soils in Lake Labish, Waldo Lake, and Lower Klamath Lake all have O horizons of this kind. Other than these, very few agricultural or rangeland soils in Oregon have O horizons.

### A horizon

The A horizon is the surface horizon of mineral soil. Its unique characteristic is a dark color formed by addition of humus (Plates 3, 4, 5, 6, 8, and 12). Granular or fine blocky structure (aggregate shape) and friable consistence (ease of crushing) also are typical.

The thickness of A horizons ranges from a few inches in dry, rangeland soils to over 20 inches (50 cm) in some Willamette Valley soils. Every cultivated agricultural soil has an A horizon.

A horizons are extremely important in maintaining soil fertility and providing a favorable environment for root growth. They should be protected from damage by erosion or compaction.

### E horizon

This horizon has a light gray or white color. It's not present in all Oregon soils, but when it is, it usually occurs immediately beneath an O or an A horizon (Plates 1, 5, 6, and 11).

E horizons are light-colored because nearly all the iron and organic matter has been removed. You can think of the E as meaning exit or leaching.

E horizons occur in several of the sandy soils along the Oregon coast. They also occur in some wet, silty soils that have dense, clayey subsoils. In the wet soils, the E horizon also has noticeably less clay than the B horizon beneath it.

### B horizon

The B horizon is the subsoil layer that changes the most because of soil-forming processes. Several kinds of changes are possible.

In some soils, the B horizon has the brightest yellowish-brown or reddish-brown color (Plates 1, 2, 4, 5, 9, and 12). In others, it has the most evident blocky or prismatic structure (Plates 2 and 3). Many B horizons have more clay than any other horizon, and you may be able to see clay skins (Plates 3, 5, 6, and 9). Each of these major kinds of B horizons is discussed more fully in the next section, "Special Kinds of A, B, and C Horizons."

### C horizon

The C horizon is weathered geologic material below the A or B horizon. Anything that you can dig with a spade but which has not been changed very much by soil-forming processes is considered C horizon (Plates 1, 2, 3, 4, 9, and 13).

### R horizon

R stands for rock. It refers to hard bedrock that you can't easily dig with a spade. Depending on the depth to bedrock, the R horizon may occur directly beneath any of the other master horizons (Plate 12).

To judge an R horizon, mark its color, and check *none* for mottles and NA for texture. Bedrock essentially is 100 percent coarse fragments, so check *more than 60 percent.* The structure type is *massive* and the grade is *structureless.*

## Special Kinds of A, B, and C Horizons

Many horizons are the result of unique processes that leave a distinct mark on the horizon. We identify these horizons with a lower-case letter immediately following the master horizon symbol. Over 25 letters and combinations of letters are possible. We'll discuss only nine that you are most likely to encounter in Oregon soils.

### Ap horizon

The surface horizon of any soil that has been plowed or cultivated is called the plow layer (Plates 2, 6, 9, and 12). That's what the p stands for. Cultivation thoroughly mixes the upper 8 to 12 inches

(20 to 30 cm) of the soil and destroys any natural horizons that may have been present.

If the original A was very thick, plowing converts the upper part into an Ap, and the lower part remains simply as a second A horizon. If the original A was very thin, then the Ap could rest on a B, a C, or a transition horizon.

Even when a soil has been severely eroded, such that all the original A is gone, plowing an exposed B or C horizon would automatically make the surface horizon an Ap.

## Bt horizon

The t stands for *texture.* Textural B horizons have distinctly more clay in them than the horizons above or below. You can feel the difference.

Some of the clay comes from the soil above the Bt. Water moving down through the soil carries very fine clay particles with it. When the downward movement stops, the clays are deposited, building up the waxy coatings we call *clay skins.* Some of the clay also comes from the weathering of original minerals in the Bt.

Bt horizons are quite common in Oregon soils. They usually have well-developed blocky or prismatic structure (Plates 3, 5, 6, and 9).

## Bg horizon

This horizon is *gleyed.* That means it's very wet for long periods of time. Iron in the soil is chemically reduced, and much of it has been leached out of the soil. As a result, gleyed horizons usually are dark gray in color (Plates 7 and 8). They also may be mottled (see page 17), but not necessarily so.

Gleyed horizons almost always tell us that the soil is poorly or very poorly drained. Gleying is not restricted to the Bg; other gleyed horizons include Ag, BAg, BCg, Cg.

## Bs horizon

We call this horizon a *spodic* horizon. It's common only in some of the sandy soils on marine terraces along the Oregon coast. A few soils at very high elevations in the Cascades and the Blue Mountains also have spodic horizons.

The color of a spodic horizon is quite distinctive. It's usually bright yellowish-brown or reddish-brown, and it fades with depth (Plate 1). Often there's a thin black layer at the top. The spodic horizon forms when iron, aluminum, and organic matter all are leached out of surface horizons, carried downward, and deposited in the subsoil.

## Bw horizon

Think of the w as meaning *weathered.* Bw horizons have been changed by weathering, but not enough to form a Bt, Bg, or Bs. In Oregon soils, the Bw differs from the C by having weak or moderate blocky structure (see page 25). The Bw also may have a little brighter color (Plates 2, 4, 11, and 12), and it may be more leached than the C.

Bw horizons are common in soils of the Cascade and Coast Range Mountains, in young soils on river floodplains and low terraces, and in many soils of eastern Oregon.

## Bx horizon

This refers to a special feature called a *fragipan.* It is a massive, dense, but not cemented, soil horizon. The fragipan is often mottled and has streaks of gray silt scattered throughout (Plate 11). The fragipan is so dense that neither plant roots nor water can penetrate, except in the gray silt streaks. In Oregon, fragipans occur only in some of the upland soils of Columbia, Washington, Multnomah, and Clackamas counties.

### Bk horizon

This horizon has an accumulation of calcium carbonate, or free lime. Carbonates leached from upper horizons have been redeposited in the Bk (Plate 9). You should be able to see white streaks or nodules of lime. These will bubble violently when a drop of hydrochloric acid (HCl) is placed on them.

Be careful though. Some soils in eastern Oregon have had free lime in them right from the beginning. They will react to the acid, too. We use the k only to indicate a horizon enriched in carbonates by translocation. A Bk horizon may very well have an ordinary C horizon beneath it that contains only its original amount of lime.

### Bkqm horizon

This horizon is called a *duripan* (Plate 10). It is enriched with calcium carbonate (k) and silica (q), and it is strongly cemented (m).

Duripans are common in several soils of eastern Oregon. Limited rainfall has leached lime and silica from the upper 10 to 20 inches of soil and redeposited them in the Bkqm. Thin, pinkish coatings of opal may be present on the upper surfaces of duripan fragments. The duripan usually is only 6 to 10 inches thick, but it is so cemented that plant roots can't go through it.

A dense mat of roots spreading horizontally is a good indicator of a duripan. Sometimes, however, there are fractures in the duripan that will allow some plant roots to find a way down. And if the pan is only weakly cemented, you can break it up even more by ripping.

For soil judging contests, mark the most appropriate color. Check *none* for mottling, NA for texture, and *more than 60 percent* coarse fragments. The structure type is *massive* and the grade is *structureless.*

### Cr horizon

Weathered bedrock, or rock that is soft enough to slice with a knife or a spade, is called Cr (Plate 13). It's rock material, and you often can see original rock structure, but it's not hard enough to be designated R.

When judging a Cr, first record its color, then check *none* for mottles, *NA* for texture, and *more than 60 percent* coarse fragments. The structure type is *massive* and the grade is *structureless*.

## Transition Horizons

Master horizons rarely change abruptly from one to another. Instead, the changes occur gradually throughout a zone that may be 5 or 10 inches thick. These zones are called transition horizons. There are three common ones in Oregon soils.

### AB horizon

This transition horizon occurs between the A and the B. It's dominated by properties of the A, but some of the properties of the B are evident. Dark colors associated with organic matter are fading because organic matter is decreasing (Plate 4). The structure often changes from granular to subangular blocky (see Chapter 4, "Soil Structure").

### BA horizon

This horizon also occurs between the A and the B, but it has more of the characteristics of the B. Generally, the structure will be the same type as the B, but less strongly expressed. The color may be a little darker than the B (Plate 3), or the clay content may be less than the maximum in the B.

### BC horizon

This is a transition from B to C. Properties of the B are dominant, but some influence of the C horizon is evident

(Plates 2 and 3). Often the clay content will be less than the maximum in the B, but more than in the C. Or the color will be fading. If the C is massive, the BC has structure, but it may have larger units and be more weakly expressed than in the B.

## Subdivisions of Thick Horizons

Sometimes one or two of the horizons in a soil are so thick that they need to be subdivided. Small changes in texture, color, or structure commonly are used to make the subdivision.

Subdivisions, or vertical sequences within any single kind of horizon, always are indicated by a number immediately following the letter symbol(s). Here are a few examples of some thick soil horizons that could be subdivided:

Thick A horizon—Al, A2 (Plate 8)

Thick Bg horizon—Bg1, Bg2 (Plate 7)

Thick Bt horizon—Bt1, Bt2 (Plate 5)

Thick Bw horizon—Bw1, Bw2 (Plate 2)

Thick C horizon—C1, C2 (Plates 3 and 4)

## More Than One Kind of Parent Material

Parent material is the geologic stuff from which soils form. It may be a river deposit, volcanic ash, clays weathered from rock in place, or one of many other kinds of materials. When all the horizons of a soil have formed in a single kind of parent material, we simply use the ordinary A, B, and C designations.

Some soils, however, have formed in more that one kind of parent material. A flooding river, for example, may deposit fresh silts on top of older sands and gravels. Or volcanic ash may be deposited on top of weathered bedrock.

If soil horizons are developed in more than one material, we place a number in front of the horizon name to indicate its position from the top down.

The geologic material at the surface is always assumed to be the first one, and the number 1 is never used.

The second geologic material is indicated by a 2, the third by a 3, and so on. Thus a soil developed in silt loam over gravel could have the following set of horizons: A-AB-B-2BC-2C.

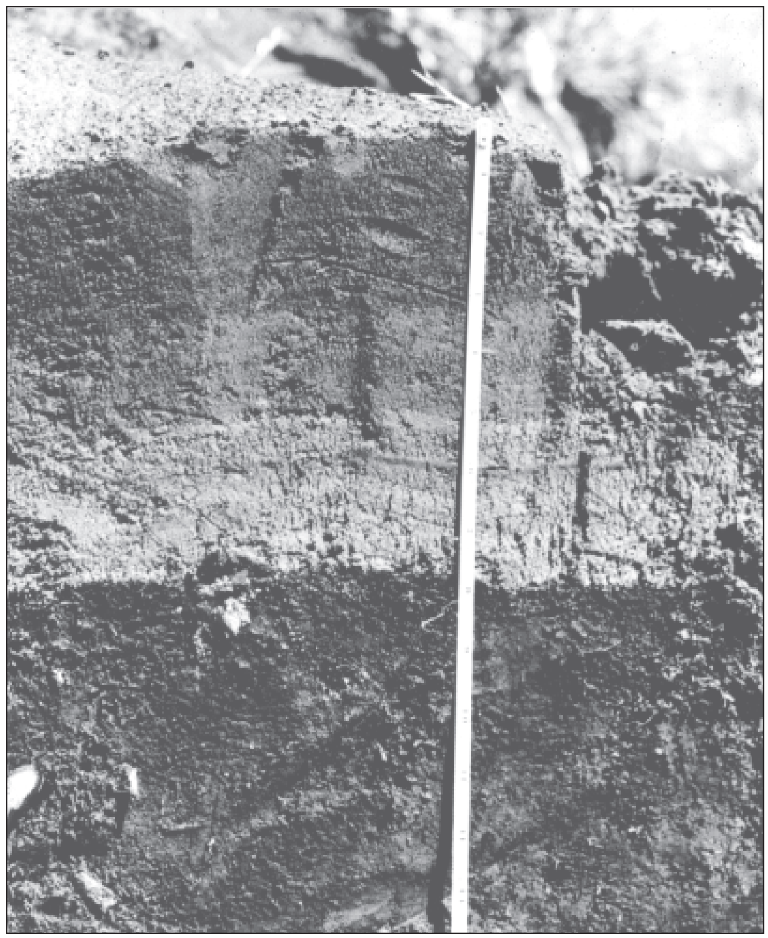


Figure 6.—Multiple parent materials. The gray material is recent volcanic ash resting on older, more weathered soil material. Notice the abrupt contact between the two contrasting materials.

## Typical Horizon Sequences

Several common Oregon soils are listed below, followed by the names of the horizons in a typical profile. Nearly all geographic areas of Oregon are represented by the soils on this list.

| | |
|---|---|
| Alicel | Ap-A-BA-Bw-2C |
| Bandon | O-E-Bs1-Bs2-Bs3-Bs4-C |
| Brenner | Ap-A-Bg1-Bg2-BCg-Cg |
| Carney | A1-A2-AB-C-2R |
| Cascade | A-Bw1-Bw2-2Bx1-2Bx2-2Bx3 |
| Dayton | Ap-E-2Bt-2BCt-3C |
| Deschutes | A-BA-Bw-2C-3R |
| Fordney | Ap-C1-C2 |
| Gem | Al-A2-BAt-Bt1-Bt2-BCt-BCtk-R |
| Hoopal | A1-A2-Bw-Bkqm-C |
| Josephine | O-A-BA-Bt1-Bt2-Bt3-C-Cr |
| Malabon | Ap-AB-Bt1-Bt2-BCt-2C |
| Nehalem | Ap-A-Bw-C |
| Nyssa | Ap-Bw-Bkq-Bkqm1-Bkqm2 |
| Oakland | A1-A2-Bt1-Bt2-Bt3-BCt-Cr |
| Quincy | C1-C2 |
| Ritzville | Ap-BA-Bw-Bk-C1-C2 |
| Salem | Ap-Bt-BCt-2C |
| Simas | A-2Bt1-2Bt2-2BCk1-2BCk2 |
| Walla Walla | Ap-A-BA-Bw-BCk1-BCk2 |

## Locating Boundaries Between Horizons

The most useful thing you can do to help yourself find and name soil horizons is to prepare a good exposure of the soil profile. Either a good pit or a road cut will do, but in either case you should clean up the face of the vertical cut. Use your knife to pick off any soil that may have fallen down from the surface or that was smeared by a shovel or a backhoe. After you have a good, fresh surface, try each of the following techniques.

1. Look for color changes. Where there is an obvious color change there also is a horizon change. Color alone, however, is not sufficient to separate all horizons. Several soils in Oregon have nearly uniform colors extending all the way through the B and into the C.
2. Take a knife and gently poke the soil every few inches from the surface down to the lower part of the pit. Often you can "feel" the firmer consistence of subsoils and restrictive layers. You may even be able to locate a contact between B and C this way.
3. Starting at the top, check the soil texture with your fingers every 2 to 4 inches. If there is a marked increase in clay from A to B, you should detect it this way. A decrease in clay from B to C also should be evident.
4. With your knife, remove a handful of soil from the upper 4 inches of soil. Carefully break it apart and observe the size, shape, and strength of structural aggregates. Repeat this process every 4 to 6 inches down through the profile. Structural changes may be a good clue to boundaries between horizons and to the presence of transition horizons.
5. Each time you locate a tentative boundary, mark it with a nail, twig, or some other convenient marker. As you consider more and more characteristics, you may want to adjust some of the boundaries up or down.
6. When you have settled on an initial set of horizon boundaries, start looking more carefully at the color, texture, structure, pores, clay skins, etc. of each horizon. With a complete set of information, you may wish to make a final adjustment in your horizon boundaries.

# Properties of Soil Horizons

After you have marked off the horizons in a soil, the next step is to carefully determine the properties of each horizon. We'll discuss only those properties that we can observe readily in the field. The most important ones are color, texture, and structure. Others include soil consistence and the characteristics of horizon boundaries.

## Color of the Soil Matrix

Soil colors give us clues about the nature of the root zone. Dark colors mean favorable amounts of humus. Gray colors suggest wetness. Brown and red colors indicate favorable air-water relations.

The soil matrix is the main body of the soil. In uniformly colored horizons, the matrix is the entire soil in the horizon. Some horizons, however, have two or more colors. The matrix color is the dominant color, the one that covers the greatest area and gives you an overall impression of the horizon's color.

The color of most soils depends on whether the soil is moist or dry. Moist soil is almost always darker than dry soil. We can always moisten a dry soil, but we may not always have time to wait for a moist soil to dry out. To be consistent, therefore, we always will judge the color of the soil when it is moist. One or two drops of water from your squirt bottle will be enough to do the job.

The apparent color of a moist soil also may depend on the amount of sunlight striking the sample. The color may seem to be a little darker on an overcast day than on a sunny day, or in a shadow rather than in open sunlight. Some variation is unavoidable, but you always should try to determine soil color in the greatest amount of light available.

We can group soil colors into four broad classes. We use descriptive names for these classes—even though each of us sees colors a little differently from everyone else. There is a more accurate way to describe soil color, but it requires special color books that are quite expensive. That method is described briefly at the end of this section.

### Dark brown, Very dark brown, Black

These colors are caused by accumulations of organic matter in soils. Usually, the darker the color, the more the organic matter, and the more fertile and productive the soil.

Dark colors are typical of A horizons (Plates 3, 4, 5, 6, 7, 8, 10, and 12). Almost all A horizons in the soils of western Oregon will have this color.

That's not the case in eastern Oregon, though. Organic matter contents are much lower, and the soils are lighter colored. In general, if an eastern Oregon soil has been cultivated, and the crop residues have been mixed into the A, then the color probably is dark brown or very dark brown. If the soil has not been cultivated, and there isn't very much native vegetation, then the A horizon is likely to have a light brown color.

Some soils have black colors extending well down into the subsoil. That's usually an indicator of wetness. Organic matter in wet soils breaks down very slowly, and the extra organic matter accumulated darkens the soil (Plate 8).

Some very clayey, sticky, shrink-swell soils may be black, too. In these soils, organic matter is mixed throughout the entire shrink-swell zone, and the soil is black, even though the organic matter content isn't particularly high.

## Light brown, Brown, Yellowish brown

These are the colors of well-aerated soil. That means that air moves freely into and out of the voids, or pore spaces, of the soil. As microbes and plant roots use up oxygen in soil pores, oxygen from the air above the soil moves in to replace it. Well-aerated soils, therefore, provide healthy homes for plant roots.

Brown colors are due to iron oxide coatings on mineral grains. Chemically, they're the same as a coating of rust on a piece of iron. These iron oxide coatings require plenty of oxygen in soil pores. If water should fill soil pores and remain there for a long time, oxygen cannot reach the iron coatings, and the soil turns gray. That's why brown colors tell us that the soil has good air-water relations and is not saturated for long periods of time.

Brown colors are typical of B and C horizons that are well-aerated (Plates 1, 2, 9, 10, 11, and 12). That's true in both eastern and western Oregon. As long as there's not enough organic matter to darken the soil, and there's plenty of oxygen to maintain iron oxide coatings, the soil almost always will be brown (or red—see next section).

## Red, Reddish brown

These colors also are caused by iron oxide coatings, and they also indicate well-aerated soil. The soil is red, rather than brown, only because the chemical form of the iron oxide is a little different.

Most red soils are very old soils, and they are very strongly weathered (Plate 5). They are more leached, more acid, and less fertile than soils having brown colors.

Red soils occur in the foothills and mountains west of the Cascades from the Columbia River to the California border. Except for the A horizon, all other horizons in these soils usually are red. Red soils are rare east of the Cascades, but there is at least one red, clayey soil in central Oregon.

## Dark gray, Light gray, White

Dark gray soils are wet soils. When soil pores are full of water, oxygen can't get in. Gradually the yellow-brown coatings are removed from mineral grains (soil particles) and are leached away. The gray color that we see is the natural gray color of the uncoated mineral grains, darkened a little by organic matter. Dark gray is typical of B and C horizons in wet soils (Plates 7, 8, and 16).

Light gray and white colors are characteristic of E horizons. They also are the colors of uncoated mineral grains, but there is almost no darkening with organic matter.

Some E horizons occur in wet soils (Plates 6 and 11). Iron is reduced and leached from the soil, often when water moves sideways on top of a tight subsoil.

Other E horizons may occur in well drained soils (Plates 1 and 5). In these soils, different chemical processes cause the loss of iron oxide coatings from mineral grains. These E horizons will have bright-colored Bs or Bt horizons below them.

## Technical descriptions of soil colors

The more technical method of soil color description uses Munsell color notations. These involve symbols like 10YR 4/3. The first part (10YR) designates a color *hue,* or pure color. The numerator of the fraction is called the *value.* This is an index of the amount of incident light reflected from the soil. The denominator is called the *chroma.* It is an index of how much white light dilutes the pure color.

The Munsell Color Company makes small color chips for each combination of hue, value, and chroma. Chips of those colors that are most frequently found in soils are arranged in special books of soil color charts.

To determine soil color in the field, you simply match the color of a soil aggregate with a chip of the same color. Then you record the symbol for that chip.

Technical descriptions of Oregon soils, published either in soil survey reports or as single-sheet official descriptions, use this more precise method of evaluating soil colors.

## Mottling

Some soil horizons have spots of one color in a matrix of a different color. For many, many years, these spots have been called *mottles*, and the soil has been said to be *mottled*. Now, soil scientists observe and describe these spots in much greater detail, and they are called redoximorphic features—redox concentrations (bright colored mottles), redox depletions (low chroma mottles), and reduced matrices (strongly gleyed soils). For our work, however, the older nomenclature of mottles still serves the purpose very well, and we'll defer the use of the newer terms to university-level soil judging.

Some mottles appear as splotches of reddish-brown in a gray matrix (Plates 7 and 16). Others appear as gray mottles in a brown matrix. In either case, mottles usually tell us that the soil has a high water table during the rainy season.

A water table is the top of a zone of saturated soil. Beneath the water table, all the soil pores are full of water. Without a supply of air, iron oxide coatings are removed from soil particles, and gray colors develop.

When the water table drops, oxygen enters the soil through root channels and large pores. Iron changes back to the yellow-brown form and coats soil particles in contact with the air. The result is a yellowish-brown mottle surrounded by gray soil.

The depth to mottles, and the number and brightness of the mottles, are keys to the degree of wetness of the soil. This will be discussed more fully in the section on internal soil drainage (page 42). There are, however, two situations in which mottles do not indicate wetness.

### How to Describe Mottles

**Abundance—**the percentage of exposed surface area occupied by mottles. Classes of abundance are:

*Few*—less than 2 percent of exposed surface

*Common*—2 to 20 percent of exposed surface

*Many*—more than 20 percent of exposed surface

**Size—**the approximate diameter of individual mottles. Size classes are:

*Fine*—diameter less than 5 mm

*Medium*—diameter of 5 to 15 mm

*Coarse*—diameter more than 15 mm

**Contrast—**the relative difference between the mottle color and the matrix color. Classes of contrast are:

*Faint*—mottles evident only on close scrutiny. Mottle color and matrix color are very nearly the same.

*Distinct*—mottles are readily seen though not striking. Mottle color and matrix color are different, though not widely so.

*Prominent*—mottles are so conspicuous that they are the outstanding visible feature of the horizon. Mottle color and matrix color are widely different.

**Color—**mottle colors are described in the same way as colors of any horizon. The most common mottle colors are yellowish-brown, dark reddish-brown, and gray.

One situation is caused by the chemical weathering of rocks. Each different mineral that makes up a rock reacts differently to chemical processes. Some minerals turn yellow, some turn red, some turn gray, and some are destroyed completely. The result of rock weathering can be a mixture of colors that may look like drainage mottles, even though the soil is quite well drained. Many Cr horizons have this kind of "mottling."

The key to avoiding this false interpretation of soil colors is to study other factors of the soil and the landscape very carefully. Concave (bowl-shaped) depressions, low-lying areas, or broad, flat terraces are landscapes that are likely to have wet soils. Mottles in these soils are probably drainage mottles. Soils that have horizons that restrict water movement also are likely to have mottles caused by wetness.

Soils on rounded hilltops and sloping hillsides shed water. They are likely to be well drained. Many of these soils are not very deep to bedrock. In these soils, the lower horizons may very well contain weathered rock fragments that look like mottles. The closer you get to the bedrock, the more mottled it may look.

But brown colors throughout the soil, and the shape of the landscape, should tell you that these "mottles" don't indicate soil wetness. You may even be able to see remnants of layering of the original rocks, and that's another clue that color variations are not due to wetness. Check *none* for mottling on your scorecard if you see this kind of color pattern.

Another false interpretation of color patterns is caused by coatings on soil aggregates. Organic matter coatings, clay coatings, or moisture films all darken the surface of soil aggregates, particularly in B horizons.

Don't confuse these coatings with mottles. And don't judge the color of the soil matrix by the color of the coatings. Always break open a soil aggregate, and judge the color of both the matrix and the mottles from a freshly exposed surface.

Mottle patterns in soils are described using four properties: abundance, size, contrast, and color. Standards for determining each feature are given in the box on page 17.

## Texture

Texture refers to the amounts of sand, silt, and clay in a soil. Depending on how much sand, silt, and clay are present, we give the texture a name like *sandy loam, clay loam,* or *silty clay loam.* Soils that also contain gravel or cobblestones may have names like *gravelly loam* or *very cobbly clay.*

Texture is an important soil property because it is closely related to many aspects of soil behavior. The ease of tilling the soil and the ease of plant root development within the soil both are influenced by soil texture. Texture affects the amounts of air and water a soil will hold and the rate of water movement through the soil.

Plant nutrient supplies also are related to soil texture. Tiny silt and clay particles

**Sand**
.05 to 2mm
feels gritty

**Silt**
.002 to .05 mm
feels smooth

**Clay**
less than .002 mm
feels sticky

provide more mineral nutrients to plants than large sand grains. We can manage sandy soils to improve their productivity, but they require more fertilizer and more frequent irrigation than silty or loamy soils.

The determination of soil texture begins by separating the soil into two broad classes of particle size, *fine earth* and *coarse fragments.* Fine earth includes all particles smaller than 2 mm in diameter. This is the fraction that passes through a no. 10 sieve. Sand, silt, and clay all are smaller than 2 mm and are the components of fine earth.

Coarse fragments include *gravel* and *cobbles* up to 10 inches (25 cm) in diameter. Rock fragments larger than 10 inches are called *stones* and *boulders.* They are described as a characteristic of the site and are discussed further in Chapter 6.

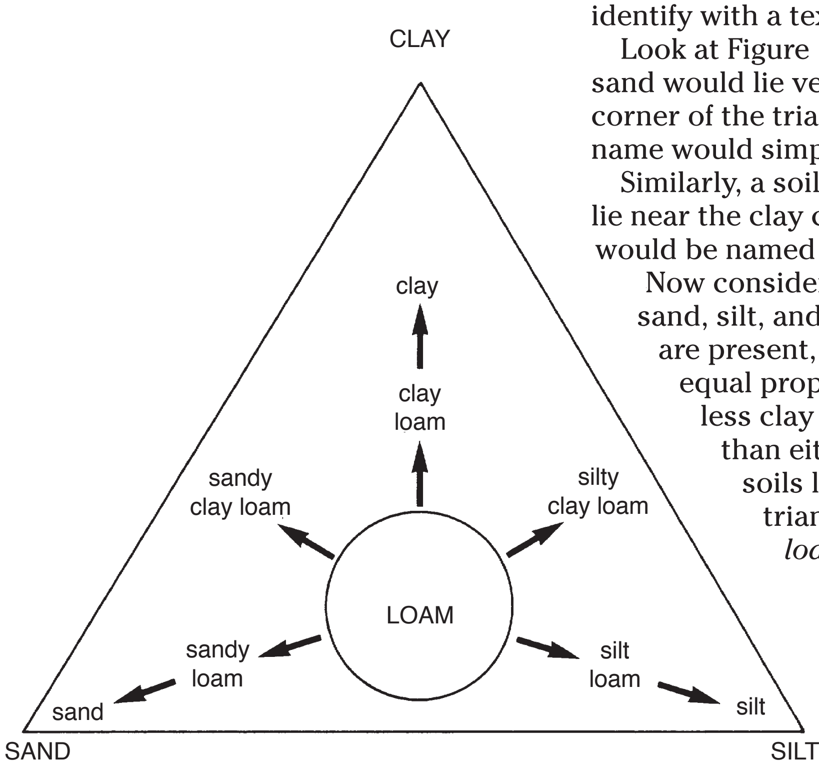



Figure 7.—Generalized textural triangle. Try thinking of each soil texture in terms of one or more steps away from a balanced mixture of sand, silt, and clay.

Sand, silt, and clay are called the *separates* of the fine earth. Sand particles range in size from .05 mm to 2 mm. They are large enough to see each grain with the naked eye, and they feel gritty.

Silt particles range in size from .002 mm to .05 mm. You cannot see them without a hand lens or microscope. Silt has a smooth feeling, like flour or corn starch. It is not sticky.

Clay particles are less than .002 mm in size. They usually are flat, or plate-shaped, and they can be seen only with high-powered microscopes. Clay feels sticky, and it can be molded into ribbons or wires.

Every soil contains a mixture of sand, silt, and clay. We use a *textural triangle* to show all the possible combinations. We also use the triangle to form groups, or classes, of soil texture, which we then identify with a textural name.

Look at Figure 7. A soil that is almost all sand would lie very close to the sand corner of the triangle. Its textural class name would simply be sand.

Similarly, a soil dominated by clay would lie near the clay corner of the triangle. It would be named simply clay.

Now consider a *balanced mixture* of sand, silt, and clay. All three separates are present, though not in exactly equal proportions. (Actually, it takes less clay to balance the mixture than either sand or silt.) These soils lie near the center of the triangle, and they are called *loams.*

Now suppose we were to upset a balanced mixture of sand, silt, and clay by adding more sand.

The sand would begin to dominate, and we'd move away from the center of the triangle toward the sand corner. The texture would change from loam to sandy loam, and ultimately to a sand.

If we were to add clay to a loam, we would get first a clay loam, then a clay. If we were to add both silt and clay, we would move away from sand toward something intermediate between silt and clay. The texture becomes a silty clay loam.

Precise boundaries between textural classes are shown in Figure 8. Each side of the triangle is a base line, or zero point, for the separate in the opposite corner. A scale runs from 0 percent at the middle of each base line up to 100 percent at the

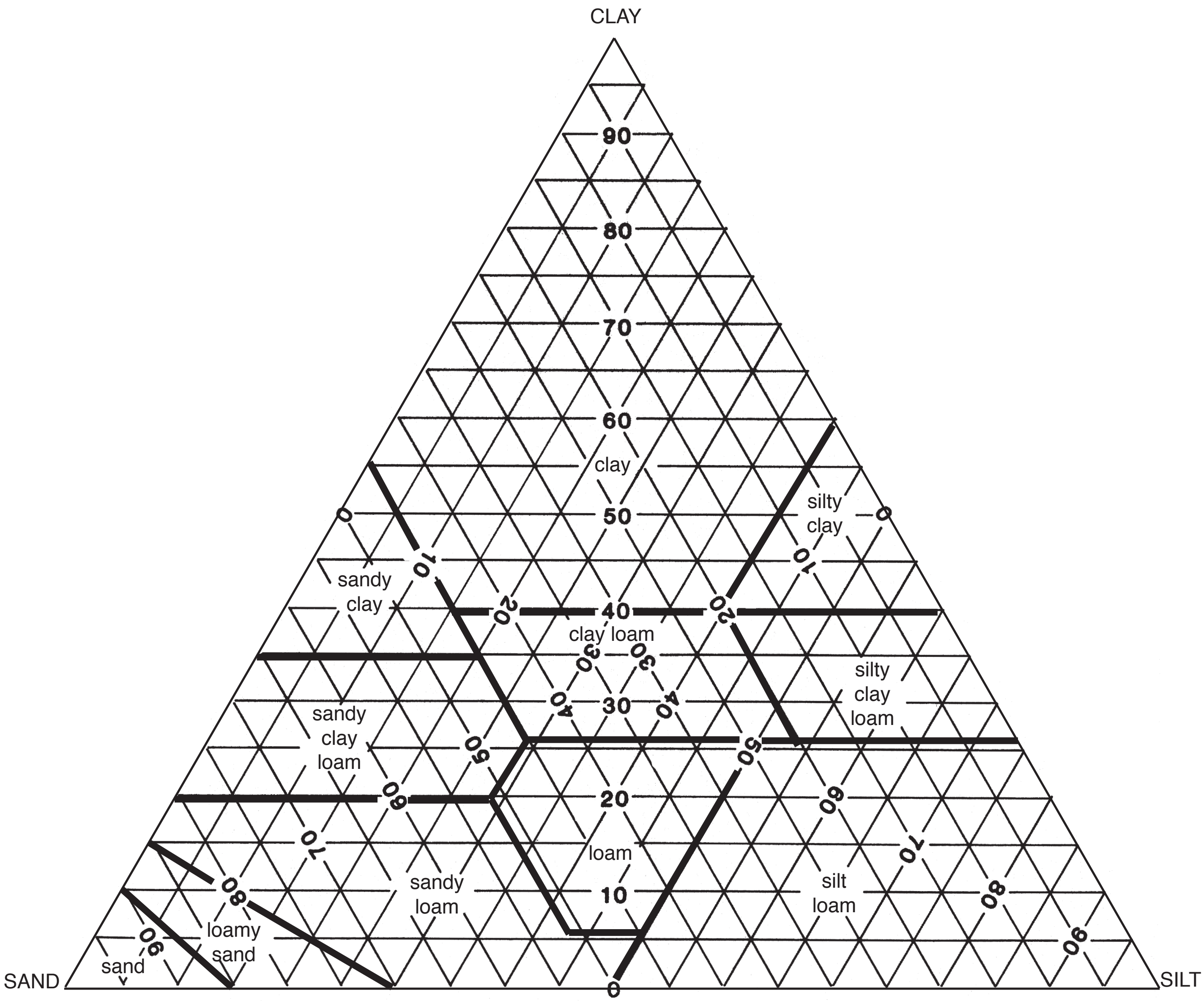



Figure 8.—Official textural triangle. The scales of sand, silt, and clay, along with the precise boundaries between soil textural classes, are used to determine the correct name for the texture of a soil sample.

corner. If we know how much sand, silt, and clay a soil has, we can easily plot its location on the triangle and see which textural class it falls into.

Here's a simple example. Suppose we have a soil that contains 40 percent sand, 45 percent silt, and 15 percent clay. Start with the clay content. Go to the midpoint of the base line running from sand to silt. Then go up to the horizontal line at 15 percent. Every soil along this line contains 15 percent clay.

Next, go to the midpoint of the base line running from silt to clay. This line represents 0 percent sand. Move along the sand scale, down and to the left, until you reach the 40 percent line. Then move down the 40 percent sand line until it intersects the 15 percent clay line. Mark that point.

If you wish, you can find the 45 percent silt line and track it to the same point. Note, however, that it takes only *two* points to determine the texture. This sample is a loam.

Figure 10.—Silty clay loam texture. This soil has 3 percent sand, 68 percent silt, and 29 percent clay. It forms a smooth ribbon about an inch long.

We determine soil texture in the field by working the soil between our thumb and fingers and estimating the amounts of sand, silt, and clay. Estimate sand by the grittiness you can feel. Estimate clay by the length of the ribbon you can form (see Figures 9, 10, and 11). The procedure for doing this is highlighted on page 22.

Figure 9.—Sandy loam texture. This soil has 73 percent sand, 23 percent silt, and 4 percent clay. When textured by feel, it forms only a short, broken ribbon.

Figure 11.—Silty clay texture. This soil has 2 percent sand, 54 percent silt, and 44 percent clay. You can squeeze the soil upward between your thumb and index finger to form a ribbon nearly 3 inches long.

## Texture by Feel

1. Fill the palm of your hand with dry soil.
2. Moisten the soil enough so that it sticks together and can be worked with the fingers. *Don't saturate it to runny mud.* If the soil sticks to your fingers, it's too wet to texture. Add more dry soil.
3. Knead the soil between your thumb and fingers. Take out the pebbles, and crush all the soil aggregates. You may need to add a little more water.
4. Continue working the soil until you crush all the aggregates.
5. Estimate the sand content by the amount of textural grittiness you feel.
   a. More than 50 percent—Sand dominates. The textural name contains the word *sandy.*
   b. 20 to 50 percent—Sand is noticeably present, but not dominant. The texture most likely is *loam* or *clay loam,* though *silt loam* or *clay* are possible.
   c. Less than 20 percent—Silt and clay dominate. The textural name is *silt loam, silty clay loam,* or *clay.*
6. Estimate the clay content by pushing the sample up between your thumb and index finger to form a ribbon.
   a. Less than 27 percent (Figure 9)—The ribbon is less than 1½ inches long. Textural names contain the word *loam* but not the word *clay.*
   b. 27 to 40 percent (Figure 10)—The ribbon is 1½ to 3 inches long. Textural names contain both the words *clay* and *loam.*
   c. More than 40 percent (Figure 11)—Clay dominates. The ribbon is more than 3 inches long. The textural name contains the word *clay* but not the word *loam.*
7. Combine your estimates of sand and clay.

| | SAND | | |
|---|---|---|---|
| CLAY | >50 | 20–50 | <20 |
| >40 | Sandy clay | Clay | Clay<br>Silty clay |
| 27–40 | Sandy clay loam | Clay loam | Silty clay loam |
| <27 | Sandy loam<br>Loamy sand<br>Sand | Loam | Silt loam |

Actually you need to learn only four key points on the textural triangle: 27 percent clay, 40 percent clay, 20 percent sand, and 50 percent sand. These points don't exactly match the textural class boundaries on Figure 8, but they're close enough to make good estimates.

### Four Key Texture Points

| | |
|---|---|
| 50 percent sand | 27 percent clay |
| 20 percent sand | 40 percent clay |

Study the locations of these key values on Figure 8 very carefully. Note that none of the texture names below 27 percent clay contain the word *clay.* Texture names between 27 and 40 percent clay contain both the words *clay* and *loam.* Texture names above 40 percent clay contain only the word *clay.*

Similarly, soils having more than 50 percent sand all have names that include the words *sand* or *sandy.* If there is less than 20 percent sand, *silt* or *silty* usually is part of the name. If the soil contains between 20 and 50 percent sand, *neither* silt nor sand is part of the name.

Additional clues to the way each kind of soil texture feels are given in the box on page 24. The effect of these different textures on things like permeability, water-holding capacity, and erosion hazard will become clearer when we discuss specific interpretations of soil behavior.

## Coarse Fragments

Coarse fragments are soil particles that are between 2 mm and 10 inches in size. Soil textural names based on the fine earth must be modified if the soil contains a significant amount of coarse fragments.

The two most common kinds of coarse fragments in Oregon soils are gravel and cobbles. *Gravel* refers to rounded rock fragments with a diameter between 2 mm and 3 inches. *Cobbles* are rounded or partly rounded, with diameters from 3 to 10 inches.

Coarse fragment names depend on the *volume* of the soil mass occupied by coarse fragments. You can estimate the volume by looking at the vertical surface exposed in a soil profile. If 50 percent of the surface consists of coarse fragments, then 50 percent of the soil volume is coarse fragments as well (see Plate 14).

Once you know both the percent by volume and the dominant size of coarse fragments, find the correct modifier in the key below. If a soil contains both gravel and cobbles, at least 60 percent of the coarse fragments must be gravel to use the gravelly term. If more than 40 percent of the coarse fragments are cobbles, use the cobbly term.

### Key to Naming Coarse Fragment Modifiers

| % by volume | Gravel 2 mm–3 inches | Cobbles 3–10 inches |
|---|---|---|
| <15 | no modifier | no modifier |
| 15–35 | gravelly | cobbly |
| 35–60 | very gravelly | very cobbly |
| >60 | extremely gravelly | extremely cobbly |

## Clues to the Feel of Textural Classes

**Sand**

— Moist sample collapses after squeezing.
— Your hands don't get dirty working the sample.

**Loamy sand**

— Sample has very little body.
— Moist soil barely stays together after squeezing.
— Just enough silt and clay to dirty your hands.

**Sandy loam**

— Sand dominates noticeably.
— Enough silt and clay to give the sample body.
— Moist soil stays together after squeezing.
— Hardly forms any ribbon at all.

**Sandy clay loam**

— Feels gritty *and* sticky.
— Forms ribbon 1 to 2 inches long.

**Sandy clay**

— Feels definitely sandy.
— Forms ribbon 2 to 3 inches long.
— A rare texture in Oregon.

**Loam**

— Sand noticeably present, but doesn't dominate.
— Sample works easily between thumb and fingers.
— Contains enough silt and clay to give sample good body.
— Sample only forms short, broken ribbons.

**Silt loam**

— Feels smooth, like flour or corn starch.
— Tends to be nonsticky.
— Only forms short, broken ribbons.

**Clay loam**

— Noticeably gritty, but sand doesn't dominate.
— Noticeably sticky.
— Noticeably hard to work between thumb and fingers.
— Forms ribbons 1½ to 3 inches long.

**Silty clay loam**

— Feels smooth and sticky.
— Contains very little sand.
— Forms ribbons 1½ to 3 inches long.

**Clay and Silty clay**

— Dry sample absorbs a lot of water before it is moist enough to work.
— Sample very hard to work between thumb and finger.
— Forms ribbon 3 to 4 inches long.

# Soil Structure

Soil structure forms when individual grains of sand, silt, and clay are bound together in larger units called *peds*. Plant roots, soil organic matter, and clay particles all provide physical and chemical binding agents. The shape of the peds formed determines the *type* of structure. The extent of ped formation, and the strength of each ped, together determine the *grade* of the structure.

Soil structure is important because it modifies some of the undesirable effects of texture on soil behavior. Structure creates relatively large pores, which favor water entry into the soil and water movement within the soil. Even clayey soils, which tend to have very tiny pores, can have good rates of water movement if they have well-developed A horizon structure.

Good soil structure also means good aeration and a favorable balance between pores that contain air and pores that store water for plant use. Soils with good structure are easy to work and provide ideal environments for plant root growth. In short, good structure means good tilth.

Organic matter is vital to the formation and maintenance of good soil structure. A horizons of western Oregon soils are naturally high in organic matter. Soil structure in these horizons tends to be well developed, and peds resist breakdown from tillage and raindrop impact.

A horizons of eastern Oregon soils are naturally low in organic matter. Soil structure tends to be weakly formed and unstable. These soils are more difficult to irrigate, and they have a higher erosion hazard.

Keeping up the organic matter level is essential if you want to maintain good soil structure. Mixing animal wastes and crop residues into the soil is an excellent way to do this. One of the real benefits of conservation tillage programs is the use of crop residues to form stable soil structure.

You can determine both the type and the grade of soil structure by carefully observing the soil and by gently breaking it apart. The first step is to study the pit face to see if structural peds are evident. If you can detect the shapes of individual peds, then the grade is probably strong.

The next step is to fill your hand with a large “lump” of soil. Observe how easily the soil breaks out of the pit face and falls into your hand. The easier it breaks out, the stronger the structure. Observe also the shapes of the peds that lie in your hand.

Then hold a large piece of the soil in both hands and gently apply pressure to break the soil apart (Figure 12). If the soil breaks easily along a natural plane of weakness, you’ve separated it into distinct peds. If the soil fractures randomly leaving an irregular, dull surface, you’ve simply forced a break through a ped.

The ease with which the soil mass breaks into peds, and the amount of unaggregated soil that remains in your hand, together indicate the structural

Figure 12.—Determining soil structure. Hold a clod of soil in both hands and apply gentle pressure. If the soil breaks easily along a natural plane of weakness, it is breaking into units of soil structure.

grade. The shapes of the peds you broke out of the soil indicate the structural type.

### Structure type

Common types (or shapes) of soil structure include *granular, platy, blocky,* and *prismatic.* Soils lacking peds are said to have either *massive* or *single* grain types of structure. Each of these common structure types is illustrated and discussed on page 27.

### Structure grade

The grade of soil structure refers to the strength and stability of structural peds. Structure grade is described using the terms *strong, moderate,* and *weak.* Definitions are in the box on this page.

Strong structures are stable structures. They provide favorable air-water relations and good soil tilth. Weak structures are unstable. Surface soils readily slake and seal when irrigated or tilled. Weak structures slow down water movement into and within the soil and increase the erosion hazard.

Two aspects of structural development work together to indicate the grade:

1. How well the entire soil mass is subdivided into distinct peds
2. How well the grains in individual peds are held together to resist breakdown and give the peds stability

### Compound structure

Some soil horizons have large structural aggregates that can be further subdivided into smaller aggregates of a different shape. Examples are blocks that break into plates and prisms that break into blocks.

Technical soil descriptions would include both situations. For soil judging, if one shape has a stronger grade, check that one. If both have the same grade, mark the smaller one.

## Grades of Soil Structure

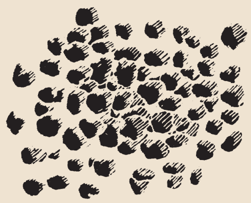
**Strong—**The soil mass is well divided into distinct and easily recognizable peds. Structure is readily apparent on the face of a soil pit. A handful of soil readily breaks into distinct peds with only very gentle pressure. Individual peds are stable and resist further breakdown. Very little if any soil remains as loose grains not bound into peds.

**Moderate—**Peds are evident in a pit face, and they are readily apparent when you gently break apart a mass of soil held in your hands. Some grains of soil may not be part of any aggregate, or easily slough off larger aggregates. Peds are stable against weak forces, but may break down under stronger pressure.

**Weak—**Peds are difficult to detect, even when you break soil apart in your hands. Many grains may not be part of any aggregate. Peds easily break down when small forces are applied.

**Structureless—**The grade applied to massive and single grain soils.

## Types of Soil Structure

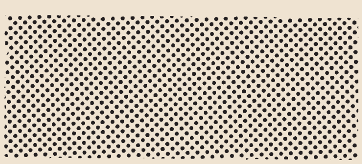


**Granular**—roughly spherical, like grape nuts. Usually 1–10 mm in diameter. Most common in A horizons, where plant roots, microorganisms, and sticky products of organic matter decomposition bind soil grains into granular aggregates.

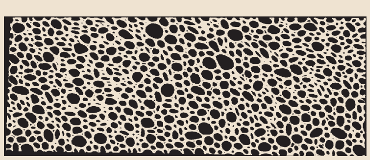
**Platy**—flat peds that lie horizontally in the soil. Most are less than 2 cm thick. Platy structure is not common in western Oregon soils, but it can occur in a tillage pan at the base of an Ap or in soil horizons where water is forced to move sideways. Many soils in the low rainfall regions (less than 12 inches) of eastern Oregon do have platy structure in the A horizon.

**Blocky**—roughly cube-shaped, with more or less flat surfaces. If edges and corners remain sharp, we call it *angular blocky.* If they are rounded, we call it *subangular blocky.* Sizes commonly range from 5–50 mm across. Blocky structures are typical of B horizons, especially Bt horizons. They form by repeated expansion and contraction of clay minerals.

**Prismatic**—larger, vertically elongated blocks, often with five sides. Sizes are commonly 10–100 mm across. Prismatic structures occur in some B and BC horizons.



**Massive**—compact, coherent soil not separated into peds of any kind. Massive structures in clayey soils usually have very small pores, slow permeability, and poor aeration.



**Single grain**—in some very sandy soils, every grain acts independently, and there is no binding agent to hold the grains together into peds. Permeability is rapid, but fertility and water-holding capacity are low.

## Soil Consistence

Consistence has to do with the strength of the soil mass. Consistence describes the resistance soil offers to pressures that could break it or change its shape. It is also related to a soil's ability to support the weight of traffic and structural loads.

When soil resistance is low, the soil is easily manipulated. Energy requirements for plowing or tillage are low, and plant seedlings can easily push their way up through the soil.

When the resistance is high, the soil is much more difficult to work. Cloddy seedbeds are more likely, and seedling emergence is more difficult.

You can determine consistence by taking a handful-sized mass of soil and applying pressure between the thumb and fingers. Because moisture content greatly affects the strength of the soil, consistence is determined at three different moisture levels: moist, dry, and wet.

In western Oregon, moist consistence is the one most frequently determined. In eastern Oregon, it is dry consistence. You can determine wet consistence for any sample by adding the proper amount of water.

### Moist consistence

Moist consistence is determined when the soil is at, or a little drier than, *field capacity.* Usually when soil is found to be moist—but not saturated—in the field, the soil is near field capacity, and we can determine the moist consistence. Common classes of moist consistence include *loose, friable, firm,* and *extremely firm.*

### Classes of Dry Consistence

**Loose**—The soil does not stick together in a mass.

**Slightly hard**—The soil crushes easily under gentle pressure between thumb and forefinger.

**Hard**—The soil is barely crushable between thumb and forefinger, but it can be broken with the hands without much difficulty.

**Extremely hard**—The soil is so resistant to deformation that it can't be broken in the hands.

### Classes of Moist Consistence

**Loose**—The soil does not stick together in a mass.

**Friable**—Soil material crushes easily under gentle pressure between thumb and forefinger.

**Firm**—Soil can be crushed between thumb and forefinger, but considerable pressure is required to overcome natural resistance.

**Extremely firm**—Soil can't be crushed between thumb and forefinger, and can only be broken apart bit by bit.

### Dry consistence

This is determined for soils that are *air dry,* even in the field. Although it may be described for any soil, it usually is the preferred system for eastern Oregon soils. Classes of dry consistence include *loose, slightly hard, hard,* and *extremely hard.*

### Wet consistence

When the soil is a little wetter than field capacity, two kinds of soil behavior are evaluated, *stickiness* and *plasticity.* Stickiness is a measure of how much the soil clings to a foreign object like a shovel or a tractor tire or your hands. Plasticity is a measure of the extent to which a soil clings to itself and can retain a shape after pressure is removed.

Stickiness is evaluated by squeezing wet soil between your thumb and fingers, then slowly pulling your thumb away. The stickier the soil, the more it will stretch and pull apart before breaking, leaving soil sticking to both thumb and fingers. The relative degree of stickiness is expressed using the terms *nonsticky, slightly sticky, sticky,* and *very sticky.*

#### Classes of Soil Stickiness

**Nonsticky—**Wet soil doesn't stick to fingers.

**Slightly sticky—**Wet soil sticks to one finger only.

**Sticky—**Wet soil sticks to both fingers and thumb, and it stretches a little before breaking as fingers are separated.

**Very sticky—**Wet soil strongly sticks to both fingers and thumb and it stretches considerably before breaking.

Plasticity is determined by rolling the soil between your hands to form a thin wire. The longer and thinner the wire you form, and the more resistant it is to whipping back and forth, the more plastic the soil. Terms used to describe plasticity are *nonplastic, slightly plastic, plastic,* and *very plastic.*

#### Classes of Soil Plasticity

**Nonplastic—**Can't form a wire by rolling between hands.

**Slightly plastic—**Only short wires (<1 cm) will form.

**Plastic—**Long wires (>1 cm) will form, but wire breaks when whipped back and forth.

**Very plastic—**Long wires (>1 cm) will form, and wire withstands whipping back and forth without breaking.

## Horizon Boundaries

The boundary between any two horizons can vary both in distinctness and in form. Some boundaries are very sharp. Others merge very gradually into the horizon below. The nature of the boundary may provide clues to soil development and to certain aspects of soil behavior. An abrupt boundary, for example, may indicate a sudden change to another kind of material, either geologic or formed by soil development. Such a change may limit root penetration, or it may signal a different rate of water movement through the soil. Gradual boundaries, on the other hand, may indicate a very young soil, or a deep, highly weathered, old soil.

The form, or shape, of horizon boundaries also may be described. Evaluation of this characteristic, however, requires careful examination all along a pit face or road cut to be sure that you have discovered the true relationships between soil horizons.

Terms used to describe boundary distinctness are *abrupt, clear, gradual,* and *diffuse*. Terms used to describe boundary form are *smooth, wavy, irregular,* and *broken*. Both sets of terms are defined in the boxes below.

### Classes of Horizon Boundary Distinctness

**Abrupt—**The boundary is less than 1 inch (2 cm) wide.

**Clear—**The boundary is 1 to 2 inches (2 to 5 cm) wide.

**Gradual—**The boundary is 2 to 5 inches (5 to 15 cm) wide.

**Diffuse—**The boundary is more than 5 inches (>15 cm) wide.

### Classes of Horizon Boundary Form

**Smooth—**Nearly a plane.

**Wavy—**Shallow pockets are wider than they are deep.

**Irregular—**Pockets are deeper than their width.

**Broken—**Parts of the horizon are unconnected with other parts.

## Special Features of Soil Horizons

Some horizons have unique properties and deserve special emphasis. These features are important because they have a significant impact on the behavior of the whole soil. Most of them restrict the flow of air and water through the soil. They also limit the depth of rooting.

As a result, soils that contain any of these special features are likely to require special kinds of management practices in order to overcome the limitations.

Some special features, namely the fragipan, duripan, and Cr, are nothing more than special kinds of master horizons. These are discussed in detail in Chapter 3. Tillage pans are special features of some Ap horizons, and they occur only in the lower part of these horizons. Slickensides are a special feature of clayey soils that shrink and swell a great deal.

Each of these special features is described below. Obviously if a soil does not contain any of these special features, the correct answer to mark on your scorecard is *none.*

### Tillage pan

A tillage pan is a compacted zone at the base of a plow layer, or Ap horizon. It forms by repeated plowing or cultivation of the soil when it is too wet. The plow smears the wet soil, breaking down the natural structure. The result is a zone of soil 1 or 2 inches thick that is either massive or has a coarse platy structure. In either case, the tillage pan restricts the movement of water to deeper parts of the soil profile.

Some tillage pans also have a thin layer of undecomposed straw right at the top of the compacted zone. When a field containing a lot of straw residue is plowed, the straw is buried under 6 or 7 inches of soil without any real mixing. In this position, air can't get to the straw, and it just stays in the soil without decaying.

It is important that you recognize a tillage pan, because it creates unfavorable conditions for plant growth. Root penetration may be limited, but the greatest problem is that a tillage pan restricts downward water movement. This is a serious problem in dryland areas, because it prevents the subsoil from receiving all the water it could and storing it for later plant use.

In wetter areas, the pan may cause the Ap horizon to fill up with water. This reduces the rate of water entry into the soil and increases the hazard of runoff and erosion.

The best way to deal with tillage pans is to prevent them from forming. One way to do that is to avoid plowing or tilling the soil when it is too wet. Ideally, the soil should be allowed to dry for several days after a heavy rain before working it again.

Another way to prevent the pan from forming is to use minimum tillage or no-till practices. Tillage pans that do exist usually can be broken up by ripping or deep-plowing the soil.

## Fragipan

A fragipan is a massive, dense subsoil Bx horizon (see definition on page 11). It is not cemented. The fragipan illustrated in Plate 11 is so dense that water cannot move through it. Instead, water builds up on top of the fragipan and moves sideways, forming the white E horizon. Note also the gray streaks of silt that are typical of fragipans.

Soils with fragipans generally are not good agricultural soils, and they pose severe limitations for homesite development as well. In most soils it is not practical to break the pan up by ripping, or to drain the soil with tile lines placed into or beneath the pan. Sometimes tile lines placed above the pan help remove some of the excess water, but in most soils wetness remains a severe limitation.

## Duripan

A duripan is a massive Bkqm horizon that is cemented with both silica and calcium carbonate (see definition on page 12). Duripans are quite common in eastern Oregon.

The duripan shown in Plate 10 is so strongly cemented that it does not slough off an exposed bank as easily as the horizons above and below it. As a result, the duripan sticks out from the face of the exposure. Duripans that are less strongly cemented may be broken up by ripping.

## Cr

A Cr horizon consists either of strongly weathered bedrock or of naturally very soft rock (see definition on page 12). In either case, you can slice Cr material with a knife or a spade.

The Cr horizon shown in Plate 13 is soft sandstone bedrock in the Coast Range. Other Cr horizons may be multicolored because of weathering. Don't confuse their colors with mottles caused by wetness (see page 18). Soils that contain Cr horizons usually occur on sloping, hilly landscapes.

## Slickensides

Slickensides (Figure 13) are polished, shiny surfaces caused by the movement of two masses of soil past each other. They are characteristic of special kinds of soils called *Vertisols.*

Vertisols are soils that have a very high clay content, and they are very sticky and very plastic. When the clays wet up, they expand, causing the soil to swell and heave.

As Vertisols dry out, the clay particles shrink, and the soil develops numerous open cracks. These cracks may extend to a depth of 2 feet or more, and they may be 1 to 4 inches wide at the surface. In this dry condition, the soil may appear to have strong blocky structure.

When a Vertisol is dry and cracked, soil from the surface often tumbles into the open cracks and partly fills them. Then as the soil wets up during the next rainy season, the clay particles expand. But since there is more material there than before, the swelling creates strong pressures that cause masses of soil to slide past each other. This shearing movement forms the polished surfaces called *slickensides.* Swelling also may result in a bumpy, irregular soil surface.

Figure 13.—Slickensides. Shiny, polished, and wavy surfaces are formed when two masses of very clayey soil move past each other. Pressures generated by swelling clays cause this movement. Slickensides are characteristic of Vertisols.

Wet, swollen soil has no structure and is best described as being "massive with intersecting slickensides." This is true even if the soil is dry and cracked and appears to be blocky. If slickensides are present, you should record the structure type of the horizon as *massive* and the structure grade as *structureless.*

Slickensides, then, are important special features because they indicate the presence of Vertisols, which have serious management limitations. Vertisols have very slow permeability, and they usually are poorly drained. Both the drainage feasibility and the irrigation suitability are poor. The most intensive crop under both irrigated and dryland conditions is permanent pasture.

# Properties of the Whole Soil

Color, texture, and structure are the primary properties of soil horizons. They are observed directly in the field.

Properties of the whole soil, however, are not so easy to observe directly. It is possible to make field measurements of water content, rates of water movement, or erosion hazard—but they require a great deal of time, talent, and expensive equipment.

We can still judge these aspects of soil behavior, though. Instead of making direct measurements, we will use information on color, texture, and structure to estimate water-holding capacity, permeability, internal drainage, and several other properties. These estimates will enable us to learn a great deal about how the soil will respond to agricultural use and management.

The sections that follow describe several key properties of the soil and tell how and why each is important. They also tell you how to use color, texture, and structure to estimate important kinds of soil behavior.

Many interpretations, both in this chapter and in Chapter 7, can be condensed into a tabular guide. The procedure is explained fully in Appendix B. Be sure you know how to use these interpretation guides, for they allow you to use a few basic soil properties to find the correct answer to a given interpretation.

## Effective Depth of Rooting

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

Soils that have restricted rooting depths are droughtier and may require more frequent irrigation. They may require more fertilizer as well.

The effective depth of rooting is simply the distance from the ground surface to the top of any soil horizon that prevents significant root penetration. Very dense or cemented horizons, and very gravelly or cobbly horizons, all limit root development.

Fragipans and claypans are not cemented, but they are so dense and have such poor structure that roots can’t penetrate very far. In a duripan, the pores are actually filled with a hard cement that binds soil grains together into a rocklike horizon. Bedrock, of course, is an obvious limit to root development.

Subsoil horizons of very gravelly or cobbly sands are effective barriers to root growth. Roots will develop in finer-textured soil above these layers, but they don’t expand into the gravelly soil. The reason is that the gravelly soil often is much drier than the fine-textured soil, and root growth is confined to the moist soil above it. If the soil is sandy and gravelly right at the surface, though, plant roots will extend throughout the coarse-textured soil material.

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

Gray colors usually indicate soil wetness. Roots of many agricultural crops don’t grow well in soil that is saturated for long periods of time. But if the water table is not present during the growing season, or if it has been lowered with artificial drainage, then gray colors don't necessarily indicate a limitation to root development. Be suspicious of gray colors, but check the texture, structure, and density before you make a decision.

Soil texture limits root growth only if the texture changes abruptly from one horizon to another. Silt loam over clay, or loam over gravelly sand, are common examples of root-limiting textures.

Textures that are nearly uniform throughout, even in clayey or gravelly soils, are not likely to prevent root growth. Other factors, however, may be responsible for limited rooting in such soils.

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

In a fragipan, for example, massive, dense silt loam restricts rooting. In many other soils, however, silt loam C horizons are open and porous and do not prevent rooting at all.

Evaluate the effects of structure and density by using your knife to probe the soil. If it probes easily and breaks off readily, structure and density probably don't limit roots. The opposite response is a sure sign of trouble.

The roots themselves may give us other clues to the effective depth of rooting. If roots are clearly visible and easy to find throughout the soil, then there is no limit to the effective depth.

Sometimes, though, only shallow-rooted plants are growing in the soil, even though the effective depth is unlimited. Absence of roots, therefore, doesn't necessarily mean there is a root depth limitation.

On the other hand, some plants may be able to send a few very fine roots partly into a fragipan, a claypan, or a gravelly horizon. Even so, most of the volume of these horizons can't support plant growth. So if you find one tiny root down at the bottom of the profile, that doesn't necessarily mean the effective depth is unlimited.

The pattern of root growth also may help you. Duripans, fragipans, and some claypans may be so firm that plant roots start growing horizontally along the top of them. A horizontal root mat is good evidence of the limit of the effective rooting depth.

**Classes of Effective Depth**

| | | |
|---|---|---|
| Deep | — | over 40 inches (>100 cm) |
| Moderately deep | — | 20 to 40 inches (50 to 100 cm) |
| Shallow | — | 10 to 20 inches (25 to 50 cm) |
| Very shallow | — | less than 10 inches (<25 cm) |

## Available Water-holding Capacity

Available water-holding capacity (AWHC) refers to the amount of water a soil can store for plants to use. Since soil provides the only reservoir of water for plants to draw upon, the size of that reservoir is one of the most important properties of the whole soil.

Soils having high AWHC's are potentially very productive. Soils having low AWHC's are droughty, more difficult to irrigate, and generally less productive.

Only a portion of the total amount of water contained in a soil is available to plants. We think in terms of three classes of soil water: gravitational, available, and unavailable.

*Gravitational water* fills large pores when the soil is saturated. It drains away quickly as soon as the water table drops or the rain stops. Plants can't make use of gravitational water.

*Available water* is held in smaller soil pores against the force of gravity. Plants can exert enough force to remove this water and use it.

*Unavailable water* is held so tightly in tiny soil pores that plant roots can't remove it. When a soil is so dry that only unavailable water remains, plants wilt and die, even though there is still some moisture left in the soil. Some soils, especially clays, contain large amounts of water that is unavailable for plant use.

The available water-holding capacity of a soil depends mainly on its texture, coarse fragments, and effective depth of rooting. Together they determine the volume of soil pores that are the right size for storing available water.

Both structure and organic matter increase the volume of water-storing pores a little bit. For most soils, however, we can make a good estimate of the AWHC by evaluating the texture and coarse fragments of each horizon within the effective depth of rooting.

Think of a soil as a giant sponge. Suppose we could squeeze this soil-sponge just enough to remove all the available water. If we could catch all this water in a pan with the same bottom area as our soil-sponge, then the depth of water in the pan is a measure of the AWHC of the soil.

Values of AWHC range from 1 or 2 inches of available water in a very gravelly soil to 12 inches or more in a deep, well drained silt loam.

Each class of soil texture has a characteristic AWHC. We express that AWHC as inches of water per inch of soil depth. To calculate the AWHC for any single horizon, multiply the inches per inch AWHC times the total thickness of the horizon.

To determine the AWHC for the whole soil, repeat this calculation for each horizon using the appropriate AWHC. Coarse fragments can't store water, so for horizons that contain coarse fragments, multiply AWHC x Depth x Percent Fine Earth. The total AWHC for the whole soil then is the sum of the AWHC's for each horizon within the rooting depth.

## AWHC Rates

| Texture | Inches/Inch |
|---|---|
| Sand | .06 |
| Loamy sand | .06 |
| Sandy loam | .12 |
| Loam | .20 |
| Clay loam | .20 |
| Silt loam | .20 |
| Silty clay loam | .20 |
| Clay | .15 |
| Silty clay | .15 |
| Sandy clay | .15 |
| Sandy clay loam | .15 |

## Classes of Soil AWHC

| | |
|---|---|
| High | More than 8 inches |
| Medium | 5 to 8 inches |
| Low | 2 to 5 inches |
| Very low | Less than 2 inches |

## Sample Calculations of AWHC

| Hor. | Depth | Texture | % Coarse Fragments | AWHC | | Thick-ness | | Fraction Fine Earth | | AWHC |
|---|---|---|---|---|---|---|---|---|---|---|
| A | 0–12 | Silt loam | 0 | 0.2 | x | 12 | x | 1.0 | = | 2.4 |
| BA | 12–20 | Silt loam | 0 | 0.2 | x | 8 | x | 1.0 | = | 1.6 |
| Bt | 20–36 | Silty clay loam | 0 | 0.2 | x | 16 | x | 1.0 | = | 3.2 |
| BC | 36–48 | Silty clay loam | 0 | 0.2 | x | 12 | x | 1.0 | = | 2.4 |
| C | 48–60 | Silt loam | 0 | 0.2 | x | 12 | x | 1.0 | = | 2.4 |
| | | | | | | | | Total Soil AWHC | = | 12.0 |
| | | | | | | | | AWHC is *high* | | |
| A | 0–4 | Loam | 0 | 0.2 | x | 4 | x | 1.0 | = | 0.8 |
| BA | 4–10 | Clay loam | 0 | 0.2 | x | 6 | x | 1.0 | = | 1.2 |
| Bw | 10–18 | Grav. clay loam | 30 | 0.2 | x | 8 | x | 0.7 | = | 1.1 |
| Bkqm | 18–28 | (Duripan) | 100 | — | | — | | — | | 0 |
| Ck | 28–40 | Loam | 10 | — | | — | | — | | 0 |
| | | | | | | | | Total Soil AWHC | = | 3.1 |
| | | | | | | | | AWHC is *low* | | |

## Field Procedure for Estimating Soil AWHC

1. Identify the horizons present in the soil profile.
2. Measure the thickness of each horizon.
3. Determine the effective depth of rooting.
4. Determine the texture and the coarse fragment content.
5. Find the AWHC rate that corresponds to the texture of each horizon.
6. Multiply AWHC x Depth x Percent Fine Earth.
7. Total the AWHC's for all horizons within the effective depth.

# Permeability

Permeability is a term that describes the rate of water movement through the soil. Because water moves through the pores of the soil, (the spaces between the grains of sand, silt, and clay), the rate of water movement depends on the amount of pore space (porosity), the size of the pores, and the connections between the pores.

We can't measure these characteristics of pores directly. We do know, however, that porosity and permeability are closely related to soil texture and structure. Thus, we can estimate permeability in the field by carefully observing the texture and structure of soil horizons.

Soil layering is another important factor that affects water movement through the soil. Any time the texture, structure, or density change abruptly, the rate of water movement changes, too.

A tillage pan, for example, has poorer structure and much smaller pores than the soil in the Ap above it. Water can't flow through the pan as fast as it can through the soil above. That's why, during heavy rainfall or irrigation, all the pores in the soil above the pan may fill with water. Any additional water that falls on the soil surface must run off, and that increases the hazard of erosion.

Subsoil layers that affect permeability include claypans and fragipans. Both have very small pores, and little or no structure to create larger pores. Water moves very slowly through these layers, and water moving through the soil above them tends to build up, or perch on top of them.

The change in permeability caused by these layers often forces water to move sideways on top of them. That's why we often see leached E horizons immediately above claypans and fragipans.

Because permeability depends on the amount and size of soil pores—and on how well interconnected they are—any soil property that increases any of these factors increases permeability.

Sandy and gravelly soils have large, well-connected pores and rapid permeability. Clayey soils have tiny pores. Their permeability is slow, unless well-developed structure creates some larger pores. Silt loams and clay loams tend to have moderate permeability, especially if the structure is moderate or strong.

Even if the structure is weak, the permeability can be moderate as long as the soil is loose and porous. But if the soil is very dense and difficult to break out with a knife, the soil is not porous, and permeability is likely to be slow.

Slickensides indicate very slow permeability. Any horizon that contains slickensides will be so swollen when wet and will have pores so small that water can hardly move at all.

Because soil layering creates different permeability rates in different parts of the soil, we're going to make separate judgments of surface soil permeability and of subsoil permeability. In both cases, we'll judge permeability as rapid, moderate, slow, or very slow according to the standards in the box on page 38.

## Surface soil permeability

The rate of water movement through surface soil directly affects irrigation, runoff, and erosion. Soils best suited for center pivot irrigation should have rapid permeability in the surface horizon. Otherwise water applied at the outer end of the pivot may run off. Soils that have slower surface soil permeability require different kinds of irrigation systems that will deliver water at acceptable rates.

Slow permeability of the surface soil also increases the hazard of erosion. If water applied to the surface, either during a rainstorm or during irrigation, can't get into the soil, then it must run off over the surface.

Figure 14.—Surface soil permeability. Characteristics of the surface soil affect the soil's ability to absorb irrigation water. Furrow irrigation is a good method for soils that have slow permeability in the surface horizon.

## Guide for Determining Soil Permeability

| | Rapid | Moderate | Slow | Moderate | Slow | Moderate | Slow | Very Slow |
|---|---|---|---|---|---|---|---|---|
| Texture | Sand<br>Loamy sand | Sandy loam<br>Silt loam<br>Loam | — | Sandy clay loam<br>Silty clay loam<br>Clay loam | — | Sandy clay<br>Silty clay<br>Clay | — | — |
| Porosity | Any | Porous | Not porous | Porous | Not porous | Porous | — | Not porous |
| Structure grade | Any | Any | Any | Any | Weak, Massive | Strong | Moderate, Weak | Massive, Vertisol |

Besides causing erosion, runoff wastes water that could be stored in the soil for plant use. In dryland wheat country, every inch of water that runs off costs about 7 bushels of wheat. Clearly, it pays to maintain the best rates of surface soil permeability possible.

One way to maintain good permeability is to incorporate crop residues so as to keep up the amount of organic matter in the surface soil. Organic matter encourages the formation of soil structure and improves the grade of the structure. In this way organic matter helps create relatively large and well-connected pores, which allow good rates of water movement through the soil.

Soils that are low in organic matter, especially silt loam and silty clay loam soils, are very susceptible to slaking, or structural breakdown. The impact of falling raindrops on weak peds in these soils causes the peds to disintegrate. Individual particles of silt and clay then clog up larger pores.

The result of slaking is a very thin surface crust that greatly reduces water entry into the soil. Runoff and erosion are serious problems in these soils.

Another way to maintain good permeability of surface soils is to stay off them when they're wet.

Driving over wet soils compacts them—it reduces the total pore space, and destroys the large pores needed for good permeability.

Tillage implements drawn through wet soil smear and compact the soil at the base of the Ap, forming a tillage pan. If you must plow the soil under wetter than ideal conditions, you should at least try to vary the depth of plowing from year to year. In some cases, you may still have to break up a tillage pan by ripping. And in all cases, adding crop residues always is a good way to help rebuild good soil structure.

When you judge the permeability of the surface soil, consider the effects of texture, structure, and porosity in all parts of the surface horizon. It's easy if they remain the same throughout.

Often, however, the A or Ap horizon may contain two or three different structures. For example, the top inch or so may have a strong granular structure because of the roots of sod-forming crops. The middle may be compacted from traffic, and the lower part may have the massive or platy structure of a tillage pan.

In any case, the permeability of the entire horizon can never be greater than the part with the slowest permeability. If a tillage pan is present, the permeability usually will be slow, regardless of the textures and structures above the pan.

### Subsoil permeability

Water movement through B and C horizons affects soil drainage, leaching of salts and fertilizers, and performance of septic tank drainfields.

Slowly permeable soils are difficult to drain with tile lines. Water moves so slowly toward the drain lines that they must be closely spaced in the soil, and that is expensive.

Slowly permeable soils also are bad for septic tank drainfields because the soil near the distribution pipes is likely to become saturated and cause drainfield failure.

Rapidly permeable soils are readily leached. Soluble salts, especially nitrogen fertilizers, are easily lost from the soil without doing the crops any good. They also contaminate groundwater.

Rapidly permeable soils don't make good waste disposal sites, either. Effluent from a septic tank drainfield is likely to reach groundwater too quickly to receive adequate biological treatment. Similarly, sanitary landfills placed on rapidly permeable soils increase the hazard of leaching dangerous chemicals into the groundwater.

Because the texture, structure, and porosity may change from horizon to horizon in the subsoil, you must evaluate the permeability of each horizon individually. The overall permeability of the subsoil is that of the least permeable horizon within the subsoil.

It is standard practice to base the evaluation of soil permeability only on horizons of porous soil material. Most B and C horizons, including fragipans and claypans, are considered in evaluating subsoil permeability. But if the soil has an R, a Cr, or a Bkqm (duripan) horizon, don't consider them. Base the permeability evaluation only on those subsoil horizons above R, Cr, or Bkqm horizons.

Normally we would evaluate the permeability of all subsoil horizons down to a depth of 60 inches. For some management practices, however, restricted permeability deep in the soil may not have much influence on the way we manage the soil for crop production.

We should be able to drain a wet soil easily, for example, as long as the soil has moderate permeability down to a depth of at least 30 inches. For this reason, we will use one more rule to judge subsoil permeability. *Base your permeability evaluation only on soil between the bottom of the A or Ap horizon and a depth of 30 inches.*

## Water Erosion Hazard

The hazard of soil erosion by water is an important concern for management of cultivated soils. Erosion damages both the productivity of the soil and the quality of water in rivers and streams.

Erodibility is closely related to the slope of the soil and the amount of runoff. As both increase, so does the erosion hazard.

Runoff is difficult to measure. But it is directly related to the texture and the permeability of the surface horizon. These two properties, plus the slope of the soil, are therefore used to evaluate the water erosion hazard. Use the "Guide for Determining Water Erosion Hazard" (page 40) to complete your evaluation.

Of all the soil textures, silt loam is the most erodible. That's because the size of silt particles is just right for water to loosen and carry over the soil surface. Sand particles are too big to easily dislodge and move. Clays are so small and flat that they are not easily dislodged, either.

One other soil factor that may affect erosion is soil depth. Soils that are shallow to restrictive layers (slowly permeable horizons) like bedrock, fragipans, or claypans are more erodible than deep soils. Their capacity to hold water is so low that extra water quickly runs off. This increases the length of time during which additional rainfall could cause damaging erosion.

Vegetation and climate are not soil factors, but they do influence the erosion hazard. Natural forest provides the best erosion protection, even on very steep slopes, because the O horizons are highly permeable.

Solid cover crops like pasture and hay also reduce erodibility. They promote water entry, absorb the impact of falling raindrops, reduce the velocity of flow across the surface, and tend to bind soil particles together and hold them in place.

Forest clearcuts and clean-tilled row crops tend to increase the erosion hazard. In both cases, water drops strike soil particles directly, causing some breakdown of soil structure and reducing the rate of water entry into the soil. And without vegetation, there are no roots to hold the soil in place and no stems and leaves to slow down the velocity of water running over the soil surface.

Climate affects erosion through the intensity of individual rain storms. The total amount of yearly rainfall is far less important than the intensity of each storm. Many storms are not particularly erosive because the rate of rainfall is slow enough to allow it all to soak in.

Occasionally, however, it rains so hard that the soil cannot absorb it fast enough. Runoff starts almost immediately, and the volume of runoff can be large. When this happens, erodible soils not protected by vegetation can lose tremendous volumes

Figure 15.—Water erosion. Water flowing over unprotected soil cuts rills and gullies into the soil and leaves sediment deposits at the base of the hill. Lost topsoil reduces soil productivity, and sediment deposits damage growing crops.

## Guide for Determining Water Erosion Hazard

| | Low | Moderate | High | Low | Moderate | High | Very high |
|---|---|---|---|---|---|---|---|
| **Texture** | Sand<br>Loamy sand<br>Sandy loam<br>Sandy clay<br>Silty clay<br>Clay | — | — | Sandy clay loam<br>Silty clay loam<br>Clay loam<br>Silt loam<br>Loam | — | — | — |
| **Slope / Permeability of surface soil** | 0–12/Any | 12–20/Any | >20/Any | 0–3/Any<br>3–7/Rapid, Mod. | 3–7/Slow, V. Slow<br>7–12/Rapid, Mod. | 7–12/Slow, V. Slow<br>12–20/Any | >20/Any |
| **Depth** | In western Oregon, increase the erosion hazard by one class if the soil is less than 20 inches deep. | | | | | | |

of soil. The result can be economic loss to farmers and degradation of the environment for all of us.

It is standard practice to judge the hazard of soil erosion under the worst possible conditions. That means bare soil, without vegetation, and without any kind of soil conservation practice to slow down water running over the surface.

Most soils you see won't be managed this poorly. But the erosion hazard is always present, and it's essential that we manage erodible soils to protect them from damage by erosion. Judging the erosion hazard in its most susceptible condition is therefore a measure of the conservation task required.

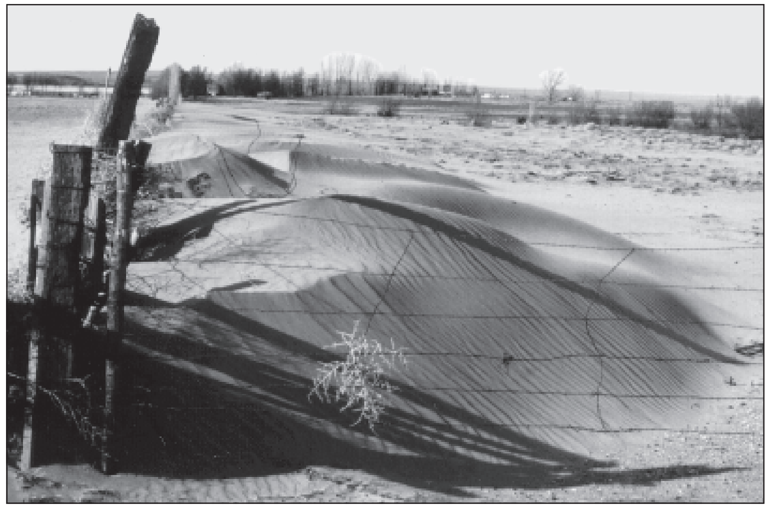


Figure 16.—Wind erosion. Blowing soil removes valuable topsoil, fills road ditches, and accumulates along fence rows.

## Wind Erosion Hazard

Climatic conditions in eastern Oregon favor soil blowing. Wind erosion is costly to agriculture because valuable topsoil is lost. Blowing sand also is abrasive and can seriously damage young crops.

Wind erosion is costly to the environment because it reduces air quality and creates a dust nuisance. Road ditches may quickly fill with sediment and require frequent cleaning.

Wind erosion also can be costly to human lives. Blowing sand and silt reduce visibility markedly. A few years ago, blowing sand was the direct cause of an accident on I-84 that involved several vehicles and resulted in a spectacular fire and the loss of several lives.

Besides a climate that favors strong, steady winds, the major soil factor that affects wind erosion is surface texture. Loam and silt loam soils will blow, but sandy loams and loamy sands are worse. That's because fine sand particles are easily picked up by the wind, and they are more abrasive.

To judge wind erosion hazard, consider first the location in Oregon, then the texture of the surface horizon. As with water erosion, evaluate the soil in the worst possible condition—with no vegetation cover.

### Guide for Determining Wind Erosion Hazard

| | Low | Low | Moderate | High |
|---|---|---|---|---|
| **Location** | Western OR | Eastern OR | — | — |
| **Texture** | Any | Sandy clay loam<br>Sandy clay<br>Clay loam<br>Silty clay loam<br>Silty clay<br>Clay | Loam<br>Silt loam | Sand<br>Loamy sand<br>Sandy loam |

## Internal Soil Drainage

When all the pores of a soil are full of water, we say the soil is *saturated*. The top of a zone of saturated soil is called a *water table*. The height of the water table, and the length of time that the soil remains saturated, determine the internal drainage of a soil.

We use five classes to describe internal soil drainage. Rapidly permeable soils that are never saturated are called *excessively drained*. Moderately permeable soils that are rarely saturated are *well drained*.

Soils that are periodically saturated in lower horizons are either *moderately well drained* or *somewhat poorly drained,* depending on the depth to the water table. Soils that are thoroughly saturated for long periods of time are called *poorly drained* soils.

Soil drainage is important because it affects the environment of plant root growth. For most agricultural crops, about half the pores in the soil should contain water. The other half should contain air. For wetland plants and ecosystems, poorly drained soils that remain saturated for long periods of time are the preferred habitat.

When the soil is saturated, roots of agricultural crops quickly become oxygen-starved, and prolonged saturation kills many plants. That's why the choice of crop plants is severely limited in poorly drained soils.

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

Saturated soils are poorly suited for homesites, too. Conventional septic tank drainfields can't be installed in these soils, because waste water doesn't receive adequate treatment. No one wants water in the basement, so special precautions must be taken when houses are built on poorly drained soils.

Wet soils are extremely valuable components of wetland ecosystems. These wet soils are called *hydric* soils. These soils support plants that provide cover, food, and nesting sites for wildlife. Hydric soils help clean up water by enhancing the removal of nitrogen, phosphorus, and sediments. And they help absorb the energy of overflowing floodwater.

For these reasons, hydric soils and the wetlands they support are valuable natural resources. That's why special efforts are made to determine their locations and make sure they are not further destroyed to support commercial developments.

It usually happens that we study soils in the field during dry seasons, after water tables have disappeared. Rarely do we observe water tables directly as they fluctuate throughout the year. That makes it necessary to determine the drainage class from clues we find in the permanent properties of the soil. Color, permeability, kinds of horizons present, soil pH, and landscape position all enter into our judgment of soil drainage.

The most important clues come from color and mottling. Brown, yellow, and red colors are characteristic of well-oxidized, well drained soils. These soils rarely are saturated—and when they are, it's only for very short periods of time.

Dark gray or bluish-gray colors reflect intense reduction, which can only be caused by long periods of saturation. Poorly drained soils have these colors.

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

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

Slow permeability, though, does suggest that excess water can't escape quickly by moving through the soil. This situation often leads to buildup of at least temporary water tables.

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

These water tables are temporary, and their presence usually is indicated by mottling just above and in the upper part of the restrictive layer. The closer these layers are to the surface, the more frequent and prolonged the perched water table will be.

On the other hand, restrictive layers deep in the soil may have little effect on internal drainage, particularly if the soil above them is moderately permeable.

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

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

Soils in low-lying areas, or on broad, level landscapes, or in depressions, may have permanent water tables just a few inches beneath the surface. They are poorly drained. Again, slow permeability compounds the problem, although poor drainage conditions can form without it.

Climate affects the internal drainage class, too. In western Oregon, total rainfall far exceeds soil capacity to store water. The excess must either run off or move down through the soil—or else the soil will have restricted drainage.

In eastern Oregon, the limited amount of rainfall rarely creates this kind of excess. Many of the soils are well drained. Only in some of the basins that have naturally high water tables will we find soils with restricted drainage. These soils often are sodic or alkaline soils as well.

The five classes of internal drainage are defined below. Soil color and depth to mottles are the primary keys to the right drainage class. Remember that some soils may have color patterns or coatings on aggregates that are not related to internal drainage.

The other factors—landscape, permeability, restrictive layers, soil pH, and climate—all are used as supporting evidence when determining drainage class.

## Excessively drained (ED)

These soils have sand to sandy loam textures and often are gravelly or cobbly (Plate 14). The permeability is rapid. They have the brownish colors of well-oxidized soils, and they are not mottled.

## Well drained (WD)

These soils may have any texture, though silt loam, silty clay loam, loam, clay loam, and sandy loam are most common. Clayey Vertisols that occur in eastern Oregon also are considered to be well drained.

Soil colors are various shades of yellowish-brown and reddish-brown, all indicating well-aerated soil (Plates 1, 2, 3, 4, 5, 9, 10, 12, and 13).

Well-drained soils generally have moderate subsoil permeability. They do not have high water tables, and there are no mottles within 40 inches (1 meter) of the surface. Occasionally, however, the lower part of the soil may be saturated for a day or two at a time. Thus, the soil below 40 inches may have a few gray mottles.

## Moderately well drained (MWD)

These soils may have any texture. Subsoil permeability usually is moderate or slow. There may be a deep, restrictive layer that temporarily perches water (Plate 11). The upper part of the soil is brown, yellowish-brown, or reddish-brown.

The lower part of the soil is mottled somewhere between 24 and 40 inches (60 and 100 cm). The mottles may be gray mottles in a brownish matrix, or they may be yellowish-brown mottles in a grayish-brown matrix. It takes only a few gray or brown mottles to indicate enough wetness to drop a soil into a moderately well-drained class.

Some clayey Vertisols in western Oregon are considered moderately well drained. They occur on convex uplands and have dark brown colors.

## Somewhat poorly drained (SWP)

These soils may have any texture and any permeability. In western Oregon, they usually occur in flat or low-lying positions that have seasonally high water tables. Some have fragipans or claypans as well. Even a few upland soils are somewhat poorly drained because they have shallow restrictive layers.

Somewhat poorly drained soils in western Oregon are rarely saturated all the way to the surface for long periods of time. They are not mottled in the Ap or A horizon. The water table is high enough to cause some mottling of the soil somewhere between 8 and 24 inches (20 and 60 cm).

The second horizon may or may not be mottled—but if it is, the matrix usually is brown, and the mottles are no more than common. A few soils have a gray E horizon that contains dark mottles (Plate 6). At increasing depths, the mottling becomes more noticeable.

In eastern Oregon, the mottling pattern may not be as easy to detect. Two kinds of somewhat poorly drained soils may occur:

1. Black or very dark brown colors extend throughout the soil. These either have yellowish-brown or reddish-brown mottles below 12 inches (30 cm), or they have a few grayish mottles throughout starting right below the Ap.
2. Soil pH values are greater than 9.0. This occurs when the soil has a high sodium content. It indicates that water from a shallow water table rises toward the surface and evaporates (Figure 17).

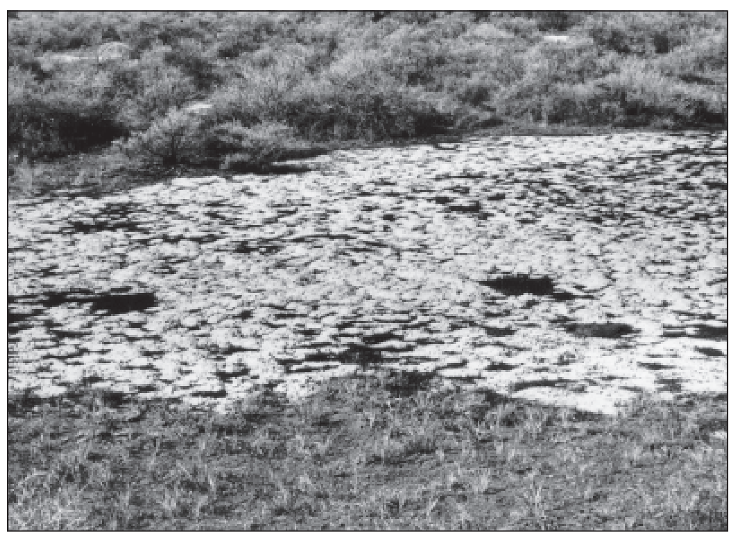


Figure 17.—Somewhat poorly drained sodic soil. In semi-arid areas, slick spots of salt accumulation are good indicators of shallow water tables and somewhat poorly drained soils. Salt grass in the foreground and greasewood in the background are other clues to the presence of sodic soils.

## Summary of Drainage Class Characteristics

| | Color | Depth to mottles | Permeability | pH | Other |
|---|---|---|---|---|---|
| **Excessive** | Brown, Red | None | Rapid | ≤ 8.2 | |
| **Well** | Brown, Red | > 40 inches | Moderate | ≤ 8.2 | E. Oregon Vertisols |
| **Moderately well** | Brown, Red | 24–40 inches | Moderate | ≤ 8.2 | W. Oregon Vertisols on convex uplands |
| **Somewhat poor** | | | | | |
| A. Western Oregon | Gray subsoil | 8–24 inches | Mod. or Slow | ≤ 8.2 | |
| B. Eastern Oregon | | | | | |
| 1. | Black | 8–12 inches | Mod. or Slow | ≤ 8.2 | |
| 2. | Black, Brown | None | Mod. or Slow | ≥ 9.0 | Sodic soil |
| **Poor** | | | | | |
| A. Western Oregon | Black, Gray | 0–8 inches | Mod. or Slow | ≤ 8.2 | Gleyed soil may not be mottled; black Vertisols in low-lying landscapes. |
| B. Eastern Oregon | Black, Gray | Variable | Mod. or Slow | ≤ 8.4 | Gleyed soil may not be mottled. |

In both cases, low-lying landscape positions and dark soil colors indicate periodically high water tables.

## Poorly drained (PD)

These soils are saturated at or near the surface for long periods each year. They either occupy low-lying or depressional areas that have permanently high water tables, or they have restrictive layers close to the surface—or both. Any texture or permeability can occur, but fine textures and slow permeabilities are most common.

In western Oregon, poorly drained soils have either mottles or small black concretions (hard pellets) right in the Ap or A. In a few soils, black colors (caused by high organic matter content) may completely mask the mottles in surface horizons (Plate 8).

Gleyed horizons are common in poorly drained soils, but they aren't required. The gleyed soil may occur right below the Ap or it may be a little farther down. It may or may not be mottled (Plate 7), but if it is mottled, common mottling (2 to 20 percent) is the norm.

Many western Oregon Vertisols are poorly drained. They occur in low-lying landscape positions and have black colors.

Poor drainage is harder to evaluate in eastern Oregon. In all cases, prolonged wetness delays the decomposition of organic matter, so the soils tend to be black throughout.

If mottles are present, they are most likely to be faint. A few poorly drained soils have yellowish-brown or reddish-brown mottles in the dark matrix immediately below the Ap or A.

Others are truly gleyed, so that the soil below the A is a gray or dark gray that becomes noticeably light gray upon drying. This gleyed soil may or may not be mottled, but if it is, the mottles tend to be darker than the matrix and gray or grayish-brown in color.

Landscapes are low-lying to depressional in every case. Poorly drained soils are not sodic soils, and the pH always is less than 9.0.

Plate 1

Plate 1.—Well-drained sandy soil with a black O horizon (4–0"), a white E horizon (0–11"), a yellowish brown Bs horizon (11–18"), and a light brown C horizon (18–30").

Plate 2

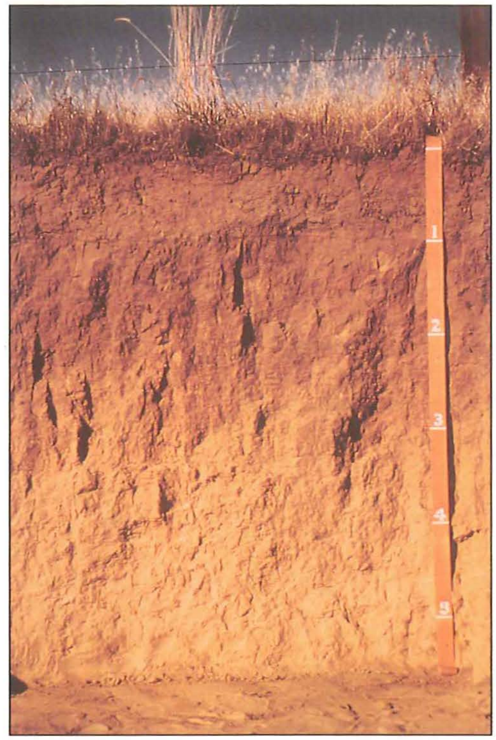


Plate 2.—Well-drained silty soil with an Ap horizon (0–11"), a thick Bw horizon (11–36"), a BC horizon (36–45"), and a C horizon (45–65"). The dry colors shown are all brown. Note the coarse prismatic structure of the Bw horizon and the massive structure of the C horizon.

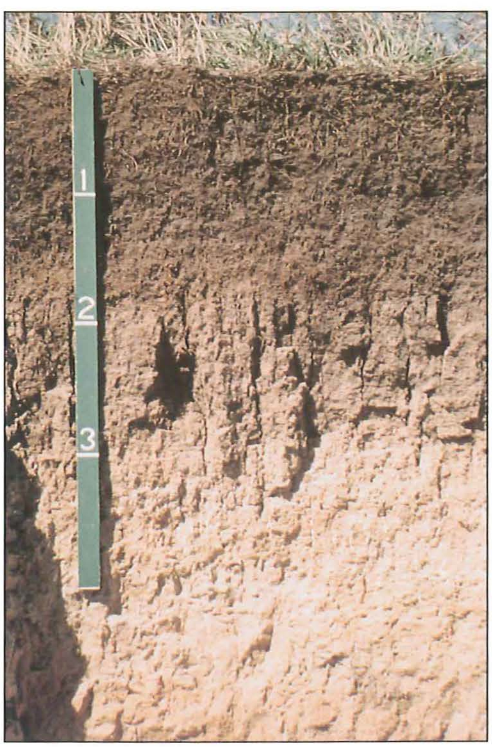


Plate 3

Plate 3.—Well-drained silty soil with a black A horizon (0–15"), a brown BA horizon (15–23"), a grayish brown Bt horizon (23–34"), a light brown BC horizon (34–48"), and a light brown C horizon (48–60"). Note the strong prismatic structure in the Bt horizon.

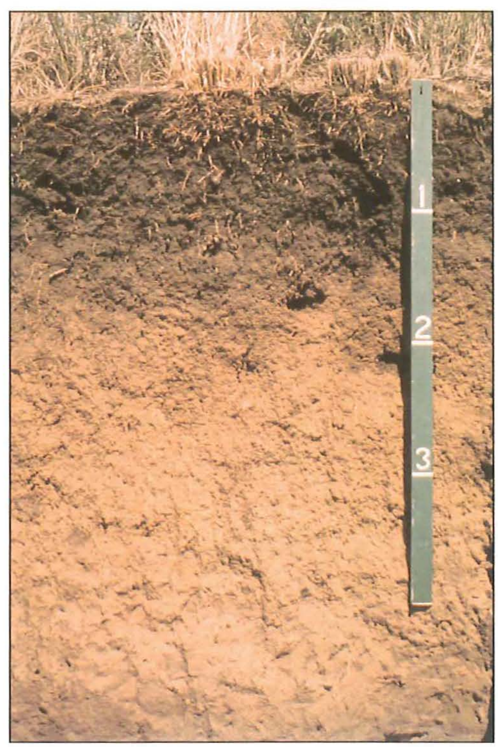


Plate 4

Plate 4.—Well-drained silty soil with a black A horizon (0–12"), a very dark grayish brown AB horizon (12–18"), a brown Bw horizon (18–30"), and a light brown C horizon (30–60").

Plate 5

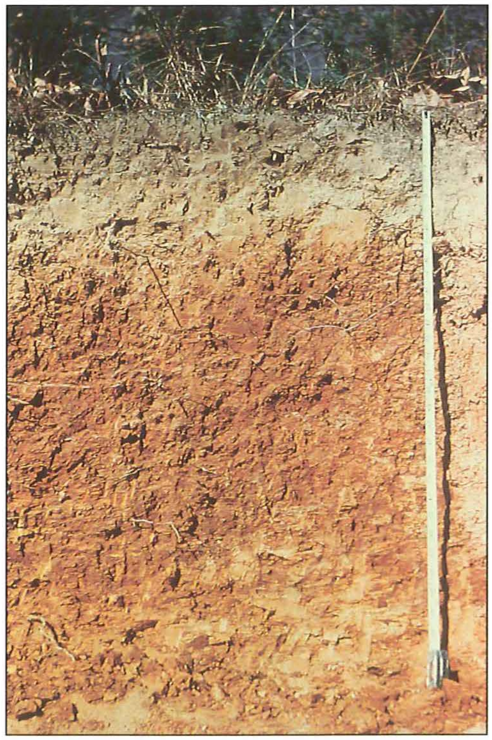


Plate 5.—Well-drained, strongly weathered soil with a thin A horizon (0–3"), a white E horizon (3–7"), a thick, reddish brown Bt horizon (7–26"), and a BC horizon (26–40").

Plate 6

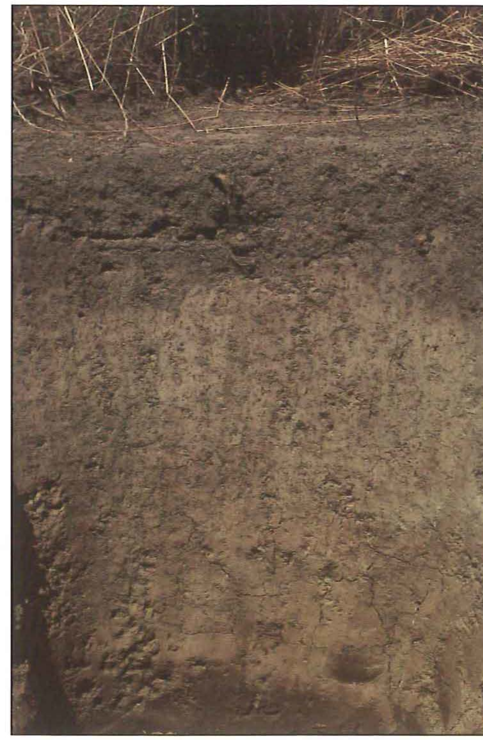


Plate 6.—Somewhat poorly drained soil with a very dark brown Ap horizon (0–10"), a gray E horizon (10–27"), and a brown Bt horizon (27–45").

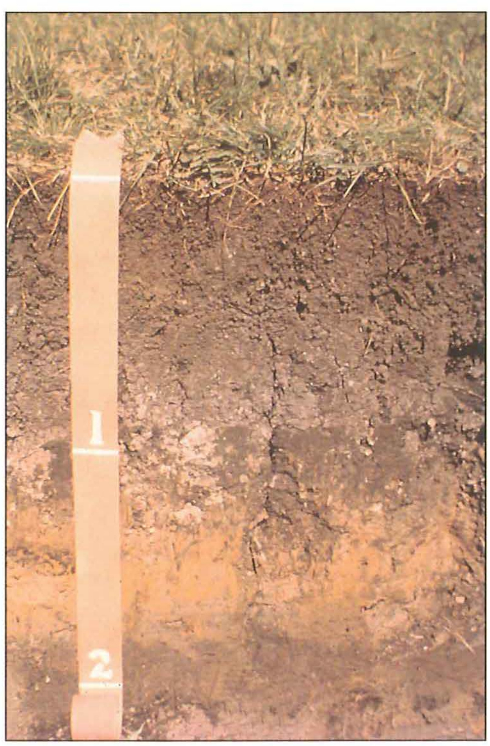


Plate 7

Plate 7.—Poorly drained soil with a black A horizon (0–15"), a gray Bg1 horizon (15–22") that has many coarse prominent yellowish brown mottles, and a gray Bg2 horizon (22–26") that is not mottled.

Plate 8

Plate 8.—Poorly drained soil with a very thick, black A horizon (0–24"), a black, gleyed Bg horizon (24–33"), and a dark gray, gleyed Cg horizon (33–48").

Plate 9.—Well-drained, partly leached soil with a dark brown Ap horizon (0–5"), a brown Bt horizon (5–16"), a white Bk horizon enriched with calcium carbonate (16–36"), and a light brown C horizon (36–42").

Plate 10.—Well-drained soil containing a duripan. This soil has a brown A horizon (0–4"), a brown Bt horizon (4–14"), and a white Bkqm horizon (14–24") that is thoroughly cemented with calcium carbonate and silica. Note how the cemented duripan sticks out from the face of the soil exposure.

Plate 11.—Moderately well-drained soil containing a fragipan. The horizons are a dark brown A (0–4"), a brown Bw (4–26"), a white E (26–30"), and a brown Bx (30–60"). Note the wedges of white silt that divide the massive Bx horizon into very coarse prisms.

Plate 12.—Well-drained soil with an R horizon. The soil has a very dark brown Ap horizon (0–8") and a yellowish brown Bw horizon (variable thickness) resting directly on consolidated bedrock.

Plate 9

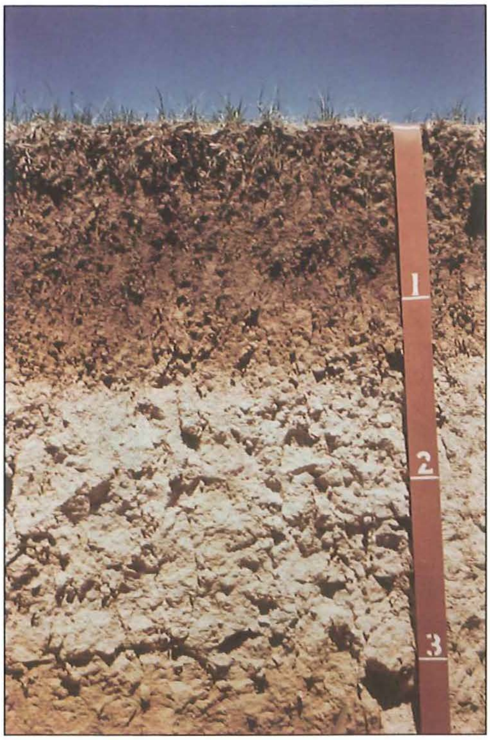



Plate 10

Plate 11

Plate 12

Plate 13.—Well-drained soil with a Cr horizon. The light brown material at the end of the spade is soft sandstone.

Plate 14.—Excessively drained soil high in coarse fragments. The gravelly A horizon contains about 30 percent coarse fragments. The extremely gravelly C horizon is structureless and single grained, and it contains about 75 percent coarse fragments.

Plate 13

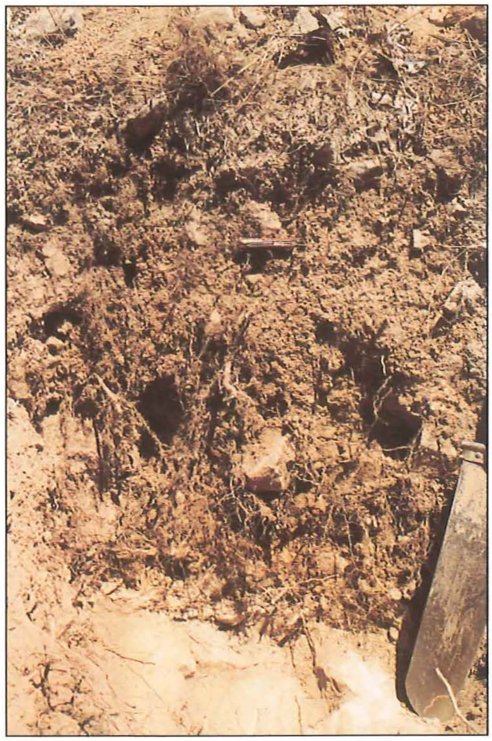


Plate 14

Plate 15.—Strong blocky structure. Notice how natural planes of weakness divide the soil both vertically and horizontally. The darker coatings on ped surfaces are clay skins.

Plate 16.—Gleyed, mottled soil. The soil matrix has a gray color, and the mottles are yellowish brown spots.

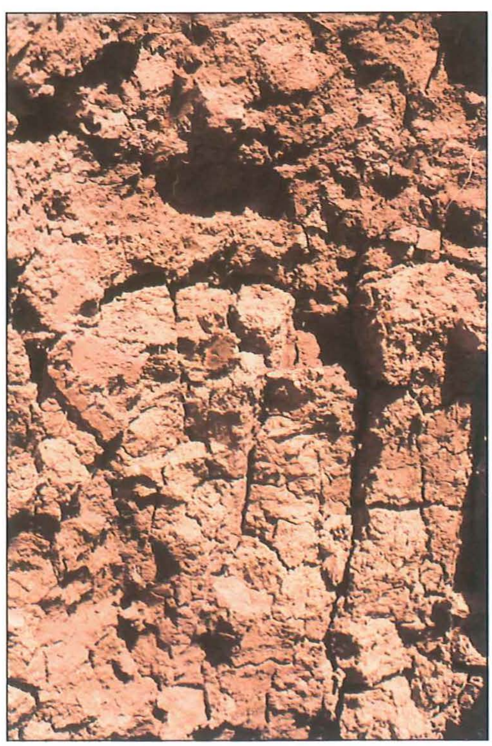


Plate 15

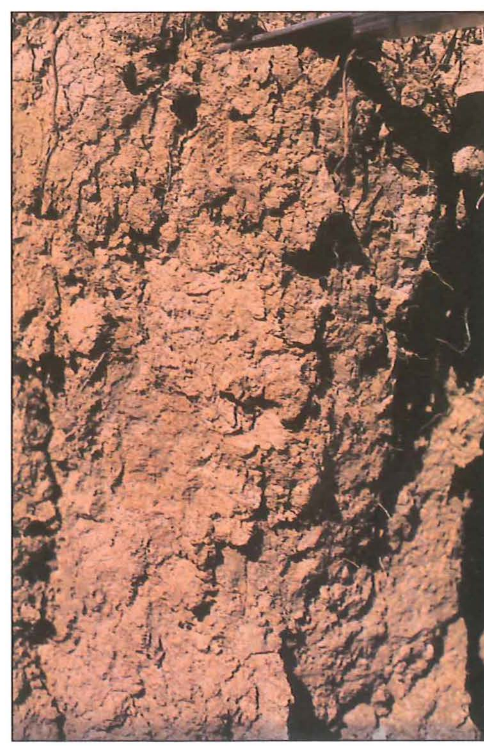


Plate 16

# Site Characteristics

Soils are more than the horizons that make up their profiles. They also are part of the landscape. The position of the soil in the landscape can tell us something about the age of the soil and the kind of geologic materials from which the soil developed.

Site characteristics affect runoff, erodibility, and internal drainage. They also affect management decisions about irrigation, choice of crop, and conservation.

Site evaluation, then, is just as important in judging soils as the description of the properties of each horizon. Five major site characteristics are used in soil judging: landform, parent material, stoniness or rockiness, slope, and aspect.

## Landform

Landforms are distinct parts of the landscape that have characteristic shapes and are produced by natural geologic processes. To evaluate landforms, you need to cast your eyes in every direction around a site to assess the general lay of the land. Consider both slope steepness and slope shape (convex, linear, or concave). The parent material also may be a guide, although the correlation between landform and parent material is not perfect.

There are many specific kinds of landforms. We will use only six rather general classes of landforms that commonly are found in Oregon.

### Upland

Uplands are the higher parts of the land surface. Most uplands are hilly, though some may be nearly level plains. Uplands include gently rounded foothills (Figure 18) and steep mountain slopes. Uplands are likely to have residual or colluvial parent materials.

Uplands also include very old, highly dissected stream terraces. Because of dissection, the terrain is all sloping, but the parent material is old alluvium.

Nearly level ridge crests and hilltops also are uplands. So are basalt plateaus in eastern Oregon. Some of the soils on these plateaus have a mantle of old alluvium or of wind-blown silts; others formed in residuum.

Sand dunes are uplands, but their parent materials are wind-blown sand. There are other situations, but the keys are the general position and shape of the surface in relation to the surrounding landscape and the amount of slope.

Figure 18.—Uplands. The tree-covered hill and the convex, rounded slopes are characteristic of upland landforms.

## Foot slope

Foot slopes occur at the base of upland hillslopes. They mark the change from upland to stream terrace or floodplain. Foot slopes usually are concave. They collect more water than they shed by runoff.

Figure 19.—Alluvial fan. The gently sloping, fan-shaped landform at the base of the mountains is an alluvial fan. The dissected landforms in the background are uplands. In the foreground, near the fence, the fan merges gradually with an old lake plain.

Figure 20.—Floodplain. The soils on a floodplain usually are very productive, but frequent flooding or long periods of standing water may restrict agricultural use of the soil.

Foot slope soils often have colluvial parent materials that accumulate by gravity movement down the upland slopes. Some foot slopes, however, may have parent materials that consist of residuum, old alluvium, or wind-blown sands or silts.

## Alluvial fan

Fans also occur at the junction between sloping uplands and nearly level valley floors. They form where a rapidly flowing stream emerges from a narrow valley onto a terrace, floodplain, or lake plain.

The fan is narrow and sloping at the upstream point of origin. It broadens and flattens as the stream spreads sediment onto the valley floor (Figure 19). The surface of a fan is gently rounded. The parent material is alluvium.

Sometimes, where several parallel streams emerge from a mountain slope, a whole series of fans will overlap to form a continuous landform of intermediate slope between the upland and the lowland.

## Floodplain

Floodplains are the nearly level surfaces next to stream channels. Every time a stream overtops its banks, the excess water flows out onto the floodplain (Figure 20).

Any given flood may not cover the entire floodplain, but all parts of the floodplain will be covered with water at least once every 100 years.

Floodplains usually are nearly level, but some have slopes up to 5 or 6 percent. Scouring by water in overflow channels may give the floodplain a rolling, hummocky appearance, especially right next to large rivers. The parent material on a floodplain is recent alluvium.

## Stream terrace

Stream terraces are abandoned floodplains. When a river cuts down through its existing floodplain, it establishes a new floodplain at a lower level. The old floodplain is left high and dry as a terrace that is no longer subject to flooding. Terraces have the same nearly level shape as floodplains, but they are at higher elevations.

At the junction between a terrace and a floodplain is a rise, called an *escarpment*. In some places the escarpment is very obvious. At others it may be a very small rise that requires close observation to detect.

Some rivers may have two or three terrace levels, each separated by an escarpment (Figure 21). Such compound landforms resemble a giant set of stairs.

Lateral erosion by a river may remove all of the floodplain on one side. The river then flows at the base of a terrace that it never overtops. In such cases, the floodplain on one side of the river will be distinctly lower than the terrace on the other side.

Because terraces have been abandoned, their parent materials are old alluvium. Soils on terraces are older and more developed than soils on floodplains.

## Lake plain

Lake plains are broad, nearly level surfaces that once were at the bottom of large lakes. They are common in the intermountain basins of Klamath, Harney, and Lake counties (Figures 17 and 22). There also are some old lake basins in central Oregon, in the Columbia Basin, and in Baker, Union, and Umatilla counties.

The Willamette Valley once held a large lake, too, but there it's very hard to tell the difference between an old lake bottom and a stream terrace. Detailed, regional geologic studies are necessary to be sure.

The parent material of lake basins is lacustrine sediments.

Figure 21.—Terraces. Three terrace levels are apparent. In the foreground is a low terrace. Beyond the fenceline an escarpment rises to a higher, nearly level terrace surface. In the background, a third terrace stands at an even higher elevation.

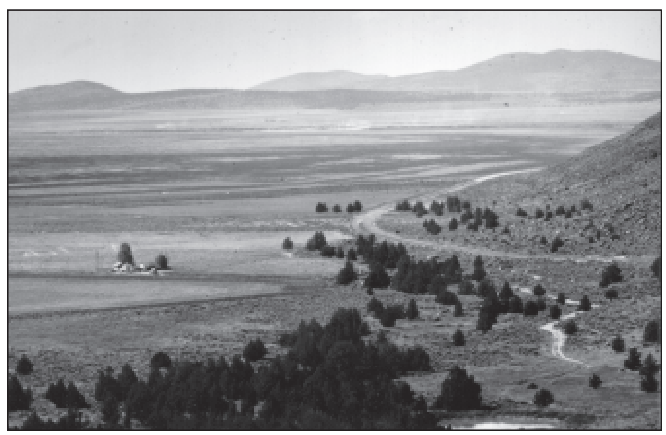


Figure 22.—Lake plain. This lake plain is the level floor of a basin surrounded by mountains. Wave-cut terraces on the surrounding slopes often mark the positions of the shorelines of the ancient lakes.

## Parent Materials

Parent material is the geologic material from which A and B horizons have developed. Some soils form in place by weathering of bedrock. We call them *residual* soils, and the parent material is called *residuum*. *Colluvium* is similar, but it has been moved downslope by the pull of gravity.

Other soils form in loose materials transported by wind, water, or ice. We call these loose materials *sediments,* and there are several kinds. Sediments carried by a river and deposited on a floodplain or a fan are called *alluvium*. Sediments deposited on the bottom of a lake are called *lacustrine*. Silty sediments carried by wind are called *loess*. Wind-borne volcanic debris is called *ash*.

Parent materials are determined by comparing A and B horizons with C and R horizons. The problem is that once A and B horizons are fully developed, the character of their original parent materials may no longer be clear.

Usually, we can assume that the C horizon is still pretty much like the original parent material of the A and B. This often is the case in deep soils that have nearly uniform textures.

In some soils, properties of the A and B are very different from those of the C and R horizons beneath them. These differences, combined with abrupt changes from B to C, or B to R, suggest two different kinds of parent materials. For these soils, it's not correct to say that the C or R horizons are like the original parent materials of the A and B.

Because many Oregon soils do have a complex geologic history, we try to determine all parent materials that have influenced the entire soil profile. If all horizons in a soil profile appear to have developed from a single kind of parent material, simply mark that answer.

Alluvium, lacustrine sediments, and volcanic ash may be distinctly layered. The layers result from different episodes of flooding or volcanic eruption. Even though these layers may have different textures, they all form from the same process, and they represent a single kind of parent material, too.

Two or more kinds of parent materials include loess resting directly on basalt rock, layers of volcanic ash mixed with layers of alluvium, and layers of lacustrine sediments on top of residuum or colluvium. Abrupt changes in color, texture, and coarse fragments provide the major clues to these situations. Mark only the response for two or more classes for these soils.

There is a close relationship between the kind of parent material and the landform of a soil. Uplands usually have residual or colluvial parent materials. Soils on floodplains and stream terraces develop from alluvium. Old lake basins contain lacustrine sediments.

Sometimes, however, it is difficult to distinguish between two similar kinds of parent materials unless you're very familiar with the geology of an area. That's why some of the parent materials described separately in the manual are grouped together on the scorecard. Seven kinds of parent materials are common in Oregon.

### Residuum

This is earthy material that accumulates by weathering of bedrock in place. Different kinds of rocks give rise to different kinds of residuum.

Basalt, andesite, and volcanic tuff weather to clayey soils. Granite and coarse sandstones weather to loamy and sandy soils. Siltstones and fine-grained sandstones weather to silt loam and silty clay loam textures.

In the strictest sense, residual materials have not been moved from the place of weathering. If we didn't allow any exceptions, there would be very few truly residual soils in Oregon.

Small movements—due to tree throw, animal mixing, soil creep, and localized slumping—occur almost everywhere, particularly in the upper foot or so of soil. Such movements shouldn't exclude a material from residuum, as long as we can be reasonably sure that the entire profile formed from material weathered from the rock that underlies it.

Generally, as depth increases in a residual material, there is a gradual increase in the amount and size of rock fragments, and they are less and less weathered. Some soils, however, may have relatively unweathered rock fragments throughout, especially in eastern Oregon, where low rainfall limits rock weathering.

Residuum is common on uplands and on some footslopes. It also may be buried beneath a thin deposit of alluvium on stream terraces or fans.

## Colluvium

This is loose, earthy material that is transported down steep slopes and deposited at the base of these slopes. Gravity is the main force, but water helps by weakening the strength of a soil mass upslope, or by local, unconcentrated runoff.

In western Oregon, colluvial deposits may have relatively unweathered angular rock fragments mixed uniformly throughout. In eastern Oregon, this standard may not help much to distinguish colluvium from residuum.

Colluvium is a common parent material on footslopes and on steep uplands.

## Recent alluvium

*Alluvium* refers to sediments deposited by running water. *Recent alluvium* refers specifically to materials on the floodplains of modern rivers. All streams and rivers carry a load of suspended sediments, particularly during periods of heavy runoff. Every time a river floods, fresh sediments are added to the recent alluvium of the floodplain.

When a river floods, water moving over the floodplain flows much more slowly than water in the main channel. Suspended sediments then have a chance to settle out on the floodplain. The coarsest sediments settle out nearest the river. Fine-textured sediments are carried farther away and settle out in quiet, backwater areas.

Repeated episodes of flooding result in gradual accumulation of thick deposits of sediment on the floodplain. These deposits may have fairly uniform textures, or they may be distinctly stratified into layers of widely different textures. If any of the layers contain coarse fragments they usually are rounded because of abrasion over long distances of stream transport.

Recent alluvium is also the parent material of an alluvial fan being formed by a modern stream emerging from steep terrain. It, too, often is stratified. Sand and gravel layers are not unusual.

Soils developed in recent alluvium are young soils, and may have nothing more than A/C profiles. If the period between deposition of fresh sediments is longer, the soil may have a simple A/B/C profile.

## Old alluvium

This is alluvium associated with a stream terrace or an abandoned alluvial fan. The alluvium once was laid down as recent alluvium on a floodplain, but abandonment of that floodplain means that there are no further deposits of fresh sediments.

If an old terrace or fan has been uplifted and highly eroded to form hills and valleys, then the landform might be an upland or a footslope, but the parent material still is old alluvium.

Soils developed in old alluvium usually have much more distinct horizon development than soils in recent alluvium.

## Lacustrine sediments

These are sediments deposited originally at the bottom of a lake. They usually are finely stratified layers of silts and clays. Some sandier deposits may occur near the shoreline of an old lake. Lacustrine deposits often exhibit distinct laminations that are apparent as platy structure.

Lacustrine sediments are the parent materials associated with lake plain landforms. In some of the old lake basins in south-central Oregon, white layers of silty diatomaceous earth may be interstratified with other lacustrine sediments.

Lacustrine sediments may occur on uplands if the old lake plain has been uplifted and dissected. They also may be on uplands, footslopes, or fans if an ancient lake temporarily covered an existing landscape of hills and valleys.

## Wind-blown sands and silts

Wind-blown sands take the form of dunes. They occur primarily along the coast, in the Columbia Basin, and in a few other isolated areas throughout Oregon.

Figure 23.—Very stony soil. Numerous large stones on the surface of the soil make tillage almost impossible. Management for improved permanent pasture, however, is practical.

The sand was derived originally from a beach deposit or from a lacustrine or floodplain deposit. Since it has been reworked by the wind, however, it is customary to refer to the material as wind-blown, or *eolian* sand.

Wind-blown silt is called *loess*. The silts originally were deposited in a lake basin or on a floodplain. Later the wind picked them up, transported them, then redeposited them on top of existing hills and valleys.

Loess is a common parent material on uplands and footslopes overlying basalt on the Columbia Plateau in north-central Oregon. It is thickest near the Columbia River and thins southward. The texture of loess also changes from a fine sandy loam at the river to silt loams and silty clay loams with increasing distance.

Soils developed in loess can be quite productive, but they are particularly susceptible to erosion.

## Volcanic ash

Volcanic ash is fine-grained material ejected from a volcano, carried by wind, and deposited in varying thicknesses (see Figure 6). It consists of a mixture of three kinds of particles: glass shards, silt and sand-sized pumice fragments, and rock fragments torn off the pre-existing wall of the volcano.

Strictly speaking, ash particles are less than 2 mm in diameter, the same as fine earth. For our purposes, we will include with volcanic ash those larger fragments, commonly referred to as “popcorn pumice,” that were deposited close to the source.

Some ash deposits are the result of wind-borne transport over several tens or hundreds of miles. Closer to the volcano, mixtures of hot gases and ash can literally flow over the surface of the ground without being sorted by the wind. Such a flow is called a *glowing avalanche*. We will include glowing avalanche parent materials with volcanic ash, as well.

Ash commonly has silt loam or sandy loam textures, becoming coarser close to the volcano. Ash typically has a very low density and tends not to compact under applied loads.

Volcanic ash usually occurs on uplands and footslopes, but it may occur as distinct layers in alluvial or lacustrine sediments.

## Stoniness and Rockiness

*Stoniness* refers to the amount of individual rock fragments larger than 10 inches (25 cm) in diameter *exposed at the soil surface* (Figure 23).

*Rockiness* refers to the amount of the land surface that consists of bedrock outcrops (Figure 24).

Neither stones nor rock outcrops are considered as part of the soil, because they are so large as to exclude both fine earth and pore space from a large volume of the soil. Both are important characteristics of the site, however, because they influence cultivation and other forms of agricultural management.

Stoniness and rockiness are judged according to the percentage of the soil surface covered by detached stones or rock outcrops. Four general classes are

Figure 24.—Extremely rocky soil. Outcrops of basalt bedrock are so numerous that soil management is limited to use of the soil for native pasture or range.

### Classes of Stoniness and Rockiness

**Not stony/Not rocky—**No stones or rocks are present, or there are too few to interfere with tillage.

***Stones*** cover less than 0.01 percent of the area.

***Rock outcrops*** cover less than 0.01 percent of the area.

**Stony/Rocky—**There are enough stones or rock outcrops to interfere with tillage, but not to make intertilled crops impractical.

***Stones*** cover 0.01 to 0.1 percent of the area—stones about 1 foot in diameter are spaced 30 to 100 feet apart.

***Rock outcrops*** cover 0.01 to 2 percent of the area—outcrops are more than 300 feet apart.

**Very stony/Very rocky—**There are so many stones or rock outcrops that tillage between crop rows is impractical. The soil still can be worked for hay crops or improved pasture.

***Stones*** cover 0.1 percent to 3 percent of the area—stones about 1 foot in diameter are spaced 5 to 30 feet apart.

***Rock outcrops*** cover 2 to 10 percent of the area—outcrops are about 100 to 300 feet apart.

**Extremely stony/Extremely rocky—**Stones or rock outcrops are so widespread that no agricultural improvements are possible. Some soils still have limited value as native pasture or range.

***Stones*** cover more than 3 percent of the area.

***Rock outcrops*** cover more than 10 percent of the area.

used here. Each is defined not only quantitatively but also in terms of impact on agricultural management.

Because stones tend to be randomly scattered over the soil surface—whereas rock outcrops are concentrated in small areas—the numerical limits of stoniness classes are different from the limits of rockiness.

## Slope

Slope, or slope gradient, refers to the steepness of the land surface. We measure slope in percent as the amount of vertical change in elevation over some fixed horizontal distance. Slope always is measured in the same direction as water would run over the surface.

We often think of slope as the "rise over the run." If two points are 100 feet apart (the run), and one point is 10 feet higher than the other (the rise), then the slope is 10 over 100, or 10 percent.

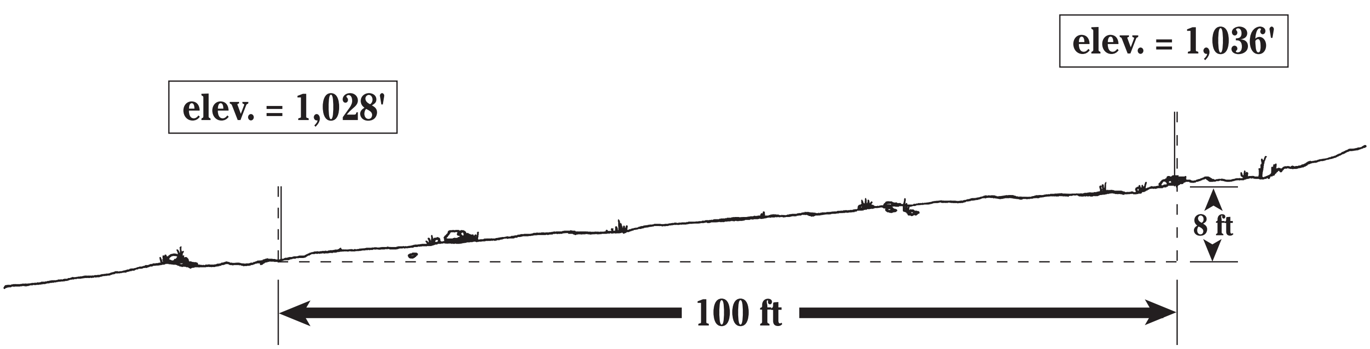
The slope of a soil is important because it affects use and management of the soil. It is directly related to soil erosion hazard, and it influences a farmer's choice of crops and conservation practices. Irrigation becomes more difficult on steeper slopes, and so does operation of farm machinery. In general, as slope gradient increases, agricultural suitability decreases.

Slope has some other characteristics besides steepness. One is slope length. Long, uniform slopes are easier to operate equipment on than short, broken slopes. But long slopes allow runoff water to gather more speed as it flows over the surface.

Long slopes are, therefore, more subject to erosion than short slopes. Diversion terraces are an effective erosion control practice specifically because they break up long slopes into several short segments (see Figure 32).

Another slope characteristic is slope shape. Slopes may be linear, concave, or convex.

***Linear*** means flat, or without curvature. Imagine a clipboard sitting on your desk. The surface of the clipboard is flat, and as it sits on your desk it is level. Now tilt it by lifting one end. The surface is still flat, but it now slopes at some gradient.




$$\% \text{ Slope} = \frac{\text{Rise}}{\text{Run}} = \frac{1{,}036' - 1{,}028'}{100'} = \frac{8'}{100'} = 8\%$$

Figure 25.—Judging soil slope. Posted elevations on two stakes a known distance apart allow easy calculation of the slope gradient.

***Concave*** means saucer-shaped or bowl-shaped. The slope gradient progressively decreases over a concave slope. ***Convex*** means just the opposite. Rounded, convex slopes get progressively steeper as you go downslope. Many hills have convex tops, linear sides, and concave footslopes.

We can measure slope gradient with a number of surveying instruments. Soil scientists usually carry an Abney level or a clinometer to measure slope. With practice, they often can estimate the slope gradient within a percent or two.

Since you probably don't have the instruments, and your experience at estimating slopes is limited, we'll use a different method for judging (Figure 25).

At each site we'll drive two stakes into the ground. We'll tell you the elevation at each stake and the horizontal distance between stakes. You'll have to calculate the difference in elevation, the rise over the run, and the percent slope. The stakes won't always be 100 feet apart, so be sure to adjust your answer to percent.

The final step is to determine the proper slope class according to the chart.

| Classes of Slope Gradient | |
|---|---|
| Nearly level | 0–3% |
| Gently sloping | 3–7% |
| Sloping | 7–12% |
| Moderately steep | 12–20% |
| Steep | >20% |

# Aspect

One final site characteristic is the aspect of the slope. Aspect is the compass direction that the slope faces.

Southerly aspects are more nearly perpendicular to the sun's rays than northerly aspects. They are exposed to the sun for longer periods of time each day. Soils on southerly aspects tend to be hotter and droughtier than soils on northerly aspects.

The vegetation on northerly aspects is more likely to be trees, whereas southerly aspects may have only grasses. Because of the vegetation difference, soils on southerly aspects are more susceptible to erosion, and they often are shallower than soils on northerly exposures.

For all these reasons, soils on southerly aspects tend to have considerably lower productivity potentials than soils on northerly aspects.

The only drawback to northerly aspects is that, at a given elevation, the growing season may be quite a lot shorter, and it takes longer for the soil to warm up in the spring.

Easterly and westerly aspects are intermediate in their response to sunlight and moisture supply. In general, an easterly aspect will be more like a northerly aspect, and a westerly aspect will be a little more like a southerly aspect.

# Management Interpretations

The first steps in evaluating soils involve learning how to identify horizons, how to describe their characteristics, and how to evaluate the behavior of the whole soil. Having done that, we now can focus our attention on use and management of soil resources.

Management interpretations sometimes are difficult to judge, because (1) they depend on interactions among several soil factors, (2) they depend on specific crops being grown, and (3) they are affected by climatic conditions.

In order for this *Manual* to have state-wide use, we've had to generalize considerably. The guidelines given in the sections that follow should be adequate for soil judging contests, but you should recognize that there may be exceptions to every one of them in specific cases. Oregon has such a diversity of soils, climates, types of agriculture, and management practices, that a general manual simply cannot account for every possibility.

As we did in Chapter 5, we've organized the interpretations into tabular guides for sequential evaluation. Refer to the Guide in Appendix B for instructions on the use of those keys.

## Feasibility of Artificial Drainage

Soils that are less than well drained often can be improved for commercial crop production by artificial drainage. Ditches, subsurface drains, or combinations of the two may be required.

The feasibility of such measures, and their design, installation, and cost, depend on the properties of the soil being drained. Moderately well-drained soils with good permeability are easy to drain. Clayey soils, soils with shallow restrictive layers, and soils that are saturated for very long periods of time are difficult to drain.

Another factor that affects drainage feasibility is the availability of outlets—having someplace to discharge water removed from the soil. Outlets may not be available in low-lying depressions or on broad, level surfaces where the water table is at or near the surface much of the time.

Outlet availability can't always be evaluated from the characteristics of the soil profile or of the immediate site. Regional studies and seasonal observations may be required. For these reasons, information on the availability of outlets will be provided at each judging site.

### Guide for Determining Drainage Feasibility

| | Good | Fair | Fair | Poor | Poor | Poor |
|---|---|---|---|---|---|---|
| Outlets | Available | — | — | — | — | Not available |
| Effective depth | Deep | — | Mod. deep | — | Shallow | Any |
| Drainage class / Subsoil permeability | MW/Any<br>SWP/Rapid, Mod. | —<br>SWP/Slow, V. slow | MW/Any<br>SWP/Any<br>PD/Rapid, Mod. | —<br>—<br>PD/Slow, V. slow | Any | Any |

The key word in this interpretation is *feasibility*. This term refers specifically to the relative ease or difficulty of draining a soil. It is not the same as drainage effectiveness.

Soils with good drainage feasibility may require nothing more than tile drains at 60- or 80-foot spacings. Good feasibility implies that it is logical and practical to invest in tile drainage, because effective drainage can be accomplished easily, and it will be profitable.

Soils with poor drainage feasibility may require tile lines at 20- or 30-foot spacings, as well as sumps, pumps, and valves. Technology exists to drain them effectively, but it may not be practical or economical to do so.

The first soil characteristic to consider is the internal drainage class. Excessively drained soils and well-drained soils don't have a wetness problem. Drainage is not needed, and that's what you should check on your scorecard.

The next factor to consider is whether or not outlets are available. If they are, then drainage feasibility can be as good as other soil properties permit. If they are not, drainage feasibility is poor, regardless of any other soil qualities.

The effective depth of rooting is an indicator of the depth of soil that can be drained effectively. In deep soils, the effective depth is not a limitation to drainage feasibility. If the effective depth is moderately deep, the drainage feasibility is no better than fair.

If there is a shallow, massive, clayey layer in the soil, then only a small volume of soil above the claypan can be drained, and the feasibility is poor.

If the soil does need drainage, then the feasibility also depends on interactions between the degree of wetness and the subsoil permeability. Moderately well-drained soils don't have a serious wetness problem, so they can be slowly permeable and still have good drainage feasibility.

Somewhat poorly drained soils must have at least moderate permeability to have good drainage feasibility. If the permeability is slow, they can have no better than fair drainage feasibility.

Poorly drained soils are so wet that they always will be difficult to drain. If they have at least moderate permeability, however, they can have fair drainage feasibility. Poorly drained soils with slow permeability have poor drainage feasibility.

Figure 26.—Tile drainage. Specialized trenching machines install continuous PVC drain tiles into the soil. The gradient of the tile lines is carefully controlled with laser beams to ensure good water flow. The depth of the tile lines and the spacing between them depend on the properties of the soil and the depth to the water table.

# Suitability for Irrigation

The best soils for irrigation are deep, nearly level, well-drained soils with good surface soil permeability and high water-holding capacity. Departures from these conditions may lower the irrigation suitability.

When we judge irrigation suitability, we are judging only the soil's ability to be irrigated. Availability of water for irrigation is *not* a factor to be considered. Neither is the specific crop to be irrigated.

The primary factors influencing irrigation suitability are slope, surface soil permeability, available water-holding capacity (AWHC), drainage class, and drainage feasibility. These are the soil properties used to determine irrigation suitability in the guide below.

Effective depth also is important, but it is so closely related to AWHC that we don't need to consider it separately. Subsoil permeability is another important factor, but its effect is accounted for in drainage feasibility.

Slope affects the choice of an irrigation system. Flood or furrow irrigation works well only on soils having slopes less than 3 percent. Wheel lines and center pivots will work on slopes up to 7 percent, but with increasing difficulty. Above 7 percent, solid sets or hand-move systems may be required. Irrigation generally is not feasible on slopes greater than 20 percent.

Surface soil permeability interacts with slope. Moderate or rapid rates are best, but slow permeability can be tolerated on nearly level slopes. As the slope increases, however, restricted rates of water absorption reduce the rates at which water can be applied.

Increasing slope/permeability restrictions limit the choice of irrigation system, the amount of equipment required, and the kind of crops that can be grown. The efficiency of irrigation also decreases, and the potential for runoff of excess water increases.

Silt loam soils under center pivots illustrate this problem. At the outer end of the circle, water must be applied at rates higher than the soil's ability to absorb it. The excess water runs off, which not only wastes water and energy, but also can cause erosion.

Available water-holding capacity determines the amount and frequency of irrigation. Deep soils with high AWHC's can support plant growth over relatively long intervals between irrigation. These soils require the least amount of equipment and offer the greatest flexibility in choice of crop and irrigation scheduling.

Shallow soils, sandy soils, or soils containing coarse fragments all require more irrigation. Farmers either have to invest in more equipment, or accept the fact that some parts of their fields may be seriously water-stressed before they can

## Guide for Determining Irrigation Suitability

| | Excellent | Good | Fair | Poor | Non-irrigable |
|---|---|---|---|---|---|
| Slope / Permeability of surface soil | 0–3/Any<br>3–7/Rapid, Mod. | 3–7/Slow<br>7–12/Rapid, Mod. | 7–12/Slow | 3–12/V. slow<br>12–20/Any | >20/Any |
| Minimum AWHC | High | Medium | Low | Very low | Very low |
| Internal drainage / Drainage feasibility | WD<br>MWD/Good<br>SWP/Good | WD<br>MWD/Good, Fair<br>SWP/Good, Fair | WD<br>MWD/Any<br>SWP/Any<br>PD/Fair | Any | Any |

get back to them with the next application of water.

The internal drainage of a soil is not a serious limitation as long as the soil can be easily drained. A somewhat poorly drained soil may have excellent irrigation suitability if it is feasible to drain it.

High water tables restrict plant growth, however, so irrigation will be less efficient if water tables persist. The effect of drainage, therefore, depends on *both* the natural wetness of the soil *and* the feasibility of lowering high water tables through artificial drainage.

Figure 27.—Irrigation suitability. Sandy soils are well-suited for center-pivot irrigation because the soil absorbs water readily. Low water-holding capacities, however, require water applications in small amounts at frequent intervals. The overall irrigation suitability, therefore, is only fair.

## Most Intensive Crop

This interpretation is really a measure of the *potential productivity* of a soil. Soil characteristics, plus climate, determine the most intensive kind of cropping system that is feasible.

Deep, well-drained, fertile soils that have an adequate water supply and a long growing season can be used for a wide variety of crops. Shallow, stony soils that receive only a few inches of rain may be best suited for range management.

Between these extremes, various combinations of texture, depth, drainage, slope, elevation, and rainfall influence both the choice of crops and potential yields.

Most farmers manage their fields in a crop rotation. As a result, a soil well-suited for potatoes (a row crop) may be used periodically for wheat to control soil-borne diseases. A soil suitable for wheat may be rotated with alfalfa (to build up nitrogen and organic matter) or with grass seed (to control disease and erosion). These and other kinds of crop rotations mean that the most intensive crop may *not* be the crop currently grown on the soil.

Some farmers deliberately use a highly productive soil for a less-intensive crop. Irrigated pasture and hay grown for an intensively managed cattle operation is an example. This doesn't necessarily represent under-use of soil potential. Rather it's an intentional decision to take advantage of the quality of soil resources in a different way.

Other reasons for choosing crops of lower intensity may include a lack of good markets and low prices.

The opposite situation sometimes occurs—using a soil at an intensity beyond its potential. Row-cropping land with a high erosion hazard is risky business. A farmer may be able to get away with it for a while, but severe erosion over several years may ultimately ruin the productivity of soil resources.

There are about 150 different kinds of crops grown in Oregon. We're going to group them into eight very general categories of crop intensity. Obviously, there will be some local exceptions to the guidelines given here.

When that happens, try to find out from your instructor or local agricultural experts what the reasons for the differences are. Remember that good soil managers may be able to use their soil resources more intensively than the guidelines suggest. Poor managers, on the other hand, may not be able to take advantage of the productivity that really exists.

Selecting the most intensive crop depends on whether or not the soil can be irrigated. Two things are required. First, the soil must have at least poor irrigation suitability. Second, irrigation water must be available.

Under these conditions, row crops or specialty crops are the most intensive. If row crops are not feasible because of limitations of climate, slope, or soil drainage, irrigated legume hay is the next most intensive. If the soil is poorly drained, or sodic, irrigated pasture may be the only irrigated crop that can be grown.

Soils that are too steep to irrigate, and irrigable soils for which no irrigation water is available, must be used for dryland crops.

Winter wheat is the most intensive dryland crop. Except for a few very wet or very alkaline soils, moisture, slope, and temperature are the major factors affecting wheat production.

In western Oregon, there's always enough moisture to grow dryland wheat. But high rainfall and steep slopes increase the erosion hazard. If wheat cannot be grown without eroding the soil, permanent pasture is the next most intensive. Very steep slopes that receive high rainfall in the Cascade, Klamath, and Coast Range mountains are used for forestry.

Wheat production in eastern Oregon requires a balance between rainfall and the water-holding capacity of the soil. As rainfall decreases, the soil's AWHC must increase to compensate.

Many soils that are suitable for wheat also are suitable for dryland hay, especially if the AWHC is medium or high. In addition, some soils that are at elevations too cold for wheat still can be used for hay.

If moisture supply or slope eliminate both wheat and hay, timber grazing is the next most intensive crop management system. There must be enough moisture to support tree growth, but slopes must not be too steep for cattle grazing.

Where low rainfall and soil AWHC are severely limiting, rangeland grazing is the best choice. On very steep, north-facing slopes of the Blue Mountains, forestry is the most intensive crop.

## Most intensive crop—irrigated

The guide on page 66 summarizes the requirements for each category of irrigated crops. More information on each crop choice is given below. Remember that the crop you see on the land at any given time may *not* be the most intensive crop.

Information on location, pH, and availability of irrigation water will be provided at each site. Use your own information on slope, irrigation suitability, AWHC, and drainage feasibility to complete your evaluation.

**Row crop/Specialty crop.** This category includes all the vegetable crops in Oregon—corn, beans, onions, potatoes, carrots, garlic, and many others. Soils with excellent

Figure 28.—Irrigated row crops. This deep, nearly level soil has moderate permeability and high water-holding capacity. Irrigation water is available, and the soil is well-suited for growing a variety of row crops. The crop shown is sugar beet seed.

or good irrigation suitability are best for row crops.

Soils with fair irrigation suitability are acceptable if they are on 0–3 percent slopes. Soils with sandy loam or loamy sand textures and fair irrigation suitability are acceptable even on slopes up to 12 percent.

Irrigable soils at high elevations in Harney, Lake, Baker, and Wallowa counties aren't suitable for row crops because the growing season is too short.

Soils in the fog belt along the Oregon Coast generally aren't suitable for row crops, either. Cool marine air throughout the year prevents many row crops from fully maturing.

Some irrigable soils are used intensively for orchards, grapes, cranberries, lily bulbs, or other specialty crops. In these cases, choose row crop as the most intensive crop regardless of irrigation suitability or climatic restrictions, as long as such use doesn't cause a decline in soil productivity.

**Legume hay.** If row crops are unsuitable, irrigated alfalfa or clover hay is the next most intensive crop. Legume hay can be grown on slopes up to 20 percent as long as the AWHC is at least low and poorly drained soils have fair drainage feasibility.

Legume hay also can be grown at high elevations with short growing seasons. It does very well in the coastal fog belt.

Keep in mind that a lot of legume hay is grown on soils that could support row crops. Usually, this hay is part of a crop rotation or an intensive cattle operation.

**Permanent pasture/Grass seed.** Some soils are so limited by texture, depth, drainage, or pH that it is not feasible to use them for cultivated crops. Extremely shallow or stony soils, poorly drained clayey soils with poor drainage feasibility, and sodic soils with very high pH are the most common situations. With irrigation,

## Guide for Determining Most Intensive Irrigated Crop

| | Row crop or Specialty crop* | Legume hay | Perm. pasture/ Grass seed |
|---|---|---|---|
| Location | All *except*—<br>High basins in Baker, Harney, Lake, Wallowa counties;<br>Coastal fog belt | Any | — |
| pH | <8.4 | <8.4 | Any |
| Slope | 0–12 | 0–20 | 0–20 |
| Irrigation suitability | Excellent<br>Good<br>Fair on 0–3% slope<br>Fair on sandy soils up to 12% slopes | Any | Any |
| AWHC | High-Low | High-Low | Any |
| Drainage feasibility | Good-Fair | Good-Fair | Any |

*Grapes, cranberries, and lily bulbs are examples of specialty crops. Disregard any other limitations if these or other specialty crops are being grown.

however, these soils can at least be managed for pasture production.

In western Oregon, several poorly drained clayey soils on nearly level terraces or floodplains are used for grass seed production rather than permanent pasture. These grasses can withstand long periods of wet soil, and farmers have taken advantage of that fact to get a little more production from these soils.

Grass seed is not an irrigated crop, but because irrigation water generally is available to these soils, it is placed in the same category as irrigated permanent pasture.

## Most intensive crop—dryland

The guides on page 69 will allow you to select the most intensive dryland crop for your soil and site conditions. Note that there are separate guides for western Oregon and for eastern Oregon. You must provide information on soil drainage, drainage feasibility, AWHC, and slope. Information on soil pH, rainfall, and elevation will be posted at each site.

**Winter wheat.** Dryland wheat can be grown on a wide variety of soils. The only exceptions are poorly drained clayey soils, soils on slopes over 20 percent, and a few soils receiving either too much or too little rain.

Wet, clayey soils are too difficult to drain for wheat production. Soils on slopes greater than 20 percent are too erosive under western Oregon rainfall conditions. Excessive rainfall makes fall planting difficult and may interfere with ripening and harvesting. Some areas of southwestern Oregon may be too droughty for wheat production.

In eastern Oregon, wheat generally is grown at elevations below 4,100 feet. At higher elevations, cold temperatures may cause either excessive winter kill or freezing of flowers in the spring.

Wheat won't do well on highly alkaline, sodic soils, so the pH must be 8.4 or less in order for wheat to be the most intensive crop.

If there are 12 inches or more of rain, the soil needs to have at least low AWHC, and wheat should be grown only on soils of less than 20 percent slope to avoid erosion.

With less than 12 inches of rain, soil water-holding capacity becomes an essential factor, so the soil must have at least medium AWHC. Erosion is less of a problem, so wheat can be grown on slopes up to 35 percent.

**Dryland hay.** Wheat and dryland hay are about equally intensive crops, and in many areas soil conditions are suitable for either one. This is particularly true if the soil water-holding capacity is medium or high.

Figure 29.—Dryland wheat. Without irrigation water, dryland wheat is the most intensive crop. Many different soils are well-suited to wheat production. Only severely limiting conditions of slope, droughtiness, excessive wetness, or soil pH mean that a soil can't be used to grow wheat.

In eastern Oregon, however, dryland hay is the most intensive crop at elevations above 4,100 feet, because wheat will not do well in such cold areas. As long as the AWHC is medium or high, total rainfall is not a serious limitation.

If soil AWHC is low, then dryland hay needs at least 18 inches of rainfall. If soil AWHC is very low, dryland hay is not a practical crop. Hay production also requires nonsodic soils (pH 8.4 or less) and slopes less than 20 percent.

**Permanent pasture/Grass seed.** In western Oregon, soils unsuited for wheat production may be suitable for dryland pasture. Poorly drained clayey soils, soils on 20 to 35 percent slopes, and soils on stream terraces in high rainfall (>60 inches) regions can be used for pasture. Many of the poorly drained soils also are used for grass seed production.

**Timber grazing.** In eastern Oregon, many soils unsuited for wheat or hay can be used for forestry and grazing combined. Careful management is required, for stands of trees must be thinned enough to allow adequate forage growth.

There must be at least 12 inches of rainfall to support tree growth. AWHC generally should be at least low, but some soils with very low AWHC may be able to support timber grazing if the rainfall exceeds 18 inches.

Elevation and slope do not offer serious limitations, except that some steep mountain slopes at high elevations may be better suited for forestry.

**Rangeland grazing.** Where rainfall, AWHC, and slope exposure (aspect), either alone or in combination, provide too little moisture for either wheat, hay, or trees, rangeland forage production is the most intensive crop. Rangeland grazing also is the only choice for dryland use of sodic soils having pH values above 8.4.

Many rangeland soils can be managed for improved forage production with such practices as brush removal, seeding of adapted grasses, rotational grazing, and development of stock ponds.

**Forestry.** Managed forests are the most intensive crop on steep slopes in high rainfall regions. In general, as the amount of rainfall increases, the more likely forestry is, regardless of slope.

Figure 30.—Timber grazing. Combined use of the soil to grow trees and provide livestock forage is very good management. The forage produces a short-term return while the timber provides a long-term return.

Figure 31.—Rangeland. Rangeland in good condition provides an ample supply of grasses for livestock grazing. Good rangelands must be managed carefully to avoid overgrazing, however, for the supply of forage is easily reduced and replaced with less valuable shrubs.

Some soils, particularly in the Coast Range, are very productive forest soils. Managed tree production can be quite profitable, and it is a wise use of the soil resource.

In eastern Oregon, forestry is the proper choice only on steep, north-facing slopes at high elevations. Forestry is considered less intensive than permanent pasture or rangeland grazing only because of the long intervals between harvests.

## Guide for Determining Most Intensive Dryland Crop—Western Oregon

| | Wheat | Permanent pasture/ Grass seed | Wheat | Permanent pasture/ Grass seed | Forestry | Permanent pasture/ Grass seed | Forestry |
|---|---|---|---|---|---|---|---|
| Slope | <12 | — | 12–20 | — | — | 20–35 | Any |
| Rainfall | <60 | Any | 30–45 | <30<br>45–60 | >60 | 30–45 | Any |
| Drainage class / Drainage feasibility | WD<br>MW/Any<br>SWP/Any<br>PD/Good, Fair | Any | WD<br>MW/Any<br>SWP/Any<br>PD/Good, Fair | Any | Any | Any | Any |

## Guide for Determining Most Intensive Dryland Crop—Eastern Oregon

**Elevation less than 4,100 feet**

| | Wheat | Timber grazing | Grazing | Grazing | Wheat | Grazing |
|---|---|---|---|---|---|---|
| pH | <8.4 | — | — | — | — | Any |
| Rainfall | ≥12 | — | — | — | <12 | Any |
| AWHC | Low–High | — | — | V. low | Med.–High | Any |
| Slope/Aspect | <20/Any | ≥20/N | ≥20/S | Any | <35/Any | Any |

**Elevation above 4,100 feet**

| | Hay | Hay | Timber grazing | Forestry | Timber grazing | Grazing | Timber grazing | Grazing | Timber grazing | Grazing |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | ≤8.4 | — | — | — | — | — | — | — | — | Any |
| Slope/Aspect | <20/Any | — | — | ≥20/N | — | <20/Any<br>≥20/N | — | — | ≥20/S | Any |
| AWHC | Med.–High | Low | — | Low–High | — | Low–High | V. low | — | Low–High | Any |
| Rainfall | Any | ≥18 | 12–18 | ≥15 | 12–15 | <12 | ≥18 | <18 | ≥15 | Any |

# Erosion Control Practice

The need for erosion control practices depends on a soil's erosion hazard and the most intensive crop that can be grown. For some crops, such as hay and pasture, the crop itself provides much of the protection needed. For others, such as row crops and wheat, specific management practices are needed to prevent soil erosion.

Regardless of the size of the erosion problem, conservation is something that farmers must be aware of—*any* soil, if managed improperly, is subject to erosion that reduces the quality of the soil resource for future generations.

The right kind of erosion control practice for any particular field, farm, or forest can be determined only by an onsite inspection. There are no magic formulas or prescriptions that fit every situation. Sometimes adequate erosion control can be achieved by simple application of one of the general practices described below. In other cases, two or three different kinds of practices may be needed. In still others, there may be measures not included in this list that are appropriate.

The important thing is to recognize the problem, know the various kinds of erosion control practices available, and use a healthy dose of common sense in managing soils so as to minimize erosion.

For the contest, use the guide on page 73 to select from the practices below the one that is the most important, even though additional practices might provide even better protection.

## Water control

This refers specifically to using the right amount of water when irrigating row crops. The danger is that if too much water is applied, or if water is applied too fast, the excess will run off.

If sloping soils are irrigated by channeling water across the field in furrows, or corrugates, great care must be taken to control the flow of water so that it doesn't start cutting rills and washing away the topsoil. This can be a serious problem if the permeability of the surface soil is slow, as in many Ontario area soils, which are low in organic matter.

If soils are irrigated with sprinkler systems, good management means keeping the water-application rate below the rate at which the soil can absorb the water. The greater the slope and the slower the permeability of the surface horizon, the greater the need for careful water management to avoid soil erosion.

## Cover crop

Many soils used for row crops are left bare during the winter growing season. Fall planting of a quick-growing crop like a spring cereal can help hold the soil in place. In the spring, the crop can easily be plowed or disked into the soil. The cover crop protects the soil from erosion, and it helps to maintain soil organic matter as well.

Cover crops are appropriate for controlling water erosion on sloping soils used for row crops and on floodplain soils used for row crops. They also are appropriate for controlling wind erosion on all soils that have a moderate or severe wind-erosion hazard.

## Standing stubble

This may be a necessary practice for some irrigated row crop soils subject to erosion by either wind or water during the winter. Usually a cover crop would be prescribed to control this erosion. But some crops in some parts of the state may be harvested so late in the season that there is no time left to plant a cover crop—and expect it to grow enough to do any good.

In these situations, it is best to leave the crop residue in place to slow down the speed of wind or water moving across the soil surface.

## Stubble mulch

This is a method of residue management that partly mixes wheat straw or other stubble into the surface soil. *Trashy fallow* and *minimum tillage* may refer to this same practice. The idea is to create a rough surface that slows down water runoff or wind speed, and improves the absorption of water into the soil.

Even if there is very little crop residue available, leaving the soil surface in a rough, cloddy condition helps accomplish the same thing.

Stubble mulch is a good practice for erosion control in most wheat fields throughout the state.

## Diversion terraces

These are channels built on the contour with a ridge on the downslope side. They are designed to catch water coming down the slope before it starts to flow fast enough to erode the soil. On long slopes, two, three, or even four terraces may be necessary so that water never has the opportunity to flow overland very far.

Many terraces are designed to trap the water behind the ridge so that it can soak into the soil. This not only conserves soil but also saves water and improves crop yields. Other terraces are designed to divert water flow across the slope into a grassed waterway, where it can run on down the slope without eroding the soil.

Diversion terraces are most common on steep slopes used for wheat production in north central Oregon. Stubble mulching is a good practice to combine with diversion terraces.

## No-till

No-till means exactly what it says. A crop is planted directly into the stubble from a previous crop, or into a sod or cover crop, without tilling the soil first. The soil isn't cultivated during the growth of the crop, either. Instead, weeds are controlled with chemical sprays.

No-till is a very effective erosion control practice because bare soil is never exposed at the surface. In addition, roots from the sod or the previous crop help keep the soil anchored in place. No-till helps maintain high organic matter levels, and it eliminates the possibility of forming a tillage pan.

All these things combine to maximize water absorption into the soil, rather than running off. Erosion control thus increases the amount of water stored in the soil for later plant use. This extra benefit permits annual cropping in some parts of Oregon that are currently restricted to wheat-fallow rotations under conventional tillage.

Figure 32.—Diversion terraces. Benches cut across long slopes reduce the erosion hazard by shortening the distance over which water can flow. When water reaches the terrace, it either sinks in or flows sideways into a grassed waterway, which conducts the water safely down the rest of the slope.

No-till won't work in every situation, and it does require some special equipment and different kinds of fertilization and weed control practices. But in many areas of Oregon, no-till can be both an effective erosion control practice and an effective soil management practice to improve yields.


Figure 33.—No-till. Special drills allow planting directly into the standing stubble of a previous crop. By leaving the crop residue in place, more water is absorbed into the soil and much less runs off. Water saved increases crop yields, and reduced runoff lowers erosion substantially.

## Strip crop

With limited rainfall, dryland wheat can be grown in a given field only every other year. During the intervening, or fallow year, the soil is left bare—or stubble-mulched—so that the soil's reservoir of available water can be restored to its maximum.

Where the rainfall is 10 inches or less, fields are managed in alternating strips of wheat and fallow to control wind erosion. The strips are perpendicular to the dominant wind direction.

Standing wheat slows down the wind and partly shelters the adjacent strip downwind. By keeping the strips narrow, there is much less opportunity for sustained winds to travel far enough over bare ground to pick up much soil. And if soil does blow, the next wheat strip will trap some of it.

## Controlled grazing

This is the proper practice for permanent pasture, timber grazing, and rangeland grazing. In most situations the purpose is to prevent overgrazing, which reduces the natural vegetative protection and increases soil erosion. You can prevent overgrazing by using proper stocking rates and by using fences and stock ponds to allow rotational grazing.

On subclover pastures in western Oregon, controlled grazing means intentional heavy stocking rates. This reduces competition from other pasture plants and provides the right conditions for subclover to set seed for the next year's crop.

## Watershed management

Erosion control is just as important in forestry as it is in agriculture. Unfortunately, there are no categories of erosion control practices that apply generally to specific situations. Each timber site must be assessed individually.

The key ingredient is to maintain maximum permeability of the surface soil. Avoiding compaction is important, as is the proper location and design of logging roads.

Choosing a suitable harvest method can accomplish much of the needed protection. Clearcutting is quite acceptable for many soil/slope combinations, but it can be quite damaging in others.

Watershed management means a systems approach, in which the soil, landscape, and vegetation all are considered in developing a suitable forest management scheme.

## Guide for Determining Erosion Control Practice

**Western Oregon**

| | Water control, Cover crop | Stubble mulch | Controlled grazing | Watershed management |
|---|---|---|---|---|
| Most intensive crop | Row crop<br>Legume<br>Grass seed | Wheat | Pasture | Forestry |

**Eastern Oregon**

| | Stubble mulch, No-till | Diversion terraces, No-till | Strip crop, No-till | Strip crop, No-till | Stubble mulch, No-till | Diversion terraces, No-till | Stubble mulch, No-till | Water control, Cover crop | Controlled grazing | Water-shed man-agement |
|---|---|---|---|---|---|---|---|---|---|---|
| Crop | Wheat | — | — | — | — | — | — | Row crop | Timber grazing, Range | Forestry |
| Rainfall | ≤10 in. | — | — | — | >10 in. | — | — | Any | Any | Any |
| Wind erosion | Low | Low, Mod. | Mod. | High | Low, Mod. | — | High | Any | Any | Any |
| Water erosion | Low, Mod. | High, V. high | Low, Mod. | Any | Low, Mod. | High, V. high | Any | Any | Any | Any |

# Reaction Correction

A neutral soil has a pH of 7.0. Acid soils have lower pH values; alkaline soils have higher values. For most crops the optimum pH is in the range from pH 6.6 to 7.3. Slight changes from this range aren't too serious, however, so we'll broaden the range a little before soil pH calls for a management correction.

Correction of soil acidity (low pH) is recommended if the pH of the surface soil is less than 6.2. Excess soil acidity makes many nutrients less available for plant growth. Some elements may even be harmful to plants.

Add lime to correct soil acidity. Lime neutralizes the acidity and raises the pH. The amount of lime to apply may be as much as 4 or 5 tons per acre, depending on how much acidity needs to be neutralized, the crop to be grown, the purity and fineness of the liming material, and the extent of mixing into the soil.

Correction of alkalinity (high pH) is appropriate if the pH of the surface soil is higher than 8.4. Excess alkalinity is caused by sodium in the soil. Sodic soils have very poor structure. Permeability is low, and the soil has a very poor physical condition for plant growth.

Several practices are necessary to correct alkalinity. Gypsum or sulfur is applied to replace the excess sodium. Irrigation is necessary to leach out the sodium, and drainage is needed to carry the sodium-laden leaching water completely out of the soil system. This lowers the pH and improves soil structure and permeability.

Two situations prevent reaction correction. Without irrigation water, alkalinity can't be corrected. If irrigation water isn't available, check *none* even if the pH is higher than 8.4.

Acidity in forest soils is not severely limiting to tree growth, and it's not practical to correct forest soil acidity, anyway. If forestry is the most intensive crop, check *none,* regardless of soil pH.

## Limitation for Septic Tank Drainfields

Any home built in an area not served by public sewers must have some kind of onsite waste disposal system. The most common system combines a septic tank with a soil drainfield. All household wastes go first into the septic tank. Solid wastes sink to the bottom, and waste water is drawn off the top for discharge into the soil.

The drainfield consists of a series of perforated plastic tile drains laid in trenches in the soil. Waste water flowing through the tile lines trickles into the soil, where further treatment and disposal occurs.

The adequacy of these systems depends more than anything else on the properties of the soil. Soil must do three things for a drainfield to function properly: accept the waste water, treat the waste, and dispose of the water. All three depend heavily on subsoil permeability.

Waste treatment is a biological process, and it requires plenty of oxygen. Waste water must move through the soil fast enough to prevent a buildup of saturated conditions, but slowly enough for microorganisms to do an effective job.

Most drainfields work satisfactorily in deep, well-drained, permeable soils. But if the soil has a slowly permeable layer, or a periodically high water table, septic tank waste water may not receive adequate treatment—and it may be the source of a health hazard.

Soils that are less than well drained have seasonal water tables that interfere with proper drainfield operation. Shallow soils don't have enough volume of soil available for treatment, and the danger of effluent breaking out at the surface is increased.

Sloping soils are poorly suited for drainfields because waste water may concentrate at the ends of tile lines and either break out at the surface or flow too rapidly downslope in the soil.

Floodplains generally are not suitable places for drainfields because floodwaters can become contaminated with sewage waste water. In eastern Oregon, however, floodplains of intermittent streams or gullies are flooded so rarely, or for such short periods of time, that septic tank drainfields can be safely installed.

Figure 34.—Septic tank drainfield. A network of perforated pipes distributes sewage effluent evenly throughout the entire area of the drainfield. Each pipeline is surrounded by crushed rock, covered with paper, then covered with soil. This drainfield is on a slope, and pipelines are installed across the slope.

Soil scientists help land use planners and prospective homebuilders by rating soil limitations for septic tank drainfield performance. Categories of slight, moderate, and severe limitations indicate the relative suitability of a soil for drainfield installation.

Soils with a slight limitation generally can be used for drainfields without modifications. Soils with moderate limitations generally can be used for drainfields, but some special practices may be needed. Increasing drainfield size, installing drainage to remove seepage water, or adding a little extra soil to the surface are examples of the kinds of things that may be needed.

Soils with severe limitations can't be used for conventional drainfields. There are, however, other ways of dealing with household sewage on these soils. Sand filters, deep tile drainage, even pumping to a remote site all are possibilities.

All of these alternatives are much more expensive than conventional drainfields, so a severe rating is really an indicator of the amount of engineering, and the cost, required to dispose of wastes properly.

Ratings of slight, moderate, and severe limitations for septic tank drainfields are interpretations based on the soil properties that affect drainfield performance. Determine the correct rating for your soil using the accompanying Guide.

## Guide for Rating Limitations for Septic Tank Drainfields

| | **Slight** | **Moderate** | **Severe** |
|---|---|---|---|
| Effective depth | ≥48 inches | ≥36 inches | <36 inches |
| Subsoil permeability | Moderate | Rapid to moderate | Any |
| Internal drainage | WD | WD, MWD | Any |
| Slope | 0–7 | 0–12 | Any |
| Landform | All except floodplains | All except floodplains of perennial streams | Any |

# Appendixes

# How to Use Interpretation Guides

## Drainage Feasibility Guide

| Factor | Feasibility Rating: Good | Fair | Fair | Poor | Poor | Poor |
|---|---|---|---|---|---|---|
| Outlets | Available | — | — | — | — | Not available |
| Effective depth | Deep | — | Mod. deep | — | Shallow | Any |
| Drainage class / Subsoil permeability | MW/Any<br>SWP/Rapid, Mod. | —<br>SWP/Slow, V. slow | MW/Any<br>SWP/Any<br>PD/Rapid, Mod. | —<br>—<br>PD/Slow, V. slow | Any | Any |

Interpretation guides for permeability, water erosion, and wind erosion in Chapter 5, and for drainage feasibility, irrigation suitability, most intensive crop, erosion control practice, and septic tank drainfields in Chaper 7, all are set up the same way.

In each case, the factors that affect the interpretation are listed down the left side. The different ratings, or classes, that are possible within each interpretation are listed across the top. Soil or site conditions that are acceptable in each rating class are given in the body of the table. This format is illustrated above.

To use these guides, always start in the upper left corner of the table. See if your soil satisfies the conditions given for the first factor in the first column.

If it does, then move down, and check the requirements for the next factor. If it doesn't, then move across the table until you come to the first column that does have acceptable conditions.

Continue moving down, and to the right if necessary, until you have evaluated all the factors. The rating at the top of the column you end up in is the correct interpretation for your soil.

Here's an example. Suppose we have a moderately deep, poorly drained soil. The subsoil permeability is slow, but drainage outlets are available.

Start in the upper left corner of the table in the row labeled "Outlets" and the column labeled "Good." The table indicates that to be rated "Good," a soil must have outlets available. Our soil does, so we move down the "Good" column to evaluate "Effective depth."

Here we see that "Good" drainage feasibility requires a deep soil. Our soil fails this standard because it's only moderately deep. So we move across the table until we reach the first column that allows moderately deep soils. That's the third column over, and it's labeled "Fair."

Having met the depth standard in the "Fair" column, we continue moving down that column to evaluate "Drainage class/ Subsoil permeability."

Here we find that moderately well and somewhat poorly drained soils are acceptable regardless of their subsoil permeability, but poorly drained soils are acceptable only if they have rapid or moderate permeability.

Our soil is poorly drained and slowly permeable, so it fails this requirement. We move to the right again, and find that poorly drained soils with slow subsoil permeability are permitted in the next column over.

This column, however, is labeled "Poor." Thus the overall drainage feasibility for this particular soil is poor.

# How To Set Up and Run A Soil Judging Contest

This information is intended primarily to help those who may be asked to organize a contest, prepare the pits at the contest site, and do the official judging and scoring. Instructors and students, however, may wish to read this section so they will have a better idea of what to expect when they arrive at a contest.

## Locating a contest site

An official contest has four soil pits. One is used as a practice or demonstration pit. The other three are used as contest pits. Each pit should represent a distinctly different soil. If at all possible, the pits should all be within a short (5- to 10-minute) walk of each other.

Local soil scientists in the Natural Resources Conservation Service, the U.S. Forest Service, the Bureau of Land Management, or the OSU Extension Service should be able to provide assistance in suggesting possible contest areas and in selecting precise locations for each pit.

These same people may be willing to serve as official judges, as well. They should not, however, be asked to arrange for the pits to be dug.

## How big should the pits be?

Ideally pits should be big enough for everyone in a group to get into the pit at the same time. For a group of 40 people, an ideal pit would be 5 feet wide, 30 feet long at the bottom, and deep enough to see all the horizons that are to be judged. This allows 20 people to use each face of the pit and provides about 1½ feet of pit wall space for each person.

In addition, both ends should be tapered up to the ground surface, bringing the total length of the pit to about 42 feet. If the soil is loose or subject to slumping, it's advisable to keep the pits shallow enough to prevent cave-ins, rather than to try and shore up a deeper pit.

When digging the pits, try to keep both walls as straight as possible and the bottom as level as possible. A good backhoe operator can dig a 30-foot pit in 1½ to 2 hours.

If the pit has water in it, use suction pumps to keep it dry while it is being judged. Wooden pallets placed in the bottom provide a very good surface to stand on while judging wet soils.

Circumstances often require the use of pits, road cuts, or streambanks that are smaller than ideal. If this is the case, there are a couple of things you can do to make it easier for the students to judge the soil.

One helpful technique is to place soil from each of the four horizons to be judged into large pans. Label all pans clearly, and place them on the ground near the pit.

Students can use the soil in these pans to judge color and texture, and they can do this while others are examining the soil in the pit. They still will have to get into the pit to determine structure, coarse fragments, horizon names, and effective depth, however.

Another helpful procedure is to rotate small groups of students into and out of the pit at 5- or 10-minute intervals, to give each student an equal opportunity to be in the pit. With large groups, it may be necessary to allow a longer total judging time in order to make sure that everybody has adequate time to study the soil profile.

## Setting up and judging the official profile

The official judge(s) should select a single area on the pit face within which all decisions regarding scorecard entries will be made. This area should be about 1½ to 2 feet wide, and it should be plainly marked with colored ribbons on each side running from the top to the bottom of the pit. Each boundary between horizons should be marked with a ribbon or string, too.

If more than four horizons are present, place a small numbered card in the middle of each horizon for which the students are to record answers on their scorecards.

Suppose, for example, a soil has an Ap-BA-Bt1-Bt2-BC-C profile, and the students are to judge the first, third, fifth, and sixth horizons. Place card number 1 in the Ap, card number 2 in the Bt1, card number 3 in the BC, and card number 4 in the C.

If fewer than four horizons are present, students normally will judge each horizon in the profile. In any case, the official judges always have the right to specify which horizons are to be judged if for any reason they do not want students to judge a particular horizon.

It is imperative, however, that students be able to easily determine which horizons they are to judge and how the horizons marked in the soil profile correspond to the four horizons listed on the scorecard.

Official judge(s) should use only the same kinds of resources for making decisions as are available to the students. That is, colors should be estimated according to the guidelines in the *Manual* without the aid of a Munsel color chart. Textures should be determined by feel without resorting to laboratory data. Coarse fragments should be estimated by eye rather than using a sieve.

The judge(s) may decide to allow more than one correct answer if the texture, color, structure, or any other property or interpretation is very close to the boundary between two choices.

## Information that must be provided at each pit site

Each pit needs to be clearly identified, either with a letter, a number, or a color-coded scorecard. Post this identification in a prominent place, to minimize the possibility that students will record their answers on the wrong card for that pit.

Additional information that the students need for judging each site includes the following:

- The upper and lower depth limits for each horizon
- The pH of each horizon
- The amount of rainfall at each site
- The elevation at each site
- Whether or not irrigation water is available
- Whether or not drainage outlets are available

Write this information in bold, clear letters on a large piece of posterboard and mount it on a stake at the pit site. You also can mount the pit identification card on the same stake.

Finally, you must provide the elevations needed for slope determination. Select an area near the pit that is to be used for judging the slope of the site. Drive two stakes into the ground, one directly downslope from the other, at a horizontal separation distance of 25, 50, or 100 feet.

Write the lower elevation on a card and tack it to the lower stake. Write the higher elevation on a card and tack it to the upper stake. Be sure that the elevation difference, when divided by the separation distance, does in fact calculate out to be the slope gradient intended.

## Supplies and equipment

The host school should provide all the stakes, posters, ribbons, pumps, and pallets needed to set up the contest pits.

They also should have enough scorecards and interpretation guides on hand to provide four scorecards and one guide for each student. Reproduce copies of the scorecard and interpretation guide from this manual (at back of book).

Students should come dressed for the weather and should bring field equipment necessary to judge the soil. Here's a list:

1. Warm clothing and a warm coat
2. Hat and gloves
3. Rain gear
4. Rubber boots
5. Clipboard
6. Clear plastic bag to cover your clipboard and keep your scorecards dry
7. Two no. 2 pencils (don't use harder pencils—the judges won't be able to read your answers)
8. Pocket knife
9. Water bottle for moistening your texture samples

## Ground rules

At the beginning of a contest, remind all students of the rules that always apply and announce any special conditions that may also apply. Ground rules include (but aren't necessarily limited to) these eight:

1. The time allowed for judging each pit is 30 minutes. Local officials may extend this limit if necessary to allow enough time to rotate small groups into and out of the pits.
2. Allow 10 minutes after each pit has been judged (and the scorecards have been collected) for an official judge to review the correct answers for that pit.
3. Allow 5 or 10 minutes, as necessary, for rotation between pits after the pit reviews have been completed.
4. The official profile, between the ribbons, is reserved as a reference area. It is not to be disturbed in any way by any of the contestants.
5. Discuss local conditions and/or local deviations from the guidelines in the Manual with the entire group at the practice pit. Examples include specific kinds of landforms and parent materials, exceptions to drainage class criteria, location within or outside of the coastal fog belt, different degrees of erosion hazard, or specific kinds of erosion control practices that may be appropriate.
6. Students must record their answers on the scorecard as the number for the correct response. Enter one and only one answer. The official judge(s) may decide to accept more than one answer, but in no case should the students give more than a single number.
7. If an answer falls right on a class boundary (for example 15 percent coarse fragments, 8 inches AWHC, 7 percent slope), always mark the next higher class.
8. Interpretation guides are allowed, and students should use them during the contest. Students aren't expected to memorize all the criteria required to reach a correct decision. However, they should be familiar with the proper way to use the guides.

## Scoring

The most important rule in scoring is to do it *consistently*. The official judge(s) should provide completed cards for each of the contest pits, from which additional keys can be made up. The scorecards are designed so that the edge of the key card can be placed right alongside the column of answers on a contestant's card.

It doesn't matter whether you mark right answers or wrong answers, as long as everyone who is helping with the scoring does it *the same way*. Similarly, it doesn't matter if you total up right answers or wrong answers, as long as everyone does it *the same way*.

In any case, each answer, on each side of the scorecard, is worth 1 point.

Scorecard graders usually enter the number of points earned in each of the boxes at the bottom of the scorecard. Some may prefer, however, to enter the number of points missed, and determine the outcome of the contest on the basis of the lowest, rather than the highest score.

Again, it doesn't matter, as long as it is done consistently.

If you have enough time, it's a good idea to double-check some of the scoring. After all cards have been graded, and team scores have been compiled, you could rescore all cards for the top 10 teams and check all the arithmetic. This ensures that the ranking of the winning teams is not affected by inadvertent errors in scoring.

# Horizon Names Used Before 1983

In 1981, the procedure for naming soil horizons was revised. The new procedure is a good one, and that's why we've used it in Chapter 3 of this *Manual*.

But if you look at soil profile descriptions in almost any soil survey report published before 1985, you'll find that some of the names are different. To help you match the older names with the present ones, we present here all the names used in Chapter 3, along with their counterparts in the older system.

| Master horizons | | Special horizons | | Transition horizons | |
|---|---|---|---|---|---|
| **Old** | **New** | **Old** | **New** | **Old** | **New** |
| O | O | Ap | Ap | A3 | AB |
| A1 | A | B2t | Bt | B1 | BA |
| A2 | E | B2g | Bg | B3 | BC |
| B2 | B | Bir | Bs | | |
| C | C | B2 | Bw | | |
| R | R | Bx | Bx | | |
| | | Bca | Bk | | |
| | | Ccasim | Bkqm | | |
| | | Cca | Ck | | |
| | | Cr | Cr | | |

| Thick horizons | | More than one parent material | |
|---|---|---|---|
| **Old** | **New** | **Old** | **New** |
| A11 | A1 | A1 | A |
| A12 | A2 | A3 | AB |
| | | B2 | B |
| B21g | Bg1 | IIB3 | 2BC |
| B22g | Bg2 | IIC | 2C |
| B21t | Bt1 | | |
| B22t | Bt2 | | |
| B21 | Bw1 | | |
| B22 | Bw2 | | |
| C1 | C1 | | |
| C2 | C2 | | |

## Typical Horizon Sequences

For each of the soils listed, the sequence of old names is listed first. Underneath the old names are the equivalent names in the new system.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Alicel | Ap | A12 | B1 | B2 | IIC | | | |
| | Ap | A | BA | Bw | 2C | | | |
| Bandon | O | A2 | B21ir | B22ir | B23ir | B24ir | C | |
| | O | E | Bs1 | Bs2 | Bs3 | Bs4 | C | |
| Brenner | Ap | A12 | B21g | B22g | B3g | Cg | | |
| | Ap | A | Bg1 | Bg2 | BCg | Cg | | |
| Carney | A11 | A12 | A3 | C | IIR | | | |
| | A1 | A2 | AB | C | 2R | | | |
| Cascade | A1 | B21 | B22 | IIBx1 | IIBx2 | IIBx3 | | |
| | A | Bw1 | Bw2 | 2Bx1 | 2Bx2 | 2Bx3 | | |
| Dayton | Ap | A2 | IIB2t | IIB3t | IIIC | | | |
| | Ap | E | 2Bt | 2BCt | 3C | | | |
| Deschutes | A1 | B1 | B2 | IIC | IIIR | | | |
| | A | BA | Bw | 2C | 3R | | | |
| Fordney | Ap | C1 | C2 | | | | | |
| | Ap | C1 | C2 | | | | | |
| Gem | A11 | A12 | B1t | B21t | B22t | B31t | B32tca | R |
| | A1 | A2 | BAt | Bt1 | Bt2 | BCt | BCtk | R |
| Hoopal | A11 | A12 | B2 | Clcasim | C2 | | | |
| | A1 | A2 | BW | Bkqm | C | | | |
| Josephine | O | A1 | B1 | B21t | B22t | B23t | C1 | C2r |
| | O | A | BA | Bt1 | Bt2 | Bt3 | C | Cr |
| Malabon | Ap | A3 | B21t | B22t | B3t | IIC | | |
| | Ap | AB | Bt1 | Bt2 | BCt | 2C | | |
| Nehalem | Ap | A12 | B2 | C | | | | |
| | Ap | A | Bw | C | | | | |
| Nyssa | Ap | B2 | C1casim | C2casim | C3casim | | | |
| | Ap | Bw | Bkq | Bkqm1 | Bkqm2 | | | |
| Oakland | A11 | A12 | B21t | B22t | B23t | B3t | Cr | |
| | A1 | A2 | Bt1 | Bt2 | Bt3 | BCt | Cr | |
| Quincy | C1 | C2 | | | | | | |
| | C1 | C2 | | | | | | |
| Ritzville | Ap | B1 | B2 | C1ca | C2 | C3 | | |
| | Ap | BA | Bw | Bk | C1 | C2 | | |
| Salem | Ap | B2t | B3t | IIC | | | | |
| | Ap | Bt | BCt | 2C | | | | |
| Simas | A1 | IIB21t | IIB22t | IIB3ca | IICca | | | |
| | A | 2Bt1 | 2Bt2 | 2BCk1 | 2BCk2 | | | |
| Walla | Ap | A12 | B1 | B2 | C1ca | C2ca | | |
| Walla | Ap | A | BA | Bw | BCk1 | BCk2 | | |

# Glossary

This glossary provides simple definitions of many of the words that are peculiar to the language of soil science. It is not a thorough document, as terms that are completely defined in the text are not always included here. In many cases, reference is given to the chapter or section in which you'll find additional information about the term.

**AWHC—**Available water-holding capacity. The maximum amount of water a soil can store for plant use. The amount of available water always is less than the total amount of water a soil can hold. See Chapter 5.

**Abrasion—**The wearing down of rock particles by friction as rocks and sand grains grind against each other during transport by a river.

**Acid soil—**Soil that has a pH below 7.0. Acid soils are leached and do not contain free lime or soluble salts.

**Aeration—**The movement of air back and forth between the atmosphere and the pores of a soil. See "Well-aerated."

**Aggregate—**A single unit of soil structure. See also "Ped," "Structure."

**Aggregation—**The formation of peds of soil structure. Organic matter (humus) and soil clays are important agents of soil aggregation.

**Air dry—**A soil that has been exposed to air and sunlight long enough to remove almost all of the water in the soil. Air dry soils do contain a very small amount of water, but plants are not able to utilize any of it.

**Alkaline soil—**Soil that has a pH higher than 7.0. Alkaline soils frequently contain either free lime or soluble salts or both.

**Artificial drainage—**Intentionally lowering the water table in wet soils by digging ditches or putting perforated tile lines in the soil. Artificial drainage improves the soil environment for root growth and makes possible more intensive use of the soil for crop production. See Chapter 7, "Feasibility of Artificial Drainage."

**Aspect—**The exposure of a slope, or the compass direction that the soil faces. See Chapter 6.

**Bacteria—**Tiny (microscopic), one-celled plants in the soil. Bacteria, along with fungi, are the main organisms that carry out decomposition of plant residues and the formation of humus.

**Bedrock—**Solid rock that is underneath the soil.

**Clay—**A single particle, or grain of soil, that is flat, or plateshaped, and less than 0.002 mm across. Clay particles make soils sticky and help bind other particles into aggregates. Clay also refers to a specific class of soil texture. A clay soil contains more than 40 percent by weight particles of clay size. See Chapter 4, "Texture."

**Clay skin—**A thin, waxy-looking coating of clay particles deposited on the surface of a soil aggregate in a B horizon. Clay skins can be seen on the surfaces of blocky peds in Bt horizons.

**Clayey—**A general term that refers to a soil that has a relatively high content of clay particles. The specific soil textural classes named clay, silty clay, and sandy clay all are called clayey soils. Some silty clay loams and clay loams with clay contents near the upper part of the allowed range also may be called clayey soils.

**Claypan—**A compact, dense soil horizon that has over 40 percent clay and poorly developed structure. Claypans have slow or very slow permeability, and they limit root penetration. Perched water tables are likely to saturate the soil above a claypan during rainy seasons.

**Coarse fragment—**Individual grains of soil that are larger than 2 mm in diameter. The most common coarse fragments in soils are gravel (2 mm to 3 inches) and cobbles (3 to 10 inches). See Chapter 4.

**Coarse-textured—**A general term that refers to soils that have a high sand content and a low clay content. Sandy loams, loamy sands, and sands all are coarse-textured soils. See also "Light."

**Cobblestone—**A coarse fragment, or piece of rock in the soil, that is between 3 and 10 inches in size. Cobblestones may be rounded if they have been carried by a river, or angular if they have broken off exposed bedrock.

**Concave—**A landform surface that is curved like the inside of a saucer or a bowl. Concave landscapes collect water and often have wet soils.

**Concretions—**Small, hard nodules in the soil that form chemically by localized concentration of free lime or iron oxide.

**Conservation—**Planned management of soil resources to prevent loss of their productive quality by erosion. Conservation practices include control of irrigation water, cover crops, stubble mulch, strip cropping, no-till, diversion terraces, and controlled grazing. See Chapter 7, "Erosion Control Practice."

**Consistence—**A soil property indicating the soil's resistance to rupture or shear. Consistence is related to the amount of energy required to manipulate the soil. Different terms are used to describe moist, dry, and wet consistence. See Chapter 4, "Soil Consistence."

**Convex—**A landform surface that is curved like the surface of a ball. Convex slopes become progressively steeper as you walk downslope. Soils on convex slopes usually are well drained.

**Creep—**Very slow movement of soil material downslope under the pull of gravity. Over a period of several years, creep contributes to the colluvial parent material that collects in foot slope landscape positions.

**Decomposer—**A general term for any organism in the soil that decays plant residues. Bacteria and fungi are the primary decomposers in soils.

**Decomposition—**The slow decay of plant residues in the soil, changing them ultimately into humus. Decomposition is carried out by tiny soil plants (bacteria and fungi) that use fresh residues as a food source and bring about the change into humus.

**Density—**The amount, or weight, of soil material in a fixed volume of soil. Soils with high density are compact and have poor structure. They prevent root penetration and water movement through the soil. Soils with low density are open and porous. Water, air, and roots all move easily through them.

**Diatomaceous earth—**A layer of lake-laid sediment composed of the shells of microscopic, single-celled plants called diatoms. Diatomaceous earth is nearly pure silica, and it usually is white.

**Dissected—**A landscape that has been cut by stream erosion into hills and valleys.

**Drainage class—**The degree of wetness of a soil, as determined by the depth to a water table in the soil and the length of time the soil remains saturated. Common drainage classes include excessively drained, well drained, moderately well drained, somewhat poorly drained, and poorly drained. See Chapter 5, "Internal Soil Drainage."

**Droughty—**Inability of a soil to store enough water to meet plant requirements. Sandy and gravelly soils are droughty because they have low water-holding capacities. Soils that are shallow to bedrock or to a dense soil horizon are droughty because they don't provide enough volume of soil for roots to grow in.

**Duripan—**A special kind of B horizon that is very hard because it has been cemented with silica and free lime. See Chapter 3, "Special Kinds of A, B, and C Horizons."

**Effluent—**The fluid discharged from a septic tank after solid wastes have settled to the bottom of the tank. Effluent flows into perforated tile lines of a drainfield, and from there into the soil, where soil microorganisms treat and purify the wastewater.

**Erosion—**Loss of valuable topsoil by the action of wind or water flowing over an unprotected soil surface.

**Fallow—**A field that is left uncropped during a growing season so that water can be stored in the soil for the next year's crop. Fallow fields must be kept free of weeds so that none of the stored moisture is removed.

**Field capacity—**The total amount of water in the soil when it is holding the maximum amount of plant-available water. If a soil becomes saturated by a rainstorm or by irrigation, it takes about 2 days for the free water, or gravitational water, to drain away. The moisture content at that time is the field capacity.

**Fine earth—**Individual soil grains that are smaller than 2 mm in diameter. Fine earth is that which will pass through a No. 10 sieve.

**Fine-textured—**A general term that refers to soils that have a high clay content. Clay, silty clay, silty clay loam, and clay loam are soils that may be considered as fine-textured. See also “Heavy.”

**Floodplain—**The nearly level surface next to a river that is covered with water when a river floods.

**Foot slope—**A landscape position at the base of uplands that usually has a concave shape and collects excess water by runoff and by seepage from higher positions. Soils on footslopes often are somewhat poorly or poorly drained.

**Fragipan—**A special kind of B horizon that is not cemented but is very dense and compact. Neither water nor plant roots will penetrate very far into a fragipan. See Chapter 3, “Special Kinds of A, B, and C Horizons.”

**Free lime—**Calcium carbonate ($CaCO_3$) in the soil. Free lime is white, and it bubbles violently when a drop of hydrochloric acid (HCl) is placed on it. Free lime occurs in soils that are only partially leached, either as part of the original parent material, or as a subsoil accumulation in a Bk horizon. The pH of soils containing free lime usually is above 7.6.

**Friable—**A soil that crumbles easily under gentle pressure. Friable soils require a minimum of energy to plow or to cultivate, and they make ideal seedbeds for seedling emergence and root expansion. Friable soils are said to be in good tilth.

**Fungi—**Plants that live in the soil and obtain their energy from the decomposition of plant residues. Fungi often have branched forms with many long, thin, white strands of tissue. Molds and mushrooms both are fungi. Fungi and bacteria are the primary decomposers in soils and change plant residues into humus.

**Glass shard—**A silt- or sand-sized fragment of volcanic ash that is made up almost entirely of silica and is commonly needle-shaped.

**Gleyed—**Soil that is very wet for long periods of time. Gleyed soils usually have dark gray colors, with or without mottles. See Chapter 3, “Special Kinds of A, B, and C Horizons (Bg).”

**Heavy—**A general term used to refer to a soil that is high in clay content. The specific soil textures named clay, silty clay, silty clay loam, and clay loam sometimes are called heavy soils. A heavy silt loam, or a heavy silty clay loam, indicates that the clay content of the soil is near the upper limit of the amount of clay permitted in that particular textural class.

**Horizon—**A layer of soil that is approximately parallel to the earth’s surface. See Chapter 3.

**Humus—**A product of microbial decomposition of plant residues that resists further decomposition and accumulates in the soil as organic matter. Humus has a black color, and its incorporation in the surface soil darkens the A horizon. Humus acts as a glue which helps form stable soil aggregates that promote good air-water relations in soils.

**Infiltration—**The rate at which water enters the soil. Infiltration depends on the texture, structure, and layering of the surface horizon. In this Manual we use the evaluation of surface soil permeability to indicate relative rates of infiltration.

**Intermittent stream—**A gully or small river that carries water only during rainy seasons. It is dry for several months each year.

**Interstratified—**Deposited as a layer of sediment between two other layers of sediment. The term usually refers to sediments deposited in thin layers at the bottom of a lake (lacustrine sediments), but it may refer to alluvial sediments deposited on a river’s floodplain as well.

**Laminations—**Very thin layers in rocks formed by the deposition of sediments at the bottom of a lake. Laminations are visible as a whole series of thin lines in cuts through such rocks.

**Leaching—**Removal of soluble minerals from the soil by movement of water through the soil over long periods of time. The more soluble the soil minerals, the faster they are leached out of the soil. Free salts are first to go, then free lime. Water-soluble fertilizers also are subject to loss by leaching.

**Light—**A general term used to refer to a soil that has a very low clay content and a relatively high sand content. Sands, loamy sands, and sandy loams all are light-textured soils because they are high in sand and low in clay.

**Lime—**Calcium carbonate. See “Free lime.”

**Linear—**A landscape surface that is flat but tilted, like a ramp. The middle parts of many hillslopes have a linear shape between a convex hilltop and a concave footslope.

**Litter—**Accumulation of dead leaves and twigs on a forest floor.

**Loam—**A specific class of soil texture that contains a balanced mixture of sand, silt, and clay. Generally the sand content is between 20 and 50 percent, and the silt content is between 30 and 50 percent. The clay content must be less than 27 percent. Loams have enough sand to be able to feel some grit, and they have enough clay to give the soil some body, but the properties and behavior of the soil are not dominated by either sand or clay.

**Mantle—**A thin layer of soil resting on top of a different kind of soil or geologic material. Examples include loess on top of basalt and lake-laid sediments on top of older residual soils.

**Matrix—**A soil color term that refers to the dominant color of the soil. In mottled soils, the matrix color is the one that covers the largest surface area, and the mottle color is the one that occurs in little spots scattered throughout the matrix.

**Medium-textured—**A general term used to refer to a soil that has relatively low contents of sand and clay and relatively high contents of silt. Loams and silt loams often are called medium-textured soils, although some clay loams and silty clay loams at the low end of their clay ranges also may be called medium-textured soils. The term loamy soil sometimes may be used to mean the same thing as a medium-textured soil.

**Microbes—**See Microorganisms.

**Microorganisms—**Tiny, microscopic plants and animals that live in the soil. Also called microbes, they decompose dead plant and animal residues and convert them into humus. Some microorganisms cause plant and animal diseases. Others are a source of antibiotics to combat diseases. Still others help make soil nutrients more available for plant use.

**Mineral—**A naturally formed chemical compound that has a nearly uniform composition and crystal form. Rocks are aggregates of one or more different minerals. In soils, the minerals quartz, feldspar, and mica are common in the silt and sand fractions. Common clay minerals are kaolinite, illite, and montmorillonite.

**Mineral grains—**Individual particles of rocks, or of the minerals that make up rocks (e.g. quartz, feldspar, or mica) that become the sand, silt, and clay particles of soils. Except for a small amount of organic matter, soils are composed almost entirely of mineral grains.

**Moderately well drained—**A soil that has a temporary water table for short periods of time in the lower part of the subsoil. The soil is mottled somewhere between 24 and 40 inches. See Chapter 5, "Internal Soil Drainage."

**Mottles—**Splotches of colored soil in a matrix of a different color. Mottles may be yellowish brown in a grayish matrix, or gray in a brown matrix. In either case, mottles indicate that the soil is periodically saturated for several days or weeks at a time. See Chapter 4, "Mottling."

**Muck—**Black, highly decomposed plant material that accumulates at the bottom of a bog or a shallow lake. Muck is so completely decomposed that the original plants cannot be identified. Accumulations of muck and peat, when exposed by draining the lake or lowering the water table, form special kinds of soils called Organic soils.

**Nitrogen—**A chemical element that also is an essential nutrient needed by plants in large quantities. In natural soil-plant systems, almost all of the nitrogen in the soil comes from microbial decomposition of plant residues, and it's stored in the soil as soil organic matter. In agricultural systems, we supplement the native supply of soil nitrogen by adding nitrogen fertilizers.

**Nodules—**Small, hard accumulations of chemical compounds in the soil. Nodules composed mainly of iron oxides usually are spherical pellets 2 to 5 mm in diameter. Nodules of calcium carbonate usually are irregularly shaped and measure up to an inch across.

**Nutrients—**Chemical elements in the soil that are required by plants to live and grow. The "big three" nutrients are nitrogen, phosphorus, and potassium. Others needed in fairly large quantities are calcium, magnesium, and sulfur. Many others are needed, but in very small quantities.

**Opal—**A mineral composed of silica that forms when silica-bearing leaching water evaporates and leaves the silica behind as a deposit in the soil. Opal often occurs in horizontal layers at the top of a duripan. See also "Silica," "Duripan."

**Organic matter—**The sum of all plant and animal material, living or dead, that is mixed into the soil. Living microorganisms are part of soil organic matter, and so is the humus they produce. So are living and dead plant roots, both large and small. Organic matter promotes good soil structure, improves rates of movement of air and water through the soil, increases the storage of water for plant use, and provides nitrogen needed by plants.

**Oxidation—**The chemical change of iron in the soil to a yellow-brown form that is just like rust. Oxidation requires free exchange of air between the soil and the atmosphere. Oxidized soils are well aerated and well or moderately well drained.

**pH—**A number on a scale from 1 to 14 that indicates the relative degree of acidity or alkalinity of the soil. A pH of 7 indicates a neutral soil, one that is neither acid nor alkaline. Smaller numbers indicate acid soils. Most western Oregon soils have pH values between 5 and 7. Larger numbers indicate alkaline soils. Most eastern Oregon soils have pH values between 7 and 9. Sodic soils have pH values of 9 or above.

**Parent material—**The original geologic material from which the horizons of a soil are formed. Parent material includes all kinds of bedrock, sediments deposited by a stream or in a lake, and wind-blown silts or volcanic ash. See Chapter 6.

**Peat—**Brown, partly decomposed plant material that accumulates at the bottom of a bog or a shallow lake. Peat is fibrous, and some of the fibers can still be recognized. Peat and muck, when exposed by draining the lake or lowering the water table, form special kinds of soils called Organic soils.

**Ped—**A single unit of soil structure. Ped shapes include granular, platy, blocky, and prismatic. Ped sizes may vary from l-mm granules to 10-cm prisms. See Chapter 4, “Soil Structure.”

**Perched water table—**The top of a zone of saturated soil that lies above a very slowly permeable soil horizon. The soil in and beneath the slowly permeable horizon may not be saturated. Because water moving down through the soil can’t enter the restrictive layer, it builds up in the soil above, creating a saturated zone perched in the soil well above a permanent water table.

**Perennial stream—**A stream or river that has water in it almost all of the time.

**Permeability—**The rate that water moves within the soil. Permeability depends on the texture, structure, and density of soil horizons. For the soil as a whole, the permeability rating is that of the least permeable horizon present. See Chapter 5.

**Poorly drained—**A soil that is saturated at or near the surface for long periods of time. Poorly drained soils are gleyed, and they often have mottles in the A or Ap horizon. See Chapter 5, “Internal Soil Drainage.”

**Pores—**Spaces between the mineral grains of a soil. Pores are relatively large in sandy and gravelly soils. They may be extremely small in clayey soils. The size, shape, and arrangement of soil pores determine the rates of water and air movement into and throughout the soil. They also control the amount of available water that a soil can store for plant use.

**Porosity—**The total amount of pore space in a soil. Porous soils have plenty of pore space. As a result, they have low densities and rapid or moderate permeability. Compact, dense soils have low total porosity. They have slow or very slow permeability.

**Profile—**A vertical section of soil that allows you to see all the horizons that are present.

**Reduction—**The opposite of oxidation. The chemical change of iron in the soil to a form that is more soluble than the oxidized form and can be leached from the soil. Reduction usually occurs when the soil is saturated and deprived of oxygen. Loss of iron oxide coatings from mineral soil grains by reduction and leaching result in a gray soil color. Reduced soils often are called gleyed.

**Restrictive layer—**A general term for any soil horizon that is slowly or very slowly permeable. Restrictive layers slow down the rate of water movement in the soil. They also impede plant root penetration.

**Ripping—**Breaking up compacted soil, tillage pans, or duripans by pulling a curved steel shank through the soil at depths ranging from 12 to 36 inches.

**Sand—**A specific grain size in the soil. Sand grains range in size from 0.05 to 2.0 mm in diameter. Sand grains are big enough to see with the naked eye, and they feel gritty. Sand is also the name of a specific class of soil texture that has more than 90 percent sand and almost no clay. See Chapter 4, "Texture."

**Salt—**A chemical compound like ordinary table salt (sodium chloride) that is very soluble in water and is readily leached out of soils. Other soluble salts include magnesium chloride and calcium chloride.

**Saturated—**Completely filled with water. When all the pores of a soil are full of water, the soil is saturated. Saturated soils prevent air from getting into soil pores, and are said to be poorly aerated. Saturated soils lead to the processes of reduction and gleying.

**Sediment—**Loose grains of mineral material deposited by a river as alluvium on a floodplain or a fan. Sediment also refers to similar deposits that accumulate on the floor of a lake. See Chapter 6, "Parent Materials."

**Separate—**A subdivision of the fine earth according to the sizes of the individual soil grains. The three separates of fine earth are sand, silt, and clay. See Chapter 4, "Texture."

**Shrink-Swell soil—**A soil that has clay particles that expand when they absorb water and contract when they dry out. Shrink-swell soils are called Vertisols, and they usually contain more than 50 percent clay. Slickensides are features of shrink-swell soils, as well. See also "Slickensides."

**Silica—**Mineral material in soil that consists of a chemical combination of the elements silicon and oxygen. Most sand and silt grains are composed of silica. Silica is very slowly soluble; but under some conditions, it can be moved downward in the soil, where it is deposited again in the pores between soil particles. These silica deposits cement the soil together into a very hard layer called a duripan. See Chapter 3, "Special Kinds of A, B, and C Horizons."

**Silt—**A specific grain size in the soil. Silt grains range in size from 0.002 to 0.05 mm in diameter. They are too small to see with the naked eye, and they feel smooth, like flour or corn starch. See Chapter 4, "Texture."

**Slaking—**The breaking down of structural aggregates, or peds, under the impact of falling droplets of water. Individual grains of silt and clay are washed off the peds and tend to clog up nearby soil pores. A thin surface crust forms that seals the soil, prevents infiltration, and increases the erosion hazard. Silty soils that are low in organic matter and have weak structure are very susceptible to slaking.

**Slickensides—**Polished shiny surfaces caused by the movement of two masses of clayey, shrink-swell soil past each other. Slickensides are characteristics of Vertisols. See Chapter 4, "Special Features of Soil Horizons."

**Sodic soils—**Soils that have high concentrations of sodium salts in them. Sodium causes the soil to have very poor structure and a pH value of 9 or above. Sodic soils occur in eastern Oregon, where evaporation causes water to move upward in the soil from a shallow water table. Salt deposits on the surface form a white crust that may be called a slick spot.

**Soluble—**Capable of being dissolved. Table salt is very soluble in water. The same salt is very soluble in soil. Free lime in soil is quite soluble, but less so than salts like table salt. Silt and sand-sized grains of rocks and minerals in soils are only very slowly soluble. It takes a very long time to remove these minerals from the soil by leaching.

**Somewhat poorly drained—**A soil that is saturated in the upper part of the subsoil for significant periods of time during the rainy season. The soil usually is gray and mottled between 10 and 24 inches. In eastern Oregon, sodic soils having pH values above 9.0 also are somewhat poorly drained. See Chapter 5, "Internal Soil Drainage."

**Stratified—**Deposited in distinct layers on a river floodplain or at the bottom of a lake. Differences in the texture or color of a sediment make these layers visible.

**Structure—**Arrangement of individual grains of sand, silt, and clay into larger units called aggregates or peds. Plant roots, humus, and clay minerals all help to hold the grains together. Structure is characterized by the type, or shape, of the peds and by their grade, or degree of development. See Chapter 4.

**Terrace—**A landform that resembles the tread of a giant stair. Terraces formed originally as river floodplains or ocean beaches. Later, as rivers cut down or ocean levels dropped, the original landform was abandoned and left at a higher level. Terraces are no longer covered with flood waters. See Chapter 6, “Landform.”

**Texture—**The amounts of sand, silt, and clay that make up a soil sample. Names are given to specific combinations of sand, silt, and clay to form textural classes such as loam, silt loam, sandy loam. See Chapter 4.

**Tilth—**The physical condition of the surface soil. Good tilth requires plenty of organic matter, good soil structure, and favorable air-water relations. Soils in good tilth are easy to work, easy for plant seedlings to emerge from, and easy for plant roots to grow in.

**Very poorly drained—**Soils that are saturated throughout, almost all of the time. They are very wet soils in swamps, bogs, and tidal lowlands.

**Water-holding capacity—**See AWHC.

**Water table—**The top of a zone of saturated soil.

**Weathering—**The changing of rocks into soils. Physical weathering breaks rock fragments down to smaller fragments. Chemical weathering destroys some original rock minerals and creates new kinds of soil minerals. See Chapter 2.

**Well-aerated—**Soil that allows easy exchange of air between the soil and the atmosphere. Well-aerated soils have plenty of pores that are big enough and sufficiently interconnected to provide pathways for air movement. They have plenty of organic matter and good structure, and they usually are well or moderately well drained.

**Well drained—**A soil that is rarely saturated above a depth of 40 inches. Well-drained soils are well aerated and have brown or yellow-brown colors. They have no mottles above 40 inches. See Chapter 5, “Internal Soil Drainage.”

# Scorecard: Oregon State Soil Judging

**Contestant** ______________________ **Site** ______________________

**School** ______________________________________________

**First Horizon**
( __ to __ inches)

_______ Color

_______ Mottles

_______ Texture

_______ Coarse Fragments

_______ Structure Type

_______ Structure Grade

_______ Special Features

_______ Horizon Name

**Second Horizon**
( __ to __ inches)

_______ Color

_______ Mottles

_______ Texture

_______ Coarse Fragments

_______ Structure Type

_______ Structure Grade

_______ Special Features

_______ Horizon Name

**Color**
1 = Dark brown, Very dark brown, Black
2 = Light brown, Brown, Yellowish brown
3 = Red, Reddish brown
4 = Dark gray, Light gray, White

**Mottles**
1 = None
2 = Few to common
3 = Many

**Texture**
1 = Sand, Loamy sand
2 = Sandy loam
3 = Loam, Silt loam
4 = Sandy clay loam, Clay loam, Silty clay loam
5 = Clay, Silty clay, Sandy clay
6 = NA—Duripan, Cr, R, O

**Coarse Fragments**
1 = <15%
2 = 15 to 35%
3 = 35 to 60%
4 = >60%

**Structure type**
1 = Granular
2 = Platy
3 = Blocky
4 = Prismatic
5 = Massive, Single grain

**Structure grade**
1 = Structureless
2 = Weak
3 = Moderate
4 = Strong

**Special features**
1 = None
2 = Tillage pan
3 = Fragipan
4 = Duripan
5 = Cr
6 = Slickensides

**Horizon name**
1 = O
2 = A
3 = E
4 = B
5 = C
6 = R
7 = AB, BA, BC

**Third Horizon**
( __ to __ inches)

Color _______

Mottles _______

Texture _______

Coarse Fragments _______

Structure Type _______

Structure Grade _______

Special Features _______

Horizon Name _______

**Fourth Horizon**
( __ to __ inches)

Color _______

Mottles _______

Texture _______

Coarse Fragments _______

Structure Type _______

Structure Grade _______

Special Features _______

Horizon Name _______

| **Total Front** | **Total Back** | **Grand Total** |
|---|---|---|
| | | |

*This camera-ready master is provided for your convenience. Please copy it as needed.*

## Properties of the Whole Soil

_______ **Effective Depth**
1 = Deep ( >40 inches)
2 = Moderately deep (20–40 inches)
3 = Shallow (10–20 inches)
4 = Very shallow(<10 inches)

_______ **Available Water-holding Capacity**
1 = High (>8 inches)
2 = Medium (5–8 inches
3 = Low (2–5 inches)
4 = Very low (<2 inches)

_______ **Surface Soil Permeability**
_______ **Subsoil Permeability**
1 = Rapid
2 = Moderate
3 = Slow
4 = Very Slow

**Water Erosion Hazard** _______
1 = Low
2 = Moderate
3 = High
4 = Very high

**Wind Erosion Hazard** _______
1 = Low
2 = Moderate
3 = High

**Internal Drainage** _______
1 = Excessive
2 = Well
3 = Moderately well
4 = Somewhat poor
5 = Poor

## Site Characteristics

_______ **Site Position**
1 = Upland
2 = Foot slopes or Fans
3 = Floodplain
4 = Stream terrace or Lake plain

_______ **Parent Material**
1 = Residuum or Colluvium
2 = Recent alluvium
3 = Old alluvium or Lacustrine
4 = Wind-blown sands or silts
5 = Volcanic ash
6 = Two or more classes

**Stoniness/Rockiness** _______
1 = None
2 = Stony/Rocky
3 = Very stony/Rocky
4 = Extremely stony/Rocky

**Slope** ______
1 = 0–3%
2 = 3–7%
3 = 7–12%
4 = 12–20%
5 = >20%

## Management Interpretations

_______ **Drainage Feasibility**
1 = Not needed
2 = Good
3 = Fair
4 = Poor

_______ **Irrigation Suitability**
1 = Excellent
2 = Good
3 = Fair
4 = Poor
5 = Non-irrigable

_______ **Most Intensive Crop**
1 = Row crop/Specialty crop
2 = Legume hay
3 = Dryland wheat
4 = Dryland hay
5 = Permanent pasture/Grass seed
6 = Timber grazing
7 = Rangeland grazing
8 = Forestry

**Erosion Control Practice** ________
1 = Water control, Cover crop, Standing stubble
2 = Stubble mulch, No-till
3 = Diversion terraces, No-till
4 = Strip crop, No-till
5 = Controlled grazing
6 = Watershed management

**Reaction Correction** _______
1 = None
2 = Correct acidity
3 = Correct alkalinity

**Limitations for Septic Tank Drainfields** _______
1 = Slight
2 = Moderate
3 = Severe

**Total Back** [ ]

Oregon State University Extension Service

Reprinted September 2007

# Interpretation Guide for Oregon Soil Judging

**Mottles**

| | |
|---|---|
| **Few** | 0–2% |
| **Common** | 2–20% |
| **Many** | >20% |

**AWHC Rates (In/In)**

| | |
|---|---|
| Sa, Lsa | .06 |
| Sal | .12 |
| L, Cl, Sil, Sicl | .20 |
| C, Sic, Sac, Sacl | .15 |

**Stoniness/Rockiness**

| | None | Stny/Rcky | Very | Ext |
|---|---|---|---|---|
| **Stones (%)** | <.01 | .01–.1 | .1–3 | >3 |
| **Rocks (%)** | <.01 | .01–2 | 2–10 | >10 |

**Wind Erosion Hazard**

| | Low | Low | Mod | High |
|---|---|---|---|---|
| **Location** | W. OR | E. OR | — | — |
| **Texture** | Any | Sacl, Sac, Cl, Sicl, Sic, C | L, Sil | Sa, Lsa, Sal |

**Permeability—Surface Soil and Subsoil**

| | Rpd | Mod | Slo | Mod | Slo | Mod | Slo | V Slo |
|---|---|---|---|---|---|---|---|---|
| **Texture** | Sa, Lsa | Sal, Sil, L | — | Sacl, Sicl, Cl | — | Sac, Sic, C | — | — |
| **Porosity** | Any | Por | Not por | Por | Not por | Por | — | Not por |
| **Structure Grade** | Any | Any | Any | Any | Wk, Mass | Str | Mod, Wk | Mass, Vert |

**Water Erosion Hazard**

| | Low | Moderate | High | Low | Moderate | High | Very high |
|---|---|---|---|---|---|---|---|
| **Texture** | Sa, Lsa, Sal, Sac, Sic, C | — | — | Sacl, Sicl, Sil, L, Cl | — | — | — |
| **Slope / Perm. of Sfc soil** | 0–12/Any | 12–20/Any | >20/Any | 0–3/Any<br>3–7/Rapid, Mod | 3–7/Slow, V Slow<br>7–12/Rpd, Mod | 7–12/Slow, V Slow<br>12–20/Any | >20/Any |

**Drainage Feasibility**

| | Good | Fair | Fair | Poor | Poor | Poor |
|---|---|---|---|---|---|---|
| **Outlets** | Available | — | — | — | — | Not available |
| **Effective depth** | Deep | — | Mod deep | — | Shallow | Any |
| **Drainage class / Subsoil perm.** | MW/Any<br>SWP/Rpd, Mod | —<br>SWP/Sl, V sl | MW/Any<br>SWP/Any<br>PD/Rpd, Mod | —<br>—<br>PD/Sl, V sl | Any | Any |

**Irrigation Suitability**

| | Excellent | Good | Fair | Poor | Non-irrigable |
|---|---|---|---|---|---|
| **Slope / Permeability of surface soil** | 0–3/Any<br>3–7/Rpd, Mod | 3–7/Slow<br>7–12/Rpd, Mod | 7–12/Slow | 3–12/V slow<br>12–20/Any | >20/Any |
| **Minimum AWHC** | High | Medium | Low | Very low | Very low |
| **Internal drainage / Drainage feasibility** | WD<br>MWD/Good<br>SWP/Good | WD<br>MWD/Good, Fair<br>SWP/Good, Fair | WD<br>MWD/Any<br>SWP/Any<br>PD/Fair | Any | Any |

*This camera-ready master is provided for your convenience. Please copy it as needed.*

### Most Intensive Crop—Irrigated

| | Row crop or Specialty crop | Legume hay | Perm pasture/ Grass seed |
|---|---|---|---|
| **Location** | All *except*—<br>High basins in Baker, Harney, Lake, Wallowa<br>Coastal fog belt | Any | — |
| **pH** | <8.4 | <8.4 | Any |
| **Slope** | 0–12 | 0–20 | 0–20 |
| **Irrigation suitability** | Excellent<br>Good<br>Fair—0–3% slope<br>Fair—sandy soils up to 12% slope | Any | Any |
| **AWHC** | High-Low | High-Low | Any |
| **Drain. feas.** | Good-Fair | Good-Fair | Any |

### Septic Tank Drainfields

| | Slight | Moderate | Severe |
|---|---|---|---|
| **Effective depth** | ≥48 in | ≥36 in | <36 in |
| **Subsoil perm.** | Mod | Rpd to mod | Any |
| **Internal drainage** | WD | WD, MWD | Any |
| **Slope** | 0–7 | 0–12 | Any |
| **Landform** | All except floodplains | All except floodplains of per. streams | Any |

### Most Intensive Dryland Crop—Western Oregon

| | Wheat | PP/ GS | Wheat | PP/ GS | For | PP/ GS | For |
|---|---|---|---|---|---|---|---|
| **Slope** | <12 | — | 12–20 | — | — | 20–35 | Any |
| **Rainfall** | <60 | Any | 30–45 | <30<br>45–60 | >60 | 30–45 | Any |
| **Drain. class / Drain. feas.** | WD<br>MW/Any<br>SWP/Any<br>PD/Good, Fair | Any | WD<br>MW/Any<br>SWP/Any<br>PD/Good, Fair | Any | Any | Any | Any |

### Most Intensive Dryland Crop—Eastern Oregon <4,100 feet

| | Wheat | TG | Graz | Graz | Wheat | Graz |
|---|---|---|---|---|---|---|
| **pH** | <8.4 | — | — | — | — | Any |
| **Rainfall** | ≥12 | — | — | — | <12 | Any |
| **AWHC** | Low–High | — | — | V low | Med–High | Any |
| **Slope/Aspect** | <20/Any | ≥20/N | ≥20/S | Any | <35/Any | Any |

### Erosion Control Practice—Western Oregon

| | Water ctrl, Cover crop | Stbl mulch | Ctrl grazing | Wtrshd mgt |
|---|---|---|---|---|
| **Most intensive crop** | Row crop<br>Legume<br>Grass seed | Wheat | Pasture | Forestry |

### Most Intensive Dryland Crop—Eastern Oregon >4,100 feet

| | Hay | Hay | Timber grazing | Forestry | Timber grazing | Grazing | Timber grazing | Grazing | Timber grazing | Grazing |
|---|---|---|---|---|---|---|---|---|---|---|
| **pH** | ≤8.4 | — | — | — | — | — | — | — | — | Any |
| **Slope/Aspect** | <20/Any | — | — | ≥20/N | — | <20/Any<br>≥20/N | — | — | ≥20/S | Any |
| **AWHC** | Med–High | Low | — | Low–High | — | Low–High | V low | — | Low–High | Any |
| **Rainfall** | Any | ≥18 | 12–18 | ≥15 | 12–15 | <12 | ≥18 | <18 | ≥15 | Any |

### Erosion Control Practice—Eastern Oregon

| | Stubble mulch, No-till | Diversion terraces, No-till | Strip crop, No-till | Strip crop, No-till | Stubble mulch, No-till | Diversion terraces, No-till | Stubble mulch, No-till | Water ctrl, Cover crop | Controlled grazing | Watershed Mgt |
|---|---|---|---|---|---|---|---|---|---|---|
| **Crop** | Wheat | — | — | — | — | — | — | Row crop | Timber grazing, Range | Forestry |
| **Rainfall** | ≤10 in. | — | — | — | >10 in. | — | — | Any | Any | Any |
| **Wind erosion** | Lo | Lo, Mod | Mod | Hi | Lo, Mod | — | Hi | Any | Any | Any |
| **Water erosion** | Lo, Mod | Hi, V hi | Lo, Mod | Any | Lo, Mod | Hi, V hi | Any | Any | Any | Any |

Oregon State UNIVERSITY | Extension Service

Reprinted September 2007