PURDUE EXTENSION

ID-72-W

INDIANA SOILS: Evaluation for Agriculture and Home Sites

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PREFACE

The goal of this publication is to teach students how to apply soil science principles to managing soils for agriculture and home sites. To achieve this goal, we identify nine key soil properties, explain how students can determine each property, and summarize this process in *evaluation* rules.

Then, we review the principles of restoration, forest management, soil conservation, crop management, soil tillage, soil fertility, manure management, landscaping, lawn care, on-site sewage disposal and other specialties. We explain the essence of these principles and summarize them in *judging* rules.

The challenge is to boil the work of experts down to explanations that students can use to determine key soil properties and to recommend the same practices that experts would recommend. Students have about 15 minutes to do all of this. In the process, the natural tendency is for experts to believe that some details are omitted, and for teachers, and especially students, to believe that there is too much material to learn. Compromises must be made and experts, teachers, and students understand this. The process is a work in progress, so we expect that changes will be made to this publication.

Two Publications

Two publications support teaching soil science in high schools and conducting soil contests. This is the basic publication that replaces *Indiana Soils: Evaluation and Conservation*, (published in 2001 as Purdue Extension publication ID-72) the basic previous publication. *Indiana Soil Evaluation Field Book* (Purdue Extension publication AY-362-W) is a new companion publication. The *Field Book* summarizes the rules in this guide and provides condensed explanations of them. We anticipate that this guide will be used mainly for classroom teaching that students will take the *Field Book* outdoors and use it in soil pits. Both publications are available from the Purdue Extension Education Store, edustore.purdue.edu.

Value to Students

This publication will help you learn about soil resources and how to take care of soil. This publication is intended to be used mainly by high school students.

These students should learn about soils because:

- They will be stewards of an important world resource
- It will benefit them directly

Stewards

A steward is a person who takes care of certain resources. Individuals act as stewards at the ballot box — when they elect people to office and when they vote on specific polices through referenda.

Some examples follow:

- Every Indiana county has a Soil and Water Conservation District that helps landowners care for their soil and water resources.
- State laws regulate (among other things) how nutrients in manure are applied to soils.
- Federal laws establish policies for preserving wetlands and controlling soil erosion.
- One of the main goals of The Food and Agriculture Organization of the United Nations is to reduce soil degradation.

Individual benefits

In a few years, most high school students will be responsible for taking care of yards on properties they own or rent. Many of those properties will have on-site sewage disposal systems that must be cared for. Other students will go on to manage farms. Still others must decide where to build a new house.

This publication deals with all these issues. This publication will discuss how to apply nutrients to lawns and home landscaping plants. It will explain how to care for septic systems. It will suggest farm practices that are suitable for specific soils. And it will explain why it is very dangerous to build houses on certain soils.

If you do not follow the guidelines outlined in this publication, it can be very costly to you and could harm the environment.

On the Cover

Overview

The photo on the cover of this publication illustrates several features we will discuss in this book. Many years ago, a stream cut into the base of a hill and the soil material fell into the stream leaving a vertical cut. The site is along Mud Pine Creek in Warren County, Indiana. The photo was taken by Ryan Schroeder, a Purdue student studying Natural Resources and Environmental Sciences, in January 2016. He dug into the materials in the cut to identify their origin. The cut is about 15 feet deep. For now, notice the many different layers and deep tree roots. After you have read more of this book, read the details about *soil parent materials* and *soil horizons*.

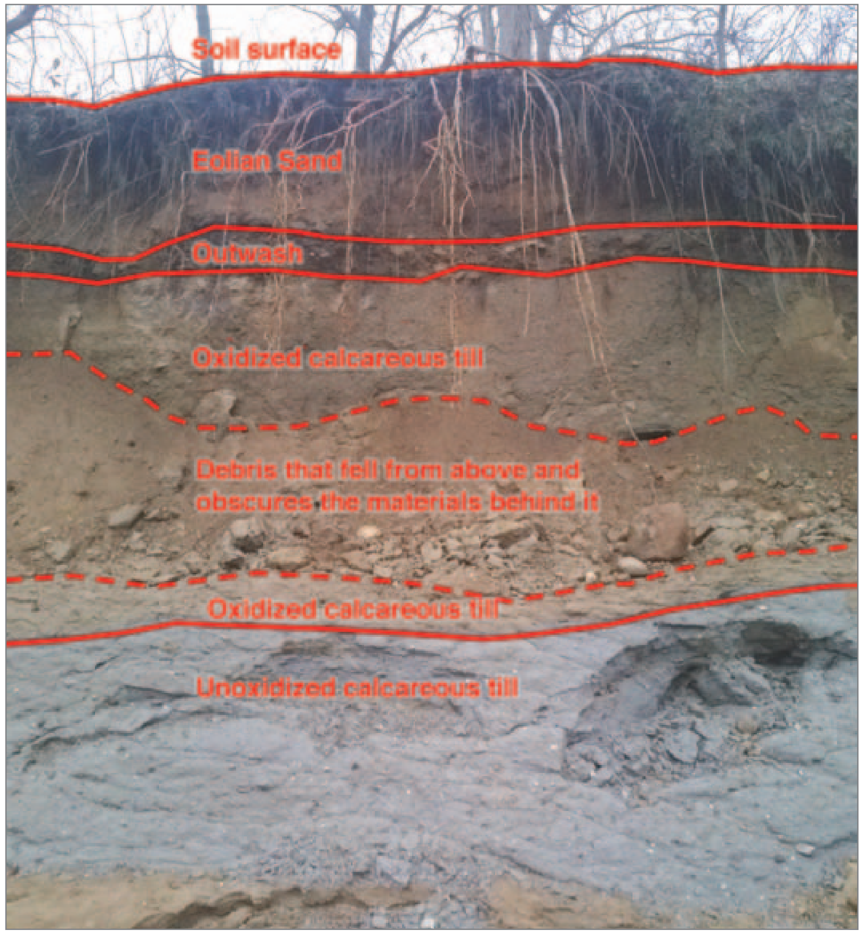


Figure 1. *This figure shows the parent materials on the cover photo. Photo provided by Ryan Schroeder.*

Details

We will explain the photo using Figures 1 and 2.

FIGURE 1. PARENT MATERIALS

Parent materials are the materials from which soils form. They were deposited thousands of years ago, and it took a few thousand years to deposit all them, but they were all in place by about 15,000 years ago. Then soil formation began. The kinds of parent materials when soil formation began are identified in Figure 1.

The material at the bottom of Figure 1 was deposited first. Most of the material in the cut was transported and deposited by a *glacier,* a large body of ice that originated in Canada and flowed to Indiana. The glacier, probably a few thousand feet thick, ground up the bedrock material over which the ice moved, and deposited the ground-up material (called *till*) at the site of the photo. When it was deposited, all the till was grayish, like the lowest material in the photo. It is called *unoxidized calcareous till*. Unoxidized means that much of the iron in the till is ferrous iron (Fe^{2+}) instead of ferric iron (Fe^{3+}), which gives till a brownish color. The glacier also ground up limestone bedrock, so the till contains carbonate minerals (is calcareous). Unoxidized calcareous till appears above and below the debris that covers the cut in the parent material sketch. This till was compacted by the weight of the glacier, so it is very dense.

Figure 2. *This figure shows the soil processes and horizons on the cover photo. Photo provided by Ryan Schroeder.*

There are stones in the till and that were rounded during transport by ice. There are even more rounded stones in the outwash that were further rounded by transport by water. Close examination shows that many of the stones are igneous and metamorphic rocks. The bedrock below Indiana consists of sedimentary rocks, so the igneous and metamorphic stones are "strangers" in Indiana, and are called are called *erratics*. They were carried here from Canada by the glacier.

Above the till is a thin layer of *outwash*, material deposited from running water generated when the glacial ice melted (meltwater). It contains mainly sand and gravel because the finer material was washed out by running water when the outwash was deposited.

Above the *outwash* is a layer of *eolian sand*. Following the retreat of the glacier and the deposition of outwash materials, strong winds blew across the bare area and picked up silt and fine sand material creating dust storms. As the wind subsided, sand settled out first as eolian sand, and then silt settled out as loess. At this site, eolian sand was deposited, but not loess.

FIGURE 2. SOIL PROCESSES AND HORIZONS

When all the parent materials were deposited, plants started to grow on them, and soil forming processes began. Then, all the till was unoxidized (grayish) and calcareous (with carbonates), like the 4Cd2 soil horizon shown in Figure 2.

Oxidation

Over the years, some of the ferrous iron (Fe^{2+}) in the till was dissolved, oxidized to ferric iron (Fe^{3+}), and precipitated as brownish iron oxide minerals. These minerals are responsible for the brownish color in the *oxidized calcareous till* (3Cd1 horizon). It comprises much of the cut surface in the photo. The till was oxidized to a depth of about 8 feet, which is the boundary between the 3C1 and 4C2 horizons. Because till is oxidized so deeply in the soil, unoxidized material is seldom, if ever, seen in a soil pit.

Carbonate Leaching

The original till also contained many carbonate minerals, such as calcium carbonate ($CaCO_3$, or lime). The acid in rain water and the acids produced by plants dissolve carbonates, and the dissolved materials are lost to the air (as carbon dioxide, CO_2), or flushed out (leached) with drainage water. This process, called *carbonate leaching*, extends to the bottom boundary of the 2Bt2 and 3Cd1 horizons, about 4 feet in the photo. The depth of carbonate leaching is often seen in soil pits. Official soil judges often post this depth (Calcareous below a certain depth) on site cards (see page 147).

Other soil forming practices include formation of soil structure, accumulation of organic matter, weathering of soil minerals and formation of clay, and movement of clay down the profile. The results of these processes are enhanced by soil organisms. One of these is the plants that grow on the soil. Note how deep the tree roots grew in this soil.

The horizon designations in Figure 2 consist of four main parts, illustrated here by the 2Bt2 designation:

- A leading number (2) that indicates the kind of parent material. If there is no leading number, (such as in the A, and Bt1 horizons) the number is assumed to be 1. For this soil, the parent materials are:
    1. Eolian (wind-blown) sand
    2. Outwash
    3. Oxidized calcareous till
    4. Unoxidized calcareous till
- An uppercase letter that indicates major kinds of horizons ("B" in the example).
- A lowercase letter that indicates major processes of soil formation. The "t" in the example indicates accumulation of clay; "d" means dense.
- Subdivisions of similar horizons (the final "2" in 2Bt2).

Credits and Acknowledgements

Authors

Don Franzmeier was a professor in the Purdue Department of Agronomy from 1967 to his retirement in 2004. His appointment was mainly research and teaching, but he also worked with soil evaluation and judging, an extension activity. He was the lead author of the previous edition of this manual, which was published in 2001. The photos in Figure 3 show that it is, indeed, time to update the manual.

Gary Steinhardt has been s a professor and extension specialist in the Purdue Department of Agronomy from 1976 to present. His work has focused on extension and teaching. He began his career by mapping soils during the summer while attending Michigan State University. He has been involved in soil judging for 4-H/FFA and at the collegiate level. He has coached the Purdue Soils Team for 30 years. He presently serves on the Board of the Indiana Registry of Soil Science. He was one of the authors of the previous edition of this manual.

Cathy Egler is a Teaching Assistant in the Purdue Department of Agronomy. She has a bachelor of science in natural resources from Ball State University and a master of science in agronomy from Purdue University. She has had professional positions in soil conservation and has been the assistant coach of the Purdue Soils Team for 15 years.

The authors thank Tony Carrell, (Purdue Extension Specialist) for devising the scorecard numbering system to make scoring and tabulating large contest results faster.

Photos

The photos in this publication will help students understand what the practices they select on contest scorecards. Some of the photos appeared in the last edition of this manual. Several new ones came from the USDA-Natural Resources Conservation Service (NRCS) Photo Gallery. After assembling the photos from those sources, we still had gaps, so we asked people for help. As a response to this request, we received photos from: Eileen Kladivko and Tony Vyn, Purdue Agronomy; Gary Struben (credited to his employer, USDA-NRCS, Indiana); Tom Bechman, editor of *Indiana Prairie Farmer* magazine and a volunteer soil judging coach; Joey Schlatter, GPS specialist with Schlatter's Inc., in Francesville, Indiana, a company specializing in drainage equipment and related technology; and Mike from the *Tiny Farm Blog*.

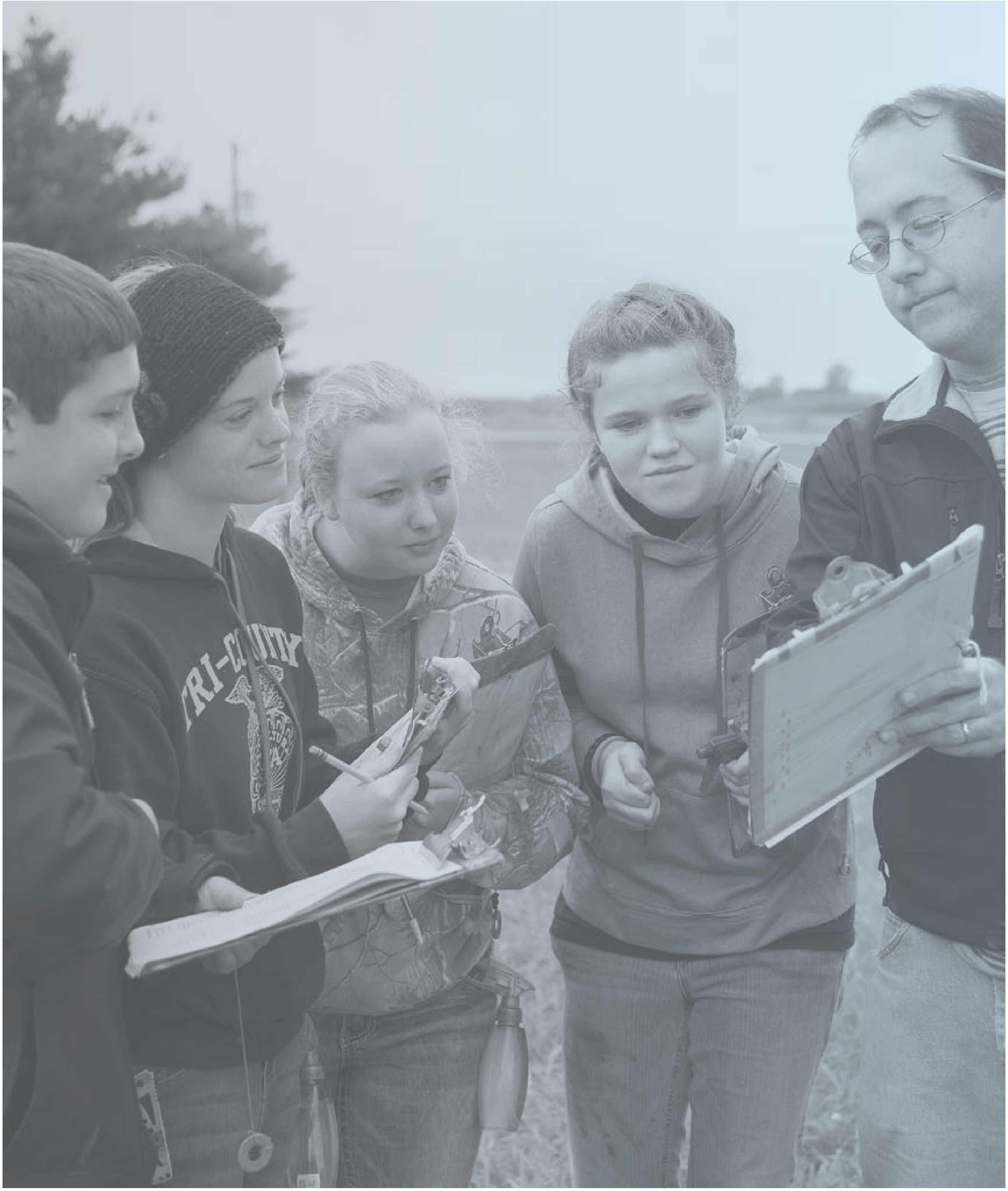
Photo sources are provided in the captions. When no source is provided, the photos and illustrations were provided by the authors or Purdue Extension.

Volunteer Reviewers

At various stages of developing the publications, teachers, official judges, the experts listed in the preface, and others reviewed parts the publications or all of the *Field Book*. We thank all these people for their interest in caring for our soil resources.

Figure 3. *These photos show author Don Franzmeier and his grandson, Chip Herendeen, when the manual was first published in 2001 and more recently. Photos provided by Gail Herendeen.*

Figure 4. *Cathy Egler (left) and Gary Steinhardt.*



CHAPTER 1 – Soil Formation

Preview of Soil, Soil Profiles, Horizons, Factors and Processes

First, we should explain that by soil we generally refer to the upper 3 or 4 feet of the land surface. We will provide a more specific definition later.

Soils are outdoors, so you must go outdoors to observe and study them. Much of what we have written here will not make sense unless you go outside and apply it when you observe an individual soil and notice how soils differ from place to place. Teachers, official judges, and soil scientist volunteers will help you with this hands-on study. Soils training is similar to medical training. If you need an operation you surely hope that your surgeon has received hands-on training in addition to reading about the surgery in books and manuals. And if you ever need to install an on-site septic system, you surely will hope that your professional has had the appropriate hands-on training.

Instructors have made studying soils more interesting to students by making it competitive. Athletes can shoot baskets individually, but they work harder if they are part of a team that competes with other teams. Similarly, you will evaluate soils in soil evaluation and judging contests. This publication will present the process of describing soils and deciding how best to use them for agriculture and for home site soils in a competitive format.

This chapter previews soil profiles and horizons — what you see in the field. This chapter also provides an overview of the factors that determine soil properties, and then discusses some of the processes that form different horizons in soils.

Soil Profiles, Horizons, and Series

In the field, you will see many **soil profiles.** Soil profiles are vertical exposures that are about 4 feet deep, usually in a pit or road cut. You will notice that a soil profile has different layers (or horizons) that are parallel to the soil surface. These horizons differ from each other in texture, color, structure, and other properties.

There are three general kinds of **soil horizons**:

- **Surface soil** (A and E Horizons) includes the upper horizons that are most affected by plant roots. They usually contain more organic matter than other horizons. Less technically, surface soil is called **topsoil**.
- **Subsoil** (B Horizons) includes the horizons between the surface soil and the substratum.
- **Substratum** (C and R Horizons) are deep horizons that have been little affected by soil forming processes. In other words, these materials are usually about the same as they were when they were deposited.

Later in the chapter, we discuss the horizons by the letter designations (A, E, B, C, and R) as designated above.

A **soil series** is a group of soils with similar profile characteristics. Their names represent the area in which they were first identified. For example, the Brookston series was named for the Indiana town by that name. Later in this chapter (in Soil Landscapes and Profiles, pages 24-31) we will use many soil series names, such as Chelsea, Hosmer, and others.

Soil Formation Factors

A factor is something that helps produce a result. Let's assume the result is a certain soil. Then there are five factors that determine what the soil is like.

Soil scientists list **soil formation factors** in three groups:

1. Soil formation factors based on the original condition of the soil:
    - Parent material
    - Relief
2. Active soil formation factors:
    - Climate
    - Organisms, especially vegetation
3. Another soil formation factor:
    - Time

We will illustrate the factors with a typical soil in northern Indiana. A long time ago, a glacier (large ice sheet) retreated from northern Indiana, and it left behind a mixture of sand, silt, and clay (this material is called **parent material**), in irregular hills. The shape of the hills is the **relief**. After the parent material was deposited, it rained on these materials, and the sun warmed them (**climate**). Plants and other **organisms** started to grow on the site to begin various processes of soil formation. The glacier retreated about 20,000 years ago (**time**) and the soil has been developing ever since. **Topography** and **landscape** are terms that are similar to relief.

You can see the effects of individual factors over areas of different sizes. You can often see the effects of the *relief* factor within a field. Soils at the top of a hill are much different from soils in a depression (basin) at the bottom of a hill.

Within a county, there are usually several different *parent materials*. Soils near a river were probably deposited by water. Soils far from a river were probably never transported or were deposited by ice, and are much different than those near the river.

The different materials might have been deposited at different *times*. Soils far from the river are probably thousands of years old; those near the river might be only as old as the last flood.

In Indiana, most soils formed under forest *vegetation*, but some (mostly in west-central Indiana) formed under prairie. These prairie soils have thick, dark surface horizons.

Indiana's *climate* varies a bit, but to see the true results of climate, you need to travel. For the extremes, you might compare the soils in the rain forest of Hawaii with soils in the desert of Nevada.

If you have a background in math, it might be of interest that there is an equation that summarizes the relationship of soil properties to soil properties to soil formation factors:

S=f (cl,o,r,p,t)

The equation states that any soil property (S) depends on climate (cl), organisms (o), relief (r), parent material (p), and time (t). There is a mnemonic device for remembering these factors: **clorpt**.

Soil Forming Processes

Notice that the soil formation factors are nouns. They each describe a thing.

In contrast, a process describes some kind of action, so the words that explain processes are verbs. Many process take place in soils.

Physical processes break larger particles break down into smaller ones, move tiny particles downward in a soil, and water moves soil particles down a slope. Chemical process dissolve some minerals completely, transform other minerals from unavailable forms to plant-available forms, and cause soluble iron to precipitate as reddish brown iron oxide. Biological processes decay plant materials and transform the products to **humus** (dark organic material), mix the soil (with worms), and transform nitrogen in the air to forms of nitrogen that are available to plants.

Of the many **soil forming processes**, we mention eight processes (or groups of processes) here, because they have noticeable effects on soil horizons. We will illustrate these soil forming processes with photos after we discuss soil horizons.

The eight soil forming processes we will discuss in this publication are:

- Carbonate minerals (ground limestone or "**lime**") dissolve.
- Other minerals weather. **Weathering** is the breaking down of rocks and minerals.
- Some materials (such as ions) are released during the weathering process and **leach** from the soil — that is, they are removed by water flowing down through the soil.
- Clay moves down the profile.
- Organic matter accumulates in surface horizons.
- Iron oxide minerals form.
- Soil particles become weakly cemented to each other. This is responsible for the Bx horizon of the Hosmer soil (Figure 1.25).
- Soil structure forms.

Definition of Soil

In this publication, we define **soil** as the material near the Earth's surface that has horizons that were created by soil-forming processes.

MAIN HORIZONS	DISTINCTIVE FEATURES
O – Organic matter. Surface leaf litter in a forest; peat or muck in a bog	i – slightly decomposed e – moderately decomposed a – highly decomposed
A – Mineral matter darkened by organic matter and/or cultivated	p — plowed
E – Horizon from which clay, iron, etc. has been lost	Usually lighter in color than A horizon
AB, EB, BE – Transition horizon between two major horizons	Horizon is more like the first listed (EB is more like E than B
B – Major subsoil horizon	g – gleyed (dominantly gray color) t – gain in clay w – weak development x – fragipan (brittle)
BC, CB –Transition horizon between two major horizons	d – dense r – weathered bedrock
R - Bedrock	

Table 1.1. *Common horizon designations for Indiana soils. Soil horizons and their designations are illustrated in the photos in Soil Landscapes and Profiles (pages 24-31). For example, the Btg horizon of the Brookston soil (Figure 1.17) has a subsoil horizon (B) that contains more clay (t) than the horizons above it and is dominantly gray (g).*

Soil Horizons in Indiana

The soil horizon designation system that we discussed earlier is used in most countries of the world. Here we discuss the kinds of horizons in Indiana soils and illustrate them with photos.

When describing a soil profile, we use the capital letters O, A, E, B, C, and R to indicate the major kinds of horizons. Often, these capital letters are followed by a lowercase letter that gives more information about the horizon. For example, a B horizon designates a subsoil horizon in which something has accumulated. A Bt horizon is a soil horizon in which clay has accumulated. Table 1.1 explains what all of these letters mean. We also describe the major letters in more detail below.

In addition to the letters, some horizon designations include a number that appears before the uppercase letter. This number represents changes in parent materials. For example, the horizons in a profile (from the top down) may be Ap, E, 2Bt, and 2C. These designations tell us that the first two horizons (Ap and E) formed in one kind of parent material (such as loess), and the lower two horizons (2Bt and 2C) formed in a different parent material (such as till).

▶ A NOTE ABOUT FIGURES

The Soil Landscapes and Profiles section (pages 24-31) includes many figures we will refer to throughout this manual. Figure 1.2 (pages 14 and 25) is a soil map of Indiana. Figures 1.14-1.27 (pages 26-29), show 14 soil profiles. The explanations for Figures 1.14 -1.27 (including the scale on the tape that shows depth) appear on pages 30-31.

In soil evaluation, you are not required to name the horizons. However, knowing the characteristics of the A, E, and B horizons will help you determine erosion classes, recognize fragipans, identify alluvium, and recognize other soil properties.

O Horizons

Soil horizons that are composed of organic materials on the surface of mineral soil are called **O horizons**. An example of an O horizon is the Trappist soil (Figure 1.27). In the Trappist soil, the organic materials are predominantly decomposing leaves from hardwood trees.

In bogs and marshes, the whole soil will have formed in organic matter, so the entire profile consists of O horizons.

A Horizons

Mineral horizons (those with little organic matter) that are near the surface are called **A horizons**. Living organisms are most active in this horizon, so an A horizon is characterized by a dark-colored humus mixed with the mineral material

Under forest vegetation, the A horizon is only a few inches thick (Miami soil, Figure 1.15). But under prairie grasses (Parr soil, Figure 1.14) or in swales (Brookston soil, Figure 1.17), the A horizon may be 25 or more inches thick. A horizons are usually the darkest of any horizon in the soil.

Within the A horizon category is the designation Ap, which is given to soil that has been mixed by plowing or cultivation.

Ap horizons consist mostly of the:

- A horizon
- A and E horizons
- Remaining A (and usually E) and part of the upper B horizons (in eroded soils)

E Horizons

A soil that develops under forests commonly has an **E horizon** a few inches below the surface. E horizon soils are lighter in color, lower in organic matter, and less fertile than A horizon soils. Clay, aluminum, iron, and some nutrients have been washed out of or leached from the E horizon.

The E horizon is apparent in the Miami soil (Figure 1.15) and the Hosmer soil (Figure 1.25). In Crosby soil (Figure 1.16), part of the E horizon remains undisturbed below the plowed (Ap) horizon, especially on the right side of the profile.

B Horizons

The mineral horizons below the A and E horizons are called **B horizons**. B horizons are also referred to as subsoil.

B horizon soils have one or more of these distinctive characteristics:

- An accumulation of clay, iron, aluminum, or a combination of these
- A prismatic or blocky structure
- Reddish or brownish colors in better drained soils
- Weak cementation, which results in brittle material

Collectively, we call the A, E, and B horizons the **solum**. If a soil lacks B and E horizons (which may be the case in recent alluvial materials) the solum contains only the A horizon.

C Horizons

Materials that cannot be designated as A, E, or B horizons because they lack soil development are called **C horizons**, or substratum. C horizons can be weathered rock material immediately below the solum that was never transported, or C horizons can be material that was moved by ice, water, or wind.

In most soils, the C horizon is like the material from which the overlying horizons formed. If this is the case, we can say that the C horizon is the parent material of the A, E, and B horizons. Sometimes, the C horizon material is different from the material in which the A, E, and B horizons formed.

R Horizons

Horizons composed of consolidated (hard) **bedrock** (such as limestone, sandstone, or shale) are called **R horizons**. In Indiana, the depth to bedrock varies from a few inches to several hundred feet.

Factors of Soil Formation in Indiana

Remember, the five soil formation factors are: parent material, relief (or topography), climate, organisms (especially vegetation), and time. Here, we provide some examples of these factors as they relate to Indiana soils.

Parent Materials

Parent material is the starting point of soil formation. Parent material largely determines a soil's range of textures (that is, how much sand, silt, and clay the soil will have). The parent material's chemical and mineral properties also affect the natural fertility of the soil it forms.

Indiana soils have many kinds of parent materials. Indiana soils include parent materials such as bedrock that was weathered and mainly remained in place, and they include parent materials that were carried some distance by ice, water, or wind. **Glaciers** (large ice sheets) transported the parent materials of many Indiana soils. The glaciers that covered Indiana were continental glaciers that covered much of the United States. Smaller valley glaciers illustrate glaciation (Figure 1.1). The map of Indiana soil regions (Figure 1.2) is based mainly on soil parent material. Chapter 2: Soil and Landscape Properties presents guidelines for identifying rocks and parent materials.

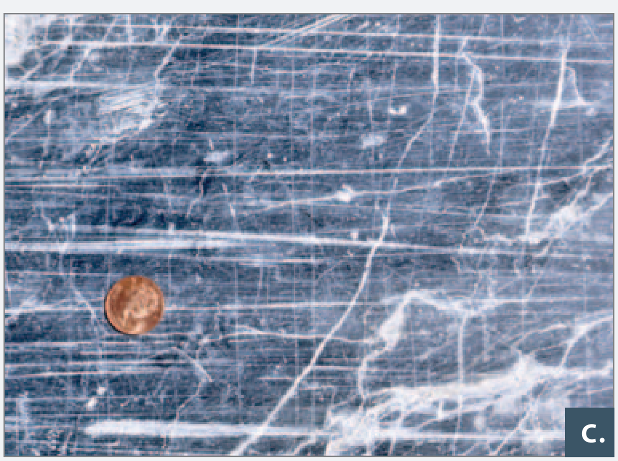


Figure 1.1. *These photos show a glacier (large ice sheet) in Canada and related features.* ***A.*** *The Athabasca glacier is a* valley *glacier and is much smaller than the* continental *glaciers that covered much of the northern United States.* ***B.*** *This meltwater stream flows fast and deposits very coarse material, mainly gravel.* ***C.*** *This photo shows striations (small grooves) on the bedrock over which a glacier has passed. Stones in the glacier scratched the surface of the bedrock. In this case, one set of striations is oriented at right angles to the other set. Apparently, the glacier advanced in one direction, retreated, and then advanced again from a different direction.*

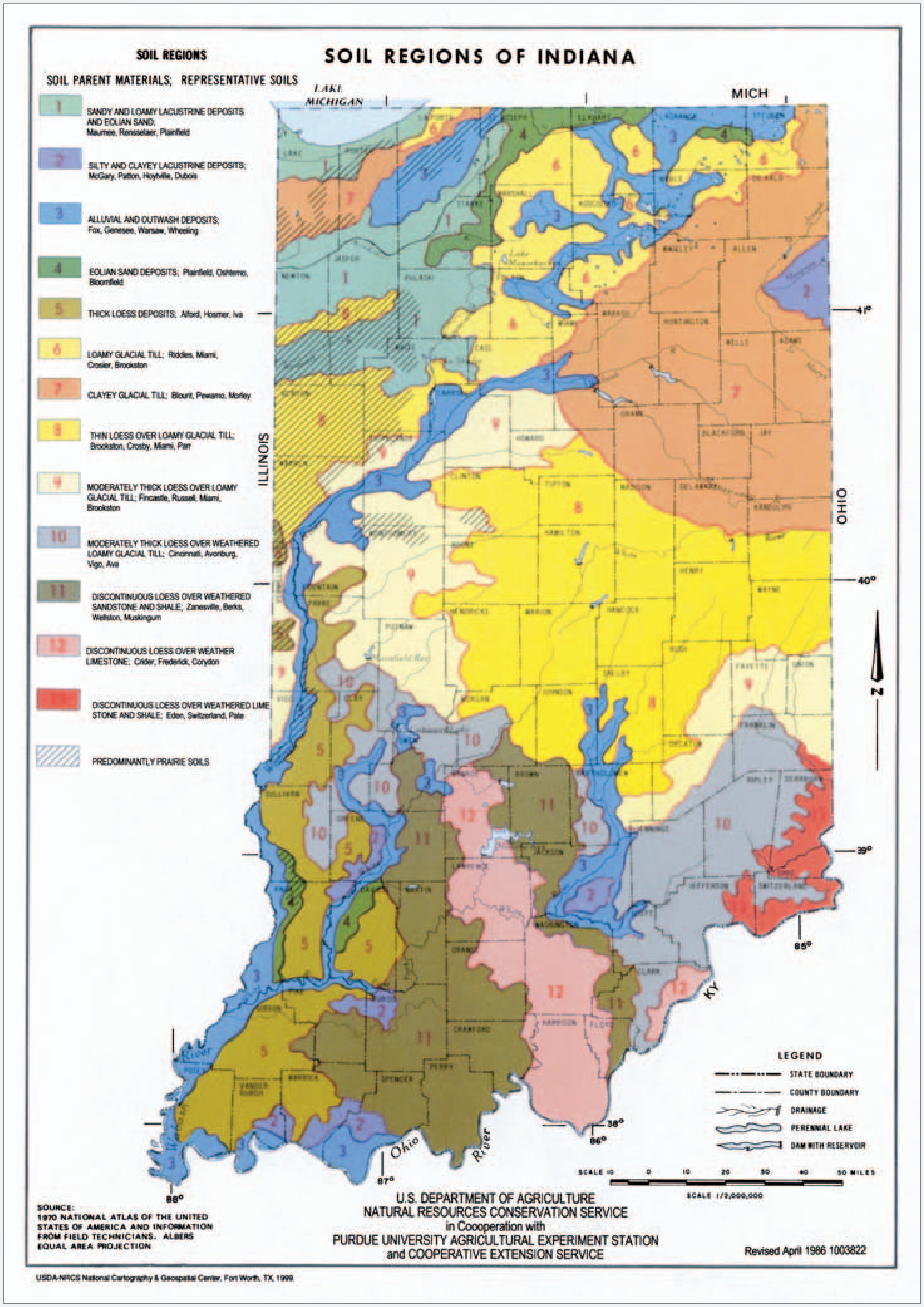


Figure 1.2. *This map shows the various soil regions of Indiana. This figure will be repeated in the Soil Landscapes and Profiles section at the end of this chapter (pages 24-31).*

Before the glacial period, Indiana's **topography** was rather rough and rolling — similar to what you now find in southern Indiana (Soil Regions 11, 12, and 13 in Figure 1.2). That's because ice never covered that part of southern Indiana. The glaciers were hundreds of miles long and hundreds to thousands of feet thick. These massive ice sheets covered most of the state during at least three different ice ages: the (1) Pre-Illinoian, (2) Illinoian, and (3) Wisconsinan Ages.

As the ice moved south, it destroyed old hills and made new ones. The ice carried material with it and buried old valleys. When the ice melted and receded, it left a layer of rock, sand, silt, and clay. Collectively, this left-behind material is call **glacial drift**.

For soil evaluation in Indiana, we recognize eight parent materials:

- Weathered bedrock
- Till
- Outwash and lacustrine deposits
- Eolian sand
- Loess
- Alluvium
- Local overwash
- Other parent materials

WEATHERED BEDROCK

Glaciers never covered south-central Indiana, so the parent material in this area is **weathered bedrock**. Weathered bedrock can further be classified into one of two categories. It is called **residuum** if it is essentially in place, and **colluvium** if it has moved a bit, especially downslope. These distinctions, however, are not made in soil evaluation. Depending on the region, various materials compose the underlying sedimentary bedrock, including:

- Mostly sandstone and shale in Region 11
- Limestone in Region 12
- Limestone and shale in Region 13

A typical soil of these regions would be a Caneyville soil (Figure 1.26) over limestone bedrock or a Trappist soil (Figure 1.27) over black shale.

In several areas, a layer of loess (see page 16) covers weathered bedrock. That loess layer ranges from a few inches to several feet thick. The loess layer is thicker near major rivers and becomes thinner away from the rivers. Loess is also thicker on nearly level uplands. It is thinner on sloping areas because it was eroded during and after the loess was deposited.

The variation in the kinds of soils formed in these areas depends on the type of bedrock, the amount of loess that covers it, and the influence of other factors, such as relief and vegetation. The upper 18 inches of the Trappist soil (Figure 1.27) formed in loess.

TILL

Glacial till (called till in this publication) is material that was deposited directly from the ice of a glacier. Till is a homogeneous mixture of sand, silt, and clay that usually contains gravel and boulders. Till makes up much of the parent material in Soil Regions 6, 7, 8, 9, and 10. In the Miami (Figure 1.15), Crosby (Figure 1.16), and Parr soils (Figure 1.14), the C horizon is glacial till.

OUTWASH AND LACUSTRINE DEPOSITS

Outwash was deposited by water flowing out of melting glaciers. It is composed of particles of varying sizes. The size depends on how fast the water that carried them was flowing. When fast-moving water slowed down, the water deposited the coarser particles as outwash. But the slower moving water continued to carry the finer particles (fine sand, silt, and clay).

Outwash deposits generally consist of layers of sandy and gravelly material. In soils that are formed from outwash, the C horizon typically consists of coarse sand and gravel, and the B horizon is finer in texture, as in the Ockley soil (Figure 1.21). Outwash makes up much of the parent material of Soil Region 3.

Lacustrine (lake bed) materials were deposited by slowly moving or ponded glacial meltwater. The coarser particles dropped out of moving water as outwash, so only the finer particles (fine sand, silt, and clay) remained to settle out of the still lake water. Lacustrine deposits are made of these finer particles.

Soil Regions 1 and 2 contain many lacustrine areas. Lacustrine areas in northern Indiana were deposited during the most recent glacial period (Wisconsinan). Many lacustrine deposits in southern Indiana are older.

EOLIAN SAND

Eolian sand was deposited by blowing winds. As glacial ice receded, there were periods when the flood plains of the glacial meltwater rivers became dry. During these dry periods, wind blew silt and sand particles from the flood plains and carried them toward the upland. The wind carried fine and medium sand particles only a short distance, then deposited in sand dunes close to the flood plain.

Eolian sand is an important soil parent material along the major rivers of southern Indiana, in the area near Lake Michigan, and in the Kankakee Valley — Soil Regions 1 and 4. For example, the parent material of Chelsea soil is eolian sand (Figure 1.22).

LOESS

Loess is the fine, silt material that was deposited by blowing winds. Silt is smaller than sand, so the wind lifted these particles higher in the air and carried them a greater distance from the flood plain than eolian sand.

Loess was blown mainly from the Wabash and White river valleys in central and southern Indiana. Near the river valleys (in Soil Region 5) loess is thick, and the soils formed in it are deep. The Hosmer soil found in Region 5 (Figure 1.25), formed in more than 5 feet of loess. Farther away from these valleys, the loess is thinner but still is the parent material of the upper part of the soil. For example, loess forms the upper horizons of most of the soils in Regions 8, 9, and 10, and of some of the soils in Regions 11, 12, and 13.

ALLUVIUM

Alluvium is parent material that was eroded from soils, transported by water, and deposited on a flood plain relatively recently. These materials are usually stratified (arranged in layers)

The Genesee soil (Figure 1.23) is markedly stratified both in particle size and color. The black color is due to its high organic matter content. Many soils on flood plains do not show this much stratification.

Large areas of alluvial soils are on the flood plains along the major rivers of Soil Region 3. You can also find smaller areas of these alluvial soils along streams in many other soil regions.

LOCAL OVERWASH

Local overwash is a parent material similar to alluvium. The difference is that local overwash was washed into closed depressions (bowl-shaped landforms) from nearby higher areas, not carried in by a stream.

OTHER PARENT MATERIALS

There are other parent materials for soils. For example, some soils formed in **organic materials** (derived from plants).

After the glaciers melted, they left water standing in depressions in outwash, lake, and till plains. Grasses and sedges grew around the edges of these lakes. After these plants died, their residues were preserved in the water and accumulated around the edges of the lakes. Later, white cedar and other water-tolerant trees grew on the areas. As these trees died, their residues also became a part of the organic accumulation.

Eventually, this relatively non-decomposed organic material filled in the lakes. The material is called **peat**. In peat, you can identify specific plant remains. Most peat has decomposed to **muck**, a black humus material in which you cannot identify the source plants.

In Indiana, organic soils are mainly in Soil Region 1, with smaller areas in Regions 3, 6, and 7. Organic soils are not used in soil evaluation contests.

RELIEF

Relief describes the shape of the land surface. Relief influences a landscape's natural drainage, water movement, erosion, plant cover, and soil temperature. In soil evaluations, relief is described by landform and slope gradient.

Relief influences natural soil drainage because the slope and shape of the soil surface determine which soils will lose water and which will gain water by overland flow. Soils on steep slopes lose water while those in depressions gain water. Consequently, soils on steep slopes are usually well-drained regardless of the parent material, while soils in depressions are usually poorly drained. Soils in flat or gently sloping areas may be well-drained if they are permeable and the water table is deep. However, if the water table is held up by slowly permeable material, the soils are wetter.

The ways natural drainage affects soil development is evident if you compare two soils that formed from similar a parent material but under different drainage conditions. For example, the poorly drained Brookston soil (Figure 1.17) and the well-drained Miami soil (Figure 1.15) both formed in loam-textured till. Brookston soils are in depressions and have thick, dark surface layers and grayish subsoils with yellow-brown spots or mottles. In contrast, Miami soils are on sloping areas and have yellowish brown colors in the upper part of the subsoil. This difference in the soil water regime has great implication for using the soil for agriculture and home sites, which we will cover in chapters 3 and 4.

Relief will vary by region in Indiana. Regions 1, 2, 3, 7, 8, and 9 are (for the most part) nearly level, but they do include some sloping areas. Region 10 has nearly level areas broken up by steep slopes or ravines along drainageways. Regions 11 (especially the eastern portion that includes Brown County) and 13 have a large proportion of steep slopes. Regions 4, 5, and 6 are more moderately sloping.

In Region 12, soils overlie limestone bedrock. They are gently sloping and usually have many closed depressions (called sinkholes) that have no surface outlets. Water moves through the bottom of the sinkholes into underground caverns. Streams flow underground through these caverns. Water flows in surface streams only during storms.

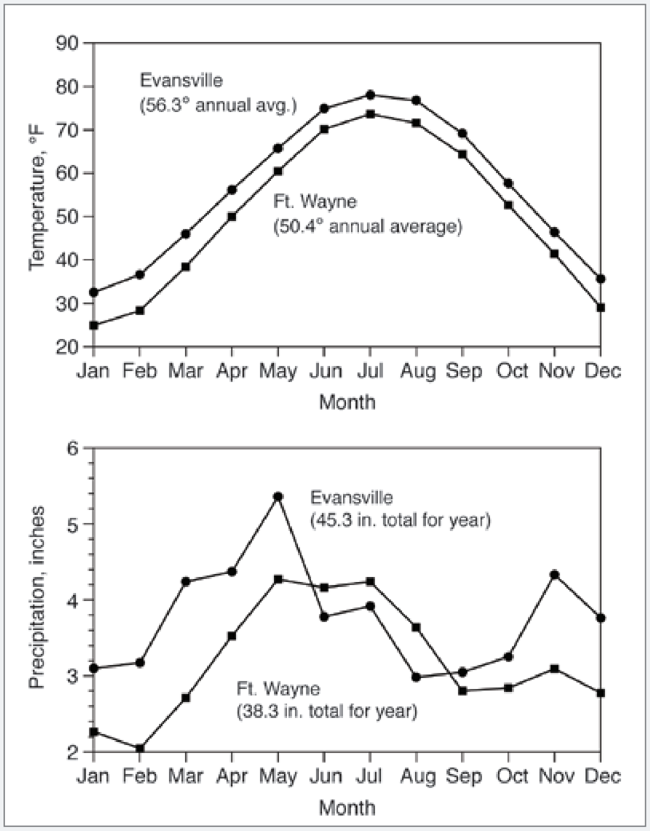


Figure 1.3. *The average annual temperature and precipitation in Fort Wayne (northeast) and Evansville (southwest) Indiana, 1981-2010.* ***Source:*** *National Oceanic and Atmospheric Administration.*

Climate

Climate strongly influences how soils form. For starters, climate determines the plant and animal life on and in the soil. It also determines the amount of water that will be available to weather minerals and transport the materials once they are released. And climate determines temperature, which in turn determines the rate of chemical weathering in the soil.

Indiana's temperatures fluctuate widely from summer to winter — this pattern is typical of mid-continental regions (Figure 1.3). There also are temperature and precipitation ranges between northern and southern parts of the state. Northeast Indiana averages almost 6ºF cooler than southwest Indiana. The amount of precipitation increases as you move from northeast to southwest Indiana.

Central Indiana gets around 38 inches of rain each year (Figure 1.4). About 26 inches evaporates from the soil surface or transpires from plants. The remaining 12 inches either moves off the soil as runoff or moves down through the soil into the groundwater. Water moving through the soil leaches (washes out) many plant nutrients from the surface and subsoil horizons. This means that most soils will require fertilization to achieve good crop yields.

Many soil parent materials contained a great deal of ground-up limestone when glaciers deposited it. But over time, this material has dissolved and leached away — from the top several inches in younger soils to the top several feet in older soils. Consequently, many of our soils tend to be acidic and need to be limed to be agriculturally productive.

Figure 1.4: 

Figure 1.4. *The average annual precipitation in Indiana and how it cycles.* ***Source:*** *Indiana Department of Natural Resources,* The Indiana Water Resource: Recommendations for the Future, *1980.*

Organisms

Many organisms influence soil formation by adding organic matter to the soil. Plant roots and earthworm tunnels also provide channels for water to move through the soil. In Indiana soils, plants have had the greatest influence, but bacteria, fungi, earthworms, animals, and human activity also have been important.

The way organic matter is distributed in a soil depends on the kinds of plants that grew on that soil. Soil bacteria and fungi break down dead plant material. Some of this broken-down material remains in the soil as humus, but some of the material breaks down even further into nutrients that plants can use.

The type of vegetation grown in a soil greatly affects the way it forms. The native vegetation of Indiana consisted mainly of deciduous hardwood forests, prairie grasses, and water-tolerant grasses and sedges. Grasses have large, fibrous root systems, which adds large amounts of organic matter throughout the upper layers of soil each year. As a result, soils that form under grasses have a thick, dark-colored surface horizon. In contrast, forests deposit leaves on the soil surface, which adds organic matter only on top of the mineral soil. As a result, soils that form under forests have a thin, dark-colored surface layer of organic material over a lighter-colored layer (Figure 1.5).

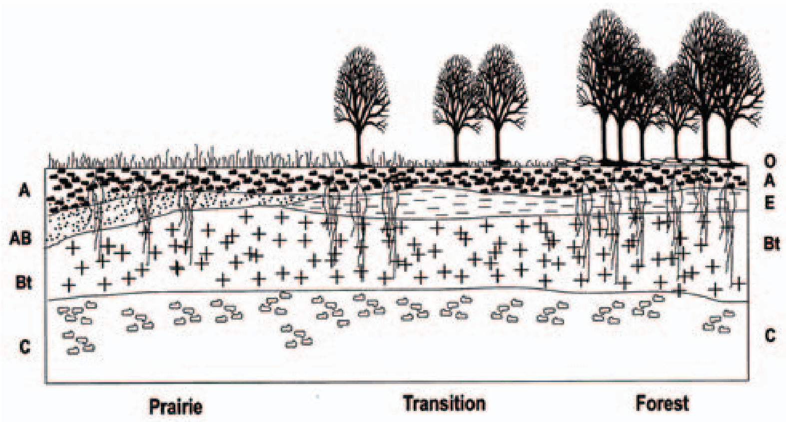


Figure 1.5. *The relationship of soil horizons to vegetation before European settlement.*

Figure 1.6. *This photo shows a landscape with soils formed under forest vegetation. The light gray areas are Crosby soils (Figure 1.16) on swells in which the A and E horizons were mixed by plowing. The dark areas are Brookston soils (Figure 1.17) in depressions in which only the dark-colored A horizon was plowed. The small reddish areas (foreground) represent areas in the Miami soils (Figure 1.15) where enough soil was lost by plowing and erosion that the Bt horizon became mixed in the plowed layer. Notice that there are several small, wooded areas that are remnants of the original forest and were never farmed.*

Figure 1.7. *This photo shows a landscape with soils formed under prairie vegetation. The landscape is similar to the landscape in Figure 1.6, but all soils in this photo are darker in color, because soils formed under prairie vegetation have darker and deeper A horizons than soils formed under forest. This is demonstrated by comparing the Parr soil (Figure 1.14) formed under prairie with the Miami soil (Figure 1.15) formed under forest. In this photo, notice the sharp color changes along straight lines in several places in the photo. The lighter color represents drier soil, and the darker color represents wetter soils. The lighter parts of the field were probably tilled several days before the photo was taken, and the surface had dried. The darker areas were plowed later and the surface was still moist. Also, notice the lack of woodlots in this prairie area.*

The photos in Soil Landscapes and Profiles (pages 24-31) clearly illustrate the influence of native vegetation on soils. Consider the Miami soil (Figure 1.15) and Parr soil (Figure 1.14). The soil-forming factors for both were similar, but the Miami formed under forests while the Parr formed under prairie vegetation. Figure 1.5 shows the Parr soil (left) and the Miami soil. The Parr soil has a deep, dark A horizon. These profile differences reflect how the soil looks from above, as illustrated in the Figures 1.6 and 1.7.

Figure 1.8 shows the distribution of soils formed under forest vegetation and under prairie vegetation. Figure 1.2 also shows the areas that were covered by prairie vegetation when European settlers arrived in the 18th and 19th centuries.

We emphasized the importance of plants, but animals are also important. Crayfish is one animal that is important (Figure 1.9). Crayfish (also called crawdads in Indiana) are small crustaceans that look like small lobsters. They live in fresh water and in saturated soils. They dig burrows that have been observed to go 4 feet or more into the soil. They dig soil out, form it into small pellets and carry the pellets up in the burrow to the soil surface. There, they use the pellets to build

Figure 1.8. *Major areas where soils formed under prairie vegetation and under hardwood vegetation in Indiana.*

Figure 1.9. A. *This field has many crayfish chimneys.* ***B.*** *A crayfish chimney up close. Photo provided by USDA-NRCS, Indiana.*

a hollow structure called a chimney. Crayfish are found in many wet soils in Indiana, but are especially abundant in soils with fragipans (Soil Region 10, Figure 1.2). They eat mainly dead plant material such as leaves.

Time

Time is a very important factor in soil formation. It usually takes a long time — hundreds or thousands of years — for soil horizons to form in parent materials. The longer a soil surface has been exposed to soil-forming agents like rain and growing plants, the greater the development of the soil.

Glaciers never covered some areas of the state (soil Regions 11 and 12). In these areas, the landscapes may be hundreds of thousands of years old. Some of the soils in these regions were eroded and then covered with loess around 20,000 years ago.

During the **Illinoian Age**, Regions 5 and 10 were glaciated and then covered with loess. In Region 5 the loess is so thick that the entire soil formed in loess. In Region 10 the loess is thinner and soils formed in loess and in till.

During the **Wisconsinan Age**, glaciers covered the northern two-thirds of the state (Soil Regions 1-9). The glaciers reached the southern boundary of these regions around 24,000 years ago. Then the glaciers advanced and retreated, and left the state (never again to return) around 15,000 years ago. As a result, the ages of the soils within Regions 1 to 9 become younger from south to north.

The soils in Region 3 are along rivers on terraces and flood plains. The flood plains are very young.

Soil-forming Processes in Indiana

Previously, we mentioned eight main soil-forming processes. Here we describe these processes and provide photos to illustrate them:

- Carbonate minerals (ground limestone or "lime") dissolve
- Other minerals weather
- Some materials that were released in weathering leach from the soil
- Clay moves down the profile
- Organic matter accumulates in surface horizons
- Iron oxide minerals form
- Soil particles weakly cement together
- Soil structure forms

Carbonate Minerals Dissolve

Carbonate minerals are so named because they contain the carbonate ion (CO_3^{2-}). In most Indiana soils, these carbonates and some bases (such as Ca^{2+}) have been leached (washed downward) by weak acid solutions from the upper part of the profile. This leaching helped develop soil horizons.

The soil evaluation site card (see page 147) lists the depth to the uppermost carbonate minerals in the soil. For example, if the site card reads, "Calcareous below 30 inches," that means that all carbonate minerals have been leached out of the upper 30 inches of soil.

In the Miami soil (Figure 1.15), the C horizon contains lime. It has been dissolved out of the A, E, and B horizons. The presence of lime means that the soils is calcareous.

Other Minerals Weather

Minerals weather by physical and chemical action. In physical weathering, ice and water transport rocks and minerals and break them down into smaller pieces in the process. Freezing and thawing also break larger particles into smaller ones. In chemical weathering, some minerals are transformed into other minerals, such as clay minerals, which remain in the soil. Other minerals are transformed into soluble products. For example, when the mineral biotite weathers, it releases some potassium that is available for plants to use.

Some Materials Leach from the Soil

Some of the soluble material released by chemical weathering moves downward in the soil profile, out of the soil entirely, and eventually travels to streams. Creeks and rivers (even those in areas where no chemical fertilizers are applied to soils) contain some soluble forms of calcium, magnesium, iron, potassium, and other elements that weathered from soil minerals. Streams in agricultural areas also contain significant amounts of chemicals that were applied as fertilizers, as will be explained in Chapter 3: Agriculture Practice (page 66).

Clay Moves Down

After the carbonates have leached out, water movement washes clay from upper horizons and deposits it in the subsoil. Some of the clay gets deposited as films (**clay skins**) in the pores between soil particles and on the structural surfaces along which water moves.

In Indiana soils, carbonate leaching and clay translocation are among the most important soil horizon formation processes. In the Miami soil (Figure 1.15) and many other soils in Soil Landscapes and Profiles (pages 24-31), Bt horizons contain more clay than those above and below the Bt.

Organic Matter Accumulates

Organic matter that accumulates in surface A horizons makes them dark. In many poorly drained soils that were formed under prairie or forest, the organic matter accumulated because water logging prevented it from being oxidized or consumed by soil organisms. In better drained prairie soils, the organic matter accumulated because of the nature of the root system. This is especially evident in the A horizon of the Parr soil (Figure 1.14), and evident in all other A horizons.

Iron Oxide Minerals Form

Iron oxide minerals are brownish or reddish. They precipitate when oxygen is present, so they are more common in better drained soils. These minerals are usually very small and cover larger clear or grayish clay, silt, and sand grains — like sesame seeds on a bun. Because iron oxides are on the surface of other minerals, they are responsible for the brownish and reddish colors of many soil horizons illustrated in Soil Landscapes and Profiles (pages 24-31). Natural Soil Drainage (page 57) provides details about the relation of soil color and soil wetness.

Soil Particles Weakly Cement Together

The term "cemented" means stuck together. Some horizons in Indiana soils are weakly cemented. Some horizons in the desert are strongly cemented and are almost as strong as concrete. Cementation is identified more by how a soil feels than how it looks.

Silica (SiO_2), iron, or carbonates cement some soil horizons. Silica is the primary cementing mineral in fragipans such as the Bx horizon of the Hosmer soil (Figure 1.25). Silica cementation, however, is much stronger in Southwest United States than in Indiana. Other compounds provide minor cementation in Indiana. In some sandy soils, iron (Fe) minerals cement small chunks in B horizons. On some hillslopes, water that contains dissolved carbonates seeps out to the surface. When the water evaporates, the remaining carbonate minerals cement soil particles together to form a concrete-like mass.

Soil Structure Forms

Soil structure is the grouping of individual soil particles into clusters or **aggregates,** called **peds**. Many peds have thin surface films of clay (Figure

Figure 1.10. *This photo shows Crosby soil in the lower Bt horizon. Note the clay skins (left).*

Figure 1.11. *This photo shows Crosby soil in the upper Bt horizon. Note the silt coats (the lighter colored surfaces).*

1.10) or silt (Figure 1.11) that make the ped more distinctive. These **clay skins** and **silt coats** are often a different color than the inside of the ped.

Soil scientists describe soil structure by noting the shape, size, and strength of peds. Figure 1.10 illustrates several different soil ped *shapes*. In many Indiana subsoils, peds are subangular blocky (shape) and 0.5 to 2 inches in all directions.

STRUCTURE SHAPE

Soil structure determines the amount and arrangement of empty spaces in the soil. This greatly influences on how readily water moves through the soil and where plant roots can grow. When the soil is saturated (holds all the water it can), water moves down the cracks and pores in the soil. Roots also penetrate through these open spaces. A ped's shape influences the path water and roots must take to get through the soil (Figure 1.12). Structure is best understood by comparing that figure with what you see in the field.

The six common soil structures shapes are:

1. Prismatic
2. Columnar
3. Angular blocky
4. Subangular blocky
5. Platy
6. Granular

The photo of Miami soil (Figure 1.15) illustrates an example of *prismatic* structure in the Bt2 horizon. Prisms are higher than they are wide. In the Bt2 horizon the cleavage or fracture surfaces (emphasized by shadows) are higher than they are wide, which is evidence of a prismatic structure. The photos of the Glynwood (Figure 1.18) and Blount (Figure 1.19) soils also show prismatic structure in the Cd horizons. The left sides of the figures show many flat prism faces. The right sides show many cuts through the faces. Prismatic structure is best demonstrated by prying loose prismatic peds in the field. In this soil, the prisms may break into blocks.

A **fragipan** is a subsoil horizon that has a brittle consistency and limits root growth and water movement. Fragipans have a special kind of *prismatic* structure. The prisms are large and coated with a gray silty material. If you look at a horizontal surface from above, the prism coatings form a polygonal (many-sided) pattern, like you might see on a giraffe's coat or in chicken wire (Figure 1.13). If you look at a vertical surface, the prism coatings look like vertical gray streaks in a cut surface (Bx horizon on the right side of the Hosmer soil photo in Figure 1.25). They show as gray faces in a chipped surface (Bx horizon on the left side of Figure 1.25).

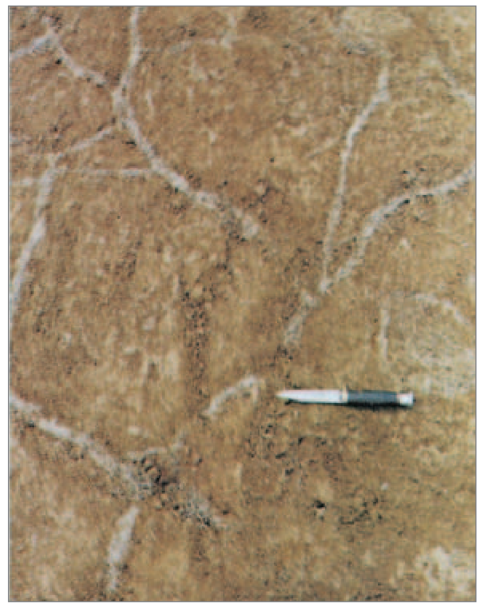


Figure 1.13. *This photo shows a horizontal section through a fragipan in Zanesville soil.*

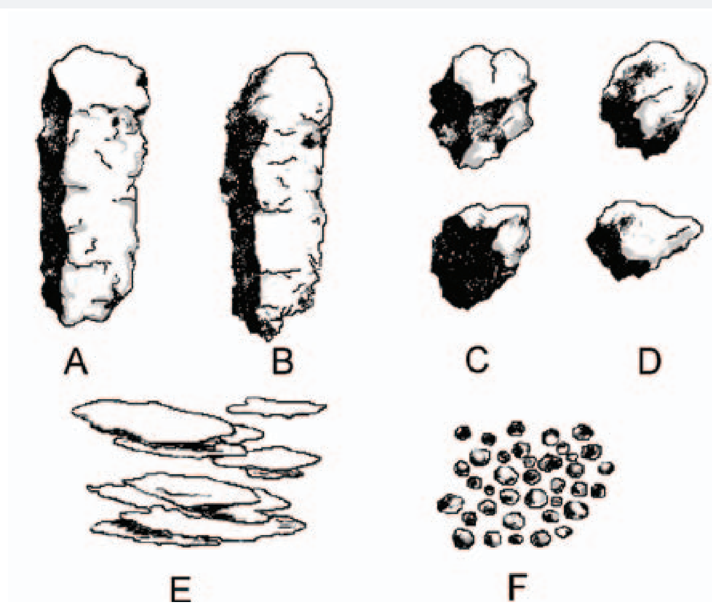


Figure 1.12. *The common shapes of soil structure.* ***A.*** *Prismatic.* ***B.*** *Columnar (rounded top).* ***C.*** *Angular blocky.* ***D.*** *Subangular blocky.* ***E.*** *Platy.* ***F.*** *Granular.* ***Source:*** *USDA,* Soil Survey Manual*, 1951.*

Blocky structure is illustrated in many Bt horizons in which part of the horizon has been picked with a knife to show structure. The vertical and horizontal dimensions of blocks are about the same. The upper Bt horizon of the Crosby soil (Figure 1.11) has fine blocky structure, but the lower Bt (Figure 1.10) has medium and coarse blocky structure.

The Parr soil (Figure 1.14) has a *granular* structure in the A horizon, but the individual granules are too small to see in the photograph.

The E horizon of the Miami soil (Figure 1.15) shows a *platy* structure. Tillage or other traffic often compacts such horizons.

Granular and blocky peds are about the same size in all directions. In prismatic peds, the long direction is vertical and the cracks between peds are mainly vertical, the same direction that roots and water move. In platy structure, however, the long direction is *horizontal* so roots or water first move downward between peds, and then must move horizontally across the plates before they find another vertical space — like following the mortar between bricks. This complex path retards water movement and root growth.

STRUCTURE SIZE

A ped's size determines the distance between the natural cracks. For example, soils such as Brookston have a prismatic structure in which many of the prism-shaped peds are about 0.5-1 inch across. On the other hand, fragipan soils (such as Avonburg) have prisms more than 4 inches across. Thus, Brookston with its smaller prisms has many more cracks through which roots can penetrate and water can flow.

STRENGTH OF SOIL STRUCTURE

Strength of development is yet another aspect of soil structure. In strongly developed structures, the peds are quite obvious, and the soil breaks up readily into peds when you dig into them or pick them with a knife or spatula. Often, soil peds have coatings, such as clay films. In weakly developed structures, the peds are less apparent.

The strength of structure development is very important in surface horizons. When raindrops hit a horizon with weakly developed structure (such as the gray surface layer of poorly drained soils on flat landscape positions as with Clermont and Cobbsfork soils), the drops destroy the structure. Individual soil particles are released and they plug up soil pores and prevent water from entering the soil. When the soil dries, it has a strong surface crust that may prevent seedlings from emerging. A soil with a strong structure, such as the dark surface layer of a prairie soil (Parr), will better withstand raindrop impact and not seal and crust so much.

Further Information

The fourth chapter of *The Natural Heritage of Indiana* (edited by Marion T. Jackson, 1997, Indiana University Press) provides general information about Indiana soils. This book also has many other chapters about Indiana's natural resources and cultural heritage.

You can find specific information about soils in county soil survey reports (printed copies). These reports are available for all counties from your Purdue Extension county office (extension.purdue.edu/pages/countyoffices.aspx) or your Soil and Water Conservation District office (iaswcd.org/contact-your-local-swcd). The USDA's Web Soil Survey (websoilsurvey.nrcs.usda.gov) has the same basic information as the soil survey reports. It is in electronic format and is updated periodically.

Soil Explorer (soilexplorer.net) shows the geographic distribution of some features discussed in this chapter for Indiana and several other states. For example, by clicking on a certain location in the state, you can learn about the dominant parent material and topography for that location. You can also learn about natural soil drainage, fragipans, and acid subsoils, which are discussed in subsequent chapters. Using this website will provide a good preview of contests held in locations that are unfamiliar to you.

Soil Landscapes and Profiles

The figures on the following pages show a soil map of Indiana (Figure 1.2) and 14 soil profiles (Figures 1.14-1.27).

The explanations for Figures 1.14-1.27 (including the scale on the tape that shows depth) appear on pages 30-31.

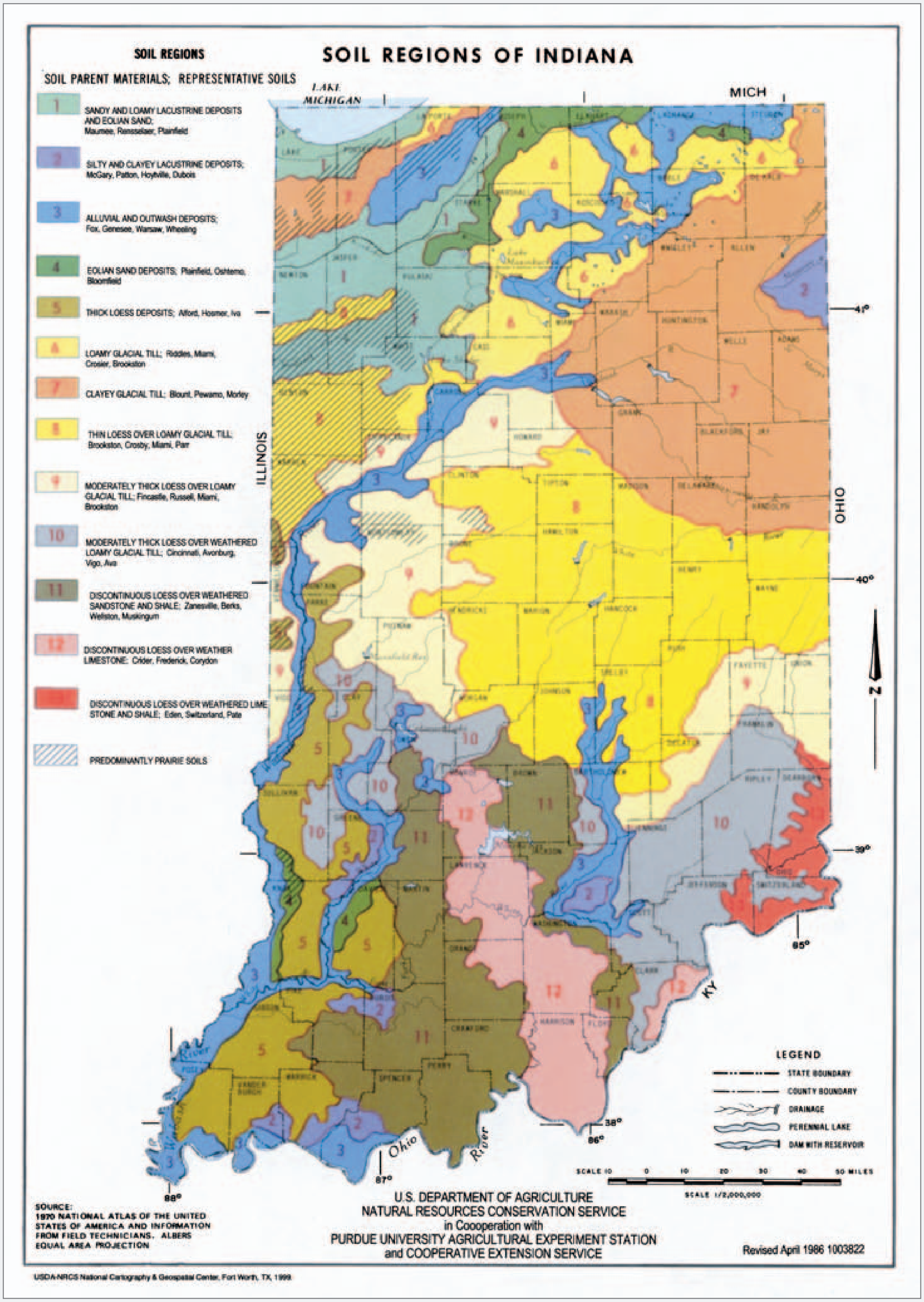


Figure 1.2. *This map shows the various soil regions of Indiana. This figure is a repeat from the one that appears on page 14.*

► The soils on this page are common in Soil Region 8 (see Figure 1.2). The Parr soil is mainly in the cross-hatched part of Region 8. The soils in Regions 6 and 9 look similar to those on this page.

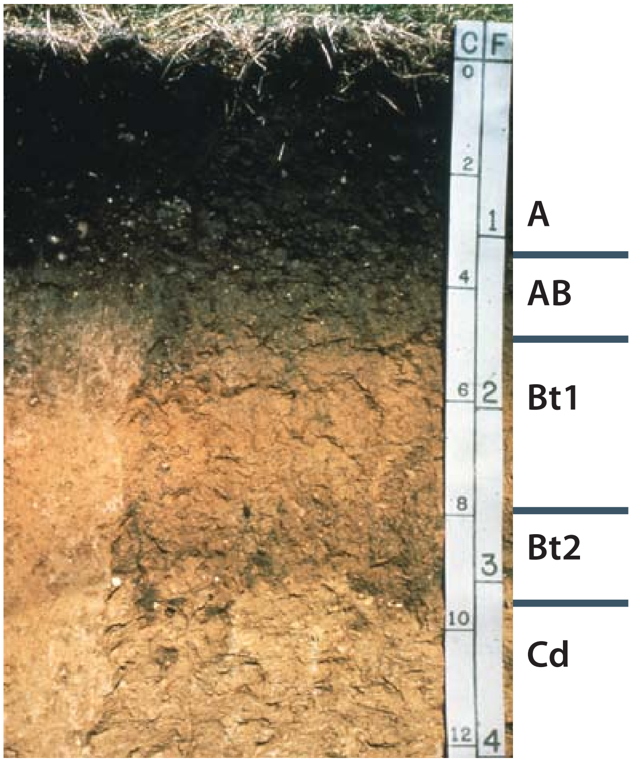


Figure 1.14. *Parr loam.*

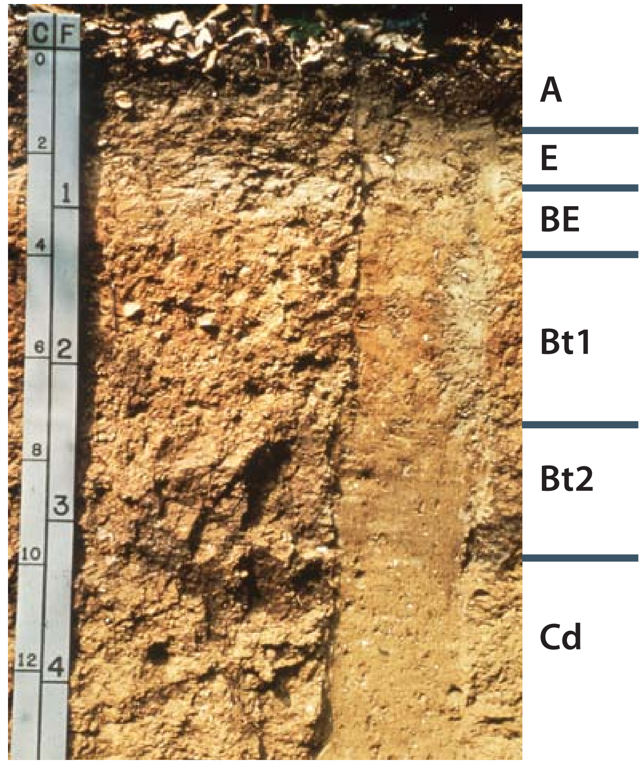


Figure 1.15. *Miami silt loam.*

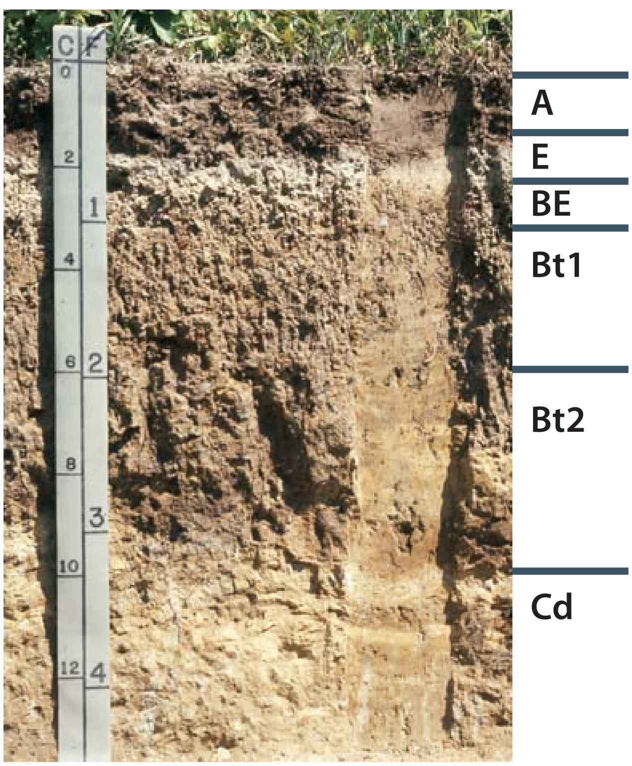


Figure 1.16. *Crosby silt loam.*

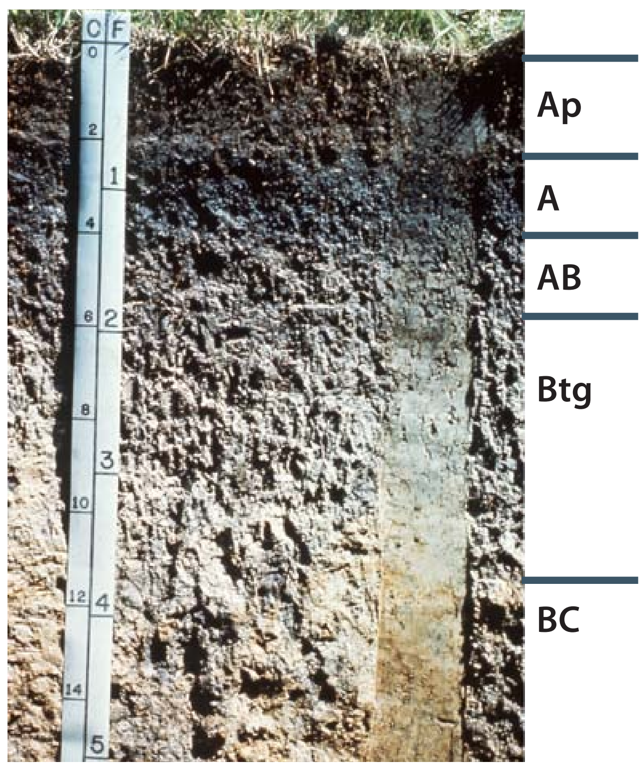


Figure 1.17. *Brookston silty clay loam.*

► The soils on this page are common in Soil Region 7 (see Figure 1.2). The landscape positions of Glynwood, Blount, and Pewamo are similar to the positions of Miami, Crosby, and Brookston, respectively, shown on the previous page.

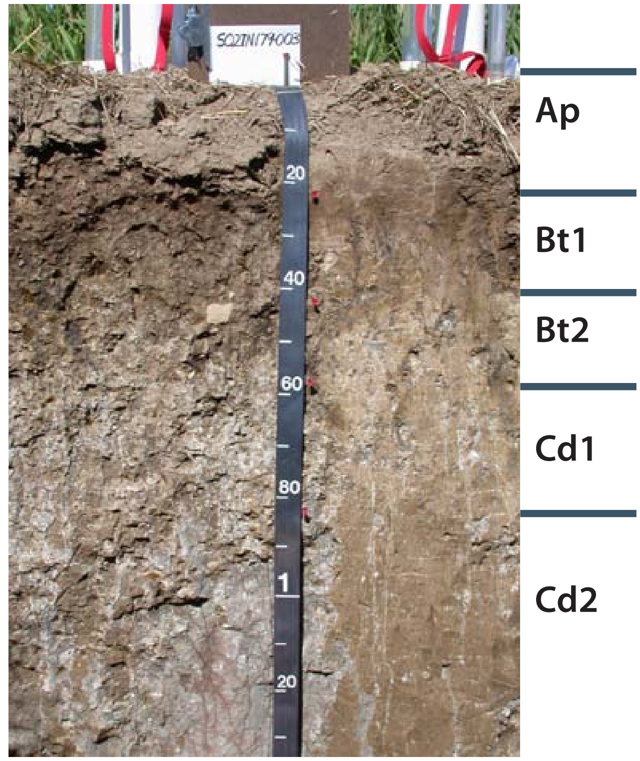


Figure 1.18. *Glynwood silty clay loam.*

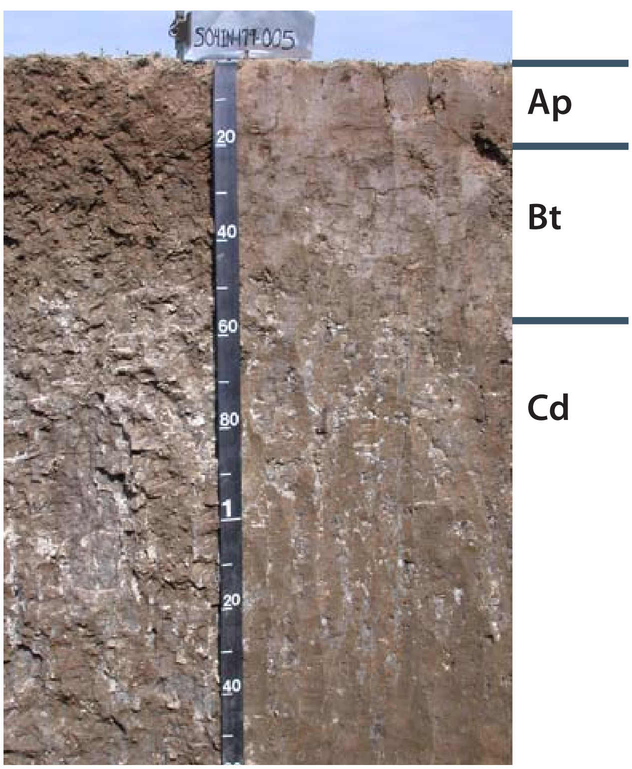


Figure 1.19. *Blount silty clay loam.*

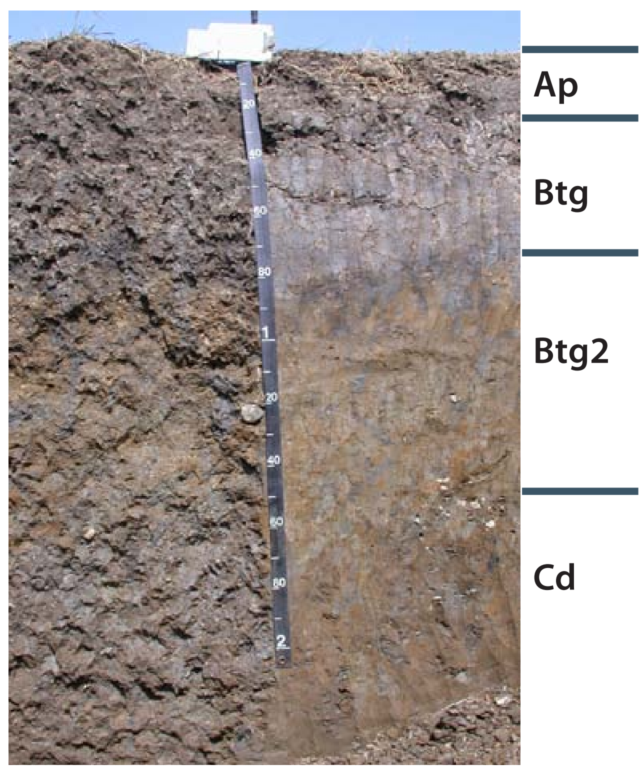


Figure 1.20. *Pewamo silty clay loam.*

▶ The soils on this page are mainly along rivers and streams — Soil Region 3 (see Figure 1.2). Genesee is on flood plains near streams, Ockley is on terraces, and Chelsea is on sand dunes.

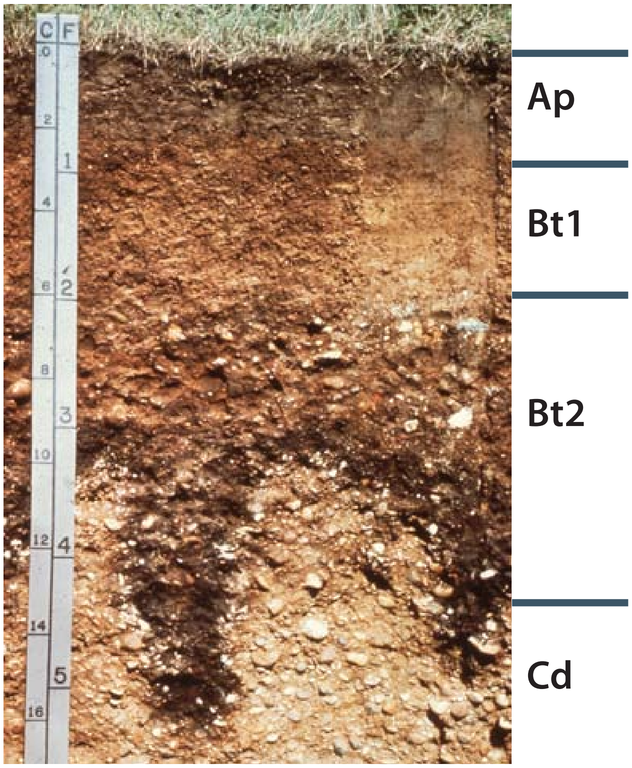


Figure 1.21. *Ockley silt loam.*

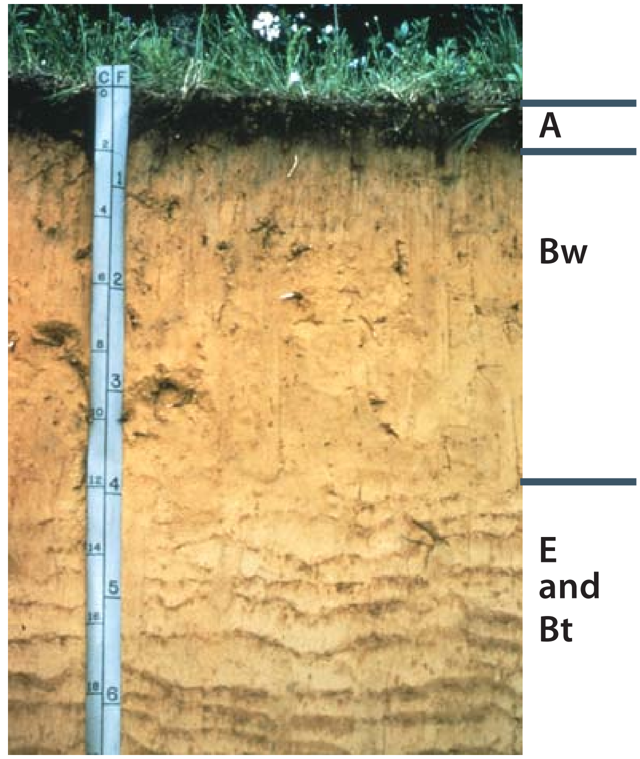


Figure 1.22. *Chelsea fine sand.*

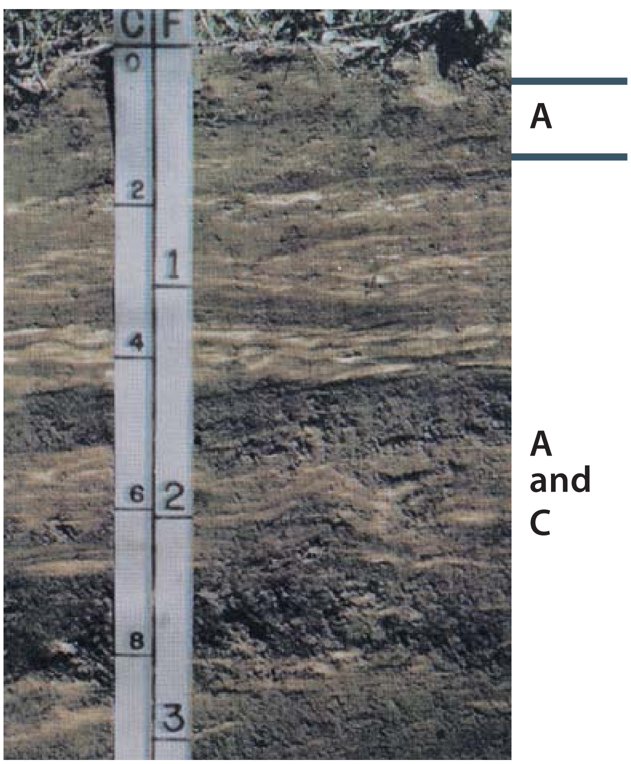


Figure 1.23. *Genesse loam.*

▶ These soils are in southern Indiana. Alford and Hosmer are in loess deposits in the southwest, Soil Region 5, Trappist represents Soil Region 11, and Caneyville represents Soil Region 12 (see Figure 1.2).

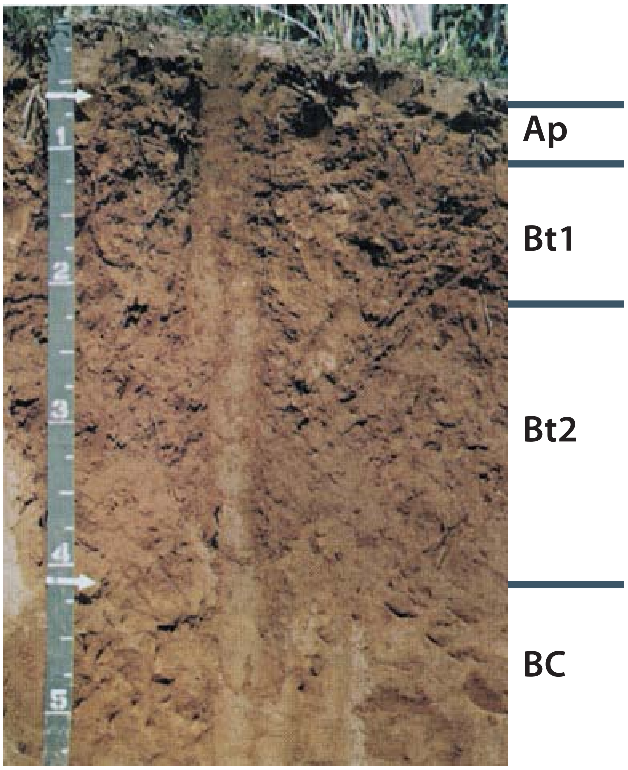


Figure 1.24. *Alford slit loam.*

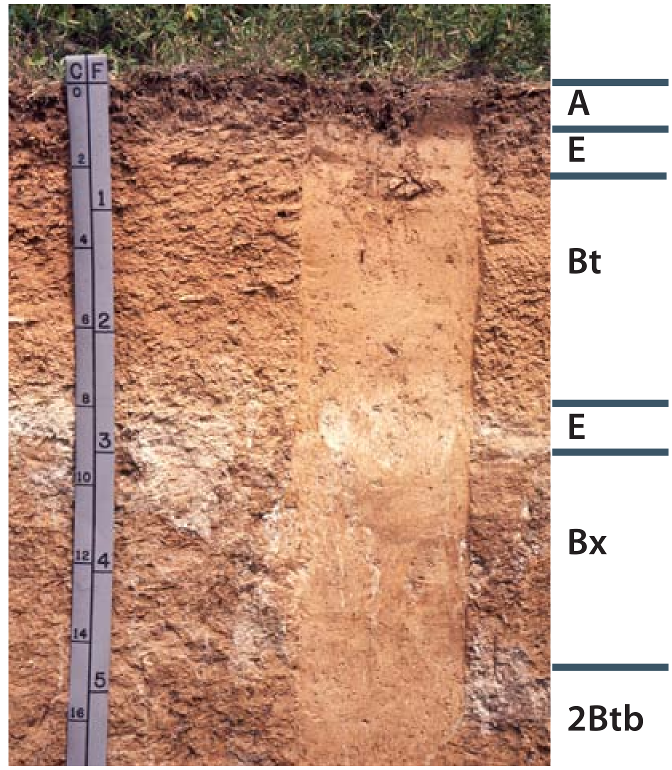


Figure 1.25. *Hosmer silt loam.*

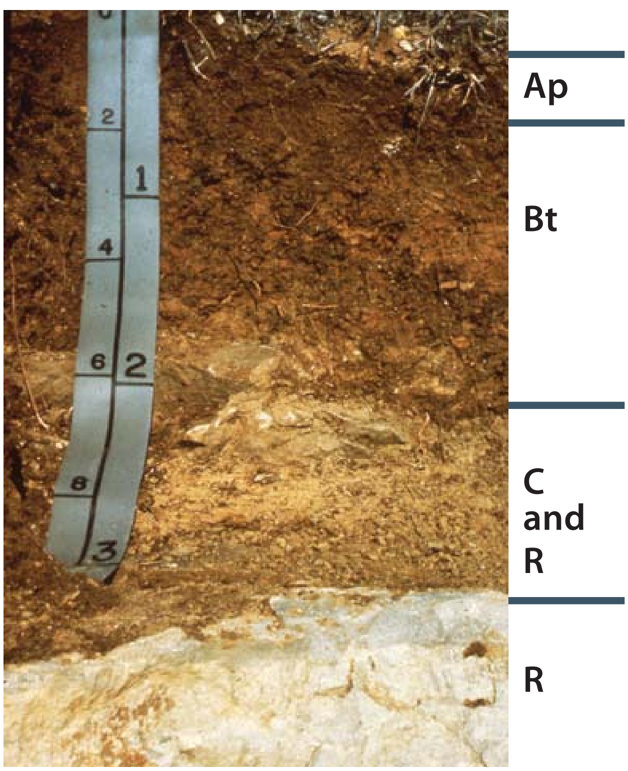


Figure 1.26. *Caneyville silty clay loam, eroded.*

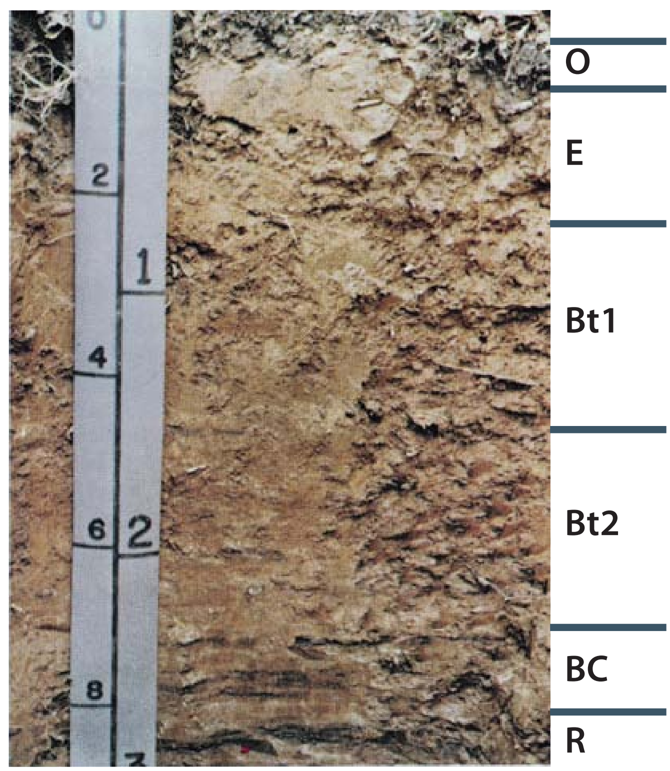


Figure 1.27. *Trappist silt loam.*

Explanation of Figures

The captions below provide more details about the soils shown in Figures 1.14-1.27.

Figure 1.14. *Parr loam. This soil formed under prairie vegetation. Notice the thick, dark A horizon. The soil formation other than vegetation (organisms) are similar to the Miami soil. The scale is decimeters (C) and feet (F). This soil is typically on sloping areas of till plains.*

Figure 1.15. *Miami silt loam. This soil developed under forest vegetation. The soil in this figure has never been plowed. It has an E horizon with platy structure below the dark A horizon. Note the clay films on the faces of the peds around 3 feet deep in the part of the profile that shows natural structure. The C horizon is glacial till. The scale is decimeters (C) and feet (F). This soil is typically on sloping areas of till plains.*

Figure 1.16. *Crosby silt loam. On the left side, the soil has been picked with a knife to show soil structure. The soil on the right has been cut with a spade. Much of the original E horizon remains below the Ap horizon. In the Bt horizon, the left side of the photo shows clay skins on ped surfaces. These surfaces are darker than the insides of peds shown in the cut surface on the right. The Cd horizon shows a bit of stratification which is not common in till. The scale is decimeters (C) and feet (F). This soil is typically on swells of till plains.*

Figure 1.17. *Brookston silty clay loam. The plow layer (Ap horizon) is not quite as dark as the A horizon below it. This may be because some light-colored Ap material was eroded from the adjacent Crosby soils, deposited on the Brookston surface, and then mixed by tillage. The cut part of the profile (right) shows the interior of soil peds. The left part, picked to reveal soil structure, shows the ped coatings, which are mainly on vertical ped surfaces. The scale is decimeters (C) and feet (F). This soil is typically in depressions of till plains.*

Figure 1.18. *Glynwood silty clay loam. This soil formed on landscape positons similar to the Miami soil, but the Glynwood soil formed from finer-textured till so all of its horizons contain more clay than similar horizons in Miami. All horizons in Glynwood also have slower permeability than those in Miami, so the Glynwood soil is moderately well-drained rather than well-drained. The units on the tape are meters and centimeters.*

Figure 1.19. *Blount silty clay loam. This soil formed on landscape positons similar to the Crosby soil, but the Blount soil formed from finer textured till, so all of its horizons contain more clay than similar horizons in Crosby. All horizons in Blount also have slower permeability than those in Crosby. The units on the tape are meters and centimeters.*

Figure 1.20. *Pewamo silty clay loam. This soil is typically in depressions, similar to Brookston s. It is usually much deeper than the nearby Blount and Glynwood soils because much soil material has eroded from these soils and was deposited in the depressions where Pewamo formed. The units on the tape are meters and centimeters.*

Figure 1.21. *Ockley silt loam. This soil formed from loess and loamy outwash over sand and gravel outwash deposits. The lower boundary of the Bt3 horizon is very irregular, with "tongues" of Bt3 material extending into the C horizon. The dark color of the Bt3 horizon is caused by the deposition of clay and organic matter leached from the horizons higher in the profiles. The scale is decimeters (C) and feet (F). The Ockley soil is usually on terraces and outwash plains.*

Figure 1.22. *Chelsea fine sand. This soil formed in sand dunes. Below 4 feet are thin bands that have slightly more clay content than the material between them. These bands are the Bt part of the horizon, and the material between them is the E part. The scale is decimeters (C) and feet (F).*

Figure 1.23. *Genesse loam. This soil formed by alternate deposition of dark-colored alluvial material high in organic matter and light-colored material low in organic matter. Both types of material were carried in by flood water. The bands of different colors are more pronounced in this particular soil than in most flood plain soils. The scale is decimeters (C) and feet (F).*

Figure 1.24. *Alford slit loam. This Alford profile formed in deep loess deposits. It has no restricting layers and holds much water for use by plants. The scale is feet (F).*

Figure 1.25. *Hosmer silt loam. This soil has a fragipan between 3 and 5.5 feet. The nearly white colors on the left side of the Bx horizon and in the lower right corner of the photograph are from silt coatings on the faces of prisms. The whitish vertical streaks in the cut surface are from prism faces at right angles to the surface. A top view of these coatings is shown in Figure 1.13. the scale is decimeters and feet.*

Figure 1.26. *Caneyville silty clay loam, eroded. This profile illustrates a soil with limestone bedrock at about 3 feet deep. The reddish color in the Bt horizon is typical of soils over limestone. The scale is decimeters (C) and feet (F).*

Figure 1.27. *Trappist silt loam. The Trappist soil formed from loess and weathered black shale. The BC horizon still shows the layered structure of the shale, but it is soft enough to cut with a knife or spade, and roots are growing in it. Below 33 inches, the rock is harder and roots do not penetrate it, making that the limiting layer. The scale is decimeters (C) and feet (F).*

CHAPTER 2 – Soil Properties

Overview of Soil Evaluation and Judging

Professionals who manage soils first evaluate soil properties, and then judge which practices are most suitable for that soil.

Evaluate means to determine the quality of something.

Judge means to form an opinion about something after careful thought.

Students use the same processes as the professionals. In soil contests, students first evaluate soil properties, and then judge which practices are most suitable for that soil. They do this in competitions to make the process more interesting. This chapter will explain how to evaluate soil properties. Chapters 3 and 4 will deal with *judging* the suitability of some agriculture and home site practices.

Soil Evaluation and Judging Procedures

In soil competitions, there are several things each student should be aware of, including the procedure at the soil pit, the site card, and the scorecards.

SOIL PIT

A soil pit is the core of soil contests. This section explains the nature of the pit and the procedure at it. We will explain some of the terms we use here later in this chapter.

The best way to understand the process is to participate in a contest. Contest organizers dig a pit with a backhoe to a depth of about 45 inches. The operators pile all the spoil (material dug from the pit) on one side of the pit, and that is the side of the pit where organizers make determinations.

Contestants gather on the other side of the pit. Usually, soil properties vary along the observation side, so the official judges mark the area where they determine soil properties with yardsticks nailed to the side of the pit (Figure 2.1). Organizers mount the site card on a sign board above this area (there is a blank site card on page 147). In order to allow all contestants to see the same soil profile, no one is allowed to dig between the yardsticks during a contest. Usually, there are four pits in a contest (two for agriculture and two for home sites), and groups of contestants rotate among the pits.

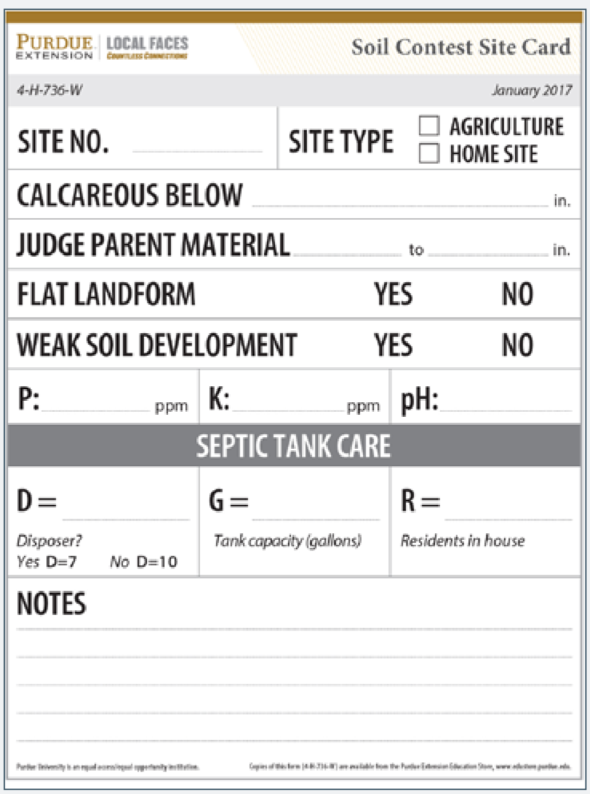
Figure 2.1. *This is a soil pit ready for evaluation. It has two evaluation areas marked with yardsticks because it was for a large contest. Most pits have one area.*

TIME AT SITE

Organizers allow contestants a certain length of time in the pit, so contestants must take turns getting into the pit. Before entering the pit, contestants can read the site card or observe features in the side of the pit such as stratification (layers of material), soil horizons (layers formed after the material was deposited), color of the soil profile and spoil, shape and size of stones and boulders, and general positon in the landscape. Once in the pit, contestants usually collect samples to determine texture and color outside the pit (to allow other students to get into the pit). Sometimes, organizers place soil material in a box or bucket for contestant use. Contestants use slope stakes near the pit to determine the percent and the shape of the slope.

SITE CARD

At each soil evaluation contest pit, there will be a **site card** posted on a signboard (Figure 2.2 and on page 147). The site card provides essential general information, such as the site number, and whether the soils are to be judged for agriculture or a home site.



PURDUE EXTENSION | LOCAL FACES COUNTLESS CONNECTIONS

Soil Contest Site Card

4-H-736-W

January 2017

SITE NO. ________ SITE TYPE ☐ AGRICULTURE ☐ HOME SITE

CALCAREOUS BELOW ________ in.

JUDGE PARENT MATERIAL ________ to ________ in.

FLAT LANDFORM YES NO

WEAK SOIL DEVELOPMENT YES NO

P: ________ ppm K: ________ ppm pH: ________

SEPTIC TANK CARE

D = ________ G = ________ R = ________

Disposer? Yes D=7 No D=10

Tank capacity (gallons)

Residents in house

NOTES

Figure 2.2. *The site card provides essential information for soil evaluation. Read it carefully.*

For evaluating soil properties, you will need to know the depth at which to evaluate parent material and the depth to calcareous material. For agriculture and home sites, the site card lists soil fertility information. For home sites, the site card also lists information about on-site sewage disposal. The site card also provides extra information under Notes.

Some properties, such as *degree of development* and *flat landscape* (defined later), are difficult for students to determine so official judges state their decisions on the site card.

SCORECARDS

Depending on the competition, the student will complete an agriculture scorecard (page 149), a home site scorecard (page 150), or both. The soil properties are the same for both scorecards (they appear on the left side of the cards). The soil practices differ (they appear on the right side of the cards). The scorecards identify specific properties and practices by a number-letter system. Circle your answer on the scorecard, circle. For example, if you chose a dune landform, circle **6D**, and if your answer is "Yes" for No-till, circle the "A" after 27 (**27A**). If organizers use electronic grading, they will give specific instructions at the contest.

CRITIQUE SESSION

After you complete your evaluations and all the competitors submit their scorecards for grading, the official judges will give their answers in the pit. They will also answer questions about properties and practices. Many teachers review the contest with their students after the critique session (Figure 2.3). We encourage you to actively participate in these sessions to help you improve in future contests.

Figure 2.3. *An instructor points out soil properties to his students in a soil contest pit.*

Soil-Landscape-Water Relations

Water moves in soil profiles and landscapes, and a soil's water status affects many agriculture and home site uses. In this section, we discuss soil-landscape-water relations and how soil water conditions are reflected in **soil morphology**, especially color.

Hydrology

Hydrology is the branch of science concerned with the properties of water and its movement. Here, we discuss hydrology as it relates to soils and landscapes. Figure 2.4 illustrates the **hydrologic cycle**. Later in this publication, we will return to many of the terms we introduce here. Precipitation falling from the atmosphere onto the soil surface moves *into* the soil by the process of **infiltration**. It then moves *through* the soil by **percolation**. Water held in the pores of soil or geologic material is **groundwater**. The process of adding water to the groundwater supply is called **recharge**.

In Figure 2.4, the upper part of the soil is **unsaturated** (the **pores** are filled with water and air). Farther down, the soil becomes **saturated** (pores are filled with water only). The upper surface of saturated soil is the **water table.** When you see a soil pit with water in it, the water surface is a continuation of the water table in the soil. The soil above that level is unsaturated, and the soil below that surface is saturated. The level of (or depth to) the water table is a very important soil property for agriculture and home site soil use.

Technically, groundwater incudes the water in pores of saturated and unsaturated soil, but most groundwater occurs in saturated soil. Groundwater moves mainly downward, but it also moves sideways and upward until it reaches a stream (Figure 2.4). Water in ditches, creeks, rivers, lakes, oceans, and other bodies is called **surface water**. The surface of water in a stream or lake is a continuation of the water table.

Some water in the soil *evaporates* directly to the atmosphere and some water is taken up by plants, which then *transpire* that water to the atmosphere. Together, these two processes are called **evapotranspiration**, which completes the hydrologic cycle.

In Figures 2.4 and 2.5, the water table is at a definite level. In reality, a water table's level varies greatly throughout the year. It is usually lowest in the fall, about the time trees lose their leaves and many plants become dormant or die and no longer take up water. It is usually highest in late spring, just before plant growth begins. But large rain storms or a prolonged drought modify this pattern. In spite of this variability, however, there is a level to which the water table tends to return in the spring

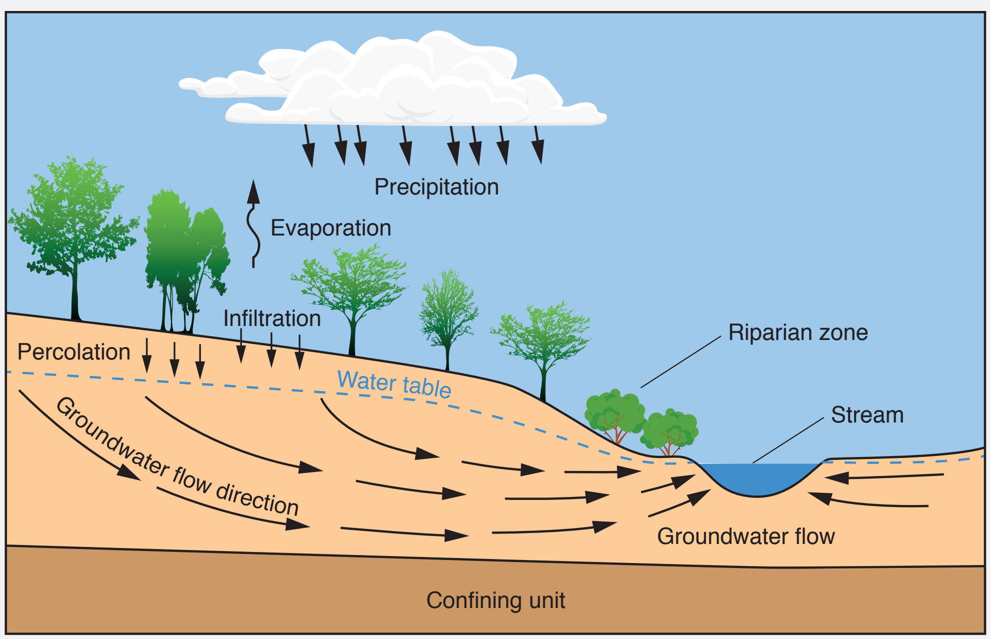
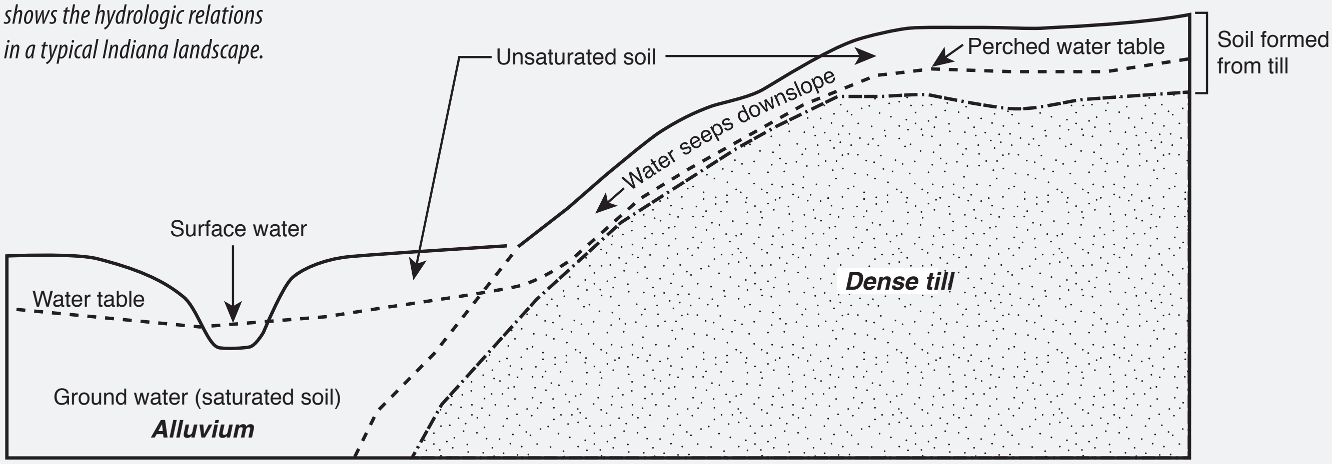


Figure 2.4. *The hydrologic cycle.*

Figure 2.5. *This illustration shows the hydrologic relations in a typical Indiana landscape.*



of most years. Soil scientists call this the **seasonally high water table** depth. This depth is shown in soil properties, especially soil color.

Figure 2.5 shows how these principles apply to many Indiana conditions. Figure 2.5 represents a glacial till upland cut by a valley with alluvium and a stream in it. The mass of till is dense (a limiting layer), but the upper part of the till (without dots) consists of A, E, and B horizons, which are not dense, largely because carbonate minerals (lime) have been dissolved to form these horizons. The dense till retards percolation, so the layers above it are saturated. The upper surface of this saturated zone is called a **perched water table**, because it is well above the water table in the valley. Water seeps (percolates) down the slope on top of the dense till surface. The strata from which ground water is pumped for various uses is called an **aquifer**.

In Figure 2.5, the upland is underlain by dense till. Fragipan and bedrock limiting layers would act similarly. Also, *outwash* could substitute for *alluvium*.

The principles illustrated here are important to understanding many soil properties, agricultural soil uses, and home site soils uses. Many of the practices described in subsequent chapters will help prevent pollution of groundwater and surface water

Iron

Iron (Fe) is of special interest because Fe chemistry is so important in representing the wetness of soils and their oxygen status. Students who have not had a chemistry course might skip to the last paragraph of the section, which summarizes how the chemical principles apply to soil evaluation.

In soil and water, iron occurs in two forms: (1) ferrous (Fe^{2+}) and (2) ferric (Fe^{3+}). In the process of **reduction**, Fe^{3+} gains an electron to become Fe^{2+}. And in the process of **oxidation**, Fe^{2+} loses an electron to become Fe^{3+}. Here's a mnemonic device to remember these processes:

oil rig — <u>o</u>xidation <u>i</u>s <u>l</u>oss and <u>r</u>eduction <u>i</u>s <u>g</u>ain in electrons

In primary minerals (the original minerals on the Earth's crust), Fe is mainly in the Fe^{2+} (ferrous) form. When these minerals weather in a soil that is not waterlogged, Fe^{2+} oxidizes to Fe^{3+} and precipitates as an **iron oxide**. These oxides are responsible for the reddish and brownish colors of soils.

Microbes are always active in soils, and they produce electrons during their respiration processes. When the soil is moist (but not saturated with water), oxygen accepts the electrons, and carbon dioxide is produced. However, when soils are saturated with water, oxygen is not available to the microbes, so the electrons they produce are accepted by other substances. One of these electron acceptors is Fe^{3+}.

Conversely, when Fe^{3+} in an iron oxide accepts an electron, it is converted to Fe^{2+} (reduced), the iron oxide dissolves, the brownish color disappears, and we see the grayish color of other soil minerals such as silicate **clay**. Thus, the more poorly drained a soil, the grayer is its subsoil.

The dissolved Fe^{2+} moves with the soil solution and eventually gets into well water. In the home water system, it stays in solution until it comes in contact with oxygen, and then it precipitates again as a brownish iron oxide. You might see signs of this iron oxide precipitation in a sink with a dripping faucet, a toilet tank or bowl, or in a shower.

In summary, brownish colors reflect unsaturated, oxidized soil conditions. Grayish colors reflect saturated, reduced soil conditions. We consider these conditions further in Natural Soil Drainage (page 57).

Soil Properties

Each scorecard asks you for information about various soil properties, including:

- Kinds of parent material
- Slope
- Landform
- Soil color
- Previous erosion
- Soil texture
- Natural soil drainage
- Limiting layer

We discuss each of these properties below.

Kinds of Parent Material

Parent material is the geologic material from which soil horizons (or layers) form. Many soils have more than one parent material — for example, loess over till. Chapter 1 discussed parent materials and the other four soil forming factors (relief, climate, organisms, and time.) Chapter 1 also described soil horizons, such as A, E, B, C, and R. If you haven't already, please read Chapter 1.

In this chapter, we use soil texture and Munsell color names to describe parent materials. If you are not familiar with these names, read the Texture (page 55) and Color (page 51) sections. Sometimes, a parent material's properties do not exactly match the guidelines for any of the parent materials listed on the scorecard. If this is the case, choose the parent material that matches the best.

Some parent materials, especially those deposited by water, are **stratified** — they are arranged in layers. If the layers are thin, you may see stratification in a soil pit (Genesee soil, Figure 1.23). If the layers are thick, however, stratification you may only see those layers in exposures that are much larger than in a pit. Generally, parent materials that have been deposited by ice and wind are not stratified (unstratified).

Parent Material Identification Zone

Every soil horizon comes from parent material. However, the same parent material often appears different in different horizons, because soil formation processes have altered it.

In C horizons, parent materials are relatively unchanged from when they were deposited. But in the A, E, and B horizons, the soil forming processes were at work on the parent material.

The following paragraphs describe parent materials that have not been changed much by soil formation processes.

In soil evaluation, the site card includes the *identification zone* where you should determine parent material. Often, the parent material identification zone is in the C or BC horizons, because the parent material in these horizons best matches the descriptions and is most related to landforms. However, in many cases, the parent material identification zone will be in horizons where the parent material has been altered (such as B horizons), because unaltered parent materials are not exposed in the pit or because of some other reason specific to the site. For these reasons, it is important to know how soil formation processes change parent materials.

How Soils Develop from Parent Materials

Chapter 1 listed eight main processes of soil formation (pages 13-20). In this chapter, we further explain these processes and illustrate them with examples.

In a high school soil evaluation competition, use the *degree of soil development* to help identify alluvium and local overwash parent materials, as well as flood plain land forms.

The list below summarizes a *normal* degree of soil development. If a soil has evidence of one or more of the following processes, the soil is said to have *normal development*. If none of the processes is very evident, the soil is said to have weak development. Official judges will indicate on the site card if they decide that the soil has *weak development*.

- *Carbonate minerals dissolve* (ground limestone or "lime"; minerals that contain CO_3^{2-}). Many parent materials contained lime when they were deposited (the materials were **calcareous**). During the thousands of years the soil developed, the lime dissolved and leached out of the upper horizons. If there is calcareous material above 20 inches, that is evidence of weak development. The site card will always provide depth to calcareous material.
- *Minerals other than carbonates also weather*. **Weathering** is the breaking down of rocks and minerals. The main evidence is that many subsoils, especially Bt horizons, contain more clay than the underlying C horizons. This extra clay resulted from physical and chemical weathering of various minerals and the transformation to clay minerals. Sometimes you can also observe stones that have been softened by weathering.
- *Some materials* (including ions) *that were released during the weathering process leach from the soil* — that is, water flowing down through the soil removes them. This process is evident in soils formed from limestone. Limestone contains much calcium (Ca), but there is little Ca in many soil B horizons above limestone. It was leached out of the soil. Carbonates were also lost during soil formation, but much of the carbonate was lost to the atmosphere as carbon dioxide gas instead of by leaching. A chemical analysis of the water in nearby streams would demonstrate a loss by leaching of various minerals.
- *Clay moves down the profile.* When water moves down the profile, it picks up clay and makes a suspension. The suspension then soaks into peds (soil structure units), and the clay adheres to the outside of the peds to form **clay skins**. Clay skins look like a thick coat of paint (see the Hosmer soil, Figure 1.25, and Figure 1.10).
- *Organic matter accumulates*. A soil with normal development is relatively dark-colored at the surface and becomes lighter as you move down in the soil. This is because the amount of organic matter is greatest as you near the surface. In contrast, alluvium is deposited in layers, and each layer can have a higher or lower organic matter content than the horizon next to it. So, in alluvium, it is not unusual for the amount of organic matter to vary by depth. If the decrease of organic matter is irregular, that indicates weak soil development — see photos of the Ockley (Figure 1.21) and Parr (Figure 1.14) soils.
- *Iron oxide minerals accumulate in the subsoil*. Iron oxides are reddish and brownish, and make the B horizon look redder or browner than the material below the B horizon. See photos of Miami (Figure 1.15), Parr (Figure 1.14) and Caneyville (Figure 1.26) soils.
- *Soil particles weakly cement together*. Cementation — such as in a fragipan (see photos of Hosmer soil, Figure 1.25, and Figure 1.13) — indicates normal development.
- *Soil structure forms*. If a soil expresses good soil structure (easily identifiable peds), that indicates normal soil development. The B horizons of the Ockley (Figure 1.21), Caneyville (Figure 1.26), Trappist (Figure 1.27), and Hosmer (Figure 1.25) soils and in the upper Crosby soil (Figure 1.11) and Figure 2.11 show examples of well-expressed soil structure (normal development).

Parent materials are closely related to landforms (see page 46). Therefore, knowing the parent material will help you identify the landform — and recognizing landforms will help you identify parent materials. Identifying parent materials will also help you identify limiting layers. In Kinds of Rocks in Parent Materials (below) we describe the guidelines for identifying parent materials in the general order of when they were deposited. If you encounter material in the parent material identification zone that does not meet any of the guidelines described here, official judges should provide the name of the parent material on the site card.

Kinds of Rocks in Parent Material

There are a few types of soil that formed from organic material (including peat and muck). However, soil contests do not include organic soils, so all soils you will see in contests are **mineral soils** — that is, soils formed from mineral material. All mineral material came originally from rocks. The discussion below describes different kinds of rocks.

Rocks are made up of one or more minerals, such as quartz. **Bedrock** is solid rock material that can be exposed at the Earth's surface, or it can be under loose material, such as loess, till, or outwash. There are many kinds of rocks from which soil parent materials were derived.

We can classify rocks into three types according to their origin:

1. Igneous rocks
2. Sedimentary rocks
3. Metamorphic rocks

IGNEOUS ROCKS

Igneous rocks formed deep in the Earth when molten rock material cooled and became solid. Igneous rocks are composed of a variety of minerals that have various colors, so they have a speckled appearance. For example, **granite** is one kind of igneous rock that contains pink, white, and some black minerals — you might see this kind of rock used for many tombstones.

SEDIMENTARY ROCKS

Sedimentary rocks formed at the Earth's surface when fragments derived from other rocks settled out in shallow seas and were cemented together. Living organisms can also form sedimentary rocks. There are four major types of sedimentary rocks:

1. **Sandstone** consists mainly of *sand* particles, which are large enough to be visible. Weathered sandstone has a scratchy feel.
2. **Siltstone** consists of accumulations of *silt*-size particles, which are too small to see. As siltstone softens and weathers, it acquires a soapy feel.
3. **Shale** consists of even smaller, clay-size particles and generally has a distinctive platy appearance. It weathers to a material that feels sticky and plastic, like modeling clay.
4. **Limestone** formed mainly from the shells of small marine animals that settled to the bottom of the sea. Limestone sometimes looks like sandstone because the shells are often about the size of sand particles. Limestone, however, consists mainly of calcium carbonate (lime) minerals, which fizz when you drip diluted hydrochloric acid on it.

METAMORPHIC ROCKS

Metamorphic rocks formed when igneous or sedimentary rocks were buried and subjected to high heat and great pressure deep within the Earth. Common metamorphic rocks can look like igneous rocks, except that some have banded colors and others appear **foliated** (scaly).

All the bedrock under Indiana consists of sedimentary rocks — either sandstone, siltstone, shale, or limestone. When exposed in a road cut, sandstone, siltstone, and shale show horizontal layering or bedding, because the rocks were deposited in layers. Limestone has a more massive appearance. Water that percolated down through cracks in the rock often dissolved vertical channels that were later filled with red soil material. Some limestone has fragments of chert, a whitish, irregularly shaped rock fragment.

Bedrock fragments usually have sharp edges and corners because they were not transported long distances and worn down. By contrast, the pebbles you find in till are quite well rounded because they were worn down and transported by glaciers. Thousands of years ago the glaciers picked up igneous and sedimentary rock that was near the Earth's surface in Canada. As the glaciers advanced into Indiana, they ground the Canadian bedrock into smaller pieces, rounding off the edges. When the glaciers melted, the rounded pebbles were left behind in till.

You can also find rounded pebbles in outwash, but because they were transported by water in addition to being ground by the glacier, they may be even more rounded than pebbles in till.

Kinds of Parent Materials Recognized in Soil Evaluation

Soils come from various parent materials:

- Weathered bedrock
- Till
- Outwash and lacustrine deposits
- Eolian sand
- Loess
- Alluvium
- Local overwash
- Other parent materials

WEATHERED BEDROCK

When physical and chemical processes break down bedrock, it is transformed into weathered bedrock. All parent materials have been weathered from bedrock to some extent, but the term "weathered bedrock" refers to materials that have remained essentially in place (**residuum**) or moved downslope and collected at the base of a slope (**colluvium**). Weathered bedrock usually contains fragments of sandstone, siltstone, shale, limestone, or chert. These fragments are usually flat and may have sharp edges and corners.

By contrast, other parent materials (such as till and outwash) were transported greater distances, so the pebbles in them are more rounded. Also, many of the pebbles in till and outwash are from igneous rocks instead of sedimentary rocks.

The texture of weathered bedrock varies widely, depending on the size of particles in the original rock. The parent material identification zone may contain weathered bedrock and bedrock — both qualify as a limiting layer.

Other parent materials can be defined more specifically, so weathered bedrock can also be identified by what it is *not*.

Siltstone, shale, and sandstone bedrock are common in Soil Region 11 (Figure 1.2). Limestone, often containing chert, underlies Soil Region 12. **Stratified** shale and limestone are common in Region 13.

The photos in Soil Landscapes and Profiles (pages 24-31) illustrate some characteristics of weathered bedrock. In the Caneyville soil (Figure 1.26), the white material below 3 feet (use the numbers on the right side of the gray tape) is continuous limestone bedrock. If official soil judges list 34 to 48 inches as the parent material identification zone, bedrock would be included in this zone. In the Trappist soil (Figure 1.27), a spade cut the soft shale in the BC horizon, just below 2.5 feet, as shown by the horizontal bedding. Harder shale (R horizon) is barely visible at the bottom of the photo.

> ▸ **EVALUATING RULE**
> **Weathered Bedrock**
>
> **Weathered bedrock** (including bedrock) has one or more of the following characteristics:
>
> - More than 80 percent of the material in the diagnostic zone is so hard that roots will not grow into it (qualifies as bedrock limiting layer).
> - Less than 80 percent of the material is hard, but sedimentary rock fragments are mainly angular, flat, or both.
> - The parent material does not meet the definition of another parent material.

TILL

Till is parent material that was deposited directly by glacial ice. The glacier (up to a few thousand feet thick) ground up the bedrock as it advanced. The glacier then transported that ground material and deposited it mainly in the central and northern parts of the state.

Till was derived mostly from nearby bedrock, but some came from more distant sources. For example, the *igneous* pebbles and boulders (granite, etc.) in the till must have come mainly from Canada, because all of Indiana is underlain by *sedimentary* rocks. These pieces of rock are called **erratics** because differ they from the size and type of rock native to the area. Figure 2.6 shows examples of erratics.

Glacial **pebbles** are more rounded than the rock fragments in weathered bedrock, because they were worn down while being pushed along under (and in) the ice.

Till consists of a mixture of clay, silt, sand, and usually coarser fragments. Most tills have medium (loam) or moderately clayey (clay loam or silty clay loam) textures. In Indiana, all till was calcareous. **Calcareous**

Figure 2.6. *These photos are examples of glacial erratics, rocks that were carried into an area that differ from the underlying bedrock. These examples are igneous and metamorphic rocks that were carried by glaciers and rounded in transit.* ***A.*** *Boulders and pebbles from Montgomery County, Indiana.* ***B.*** *Pebbles in a spoil pile in Tippecanoe County, Indiana.* ***C.*** *A huge granite rock from southern Michigan. It is not rounded much because of its size.*

means that the till contains carbonate minerals, such as calcium carbonate ($CaCO_3$), also called lime. These minerals came from the limestone bedrock the glaciers ground up.

Most of the glacial tills in Indiana contained around 20 to 40 percent of carbonate minerals when they were deposited. When the A and B horizons formed, the carbonate minerals were dissolved, and the carbonates were leached out of the upper soil profile.

However, not all calcareous materials are till. Other materials, such as outwash, loess, or alluvium may also be calcareous. The site card in each soil pit notes the upper depth to calcareous material. The tills in Indiana were deposited by glaciers that were hundreds of feet or even a few thousand feet thick. The weight of the ice compressed or compacted the till to a very high density. Till with high bulk density (weight/volume) is called **dense till** and is considered to be a limiting layer for soil evaluation. In Indiana, most till is dense (bulk density more than 1.75 g/cm3).

Most of the volume of dense till is solid particles; it contains little pore space. Since roots grow through soil pores, soil horizons with few pores also have few roots. Quite often, dense till breaks apart into a platy structure, with plates around 1/8- to 1/2-inch thick. This structure was probably formed when the till was deposited rather than through later soil forming processes. In such till the vertical cracks between plates are offset (like bricks in a wall) so that after a root grows down through one vertical crack, it must grow sideways to find another downward crack. This greatly restricts root growth.

As you go downward in till soils, the peds get larger, and the spaces between peds are farther apart. Within the depth of a soil pit, the spaces/cracks between peds may become coated with whitish carbonate minerals. The surrounding browner soil is shown in Figure 2.7. It appears much like a fragipan (Figure 1.13). The main difference between the two is that till is alkaline and calcareous, while fragipans are acidic.

Till is common in Soil Regions 6, 7, 8, 9, and 10 (Figure 1.2). In Regions 6, 8, 9, and 10 most till-derived C horizons are medium (loam) texture. A few are

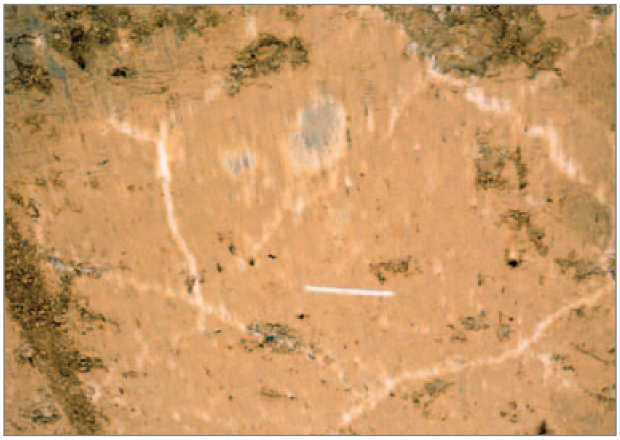


Figure 2.7. *This photo shows a horizontal section through till. The white streaks are carbonate coats. The brownish material is calcareous dense till. The white scale bar (six inches) is in a many-sided shape (polygon) called a prism.*

moderately sandy (sandy loam borderline loam). However, the *upper* horizons of many soils in these regions formed in loess. In Region 9, the loess is between 20 and 40 inches thick. In Regions 6 and 8, the loess is less than 20 inches thick. B horizons that formed in loam till are mainly clay loam, and those that formed in loess are mainly silty clay loam — both are considered moderately clayey for soil evaluation. The photos of the Miami (Figure 1.15), Crosby (Figure 1.16), and Parr (Figure 1.14) soils show dense till C horizons that fall in the *loam* texture class.

In Soil Region 7, the till is usually moderately clayey or clayey (clay loam or finer texture classes), which is finer than in Regions 6 and 8. In the Glynwood (Figure 1.18), Blount (Figure 1.19), and Pewamo (Figure 1.20) soils, the Cd horizons are in the silty clay or clay texture classes. Within Region 7, both the C and B horizons are highest in clay content in Allen County, and the clay content decreases to the north, west, and south.

In Region 10, deep loess deposits buried soil horizons that formed in older till. On nearly level areas, the loess is thicker than 4 feet, the depth of many soil evaluation pits. On steeper slopes of Region 10, however, the loess is often thinner and pits may expose till-derived horizons.

▸ EVALUATING RULE
Till

Till has *all* of these characteristics:

- Pebbles, if present, are mainly igneous, rounded, and randomly distributed
- Not stratified/not layered — material is homogeneous (mixed)
- Calcareous in C horizons
- Usually has platy depositional structure in C horizons
- Common texture and color combinations found in C horizons:
  - Medium texture (loam) and brownish (10YR 5/4, 5/6, 5/3), **or**
  - Moderately clayey texture (clay loam, silty clay loam) and near the brownish/gray boundary (10YR 5/3, 5/4, 5/2)

OUTWASH AND LACUSTRINE DEPOSITS

When the ice that deposited till melted, the meltwater carried away a lot of gravel, sand, silt, and clay. The meltwater flowed very rapidly when it first left the glacier, but as the streams spread out, they slowed down. This allowed the sand and gravel to settle out as material called outwash.

Outwash contains very little silt and clay, and generally is stratified (layered). However, in some materials (especially coarse sand and gravel) the layers are so thick that only one may be visible in a soil pit.

In some places, meltwater streams flowed into lakes. In the still water of the lake, the fine material (such as silt and clay) gradually settled out. Streams that flowed into lakes, however, also carried coarser material (sand) that immediately settled out. These lake (or lacustrine) deposits contain much silt and clay, but may also contain sand near the edges. Outwash and lacustrine deposits grade into each other and therefore, are not separated in high school soil evaluations.

According to soil evaluation guidelines, all outwash and lacustrine parent materials must be stratified except material that qualifies as a coarse sand and gravel limiting layer. "Stratified" in the rule means that material *in the parent material identification zone* consists of layers that are visibly different from each other.

Alluvium may also be stratified, but outwash soil horizons have more soil development. Signs of soil development include:

- Distinct color differences between horizons. For example, a profile that has a *dark* A horizon, a *pale* E horizon, and a *brownish* or *reddish* B horizon.
- Better soil structure development. For example, subsoil (B horizon) that contains blocky peds.
- Evidence of downward clay migration. That is, you will see more clay in the subsoil (Bt horizon) than near the surface (A and E horizons).
- Presence of clay films on the outsides of peds. Clay films are usually darker than the insides of peds and coat the peds like a thick coat of paint. The "paint" may cover up sand grains within the ped.

► EVALUATING RULE
Outwash and Lacustrine Deposits

Outwash and lacustrine deposits have *all* of these characteristics:

- Pebbles, if present, are mainly rounded and occur in layers (stratified)
- Material is either:
  - In the sandy texture group, and the sands are mainly > 0.5 mm in diameter (qualifies as a coarse sand and gravel limiting layer if it is thick enough), **or**
  - In any texture group and is *stratified* (consists of layers that are clearly visible)
- If official judges determine the parent material is outwash or lacustrine material, but the profile does not show clear stratification, or the material is not coarse sand and gravel, officials will give the parent material on the site card.

EOLIAN SAND

When the glaciers melted, it caused great floods on the ancient flood plains that are now terraces. During the winters, the melting slowed, resulting in the plains becoming barren mud flats. Wind blowing over the barren flats picked up certain particles and carried them away. The large materials (coarse sand and gravel) mainly stayed in place. The medium-size materials (fine and medium sand) moved by skips and jumps.

Eventually this process accumulated piles of wind-transported **eolian sand** into hills called dunes. Fine and medium sands are 0.1 to 0.5 millimeter in diameter. They can be identified by comparing the sand from a soil pit with two grits (sizes of sand particles) of sandpaper.

Some eolian sand soils have **lamellae**, which are thin layers that contain somewhat more clay than the material above or below them (see Chelsea soil, Figure 1.22). Eolian sand deposits are common in Soil Regions 1 and 4 (Figure 1.2) and in smaller areas scattered around the state. The Chelsea soil formed in eolian sand. The reddish brown bands in the subsoil are lamellae.

► EVALUATING RULE
Eolian Sand

Eolian sand has *all* of these characteristics:

- Sandy texture with no gravel or pebbles
- Sand grains are mainly 0.1 to 0.5 mm in diameter (between 150-grit and 40-grit sandpaper)
- Not stratified, but may have lamellae that are sandy or moderately sandy

LOESS

As the wind blew over the barren flats of terraces and outwash plains left by retreating glaciers, the wind picked up silt-size grains. Silt particles are smaller than sand, so the wind lifted them higher in the air and carried them further than eolian sand. These fine grains were eventually deposited as **loess**.

Since loess settled out from the air and was never under the weight of glacier ice, it was not compacted and is not dense. Soil B horizons (including fragipans) are silty clay loam or heavy (high-clay) silt loam. Loess-derived silt loam A horizons are very common in many areas of Indiana.

Loess is the only parent material of a few soils, and is the uppermost parent material of many soils in Indiana. It is not stratified. It commonly forms silt loam A horizons, silty clay loam or heavy silt loam B horizons, and silt or silt loam C horizons.

Loess deposits are very thick in Soil Region 5 (Figure 1.2), so most of the soils are formed entirely in loess. Some C horizons are calcareous, but most are not. In Region 10, loess is almost as thick as it is in Region 5 (especially on nearly level areas), and it covers soils formed from older till.

In Soil Regions 8 and 9, loess overlies till, and soils formed in both parent materials. Loess covers soils formed from bedrock in Regions 11, 12, and 13. Loess also covers soils formed from outwash and lacustrine deposits in areas too small to show on the Soil Region Map. The Alford soil (Figure 1.24) and the upper 5 feet of the Hosmer soil (Figure 1.25) formed in loess.

▸ EVALUATING RULE
Loess

Loess has *all* of these characteristics:

- May or may not be calcareous
- No pebbles, or if present, very few
- Silt, silt loam, or silty clay loam texture in surface or subsoil
- Not stratified (in contrast to water-deposited material, which is stratified)
- Not dense (in contrast to most till)

ALLUVIUM

Alluvium is soil material that was eroded from soils, transported by water, and deposited on a flood plain relatively recently. Flood plains are low in the landscape and are near streams. The material that the water carried and deposited is called **sediment**.

The sediment's texture and organic matter content depend on the kind of soil from which the material was eroded. For example, a storm, may mainly erode A horizons, so the sediment would be dark. Another storm, however, may be severe enough to cut gullies into B and C horizons, so the sediment was lighter in color. Because of this process dark and light layers alternate in the parent material identification zone of some soils formed in alluvium.

You can find soils formed in alluvium mainly along the major streams of Soil Region 3 (Figure 1.2), and along smaller streams and drainageways in many other regions. The Genesee soil (Figure 1.23) formed in alluvium. The photo illustrates a sequence of light-dark-light layers and weak soil development.

In other soils, the sediment was calcareous, so the alluvium was calcareous to the surface. Because alluvium is very young, there was little time to leach calcareous material out of upper layers. Calcareous material above 20 inches indicates that the parent material is alluvium.

Some alluvium lacks dark and light layers and is not calcareous. In such soils, soil scientists identify alluvium by soil development because of the short time that the alluvium was in place. In contrast, parent materials on terraces and uplands were in place for a much longer time and the soils on them have normal soil development.

Because weak soil development grades by small changes into normal soil development, official judges will circle "Yes" for "Weak soil development" on the site card if the soil in the parent material zone has weak development. They will circle "No" if the soil has normal development.

▸ EVALUATING RULE
Alluvium

Alluvium has *both* of these characteristics:

- The site is low in the landscape (on a flood plain).
- The soil has at least one of the following:
  - Distinct layers of light- and dark-colored soil material in the parent material zone
  - Calcareous material above 20 inches
  - On the site card, "Weak soil development" is circled "Yes"

LOCAL OVERWASH

Flooding occurs when water from a stream covers a soil. In contrast, **ponding** occurs when water from nearby higher areas cover a soil. Local overwash is similar to alluvium, except that overwash is soil material that eroded from nearby hillslopes or swells, then deposited on top of soils somewhat lower in the landscape. **Overwash** is usually found in **depressions** (**swales**) on uplands and terraces, but never on flood plains.

Usually, overwash was eroded from lighter colored soil horizons and overlies darker colored horizons. If overwash buries a light-colored horizon, it may be difficult to distinguish the buried layer. If this is the case, official judges should give the parent material on the site card. If the overwash is 20 inches or more thick, the landform is called a **filled depression** in soil evaluation.

> **EVALUATING RULE**
> **Local Overwash**
>
> **Local overwash** has *all* of these characteristics:
>
> - More than 20 inches thick (but the parent material identification zone may not include all 20 inches)
> - Buries a darker horizon
> - Soil horizons in and above the parent material zone have weak development
> - Not on a floodplain

OTHER PARENT MATERIALS

If the material in the parent material zone does not fit any of the guidelines above, official judges will write the name of the parent material on the site card.

Slope

The **slope gradient** (which we refer to simply as "slope") is the angle that the soil surface slants from the horizontal. It is expressed as a percentage, which is the number of feet of rise or fall in 100 feet of horizontal distance. For example, if point B is 100 feet away from point A, and point B is 4 feet higher than point A, the slope is 4 percent.

Slope gradient and length are important because they influence the rate at which runoff flows over the soil surface and erodes the soil. In addition, a slope's shape (flat, concave, or convex) and length are important properties of soil surfaces, because shape determines if water will run off the site or run onto the site. Slope also affects the use of farm machinery. Some fields are so steep that cultivation is impractical even if the soil is good.

For home sites, steep slopes affect house construction and landscape maintenance. And you can't build traditional septic tank waste disposal systems on steep slopes, because effluent will seep to the surface downslope from the soil absorption field. Also, these systems should not be built in depressions because surface water flows into a depression and then moves downward in the soil where it competes with water from the soil absorption field, as explained in Chapter 4.

Figure 2.8. *The contestant in this photo is measuring a slope with a slope finder (see page 148).*

In soil evaluation, contest officials set up two stakes to indicate where contestants should determine the slope. The stakes are usually set 20 to 100 feet apart. The distance between the two slope stakes varies because slope lengths are different in different landscapes. Contestants use a slope finder (page 148) to measure the slope to the nearest degree from the top of one stake to the top of the other (Figure 2.8). Table 2.1 shows the slope break points used in soil evaluation, a description of each slope, the designation of the slope in soil surveys, and the scorecard designation. Mark your scorecard according to the letters in the Scorecard Designation column.

Table 2.1. *Slope classes used in soil evaluation.*

SCORECARD DESIGNATION	SLOPE (%)	DESCRIPTION
3A	0-2	Nearly level
3B	3-6	Gently sloping
3C	7-12	Moderately sloping
3D	13-18	Strongly sloping
3E	19-25	Moderately steep
4A	26-35	Steep
4B	> 35	Very steep

Landforms and Their Components

Landforms are made of several features that together make up the land surface. Landforms may be large (such as a river terrace or flood plain), or small (such as a dune). A **landscape** is made up of several related landforms.

Landforms are recognized by their shape (or "lay of the land"), by their position relative to other landforms, and by the kind of material under the landform. Many Indiana soils formed from two or more parent materials. Usually it is the *lower* parent material that is most related to the landform.

For example, many soils formed in loess over till. It is the till that is mainly responsible for the shape of the land surface — the loess merely drapes over the till. For this reason, the parent material identification zone is usually deep in the pit. Landforms are important in understanding the relationship between a soil and its neighbors.

Landform Groups

There are three major **landform groups**:

1. Upland
2. Terrace
3. Bottomland (flood plains)

These three major landform groups form a stair-step pattern in many landscapes (Figure 2.9) and are extensive in Indiana. Visualize a sidewalk that leads to a single step and onto a porch. The porch illustrates an **upland,** the step illustrates a **terrace**, and the sidewalk illustrates **bottomland** (or flood plain).

UPLANDS

Uplands are the highest parts of the landscape. They lie above the lowlands that are associated with rivers and streams. Uplands are underlain mostly by unstratified materials (without layers of contrasting particle-size), such as weathered bedrock, till, or loess. In the glaciated part of the state, the nearly level uplands areas are called **till plains**, and the uplands areas with irregular hills are called **moraines**. There are also areas of outwash and lacustrine deposits on uplands. The landforms on these deposits are described in Terraces (below).

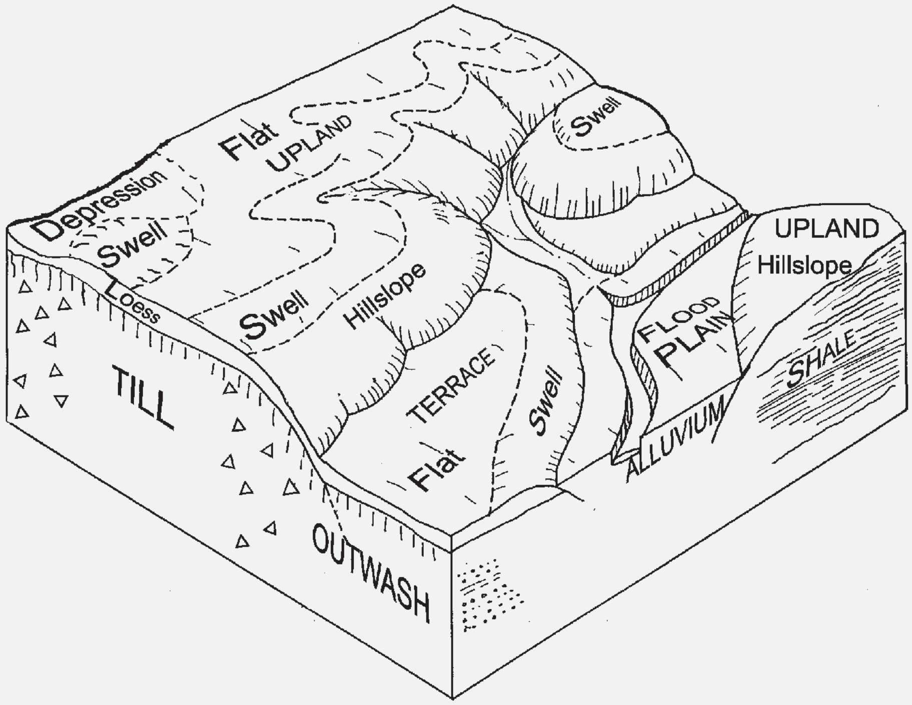
TERRACES

Terraces are at intermediate levels in the landscape (somewhere between uplands and flood plains), and are associated with a river or stream. Most terraces are on outwash that running water deposited thousands of years ago.

Terraces usually have a nearly level top surface (like the tread of a stair) and a short slope leading down from that surface (like the riser of a stair.) For soil evaluations, landforms that formed on other water-deposited parent materials are included with terraces. These landforms include **outwash plains** (landforms on outwash not in a valley), **eskers** (long ridges of outwash), **kames** (cone-shaped hills of outwash), and **lake plains** (landforms in former lakes underlain by relatively fine-textured material.) For soil evaluation purposes, the parent material of terraces, outwash plains, eskers, kames, and lake plains is outwash/lacustrine deposit, and the landform is outwash.

Most soils that formed in outwash on slopes of 3 percent or more are well-drained. In outwash-derived soils on nearly level slopes (0 to 2 percent), the

Figure 2.9. This block diagram shows various characteristics. Parent materials and landforms are labeled in uppercase letters (such as TILL and UPLAND). Landform components are labeled in upper- and lowercase letters (such as Swell).



natural drainage varies greatly. Soils in depressions are usually poorly drained. Soils on **swells** (convex landform with slopes of 2 percent or less) vary greatly in natural drainage, depending on the depth to the water table and on **soil permeability**. Soils on lake plains are usually finer-textured than outwash soils and tend to be more poorly drained.

BOTTOMLANDS

Bottomlands or **flood plains** are low-lying lands along a river or stream. They formed when sediment eroded from higher areas was deposited during periods of **flooding**. Some of the floods occurred recently, so the sediment is young and soils formed in sediment do not have distinct horizons.

As you walk toward a soil pit, observe if the pit is on an upland, terrace, or bottomland. These are *groups* of landforms. We describe specific landforms below, and you will see how we use parent material to help determine a landform.

Landforms Not Subdivided

The landforms described in this section are not divided into components, unlike the landforms described in the Landform Components section (page 48).

DUNES

Dunes are hilly deposits of eolian sand that have no obvious stratification or layers. They are usually on terraces, but might be on uplands. The Chelsea soil (Figure 1.22) formed in eolian sand on a dune. The E and Bt horizons in Chelsea are lamellae — unstratified parent material.

Sandy deposits, on nearly level terraces and outwash plains, that meet the definition of eolian sand were initially deposited by water, then reworked by the wind. They are included with outwash landforms for soil evaluation.

FLOOD PLAINS

Flood plains are near rivers and streams on the lowest part of the landscape. Flood plains are nearly level and subject to flooding. Flood plains are made up of alluvium, which is often stratified and can be similar in texture to outwash and lacustrine deposits.

Because flood plains are much younger landforms than outwash or lacustrine, flood plain soils have much less development than those on terraces, outwash plains, and lake plains. The **natural levee** (labeled "Swell" next to the flood plain on Figure 2.9) is an area near a stream that is somewhat higher than the rest of the flood plain. The natural levee is where the stream first deposits its load during a flood.

Usually, soils on natural levees are well-drained. Although a flood plain is usually near a stream, one may not be able to see the stream from the soil evaluation site. Look for evidence of flooding, such as debris arranged in curved rows in a field, debris caught on fences or plants, water marks on trees, or surface deposits of new sediment.

The natural drainage of soils on flood plains depends on soil permeability (how quickly water travels through the pores of the soil), elevation relative to the stream channel, and depth to the water table. The Genesee soil (Figure 1.23) is well-drained.

For crop production, flooding before or after the growing season may cause problems, but flooding does not prevent farming altogether. If a late spring flood occurs, a farmer can delay planting or replant with a shorter season crop such as soybeans or sorghum. Flooding, no matter what time of the year, causes obvious problems for home sites. Houses should not be built on flood plains.

FILLED DEPRESSIONS

Some **depressions** on uplands and terraces have been partially filled with sediment washed in from nearby higher landforms. Soils formed in this **local overwash** usually have weaker structure, lighter color, and less clay than the underlying buried soil. If the local overwash is 20 or more inches thick, the site is called a **filled depression.** If the overwash material is less than 20 inches thick, the site is called an upland depression or an outwash depression.

Landform Components

We can divide uplands and terraces into **landform components** based on the slope's gradient and shape. The slope break between 2 and 3 percent is important in naming landform components in soil evaluation. Slopes that incline 3 percent or more are called hillslopes; those that slant 2 percent or less are called swells, flats, or depressions (depending on their shape when you look at them from the side).

CONVEX, CONCAVE, OR FLAT?

If a slope is 2 percent or less, we distinguish between convex, concave, and flat landforms (Figure 2.10):

- *Convex* forms are shaped like an upside-down bowl — these are called **swells**.
- *Concave* forms are shaped like an upright bowl or a channel — these are called **depressions**. Depressions are also called swales. Depressions can be closed or open. A closed depression is bowl-shaped and has no outlet. Water that flows into it either soaks into the soil or evaporates. An open depression, on the other hand, allows water to move through it, because it is shaped like a channel or drainageway. This distinction is important for some uses, but it is not used in soil evaluation.
- *Flat* forms do not slope enough to tell if they are convex or concave so the landform component name is **flat**.

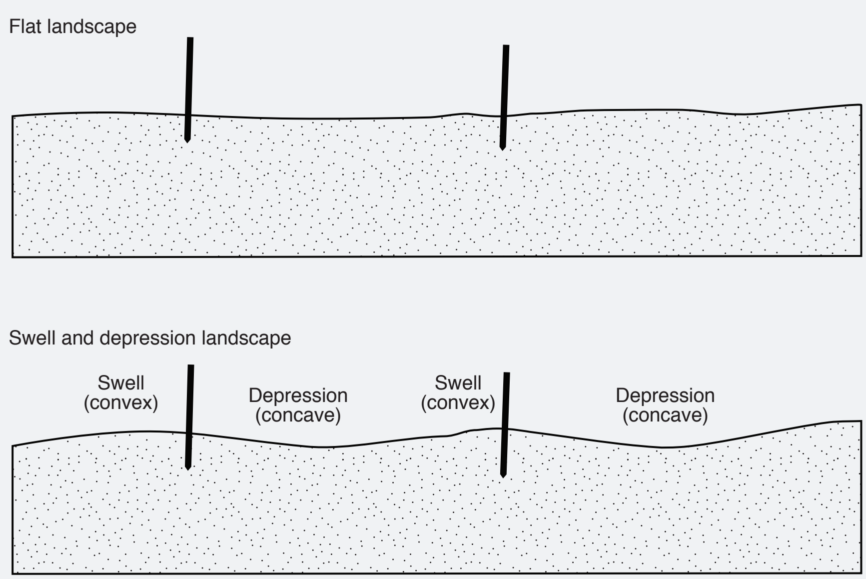


Figure 2.10. This illustration shows flat, swell, and depression landscapes. In the bottom illustration, slope stakes are set to show a depression.

Figure 2.11. This photo shows a Miami-Crosby-Brookston landscape in central Indiana.

The distinction between these three landform components is often very subtle. Therefore, *official judges will indicate on the site card if the area is flat, and they will place slope stakes to show if the slope shape is convex or concave*. If the surface rises between the stakes, it is convex; if it falls, it is concave. Figure 2.10 shows the difference between a flat landscape and a swell-depression landscape.

For soil evaluators, an efficient procedure is to:

1. Read the site card. If "Yes" is circled for Flat Landform and the slope is 2 percent or less, then the landform is flat.
2. If "No" is circled for Flat Landform, then determine the slope. If it is 2 percent or less, then observe the *surface* between slope stakes.
   a. If the surface rises, the landform is a swell
   b. If the surface falls, the landform is a depression

UPLAND SWELLS AND UPLAND DEPRESSIONS

Much of the nearly level glaciated upland of northern and central Indiana has a **swell-and-depression** topography. This wavy terrain is called a till plain. A till plain consists of swells on the convex rises, and depressions on the concave lower areas of the landscape.

In the forested part of the state (Figure 1.8), soils on swells have light-colored surfaces and soils in depressions have dark-colored surfaces. The overall "salt and pepper" appearance of the landscape (Figure 2.11) is gently undulating with less than 2 percent slope between the high points of the swells and the low points of the depressions.

Upland swells usually have somewhat poorly drained soils, such as Crosby (Figure 1.16). However, the soils may be better drained in the upland swell position on sandy materials. Upland depressions usually have poorly drained soils such as Brookston (Figure 1.17). Swell-and-depression landscapes are common in soil Regions 6, 7, 8, and 9 (Figure 1.2).

Figure 2.11 illustrates swell-and-depression topography in Shelby County. The lightest areas are swells with Crosby soils, and the darkest areas are depressions with Brookston soils. The brownish or reddish spots to the right are Miami soils (Figure 1.15) on gentle slopes that have been eroded.

The salt-and-pepper landscape in Figure 2.11 also helps explain why the Ap horizon of Brookston soil (Figure 1.17) is not as dark as the unplowed A horizon below it. Erosion has removed gray and brownish material from the swells (Crosby) and hillslopes (Miami) and deposited it on top of the Brookston surface. Each year, as farmers plow the soil, they mix this transported material with the original Brookston surface, causing it to lighten in color.

UPLAND FLATS

In Soil Regions 5 and 10 in southern Indiana, the uplands have even less relief and lower slope percentages than the swell-and-depression topography farther north. Some of these uplands are so flat, in fact, that it is difficult to determine whether the surface is concave or convex. **Flat** upland landscapes (often called "gray flats") usually have poorly drained soils. Examples of gray flats are the Clermont, Cobbsfork, and Hoosierville soils. Near the edges of large flat areas, the slope tends to be convex and the soils, such as Avonburg or Vigo, are usually somewhat poorly drained.

HILLSLOPES

Hillslopes are landform components with slopes of 3 percent or greater. On 3 to 6 percent slopes, soils are usually well- or moderately well-drained. In some cases, there may be small areas of somewhat poorly drained soils on 3 to 6 percent slopes. All hillslopes (whether 3 percent or 35 percent) have some degree of erosion hazard.

Most soils with more than 6 percent slope are well-drained. Miami (Figure 1.15), Parr (Figure 1.14), Chelsea (Figure 1.22), Caneyville (Figure 1.26), Trappist (Figure 1.27), Alford (Figure 1.24), and Hosmer (Figure 1.25) soils are typical soils found on 6 percent or greater slopes. A few moderately well-drained soils with fragipans as well as soils with fine-textured subsoils may be on slopes greater than 6 percent.

Soil Evaluating Rules for Landforms

The landforms listed in this section are described further by their components.

▸ EVALUATING RULE
Upland Landforms

Upland landforms have these two characteristics:

- Parent material is weathered bedrock, till, or loess
- Soil has normal development

Upland landforms are further differentiated as:

- **Upland hillslope** — slope is 3 percent or more
- **Upland swell** — slope is 2 percent or less and surface is convex
- **Upland flat** — slope is 2 percent or less and surface is flat ("Yes" is circled for "Flat landscape" on the site card)
- **Upland depression** — slope is 2 percent or less and surface is concave

▸ EVALUATING RULE
Landforms on Outwash and Lacustrine Deposits

Landforms on outwash and lacustrine deposits (abbreviated Outwash/Lacustrine) have these *two sets* of characteristics:

1. "Weak soil development" is circled "No" on the site card
2. One of the following:
   – Parent material is outwash or lacustrine deposit, with any slope **or**
   – Parent material qualifies for eolian sand and slope is 2 percent or less

Outwash/lacustrine landforms are further differentiated as follows:

- **Outwash/lacustrine hillslope** — slope is 3 percent or more
- **Outwash/lacustrine swell** — slope is 2 percent or less and surface is convex
- **Outwash/lacustrine flat** — slope is 2 percent or less and surface is flat ("Yes" is circled for "flat landform" on the site card)
- **Outwash/lacustrine depression** — slope is 2 percent or less and surface is concave

▸ **EVALUATING RULE**
Dune

A **Dune** has *both* of these characteristics:

- Parent material is eolian sand
- Slope is 3 percent or more

▸ **EVALUATING RULE**
Flood Plain

A **Flood plain** has *all* of these characteristics:

- Parent material is alluvium
- Located low in the landscape
- "Weak soil development" is circled "Yes" on the site card

▸ **EVALUATING RULE**
Filled Depression

A **Filled depression** has *all* of these characteristics:

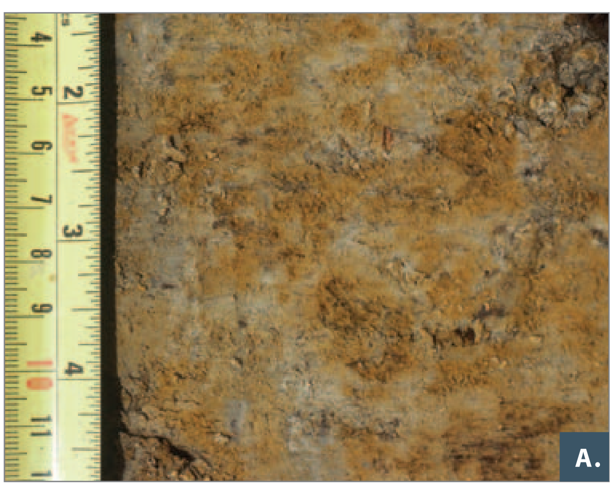
- Parent material is local overwash that is 20 inches or more thick
- Most nearby landforms are uplands or outwash landforms (not floodplains)
- "Weak soil development" is circled "Yes" on the site card

Soil Color

Soil color is important because it helps identify several other important soil properties. In surface horizons, dark colors indicate high organic matter content. Organic matter, in turn, is responsible for many desirable physical and chemical soil properties. Soils with high organic matter take up water faster, store more water, are more resistant to erosion, tend to form fewer surface seals and crusts, and are easier to till than soils with low organic matter. High organic matter soils also hold more plant nutrients.

In subsoil horizons, color reflects the natural drainage conditions and the soil's degree of development. For example, more reddish and/or brownish colors in the B horizon than in the C horizon indicate well- and moderately well-drained soils.

Grayish colors in the subsoil indicate wet soils. In poorly drained soils, the subsoils are dominantly gray. In somewhat poorly drained soils, the subsoils are dominantly brownish with gray areas (like the black and white pattern of a Holstein cow) shown Figure 2.12.



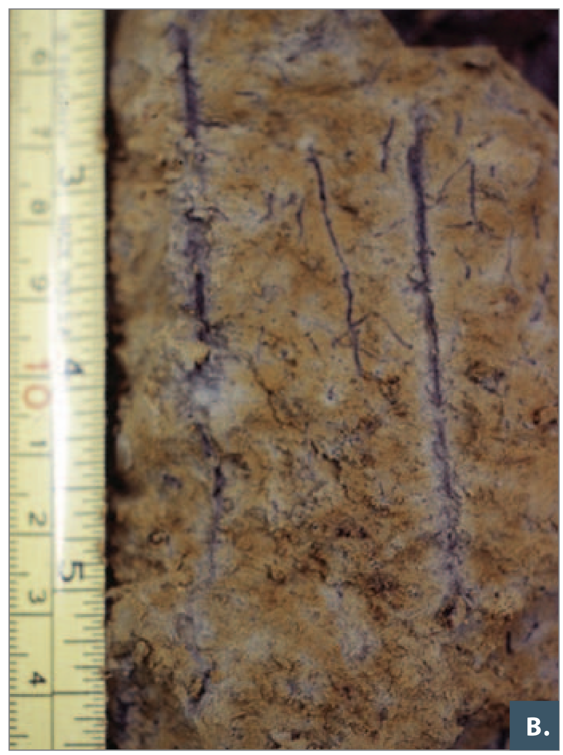


Figure 2.12. *These photos show mottles of brownish and grayish colors. The brownish color is predominant.* ***A.*** *The colors are arranged randomly.* ***B.*** *The grayish color is mainly along root channels (the dark vertical streaks).*

MUNSELL COLOR SYSTEM

Contestants determine soil colors by comparing the moist soil with standard Munsell soil color charts (Figure 2.13). It is important to use a moist soil sample, because moist soil is much darker than dry soil (see Figure 1.7), and official judges always determine color on moist samples. The **Munsell system**, arranges color samples according to three properties: hue, value, and chroma (Figure 2.14).

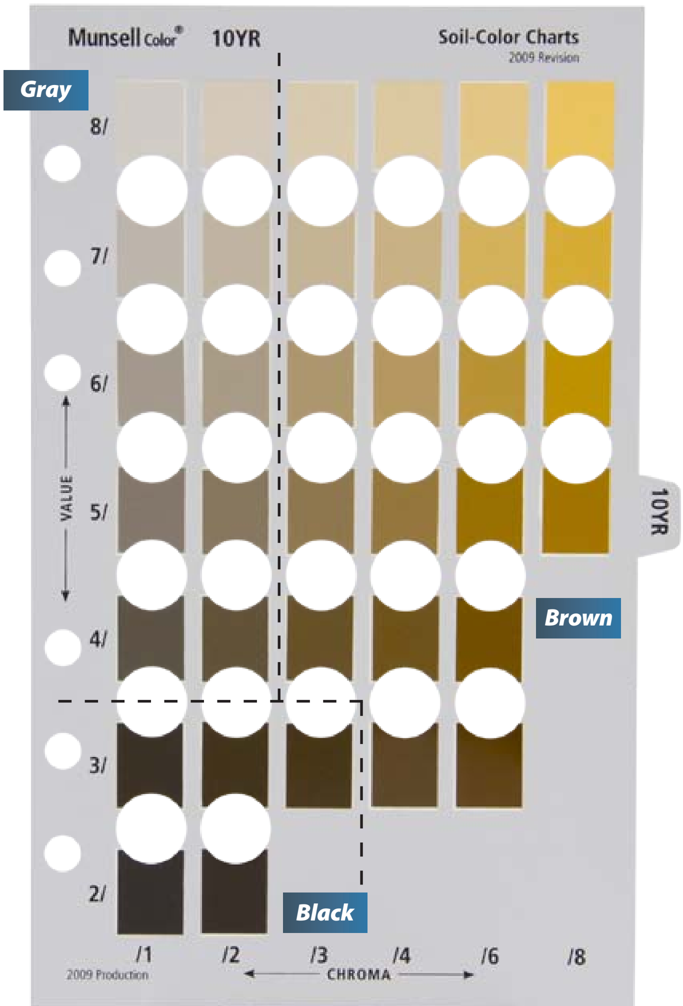


Figure 2.14. A sample Munsell color chart showing the definitions of soil evaluation color groups: gray, brown, and black. The grouping applies to all hues (pages in a color book). Munsell Color chart provided by X-Rite, Inc., munsell.com.

Figure 2.13. A contestant determines a soil's color using a Munsell color chart.

Hue refers to the colors of the rainbow (spectral colors). It is presented with numbers and letters. For example, in a Munsell chart, you may see hue numbers and letters such as 10YR, 5R, 2.5Y. Each letter and number has a meaning. The letter Y stands for yellow, R for red, and YR for a mixture of yellow and red. A Munsell color book provides different hues on separate pages.

Value represents how light or dark the color is. In a Munsell chart, value changes up and down the page. Darker colors are arranged toward the bottom of the page, while lighter colors are arranged toward the top.

Chroma represents the strength or purity of the spectral color. In a Munsell chart, chroma is measured across the page. The neutral colors (black, gray, or white) are arranged on the left. More pure colors (red, brown, yellow) are arranged on the right.

The 10YR is the most commonly used Munsell hue page in Indiana. The next most common hues are 7.5YR (which is redder than 10YR) and 2.5Y (which is more yellow/olive than 10YR).

SOIL COLOR CLASSES

To determine a soil's color, compare a moist soil sample to a Munsell soil color chart and pick the chip that matches best. All soil colors can be placed into three soil evaluation groups: **gray**, **brown**, and **black**. The groups are based on the value and chroma (defined in Figure 2.14) regardless of hue. A group includes many color chips such as 10YR 4/6 (dark yellowish brown).

While gray, brown, and black are specifically defined **color groups**, terms such as "light," "dark," "grayish," and "brownish" are relative. Brownish colors fall along the right of the color chart; grayish colors to the left; light colors are to the top; dark colors are to the bottom. Some brownish colors may appear to be on the red side of brown (5YR and 2.5YR hues), and some may appear to be on the olive side of brown (2.5Y and 5Y hues.)

SURFACE HORIZON COLOR

In some surface horizons, a soil ped has different colors from its outside to its inside. When you determine a surface horizon's color, crush a moist soil sample between your thumb and forefinger.

In some soils (especially in grass) the soil may be darker at the surface than it is a few inches deeper. For this reason, select a sample from the center of the surface horizon when determining color. Official judges may specify the depth from which you should take your sample to determine soil color. If you have a soil color that is close to a boundary between two colors on the Munsell chart, officials should give the Munsell designation on the site card.

> ▸ **EVALUATING RULE**
> **Determining Surface Color**
>
> Determine the **Surface soil color group** from the center of the surface horizon, unless the site card gives a specific depth. Crush moist soil material between your fingers and compare it with a Munsell color chart. Mark **gray, brown**, or **black** on the scorecard.

Many Indiana surface horizons have colors between 10YR 3/3 and 10YR 4/3. If the color is near this class boundary, or other boundaries, officials should provide the Munsell designation on the site card.

SUBSOIL HORIZON COLOR

You can use the subsoil color to determine **natural soil drainage**. Unlike surface samples, you should *not* crush subsoil samples for determining color.

An **aggregate** is a collection of many soil particles. A **ped** is a soil structural unit composed of many aggregates that formed by natural processes. Peds are separated from each other by natural spaces so they can be easily removed from a soil profile.

Look at both the inside and outside of a ped. To look inside a ped, break it apart, cut through it with a knife or spatula, or look at the face of the pit that has been cut with a spade — right sides of the Miami (Figure 1.15) and Hosmer (Figure 1.25) soils. Estimate if the inside of the ped has more brown or gray colors (refer to color chart). The more abundant color is called the **dominant soil color**. Also, look at the outside surface of the ped, which is usually is a clay skin or a silt coat (explained later in the Location of Soil Colors, page 58).

Consider both the inside and the clay skin colors, then decide if there is more gray or more brown. One coach summarized this process by asking students if the soil looked like a brown suit with gray spots or a gray suit with brown spots. Use this color information to determine natural soil drainage. Natural Soil Drainage (page 57) explains the significance of the two colors.

Previous Erosion

This section explains how soil evaluators describe the amount of erosion that has already happened. Our explanation is based on the kinds of soil horizons as discussed in Chapter 1.

Before they were farmed, Indiana soils had a dark A horizon that varied in thickness from a few inches to a few feet. In areas with thinner A horizons there usually was a light-colored E horizon just below the A. Below the E horizon was a B horizon (or in areas with thicker A horizons, the B horizon was below the A horizon).

Moldboard plowing mixed the upper horizons (A, E, or both) to create an Ap horizon. Where the original A horizon was thick, the Ap horizon was dark. Where the original A horizon was thin, the Ap horizon was usually grayish.

In most soils, erosion removed some of the Ap horizon, so when the soil was next plowed, the plow cut into lower horizons, often reaching B horizons. Farmers plowed to about the same depth every year, so there was a clearly defined lower boundary of the Ap horizon.

However, as the use of moldboard plowing faded, the lower boundary of the Ap horizon became less distinct. If that is the case, the upper eight inches is considered to be the Ap horizon. As soil erosion has continued, the Ap horizon includes even more B horizon soil. That means, *the more B horizon material the Ap contains, and the less A and E horizon material the Ap contains, the greater the amount of erosion at that site*.

In many soil pits, you can see the B horizon, but you cannot observe the original A and E horizons, because they have been lost to erosion or mixed with other horizons. We do know, however, that A and E horizons are more *friable* than B horizons, so we equate "more friable material" with A and E horizons.

Friable soil is soil that crumbles easily. The guidelines below explain how to identify material in the Ap that is more friable than the B horizon. This B horizon is often called the *reference horizon*.

When you determine **previous erosion** in a competition, the *reference horizon* is the B horizon or C horizon just below the Ap horizon.

Material that is more friable has some combination of these traits:

- It crumbles more easily in your fingers than other materials
- It is darker in color (that is, it is higher in organic matter)
- It provides less resistance when you poke it with knife
- It contains more roots
- If the lower boundary of the Ap horizon is indistinct or if the Ap is less than 8 inches thick, consider the upper eight inches to be equivalent to the Ap horizon.

▸ EVALUATING RULE
Previous Erosion

Mark **Previous erosion o**n your scorecard this way. If the Ap horizon is underlain by:

- An **A** or **E** horizon, mark: NONE TO SLIGHT
- A **C** horizon, mark: SEVERE
- A **B** horizon, then **previous erosion** depends on the percentage of more friable material in the Ap horizon or in the upper eight inches if the Ap is less than eight inches. If the percentage of friable material in this layer is:
  - 76 to 100, mark: None to Slight
  - 26 to 75, mark: MODERATE
  - 0 to 25, mark: SEVERE

The latter part of the rule refers to the *amount* of friable material. The *pattern* of more friable material and less friable material in the upper 8 inches can vary among sites. The upper part of the Ap can be composed almost entirely of more friable material, while the lower part can be composed mostly of less friable material (like the dark brown and white layers of a separated Oreo cookie). Or, the materials could be mixed (like chocolate chips in a cookie — is the percentage of chocolate chips in your cookie more like none or moderate?).

Another clue that will help you determine the amount of previous erosion is the depth to calcareous material. If the depth to calcareous material is much less than other soils in the area, then the soil is likely to be severely eroded.

Soil evaluators often have the opportunity to compare similar soils (one severely eroded, the other slightly eroded) and to think about the relative ability of the two soils to grow plants. This comparison will demonstrate the importance of using soil-conserving practices, as described in Chapter 3.

Soil Texture

Soil texture refers to the relative proportion of sand, silt, and clay in the soil. The texture triangle (Figure 2.15) shows the limits in the percentages of sand, silt, and clay for *texture classes* and *texture groups*. Specific classes (such as *silt loam*) are shown in lighter print. Groups of classes (such as *medium*) are shown in darker print. The texture triangle is based on soil material less than 2 millimeters in diameter, the upper size limit of sand. Material larger than sand (and up to 3 inches in diameter) is called **gravel**.

All soil texture triangles place soils very high in clay near the top. Textures high in sand are in the lower-left corner, and soils high in silt are near the lower-right corner. Soils with relatively equal amounts of sand, silt, and clay are in the center of the triangle.

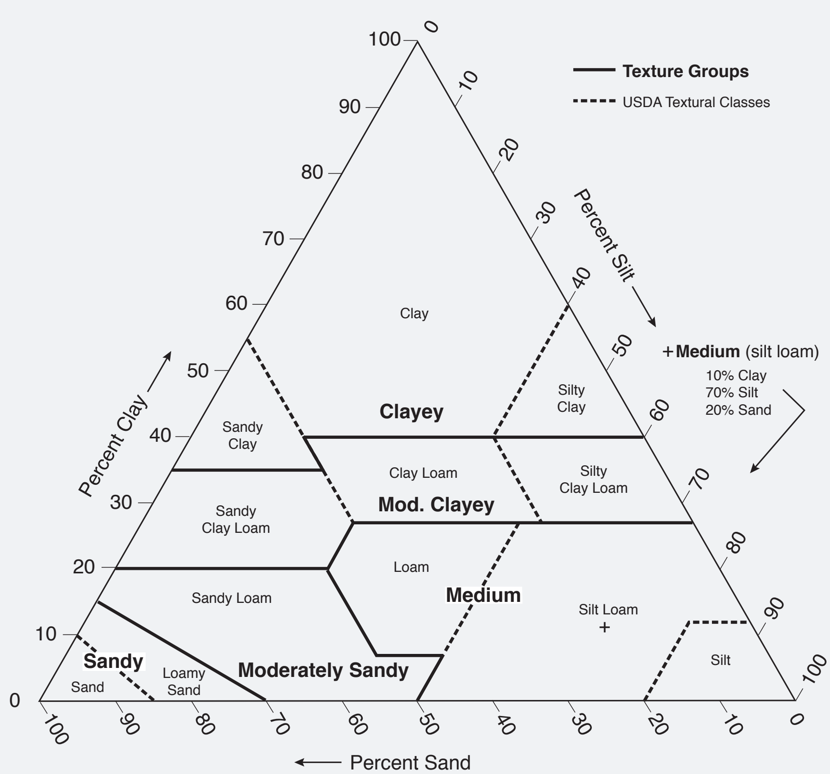
Texture is an important soil characteristic, because it determines or influences many other properties. Texture mainly determines how fast water will run into or through a soil horizon, how much water the horizon will hold, and how easily the soil can be tilled. This, in turn, affects many agricultural and home site uses.

HOW TO DETERMINE TEXTURE

Estimate texture by working the soil with your hands, then feeling it with your thumb and fingers (Figure 2.16). Soils are often too dry for estimating texture, so you must moisten them first. You should carry a small water container to moisten samples — squirt-top plastic bottles are handy.

Figure 2.16. *A contestant determines soil texture.*

Figure 2.15. *This soil texture triangle shows texture classes (dashed lines) and soil evaluation texture groups (solid lines). A soil sample located at the + point on the triangle would be composed of 10 percent clay, 70 percent silt, and 20 percent sand. This soil falls under the medium texture and silt loam texture class.*



To estimate texture, take a heaping tablespoon of soil and mold it with your hand. While squeezing the soil, slowly add water until the sample mimics modeling clay and you can form it readily into different shapes.

When the sample is moist enough, squeeze it in your hand and observe the kind of cast it forms (Figure 2.17). Making a cast is especially helpful to identify sandy and moderately sandy textures, Soils that are finer than moderately sandy all make good casts.

After you determine the kind of cast the sample makes, rub the soil between your thumb and forefinger and try to make a thin ribbon (Figure 2.16). You will evaluate the strength of the cast, the length and rigidity of the ribbon, the smoothness and shininess of the rubbed soil ribbon, and the stickiness of the sample to determine soil texture.

There are five basic classes used in soil evaluation:

1. Sandy
2. Moderately sandy
3. Medium
4. Moderately clayey
5. Clayey

The descriptions below will help you get started with determining soil textures. But to develop your skills, you should work with samples of known textures and compare your results with those of experienced people.

The **sandy** texture group includes the sand and loamy sand texture classes. Soil samples with a sandy texture do not stick together enough to form a cast (Figure 2.17A), or they form a weak cast that can falls apart with any but the most gentle handling.

You cannot form sandy soils into a ribbon, and when you rub the surfaces they appear very grainy. Sandy soils are not sticky.

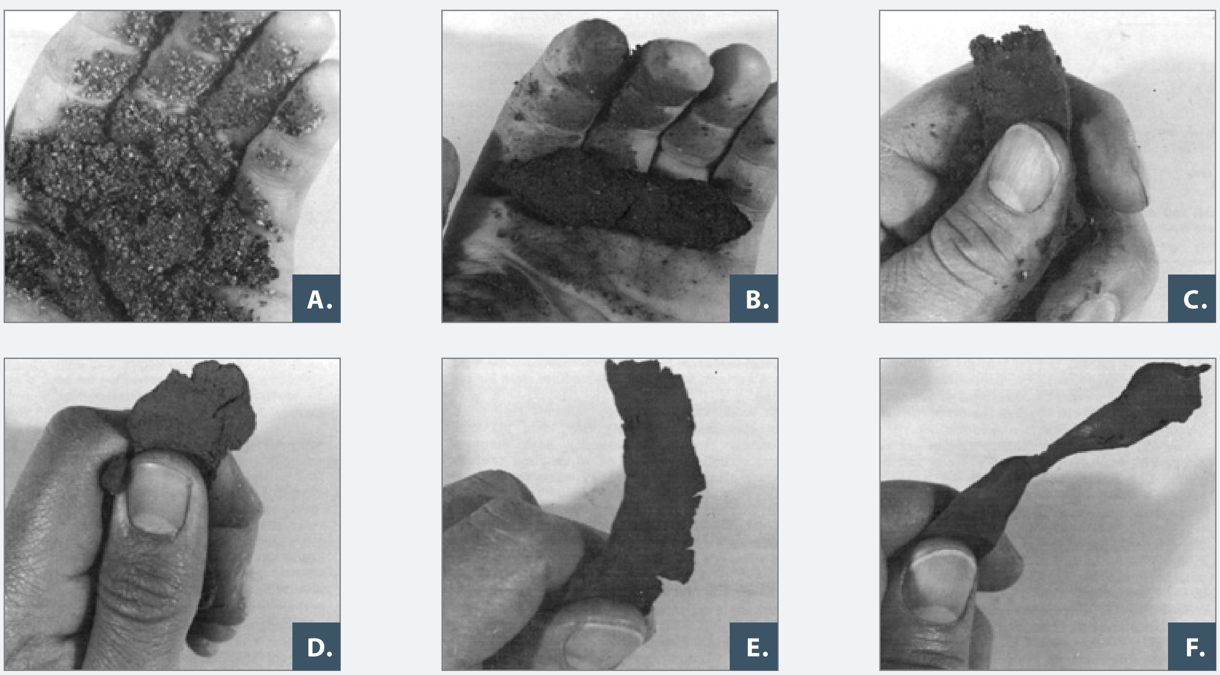


Figure 2.17. *These photos show the casts of different soil samples when you squeeze them in your hand to determine soil texture. A. This soil has a sandy texture. B and C. These soils are moderately sandy texture. D. This soil has a medium texture. E. This soil has a moderately clayey texture. F. This soil has a clayey texture.*

The **moderately sandy** texture group is the same as the sandy loam class. Soil samples with a moderately sandy texture form a good cast (Figure 2.17B) and a weak ribbon (Figure 2.17C).

When you rub the surfaces, samples appear grainy, but you can see the "glue" (silt and clay) that holds the sand grains together. Moderately sandy soils are not sticky.

The **medium** texture group includes the loam, silt loam, and silt classes. Soil samples with a medium texture form a good cast and a moderately weak ribbon (Figure 2.17D). The ribbon's strength varies from somewhat better than the ribbon shown in Figure 2.17C to somewhat weaker than the one shown in Figure 2.17E.

In Indiana, many of the medium texture soils are silt loams. Medium-textured soils are slightly sticky.

The **moderately clayey** texture group includes the sandy clay loam, clay loam, and silty clay loam classes. Soil samples with a moderately clayey texture form a fairly long ribbon because they contain moderately high amounts of clay (Figure 2.17E). The appearance varies from very smooth to very grainy. Moderately clayey soils are relatively sticky.

The **clayey** texture group includes the sandy clay, clay, and silty clay classes. The clay content of clayey soils varies considerably, but all clayey soils form a long ribbon that you can squeeze very thinly and it will still support its own weight (Figure 2.17F).

When you rub the surfaces, samples appear mainly very smooth and shiny or waxy, but they could have some graininess. Clayey soils are very sticky.

▸ EVALUATING RULE
Surface Texture

For **surface texture**, determine the texture group in the Ap horizon or the upper 8 inches of soil if the Ap is less than 8 inches thick.

▸ EVALUATING RULE
Subsoil Texture

For **subsoil texture**, determine the texture of the finest layer (contains the most clay) exposed below the surface horizon.

If conditions warrant, contest officials may write on the site card the depth where students should sample to evaluate surface and/or subsoil texture. Alternatively, officials may put samples in a bucket outside the soil pit.

Natural Soil Drainage

SOURCE OF SOIL COLOR

Soil consists largely of grayish soil material and pigmenting material. There are three main pigmenting materials:

1. **Organic matter or humus** is responsible for making surface horizons dark (as shown in several of the photos in Soil Landscapes and Profiles, pages 24-31). These colors are important but are not used to determine natural soil drainage classes.
2. **Iron oxides** are responsible for browns and reds in soils. Consider a rusty nail. That rust is an iron oxide. Examples of the color of iron oxide minerals in soils are the Bt horizons in the Parr (Figure 1.14), Ockley (Figure 1.21), Caneyville (Figure 1.26), and Alford (Figure 1.24) soils. These colors are very important in determining natural soil drainage.
3. **Manganese oxides** are black minerals that are usually in small masses (called concretions) because they are often roundish. The small black spots in the lower parts of The Crosby (Figure 1.16) and Brookston (Figure 1.17) soils are manganese concretions. Black manganese concretions indicate some periods of wetness, but they are not used to define natural drainage classes.

We determine soil drainage classes largely by the presence or absence of iron oxide minerals. When a soil is aerated (not saturated with water), oxygen is plentiful and a thin layer of iron oxide minerals coats the grayish soil material to make the soil brownish or reddish.

On the other hand, when a soil is saturated with water for a few weeks or more, the oxygen is depleted and the iron oxide minerals dissolve. As a result, you see the grayish soil material. So, if you see soils that are grayish throughout the subsoil, they are poorly drained.

If a soil horizon has periods of aeration and periods of saturation, it will develop masses of brownish soil and masses of grayish material. Such soils have an intermediate drainage class — somewhere between well- and poorly drained. The natural soil drainage flow chart (Figure 2.19) shows how you use the relative amounts of gray colors in certain horizons to determine a soil's natural soil drainage.

Some soils are periodically saturated because there is slowly permeable layer (often a C horizon) that holds up water in the A and B horizons for at least several weeks during the year. The depth to free water (water table) usually varies greatly during the year. Typically, it is lowest at the end of the growing season when plants stop using water. From then on, the water table rises until plant growth starts again in the spring. Water table levels vary greatly from year to year.

LOCATION OF SOIL COLORS

To determine natural soil drainage, you must consider the colors of soil peds — both inside and on the surface (see Soil Color, page 51). The inside of a ped is what you see on the face of a soil pit that has been shaved with a spade. The surface of a ped is what you see when you pick the surface with a knife, and soil material falls away along natural breaks in the soil.

You can also remove a few peds from the wall of a pit (leave some of the peds intact to see the surfaces) and cut through some peds with a knife or spatula to observe the insides. Ask your coach or an official to help you examine ped interiors and ped surfaces. Estimate the percentages of gray material and brown material (Figure 2.14) that show on these inside exposures.

Also, estimate the percentages of gray material and brown material on the clay skins. To do this, you must first distinguish clay skins from silt coats and carbonate coats on soil ped surfaces (Figure 2.18).

Clay skins coat peds like a layer of paint. They often have a somewhat shiny or waxy appearance. A clay skin can be in any of the three main color classes (gray, black, or brown), but it is usually somewhat different in color from the inside of the ped.

Silt coats and **carbonate coats** appear grainy or dusty, and they are usually light gray to white when dry on soils of all drainage classes. If you drop water on a thin, dry silt coat, the silt becomes practically invisible. Silt coats, tend to be lighter (Munsell value 7 or 8) than clay skins, which are often darker gray or brownish (Munsell value 4 or 5).

Carbonate coats are calcareous, and they usually coat large peds that are calcareous on the inside. Carbonate coats are typically found in dense till. They look much like the light-colored silt coats in fragipans.

In summary, clay skins appear to be painted on and waxy. They are usually dark gray or brownish when moist. On the other hand, silt coats and carbonate coats appear dusty or grainy. They are usually light gray when moist, and very light gray to white when dry.

DETERMINING NATURAL SOIL DRAINAGE

A soil that has definite brown masses and definite gray masses is called **mottled**. The brownish masses are called "brown mottles," "iron concentrations," or just "concentrations." The gray masses are called "gray mottles," "iron depletions," or just "depletions." When you use the soil drainage key, you will be asked to determine the percentages of brown and gray colors in a soil horizon.

When you determine the color of a subsoil horizon before using the drainage key, give equal consideration to the *interior of peds* and the *clay skins on ped surfaces*. Do not consider the color of silt coats.

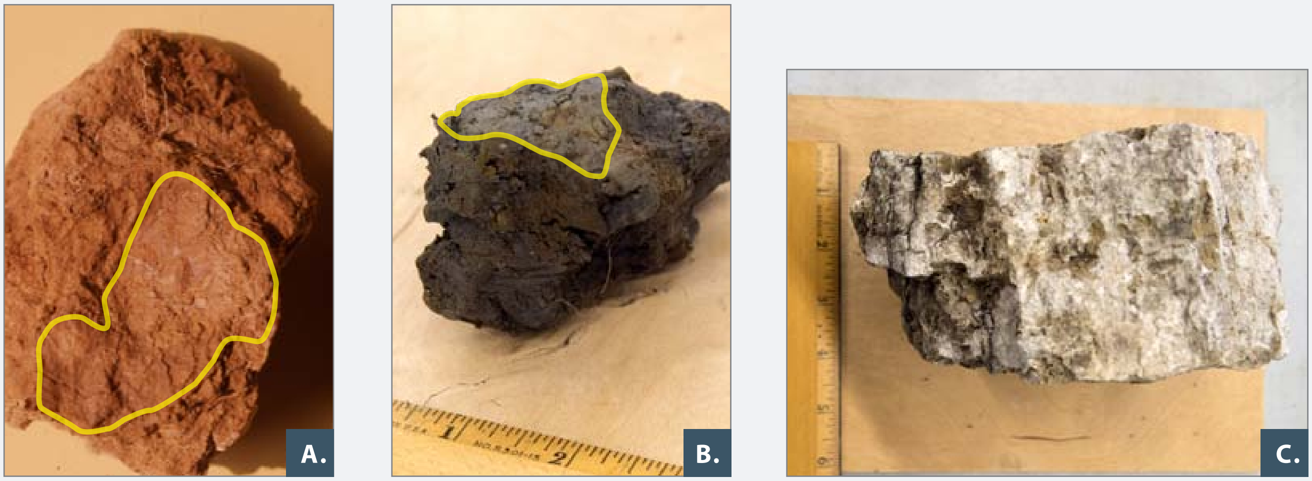
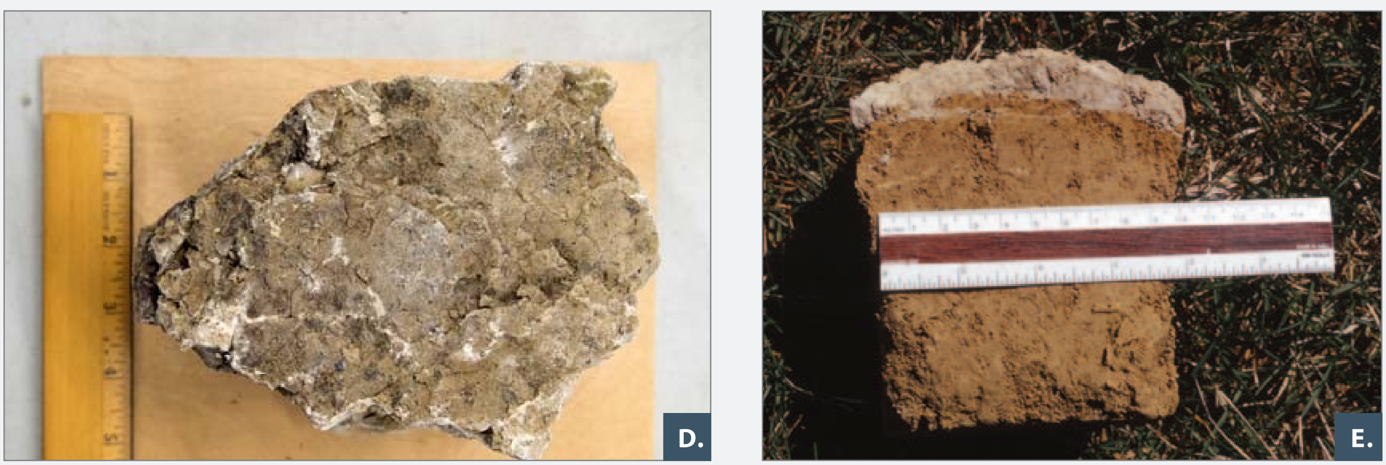


Figure 2.18. *These photos show clay skins, silt coats, and carbonate coats.* ***A.*** *The outlined area shows a brown clay skin on a subangular blocky ped shows that clay moved down the profile and was deposited on a ped surface in a Bt horizon. The color of the ped and the clay skin indicates that the soil from which the ped was collected is well drained.* ***B.*** *A gray clay skin on a gray ped shows similar translocation of clay, but the soil is poorly drained.* ***C.*** *A portion of a prism from the C horizon of a soil formed in calcareous till. The whole prism was much taller (in the direction of the numbers on the ruler) than the part shown. The prism is coated with carbonate minerals that were translocated down the soil profile.* ***D.*** *The inside of the same prism.* ***E.*** *A silt coat on a piece of fragipan prism.*



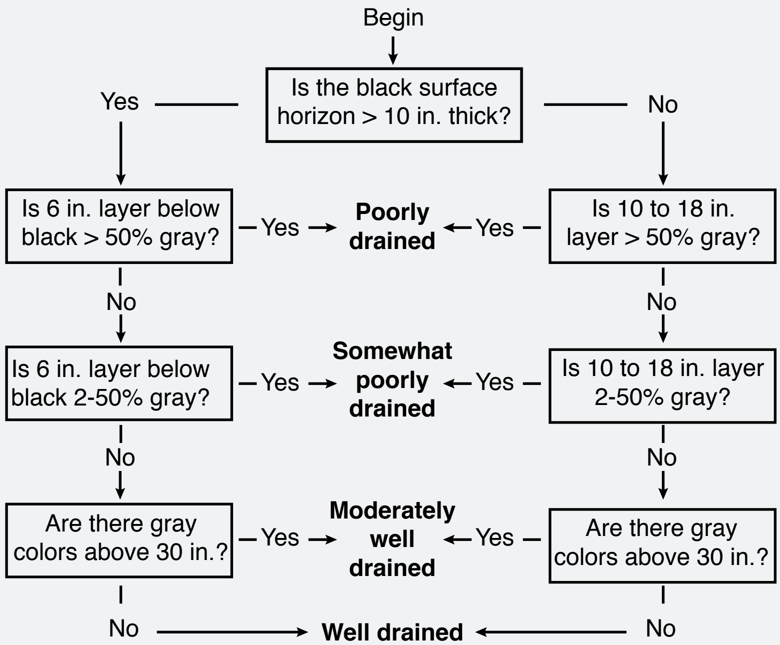


Figure 2.19. *This soil key is a flow diagram for determining natural soil drainage. See Figure 2.14 for the definition of black and gray soil evaluation color groups.*

▸ EVALUATING RULE
Natural Soil Drainage

Determine **Natural soil drainage** using the soil key (Figure 2.19).

To use the soil key:

1. Measure the thickness of the black surface horizon. If it is greater than 10 inches, use the left side of the diagram; if it is 10 inches or less, use the right side.
2. Find the 6-inch zone (left side of diagram) or 8-inch zone (right side) in which to examine soil color closely.
3. Decide if the combined color of ped interiors and clay skins in that zone is predominantly gray or predominantly brown.
4. Determine if there are any gray colors above 30 inches

If the drainage class you get from using the flow chart does not represent the soil very well, officials may provide the natural soil drainage on the site card.

Figure 2.20 explains the third step of the rule. The illustration represents a piece of soil about 2 inches across that has been cut through the middle. The figure shows one complete ped and part of five other peds. The peds have a subangular blocky structure because the corners are rounded, not sharp. The illustration shows that the inside of the peds are mottled brown and gray. The areas of the two colors are about the same, but the percentage of the brown color is somewhat greater. So, we say that brown is the **dominant color** and the gray colors are **iron depletions**. We see also that all the peds are coated with gray clay skins. According to part three of the rule we must consider the *combined* color of ped interiors and clay skins. All clay skins are gray, so the *combined* color is gray.

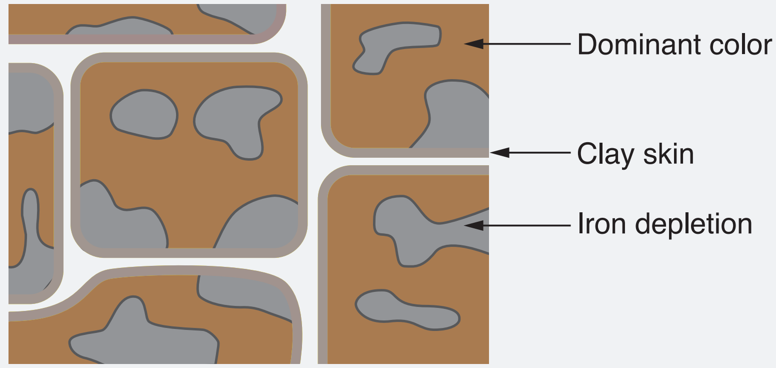


***Figure 2.20.** This illustration depicts a section through a soil sample about 2 inches across that shows one ped and parts of five other peds. The clay skins are larger than they actually are to show their color.*

Limiting Layers

There are four *kinds* of **limiting layers** recognized in soil evaluation:

1. Bedrock
2. Dense till
3. Fragipan
4. Coarse sand and gravel

▸ **EVALUATING RULE**
All Limiting Layers

To be a **limiting layer**, the layer must be more than 10 inches thick. If the layer or material meets the requirements in an individual rule and extends to the bottom of the pit, assume that it is more than 10 inches thick, thus a limiting layer.

There are also three recognized *depth zones* to a limiting layer:

- 0 to 20 inches
- 21 to 40 inches
- More than 40 inches (or no limiting layer visible in soil pit)

The kind of limiting layer and the depth of the layer combine to make nine distinct soil evaluation classes. They are listed on the scorecards.

Bedrock, dense till, and fragipans have little pore space, so they restrict root penetration and conduct water or sewage effluent very slowly. Figure 2.21 shows that a fragipan restricts downward root growth. On the other hand, few roots grow into coarse sand and gravel, because it has big spaces between the particles and cannot hold much water.

The depth to a limiting layer is important because it determines how much soil material is available for plant roots. A shallow (thin) soil limits how much water the soil can hold for plant growth. For home sites, the depth to a limiting layer largely determines the kind of soil absorption field that is suitable for the site.

Figure 2.21. This photo shows a tap root (outlined in yellow) that branched out when it grew down to the top of a fragipan. The top of the fragipan is where the root branched to the side.

LIMITING LAYER: BEDROCK

Bedrock gradually weathers to become weathered bedrock parent material, and then continues to change to become another kind of soil horizon. The Evaluating Rule below describes when rock material is hard enough and continuous enough to be considered a limiting layer.

▸ EVALUATING RULE
Bedrock Limiting Layer

Bedrock is considered a limiting layer if more than 80 percent of the layer is rock material that it meets *one or both* of the following:

- It cannot be cut with a spade or dug into with a knife
- Roots cannot grow into it

LIMITING LAYER: DENSE TILL

The Till section (page 15) describes till's characteristics. In Indiana, practically all till is dense.

Also, in horizons that are transitional between B and C horizons, clay skins might penetrate into till, which decreases the horizon's bulk density. *For soil evaluation, however, all calcareous till is considered dense*. Therefore, the criteria used to identify till parent material are used to identify dense till.

From a standpoint of land use, **dense till** limits the depth to which the roots of a crop can grow. In addition, dense till is very slowly permeable and affects the type of septic system design recommended for home waste disposal.

▸ EVALUATING RULE
Dense Till Limiting Layer

Dense till has *all* of these characteristics:

- Pebbles, if present, are mainly igneous, rounded, and randomly distributed
- Not stratified/not layered — material is homogeneous (mixed)
- Calcareous in C horizons
- Usually has platy depositional structure in C horizons
- Common texture and color combinations found in C horizons include:
  - Medium texture (loam) and brownish (10YR 5/4, 5/6, 5/3), **or**
  - Moderately clayey texture (clay loam, silty clay loam) and near the brown/gray boundary (10YR 5/3, 5/4, 5/2)

FRAGIPANS

Fragipans are firm, **brittle** subsoil horizons through which water moves very slowly and roots do not penetrate easily. A soil is considered brittle if a moist piece of soil (about ½- to 1 inch across) ruptures suddenly or pops when you press it between the thumb and forefinger rather than deforms slowly. Fragipans are usually medium or moderately clayey in texture — near the boundary of silt loam and silty clay loam (see Figure 2.15). Usually, the upper surface of a fragipan is 20 to 50 inches below the soil surface. A fragipan is 10 to 30 or more inches thick.

Fragipans are most easily recognized by their overall appearance. They consist of large structural units called prisms, which are taller than they are wide. The outside face of a prism is covered with gray coatings that consist mainly of silt in the upper part of the fragipan and of silt and clay in the lower part.

The photo of Hosmer soil (Figure 1.25) shows these prism coatings just to the right of the tape at 3 feet, as well as in the lower right hand corner. The shaved part of the soil profile cuts through some prism coatings at a right angle in Figure 1.25. In some soils, the gray material also forms a continuous layer just above the fragipan (at 3 feet in Figure 1.25). This gray material tapers like a funnel into the gray silty streaks that coat the peds. The interior of the prism is brownish and mottled with gray. In poorly drained soils, gray colors may dominate. The interior material is firm and brittle when moist.

The prism coatings appear as gray vertical streaks in a soil profile. When viewed from the top, they form a polygonal pattern (something like the skin of a giraffe or chicken wire, but with a less regular pattern, see Figure 1.13). Prisms must be, on average, more than

Figure 2.22. A. *This photo shows a horizontal surface in a fragipan. The brownish material is the* inside *of a prism. The light gray material is a* coating *on the prism. The round feature in the lower right is probably a filled crayfish burrow (see Figure 1.9). Photo provided by USDA-NRCS, Indiana.* ***B.*** *This photo shows a stepped surface in a soil with a fragipan. The units of the numbers on the right side of the tape are feet. The section from 1 to 2.5 feet is a vertical exposure, 2.5 to 3.5 feet is horizontal, and 3.5 to 5 feet is vertical. The upper boundary of the fragipan is about 2 ft.*

4 inches across to be considered a fragipan. Figure 2.22 shows how a fragipan looks from different viewpoints — the way you might see in a contest.

Roots grow downward in the gray silt between the prisms, but not through the interior of the prisms. A horizontal shelf or surface through the prisms will be dug in soil evaluation pits (see Chapter 5, Site Selection and Preparation.)

Fragipan soils present special problems for farming. Water can't penetrate a fragipan very quickly, so the soil above the pan becomes waterlogged in spring. Roots cannot penetrate into fragipan prisms, so crop plants get very little water from fragipan horizons. In the winter, freezing and thawing cycles may have plants with long taproots (like alfalfa) out of the soil.

In Indiana, fragipans occur mainly in Soil Regions 5, 10, and 11, with a few in Regions 12 and 13 where the loess is fairly deep (see Figure 1.2).

EVALUATING RULE
Fragipan Limiting Layer

A **fragipan** limiting layer must have *all* of these characteristics:

- Prisms that, on average, are 4 inches or more wide
- The material inside the prisms is brittle
- The prisms contain few or no roots

LIMITING LAYER: COARSE SAND AND GRAVEL

Coarse sand and gravel, as in the Ockley soil (Figure 1.21), limits root growth because of its low ability to supply water to plants. Although fine sands have relatively high water-supplying abilities, the wide spaces between coarse sands hold very little water. Therefore, an arbitrary limit based on sand size, has been established between the sandy materials that restrict plant growth and those that do not. This limit is between the medium sands and the coarse sands.

Soil evaluation defines "coarse sand and gravel" as sandy material (see Figure 2.15) in which most of the sand particles are larger than 0.5 mm (the size of grains on 40-grit sandpaper). Most coarse sands also contain quite a bit of gravel, but some coarse sand does not. Usually, when you moisten and squeeze coarse sand, it will not form a cast, or if it does, the cast will not hold its shape when gently tossed up and down in the air. Sandy materials that are not limiting layers include some water-deposited sandy materials and eolian sand deposits.

Thin bands of coarse sand and gravel are less of a limitation than thick deposits. So, in order to considered a limiting layer in soil evaluation, a layer of coarse sand and must be 10 or more inches thick. Coarse sand and gravel can be the lowest horizon in the soil pit, or it can be found between finer textured layers.

Coarse sand and gravel layers do not affect water availability if the water table is permanently within reach of the plant roots. However, most poorly and very poorly drained soils in Indiana have a fluctuating water table, which becomes low enough in summer to make the subsoil's water-holding capacity important. Therefore, in soil evaluation, coarse sand and gravel layers are considered to be limiting, regardless of drainage class.

▸ **EVALUATING RULE**
Coarse Sand and Gravel Limiting Layer

A **coarse sand and gravel** limiting layer has *both* of these characteristics:

- It qualifies for the sandy texture group, and the sands are mainly > 0.5 mm in diameter (the size of 40-grit sandpaper)
- Gravel is usually present, but may be lacking

Soil Health

Soil health has received much attention in recent years. The paragraphs below come from the Soil Health webpage of the USDA-Natural Resources Conservation Service (www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health).

> **Soil health**, also referred to as soil quality, is the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. The key word in the definition is *living*. Only living things can have health, so viewing soil as a living ecosystem reflects a fundamental shift in the way we care for our nation's soils. Soil isn't an inert growing medium. It is teeming with billions of bacteria, fungi, and other microbes that are the foundation of an elegant symbiotic ecosystem. Soil is an ecosystem that people can manage to provide nutrients for plant growth, absorb and hold rainwater for use during dryer periods, filter and buffer potential pollutants from leaving our fields, serve as a firm foundation for agricultural activities, and provide habitat for soil microbes to flourish and diversify to keep the ecosystem running smoothly.
>
> Healthy soil gives us clean air and water, bountiful crops and forests, productive grazing lands, diverse wildlife, and beautiful landscapes. Soil does all this by performing five essential functions:
>
> 1. Regulating water — Soil helps control where rain, snowmelt, and irrigation water goes. Water and dissolved solutes flow over the land or into and through the soil.
> 2. Sustaining plant and animal life — The diversity and productivity of living things depends on soil.
> 3. Filtering and buffering potential pollutants — The minerals and microbes in soil are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposits.
> 4. Cycling nutrients — Carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed, and cycled in the soil.
> 5. Physical stability and support — Soil structure provides a medium for plant roots. Soils also provide support for human structures and protection for archeological treasures.

6. Notice that many agriculture and home site practices that are described in the next two chapters promote soil health.

CHAPTER 3 – Agriculture Practices

After you evaluate a soil and mark your property answers on a scorecard, it is time to judge a soil. There are two scorecards — one for agriculture practices (page 149), another for home site practices (page 150). This chapter examines how to judge soils for agricultural use. All of the Judging Rules in this chapter refer only to the agriculture site scorecard. Chapter 4 will explore how to judge home site soils.

Land Use Overview

In this section, we discuss two overview considerations about using soils:

If pre-settlement vegetation is to be restored, what kind of vegetation should be established?

How well suited is the soil for agriculture?

Restore Pre-settlement Vegetation

In Chapter 1, we explained that organisms, especially vegetation, is one of the factors of soil formation and that the nature of vegetation affects soil properties. In Indiana, the kind of vegetation has changed greatly over the years. Thousands of years ago, glaciers covered most of the state. When the glacial ice melted and soil formation began, the climate was much colder than it is now and the vegetation was probably similar to the current vegetation in northern Canada and Alaska. After the glaciers left, the temperature warmed and the vegetation adapted to the climate. Native Americans also influence the vegetation somewhat.

The big change in vegetation, however, occurred after European settlers arrived, and especially after they began using large machines to manage soils. The change has become so extensive that now there are very few areas in which the vegetation is like it was when the settlers arrived – the *pre-settlement vegetation*. So, now there is a movement to preserve the few areas of pre-settlement vegetation remaining and to restore areas that have been farmed to pre-settlement conditions. If the goal is to restore vegetation to its pre-settlement conditions, we must know what the vegetation was like at that time. Soil properties tell us a lot about pre-settlement vegetation, and that is the point of the first practice in this chapter. It has nothing to do with agriculture practice, unlike all the other practices discussed, but it is included with agriculture instead of home sites.

Almost any site can be restored to its original vegetation. So, when you are looking at your agriculture site scorecard, interpret soil judging item 15 to mean, "If you determine that the soil should be restored, which plant communities should be established?" *not* "Is the soil better suited for restoration than for crop production?"

When European settlers first arrived in Indiana, practically all of the state was **mesic forest**, **prairie**, or **wetland** ("mesic" means medium moisture conditions). Gradually, farmers cleared the forest, drained wetlands, and plowed up the prairie, so very few of the original plant communities remain.

If you plan to restore the original vegetation, then the vegetation should match the kind of vegetation that was present when settlers first cleared the land, as shown in the rules below.

► **JUDGING RULE**
15. Restore Original Vegetation

For **Restore original vegetation** (15 on agriculture scorecard) select:

- **Wetland** if the soil is poorly drained
- **Prairie** if the soil is somewhat poorly drained, moderately well-drained or well-drained and has a black surface horizon that is more than 10 inches thick
- **Mesic forest** if the soil does not qualify for wetland or prairie
- If the area being evaluated still has its original vegetation, interpret the rule as "Preserve" instead of "Restore" original vegetation.

Prime Farmland

Much land in Indiana will continue to be farmed. The rest of this chapter deals with how best to farm the land while protecting the soils.

In recent years, many have expressed concerns about losing excellent farmland to nonagricultural uses such as highways, urban sprawl, apartments, shopping centers, industrial areas, and surface mines. To help local governments preserve soils for continued food production, the U.S. Department of Agriculture defines prime farmland as land capable of producing good yields of adapted crops in most years. The USDA's definition relies on soil properties, many of which are determined in soil evaluation. Many local, state, and federal planning units consider prime farmland soil properties as a guide for identifying land that should remain agricultural rather than be used for urban development.

Soils that are frequently flooded, have low water-holding capacity (they are sandy, or shallow to a limiting layer), or are very erodible (usually on slopes steeper than 6 percent) are excluded from the definition of prime farmland.

> ▸ **JUDGING RULE**
> **16. Prime Farmland**
>
> Mark "Yes" for **Prime farmland** (16 on agriculture scorecard) if the soil has *all* of these properties:
>
> - Its subsoil texture is moderately sandy or finer
> - It is more than 20 inches to a bedrock or coarse sand and gravel limiting layer
> - It has a slope of 6 percent or less
> - Landform is not a floodplain

Figure 3.1. *These photos show soils that have severe water erosion. Photo provided by USDA-NRCS, Indiana.*

Erosion and Compaction Potentials

Most Indiana soils will continue to be used for agriculture, but this uses can potentially harm the soil (on-site degradation) or pollute other areas (off-site degradation). Most sections of this chapter explain how to manage the soil for agriculture while minimizing both on-site and off-site degradation.

Water Erosion

Soil erosion is the most serious soil-degrading process, not only in Indiana, but also in the rest of the world (Figure 3.1). Each year, over 45 million tons of soil erodes from Indiana's cropland, pastures, forests, and other places where people live and work, such as residential areas, industrial areas, and parks. Another 17 million tons of soil erodes from stream banks, gullies, roadsides, and construction sites.

The Universal Soil Loss Equation (USLE) can predict the amount of soil erosion. According to this equation, the amount of erosion caused by water depends on:

- **The energy of the rainstorms** (R factor). In Indiana, this energy increases from northeast to southwest.
- **The erodibility of the soil** (K factor). In general, medium-textured soils, especially silty ones, are more erodible than sandy or clayey soils. Also, soils low in organic matter (grayish and brownish surface horizons) are more erodible than those high in organic matter (dark colored).
- **Length of slope** (L factor). Long slopes erode much more than short ones, because the amount of runoff water increases with distance down the slope.

- **Gradient (%) of slope** (S factor). Water runs faster on steep slopes than on nearly level ones, and faster moving water can remove and carry more soil material. This factor is very important for predicting the amount of soil erosion if no soil conservation practices are used and is emphasized in soil judging.
- **Cropping and management practices** (C factor). These practices include the kind of tillage the farmer uses and the kind and amount of cover on the soil. Living or dead plant material reduces the impact of raindrops on the soil and anchors soil particles in place.
- **Mechanical practices** (P factor). This includes farming on the contour (level rows across the slope) and terraces. These practices reduce the speed of down-slope water flow and thus decrease erosion.

These factors can be divided into two classes. The factors, R, K, L, and S are natural features of the soil and climate that humans cannot change. Of these four factors, the amount of erosion depends mainly on slope gradient, S. Thus, slope gradient (steepness) appears in several rules.

The goal of controlling soil erosion is to keep soil loss less than the **tolerable soil loss**, the maximum rate of annual soil loss that will permit crop **productivity** to be sustained economically and indefinitely. In Indiana, tolerable soil loss is generally 2 to 5 tons per acre annually — the lower number is for shallow soils.

However, farmers and others can set the C and P factors by the kind of tillage and cropping systems they decide to use. In the Cropping Practices section, we describe the practices most used in Indiana that affect the C factor.

In soil judging, the potential for water erosion depends largely on the steepness of slope. Slope steepness (percent) appears in several rules. The rule below also reflects that shallow soils need special care because losing even a little bit of a shallow soil will greatly affect the soil's ability to grow plants.

▸ **JUDGING RULE**
17. High Potential for Water Erosion

Mark "Yes" for **High potential for water erosion** (17 on agriculture scorecard) if the soil has *one* of these properties:

- 20 inches or less to any limiting layer and slope is more than 2 percent
- More than 20 inches to any limiting layer and slope is more than 6 percent

Wind Erosion

Eolian sand (page 16) is material that was picked up, carried by the wind, and deposited thousands of years ago. Now, the wind can pick up the same material again in the process of wind erosion (Figure 3.2). The rule identifies material that can be readily transported by wind.

Figure 3.2. *Wind erosion. Photo provided by USDA-NRCS.*

▸ **JUDGING RULE**
18. High Potential for Wind Erosion

Mark "Yes" for **High potential for wind erosion** (18 on agriculture scorecard) if the soil has a sandy or moderately sandy surface texture.

Soil Compaction

Soil compaction is also a serious problem in Indiana. It occurs when a certain amount of soil is packed into a smaller volume. The main cause of compaction is excessive tillage and traffic, especially when the soil is wet. Therefore, you can minimize soil compaction by reducing the amount of tillage and by avoiding driving on the soil when it is too wet. Some of the practices that control erosion (such as conservation tillage) also minimize compaction.

Nearly all soils can be seriously compacted. Poorly and somewhat poorly drained soils are most subject to compaction because they are often wet when they are tilled or driven on. Also, soils low in organic matter (grayish or brownish in color) are most at risk. It is difficult to compact very sandy soils. Soil compaction potentials should be kept in mind in deciding when tillage, planting, or harvest operations should be done.

> ▸ **JUDGING RULE**
> **19. High Potential for Soil Compaction**
>
> Mark "Yes" for **High potential for soil compaction** (19 on agriculture scorecard) if the soil has *both* of these properties:
>
> - Natural drainage that is somewhat poor or poor
> - Surface texture that is moderately sandy or finer

Buffers and Cover Crops

This section describes several farming practices that protect soil and water resources by maintaining vegetative cover. Such practices include conservation buffers and cover crops. These practices slow water runoff, trap sediment, and enhance water infiltration into the soil in the buffer. For soil judging, they are marked according to the rules below, even if the soil pit is not in a cropped field.

Grassed Waterways

Grassed waterways are strips of grass in cropland areas where water flow concentrates (Figure 3.3). While grassed waterways are primarily used to prevent **gully** erosion, they can be combined with filter strips to help trap contaminants and sediment. Grassed waterways are used in sloping cropped fields.

Figure 3.3. *These photos show grassed waterways. A. A newly established with a structure at the end to control erosion. B. An established waterway. Photos provided by USDA-NRCS, Indiana.*

> ▸ **JUDGING RULE**
> **20. Grassed Waterways**
>
> Mark "Yes" for **Grassed waterways** (20 on agriculture scorecard) if the slope is 3 to 18 percent.

Windbreaks

A windbreak is a row of trees, shrubs, or other vegetation used to reduce wind erosion, protect young crops, and control blowing snow (Figure 3.4). Windbreaks are placed near the field boundary that is most nearly perpendicular to the direction of the prevailing wind — since most prevailing winds come from the west in Indiana, most windbreaks are oriented north-south. The parent materials of many sandy and moderately sandy soils were deposited by wind, and these soils are especially subject to wind erosion. Many of these soils are common in Soil Region 1, but windbreaks are also used in other regions.

Figure 3.4. A windbreak at the edge of a field. Photo provided by USDA-NRCS.

▸ **JUDGING RULE**
21. Windbreaks

Mark "Yes" for **Windbreaks** (21 on agriculture scorecard) if the surface texture is sandy or moderately sandy.

Filter Strips

Filter strips are long, narrow strips of vegetation (usually grass) that are established between fields and waterways (such as streams, ditches, and drainageways) (Figures 3.5 and 3.6). Filter strips slow the flow of runoff from fields and trap sediment, nutrients, pesticides, and other pollutants before they reach surface waters. Filter strips also protect the soil from erosion.

Filter strips typically vary from 20 feet wide (on nearly level soils) to 60 feet wide (on sloping soils). They can be planted to **forage crops** from which hay can be harvested.

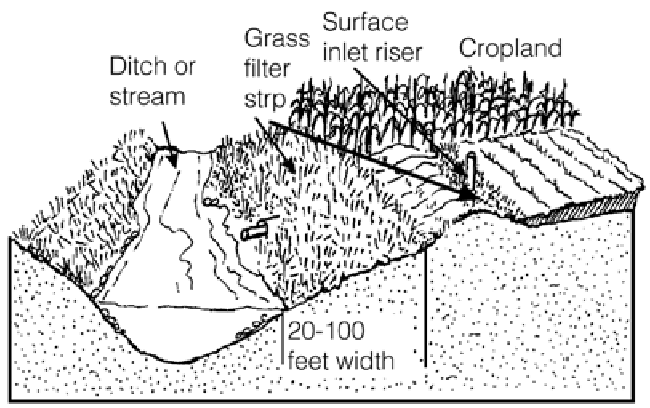


Figure 3.5. This illustration shows a filter strip and a surface inlet.

Figure 3.6. This photo shows a filter strip (green) at the edge of a crop field (brown). There is a small stream in the strip where trees are growing. Photo provided by USDA-NRCS, Indiana.

Filter strips are established along areas in which water flows, but these areas cannot be identified using properties determined in a soil pit. Soil judgers identify places in the contest area that they believe are appropriate for filter strips and make a note about the location. They will compare their judgement with that of coaches and contest officials during the critique session. Soils on slopes more than 18 percent are not used as cropland and thus do not need filter strips.

Strip cropping is practice of growing crops in a systematic arrangement of equal width strips across a field. It is used in areas that have long, uniform slopes, but these kinds of slopes are not common in Indiana.

► **JUDGING RULE**
22. Consider Filter Strips

Mark "Yes" for **Consider filter strips** (22 on agriculture scorecard) for soils with slopes of 18 percent and less.

Official judges may identify locations in the soil judging area they believe are suitable for filter strips during the critique session.

Cover Crops

A cover crop is a crop grown between periods of regular crop production to prevent soil erosion and provide other environmental benefits (Figure 3.7). Typically cover crops are planted about the time farmers harvest **row crops** such as corn and soybeans. Farmers terminate the cover crop before they plant the next summer crop. Cover crops provide soil cover during late fall, winter, and early spring. Grasses, legumes, and other crops can be used as cover crops. Currently the more common species include annual ryegrass, cereal rye, crimson clover, turnips, and oilseed radishes.

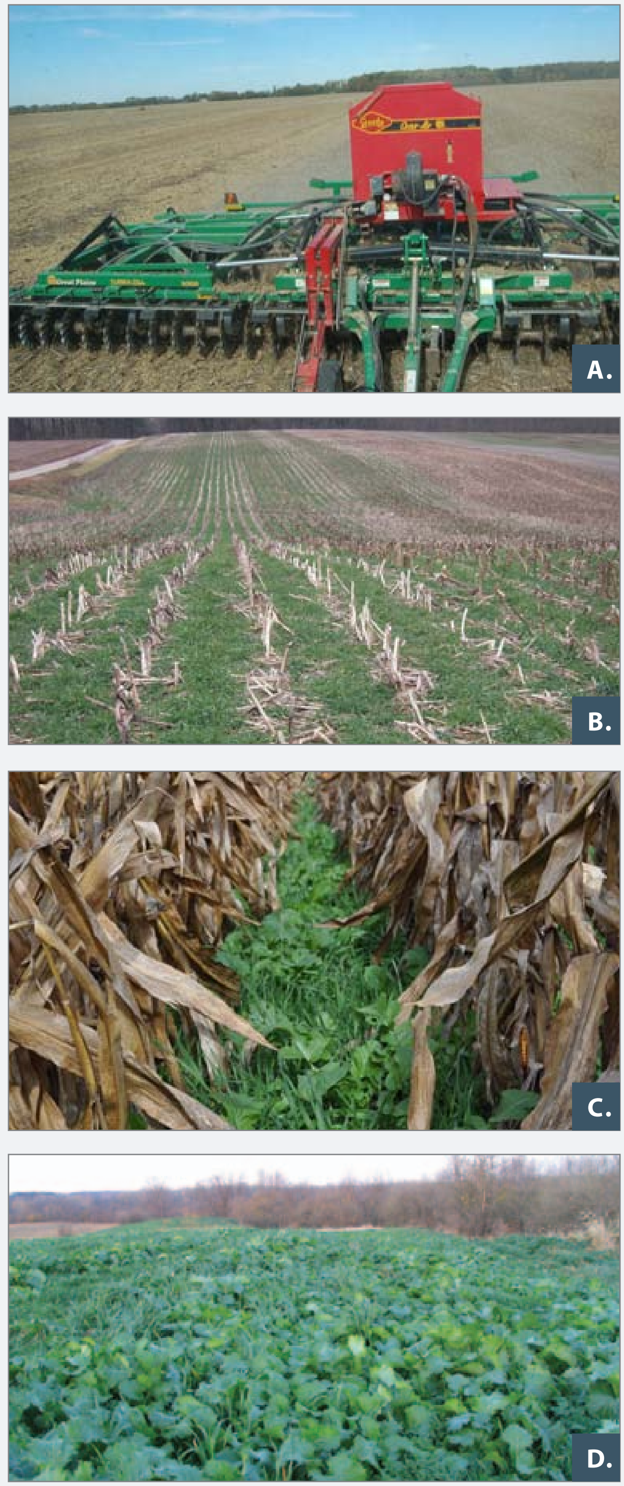


__Figure 3.7.__ These photos show various cover crops. __A.__ This farmer is seeding a cover crop with a vertical tillage tool in the fall after soybean harvest. Photo provided by Tom Bechman. __B.__ This cereal rye cover crop is planted in cornstalks. Photo provided by Eileen Kladivko. __C.__ These rye and radish cover crops are growing in mature corn. Photo provided by USDA-NRCS, Indiana. __D.__ This radish cover crop provides complete cover after soybean harvest. Photo provided by USDA-NRCS, Indiana.

Cover crops may be seeded from an airplane into a standing corn or soybean crop where seeds end up on the soil surface. However, some crops must be seeded into the soil, which must be done after the crop is harvested. Early seeding to get plants well established before cold weather is essential to successful cover crop development. Cover crops are planted for their benefit to soil or environmental quality and not for harvest. Some cover crops may also be suitable for grazing or haying, but then they are a forage crop and should be managed as such. After the cover crop has done its job, it must be terminated before the next summer crop is established. Some crops die over winter, some are killed with an herbicide, and others might be killed by tillage or by crimping the plant stems. One problem associated with oilseed radish is the odor that occurs during their decomposition.

The publication, Managing Cover Crops: Cover Crops for Modern Cropping Systems by Eileen Kladivko (Purdue Extension publication AY-352-W, available from the Education Store, edustore.purdue.edu) explains the benefits of cover crops.

The benefits of cover crops include:

Scavenge nitrogen (N). Cover crops can scavenge or "trap" residual soil nitrate to prevent it from leaching into drainage water. This protects water quality. Some of the scavenged nitrogen (N) will be available to succeeding cash crops while the rest helps build soil organic matter.

Produce N. Legumes "fix" atmospheric N for their own use. After you terminate the legume cover crop, it will release much of this N into the soil as the residues decompose, providing available N to succeeding crops.

Reduce erosion. The classic use of cover crops is to cover the soil surface to protect against both water and wind erosion, thus conserving the soil resource base.

Build soil health. Cover crops improve soil physical properties, increase soil organic matter, and increase soil biological activity. Fibrous roots build soil aggregation, and deep-rooted crops improve permeability. Some tap-rooted crops help break up compacted layers, which improves water flow, aeration, and cash-crop rooting. Cover crops stimulate soil biological activity by providing additional food in the cover crop shoot and root residues. Cover crops left as a **mulch** at the soil surface can also conserve soil moisture for later use by the cash crop.

Suppress weeds. Some cover crops can suppress weeds by competition, shading, or allelopathy (which is when a plant produces an organic compound that negatively affects other plants). Unfortunately, some cover crops can also become weeds in subsequent cash crops if you do not carefully manage them.

Recycle nutrients. Although most growers focus on nitrogen, cover crops may also help recycle other nutrients by reducing erosion, building soil organic matter, and increasing soil biological activity.

Protect water quality. When cover crops scavenge residual soil N, they can reduce N losses to drainage water. Covers also reduce erosion and the losses of both phosphorus and pesticides that are bound to the sediments.

Enhance wildlife habitat. Cover crops can provide water, cover, and food for birds and other wildlife and increase landscape diversity. They may also provide habitat for pollinators and other beneficial insects.

The two *major* benefits of cover crops to the producer and to the environment are to control erosion control and to scavenge nitrogen. Controlling erosion aids the farmer by keeping soil and nutrients in place and minimizes the **contamination** of water bodies downstream with nutrients such as phosphorus. A cover crop keeps nitrate N in the soil and available for later use and minimizes nutrient contamination downstream.

For soil evaluation, cover crops are recommended for use on all soils that would be left bare for a time without their use — that is, all soils with slopes of 18 percent or less. Beyond that requirement, soil judgers must think about *why* cover crops are used. The erosion control benefit of cover crops is greater for most sloping soils, and the N conservation benefit is greater for soils that have a high potential for leaching of nitrate to the groundwater and to surface water through subsurface drainage systems. The later includes all soils with 0-2 percent slopes and those on 3-6 percent slopes that have sandy subsoil or have a coarse sand and gravel limiting layer.

▸ **JUDGING RULE**
23. Cover Crops

Choose the **Most significant benefit of Cover crops** (23 on agriculture scorecard) for this site by marking:

- **Scavenge nitrogen** if the soil has *either* of these properties:
  - Slope is 0-2 percent
  - Slope is 3-6 percent and the soil has a sandy subsoil or a coarse sand and gravel limiting layer
- **No need** if the slope is more than 18 percent (the soil is not tilled)
- **Erosion control** for all other soils

Cropping Systems

A cropping system refers to the kind of crops grown and their sequence over a time period of several years. This section describes the kinds of cropping systems commonly used in Indiana and how well these systems protect soils from erosion. The potential for soil erosion largely determines the kind of cropping system a farmer can use on a certain soil. Cropping systems are closely related to the tillage practices described above. Timber stand improvement does not involve typical farm crops, but is listed with the cropping practices described below.

Timber Stand Improvement (TSI)

Timber stand improvement (TSI) is a practice that improves the quality of a timber stand. Landowners allow the best trees in a stand to grow so they can eventually be harvested, and they remove other trees and vines that may be in the way of the good trees.

▸ **JUDGING RULE**
24. Forestry with TSI

Mark "Yes" for **Forestry with TSI** (24 on agriculture scorecard) for all soils.

Permanent Pasture

Permanent pasture is land with perennial vegetation that is used for grazing rather than for harvesting hay.

▸ **JUDGING RULE**
25. Permanent Pasture

Mark "Yes" for **Permanent pasture** (25 on agriculture scorecard) for soils with slopes 25 of percent or less

Crop Rotation

Crop rotation refers to growing a certain sequence of different crops in a field, in contrast to continuous cropping. The main row crops in Indiana are corn and soybeans. Farmers often grow them in a rotation with each other.

There are many possible combinations of crops and the length of time they are grown in a crop rotation. The rotation assumed for the rule below provides almost continuous cover and protects the soil from erosion on slopes as steep as 18 percent.

In the following discussion:

Forage crops include perennial crops grown in a rotation for animal feed as hay or pasture.

Cover crops are grown between periods of regular crop production, usually with corn and soybeans.

Small grains refer to a variety of crops. Winter wheat is the most common small grain crop in Indiana, but oats and barley are also grown.

The rotation assumed for the rule is designated C-G-F-F-F-F, a six-year cycle — C = corn, G = small grain (wheat), and F = forage crop. In year one, farmers plant corn in the forage crop residue. In year two, they plant a mixture of seeds for wheat, a legume, and a grass in the corn residue. After harvesting the wheat, the field fills in with the grass-legume mixture, which remains in place for four years.

▸ **JUDGING RULE**
26. Crop Rotation

Mark "Yes" for **Crop rotation** (26 on agriculture scorecard) for soils with slopes of 18 percent or less.

Tillage Practices

Tillage is what farmers do to prepare land for planting. Depending on the cropping system, farmers may till the soil every year, or they may never completely till it. The more a soil is tilled, the more subject it is to erosion and compaction.

Conservation Tillage

Conservation tillage includes all tillage systems that leave at least 30 percent of the soil surface covered with live plants or crop residue at planting time. It includes no-till and strip-till. Conservation tillage became popular after manufacturers developed new herbicides that control weeds without **plowing** and they developed planters that can drill or slice through heavy residue cover. Controlling erosion by leaving crop residue on the surface is one of the chief benefits of conservation tillage systems. No-till is the main kind of conservation tillage in Indiana. **Minimum tillage** is a similar, but less specific, term.

No-till

In no-till planting, farmers plant the crop in soil that has a residue cover (Figure3.8). The residue may be left from a previous row crop (such as soybeans or corn) or from vegetation that was recently killed with herbicides (such as a cover crop).

No-till double cropping is planting soybeans into small grain stubble immediately after harvesting the small grain crop, usually in early July. No-till planting saves fuel because of fewer tillage trips over the land.

No-till planting is especially well suited for erodible, well-drained soils where the increased cover greatly reduces erosion and moisture loss through evaporation. Corn and soybeans planted in a no-till system generally yield more on these soils than when a moldboard plowing system is used. Wheat can also be seeded by the no-till method, but a special drill is needed. No-till wheat is usually grown in a rotation with other crops. No-till is also used in renovating a pasture.

On many poorly and somewhat poorly drained soils, however, corn grown in corn residue under no-till sometimes yields less than corn grown under moldboard plowing. This occurs because wetter soils warm up slowly in the spring if they are covered with heavy residue from previous crops. These cool, early-season soil temperatures (and perhaps other factors) retard crop growth and result in a yield reduction. The cost of the yield reduction, however, is often offset by lower fuel and equipment costs. Yields for corn planted no-till after soybeans, on the other hand, are only slightly reduced. For this reason, farmers first began no-till operations by planting corn after soybeans. When better seeding machinery and herbicides became available, more farmers planted soybeans directly into soil with crop residue.

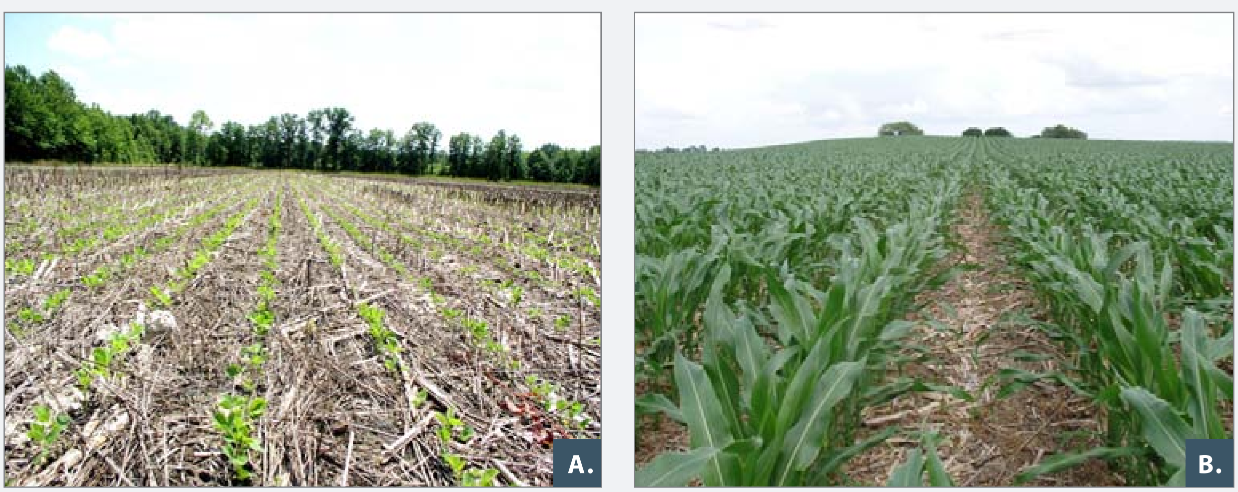


Figure 3.8. These photos show examples of no-till practices. A. This image shows small soybeans in corn residue. B. This image shows corn in corn residue. Photos provided by USDA-NRCS, Indiana.

Less than 10 percent of all cropland was managed in a no-till system in 1990, but no-till crop production grew rapidly during the 1990s. Initially, corn was considered to be better suited to no-till than soybeans, but the development of the no-till drill to plant soybeans in corn residue and better herbicides resulted in steady increases in the acreage of no-till beans. The percentage of corn land in no-till increased until 1993, and then held steady at 20 to 25 percent (Figure 3.9). The percentage of soybeans in no-till increased to around 40 percent in 2000 and then remained at about the level.

No-till double cropping is the practice of planting soybeans into small grain stubble immediately after harvesting the small grain crop (usually in late June). No-till planting saves fuel because it requires fewer tillage trips over the land.

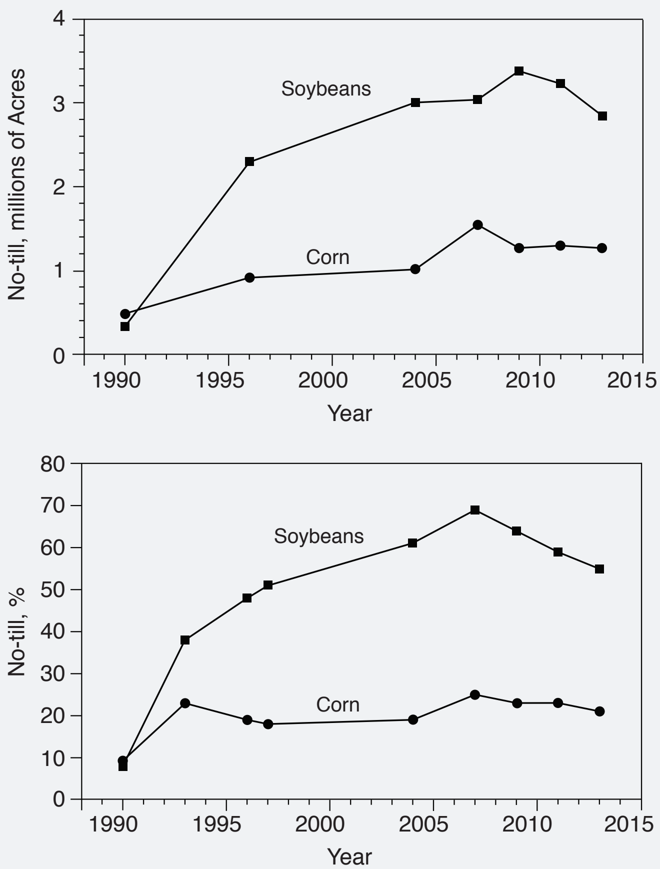


Figure 3.9. *This graph shows the adoption of no-till planting of corn and soybeans in Indiana.*
Source: *Indiana State Department of Agriculture.*

Strip-till

Strip-till is a tillage method in which a strip of soil is tilled in a field covered with plant residue (Figure 3.10). Some of the residue is pushed to the side before the strip is tilled, but some gets buried in the process. Usually, about 75 percent of the original residue remains on the field after strips are created, but none remains on top of the strip. Typically, strips are 6 to 8 inches wide, 4 to 8 inches deep, and spaced 30 inches apart. Thus, most of the field is not tilled. Strips are usually prepared in the fall, but they are also prepared in the spring. Usually, granular fertilizer is placed near the bottom of the tilled strip. Corn or soybeans are planted in the center of the strip in the spring. Careful driving or guidance is needed to plant the seed exactly in the center of a strip, and this guidance is often assisted by global positon system equipment GPS with real time kinematic — RTK). The strips are a few inches higher than the rest of the field when they are made, but they settle down to 1 or 2 inches higher at planting time.

Figure 3.10. *Tilled strips being created in a field with soybean residue. Photo provided by Tony Vyn.*

In poorly and somewhat poorly drained soils, crops sometimes get off to slow start in no-till fields, because the soils are wet and cool after planting. In strip till, the soil in the strip is bare and open to the sun, allowing it to warm up. Also, because the strip is higher than the rest of the field, it is a bit drier. Furthermore, the fertilizer is placed where it is available for early plant growth. For these reasons, strip-till might result in greater crop yields than no-till in some fields.

Strip-till has the same soil requirements as no-till and is considered the same as no-till for soil judging.

▶ **JUDGING RULE**
27. No-till or Strip-till

Mark "Yes" for **No-till or strip-till** (27 on agriculture scorecard) for soils that have *both* of these properties:

- 6 percent or less slope, **and**
- Either:
  - Well-drained or moderately well drained soils with any surface texture, **or**
  - Poorly or somewhat poorly drained soils with moderately clayey or coarser surface texture.

Moldboard or Chisel Plowing

For many years, **moldboard plowing** was the usual method for primary tillage (Figure 3.11). It is considered a "clean tillage" practice. It inverts the surface soil, to a depth of 7 to 10 inches, and covers the previous crop residue so there is no cover to protect against erosion. Much of the organic matter is placed in the lower part of the plow layer. Often, moldboard plowing is followed by several other shallow tillage operations with a disc harrow or field cultivator. Moldboard plowing leaves the soil bare and very subject to erosion, so it should be done in the spring, instead of fall, to minimize the time the soil is bare. The only soils on which moldboard plowing can be used safely are those with very little wind or water erosion hazard and those less likely to become compacted.

Over the years, a **plowpan** has developed in some soils. It is a dense layer beneath the common depth of plowing (usually 8 to 10 inches) that develops because of the weight of tractors and equipment and the downward pressure of a moldboard plow. It can be broken up by **deep tillage** or **ripping**, tilling below the common depth of tilling.

Chisel plowing utilizes a chisel-shaped implement that can be adjusted to a desired depth, for example, 8 to 10 inches (Figure 3.12). Chisel plowing does not invert the soil but rather leaves it rough and cloddy. Chisel plows are equipped with chisel points spaced 12 to 15 inches apart. Some types have a gang of discs in front of the chisel to cut the residue and to avoid clogging the chisel. Straight or twisted chisel points or sweeps may be used, depending on how much residue incorporation is desired. Narrow, straight chisels leave as much as 80% of the corn residue on the surface, while wide, twisted points leave very little residue.

Figure 3.11. These photos show two views of moldboard plows. ***A.*** *A moldboard plow out of the ground. The disk in front (far right) makes a shallow slit in the residue and soil surface. The shiny object is the plow. An important attribute is that soil does no stick to the metal surface of the plow (it "scours"). This implement has five units (a five-bottom plow).* ***B.*** *A four-bottom plow in action. It turns the soil completely over and buries almost all of the plant residue. Photo provided by* Tiny Farm Blog.

__Figure 3.12. A.__ A chisel plow. The disk blades in front (left) cut through residue such as corn stalks and create a slice in the soil. The second and third units (behind tires) are the chisel plow shanks and shovels, four in the second unit and five in the third unit. They till about 10 inches deep. The last unit consists of S-shaped shanks and triangular shovels (sweeps) that smooth out the soil surface. __B.__ A close-up taken from the other side of the implement shows details of the chisel shanks and shovels. These shovels are not twisted, so they bury less plant residue. __C.__ Chisel plowing with a different implement. This one left little residue on the surface. 3.12C provided by Tom Bechman.

Chisel plowing after corn is usually most successful if it is done in the fall. Then soils are chiseled 8 to 10 inches deep. In the spring, a field cultivator, disc harrow, or similar implement is usually used for secondary tillage because chisel plowing leaves the soil very cloddy (Figure 3.13). If chisel plowing is done in the spring, it should be done to a depth of only 4 to 6 inches to avoid the deeper layers that are often wetter. The runoff and erosion control effectiveness of chisel plowing depends on the amount of residue left on the surface, tillage direction (down or across the slope), and degree of soil roughness.

Figure 3.13. Using a disk/ field cultivator to prepare a field with corn residue for planting soybeans. Photo provided by Tom Bechman.

For soil judging, moldboard plowing and chisel tillage are grouped together.

▸ **JUDGING RULE**
28. Chisel or Moldboard Plowing

Mark "Yes" **Chisel or moldboard plowing** (28 on agriculture scorecard) for soils with *all* of these properties:

- Slope is 2 percent or less
- Medium or finer surface texture
- Poorly or somewhat poorly drained

RULES AND COVER CROPS

The rules above assume that cover crops *are not* used. If cover crops *are* used, a practice may be used on slopes greater than those stated in the rule. For example, No-till might be used on slopes steeper than 6 percent. Making these kinds of recommendations, however, are left to professional soil conservationists and are beyond the scope of soil judging.

Notice that soils on steep slopes have few options for tillage and cropping; soils on gradual slopes have more options.

Water Management

Managing water is a critical component of farm operations. Soil judging contestants decide if it is feasible to:

- Drain wet soils
- Irrigate droughty soils
- Install structures that control water flow and soil erosion

Drainage

Plants must have water and oxygen in their **root zones** if they are to thrive. Poorly drained and somewhat poorly drained soils have so much water that there is little available oxygen in the root zone, essentially suffocating the plant. Before one can use these soils for efficient crop production, the water must be removed to allow room in the pore spaces for air.

Systems that remove excess water from the soil surface and within the soil may be called *man-made drainage* or *artificial drainage* (in contrast with *natural drainage* described in Natural Soil Drainage, page 57). In this section, we refer to all artificial systems simply as drainage. Drainage allows for timely field operations and helps crops get an early start. Another benefit of drainage is that it decreases ponding in swales. In un-drained fields, water may pond in low areas long enough to kill or greatly harm crop plants.

There are three drainage practices commonly used in Indiana:

1. Surface drainage, which involves grading the field to facilitate the movement of surface water off the field
2. Open ditch drainage, which removes subsoil water through open ditches
3. Tile drainage, which removes subsoil water through underground drain lines. The drain lines are now mainly made of perforated plastic tubes, but formerly they were made of ceramic tubes, called tiles. Those drain lines were called "tile drains," and that name is still used.

SURFACE DRAINAGE

Shallow surface drainage includes any system of grading the soil surface to facilitate water removal by overland flow. For many soils, this practice is used to supplement subsurface and open ditch systems. For some soils, it is the only system used. This includes soils that are shallow to bedrock and soils that have very slow permeability. However, soils less than 40 inches to bedrock and poorly or somewhat poorly drained are rare in Indiana.

In some landscapes, the upland flats are so large that no outlets are available for subsurface drains. In other places, the soils formed in lake bed materials may lie so low in respect to stream level that it is impossible to use subsurface systems unless the drainage water is pumped. In practice, surface drainage might be the only system used for these soils.

OPEN DITCH DRAINAGE

Open ditches are artificial, open drains constructed for the purpose of removing surplus water from wet land. They work effectively in deep soils with sandy subsoil or substratum textures. Open ditches can be supplemented by subsurface drains using special practices to ensure that sand is kept out of the drain tubes.

TILE DRAINAGE

Tile drainage removes subsurface water through a line or series of lines of perforated plastic tubing installed at a definite grade, often at depths of 36 to 42 inches beneath the surface (Figure 3.14). Subsurface drainage is an expensive practice, and a careful survey should be made first to ensure that the land is suitable for tiling and that adequate outlets are available. These outlets can be open ditches or large tile lines, or sometimes drains may outlet directly to a stream channel or pump outlet.

Figure 3.14. A. *This photo shows tile drainage being installed. The perforated yellow tube is installed underground, almost level, but with a slight slope so it drains to an outlet. It is deeper under swells than under depressions. The placement of the tube in the soil is guided by laser beam or enhanced GPS (RTK) technology.* ***B.*** *This image shows a larger machine with the working parts out of the ground. The machine moves toward the left. 3.14A provided by Tom Bechman; 3.14B provided by Joey Schlatter.*

Some soils are difficult to drain with a subsurface system because they have slow permeability in the subsoil. Tile drainage is not recommended for these soils. Other soils are on such large, flat areas it is difficult to obtain outlets for the drains. This factor is not considered in soil evaluation, but it should be kept in mind when planning a system. A fiberglass fabric "sock" is fit over the plastic tubing lines to keep sediment out of them in some silty and sandy soils.

EFFECTS OF DRAINAGE

Drainage is necessary for efficient crop production on many soils of Indiana, but it may have beneficial or adverse effects on the environment. Drainage of wetlands results in loss of wildlife habitat. It also may increase the chance of down-stream flooding because water leaves drained fields faster than undrained areas, and increases peak flow in streams that drain the fields.

Several studies that compared drained agricultural land with undrained agricultural land are summarized in the former Ohio State University Extension publication, *Effects of Drainage* (edited by L.A. Zucker. and L. C. Brown).

Here are some of the results from that publication:

- Total discharge of water (overland flow plus subsurface drainage) is similar.
- Up to 63 percent of the rain that falls on a drained field leaves the field through the drainage system.
- Overland flow is 29 to 65 percent less in drained fields.
- Sediment loss by erosion, caused by overland flow, is reduced by 16 to 65 percent in drained fields.
- Phosphorus (P) loss is reduced by up to 45 percent in drained fields because much of the P moves with sediment.
- Total nitrogen (N) loss is reduced in drained fields because much of the N also moves with the sediment.
- Loss of nitrate-N, a soluble N ion, is increased in drained fields because nitrate moves with water.

In summary, drainage improves water quality by reducing the amount of sediment and P in the water, but worsens water quality by increasing the amount of nitrate. Nitrate-N is present in subsurface drainage water at all times, but is usually most concentrated when water first begins to flow from the tiles after the **growing season**, usually in late fall or early winter.

Often, the nitrate level in tile outflow from fields is higher than allowed in drinking water. Many of the tile drains flow into streams that are tributaries of rivers that are used as city water supplies, so it is important to reduce the amount of nitrate flowing to the rivers

Current federal programs discourage draining wetlands for crop production — draining them could lead to losing federal benefits. The rule described below assumes that the field has been drained previously.

Usually, somewhat poorly drained and poorly drained soils respond to artificial drainage, so most of those soils are checked "Yes" for drainage. The exception is somewhat poorly and poorly drained soils on flood plains. Some of these soils can be drained, but many have flooding problems that make drainage impractical.

▸ JUDGING RULE
29. Drainage

Mark "Yes" for **Drainage** (29 on agriculture scorecard) if the soil has *both* of these characteristics:

- Natural drainage is poor or somewhat poor
- Landform is not a flood plain

Irrigation

Irrigation involves adding water to soils to help produce crops. Whether crop irrigation will be beneficial usually depends on the soil properties, crop types, the farmer's management skills, and the weather during the growing season.

Some soils that hold very little water in the profile such as sandy soils and shallow soils will respond well to irrigation. Specific soil properties are stated in soil judging rule 66 below. The most common irrigation systems in Indiana are center pivot systems, travelling sprinkler systems, and sub-irrigation.

Center pivot water systems spray water from sprinklers along a horizontal pipe that rotates around a pivot at one end of the pipe. The water supply comes through the pivot from streams or a well. Wheels support the pipe as it rotates. Electric motors or gasoline or diesel engines usually drive the unit.

Travelling sprinkler systems use a large sprinkler (big gun) that is attached to a flexible hose and rotates 360 degrees. The sprinkler is mounted on a cart that moves in a straight path through a field.

Sub-irrigation systems supply water underground. In sandy soils these systems can be combined with open ditch drainage. During the wettest part of the year, the ditches remove water from the field. When plants begin to use water, farmers block the flow of water in the ditches. During drought, farmers can pump water from streams into the ditches. In finer textured soils, farmers adjust the water level using control boxes in drainage (tile) lines.

Three basic soil properties influence the likelihood of a soil to respond to irrigation: texture, structure, and depth. These are the properties that determine the soil's water holding capacity, infiltration rate, and permeability. Generally, the sandier the soil texture and shallower the depth, the greater will be the crop response to irrigation.

Water-holding capacity is the major factor affecting suitability for irrigation. Soils vary greatly in their ability to hold available water, depending primarily on their texture and depth. Silty soils hold the most plant-available water. Deep silt loam soils (which are the best agricultural soils from a water-holding standpoint) are capable of storing as much as 12 inches of water in a 5-foot depth. Sandy soils (especially coarse sands) may hold as little as 2 to 3 inches of available water in a 5-foot depth. Clayey soils hold more water than silty soils but hold some of the water so tightly that plants cannot use it. Many Indiana soils are droughty because they are shallow. For example, soils formed from outwash may consist of 2 feet of relatively fine material like silt loam and clay loam over sand and gravel. These sand and gravel layers hold very little water.

Water **infiltration** is also very important in determining the suitability of soils for irrigation. Generally, infiltration is highest on coarse-textured (sandy) soils and decreases as texture becomes finer. Infiltration rate is also affected by condition of the soil at the time of rainfall or sprinkler irrigation. For example, a weakly-structured medium textured soil (loam or silt loam), when exposed to rainfall without protective cover, seals at the surface which greatly reduces water intake. When the same soil is protected by crop residue or a full crop canopy, however, this seal doesn't form and intake remains high.

Good soil permeability is essential for successful irrigation. Lack of internal water movement can result in a buildup of water that will exclude oxygen from the root zone and restrict plant growth. Sandy soils are ideally suited for irrigation because they contain a high proportion of large pores and are rapidly permeable, but finer-textured soils may or may not have good permeability, depending on their structure.

Soils that respond significantly to irrigation are the sands and loamy fine sands, and the silt loams, loams, and sandy loams that are shallow or moderately deep over coarse sand and gravel. This is reflected in the soil judging rule below.

Some of the sandy soils suitable for irrigation are susceptible to wind erosion and need to be protected by winter cover crops or crop residue. Remember that a farmer will consider factors in addition to those listed in the rule to make a decision about irrigation. They include size of the suitable soil area, availability of water, location, type of crops to be grown, potential economic returns, and others. The rule for irrigation, below, assumes that the soil is used for cropland, even though other possible land uses may be marked "Yes" on the scorecard.

▸ JUDGING RULE
30. Irrigation

Mark "Yes" for **Irrigation** (30 on agriculture scorecard) if the soil has *both* sets of properties:

- Slope is 6 percent or less, **and**
- Either:
  - Subsoil is sandy or moderately sandy, **or**
  - Soil has a coarse sand and gravel limiting layer within 40 inches of the surface

Terraces

A **terrace** is an embankment or ridge constructed across sloping soils on the contour or at a slight angle to the contour. A terrace intercepts surface runoff so that it can soak into the soil or flow slowly through a grass waterway or a tile outlet.

A terrace system breaks a long slope into shorter segments, which reduces soil erosion — a shorter slope is represented by a smaller L factor in the Universal Soil Loss Equation. Terraces are constructed parallel to each other and parallel to the direction of field operations. You can minimize interfering with farming operations if you space the terraces so they are multiple widths of the planting and harvesting equipment.

Soil judging considers two kinds of terraces:

1. Water and sediment control basins (WASCOBS) — these are more common in Indiana
2. Parallel tile outlet (PTO) terraces

Water and sediment control basins (**WASCOB**s) are created when small dams or terraces are built across natural drainageways in the field, mainly to control gully erosion (Figure 3.15). No-till or some other conservation tillage system is necessary to control sheet and **rill** erosion when terraces are part of the management system so that the basin created by the terrace does not rapidly fill with sediment.

Parallel tile outlet (**PTO**) terraces (Figure 3.16) are used on much agricultural land in some states, but they are uncommon in Indiana. They are constructed parallel to each other and, where possible, parallel to the direction of field operations. These terraces eliminate production losses associated with **point rows** and minimize interference to farming operations when they are spaced at multiple widths of the planting and harvesting equipment. Some terraces are constructed with steep back-slopes that are kept in grass (Figure 3.15C). Most, however, are broad-based, having gently-sloped ridges that can be cultivated as a part of the field (Figure 3.15B).

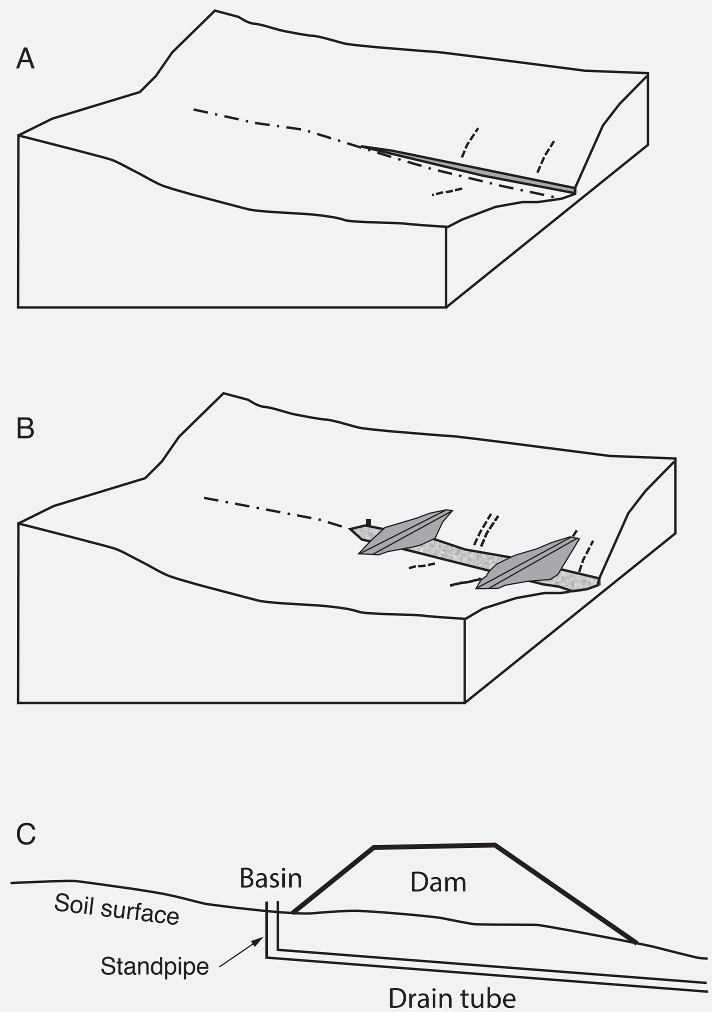


Figure 3.15. *Sketches of a long drainageway before (A) and after (B) installing water and sediment control basins (WASCOBs). (C) A cross-section through one basin.*

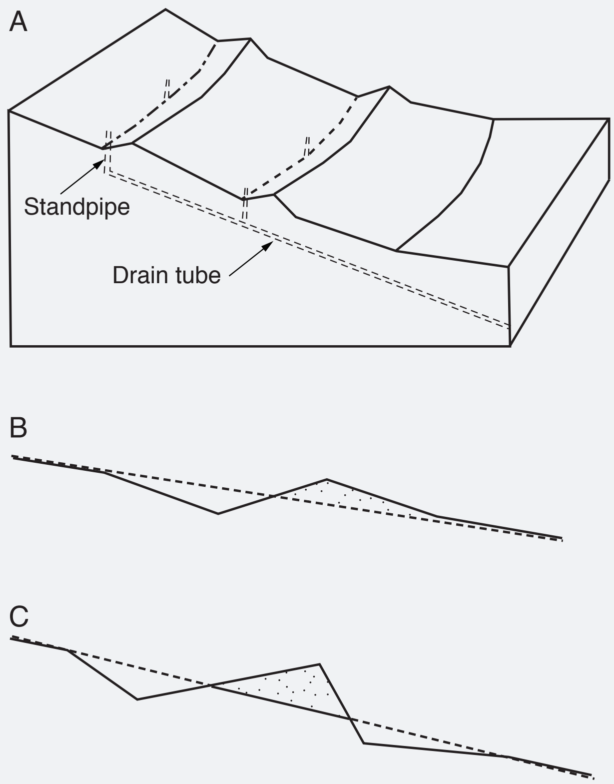


Figure 3.16. Sketch of a parallel tile outlet terrace (PTO). (B) Most terraces are wide enough so crops can be planted on them.

The surface inlet (called a riser) controls the discharge rate, temporarily storing some of the runoff. The storage period is long enough for sediment to settle out of the water, but not so long as to damage the crop.

▸ **JUDGING RULE**
31. Terraces

Mark "Yes" for **Terraces** (31 on agriculture scorecard) if the soil has *all* of these properties:

- Soil is well-drained, moderately well-drained, or somewhat poorly drained
- It is more than 40 inches to any limiting layer
- Slope is 3 to 12 percent
- Subsoil texture is medium or finer

Plant Nutrient Application

The two main goals of **plant nutrient** management are to:

1. Supply enough plant nutrients to get good crop yields (see Chapter 3)
2. Avoid providing so much of a nutrient that the excess causes off-site problems

Over the past several years, public discussion has shifted from emphasizing the first goal to emphasizing the second. This is reflected in soil judging. For many years, a choice was whether or not to add fertilizer. In the 2001 edition of this manual, options to deplete P and K were added, because in some cases the levels of those nutrients were becoming too high.

In all environments, some plant nutrients move from the land to rivers, lakes, and oceans. This movement is greatly accelerated in systems people manage, such as farms, industries, home sites, and highways. The excess nutrients from these sources often end up in the downstream water bodies. The **pollution** sources have been divided into **point sources** (such as factories) and **nonpoint sources** (such as farms). Generally, those from point sources are easier to manage.

Two main kinds of water pollution from nonpoint sources are eutrophication and chemical contamination of drinking water

Eutrophication is the process that causes water bodies to become so low in oxygen that much aquatic life (such as fish) can no longer live in the water. It happens when high levels of nutrients (mainly N and P) reach the water; **algae** and plants grow rapidly as a result, they die, and oxygen is consumed as they decompose. Usually, N is the main culprit in salt water (gulfs and oceans) and P, in fresh waters (rivers and lakes).

Nitrate poisoning. Drinking water can become contaminated by many chemicals that come from point sources such as industrial plants and road spills. A serious contaminant from nonpoint sources is nitrate. If people (especially infants) consume water that is too high in nitrate, their blood may not be able to transport enough oxygen to their tissues, and the skin turns blue (methemoglobinemia, or blue baby syndrome). Babies may become susceptible when their formula is diluted with water high in nitrates.

Examples of Water Pollution

Pollution of water bodies has become a serious problem in recent years. Nonfarm people are concerned because pollution might contaminate their drinking water, increase the cost of domestic water, ruin commercial fishing, limit water sports (such as swimming and fishing), or cause other problems. Farmers should be concerned because, if they do not limit their contribution of plant nutrients to streams, it is likely that regulations will be enacted that will greatly complicated their farm operations. Some recent examples of water pollution are described below. They are reprinted from the book, *Soil Science Simplified* by D.P. Franzmeier, W. W. McFee, and J. G. Graveel (2016, Waveland Press).

> Plant nutrients removed from a soil also cause off-site problems. The nutrients move in solution and as ions absorbed on clay particles. Three examples of contamination follow.

GULF OF MEXICO

> A notable example of this problem, because of its magnitude, is the dead zone in the Gulf of Mexico. It is an area in which the water has low oxygen content (**hypoxia**) or no oxygen (**anoxia**) causing marine life to move out of the area (if they are able) or die; thus, the term "dead zone."
>
> The main cause of low or no oxygen is the contribution of plant nutrients from the Mississippi River, which drains a major part of the farmland in the United States. The chief plant nutrients are N (which moves mainly in solution) and P. Phosphorus is carried primarily on soil particles, but in the Gulf, it is exchanged by other ions and much P ends up in solution. Much of the N and P come from farmland, but some comes from sewage treatment plants, industries, lawns, golf courses, septic systems, and other sources.
>
> In the Gulf, these nutrients are used by **phytoplankton**, a collection of small plants that live near the water surface. In the process of **photosynthesis**, they use sunlight to convert carbon dioxide (CO_2) and water into organic compounds and oxygen (O_2). When these organisms die, they sink to the bottom where they are decomposed by other organisms (mainly bacteria) via the process of respiration which uses O_2. On first examination, it appears that photosynthesis *makes* O_2 and **respiration** *uses* a similar amount of O_2, resulting in no net change in the O_2 supply. The reason that this is *not* the case is that photosynthesis occurs near the surface and the O_2 produced goes into the air. On the other hand, respiration by the decomposing microbes occurs deep in the Gulf and depletes the limited O_2 supply of this water.

LAKE ERIE

> Many people living in southeast Michigan and northwest Ohio (including Toledo) get their drinking water from Lake Erie. For three days in August 2014, more than 400,000 people in this area could not drink water from their water system because it contained toxic material.
>
> Harmful **algal blooms** have been growing in Lake Erie for several years. Algae blooms occur all over the world, not only in Lake Erie. Some of these blooms contain cyanobacteria that produce the toxin microcystin. In August, enough of the toxin got into the domestic water system to make the water unsafe for drinking and bathing.
>
> Algae growth is stimulated by plant nutrients, especially P, much of which comes from fertilizer and manure. Other sources are domestic sewer

systems and on-site (septic) sewage systems. In 2015, the Ohio legislature passed a bill that bans applying fertilizer and manure to soils that are frozen or saturated with water, conditions under which much runoff occur.

DES MOINES WATER

High levels of nitrate in drinking water have been linked to **blue baby syndrome**, which develops when a baby's blood is deficient in oxygen, and to other health problems. The federal government has set the upper limit for nitrate for safe drinking water at 10 mg of nitrate per liter of water (mg/L).

Des Moines, Iowa, residents get their water mainly from the Des Moines and Raccoon Rivers that drain land used for intensive corn and soybean production. In the spring (or any wet period) a water surplus leaches through the soil and carries excess nitrate with it. Consequently, at times the nitrate levels in the rivers exceed the 10 mg/L standard. When this occurs the Des Moines Water Works must activate its ion exchange facility to reduce nitrate concentrations to safe levels.

In 2013, the facility was used for 74 days at a cost of $900,000. In the nitrate treatment systems, nitrates are removed by passing river water through anion exchange resins. In another part of the book we discussed cation exchange in which negative charges on clay and organic matter attract cations such as Ca^{2+} and Mg^{2+}. Anion exchange resins function in the opposite way. They have positive charges and attract anions such as NO_3^-. The anion exchange resin is rejuvenated by flushing it with sodium chloride. The chloride ion (Cl–) replaces and both ions and Na+ are returned to the rivers downstream from where the drinking water enters the water treatment facility. It is apparent that it would be better to reduce the nitrate in the water source.

Specific Sources of Pollution

The U.S. Geological Service (USGS) studies sources of N and P in water bodies. They measure water flow and collect water for chemical analyses in many streams in the country. They summarize the data using the USGS SPARROW (SPAtially-Referenced Regressions On Watershed Attributes) model. Figure 3.17 shows the sources of N and P in water that flows to the Gulf of Mexico.

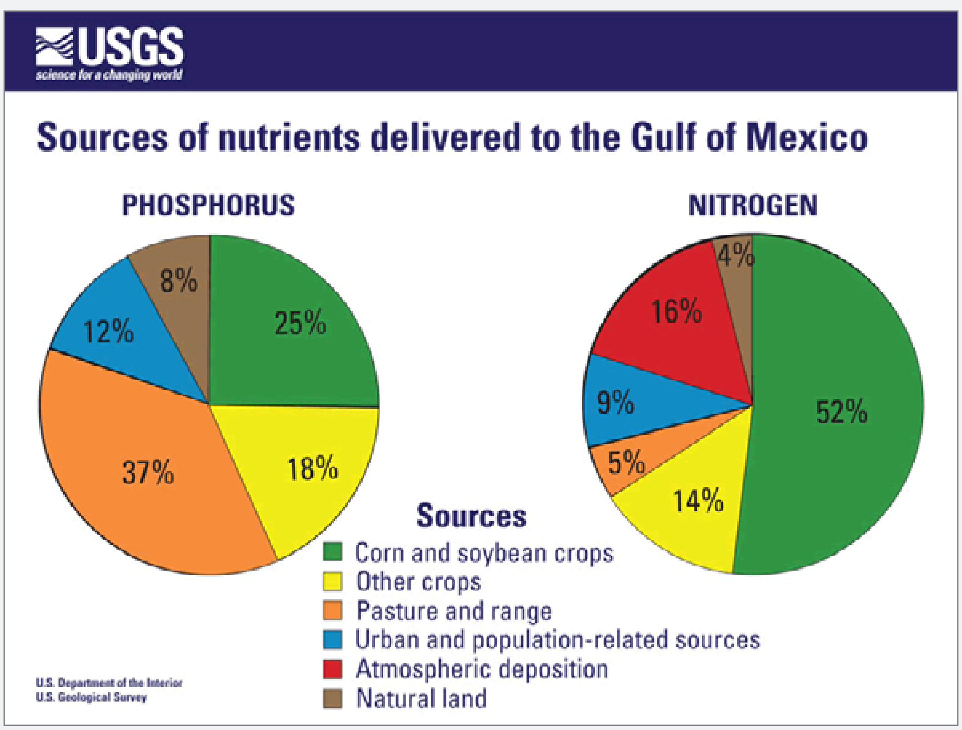


Figure 3.17. Sources of nutrients delivered to the Gulf of Mexico. Illustration provided by U.S. Geological Survey.

This is how the USGS interprets Figure 3.17:

- Sixty six percent of nitrogen originates from cultivated crops (mostly corn and soybean) and 5 percent comes from animal grazing and manure. Atmospheric contributions also are important, accounting for 16 percent of nitrogen.
- Animal manure on pasture and rangelands and crop cultivation are the largest contributors of P, accounting for 37 and 43 percent, respectively. Findings suggest that P associated with the wastes of unconfined animals is a much larger source of P in the Mississippi River Basin than previously recognized. Current animal manure management emphasizes controlling nutrients primarily from confined animal facilities.
- In total, agricultural sources contribute more than 70 percent of the N and P delivered to the Gulf, versus only 9 to 12 percent from urban sources. Such findings show the dominance of agricultural nonpoint sources outside urban areas in the Mississippi River Basin.
- The USGS also determined the contribution of individual states to the N and P in water that flows to the Gulf (Figure 3.18).

The facts that much of the N and P come from agriculture and from Indiana emphasize that nutrient management is a serious concern for all people of Indiana, especially those involved with soil management.

Soil Sampling and Fertilizer Recommendations

Soil tests are critical for managing all fertilizer programs, so we discuss them before we describe the programs. To decide how much P fertilizer, K fertilizer, and lime to apply, you must first take a soil sample.

The instructions provided here for collecting soil samples listed below are from *Soil Sampling for P, K, and Lime Recommendations* (Purdue Extension publication AY-281-W), available from the Education Store, edustore.purdue.edu.

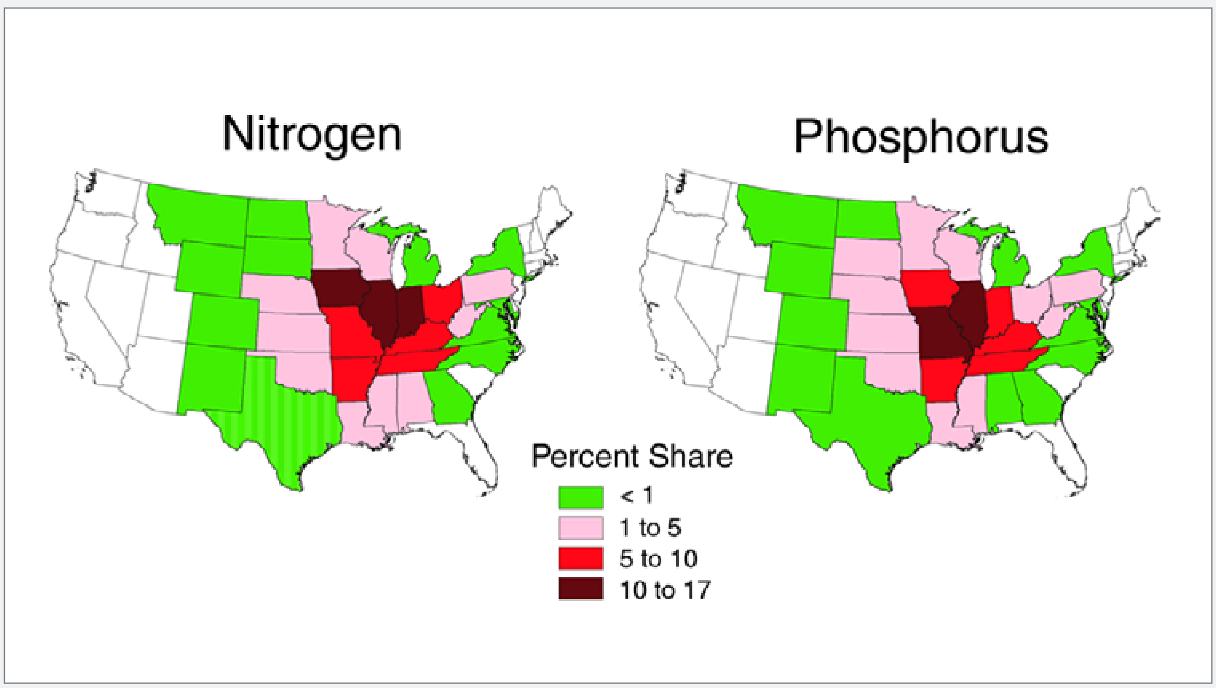


Figure 3.18. *These maps show that Indiana is a major contributor of N and P to Gulf waters. Illustration provided by U.S. Geological Survey*

1. To take a soil sample you need a sampling tube, auger or spade, and a clean plastic pail. Get sample containers from the lab where you are sending the samples for analysis.
2. Sample different soils, or areas treated differently in the past. Get equal-sized cores or slices from 15 or more places in each sampling area using a probe, auger, or spade. Do not mix light- and dark-colored soils together.
3. Take samples for P, K, and lime from the top 0-8 inches in most fields. (In no-till fields, it might be necessary to take samples from 0-4 inches and from 4-8 inches — see the reference below).
4. Place cores or slices in a clean plastic pail. Mix them together thoroughly, breaking up the cores or slices. If soil is muddy, dry it before mixing. If soil crumbles easily, dry after mixing.
5. Spread mixture out on clean paper to dry. Do not heat in the oven or on the stove. Do not dry in places where fertilizer or manure may get in the sample.
6. Fill the sample bag to the line with air-dry soil. Discard the rest. Label and number the sample container.
7. Identify the sample and record the cropping and fertilizer information requested using a field and cropping information sheet provided by the lab doing the analysis.
8. Draw a field sketch or farm map on a separate sheet and keep it in your files for your records, and to assist in developing your management plan.
9. **Important!** Your recommendations will be no better than the information that you give.

Send your soil samples to a soil testing laboratory along with information about your cropping plans. They will send you the results of their laboratory tests which measure the amounts of *available* P and K in units of parts per million (ppm). A test result of 10 ppm P, for example, means that the soil has 10 pounds of available P in 1,000,000 pounds of soil. In some cases, results are reported in units of *pounds per acre* in place of ppm. When that happens, the pounds per acre is double the ppm: so, 1 ppm equals 2 pounds per acre.

The lab also measures soil **pH** and lime the results of a lime requirement test. The lab will also send recommend fertilizer and application rates based on published guidelines (Corn and soybean guide. ID-179, 2015). The application rates for soil judging are greatly condensed compared to those a farmer uses.

Managing Inorganic Fertilizer

Much chemical fertilizer is applied to farm crops in Indiana. Fertilizers are applied to most crops, but we emphasize corn because it is the crop that receives the most fertilizer. Soybeans receive less nitrogen (N) fertilizer because they utilize N fixed from the atmosphere. The kinds of fertilizer discussed below are the most commonly used ones in Indiana.

We consider six factors to consider in a fertilization program:

1. Nutrient content
2. Physical form
3. Amount applied
4. Time of application
5. Place of application
6. Fertilizer loss

NUTRIENT CONTENT

Farm fertilizers contain mainly the plant nutrients, nitrogen (N), phosphorus (P), and potassium (K). Fertilizer labels show their **grade** — the amounts of N, P, and K (actually, N, P_2O_5, and K_2O) in the bag, truck, or tank. For example, if the label for diammonium phosphate (DAP) reads 18-46-0, it contains 18 percent N, 46 percent P_2O_5, and no K_2O. DAP is made from phosphoric acid and ammonia.

Figure 3.19. *This vehicle is spreading P and K dry fertilizer in southern Indiana. Photo provided by Tom Bechman.*

PHYSICAL FORM

Fertilizers are applied in solid, liquid, and gas forms.

Solid

Fertilizer applied as a solid is called *granular* or *dry* and is frequently applied in a **broadcast** application — that is, spread all over the surface, not in bands. DAP is one of the main fertilizers applied dry (Figure 3.19). Others include potassium chloride, (called potash, 0-0-60) and monoammonium phosphate (MAP, 11-52-0). Urea (46-0-0) and ammonium sulfate (21-0-0, plus 24 percent sulfur) are common N fertilizers that can be applied as granules or as a liquid solution.

Liquid

Many farmers apply most of the corn's N requirement in the form of liquid fertilizer (Figure 3.20). The most common one is urea ammonium nitrate (UAN, 28 to 32 percent N, no P or K). It is made by combining solutions of urea and ammonium nitrate. There are many formulations of liquid fertilizer that contain various sources of N, P, and K that are available in the marketplace

Figure 3.20. *Applying liquid fertilizer to corn.* ***A.*** *This vehicle is applying fertilizer at the V-12 stage with a high-clearance sprayer. V-12 means that the corn plants have 12 leaves each.* ***B.*** *Applying nutrients to foliage with Y-drops, which are devices that place the N solution about 2 inches from the corn plant. Photos provided by Tom Bechman.*

Figure 3.21. *This implement is applying anhydrous ammonia on a field with corn residue cover. The white tank ("nurse tank") contains ammonia under pressure. Photo provided by USDA-NRCS.*

Gas

Some farmers apply the bulk of the crop's N requirement as anhydrous ammonia (82-0-0). Ammonia (NH_3) is typically a gas, but under pressure it becomes a liquid which is how it is delivered to a farmer. In the field, the application implement cuts a slot in the soil about 6 to 8 inches deep, and the liquid is released into that slot where it volatilizes to ammonia gas. The slot is closed by the applicator and the NH_3 readily combines with soil water to become ammonium (NH_4^+). Figure 3.21 shows an anhydrous ammonia applicator followed by a nurse tank which contains NH_3 under pressure.

AMOUNT APPLIED

Little available N carries over from one year to the next, so enough N is applied to last through the growing season (usually near the beginning of the crop year). For soil judging, N fertilizer application rates depend on the yield potential of the soil. In practice, the cost of N fertilizer and the price of corn are also considered (See *Nitrogen Management Guidelines for Corn in Indiana*, by Jim Camberato and Robert Nielsen (available from the Purdue Department of Agronomy).

Available P and K do carry over from year to year, so the goal is to maintain adequate levels of these nutrients in the soil as determined by soil tests. The methods used in these tests are documented in *Tri-state Fertilizer Recommendations for Corn, Soybeans, Wheat, and Alfalfa*. (1995, M.L. Vitosh, J.W. Johnson, and D.B. Mengel, Michigan State University Extension Bulletin E-2567).

TIME OF APPLICATION

The goal is to apply the nutrient (especially N) just before it is used by the crop to minimize loss via erosion, leaching, or volatilization.

Fertilizer may be applied:

- In the fall – if care is taken to avoid loss (not recommended for N).
- With tillage (such as strip-till) in the fall or spring.
- In early spring before other operations (such as tillage).
- With planting — this is called **starter fertilizer**. Many planters have applicators for applying liquid fertilizer.
- To the growing crop. For example, N fertilizer may be applied to corn after emergence and until it is about 6 to 16 inches high or too high for the equipment. This is called **side dressing**.

PLACE OF APPLICATION

Fertilizer can be applied:

- On the surface. With granular fertilizer, this is called broadcasting. Liquid fertilizer can also be sprayed on the surface.
- Below the surface:
  - Anhydrous ammonia is injected about 6 to 8 inches deep so it is not lost by volatilization.
  - Starter fertilizer is usually placed 2 inches below and 2 inches to the side of the seed. It usually contains N and P and is applied in relatively small amounts.
  - Strip-till fertilizer is placed near the bottom and center of the tilled strip.
  - Side dressing fertilizer is injected between the rows, about 6 to 8 inches deep.

FERTILIZER LOSS

In most fertilizers, at least 50 percent of the N is in the ammonium (NH_4^+) form, or a form that converts readily to ammonium. Ammonium is held tightly in the soil because the positive charge is attracted to the negative charge (cation exchange capacity, CEC) on soil clay and organic matter. Bacteria in the soil, however, convert NH_4^+ to nitrate (NO_3^-) in the process of **nitrification**. Nitrate is held loosely in the soil because it is not attracted by soil CEC, so it can be leached from the soil and move to surface water or ground water. When soils are saturated, NO_3^- can also be converted to several N-containing gases that may be lost to the environment. To reduce the amount of nitrification, **nitrification inhibitors** can be added to the fertilizer.

Urea (46-0-0) is applied to the soils in granular and liquid forms. Urea is converted by enzymes in the soil to NH_3 and NH_4^+ rapidly after application in a process called **hydrolysis**. If present on the soil surface, NH_3 can be lost to the atmosphere. To minimize loss, urea can be applied when rain is expected, or urea can be tilled into the soil. Also, urea hydrolysis inhibitors can be added to urea to delay its conversion to ammonia and loss by volatilization.

Phosphorus and potassium fertilizer compounds are not lost by volatilization and are held quite tightly by soils. They are lost mainly by erosion. With very high levels of available P in the soil, some can be lost by leaching, however.

SUMMARY

With six factors to consider, and several choices for each factor, there is an almost endless number of options for a farm fertilizer program.

Managing Organic Fertilizer (Manure)

Indiana has a large animal industry that produces much **manure**. Planning the distribution of this manure in an environmentally sound manner is especially challenging because managing manure is much more complex than managing inorganic fertilizer. Also, recent state laws require that practically all livestock farms must have a manure management plan. Because of the complexity of managing manure and legal requirements, the process is best carried out using a computer program such as the Purdue Manure Management Planner (www.purdue.edu/agsoftware/mmp). Local extension and conservation personnel are available to help livestock farmers use the planner. Notice that much of the soil information required to run the model is the same as the soil properties evaluated in soil judging contests.

N AND P MOBILITY IN SOIL

As discussed earlier, N and P are the nutrients of most environmental concern, but N and P act much differently in soils. P is held tightly by soil particles, so it moves mainly as a solid and is lost by erosion. N, on the other hand moves with soil water instead of soil particles. N is generally converted to nitrate (NO_3^-) which is very soluble in water. It can leave the soil as runoff or leach through the soil profile. In soils with very high levels of P, however, P can also move in solution or suspension.

MANURE MANAGEMENT MODEL INPUTS

These are some, but not all, of the inputs needed to use the Manure Management Planner:

- **Soil test results**. There is a good test for available for available P. Some soils are already so high in P that no more should be applied. For other soils, the amount to apply depends on the current level. There is no good test for available soil N, so the N fertilizer recommendations are usually based on the crop to be grown, the previous crop, and (except for corn) the anticipated yield of the planned crop.
- **Manure form**. Manure is handled in solid or liquid form which is essential information for a model. If it is a solid, it might be hauled to the field and stored for a short time until it can be applied. **Manure staging** is the temporary placement of solid manure in a pile at a site where the manure will be land-applied and is most commonly used with poultry litter. Figure 3.22 shows liquid manure being injected into the soil.
- **Manure composition**. Manure varies in its N and P contents and lab results are needed by the planner.
- **Expected crop yield**. This predicts the amount of a nutrient that will be taken up by the crop.
- **Erosion potential**. Because P moves with particles, soil erosion is a major concern in P management. On page 68, we described the how the Universal Soil Loss Equation (USLE) is used to predict erosion. The models use a revised version of USLE, called RUSLE2.
- **Leaching potential**. The potential for solutions to leach through the soil is especially important for N.
- **Distance from a stream or ditch**. Manure cannot be applied in close proximity to a ditch or stream, and the setback distance is greater for surface-applied manure than incorporated or injected manure. Also, setback distances increase as the slope of the field increases.

The **limiting nutrient** for manure application is the first plant nutrient (N or P) to become ample for crop production but will become excessive, and could contribute to off-site pollution, if more of the nutrient is applied. If manure is added to the soil frequently using N as the target nutrient for application rate, soil test P levels will increase. Applying manure at a rate to meet crop N requirements can supply enough

Figure 3.22. *These photos show liquid manure application by surface application (A) and injection (B). Photos provided by USDA-NRCS.*

P for two to four years of crops. Once soil test levels become high, P becomes the limiting nutrient and manure must be managed to keep soil test P from increasing either by decreasing the rate of manure application or by decreasing the frequency of manure applications. State rules determine the soil test P level at which manure must be managed using P as the limiting nutrient.

There is no specific soil judging item for manure, but contestants should assume that when they choose "apply" a nutrient on the scorecard, the nutrient can be added as chemical fertilizer or manure.

Summary of Field Operations

We considered tillage practices and nutrient application practices in separate sections, Tillage Practices and Plant Nutrient Application. There are many ways to combine these practices. Table 3.1 shows some typical combinations, but in practice, the sequence of operations depends greatly on soil moisture conditions around planting time. Every field operation takes time and uses fuel. In addition to their soil-conserving benefits, conservation tillage practices such as non-till and strip-till are generally cost-effective.

Table 3.1. *Typical minimum tillage and fertilizer application operations for corn following soybeans in the Midwest.* ***Source:*** *G, W. Randall (personal communication).*

TILLAGE SYSTEM	MINIMUM FIELD OPERATIONS
Chisel plow	1. Apply P and K (broadcast) 2. Chisel plow 3. Apply N (broadcast or band) 4. Field cultivate 5. Plant
Reduced tillage	1. Apply N (broadcast or band) 2. Apply P and K (broadcast) 3. Field cultivate 4. Plant
Strip-till	1. Prepare strip (apply P and K in strip) 2. Apply N 3. Plant
No-till	1. Apply N (broadcast and/or band) 2. Plant (Apply P and K with planter)

Soil Judging Rules — Plant Nutrient Application

Soil judging rules are based on previous discussions of nutrient management.

NITROGEN

For soil judging, N application rates depend on the potential of soils to produce crops, especially corn and wheat. Crop yield potential depends on water-holding capacity, plant rooting ability, and other important soil properties. For soil evaluation, soils with the highest yield potential have a "high" recommended N rate. Those with somewhat lower expected yields have a "medium" N requirement. Many of these soils are still very productive.

▸ JUDGING RULE
32. Nitrogen (N)

There are three application rates for **Nitrogen (N)** (32 on agriculture scorecard), select:

- **High** if the soil has *all* of these properties:
  - Soil is more than 40 inches to any limiting layer
  - The subsoil and surface soil textures are medium or moderately clayey
  - Soil is poorly drained or somewhat poorly drained
  - Surface color is black
- **Medium** for other soils that have *all* of these properties:
  - Soil is more than 20 inches to any limiting layer
  - The subsoil and surface soil textures are moderately sandy or finer
  - The slope is 12 percent or less
- **Low** (or no nitrogen) for all other soils

PHOSPHORUS

For soil judging, P application rates depend on soil test values which are reported on the site card in ppm units.

> ▸ **JUDGING RULE**
> **33. Phosphorus (P)**
>
> There are three application rates for **Phosphorus (P)** (33 on agriculture scorecard), select:
>
> - **Add** if available P is less than 15 ppm
> - **None** if available P is 15-100 ppm
> - **Deplete** if available P is greater than 100 ppm

POTASSIUM

The previous discussion has emphasized N and P because those are the nutrients that cause most off-site pollution. Another important nutrient is potassium (K).

K is also very important as a plant nutrient. It controls stomate opening and closing, which influences transpiration of water from the plant leaves. It tends to improve stalk strength and reduce lodging that can be caused by heavy N fertilization. It can delay early ripening that can be caused by P. Application of K according to soil test results can increase both yield and quality of crops produced.

Unusually high available K soil tests are rare in Indiana, but provision is made in soil evaluation for very high levels.

For soil judging, K application rates depend on soil test values which are reported on the site card in ppm units.

> ▸ **JUDGING RULE**
> **34. Potassium (K)**
>
> There are three application rates for **Potassium (K)** (34 on agriculture scorecard), select:
>
> - **Add** if available K is less than 100 ppm
> - **None** if available K is 100-250 ppm
> - **Deplete** if available K is greater than 250 ppm

LIME

Liming is the application of material that will reduce the acidity (raise the pH) of the soil and supply it with calcium (Ca). Lime is any material that is added to the soil to correct an acid condition. Usually ground limestone is used.

Soil acidity is measured on the pH scale; pH 7.0 is neutral, higher pH values are alkaline, and lower pH values are acid. For most agricultural crops, the soil should have a pH of 6.5 to 6.8. For corn and soybean rotations, soil pH values in the range of 6.0 to 6.5 are adequate.

For soil judging, lime rate recommendations depend on soil acidity.

> ▸ **JUDGING RULE**
> **35. Lime**
>
> There are two application rates for **Lime** (35 on agriculture scorecard), select:
>
> - **Add** if the soil pH is 6.4 or lower as noted on the site card
> - **None** if the soil has a different pH

NITROGEN

For soil judging, it is assumed that the soil is used for crop production and N fertilizer is applied. Then the soil has at least a medium potential to cause N pollution. N applied to some soils is especially likely to result in groundwater pollution, and N applied to other soils is especially likely to result in surface water pollution. These soils are identified in the rule.

► JUDGING RULE
36. Nitrogen Pollution Potential

There are three possible ratings for N**itrogen pollution potential** (36 on agriculture scorecard):

- **High for groundwater** if the soil has *both* of these properties:
  - A sandy subsoil and/or a coarse sand and gravel limiting layer
  - Soil is moderately well-drained or well-drained
- **High for surface water** if the soil has *both* of these properties:
  - Soil is poorly drained or somewhat poorly drained
  - Soil is not on a flood plain
- **Medium** for other soils

PHOSPHORUS

When **soil fertility** levels are too high, nutrients can be removed from the soil by taking grain, hay, or other plant material off the field. Forage crops such as alfalfa remove large amounts of P and K.

► JUDGING RULE
37. Phosphorus Pollution Potential

There are three possible ratings for **Phosphorus pollution potential** (37 on agriculture scorecard):

- **High** for soils on slopes steeper than 12 percent.
- **Medium** for all soils on:
  - 7-12 percent slopes
  - 3 to 6 percent slopes in which the surface texture is medium or moderately clayey
- **Low** for other soils

CHAPTER 4 – Home Site Practices

Many new houses are built on soils that were once farmland or natural land. Some of these soils are well suited for houses and yards. Other soils may be less suited for home sites, and special construction designs and management practices are needed to deal with soil limitations. All these houses generate sewage, which flows from toilets and other household sources. Some new houses are connected to a sewer system, and sewage is treated in a centralized plant. In houses that are connected to a sewer system, the sewage is treated in an on-site sewage treatment system, which generally consists of a septic tank and a soil absorption field located on the house lot.

This chapter has four main sections:

1. Site selection and construction practices
2. Landscape and lawn practices
3. On-site sewage disposal — technical background
4. On-site sewage disposal — practices.

Two key questions that direct the flow of soil judging are:

1. Are the soils suitable for a home site?
2. Are the soils suitable for a soil absorption field?

If the answer to either of these questions is "No," the judging process is greatly shortened.

Site Selection and Construction Practices

People who plan to build a house must consider various soil and landscape features. Many homes in Indiana are on sites where serious problems will occur if soil and landscape conditions are not considered. Wet basements, poor surface drainage, excessive settling, and home sewage disposal system failures are frequently encountered problems.

Builders, developers, and planning commissions are becoming more conscious of how soils affect new development. Many are now routinely considering soil properties in the plan and design of individual home sites and subdivisions in communities that are expanding into rural Indiana. Many people are concerned about the competition between urban development and agricultural production for the same land. This conflict is leading toward consideration of preserving good agricultural land for crop production (see Prime Farmland, page 67). Urban development located in areas not well suited to intensive row crop production would lessen this conflict. Once land is used for houses, it is very difficult to ever use it for growing crops.

Ideal home sites have deep, well-drained, gently sloping, medium-textured soils that do not flood. Preferably, the surface soil is dark and not eroded. Nationwide, these are also desirable properties for crop production, which places the competition for "the best land" into focus. In Indiana, another set of conditions often occurs. Many of our best soils for row crop production are deep, level, poorly or somewhat poorly drained, and medium textured. These soils are excellent agricultural soils after proper drainage systems have been installed. They occur in wide areas near many of Indiana's major cities. Thus, there is considerable pressure for their development, even though most of them are considered to have severe limitations for home sites.

Soil Properties

The same soil properties used to determine agricultural practices are used to judge home site practices. This section addresses the significance of the various properties to constructing a home site.

LANDFORM

Landforms have direct and indirect influences on the suitability of a site for building homes. Directly, they largely determine if a site will receive water from other areas. Indirectly, landforms influence the natural drainage of a soil. Flood plains are nature's location for storing excess floodwater. Floodwaters spread out over the flood plain and are retained there during periods of high runoff and flow. As the stream or river level drops, the water stored on the flood plain gradually returns to the stream channel by surface flow and percolation through the soil.

All too often we read reports of lives that were lost and houses that were destroyed because of floodwater. Most of these houses were built on flood plains. *Many of these losses could have been prevented by following the soil judging rule that says that houses should not be built on flood plains*.

Depressions on uplands and terraces usually accumulate water from upslope. This water, plus the rain that falls on the depression, must percolate through the soil, so soils in depressions may not be able to absorb all these waters in addition to home sewage. *Another soil judging rule states that on-site systems should not be installed in depressions*.

SLOPE

The ideal slope for home sites is 2 to 6 percent. Flat areas are less desirable because much grading may be required to slope the land to carry surface water away from buildings. On slopes steeper than 6 percent, problems of erosion, soil stability, and septic effluent seepage can occur. The steeper the slope, the more serious the problems can be. Soils on very steep slopes may be physically unstable, and houses built on them may tend to slide downhill unless proper foundation construction practices are followed. Besides complicating construction, these slopes make landscaping (such as establishing grass or shrubs) much more difficult.

Houses built on slopes may receive water from higher areas by surface flow and subsoil seepage. This water should be diverted away from the house to keep the area near the house and the basement as dry as possible.

SURFACE COLOR, TEXTURE, AND EROSION

Surface colors and textures generally do not impose serious limitations for home sites, although dark-colored, medium, or moderately sandy surface soils with high organic matter contents are beneficial in the establishment of grass or other landscape improvements.

The texture of a surface soil mainly affects its use for growing lawns, shrubbery, and trees around the home site. Clayey and sandy surface textures are less desirable. Fine-textured soils remain wet and soggy for a long period after rain and become hard when dry. Sandy soils lack water- and nutrient-holding capacity and may require improvement with topsoil or organic matter. In some instances, builders stockpile the topsoil removed in construction and replace it on the surface after final grading.

Valuable surface soil has been eroded from moderately or severely eroded soils and the more clayey subsoil may be near the surface or exposed. This makes it more difficult to grow a lawn and other plantings.

SUBSOIL TEXTURE

Subsoil texture is a very important property in home site evaluation. It affects the transmission rate of water through the soil (permeability) and the swell-shrink potential of a soil, which, in turn, affects foundation performance. Soil structure also has an important effect on permeability.

Usually, finer-textured soils transmit water more slowly than sandy textured ones. Therefore, water may drain so slowly through clayey and moderately clayey soils that it accumulates around the foundation and seeps into the basement. Poorly and somewhat poorly drained soils are more likely to have this problem than well-drained soils. These factors illustrate the wisdom of establishing good surface and subsurface drainage away from the house.

Relative to sandier soils, some fine-textured soils can bear less foundation weight and are more likely to shrink (occupy less space) during dry weather and to swell (expand) during wet periods. The forces involved in shrinking and swelling may be enough to crack and move the foundation walls. The shrink-swell properties of fine-textured soils depend on the type of clay mineral present. Fortunately, extreme cases are rare in Indiana, although troublesome foundation settling and movement are common in many areas of the state.

SOIL DRAINAGE

Water flows over the surface or moves through the profile of well-drained soils fast enough that the soil is not wet for long periods of time. These soils are ideal for home sites. Any restriction of drainage (either because of impermeable subsoils or high water tables) can cause wet basements and unusable yard areas. Wet soils impose further restrictions on home sites that depend on on-site sewage disposal, as explained later in On-site Sewage Disposal (pages 106-125).

LIMITING LAYERS

If bedrock occurs within the depth of excavation for basements, the builder must blast it out to excavate for a basement or otherwise adapt the foundation design. Either of these choices would greatly increase construction costs. Fragipans and dense till transmit water and sewage effluent so slowly that they limit use of on-site sewage disposal systems. Coarse sand and gravel soil horizons also create problems for on-site sewage disposal systems because they transmit effluent so fast that it does not get treated in the soil.

Is the Soil Suitable for a Home Site?

Sites that are subject to flooding and severe ponding are not suitable home sites. **Flooding** refers to areas that get covered with water from a stream. **Ponding** refers to areas where the water comes instead from nearby higher areas.

Depressions on uplands and terraces are subject to ponding. Builders can compensate for minor ponding problems. If a depression has more than 20 inches of recent sediment over the original soil, however, the area has major problems and should not be used for a home site.

> ▸ **JUDGING RULE**
> **15. Is the Soil Suitable for a Home Site**
>
> Is the Soil Suitable for a Home Site? (15 on home site scorecard) Mark:
>
> - **No** if the landform is a flood plain or a filled depression — if you mark "No" here, then mark all subsequent home site (52-74) "No," "Not applicable," or "N/A."
> - **Yes**, if the land form is *not* a flood plain or filled depression —proceed to judging rule 16.

Construction Practices and Rules

This section covers the nine soil judging rules that apply directly to construction practices.

PRESERVE AND PLANT TREES

Trees on home sites provide a range of environmental, social, and economic benefits that improve the quality of life. The National Arbor Day Foundation lists eight reasons to plant trees:

1. Trees conserve energy in the summer, and save you money. Properly planted trees can cut your air conditioning costs by 15 to 35 percent.
2. Trees help clear the air. Trees produce the oxygen we breathe and reduce air pollution by lowering air temperature through respiration and by retaining particulates.
3. Trees bring songbirds close by. Birdsong will fill the air as trees provide nesting sites, food, and cover for countless species.
4. Trees around your home can increase its value by 15 percent or more. Studies of comparable houses with and without trees place a markedly higher value on those whose yards are sheltered by trees.
5. Trees help clean our rivers and streams. Trees hold the soil in place and reduce polluted runoff into our waterways.
6. Trees conserve energy in the winter. Trees can slow cold winter winds, and can cut your heating costs 10 to 20 percent.
7. Trees fight global warming. As they grow, trees remove carbon dioxide from the atmosphere, the major contributor to global warming. Trees planted near our homes and in our communities moderate temperatures and reduce the need for air conditioning and heating produced by burning fossil fuels, a major source of excess carbon dioxide.
8. Trees make your home and your neighborhood more beautiful. Trees mark the changing seasons, and add grace and seasonal color. Trees make a house feel like a home.

Because older trees provide more benefits, it is especially important to preserve existing trees. Most tree roots are in the upper 12 inches of soil where compaction caused by heavy equipment can damage them. The main area of concern is inside a tree's dripline, which is the area directly under the tree canopy. If there is construction activity on a home site, you should erect a fence around the dripline to keep out all construction activity.

All potential home sites that have no trees will benefit from planting new trees, and most sites with a few trees will benefit from planting more. However, you must consider the site conditions when selecting tree species. For example, you should plant only low-growing trees under power lines.

> ▸ **JUDGING RULE**
> **16. Preserve Existing Trees and Plant New Ones**
>
> Mark "Yes" for **Preserve existing trees and plant new ones** (16 on home site scorecard) for all sites.

STOCKPILE TOPSOIL

Surface soil horizons (topsoil) provide a better medium for lawns and gardens than subsurface horizons. For this reason, after workers have protected all trees on a site, they should remove and stockpile all the topsoil on a home site (Figure 4.1).

Figure 4.1. *On this construction site an excavator has stockpiled A horizon material (front of excavator) and A and B horizon material (left of excavator).*

Construction activities will mix and compact the deeper soil horizons and parent materials. After construction is complete and the site has been graded to establish surface drainage, spread the stockpiled topsoil on the surface with as little compaction as possible.

MAINTAIN SOIL COVER DURING CONSTRUCTION

Construction on all sites (especially sloping ones) should be done with the least possible disturbance of vegetation. When vegetation is removed, new vegetation should be established as soon as possible to reduce erosion and offsite damage from sediment resulting from erosion. As a general rule, a site should be vegetated within days of the last construction activity and even if construction is not completed. Annual ryegrass can be used for temporary cover. If the site is to be under construction for a more than a few months, perennial grass species should be seeded.

Several other practices can be used to protect building sites. Structures to stabilize slopes will help control erosion. Some erosion is inevitable and the sediment produced should be kept on the building site. On larger sites, runoff from hard surfaces such as streets and parking lots must be held temporarily in water retention basins and released slowly to protect downstream areas from large surges of runoff.

Soil compaction during construction will cause the homeowner problems for many years in growing grass and other plants. It may also ruin a site for installing an on-site sewage disposal system. Some compaction is inevitable, but the area that is compacted should be kept to a minimum. In some areas, part of the lot is fenced off before construction begins and builders are not allowed into this area. This is a wise and prudent approach to managing any building site.

▸ JUDGING RULE
17. Maintain Soil Cover During Construction

Mark "Yes" for **Maintain soil cover during construction** (17 on home site scorecard) if the slope is greater than 2 percent

IMPROVE SURFACE DRAINAGE

Good surface drainage is important and frequently needed in Indiana. The flat and gently sloping topography of central and northern Indiana has very slow surface drainage. This relatively flat area is dominated by poorly and somewhat poorly drained soils. Much of the flat topography in the southeastern part of the state has even slower surface drainage. Homes located on these soils need special care beyond simply grading the lot to provide water movement away from the house. Poorly drained soils are often in depressions that receive water from higher areas and are frequently ponded.

Drainage of surface waters should be channeled away from the house and from on-site sewage system absorption fields. If this is not done, the surface water will make the high water table problem worse. Home sites should be carefully chosen with surface drainage in mind. Sloping sites may need surface drainage to improve home site suitability. If this is the case, special emphasis is needed to avoid directing water onto the on-site sewage system. Level sites on poorly drained or somewhat poorly drained soils always require special attention. Sloping soils are assumed to have sufficient relief with proper design to carry surface water off the site or at least away from the buildings.

▸ JUDGING RULE
18. Improve Surface Drainage

Mark "Yes" for **Improve surface drainage** (18 on home site scorecard) if the soil has *both* of these properties:

- Poorly drained or somewhat poorly drained soils
- Slope is 0-2 percent

SUITABILITY OF SOIL FOR BASEMENT

Many people want basements under their houses, but some soil properties limit basements and are very difficult and expensive to overcome.

Soil properties that limit basements include:

- **High water tables.** Well-drained soils have a deeper water table and have few drainage problems associated with a basement. Foundation drainage (soil judging item 23, page 103) can alleviate some but not all high water table limitations.
- **Excavation problems.** The presence of bedrock makes it very difficult to excavate for the basement and should be avoided as it incurs significant additional costs and complications for builders
- **Steep slopes.** Steep slopes require very careful design if a basement is included in house plans so that depth can be maintained. Buildings on very steep slopes may slip downslope if not built properly.
- **Swelling clays.** Some kinds of clay swell up when they get wet. This swelling can exert so much pressure on basement walls that they crack and buckle. This is one phase of the problem explained in soil judging item 20 (page 101). Swelling clays also cause problems for on-site sewage disposal systems.

▸ JUDGING RULE
19. Is the Soil Suitable for a Basement?

Mark "Yes" for **Is the soil suitable for a basement?** (19 on home site scorecard) if the soil has *all* of these properties:

- Soil is well-drained
- No bedrock closer than 40 inches from the soil surface
- Slope is 12 percent or less

Soils with high clay contents cause special construction problems for houses. In soils with coarser textures, the friction between large particles (sand and gravel) support the weight of the structure. Clayey soils lose strength rapidly as they take up moisture. Clay particles have layers of water between them and slide easily over each other. For this reason, it is important to increase the size (width and depth) of footings on clayey subsoils.

Also, many fine-textured soils expand when they are wet and shrink when dry. If workers backfill the excavated area around basement walls with soil material, a space will develop between the wall and the soil when the soil dries out and shrinks. Soil material might fall into this space, and when the soil becomes wet again, it will swell, and that added soil material will press into the building's foundation wall and may cause it to crack. Backfill the excavated area around basement walls with pea gravel to minimize this swelling pressure.

▸ JUDGING RULE
20. Design for High-clay Subsoils

Mark "Yes" for **Design for high-clay subsoils** (20 on home site scorecard) if the subsoil texture is clayey.

POTENTIAL CONSTRUCTION HAZARDS ON SLOPES

Soils on steep slopes cause some special problems for equipment operations. There is a great rollover hazard on slopes that are greater than 12 percent. This is true for both construction equipment and lawn maintenance equipment. Great care must be exercised when operating equipment on steep slopes. Homeowners should be aware of these problems when planning and building houses and should discuss them with builders and contractors.

> ▸ **JUDGING RULE**
> **21. Potential Construction Hazards on Slopes**
>
> Mark "Yes" for **Potential construction hazards on slopes** (21 on home site scorecard) if the slope is more than 12 percent.

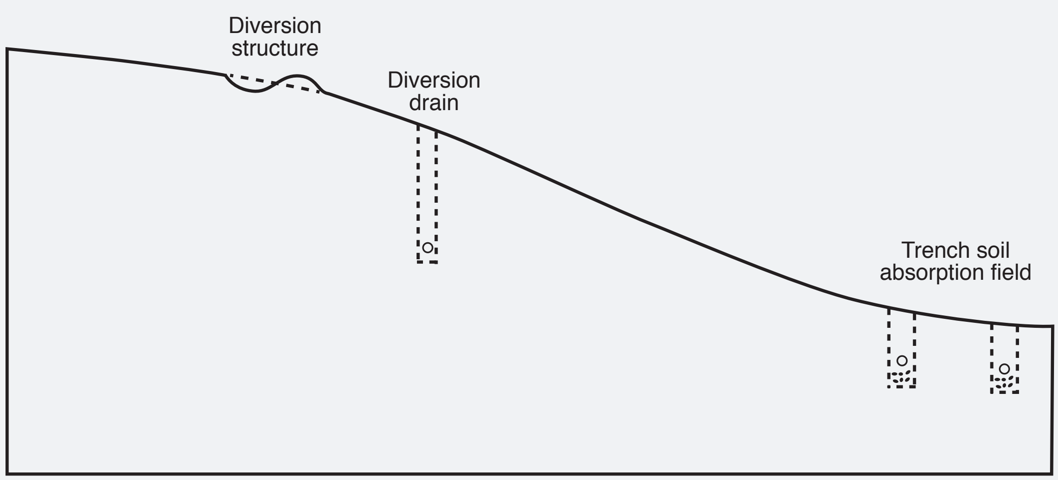
INSTALL DIVERSION STRUCTURES AND DRAINS

To avoid soggy areas around the house and wet basements, builders must make provisions to divert surface and subsurface water away from the building. If a house is built on sloping land (but not at the top of a hill), the lot may receive a lot of runoff from the land above it.

Surface water diversion structures divert *surface* water away from the house and on-site sewage systems. *Subsurface* drain tubes, called **diversion drains**, collect seepage water and divert it away from the protected area (Figure 4.2). The bottom of the diversion drain trench must be at least 2 inches into the slowly permeable limiting layer (dense till, fragipan, or bedrock) to be effective. Subsurface drains installed for on-site sewage systems must be free flowing (no pumps). They flow downslope into a receiving body of water or a larger drain. Care should be taken, however, that the diverted water does not cause problems for downslope properties.

> ▸ **JUDGING RULE**
> **22. Install Diversion Structures and Drains**
>
> Mark "Yes" for **Install diversion structures and drains** (22 on home site scorecard) if the soil has *both* of these properties:
>
> - Slope is more than 2 percent
> - Either:
>   - There is a bedrock, dense till, or fragipan limiting layer closer than 40 inches to the soil surface
>   - Subsoil texture is moderately clayey or clayey

Figure 4.2. Cross-section through a surface water diversion and a diversion drain.



PROVIDE FOUNDATION DRAINAGE

Water in saturated soils causes many problems for basements.

- It can seep through the wall and floor to cause wet basements.
- The pressure of water itself can cause basement walls to buckle.
- Some clay minerals swell when they get wet. The pressure on basement walls due to swelling clay can be much greater than the pressure of water itself, so swelling clay is a serious problem, especially for high clay soils (Judging Rule 20).
- These problems can be lessened by installing a footing drain system around the foundation. This system consists of these components (Figure 4.3):
- A sheet of polyethylene film below the basement floor.
- A layer of pea gravel under the basement floor.
- A ring of perforated plastic tubing in this pea gravel.
- A ring of perforated plastic tubing that goes around the outside and below the foundation.
- A system to remove drainage water. It can be a tube that drains by gravity if the house is high in the landscape, but in most cases, it is s sump pump that pumps the water to a surface outlet way from the house.

Remember that good surface drainage should be combined with this practice.

> ▸ **JUDGING RULE**
> **23. Provide Foundation Drainage**
>
> Mark "No" for **Provide foundation drainage** (23 on home site scorecard) if the soil has *both* of these properties:
>
> - Soil is well drained
> - Either:
>   - Subsoil texture is sandy
>   - The soil has a coarse sand and gravel limiting layer closer than 40 inches below the soil surface
> - Mark "Yes" for all other soils

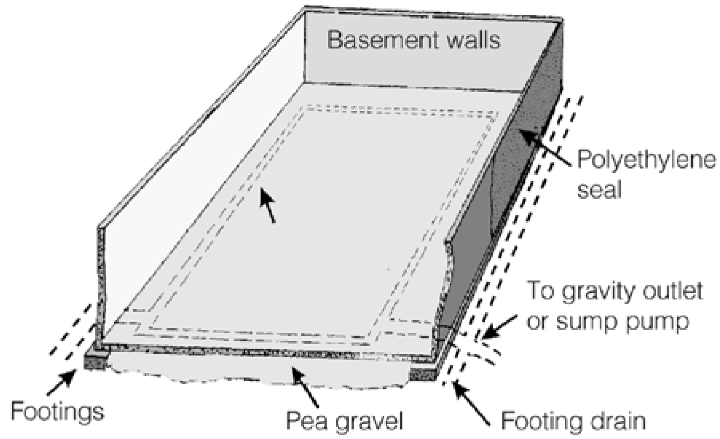


Figure 4.3. *This illustration shows foundation construction that includes footing drains.*

HIGH RISK FOR CAVE-IN DURING CONSTRUCTION

All excavations have a potential to cave in. A cubic yard of soil can weigh as much as a car. Trenches and excavations are very common places for worker fatalities. There is always risk and care must be exercised to insure the safety of all. Check with local authorities for details. Practices that should be considered include keeping equipment away from trench edges. Both the weight of the equipment itself and vibrations from movement can put the trench walls at risk of collapse. Keep spoil piles (material removed from an excavation) at least 2 feet from the trench edges. Some excavations can be benched or stair-stepped, so that the segments of the wall created are not as high and would not have as much risk of collapse. Some situations can be made safer by sloping the walls of the trench. Be especially observant of trench conditions following a rainstorm or any other water movement onto the site. Some soils are more prone to difficulties than others and it is important to take special precautions when working with these soils to avoid problems associated with cave-ins. Sandy soils do not hold together as well as clay soils to give stability to trench walls.

> ▸ **JUDGING RULE**
> **24. High Risk for Cave-in During Construction**
>
> Mark "Yes" for **High risk for cave-in during construction** (24 on home site scorecard) if the subsoil texture is sandy or the soil has a coarse sand and gravel limiting layer

Landscape and Lawn Practices

Plants thrive best when they are well-suited to the soil they grow in. Once established, turf and landscape plantings need continued care, particularly fertilization. This section explains how soils are important in lawn and landscaping practices. The practices considered for soil judging involve soil acidity and the nutrient elements nitrogen (N), phosphorus (P), potassium (K), and calcium (Ca).

MANAGE SOIL REACTION

Some landscaping and garden plants (such as azaleas, rhododendrons, blue hydrangeas, and blueberries) grow best in acid soil. For azaleas and rhododendrons, the optimum pH is about 5.5, with a range of 4.5 to 6.0. Blueberries prefer a soil pH of around 4.0 to 5.0. In general, hydrangeas are pink in alkaline soil and blue in acid soil. Blue hydrangeas require a pH of about 5.0 for good color. The pH of many soils can be lowered to meet the pH requirements of these plants. Soil pH is raised by adding lime.

Several soil amendments acidify soil and decrease soil pH. N fertilizers that contain ammonia compounds (NH_3, NH_4^+) and urea [$(NH_2)_2CO$] reduce soil pH over a period of years whether or not acidification is desired. Ammonia is converted to nitric acid (HNO_3) by nitrifying bacteria:

$$NH_3 + 2O_2 \longrightarrow HNO_3 + H_2O$$

Nitric acid makes the soil more acidic. Soils used for crop production are generally heavily fertilized with ammonia compounds and thus need to be limed periodically.

Soils can also be acidified by adding sulfur (S). S is converted to sulfuric acid (H_2SO_4), also by microbial action:

$$2S + 3O_2 + 2H_2O \longrightarrow 2H_2SO_4$$

Sulfuric acid also makes the soil more acidic. This reaction takes several weeks because microbial populations must be built up to carry it out. Aluminum sulfate, $Al_2(SO_4)_3$, can be added instead of S to lower soil pH.

Many soils can be acidified to grow acid loving plants. Some soils, however, contain lime ($CaCO_3$), which must be dissolved before the soil can be acidified. These soils usually have pH values of 8.0 or higher. Acidifying these soils could require much S and take a long time. It may be more practical to choose species that do not need acid soil, as reflected in soil evaluation rules.

> ▸ **JUDGING RULE**
> **25. Manage Soil Reaction for Acid-loving Shrubs**
>
> Mark **Manage soil reaction for acid-loving shrubs** (25 on home site scorecard):
>
> - **No application** if the soil pH is 5.6 or less
> - **Apply sulfur** if the pH is 5.7 to 7.9
> - **Plant other species** if the pH is 8.0 or more

Turfgrass tolerates a fairly wide pH range. Turf specialists consider a pH between 6.0 and 7.5 to be optimal for grass growth. If soil pH is less than 6.0, they recommend lime application. Lime increases soil pH and supplies Ca and usually magnesium to the soil. If soil pH is more than 7.5, it is not optimal for most turfgrass species. Applying elemental S can lower pH over a long period of time, but it is often not practical. Instead, homeowners can increase the N fertilizer application rate by 25%. The extra N promotes soil acidification. Also, many micronutrients (such as iron and manganese) are less available to plants at high soil pH than at low pH. The extra fertilizer may contain some of these micronutrients. If the soil pH is very high, it is difficult to change pH, and more practical to plant grass species adapted to those conditions.

> ▸ **JUDGING RULE**
> **26. Manage Soil Reaction for Lawns**
>
> Mark **Manage soil reaction for lawns** (26 on home site scorecard):
>
> - **Apply lime** if the pH is 5.9 or less
> - **No application** if the pH is 6.0 to 7.5
> - **Plant other species** if the pH is 7.6 or greater

Figure 4.4. *This photo shows the effect of unevenly applied N fertilizer. The green strips received N fertilizer but the rest of the lawn did not. Photo provided by Cale Bigelow.*

MANAGE SOIL FERTILITY

Lawns are fertilized mainly with N, P, and K. The amount of N fertilizer to apply to lawns depends mainly on the overall lawn management level the homeowner chooses to use. The maximum application rate (5 pounds of N per 1,000 square feet of lawn) is for homeowners who want the greenest lawn and are also willing to devote considerable time to mowing and irrigation (Figure 4.4). In this maximum program, homeowners apply N four times a year. The minimum rate is for those who are satisfied with a less attractive lawn. In the minimum program, homeowners apply N only in September.

N fertilizers come in two basic forms: quick-release (soluble) N and slow-release (insoluble) N. Quick-release N normally causes a plant growth and color response in a week or less, whereas slow-release N will cause a response in three to 10 weeks or more. Quick-release N is inexpensive and may burn leaf blades if applied improperly. Slow-release forms tend to be more expensive but will rarely burn leaf blades even when applied at temperatures above 85oF. Both N forms can and should be used on lawns. Both forms of N are often blended in one fertilizer bag. This is advantageous because the quick-release N gives a response shortly after application and the slow-release N results in a more gradual and longer response. Quick-release forms of N are urea, urea ammonium sulfate, potassium nitrate, and ammonium chloride. Slow-release forms include sulfur coated urea, polymer coated urea, methylene urea, and natural organics.

Lawn fertilizer application rates for P, K, and lime are based on soil tests which are done on samples collected by a homeowner and sent to a soil testing laboratory. Instructions for taking soil samples — from *Soil Testing for Lawns* (Purdue Extension publication AY-18-W), available from the Education Store, edustore.purdue.edu — are reprinted below.

> Here are some things to do when collecting a soil sample:
>
> - Contact your soil testing lab for the fee structure, mailing containers, and other information.
> - Use a small shovel or soil probe to sample to a 3-inch depth.
> - Take approximately 10 to 15 samples per lawn and remove thatch and live plant material.
> - Combine the samples to make one composite sample. Do not mix soils of different textures and colors, from areas differing sharply in elevation, or from disturbed sites and undisturbed sites.
> - Air dry the sample before sending to the laboratory.

Soil test results for P and K are reported in units of parts per million (ppm), and fertilizer application rates are based on these tests. The relationship is explained Turfgrass Management: Establishing a Lawn from Sod (Purdue Extension publication AY-28-W), available from the Education Store, edustore.purdue.edu. For soil judging, application rates are simplified to "Yes" or "No" for fertilizer application.

Many lawn fertilizers contain no P because it is adequate in many soils and excessive fertilizer P may eventually pollute water in lakes and oceans.

It is best to fertilize lightly in spring and early summer, little or none in summer, and heavy in fall. In the fall, soil temperature is high relative to air temperature, which encourages growth of roots more than growth of leaves. A vigorous root system benefits the plants through subsequent growing seasons.

> ▶ **JUDGING RULE**
> **27. Apply Phosphorus (P) to Lawn**
>
> Mark "Yes" for **Apply phosphorus (P) to lawn** (27 on home site scorecard) if available P is less than 25 ppm

> ▶ **JUDGING RULE**
> **28. Apply Potassium (K) to Lawn**
>
> Mark "Yes" for **Apply potassium (K) to lawn** (28 on home site scorecard) if available K is less than 75 ppm

MOWING

Mowing is also important for lawn care. Turf experts say that improper mowing causes more problems on lawns than any other maintenance practice. Most lawns are mowed too short, not often enough, and/or with a dull blade. Mowing height depends on grass species, but most common species grown in Indiana (except zoysia) should be mowed at 3.0 to 3.5 inches — longer in shaded areas. Lawns should be mowed frequently enough so as not to remove more than one-third of the leaf blade in a single mowing. Mower blades should be sharpened four to six times a year. It is recommended that usually clippings should be left on the lawn instead of bagged and removed.

On-site Sewage Disposal – Technical Background

This section explains how **on-site sewage disposal** systems work and describes different kinds of systems. It provides the technical background for the next section, On-site Sewage Disposal — Practices (page 121), which explains why some soils are not suitable for any kind of on-site system, and defines the soil requirements for specific systems by way of soil judging rules. Some readers might start with the Practices section first, and study the Technical Background section after they have had some experience with soils outdoors. To accommodate this sequence, some of the information in this section is summarized in the Practices section.

This Technical Background section is divided into five parts:

1. Overview (pages 106-108) describes on-site systems and their importance in Indiana
2. Septic Tanks (Initial Treatment) describes the first system for treating sewage in all on-site systems
3. Soil Absorption Fields (Final Treatment) discusses further treatment of effluent from a septic tank
4. Secondary Treatment describes optional systems placed between septic tanks and soil absorption fields
5. Effectiveness of Sewage Treatment and Consequences of System Failure considers how well these systems perform and what happens if systems fail

Overview

SEWAGE AND ITS DISPOSAL

Sewage is liquid-carried waste generated as part of normal living. It comes from toilets, bathtubs, showers, sinks, washing machines, dishwashers, and other sources. In cities and towns, water is piped to homes through a water system, and sewage flows through sewer lines to a central treatment plant.

Home sites that are not served by centralized water and sewer systems usually draw water from wells and treat sewage with **on-site sewage disposal systems**, which process sewage on the site where it is produced.

SIGNIFICANCE OF ON-SITE SEWAGE SYSTEMS

More than 26 million homes (almost 25 percent of the U.S. population) dispose of domestic sewage through on-site sewage systems rather than a central sewer system. Every day, on-site sewage systems in the United States collect, treat, and release about 4 billion gallons (15,000,000 m3) of treated effluent per day from homes, businesses, and recreational facilities. This percentage might grow. The U.S. Environmental Protection Agency concluded that well designed on-site sewage systems are more cost effective than centralized systems.

In Indiana, there are approximately 800,000 on-site sewage systems (including commercial applications) that serve more than one-third of the people for sewage treatment and dispersal. Local health departments issue more than 10,000 permits per year for new systems, and about 6,000 permits for replacement of failed systems. Serious problems still exist, however, and must be addressed. According to a survey of county environmental health specialists, a significant number of homes in the country and small towns do not have an operating on-site sewage system or the existing system has failed, and untreated sewage is discharged directly to the land surface, ditches, or streams. This untreated sewage represents a health hazard for the community and pollutes the environment.

One of the major differences between a home with an on-site sewage system versus a home served by a central sewage treatment plant is that the on-site sewage system must be maintained by the homeowner. Treatment and dispersal of sewage should be one of the primary concerns of any homeowner with an on-site sewage system.

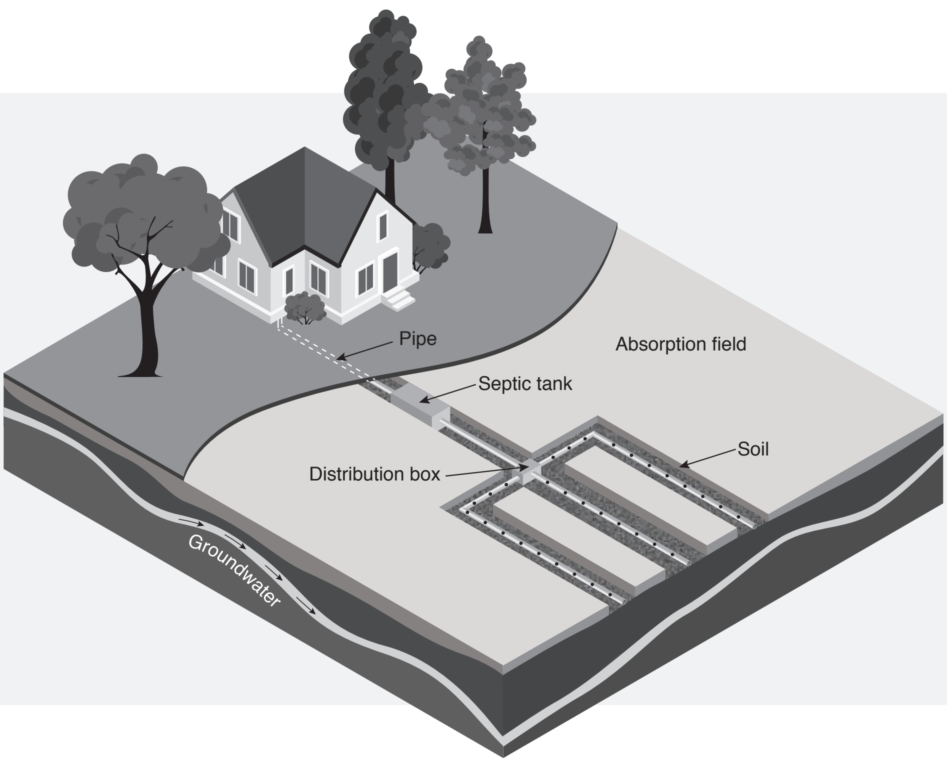
HOW ON-SITE SEWAGE SYSTEMS WORK

All on-site sewage disposal systems have two main parts:

1. A **septic tank**, which processes the sewage and produces effluent
2. A **soil absorption field**, which allows the soil to absorb and further treat the effluent.

These components are illustrated in Figure 4.5. In some cases, a pump dosing tank or a secondary treatment unit is installed between the septic tank and the soil absorption field.

__Figure 4.5.__ This illustration shows a typical arrangement of the septic tank, distribution box, and soil absorption field.



On-site sewage systems work on the same principle as a centralized sewage treatment facility. Treatment involves a three-step process:

1. Separation of the waste.
2. Treatment of the waste by anaerobic and aerobic microorganisms. Aerobic organisms require oxygen and anaerobic ones can live without oxygen.
3. Dispersal of the remaining products.

Sewage may also include water from the periodic regeneration of water softeners. In Indiana, it is illegal for the homeowner to discharge sewage, even after treatment, to the open environment. Often, water from softener recharge goes to the septic tank. However, it may also be discharged to a separate soil absorption field installed just for that purpose, or it may bypass the septic tank and enter the soil absorption field with effluent from the septic tank.

Septic Tank — Initial Treatment

The first sewage treatment step in all on-site sewage disposal systems is a septic tank. In most systems, the effluent from the septic tank flows directly to a distribution box by gravity. In some cases, the effluent flows from a septic tank to a secondary treatment system or to a pump dosing tank instead of to a distribution box.

Septic Tank

In a conventional on-site sewage system, sewage flows from the house into a watertight, underground septic tank (Figure 4.6). Many different types of organisms live in sewage, and the **anaerobic organisms** are critical for treating it in the septic tank. Many of these organisms originate in the human gut and continue the digestion process on the waste that began in the human digestion process. Unfortunately, not all the pathogens are rendered harmless in this process and additional treatment is required from **aerobic organisms** in the soil absorption field to kill them. Although the effluent appears clear it still contains many pathogens and much organic matter.

Septic tanks are made of concrete, fiberglass, or plastic and must be watertight. Previously, most septic tanks had a single compartment, but two-compartment tanks or two single compartment tanks in series are becoming more common. For designing

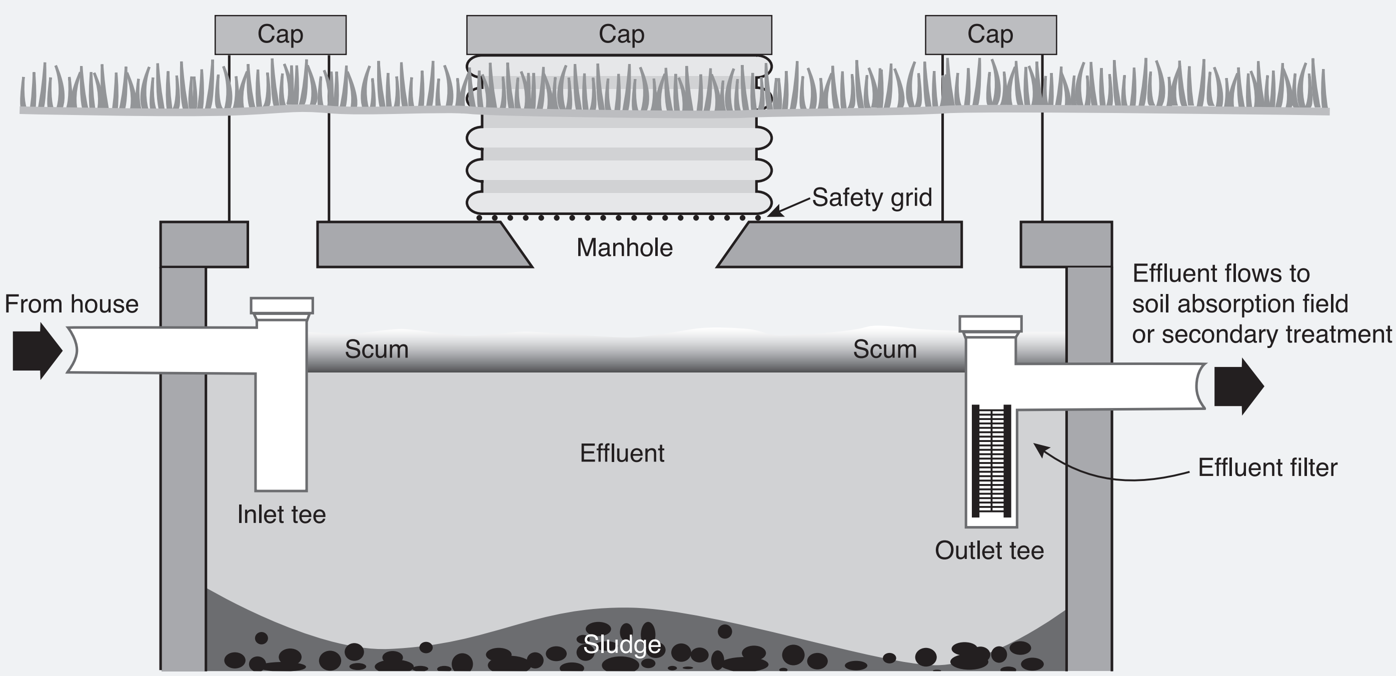


Figure 4.6. *This illustration shows a cross-section through a typical septic tank.*

on-site sewage systems, the amount of sewage to be processed is estimated from the number of bedrooms in the house. Although the *actual* number of residents determines water use, the on-site sewage system plan is based on the *potential* number of residents, assuming two people per bedroom. The size of the tank is such that it retains sewage for at least two days. Most septic tanks hold 1,000 to 1,500 gallons, but larger tanks are available. Anaerobic microorganisms in the tank decompose much of the organic matter in the sewage before it is discharged

The septic tank might be described as a settling tank where solids as well as fats, oils and greases are stored. Sewage contains pathogens, nutrients, soils, clothing fibers, prescription medicines, and even heavy metals (from cosmetics). In a properly functioning septic tank, the waste forms three distinct layers (Figure 4.6). Heavy solids settle to the bottom of the tank to form a **sludge** layer. Fats, oils and, greases and other floatables float to the surface to form a **scum** layer. The middle, and largest, layer is the liquid **effluent**. The sludge and scum layers resist treatment by microorganisms. Figure 4.6 shows ports for observing and cleaning that reach the soil surface. This is essential for maintaining the tank. In many older systems, the ports were buried. Septic tanks can be retrofitted by installing watertight access ports. This should only be done by qualified on-site sewage system installers. The ports are fitted with securely fastened lids, and in Indiana they must have a secondary safety grid. The grid is inexpensive insurance that prevents a small child or adult from inadvertently falling into the tank.

Sludge and scum build up in the septic tank over time, so periodic pumping is necessary (soil judging item 31). If these layers become too thick, then the sewage is not treated properly before the effluent is discharged to the absorption field. In extreme cases, sludge and scum accumulate to such an extent that the entire system fails.

All septic tanks have **baffles** (the T-shaped tubes in Figure 4.6) at the inlet and outlet to ensure proper flow patterns. The inlet baffle slows the speed of sewage flow into the tank. If the sewage enters too fast or in too great a volume, it will stir up the sludge and scum layers which could cause the system to discharge excessive solids to the soil absorption field, eventually causing the absorption field to fail. Keeping solids out of the absorption field prevents this clogging, extends the time that a soil can effectively treat effluent, and reduces the potential for expensive repair or replacement. A small opening between the top of the inlet baffle and the tank cover allows gases generated in the tank to vent back through the house sewer stack. Venting prevents an air lock from developing and permits the smooth flow of sewage through the system.

An effective safeguard to keep solids out of the absorption field is the use of an **outlet filter** at the outlet baffle of the septic tank. Septic tank outlet filters are now required in Indiana for all new septic tank installations. Local health departments may also require existing tanks to be retrofitted with outlet filters. These filters must be periodically cleaned to insure proper operation and to prevent sewage back-up into the home (soil judging item 30). An outlet filter is an inexpensive but effective way to protect the expensive soil absorption field.

DISTRIBUTION BOX

In a conventional subsurface on-site system, when effluent leaves the septic tank, it flows to a distribution box, which has a number of openings for pipes that distribute the effluent evenly to all lines (laterals) of the absorption field (Figure 4.7). To ensure even distribution of the effluent, distribution boxes must be level and stable.

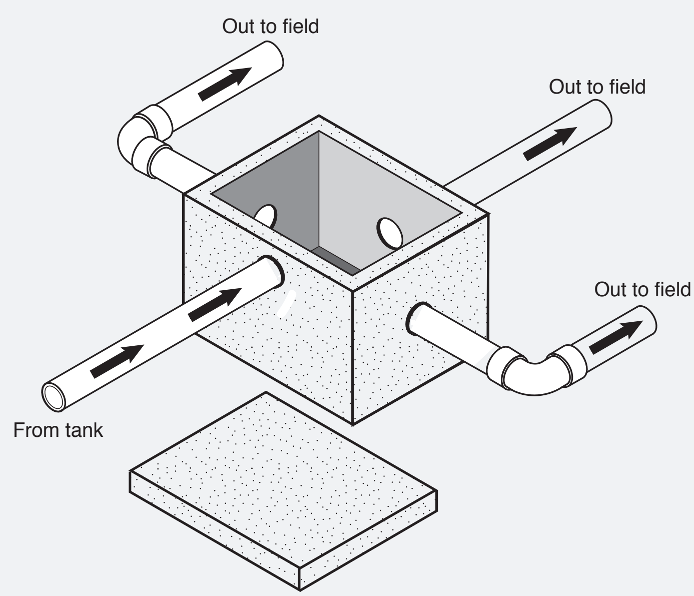


Figure 4.7. *An illustration of a distribution box.*

Soil Absorption Field — Final Treatment

FUNCTION OF AND DESIGN OF SOIL ABSORPTION FIELDS

Septic tanks remove most of the solid wastes from sewage, but septic tank effluent still contains much organic material and many potentially disease-causing microorganisms that must be removed. This treatment is done in soil. In a typical system, effluent flows from the distribution box to a series of pipes in the soil absorption field called **laterals**. The pipes are surrounded by aggregate of some type in carefully designed trenches. The effluent flows out of the pipe into the aggregate in the trench, and then into the aerated soil for final treatment by aerobic microorganisms.

The first step in planning an on-site system is to get a soil evaluation. A **certified soil scientist** determines essential landscape position and soil profile information. Then, a **regulator** uses this information to decide if the site is suitable for an on-site system. If it is suitable, a **system designer** designs a system.

Soil Properties — Permeability

For the treatment to operate successfully, the soil must absorb and transmit effluent at a rate appropriate for the soil and the volume of effluent discharged to the soil absorption field. If the rate is too slow, the soil will not accept the effluent at the rate it is produced. If the rate is too fast, the effluent moves through the soil before the microbes can treat it. In soil evaluation, the soil horizons that transmit water too fast or too slowly are called limiting layers. Fragipans, dense till, and bedrock transmit effluent too slowly, while coarse sand and gravel transmit effluent too quickly. There must be sufficient moderately permeable, well-aerated soil between the bottom of an absorption field and the top of a limiting layer to properly treat the effluent. Some soils with clayey subsoil textures may be too slowly permeable, but for soil judging purposes we assume that this limitation can be overcome by using a larger absorption field. In many situations, this may not be practical.

Soil Properties — Aeration

Good aeration is also necessary for treating effluent in a soil absorption field. Many soils in Indiana are poorly or somewhat poorly drained. The water table in these soils tends to be high in the soil profile in the winter and early spring, and aeration is poor in horizons saturated with water. The level to which the water table often stands during the wet season (but not the highest level of the season) is called the **seasonally high water table**. The depth to this water table is reflected by the natural soil drainage class as described in Natural Soil Drainage (page 57 Chapter 2). The water table typically falls in late spring and summer when the weather gets warm, evaporation increases, and plants pump water out of the soil. When the water table is low, most of the soil pores are filled with air, oxygen moves through the soil easily, and aerobic microorganisms flourish. When the water table is high, however, all of the pores are filled with water, there is no room for oxygen, and effluent cannot move through the soil. For a soil to treat sewage effluent aerobically, there always must be an unsaturated (aerobic) zone between the bottom of the absorption trench or bed and the water table when it is at its seasonal high. In Indiana, this zone must extend for at least 24 inches below the trench bottoms for a subsurface system and at least 20 inches below the ground surface for an aboveground system, such as an elevated sand mound.

The first part of a soil evaluation is based mainly on soil landscape information — soil absorption fields should not be installed in depressions. If the soil is suitable for some kind of system, the soil scientist provides information from which two important characteristics can be derived:

1. Soil permeability (estimated from soil texture, structure, consistence, and other soil properties)
2. Depth of the seasonally high water table (estimated using soil color and landscape position information)

System Design and Installation

The system designer uses this soil information and an estimate of the volume of sewage that must be treated to design the system. Examples of how soil profile and landscape information relates to specific kinds of soil absorption fields are provided in the judging rules.

The estimate of soil permeability is referred to as the **soil loading rate**, which estimates the rate the soil absorbs the effluent. The size of the absorption field always depends on the permeability of the soil and the volume of sewage that must be treated.

The kind of soil absorption system that is suitable to the site and the size of the system are based on soil characteristics. The absorption field must be in natural soil (not fill), because the permeability of fill is difficult (if not impossible) to predict. The permeability of natural soil can also be greatly reduced by compaction from driving heavy equipment on it. To prevent this compaction, the proposed site should be fenced off before construction begins so it will not be disturbed. Also, on-site sewage systems should not be installed when the soils are wet because wet soils are easily compacted and smeared.

SOIL PROCESSES

Sewage contains nutrients, such as nitrates and phosphates that may pollute waterways and groundwater supplies. Excessive nutrients in drinking water supplies can be harmful to human health and can degrade lakes and streams by enhancing weed growth and algal blooms. Examples of water pollution are presented in Examples of Water Pollution (page 85).

Soils treat the effluent through physical, chemical, and biological processes. The soil also acts as a natural buffer to filter out many of the harmful bacteria, viruses, and excessive nutrients, effectively treating the sewage as it passes through the unsaturated zone before it reaches the groundwater (Figure 4.8).

Aerobic soils in the treatment zone treat effluent by four processes:

1. Microorganisms treat most of the effluent in soils. A different set of bacteria lives in the aerobic soil than in the anaerobic septic tank. These aerobic bacteria break down organic compounds in the effluent mainly to carbon dioxide and water. They also kill and consume many of the harmful bacteria.
2. Negative charges on soil particles attract dissolved cations. Soil clays have negative charges that attract and hold dissolved cations in the septic tank effluent such as sodium (Na^+), calcium (Ca^{2+}), and potassium (K^+).
3. Soil particles absorb some soluble components of the effluent by other processes. For example, dissolved phosphate can be chemically absorbed by iron oxide minerals in the soil.
4. Some soluble materials (such as reduced iron and manganese) oxidize and precipitate out when they reach the aerated soil. Oxidation and precipitation were explained in Iron (page 36).

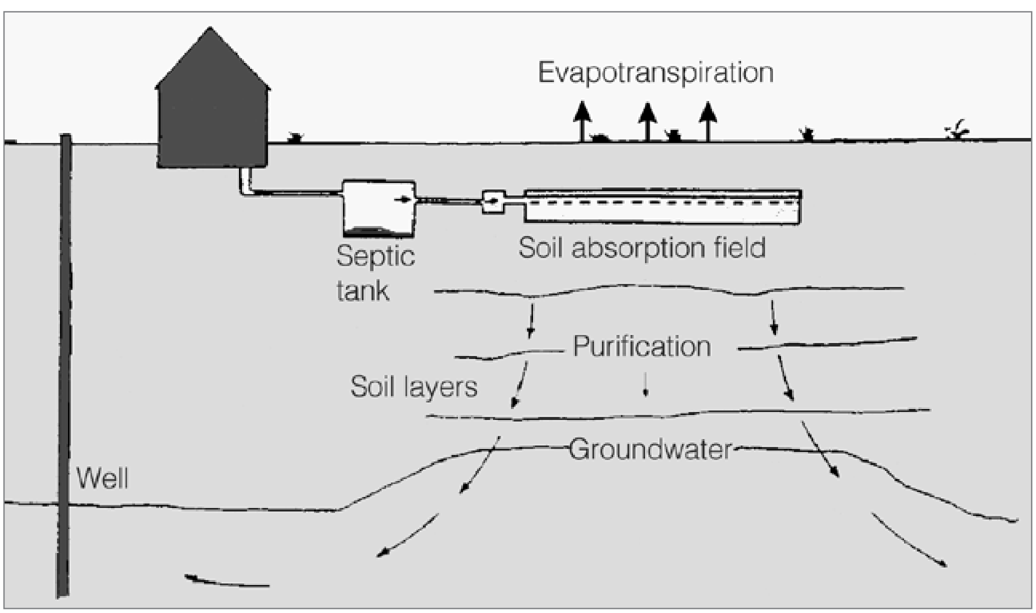


Figure 4.8. *Side view of a septic tank, distribution box, and soil absorption field.*

Biomats

Biomat formation is an important process that occurs in the soil absorption field.

According to *Biomats* (a former Penn State University Extension publication), a:

> **biomat** is a black, slimy, jelly-like, slowly permeable layer of partially decomposed organic waste containing microorganisms and their byproducts. Biomats are often found on the aggregate-soil interface at the bottom and sidewalls of absorption field trenches. Biomats form because the infiltrating soil surfaces, designed to be oxygen-rich (aerobic), have become wet and oxygen starved (anaerobic).

Biomats greatly reduce the rate at which effluent is absorbed by the soil. They form in most soil absorption fields because, even though they are aerobic most of the time, they become anaerobic during periods of wet weather and high on-site system use.

One way to reduce biomat formation is to install secondary treatment systems to treat the effluent to reduce its organic matter content (see Secondary Treatment, page 118). Soil absorption fields last longer if there is little or no biomat.

Soil Absorption Field Variables

Effluent from the septic tank is usually distributed to a soil absorption field through perforated pipes (called **lateral lines**) surrounded by aggregate. Soil absorption fields differ in a variety of ways, including the:

- Vertical placement of lateral lines — either below the original soil surface in trenches or above the surface in sand mounds
- Kind of material through which effluent is distributed in trenches — aggregate, plastic chambers, etc.
- Timing of effluent application — seepage or in doses
- Type of flow — gravity flow vs pressurized
- Type of drainage — unassisted or supplemented by drainage near the soil absorption field

VERTICAL PLACEMENT

Effluent can be released to the soil:

- Below the surface in trench systems
- Near the surface in drip distribution systems
- Above the surface in elevated sand mounds

These systems will be described in detail later.

DISTRIBUTION MATERIAL IN THE TRENCH

In the trench, effluent flows from the distribution laterals into some kind of material. Some of these materials include:

- Aggregate, gravel or crushed rock material that is about 0.5 to 2.5 inches in diameter is commonly used to distribute effluent. In Indiana, it is mainly gravel from outwash or crushed limestone. Shredded tire chips are also approved.
- Polyethylene chambers may be used instead of aggregate in a trench. A chamber is an open-bottom, arch-shaped, plastic structure about 2 to 3 feet wide, 6 to 94 feet long, and 1 to 1.5 feet high (Figure 4.9). Several chambers are joined end-to-end to fit into a standard 3- foot-wide trench. After they are laid in the trench they are covered with soil material. Effluent flows from a distribution line onto the bare trench bottom where it is absorbed.

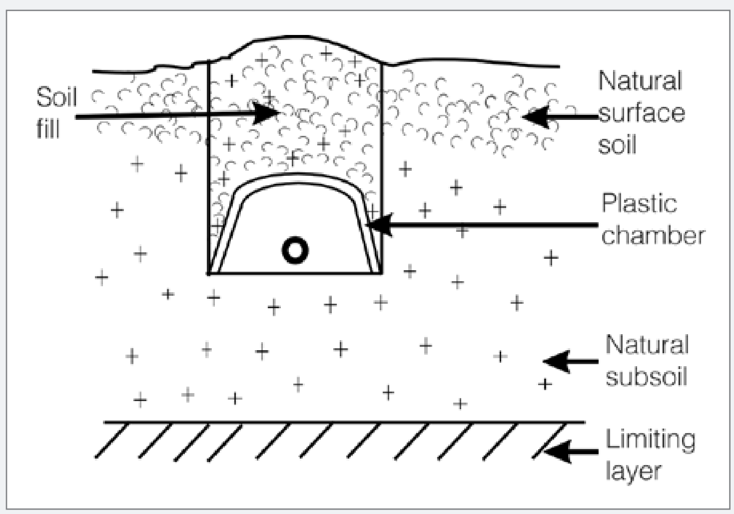


Figure 4.9. *A cross-section through one trench of a soil absorption field with a plastic chamber for distributing effluent.*

- Sand-lined pipe systems can be used in place of an aggregate-based trench system. Sand lined pipes are a new approach and feature large pipes laid in a sand bed of INDOT Specification 23 sand. Sewage flows or is pumped into a continuous set of pipes from the septic tank where it flows through the pipes, through the sand, and then is absorbed by the underlying soil. This system can be used on soil slopes up to 15 percent and in elevated sand mound systems on slopes up to 6 percent.

TIMING OF APPLICATION AND PRESSURE IN EFFLUENT DISTRIBUTION LINES

In many systems, effluent flows into the soil absorption field by gravity whenever new sewage enters the septic tank. This system (and its variations) include:

- **Gravity flow**. Effluent flows slowly by gravity to and through distribution pipes of the absorption field. The goal is to evenly distribute the effluent but this can be difficult with gravity flow. An impermeable biomat forms on the soil surface where the effluent is first absorbed by the permeable soil. Initially this is at the beginning of the bed, but when that area becomes impermeable, the next permeable soil is farther down the line. With time, absorption occurs farther and farther down the line until no permeable soil remains. Then the system fails. This is commonly referred to as "progressive creep" or "progressive failure."
- **Flood dosing** (low-pressure dosing). In this system, effluent flows from the septic tank into a dosing tank, is then pumped in doses into the distribution box, and then flows from there by gravity through the distribution laterals in the soil absorption field. Flood dosing can be used in sand-lined pipe systems where the distribution laterals are higher than the septic tank. Flood dosing is also required where the total lineal footage of the trenches is more than 500 feet, and where the limiting layer is from 24 to 30 inches below the trench bottoms. It has an advantage over gravity flow because large doses of sewage effluent are delivered in a short time so most of each trench will be used for absorption. The soil absorption field will also have the opportunity to rest between sewage effluent doses, which encourages aerobic conditions in the soil absorption field.
- **Pressure distribution systems**. This system is similar to the flood dose system except that effluent is pumped throughout the sewage effluent distribution laterals under pressure, which provides more uniform distribution to each throughout the whole system. It is used for large absorption fields, subsurface trench systems with unequal trench lengths, elevated sand mounds, and drip distribution systems. It is the optimal method for equal sewage effluent application throughout the entire soil absorption field system.

SUPPLEMENTAL DRAINAGE

Surface **diversions structures** divert *surface* flow from upslope away from the home site and soil absorption fields. Without these practices, much of the upslope surface water would flow onto the soil absorption field, which could cause it to fail. Likewise, **diversion drains** collect subsurface water and carry it away from the home site and soil absorption field. These structures and drains were described for soil judging item 22 (page 102) and are illustrated in Figure 4.2. They are installed only on the upslope side of a soil absorption field.

Perimeter drains, on the other hand, are installed *around the entire field* (Figure 4.10). These drains are used to lower a seasonally high water table. They must be at least 10 feet horizontally from the absorption field, and usually 3 feet deeper than the bottom of the subsurface soil absorption field trenches. For elevated sand mounds, the drain is usually at least 32 inches below existing grade. Perimeter and interceptor drains must flow by gravity (no pumps) to an open ditch or stream.

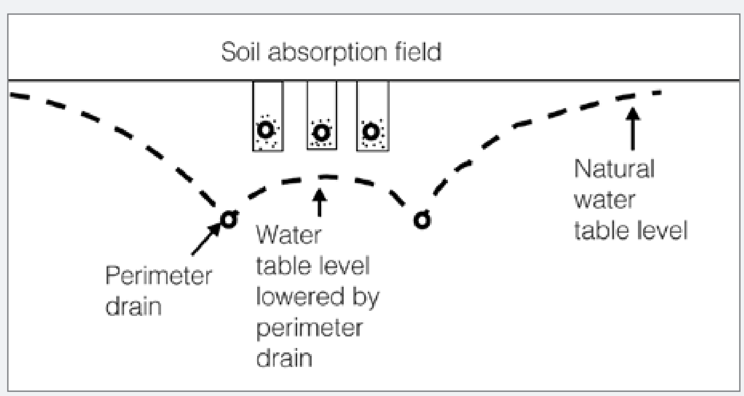


Figure 4.10. *A cross-section of a soil absorption field with three parallel lines and a perimeter drain. In Indiana, the perimeter drain must be at least 10 feet from the edge of the field and 3 feet below the bottom of the trenches.*

Kinds of Soil Absorption Fields Used in Soil Judging

On-site sewage treatment options can be used in different combinations to produce several soil absorption systems. We describe a few of the most common here.

SUBSURFACE TRENCH SYSTEMS

Most soil absorption fields are trench systems, but there are several variations of this system. In the **gravity flow** option, when the sewage level in the septic tank rises above the outlet pipe effluent flows by gravity, without pumps, to a distribution box, which splits the flow to pipes in the trenches of the soil absorption field. The perforated distribution pipes in the trenches are surrounded by aggregate, usually gravel. A geotextile fabric is laid on top of the aggregate to keep soil material out of the aggregate, and then the trench is covered with soil material. Figure 4.8 shows a side view of a septic tank and gravity flow subsurface trench system. The bottoms of the aggregate trenches must be at least 24 inches above a limiting layer and at least 24 inches above a seasonally high water table. A shallow seasonally high water table may be lowered to the appropriate depth through the use of a properly designed and installed subsurface drainage system. The size of the system depends on the permeability of the soil in which it is installed and the number of bedrooms in the home. Generally, finer textured soils have slower permeability than coarser textured soils.

Other variations of the trench system are the **flood dose** system and the **pressure distribution** system. These variations were explained in Flood Dosing (page 113) and Pressure Distribution (page 113).

ELEVATED SAND MOUND SYSTEM

This system is built on top of the soil if a limiting layer or a seasonally high water table is too close to the surface for a trench system to be used (Figure 4.11). Specifically, a layer of washed sand (INDOT Specification 23) is placed on the soil surface, which has been prepared by cutting removing excess vegetation and then plowing or chisel plowing the surface to a prescribed depth. Small-diameter distribution pipes are placed in an aggregate bed on top of the sand, and the aggregate and pipes are covered with geotextile barrier material and soil fill material (Figure 4.12). For an elevated sand mound system, the original soil surface must be at least 20 inches above a limiting layer or a seasonally high water table unless the seasonally high water table can be lowered to at least 20 inches below the surface by subsurface drainage. The septic tank effluent is collected in a separate dosing tank and the entire pipe distribution network is pressurized by the use of a pump in the dosing tank. The components of a sand mound system are illustrated in Figure 4.13). By rule, elevated sand mound systems cannot be used on soils that have a slope of more than 6 percent because effluent might seep out and pond on the ground surface.

Figure 4.11. *This photo shows an elevated sand mound in a wooded area. The solid yellow line shows the side boundary of the mound, and the dashed line shows the end boundary. No trees will be growing on the mound.*

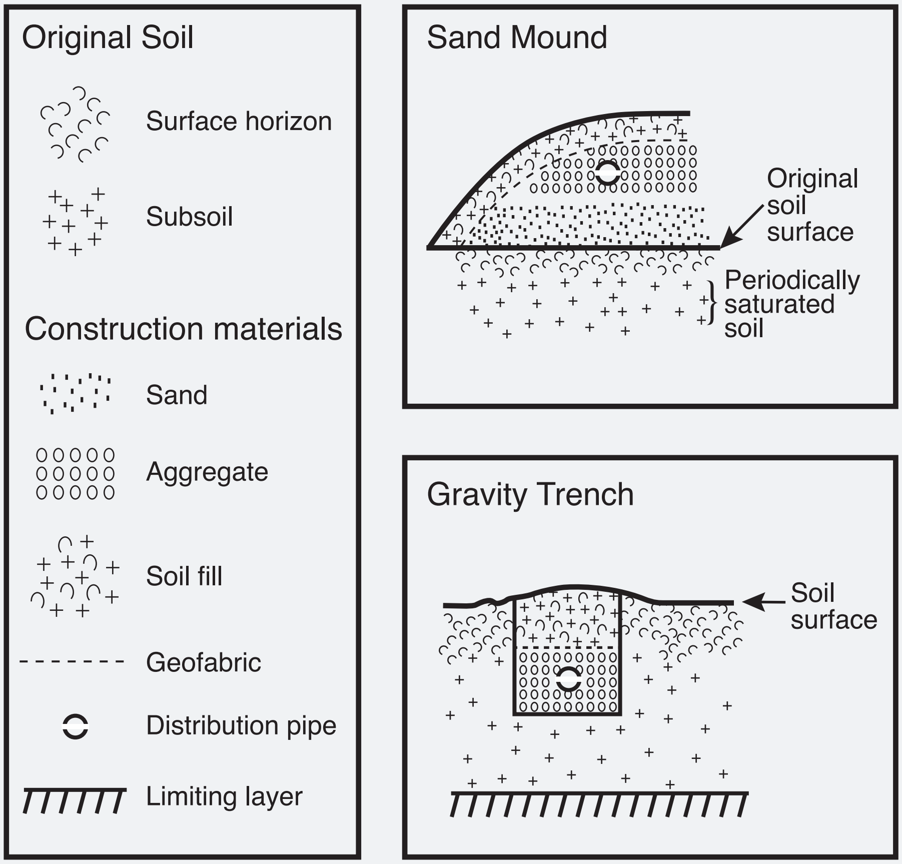


Figure 4.12. *Cross-sections through one line of a soil absorption field in an elevated sand mound system and a gravity trench system. A soil absorption field usually has several lines.*

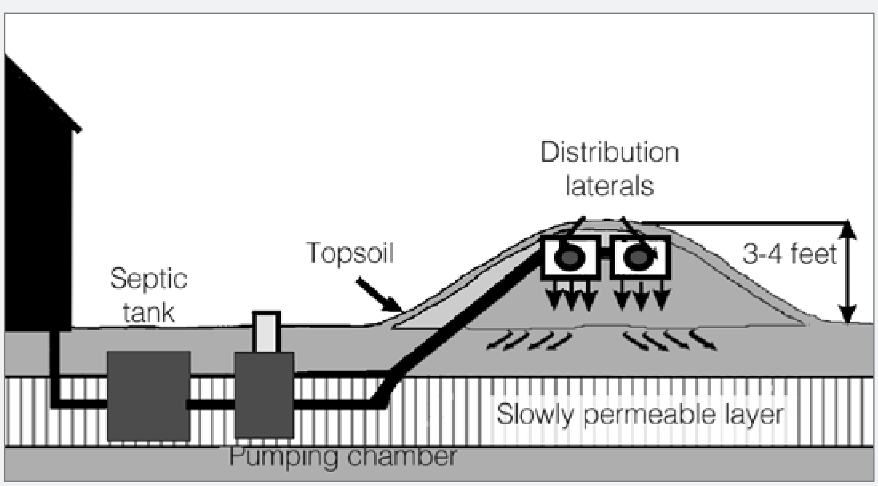


Figure 4.13. *A cross-section showing the components of an elevated sand mound system.*

DRIP DISTRIBUTION SYSTEM

In this system, effluent is injected into surface soil horizons. The system uses small-diameter tubing with evenly spaced emitters placed in the tubing (Figure 4.14). The small-diameter tubing is knifed or trenched into the ground to a depth of 6 to 12 inches, using a trencher or vibratory plow (Figure 4.15). There is no aggregate placed around the drip tubing. When the system is pressurized using a pump in the dosing tank, effluent drips from the emitters into the soil in the biologically active zone of the soil. In this way, effluent provides water and nutrients to lawns, natural areas, or crops. The topsoil and plant root system provides an excellent environment for treating effluent.

Compared with the gravity flow trench, in the drip system:

- The distribution lines are much smaller in diameter and much longer
- The interface area between the trench or slot and the soil is much greater
- Nutrients are added in the rooting zone of the original soil
- Pumps are required; they are not needed in gravity flow trenches
- In Indiana, secondary treatment is required for all subsurface drip irrigation systems
- Freezing of the soils in the absorption area may be a problem if the system is not in continuous use throughout the winter

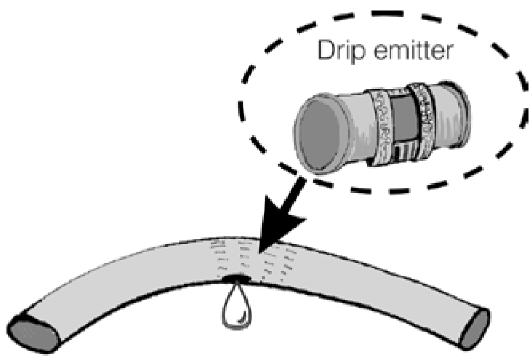


Figure 4.14. *Detail of one drip distribution emitter in a plastic line of a drip distribution system.*

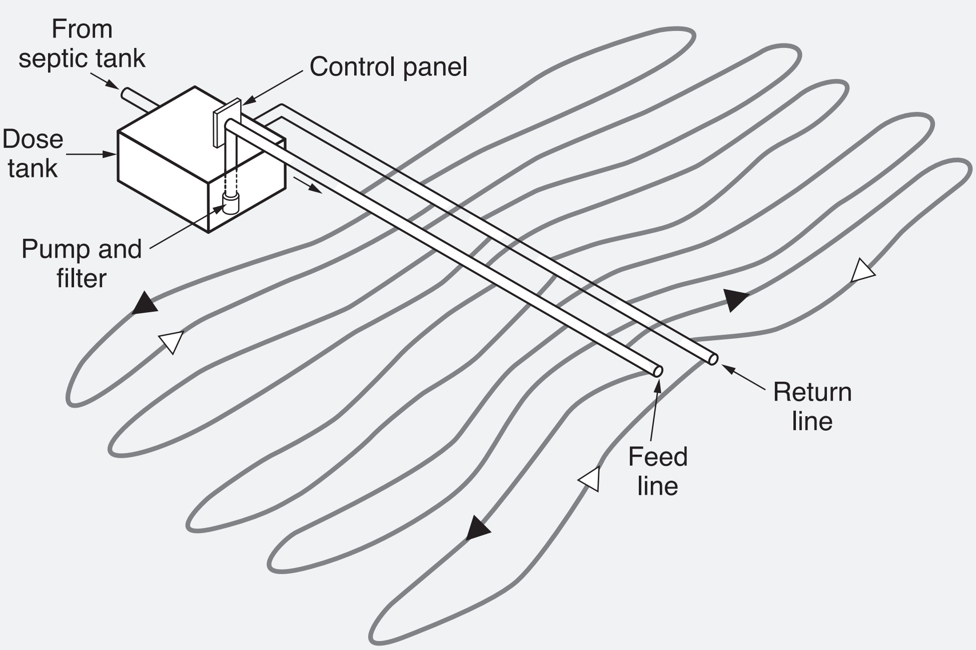


Figure 4.15. *Design of lines in a typical drip distribution system.*

LOCATIONS OF SEPTIC TANKS AND WELLS AND SEPARATION DISTANCES

It is critical that drinking water wells have sealed casings. Also, on-site sewage systems (both yours and your neighbor's) must be located *downhill* from wells. This will help prevent contaminants from seeping into and mixing with drinking water (Figure 4.16).

Furthermore, soil absorption fields must be located specified *distances* away from drinking water wells, streams, lakes, houses, water supply lines, and property lines. These distances are referred to as *minimum horizontal separation* (Figure 4.17).

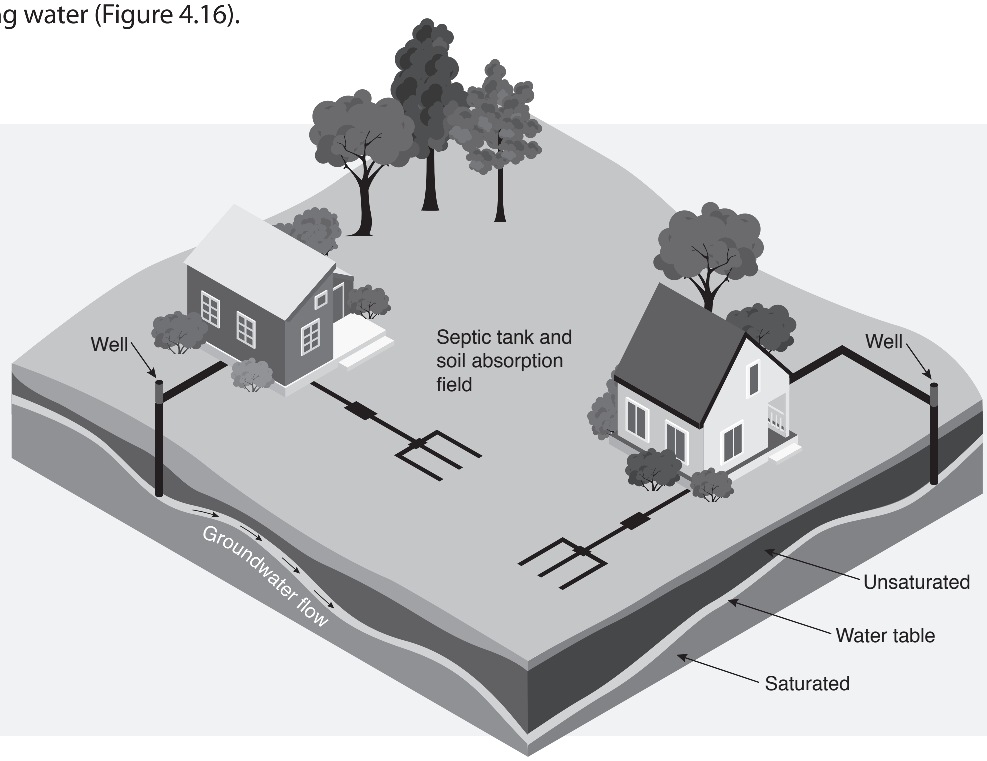


Figure 4.16. *This illustration shows the correct locations of water wells and soil absorption fields.*

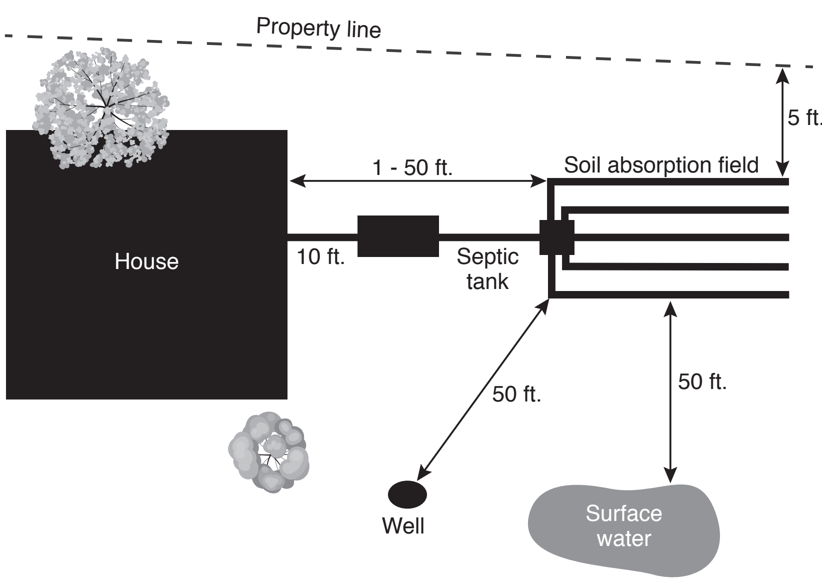


Figure 4.17. *This illustration shows the minimum horizontal separation distances in Indiana. The distance between the house and the soil absorption field is less if the field is downslope from the house and vice versa.*

Secondary Treatment

Effluent from the septic tank may sometimes appear clean, but it is highly contaminated. Secondary treatment can remove many of these contaminants. We will now describe two kinds of secondary treatment (sand or media filters and aerobic treatment units), but many other kinds are available.

Secondary treatment systems require more maintenance than conventional systems because they have pumps, valves, and other mechanical equipment that must be checked and serviced on a regular basis. Secondary treatment systems must be serviced by professionals who have been trained and certified by the manufacturer. In Indiana, the effluent from secondary treatment must be discharged to a soil absorption field for further treatment by the soil rather than discharged onto the soil surface or into surface water.

Some homeowners use secondary treatment in wooded settings so they can use a subsurface drip distribution system instead of clearing an area large enough for a conventional trench soil absorption field. Secondary treatment systems can also be used to replace soil absorption fields, especially where there is insufficient room for a full-size system. Check with your local health department before planning one of these systems to make sure they are allowed in your area.

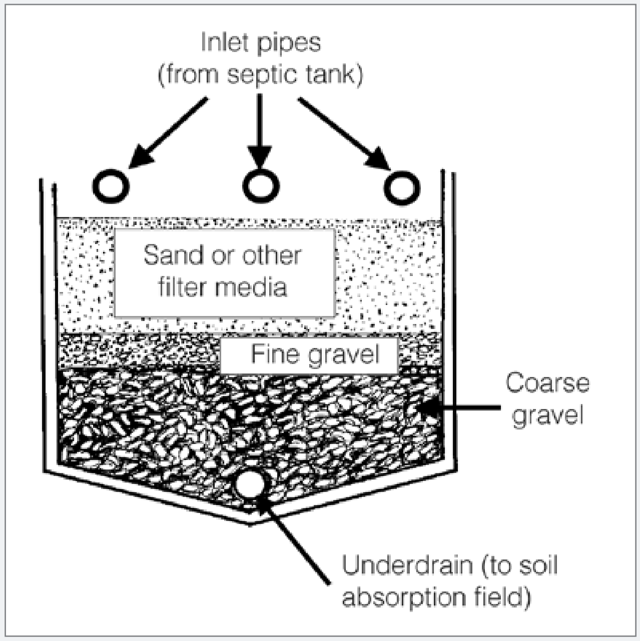


Figure 4.18. *A cross-section through an intermittent flow sand filter.*

SAND OR MEDIA FILTERS

A sand filter is a bed of sand or similar aggregate media through which septic tank effluent passes in the presence of air. A media filter is similar to a sand filter except that it typically uses a geotextile fabric on which the bacteria attach, grow, and treat effluent. A typical sand filter is shown in Figure 4.18. The filter has an impermeable shell, usually made from concrete. It can be on top of the soil surface, partially buried, or completely buried. It must be properly vented to allow the system to maintain an aerobic environment. At the bottom is an underdrain system made from perforated plastic pipe placed in an aggregate bed (usually gravel). Over the gravel is 2 to 3 feet of sand or a similar filter medium. Near the top of the sand are several distribution lines also made from perforated plastic pipe and placed in gravel. Effluent is pumped from the septic tank in periodic doses. Between the doses of effluent, the bed drains completely and the pores are filled with air, so that the bed is always aerobic (oxygen present). The sewage effluent from the filter is then discharged to the soil absorption field.

Sand filters accomplish much of their treatment through biological processes. They are home to a variety of organisms, many of which contribute to treatment by consuming the organic matter in sewage. Bacteria are the most abundant organisms in the filters, and they do most of the work. After the filter has had a chance to mature — usually after approximately two weeks of use — a miniature ecological system develops as the organisms multiply. A small amount of odor is usually produced in a properly functioning sand filter.

There are two main variations in design and function of sand filters: single-pass and recirculating. In the single-pass (or intermittent) sand filter, effluent passes through the system one time, and most of the N in the effluent goes to the soil absorption field (Figure 4.18). Single-pass filters remove 80 to 90 percent of the suspended solids and biological oxygen demand (BOD, a measure of the amount of organic matter in the effluent), but only about 50 percent of the N in the effluent.

In a recirculating sand filter, most of the effluent that has passed through the sand filter is pumped back to a recirculating tank, and only 15 to 25 percent of it is pumped to the soil absorption field. Because the effluent passes through the sand filter several times it is cleaner than that from a single-pass system, and less odor is produced. Recirculating systems are as effective in removing organic matter (BOD) and suspended solids (TSS) as single-pass systems, but the real treatment benefit is that they remove more N. A recirculating sand filter requires about a quarter the size of a single-pass unit.

Sand filters require periodic maintenance. The pumps must be checked and maintained, and an alarm system is recommended to let the owner know if a pump has failed and water is backing up in the system.

AEROBIC TREATMENT UNITS

Aerobic treatment units are tanks in which air is mixed with septic tank effluent by injecting, mixing, or agitating it. Bacteria that thrive in oxygen-rich environments break down most of the organics in effluent.

Aerobic units come in many sizes and shapes — rectangular, conical, etc. They may be either suspended growth units or attached growth units.

In suspended growth units, forced air mixes with sewage in the aeration chamber, and the oxygen supports the growth of aerobic bacteria that digest the solids in sewage. In fully suspended units, the bacteria and solids are suspended in the liquid, unattached to any surface. However, some aerobic treatment units now employ a surface on which the bacteria can attach and grow. Figure 4.19 shows a typical unit.

Continuous flow designs allow the sewage to flow through the unit at the same rate that it leaves the home. Batch process designs use pumps or siphons to control the amount of sewage in the aeration tank and to discharge the treated sewage in controlled amounts after a certain period of time. Electric pumps supply air, so the systems have some energy costs. Lower temperatures tend to slow down most biological processes, and higher temperatures tend to speed them up, so cold weather can have adverse effects on the performance of aerobic units. Aerobic treatment units can release partially treated effluent if they malfunction and must be provided with alarms to alert homeowners of malfunctions.

Because the effluent from a properly maintained aerobic unit is much cleaner than from septic tanks, their use can extend the life of a soil absorption system, not only due to decreased BOD and TSS, but also due to increased dissolved oxygen levels.

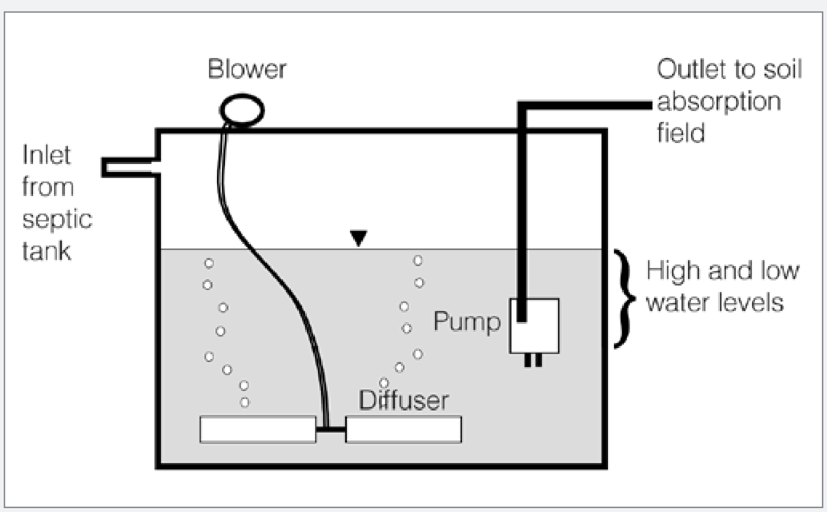


Figure 4.19. *A cross-section of an aerobic treatment unit.*

Effectiveness of Sewage Treatment and Consequences of System Failure

This section provides data that demonstrate how well on-site systems treat sewage and explains how some systems fail.

EFFECTIVENESS OF SEWAGE TREATMENTS

Table 4.1 shows the effectiveness of a septic tank and a secondary treatment system in treating sewage. The data in the sources has been generalized to create this table. The table shows the composition of sewage, effluent from a septic tank, and effluent from a secondary treatment system.

In the table, **total solids** describes all the solid material (what is left when all the water is evaporated).

Suspended solids describes the material that does not settle out of a suspension solution, but can be filtered out.

BOD5 (biological oxygen demand) measures the amount of dissolved oxygen that organisms are likely to need to degrade wastes in sewage in five days. It reflects the organic matter content.

Notice the large decrease in solids, from 850 mg/l down to 90 mg/l. as the material passes through the septic tank. This shows that sewage is largely liquefied in the septic tank, but the resulting effluent is still high in organic matter (BOD5). The content of organic matter is decreased substantially as the liquid passes through secondary treatment — BOD5 decreases from 130 down to 8 mg/l. Biomats form when the effluent is rich in organic matter, so the reduced organic matter content retards biomat formation. The N content of sewage is reduced very little in a septic tank. As explained above, some kinds of secondary treatment reduce the N content of effluent.

On-site Sewage System Failure

The Indiana State Department of Health recognizes three symptoms of on-site sewage system failure:

1. Sewage backs up into the house
2. Untreated sewage comes to the surface of the ground
3. Untreated sewage flows to surface water or groundwater

The health hazard associated with sewage in the home is obvious to the occupants, but the second two failures may not be as clear. If untreated sewage comes to the surface it can pose a risk to any person or animal who walks or plays in the area. Many disease-causing viruses, parasites, and bacteria are present in sewage. They originate from people and animals who are infected with or are carriers of a disease. Some illnesses from sewage-related sources are relatively common. Gastroenteritis can result from a variety of pathogens in sewage, and cases of illnesses caused by the parasitic protozoa *Giardia lambia* and *Cryptosporidium* are not unusual in the United States. Other important sewage-related diseases include hepatitis A, typhoid, polio, cholera, and dysentery. Outbreaks of these diseases can occur as a result of drinking water polluted by sewage. People, animals, and insects that come in contact with sewage can spread some of these illnesses.

Sewage contains large amounts of N and P. Organisms responsible for treatment of sewage in most on-site sewage systems require only small amounts of these nutrients, so there is a large excess of them in the water that remains even after treatment. If water bodies become very rich in these nutrients, algae grow vigorously and the water becomes depleted of oxygen. This condition is called eutrophication (see Glossary, page 134).

Table 4.1. Representative values for the composition of sewage, effluent from septic tank, and effluent from secondary treatment units.

MATERIAL	SEWAGE MG/LITER	SEPTIC TANK EFFLUENT	SECONDARY TREATMENT EFFLUENT
Total solids	850	90	5
Suspended solids	250	90	5
BOD5	250	130	8
Total N	70	50	35

Sources: *Design Manual: Onsite Wastewater Treatment and Disposal Systems* by the U.S. Environmental Protection Agency (1980); and *University Curriculum Development for Decentralized Wastewater Management: Wastewater Characterization* by Mark Gross (2004).

SUMMARY: STEPS TO SUCCESSFUL ON-SITE SYSTEMS

In summary, on-site sewage systems should effectively treat sewage for many years if they are:

- Developed from accurate soil information for the site
- Designed according to specific soil conditions present on the site
- Installed according to the approved plansInstalled when soil is not too wet
- Maintained by the owner

Any weak link in this chain will result in premature failure of the on-site sewage system.

On-Site Sewage Disposal — Practices

This section explains the relationship between soils and soil absorptions fields. It also explains how to care for on-site systems. Some soils are unsuitable for soil absorption fields. To save time and effort, let's see if the site is suitable for any kind of system.

▸ JUDGING RULE
29. Is the Soil Suitable for an Absorption Field?

Mark "No" for **Is the soil suitable for an absorption field?** (29 on home site scorecard) if the soil has *one or more* of these properties:

- It has a limiting layer of bedrock, fragipan, sand and gravel, or dense till closer than 20 inches to the surface
- It has a slope greater than 25 percent
- The landform is an upland depression or an outwash depression
- If you mark "No", mark all onsite practices (30-38) "No" or "N/A"

Mark "Yes" if the soil has none of the properties, and continue to judging rule 30

If you mark "No" for this item, a house may be built on this site only if it is served by a centralized sewer system. If the soil is suitable for a soil absorption field, we will examine the details of installing and maintaining a system. We will start with the septic tank because it is the first component of the system.

Septic Tank Practices

SEPTIC TANK CARE — OUTLET FILTER

A septic tank has an outlet filter that removes solid material that does not break down (toothpicks, hair, foil, etc.) from the effluent. The filter must be cleaned periodically, otherwise, the solid material will get into the soil absorption field and slow its ability to absorb effluent.

The more people living in the house, the more frequently the filter must be cleaned. The actual time intervals between cleanings may vary from these rules based on the occupants' lifestyle choices.

▸ JUDGING RULE
30. Septic Tank Outlet Filter Cleaning Interval

For **Septic tank outlet filter cleaning interval** (30 on home site scorecard), select *one* of these options:

- 1-3 people in the home — clean septic tank outlet filter once a year
- 4 or more people in home — clean septic tank outlet filter every six months

SEPTIC TANK CARE — TANK PUMPING

Homeowners must have scum and sludge removed from the septic tank periodically to keep the system from failing. However, you can't just remove scum and sludge, so the entire contents of the tank are removed at cleaning time.

The time between tank cleanings:

- Increases with larger septic tanks — larger tanks store more sludge and scum
- Decreases if the house has a garbage disposer — much ground up garbage from the disposer does not digest quickly and settles out as sludge
- Decreases with more residents — each resident contributes to the accumulation of sludge and scum

Judging rule 31 provides the equation for this relationship.

▶ **JUDGING RULE**
31. Septic Tank Pumping Interval

Calculate the **Septic tank pumping interval** (31 on home site scorecard) using this equation:

$$PI = \frac{(D \times G) / 1{,}000}{R}$$

Where:

PI = Pumping Interval (in years)

D = 7 if garbage disposal is checked "Yes" on site card

D = 10 if garbage disposal is checked "No"

G = Septic tank capacity (in gallons)

R = Number of residents in the house

Select the closest answer on the score card

Round your answer to the nearest whole number, and round 0.50 down to be conservative — round 3.50 years down to 3. If your calculation is 5 or more years, choose 5 years on the scorecard.

Here are some example calculations using the equation:

$$PI = \frac{(D \times G) / 1{,}000}{R}$$

Example 1. Five people live in the house, which has a 1,000-gallon septic tank and a garbage disposer. Therefore, D = 7, G = 1,000, and R = 5.

$$PI = \frac{(7 \times 1{,}000) / 1{,}000}{5} = \frac{7}{5} = 1.4$$

Round to 1 year, "A" on the score card.

Example 2. Three people live in the house, which has a 1,500-gallon septic tank and no garbage disposer. Therefore, D = 10, G = 1,500, and R = 3.

$$PI = \frac{(10 \times 1{,}500) / 1{,}000}{3} = \frac{15}{3} = 5$$

5 years is "D" on the scorecard.

Soil Absorption Field Practices

This section explains how the principles discussed above relate to soil judging practices. A soil absorption field is an area of soil that further processes effluent from a septic tank. In the soil, aerobic organisms (those that require oxygen) further treat the effluent. In addition to processing effluent biologically, the soil adsorbs some products (such as phosphates) chemically. The absorption field must have at least 24 inches of aerated soil to effectively treat effluent.

The list below compares soil properties that are ideal for soil absorption fields with those properties that make the soil unsuitable for a field:

Flooding and ponding. Soils suitable for soil absorption fields are not flooded or ponded with water. Soils prone to flooding and ponding are unsuitable.

Soil permeability. Soils suitable for soil absorption fields have soil layers that have moderate permeability. Soil layers with very slow permeability are unsuitable, because they cannot absorb effluent as quickly as it is produced. Unsuitable layers include bedrock, dense till, and fragipan limiting layers. Also, if the permeability is too high, the effluent will flow through the soil very fast and not remain in the soil long enough for aerobic organisms to treat it. Unsuitable layers include coarse sand and gravel.

Water table. In ideal soils, the water table is deep. If the seasonally high water table is shallow there is not enough aerated soil to treat the effluent. Subsurface drainage or alternative designs can lower the water table and improve the chances for successful systems.

Slope. In soils with gradual slopes, effluent moves downward and is processed. Several kinds of absorption fields can be used on these soils. In soils with steep slopes, effluent might seep to the surface before it is processed. Soils with slopes of more than 25 percent are not suitable for soil absorption fields. Also, soils in depressions are not suitable because surface water moves into the depression and tends to keep the water table high.

Next, we describe several kinds of absorption fields. Then we describe secondary treatment and additional drainage, which help soil absorption fields function better.

SUBSURFACE TRENCH, GRAVITY FLOW SYSTEMS

Subsurface trench, gravity flow systems are commonly used for soil absorption fields. In these systems, effluent flows by gravity from the septic tank, through a distribution box, and then to distribution lines (laterals) that are in trenches that are about 10 to 36 inches deep and 18 to 36 inches wide. The length of the laterals depends on how much effluent a soil can absorb in a day (called the soil loading rate) and the amount of effluent from the septic tank. In any case, a lateral must be less than 100 feet long.

Each lateral consists of a perforated plastic pipe (usually four inches in diameter) that is surrounded by aggregate (usually gravel) in the trench. A geotextile fabric (wide enough to cover the trench) is laid on top of the aggregate to keep soil material out. The fabric is covered with soil material.

In subsurface trench gravity flow systems, effluent flows through the distribution box to laterals. When the effluent level in the septic tank rises above the outlet pipe, the effluent flows out of the tank by gravity. From the laterals, the effluent moves through the aggregate and the soil where aerobic microorganisms break down the organic components. The soil itself also filters out and adsorbs some effluent components.

▸ JUDGING RULE
32. Subsurface Trench, Gravity Flow System

Mark "Yes" for **Subsurface trench, gravity flow system** (32 on home site scorecard) if the soil has *all* of these properties:

- No bedrock, fragipan, coarse sand and gravel, or dense till limiting layer within 40 inches of the soil surface
- Soil is well-drained
- Subsoil texture is moderately sandy, or medium
- Slope is 12 percent or less

SUBSURFACE TRENCH, FLOOD DOSE SYSTEMS

Subsurface trench, flood dose systems are similar to gravity flow systems, except that flood dose systems *pump* effluent. Effluent flows from the septic tank into a dose tank. Periodically, the system pumps effluent from the dose tank, through the distribution box, and then to the laterals.

These systems can be used where the absorption field is higher than the septic tank, or more commonly, where the soil absorption field has long laterals because the soil has a low loading rate. Compared to gravity flow systems, flood dose systems have an advantage: A large dose of effluent will fill all trenches more evenly and more of the trench will be used for absorption.

▸ JUDGING RULE
33. Subsurface Trench, Flood Dose System

Mark "Yes" for Subsurface trench, flood dose system (33 on home site scorecard) if the soil has *all* of these properties:

- No bedrock, fragipan, sand and gravel, or dense till limiting layer within 40 inches of the soil surface
- Soil is well-drained
- Subsoil texture is moderately clayey or clayey
- Slope is 12 percent or less

SUBSURFACE TRENCH, PRESSURE DISTRIBUTION SYSTEMS

Subsurface trench, pressure distribution systems pump effluent under pressure all the way to the distribution laterals. This distributes effluent more uniformly to each lateral. These systems are particularly well-suited to areas where the subsoil is fine and medium sand (such as in the eolian parent material of sand dunes). Elevated sand mounds and drip distribution systems also use pressure dosing.

> **JUDGING RULE**
> **34. Subsurface Trench, Pressure Distribution System**
>
> Mark "Yes" for **Subsurface trench, pressure distribution** system (34 on home site scorecard) if the soil has *all* of these properties:
>
> - No bedrock, fragipan, sand and gravel, or dense till limiting layer within 40 inches of the soil surface
> - Soil is well-drained
> - Subsoil texture is sandy
> - Slope is 12 percent or less

ELEVATED SAND MOUND SYSTEMS

Elevated sand mound systems are used when there is a limiting condition near the soil surface — such as a limiting layer or a high water table. In elevated sand mound systems, installers place a layer of sand at least 12 inches thick on the soil surface, then place distribution pipes (laterals) in an aggregate (gravel) bed about 12 inches thick on top of the sand. Installers then cover the aggregate bed tubes with geotextile and soil fill.

The effluent flows into a dose tank and then is pumped into the mound under pressure — usually four times a day. Do not use mound systems on soils that have a slope of more than 6 percent, because effluent might seep out and pond around the mound's base.

> **JUDGING RULE**
> **35. Elevated Sand Mound System**
>
> Mark "Yes" for **Elevated sand mound system** (35 on home site scorecard) if the soil has *all* these properties:
>
> - No bedrock, fragipan, coarse sand and gravel, or dense till limiting layer above 20 inches
> - Soil is well drained or moderately well drained
> - Slope is 6 percent or less

DRIP DISTRIBUTION SYSTEMS

Drip distribution systems treat sewage in a septic tank just like other systems. From the tank, effluent flows to a dose tank and then is pumped to a secondary treatment device (described later) that further cleans the effluent. This cleaner effluent is distributed under pressure to drip tubing lines. These small-diameter tubes have outlet ports spaced along the tubes. The ports open when the effluent in the tubes is under pressure and close when the pressure subsides. These tubes are placed in slots cut into surface soil horizons.

The system injects effluent into the biologically active zone of the soil. In this way, the effluent provides water and nutrients to lawns, natural areas, or crops. The topsoil and plant root system provide an excellent environment for treating effluent. Professionals can install drip distribution systems on much steeper slopes than other on-site sewage systems. If secondary treatment does not clean the effluent, the outlets ports would soon become clogged.

SOIL ABSORPTION FIELD SUPPLEMENTS

Some supplemental practices help absorption fields function better. They are explained below. Two of the supplements, perimeter drains and interceptor drains, lower the seasonally high water table so the absorption field has sufficient aerated soil to process effluent properly.

Perimeter drains are installed in soils with slopes of 2 percent or less. They completely *surround* soil absorption fields. They are installed at least 10 feet from the outside edge of a field and are placed deep enough so that the seasonally high water table is more than 2 feet below the bottom of the absorption field trench. But to work properly these drains must have an outlet for the water to drain by gravity — and this requirement is often difficult to meet. For soil judging, they are used with sand mounds.

Interceptor drains are installed in soils with slopes of 3 percent or more and only on the *upslope* side of an absorption field. These drains keep groundwater from seeping into the field. Although it is not included in soil judging rules, *interceptor drains should be used with any absorption field in which water could seep through the soil profile into the absorption field*. They are similar to diversion drains (see judging rule 22 and Install Diversion Structures and Drains, page 102), except that interceptor drains are installed closer to the fields.

Secondary treatment of effluent. Effluent that flows out of a septic tank may appear clean, but it contains significant amounts of organic matter and other contaminants. Secondary treatment removes much of this organic matter after it leaves the septic tank and before it moves to the soil absorption field. Secondary treatment also adds oxygen to the effluent to encourage aerobic decomposition of organic matter. Some secondary treatment systems inject air into effluent. Other systems allow effluent to absorb oxygen passively as it trickles down through sand or other media such as geotextile fabric. The resulting effluent is much cleaner, which extends the life of the soil absorption field.

Soil judging rules are based on systems that *do not use* secondary treatment, except for drip distribution, which requires secondary treatment.

ELEVATED SAND MOUND

The rules below combine ordinary absorption fields with supplements.

▸ JUDGING RULE
36. Elevated Sand Mound System and Perimeter Drainage

Mark "Yes" for **Elevated sand mound system and perimeter drainage** (36 on home site scorecard) if the soil has *all* these properties:

- No bedrock, fragipan, coarse sand and gravel, or dense till limiting layer above 20 inches
- Soil is somewhat poorly drained or poorly drained
- Slope is 6 percent or less

Most poorly and somewhat poorly drained sites are on slopes of 2 percent and less. If the slope is 3 percent or greater, an interceptor drain will be installed instead of a perimeter drain.

DRIP DISTRIBUTION

Secondary treatment is *required* for drip distribution systems. It will extend the life of *any* absorption system, however, as reflected in these rules.

▸ JUDGING RULE
37. Drip Distribution System and Secondary Treatment

Mark "Yes" for **Drip distribution system and secondary treatment** (37 on home site scorecard) if the soil has *all* these properties:

- No bedrock limiting layer within 20 inches
- Soil is well-drained
- Slope is 25 percent or less

SECONDARY TREATMENT

As seen in the rule above, secondary treatment is required for drip distribution. It can also be used with other systems.

JUDGING RULE

38. Secondary Treatment

Mark "Yes" for Secondary treatment (number 38 on home site scorecard) if you marked "Yes" for at least one soil absorption field practice (numbers 32-37).

Actual Practice and Innovative Systems

Soil judgers may mark several suitable systems "Yes." In practice, usually the least expensive one is chosen.

Some of the depth and slope limits in soil judging rules are not the same as state laws. For example, state law allows trench systems on slopes of 15 percent or less, but soil judging limits are at 12 percent and 18 percent, so we set the limit at 12 percent.

The discrepancy also applies to some depth limits. Soil judging rules demonstrate general principles, but if you plan to install an on-site sewage system, always check with county health officials first to know community requirements.

Also note that there are many innovative systems we don't mention in this guide that might be applicable and practical for some sites, such as sand-lined large pipes and aerobic treatment units that digest effluent more completely by pumping air through it before sending the effluent to the absorption field. Always check with a certified on-site system installer and local public health officials for details about these and other systems.

Soil Water Cycle

In summary, an ideal on-site sewage system cycles water in this way:

1. Homeowners pump water into the house from an aquifer (underground layer saturated with water).
2. They use the water for drinking, bathing, flushing toilets, washing dishes and clothes, etc. This water use adds impurities that transform the water into sewage.
3. The sewage enters the septic tank where anaerobic microbes partially treat it to produce mainly liquid effluent. Resistant solids settle on the bottom of the tank, and scum floats on top of the effluent. The scum and solids must be pumped from the tank periodically.
4. The partially treated effluent flows from the tank through the outlet filter and into the soil absorption field.
5. In the absorption field, aerobic microbes break down organic contaminants and harmful organisms in the effluent, and soils adsorb inorganic contaminants.
6. The treated water moves into the aquifer.

Note that this list starts and ends with water in an aquifer and thus describes a cycle. This cycle illustrates how important soil is in maintaining a safe supply of household water.

Practical Tips for Homeowners

Many soil judging students live in homes with on-site sewage disposal systems. This section provides practical advice for them and other homeowners.

Causes and Prevention of On-site System Failure

If a soil absorption field fails, the entire on-site sewage disposal system shuts down. If the field fails, a location for a replacement system must be found first. In some cases, no new location is available, and then the options are to connect the home to a central sewer system or abandon the home. None of these options are good. If a new location for an absorption field is available, a new field can be installed at great expense. This is also not good for the homeowner. Therefore, it is very important to make the soil absorption field last as long as possible.

More information about on-site system maintenance is available in two Purdue Extension publications: *Home & Environment: Operating and Maintaining an Onsite Sewage System* (ID-142-W) and *Home & Environment: Cleaning an Onsite Sewage System* (HENV-105-W). Both publications are available from the Education Store, edustore.purdue.edu.

Table 4.2 summarizes the main causes of failure of on-site sewage disposal systems and ways to help prevent failure. Following the prevention practices will save a family much grief and expense. This will require the help of several professionals: certified soil scientists to find suitable locations for an absorption field, experienced designers, certified installers, and qualified septic care professionals.

Engage Qualified Professionals

In Indiana, property owners must obtain a permit from the county health department for on-site sewage systems for single family residences. For commercial on-site sewage systems and for systems using experimental or innovative technology, the owner must obtain a permit from the Indiana State Department of Health unless the project has been delegated back to the county health department. Make sure to check with these agencies before planning or installing any on-site sewage system. Soil evaluations for all of these on-site sewage systems must be conducted by certified soil scientists. Also, many counties require certification or licensure of on-site sewage system designers and/or installers. Always use qualified contractors who have had experience installing systems locally, and consider using a maintenance firm with good recommendations to inspect required filters and to pump the septic tank as needed.

Table 4.2. *Summary of why some on-site sewage disposal systems fail and how practices that are considered in soil judging help to prevent failure.*

CAUSES OF FAILURE	WAYS TO PREVENT FAILURE
Saturated soil conditions in the absorption field prevent movement of effluent into the field (common in older systems).	Install absorption fields only in suitable soils (soil judging items 29, 32-37)
Slow soil permeability prevents absorption of effluent at the rate it is produced (common in older systems).	Install absorption fields only in suitable soils (soil judging items 29, 32-37). Make sure that the system is properly designed and is large enough. The size depends mainly on the number of people using the system and the permeability of the soil.
Solids floating in the septic tank effluent clog lateral lines and the soil absorbing surface	Make sure system has a filter and clean it regularly (soil judging item 30)
Sludge moving out of the septic tank with the effluent clogs lateral lines and the soil absorbing surface.	Make sure system has a filter and clean it regularly (soil judging item 30). Pump septic tank when needed (soil judging item 31).
Biomat formation retards movement of effluent into the soil.	Install treatment (soil judging item 38).

CHAPTER 5 – Planning and Arranging Soil Contests

Usually, local arrangements are made by a Purdue Extension educator and a local soil conservationist. Specific site selection and official evaluation is done by a soil scientist with the USDA-Natural Resources Conservation Service (USDA-NRCS), a Purdue Extension specialist, and a soil scientist certified by the Indiana Registry of Soil Science.

Area contests rotate among counties within a Purdue Extension area, and a Purdue Extension educator is primarily responsible for local arrangements because the contest is a 4-H activity.

Early Planning

Several tasks that must be done well before the contest. We discuss these tasks below.

Find a Suitable Site

Finding a suitable site is usually done in cooperation with a soil conservationist in your county who knows conservation-minded landowners who support the effort to educate young people on better soil management. The site should have a variety of soils and should be accessible to a backhoe. Public land, pasture land, and Conservation Reserve Program (CRP) land work well, but other areas are satisfactory. If possible, the contest area should also have a place to grade scorecards and give awards. It is sometimes difficult to find a location that serves all purposes.

Arrange for a Backhoe to Dig At Least Four Pits for the Contest

The Soil and Water Conservation District may have suggestions of land improvement contractors or on-site wastewater installers with backhoes who would be willing to help. Sometimes it is learned after the backhoe leaves that the soil in a certain pit presents problems for soil evaluation. In these cases, an extra pit is desirable. Most conservationists know contractors, farmers, or state or county highway people who have a backhoe; often, the work is donated.

Call 811 Before You Dig

Call before you dig! Contact Indiana Underground Plant Protection Service by calling 811 at least two full working days before digging the pits so you don't damage underground utilities (you can also learn more at Call811.com). It is the law! This is to prevent accidents and possible loss of life from digging into underground utilities.

Providing the locations of underground utilities is a free service. You will need to provide the following information:

- County
- Township
- Street address
- Type of work
- Name of caller
- Title
- Telephone number
- Best time to call
- Start date
- Start time
- Contractor
- Contractor address

Arrange for Items to Conduct the Contest

You will need eight slope stakes for the contest. The best stakes are 48-inch plastic temporary fence posts but steel fence posts or wooden 2x2's can be used (Figure 5.1). Two stakes are needed for each site. Eight yardsticks with holes drilled at 10, 20 and 30 inches, and some nails to attach the yardsticks to the face of the pit are also needed. You will also need four sign boards on which to mount site cards (see the site card on page 147) at each evaluation site. If it appears that the water table in a pit may be high or rain is anticipated, it will be helpful to know where planks, concrete blocks, old pallets (sawed in two), and straw could be obtained. Buckets, or ideally a trash pump, would be useful to remove water from the pit. Experience has shown that the best approach to handle soil pits full of water is to first pump the water out of the pit and place lots of straw on the wet trench bottom. The final step is to place the pallets on top of the straw. A few buckets or boxes should be available when the soil scientists are evaluating the site. For potentially confusing situations, they will place soil material in containers that participants may use for evaluation. Contestants must furnish their own water for estimating soil texture, slope-finders, and color charts. In most extension areas, there is a set of this equipment that is passed from educator to educator in the county rotation for hosting the area contest.

Figure 5.1. *A small plastic fence post serves as a slope stake.*

Arrange for Site Monitors, Group Supervisors, and Graders

Four site monitors are needed to control each of the evaluation sites. These individuals will ensure that there is no improper behavior on the part of the contestants and collect scorecards, if that is required. In most cases, an adult accompanies each group of contestants as they rotate among the four sites to enforce rules and address any appearance of unfair collusion during the rotation. These individuals are often Purdue Extension educators or vocational agriculture instructors.

Schedule people to grade scorecards, tabulate results, calculate scores, present awards, and do other tasks that may arise. Some of this work can be done by machines. On the scorecards, the numbers and letters that represent alternative answers are arranged to allow for electronic scanning and grading.

Activities Immediately Before and During a Contest

In this section, we describe activities that should be done a day or so before the contest or the day of the contest.

Site Selection, Preparation, and Official Evaluation

Usually, the official judges at an area contest will be a USDA-NRCS soil scientist, a Purdue Extension specialist and a soil scientist certified by the Indiana Registry of Soil Science. Within the area selected, the judges will select four evaluation sites, supervise the backhoe digging, prepare the pit face to be judged, set slope stakes, supply standard information and special notes on the site card, and do the official evaluation a day or so before the contest. In some cases, soil properties do not fit clearly into a soil evaluation class, or the practices selected according to the rules are not logical choices. In these cases, official judges should give the correct answers on the site card. Before the contest, judges will furnish copies of the official scorecards for use by the graders.

The soil pits should be no more than 48 inches deep to comply with U.S. Occupational Safety and Health Administration (OSHA) safety requirements. Soil pits should be at least 24 inches wide and 8 to 12 feet long, depending on the number of contestants anticipated (Figure 5.2). The pits should be oriented so the sun will shine on one long side. On that side, a section of the profile about 1 foot wide will be marked off. Contestants must not to dig in this area. They should look at the soil in the section that has been marked off, but not disturb it so that all contestants can observe the same features. Usually, part of the section is picked to show soil structure and part is cut to show interior colors. This section can be marked by flags at the surface and by two yard sticks on each side secured to the soil by large nails (Figure 5.3).

Figure 5.2. *This illustration shows a soil judging pit with approximate dimensions. An optional 2-foot by 2-foot shelf to expose fragipan characteristics is shown along one side of the pit.*

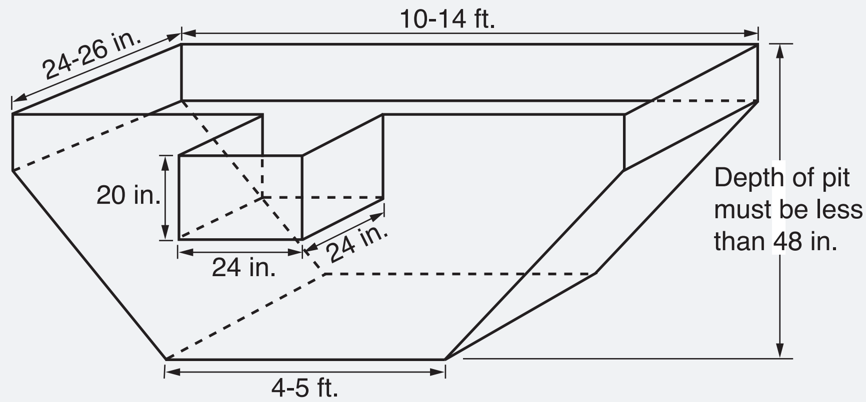


Figure 5.3. *Two yardsticks attached to the side wall of a soil pit mark the area where official grading was done. Constants do not disturb this area, so all of them can see the soil as the judges saw it.*

In contests that have or might have fragipan soils, part of each pit face should be shaved to expose vertical cracks and color contrasts that are not apparent on the natural prism faces. If possible, provide a horizontal cut to expose the polygonal pattern formed by the gray prism coatings. This surface should be flagged and the contestants not allowed to walk on or dig in it.

Two slope stakes should be set about 20 to 100 feet apart. Contestants will stand near one stake and sight to the same height on the other with a slope finder (page 148) to determine the slope. Contestants need to furnish their own small water bottles to aid in determining texture (Figure 5.4).

Figure 5.4. *Contestants furnish their own water bottles.*

Conducting the Contest

Contestants are divided into four groups. Each group moves to a site (pit), a signal is sounded, and they begin evaluation and mark their answer on the score card. After a predetermined time (around 12 to 15 minutes), they stop the process at the sound of another signal. Usually, a vehicle horn is used and it is important to designate a person for this purpose and no other. The groups are then allowed time to move on a rotation basis to the next site and start the evaluation process again when all are ready and the signal is sounded. Contestants may carry clipboards, water bottles, slope finders, and color charts. Two sites are judged for agriculture sites and two for home sites. Contests circle their answers on the scorecards and make sure that the names and number blanks in the lower right of the scorecards are filled in. At each site, a site monitor supervises the evaluation and makes special announcements as necessary.

Grading and Tabulating

Official scorecards are prepared by the official judges. For some contests, contestants hand in their scorecards, which are graded by volunteers. For other contests, grading is done by a machine. Contestants transfer their answers to a *bubble sheet*, a form used to grade multiple choice question in which the student makes a mark with a number two pencil between parallel dashed lines. Bubble sheets are fed into a machine (Figure 5.5), which reads the forms optically, compares contestant's answers with the official ones, and reports the number of correct answers. Contestants will be told how grading is to be done at each contest.

Figure 5.5. *Bubble sheets are fed into a machine for electronic grading.*

Critique

One of the most important phases of soil evaluation is the critique session. It is held after the contestants have completed evaluation of all four sites and while their scorecards are being graded. The judges give the official results and explain their decisions. They may also explain how the soil developed and how it relates to the surrounding soils.

After the critique session, some judges take their students back to the soil pits to review the soil properties with them. Coaches also review the practices students selected to learn if they remembered the rules (Figure 5.6). These reviews help reinforce what contestants have done correctly and to learn from their mistakes.

Figure 5.6 *A teacher reviews official answers with his students.*

Questions and Resources

In this section, we list the offices and people who can answer questions about technical and procedural aspects of contests.

Local and County Offices

Nearby resources and their area of expertise:

- High school agriculture science teachers can answer many questions about topics covered in soil judging competitions.
- County extension staff can answer many questions about agriculture and home landscaping.
- County soil and water conservation staff are knowledgeable about soil conservation and management practices. They are also familiar with rules about erosion control and draining wetlands.
- County health officers know about requirements and regulations dealing with single family on-site sewage disposal systems. Larger systems are handled by state offices.

State Offices and Individuals Dealing with Soil Evaluation and Judging

PUBLISHED MATERIAL

The Purdue Extension Education Store offers many publications of interest at **edustore.purdue.edu** or **765-494-6794**.

Here are some of the publications available from the Education Store:

- *Indiana Soil Evaluation Field Book* (AY-362-W). This is designed for students to use in the field. It is a condensed version of this publication and contains all rules and some explanation.
- *Indiana Soil Evaluation Scorecard: Site Card* (4-H-736-W, also on page 147).
- *Slope Finder* (4-H-408-W, also on page148).
- *Indiana Soil Evaluation Scorecard: Agriculture Site* (4-H-394-W, also on page 149).
- *Indiana Soil Evaluation Scorecard: Home Site* (4-H-255-W, also on page 150 in this book).

SOIL SAMPLES, COLOR CHARTS, ETC.

The Purdue Agronomy Club sells soil reference texture samples, Munsell soil color cards, and soil pH kits. Learn more at **ag.purdue.edu/agry/agryclub**.

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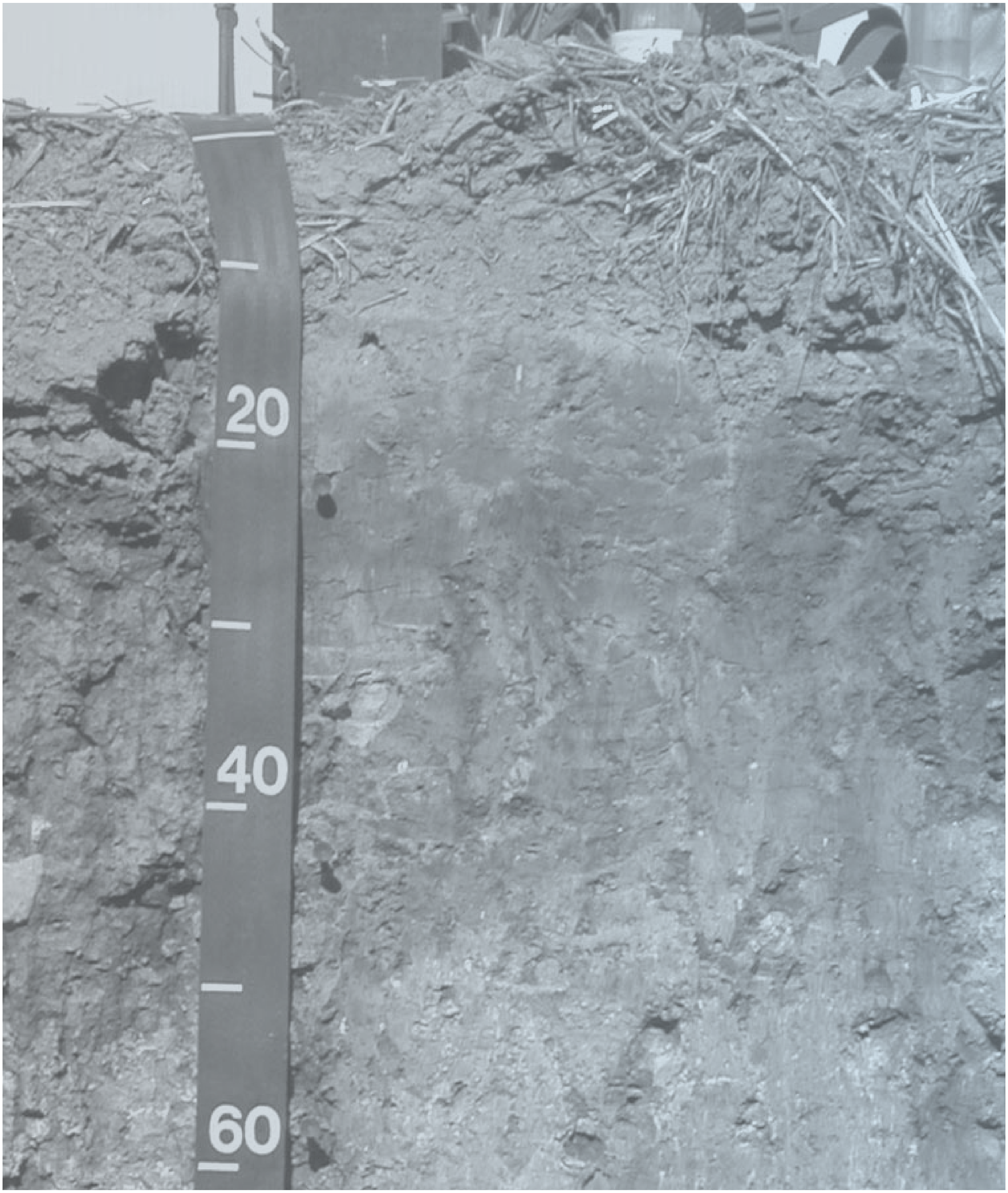

CHAPTER 6 – Glossary

A horizon. The surface mineral horizon in which organic matter has accumulated. It is generally darker than lower horizons. A and E horizons comprise the surface soil.

aerobic organism. Organisms that require oxygen to live and function.

aerobic treatment unit. A tank in which air is mixed with septic tank effluent by injecting, mixing, or agitating it.

aggregate material. Gravel or crushed rock material (about 0.5 to 2.5 inches in diameter) used to distribute effluent in a trench or mound of an on-site wastewater disposal system.

aggregate, soil. Many fine particles held in a single mass or cluster. Natural soil aggregates (such as granules, blocks, or prisms) are called peds. Clods are aggregates produced by tillage or traffic on the soil.

algae. Organisms that are single-celled, colonial, or multi-celled, and are usually aquatic and photosynthetic.

algal bloom. Abnormally rapid algae growth, often caused by high levels of nutrients and organic material.

allelopathy. The beneficial or harmful effects of one plant on another plant.

alluvium. Material such as sand, silt, or clay deposited relatively recently by streams.

anaerobic organisms. Organisms that live and function in the absence of oxygen.

aquifer. Geologic material that is saturated with water and is commonly used as a source of household water.

available water capacity (available moisture capacity). The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field moisture capacity and the amount at wilting point. It is expressed as inches of water per inch of soil.

B horizon. The mineral horizon below an A or E horizon, also called subsoil. The B horizon has distinctive characteristics identified by (1) an accumulation of clay, iron, aluminum, silica, and/or humus; (2) prismatic or blocky structure; (3) redder or browner colors than those in the A horizon; or (4) a combination of these.

baffle. A device in a septic tank that reduces mixing of the contents of the tank when new sewage enters it.

bedrock. Solid rock underlying loose deposits such as soil, till, loess, etc. Bedrock is recognized as a limiting layer.

bedrock. Solid rock that underlies the soil, sometimes many feet deep. It is sometimes exposed at the surface of the earth, especially in southern Indiana. It may qualify as a *limiting layer*.

biochemical oxygen demand (BOD). A measure of the amount of dissolved oxygen that organisms are likely to need to degrade wastes in sewage. It depends on the organic matter content of the sewage.

biomat. A black, slimy, jelly-like, slowly permeable layer of partially decomposed organic waste that contains microorganisms and their by-products that forms on the surface of soil that absorbs effluent.

bottomlands. A group of landforms at low elevations, near streams. See *flood plain*.

brittle. The term used to describe soil that ruptures suddenly or "pops" rather than deforms slowly when a small piece is pinched between thumb and forefinger.

brown mottle. A brownish area in a generally grayish area. The brownish area indicates an area of chemical oxidation.

C horizon. The mineral horizon (excluding bedrock) that is little affected by soil-forming processes. It is also called substratum. The material of a C horizon may be either like or unlike that from which the A, E, or B horizons formed.

calcareous soil. Soil that contains enough calcium carbonate (commonly with magnesium carbonate) to effervesce (fizz) visibly when treated with cold, dilute hydrochloric acid.

carbonate coat. A white or light-gray calcareous covering on ped surfaces. Typically, carbonate coats are found only in dense till and have a dusty or grainy appearance. Carbonate coats fizz very rapidly if hydrochloric acid is dripped on them.

carbonate mineral. A mineral composed largely of the carbonate ion (CO_3^{2-})

certified soil scientist. A soil scientist who has met certain standards that include education, experience, and examination.

chamber. A device that is used instead of aggregate (gravel) in an on-site sewage system's soil absorption field. Many chambers are made of plastic.

chisel tillage. Tillage with an implement having one or more soil-penetrating points that loosen the subsoil and bring clods to the surface.

chroma (color). The component of the Munsell color system that deals with the purity of color. The lower the chroma, the "muddier" the color appears to be.

clay skin (film). A thin coating of oriented clay on the surface of a soil aggregate or ped. Clay films are usually darker than the inside of peds and coat the peds like a coat of paint. They often have a somewhat shiny or waxy appearance. Synonyms are clay coat and clay skin.

clay. The term is used in different ways.

As a soil separate, the mineral soil particles that are less than 0.002 millimeter in diameter.

As a soil textural class, the area shown on a texture triangle.

As a clay mineral, the arrangement of its atoms, such as in kaolinite or smectite.

climate. The kind of weather that a region has over a period of years based on conditions of heat and cold, moisture and dryness, clearness and cloudiness, wind and calm. One of the five soil formation factors.

CLORPT. A mnemonic device to help remember the five soil formation factors: climate, organisms, relief, parent material, and time.

colluvium. Loose material transported by surface runoff or slow continuous downslope creep that collects at the base of a slope.

color group. Groups of Munsell colors. In soil evaluation, three groups are defined: gray, brown, and black

compaction, soil. The movement of soil particles closer together by external forces, such as falling rain, livestock traffic, or the weight of farm equipment. Compaction increases the bulk density and decreases the pore space between the particles of soil. With less pore space, the movement of water, air, and roots through the soil becomes more difficult and soil productivity decreases.

conservation buffer. A permanent strip of grasses, shrubs, and/or trees designed to intercept nutrients and pollutants, slow water runoff, trap sediment, enhance water infiltration, and provide wildlife habitat.

conservation tillage. Any tillage or planting system in which at least 30 percent of the soil surface is covered by plant residue after harvesting to reduce erosion. Examples of conservation tillage include practices such as strip-till, ridge-till, reduced or minimum till and no-till.

conservation. Use of natural resources in a way to assure their continuing availability for future generations; the wise and intelligent use or protection of natural resources.

contaminated/contamination. The addition of anything impure or unclean to something that was pure or clean.

contour tillage. Tillage of soil along the contour of a hill (at the same elevation) rather than up and down a hill. It is a common practice used to reduce soil erosion in hilly terrain.

cover crop. A crop grown between periods of regular crop production to prevent soil erosion and provide other environmental benefits.

crop rotation. The practice of growing different crops in succession on the same land to help maintain healthy, productive soils.

crop. Any plant product of cultivated agriculture, as distinguished from natural production or wild growth.

deep tillage. Tilling a soil below normal depth, ordinarily to shatter a plowpan. Also called ripping.

degradation, soil. The usually irreversible deterioration of the soil, resulting in reduction of soil productivity. Erosion and soil compaction are major causes of soil degradation in Indiana.

dense glacial till. Glacial till that was compressed or compacted due to the weight of glacial ice. It has a density greater than 1.75 g/cm3. See *glacial till*.

depletion (iron). A gray area (mottle) in a generally brownish background that is due to lack of iron oxides. It indicates saturated soil conditions and chemical reduction.

depression. Concave (shape of a bowl) area with a 2 percent or less slope in the midst of generally level land. A closed depression is bowl-shaped and has no outlet for water. An open depression is channel-shaped and water flows through it. See *swale*.

development, soil. The process of changing soil parent material to an A, E, or B horizon.

distribution box. A component of a septic system that receives effluent from the septic tank and releases it evenly to several lateral lines of the soil absorption field.

diversion structure. A ridge of soil built on top of the original soil surface to divert surface water away from a home site and soil absorption field.

dominant soil color. The most common or abundant color of the inside of a soil ped or aggregate.

drip distribution system. A kind of soil absorption field in which septic tank effluent that has undergone secondary treatment is pumped into small diameter pipes and released through emitters place about six inches deep in the soil.

dune. A mound, ridge, or hill of wind-blown sand.

E horizon. The mineral horizon below the A horizon that is light in color and low in clay content, compared with underlying horizons. Percolating water removes, clay, iron, and aluminum from E horizons.

***E. coli.* (*Escherechia coli*).** Bacteria commonly found in human and animal waste. Its presence is used as an indicator of poor water quality.

effluent. The middle (liquid) layer in a septic tank that flows to a soil absorption field. It usually contains small suspended solids as well as nutrients, pathogens, and contaminants. The layer above effluent is *scum*, and the layer below is *sludge*. The scum and sludge layers must be removed by periodic pumping, and the effluent is removed with them.

elevated sand mound. A kind of soil absorption field, built mainly of sand and aggregate, on top of the normal soil surface. It is used mainly when the soil has restrictions that prevent the use of a trench system.

eolian sand. Soil parent material accumulated through wind action; includes eolian sand (mainly in dunes) and loess.

erosion (soil). The removal of soil from where it was originally formed.

erosion. Wearing away of the land surface by running water or wind. Although erosion is a natural process, it is often accelerated above tolerable limits by human activities such as intensive farming and urban development.

erratic (glacial). A piece of rock different from the kind of rock that underlies the area. In Indiana, igneous and metamorphic pebbles and boulders are erratics that were carried here from Canada by glaciers.

esker. A narrow, winding ridge of stratified gravelly and sandy outwash deposited by a stream flowing in a tunnel beneath a glacier.

eutrophication. The overgrowth of aquatic vegetation followed by death, decay, oxygen depletion, and an imbalance of plants and animals in a lake or other body of water.

evapotranspiration. The evaporation of water vapor by plants to the atmosphere.

fertility, soil. The quality that enables a soil to provide plant nutrients (in adequate amounts and in proper balance) for the growth of specified plants when light, moisture, temperature, tilth, and other growth factors are favorable.

filled depression. A depression partially filled with sediment.

filter strips. A form of conservation buffer placed along drainage ways and streams. It is composed of grass and other vegetation and used to trap sediment, nutrients from manure and fertilizer, pesticides, and other pollutants so they do not enter the body of water.

flat. A landscape component with a very small slope gradient.

flood plain. Nearly level alluvial plain that borders a stream and is subject to flooding unless protected artificially. Also a landform group.

flooding. Temporary covering of soil with water from overflowing streams.

foliated. Mineral aggregates that flake easily. Many metamorphic rocks are foliated.

forage (crop). Grasses, alfalfa, etc., planted for food for domestic animals. Forage can be grazed by livestock or cut for hay.

forest, mesic. Large, dense growth of trees and other woody vegetation covering a large area.

fragipan. Loamy, brittle subsurface horizon low in porosity and content of organic matter, and low or moderate in clay but high in silt. A fragipan appears cemented and restricts roots. When dry, it is hard or very hard and has a higher bulk density than the horizon or horizons above. When moist, it tends to rupture suddenly under pressure rather than to deform slowly.

friable soil material. Soil material that feels crumbly and is ideal for root growth.

glacial drift. General term for the sand, silt, and clay transported and deposited when a glacier melted. *Glacial till* (deposited directly from ice) and glacial outwash (deposited by the melt water of glacial ice) are specific examples of glacial drift.

glacial till. See *till, glacial*; compare to *dense glacial till*.

glacier. A large, thick mass of ice that moves slowly due to its own weight. Glaciers that originated in Canada moved down into United States and covered most of Indiana thousands of years ago.

granite. A common type of igneous rock composed of quartz, along with other minerals that are often pink, gray, and sometimes black.

grassed waterway. Natural or constructed waterway, typically broad and shallow, seeded to grass as protection against erosion. Conducts surface water away from cropland.

gravel. Rounded or angular fragments of rock up to 3 inches (2 millimeters to 7.5 centimeters) in diameter. An individual piece is a pebble.

graze. To consume any kind of standing vegetation by domestic livestock.

groundwater. Water found in pores (spaces between particles) underground; the upper surface of groundwater is the water table. Groundwater is a source of drinking water for much of Indiana.

growing season. Period of time when plants can grow and reproduce without frost damage.

gully. Miniature valley with steep sides cut by running water and through which water ordinarily runs only after rainfall. The distinction between a gully and a rill is one of depth. A gully generally is an obstacle to farm machinery and is too deep to be eliminated by ordinary tillage; a rill is of lesser depth and can be smoothed over by ordinary tillage.

harvest. To cut, reap, pick, combine, or gather any crop from the earth that is of value to people.

herbicide. A chemical used to kill unwanted plants.

hillslope. A landform component with 3 percent or greater slope.

horizon, soil. Layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes.

hue. The component of the Munsell color system that deals with wavelength (color), for example, red, black, gray.

humus (humified). Well-decomposed, more-or-less stable part of the organic matter in mineral soils.

hydrologic cycle. The continual movement of water over, in, and through the earth and its atmosphere as it changes from one form — solid, liquid, or vapor — to another.

hydrology. The branch of science concerned with the properties of water and its movement.

igneous rocks. Rocks formed from melted rock. Although Indiana has no bedrock that is igneous, igneous rocks were carried to the state thousands of years ago by glaciers that originated in Canada. See *erratics*.

Illinoian stage (age). The period of glacial activity around 100,000 to 200,000 years ago.

infiltration. Downward movement of water into the immediate soil surface. In contrast, *percolation* is movement of water through soil layers or material.

infiltration. The process by which water on the surface enters the soil.

interceptor drain. A subsurface drain line placed uphill from a soil absorption field that prevents water from entering into the field.

iron oxide. A compound of iron (Fe) and oxygen (O). Iron oxide give soils brownish and reddish colors.

irrigation. Application of water to soils to assist in production of crops.

kame. An irregular, cone-shaped hill of outwash.

lacustrine deposit. Material deposited in lake water and exposed when the water level was lowered.

lake plain. A large flat landform that was the bottom of a former lake.

lamellae. Thin bands of clay-enriched sandy soil material. For example, the Chelsea soil (Figure 1.22).

land use. Utilization of an area for farming, residential, or industrial purposes.

landform component. A certain part of a landform such as hillslope, depression, or swell.

landform group. Several individual landforms that have similar elevational positions. We recognize three groups: *uplands*, *terraces*, and *bottomlands* (or *flood plains*).

landform. A physical feature on the Earth's surface that has a characteristic shape and was produced by natural causes. Examples of landforms include *terrace*, *flood plain*, and *dune*.

landscape. The area that can be viewed from one spot. It is made up of landforms.

lateral lines. A perforated pipe that receives effluent from a septic tank and carries it to the soil absorption field.

leach (leaching). Removal of materials such as nutrients or pollutants by water flowing down through the soil.

lime. Crushed limestone, consisting largely of calcium carbonate ($CaCO_3$) that reduces the acidity (raises the pH) of the soil and supplies it with calcium.

limestone. A common *sedimentary rock* formed from the accumulation of carbonate minerals (for example, $CaCO_3$) usually by biologic action.

limestone. A *sedimentary rock* consisting mainly of calcium carbonate (lime).

limiting layer. A soil layer that limits the ability of the soil to provide water and nutrients for plant growth and/or to treat septic tank effluent. Four kinds of limiting layers are recognized in soil evaluation: *bedrock*, *dense till*, *fragipans*, and *coarse sand and gravel*.

local overwash. Overwash that originates from local higher areas instead of that transported by a stream.

loess. Material consisting mainly of silt-size particles, deposited by wind.

metamorphic rocks. Rocks formed from previously existing rocks that have been buried and subjected to high temperatures and great pressure deep to the extent their chemical composition has been altered.

mineral (material). Naturally occurring, inorganic material found in the Earth's crust.

mineral soil. Soil that is mainly mineral material rather than organic material. Its bulk density is greater than that of organic soil.

minimum tillage. The least tillage needed for crop production.

moldboard plowing. A "clean tillage" practice that inverts the soil to a depth of 7 to 10 inches and buries the previous crop residue, leaving no cover to protect against erosion.

moraine. Irregular hills of till deposited by a glacier.

mottle. Irregular spot or patch of one color (the minor one) in a background of another color (the dominant or major one). When gray is the dominant color or mottles, it generally indicates poor aeration and restricted drainage.

muck. Dark-colored, finely divided, well-decomposed organic soil material mixed with mineral soil material. The content of organic matter is more than 20 percent.

mulch. Protective covering such as crop residue, straw, manure, or other organic matter spread or left on the ground to prevent erosion, reduce evaporation, maintain even soil temperature, control weeds, and/or enrich the soil.

Munsell color notation. Designation of color by specifying three variables: hue, value, and chroma. For example, a notation of 10 YR 6/4 is a color of 10 YR hue, value of 6, and chroma of 4. Determined using a color chart.

natural levee. A small naturally occurring ridge near a steam on a flood plain.

natural soil drainage. Refers to the water regime of a soil through the year. Natural drainage classes are identified in the field (and in this publication) by the amount of reduction features, or gray color in the soil profile. Gray color results from chemical reduction that occurs when a horizon is saturated (below the water table). The classes recognized in soil evaluation are well-drained, moderately well-drained, somewhat poorly drained, and poorly drained.

nitrate poisoning. Health risks, especially to infants, caused by high nitrate levels in drinking water. The condition in infants is called methemologlobinemia, or blue baby syndrome.

nonpoint source pollution. Pollution from broad areas of land such as farms, parking lots, and residential areas. The greatest source of nonpoint source pollution is sediment due to soil erosion.

no-till planting. A crop (such as corn) is planted directly in soil that has a residue from a previous crop (for example, soybean) without any sort of tillage plowing (or disking) of the soil.

nutrient, plant. Any of the elements taken in by a plant, essential to its growth, and used by it in the production of food and tissue.

O horizon. An organic layer consisting of fresh and decaying plant residue. On the surface of a mineral soil, it consists of leaves, needles, twigs, etc. In an organic soil, all horizons of the profile are O horizons.

OIL RIG. A mnemonic device to help remember that in chemical reactions: **O**xidation **I**s **L**oss and **R**eduction is **G**ain of electrons.

on-site sewage disposal system. A sewage treatment system in which the treatment is done at the site (for example, house lot) where the sewage is generated instead of at a central sewage treatment facility. It consists of a septic tank and soil absorption field, and sometimes other devices.

open ditch drainage. Channels or open drains constructed for removing surplus water from land.

organic material. Very dark to black soil component that formed from partially decomposed vegetation and animal residue.

organisms. One of the five soil formation factors.

outlet filter. A filter at the outlet of a septic tank that intercepts solid materials that could damage a soil absorption field. The filter must be cleaned periodically.

outwash plain. A large, mostly level area not confined in a river valley that is composed of outwash material (sand and gravel).

outwash, glacial. Stratified sand and gravel produced by glaciers and carried, sorted, and deposited by water that originated mainly from the melting of glacial ice. Glacial outwash is commonly in *terraces*, *eskers*, *kames*, or *outwash plains*.

overwash. Material washed into depressions from nearby higher areas.

oxidation (chemical). A chemical reaction in which an atom loses electrons. In soils, iron oxides give soils reddish and brownish colors indicative of free drainage See *OIL RIG*.

parallel tile outlet (PTO). Terraces that are constructed parallel to one another and that use a surface inlet riser to discharge surface water runoff through subsurface drains and tiles to a ditch or other appropriate outlet.

parent material. The great variety of unconsolidated organic and mineral material in which soil forms. Consolidated bedrock is not yet parent material by this concept. One of the five soil formation factors.

pasture. A field of perennial vegetation (lasts for many years) that is used for grazing livestock.

pathogens. Organisms (such as bacteria and viruses) that can cause disease.

peat. Unconsolidated organic material, largely undecomposed, that has accumulated under excess moisture.

pebble. A small stone rounded when transported by ice and water.

ped. Individual natural soil aggregate, such as a granule, prism, or block.

perched water table. A water table that is maintained above a layer with very slow permeability

percolate (percolation). Downward movement of water through the soil.

perimeter drain. A subsurface drain line placed all around and below a soil absorption field to lower the natural water table enough so there is aerated soil below the field. The drain must meet specific position and outlet requirements.

permeability (soil). The rate at which water moves through the soil.

permeable (permeability). The quality that enables the soil to transmit water or air. Slow or low permeability means that water and air move very slowly through the soil. It is expressed as a rate (inches of water per hour).

pH. The scale used to determine the acidity or alkalinity of a substance based on its hydrogen ion content. The scale ranges from 0 to 14, with 7 being neutral. The zero end is most acidic, while the 14 end is most alkaline.

photosynthesis. The manufacture of carbohydrate from carbon dioxide and water. The process uses energy from the sun and releases oxygen.

plow. To cut through and turn over a layer of topsoil.

plowpan. Compacted layer formed in the soil directly below the plowed layer.

point rows. A partial row of crop that does not continue the entire length of the field due to irregular field borders or an obstruction such as a wetland.

pollution. The introduction of something harmful into the environment.

point source pollution. *Pollution* from a specific point. Examples are municipal sewage treatment plants and industrial discharges into streams.

ponding. Standing water on soils in closed depressions. Unless the soils are artificially drained, the water can be removed only by moving down through the soil or evapotranspiration.

pores. Small, sometimes microscopic, passages in rock and soil that allow the passage of fluids and air.

prairie. An area that supports mainly grasses with few or no trees.

prime farmland. Soils that have the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and other crops.

processes (of soil formation). Physical, chemical, and biological processes that convert *parent material* into soil.

productivity, soil. Capability of a soil for producing a specified plant or sequence of plants under a specified system of management. Productivity is measured in terms of output, or harvest, in relation to input.

profile, soil. Vertical section of the soil extending through all its horizons and into the parent material. In three dimensions, it is called a pedon.

quartz. A mineral composed of silicon and oxygen (SiO2). It is one of the most common minerals in the igneous rock called granite. Most sand grains in soils are quartz.

R horizon. Consolidated (hard) rock beneath the soil. The rock commonly underlies a *C horizon*, but can be directly below an *A*, *E*, or a *B horizon*.

recharge (of groundwater). The process by which water (from rainfall, snowmelt, and other sources) flows into a water-bearing geologic formation (aquifer).

reduction (chemical). A chemical reaction in which an atom gains electrons. In soils, the process tends to result in grayish colors because brownish iron oxides are dissolved. See *OIL RIG*.

regulator. The person making sure that the design of an on-site sewage disposal system meets state standards. For most single-home systems, the regulation is at the county level, and for other systems it is at the state level.

relief. The difference in elevation between the highest and lowest points in the landscape. One of the five soil formation factors.

residue, crop. Part of a plant left in the field after harvest. The practice of leaving crop residue is encouraged because it provides a covering for the soil to protect it against erosion.

residuum (residual soil material). Unconsolidated, weathered, or partly weathered mineral material that accumulates over disintegrating rock.

respiration. The exchange of gases in order to obtain the compounds required for energy; specifically, the use of oxygen which organisms use to break down food (carbohydrates) into energy plus carbon dioxide and water.

rill. A steep-sided channel resulting from accelerated erosion. A rill is generally a few inches deep and not wide enough to be an obstacle to farm machinery.

ripping. See *deep tillage*.

root zone. The part of the soil that can be penetrated by plant roots.

row crops. Crops such as corn and soybeans that are planted in rows more far enough apart so that equipment to control weeds, apply chemicals, and harvest crops can be driven through the field without running over plants. Now, corn is usually planted in 30-inch rows, and soybeans are planted in 15-inch rows.

runoff. The movement of water across a surface to a stream or other body of water.

safety grid. A grid placed above the inspection and cleaning ports of a septic tank to prevent people from falling into the tank.

sand filter. A secondary effluent treatment system consisting of a bed of sand through which septic tank effluent passes in the presence of air and is further purified before it is passes to the soil absorption field. Some units use media such as geotextile fabric instead of sand.

sand. As a soil separate, individual rock or mineral fragments from 0.05 millimeter to 2.0 millimeters in diameter. Most sand grains consist of quartz. As a soil textural class, a soil that is 85 percent or more sand and not more than 10 percent clay.

sand-lined pipe. A system used instead of aggregate in some *soil absorption fields*.

sandstone. A common *sedimentary rock* formed from sandy sediment.

sandstone. *Sedimentary rock* containing dominantly sand-size particles.

saturated soil. The part of the soil in which all the pores are completely filled with water. The water table is at the top of the saturated zone. See *water table*.

scum. The upper (floating) layer in a septic tank. It must be removed by periodic pumping of the contents of the tank. The layers beneath the scum are *effluent* and *sludge*.

seasonally high water table. The height to which the water table rises during the wettest part of the year. It is usually identified by soil morphological features, especially color.

secondary treatment unit. A device in which *septic tank* effluent is further treated under aerobic conditions. Two kinds are described: a sand or media filter, and an aerobic treatment unit.

sediment. The material suspended in or carried by wind or water that settles when, that which carries it, becomes calmer.

sedimentary rock. Rock made up of particles deposited in water and cemented together. The chief kinds are *sandstone* (formed from sand), *siltstone* (formed from silt), *shale* (formed from clay), and *limestone* (formed from the calcium carbonate in marine animal shells).

septic system. Wastewater treatment systems that use a septic tank and soil to treat small wastewater flows, usually from individual homes. They are typically used in rural or large lot settings where centralized wastewater treatment is impractical. An on-site wastewater disposal system consists of a *septic tank*, a *distribution box*, and a *drain field* or *soil absorption field*.

septic tank. An underground tank usually made of concrete that temporarily holds wastewater from a household so that heavy solids and lighter scum are allowed to separate from the wastewater. The solids stored in the tank are decomposed by bacteria, and the remnants are later removed, along with the lighter scum, by a professional septic tank pumper. See *septic system*.

series, soil. A group of soils, formed from a particular type of parent material, having horizons that, except for the texture of the A or surface horizon, are similar in all profile characteristics and arrangement in the soil profile. Among these characteristics are color, texture, structure, r eaction, consistence, and mineralogical and chemical composition.

sewage. Liquid-carried waste generated as part of normal living. It comes from toilets, bathtubs, showers, sinks, washing machines, dishwashers, and other sources.

shale. A common *sedimentary rock* formed from clayey sediment.

sheet erosion. Removal of a fairly uniform layer of soil material from the land surface by the action of rainfall and runoff water; does not follow a channel.

silica. Compounds so silicon (Si) and oxygen (O). Quartz (SiO2) is one kind of silica, but there are many other forms.

silt coat. Coatings of silt grains on *ped* surfaces. Silt coats appear to be dusty and powdery, like sugar on a donut. Thin silt coats can be distinguished from clay skins by moistening the sample. If the coating is silty, the color of the coating disappears and the underlying color of the ped comes through. A clay film will keep its color when moist. Silt coats are *not* an indicator of natural drainage, whereas the presence of gray clay coats or films can be.

siltstone. A common *sedimentary rock* formed from silty sediment.

slope (gradient). Inclination of the land surface from the horizontal. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100. Thus, a slope of 20 percent is a drop of 20 feet in 100 feet of horizontal distance.

sludge. The lowest layer in a *septic tank* that settles out of the *effluent* (middle layer) mainly as a solid material. It must be pumped out of the tank periodically.

small grains. Crops such as wheat, barley, oats, and rye that are usually seeded in narrow rows (less than 10 inches apart). These crops produce most of their growth during cool seasons (late fall to early winter).

soil absorption field. A system of drain lines through which *effluent* moves to the soil where it is further purified by soil microbes. Located in an unsaturated zone of the soil, the absorption field contains perforated pipes that allow wastewater to trickle into the soil. The soil acts as a natural buffer to filter out many of the harmful bacteria, viruses, and excessive nutrients after it leaves the septic tank and before it enters the *groundwater*. Synonyms include septic absorption field and drain field.

soil conservation. Practices to maintain healthy soil by minimizing soil erosion, soil nutrient depletion, and soil compaction. See *conservation buffer*, *conservation tillage*, *contour tillage*, *filter strips*, *no-till planting*, *PTO*, and *WASCOBs*.

soil formation factor. Factor, in general, means an influence that contributes to an outcome. If the outcome is a certain soil, then the factors (influences) of its formation are parent material, relief, climate, organisms (plants), and time. See "*CLORPT*.

soil loading rate. The rate at which soil accepts effluent. Soils with rapid permeability have high loading rates. The lower the loading rate the larger a soil absorption field must be.

soil morphology. A description of basic soil properties observable in the field, such as texture, color structure, consistence

soil survey. An inventory of soil resources. It consists of soil maps, technical information about soils, and information about using soils. Soil surveys are usually published by counties.

soil. The material near the Earth's surface that has horizons that were created by soil-forming processes.

solum. Upper part of a soil profile, above the *C horizon*, in which the processes of soil formation are active. The solum in mature soil consists of the *A*, *E*, and/or *B horizons*. Generally, the characteristics of the material in these horizons are unlike those of the underlying material. Living roots and other plant and animal life in the soil are largely confined to the solum.

splash erosion. The particles of soil that are loosened and thrown into the air by raindrops that strike with considerable speed and energy.

stratification (stratified). Deposited in strata, or layers, usually by water.

strip cropping. Growing crops in a systematic arrangement of strips or bands that provide vegetative barriers to wind and water erosion.

strip-till planting. Planting seeds such as corn or soybeans in a narrow strip that has been cleared of plant residue and tilled. Much like *no-till* planting, except that residue from a previous crop is cleared from a narrow strip in which seeds are planted.

structure, soil. The grouping of individual soil particles or aggregates into units called *peds*. The principal forms of soil structure are platy (laminated), prismatic (vertical axis of aggregates longer than horizontal), columnar (prisms with rounded tops), blocky (angular or subangular) and granular.

subsoil. Technically, the *B horizon*; roughly, the part of the *solum* below plow depth.

substratum. The part of the soil below the *solum* (*C horizon*) that lacks development.

subsurface drainage. Underground drainage system that removes subsurface water through a series of clay or concrete tiles or perforated plastic tubing installed at a slight grade to facilitate flow to an outlet.

surface drainage. (1) The natural pattern by which water moves across the soil surface as overland flow. (2) A man-made system of grading the soil to enhance overland flow.

surface inlet riser. A pipe intake that extends above the ground and directs surface or ponded water into an underground tile or outlet. See *parallel outlet terraces*.

surface soil. The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, ranging in depth from 4 to 10 inches. Frequently designated as plow layer, topsoil, or Ap horizon.

surface water. Any body of water on the Earth's surface such as lakes, rivers, and creeks. It also includes water in drainage ditches and water that seeps from a hillside. Surface water is the source of drinking water for many cities.

swale. Concave (the shape of a bowl) landform with a 2 percent or less slope. See *depression*.

swell. Convex (shape of a ball) landform with a 2 percent or less slope.

swell-and-depression topography. Composed of both *swells* (small rises) and *depressions* (small indents), which results in "rolling" scenery.

swelling clay. Some clays swell when wet and shrink when dry. Shrinking and swelling can damage roads, dams, building foundations, and other structures. They can also damage plant roots.

system designer. The person or company that designs an on-site sewage system

system installer. The person or company that installs an on-site sewage system.

terrace (geologic). An old alluvial plain, ordinarily flat or undulating, bordering a river, a lake, or the sea. A stream terrace is seldom subject to overflow. Also, a group of similar landforms.

terrace (structure). Embankment or ridge constructed across sloping soils on the contour or at a slight angle to the contour. The terrace intercepts surface runoff so that it can soak into the soil or flow slowly to a prepared outlet without harm. A terrace in a field is generally built so that the field can be farmed.

texture group. Five groups are used in soil evaluation. Each group is comprised of one or more soil texture *classes* as listed below:

sandy – sands and loamy sands

moderately sandy – sandy loam

medium – loam and silt loam

moderately clayey – clay loam and silty clay loam

clayey – sandy clay, clay, and silty clay

texture, soil. The relative proportions of sand, silt, and clay particles in a mass of soil.

tile drainage. Underground drainage system composed of clay or concrete tiles or perforated plastic tubing installed at a slight grade to facilitate the flow of subsurface water to an appropriate outlet. (Synonym: subsurface drainage)

till plain. An extensive flat to undulating landform underlain by *glacial till*.

till, glacial. Unsorted, nonstratified (not layered) material transported and deposited by glacial ice. It consists of a mixture of clay, silt, sand, pebbles, and boulders in various proportions. Calcareous till is recognized as a limiting layer.

tillage. Preparation of the land for planting. Traditionally this was done by moldboard plowing and disc harrowing. Conservation tillage (ridge-till, minimum till, no-till, etc.) is now the preferred method so as to control erosion. See *conservation tillage*.

time. How long a soil has existed. One of the five soil formation factors.

tolerable soil loss (T). The amount of soil that can be eroded without causing long-term harm to farming productivity. In Indiana, the tolerable soil loss for most soils is 2 to 5 tons per acre per year.

topography. The detailed physical features of an area, such as plains, hills, and other land features.

topsoil. The upper part of the soil, which is the most favorable material for plant growth. It is ordinarily rich in organic matter.

trench systems. Soil absorption field systems in which absorption takes place in trenches in the original soil. Three kinds of trenches are recognized in soil judging: gravity flow, flood dose, and pressure distribution.

TSI (timber stand improvement). The practice of removing poor trees and vines so that the better trees may grow better

unsaturated soil. The part of the soil in which pores are filled partly with air and partly with water. This is the area above the water table. See *water table* and *groundwater*.

upland. A landform group at high elevations (above terraces). Most of Indiana consists of uplands.

USLE. Universal soil loss equation. An equation that estimates the amount of soil lost by water erosion. The inputs are slope gradient, slope length, soil erodibility, rainstorm energy, cropping and practices, and mechanical factors (contour tillage, terraces, etc.). The equation is:

A = R x K x LS x C x P

Where A is the average annual soil loss by water erosion (tons per acre). The inputs are rainstorm energy (R), soil erodibility (K), slope length (L), slope steepness (S), tillage and cropping practices (C), and mechanical practices such as terraces (P). Several of these inputs are considered in soil judging.

value (color). The component of the Munsell color system that deals with the lightness and darkness of color. A value of one is very dark, and a value of eight is very light;

water and sediment control basins (WASCOBs). Shorter versions of parallel tile outlet terraces that are built only across the natural drainage ways in the field rather than the entire field. They are constructed mainly to control gully erosion. See *parallel tile outlet*.

water table. Upper boundary of saturated soil.

weathered bedrock. Bedrock that is broken down by physical and/or chemical processes. Although it is still rock, it is soft enough that roots can grow into it.

weathering. All physical and chemical changes produced in rocks or other deposits at or near the Earth's surface by atmospheric agents. These changes result in disintegration and decomposition of the material.

wetlands. Areas of hydric soil that are saturated with water at or very near the surface for at least several weeks during the growing season and support water-loving plants such as cattails and reeds. Sometimes wetlands are "constructed" specifically to purify effluent from a septic tank, using the same principle as a natural wetland with plants and microbes to purify the water that flows into it.

windbreak. A conservation buffer composed of trees and shrubs used to reduce wind erosion, protect young crops, and control blowing snow.

Wisconsinan age. The period of glaciation around 12,000 to 100,000 years ago.

RESOURCES – Site Card and Scorecards

PURDUE EXTENSION | LOCAL FACES COUNTLESS CONNECTIONS

Soil Contest Site Card

4-H-736-W

March 2017

SITE NO. ______	**SITE TYPE** ☐ AGRICULTURE ☐ HOME SITE

CALCAREOUS BELOW ______ in.

JUDGE PARENT MATERIAL ______ to ______ in.

FLAT LANDFORM YES NO

WEAK SOIL DEVELOPMENT YES NO

P: ______ ppm	**K:** ______ ppm	**pH:** ______

SEPTIC TANK CARE

D = ______	**G =** ______	**R =** ______
Disposer? *Yes* **D=7** *No* **D=10**	*Tank capacity (gallons)*	*Residents in house*

NOTES

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Slope Finder

4-H-408-W
January 2017

PIVOT POINT

SIGHTING LINE

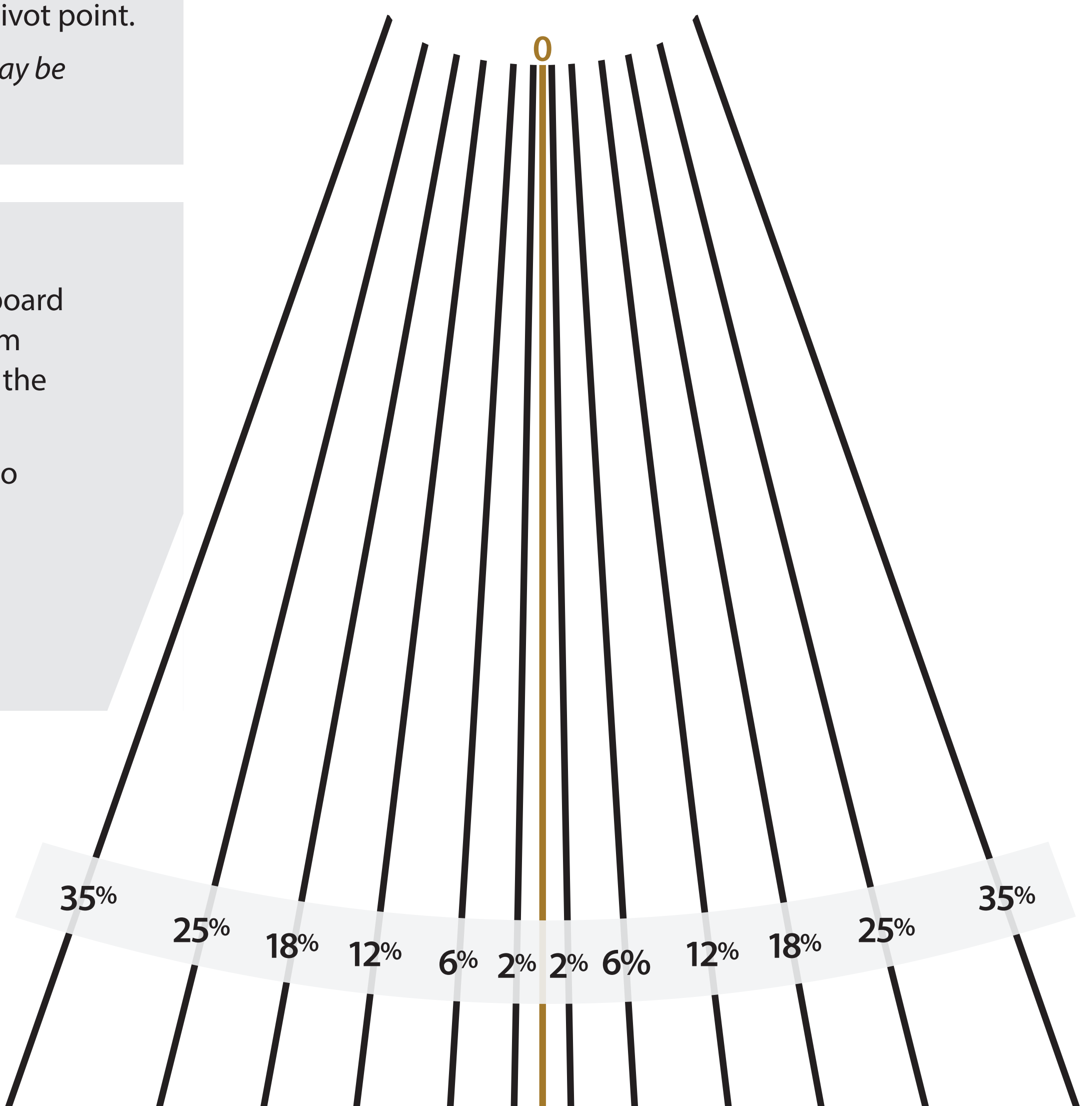
PREPARATION

- Mount this form on the back of a board (clip board, plywood, particle board) with the sighting line parallel to the edge of the board.
- Drill a hole through the pivot point.
- Tie a weight to one end of a string and attach the other end to the pivot point.

A sighting aid, such as a tube, may be added to the top of the board.

USE

- Sight along the edge of the board or along the sighting line from the top of one slope stake to the top of the other.
- Allow the weight and string to hang free.
- When it stabilizes clamp the string to the board with your fingers, and read % slope.



PURDUE EXTENSION | LOCAL FACES COUNTLESS CONNECTIONS

PURDUE EXTENSION | LOCAL FACES COUNTLESS CONNECTIONS

Indiana Soil Evaluation Scorecard

4-H-394-W — AGRICULTURE

I. SOIL PROPERTIES *(5 points each, 45 total)*

A. PARENT MATERIAL

1A Weathered bedrock
1B Till
1C Outwash/Lacustrine deposits
1D Eolian sand
1E Loess
2A Alluvium
2B Local overwash

B. SLOPE

3A 0-2%
3B 3-6%
3C 7-12%
3D 13-18%
3E 19-25%
4A 26-35%
4B >35%

C. LANDFORM

5A Upland hillslope
5B Upland swell
5C Upland flat
5D Upland depression
5E Outwash/Lacustrine hillslope
6A Outwash/Lacustrine swell
6B Outwash/Lacustrine flat
6C Outwash/Lacustrine depression
6D Dune
6E Flood plain
7A Filled depression

D. SURFACE SOIL COLOR GROUP

8A Gray
8B Brown
8C Black

E. PREVIOUS EROSION

9A None to slight
9B Moderate
9C Severe

F. SURFACE TEXTURE

10A Sandy
10B Moderately sandy
10C Medium
10D Moderately clayey
10E Clayey

G. SUBSOIL TEXTURE

11A Sandy
11B Moderately sandy
11C Medium
11D Moderately clayey
11E Clayey

H. NATURAL SOIL DRAINAGE

12A Poorly
12B Somewhat poorly
12C Moderately well
12D Well

I. LIMITING LAYER

13A Bedrock, 0-20 in
13B Bedrock, 21-40 in
13C Dense till, 0-20 in
13D Dense till, 21-40 in
13E Fragipan, 0-20 in
14A Fragipan, 21-40 in
14B Coarse sand & gravel, 0-20 in
14C Coarse sand & gravel, 21-40 in
14D None within 40 in

II. AGRICULTURE PRACTICES *(3 pts. each, 69 total)*

A. LAND USE OVERVIEW

15 Restore original vegetation to:
A - Wetland; **B** - Prairie; **C** - Mesic forest

Yes No
16 A B Prime farmland

B. EROSION AND COMPACTION POTENTIALS

17 A B High for erosion by water
18 A B High for erosion by wind
19 A B High for soil compaction

C. BUFFERS AND COVER CROPS

20 A B Grassed waterways
21 A B Windbreaks
22 A B Filter strips
23 Most significant benefit of cover crops:
A - Scavenge N; **B** - No need; **C** - Erosion control

D. CROPPING PRACTICES

Yes No
24 A B Timber stand improvement (TSI)
25 A B Permanent pasture
26 A B Crop rotation

E. TILLAGE PRACTICES

27 A B No till
28 A B Moldboard or chisel plowing

F. WATER MANAGEMENT

29 A B Drainage
30 A B Irrigation
31 A B Terraces

G. PLANT NUTRIENT APPLICATION

		A	B	C
32	N:	Low	Med.	High
33	P:	Add	None	Deplete
34	K:	Add	None	Deplete
35	Lime:	Add	None	

H. NUTRIENT POLLUTION POTENTIAL

36 Nitrogen pollution potential:
A - High, ground water; **B** - High surface water; **C** - Med.
37 Phosphorus pollution potential:
A - High; **B** - Medium; **C** - Low

Team / Contestant number: ____________

Contestant name: ____________

School / Club name: ____________

Site number: ____________

SCORE

Part I *(45 points possible)*: ____________

Part II *(69 points possible)*: ____________

Total *(114 points possible)*: ____________

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PURDUE EXTENSION | LOCAL FACES COUNTLESS CONNECTIONS

Indiana Soil Evaluation Scorecard

4-H-255-W **HOME SITE**

I. SOIL PROPERTIES *(5 points each, 45 total)*

A. PARENT MATERIAL

1A Weathered bedrock
1B Till
1C Outwash/Lacustrine deposits
1D Eolian sand
1E Loess
2A Alluvium
2B Local overwash

B. SLOPE

3A 0-2%
3B 3-6%
3C 7-12%
3D 13-18%
3E 19-25%
4A 26-35%
4B >35%

C. LANDFORM

5A Upland hillslope
5B Upland swell
5C Upland flat
5D Upland depression
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6B Outwash/Lacustrine flat
6C Outwash/Lacustrine depression
6D Dune
6E Flood plain
7A Filled depression

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8B Brown
8C Black

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9A None to slight
9B Moderate
9C Severe

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12A Poorly
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I. LIMITING LAYER

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13B Bedrock, 21-40 in
13C Dense till, 0-20 in
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13E Fragipan, 0-20 in
14A Fragipan, 21-40 in
14B Coarse sand & gravel, 0-20 in
14C Coarse sand & gravel, 21-40 in
14D None within 40 in

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II. HOME SITE PRACTICES *(3 pts. each, 72 total)*

A. SITE SELECTION AND CONSTRUCTION PRACTICES

Yes No
15 A B Is the soil suitable for a homesite?
If NO, mark practices 16-38 as NO, N/A, or No application
16 A B Preserve trees & plant new ones
17 A B Maintain soil cover during construction
18 A B Improve surface drainage
19 A B Is the soil suitable for a basement?
20 A B Design for high-clay subsoils
21 A B Potential construction hazards on slopes
22 A B Install diversion structures and drains
23 A B Provide foundation drainage
24 A B High risk for cave-in during construction

B. LANDSCAPE AND LAWN PRACTICES

25 Manage soil reaction for acid-loving shrubs
A - No application; **B** - Apply sulfur; **C** - Plant other species
26 Manage soil reaction for lawns
A - Apply lime; **B** - No application; **C** - Plant other species
Yes No
27 A B Apply phosphorus (P) to lawn
28 A B Apply potassium (K) to lawn

C. ON-SITE SEWAGE DISPOSAL - SUITABILITY

Yes No
29 A B Is soil suitable for an absorption field?
If NO, mark practices 30-38 as NO or N/A

D. SEPTIC TANK PRACTICES

30 Septic tank outlet filter cleaning interval
A - 6 months; **B** - 1 year; **C** - N/A
31 Septic tank pumping interval (PI, years)
31A 1-2
31B 3
31C 4
31D ≥5
31E N/A

$$PI = \frac{(D \times G) / 1{,}000}{R}$$

PI = (___ x ___) / 1,000 / ___ PI=______

D=Disp. (Y = 7; N = 10); G = tank size, gal.; R = Resid.

E. SOIL ABSORPTION FIELD PRACTICES

Yes No
32 A B Subsurface trench, gravity flow system
33 A B Subsurface trench, flood dose system
34 A B Subsurface trench, pressure distrib. system
35 A B Elevated sand mound system
36 A B Elev. sand mound & subsurface drain
37 A B Drip distribution & secondary treatment
38 A B Secondary treatment

Team / Contestant number: __________

Contestant name: __________

School /Club name: __________

Site number: __________

SCORE

Part I *(45 points possible)*: __________

Part II *(72 points possible)*: __________

Total *(117 points possible)*: __________

Notes

ID-72-W August 2017

PURDUE UNIVERSITY

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