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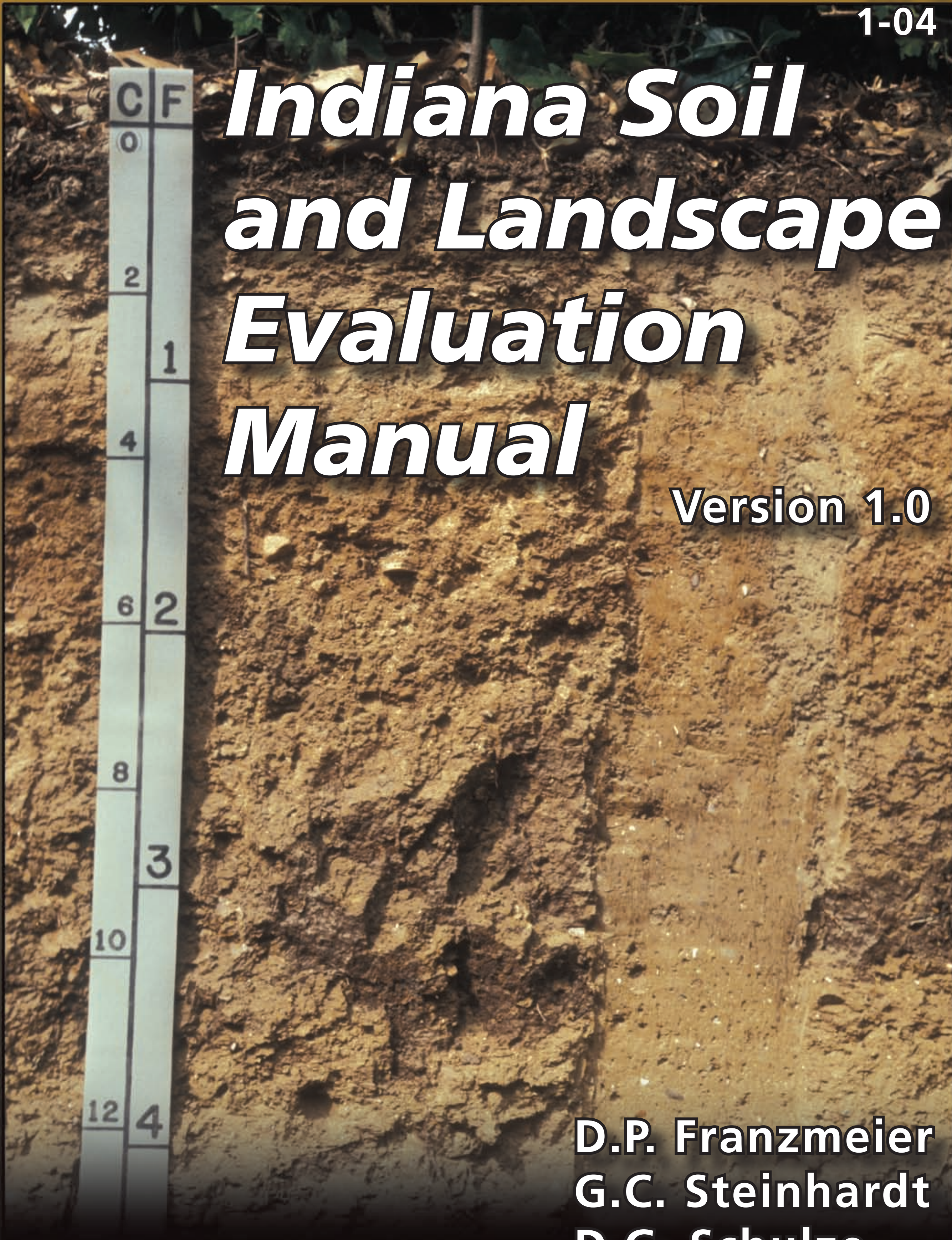
Indiana Soil and Landscape Evaluation Manual

Version 1.0



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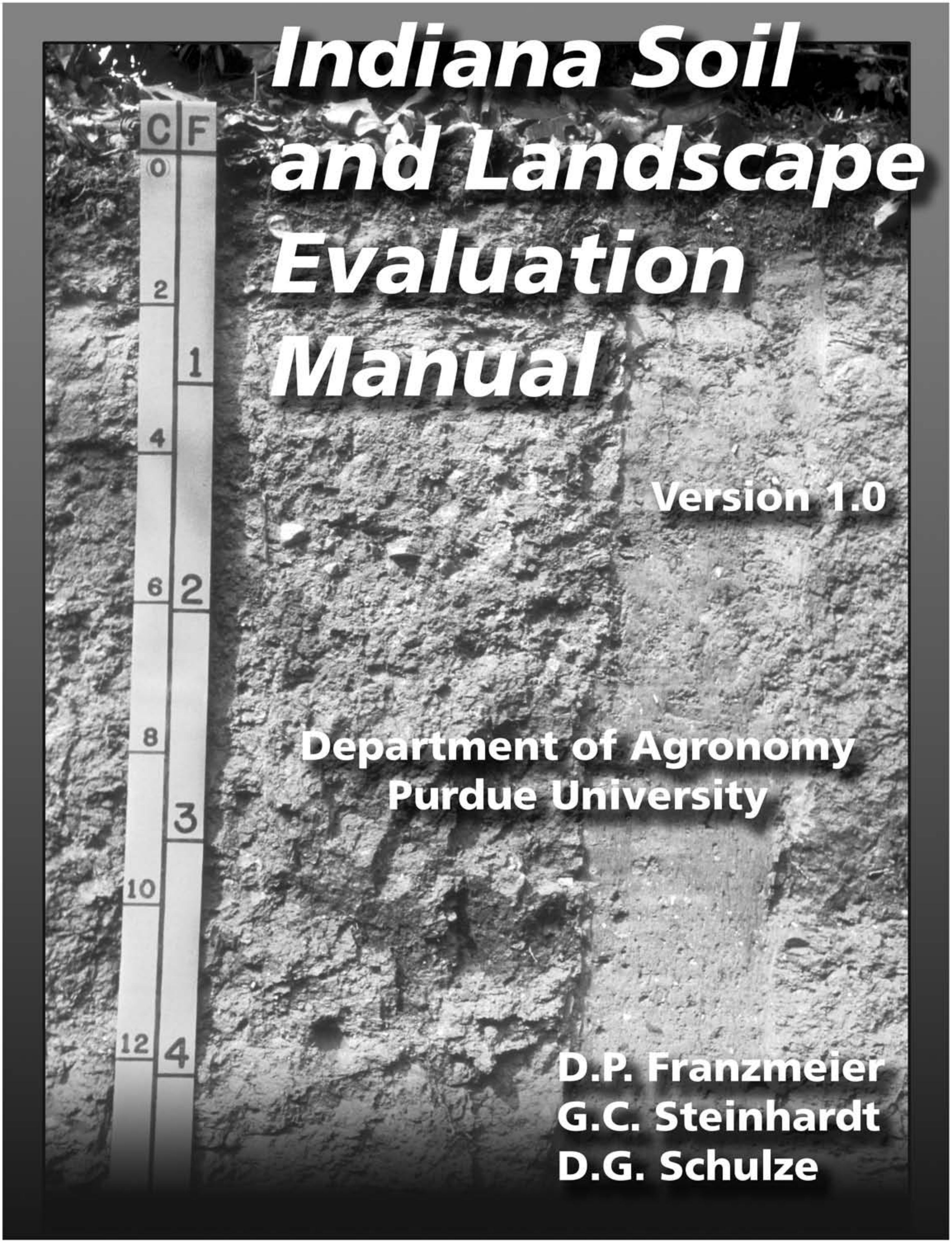
PURDUE
UNIVERSITY

Front cover photo:

Profile of Miami Silt loam. This series was selected by Indiana soil scientists to be the state soil. The scale on the gray panel is in decimeters and feet. The upper 18 inches (46 cm) of the soil formed in Wisconsinan age loess, and the lower part formed in Wisconsinan till. The soil has distinctive O, A, and E, horizons in the upper 12 inches (30 cm), Bt horizons 12 to 42 inches (107 cm), and dense till (Cd horizons) below 42 inches. The soil is found in central Indiana (see back cover).

Back cover diagram:

Block diagram showing the landscape in Soil Region 9. The Miami soil (front cover) occurs on bevel landforms.



Indiana Soil and Landscape Evaluation Manual

Version 1.0

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INTRODUCTION

This publication presents methods for describing soils and landscapes. Its goal is to foster better communication between soil scientists who write soil and landscape evaluation reports and the environmental specialists who read the reports and decide how to use a soil. Many of these decisions greatly influence soil and water quality, so it is the vision of the authors that this manual will help protect our soil and water resources. The material in this manual was derived from manuals, field books, glossaries, and classification systems that are generally used by soil scientists to prepare reports for other soil scientists. Many people who use soil evaluation reports, however, are not soil scientists, so the authors tried to make the technical material and the resulting reports, understandable to non-specialists and to adapt it to Indiana conditions. Much of the material in the manual came from a laboratory manual for a course in Soil Classification, Genesis, and Survey (Franzmeier, 1996). It was further adapted here to be used by environmental officers. The manual will also be used by students, many of whom will prepare soil and landscape reports in the future.

If the soil evaluator wishes to describe soil and landscape features in more detail than is prescribed herein, or to describe conditions not covered in the Manual, he or she should report them in any suitable format. The Manual is not intended to limit the kind of information relayed by evaluators.

The first three chapters deal with the nature of the site—its location, the kind of geological material, and the “lay-of-the-land.” Chapter 4 deals with the soil profile, mainly underground features. Chapter 5 discusses how information is reported and used.

We believe that as the manual is used, corrections and improvements will be made, so this document is called version 1.0, allowing for future revisions as other version numbers. Please send your written comments to Don Franzmeier, Department of Agronomy, Purdue University, 915 West State Street, West Lafayette, IN 47907-2054, or by e-mail<dfranzme@purdue.edu>.

CHAPTER 1

LOCATION

In this section, the location of the site is described in sufficient detail that a person can find the exact point where the investigation was done. For immediate use, a general or narrative location, not related to an accepted coordinate system might be used. For longer term use and for storing records in a geographic information system locations must be given using a coordinate system, however.

The location of an evaluation should also be marked with a wire flag, stake, post, or other marker. These markers can be moved or lost, however. If soil information is challenged, it will be to the advantage of the evaluator to be able to find the exact location of an observation site.

GENERAL LOCATION

This location is given relative to a local landmark such as a building, tree, corner of a lot in a subdivision or other local reference point. Such a location description is useful for the immediate application of an investigation. Distances to a reference point may be visually estimated, paced off (by counting steps), measured using a wheel or a tape, measured with survey instruments, or otherwise determined. The direction in which the distance was estimated or measured must also be shown.

COORDINATE LOCATION

Locations may also be described by using a system that specifies the exact location on the earth's surface. These systems give the location using two numbers, one giving the distance or angle north or south of a reference point or line, and the other, the distance or angle east or west of point or line. The most commonly used coordinate systems are latitude-longitude, universal transverse mercator, state plane, and the U.S. rectangular survey. Programs are available to convert the location given in one of these systems to another system, but it will be much more convenient to use the system recommended by the agency or client for whom a report is prepared. Also, when a county or other entity puts its information into a database or geographic information system, locations according to a coordinate system will be essential.

Latitude-Longitude System

Any location on Earth can be described by two numbers — its latitude and its longitude. For example, the location of the pedon used for the official series description for the Crosby soil is 39 degrees, 58 minutes, 41.76 seconds north latitude; and 85 degrees, 28 minutes, 56.43 seconds west longitude.

The latitude of some point on the earth's surface north of the equator is the elevation angle of that point above the equator followed by "north." The latitude of Evansville, IN, for example, is about 38 degrees (°) north. South of the equator, latitude is the angle below the equator. The latitude of Sydney, Australia, is about 38 degrees south.

On the globe, lines of constant longitude ("meridians") extend from pole to pole, like the segment boundaries on a peeled orange. Every meridian must cross the equator. Since the equator is a circle, we can divide it — like any circle — into 360 degrees. Zero degrees longitude, the prime meridian, was arbitrarily set at the old Royal Astronomical Observatory in Greenwich, England, at the eastern edge of London. The longitude of St. Louis, MO, is about 90 degrees meaning that it is one-quarter of the way around the earth, going west from Greenwich.

Actually, latitude and longitude are both angles, measured in degrees, minutes, and seconds of arc, denoted by the symbols (°, ', ") e.g. 39° 58' 41.76" means an angle of 39 degrees, 58 minutes and 41.76 seconds (do not confuse this with the notation (',") for feet and inches). A degree contains 60 minutes of arc and a minute contains 60 seconds of arc. You may omit the words "of arc" where the context makes it absolutely clear that these are not units of time.

Universal Transverse Mercator System

The Universal Transverse Mercator (UTM) system is becoming widely used because it is available on Global Positioning System instruments. The UTM coordinate system divides the Earth into 60 zones that are each 6 degrees of longitude wide. Each zone is banana-shaped. The top is near the north pole, the bottom is near the south pole, and the zone is about 670,000 m (416 miles) wide at the equator. Indiana is entirely in zone 16, between longitudes 84° in Ohio and 90° in Illinois. Within each zone, east-west distances are referenced to a north-south central meridian that goes down the center of the zone, and north-south distances are referenced to the equator. The central meridian of zone 16 follows longitude 87°, which is west of Michigan City in the north and west of Huntingburg in the south. The central meridian is arbitrarily assigned a coordinate of 500,000 m E, called the easting value. Because of this assignment and the width of the zone, there are only easting distances, no westings. On the USGS quad sheets, tick marks showing UTM coordinates are printed in blue on the edges of the map. Their labels are complete near the southeast and northwest corners of the map (e.g. $^{5}53^{000m}$ E., $^{44}01^{000m}$ N.) and are abbreviated in between e.g., $^{5}52$, $^{44}02$). The coordinates for the official Crosby soil series description, for example, has coordinates 629,593 m easting, and 4,426,452 m northing. This means that the pedon is 129,593 m east of the 87° longitude line and 4,426,452 m north of the equator. GPS instruments usually give location information in latitude-longitude or UTM coordinates.

When giving UTM coordinates, it is important to specify the zone number and the basic locations (datum) on which the coordinates are based. This is shown in the lower left corner of USGS topographic maps, for example:

> 1,000-meter Universal Transverse Mercator grid ticks, zone 16, shown in blue. 1927 North American datum.

The last sentence is abbreviated NAD 27. Another common datum is NAD 83. The location coordinates according to NAD 83 will differ from those according to NAD 27, illustrating that one must report the datum used.

State Plane Coordinate System

The State Plane Coordinate System is similar to the UTM system except that SPCS zones usually follow state and county boundaries instead of latitude-longitude lines, and distances are given in feet instead of meters. The system is used mainly by surveyors. Published soil surveys in Indiana show state plane coordinates along with U.S. rectangular survey information.

U.S. Rectangular Survey System

The original land survey in most of Indiana divided the land into townships, ranges, and sections (Steinhardt and Franzmeier, 1997). A *section* is an area of land one mile square with boundaries oriented north-south and east-west. Thirty-six sections, 6 x 6, comprise a survey or legal *township*. Within a township, section one is in the northeast corner and section 36 is in the southeast corner (Fig. 1a and 1b). Townships are numbered relative to a north-south principal meridian and an east-west base line. A principal meridian is a major north-south line, and a base line is a major east-west line. Except for those states settled before this survey system was initiated, all states have at least one principal meridian and one base line. Accordingly, township T18N, R9E is the18th township north of a baseline and the ninth township east of a principal meridian. Some townships are south of the base line, and some are west of the prime meridian. The principal meridian and baseline for most land in Indiana cross in southern Orange County. Another principal meridian follows the Indiana-Ohio boundary. Survey townships are not to be confused with civil or political townships, which are units of government and are identified by a name (e.g. Wabash Township). A few areas of the state, such as part of Knox County, are excluded from the Rectangular Survey because they were surveyed before the Rectangular Survey started.

A point within a section can be located relative to the distance north or south and east or west of one of *five points* in a section, which are the four corners and the center. Using this system, no distance should be more than 1/4 mile, 1320 feet. This five point system is commonly used. The pedon for the official Miami series description, for example, is 800 feet west and 300 feet south of the northeast corner of sec. 6, T15N, R1E, in Hendricks County. An advantage of the Rectangular Survey is that practically all property surveys and survey markers on the ground use that system.

Figure 1a. Illustration of U.S. Rectangular Survey System. a) Pattern followed for numbering the sections within a survey township. Detail of Section 10 as shown below. (Steinhardt Franzmeier, 1997)

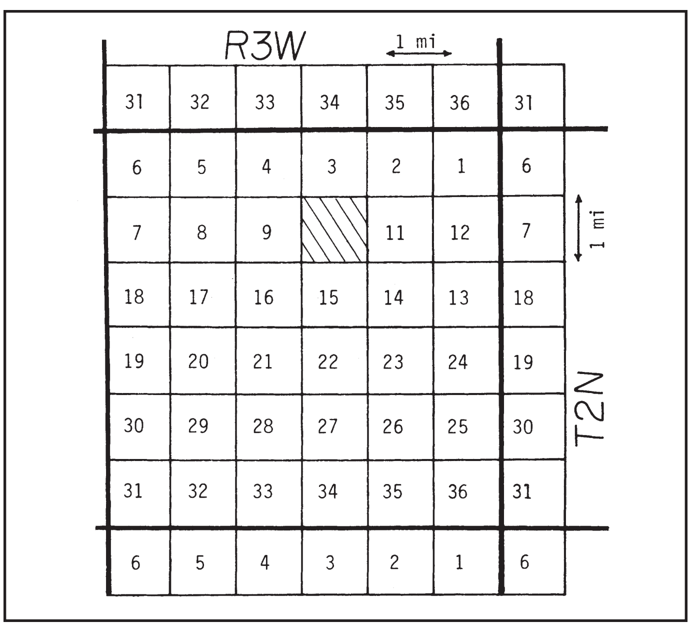
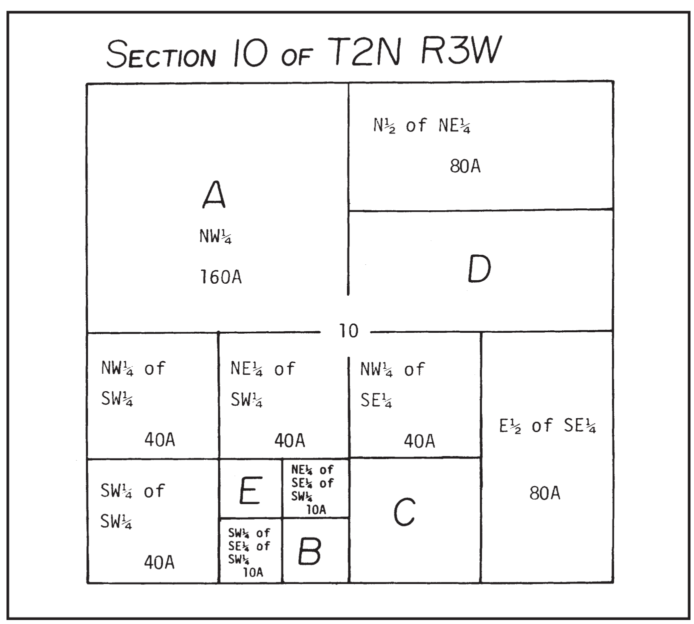


Figure 1b. Detail of Section 10 of T2N R3W illustrating the fractioning system used to locate and describe spsecific parcels of land. Parcel 'C' is described as SW1/4 of SE1/4 of Sec. 10 T2N R3W, 2nd Principal Meridian; Parcel 'D' is the S1/2 of NE1/4 of Sec. 10 T2N R3W, 2nd Principal Meridian; and Parcel 'E' is the NW1/4 of SE1/4 of SW1/4 of sec. 10 T2N R3W, 2nd Principal Meridian. (Steinhardt Franzmeier, 1997)



CHAPTER 2

SOIL PARENT MATERIALS

Soil *parent material* is the geologic materials from which a soil formed. The parts of the soil altered by soil formation are called A and B horizons, collectively called *solum*. The underlying C horizons represents relatively unaltered parent material.

In any soil investigation, it is essential to identify the kinds of parent materials (Table 1). Knowing the kind of parent material will help identify the landform and vice versa. If the parent material is mainly fine and medium sand, for example, it is likely that the material was deposited by wind, and may be a dune.

Parent materials vary greatly in their permeability, and so influence the water regime in the solum. In addition, soil formation processes alter the permeability of parent materials. Consequently some layers or soil horizons transmit water very rapidly and some transmit water so slowly that they hold up the water table. If downward water movement is restricted, it can move laterally through the soil if it is sloping. Generally, restrictive soil horizons parallel the land surface, so the shape of the land surface controls lateral water movement in the landscape. Dense till, for example, has very slow permeability and tends to perch water in and above the till. This results in poorly and somewhat poorly drained soils on level uplands, and seep areas on hillsides. Most bedrock strata also restrict downward water movement. The exception is limestone which often has fractures and channels caused by dissolution of limestone. Except for fragipans, most soil horizons formed in loess have relatively rapid permeability. Fragipans, like dense till and much bedrock, have very slow permeability.

Outwash, on the other hand, has very fast permeability and very low available water holding

Table 1. Definitions of parent materials.

Alluvium — Material deposited by a stream in relatively recent time.

Beach deposit — Material (usually sandy) deposited by wave action on the beach of a lake or a former lake.

Bedrock — Solid rock at the surface of the earth or underlain by soil or other unconsolidated deposit. In Indiana, bedrock includes sedimentary rocks, such as sandstone, siltstone, shale, and limestone.

Colluvium — Loose, heterogeneous material transported by unconcentrated surface runoff or slow continuous downslope creep, collecting at the base of a slope; similar to hillslope sediments, but usually used in steeply sloping landscapes such as bedrock hills.

Coprogenous earth — Material that was deposited in a lake and contains many fecal pellets, is dark in color, has gel-like consistence when moist, and, when dried, shrinks greatly, becomes very hard, and does not re-wet.

Depression fill — A thin deposit in depressions derived by erosion processes from upslope.

Diatomaceous earth — Material deposited in a lake that contains many diatom shells, which are high in silica.

Drift — Any rock material transported by a glacier and deposited by ice or by melt water; A collective term for till and outwash. Specify if the material is till or outwash if possible.

Eolian sand — Sand transported and deposited by the wind, mainly medium and fine sand.

Hillslope sediment — A thin deposit on lower slope positions derived by erosion processes from upslope; similar to colluvium, but usually in thinner deposits; in Indiana, it often occurs in gently sloping landscapes, such as till plain depressions.

Lacustrine deposit — Inorganic material, mainly silt and clay, deposited in a lake or other body of still water by non-biological processes.

Limnic material — Organic and inorganic material that was deposited in a lake by algae, diatoms, or other organisms. Limnic materials include coprogenous earth, marl, and diatomaceous earth.

Loess — Mainly silt-size material transported and deposited by the wind.

Marl — Material deposited in a lake that is light in color and contains much $CaCO_3$, largely fragments of shells.

Organic deposit — An accumulation of partially decayed plant material. Usually it occurs as thick deposits in former lakes or as thin surface layers, overlying mineral soil material, under forest. Organic deposits are subdivided according to their degree of decomposition — fibric material (peat) is slightly decomposed, hemic material (mucky peat) is moderately decomposed, and sapric material (muck) is highly decomposed.

Outwash — Stratified coarse-textured material washed out from a glacier by meltwater streams and deposited in front of the margin of an active glacier Particle size is mainly sand and gravel.

Residuum — (saprolite) Unconsolidated weathered or partly weathered mineral material that accumulates by disintegration of bedrock essentially in place.

Till — Unsorted and unstratified material deposited by glacier ice, and consisting of a heterogeneous mixture of clay, silt, sand, gravel, stones, and boulders; dense till has a bulk density of $\geq$1.75 Mg m^{-3} (g/cm^3), and friable till has a density of <1.75 Mg m^{-3}.

Most of the definitions in this table were derived from the Glossary of Geology (Jackson, 1997) and Soil Taxonomy (Soil Survey Staff, 1999).

capacity, which result in droughty soils. Soils formed in loess have high available water holding capacity, but they are very subject to water erosion and they tend to form surface crusts readily if the organic matter content is low. Soils formed from eolian sand are especially subject to wind erosion. If the parent material was carried by the wind, the soil material can also be picked up by the wind. The kind of parent material also influences soil chemical properties. Much of the till in Indiana is calcareous, which tends to keep the pH of the entire soil relatively high and maintain high levels of exchangeable Ca and Mg. On the other hand, some shale bedrock contains sulfur and the soils formed from them are very acid and high in aluminum, which may cause plant toxicity problems.

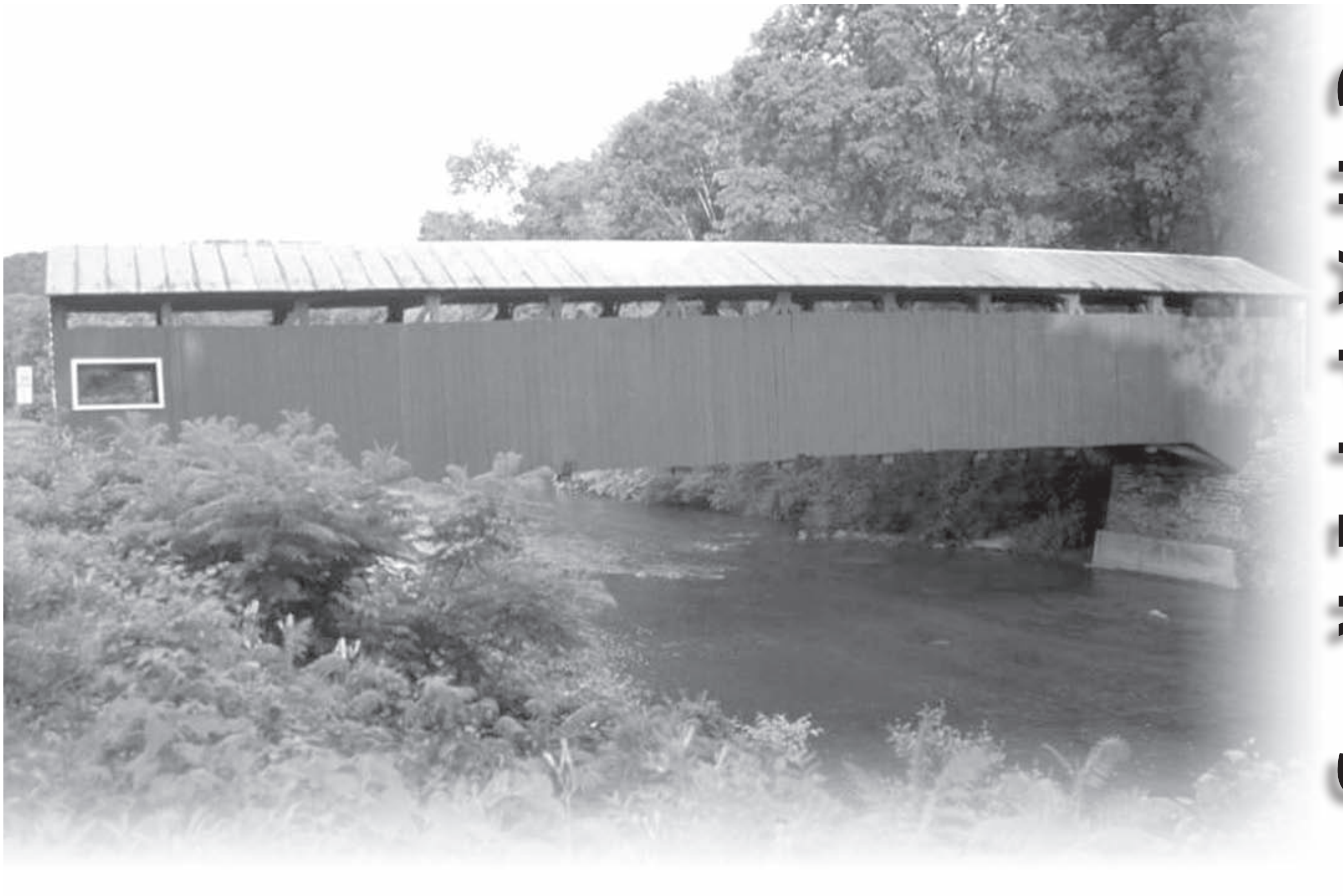
Some parent materials are further described by the age of the deposit. The age of the various geologic periods and glacial events of the Quaternary Period are listed in Table 2. Essentially all of Indiana is underlain by sedimentary bedrock deposited during the Ordovician, Silurian, Devonian, Mississippian and Pennsylvanian Periods, millions of years ago. Soils had formed on these rocks, but many of these soils were eroded. Many of the eroded soils were later covered with deposits related to Wisconsinan and Illinoian glaciations, 10s to 100s of thousands of years ago. In southern Indiana, beyond the area covered by glaciers, many old eroded soils, formed in bedrock, were highly eroded and then covered by younger deposits, especially loess. The old, buried soils are called paleosols.

Table 2. Geologic time scale. Most geologic materials in Indiana were deposited during periods in bold type.

Time, millions of years	Geologic Period	Time, years	Subdivision of Quaternary Period
1.8 - present	**Quaternary**	8,000 - present	**Holocene Epoch**
65 - 1.8	Tertiary	1,800,000 - 8,000	**Peistocene Epoch**
145 - 65	Cretaceous	75,000 - 8,000	**Wisconsinan glacial**
213 - 145	Jurassic	200,000 - 75,000	Sangamon interglacial
248 - 213	Triassic	250,000 - 200,000	**Illinoian glacial**
286 - 248	Permian	600,000 - 250,000	Yarmouth* interglacial
325 -286	**Pennsylvanian**	750,000 - 600,000	Kansan* glacial
360 - 325	**Mississippian**	900,000 - 750,000	Aftonian* interglacial
410 - 360	**Devonian**	? - 900,000	Nebraskan* glacial
440 - 410	**Silurian**		
505 - 440	**Ordovician**		
544 - 505	Cambrian		
4,500 - 544	Precambrian		

***** These names are used in much older literature, but because the ages of glacial events older than 200,000 years cannot be determined accurately, the names are usually not used in recent literature.*

Because of uncertainties about the ages of older glacial events during the Pleistocene, the ages older than Illinoian are now called Pre-Illinoian instead of Kansan or Nebraskan. During the Pleistocene, soils were formed mainly during the warm interglacial periods. Many of these soils were also subsequently eroded, and some were buried by younger loess. In Indiana, soils that are now paleosols formed during many different geologic times.



CHAPTER 3

LANDSCAPES, LANDFORMS, AND LANDFORM COMPONENTS

The objective of this chapter is to foster an understanding of the landscape relations of a site, i.e., "lay-of-the-land," and to provide terminology that will encourage effective communication about soils in their natural setting. Landscape relations affect how water moves over and through soils.

The spatial setting of soils in the landscape is described at several levels of generalization. From more general to more specific, they are:

(1) Physiographic divisions and soil regions shown on small maps of the state

(2) Landscapes

(3) Landforms

(4) Landform components

(5) Additional descriptors

PHYSIOGRAPHIC DIVISIONS and SOIL REGIONS

The Physiographic Units of Indiana were first described by Prof. C. A. Mallot in 1922, and were redefined and named as Physiographic Divisions (Fig. 2) by Gray (2000). They represent the shape of the land surface, whether it is hilly, flat, or in between. The legend for Figure 2 includes some terms that are explained below.

Ice disintegration features. Landscape features formed when ice melted in place (stagnant ice). They are characterized by strata and bodies of outwash intermingled with masses of till.

Ridged till. Ridges of till, usually oriented parallel to the ice front. For example, in the Valparaiso Morainal Complex the ridges are concentric around the southern shore of Lake Michigan.

Tunnel valleys. Tunnel valleys are broad, flat-bottomed troughs as much as a mile wide and 20 miles long that cut sharply across morainal uplands, usually perpendicular to ridges of till. They were major outlets through which meltwater was channeled beneath the glacier or within ice-walled open conduits to the margin of the ice. The tunnel valleys themselves contain a complex interspersion of bodies of till and stratified drift. They end in outwash fans in front of the moraines.

The ages of the geologic deposits, which are closely related to physiography, are given in Table 2. The area between the lines labeled "Southern limit of Wisconsin glacial deposits" and "Southern limit of older deposits" in Figure 2 has been considered to consist mainly of Illinoian age deposits, but some deposits might be older.

The map of the Soil Regions (Fig. 3), at a similar scale, reflects the nature of the soil parent material as well as the shape of the land surface. It also shows the areas that were in prairie vegetation when settlers first arrived.

The Soil Regions map (Fig. 3) generally reflects the Physiographic Division map, but there are important differences. The soil map is based mainly on the kinds and ages of the parent materials in which the soils formed, while the physiographic division map is based mainly on the shape of the land surface. Loess, around 0.5 to 2 m thick, covers much of the state. This thickness of loess changes the overall topography very little, so loess deposits are not reflected in the physiographic divisions. Loess, however, greatly influences soil properties, and is reflected in the definitions of soil regions.

Figure 2. Descriptions (below) and map (facing page) of the physiographic divisions and glacial boundaries of Indiana (Gray, 2000).

Physiographic Divisions of Indiana

Northern Moraine and Lake Region

Lake Michigan Border
Beach ridges, dunes, lake plains, and minor morainal areas

Valparaiso Morainal Complex
Ridged till of northern source crossed by tunnel-valleys and bounded by an alluvial-fan apron

Kankakee Drainageways
Broad tracts of sandy outwash, lake plains, and scattered clusters of dunes

St. Joseph Drainageways
Broad tracts of sandy outwash

Plymouth Morainal Complex
Disorganized ridged till and stratified drift of northern, northeastern, and eastern source

Warsaw Moraines and Drainageways
Ridged till of eastern source crossed by tunnel-valleys and bounded by an alluvial-fan apron

Auburn Morainal Complex
Ridged till of eastern source and minor areas of outwash

Maumee Lake Plain Region

Lake plain with a few low beach ridges

Central Till Plain Region

Bluffton Till Plain
Large areas of till plain with a concentric series of end moraines

Iroquois Till Plain
Till plain of very low relief with minor areas of end moraine

Tipton Till Plain
Till plain of low relief with extensive areas of ice-disintegration features

New Castle Till Plains and Drainageways
Till plains of low relief crossed by many major tunnel-valleys

Central Wabash Valley
Till plain deeply dissected by the Wabash River and major tributaries

Southern Hills and Lowlands Region

Wabash Lowland
Broad terraced valleys and low till-covered hills

Boonville Hills
Bedrock hills of moderate relief

Martinsville Hills
Bedrock hills of high relief strongly modified by pre-Wisconsin glacial activity

Crawford Upland
Bedrock hills of high relief

Mitchell Plateau
Rolling clay-covered upland of low relief and large areas of karst, entrenched by major valleys

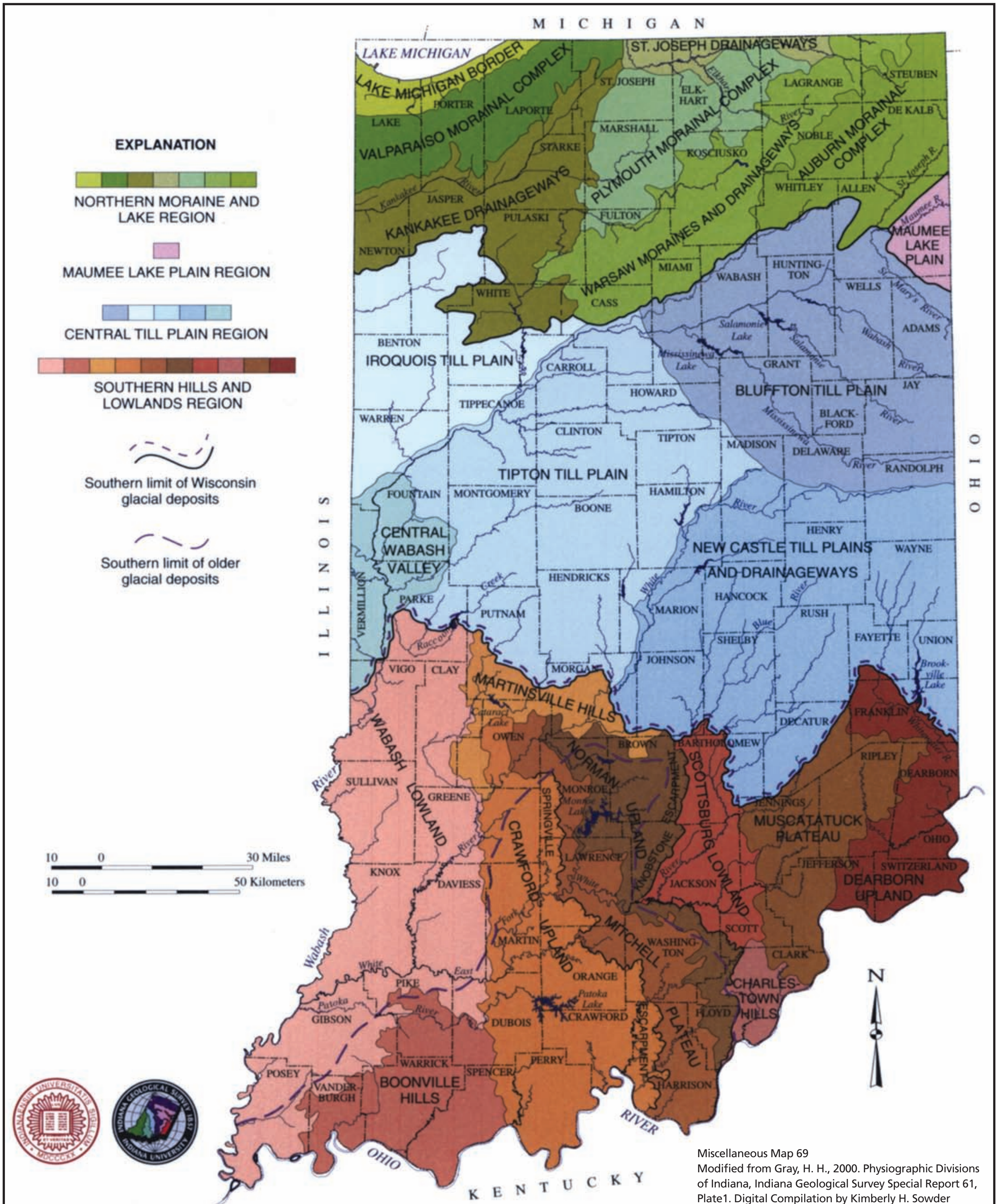
Norman Upland
Bedrock hills of high relief

Scottsburg Lowland
Broad terraced valleys and low till-covered hills

Charlestown Hills
Bedrock hills of low relief somewhat modified by pre-Wisconsin glacial activity

Muscatatuck Plateau
Broad till-covered uplands entrenched by major valleys

Dearborn Upland
Bedrock hills of high relief



Miscellaneous Map 69
Modified from Gray, H. H., 2000. Physiographic Divisions of Indiana, Indiana Geological Survey Special Report 61, Plate1. Digital Compilation by Kimberly H. Sowder

MAP OF INDIANA SHOWING PHYSIOGRAPHIC DIVISIONS
By Henry H. Gray 2001

Loess that was deposited about 15,000 to 20,000 years ago covers materials that are very different from each other in age (Table 2) and in stage of weathering. In Soil Regions 1 through 9 (except 5) loess was deposited shortly after the underlying till or other material was deposited in Wisconsinan time. In Soil Region 10, however, the material under the loess was deposited a few hundred thousand years ago in Illinoian time, and in Soil Regions 11 and 12 the rock under the loess was deposited hundreds of millions of years ago. The parent material in Region 5 is deep loess which covers materials of different ages.

Superimposed on the soil regions map (Fig. 3) is a shading pattern that depicts pre-settlement natural vegetation. At the time of European settlement, most of the state was cover by hardwood forest. Some of the state, however was under prairie, and these areas

Figure 3. Descriptions (below) and map (facing page) of the Soil Regions (SR) of Indiana.

SR 1 — Low-lying, sandy and loamy, wet soils on sandy outwash and lacustrine plains with scattered dry sand dunes; mainly Aquolls, Psamments, and Udolls, used for row crops, and recreation areas.

SR 2 — Medium- and fine-textured, wet soils on lake plains; mainly Aqualfs, Aquolls, and Aquepts, used for row crops.

SR 3 — Medium- and coarse-textured, dry soils on outwash plains, terraces, and flood plains; mainly Udalfs, Udolls, Ochrepts, and Fluvents, used for row crops and natural vegetation.

SR 4 — Dry soils on sand dunes; mainly Udalfs and Psamments, used for forage crops, row crops, fruits and vegetables.

SR 5 — Silty, moist soils on loess hills; mainly Udalfs and Aqualfs, many with fragipans, used for row and forage crops.

SR 6 — Rolling, loamy, moist soils on Wis-consinan end moraines; mainly Udalfs and Aqualfs, used for forage crops (largely for dairy cattle), and row crops.

SR 7 — Fine-textured, wet soils on Wisconsinan till plains; mainly Aqualfs, Aquolls, and Udalfs, used for row crops.

SR 8 — Medium-textured, wet soils on Wisconsinan till plains; mainly Aqualfs, Aquolls, Udalfs, and Udolls, used for row crops.

SR 9 — Medium textured, wet soils on loess-capped Wisconsinan till plains; mainly Aqualfs, Aquolls, Udalfs, and Udolls, used for row crops.

SR 10 — Silty, wet soils on thick loess over Illinoian till; mainly Aqualfs and Udalfs, many with fragipans, used for row crops.

SR 11 — Hilly, silty, moist soils formed in loess and siltstone, sandstone, and shale; mainly Udalfs, many with fragipans, used for forestry, pasture, and forages.

SR 12 — Fine-textured, moist soils formed in loess and weathered limestone on karst topography; mainly Udalfs, used for pasture, forage crops, and row crops.

SR 13 — Hilly, medium-textured moist soils formed in loess and weathered shale and limestone; mainly Udalfs, used for forage crops and pasture.

Explanation of terms and patterns:

Dry — Mainly well drained soils with low water holding capacity.

Moist — Mainly medium textured soils with moderate water holding capacity and a range of natural drainage conditions.

Wet — Mainly poorly and somewhat poorly drained soils.

Meanings of formative elements:

Aqu-: Poorly drained soils.

Fluv-: Soils on flood plains.

Ochr-: Light-colored surface horizons.

Psamm-: Sandy soils.

Ud-: freely drained soils in a humid climate.

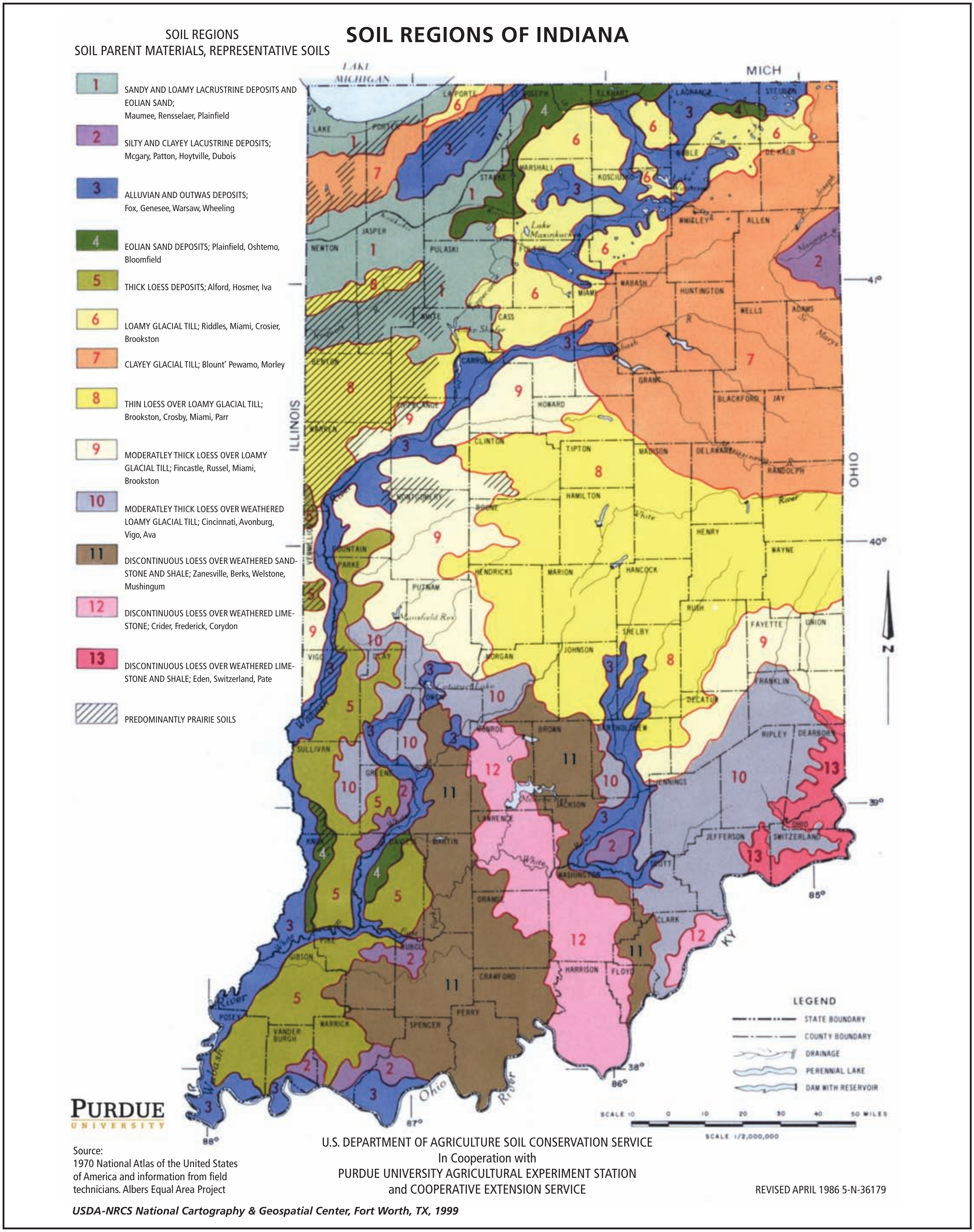
-alfs: soils with a subsoil clay accumulation.

-epts: weakly developed soils.

-ents: soils that lack distinctive horizons.

-olls: soils with a dark surface horizon.

Predominantly prairie soils. Dark colored soils cover the entire landscape. The rest of the state has predominantly forested soils with light soils on the higher areas.


SOIL REGIONS OF INDIANA
SOIL REGIONS
SOIL PARENT MATERIALS, REPRESENTATIVE SOILS
1 SANDY AND LOAMY LACRUSTRINE DEPOSITS AND EOLIAN SAND; Maumee, Rensselaer, Plainfield
2 SILTY AND CLAYEY LACUSTRINE DEPOSITS; Mcgary, Patton, Hoytville, Dubois
3 ALLUVIAN AND OUTWAS DEPOSITS; Fox, Genesee, Warsaw, Wheeling
4 EOLIAN SAND DEPOSITS; Plainfield, Oshtemo, Bloomfield
5 THICK LOESS DEPOSITS; Alford, Hosmer, Iva
6 LOAMY GLACIAL TILL; Riddles, Miami, Crosier, Brookston
7 CLAYEY GLACIAL TILL; Blount' Pewamo, Morley
8 THIN LOESS OVER LOAMY GLACIAL TILL; Brookston, Crosby, Miami, Parr
9 MODERATLEY THICK LOESS OVER LOAMY GLACIAL TILL; Fincastle, Russel, Miami, Brookston
10 MODERATLEY THICK LOESS OVER WEATHERED LOAMY GLACIAL TILL; Cincinnati, Avonburg, Vigo, Ava
11 DISCONTINUOUS LOESS OVER WEATHERED SAND-STONE AND SHALE; Zanesville, Berks, Welstone, Mushingum
12 DISCONTINUOUS LOESS OVER WEATHERED LIME-STONE; Crider, Frederick, Corydon
13 DISCONTINUOUS LOESS OVER WEATHERED LIME-STONE AND SHALE; Eden, Switzerland, Pate
PREDOMINANTLY PRAIRIE SOILS
LAKE MICHIGAN
MICH
ILLINOIS
OHIO
KY
41°
40°
39°
38°
85°
86°
87°
88°
N
LEGEND
STATE BOUNDARY
COUNTY BOUNDARY
DRAINAGE
PERENNIAL LAKE
DAM WITH RESERVOIR
SCALE 10 0 10 20 30 40 50 MILES
SCALE 1/2,000,000
PURDUE UNIVERSITY
Source:
1970 National Atlas of the United States of America and information from field technicians. Albers Equal Area Project
U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE
In Cooperation with
PURDUE UNIVERSITY AGRICULTURAL EXPERIMENT STATION
and COOPERATIVE EXTENSION SERVICE
REVISED APRIL 1986 5-N-36179
USDA-NRCS National Cartography & Geospatial Center, Fort Worth, TX, 1999

are shown by a diagonal line pattern. In the originally forested areas, soils on the higher parts of the landscape are light in color and those in the lower parts are mainly dark. In prairie areas, however, soils are dark across the whole landscape, except where they have been eroded. Thus, soils are a good indicator of native vegetation.

LANDSCAPES

A landscape, in general terms, is the portion of the land surface that the eye can see in a single view. A landscape painting, for example, is an artist's representation of a landscape. More technically a landscape is a collection of landforms (Ruhe, 1969). Thus, in general, landscapes are larger than landforms, and landforms are larger than landform components, but no universal size limits have been set.

LANDFORMS

A *landform* is a physical feature on the Earth's surface that has a characteristic shape and was produced by natural causes (Ruhe, 1969). Some landforms were formed by *erosional* processes, and others by *depositional* or constructional processes. The current shape of a depositional surface is about the same as when the material beneath it was deposited, so there is a close association between depositional landforms and parent materials. Dunes, moraines, terraces, lake plains, and flood plains have depositional surfaces. Hills carved out of bedrock and ravines cut into various deposits by geologic water erosion have erosional surfaces, and have less association between landforms and parent materials.

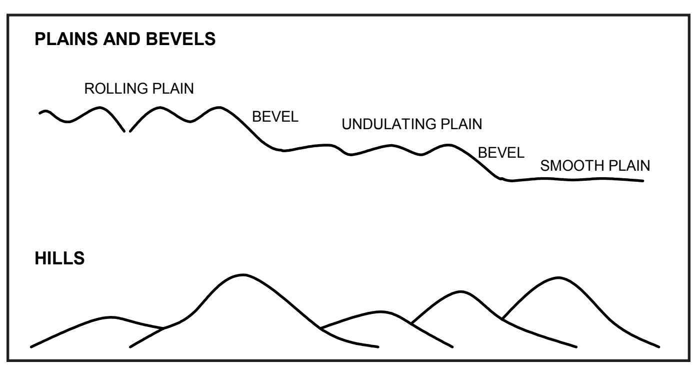
In general usage, the term *hill* means an elevation of the land surface. *Hillslope* is a more technical term that refers to the portion of a hill from the top of a hill to the drainageway at the bottom of the hill. Hillslopes can be divided into specific components. In this section the term *hills* is used in a more restrictive sense, as explained below. Whether the term is used in a general or restrictive sense should be apparent from the context.

Plains-bevels-hills

We use three terms to describe landforms in Indiana: plains, bevels, and hills. A *plain* is a land surface that is flat to gently sloping in overview, but may be smooth, undulating, or rolling on closer examination (Fig. 4). Karst plains, till plains, outwash plains, terraces, sand plains, lake plains, and flood plains, are plain landforms. Lake plains and flood plains are often smooth. Till plains are undulating. Karst plains are rolling, but the summits all have about the same elevation (accordant summits). The Great Plains of the U.S. and the High Plains of Texas also have mostly rolling topography.

A *bevel* is a sloping surface that cuts a plain. When a woodworker starts with a board that has all square corners and saws or planes the edge at a 45° angle, the surface created is called a bevel. The process is similar in landscapes. Over geologic time water erosion cuts back into a plain and the cut surface is called a bevel. Streams cut a much more jagged surface than the saw or plane, however. Rogers (undated) uses another analogy in describing a beveled surface in New York state: "The broad bands on the map in that area are the patterns made by stacked layers that have been beveled at a low angle by erosion. (Visualize a layer cake sliced at a low angle instead of the usual vertical.)." More technically, a *bevel* is an erosion surface that cuts, and descends from, a plain. A bevel is named for the plain from which it descends, e.g., a till plain bevel cuts and descends from a till plain. A terrace bevel descends from a terrace, down to a lower terrace level or to a flood plain. The bevel of a flood plain may descend to a river. The terms *bevel* (used as a noun or a verb) and *beveled* are commonly

Figure 4. Cross-sectional diagram illustrating three major kinds of landforms: plains, bevels, and hills. In a *rolling plain,* such as a karst plain, the high areas (crests) are about the same elevation, but the tops of *hills*, such as in a moraine, are different elevations.



used in geology and soil science (Ruhe, 1969, p. 87; Ruhe et al., 1967, page 75).

The term *hills,* as used here in a more restrictive geomorphic sense, refers to a set of hills with different summit elevations (discordant summits). Examples include moraines, kames, dunes and highly dissected bedrock areas. In contrast, the summits of rolling plains are similar in elevation (Fig. 4). *Bevels* may appear to be "hilly" to the casual observer but they differ in that bevels are always associated with the edges of plains, while hills are not. A bevel may also cut a hill, but because it is very difficult to distinguish the slope related to the bevel from the slope of the hill, bevels that cut hills are considered part of the hill.

The Landforms of Indiana

Landforms vary greatly in their size and shape. Some landforms cover areas of hundreds of square miles (kilometers), while other landforms may cover only a few acres (hectares).

Landform Names

Hills and plains are often named for the material in which they formed or the process by which the material was deposited, e.g., sandstone hills, loess hills, till plains, outwash plains, and flood plains (Table 3). In some cases the kind of material is implied in the landform name, e.g., moraine, terrace, and dune. Bevels are named for the plain from which they descend.

Some problems arise in naming landforms covered with loess. A foot or so (half-meter) of loess does not greatly change the shape of the land surface it covers, and soil properties tend to be influenced more by the material below the loess than by the loess itself. On the other hand, several feet (meter) of loess changes the shape of the land surface somewhat, but this much loess greatly influences soil properties. Some arbitrary cut-off points are needed to name landforms. Accordingly, a plain is called a *loess plain* and a hill is called a *loess hill* if the loess mantle is thicker than six feet (2 m). In mapping soils, few observations extend deeper than six feet, so in loess more than six ft. deep, it is not known with much certainty what kind of material below the loess controls the shape of the land surface. For example, the loess may be on bedrock, till, lacustrine deposits, or outwash. If the loess is thinner than six feet on plains or hills, the landform is named for the kind of underlying material.

To preserve a relationship in the names of landforms within a landscape, a bevel landform is named for the plain from which it descends. Thus, a bevel that descends from a loess plain is called a *loess plain bevel* regardless of the thickness of loess on the bevel. Usually loess is thinner on a bevel than it is on the associated plain, so a loess plain bevel often has less than six feet of loess.

The landforms that occur in Indiana are defined in Table 3. To make it easier to remember their major properties, they are grouped according to their size. The large landforms cover extensive areas of the state and consist of various large plains and hills. Some of the large landforms, like terraces and flood plains, are long and linear and are associated with streams and rivers. The various bevels are long, linear landforms, too. Many of them are associated with streams and rivers, although not exclusively.

The small land forms usually cover only a few acres (hectares) within the large landforms. It is not unusual, for example, to find kames, eskers, beach ridges, and bogs within a till plain, or kames, bogs, and dunes associated with the terraces and flood plain of a river.

For many years in Indiana, certain land areas have been called uplands, terraces, or bottomlands. *Terraces* are defined (Table 3) and *bottomlands* are equivalent to flood plains. All other landforms are *uplands,* including dunes, kames, and beach ridges

Landscapes Versus Landforms Revisited

Now that landforms have been defined, it is easier to understand the difference between "landscapes" and "landforms." For example, by standing on a till plain and looking across a river valley, one can often see landforms like a till plain, a till plain bevel, a terrace, a terrace bevel, a floodplain, a floodplain bevel, and perhaps a kame or dune, all from the same vantage point. All of these landforms

Table 3. Definitions of landforms.

Large landforms that cover extensive areas (up to hundreds of square miles)

Hills - describe further with component descriptors for hill and bevel landforms.

Limestone hills — A set of hills overlying limestone.

Sandstone hills — A set of hills mainly on weathered sandstone, siltstone, or shale in the Norman Upland, Martinsville Hills, Crawford Upland, and Boonville Hills physiographic divisions.

Shale hills — A set of hills mainly on weathered shale, or interbedded shale and limestone in the Dearborn Upland and Muscatatuck Plateau physiographic divisions..

Moraine — A mound, ridge, or other distinct accumulation (depositional surface) of glacial drift, predominantly till.

Loess hills — A set of hills on deep loess (>about 6 ft. or 2 m). Usually a landform below the loess controls the topography, but the nature of this underlying landform may not be known because of the thick loess cover. Where loess is thinner, the landform is named according to the material below the loess (e.g., till).

Kame moraine — A moraine that contains numerous kames.

Dune — A low mound, ridge, bank, or hill of loose, wind-blown sand. Collectively, *dunes or dune field*. An individual dune may be small, but a dune field may be relatively large.

Plains - describe further with component descriptors for plain landforms

Sandstone plain — A nearly level surface underlain by sandstone, siltstone, or shale.

Karst plain[1] — A type of topography that is formed on limestone by dissolution, and that is characterized by sinkholes, caves, and underground drainage.

Till plain — An extensive area, with a flat to undulating surface, underlain mainly by till

Loess plain — A nearly level surface on deep loess (> about 6 ft. or 2 m). Usually a plain landform below the loess controls the topography, but the nature of this underlying plain may not be known because of the thick loess cover. Where loess is thinner, the landform is named according to the material below the loess (e.g., till).

Outwash plain — A broad, gently sloping area of outwash, not contained in a valley, deposited by meltwater streams flowing in front of or beyond a glacier.

Terrace — A long, narrow, relatively level or gently inclined surface, bounded on one edge by a steeper descending slope (terrace bevel) and along the other edge by a steeper ascending slope, contained in a valley and composed of unconsolidated material such as outwash. Also called a tread.

Lake plain — A nearly level surface marking the floor of an extinct lake that had been filled in by well-sorted deposits, mostly silt and clay size, from inflowing streams.

Sand plain — A sand-covered plain consisting of sandy outwash.

Flood plain — The surface or strip of relatively smooth or level land adjacent to a river channel, constructed by the present river in its existing regimen and covered when the river overflows its banks.

Bevels (associated with plains, above) - describe further with component descriptors for hill and bevel landforms

Sandstone plain bevel — An erosional surface that descends from a sandstone plain.

Till plain bevel — An erosional surface that descends from a till plain.

Loess plain bevel — An erosional surface that descends from a loess plain. Usually the loess is thinner on the bevel than on the plain.

Outwash plain bevel — An erosional surface that descends from an outwash plain.

Terrace bevel — An erosional surface that descends from a terrace. Also called a riser.

Lake plain bevel — An erosional surface that descends from a lake plain.

Flood plain bevel — An erosional surface that descends from a flood plain.

Smaller landforms - describe further with appropriate descriptors

Alluvial fan — A low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or segment of a cone.

Beach ridge — An essentially continuous mound of beach deposits beyond the beach that has been heaped up by wave action.

Beach — The gently sloping shore of a body of water that is washed by waves.

Bog — A lake or depression filled with organic soil. The term is used in a general sense; more specific definitions may differentiate among bog, marsh, swamp, fen, or other types. Large bogs are considered to be landforms, and small ones to be landform components.

Esker — A long, narrow sinuous ridge composed of irregularly stratified sand and gravel that was deposited by a stream flowing in a stagnant or retreating glacier.

Kame — A low mound, knob, hummock, or short irregular ridge composed of stratified sand and gravel deposited by a subglacial stream as a fan or delta at the margin of a melting glacier.

Raised bog — An area of organic soil in which the center is higher than the margins.

Strath terrace — A terrace underlain by bedrock.

Most of the definitions in this table were derived from the *Glossary of Geology* (Jackson, 1997).

[1] Although positions on the gently rolling areas of a karst plain are best described using plain components, positions within deeper sinkholes are often best described using hillslope components.

together make up the landscape that one sees from that vantage point.

LANDFORM COMPONENTS

The landforms just discussed can be subdivided further into a number of *landform components*. One set of names (descriptors) is used for all landforms classed as "hills" or "bevels" in Table 4, while another set is used for all landforms classed as "plains." A few descriptors, for example, sink hole, natural levee, and bog, are used only for specific landforms.

Hillslope Components

This set of terms is used mainly with hill and bevel landforms. The geometry of a slope can be characterized by describing its form as if one first cut through the hillslope vertically to view it from the side, the slope profile, and then cut through the hillslope horizontally to view it from the top, the slope contour (Ruhe, 1975).

Theoretical Geometric Forms of Hillslopes

Slope contours and slope profiles can be convex, straight, or concave. Combining slope contours and slope profiles results in nine general *geometric forms of hillslopes* (Fig. 5). To further illustrate these forms, the outside of a ball is convex-convex (VV), the inside of a bowel is concave-concave (CC), and the inside of a funnel is linear-concave (LC). Although we will not use the convex-convex, linear-concave, etc. terminology in our descriptions of a specific site, we will show below how certain areas of hillslopes tend to conform to one of these nine basic forms.

Hillslope Component Descriptors

Two sets of descriptive terms are used to describe a specific point on a hillslope. One set describes the slope profile, the other describes the slope contour. The slope profile descriptors consist of seven terms defined in Table 4 and illustrated in Figures. 6 and 7. The top of a hill or a bevel can be described as either a summit or a crest, depending on the topography of the immediate area. The slope contour descriptors consist of the three terms, nose slope, side slope, and head slope. These terms are defined in Table 4 and illustrated in Figure 6.

Combining slope contour and slope profile terms, the colloquial term, "knob," can be defined more precisely as a *nose slope, shoulder*, and the colloquial term "cove" or "hollow" as a *head slope, footslope*. The sequence of most of the profile descriptors is easy to remember if one thinks of the sequence from head to toe in the human body. The "summit" or "crest" is the top of the head, then comes the shoulder (slope), back (slope), foot (slope), and toe (slope). Slope contours determine if flow lines converge or diverge downslope. On head slopes, flow lines converge and runoff tends to be concentrated (as water flowing through a funnel). On nose slopes, however, flow lines diverge and runoff tends to be dispersed (as water poured on a ball). This distinction is important in understanding water erosion. Concentrated flow could result in gully erosion. On the other hand, divergent flow might be responsible for much sheet erosion. Hillslope profile terms are used to name all hill and bevel landform components; slope contour terms can be added if it seems to be important.

Plain Components

Another set of descriptive terms is used to define the components of undulating plain landforms. A *swell* is a slight convex rise in a gently undulating landscape, and a *knoll* is a more distinct rise. An arbitrary break is set at 3 % slope to distinguish the two. Similarly, a *pothole* is a more pronounced concave landform than a depression, but no slope gradient limits are set. A pothole could be within a depression.

Plain components can be thought of as symmetrical around flat. That is, a pothole has the opposite shape of a knob, and depression is the inverse of swell (Fig. 7). Plain components can be further subdivided if necessary. For example, one could call a certain area the shoulder of a till plain swell.

ADDITIONAL DESCRIPTORS

Additional terms can be used to describe specific points or small areas in a landscape quantitatively. They include relief, slope length, slope aspect, and slope gradient. These terms are defined in Table 5.

TERMINOLOGY
Binomial Nomenclature

In plant taxonomy, two terms, a genus and species name, identify a specific kind of plant. This binomial system of nomenclature is familiar to many people, and is proposed here to describe landscapes. A landform name plus a landform component name describe a relatively specific location on the land surface. For example, a certain site could be a till plain bevel, shoulder. Another site, probably in a forest, could be described as a sandstone hill, backslope.

In some cases additional descriptors can be added as shown in italics in these examples: Sandstone hill, backslope, *north aspect*; Till plain bevel, shoulder, *head slope*; Terrace, swell, *shoulder;* Karst plain, sinkhole, *backslope*; Till plain, depression, *footslope*. The last example describes the very bottom of a depression. It would accumulate water more readily than a till plain, depression

Table 4. Definitions of landform components. Terms are listed under the heading of the landform with which they are *usually* associated, but they may be used with other landforms. For example, potholes may occur in a moraine, a hill landform.

Component descriptors used mainly with hill and bevel landforms

Slope Contour descriptors

Head slope — A slope at the head of a small stream or drainageway, represented by concave contour lines and drainage lines that converge downward.

Nose slope — A slope at the end of a ridge, represented by convex contour lines and drainage lines that converge downward.

Side slope — A slope between a head slope and a nose slope, represented by straight contours and drainage lines.

Slope profile descriptors

Backslope — The straight and concave mid-portion of the hillslope. Some large backslopes may contain benches, scarps, or outcrops.

Bench — A long, narrow, relatively level or gently inclined surface cut into bedrock, bounded on one edge by a steeper descending slope and along the other edge by a steeper ascending slope.

Scarp — A very steep slope or cliff.

Outcrop — A part of the rock stratum that is exposed at the surface.

Crest — A convex surface at the top of a hill, or ridgetop; narrow tops of joined shoulders.

Drainageway — A course along which water moves in draining an area; narrow area of joined footslopes if cross section is U-shaped, or of joined backslopes if it is V-shaped.

Footslope — The gently sloping, slightly concave slope below the backslope.

Shoulder — Convex upper portion of the hillslope.

Summit — A broad, nearly level or gently sloping surface; when it is very large, it may be called a plain.

Toeslope — The lowest part of the hillslope formed on alluvium; when it is large, it may be called a floodplain.

Component descriptors used mainly with plain landforms

Depression — A slightly concave area in the midst of generally level land; an *open depression* has a natural outlet for surface drainage, and a *closed depression* has no natural outlet.

Flat — A general term for a level or nearly level surface marked by little or no relief; a surface with no apparent convexity or concavity. The term may be modified by adjectives that describe more specifically a location within the flat, such as the **interior** or **rim** of a flat.

Kettle — A depression in drift, made by the wasting away of a mass of glacier ice that had been wholly or partially buried in the drift.

Knoll — A small, low, convexly-rounded hill with slope >3%.

Pothole — A pot-shaped pit or hole, not over limestone, with no outlet; deeper and with steeper sidewalls than a depression. A pothole is usually smaller and tends to have more poorly drained soils than a kettle, but the two terms are not well differentiated.

Sinkhole — A depression, commonly funnel-shaped, over limestone, with underground drainage.

Swell — A well-rounded hill with slope ≤3%.

Component descriptors used with specific landforms, mainly flood plains

Backland — The lowland of a flood plain, between the natural levee and the base of a valley slope, that is not swampy or marshy.

Backswamp — Extensive marshy or swampy area of flood plains between a natural levee and the valley side.

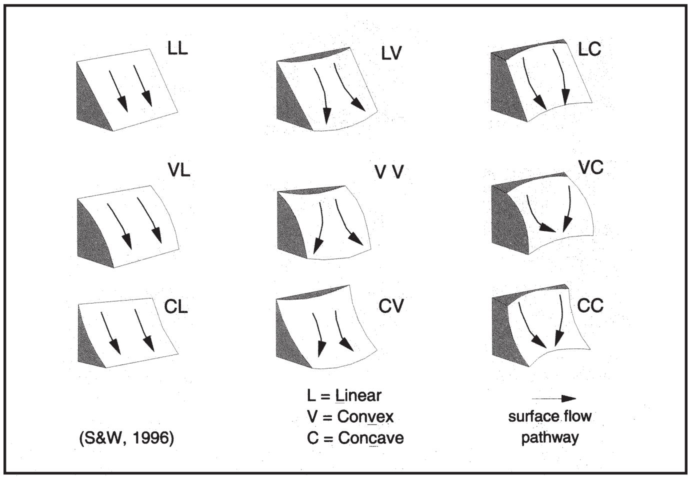
Bog (See definition under landforms.) — A small bog may be considered to be a landform component, e.g. a component of a lake plain.

Channel — The bed where a stream flows, may flow, or has flowed. Usually used with flood plains.

Natural levee — A long, broad, low ridge or embankment of sediment, built by a stream on its flood plain along its channel. Natural levees are built during floods when water overflows the normal banks and deposits the coarsest part of its load.

Most of the definitions in this table were derived from the *Glossary of Geology* (Jackson, 1997) and Ruhe (1975).

Figure 5. Geometric components of hillslopes. Slope shape is described in two directions: 1) slope profile or how the slope looks from the side (linear, convex, or concave) and 2) slope contour or how it looks from above, or the shape of contours on a topographic map (linear, convex, or concave). In the diagram, the pairs of letters refer to the two viewing points; for example, CV means that the slope is concave (C) in side view and convex (V) when viewed from above. (From *Handbook*, adapted from Ruhe,1975).



backslope. These additional descriptors might be especially helpful to those who decide how to use soils for home sites or other intensive uses.

Use in Narrative Descriptions

The terminology can be used in narrative descriptions and applied at different degrees of generalization or to different scales of maps. When used to describe a soil series, such as in an official soil series description or in the description of a typifying pedon in a published soil survey, a more general description is used:

> *Miami soils* formed in less than 20 inches (50 cm) of loess over calcareous loam till. They occur on shoulders and backslopes of moraines and till plain bevels and on knolls of till plains.

> *Weikert soils* formed in weathered sandstone, siltstone, and lesser amounts of shale. They occur mainly on steep backslopes of sandstone hills, but may also occur on shoulders and footslopes.

The terminology used to describe the landscape position of a map unit (a collection of delineations) can be more specific:

> Delineations of *Miami silt loam, 2 to 6 percent slopes, eroded* are mainly on shoulders of till plain bevels, especially those shoulders on nose slopes.

A specific site, such as a pedon sampled for laboratory analysis, can be defined more quantitatively:

> A pedon of the Miami soil was sampled in a *Miami silt loam, 2 to 6 percent slopes, eroded* delineation, on an upper part of a nose slope shoulder on a till plain bevel. The slope gradient is 4% and the aspect is 20^{o} (north-northeast).

Figure 6. Geomorphic components of hillslopes (Ruhe, 1975) The upper diagram is a view from above, the lower diagram is a view from the side and represents a cross section through any of the dashed lines in the stippled area of the upper diagram.

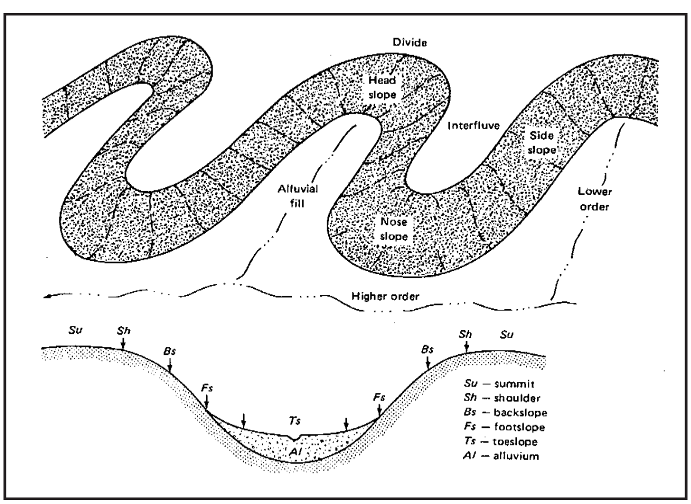


Figure 7. Cross-sectional diagram illustrating landform components. A crest is the coalescence of two shoulders, a drainageway is the coalescence of two footslopes. A swell has a slope gradient of ≤3%; a knoll, ≥3%. Landform components are defined in Table 4.

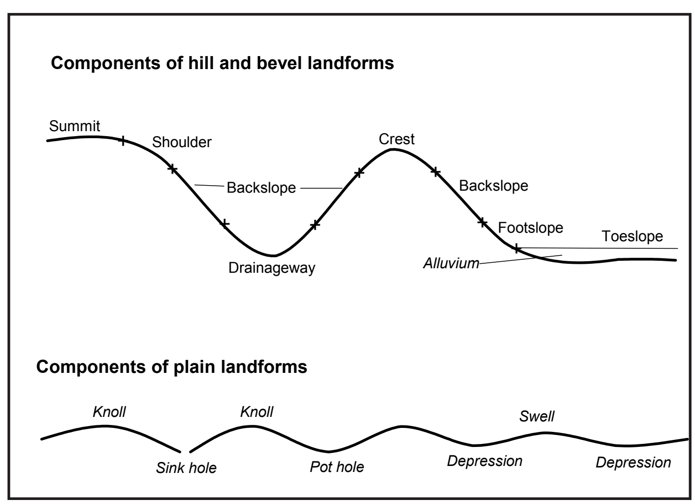


Table 5. Quantitative descriptors for landforms and landform components.

Relief The difference in elevation within a landscape or between two specific landforms or point.

Slope length The linear distance between two points on a hillslope, e.g., between the divide and the stream channel, or the length of a specific hillslope component. Soil length is a component of many soil erosion prediction models, and the models may vary in how to determine slope length.

Slope aspect The direction toward which a slope faces.

Slope gradient The degree of inclination with respect to the horizontal. In soil science, gradient is usually expressed in percent, e.g., the number of feet of vertical rise in 100 feet of horizontal distance.

The local relief is 30 ft. (9 m). The soil formed in 13 in (32 cm) of loess over dense, calcareous loam till.

RELATION OF SOILS, PARENT MATERIALS, LANDFORMS, AND LANDFORM COMPONENTS

Knowing the kind of parent material aids the identification of landforms, and knowing the kind of landform aids the identification of parent materials. One learns to identify them together. The shape of the landform determines how water moves across the land surface and, to a large extent, how it moves beneath the surface. Because of its influence on water movement, the kind of landform has a major influence on water erosion. In models that predict water erosion, hillslope length and gradient are the major factors that determine the amount of soil lost. Because of water movement within a landscape, hillslope position also influences the amount of water available for plant growth. Soils in depressions tend to receive water from those higher in the landscape during the growing season. In most years this is beneficial to crop yield, but in wet years crops may drown out in depressions. Landscape position is also very important in deciding where to build a house or place an on-site waste disposal system. Homes have become unlivable because the disposal system was placed in a depression, and the soil had to accept surface run-on in addition to the water supplied through effluent lines.

BLOCK DIAGRAMS

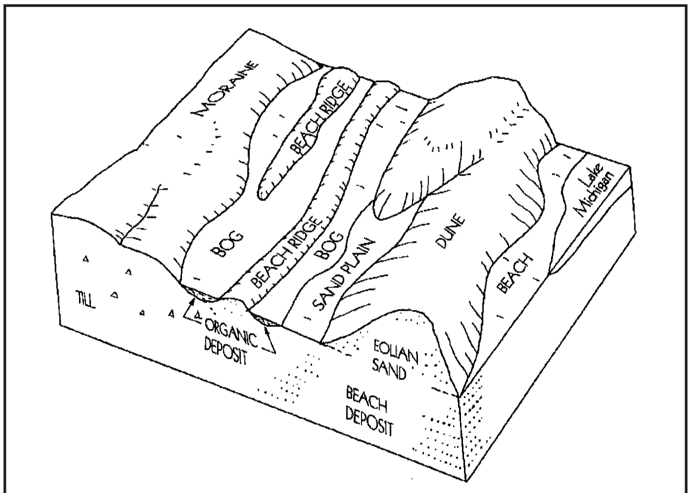
Block diagrams illustrate the relationships among parent materials, landforms, and landform components. In these diagrams, parent materials are labeled with upper case letters on the side faces of a diagram, landforms are labeled in upper case letters on the surface, and landform component names are in upper and lower case letters on the surface.

Figure 8 shows the relation among landforms near the southern tip of Lake Michigan. If the diagram were larger, summit, backslope, and footslope components could be identified on the moraine and dune. These terms could also be used on the beach ridge if it were fairly large; smaller beach ridges generally would not be subdivided into components.

The Kankakee Drainageways physiographic division (Fig. 9) formed when glacial meltwater streams meandered across the former flood plain and deposited sandy outwash material to form a sand plain. When the plain dried out, wind picked up sand grains and piled some into dunes. The upper part of the soils on the flat sand plain also may have been re-worked by the wind. The flood plain is only slightly lower in elevation than the sand plain.

In southwestern Indiana (Fig. 10), a band of dunes parallels the terraces of the Wabash and White Rivers. East of the dunes (right side of the diagram), loess covers an older landscape underlain by Illinoian

Figure 8. Block diagram illustrating landforms and parent materials in Soil Region 1 (Lake Michigan Border) and Soil Region 7 (Valparaiso Morainal Complex).



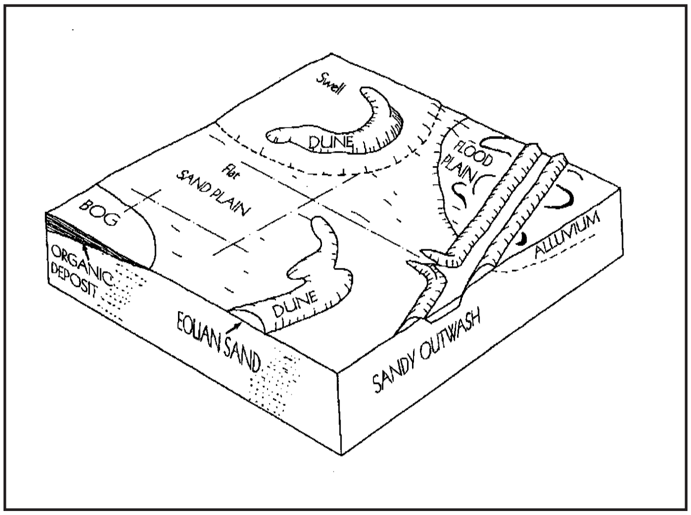


Figure 9. Block diagram illustrating landforms and parent materials in Soil Region 1 (Kankakee Drainageways). The channelized stream on the right illustrates the Kankakee River.

(or older) till. The loess becomes thinner eastward from the Wabash and White River valleys from which the loess originated. Where loess is thicker, the landforms are called loess hills.

Both outwash plains and terraces consist of outwash deposits. They differ in that a terrace is enclosed in a valley and an outwash plain is not (Fig. 11). The backland is the lower part of the flood plain, back from the stream. The higher part near the stream is a natural levee. The parent materials of kames and eskers is also outwash.

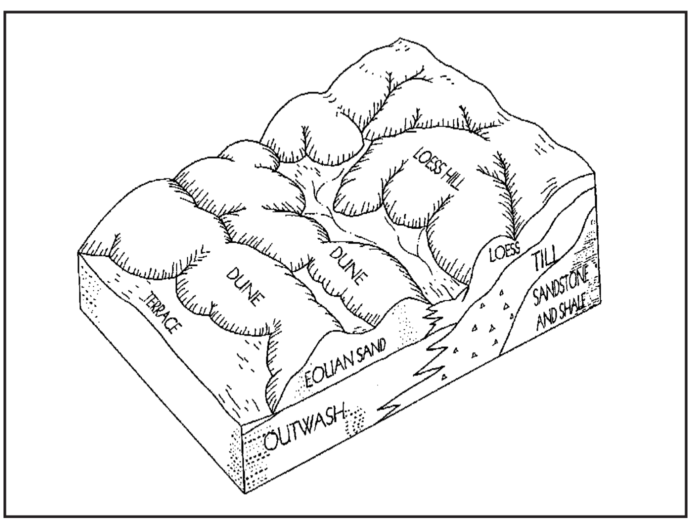


Figure 10. Block diagram illustrating landforms and parent materials in Soil Region 5 (Wabash Lowland) near the lower Wabash and White River Valleys.

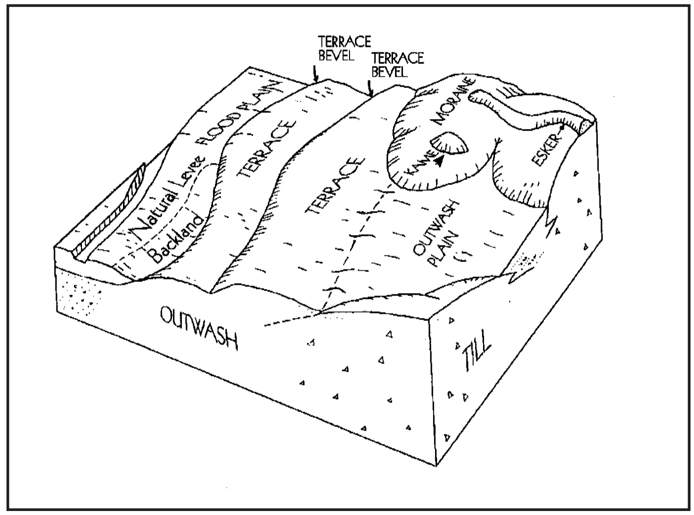


Figure 11. Block diagram illustrating landforms and parent materials in Soil Regions 3 and 6 (Plymoth Morainal Complex and Warsaw Moraines and Drainageways).

The till plains of central and northern Indiana have swell-and-swale topography. The swales, or depressions, mostly have open drainage (Fig. 12). The till plain bevel includes all of the sloping land between the till plain and the terrace or flood plain.

Wisconsinan loess was deposited soon after the till below it in Soil Region 9. Loess deposits smoothed out the landscape by filling in the low areas on the till

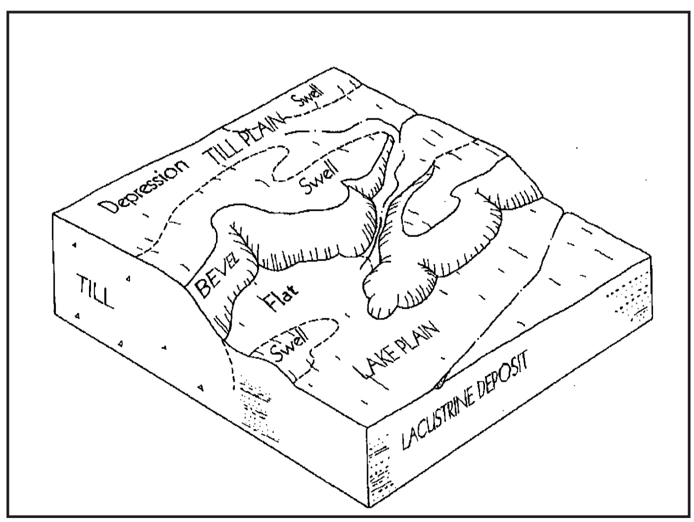
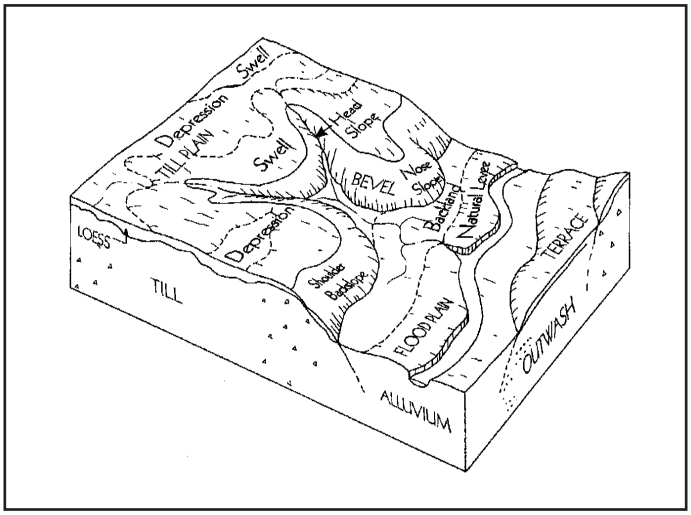


Figure 12. Block diagram illustrating landforms and parent materials in Soil Region 7 (Bluffton Till Plain and Auburn Morainal Complex) and Soil Region 8 (TiptonTill Plain and New Castle Till Plains and Drainageways), with little or no loess mantle (left side of the diagram), and in Soil Region 2 (Maumee Lake Plain, right side of the diagram).

Figure 13. Block diagram illustrating parent materials, landforms, and landform components in Soil Region 9 (Tipton Till Plain and New Castle Till Plains and Drainageways) with a mantle of loess.



surface (Fig. 13). In many depressions there are strata of depression fill sediments between the loess and the till. Apparently these materials were eroded from higher areas around the depression after the glacier receded and before most of the loess was deposited and the landscape became stabilized by vegetation. On the till plain in forested areas, the swells have light colored somewhat poorly drained soils (Aqualfs), and the depressions have dark-colored poorly drained soils (Aquolls). In prairie areas, the soils on the swells are Mollisols. Swells and depressions occur in a random pattern, like the spots on a Dalmatian dog, in this soil region. Several landform components are identified in this diagram. Shoulder and backslope are slope profile terms, and nose slope and head slope are slope contour terms. The area where BEVEL is printed is a side slope.

A moraine is a depositional feature consisting of irregular hills. After the glacier retreated, occasional blocks of ice remained in the glacial deposits. When the ice blocks melted, the deposits collapsed into the cavity, creating closed depressions, called kettles, in the till and in the outwash (Fig. 14). Some of them filled with water to form lakes. Organic soils formed in many of these lakes.

South of the Wisconsinan till region, the landscapes are older. In Soil Region 10, Wisconsinan loess covers a plain that has been called an Illinoian till plain. Recent studies, however, have shown that the glacial drift below the loess might be older than Illinoian age, and that it contains outwash in addition to till (Gamble et al., 1990). Also, the surface could be an erosional surface rather than a depositional surface. According to the convention used here, the area is called a loess plain because the loess on it is more than 6 ft. (1.8m) thick. This name is appropriate because properties of soils on this plain are influenced more by the thick loess than by the till or drift below it. In the loess plain of Soil Region 10 the surface is

Figure 14. Block diagram illustrating landforms and parent materials in Soil Region 6, in till, on the left side of diagram and Soil Region 3, in outwash, on the right side. Both are in the Plymouth Morainal Complex and Warsaw Moraines and Drainageways physiographic divisions.

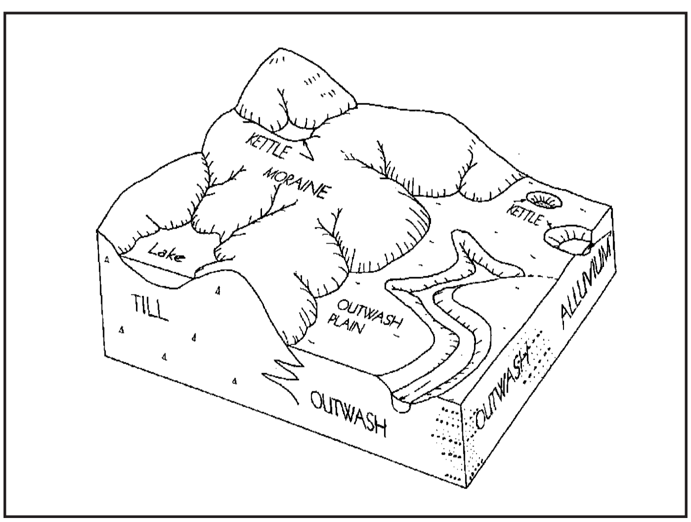


Figure 15. Block diagram illustrating landforms and landform components parent materials in Soil Region 10, the loess-mantled Pre-Wisconsinan Till Plain (Muscatatuck Plateau).

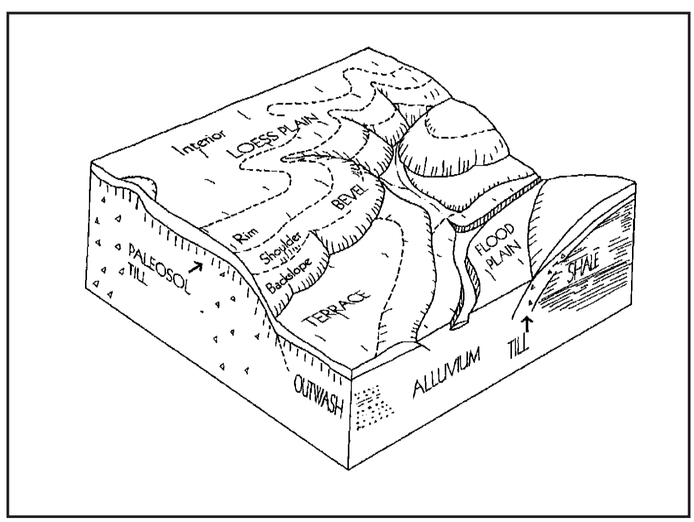


Figure 16. Block diagram illustrating landforms, landform components, and parent materials in Soil Region 11 (Crawford and Norman Uplands).

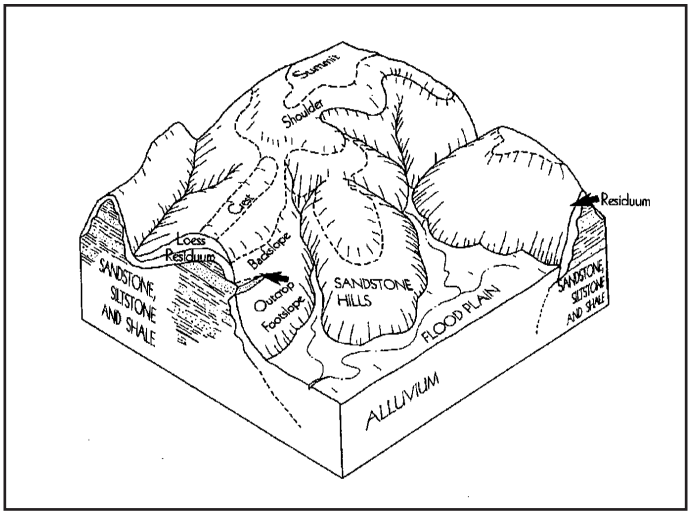
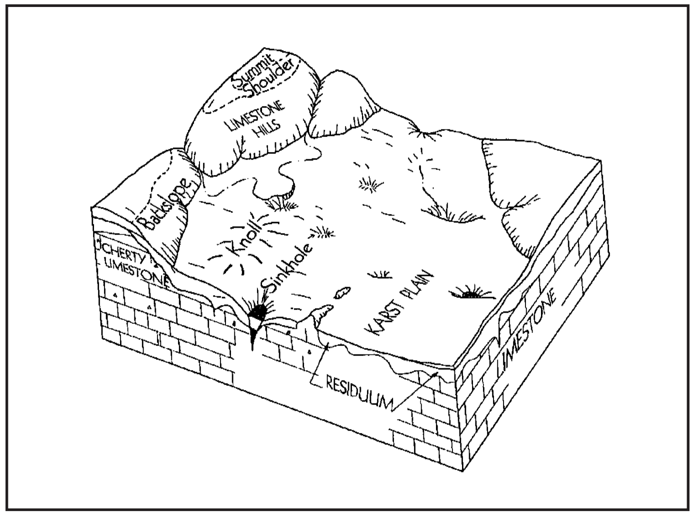


Figure 17. Block diagram illustrating landforms, landform components, and parent materials in Soil Region 12 (Mitchell Plateau).



much flatter than it is in Wisconsinan till areas, and the somewhat poorly drained soils form a rim around the poorly drained soils in the interior. Both are on the same flat surface, but the rim is at the edge of the upland flat, near the shoulder (Fig. 15). On the loess plain surface are a few small hills, as shown on the left side of Fig. 15, that remained after the rest of the plain had been eroded. The paleosol (old buried soil) below the loess is deeper on these hills than it is on the rest of the plain. Except for those on steeper backslopes, the soils above the paleosol have fragipans.

The most highly dissected landscapes of Indiana are in Soil Regions 11 and 13, which are mature landscapes with much relief (Fig. 16). As sketched, the summit at the top of the diagram is a landform component of the sandstone hills. It could also be called a crest. If it were larger, it could be called a sandstone plain, and the slopes leading down from the plain could be called a sandstone plain bevel.

Soil Region 12, the Mitchell Plateau, a classic karst plain, is underlain by limestone. Part of this region has open drainage, as illustrated by the drainageways between the limestone hills in the left part of Fig. 17, and part has closed drainage through sinkholes, illustrated in most of the rest of the diagram. Sinkhole is a landscape component name, but positions within a sinkhole could be further described with additional slope component terms such as crest, knoll, backslope, or footslope.

CHAPTER 4

SOIL MORPHOLOGY

The purpose of this chapter is to explain how pedons are described. A pedon is a three-dimensional body of soil with a surface area of about one square meter. It is essentially a soil profile, but it has a third dimension. Soil evaluators will use this chapter as a guide for describing a pedon. Report readers will use it to help them understand what the soil scientist has described. The chapter also explains the significance of the various soil characteristics, especially as they pertain to plant growth and purification of wastewater. Most of the material in this chapter is from the *Soil Survey Manual* (Soil Survey Staff, 1993) and the *Field Book for Describing and Sampling Soils* (*Field Book,* Schoeneberger, et al., 2002). The detailed descriptions produced by following these references are meant mainly for other soil scientists, but the chief users of reports written using this manual are specialists in other areas, so some of the material herein has been adapted to their needs. We follow the references fairly closely, and we note where we deviated from them. The deviations are of little interest to most users of this publication, but we do explain the details. Generally, the abbreviations recorded on the evaluation form follow the conventional codes in the *Field Book*. Some were shortened, however, to make the evaluation forms more compact.

This chapter is subdivided into sections on the various soil properties — color, texture, etc. Most sections have three subsections:

1) The first one, unless it is intuitively obvious, explains the nature of the property.
2) The Determination section gives additional suggestions about how to determine the property in the field, especially in Indiana.
3) The Significance section explains why the property is important, what information it furnishes about how the soil formed, and how it might be used.

In addition to their use for deciding how to use a soil, pedon descriptions are used to classify a soil and to define the map units of soil surveys.

Soil classification, in turn, helps us remember soil properties, understand the relationships among soils, and organize knowledge about them. Soil surveys show us where the various soils are located. Thus, soil morphology helps us extrapolate information about soils from one area to another. For example, if research was done on the Drummer soils at the Agronomy Research Center, it is likely that it would apply directly to similar soils in other parts of Indiana or nearby states. What constitutes "similar" soils is determined by their morphology.

DEPTH

The depth at which some feature or layer occurs is very important for agriculture, wastewater treatment, and many other soil uses. Depth is usually recorded in inches for applied work, such as onsite wastewater disposal, and in centimeters for college teaching and basic work, such as sampling for laboratory analysis.

Determination

First, pedons are divided into horizons. This process is arbitrary, but with a few guidelines, different people will place the major breaks in the profile at about the same depth. These are some of the major distinctions to look for in Indiana soils:

1) **Lower boundary of the A horizon**. If the soil has been plowed, look for a sharp break around 6 to 10 inches (15 to 25 cm), the common depth of plowing. If the soil has a dark surface horizon (mollic epipedon), look for the depth at which the soil material is no longer dark enough to qualify — when its value becomes more than three, its chroma becomes more than three, or both.
2) **Increase in sand content**. In Indiana, loess is the uppermost parent material of many soils. It covers glacial till, glacial outwash, paleosols, or other materials. Paleosols are old soils, often eroded, that have become buried by another deposit, especially loess. Downward in the profile, a sharp decrease in silt content corresponds with the lower boundary of loess. This boundary is usually recognized by the converse condition — a downward increase in sand content (loess over till or outwash) or in clay content (loess over a paleosol). This boundary is indicated by a change in the numerical prefix, e.g. A, E, Bt1, 2Bt2, 2C, etc.
3) **Presence of carbonates**. Carbonates are detected by observing fizzing (effervescence) when dilute HCl is dropped on the soil. The upper boundary of a calcareous horizon indicates the depth to which carbonates have been leached and it constitutes an important horizon separation, often between B and C horizons.

Insert markers such as nails or golf tees in the soil at the horizon boundaries, and record their depths from the surface. Usually about 5 to 8 horizons are adequate to represent a pedon. For detailed studies, further separations might be necessary.

Significance

The thickness of the soil above a layer that limits root growth is especially important to plant growth. The depth of the root-limiting layer and the available water holding capacity of the soil above it largely determine the ability of plants growing on a soil to withstand a drought. The depth to a layer that has very slow permeability is also very important for agricultural drainage and onsite wastewater disposal.

BASIS FOR DESCRIPTION

Users of soil reports should know what kind of soil samples were used to describe each horizon, so soil scientists should record this information. This Basis for Description could be different for the various horizons. For example, an evaluator might dig a small pit to observe upper horizons and then use a probe to sample lower ones. One characteristic described is soil structure. Structure units vary in size from a few millimeters to many centimeters. If a soil scientist describes coarse prismatic structure, in which structure units are more than 10 cm (4 inches) across, and he used a one-inch probe to sample the soil, it is obvious that he is either guessing at the structure, or more likely, is basing the determination on having seen similar soils in large pits or other exposures. Also, it is difficult to determine the percentages of different colors in a horizon from an auger sample. For each horizon, record this information:

1) width of the soil section observed to the nearest inch, followed by
2) an upper case letter to indicate the kind of sample:

   T = tube (probe or core sample),

   A = auger (screw, bucket, etc.),

   D = post hole digger (examined material removed)

   P = face of pit.

For a soil probe or tube sampler, the entry may be 1T and for a large pit it may be 36P.

Significance

If decisions about how to use a soil depend on a certain property, clients may wish to ascertain that the soil scientist observed that property using a suitable sample. For example, if the percentage of gray color is critical, a sample collected with an auger that mixes up the soil might not be suitable. Further, if the degree of structure development is critical, an undisturbed sample at least several inches across should be used.

Report readers can set minimum requirements for the kind of sample used, but they must be aware that the nature of the site or lot might limit the kind of sampling that may be done. For example, use of backhoes might be prohibited in some areas.

HORIZON DESIGNATIONS

Soil horizon designations are shorthand symbols that provide an overview of the pedon or profile. Horizon designations indicate if the soil formed from one kind of parent material or several kinds, and how the material has changed during soil development. They represent the investigator's interpretations of genetic relationships among the layers of a soil.

Horizon designations are not equivalent to the diagnostic horizons of *Soil Taxonomy* (Soil Survey Division Staff, 1999). Horizon designations express a qualitative judgment about the kind of changes believed to have taken place during soil formation. Diagnostic horizons are quantitatively defined features used to classify soils. Changes implied by horizon designations may not be large enough to justify recognition of diagnostic criteria. For example, a Bt horizon is usually, but not always, an argillic horizon.

The description of the Crosby soil in Chapter 5 (Table 18, page 52) is used to illustrate horizon designations. It has the horizon sequence Ap - BE - Bt1 - 2Bt2 - 2Bt3 - 2BCt - 2Cd. Five kinds of symbols are used in various combinations to designate horizons, numerical prefixes, master horizons, horizon suffixes, numerical suffixes, and the prime symbol. All but the last are used in the Crosby soil.

Numerical Prefixes

The initial number indicates differences in parent materials. The number "1" is not used. Horizons without a number before the upper case letter were formed in the only parent material of the pedon, or the uppermost parent material. In the example, the upper three horizons formed in loess (14 inches thick), and the lower four horizons formed in till. Symbols to identify discontinuities, are used only when they will contribute substantially to the reader's understanding of relationships among horizons. Stratification common to soils formed in alluvium is not designated as a discontinuity unless particle size distribution differs markedly (strongly contrasting particle-size class, as defined by *Soil Taxonomy*) from layer to layer. Even though a layer below material 2 is similar to material 1, it is designated "3" in the sequence. The numbers indicate a change in the material, not the type of material. In Indiana, a "2" parent material often is overlain by loess because loess is a common surficial parent material.

Master Horizons

The capital letters O, A, E, B, C, R, and W represent the master horizons and layers of soils (Table 6). The capital letters are the base symbols to which other characters are added to complete the designations. Most horizons are given a single capital letter symbol, but transitional horizons and combinational horizons usually require two. The example has A, BE, B, BC, and C master horizons.

In **transitional horizons** properties of one master horizon dominate over properties of another. Two capital letter symbols are used, e.g., AB, EB, BE, BC, or CB. The master horizon symbol that is given first

Table 6. Definitions of master horizons.

O — Layers dominated by organic material. Some are saturated with water for long periods or were once saturated but are now artificially drained; others have never been saturated.

A — Mineral horizons that formed at the surface or below an O horizon, that exhibit obliteration of all or much of the original parent material structure, and that show one or more of the following: (1) an accumulation of humified organic matter intimately mixed with the mineral fraction and not dominated by properties characteristic of E or B horizons (defined below) or, (2) properties resulting from cultivation, pasturing, or similar kinds of disturbance.

E — Mineral horizons in which the main feature is loss of silicate clay, iron, aluminum, or some combination of these, leaving a relative concentration of sand and silt particles. These horizons exhibit obliteration of all or much of the original rock structure.

B — Mineral horizons below an A, E, or O horizon with structure different from the parent material and that show one or more of the following:

1) illuvial concentration of silicate clay, iron, aluminum, humus, or silica, alone or in combination;

2) evidence of removal of carbonates;

3) residual concentration of sesquioxides (iron and aluminum);

4) coatings of sesquioxides that make the horizon conspicuously darker, higher in chroma, or redder in hue than overlying and underlying horizons without apparent illuviation of iron;

5) alteration that forms granular, blocky, or prismatic structure; or

6) brittleness.

C — Mineral horizons, excluding hard bedrock, that are little affected by pedogenic processes and lack properties of O, A, E, or B horizons. Most are mineral layers. The material of C layers may be either like or unlike that from which the solum presumably formed. The C horizon may have been modified even if there is no evidence of pedogenesis.

L — Limnic soil material (Organic or inorganic material deposited in a lake by biological processes).

R — Hard bedrock.

W — A layer of water, either within a soil or above a soil surface. The water is usually frozen (Wf), thus permafrost. (Not used in Indiana).

designates the kind of horizon whose properties dominate the transitional horizon. The BC horizon of the example has characteristics of the overlying B horizon and the underlying C horizon, but is more like the B than like the C.

In some cases, a horizon can be designated as transitional even if one of the master horizons to which it is apparently transitional is not present. For example, a BE horizon may be recognized in a soil in which the original E horizon was eroded, as in the Crosby description Also, a BC horizon may be recognized even if no underlying C horizon is present; it is transitional to the assumed parent material.

Combination horizons have distinct recognizable properties of two kinds of master horizons (rather than a blend of properties). The two capital letters are separated by a slash (/), as E/B or B/C. Usually, parts of one type of horizon are surrounded by the other.

Horizon Suffixes

Lower case letter suffixes indicate specific characteristics of master horizons (Table 7). The word "accumulation" used in many definitions of this table means that the horizon must have more of the material in question than is presumed to have been present in the parent material. In the example pedon, the B horizons show evidence of clay translocation (t), and the C horizon is dense till (d). B horizons must have a suffix.

Numerical Suffixes

A horizon designated by a single letter or a combination of letters may need to be subdivided. The numbers used for this purpose always follow all letters. Within a C, for example, successive layers could be C1, C2, C3, and so on; or, if the lower part is gleyed and the upper part is not, the designations could be C1-C2-Cg1-Cg2 or C-Cg1-Cg2-R. The numbering of vertical subdivisions within a horizon is not interrupted at a change in parent material (indicated by a numerical prefix) if the same letter combination is used in both materials, as shown in the example pedon: Bt1 - 2Bt2 - 2Bt3. In this example, the Bt horizon is subdivided into three subhorizons, one in loess and two in till.

The Prime (')

This symbol is used to indicate the second occurrence of an identical horizon in a pedon. It is seldom used for Indiana soils. It may be used, however, for some soils with fragipans that have not

Table 7. Horizon suffixes used to modify master horizons.

a* — Highly decomposed organic material	**k** — Accumulation of carbonates
b* — Buried genetic horizon	**m** — Cementation or induration
c — Concretions or nodules	**ma*** — Marl (used only with L)
co* — Coprogenous earth (used only with L)	**n** — Accumulation of sodium
d* — Densic layer; physical root restriction	**o** — Residual accumulation of sesquioxides
di — Diatomaceous earth (used only with L)	**p*** — Tillage or other disturbance
e — Moderately decomposed organic material	**q** — Accumulation of silica
f — Permanently frozen soil or ice (permafrost); not seasonal ice	**r*** — Weathered or soft bedrock
ff — Dry permafrost	**s*** — Illuvial accumulation of sesquioxides
g* — Strong gleying (gray color)	**ss** — Slickensides
h — Illuvial accumulation of organic matter	**t*** — Accumulation of silicate clay
i — Slightly decomposed organic material	**v** — Plinthite
j — Accumulation of jarosite (a yellowish mineral common in tidal marsh soils)	**w*** — Weak color or structure devlopment
jj — Evidence of cryoturbation (churning by frost action)	**x*** — Fragipan characteristics
	y — Accumulation of gypsum
	z — Accumulation of salts more soluble than gypsum
	*Common in Indiana soils.

been tilled or eroded. Such soils have an upper E horizon from which clay and iron have been leached downward in the profile and a lower E horizon from which clay and iron have been leached by lateral water movement over the fragipan. The horizon sequence in such a soil may be A - E - Bt - E' - Btx - 2Btb. The lower E horizon is differentiated from the upper E by the ' symbol. In this soil, the 2Btb horizon is part of a paleosol. Probably, a soil formed in an older parent material, such as Illinoian till (parent material 2). The upper horizons of this soil were eroded off, and the remaining soil profile was covered by Wisconsinan loess (parent material 1). Then a fragipan (x) formed in the loess.

Determination and Significance

Look first for major differences: parent material changes (new prefix number), A horizon vs. B horizon, and B vs. C. Use horizon suffixes (lower case letters) to describe the results of recognizable processes, even though this process has not been strong enough to develop a horizon recognized in *Soil Taxonomy*. For example, use the letter *t* if you see evidence of clay illuviation even if the horizon does not qualify as an argillic horizon. In other words, an argillic horizon should have a *t* designation, but a horizon with a *t* designation is not necessarily an argillic horizon. Likewise, a horizon with an *x* has brittle characteristics, but it might not qualify as a fragipan. Horizon designations show changes with depth in the pedon. They also reflect the major process of soil formation, such as clay illuviation (t), and gleying (g), reduction processes recognized by gray colors.

BOUNDARY

A boundary is a surface or transitional layer between two adjoining horizons or layers. Most boundaries are zones of transition rather than sharp lines of division.

Determination

The locations of major boundaries are best seen by standing back from the soil face to get an overview of the horizons. On closer examination, one can trace a boundary on the face of a soil pit to characterize the topography of the boundary. Two features are described, distinctness and topography.

Distinctness — Distinctness refers to the thickness of the zone within which the boundary can be located (Table 8). The distinctness of a boundary depends partly on the degree of contrast between the adjacent layers and partly on the thickness of the transitional zone between them. Usually more strongly developed soils have more distinct horizons. Distinctness is defined in terms of thickness of the transitional zone.

Topography — Topography refers to the irregularities of the surface that divides the horizons (Fig. 18). Even though soil layers are commonly seen in two dimensions, they are actually three-dimensional.

Significance

Horizon boundaries are of interest mainly to pedologists who study how soils formed. They have little practical value in deciding how to use a soil.

COLOR, THE MUNSELL SYSTEM

Soil color is determined by comparing a soil with a set of color chips, similar to the paint color samples

Table 8. Descriptive terms for soil boundaries and their abbreviations (use either numbers or classes to report distinctness).

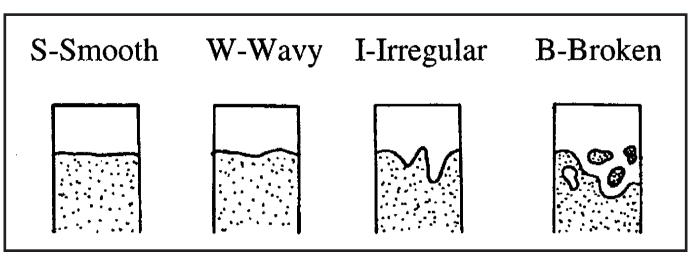
Distinctness classes*		Topography classes	
Very abrupt (V)	<0.5 cm thick	Smooth (S)	The boundary is a plane with few irregularities.
Abrupt (A)	0.5 - 2 cm thick	Wavy (W)	The boundary has undulations in which depressions are wider than they are deep.
Clear (C)	2 - 5 cm thick	Irregular (I)	The boundary has pockets that are deeper than they are wide.
Gradual (G)	5 - 15 cm thick	Broken (B)	One or both horizons separated are discontinuous and the boundary is interrupted; irregular pockets.
Diffuse (D)	> 15 cm thick		

* For reporting numbers directly, list the height in cm in which the change from one horizon to the next occurs.

in a hardware store. Color is expressed in the Munsell system (Munsell, 2003). This system uses three elements of color — *hue*, *value*, and *chroma* — to make up a color notation. The notation is recorded in the form: hue, value/chroma — for example, 10YR 3/2.

Hue is that attribute of a color by which we distinguish red from green, blue from yellow, etc. There is a natural order of hues: red, yellow, green, blue, purple. One can mix paints of adjacent colors in this series and obtain a continuous variation from one color to the other. For example, red and yellow may be mixed in any proportion to obtain all the hues from red through orange to yellow. The same may be said of yellow and green, green and blue, blue and purple, and purple and red. This series returns to the starting point, so it can be arranged in a circle. In the Munsell system, red, yellow, green, blue, and purple are called principal hues and are placed at equal intervals around this circle. Black and white colors occur in the center of the circle. Five intermediate hues: yellow-red, green-yellow, blue-green, purple-blue and red-purple are inserted between the principal hues, making ten hues in all. For simplicity, the initials are used as symbols to designate the ten hue sectors: R, YR, Y, GY, G, BG, B, PB, P and RP. Different hues are on different pages of the Munsell color book.

Figure 18. Topography of Horizon boundries.



Value indicates the lightness of a color. The scale of value ranges from 0 for pure black to 10 for pure white. Black, white and the grays between them are called neutral colors. They have no hue. Colors that have a hue are called chromatic colors. The value scale applies to chromatic as well as neutral colors. Color value changes up and down on a Munsell color page.

Chroma is the degree of departure of a color from the neutral color of the same value. Colors of low chroma are sometimes called weak, while those of high chroma are said to be highly saturated, strong or vivid. Imagine mixing a vivid yellow paint, a little at a time, with a gray paint of the same value. If you started with gray and gradually added yellow until the vivid yellow color was obtained, you would develop a series of gradually changing colors that increase in chroma. The scaling of chroma is intended to be visually uniform and is very nearly so. The units are arbitrary. The scale starts at zero, for neutral colors, but there is no arbitrary end to the scale. As new pigments have become available, Munsell color chips of higher chroma have been made for many hues and values. The chroma scale for normal reflecting materials extends beyond 20 in some cases. Fluorescent materials may have chromas as high as 30. Chroma increases from left to right on the soil color chart. A chroma of 8 (written as /8) is the maximum used for soils.

Determination

Soil color is described for two kinds of soil features, *matrix* and *additional morphological features*. Color is described for **moist** soil unless otherwise noted.

If the soil sample is not already moist, add a little water and set it aside for the water to soak into the soil. For surface horizons and subsurface horizons that appear to have colors of a mollic epipedon (dark colored surface horizon), crush or rub the sample before comparing it with the color chart. In some of these horizons, the outside surface of peds are darker than the interior, and thus different colors could be described. The convention of crushing the sample was adopted because many of these horizons are mixed by tilling the soil. For other horizons, describe colors of the inside and outside of intact peds. If the soil has well developed structure, the ped surfaces will often have a different color than the ped interior.

Matrix color*

The matrix is essentially the "ordinary" soil material. Specifically, it includes all material within a ped (natural piece of soil) except additional morphological features (defined subsequently).

The matrix may be all one color or it may be two or more colors; these kinds of color are recognized:

Dominant color (d) — the only color or the most prevalent or abundant color of the matrix.

Redox depletion (r, reduction) — Gray colors. The material is devoid of major pigmenting materials such as organic matter (dark), manganese oxides (black), and iron oxides (brown, red, or yellow) due to depletion of iron and manganese by reduction. The gray color is mainly due to the silicate minerals. Typical colors have values of 4 or more and chromas of two or less, such as (value/chroma) 4/2, 4/1, 5/2, and 5/1. Sometimes 3-chroma colors (4/3) may indicate reduction, especially in sandy soils. The term "redox" is shortened from "redoximorphic", morphological features caused by reduction and oxidation processes. Redox depletions are also called gray mottles.

Redox accumulation (a) — Brownish colors. Soil material showing reddish, brownish, or yellowish color due to concentrations of iron oxide minerals. Typical colors have brownish and reddish hues (10YR, 7.5YR, 5YR, etc.) and chroma of three or more (5/3, 5/4, 5/6, 6/3, etc.). Also called high-chroma mottles, reddish mottles, etc.

Variegated color (v) — Colors different from the dominant color that are not due to oxidation and reduction processes. The color might be due to the color of the parent material (e.g. gray-green shale), stripping of organic pigment from sand grains (e.g. the stripped matrix hydric indicator for sandy soils), soil mixing or other processes.

*This terminology follows the protocol for soil micromorphology in which s-matrix (matrix including skeleton grains) is the material within peds (or non-structured material) in which pedological features occur (Brewer, 1964). His pedological features are similar to our additional morphological features. In the Soil Survey Manual there is no mention of matrix in describing color. It states that "dominant color is the color that occupies the greatest volume of color of the horizon" (not of the matrix as suggested here). In describing matrix pores and matrix suction, the term as used in the SSM has about the same connotation as our definition, essentially all the material within a ped. In the Field Book, the term matrix is used but not defined. It appears to refer to the dominant color within peds, the equivalent of our dominant color of the matrix. Thus, in the Field Book, matrix does not refer to all the material in the ped. This leads to problems when we also refer to matrix flow of water. If the interior of a ped is 60% brown and 40% gray, does water move only through the brown material?

Figure 19 illustrates several soil features and how their color is recorded in an evaluation form for onsite sewage disposal. The color of redox depletions, (see description above) is recorded in the second set of columns along with the percent of this color in the matrix. All other colors are recorded in the first set of columns. Record the kind of color, e.g., dominant (d), redox accumulation (a), variegated (v); the Munsell designation; and the volume percent of the color in the matrix. The total of all percentages in the "Matrix Colors" column set for a horizon should equal 100.

In other evaluation forms, classes of size, abundance, and contrast of mottles may be recorded (Table 9). Some diagrams that illustrate the percent of area shaded black (Fig. 20) can be used to estimate percent of a feature in the field.

Significance

Mineral soils consist mainly of quartz and silicate minerals, which in silt and clay appear gray. Other colors come mainly from organic matter, iron oxide minerals, and manganese oxide minerals. Organic matter imparts black or very dark colors to the soil.

Table 9. Criteria for reporting abundance, size, and contrast of mottles (redox depletions, redox accumulations, etc.). For abundance and size, either report numbers directly or report classes.

Contrast classes

Hues are the same*		
ΔValue	ΔChroma	Contrast
0	≤1	Faint (F)
0	2	Distinct (D)
0	3	Distinct
0	≥4	Prominent (P)
1	≤1	Faint
1	2	Distinct
1	3	Distinct
1	≥4	Prominent
2	≤1	Faint
2	2	Distinct
2	3	Distinct
2	>4	Prominent
3	<1	Distinct
3	2	Distinct
3	3	Distinct
3	>4	Prominent
>4	—	Prominent

Hues differ by one page*		
ΔValue	ΔChroma	Contrast
0	≤1	Faint
0	2	Distinct
0	≥3	Prominent
1	≤1	Faint
1	2	Distinct
1	≥3	Prominent
2	≤1	Distinct
2	2	Distinct
2	≥3	Prominent
>3	—	Prominent

Hues differ by two pages*		
ΔValue	ΔChroma	Contrast
0	0	Faint
0	1	Distinct
0	≥2	Prominent
1	≤1	Distinct
1	≥2	Prominent
>2	—	Prominent

Hues differ by 3 or more pages*
Contrast is Prominent

Abundance

Direct - report the percentage of the matrix occupied by the mottle

Classes

Few (f)	< 2% of matrix
Common (c)	2 to 20% of matrix
Many (m)	20 to 50% of matrix

Size

Direct - report the size in mm of an average-size mottle

Classes

Fine (1)	< 2 mm
Medium (2)	2 to 5 mm
Coarse (3)	5 to 20 mm
Very coarse (4)	20 to 76 mm
Extremely coarse (5)	>76 mm

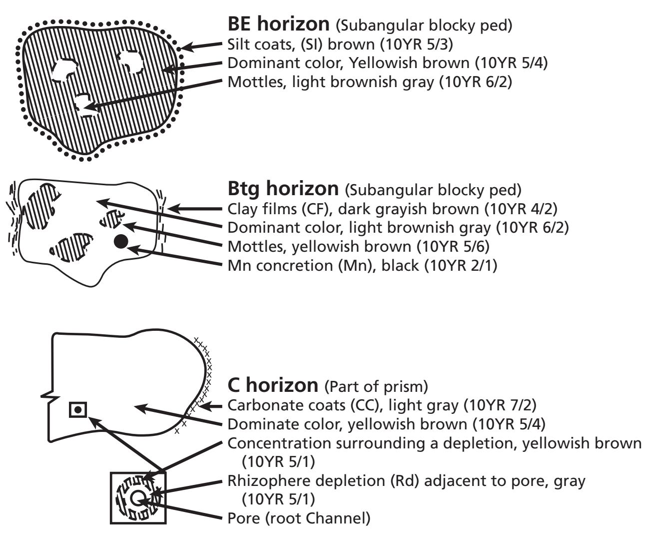
***If both colors have a value ≤3 and a chroma ≤2, the contrast is Faint, regardless of hue differences.**

A certain amount of organic matter makes a sandy soil darker than a clayey soil. Iron oxide minerals impart yellowish, brownish or reddish colors to soils. Specifically, hematite is reddish (5R to 2.5 YR hues), goethite is yellowish brown (7.5 YR to 2.5Y), and ferrihydrite is reddish brown (5YR to 7.5 YR) (Schwertmann and Taylor, 1989). Manganese oxide minerals are black or very dark brown.

Because of certain reduction and oxidation (redox) reactions, soil color indicates much about the moisture regime and the aeration condition of a soil. The Fe in iron oxide minerals is in the oxidized, or ferric, form, indicated by Fe^{3+} (or FeIII). The minerals usually carry a positive charge and are adsorbed on the negatively charged silicate clay surfaces, which gives the soil a red, yellow, or brown color.

When all the soil pores are filled with water, air is excluded from them. Through respiration, soil microorganisms use the remaining oxygen and the soil organic matter in the soil solution to produce carbon dioxide, CO_2, and water. When the oxygen is used up, the soil becomes anaerobic. Then microbes, probably a different population of them, start reducing other components of the soil such as those containing nitrogen, iron, and manganese. To carry out the reduction process, the organisms require a food source which is soil organic matter. Reduction of manganese and, especially, iron leave their mark in the morphology of the soil. When the soil is saturated, microorganisms reduce Fe^{3+} to Fe^{2+} (FeII), and the Fe-oxide minerals dissolve. This microbial process occurs whenever the soil is not frozen, but occurs more rapidly when the soil is warmer. The reduction process makes the soil material appear gray because the pigmenting minerals are dissolved and one then sees the silicate minerals This "graying" process is called *gleying*. The dissolved Fe^{2+} may move completely out of the soil,

Figure 19. Cross section diagrams through peds of several horizons illustrating the location of colors and how they are described on a report form. Under the heading Matrix colors, the percentages should total 100 for each horizon.

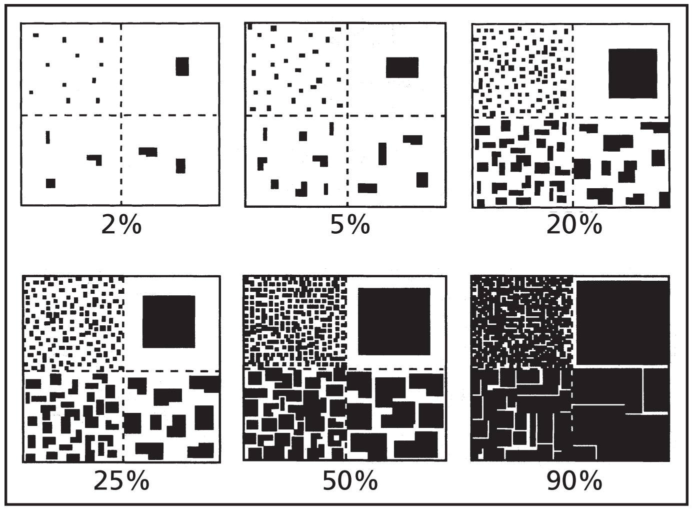


3			4					8		
Horizon designation			Matrix Colors					Addditional features		
			Other colors			Redox depletions		Kind	Color	%
Pr	Mst	Suffi	K	Munsell	%	Munsell	%			
BE			*d*	*10YR 5/4*	*85*	*10YR6/2*	*15*	*Sl*	*10YR 5/3*	*100*
B		*tg*	*a*	*10YR 5/6*	*30*	*10YR 6/2*	*70*	*CF*	*10YR 4/2*	*40*
								Mn	*10YR 2/1*	*2*
C			*d*	*10YR 5/4*	*98*			*CC*	*10YR 7/2*	*20*
			a	*10YR5/6*	*2*			*Rd*	*10YR 5/1*	*2*

resulting in a uniform grayish soil color, or it may move a short distance in the soil before it is oxidized to Fe^{3+} to form iron oxide minerals, which appear as reddish or brownish mottles or redox accumulations, when the soil is again aerated and oxidized. Similar processes occur for manganese, but the oxidized forms of Mn are black.

Reduction processes are especially active at surfaces within the soil, such as ped and pore surfaces, because at these surfaces there is an abundance of organic carbon and microorganisms. Roots grow in these voids, the soil solution in them contains dissolved organic carbon, and microorganisms like to attach themselves to these surfaces. Thus, gray clay films and other surface features are an early indication of reducing conditions in the soil. With more intense reduction, more and more of the matrix becomes reduced and gray until all of it is gray. "Gray color" refers mainly to those with value of 4 or more and chroma of 2 or less. In some cases, 3-chroma colors indicate reduction.

Figure 20. Illustrations of percent of area covered for estimating quantity of mottles (redox depletions, etc.). From *Field Book.*



In summary, four conditions are necessary for reduction to take place:

1) The soil must be saturated with water to exclude air from the pores (oxygen diffuses much more slowly through water than through air).
2) Soil organisms must be present.
3) The organisms need a food source, soil organic matter (organic carbon), which usually is more abundant near the soil surface.
4) The temperature needs to be warm enough for the organisms to function — not freezing. Usually the higher the temperature, the more rapid the reduction.

These conditions can be recalled by the memory aid SCOT for Saturation, organic Carbon, Organisms, and Temperature.

Generally saturation and reduction occur together, but it is becoming apparent that they should be thought of as two distinct processes. Some soils that show few or no reduction features are saturated almost as much as those that show many reduction features. The soils that are frequently wet but lack reduction features are often on shoulders and backslopes of bevels below the plain (e.g. till plain) on which the soils are mainly poorly and somewhat poorly drained. On these soils the water table is held up throughout the landscape by slowly permeable material (e.g., dense till). In these landscapes, water appears to move laterally very slowly through the nearly level soils on the plain, but it moves more rapidly through the sloping soils on the bevel. The faster flow through the soils on the slopes probably helps to incorporate oxygen into the soil water. Soils with a high water table but few or no redox depletions are classified in *oxyaquic* classes in *Soil Taxonomy.*

Soil color, and what it signifies about the water and oxidation-reduction regimes of the soil, is very important to both agricultural and non-agricultural uses of soils. In agriculture, before we knew a lot about the details of oxidation and reduction processes, it was known that soils with gray colors in the subsoil must be artificially drained if they were to be most productive. Water itself does not retard plant growth. Many plants, however, do not grow well if the soil water lacks oxygen. Apparently, if a soil is sufficiently anaerobic to reduce Fe compounds, it is sufficiently anaerobic to retard the growth of many crop plants. Thus, tile drains were installed in soils with gray colors.

For onsite home waste disposal, soil color is also very significant. In these systems sewage is first treated in a septic tank under *anaerobic* conditions. Further treatment must occur in the soil under *aerobic* conditions. If the soil were also anaerobic, the septic tank would, in effect, extend from the inlet pipe to the aquifer. A soil used for a soil absorption field is likely to become much more anaerobic than the soil was before such use. Examine the effect of the four conditions (SCOT) necessary for anaerobic processes and reduction to occur in soils when used for waste treatment:

1) The soil becomes more saturated — more water is supplied to it.
2) The soil has a greater energy supply — septic effluent is high in organic carbon.
3) The soil contains more microbes — sewage is full of them.
4) The soil is warmer because of microbial activity, and warm water from dish washers, showers, etc.

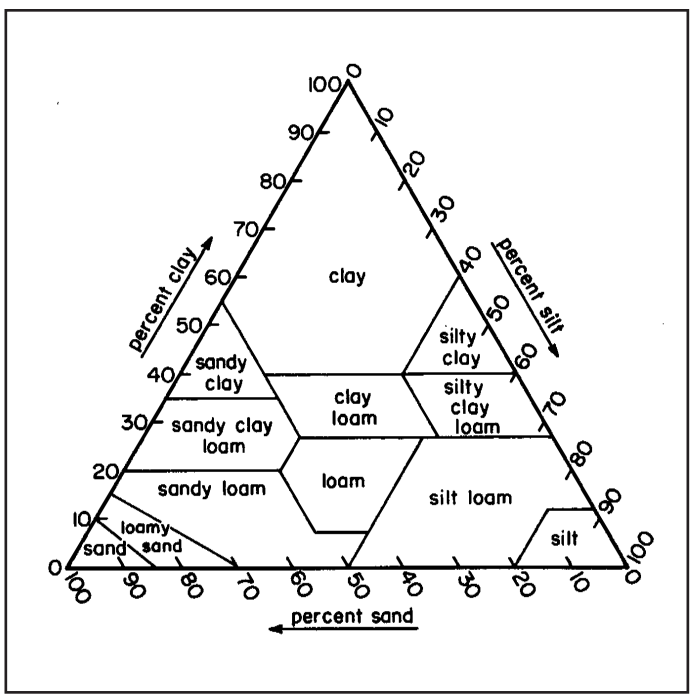
TEXTURE

Soil texture refers to the relative amounts of sand, silt, and clay in a soil sample, and to the size of the sand grains. Texture classes, based on material <2mm in diameter, are shown in the texture triangle (Fig.21). In addition to the classes shown in that diagram, the size of sand in the sandy classes is used in texture names, for example coarse sand, or loamy very fine sand. Rock fragments (> 2mm in diameter) are described in separate columns. Texture is estimated in the field, but field estimates should be checked against laboratory determinations periodically. Sand particles feel gritty and can be seen individually with the naked eye. Silt particles cannot be seen individually without magnification; they have a smooth, floury feel to the fingers when dry or wet. Clayey soils in Indiana feel sticky because they contain 2:1 clays such as smectite. In some parts of the world, especially tropical areas, clayey soils feel less sticky because they contain more kaolinite and oxide minerals.

Determination

In determining texture, try making a cast by squeezing a small amount of moist soil (size of marble to size of golf ball) in your hand, and then forming a ribbon by pressing a smaller amount between the thumb and finger. The cast is especially helpful for sandy soils, which do not form ribbons. The ribbon tells one more about clayey soils. Observe the strength of the cast or ribbon. Two guides for determining soil

Figure 21. Soil texture triangle.



texture, used in introductory soil science courses are shown (Figs. 22 and 23).

Abbreviations of textural classes, recorded on the description form, consist of these seven elements:

Clay(ey)	C	Coarse (CO)
Silt(y)	SI	Fine (F)
Sand(y)	S	Very (V)
Loam(y)	L	

For example, VFSL = very fine sandy loam, SICL = silty clay loam.

Significance

Clay particles have a large surface area relative to their mass and also have negative charges. Thus, they are responsible for much of the chemical activity of the soil. Clay particles hold cations, such as Ca^{2+} and K^{+}, on the negative exchange sites.

Clays also hold water tightly. Soils high in clay have high water contents at field capacity, and also fairly high water contents at the wilting point, so they have a moderately small available water holding capacity. Soils high in silt hold much water at field capacity, but little at the permanent wilting point, so they have a high available water holding capacity. Soils low in organic matter, especially silty soils, form surface crusts readily. Sands, especially medium and coarse sands, hold little water at both field capacity and wilting point, so they have little available water.

In general, sandy soils have very rapid permeability, and clayey soils have very slow permeability, but

Figure 22. Outline for determining soil texture by feel. (Used in the introductory soil science course at Purdue University).

1. Moisten a sample of soil the size of a golf ball don't get it very wet. Work it until it is uniformly moist; then squeeze it out between the thumb and forefinger to try to form a ribbon.
2. Our first decision: If the moist soil is:
   - a. Extremely sticky and stiff = One of the CLAYS
   - b. Sticky and stiff to squeeze = One of the CLAY LOAMS
   - c. Soft, easy to squeeze, only slightly sticky = One of the LOAMS
3. Our second decision: Do we need an adjective to refine our description:
   - a. The soil feels very smooth = Use ajective SILT or SILTY
   - b. The soil feels somewhat gritty = Use no adjective
   - c. The soil feels very, very gritty = Use adjective SANDY
4. Our Final Refinement: The true texture triangle has small additional changes
   - a. The lines jog a little.
   - b. There are three additional (and less common) classes: sand loamy sand, silt.
5. Beware, the feel of a soil is modified by:
   - a. The amount of moisture present. Compare them at like moisture contents.
   - b. The amount of organic matter. This especially affects clayey soil. Very high amounts of organic matter cause the soil to be "chaffey" causing an over-estimation of silt content.
   - c. The kind of clay. In tropical and subtropical regions different types of clay, particularly kaolinite, predominate and give different feel.

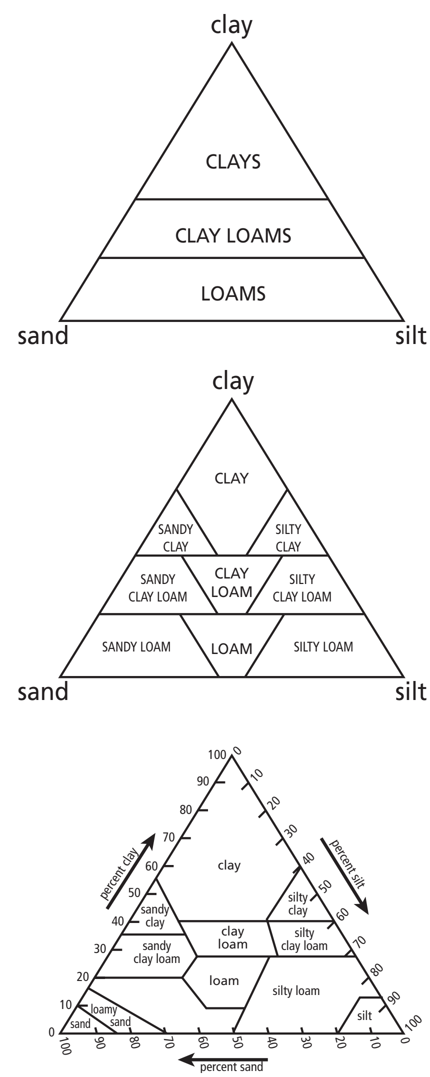
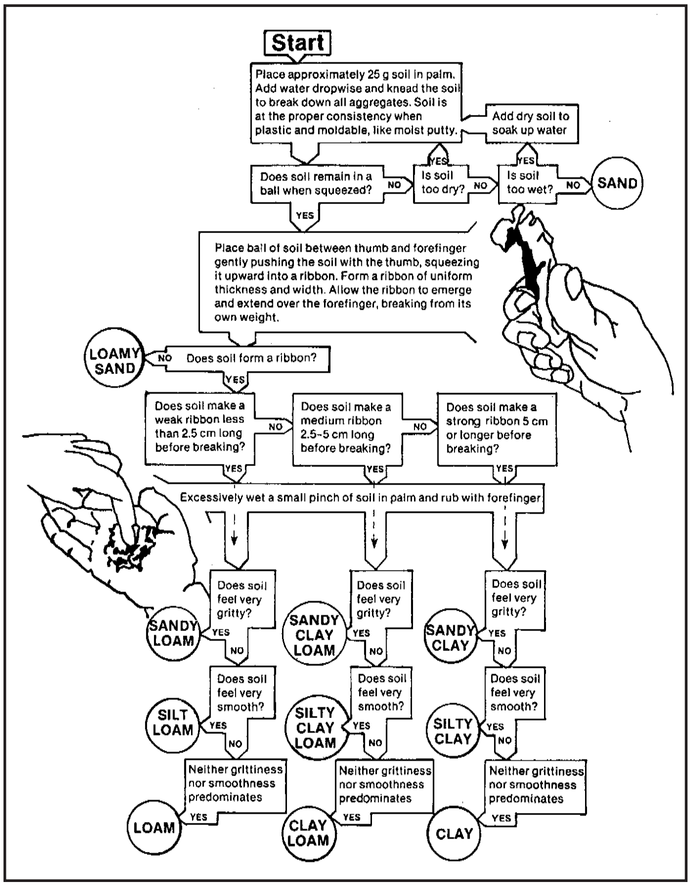


Figure 23. Flow chart for determining soil texture by feel (Thein, 1979). Used with permission of the American Society of Agronomy.



this property also depends greatly on soil structure. Texture is very important for onsite wastewater disposal. Some soils with very coarse sand texture are not suitable for soil absorption fields because water moves through them so fast that there is not enough time for purification to occur. Also some soils very high in clay are not suitable because they accept effluent too slowly. Between these texture extremes, soil texture greatly determines the required size of a soil absorption field.

STRUCTURE

Soil structure refers to units composed of primary particles. A natural structure unit is called a *ped*. The cohesion within peds is greater than the adhesion among peds. As a consequence, the soil mass tends to rupture along ped boundaries. The surfaces of peds tends to persist through cycles of wetting and drying in place. Commonly, the surface of a ped differs from its interior in composition, in organization, or both.

In soils that have structure, the shape, size, and grade (distinctness) are described (Table 10, Fig. 24). Size of structure units can be given in numbers or in class names (Fig. 25). "Strong fine granular structure" is used to describe a soil that separates almost entirely into discrete units that are loosely packed (strong), roughly spherical (granular), and mostly between 1 and 2 mm in diameter (fine).

In contrast to peds, earthy *clods* and *soil fragments* are not formed through soil development. Clods are usually man made. Soil fragments are units of undisturbed soil with bounding planes of weakness that are formed on drying without application of external force and which do not appear to have predetermined bounding planes.

Some soils lack structure and are referred to as *structureless*. Structureless soil material may be either *single grain* or *massive*. Single grain soil material is usually sandy, and is very friable, soft or loose. On rupture, more than 50 percent of the mass consists of discrete mineral particles. Massive soil material also lacks structure but differs from single grain in that upon rupture it does not break along any predictable boundary.

Some soils have *simple structure*, in which each ped is an entity without component smaller peds. Others have *compound structure*, in which large peds are composed of smaller peds. One kind of compound structure, illustrated in Figure 26, is described as

Figure 24. Sketches of the soil structure shape classes. A, prismatic; B, columnar; C, angular blocky; D, subangular blocky; E, platy; F, granular.

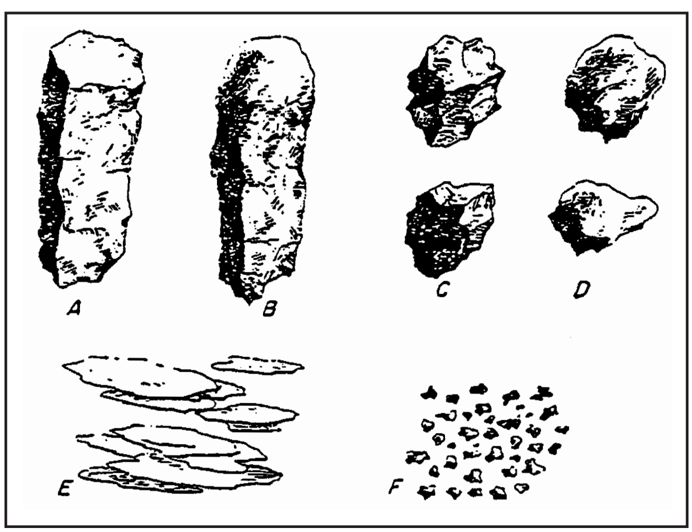


Table 10. Classes of grade, size, and shape of soil structure. For size, either report numbers directly or report classes. For Ap horizons report the degree of compaction (Table 11) as primary structure, and describe secondary structure from this table (usually granular).

Grade (strength of development)

Class	**Definition**
Structureless (0)	No observable structure (massive or single grain)
Weak (1)	Structure barely observable in place; few peds survive digging
Moderate (2)	Peds are well formed and evident in place; many peds survive digging
Strong (3)	Structure distinct in place; peds separate cleanly; most peds survive digging

Size *Direct reporting*:- Report ped size in mm. Measure smallest dimension of ped (e.g., platy ↕, prismatic and columnar ↔, granular and blocky ↕or ↔).

Class	**Granular, Platy* mm**	**Prismatic, Columnar, Wedge mm**	**Angular & Subangular Blocky mm**
Very fine (vf)	<1	<10	<5
Fine (f)	1 - 2	10 - 20	5 - 10
Medium (m)	2 - 5	20 - 50	10 - 20
Coarse (c)	5 - 10	50 - 100	20 - 50
Very coarse (vc)	>10	100 - 500	>50
Extremely coarse (ec)		>500	

* For platy structure, substitute the term *thin* for *fine* and *thick* for *coarse.* **Type (Shape)**

Class	**Description**
Structureless	
Single grain (sg)	Loose, no structure; usually sand
Massive (m)	Finer-texture material that does not break along predictable boundaries
Natural structure	
Granular (gr)	Rounded; width ≈ height
Platy (pl)	Flat and plate-like; wider than high
Blocky	Blocky-like; width ≈ height
Angular (abk)	Sharp corners
Subangular (sbk)	Rounded corners
Prismatic (pr)	Prominent vertical faces; higher than wide
Columnar (cpr)	Like prismatic but with rounded tops
Wedge (weg)	Elliptical interlocking lenses that terminate in acute angles, bounded by slickensides
Artificial or man-modified structure	
Compacted (cmp)	Applies to Ap horizons; estimate degree of compaction (Table 11)
Cloddy (cdy)	Irregular blocks created by disturbance.

shown or as “Moderate coarse prismatic breaking to weak medium subangular blocky structure.”

Determination

Use different clues to detect characteristics of soil structure. Look at their shape and size both in place and as peds are dug from the soil face. Observe how peds come out of the pit when digging with a spade how the structure and the pattern of planar voids appears in the face of the pit. Also, watch how pieces of the soil fall out when you remove a smaller amount with a knife. Usually strong structure has distinctive surface coatings, such as clay films, that separate one ped from another.

Soil Compaction

Ordinary methods for describing structure are not well adapted to describing upper soil horizons that have been compacted by field operations. Traditionally Ap horizons have been described as having granular

Figure 25. Figures illustrating soil structure size class **limits.** For example, a medium subangular blocky ped is larger than the square above the word *medium* (1cm), but smaller than the square below it (2cm).

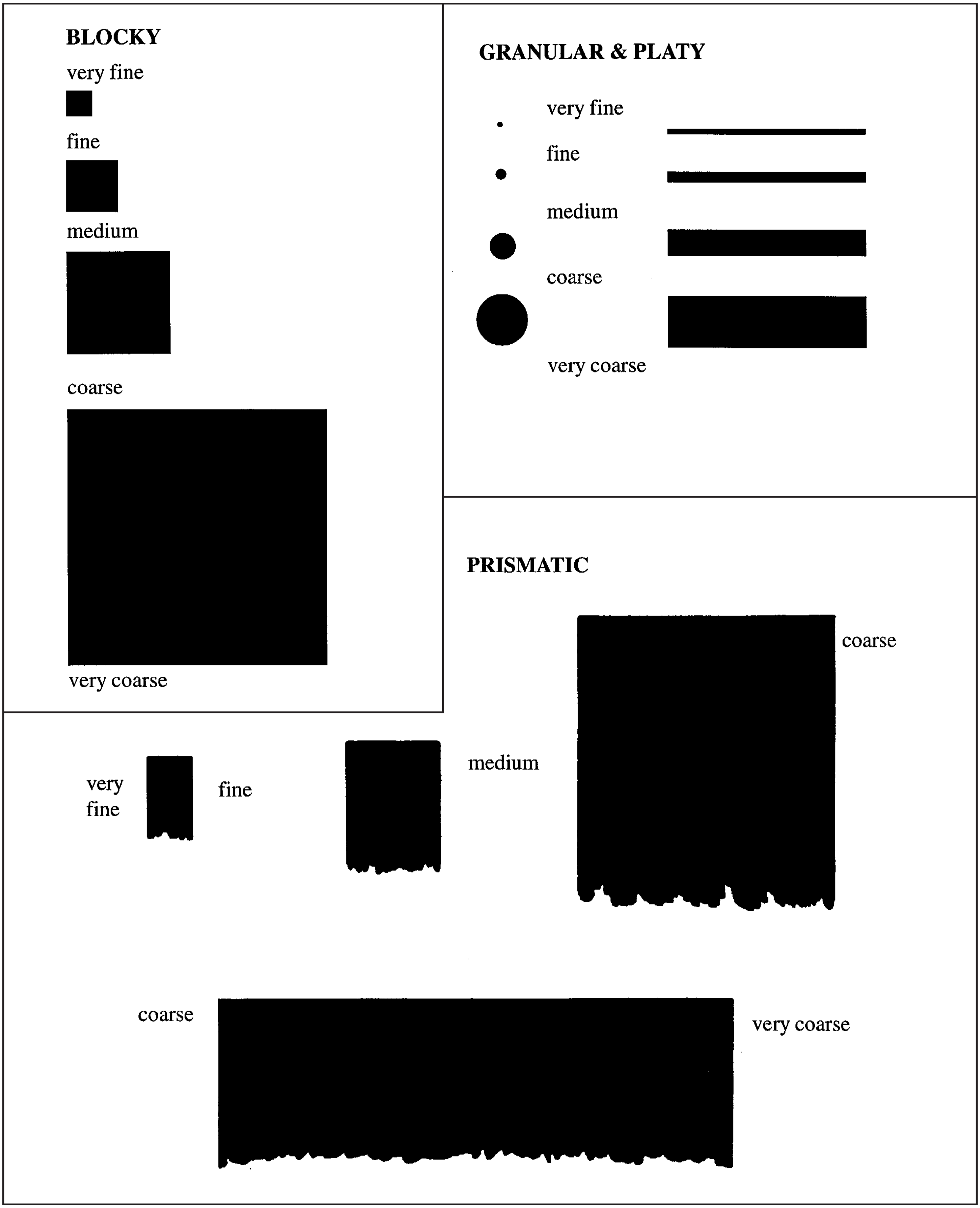
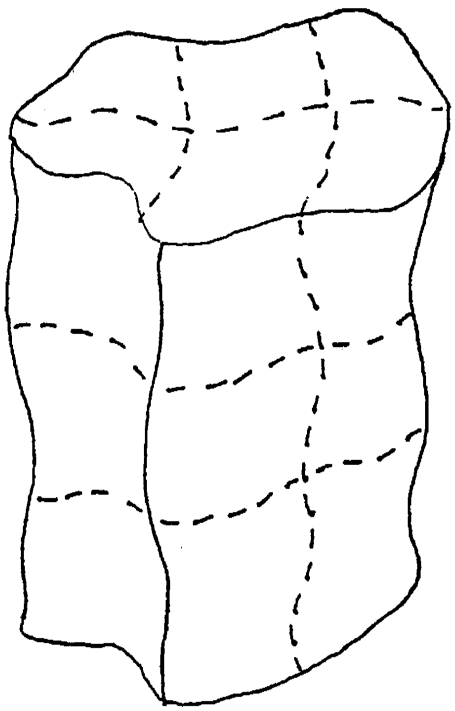


Figure 26. Sketch illustrating compound structure and how it is recorded.



6		
Structure		
Grade	Size, mm	Shape
2	60	pr
1	15	sbk

structure, similar to pedons that were never farmed, because the soil breaks down into granules after it has been manipulated. This can be demonstrated by reading official soil series descriptions and published soil surveys. Surely some or all of these soils have been compacted to some degree by farming operations. This is misleading because the virgin soil and the farmed soil have much different structure. The definition of massive structure does not fit these soils very well.

To overcome this problem we propose that a primary and a secondary structure be described for all Ap horizons. The primary structure represents the degree of compaction, and the secondary structure describes the peds after they have been manipulated to some degree. Thus, the structure could be said to be "moderately compacted, granular." We suggest that all Ap horizons be placed in one of three compaction

Table 11. Classes of compaction for describing the primary structure of Ap horizons. Report class under the Grade column and "cmp" under the Shape column.

Class	Description
Slight (1)	Very little compaction, but more than in a soil that had never been tilled. Typically soils are in perennial vegetation such as pasture or hay.
Moderate (2)	Noticeable compaction, typical for a soil mainly in row crops.
Severe (3)	Compaction is very evident. Roots excluded from large volumes of soil, noticeable effect on crop growths, or other symptoms of compaction.

classes: slight, moderate, or severe. Descriptive limits are given in Table 11. After we gain more experience in rating compaction, we should be able to define the class more specifically, perhaps by measuring bulk density.

Significance

Soil structure is important because water and roots often move through soil voids more readily than through the interiors of peds. The shape and size of **voids** is important. The **size** of peds determines the interval at which water and roots may move through voids in a horizon. **Shape** of peds is also important (Truman and Franzmeier, 2002). Compare for example the shape of voids in granular structure (picture a pile of marbles) to the shape of pores in platy structure (picture the mortar in a brick wall). The path that roots or water must follow to move through the soil is much more tortuous in platy structure than in granular structure. Blocky structure is intermediate. The **grade** of structure determines how stable the structure units are. Strong structure provides better developed voids than weak structure.

During a hard rain, water can move down through large voids in the soil to an underground drain before the ped interiors become saturated in a process called *preferential* or *by-pass flow*. Thus, soil structure is useful for predicting saturated hydraulic conductivity.

Compaction greatly affects seedling emergence, patterns of root growth, infiltration, erosion, and other properties important for crop production (Truman and Franzmeier, 2002). Surface compaction is also very important in effluent absorption. In some systems effluent lines are in the surface horizon or above it, in sand mounds. Compaction greatly decreases the permeability of surface horizons and their ability to absorb and transmit effluent. Soil absorption fields must be aerobic, which means that air must diffuse downward through the soil surface. Typically, after building a new house, a lawn is established over a subsurface soil absorption field using much heavy equipment. Then grass is seeded and watered every day to get it started. In this situation it is possible that the heavy equipment compacted the soil, leaving little pore space. The small amount of pore space remaining is filled with water due to frequent irrigation. If all pores are filled with water, oxygen cannot move to the subsoil to keep it aerobic, and the field does not function properly. Thus home lawns must be managed to keep the subsoil aerobic.

CONSISTENCE

Soil consistence is the degree and kind of cohesion and adhesion that soil exhibits. In general, it describes the strength of the soil. Consistence classes are defined mainly on the basis of the resistance of soil material to rupture. The term "brittle" refers to the **manner** of rupture. Brittle materials, such as fragipans, rupture suddenly when pressure is slowly applied.

Determination

Consistence is highly dependent on the soil-water state. Different terms are used to describe moist consistence than are used to determine dry consistence. Consistence is determined by the amount of force needed to rupture a piece of soil about 3 cm across (Table 12). Most soil materials deform gradually when they are compressed. If, instead, the block of soil "pops" or shatters when it is compressed, the soil is brittle, and the brittle designator, BR, is reported.

The method described above does not work well with dense till. In place, it is very strong. It is very difficult to dig through it with a spade, push probe, or auger. If a truck-mounted power probe is used, the back of the truck will be lifted off the ground when the probe hits dense till. Backhoes noticeably work harder when they encounter dense till. Often however, a hand specimen ruptures rather easily when pressed between

Table 12. Consistence classes based on a 25 to 30 mm cube of soil.

Manner of Failure

If a block of soil ruptures abruptly ("pops" or shatters) when pressed between thumb and finger, the manner of failure is Brittle. Report (BR) as moist consistence. If the block of soil deforms slowly, record the Rupture Resistance (below).

Rupture Resistance*

Class, dry	Class, moist	Test operation
Loose (L)	Loose (L)	Specimen not obtainable
Soft (S)	Very friable (VFR)	Fails under very slight force applied slowly between thumb and forefinger
Slightly hard (SH)	Friable (FR)	Fails under slight force applied slowly between thumb and forefinger
Moderately. hard (MH)	Firm (FI)	Fails under moderate force applied slowly between thumb and forefinger
Hard (HA)	Very firm (VFI)	Fails under strong force applied slowly between thumb and forefinger
Very hard (VH)	Extremely firm (EF)	Cannot be broken between thumb and fore-finger, but can be broken between two hands
Extremely hard (EH)	Slightly rigid (SR)	Cannot be broken in hands, but can be broken under foot by applying full body weight
Rigid (R)	Rigid (R))	Cannot be broken under foot, but can be broken by blows from a hammer
Very rigid (VR)	Very rigid (VR)	Cannot be broken by blows from a hammer

* For horizons with fragic characteristics, record brittle (B) manner of failure in addition to rupture resistance class, e.g., VFI, B.

thumb and finger, and it might even shatter to suggest that it may be brittle. The hand test might depend on the orientation of the sample in place. The sample might appear to be stronger if pressure is applied from top to bottom relative to its position in place than if pressure is applied from side to side. The clues about the strength of the soil in place should take precedence over the hand test. If the horizon is difficult to dig, as described above, describe the consistence, when moist, as very firm or extremely firm.

Significance

Friable consistence is ideal for root penetration and plant growth. Also friable materials are relatively permeable to water. Very firm consistence indicates the presence of a limiting layer such as dense glacial till. Brittle consistence, along with other morphological features, indicates the presence of a fragipan. A soil with loose consistence might slump in a ditch bank.

ADDITIONAL MORPHOLOGICAL FEATURES

This section explains how to describe morphological features such as clay films and concretions. These features reflect important pedological processes and also are significant to soil interpretations. Many kinds of additional features can be described for each horizon. It is up to the soil evaluator to decide which are most important to the user of the evaluation report.

Some features occur within peds, such as manganese concretions, and others occur on ped surfaces, such as clay films. The kind (Table 13), color (Munsell) and abundance (Table 14) of the features may be recorded. For surface features, record the percent of the surfaces covered or the class based on that percentage. For example, the percent of the surfaces of subangular blocky peds that are coated with clay films. For features within peds, record the percent (or class) of the volume of the ped occupied by the feature. Illustrations of silt coats, clay films, carbonate coats, Mn concretions, and depletions and concentrations associated with a root channel are shown in Figure 19, along with an example of how they are described in the description form. These kinds of additional features are common in Indiana soils. If you find features not covered in this section, describe them in the Notes section

Determination

Examine ped surfaces or near surfaces to learn if they differ from the adjacent material in the interior of the peds in texture, color, orientation of particles, or reaction to various tests. A hand lens to magnify the feature is helpful. Cut a ped to observe features within the ped.

Table 13. Kinds of additional morphological features

Within peds (Code consists of upper case letter + lower case letter)

Carbonate concentrations (Ca) — Whitish concentrations that are identified by adding a few drops of HCl to the surface and watching for a fizzing reaction, as explained in the Reaction section.

Clay bridges (Cb) — Clay particles that form bridges between sand grains in coarse-textured soils, usually Bt horizons. The clay grains are oriented like a pack of cards (as seen in micromorphology studies). Clay bridges, usually reddish brown color, provide evidence for clay illuviation processes and thus argillic horizons. They usually occur in the matrix of weakly developed peds [Ma].

Iron concentrations (Fe) — Reddish or dark reddish brown zones not associated with ped surfaces or pores.

Manganese concretions (Mn) — Black specks or masses within peds. The presence of Mn can be identified by applying a few drops of 3% hydrogen peroxide to the feature. Mn catalyzes the conversion of H_2O_2 to H_2O and O_2. The production of oxygen gas is observed as release of small bubbles or fizzing.

Rhizosphere concentration (Rc) — A circular brownish or reddish zone around the outside of gray rhizosphere depletion.

Rhizosphere depletion — (Rd) A circular gray zone around a root channel or pore. Often there is rhizosphere concentration around the outside of this gray zone.

Surface concentration (Sc) — A planar brownish or reddish zone associated with a planar void; often there is a surface depletion between this concentration and a void.

Surface depletion (Sd) — A planar gray zone near the surface of ped; often found near the surface of a fragipan prism.

On ped surfaces (Code consists of two upper case letters)

Carbonate coats (CC) — White or light gray calcareous coatings on ped surfaces usually in upper C horizons. They usually are very effervescent because the secondary carbonate minerals are very fine and react quickly with acid.

Clay films (skins) (CF) — Thin layers of oriented, translocated clay that often appear to be waxy, with low luster. They seem to be painted on the ped and may have a color different from the matrix (interior) color. If there is sand in the matrix, the clay coating covers up the grains so they cannot be seen in the coating.

Iron coats (FE) — Reddish or brownish coatings on ped surfaces not associated with clay skins.

Manganese coats (MN) — Black coatings on ped surfaces that fizz with H_2O_2 application.

Organic matter coats (OM) — Dark coatings, that do not froth with H_2O_2 application, on ped surfaces, usually immediately below A horizons.

Silt coats (SI) — Coatings of silt grains on ped surfaces. They appear to be dusty and powdery, like sugar on a donut. Thin silt coats can be distinguished from clay films by moistening the sample. If the coating is silty, the color of the coating disappears and the underlying color comes through, like when you dunk the donut, but a clay skin keeps its color when moist. Silt coats often originate by removal of clay from a silty clay ped coating.

Slickensides (SS) — Outer surfaces of peds that have been altered when one surface slides across another surface, as shown by small ridges, valleys, grooves, striations, etc. In contrast to clay films, they are not coatings. If the ped contains sand, sand grains may show on a slickenside surface, and this surface is usually the same color as the ped interior.

Table 14. Abundance classes for additional features. Report either the class or the percentage of the matrix or of ped surface occupied by the feature. (see fig. 20, page 35)

Classes	On ped surfaces, % of surface area	Within peds, % of soil volume
Very few (vf)	< 5	—
Few (f)	5 - 25	< 2
Common (c)	25 - 50	2 - 20
Many (m)	50 - 90	> 20
Very many (vm)	>90	

Significance

Clay films are important indicators of translocation of clay from one horizon to another. Clay moving downward in suspension or in a slurry becomes plastered on a ped surface to form a clay film. Apparently the Bt horizon is slowly moving downward in the soil profile. Usually the best developed clay films are in the lower Bt and BC horizons, indicating that they are forming there. On the other hand clay films are destroyed and replaced with silt coats in the upper Bt or BE horizons. The color of clay films is also a reliable indicator of reduction processes. Usually iron-oxides are adsorbed on the surfaces of the individual clay particles that comprise the clay film. These clay films line the pores and voids through which roots and soil solutions move. The solutions often contain dissolved organic compounds which serve as an energy source for microorganisms that cause reduction of Fe and Mn compounds. The solutions move through the large soil pores in preference to the pores in the matrix of the peds. Thus, the clay film on the ped surfaces, the interface between the ped and the void, is more sensitive to soil reduction than the ped interior. In some somewhat poorly drained soils, the aquic moisture condition is recognized by gray clay films instead of by gray redox mottles within the peds. Clay films may also occur on prism faces in the uppermost calcareous horizons of soils formed in till.

Silt coats form where clay and the iron oxide minerals on the clay surface have been stripped from the ped surface. They are best developed in EB, BE or upper Bt horizons. This process takes place in soils of different drainage classes, so silt coatings are not necessarily indicators of reduction processes.

Carbonate coats are common on prism faces in the upper calcareous horizons of soils formed in calcareous till. In some soils, however, these uppermost calcareous prisms have clay films, and then the carbonate coats are somewhat deeper in the profile. The limy ped coatings effervesce vigorously when HCl solution is applied, which indicates that the carbonate material consists mainly of calcium carbonate precipitated from solution as fine-grain coatings. Apparently soil suspensions are moving preferentially down through the planar voids of the till. First, clay in suspension is deposited on ped surfaces, and then carbonate minerals precipitate near or on these surfaces.

Manganese concretions and other concentrations show that reduction-oxidation processes have occurred in the soil. After a soil becomes saturated with water and reduction processes begin, Mn oxides precipitate before Fe oxides. After the water table recedes and the soil becomes oxidized, however, Fe oxides precipitate before Mn oxides. Accumulations and depletions of Mn, along with Fe, are used to define redox accumulations and redox depletions. Mn oxides precipitate and are dissolved by microbiological processes.

Slickensides are the result of shrinking and swelling processes in soils. These processes may result in very slow permeability when the soil becomes moist and swells up to close voids.

ROCK (COARSE) FRAGMENTS

Rock fragments are those > 2mm in diameter. Record the average size of rock fragments and their estimated percentage by volume in the % column.

If a detailed description of coarse fragments is needed, see the *Field Book*. It defines descriptors for shape and size of fragments. Size class limits are different for different shapes, so the system is complex. Examples of class names are gravelly, very stony, and extremely flaggy.

Coarse fragments, especially large ones, cause problems for tilling the soil. Many coarse fragments in subsoils reduce the available water holding capacity of the soil. Also, high contents of rock fragments in sandy soils result in very high permeability rates.

ROOTS AND PORES

The amount of roots in a soil horizon varies greatly with plant species, time, and other factors. Therefore, unless those variables are controlled, it is difficult to interpret a description of roots. One situation in which a description might be useful is to help characterize the degree of compaction in surface horizons. This should be done under an actively growing crop. A simple, straightforward method of describing roots may be to record the average spacing between roots in mm. This might be recorded as an additional note.

If a detailed description of roots is needed, see the *Field Book.* It describes how to determine the number of roots in an assessed area, but the size of the assessed area changes with the size of the root. A similar system is used for pores.

Root distribution in soils may help identify layers that are restrictive to root growth and have very slow permeability.

REACTION

Two aspects of soil reaction are described, pH and effervescence. The pH scale ranges from 1 (acid) to 14 (alkaline) with pH 7 being neutral. Calcareous soil materials have a pH around 8.0 to 8.2. The descriptive terms for pH and the approximate base saturation value are in Table 15.

Calcium carbonate (calcite) effervesces (forms bubbles) when a few drops of cold dilute hydrochloric acid (1 normal, about a 1:20 dilution of concentrated HCl) are dropped onto the soil. Effervescence is not always observable for sandy soils. The reaction can sometimes be heard although effervescence is not visible.

Dolomite reacts with cold dilute acid slightly or not at all and may be overlooked. Dolomite can be detected by heating the sample, by using more concentrated acid, and by grinding the sample. The effervescence of powdered dolomite with cold dilute acid is slow and frothy and the sample must be allowed to react for a few minutes. The amount and expression of effervescence is affected by the size, mineralogy, and amount of carbonates, so effervescence cannot be used to estimate the amount of carbonate. Four classes of effervescence are used:

Very slight (VS):	few bubbles seen
Slight (SL):	bubbles readily seen
Strong (ST):	bubbles form low foam
Violent (VE):	thick foam forms quickly.

Determination

Soil pH is determined with indicator dyes. Bromcresol green has a pH range of 3.8 to 5.4. It is yellow at pH 3.8 and lower, green at the midpoint, 4.6, and blue at pH 5.4 and higher. Chlorphenol red has a range of 4.8 to 6.4 (yellow, orange, red), and bromthymol blue has a range of 5.8 to 7.4 (yellow, green, blue). In practice, place three samples of each horizon in a spot plate well, one for each dye. Add enough dye to wet the soil to somewhat more than saturation — it should have some free dye at the edge, but the sample should not be immersed. Mix the suspension, let it stand a few minutes and read it with a pH color chart. Often you can see the color of the dye best at the very edge of the suspension. The pH of most soils is covered by the pH range of two dyes, which provides a cross check. For more efficiency, you might start with chlorphenol red and then decide which of the other dyes should be used.

For the HCl test, add a few drops of the solution and watch for and listen to the reaction.

Significance

Soil pH reflects the degree of soil development. In general, basic cations are replaced with acidic ones during soil formation, and the soil becomes more acid.

Table 15. Class of pH values and approximate base saturation for each class (Franzmeier, et al. 1990). Report either the class or the pH value directly.

Class	pH range	Base saturation
Ultra acid	<3.5	<5
Extremely acid	3.5 to 4.4	5
Very strongly acid	4.5 to 5.0	27
Strongly acid	5.1 to 5.5	41
Moderately acid	5.6 to 6.0	55
Slightly acid	6.1 to 6.5	70
Neutral	6.6 to 7.3	84
Slightly alkaline	7.4 to 7.8	99
Moderately alkaline	7.9 to 8.4	100
Strongly alkaline	8.5 to 9.0	100
Very strongly alkaline	>9.0	

Soils that have a high pH are usually rich in cations such as Ca^{2+}, Mg^{2+}, and K^{+}. Very low pH indicates that the soil could have Al-toxicity problems. In general, many potentially toxic heavy metals are less soluble at high pH, and less likely to be taken up by plants. Also, micronutrients tend to be more available to plants at lower pH values.

The presence of free carbonates is generally associated with unweathered, or slightly weathered, parent material. Often the glacial till at or a few cm below the uppermost carbonates in the profile is dense and acts as a limiting layer for plant roots and movement of water and effluent. Thus the presence of carbonates in till-derived soils often is a sign of slower permeability.

NATURAL SOIL DRAINAGE CLASS

The natural soil drainage class depends largely on the color of the matrix and of additional features (Table 16). It is discussed here, after the discussion of the properties it depends on, but it may be recorded under Site and Pedon Information.

The relative wetness, or more accurately the degree of reduction, of a soil is indicated by its natural drainage class. Guidelines for determining drainage classes in Indiana are listed in Table 16. They depend largely on the uppermost depth at which redoximorphic depletions occur. These "gray features" refer to gray matrix colors, gray mottles that are at least common in abundance (>2%), or gray clay films. The diagnostic zone for soils with ochric epipedons is 25 to 45 cm deep. For soils with mollic epipedons, it is the 20 cm zone immediately below the mollic epipedon.

Table 16. Color of subsoil in soils of different natural drainage classes. (Franzmeier, et al., 2001).

Natural Drainage Class (Depth of diagnostic zone)	**Description of diagnostic zone**
Well and better drained (B horizon, down to 40 inch depth)	Diagnostic zone is entirely brownish, with few or no gray mottles or gray clay films. Some soils have silt coats in the upper B horizon.
Moderately well drained (B horizon, down to 40 inch depth)	Upper part of the diagnostic zone is brownish with few or no gray mottles (similar to well drained). Between 18 and 40 inches there are gray mottles, gray clay films, or both. Many soils have silt coats in the upper B horizon. Many soils have black Mn concentrations in the lower part of the zone.
Somewhat poorly drained (B horizon down to 18 inch depth)	Brownish colors predominate in the diagnostic zone, but above 18 inches there are gray mottles, gray clay films, or both. Most blocky peds have clay films, generally brownish in upper part and gray in lower part of the zone. Many soils have silt coats in the upper B horizon. Many soils have black Mn concentrations in and below the zone.
Poorly drained (upper 10 inches of B horizon)	Subsoils are almost entirely gray. Where the surface horizon is dark-colored, the colors are dark gray and dark ped coats and fillings are common. Where the surface is light-colored, the ped interior, clay films, and fillings are all light gray. There are common or many brownish mottles. Black Mn-rich concentrations are in patches throughout the B horizon.
Very poorly drained (upper 10 inches of B horizon)	Subsoils are almost entirely gray, mostly olive gray. Commonly, dark soil material coats peds and fills cracks, channels and burrows. There are few or common brownish mottles.

Technical definitions. Munsell color designations (where hue is not specified, any qualify): Gray - Value $\geq$ 4, chroma $\leq$ 2. Olive gray - 2.5Y or 5Y hue, value $\geq$ 4, chroma $\leq$ 2. Brownish - Value $\geq$ 4, chroma $\geq$ 3. Dark - Value $\leq$ 3, chroma $\leq$ 3. Black - near 10YR 2/1. Amount of surface coats: Few - < 2% of surface. Common 2 - 20%. Many >20%.

CHAPTER 5

REPORTING AND INTERPRETING SOIL AND LANDSCAPE INFORMATION

The preceding chapters explain various attributes of soils and landscapes, how they are described, and their significance. This chapter explains how this information is presented and used. Traditionally, much descriptive information was gathered numerically but presented verbally, as class names. Here we compare the verbal and numeric methods of reporting information. Students will use this manual in field oriented classes. They will experience a smooth transition when they use the manual in their professional work after graduation. The manner of reporting results, however, differs among courses and among different uses of professional reports. In this chapter we describe the use of the manual for two courses and for the purpose of evaluating soils and landscapes for onsite sewage disposal.

REPORTING CLASSES OR NUMBERS

For many properties, either a number can be reported directly or the class name based on these numbers can be reported. The *Soil Survey Manual* and *Field Book* define classes for many soil properties that are based on quantitative measurements or estimates. Class names and their definitions are given in this manual. For example, the class names for the area percentage of mottles are:

0 to 2%	Few
2 to 20%	Common
>20%	Many

We believe that communication between a soil scientist and the consumer of soil information can be improved by reporting numbers instead of classes. For example, the abundance of gray mottles (redox depletions) in a soil is related to the degree of reduction of the soil and its time of saturation. A soil scientist may estimate that a certain soil horizon has

15% gray mottles. If the scientist reports classes, he or she converts that number to a class name (common) from memory or by referring to a table, and reports the class. The user of a report reads the class name, and refers to a table to learn what the name means in numbers (2 to 20%), but does not know if the soil has closer to 2% or to 20% mottles. We believe reporting the abundance of mottles in numbers instead of words is more straightforward and meaningful to the reader of a report.

Take pH, for another example. The soil scientist determines the pH of a soil horizon with a field kit to be 5.5. The scientist finds in a table that the class name for pH 5.5 is “strongly acid” and reports that phrase. The report user reads the class name and finds in a table that “strongly acid” means pH 5.1 to 5.5, but does not know what the pH of the soil is within that range. Again, we believe that we can transfer information from soil scientist to the user more efficiently and accurately by reporting the number directly instead of a class.

Reporting numbers instead of classes also allows for learning more about using soils. Take size of soil structure units, for example. Using classes, we can report if prisms are 50 to 100 mm (2 to 4 inches) across or more than 100 mm across. Saturated hydraulic conductivity (Ksat) is greatly dependent on the amount of large pores in the soil, such as those between prisms. It is possible that the limiting Ksat for some soil use does not coincide with a size break for soil classes, say 75 mm. Using classes it would be impossible to test if a break, such as at 75 mm, is significant to use of the soil.

SOIL EVALUATION FOR ONSITE SEWAGE DISPOSAL

Most agencies in Indiana responsible for approving onsite sewage disposal systems require pedon and landform evaluations of potential sites for soil absorption fields. The reports are used for both approval of a system and its design. For this use, few readers of soil reports are soil scientists, so the goal here is to supply the information needed by these people, but not to overload the report with information that is not pertinent to onsite sewage disposal. For example, the form we present for evaluating soils for onsite sewage disposal systems does not include soil pH because it is not critical to absorption of effluent. If, however, soils were to be evaluated for biosolid (sludge) application, pH would be very important because high soil pH is a desirable attribute for soils to which biosolids are to be applied. Heavy metals tend to be less soluble at higher soil pH values, so a high pH tends to keep them in place in the soil. Thus, a soil report for biosolid application would, most likely, be different from the one presented.

Onsite Sewage Treatment Processes and Related Soil Processes

Sewage Treatment Processes

In onsite systems, sewage is first processed by anaerobic (oxygen absent) processes in a septic tank. Next, effluent from the tank is processed aerobically (oxygen present) in a soil absorption field. Finally, water in the effluent is returned to an aquifer to be used as drinking water. To effective purify the effluent, the treatment zone (18 to 24 inches of soil below the effluent trench or drain) of the soil absorption field must have certain characteristics:

Aerated — Not saturated with water for extended periods and thus aerobic. If the absorption field is anaerobic, the septic tank would essentially extend from the sewage inlet pipe to the aquifer.

Permeability not too fast — If effluent moves through the soil too rapidly, there is not enough time for soil microbes to purify it.

Permeability not too slow — If the soil does not absorb effluent as fast as sewage is supplied to the septic tank, sewage will back up into the house.

Not subject for flooding or ponding — addition of surface water may greatly overload an absorption field.

No soil disturbance other than normal agricultural tillage — Our experience with relating the performance of onsite systems to soil properties is based on undisturbed soils, and we have little experience with disturbed soils. Also, during the disturbing process, the soil has often been compacted, greatly reducing its permeability.

Soil Processes, Saturation vs. Reduction

Saturation with water and reduction are two distinct soil processes but they are related and are often confused. Usually, after a soil horizon has been saturated for several weeks, Fe and Mn are chemically reduced, become soluble, and move within the horizon or out of it entirely. The soil mass from which Fe and Mn move takes on a gray color. The gray masses may range from a small fraction of a soil horizon, up to all of the horizon. They are called gray mottles or redoximorphic (redox) depletions.

Because of the usual association of saturation and reduction the two processes have become intermingled. One example of this is the definition and application of natural soil drainage classes in the *Soil Survey Manual*. These classes are *defined* according to *saturation* conditions, but soil scientists in the field *apply* the information using *reduction features* when they identify natural drainage classes by the presence or absence of redox features. For another example, many regulations refer to a "seasonal high water table" (SHWT), which implies *saturation* due to a high water table. In practice, however, SHWT is identified by *reduction* features as shown in the color pattern. Furthermore, when considered as a saturation term, SHWT is ambiguous. For example, does it refer to a) the highest point the water table has ever reached? b) the highest point it reached in 10 years?, c) the point at which the soil is saturated 10% of the time?, d) the point at which it is saturated half the time?, or e) some other duration of saturation?

In an attempt to answer these questions, we examined the results of several water table studies in Indiana. First, we considered those soils in which the depth to "seasonal high water table" coincides fairly well with depth to redox features (Franzmeier, 2003). We called these soils "responsive soils." They are mainly poorly and somewhat poorly drained soils with light-colored surface horizons (Aqualfs) on plains underlain by an aquitard, a layer that holds up the water table, such as dense till or a fragipan. In these soils the ground water is relatively stagnant. We plotted water table depth *vs.* time curves for soils that were studied for a few years up to 10 years. From these curves we calculated the percent of time the soil was saturated at all depths (Franzmeier and Kladivko, 2001), and plotted the results in a graph with depth on the y axis and time on the x axis. In a soil in which the water table rises and falls during the year, the percent time saturated increases fairly regularly down the profile. (The line goes from upper left to lower right in a graph). On the same graph we plotted the depth of uppermost redox depletions, a horizontal line. From the intersection of these two lines, we read the percentage of time saturated that corresponds to uppermost redox depletions. On average, these features corresponded to 8% time saturated (one month out of a year) for the responsive soils. In other words, a few days of saturation during the year did not result in the formation of redox features, but saturation for half the time during the year resulted in many redox features. Saturation for 8% of time corresponded, on average, to the depth of the uppermost redox features. Usually this month of saturation was continuous. We called this condition SatX (Franzmeier, 2003), where X = the percent of time saturated that corresponds to the onset of redox feature formation. For the responsive soils tested (series such as Crosby, Fincastle, Avonburg, and Clermont), the average value for x was 8% of time, thus Sat8. The value for X probably is greater in soils in which uppermost redox features are deeper (moderately well drained soils), because there is less food for microbes deeper in the soil.

To summarize, in upper horizons of many Indiana soils ("responsive" set), the depth to uppermost redox depletions (*reduction*) corresponds to the depth at which the soil is saturated 8% of the time (*saturation*). In lower horizons, e. g., those used to separate moderately well from well drained soils, the time of saturation that corresponds to uppermost redox depletions is probably longer than 8 percent of time because these horizons contain less organic carbon needed by microbes to reduce iron.

This relation does not apply to "non-responsive" soils, however. They are saturated more than 8% of the time, but do not show redox features. They include "seepy" soils and dark-colored poorly drained soils (Aquolls). The "seepy" classes includes a condition called *oxyaquic* (oxygen-containing wet soil) in *Soil Taxonomy*. In Indiana, these soils are often on bevels descending from plains underlain by an aquitard, in which the better drained soils of a toposequence are at a **lower** elevation than the wetter soils. Apparently groundwater moves laterally off the plain through these soils. In these soils, Sat8 usually, but not always, is much higher in the profile than the uppermost redox depletions. In Aquolls, which usually are in landscape depressions, the dark color of organic matter in A horizons masks the gray redox features, and in such soils Sat8 is practically always above the uppermost visible redox features. For example, a very poorly drained soil may have a 20-inch dark colored A horizon (mollic) over a gray B horizon. In this soil, the depth of Sat8 is most likely within the dark A horizon, not at the upper boundary of the gray B horizon.

Reporting Soil and Landscape Information for Onsite Sewage Disposal

Table 17 is a form that we suggest for reporting information important for onsite sewage disposal. A larger version is on the inside back cover of this book. The upper part, *Site and pedon information*, is for reporting location, site information and whole-soil information, such as kinds of parent material.

The middle part, *Soil morphology*, is for describing individual horizons. The next part summarizes the *limiting conditions* for onsite systems, based on soil and landscape characteristics. Space is also provided for *Additional notes* which can be used to describe features that do not fit well into classes defined in the manual. Use the back of the sheet if necessary.

In the form, we specify that numbers be reported directly, instead of class names, for the abundance of redox accumulations and depletions, abundance of additional features (e.g., clay films), size of peds, and size and amount of coarse fragments. If a user prefers class names, he may request that they be reported.

Items and columns are numbered. **This allows the user of soil information to specify which items or columns should be completed by the soil scientist**. For example, an environmental officer in a county that uses a geographic information system may require that item 9 of the site and pedon information section be completed using UTM coordinates.

Example of Completed Form

The official series description for the Crosby soil is in Table 18. This description is intended to be read mainly by soil scientists. This description was used to complete the form for the Crosby soil (Table 19). To fill in the table, we guessed at some numerical values for which class names were reported, e.g., abundance of colors, size of peds, abundance of clay films, and size and amount of rock fragments.

We also generalized some information. Described in the 2Bt3 horizon are "many medium distinct yellowish brown (10YR 5/6) and prominent strong brown (7.5YR 5/8) masses of iron accumulation in the matrix." The distinction between these two colors of brownish mottles (redox accumulations) is not important for onsite interpretations, so on the form we grouped them together as 10YR 5/6 color. The "many" class allows $\geq$20% of each brownish color, thus 40 - 100% of the soil, so we guessed they comprised 45% of the matrix, allowing 55% for the dominant 10YR 5/4 color. In the narrative description it is not stated or implied if the gray color (10YR 5/2) of the BE horizon was due to eluviation of Fe-oxides (E) or reduction process (B). In this horizon, the B component was greater than the E component, and the B component would be gray because of reduction, not eluviation, so the entire gray color was considered to be a reduction feature as reported in the table.

Table 20 summarizes the information in the Evaluation Report. Some people may wish to copy it and use it as a crib sheet.

Soil Interpretations, Limiting Conditions

Soil interpretation refers to the process of using soil information to decide how best to use a soil for a specific purpose. The six items under *Limiting conditions* at the bottom of the form are interpretations for the purpose of onsite sewage disposal.

Many soil properties vary gradually, and at some point on this continuum regulatory agencies place a limit that sets the values of this property that are acceptable and the values that are not acceptable for a particular soil use. Take texture for example. Very coarse textured soils transmit water so fast that purification of effluent does not occur, and very clayey soils do not accept effluent fast enough. Somewhere along the coarse-fine continuum, a regulatory agency must place limits. Just where these limits are placed may vary from time to time and with different agencies. When we

Table 17. Soil and Landscape Evaluation Report for Onsite Sewage Disposal (Based on *Indiana Soil and Landscape Evaluation Manual, 2003*).

Site and pedon information

1. Site:
2. Evaluator:
3. Date:
4. Soil Survey (sheet no.):
5. Soil map uit:
6. Location, relative:
7. Land cover:
8. Location, coordinate:
9. Particle-size family:
10. Slope:
11. Parent material(s)
12. Weather:
13. Landform:
14. Landform component:
15. Modifier:

Soil morphology

1	2	3			4					5	6			7	8			9		10
Depth	Basis	Horizon			Matrix colors					Texture	Structure			Cons-	Additional features			Rock frg.		Effer
in.	in.	designation			Other colors			Redox depletions		class	Grade	Size	Shape	isten.	Kind	Munsell	%	Size	%	vesc.
		Pfx	Mast	Sfx	Knd	Munsell	%	Munsell	%			mm						mm		

Limiting conditions

1. Depth to slow permeability; kind of layer:
2. Depth to rapid permeability; kind of layer:
3. Depth to redox depletions (gray colors):
4. Depth to Sat8 (saturation 8% of the time):
5. Is there evidence of disturbance (other than tillage)? Depth:
6. Is there soil or landscape evidence of flooding or ponding?

Are there additional comments on the back of this page?

Additional notes, comments, and seal of evaluator

wrote this manual, state rules were in a state of flux, so some of the discussions that follow are not very specific. When new state rules are approved, more specific information on how to interpret soil and landscape information can be provided. Six interpretations are listed on the form (Table 17).

1. Depth to slow permeability; kind of layer. The limit for slow permeability (e. g., cm per day) is not specified. The layers with slow permeability are dense till (or layers transitional to dense till), fragipans (or layers with fragic characteristics), bedrock, and possibly other layers such as very fine lacustrine material.
2. Depth to rapid permeability; kind of layer. Again the limit for fast permeability is not specified. The layers with slow permeability are high in coarse sand, gravel, or both.
3. Depth to redox depletions (gray colors). This usually refers to more than 2% gray reduction features in the matrix, dominantly gray clay films, or both. Gray colors are those with value $\geq$4 and chroma $\leq$2.

Table 18. Part of the official series description of the Crosby soil.

Ap — 0 to 8 inches; dark grayish brown (10YR 4/2) silt loam, light gray (10YR 7/2) dry; moderate medium granular structure; friable; many fine roots; strongly acid; abrupt smooth boundary. (6 to 10 inches thick)

BE — 8 to 11 inches; grayish brown (10YR 5/2) silt loam; moderate thin platy structure; friable; common fine roots; few fine distinct yellowish brown (10YR 5/4) masses of iron accumulation in the matrix; moderately acid; clear wavy boundary. (0 to 9 inches thick)

Bt1 — 11 to 14 inches; brown (10YR 5/3) silt loam; moderate medium subangular blocky structure; firm; few fine roots; many distinct dark grayish brown (10YR 4/2) clay films on faces of peds; many medium distinct yellowish brown (10YR 5/6) masses of iron accumulation in the matrix; many medium distinct gray (10YR 6/1) iron depletions in the matrix; strongly acid; clear smooth boundary. (0 to 10 inches thick)

2Bt2 — 14 to 22 inches; brown (10YR 5/3) silty clay loam; moderate medium subangular blocky structure; firm; few fine roots; many distinct dark grayish brown (10YR 4/2) clay films on faces of peds; many medium distinct yellowish brown (10YR 5/6) masses of iron accumulation in the matrix; many medium distinct gray (10YR 6/1) iron depletions in the matrix; 2 percent rock fragments; strongly acid; clear smooth boundary.

2Bt3 — 22 to 28 inches; yellowish brown (10YR 5/4) clay loam; weak medium subangular blocky structure; firm; many distinct dark grayish brown (10YR 4/2) clay films on faces of peds and as linings in pores; many medium distinct yellowish brown (10YR 5/6) and prominent strong brown (7.5YR 5/8) masses of iron accumulation in the matrix; 3 percent rock fragments; neutral; clear smooth boundary. (Combined thickness of the 2Bt horizon is 8 to 24 inches.)

2BCt — 28 to 36 inches; brown (10YR 5/3) loam; weak coarse subangular blocky structure; firm; few distinct dark grayish brown (10YR 4/2) clay films on faces of peds and as linings in pores; common fine distinct yellowish brown (10YR 5/6) and few fine faint yellowish brown (10YR 5/4) masses of iron accumulation in the matrix; 7 percent rock fragments; slightly effervescent; slightly alkaline; clear smooth boundary. (0 to 10 inches thick)

2Cd — 36 to 80 inches; brown (10YR 5/3) loam; massive; very firm; common fine distinct yellowish brown (10YR 5/6) and few fine faint yellowish brown (10YR 5/4) masses of iron accumulation in the matrix; 7 percent rock fragments; strongly effervescent; slightly alkaline.

TYPE LOCATION: Henry County, Indiana; about 2 miles north of Cadiz; 1,000 feet north and 330 feet west of the southeast corner of sec. 27, T. 18 N., R. 9 E.; USGS New Castle West, Indiana topographic quadrangle; lat. 39 degrees 58 minutes 41.76 seconds N. and long. 85 degrees 28 minutes 56.43 seconds W., NAD 27; UTM Zone 16, 629593 easting and 4426452 northing, NAD 83.

4. Depth to Sat8. It appears from the earlier discussion (see page 49) that Sat8 is a more quantitative term for what is meant by "seasonal high water table." In many soils Sat8 corresponds, on average, with the uppermost depth of redox depletions. The question is how to estimate Sat8 in other "non-responsive soils." We suggest using these guidelines:

   For "seepy" soils, those on bevels that descend from a plain underlain by an aquitard, estimate Sat8 to be about 6 inches deeper than Sat8 for the somewhat poorly drained soils on the plain above the bevel. For Aquolls, if at least part of the mollic horizon has 1-chroma color, estimate Sat8 to be at the surface. If all of the mollic horizon has 2- or 3-chroma, estimate Sat8 to be half way between the uppermost visible redox depletions and the surface.

   Soil scientists must use their best judgment in estimating the depth of Sat8 for soils that do not clearly fall into one of the groups outlined above. The guidelines above need to be tested by research and practical experience. For soil scientists, if the guidelines above do not agree with your experience, please forward suggested revisions, and evidence to substantiate them, to the authors of this manual.

5. Is there evidence of disturbance (other than tillage)? Depth. Often absorption fields are not allowed in disturbed material such as fill from an excavation, for example.
6. Is there soil or landscape evidence of flooding or ponding? Absorption fields are generally not allowed on flood plains and in areas that are frequently ponded.

SOIL MORPHOLOGY COURSES AND COLLEGIATE SOILS CONTESTS

Conventions followed in some soil morphology courses at Purdue University (Agronomy 155 and 355) are based on the information in this manual, but they also follow guidelines used in regional and national soils contests. Students may participate in two kinds of contests, one sponsored by the America

Table 19. Soil and Landscape Evaluation Report for Onsite Sewage Disposal Completed for Crosby silt loam.

Site and pedon information

1. Site: *Example of form completed for Crosby silt loam*
2. Evaluator: *John Doe*
3. Date: *7/15/03*
4. Soil Survey (sheet no.): *Henry (20)*
5. Soil map unit: *Crosby silt loam, 0-3% slopes*
6. Location, relative: *100 ft. N, 500 ft. W of SE corner of lot 12, Beanfield Subdivision*
7. Land cover: *Soybean stubble*
8. Location, coordinate: *UTM: 629,593 E;4,426,425 N; Zone 16;NAD83*
9. Particle-size family: *Fine*
10. Slope: *2%*
11. Parent material(s) *1 Loess, 2 Till*
12. Weather: *Sunny, 82°*
13. Landform: *Till plain*
14. Landform component: *Swell*
15. Modifier: *Backslope*

Soil Morphology

1		2	3			4					5	6			7	8			9		10
Depth in.		Basis in.	Horizon designation			Matrix colors					Texture class	Structure			Cons-isten.	Additional features			Rock frg.		Effer vesc.
						Other colors			Redox depletions			Grade	Size mm	Shape		Kind	Munsell	%	Size mm	%	
			Pfx	Mast	Sfx	Knd	Munsell	%	Munsell	%											
0	8	24 P		A	p	d	10YR 4/2	100			SIL	2 2	 4	cmp gr	FR						
8	11	24 P		BE		a	10YR 5/4	5	10YR 5/2	95	SIL	2	2	pl	FR						
11	14	24 P		B	t 1	d a	10YR 5/3 10YR 5/6	45 30	10YR 6/1	25	SIL	2	10	sbk	FI	CF	10YR 4/2	50			
14	22	24 P	2	B	t 2	d a	10YR 5/3 10YR 5/6	45 25	10YR 6/1	30	CL	2	15	sbk	FI	CF	10YR 4/2	60			
22	28	24 P	2	B	t 3	d a	10YR 5/4 10YR 5/6	55 45			CL	2	20	sbk	FI	CF	10YR 4/2	75			
28	36	24 P	2	BC	t			85 15			L	1	40	m	VFI	CF	10YR 4/2	15	20	7	SL
36 40	40 50	24 P 3 A	2	C	d			90 10			L								30	7	ST

Limiting conditions

1. Depth to slow permeability; kind of layer: *28 in., dense till*
2. Depth to rapid permeability; kind of layer: *NA*
3. Depth to redox depletions (gray colors): *8 in.*
4. Depth to Sat8 (saturation 8% of the time): *8 in.*
5. Is there evidence of disturbance (other than tillage)? *No* Depth:
6. Is there soil or landscape evidence of flooding or ponding? *No*

Are there additional comments on the back of this page? *No*

Additional notes, comments, and seal of evaluator

Society of Agronomy (ASA), and the other sponsored by the National Association of College Teachers of Agriculture (NACTA).

Score Card Instructions

Four features of soils may be judged: 1) morphology, 2) site characteristics, 3) interpretations and 4) classification. *The Soil Survey Manual*, (Soil Survey Division Staff, 1993); *Soil Taxonomy*, (Soil Survey Division Staff, 1999); and *Keys to Soil Taxonomy*, current edition, will be used as guides. Any significant deviations from these references for a contest will be noted. Score cards used in the two kinds of contests are similar, but not identical. The NACTA score card (Tables 21 and 22) includes all four features, and the ASA score card (Tables. 23 and 24) includes all except interpretations.

I. Scorecard: Soil Morphology

Soil morphology is discussed in Chapter 4 of this manual. Acceptable abbreviations for soil morphology terms are listed in Table 25. These abbreviations must be used. Any other abbreviations will be marked incorrect. If no entry is needed for any box on the front of the scorecard, it must be marked with a dash (-) and not left blank. Blank boxes will be marked incorrect. The outline below follows the headings on the scorecards. The

Table 20. Explanation of columns in Soil Evaluation Report for Onsite Sewage Disposal. See appropriate table or text for definition and explanation of terms.

No.	Explanation
Site and pedon information	
1	**Site**. Often the name of a subdivision or developer.
2	**Evaluator**. The name is essential.
3	**Date.** The date the field work was completed.
4	**Soil Survey (sheet number)**. Most soils surveys are named by county, but some are for more than one county. Also, list the map sheet number.
5	**Soil map unit**. Name, not symbol, of the map unit in the survey listed in item 4.
6	**Location, relative**. E.g., the location within a subdivision lot or plot of land.
7	**Land cover**. Provides information about the vegetation or other cover at the site. It might be of special interest when surface absorption systems will be considered.
8	**Location, coordinate**. According to latitude-longitude, U.S. rectangular survey (5-point system), UTM, or state plane coordinate system. Determined with a GPS instrument or measured from a topographic map.
9	**Particle size family.** Required for design of a perimeter drain system.
10	**Slope.** Usually essential for approving a site.
11	**Parent material(s)**. Must agree with the horizon designation prefix of the **Soil morphology** section
12	**Weather**. Required by some agencies interested in the conditions when the investigation was done, e.g., was there snow on the ground?
13	**Landform.** Helps to predict where water moves in a landscape.
14	**Landform component**. Helps to predict where water moves in a landscape.
15	**Landform component modifier** Additional information about the landscape.
Soil morphology	
1	**Depth**. Upper and lower horizon depth in inches.
2	**Basis**. The kind of soil exposure observed for each horizon: Width of the soil section observed to the nearest inch, followed by: t = tube (probe or core sample), a = auger (screw, bucket, etc.), d = post hole digger (examined material removed), p = face of pit. E.g.,: *2a* = 2 inch auger.
3	**Horizon designation**. Numerical prefix (**Pfx**, parent material), **Mast**er horizon (A, E, B, C. etc.), Horizons suffix(es) (**Sfx**)to designate major processes such as clay migration (t), and numerical suffix to show the subdivision of a horizon.
4	**Matrix colors**. The matrix is all the material inside a ped except that described as additional morphological features (e.g. manganese concretions; column set 8). Report all redox depletions (gray drainage colors) in the **Redox depletions** column. Report all other colors, including gray colors not due to reduction, in the **Other Colors** column set. Report the abundance of color features in volume percent, not the class (e.g., "common"). The total of all percentages in this section should equal 100 for each horizon.
5	**Texture class**. Estimate the class. The abbreviations can be deciphered by knowing the meanings of only seven elements: C = Clay, SI = Silt(y), S = Sand(y), L = Loam(y), F = Fine, CO = Coarse, V = Very.
6	**Structure**. For Ap horizons record the degree of compaction on the first line. On the second line, report the nature of structure the compacted horizon breaks to. For subsoil horizons with compound structure, record the primary (larger) structure on the first line and the smaller structure on the second line. Grade Ð distinctness of development; 1 = weak, 2 = moderate, 3 = strong. Size Ð size (mm) across the smallest dimension of representative ped. Shape Ð gr = granular, sbk = subangular blocky, abk = angular blocky. pl = platy, pr = prismatic, m = massive.
7	**Consistence**. An indication of soil strength. The name of the class indicates the moisture content when consistence was determined.
8	**Additional morphological features**. Attributes and examples: Kind: CF = clay films on ped surfaces; Mn = Mn concretions inside peds Munsell color % of surface covered or % of volume of ped interior.
9	**Rock fragments**. Average size in mm of material >2mm in diameter and the volume percent occupied by this material.
10	**Effervescence**. For the most effervescent material (often carbonate coats) using the scale, VS = very slight, SL = slight, STt = strong, VE = violent.
Limiting conditions (Record depth in inches)	
1	**Depth to slow permeability**. The horizons generally responsible are dense till, fragipans, and bedrock.
2	**Depth to rapid permeability**. The horizons generally responsible contain much coarse sand and usually gravel.
3	**Depth to redox depletions**. Presence indicates limiting, anaerobic conditions.
4	**Depth to Sat8 (saturation 8% of the time, one month/year).** In many soils this corresponds to the depth to redox depletions. In other soils (e.g., oxyaquic soils and Aquolls) it might differ.
5	**Is there evidence of disturbance (other than tillage)?** Such disturbance is indicated by soil horizons not in their normal positions (A horizons buried by human activity, B and C horizons mixed, etc.)
6	**Is there soil or landscape evidence of flooding or ponding?** Soil evidence could be very weak soil development, irregular decrease in organic matter content downward in the profile, etc. Flood plain landforms and closed depression landform components comprise landscape evidence of flooding or ponding.

item numbers below refer to the column number within a section, such as Texture.

A. Horizonation

Horizon designations are discussed in Chapter 4. Only special rules and conventions that apply to contests are included here. The terms "numerical prefixes," "horizon suffixes," etc. are new names that are currently used in the Cooperative Soil Survey.

1. **PM** - (Parent Material, now called **Numerical prefixes.** See Chapter 4.) The "l" for the first parent material is understood and should not be entered. Enter a dash (-) instead.
2. **LTR -** (Letter, see **Master horizon** in Chapter 4).

3. **Sub** - (Subordinate Distinction, now called **Horizon suffixes**. See Chapter 4.) Enter the subordinate distinction(s) of the master horizon. For contest purposes, be familiar with the following: b, d, g, k, p, r, s, ss, t, w, x, y, and z. The conventions for ordering multiple subordinate distinctions will be waived for the contest, i.e. Btk = Bkt.

4. **No** - (Number, now called **Numerical suffixes**. See Chapter 4.) Enter Arabic numerals whenever a horizon identified by a single combination of master and subordinate distinction letters needs to be subdivided. All master and subscript letters must be the same. (i.e. Btkl - Btk2 is correct; Btkl - Btky2 is incorrect; Btkl - 2Btk2 is correct).

5. **Lower Depth** - In order for the students and judges to have a common base, the following guidelines will be used. From four to six horizons will be described within a specified depth. The contestant should determine the depth in cm from the soil surface to the lower boundary of each horizon. Thus, for a Btl that occurs between 23 and 37 cm below the surface, the contestant should enter 37 in the Lower Depth Column.

   Contest officials will place a marker somewhere in the third horizon. Unless otherwise noted on the Site Card, no horizon less than eight cm. thick (no matter how contrasting) will be described. If the Site Card does not indicate a horizon thinner than eight cm is present and one occurs in the profile, combine it with the adjoining horizon that is most similar. When two horizons combine to a total thickness of eight cm or more, always describe the properties of the thicker horizon.

   Depth measurements should be made in the control zone. The allowed range for answers will depend on the distinctness, and to a lesser degree, the topography of the boundary, as determined by the judges.

   If a lithic or paralithic contact occurs anywhere in the exposed control zone (within 150 cm. of the soil surface), it must be considered in answering topics in Part II including: Effective Soil Depth, Permeability and Water Retention Difference, as well as in any rating charts used in Part III. This is true even if the contact is at, or below, the specified description depth, and is not an actual horizon in the contest profile description. If such a situation arises, assume your last horizon's properties extend to the contact. Be sure to note the contact depth, while in the pit, even if it is below the description depth.

   If the contact is within the specified description depth, it should be described as one of your horizons, and the appropriate nomenclature applied (i.e. Cr or R). Morphological features need not be recorded for Cr or R horizons. If they are, graders will ignore them and no points will be deducted.

6. **Distinctness of Boundary** - The distinctness of each horizon boundary, except the last is to be evaluated. For the last horizon, enter a dash (-) in the box on the scorecard. The topography, or shape, of the boundaries will not be directly considered, but it could influence contest officials.

   As a guide, the following system will relate lower depth and distinctness of boundary. When scoring answers for the lower depth there is an adjustment for the distinctness of the boundary. For full credit the lower depth must be within the ranges listed in parentheses in Table 25 for each of the distinctness of boundary classes. Contest officials may modify this method of determining full credit on a given site.

B. Texture

1,2. **% sand and % clay** - Estimates of percent sand and percent clay should be made for each horizon, and entered in the appropriate columns. Answers within plus or minus five of the actual values will be given full credit. Partial credit may be given at the discretion of the contest officials. Actual contents of sand and clay will be determined by laboratory

Table 21. Scorecard for Region III, ASA collegiate soils contests, front.

SCORECARD

REGION III, ASA COLLEGIATE SOILS CONTEST

Site No. ______

Contestant I.D. ________

CONTESTANT NAME ___________________________

SCHOOL _________________________

TOTAL SCORE _____________

Describe ____ Horizons to a depth of ____________ cm. Nail in third horizon at _______ cm

I. Soil Morphology

A. HORIZONATION					B. TEXTURE				C. COLOR			D. STRUCTURE		E. CONSIST	F. MOTTLES		SCORE
Master PM-LTR (2) (2)	Sub (2)	No (2)	Lower Depth (CM) (2)	Dist (2)	Sand % (± 5) (2)	Clay % (+ 5) (2)	Crse. Frag (2)	Class (2)	Hue (2)	Value (2)	Chroma (2)	Grade (2)	Shape (2)	Moist Strength (2)	Abun-dance (2)	Contrast (2)	

PAGE TOTAL ___________________________

analysis on selected horizons. These estimates will also be used as "tie breakers" in scoring.

3. **Coarse Fragments** - Modification of textural classes is made in the coarse fragment column when the soil contains more than 15 percent, by volume, coarse fragments. For the purposes of this contest, the modifiers listed in Table 26 will be used when the volume of rock fragments is between 15 and 35 percent.

   If the volume of coarse fragments is between 35 and 60%, prefix the appropriate modifier with the word "very." If the volume is greater than 60%, use the prefix "extremely." Enter the correct abbreviation from Table 25 for the coarse fragment modifier in the coarse fragment column. Do not enter percent values for coarse fragments. If coarse fragment modifiers are not needed, enter a dash in the space on the scorecard.

4. **Texture class** - (see, Texture Chapter 4) The textural class for the less than 2 mm fraction of each horizon is to be entered in the Class column. Any deviation from the standard nomenclature (e.g., silty loam or loamy clay) will be incorrect. Acceptable abbreviations are given in Table 25. For sand, loamy sand, and sandy loam textures, modifiers must be used if needed (i.e., very fine, fine, or coarse).

C. Color

1, 2, 3. **Munsell color** - Designate moist color using Munsell color book notation according to the columns on the scorecard for hue, value and

Table 22 Scorecard for Region III, ASA collegiate soils contests, back.

II. Site and Soil Characteristics

A. Parent Material (5)

____Recent alluvium
____Glacial outwash
____Lacustrine deposit
____Loess
____Eolian sand
____Beach deposit
____Glacial till
____Colluvium
____Residuum

B. Landform (5)

1. Constructional

____Flood plain
____Stream terrace
____Kame/esker
____Alluvial fan
____Beach ridge
____Loess hillslope/plain
____Outwash plain
____Sand dune
____Lake plain
____Till plain /drumlin/moraine

2. Erosoinal

____Upland headslope
____Upland sideslope
____Upland noseslope
____Interfluve

C. Slope Profile (5)

____Summit
____Shoulder
____Backslope
____Footslope
____None

D. Slope (5)

____0-1.9%
____2-4.9%
____5-9.9%
____10-14.9%
____15-20%
____ > 20%

E. Erosion Class (5)

____Class 1
____Class 2
____Class 3
____Class 4
____Deposition

F. Hyd. Cond., Surf. (5)

____High
____Moderate
____Low

G. Hyd. Cond., Limiting (5)

____High
____Moderate
____Low

H. Surface Runoff (5)

____Negligible
____Very low
____Low
____Medium
____High
____Very high

I. Soil Wetness Class (5)

____1 (> 150 cm)
____2 (100-150 cm)
____3 (50-99 cm)
____4 (25-49 cm)
____5 (< 25 cm)

J. Effective Soil Depth (5)

____Very deep (> 150 cm)
____Deep (100-150 cm)
____Mod. Deep (50-99 cm)
____Shallow (25-49 cm)
____Very shallow (< 25 cm)

K. Water Retention, Difference (5)

____Very low (< 7.5 cm)
____Low (7.5-14.9 cm)
____Mod. (15-22.5 cm)
____High (> 22.5 cm)

III. Soil Classification

A. Epipedon (5)

____Mollic
____Umbric
____Ochric
____None

B. Subsurface Horizon or Feature (5)

____Albic
____Argillic
____Calcic
____Cambic
____Fragipan
____Natric
____Spodic
____Lithic
____Paralithic
____None

C. Order (5)

____Alfisol
____Entisol
____Inceptisol
____Mollisol
____Ultisol
____Spodosol

D. Suborder (5)

____Alb
____Aqu
____Bor
____Fluv
____Ochr
____Orth
____Psamm
____Ud
____Umbr
____Ust

E. Great Group (5)

____Alb
____Argi
____Calci
____Dystr(o)
____Endo
____Eutr(o)
____Fluv
____Fragi
____Gloss(o)
____Hapl
____Natr(i)
____Ochr
____Pale
____Psamm
____Quartzi
____Ud(i)
____Umbr

PAGE TOTAL SCORE_________

chroma. Color names will not be accepted. Partial credit may, at the discretion of the judges, be given for colors close to the official answers. In the case of surface horizons, determine color on crushed samples. The color recorded for any other horizon, including a mottled horizon, should be the dominant color.

D. Structure

1,2. **Grade and shape** - Record the dominant grade and ghape of structure for the horizon. If different kinds of structure are present in a horizon, give the shape and grade of the structure that is most common. If the most common structure is compound (one kind breaking to another), describe the one having the stronger grade. If the

Table 23. Scorecard for NACTA soils contests, 4-year division.

SCORECARD
NACTA SOILS CONTEST
4 YR DIVISION

Site No. ______

Describe ____ Horizons to a depth of ___________ cm. Nail in third horizon at _______ cm

Contestant I.D. ________
CONTESTANT NAME ______________________
SCHOOL ______________________
TOTAL SCORE ___________

I. Soil Morphology

A. HORIZONATION					B. TEXTURE				C. COLOR			D. STRUCTURE		E. CONSIST	F. MOTTLES		SCORE
Master PM-LTR (2) (2)	Sub (2)	No (2)	Lower Depth (CM) (2)	Dist (2)	Sand % (± 5) (2)	Clay % (+ 5) (2)	Crse. Frag (2)	Class (2)	Hue (2)	Value (2)	Chroma (2)	Grade (2)	Shape (2)	Moist Strength (2)	Abun-dance (2)	Contrast (2)	

PAGE TOTAL ___________________________

structural peds are of equal grade then enter the shape and grade of the larger peds. If the horizon has no structural arrangement, use structureless and enter a zero (0) in the grade column and single grained or massive in the shape column. Abbreviations are listed in Table 25.

E. Consistence

1. See Chapter 4. Determine on moist samples. Abbreviations are in Table 25.

F. Mottles

1,2. **Abundance and Contrast** - Record for any mottles that are present (COLOR, Chapter 4). For this contest, mottles will be considered as subdominant colors (high or low chroma) in ped interiors, or on ped surfaces that are the result of oxidation-reduction. The following features will not be considered mottles: clay skins, skeletans, or other ped coatings, concretions, nodules, krotovinas, rock fragment colors, roots, and mechanical mixtures of horizons, such as B materials in an Ap horizon.

If there are mottles of more than one color, use the most abundant kind in making abundance and contrast determinations. If bi-colored mottles are equally abundant, then use the most contrasting one. If no mottles are present, enter a dash (-) in both boxes. For all contrast determinations, compare the mottle color to the dominant color that you determined in part C. See Table 25 for amount and abbreviation of mottle abundance. See Table 27 for guidelines for determining contrast. Enter abbreviations only on scorecard.

Table 24. Scorecard for NACTA soils contests, 4-year division, back.

II. Site and Soil Characteristics

A. Landform (5)

1. Constructional
____Floodplain
____Stream terrace
____Alluvial fan
____Beach ridge
____Sand dune
____Lake plain
____Loess hillslope
____Outwash plain
____Till plain/drumlin /moraine
____Kame/esker

2. Erosional
____Upland

B. Parent Material (5 each)

____Alluvium
____Glacial outwash
____Lacustrine deposit
____Glacial till
____Loess
____Eolian sand
____Beach deposit
____Colluvium
____Residuum

C. Slope Profile (5)

____ Concave
____ <1%
____ 1-4.9%
____ 5-9.9%
____ 10-14.9%
____ 15-20%
____ >20%

D. Erosion Class (5)

____Class 1
____Class 2
____Class 3
____Class 4
____Deposition

E. Runoff (5)

____Negligible
____Very Low
____Low
____Medium
____High
____Very high

F. Soil Drainage Class (5)

____ Well drained
____ Moderately well
____ Somewhat poorly
____ Poorly

G. Effective Soil Depth (5)

____Very deep (> 150 cm)
____Deep (100-150 cm)
____Mod. Deep (50-99 cm)
____Shallow (25-49 cm)
____V. shallow (< 25 cm)

H. Hyd. Cond., Surf. (5)

____High
____Moderate
____Low

I. Hyd. Cond., Limiting (5)

____High
____Moderate
____Low

J. Water Retention, Difference (5)

____Very low (< 7.5 cm)
____Low (7.5-14.9 cm)
____Mod. (15-22.5 cm)
____High (> 22.5 cm)

III. Soil Interpretations

A. Suitability as source of roadfill material (5)

____ Good
____ Fair
____ Poor
____ Most restrictive featureB. Septic tank absorption fields (5)
____ Slight
____ Medium
____ Severe
____ Most restrictive feature

C. Limitation for sewage lagoons (5)

____ Slight
____ Moderate
____ Severe
____ Most restrictive feature

IV. Soil Classification

A. Epipedon (5)

____ Mollic
____ Ochric
____ None

B. Subsurface Horizon/ Feature (5 each)

____ Albic
____ Argillic
____ Calcic
____ Cambic
____ Fragipan
____ Lithic
____ Paralithic
____ None

C. Order (5)

____ Alfisol
____ Entisol
____ Inceptisol
____ Mollisol
____ Ultisol
____ Vertisol

PAGE TOTAL __________

II. Scorecard: Site and Soil Characteristics

This part of the contest evaluates soil parent material, landforms, soil depth, soil wetness, and other characteristics. No guidelines have been accepted, so they are furnished for each contest.

III. Scorecard: Soil Interpretations

Soil interpretations are made for NACTA contests, but not ASA contests. Guidelines are given for soil suitability for roadfill (Table 28), soil suitability for soil absorption fields in onsite wastewater disposal systems (Table 29), and soil suitability for sewage lagoons (Table 30).

IV. Scorecard: Soil Classification

Soils are classified using *Soil Taxonomy* into the great group level in ASA contests, but only to the order level in the NACTA contests. Rules are distributed for each contest.

Collegiate Soils Contest Rules

1. Information required for the contest will be posted on a site card (Figure 27).
2. Each team will consist of four members judging four sites. One alternate may compete for individual awards only. The top three individual scores for each team at each site will be added together and totaled for all four sites. This will be used as the score for the team competition. The individual awards will be based on the the total score for all four sites, as shown in Table 31.
3. The tiebreaker for individual scores will be their estimate of the percent clay for the surface horizon of Site 1. The individual closest to the official clay percentage on the scoring key will

Figure 27. Illustration of site card for collegiate soils contests.

COLLEGIATE SOILS CONTEST

SITE CARD

SITE NO. __________

Describe _____________ horizons to a depth of ____________ cm.

Marker is in the third horizon at ___________ cm.

Horizon	pH	% Base Sat.	% Organic C	% $CaCO_3$
1.				
2.				
3.				
4.				
5.				
6.				

Table 25. List of abbreviations used for soil morphology in collegiate contests.

Distinctness of Boundary (Lower depth range from official description):			
Abrupt=A (±1 cm)	Clear=C (±3 cm)		
Gradual=G (±8 cm)	Diffuse=D (±15 cm)		
Textural Classes:			
Coarse sand	= COS	Sandy clay loam	= SCL
Sand	= S	Loam	= L
Fine sand	= FS	Clay loam	= CL
Very fine sand	= VFS	Silt	= SI
Loamy coarse sand	= LCOS	Silt loam	= SIL
Loamy sand	= LS	Silty clay loam	= SICL
Loamy fine sand	= LFS	Silty clay	= SIC
Loamy very fine sand	= LVFS	Sandy clay	= SC
Coarse sandy loam	= COSL	Clay	= C
Sandy loam	= SL		
Fine sandy loam	= FSL		
Very fine sandy loam	= VFSL		
Coarse Fragments:			
Gravelly	= GR	Channery	= CH
Very gravelly	= VGR	Very channery	= VCH
Extremely gravelly	= EGR	Extremely channery	= ECH
Cobbly	= CB	Flaggy	= FL
Very cobbly	= VCB	Very flaggy	= VFL
Extremely cobbly	= ECB	Extremely flaggy	= EFL
Structure, Grade:			
Structureless = 0	Weak = 1	Moderate = 2	Strong = 3
Structure, Shape:			
Granular	= GR	Angular blocky	= ABK
Platy	= PL	Subangular blocky	= SBK
Prismatic	= PR	Single grain	= SGR
Columnar	= CPR	Massive	= MA
Consistence:			
Loose	= L	Firm	= FI
Very Friable	= VFR	Very Firm	= VFI
Friable	= FR	Extremely Firm	= EFI
Mottles:			
Abundance	Few	<2%	= F
	Common	2-20%	= C
	Many	>20%	= M
Contrast	Faint	= F	
	Distinct	= D	
	Prominent	= P	

be the winner of the tie. If that should fail to break the tie the next lower horizon will be used and so forth until a winner of the tie is determined. Tabulating the cumulative scores of all four team members will break team ties. If this should result in a tie the percent clay estimates for the surface horizon of Site 1 of all four team members will be added together and averaged. The team with an average estimate closest to the official key will be the winner of the tie. If this fails to break the tie, the next lower horizon will be used and so forth until the tie is broken.

4. Fifty minutes will be allowed for judging each site. This will be divided between time in the pit, time out of the pit and time open for all. For half of the group it will be: ten minutes in the pit; ten minutes out; ten minutes in; ten minutes out; ten minutes open for all. For the other half of the group it will be: ten minutes out of the pit; ten minutes in; ten minutes out; ten minutes in; ten minutes open for all. Contestants will alternate starting in and out of the pit at each site. For large numbers of contestants, it may be necessary to provide more than one profile at each site.
5. Contestants may use a clipboard, hand level, containers for samples, pencil (no ink pens), knife, water and acid bottles, Munsell color book (Hue 10R to Hue 5Y), non-programmable calculator and tape (metric preferred - all depths will be in cm.).
6. Each site will require contestants to describe from four to six mineral horizons. In each pit, a control zone will be clearly marked, and is to be used for the measurement of horizon depths and boundary. This area will be the officially scored profile and must not be disturbed. It is recommended that one or two official meter sticks be affixed to the soil pit wall on either side of the official judging zone. The profile depth to be considered, number of horizons to be described, and any chemical or other relevant data will be provided at each site on a Site Card. A marker will be placed somewhere in the third horizon to assist contestants in determination of lower depth. The depth in cm from the surface to the marker will be given on the Site Card. A sample Site Card is given in Attachment 3.
7. Site monitors will be present at each pit to enforce rules and keep time. The official

Table 26. Characterization of coarse fragments for soils contests.

Coarse Fragment	Abbreviation	Size	Example
Gravelly	GR	0.2 — 7.6 cm.	Very coarse sand to apple size
Cobbly *(includes stones and boulders)*	CB	7.6 — 25 cm. and larger	Apple to large cantaloupe size and larger
Channery	CH	0.2 — 15 cm.	Long and flat; up to size of a hand
Flaggy *(includes stones and boulders)*	FL	15 — 38 cm. and larger	Long and flat, hand to length of a forearm and larger

judges for the contest should be Natural Resource Conservation Service, university or other professional soil scientists. If possible, a team composed of two or more soil scientists should be the official judges.

8. Each contestant must give his or her scorecard to the pit monitor before moving to the next site. Each contestant must insure that their scorecard has his or her name, contestant number, university and site number on it prior to submitting it to the site monitor.
9. Stakes will be set near each site for slope measurement. Slopes will be measured between the stakes. The stakes should be set at approximately the same height, although this is not required. Contestants must be prepared to measure the actual slope of the soil surface between the stakes, regardless of the height of the stakes.

PEDOLOGY COURSE, AGRY 565

The form provided as Table 32 will be used to report site and pedon information in AGRY 565, "Soil Classification, Genesis, and Survey." We will use the terminology described earlier in this bulletin. Specific instructions follow for each part of the form.

Site and pedon information

1. Site: The name of the site as provided by the instructor.
2. Evaluator: Your name and the names of any lab partners.
3. Date: The date on which the soil was described.
4. Soil Survey (sheet no.): Locate the site on the published soil survey report and enter the county, and map sheet number.
5. Soil Map Unit: Enter the soil map unit for the site as obtained from the soil survey report.

Table 27. Guidelines for determining contrast of mottles for college soils contests.

Contrast	Abbreviation	Required Differences in Munsell Units			
		Hue	Value		Chroma
Faint	F	0	≤ 2	and	≤ 1
Distinct	D	0	3 to 4	or	2 to 4
		1	≤ 2	and	≤ 1
Prominent	P	0	> 4	or	> 4
		1	> 2	or	> 1
		2	≥ 0	or	≥ 0

Table 28. Guidelines for evaluating suitability of soils for roadfill for NACTA contests.

Property	Good	Fair	Poor	Feature
Depth to bedrock	> 150 cm.	100 -150 cm.	< 100 cm.	Depth to Rock
Depth to cemented pan	> 150 cm.	100 — 150 cm.	< 100 cm.	Cemented Pan
Shrink Swell	< 8 cm. clay	8 — 16 cm. clay	> 16 cm. clay	Shrink Swell
Texture (avg. 25 — 100 cm.)	S, LS, SL	L, SCL	all others	Low Strength
% >8 cm. stones, 0 to 40 cm.	< 25%	25 — 50%	> 50%	Large Stones
Depth to high water table	> 90 cm.	30 — 90 cm.	< 30 cm.	Wetness
Slope	< 15%	15 — 25%	> 25%	Slope

6. Location, relative: Describe the location of the site using the U.S. Rectangular System as described in Chapter 1 of this manual.
7. Land cover: Describe the land cover, i.e., grass, hardwood forest, cultivated field with corn stubble, etc.
8. Location, coordinate: Give the GPS coordinates for the site.
9. Slope: Slope in % as measured using an Abney Level or clinometer.
10. Parent material(s): Enter the presumed parent materials after writing the soil description.
11. Weather: Describe whether it is sunny or overcast, and the approximate temperature. (Colors sometimes match a little differently depending on the lighting conditions.)
12. Landform: Use terminology from Table 3.
13. Landform component: Use terminology from Table 4.
14. Modifier: Enter any appropriate additional descriptors from Table 5.

Soil Morphology

1. Depth: Enter the depth to the lower boundary of the horizon in centimeters first and below it in parentheses in inches (2.54 cm = 1 inch). *Soil Taxonomy* definitions are written in centimeters, while soil survey reports and official series descriptions generally have depths given in inches, so having both on the description will be handy.
2. Basis for description: See page 28. Note that the basis can be different for different horizons. The upper horizons might be obtained with a spade,

Table 29. Guidelines for evaluating suitability of soils for septic tank absorption fields for NACTA contests.

Property	Slight	Moderate	Severe	Feature
Flooding	none	rare	freq. / occas.	Flooding
Depth to bedrock	> 180 cm.	100 — 180 cm.	< 100 cm.	Depth to Rock
Depth to cemented pan	> 180 cm.	100 — 180 cm.	< 100 cm.	Cemented Pan
Ponding	no	——— -	yes	Ponding
Depth to high water table	> 180 cm.	120 — 180 cm.	< 120 cm.	Wetness
Permeability (60 — 150 cm.)	S, LS, SL	SCL, L, SIL, SI	all others	Percs Slowly
Permeability (60 — 150 cm.)	all others	———	S, LS	Poor Filter
Slope	< 8%	8 — 15%	> 15%	Slope
% > 8 cm. stones, 0 to 40 cm.	< 25%	25 — 50%	> 50%	Large Stones

Table 30. Guidelines for evaluating suitability of soils for sewage lagoons for NACTA contests.

Property	Slight	Moderate	Severe	Feature
Permeability (30 — 150 cm.)	all others	SCL, L, SIL, SI	S, LS, SL	Seepage
Depth to bedrock	> 150 cm.	100 — 150 cm.	< 100 cm.	Depth to Rock
Depth to cemented pan	> 150 cm.	100 — 150 cm.	< 100 cm.	Cemented Pan
Flooding	none, rare	———	occas., freq.	Flooding
Slope	< 2%	2 — 7%	> 7%	Slope
Ponding	no	———	yes	Ponding
Depth to high water table	> 150 cm.	110 — 150 cm.	< 110 cm.	Wetness
% >8 cm. stones, 0 to 40 cm.	< 20%	20 — 35%	> 35%	Large Stones

Table 31. Illustration of scoring for collegiate soils contests. Note that the team score is not the sum of the individual scores. Scores in **bold** were not used to compute the Team Score.

STUDENT	SITE 1	SITE 2	SITE 3	SITE 4	TOTAL individual
Jones	232	241	254	183	910
Smith	261	262	313	186	1022
Brown	**208**	277	**251**	171	907
Green	275	**234**	289	**167**	965
TEAM	768	780	856	540	

Team Score = 2944

while deeper horizons might be obtained with an auger or probe.

3. Horizon Designation: See page 29.
4. Matrix colors: See page 33.
5. Texture: See page 36. Enter the texture class, then enter the percentage of sand and clay below it to the nearest 5%.
6. Structure: Enter the structure as described on page 38.
7. Consistence: Enter the consistence as described on page 42.
8. Additional features: Enter additional morphological features as described on page 43.
9. Rock fragment: Enter percentage of rock fragments as describe on page 44.
10. Effervescence: See page 45.

Limiting conditions, additional notes, and comments (See page 50)

1. Depth to slow permeability; kind of layer.
2. Depth to rapid permeability; kind of layer.
3. Depth to redox depletions.
4. Depth to Sat8 (saturation 8% of the time).
5. Is there evidence of disturbance (other than tillage)? Depth: Describe any evidence for prior disturbance.
6. Is there soil or landscape evidence for flooding or ponding?
7. Classification: Enter the classification using the simplified keys provided in class.

Table 32. Soil and Landscape Evaluation Report for AGRY 565 (Based on Indiana Soil and Landscape Evaluation Manual, 2003)

Site and pedon information

1. Site:
2. Evaluator:
3. Date:
4. Soil Survey (sheet no.):
5. Soil Map Unit:
6. Location, relative:
7. Land cover:
8. Location, coordinate:
9. Slope:
10. Parent material(s)
11. Weather:
12. Landform:
13. Landform component:
14. Modifier:

Soil morphology

1	2	3			4					5	6			7	8			9		10
Depth	Basis	Horizon			Matrix colors					Texture	Structure			Consis-	Additional features			Rock frag.		Efferv-
cm,	in.	designation			Other colors			Redox depletions		class	Grade	Size	Shape	tence	Kind	Munsell color	%	Size	%	escence
(inches)		Prefix	Master	Suffix	Kind	Munsell color	%	Munsell color	%	(sand, clay)		mm						mm		
( )																				
( )																				
( )																				
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( )																				
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( )																				
( )																				

Limiting conditions, additional notes and comments

1. Depth to slow permeability; kind of layer:
2. Depth to rapid permeability; kind of layer:
3. Depth to redox depletions (gray colors):
4. Depth to Sat8 (saturation 8% of the time)?
5. Is there evidence of disturbance (other than tillage)? Depth:
6. Is there soil or landscape evidence of flooding or ponding?
7. Classification: Order __________, Suborder ______________, Great Group _______________________, Subgroup ___________________________
   Family (particle-size) ______________________, (mineralogy) ____________________, (temperature regime) _________________

Are there additional comments on the back of this page?

References

Brewer, Roy 1964. Fabric and mineral analysis of soils. Wiley, New York.

Franzmeier, D. P. 1996. Laboratory manual for soil classification, genesis, and survey, Agronomy 565, 2nd edition. Department of Agronomy, Purdue University.

Franzmeier, D. P. 2003. Soil saturation and soil reduction. Agronomy Abstracts.

Franzmeier, D. P., G, C. Steinhardt, and B. R. Brasher. 1990. Relation of cation exchange capacity to clay and organic carbon contents of Indiana soils. Proceedings of the Indiana Academy of Science 99:107-112.

Franzmeier, D. P., and E. J. Kladivko. 2001. Drainage and wet soil management: Wet soils of Indiana. AY-301. Purdue Univ. Coop. Ext. Serv., W. Lafayette, IN.

Gamble, E. E., M. J. Mausbach, H. R. Sinclair, and D. P. Franzmeier. 1990. A reevaluation of the "Illinoian Till Plain" and the origin of the gritty loess substratum of Avonburg and Clermont soils in southeastern Indiana. U. S. Dept. of Agric., Soil Conservation Service. Soil Survey Investigations Report no. 41. U. S. Govt. Printing Office.

Gray, H. H. 2000. Physiographic divisions of Indiana. Special Report 61. Indiana Geological Survey, Bloomington.

Jackson, J. A. (editor). 1997. Glossary of geology, 4th. ed. American Geological Institute. Alexandria, VA. 769 p.

Munsell. 2003. Munsell Color Order System. [http://www.munsell.com/].

Rogers, W. B., Y. W. Isachsen, T. D. Mock, and R. E. Nyahay. (undated). Overview of New York geology. [http://gretchen.geo.rpi.edu/roecker/nys/nys_edu.pamphlet.html].

Ruhe, R. V. 1969. Quaternary landscapes in Iowa. Iowa State Univ. Press, Ames, Iowa.

Ruhe, R. V. 1975. Geomorphology. Houghton Mifflin, Boston, MA.

Ruhe, R. V., R. B. Daniels, and J. G. Cady. 1967. Landscape evolution and soil formation in southwestern Iowa. USDA Soil Conservation Service Technical Bulletin 1349.

Schoeneberger, P. J., D. A. Wysocki, E. C. Benham, and W. D. Broderson (editors). 2002. Field book for describing and sampling soils. Version 2.0. Natural Resources Conservation Service. National Soil Survey Center, Lincoln, NE.

Schwertmann, U., and R. M. Taylor. 1989. Iron oxides. p. 379 - 438 *In* J. B. Dixon and S. B. Weed (editors). Mineral in soil environments, 2nd edition. Soil Sci. Soc. Amer., Madison, WI.

Soil Survey Division Staff. 1993. Soil survey manual. U. S. Dept. of Agric. Handbook No. 18. U. S. Govt. Printing Office, Washington, D. C.

Soil Survey Division Staff. 1999. Soil taxonomy second edition. Survey Manual. U. S. Dept. of Agric. Handbook No. 436. U. S. Govt. Printing Office, Washington, D. C.

Steinhardt, G. C., and D. P. Franzmeier. 1997. Indiana land surveys, their development and uses. AY-237. Coop. Extension Service, Purdue Univ., W. Lafayette, IN 47907.

Thien, S. J. 1979. A flow diagram for teaching soil texture by feel analysis. J. Agronomic Education 8:54-55.

Truman, C. C., and D. P. Franzmeier. 2002. Structure, pedological concepts and water flow. p. 1263-1268 *In* Encyclopedia of Soil Science. Marcel Dekker.

Index

V

W

A larger version of Table 17 (opposite) may be copied for field and office use. An electronic version is available on the website, <http://isco.purdue.edu/irss/>

Site and pedon information

1. Site:
2. Evaluator:
3. Date:
4. Soil Survey (sheet no.):
5. Soil map uit:
6. Location, relative:
7. Land cover:
8. Location, coordinate:
9. Particle-size family:
10. Slope:
11. Parent material(s)
12. Weather:
13. Landform:
14. Landform component:
15. Modifier:

Soil morphology

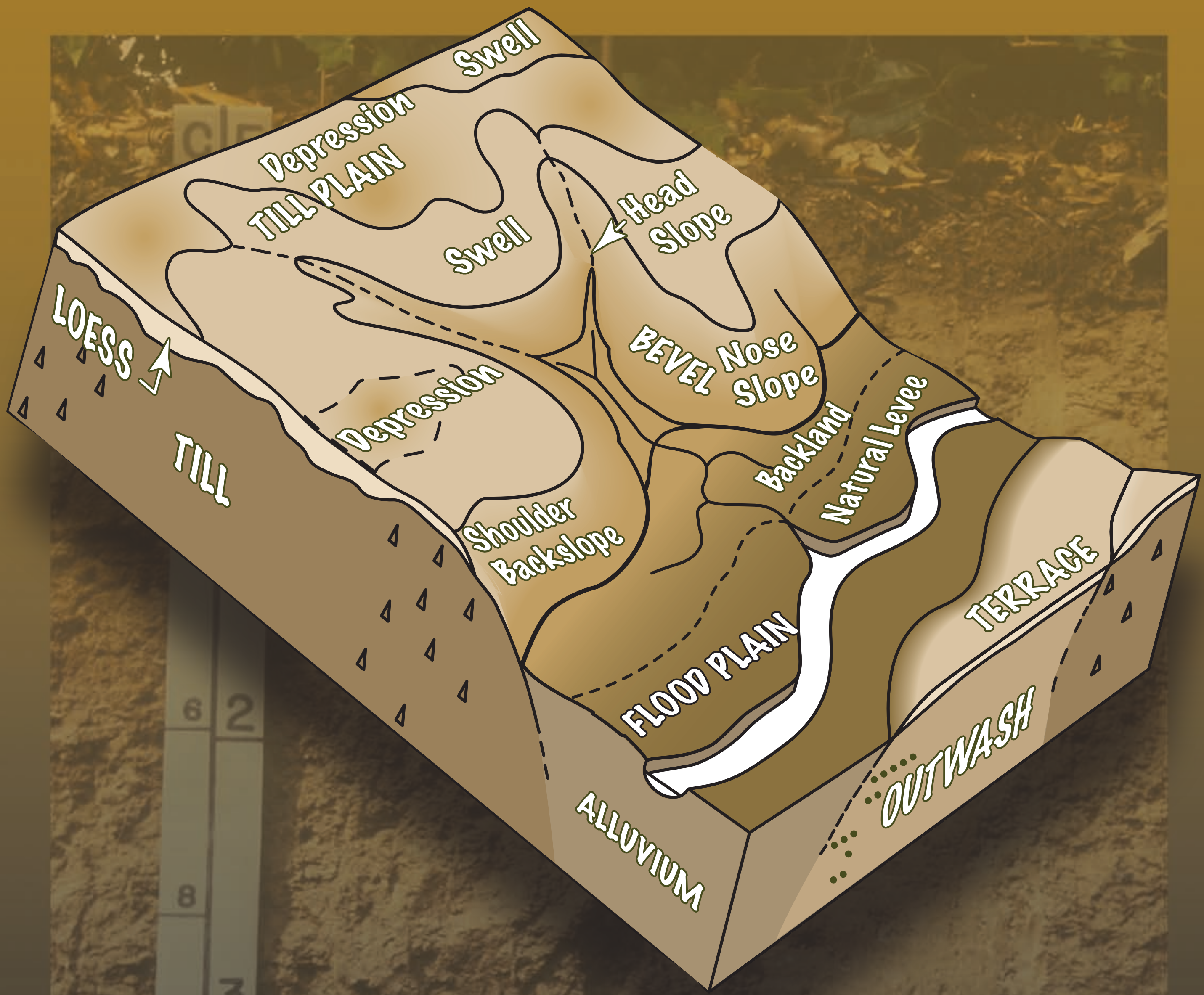
1	2	3			4					5	6			7	8			9		10
Depth in.	Basis in.	Horizon designation			Matrix colors					Texture class	Structure			Cons-isten.	Additional features			Rock frg.		Effer vesc.
					Other colors			Redox depletions			Grade	Size mm	Shape		Kind	Munsell	%	Size mm	%	
		Pfx	Mast	Sfx	Knd	Munsell	%	Munsell	%											

Limiting conditions

1. Depth to slow permeability; kind of layer:
2. Depth to rapid permeability; kind of layer:
3. Depth to redox depletions (gray colors):
4. Depth to Sat8 (saturation 8% of the time):
5. Is there evidence of disturbance (other than tillage)? Depth:
6. Is there soil or landscape evidence of flooding or ponding?

Are there additional comments on the back of this page?

Additional notes, comments, and seal of evaluator



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