SOIL SURVEY OF

# Crawford County, Iowa

United States Department of Agriculture
Soil Conservation Service
In cooperation with
Iowa Agricultural and
Home Economics Experiment Station

Issued April 1973

**Major fieldwork for this soil survey was done in the period 1959–63. Soil names and descriptions were approved in 1969. Unless otherwise indicated, statements in the publication refer to conditions in the county in 1967. This survey was made cooperatively by the Soil Conservation Service and the Iowa Agricultural and Home Economics Experiment Station. It is part of the technical assistance furnished to the Crawford County Soil Conservation District.**

**Either enlarged or reduced copies of the soil map in this publication can be made by commercial photographers, or they can be purchased on individual order from the Cartographic Division, Soil Conservation Service, United States Department of Agriculture, Washington, D.C. 20250.**

# HOW TO USE THIS SOIL SURVEY

THIS SOIL SURVEY contains information that can be applied in managing farms and woodlands; in selecting sites for roads, ponds, buildings, and other structures; and in judging the suitability of tracts of land for farming, industry, and recreation.

## Locating Soils

All the soils of Crawford County are shown on the detailed map at the back of this publication. This map consists of many sheets made from aerial photographs. Each sheet is numbered to correspond with a number on the Index to Map Sheets.

On each sheet of the detailed map, soil areas are outlined and are identified by symbols. All areas marked with the same symbol are the same kind of soil. The soil symbol is inside the area if there is enough room; otherwise, it is outside and a pointer shows where the symbol belongs.

## Finding and Using Information

The "Guide to Mapping Units" can be used to find information. This guide lists all the soils of the county in alphabetic order by map symbol and gives the capability classification of each. It also shows the page where each soil is described and the page for the capability unit in which the soil has been placed.

Individual colored maps showing the relative suitability or degree of limitation of soils for many specific purposes can be developed by using the soil map and the information in the text. Translucent material can be used as an overlay over the soil map and colored to show soils that have the same limitation or suitability. For example, soils that have a slight limitation for a given use can be colored green, those with a moderate limitation can be colored yellow, and those with a severe limitation can be colored red.

*Farmers and those who work with farmers* can learn about use and management of the soils from the soil descriptions and from the discussions of the capability units.

*Game managers, sportsmen, and others* can find information about soils and wildlife in the section "Use of the Soils for Wildlife and Recreation."

*Engineers and builders* can find, under "Engineering Uses of the Soils," tables that contain estimates of soil properties and information about soil features that affect engineering practices.

*Scientists and others* can read about how the soils formed and how they are classified in the section "Formation and Classification of the Soils."

*Newcomers in Crawford County* may be especially interested in the section "General Soil Map," where broad patterns of soils are described. They may also be interested in the information about the county given at the beginning of the publication and in the section "General Nature of the County."

**Cover picture:** Farm ponds and terraces in the Marshall association.

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# SOIL SURVEY OF CRAWFORD COUNTY, IOWA

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UNITED STATES DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE, IN COOPERATION WITH THE IOWA AGRICULTURAL AND HOME ECONOMICS EXPERIMENT STATION

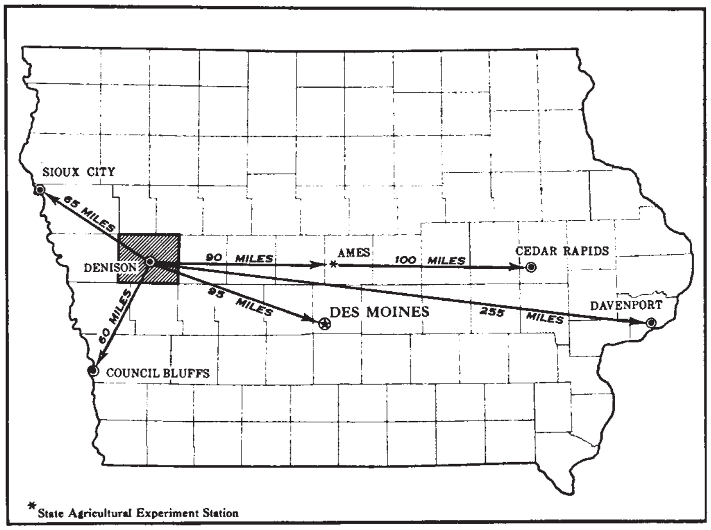


*Figure 1.*—Location of Crawford County in Iowa.

CRAWFORD COUNTY is in the western part of Iowa (fig. 1). It has an area of about 458,240 acres. Denison is the county seat and largest town in the county.

Crawford County is mainly agricultural, and most of the acreage is in farms. The principal crops are corn, soybeans, oats, hay, and pasture plants, but most of the cropland is in corn. The production of livestock far exceeds other kinds of farming and consists mainly of hog raising and cattle feeding. The slaughtering of hogs and cattle and packing the meat is the principal and most rapidly growing industry in the county.

## *How This Survey Was Made*

Soil scientists made this survey to learn what kinds of soil are in Crawford County, where they are located, and how they can be used. The soil scientists went into the county knowing they were likely to find many soils they had already seen and perhaps some they had not. They observed the steepness, length, and shape of slopes, the size and speed of streams, the kinds of native plants or crops, the kinds of rock, and many facts about the soils. They dug many holes to expose soil profiles. A profile is the sequence of natural layers, or horizons, in a soil; it extends from the surface down into the parent material that has not been changed much by leaching or by the action of plant roots.

The soil scientists made comparisons among the profiles they studied, and they compared these profiles with those in counties nearby and in places more distant. They classified and named the soils according to nationwide, uniform procedures. The *soil series* and the *soil phase* are the categories of soil classification most used in a local survey (*23*).[1]

Soils that have profiles almost alike make up a soil series. Except for different texture in the surface layer, all the soils of one series have major horizons that are similar in thickness, arrangement, and other important characteristics. Each soil series is named for a town or other geographic feature near the place where a soil of that series was first observed and mapped. Colo and Marshall, for example, are the names of two soil series. All the soils in the United States having the same series name are essentially alike in those characteristics that affect their behavior in the undisturbed landscape.

Soils of one series can differ in texture of the surface soil and in slope, stoniness, or some other characteristic that affects use of the soils by man. On the basis of such differences, a soil series is divided into phases. The name of a soil phase indicates a feature that affects management. For example, Colo silt loam, overwash, is one of two phases within the Colo series.

After a guide for classifying and naming the soils had been worked out, the soil scientists drew the boundaries of the individual soils on aerial photographs. These photographs show woodlands, buildings, field borders, trees, and other details that help in drawing boundaries accurately. The soil map at the back of this publication was prepared from aerial photographs.

The areas shown on a soil map are called mapping units. On most maps detailed enough to be useful in planning the management of farms and fields, a mapping unit is nearly equivalent to a soil phase. It is not exactly equivalent, because it is not practical to show on such a map all the small, scattered bits of soil of

[1] Italic numbers in parentheses refer to Literature Cited, p. 59.

some other kind that have been seen within an area that is dominantly of a recognized soil phase.

Some mapping units are made up of soils of different series, or of different phases within one series. One such mapping unit shown on the soil map of Crawford County is the soil complex.

A soil complex consists of areas of two or more soils, so intermingled or so small in size that they cannot be shown separately on the soil map. Each area of a complex contains some of each of the two or more dominant soils, and the pattern and relative proportions are about the same in all areas. The name of a soil complex consists of the names of the dominant soils, joined by a hyphen. An example is Judson-Colo-Nodaway complex, 2 to 6 percent slopes.

While a soil survey is in progress, samples of soils are taken, as needed, for laboratory measurements and for engineering tests. Laboratory data from the same kinds of soil in other places are assembled. Data on yields of crops under defined practices are assembled from farm records and from field or plot experiments on the same kinds of soil. Yields under defined management are estimated for all the soils.

But only part of a soil survey is done when the soils have been named, described, and delineated on the map, and the laboratory data and yield data have been assembled. The mass of detailed information then needs to be organized in a way that is readily useful to different groups of readers, among them farmers and engineers.

The soil scientists set up trial groups on the basis of yield and practice tables and other data. They test these groups by further study and by consultation with farmers, agronomists, engineers, and others. Then they adjust the groups according to the results of their studies and consultation. Thus, the groups that are finally evolved reflect up-to-date knowledge of the soils and their behavior under current methods of use and management.

# General Soil Map

The general soil map at the back of this survey shows, in color, the soil associations in Crawford County. A soil association is a landscape that has a distinctive proportional pattern of soils. It normally consists of one or more major soils and at least one minor soil, and it is named for the major soils. The soils in one association may occur in another, but in a different pattern.

A map showing soil associations is useful to people who want a general idea of the soils in a county, who want to compare different parts of a county, or who want to know the location of large tracts that are suitable for a certain kind of land use. Such a map is a useful general guide in managing a watershed, a wooded tract, or a wildlife area, or in planning engineering works, recreational facilities, and community developments. It is not a suitable map for planning the management of a farm or field or for selecting the exact location of a road, building, or similar structure, because the soils in any one association ordinarily differ in slope, depth, stoniness, drainage, and other characteristics that affect their management.

The four soil associations in Crawford County are described in the following pages.

## *1. Monona-Ida association*

*Nearly level to steep, well-drained silty soils on uplands*

This association (fig. 2) consists of nearly level to steep soils on a series of rounded ridges that have smooth, convex side slopes leading to the drainageways. It is in the rolling, hilly area of the county, mainly in the western half (fig. 3). Slopes mostly range from 9 to 25 percent, but some slopes range up to 40 percent in the most dissected parts of the association. These are mainly where drainageways and smaller streams are descending to larger streams, such as the Boyer River.

This association makes up about 43 percent of the county. Monona soils make up about 60 percent of the association; Ida soils, about 12 percent; and minor soils, the remaining 28 percent. Monona and Ida soils formed in thick loess under prairie vegetation.

Monona soils are on the broader ridges and long, smooth side slopes. The largest areas of these soils are moderately or strongly sloping. Monona soils have a surface layer of very dark brown and very dark grayish-brown silt loam. Beneath is dark-brown to dark yellowish-brown, moderately permeable silt loam. These soils are typically slightly acid in the surface layer and slightly acid or neutral in the subsoil.

Ida soils are on narrow, undulating ridgetops and side slopes. Slopes range from moderate to steep. Ida soils have a surface layer of dark-brown to brown silt loam. Beneath is very friable, yellowish-brown silt loam. These soils are calcareous at or near the surface, and lime concretions are throughout.

Monona and Ida soils are easy to till and respond well to good management.

Minor soils in this association are those of the Adair, Chute, Knox, Dow, Napier, Sparta, Shelby, and Salida series on uplands and those of the Kennebec, Colo, Nodaway, and Napier series on bottom lands.

Soils in this association are used for crops and pasture. Corn, soybeans, oats, and crops for rotation hay and pasture, such as alfalfa, alfalfa-bromegrass mixtures, and red clover, are the main crops. Some of the steeper soils and some of the soils on the bottom lands are used for permanent pasture. The moderately sloping to steep soils on the uplands are subject to severe sheet and gully erosion.

Farming in the association is diversified. Much of the grain and forage is fed to livestock. Hog raising and fattening and cattle feeding are the major livestock enterprises. Dairying and the raising of poultry and sheep are of minor importance.

Most roads in this association follow section lines, but a few are on ridgetops or in valleys. Contoured and terraced fields, structures for gully control, and farm ponds are common features of the association. Fields generally are rectangular, but a few are irregular in shape because of the landscape patterns. Contour farming has reduced the number of rectangular fields.

*Figure 2.*—A typical landscape in the Monona-Ida association.

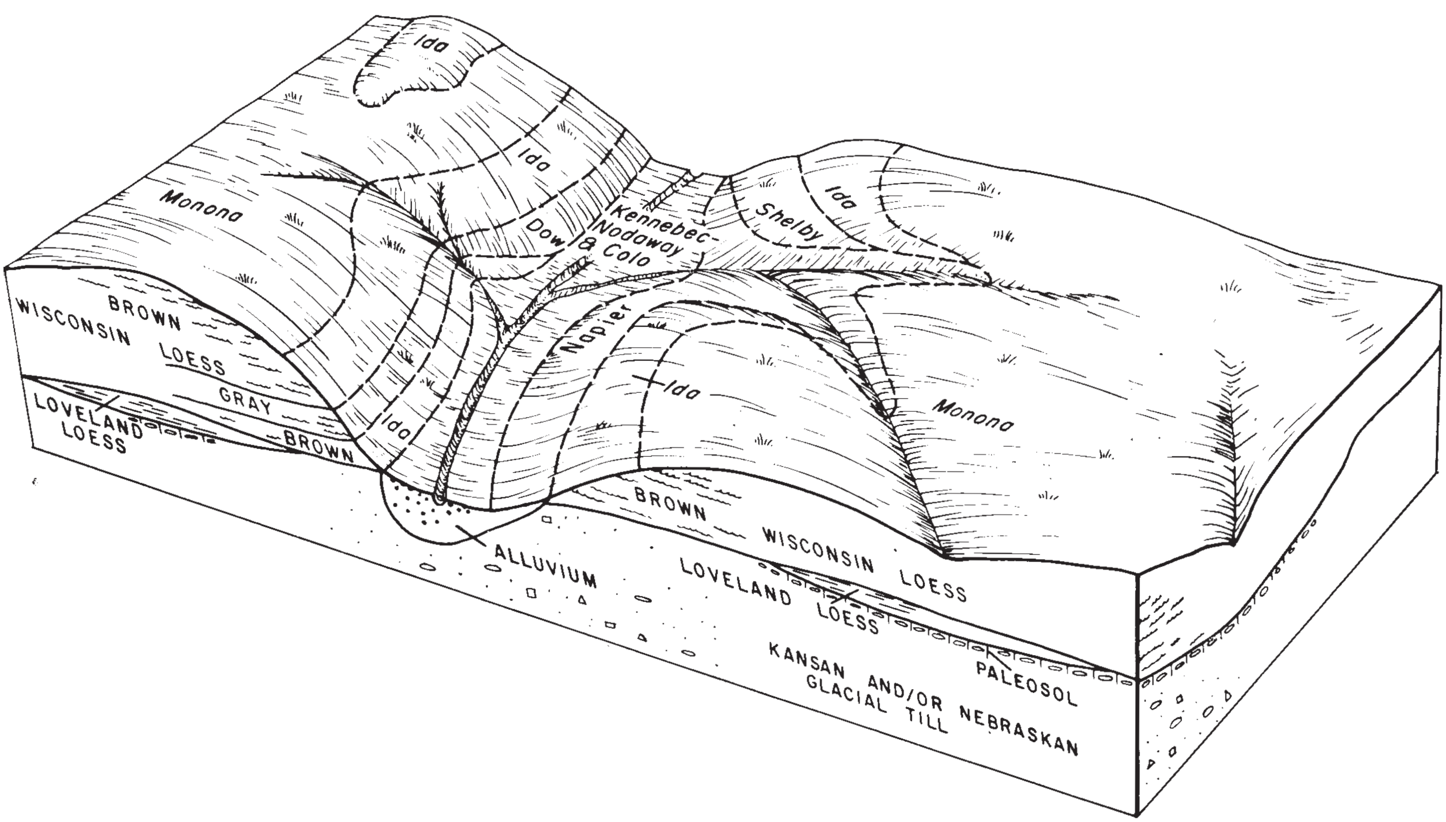


*Figure 3.*—Relationship of slope and parent material to the soils of the Monona-Ida association.

## 2. *Marshall association*

*Nearly level to moderately steep, well-drained silty soils on uplands*

This association consists of nearly level or gently sloping soils on a series of broad ridges and smooth, gently sloping to moderately steep soils on side slopes leading to drainageways (fig. 4). It is in the eastern and north-central parts of the county.

This association makes up about 31 percent of the county. Marshall soils make up about 70 percent of the association and minor soils, the remaining 30 percent.

Marshall soils formed in thick loess under prairie vegetation. These soils have a surface layer of very dark brown and very dark brown to very dark grayish-brown silty clay loam. Beneath is brown, friable, silty clay loam. These soils are typically slightly acid in the surface layer and subsoil and are moderately permeable. The largest areas are moderately and strongly sloping. Marshall soils respond well to good management.

The minor soils in this association are mainly those of the Shelby, Adair, Salida, and Sparta series on uplands; of the Kennebec, Colo, Nodaway, and Zook series on bottom lands; and of the Judson, Colo, and Nodaway series in the drainageways and on narrow stream bottoms.

Most of this association is used for crops. Corn is the main crop, but soybeans, oats, and crops for rotation hay and pasture, such as alfalfa, alfalfa-bromegrass mixtures, and red clover, are also grown. A few areas, mainly along streams, are used for permanent pasture. These soils are susceptible to sheet and gully erosion, especially the steeper soils. In places bottom-land soils need drainage or flood protection.

Most farms are of a diversified type where livestock is kept, but more grain is produced as a cash crop than in the Monona-Ida association. Hog raising and fattening and cattle feeding are the major livestock enterprises. Dairying and the raising of poultry and sheep are of minor importance.

Roads in this association are mainly gravelled and hard surfaced, and most of them follow section lines. More fields are rectangular in shape than in the Monona-Ida or Monona-Marshall associations, but contoured and terraced fields are common.

## 3. *Monona-Marshall association*

*Gently sloping to steep, well-drained silty soils on uplands*

This association consists of gently sloping to steep and hilly soils on successive, rounded ridges that have long, smooth side slopes leading to the drainageways. It extends from the northern to the southern borders of the county and is mainly in the central part of the county.

This association makes up about 18 percent of the county. It is a transitional area between the Marshall

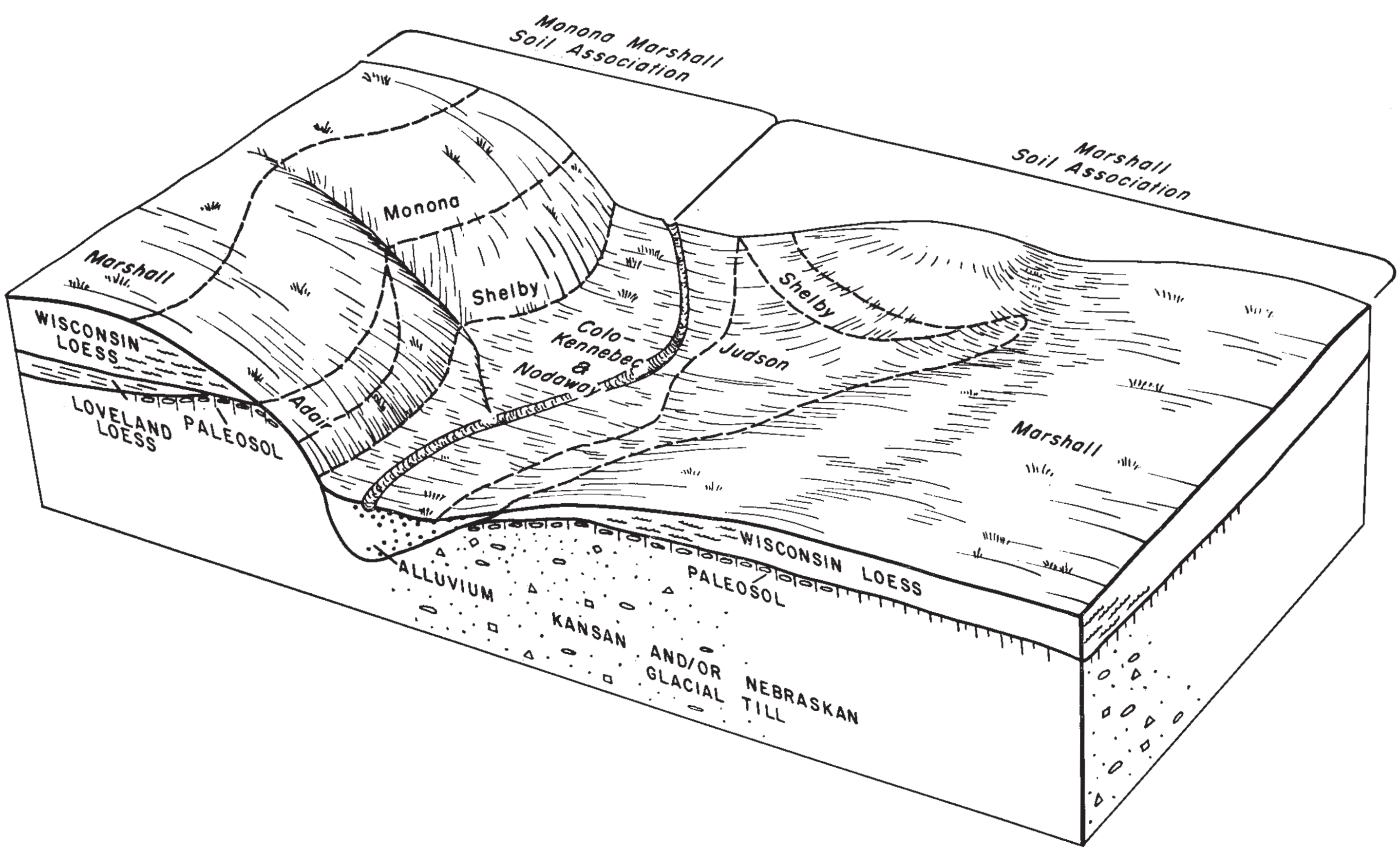


*Figure 4.*—Relationship of slope and parent material to the soils of the Marshall and Monona-Marshall associations.

and the Monona-Ida soil associations. Monona soils make up about 39 percent of the association; Marshall soils, about 15 percent; and minor soils, the remaining 46 percent. Monona and Marshall soils formed in thick loess.

Monona soils are on the less stable ridgetops and steeper side slopes (see fig. 4). These soils have a surface layer of very dark brown and very dark grayish-brown silt loam. Beneath is dark-brown to dark yellowish-brown silt loam. These soils are typically slightly acid in the surface layer and slightly acid or neutral in the subsoil.

Marshall soils generally are on the broader ridgetops and the more gently sloping side slopes. These soils have a surface layer of very dark brown and very dark brown to very dark grayish-brown silty clay loam. Beneath is brown, friable silty clay loam. These soils are typically slightly acid in the surface layer and subsoil.

Monona and Marshall soils are moderately permeable. They are easy to till and respond well to good management.

Minor soils in this association are those of the Ida, Knox, Shelby, Adair, Salida, Steinauer, Chute, and Sparta series on uplands and mainly those of the Judson, Nodaway, Kennebec, and Colo series on bottom lands and drainageways.

Most of the association is used for crops. Corn is the main row crop, but soybeans, oats, and crops for rotation hay and pasture, such as alfalfa and alfalfa-bromegrass mixtures, are grown. Most areas of steep soils and some areas of soils on bottom lands are used for permanent pasture. Gently sloping to steep soils are susceptible to erosion. Some areas on bottom lands need drainage or protection from flooding.

Most farms are of the diversified type where livestock is kept. Much of the grain and forage is fed to livestock. Hog raising and fattening and cattle feeding are the major livestock enterprises. Dairying and the raising of poultry and sheep are of minor importance.

Roads in this association are mainly gravelled and hard surfaced. Most roads follow section lines, but a few are on ridgetops or in valleys. Contoured and terraced fields, structures for gully control, and farm ponds are common. Fields generally are rectangular, but some are irregular in shape because of the landscape patterns. Contour farming has reduced the number of rectangular fields.

### *4. Kennebec-Nodaway-Colo association*

*Nearly level, moderately well drained and poorly drained silty soils on flood plains*

This association consists of nearly level soils on the flood plains of the Boyer, Nishnabotna,[2] Soldier, and Middle Soldier Rivers. These areas are roughly parallel to the rivers and range from ¼ mile to 1 mile in width. They average about ½ mile in width. The river channels have been straightened in most places. This eliminates some of the irregularity of these areas. The rivers are stabilized so that the channels do not migrate within the flood plains.

This association makes up about 8 percent of the county. Kennebec soils make up about 35 percent of the association; Nodaway soils, about 24 percent; Colo soils, about 10 percent; and minor soils, the remaining 31 percent.

Kennebec soils are generally separated from the stream channels by Nodaway soils, but in some places they are next to the stream channels. Nodaway soils are generally nearest the stream channels and are the most recent alluvial sediments. Colo soils are generally adjacent to the uplands and are farthest from the stream channels.

Kennebec soils have a thick surface layer of black and very dark brown silt loam. Beneath is very dark gray and very dark grayish-brown, friable silt loam. The soils are typically slightly acid throughout.

Nodaway soils have a surface layer of very dark grayish-brown silt loam. Beneath is stratified, dark grayish-brown, brown, and very dark gray, friable loam to silt loam that contains strata of silty clay loam to silty clay and sandy loam. These soils are neutral throughout.

Colo soils have a thick surface layer of black silty clay loam that is friable in the upper part and firm in the lower part. Beneath is black and very dark gray, firm silty clay loam. These soils are typically slightly acid or neutral in the surface layer.

Kennebec and Nodaway soils are moderately well drained and moderately permeable. Colo soils are poorly drained and moderately slowly permeable.

Minor soils in this association are those of the Judson, Napier, and Zook series. The Judson and Napier soils are on foot slopes adjacent to flood plains. The Zook soils are generally some distance away from the streams.

Most of this association is used for crops. Corn and soybeans are the main crops, but small grain and hay are also grown. A few areas are used for permanent pasture. These soils are flooded occasionally to frequently and need drainage in places. They respond well to good management.

Some farmsteads are in this association. In most places the farmsteads are on uplands, and the farms include soils of both uplands and bottom lands. The fields are generally rectangular, and many are large. Roads cross this association only where bridges cross the rivers.

## Descriptions of the Soils

In this section the soils of Crawford County are described in detail. The procedure is to describe first the soil series and then the mapping units in that series. Thus, to get full information on any one mapping unit, it is necessary to read both the description of that unit and the description of the soil series to which the unit belongs.

Each series description contains a short description of a soil profile considered representative of the series and a much more detailed description of the same profile that scientists, engineers, and others can use in making highly technical interpretations. Many of the terms

[2] Nishnabotna River is used throughout this survey as an abbreviated form of West Fork West Nishnabotna River, the name used on the detailed soil map.

used in describing soil series and mapping units are defined in the Glossary, and some are defined in the section "How This Survey Was Made."

The approximate acreage and proportionate extent of the soils are shown in table 1. The "Guide to Mapping Units" lists the mapping units of the county and shows the capability unit in which the mapping unit has been placed and the page where each of these is described. Unless otherwise stated, all color terms in the survey are for moist soil.

## Adair Series

The Adair series consists of moderately well drained and somewhat poorly drained soils that formed in glacial till on uplands. These soils formed in parts of the profile of soils developed in an earlier geologic period. The older soils were later covered by loess. Afterward, they were exposed by geologic erosion. The Adair soils formed under prairie vegetation.

Adair soils are mainly on somewhat stabilized, extended ridges or on the shoulders of slopes that range from 9 to 18 percent. They are at the base of side slopes in places.

In a representative profile, the surface layer is dark-brown clay loam about 7 inches thick. The subsoil, to a depth of about 17 inches, is dark yellowish-brown, firm clay loam and light clay. Below this, to a depth of about 34 inches, is brown and yellowish-red, very firm heavy clay loam that contains a few mottles of yellowish red. The substratum, beginning at a depth of about 34 inches, is yellowish-brown, very firm light clay loam that contains some grayish brown.

Adair soils have high available water capacity and are slowly permeable. They are typically medium acid in the surface layer. The organic-matter content is generally low. Available nitrogen and phosphorus are low or very low, and available potassium is low or medium.

Adair soils are mainly used for hay or pasture, but small areas in cultivated fields are generally managed the same as the surrounding soils. They are susceptible to erosion and are wet at times because of seepage.

Representative profile of Adair clay loam, 9 to 14 percent slopes, severely eroded, on a northeast-facing slope, 720 feet east and 300 feet south of the northwest corner of NW¼NE¼ sec. 32, T. 83 N., R. 38 W.

Ap—0 to 7 inches, dark-brown (10YR 3/3) clay loam; moderate, medium, subangular blocky structure breaking to fine subangular blocky and fine granular; friable; medium acid; clear, smooth boundary.

B1—7 to 12 inches, mixed colors, 80 percent dark yellowish-brown (10YR 4/4) and 20 percent very dark grayish-brown (10YR 3/2) clay loam; moderate, medium, subangular blocky structure breaking to fine subangular blocky and fine granular; weak band of pebbles at base of horizon; firm; slightly acid; clear, smooth boundary.

IIB2t—12 to 17 inches, dark yellowish-brown (10YR 4/4) light clay; few, coarse, distinct mottles of yellowish red (5YR 4/6); moderate, medium, subangular blocky structure breaking to fine subangular blocky; firm; some discontinuous clay films; slightly acid; gradual, smooth boundary.

IIB31—17 to 26 inches, brown (7.5YR 4/4) and yellowish-red (5YR 5/6) heavy clay loam and some pebbles; moderate, medium, subangular blocky structure breaking to fine subangular blocky; many dark purplish-black stains; very firm; slightly acid; gradual, smooth boundary.

IIB32—26 to 34 inches, yellowish-brown (10YR 5/6) heavy clay loam and some pebbles; few, medium, distinct mottles of yellowish red (5YR 5/6); weak, medium, subangular blocky structure breaking to fine subangular blocky; some pebbles; very firm; slightly acid; gradual, smooth boundary.

IIC1—34 to 47 inches, yellowish-brown (10YR 5/4) light clay loam; few, fine, distinct mottles of grayish brown (10YR 5/2) and few, fine, faint mottles of yellowish brown (10YR 5/6); massive; few, soft, dark reddish-brown (5YR 2/2) manganese stains; very firm; slightly acid; diffuse, smooth boundary.

IIC2—47 to 60 inches, mixed colors, 60 percent yellowish brown (10YR 5/4) and 40 percent grayish-brown (10YR 5/2) light clay loam; many, soft, dark reddish-brown (5YR 2/2) manganese stains and some manganese accumulations of the same color in cracks; massive; very firm; neutral.

The surface layer is dominantly clay loam in texture but ranges to silty clay loam or light clay. It ranges from very dark brown to very dark grayish brown, dark brown, and dark yellowish brown. It is as much as 7 inches thick.

The subsoil ranges from clay loam to clay. It is typically brown, dark reddish brown, reddish brown, or yellowish red in the upper part. In places where reddish colors do not make up a part of the matrix color reddish mottles are present. The reddish colors or mottles decrease with depth. The lower part of the subsoil is dark yellowish brown or yellowish brown. Mottles range from brown or dark grayish brown to light brownish gray and yellowish red.

The substratum is dominantly dark yellowish brown or yellowish brown. In most places grayish-brown or light brownish-gray colors are present as mottles or as a part of the matrix color.

Adair soils are typically leached to a depth of 40 inches or more and are medium acid or slightly acid in the surface layer and subsoil.

The surface layer of the Adair soils in Crawford County is thinner, lighter colored, or both, than is defined as the range for the series. These differences do not significantly alter their usefulness or behavior.

Adair soils have a higher content of clay and are firmer in the subsoil than the associated Shelby soils, which lack reddish colors in the subsoil.

**Adair soils, 9 to 14 percent slopes, severely eroded** (AdD3).—These soils have the profile described as representative for the series. In most areas the surface layer is dark brown to dark grayish brown or dark yellowish brown, but in places it is very dark grayish brown. It is mainly clay loam, but in places it is clay or silty clay loam. The subsoil has been mixed by tillage with the remaining part of the surface layer.

These soils are mostly on extended narrow ridges and the noses of these ridges, but they are also on the rounded shoulders of side slopes. They are generally downslope from Monona soils and upslope from Shelby soils. Most areas are long and narrow. Included in mapping were a few acres of Adair soils that have slopes of 5 to 9 percent.

Most of the acreage is used for hay or pasture. The soils are not suited to row crops, but small areas in cultivated fields are generally managed the same as the surrounding soils. Some areas can be used for wildlife. Adair soils are susceptible to erosion, and in places gullies have formed. They are seasonally wet because of seepage from higher lying areas. Tilth is poor. (Capability unit VIe-2)

TABLE 1.—*Approximate acreage and proportionate extent of the soils*

| Soil | Acres | Percent |
|---|---|---|
| Adair soils, 9 to 14 percent slopes, severely eroded | 302 | 0. 1 |
| Adair soils, 14 to 18 percent slopes, severely eroded | 388 | . 1 |
| Chute fine sandy loam, 6 to 12 percent slopes, severely eroded | 202 | (1) |
| Chute fine sandy loam, 12 to 20 percent slopes, severely eroded | 66 | (1) |
| Colo silt loam, overwash | 2, 604 | . 5 |
| Colo silty clay loam | 1, 522 | . 3 |
| Dow silt loam, 5 to 9 percent slopes, moderately eroded | 208 | (1) |
| Dow silt loam, 9 to 14 percent slopes, moderately eroded | 604 | . 1 |
| Dow-Ida silt loams, 9 to 14 percent slopes, severely eroded | 180 | (1) |
| Dow-Ida silt loams, 14 to 20 percent slopes, severely eroded | 322 | . 1 |
| Dow-Monona silt loams, 5 to 9 percent slopes, moderately eroded | 101 | (1) |
| Dow-Monona silt loams, 9 to 14 percent slopes, moderately eroded | 1, 017 | . 2 |
| Dow-Monona silt loams, 9 to 14 percent slopes, severely eroded | 544 | . 1 |
| Dow-Monona silt loams, 14 to 20 percent slopes, moderately eroded | 415 | . 1 |
| Dow-Monona silt loams, 14 to 20 percent slopes, severely eroded | 1, 122 | . 3 |
| Ida silt loam, 5 to 9 percent slopes | 3, 264 | . 7 |
| Ida silt loam, 5 to 9 percent slopes, severely eroded | 8, 735 | 1. 9 |
| Ida silt loam, 9 to 14 percent slopes | 966 | . 2 |
| Ida silt loam, 9 to 14 percent slopes, severely eroded | 8, 235 | 1. 8 |
| Ida silt loam, 14 to 20 percent slopes, severely eroded | 8, 516 | 1. 9 |
| Ida silt loam, 20 to 30 percent slopes, severely eroded | 1, 632 | . 4 |
| Judson silty clay loam, 0 to 2 percent slopes | 301 | . 1 |
| Judson silty clay loam, 2 to 6 percent slopes | 5, 085 | 1. 1 |
| Judson-Colo-Nodaway complex, 2 to 6 percent slopes | 30, 250 | 6. 6 |
| Kennebec silt loam | 9, 369 | 2. 0 |
| Kennebec silt loam, overwash | 5, 331 | 1. 2 |
| Knox silt loam, 5 to 14 percent slopes | 289 | . 1 |
| Knox silt loam, 14 to 20 percent slopes | 802 | . 2 |
| Knox silt loam, 20 to 30 percent slopes | 616 | . 1 |
| Marshall silty clay loam, 0 to 2 percent slopes | 720 | . 2 |
| Marshall silty clay loam, 2 to 5 percent slopes | 16, 151 | 3. 5 |
| Marshall silty clay loam, 2 to 5 percent slopes, moderately eroded | 8, 008 | 1. 8 |
| Marshall silty clay loam, 5 to 9 percent slopes | 12, 520 | 2. 1 |
| Marshall silty clay loam, 5 to 9 percent slopes, moderately eroded | 20, 939 | 4. 5 |
| Marshall silty clay loam, 9 to 14 percent slopes | 2, 248 | . 5 |
| Marshall silty clay loam, 9 to 14 percent slopes, moderately eroded | 39, 933 | 8. 7 |
| Marshall silty clay loam, 9 to 14 percent slopes, severely eroded | 3, 418 | . 9 |
| Marshall silty clay loam, 14 to 20 percent slopes, moderately eroded | 5, 242 | 1. 2 |
| Marshall silty clay loam, 14 to 20 percent slopes, severely eroded | 2, 228 | . 5 |
| Monona silt loam, 0 to 2 percent slopes | 888 | . 2 |
| Monona silt loam, 2 to 5 percent slopes | 5, 285 | 1. 2 |
| Monona silt loam, 2 to 5 percent slopes, moderately eroded | 7, 543 | 1. 7 |
| Monona silt loam, 5 to 9 percent slopes | 5, 695 | 1. 3 |
| Monona silt loam, 5 to 9 percent slopes, moderately eroded | 30, 266 | 6. 6 |
| Monona silt loam, 5 to 9 percent slopes, severely eroded | 2, 127 | . 5 |
| Monona silt loam, 9 to 14 percent slopes | 1, 792 | . 4 |
| Monona silt loam, 9 to 14 percent slopes, moderately eroded | 54, 152 | 11. 8 |
| Monona silt loam, 9 to 14 percent slopes, severely eroded | 10, 314 | 2. 3 |
| Monona silt loam, 14 to 20 percent slopes, moderately eroded | 16, 935 | 3. 7 |
| Monona silt loam, 14 to 20 percent slopes, severely eroded | 15, 782 | 3. 5 |
| Monona silt loam, 20 to 30 percent slopes, moderately eroded | 2, 592 | . 6 |
| Monona silt loam, 20 to 30 percent slopes, severely eroded | 3, 761 | . 8 |
| Monona silt loam, 30 to 40 percent slopes, severely eroded | 710 | . 2 |
| Napier silt loam, 2 to 5 percent slopes | 10, 211 | 2. 2 |
| Napier silt loam, 5 to 9 percent slopes | 5, 357 | 1. 2 |
| Napier silt loam, 9 to 14 percent slopes | 229 | . 1 |
| Napier-Gullied land complex, 2 to 10 percent slopes | 2, 348 | . 5 |
| Napier-Kennebec-Nodaway silt loams, 2 to 5 percent slopes | 46, 744 | 10. 2 |
| Napier-Kennebec-Nodaway silt loams, 5 to 9 percent slopes | 6, 346 | 1. 4 |
| Nodaway silt loam | 8, 796 | 1. 9 |
| Salida gravelly loam, 9 to 14 percent slopes, moderately eroded | 407 | . 1 |
| Salida gravelly loam, 14 to 25 percent slopes, moderately eroded | 258 | . 1 |
| Shelby loam, 5 to 9 percent slopes, moderately eroded | 271 | . 1 |
| Shelby loam, 9 to 14 percent slopes, moderately eroded | 3, 080 | . 7 |
| Shelby loam, 14 to 18 percent slopes, moderately eroded | 3, 438 | . 8 |
| Shelby loam, 18 to 25 percent slopes, moderately eroded | 1, 194 | . 3 |
| Shelby cobbly loam, 14 to 35 percent slopes | 331 | . 1 |
| Shelby soils, 9 to 14 percent slopes, severely eroded | 912 | . 2 |
| Shelby soils, 14 to 18 percent slopes, severely eroded | 2, 069 | . 5 |
| Shelby soils, 18 to 25 percent slopes, severely eroded | 1, 427 | . 3 |
| Shelby soils, 25 to 35 percent slopes, severely eroded | 831 | . 2 |
| Sparta fine sandy loam, 5 to 9 percent slopes, moderately eroded | 160 | (1) |
| Sparta fine sandy loam, 9 to 14 percent slopes, moderately eroded | 447 | . 1 |
| Sparta fine sandy loam, 14 to 20 percent slopes, moderately eroded | 172 | (1) |
| Steinauer clay loam, 9 to 14 percent slopes, severely eroded | 164 | (1) |
| Steinauer clay loam, 14 to 18 percent slopes, severely eroded | 113 | (1) |
| Zook silt loam, overwash | 219 | (1) |
| Zook silty clay loam | 331 | . 1 |
| Borrow areas | 65 | (1) |
| Gravel pits | 75 | (1) |
| Sanitary fill | 8 | (1) |
| Total | 458, 240 | 100. 0 |

[1] Less than 0.05 percent.

**Adair soils, 14 to 18 percent slopes, severely eroded** (AdE3).—These soils have a surface layer that is dark brown to dark grayish brown or dark yellowish brown and 3 to 7 inches thick in most places. In some areas the surface layer is very dark grayish brown. The texture is dominantly clay loam but is clay or silty clay loam in places. The present surface layer consists mainly of subsoil material mixed by tillage with the remaining part of the original surface layer.

These soils are mostly on the shoulders of side slopes below Monona soils and on the lower parts of side slopes in a few places. They are upslope from Shelby soils. The areas are generally long and narrow.

Most of the acreage is used for hay or pasture. The soils are not suited to row crops, but some small areas in cultivated fields are managed the same as the surrounding soils. They are better suited to permanent vegetation than to other uses. Some areas provide wildlife food and cover. The soils are susceptible to erosion, and gullies have formed in places. They are seasonally wet because of seepage from higher lying areas. Tilth is poor. (Capability unit VIIe-1)

## Chute Series

The Chute series consists of excessively drained soils that formed under prairie vegetation in calcareous fine sands deposited by wind. These soils are in small areas on crests of ridges and on convex side slopes on uplands adjacent to the Boyer River and its tributaries. Slopes are 6 to 20 percent.

In a representative profile, the surface layer, about 9 inches thick, is sandy loam in the upper part and loamy fine sand in the lower part. The upper part is very dark grayish brown. The lower part is dark brown with some light yellowish brown. Below this is light yellowish-brown to brownish-yellow very friable fine sand.

Chute soils have very low available water capacity and are rapidly or very rapidly permeable. They are mildly alkaline or moderately alkaline and are calcareous throughout. The organic-matter content is low. Available nitrogen and phosphorus are very low, and available potassium is medium.

These soils are generally used for hay or pasture, but many small areas are cultivated along with surrounding soils that are better suited to crops. They are droughty and are subject to water erosion and soil blowing.

Representative profile of Chute fine sandy loam, 6 to 12 percent slopes, severely eroded, on the crest of a sandy knoll that slopes to the northeast and to the southwest, 700 feet north and 200 feet west of the southeast corner of SE¼NE¼ sec. 35, T. 83 N., R. 39 W.

Ap—0 to 5 inches, very dark grayish-brown (10YR 3/2) fine sandy loam; very weak, medium and fine, subangular blocky structure breaking to single grain; very friable; mildly alkaline; calcareous; gradual, smooth boundary.

A3—5 to 9 inches, mixed colors, 70 percent dark-brown (10YR 3/3) and 30 percent light yellowish-brown (10YR 6/4) loamy fine sand, brown (10YR 4/3) when crushed; very weak, medium and fine, subangular blocky structure breaking to single grain; very friable; many worm casts; mildly alkaline; calcareous; abrupt, smooth boundary.

C—9 to 72 inches, light yellowish-brown (10YR 6/4) to brownish-yellow (10YR 6/6) fine sand; single grain; very friable; moderately alkaline; calcareous.

The surface layer ranges from 3 to 10 inches in thickness. It is typically very dark grayish brown, dark grayish brown, dark brown, or brown, but in places it is dark yellowish brown to light yellowish brown. The darker colored surface layer is generally in noncultivated areas. In most places the surface layer is fine sandy loam, but in places it is loamy fine sand.

The substratum is yellowish-brown to light yellowish-brown or brownish-yellow loamy fine sand or fine sand.

In places these soils are leached to a depth of the darkened surface layer.

Chute soils are not leached, as are Sparta soils, and are calcareous at or near the surface. Chute and Sparta soils formed in similar material.

**Chute fine sandy loam, 6 to 12 percent slopes, severely eroded** (ChD3).—This soil has the profile described as representative for the series. In places the soil has been so severely eroded that the surface layer is mostly brown to light yellowish brown. It is generally in areas less than 5 acres in size on the crests of ridges and on convex side slopes. Very small areas are indicated on the soil map by a symbol for sand.

This soil is not suited to row crops, but it is generally in small areas in cultivated fields and is managed the same as the surrounding soils. It is better suited to hay or pasture and is also suited to use as wildlife habitat. It is droughty and susceptible to water erosion and soil blowing. Organic-matter content is low, but tilth is good. (Capability unit VIs-1)

**Chute fine sandy loam, 12 to 20 percent slopes, severely eroded** (ChE3).—This soil has a surface layer of dark-brown or dark grayish-brown fine sandy loam 3 to 7 inches thick in most places. In places the color is brown to light yellowish brown. This soil is generally in small areas on convex side slopes. Very small areas are indicated on the soil map by a symbol for sand.

This soil is not generally cultivated unless it is in a small area surrounded by cultivated soils. It is droughty and susceptible to soil blowing and water erosion. It is suited to hay or pasture if the areas are large enough to manage separately. It is also suited to wildlife habitat. (Capability unit VIIs-1)

## Colo Series

The Colo series consists of nearly level, poorly drained soils that formed in moderately fine textured silty alluvium under a cover of water-tolerant prairie grasses. These soils are on flood plains along major and minor streams and in wide drainageways.

In a representative profile, the surface layer is black silty clay loam about 37 inches thick. Below this is black and very dark gray, firm silty clay loam.

Colo soils have high available water capacity and are moderately slowly permeable. They are typically slightly acid or neutral in the surface layer. The organic-matter content is high. Available nitrogen is medium or low, available phosphorus is low or very low, and available potassium is medium.

These soils are subject to flooding and surface deposition of overwash. Many areas are wet because of a high water table or flooding unless they are drained and protected from flooding. Most areas are not flooded frequently enough to prevent cultivation.

Representative profile of nearly level Colo silty clay loam, 300 feet east of the northwest corner of SW¼ sec. 1, T. 84 N., R. 37 W.

Ap—0 to 6 inches, black (10YR 2/1) silty clay loam; weak and moderate, fine and medium, subangular blocky and fine, granular structure; friable; many fine roots; slightly acid; clear, smooth boundary.

A11—6 to 14 inches, black (10YR 2/1) silty clay loam; weak and moderate, fine and medium, subangular blocky structure; friable; many fine roots; neutral; gradual, smooth boundary.

A12—14 to 26 inches, black (10YR 2/1) silty clay loam; moderate, medium, subangular blocky structure breaking to fine subangular blocky; friable; neutral; gradual, smooth boundary.

A13—26 to 37 inches, black (10YR 2/1) silty clay loam; weak, medium, subangular blocky structure breaking to fine subangular blocky; firm; neutral; diffuse, smooth boundary.

B2—37 to 48 inches, black (10YR 2/1) silty clay loam; weak, medium, subangular blocky structure breaking to fine subangular blocky; firm; neutral; diffuse, smooth boundary.

B3g—48 to 60 inches +, very dark gray (N 3/0) silty clay loam; weak, medium, subangular blocky structure breaking to massive; firm; mildly alkaline.

Colo soils are black or very dark gray in the upper 36 inches unless recent overwash is present. Overwashed Colo soils have a layer on the surface that is very dark grayish-brown or dark grayish-brown silt loam 6 to 15 inches thick. The surface layer is 24 to 40 inches thick in most places. The underlying subsoil or substratum ranges from black to dark gray. The depth described in the representative profile does not extend to the substratum.

Texture throughout the profile is light to medium silty clay loam. The surface layer is generally slightly acid or neutral, but in places the upper 1 foot of the profile is medium acid.

Colo soils are finer textured throughout, more poorly drained, and less friable than Kennebec soils. They lack the stratification of the Nodaway soils and are darker colored, more poorly drained, and finer textured throughout. Colo soils are similar to Zook soils to a depth of about 12 inches but are not so fine textured below that depth. These soils are associated on the landscape, and all formed in alluvium.

**Colo silt loam, overwash** (0 to 2 percent slopes) (Co).—This soil has a profile similar to that described as representative for the series, except that it has recent deposits of sediment that consists of very dark grayish-brown or dark grayish-brown silt loam, 6 to 15 inches thick, on the surface.

This soil is in the rolling areas of the county where there has been considerable erosion in the adjacent uplands. In most places it is associated with Nodaway, Kennebec, or other Colo soils of the bottom lands. Most areas are large. Small areas are subject to flooding and receive deposits of sediments.

This soil is generally cultivated and is well suited to row crops. It is easy to till, but it is somewhat less fertile than soils without overwash. This soil is poorly drained, but if the overwash layer is thick enough, the surface does not remain wet for long periods. In places flooding or siltation causes damage to crops in some years. (Capability unit IIw–1)

**Colo silty clay loam** (0 to 2 percent slopes) (Cs).—This soil has the profile described as representative for the series. It is along streams and drainageways. In many places in the larger valleys, it is adjacent to Nodaway or Kennebec soils, which are along the streams. It is also associated with Zook soils. This soil generally occurs as large areas.

This soil is generally cultivated, and most areas are well suited to row crops. Frequently flooded or inaccessible areas are commonly in permanent pasture. Poor drainage and a tendency to become cloddy if tilled when wet delay tillage in some years. In many narrow drainageways this soil is dissected by streams that cannot be crossed with farm machinery. Old meandering channels that tend to pond also hinder cultivation in places (fig. 5). In some places flooding causes damage to crops in some years. (Capability unit IIw–1)

## Dow Series

The Dow series consists of well-drained soils that formed in calcareous loess under prairie vegetation. Dow soils are on uplands on narrow ridges that are lower than adjacent side slopes. They are also moderately sloping to moderately steep on shoulders of side slopes in the Monona-Ida and Monona-Marshall soil associations. These soils also occur in narrow bands on convex side slopes. In these areas they are mapped in a complex with Monona or Ida soils. Slopes are 5 to 20 percent.

In a representative profile, the surface layer is brown silt loam about 6 inches thick. Below this, to a depth of about 15 inches, is grayish-brown, friable silt loam that contains mottles of strong brown and yellowish brown. Below this is light brownish-gray, very friable silt loam that contains mottles of strong brown and reddish brown.

Dow soils have high available water capacity and are moderately permeable. These soils are moderately alkaline and calcareous throughout. The organic-matter content is low. Available nitrogen and phosphorus are very low, and available potassium is medium. Zinc is deficient in places.

Most areas of these soils are cultivated, but the moderately steep soils are generally used for hay or pasture. Dow soils are subject to sheet and gully erosion.

*Figure 5.*—Colo soils on bottom lands and Monona soils in background.

Representative profile of Dow silt loam, 9 to 14 percent slopes, moderately eroded, on an east-facing convex slope, 115 feet south and 410 feet west of the northeast corner of SE¼ sec. 31, T. 82 N., R. 40 W.

Ap—0 to 6 inches, brown (10YR 4/3) silt loam; weak, medium, subangular blocky structure breaking to weak, fine, granular; friable; moderately alkaline; calcareous; clear, smooth boundary.

C1—6 to 15 inches, grayish-brown (2.5Y 5/2) silt loam; few, fine and medium, distinct mottles of yellowish brown (10YR 5/6) and few, fine, distinct mottles of brown (7.5YR 5/6); very weak, medium, subangular blocky structure; very friable; moderately alkaline; calcareous; gradual, smooth boundary.

C2—15 to 40 inches, light brownish-gray (2.5Y 6/2) light silt loam; few, fine, distinct mottles of strong brown (7.5YR 5/6) and few, fine mottles of reddish brown (5YR 4/4); massive; very friable; moderately alkaline; calcareous.

The surface layer in moderately eroded Dow soils is typically very dark grayish brown to dark brown or brown. The surface layer in severely eroded areas is brown to grayish brown. It is typically less than 8 inches thick, depending on the severity of erosion and the depth of plowing.

The substratum ranges from grayish brown to brownish gray and olive gray. Depth to calcareous material is typically 10 inches or less. In many places hard concretions of lime and hard tubular iron oxides (pipestems) are in the substratum. Mottles in the substratum are yellowish brown, reddish brown, strong brown, and olive gray.

Dow soils are associated with Ida and Monona soils. They are similar to the Ida soils, except that they formed in grayish (deoxidized) loess. They differ from the Monona soils in being calcareous at or near the surface and in having grayish colors that begin below the surface layer.

**Dow silt loam, 5 to 9 percent slopes, moderately eroded** (DoC2).—This soil has a very dark grayish-brown to dark-brown plow layer in most places. It is generally in small areas on the tops of narrow ridges and on the shoulders of side slopes. Monona soils are commonly upslope and downslope from this soil. Included in mapping were some severely eroded areas where the plow layer is brown or dark grayish brown. Also included were a few areas of Ida soils that are yellowish brown below the surface layer.

This soil is generally cultivated along with the surrounding soils. It is susceptible to sheet and gully erosion but is suited to row crops if erosion is controlled. Natural fertility is very low. Tilth is generally fair. Available nitrogen and phosphorus are very low and commonly limit crop growth. (Capability unit IIIe–3)

**Dow silt loam, 9 to 14 percent slopes, moderately eroded** (DoD2).—This soil has the profile described as representative for the series. It is on narrow ridges and on the shoulders of slopes. It is generally downslope from Monona soils and upslope from Shelby or Napier soils. Generally, areas of this soil are so small that they are farmed along with surrounding soils. Included in mapping were some severely eroded areas where the plow layer is mostly substratum material mixed with the thin surface layer. In these areas the plow layer is dark grayish brown or grayish brown.

This soil is generally cultivated along with surrounding soils. It is susceptible to sheet and gully erosion, but it is suited to row crops if erosion is controlled. It is also well suited to hay and pasture crops. Natural fertility is very low. Tilth is generally fair. Available nitrogen and phosphorus are very low and commonly limit crop growth. (Capability unit IIIe–4)

**Dow-Ida silt loams, 9 to 14 percent slopes, severely eroded** (DsD3).—This complex consists of about 50 to 75 percent Dow soils and 25 to 50 percent Ida soils. The plow layer is typically brown or dark grayish brown.

These soils are in bands along side slopes. They are generally downslope from Ida or Monona soils and upslope from Napier soils (fig. 6). In places Shelby soils are between these soils and the Napier soils. Most areas are small. Many areas were included that are only moderately eroded, and in these areas the surface layer is darker.

Most of this complex is cultivated. The soils are susceptible to severe sheet and gully erosion, but they are suited to row crops if erosion is controlled. They are also well suited to hay and pasture crops. Natural fertility is very low. Soil tilth is generally fair, but the surface layer tends to crust when it drys out after rains. Available nitrogen and phosphorus are very low and commonly limit crop growth. (Capability unit IIIe–4)

**Dow-Ida silt loams, 14 to 20 percent slopes, severely eroded** (DsE3).—This complex consists of about 60 to 80 percent Dow soils and 20 to 40 percent Ida soils. The plow layer is typically brown or dark grayish brown. In uncultivated areas the surface layer is typically only about 3 inches thick. The dark yellowish-brown or yellowish-brown substratum of the Ida soils and the grayish-brown substratum of the Dow soils is exposed in many places. These soils are in bands on side slopes. They are generally downslope from Monona or Ida soils and upslope from Sheby or Napier soils. Most areas are small.

The soils of this complex are not well suited to cultivation, but small areas are generally managed along with the surrounding soils. They are susceptible to severe sheet and gully erosion. A crop of corn is commonly grown when existing hay or pasture crops need to be plowed and reseeded. The soils are better suited to forage crops most of the time. Natural fertility is very low. Available nitrogen and phosphorus are very low and commonly limit crop growth. (Capability unit IVe–2)

*Figure 6.*—Severely eroded Dow soils are on the low ridges. Ida soils are in the higher areas, and Napier soils are in the drainageways.

**Dow-Monona silt loams, 5 to 9 percent slopes, moderately eroded** (DwC2).—This complex consists of about 40 to 60 percent Dow soils and 40 to 60 percent Monona soils. The plow layer is generally very dark brown, very dark grayish brown, or dark grayish brown, but a few included severely eroded areas are lighter in color. These soils are in bands on side slopes and on eroded noses at the end of narrow ridges. They are generally downslope from Monona or Ida soils and upslope from Napier soils or areas of Napier-Kennebec-Nodaway silt loams. Most areas are small.

Most areas of this complex are cultivated. The soils are susceptible to sheet and gully erosion, but they are suited to row crops if erosion is controlled. Natural fertility of the Dow soil is very low. Available nitrogen and phosphorus are very low and commonly limit crop growth. (Capability unit IIIe-3)

**Dow-Monona silt loams, 9 to 14 percent slopes, moderately eroded** (DwD2).—This complex consists of about 50 to 75 percent Dow soils and 25 to 50 percent Monona soils. The plow layer is generally very dark grayish brown, dark brown, or dark grayish brown. These soils are generally downslope from Monona or Ida soils and upslope from Napier soils. In places Shelby soils are downslope from this complex.

The soils of this complex are susceptible to sheet and gully erosion, but they are suited to row crops if erosion is controlled. They are also well suited to hay and pasture. Natural fertility of the Dow soil is very low. Available nitrogen and phosphorus are very low and commonly limit crop growth. (Capability unit IIIe-4)

**Dow-Monona silt loams, 9 to 14 percent slopes, severely eroded** (DwD3).—This complex consists of about 50 to 75 percent Dow soils and 25 to 50 percent Monona soils. The surface layer is typically dark brown to grayish brown and consists partly or mainly of subsoil material. These soils are in bands on side slopes and on noses at the end of narrow ridges. They are generally downslope from Monona or Ida soils and upslope from Shelby or Napier soils. Most areas are small.

The soils of this complex are generally cultivated. They are susceptible to severe sheet and gully erosion, but they are suited to row crops if erosion is controlled. They are also well suited to hay and pasture. Natural fertility of the Dow soil is very low. Available nitrogen and phosphorus are very low and commonly limit crop growth. (Capability unit IIIe-4)

**Dow-Monona silt loams, 14 to 20 percent slopes, moderately eroded** (DwE2).—This complex consists of about 60 to 80 percent Dow soils and 20 to 40 percent Monona soils. The surface layer is very dark grayish brown, dark grayish brown, or brown in most places. In uncultivated areas this layer is generally about 3 to 7 inches thick and is a little darker in places. These moderately steep soils are in bands on long side slopes. They are generally downslope from Monona or Ida soils and upslope from Shelby or Napier soils. Most areas are small.

This complex is generally used for hay or pasture. The soils are not well suited to cultivation, because they are steep and the hazard of erosion is severe. They are better suited to hay or pasture than to row crops. A crop of corn is commonly grown when hay or pasture crops need to be plowed and reseeded. Natural fertility of the Dow soil is very low. Available phosphorus is low and commonly limits the growth of legumes. (Capability unit IVe-2)

**Dow-Monona silt loams, 14 to 20 percent slopes, severely eroded** (DwE3).—This complex consists of about 60 to 80 percent Dow soils and 20 to 40 percent Monona soils. Most areas are in narrow bands on side slopes. The soils are so eroded that the surface layer typically is only about 3 inches thick and is brown or dark grayish brown. The brown subsoil of the Monona soils and the grayish-brown, calcareous substratum of the Dow soils are exposed in many places.

This complex is mainly used for hay and pasture and is better suited to those crops than to row crops. The soils are not well suited to cultivation, because the surface layer is eroded, the soil is steep, and there is a hazard of further sheet and gully erosion. A crop of corn is commonly grown when hay or pasture crops need to be plowed and reseeded. Natural fertility of the Dow soil is very low. Available phosphorus is low and commonly limits the growth of legumes. (Capability unit IVe-2)

## Ida Series

The Ida series consists of well-drained soils that formed in thick, calcareous loess under prairie vegetation.

Ida soils are on uplands on ridgetops and side slopes. Most areas are on convex hillsides where runoff is rapid. The less sloping Ida soils are on ridgetops. Ida soils are mainly in the Monona-Ida and Monona-Marshall soil associations. They occur mainly as small areas in the Marshall soil association. Slopes range from 5 to 30 percent.

In a representative profile, the surface layer is dark-brown silt loam about 8 inches thick. The surface layer is underlain by dark yellowish-brown and yellowish-brown, very friable silt loam. Some gray and strong-brown mottles are in the lower layers.

Ida soils have high available water capacity and are moderately permeable. They are moderately alkaline and calcareous throughout. Their organic-matter content is very low. Available nitrogen is very low, available phosphorus is very low, and available potassium is medium or high.

Moderately sloping to moderately steep Ida soils are generally cultivated, but the moderately steep soils are more often used for hay and pasture than for row crops. The steep Ida soils are generally used for permanent pasture. Ida soils are susceptible to sheet and gully erosion.

Representative profile of Ida silt loam, 5 to 9 percent slopes, severely eroded, on a narrow, southeast-facing ridgetop, 90 feet north and 180 feet east of the southwest corner of the SE¼ sec. 7, T. 85 N., R. 41 W.

Ap—0 to 8 inches, dark-brown (10YR 3/3) silt loam; brown (10YR 4/3) when crushed; weak, fine, granular structure; very friable; few lime nodules; calcareous; mildly alkaline; clear, smooth boundary.

C1—8 to 17 inches, dark yellowish-brown (10YR 4/4) silt loam; yellowish brown (10YR 5/4) when crushed; weak, fine, granular structure; very friable; few lime nodules; calcareous; moderately alkaline; gradual, smooth boundary.

C2—17 to 25 inches, yellowish-brown (10YR 5/4) silt loam; massive; some vertical cleavage; very friable; few lime nodules; calcareous; moderately alkaline; gradual, smooth boundary.

C3—25 to 40 inches, yellowish-brown (10YR 5/4 to 5/6) silt loam; brownish yellow (10YR 6/6) when crushed; common, medium, gray mottles and few, fine, strong-brown mottles; massive; some vertical cleavage; few, soft, dark spots; few lime nodules; calcareous; moderately alkaline.

The surface layer or plow layer of Ida soils is typically less than 8 inches thick and ranges from very dark grayish brown to dark yellowish brown. The color and thickness are influenced by land use, the severity of erosion, and depth of plowing. Hard lime concretions are abundant on the surface in many places.

The substratum is typically yellowish brown but ranges from dark yellowish brown to brownish yellow. Mottles in the substratum range from yellowish brown to strong brown to grayish brown or light brownish gray.

The range of Ida soils includes those that are leached to a depth of a few inches in the surface or plow layer. This layer ranges from neutral to moderately alkaline.

Ida soils are associated with Monona and Dow soils. Ida soils are calcareous at or near the surface, but Monona soils are leached to a depth of 2 feet or more. They are lower in organic-matter content and in natural fertility than Monona soils. They lack the grayish colors that are typical of Dow soils.

**Ida silt loam, 5 to 9 percent slopes** (IdC).—This soil has a plow layer of very dark grayish brown to dark brown. It is mainly on narrow ridgetops, but some areas are on side slopes. It is generally upslope from other Ida soils or Monona soils. Included in mapping were a few areas of Ida soils where the slope is 2 to 5 percent.

This soil is generally cultivated. It is susceptible to sheet and gully erosion, but it is suited to row crops if erosion is controlled. Tilth is fair or good, but in places the surface layer tends to crust after rain. Natural fertility is very low. Available nitrogen and phosphorus are very low and commonly limit crop growth. (Capability unit IIIe-3)

**Ida silt loam, 5 to 9 percent slopes, severely eroded** (IdC3).—This soil has the profile described as representative for the series. In places, the plow layer is mostly dark yellowish-brown substratum material, and little or none of the original surface layer remains. This soil is on narrow ridgetops, on side slopes, and on the noses of narrow ridges. It is generally upslope from other Ida soils or Monona soils.

This soil is generally cultivated. It is susceptible to sheet and gully erosion, but it is suited to row crops if erosion is controlled. Tilth is generally fair, but the surface layer in most places tends to crust after rain. Natural fertility is very low. Available nitrogen and phosphorus are very low and commonly limit crop growth. (Capability unit IIIe-3)

**Ida silt loam, 9 to 14 percent slopes** (IdD).—This soil generally has a very dark grayish-brown or dark-brown plow layer. In uncultivated areas it has a surface layer about 3 to 7 inches thick that is similar in color. It is on narrow ridgetops, on side slopes, and on the noses of narrow ridges. This soil is mainly adjacent to other Ida soils or Monona or Dow soils.

This soil is generally cultivated, but some areas are used for permanent pasture. It is susceptible to severe sheet and gully erosion, but it is suited to row crops if protected from erosion. It is also well suited to hay and pasture. Tilth is generally fair, but the surface layer tends to crust after rain. Natural fertility is very low. Available nitrogen and phosphorus are very low and commonly limit crop growth. (Capability unit IIIe-4)

**Ida silt loam, 9 to 14 percent slopes, severely eroded** (IdD3).—This soil, in most places, has a plow layer that is dark grayish brown, brown, or dark yellowish brown. In uncultivated areas the darkened surface layer is less than 3 inches thick and is generally dark brown or brown. This soil is on narrow ridgetops, side slopes, and on noses of narrow ridges. This soil is mainly adjacent to other Ida soils or Monona or Dow soils.

This soil is generally cultivated, but some areas are used for hay and pasture much of the time. It is susceptible to severe sheet and gully erosion, but it is suited to row crops if erosion is controlled. Tilth is generally fair to poor, and the surface layer tends to crust after rain. Natural fertility is very low. Available nitrogen and phosphorus are very low and commonly limit crop growth. (Capability unit IIIe-4)

**Ida silt loam, 14 to 20 percent slopes, severely eroded** (IdE3).—This soil typically has a dark-brown or brown surface layer, less than 3 inches thick, in uncultivated areas. In cultivated areas the plow layer is typically brown or dark yellowish brown. This soil is mainly associated with other Ida soils or Monona soils, but in places it is associated with Dow soils. Ida soils are generally upslope from Napier soils or Napier-Kennebec-Nodaway silt loams. Included with this soil in mapping were a few moderately eroded areas that have a thicker surface layer or a darker plow layer. Some areas of this soil are on ridges, but most areas are on side slopes.

This soil is not well suited to row crops because it is moderately steep and is susceptible to severe sheet and gully erosion. It is generally in pasture and hay. A crop of corn is commonly grown when stands of hay or pasture need to be plowed and reseeded. Tilth is generally fair, but the surface tends to crust after rain. Natural fertility is very low. Available phosphorus is low and commonly limits crop growth of legumes. (Capability unit IVe-2)

**Ida silt loam, 20 to 30 percent slopes, severely eroded** (IdF3).—This soil typically has a brown surface layer less than 3 inches thick. It is mainly on side slopes and is generally upslope from Napier soils or Napier-Kennebec-Nodaway silt loams. Included with this soil in mapping were a few areas that have a very dark grayish-brown or dark-brown surface layer about 3 to 7 inches thick.

This soil is not suited to cultivation, and it is mainly used for permenent pasture. It is susceptible to severe sheet and gully erosion. Natural fertility is very low. In some places machinery can be used to fertilize and renovate existing pasture to increase productivity, but using machinery is generally hazardous. (Capability unit VIe-1)

## Judson Series

The Judson series consists of moderately well drained and well drained soils. These soils formed under prairie vegetation in silty alluvium that washed from nearby hillsides.

These soils occupy low foot slopes that are generally at the base of long, loess-covered slopes. They are also on fans at the outlets of upland drainageways. In places they are in a complex with Colo and Nodaway soils in narrow drainageways. Slopes range from 2 to 6 percent.

In a representative profile, the surface layer is silty clay loam about 32 inches thick. The upper 8 inches is very dark grayish brown. The lower part is very dark brown. The subsoil is very dark grayish-brown and brown, friable silty clay loam. The substratum, beginning at a depth of about 52 inches, is dark yellowish-brown, friable silty clay loam.

Judson soils have very high available water capacity and are moderately permeable. They are typically medium acid in the surface layer. The organic-matter content is high. Available nitrogen is medium or low, available phosphorus is low, and available potassium is medium.

Judson soils are mainly under cultivation. Nearly level areas, or those on fans at the outlets of upland drainageways, are subject to occasional flooding and surface deposition. The steeper slopes are susceptible to sheet and gully erosion.

Representative profile of Judson silty clay loam, 2 to 6 percent slopes, on a southeast-facing slope, 235 feet east and 117 feet north of the southwest corner of SE¼SE¼ sec. 27, T. 83 N., R. 37 W.

Ap—0 to 8 inches, very dark grayish-brown (10YR 3/2) light silty clay loam; weak, fine to medium, subangular blocky structure breaking to moderate, fine, granular and fine, subangular blocky; friable; many, fine, decomposing roots; many worm casts; medium acid; clear, smooth boundary.

A1—8 to 24 inches, very dark brown (10YR 2/2) light silty clay loam; weak, fine to medium, subangular blocky structure breaking to fine, granular and fine, subangular blocky; friable; many fine roots; many worm casts; a krotovina 3 inches in diameter; medium acid; diffuse, smooth boundary.

A3—24 to 32 inches, very dark brown (10YR 2/2) light silty clay loam; very dark grayish brown (10YR 3/2) when crushed; weak, fine to medium, subangular blocky structure breaking to fine, granular and fine, subangular blocky; friable; few fine roots; many worm casts; medium acid; diffuse, smooth boundary.

B1—32 to 42 inches, 70 percent very dark grayish-brown (10YR 3/2) and 30 percent brown (10YR 4/3) light silty clay loam; dark brown (10YR 3/3) when crushed; weak, fine to medium, subangular blocky structure; friable; slightly acid; gradual, smooth boundary.

B2—42 to 52 inches, 60 percent brown (10YR 4/3) and 40 percent very dark grayish-brown (10YR 3/2) silty clay loam; dark yellowish brown (10YR 4/4) when crushed; moderate, medium to fine, subangular blocky structure breaking to fine, subangular blocky; friable; few worm casts; slightly acid; clear, smooth boundary.

C—52 to 70 inches, dark yellowish-brown (10YR 4/4) silty clay loam; yellowish brown (10YR 5/4) when crushed; many, fine, faint mottles of gray and reddish brown; very weak, medium and coarse, subangular blocky structure to massive; friable; many black stains; few wormholes; neutral.

The surface layer ranges from 24 to 36 inches in thickness. It is black or very dark brown in the upper part, except in places where overwash is present. If present, the overwash is generally very dark grayish brown, but the range in color includes dark grayish brown and dark brown. The overwash is 6 to 15 inches thick and is silt loam or light silty clay loam. In many places the lower part of the surface layer is very dark grayish brown.

The subsoil is dark brown or brown when crushed. In many places very dark grayish-brown colors are present as coatings on peds, or as a result of mixing of soil material. These colors occur especially in the upper part. The subsoil extends to depths of 40 to 60 inches.

The substratum is brown to yellowish brown. In places a few dark yellowish-brown to strong-brown or gray mottles are present in the subsoil and the substratum.

Judson soils are slightly acid or medium acid in the surface layer and subsoil.

Judson soils have more clay throughout the profile than Napier soils. They are dark brown or brown beginning at a depth of 3 feet or less, but Kennebec soils are dark colored to a depth of 40 inches or more. All of these soils formed in alluvium.

**Judson silty clay loam, 0 to 2 percent slopes** (JdA).—This soil has a profile similar to that described as representative for the series, but in many places the upper part of the surface layer is black or very dark brown and the surface layer is slightly thicker. This soil is generally on alluvial fans downslope from other Judson soils and adjacent to soils on bottom lands. Most areas of this soil are small.

This soil is generally cultivated and is well suited to row crops. Tilth is good. This soil is wet for long periods in some places after rain. The hazard of flooding and surface deposition is slight. (Capability unit I–2)

**Judson silty clay loam, 2 to 6 percent slopes** (JdB).—This soil has the profile described as representative for the series. In many areas, however, the upper part of the surface layer is black or very dark brown. This soil occupies low foot slopes and fans at outlets of upland drainageways. It is generally downslope from the Marshall soils on adjacent upland slopes. The areas are generally long and narrow and are managed along with other soils, commonly those of the adjacent bottom lands. Included are a few areas where the slope is as much as 9 percent.

This soil is generally cultivated. It is well suited to row crops if erosion is controlled. In some places this soil receives runoff from higher lying areas and is susceptible to some deposition or gullying. It is subject to flooding by small streams in places. Soil tilth is generally good. (Capability unit IIe–2)

**Judson-Colo-Nodaway complex, 2 to 6 percent slopes** (JnB).—This complex (fig. 7) consists of approximately 35 to 45 percent Judson soils, 30 to 40 percent Colo soils, and, in the Monona-Marshall soil association, 20 to 30 percent Nodaway soils. Included are areas in the Marshall soil association where the amount of Nodaway soils is less, and in some delineations the areas consists only of Judson and Colo soils.

This complex generally occurs along drainageways and minor streams, mainly in long, narrow areas. In most places Nodaway soils are next to the drainageways, Judson soils are on the foot slopes, and Colo soils occupy the areas in between.

Most of this complex is cultivated. The soils are well suited to row crops. Inaccessible areas, those cut by meandering stream channels or by gullies, or those associated with soils that are not suited to cultivation are used for pasture. Most areas are susceptible to gully erosion and flooding. Some areas tend to remain wet. (Capability unit IIw–1)

*Figure 7.*—An area of Judson-Colo-Nodaway complex. This tract consists mainly of Judson and Colo soils; it is in the Marshall association.

## Kennebec Series

The Kennebec series consists of moderately well drained, nearly level soils that formed in silty alluvium under prairie vegetation. These soils are on flood plains along streams.

In a representative profile, the surface layer is silt loam about 41 inches thick. The upper part is black, and the lower part is very dark brown. Below this is very dark gray and very dark grayish-brown, friable silt loam that has some dark-brown to yellowish-brown mottles or oxides.

Kennebec soils have very high available water capacity and are moderately permeable. They are typically slightly acid throughout. The organic-matter content is high. Available nitrogen is medium or low, and available phosphorus and potassium are medium.

Most areas of Kennebec soils are cultivated. The soils are subject to flooding and deposition in places.

Representative profile of Kennebec silt loam, on a first bottom, 528 feet south and 62 feet east of the northwest corner of NW¼SW¼ sec. 27, T. 82 N., R. 41 W.

Ap—0 to 8 inches, black (10YR 2/1) silt loam; cloddy, breaking to weak; very fine, granular structure; friable; few fine roots; slightly acid; clear, smooth boundary.

A11—8 to 18 inches, black (10YR 2/1) silt loam; weak, fine, subangular blocky structure and weak, fine, granular; friable; many fine pores; few fine roots; common wormholes; slightly acid; diffuse, smooth boundary.

A12—18 to 32 inches, very dark brown (10YR 2/2) silt loam; weak, fine, subangular blocky structure; friable; black (10YR 2/1) coatings on peds; many fine and medium pores; common wormholes; slightly acid; diffuse, smooth boundary.

AC—32 to 41 inches, very dark brown (10YR 2/2) heavy silt loam; weak, fine, subangular blocky structure; friable; many fine and medium pores; many large wormholes; many very dark brown worm casts; slightly acid; diffuse, smooth boundary.

C1—41 to 54 inches, very dark gray (10YR 3/1) heavy silt loam; very dark grayish brown (10YR 3/2) when crushed; very weak, fine, subangular blocky structure; friable; many fine and medium pores; many large wormholes; some worm casts; many, fine, distinct, dark-brown concretions are visible when soil is rubbed; slightly acid; diffuse, smooth boundary.

C2—54 to 58 inches, very dark grayish-brown (10YR 3/2) heavy silt loam; common, medium, distinct mottles of dark brown and dark yellowish brown and few, fine, faint mottles of gray; structureless; massive; friable; few, soft, dark accumulations of an oxide; slightly acid.

The surface layer is black, very dark brown, or very dark gray. It is as much as 36 inches or more in thickness. The texture is typically silt loam throughout but ranges to light silty clay loam. Overwash, if present, is very dark grayish-brown or dark grayish-brown silt loam 6 to 15 inches thick.

The substratum is black, very dark gray, dark gray, very dark grayish-brown, or dark grayish-brown silt loam. The boundary between the surface layer and substratum is indistinct in many places. Soft, dark, oxide accumulations and mottles of dark brown to yellowish brown, gray, or grayish brown are present at a depth below 36 inches in places.

The Kennebec soils range from slightly acid to neutral throughout.

Kennebec soils are darker in color and lack the distinct stratification that is present in the Nodaway soils. They are better drained, more friable, and not so fine textured as the Colo and Zook soils. Kennebec soils resemble Judson and Napier soils but have dark colors to a greater depth. All of these soils formed in alluvium.

**Kennebec silt loam** (0 to 2 percent slopes) (Kb).—This soil has the profile described as representative for the series. It is nearly level soil and is on flood plains along streams. Included in mapping were about a thousand acres of moderately well drained and well drained soils that are browner in color at a depth below 30 inches than the soil described as representative of the series.

This soil is generally cultivated, and row crops are well suited. It is subject to occasional flooding, but flooding generally occurs in spring before planting time.

Wetness is generally not a hazard, except in the lowest areas during very rainy periods. Tilth is good. (Capability unit I-2)

**Kennebec silt loam, overwash** (0 to 2 percent slopes) (Kc).—This soil is similar to Kennebec silt loam, except that it has 6 to 15 inches of recent, very dark grayish-brown or dark grayish-brown silt loam overwash covering the surface. It is generally at the foot of steep, erodible slopes, or it is in areas where floodwater slows and deposits material. This overwash material is lighter colored and less fertile than the representative Kennebec soil.

This soil is generally cultivated, and row crops are well suited. Flooding generally occurs before crops are planted, but in places crops are damaged in some years by floodwaters or siltation. More fertilizer is needed than on Kennebec silt loam because the surface layer is less fertile. (Capability unit I-2)

## Knox Series

The Knox series consists of well-drained soils that formed in thick loess under vegetation that consisted of trees and grass. These soils are on upland ridgetops and side slopes. Most areas are along stream valleys, mainly the Boyer River and its tributaries. Slopes range from 5 to 30 perecent.

In a representative profile, the surface layer is black silt loam about 6 inches thick. Below this is a subsurface layer of very dark grayish-brown and dark-brown, friable silt loam about 3 inches thick. The subsoil extends to a depth of about 60 inches. The upper part is brown, friable silt loam; the middle part is dark yellowish-brown, friable and firm silty clay loam; and the lower part is yellowish-brown, friable silt loam. It has some light brownish-gray silt coatings on peds when dry and some dark-brown, discontinuous clay films on the peds.

Knox soils have high available water capacity and are moderately permeable. They are generally leached of carbonates to a depth of 48 inches or more and are typically medium acid in the surface and subsurface layers. Their organic-matter content is low. Available nitrogen and phosphorus are low or very low, and available potassium is medium or high.

Most areas of Knox soils are used for woodland pasture. The soils are susceptible to sheet and gully erosion if cultivated.

Representative profile of Knox silt loam, 5 to 14 percent slopes, on a south-facing slope, 350 feet south and 300 feet west of the northeast corner of SW¼SW¼ sec. 7, T. 83 N., R. 38 W.

A1—0 to 6 inches, black (10YR 2/1) silt loam; moderate, medium to fine, subangular blocky structure tending to weak, fine, platy breaking to fine, subangular blocky and fine, granular; very friable; common medium and fine roots; medium acid; clear, smooth boundary.

A2—6 to 9 inches, mixed very dark grayish-brown (10YR 3/2) and dark brown (10YR 3/3) silt loam; weak, fine, platy structure breaking to fine, subangular blocky; very friable; few medium and fine roots; medium acid; gradual, smooth boundary.

B1—9 to 16 inches, brown (10YR 4/3) silt loam; moderate, medium, subangular blocky structure breaking to fine, subangular blocky; very dark grayish-brown (10YR 3/2) faces of peds; some light brownish-gray (10YR 6/2) silt coatings on peds when dry; few coarse to fine roots; medium acid; gradual, smooth boundary.

B21t—16 to 22 inches, brown (10YR 4/3) silty clay loam; moderate, medium, subangular blocky structure breaking to fine, subangular blocky; friable; some light brownish-gray (10YR 6/2), thin silt coatings on peds when dry and some thin, discontinuous, dark-brown (10YR 3/3) clay films on peds; few coarse and medium roots; medium acid; gradual, smooth boundary.

B22t—22 to 31 inches, brown (10YR 4/3) silty clay loam; moderate, coarse and medium, subangular blocky structure; friable; some patchy, light brownish-gray (10YR 6/2) silt coatings on peds when dry and some thin, discontinuous, dark-brown (10YR 3/3) clay films on peds; few coarse and medium roots; medium acid; gradual, smooth boundary.

B23t—31 to 38 inches, dark yellowish-brown (10YR 4/4) silty clay loam; few, fine, faint mottles of light gray (10YR 6/1); moderate, medium and coarse, subangular blocky structure; firm; few, discontinuous, light brownish-gray (10YR 6/2) silt coatings when dry and some, discontinuous, dark-brown (10YR 3/3) clay films on peds; medium acid; gradual, smooth boundary.

B31t—38 to 52 inches, dark yellowish-brown (10YR 4/4) light silty clay loam; common, medium and fine, distinct mottles of light gray (10YR 6/1) and few, fine, distinct mottles of black; moderate, coarse and medium, subangular blocky structure; firm; nearly continuous, light brownish-gray (10YR 6/2), grainy silt coatings when dry; very few, thin, discontinuous, dark-brown (10YR 3/3) clay films on peds; slightly acid; gradual, smooth boundary.

B32—52 to 60 inches, yellowish-brown (10YR 5/4) silt loam; common, fine, distinct mottles of light gray (10YR 6/1) and few, fine, distinct mottles of black; weak, coarse and medium, subangular blocky structure; light brownish-gray (10YR 6/2) grainy silt coatings on peds when dry; friable; slightly acid.

The surface layer is black to very dark gray or very dark grayish-brown silt loam 6 to 10 inches thick. In uncultivated areas a subsurface layer that is very dark grayish brown, dark grayish brown, or dark brown is present. This layer has weak, platy structure. This layer is generally not more than 6 inches thick.

The subsoil extends to depths of 36 to 60 inches or more. It is dark brown to dark yellowish brown in the upper part and brown to yellowish brown in the lower part. It is light or medium silty clay loam in the finest part.

The substratum, not shown in the representative profile, is brown to yellowish brown.

Knox soils are medium acid to slightly acid in the surface layer and subsurface layer and in the upper part of the subsoil. The lower part of the subsoil is neutral in some places.

Knox soils typically have a thinner surface layer and vary more widely in clay content between the surface layer and subsoil than Marshall or Monona soils. These soils have a grayish, platy subsurface layer in uneroded areas that is lacking in Marshall and Monona soils. All of these soils formed in loess on uplands.

**Knox silt loam, 5 to 14 percent slopes** (KnD).—This soil has the profile described as representative for the series. Included in mapping were a few areas that are cultivated. In these areas the very dark grayish-brown and dark-brown subsurface layer has mixed with the very dark grayish-brown plow layer. This soil is on convex sides slopes and sloping ridgetops. Most areas are small.

Most areas of this soil are in trees and grass and are used for woodland pasture. If cleared and cultivated, this soil is susceptible to erosion. Cleared areas are suited to row crops if erosion is controlled. This soil is also well suited to small grains and hay or pasture. (Capability unit IIIe-2)

**Knox silt loam, 14 to 20 percent slopes** (KnE).—This soil has a surface layer, about 6 to 8 inches thick, of black to very dark grayish-brown silt loam in most places. The subsurface layer is very dark grayish-brown, dark grayish-brown, or dark-brown silt loam. This layer has weak, platy structure. In some areas, however, the surface layer is only about 4 to 6 inches thick, and in the few cultivated areas, the subsurface layer is mixed in the plow layer. This soil is on convex side slopes.

In many places this soil is downslope from Monona soils that are on ridgetops and is upslope from Napier-Kennebec-Nodaway silt loams. In some places Knox soils are downslope from Marshall soils and upslope from Napier soils or such bottom-land soils as Kennebec or Colo soils. Most areas are small.

Most areas of this soil have not been cleared and are used for woodland pasture. This soil is susceptible to severe sheet and gully erosion if cultivated and is not well suited to row crops. It is better suited to hay and pasture. Areas that have not been cleared are very well suited to wildlife habitat or recreation. (Capability unit IVe–1)

**Knox silt loam, 20 to 30 percent slopes** (KnF).—This soil has a surface layer of very dark grayish brown about 6 to 8 inches thick. It is on convex side slopes. In many places this soil is downslope from Monona soils that are on ridgetops and upslope from Napier-Kennebec-Nodaway silt loams. In some places this soil is downslope from Marshall soils and upslope from Napier soils or such bottom-land soils at Kennebec or Colo soils.

Most areas of this soil have not been cleared and are used for woodland or pasture. If cleared, this soil is susceptible to severe sheet and gully erosion. It is not suited to cultivation. It is suited to woodland or permanent pasture and is well suited to wildlife habitat and recreation. (Capability unit VIe–1)

## Marshall Series

The Marshall series consists of well-drained soils formed in thick loess under prairie vegetation.

These soils are on upland ridgetops or divides and on side slopes. They are also on high benches that are not subject to flooding. Slopes range from 0 to 20 percent.

In a representative profile, the surface layer is very dark brown to very dark grayish-brown silty clay loam about 20 inches thick. The subsoil is mainly brown, friable silty clay loam to a depth of about 37 inches. Below this it is brown silt loam and contains mottles of olive gray and strong brown. The substratum, beginning at a depth of 44 inches, is brown, dark yellowish-brown, and yellowish-brown, friable silt loam that contains mottles of olive gray, brown, and strong brown. Part of the substratum has matrix colors of light brownish gray and strong brown.

Marshall soils have high available water capacity and are moderately permeable. The surface layer and subsoil are typically slightly acid. Their organic-matter content is low in the moderately steep, eroded soils and medium in the gently sloping soils. Available nitrogen and phosphorus are low or medium, and available potassium is medium or high.

Except for the steeper soils, most areas of these soils are cultivated. Runoff is slow on the nearly level soils, but as slope increases, the susceptibility to sheet and gully erosion also increases.

Representative profile of Marshall silty clay loam, 0 to 2 percent slopes, on a convex southeast-facing slope, 1,320 feet south and 100 feet west of the northeast corner of SE¼ sec. 12, T. 83 N., R. 37 W.

A1—0 to 12 inches, very dark brown (10YR 2/2) silty clay loam; moderate, very fine and fine, granular structure; friable; plentiful roots and worm casts; slightly acid; gradual, smooth boundary.

A3—12 to 20 inches, very dark brown (10YR 2/2) to very dark grayish-brown (10YR 3/2) silty clay loam; moderate, fine, granular and fine, subangular blocky structure; friable; many fine roots; slightly acid; gradual, smooth boundary.

B1—20 to 29 inches, dark-brown (10YR 3/3) and brown (10YR 4/3) silty clay loam; moderate, fine, granular and fine, subangular blocky structure; friable; many fine roots; slightly acid; gradual, smooth boundary.

B2—29 to 37 inches, brown (10YR 4/3) silty clay loam; moderate, fine and medium, subangular blocky structure; friable; many fine roots; slightly acid; gradual, smooth boundary.

B3—37 to 44 inches, brown (10YR 4/3) heavy silt loam; common, fine, distinct mottles of olive gray (5Y 5/2) and many, fine, faint mottles of strong brown (7.5YR 5/6); weak, medium, subangular blocky structure; friable; few fine roots; slightly acid; gradual, smooth boundary.

C1—44 to 54 inches, brown (10YR 4/3) silt loam; common, coarse, distinct mottles of olive gray (5Y 5/2), common, fine, distinct mottles of brown (7.5YR 5/2), and common, fine, distinct mottles of strong brown (7.5YR 5/6); massive; friable; neutral; gradual, smooth boundary.

C2—54 to 66 inches, mottled 50 percent dark yellowish-brown (10YR 4/4), 30 percent light brownish-gray (10YR 6/2), and 20 percent strong-brown (7.5YR 5/8) silt loam, yellowish brown (10YR 5/4) when kneaded; massive; friable; few, fine, soft, dark oxide accumulations; neutral; diffuse, smooth boundary.

C3—66 to 94 inches, yellowish-brown (10YR 5/4) silt loam; many, fine distinct mottles of strong brown (7.5YR 5/8); massive; friable; few, fine, soft, dark oxide accumulations; neutral.

The surface layer ranges from about 10 to 15 inches in thickness in most places unless eroded, but in nearly level areas it is as much as 20 inches in thickness. Eroded soils have a surface layer that is as little as about 3 inches in thickness. The surface layer ranges from black to very dark brown and very dark grayish brown in most soils but ranges to lighter colors in severely eroded soils. It ranges from heavy silt loam to silty clay loam. Several black krotovinas and worm casts are throughout the profile.

The subsoil is typically dark brown or brown in the upper part and brown to yellowish brown in the lower part. The lower part of the subsoil is light silty clay loam or heavy silt loam.

The substratum ranges from brown to yellowish brown. Mottling is generally not present at a depth of less than 30 inches, but in many places common to many, olive-gray to grayish-brown and strong-brown mottles are below this depth.

Marshall soils are slightly acid to medium acid in the surface layer and subsoil.

The severely eroded Marshall soils have a surface layer that is thinner and lighter colored than is defined as the range for the series. This does not significantly alter their usefulness or behavior.

Marshall soils are associated with Judson soils. Marshall soils have a thinner surface layer than Judson soils. They have more clay in the surface layer and subsoil than Monona soils and are leached of carbonates to greater depths than those soils. Marshall and Monona soils formed in loess.

**Marshall silty clay loam, 0 to 2 percent slopes** (MaA).—This soil has the profile described as representative for the series; in many places, however, the surface layer is about 12 to 18 inches thick. It is on broad, upland divides, generally upslope from other Marshall soils. Included in mapping was one small area of a nearly level Marshall soil on a bench. Also included were a few acres of a somewhat poorly drained soil that has a thicker dark-colored surface layer and grayish-brown colors in the subsoil.

This soil is generally cultivated and is well suited to row crops. Because this soil is nearly level, there is no serious hazard of erosion. Tilth and physical characteristics are good. (Capability unit I–1)

**Marshall silty clay loam, 2 to 5 percent slopes** (MaB).—This soil has the profile described as representative for the series, except that in many places the surface layer is about 10 to 16 inches thick. Most areas are gently sloping and on broad ridgetops and convex side slopes. About 300 acres of this soil is on high benches along stream valleys; in these areas the underlying material is sand and gravel, and gravel pits are present in places. This soil is generally upslope from steeper Marshall soils and the Judson-Colo-Nodaway complex in drainageways. Most areas are large.

This soil is generally cultivated. It is susceptible to some sheet erosion, especially in the more sloping areas, but it is well suited to row crops if erosion is controlled. Tilth and physical characteristics are good. (Capability unit IIe–1)

**Marshall silty clay loam, 2 to 5 percent slopes, moderately eroded** (MaB2).—This soil typically has a surface layer that is very dark brown or very dark grayish brown. Some of the dark-brown or brown subsoil has been mixed into the plow layer in places. This soil is primarily on narrow ridgetops and on side slopes. About 450 acres of this soil is on high benches along stream valleys; in these areas the underlying material is sand and gravel, and gravel pits are present in places. Most areas are large.

Most of the acreage is cultivated. It is susceptible to sheet erosion, but it is well suited to row crops if erosion is controlled. The organic-matter content is generally low or medium. Tilth is fair in most places. (Capability unit IIe–1)

**Marshall silty clay loam, 5 to 9 percent slopes** (MaC).—This soil has a surface layer of very dark brown to very dark grayish-brown silty clay loam about 7 to 12 inches thick. It is on ridgetops and on convex side slopes. About 200 acres of this soil is on high benches along stream valleys; in these areas the underlying material is sand and gravel, and gravel pits are present in places. Most areas are large.

Most of the acreage is cultivated. It is susceptible to sheet erosion, but it is suited to row crops if erosion is controlled. Tilth is generally good. (Capability unit IIIe–1)

**Marshall silty clay loam, 5 to 9 percent slopes, moderately eroded** (MaC2).—This soil has a surface layer that, in most places, is very dark brown or very dark grayish-brown. Included in mapping were a few severely eroded areas where this layer is a mixture of subsoil material and the remaining surface layer. In these places the plow layer is dark brown. This soil is generally on undulating ridgetops and moderately sloping convex side slopes (fig. 8). About 80 acres of this soil is on high benches along stream valleys. In these places the underlying material is sand and gravel, and gravel pits are present in places. Most areas are large.

Most of this soil is cultivated. It is susceptible to sheet erosion, but it is suited to row crops if erosion is controlled. The organic-matter content is low or medium. Tilth is fair in most places. (Capability unit IIIe–1)

**Marshall silty clay loam, 9 to 14 percent slopes** (MaD).—This soil has a surface layer of very dark brown or very dark grayish-brown silty clay loam about 7 to 12 inches thick. In many places mottles of gray to strong

***Figure 8.*****—An area of Marshall silty clay loam, 5 to 9 percent slopes.**

brown occur higher in the profile than in the profile described as representative for the series. It is mostly on straight to convex side slopes. It is generally downslope from other Marshall soils and upslope from the Judson-Colo-Napier complex, which are in drainageways. Most areas are large.

Some areas of this soil are cultivated, but many areas are in permanent pasture because they are associated with steeper soils or are inaccessible to manage efficiently for crops. This soil is susceptible to sheet and gully erosion, but it is suited to row crops if erosion is controlled. It is also well suited to small grains or hay or pasture. Tilth is good in most places. (Capability unit IIIe-2)

**Marshall silty clay loam, 9 to 14 percent slopes, moderately eroded** (MaD2).—This soil has a surface layer that, in most places, is very dark grayish brown. In places some of the brown subsoil is mixed into the plow layer. In many places mottles of gray to strong brown are higher in the profile than in the profile described as representative for the series. This soil is mostly on straight to convex side slopes. About 70 acres of this soil is on high benches along stream valleys. In these places the underlying material is sand and gravel, and gravel pits are present in places. The soil is generally downslope from other Marshall soils and upslope from Judson soils or the Judson-Colo-Nodaway complex, which are in drainageways. This soil is one of the most extensive in the county.

Most of this soil is cultivated. It is susceptible to sheet and gully erosion, but it is suited to row crops if erosion is controlled. It is also well suited to small grains or hay or pasture. The organic-matter content is generally low. Tilth is fair or poor. (Capability unit IIIe-2)

**Marshall silty clay loam, 9 to 14 percent slopes, severely eroded** (MaD3).—This soil has a surface layer that, in most places, consists of dark-brown or brown material from the subsoil. In many places mottles of gray to strong brown are higher in the profile than in the profile described as representative for the series. This soil is on straight to convex side slopes. It is generally downslope from other Marshall soils and upslope from Judson soils or the Judson-Colo-Nodaway complex, which are in drainageways. Most areas are large.

This soil is generally cultivated. It has had much of the original surface layer removed by erosion. It is susceptible to severe sheet and gully erosion, but it is suited to row crops if protected from erosion. Small grains and hay and pasture crops, especially legumes, are also well suited. The organic-matter content is low. Tilth is generally poor. (Capability unit IIIe-2)

**Marshall silty clay loam, 14 to 20 percent slopes, moderately eroded** (MaE2).—This soil typically has a very dark grayish-brown plow layer, or in uncultivated areas, a surface layer that is similar in color and is 3 to 7 inches thick. The depth to the silt loam substratum tends to be a few inches less than in the profile described as representative for the series. Gray to strong-brown colors are also higher in the profile. This soil is generally on convex side slopes. It is downslope from less sloping Marshall soils and upslope from Judson soils or the Judson-Colo-Nodaway complex, which are in drainageways. About 80 acres of this soil has a surface layer about 7 to 10 inches thick. Some areas have outcrops or narrow bands of Shelby soils between this soil and the drainageways.

Most areas of this soil are used for hay and pasture most of the time. This soil is susceptible to severe sheet and gully erosion, but it is suited to cultivation if erosion is controlled. A crop of corn is commonly grown when stands of grasses or legumes need to be plowed and reseeded. Tilth is generally fair. (Capability unit IVe-1)

**Marshall silty clay loam, 14 to 20 percent slopes, severely eroded** (MaE3).—In cultivated areas this soil typically has a dark-brown or brown plow layer that is mainly subsoil. In uncultivated areas a very dark grayish-brown surface layer, less than 3 inches thick, overlies the dark-brown or brown subsoil. The subsoil is exposed in many places. Depth to the silt loam substratum tends to be a few inches less than in the representive profile. Gray to strong-brown mottles are also higher in the profile. This soil is mostly on convex sides slopes. It is generally downslope from less sloping Marshall soils and upslope from Shelby soils. In places it is upslope from and adjacent to Judson soils or the Judson-Colo-Nodaway complex, which are in drainageways. Included in mapping were a few small areas where reddish, clayey soils are at the surface. These are shown on the map by a symbol. Most areas are small.

This soil is generally cultivated, but it is not used extensively for row crops because of the eroded surface layer, steepness, and susceptibility to severe sheet and gully erosion. It is better suited to hay and pasture than to row crops. A crop of corn is commonly grown when existing stands of hay or pasture need to be plowed and reseeded. The organic-matter content is low. Tilth is generally fair or poor. (Capability unit IVe-1)

## Monona Series

The Monona series consists of well-drained soils that formed in loess under prairie vegetation.

Monona soils are on ridgetops and side slopes. They are mainly on uplands in the Monona-Ida and Monona-Marshall associations, but also are on high benches along some of the major streams.

In a representative profile, the surface layer is silt loam about 15 inches thick. The upper part is very dark brown, and the lower part is very dark grayish brown. The subsoil is friable silt loam to a depth of about 38 inches. The upper part is dark brown, the middle part is brown, and the lower part is dark yellowish brown. The substratum is mainly yellowish-brown and some olive-gray, friable silt loam that has mottles of grayish brown and strong brown (fig. 9).

Monona soils have high available water capacity and are moderately permeable. They are typically slightly acid in the surface layer and slightly acid or neutral in the subsoil. Their organic-matter content is low or medium. The fertility level of these soils varies with the degree of erosion, but generally available nitrogen is low, available phosphorus is low, and the available potassium is high.

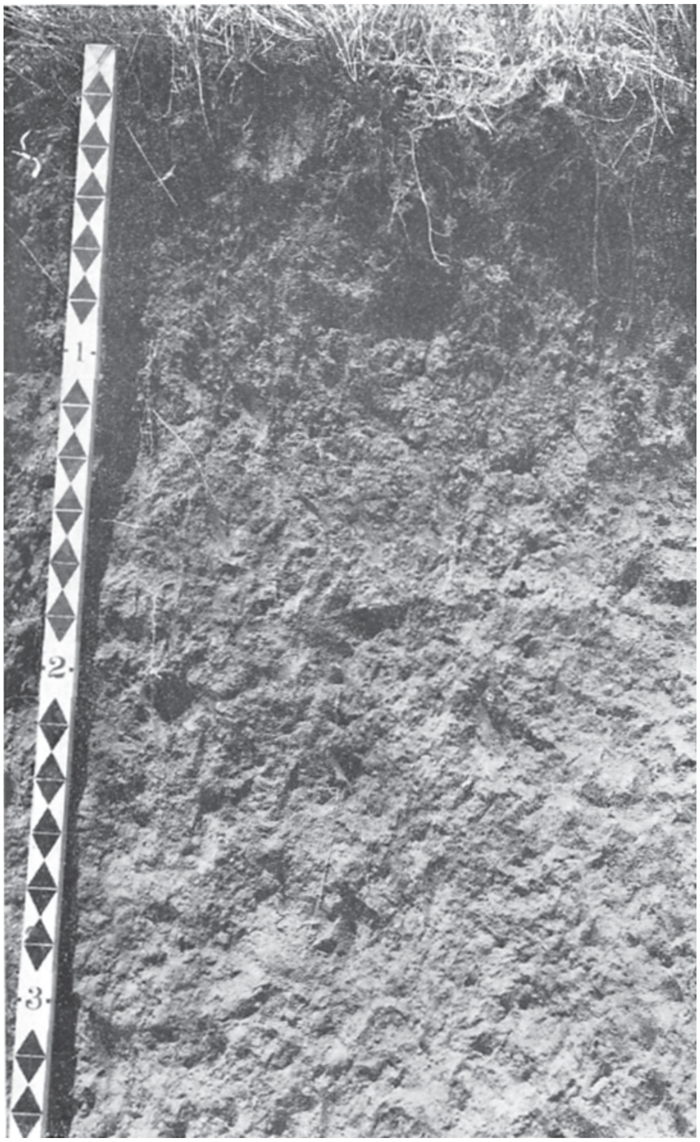

*Figure 9.*—Profile of Monona silt loam.

Nearly level to moderately steep Monona soils are mainly cultivated. Steep Monona soils are generally in pasture. All of the soils except for the nearly level Monona soils are susceptible to sheet and gully erosion. The severity of the erosion hazard increases as slope increases.

Representative profile of Monona silt loam, 0 to 2 percent slopes, on a ridgetop that is a distinct watershed divide, 500 feet east and 20 feet north of the southwest corner of sec. 35, T. 84 N., R. 41 W.

Ap—0 to 8 inches, very dark brown (10YR 2/2) silt loam; cloddy breaking to weak, fine, granular structure; friable; few fine roots; slightly acid; abrupt, smooth boundary.

A3—8 to 15 inches, very dark grayish-brown (10YR 3/2) silt loam; weak, fine, subangular blocky and weak, fine, granular structure; friable; many fine and medium pores; few fine roots; some mixing of very dark grayish-brown peds; slightly acid; gradual, smooth boundary.

B1—15 to 21 inches, dark brown (10YR 3/3) silt loam; weak, medium, prismatic structure breaking to weak, fine, subangular blocky; friable; very dark grayish-brown (10YR 3/2) ped faces; few fine and medium pores; few fine roots; few peds coated with very dark brown stains, probably organic; slightly acid; gradual, smooth boundary.

B2—21 to 29 inches, brown (10YR 4/3) heavy silt loam; weak, medium, prismatic structure breaking to weak, fine, subangular blocky; friable; dark-brown (10YR 3/3) ped faces; many fine and medium pores; few very fine roots; old root channel fillings of brown (10YR 4/3); some very dark brown (10YR 2/2) coatings on a few peds; neutral; gradual, smooth boundary.

B3—29 to 38 inches, dark yellowish-brown (10YR 4/4) silt loam; weak, fine, subangular blocky structure to massive; friable; abundant very fine and fine pores; few large wormholes; neutral; diffuse, smooth boundary.

C1—38 to 46 inches, dark yellowish-brown (10YR 4/4) silt loam; massive; friable; abundant pores; few wormholes or old root channels; neutral; gradual, smooth boundary.

C2—46 to 48 inches, yellowish-brown (10YR 5/4) silt loam; 30 percent of matrix is olive (5Y 5/3); massive; friable; many fine pores; many, fine, soft oxides; neutral; horizon is distinctly coarser in texture than C1; diffuse, smooth boundary.

C3—48 to 89 inches, yellowish-brown (10YR 5/4) silt loam; few, fine, faint mottles of grayish brown (10YR 5/2) and few, fine, faint mottles of strong brown (7.5YR 5/6); massive; friable; many, fine, soft oxides; neutral.

The surface layer ranges from 10 to 15 inches in thickness in most places unless eroded, but in nearly level areas the thickness is as much as 18 inches. In eroded areas this layer is as thin as 3 inches. It is typically very dark brown or very dark grayish brown except in severely eroded areas where the colors are lighter. It is silt loam or light silty clay loam.

The subsoil, about 12 to 24 inches thick, ranges from brown to yellowish brown. In places very dark grayish-brown colors are in the upper part of the subsoil, generally as coatings on peds. Dark brown is also in the range of color in the upper part of the subsoil. The upper part of the subsoil is silt loam or light silty clay loam.

The substratum is brown to yellowish brown. Mottles range from olive and olive gray to strong brown. The depth to calcareous material varies widely, depending upon the landscape position and the severity of erosion.

Steep soils on convex slopes are calcareous as near the surface as 24 inches. Those Monona soils on benches or nearly level divides are leached to a depth of about 6 feet or more in places. Monona soils range from slightly acid to medium acid in the surface layer and are slightly acid or neutral in the subsoil. The substratum is neutral to moderately alkaline.

The severely eroded Monona soils have a surface layer that is thinner and lighter colored than is defined as the range for the series. These differences do not significantly alter their usefulness or behavior.

The Monona soils are not calcareous at or near the surface, as are Ida soils. They differ from Knox soils in typically having a thicker surface layer, in lacking a grayer subsurface layer, and in varying less widely in clay content between the surface layer and the subsoil. Monona soils have browner colors in the profile than Dow soils and are not calcareous so high in the profile. They differ from Napier soils in having a thinner surface layer. Monona soils have less clay in the surface layer and subsoil and are not so deeply leached as Marshall soils. All the soils, except Napier soils, formed in loess.

**Monona silt loam, 0 to 2 percent slopes** (MoA).—This soil has the profile described as representative for the series. In places, however, the surface layer is a few inches thicker. Most of this soil is on high benches. Some is on broad, relatively stable ridgetops. Most areas of this soil are large.

Most of this soil is cultivated. It is well suited to row crops. The hazard of erosion is slight. Tilth and physical characteristics are good. (Capability unit I–1)

**Monona silt loam, 2 to 5 percent slopes** (MoB).—This soil has the profile described as representative for the series, except that the surface layer is a few inches thinner in places. It is mainly on broad, slightly rounded ridgetops. It is generally upslope from moderately sloping or strongly sloping Monona soils.

This soil is generally cultivated. It is susceptible to erosion, but it is well suited to row crops if erosion is controlled. Tilth and physical characteristics are good. (Capability unit IIe–1)

**Monona silt loam, 2 to 5 percent slopes, moderately eroded** (MoB2).—This soil typically has a very dark grayish-brown plow layer. It is mainly on slightly rounded, narrow ridgetops and generally is upslope from moderately sloping or strongly sloping Monona soils. Included in mapping were a few severely eroded areas where this layer is generally dark brown or brown.

Most of this soil is cultivated. It is susceptible to erosion, but it is well suited to row crops if protected from erosion. Tilth is good in most places. (Capability unit IIe–1)

**Monona silt loam, 5 to 9 percent slopes** (MoC).—This soil has a very dark brown or very dark grayish-brown surface layer about 7 to 12 inches thick. In many places the subsoil is somewhat thinner than that in the profile described as representative for the series. This soil is generally calcareous at a depth of about 3 to 4 feet. It is mainly on side slopes and on long, narrow ridgetops.

Most of this soil is cultivated, but some areas are in permanent pasture. This soil is susceptible to erosion, but it is suited to row crops if erosion is controlled. Tilth and physical characteristics are good. (Capability unit IIIe–1)

**Monona silt loam, 5 to 9 percent slopes, moderately eroded** (MoC2).—This soil typically has a very dark grayish-brown plow layer. In places some of the dark-brown subsoil material is mixed with this layer. In many places the subsoil is somewhat thinner than in the profile described as representative for the series. This soil is generally calcareous at a depth of about 3 to 4 feet.

This soil is mainly on side slopes and long, narrow ridgetops. It is one of the most extensive soils in the county. Most areas are large.

Most of this soil is cultivated. It is susceptible to erosion, but it is suited to row crops if erosion is controlled. The organic-matter content is low to medium, but tilth is good in most places. (Capability unit IIIe–1)

**Monona silt loam, 5 to 9 percent slopes, severely eroded** (MoC3).—This soil typically has a dark-brown plow layer that consists mainly of subsoil material mixed with the remaining surface layer. In many places the subsoil is somewhat thinner than in the profile described as representative for the series. This soil is generally calcareous at a depth of about 3 to 4 feet. It is on long, narrow ridgetops and side slopes. Most areas are small.

Most of this soil is cultivated. It is susceptible to sheet and gully erosion, but it is suited to row crops if erosion is controlled. Natural fertility is lower than on less eroded Monona soils. Tilth and physical characteristics are generally only fair because of the thin surface layer and the low organic-matter content. (Capability unit IIIe–1)

**Monona silt loam, 9 to 14 percent slopes** (MoD).—This soil typically has a very dark grayish-brown surface layer about 7 to 12 inches thick. The subsoil is typically thinner, and mottles are higher in the profile, than in the profile described as representative for the series. This soil is calcareous at a depth of 30 to 40 inches in many places.

This soil is mainly on side slopes. It is generally downslope from less sloping Monona soils. In many places it is upslope from Napier soils or Napier-Kennebec-Nodaway silt loams. Most areas are small.

Most of this soil is cultivated. It is susceptible to sheet and gully erosion, but it is suited to row crops if protected from erosion. It is also well suited to small grains and hay or pasture. Tilth and physical characteristics are good. (Capability unit IIIe-2)

**Monona silt loam, 9 to 14 percent slopes, moderately eroded** (MoD2).—This soil typically has a very dark grayish-brown plow layer. Some of the subsoil material is mixed into this layer. The subsoil is typically thinner, and mottles are higher in the profile than in the profile described as representative for the series. This soil is calcareous at a depth of 30 to 40 inches in many places.

This soil is mainly on side slopes, generally downslope from less sloping Monona soils. In many places it is upslope from Napier soils or Napier-Kennebec-Nodaway silt loams. It is the most extensive soil in the county. Most areas are large.

Most of this soil is cultivated. It is susceptible to sheet and gully erosion, but it is suited to row crops if erosion is controlled. It is also well suited to small grains and hay and pasture. Organic-matter content is low, but tilth is generally fair. (Capability unit IIIe-2)

**Monona silt loam, 9 to 14 percent slopes, severely eroded** (MoD3).—This soil typically has a dark-brown or brown plow layer that consists mainly of subsoil material. The subsoil tends to be thinner, mottles are higher in the profile, and this soil is not generally leached so deeply as the soil that has the profile described as representative for the series. This soil is calcareous at a depth of about 30 to 40 inches in many places.

This soil is mainly on side slopes. It is generally downslope from less sloping Monona soils. In many places it is upslope from Napier soils or from Napier-Kennebec-Nodaway silt loams. Areas of this soil vary in size, but are generally not large.

Most of this soil is cultivated. It is susceptible to severe sheet and gully erosion, but it is suited to row crops if erosion is controlled. Small grains and hay and pasture crops, especially legumes, are also well suited. Natural fertility is lower than on less eroded Monona soils. Tilth is generally fair or poor because of the thin surface layer, which is low in organic-matter content. (Capability unit IIIe-2)

**Monona silt loam, 14 to 20 percent slopes, moderately eroded** (MoE2).—This soil typically has a very dark grayish-brown plow layer. Some of the subsoil has been mixed into the plow layer in places. The subsoil is generally thinner, mottles are higher in the profile, and this soil is generally not leached so deeply as the soil that has the profile described as representative for the series.

The soil is calcareous at a depth of 24 to 36 inches in most places. This soil is on side slopes. In some places it is upslope from Shelby soils, and in many places it is upslope from Napier soils or from Napier-Kennebec-Nodaway silt loams. Included in mapping were about 300 acres of a slightly eroded soil that has a very dark brown or very dark grayish-brown surface layer about 7 to 10 inches thick.

This soil is generally cultivated. It is not well suited to row crops, because it is moderately steep and is susceptible to severe sheet and gully erosion. It is generally used for hay and pasture. A row crop is commonly grown when stands of hay or pasture need to be plowed and reseeded. The organic-matter content is low, but tilth is generally fair or good. (Capability unit IVe-1)

**Monona silt loam, 14 to 20 percent slopes, severely eroded** (MoE3).—This soil, in most areas, has a surface layer that is a dark-brown or brown plow layer that consists mainly of subsoil material mixed in tillage. The subsoil is thinner, mottles are higher in the profile, and this soil is not generally leached so deeply as the soil that has the profile described as representative for the series. The soil is calcareous at a depth of 24 to 36 inches in most places.

This soil is on side slopes. In some places it is upslope from Shelby soils, and in most places it is upslope from Napier soils or Napier-Kennebec-Nodaway silt loams.

This soil is generally used for hay and pasture. It has been used for cultivated crops often enough in the past that it is severely eroded. It is not well suited to row crops, because it is moderately steep and susceptible to severe sheet and gully erosion. A row crop is commonly grown when stands of hay or pasture need to be plowed and reseeded. Natural fertility is lower than that of less eroded Monona soils. Tilth is generally fair or poor because of the mixing of the surface layer with the subsoil and the low organic-matter content. (Capability unit IVe-1)

**Monona silt loam, 20 to 30 percent slopes, moderately eroded** (MoF2).—This soil typically has a very dark grayish-brown or very dark brown surface layer about 3 to 7 inches thick. The subsoil is thinner, mottles are higher in the profile, and the soil is not leached so deeply as the soil that has the profile described as representative for the series. The soil is calcareous at a depth of 24 to 36 inches in most places. Included in mapping were about 250 acres of a Monona soil that has a surface layer about 7 to 10 inches thick and about 200 acres of Marshall silty clay loam on similar slopes.

This soil is on side slopes. In most places it is upslope from Napier soils or Napier-Kennebec-Nodaway silt loams, but in some places it is upslope from Shelby soils.

This soil is mainly in permanent pasture. It is better suited to pasture than to crops that require much tillage. It is susceptible to severe sheet and gully erosion, and it is not suited to row crops. Gullies are present in places. There is some risk if farm machinery is used on such steep slopes, but the carrying capacity of many pastures is increased by renovation and seeding to suitable grasses and legumes. (Capability unit VIe-1)

**Monona silt loam, 20 to 30 percent slopes, severely eroded** (MoF3).—This soil is so severely eroded that the surface layer is about 3 inches thick. The brown subsoil is exposed in many places. The subsoil is thinner, mottles are higher in the profile, and the soil is not leached so deeply as the soil that has the profile described as representative for the series. The soil is calcareous at a depth of 24 to 36 inches in most places. Included in mapping were about 300 acres of severely eroded Marshall silty clay loam on similar slopes.

This soil is on side slopes. In most places it is upslope from Napier soils or Napier-Kennebec-Nodaway silt loams, but in some places it is upslope from Shelby soils.

This soil is mostly used for permanent pasture. It is not suited to cultivation. It is susceptible to further severe sheet and gully erosion. Gullies are present in places. There is some risk if farm machinery is used on such steep slopes, but the carrying capacity of many pastures is increased by renovation and seeding of suitable grasses and legumes. (Capability unit VIe-1)

**Monona silt loam, 30 to 40 percent slopes, severely eroded** (MoG3).—This soil has a surface layer that is generally 3 inches thick. The subsoil is not leached so deeply as the soil that has the profile described as representative for the series. The soil is calcareous at a depth of 24 to 36 inches in most places. The brown subsoil is exposed in many places. Included in mapping were about 75 acres where the surface layer is as much as 8 inches thick. Also included were a few small areas of Knox soils that have a grayish subsurface layer and about 115 acres of Ida soils that are calcareous at or near the surface.

This soil is on side slopes. In most places it is upslope from Napier soils or Napier-Kennebec-Nodaway silt loams.

This soil is generally used for permanent pasture. A few areas are wooded but are generally used as wooded pasture rather than woodland. The soil is susceptible to severe erosion, and it is not suited to cultivation. It should be left in permanent vegetation. The wooded areas are suited to wildlife habitat. (Capability unit VIIe-1)

## Napier Series

The Napier series consists of well-drained, silty soils. These soils formed in local alluvium that washed from nearby hillsides under prairie vegetation.

Napier soils are on foot slopes downslope from long, upland slopes and on fans at outlets of upland drainageways in a complex with Kennebec and Nodaway soils. Slopes range from 2 to 14 percent.

In a representative profile, the surface layer is silt loam about 31 inches thick. The upper part is very dark brown, and the lower part is very dark grayish brown. Below this, the subsoil is dark-brown and brown, friable silt loam.

These soils have very high available water capacity and are moderately permeable. They are medium or slightly acid in the upper part of the surface layer and neutral below. Their organic-matter content is high. Available nitrogen is medium or low, available phosphorus is low, and available potassium is high.

Napier soils are mainly cultivated, but some areas are in pasture. Those soils on the flood plains are subject to flooding and occasional deposition. Those on slopes are susceptible to sheet and gully erosion.

Representative profile of Napier silt loam, 2 to 5 percent slopes, on a convex fan, 280 feet south and 849 feet east of the northwest corner of sec. 30, T. 84 N., R. 41 W.

A1—0 to 4 inches, very dark brown (10YR 2/2) silt loam; weak, very fine, granular structure; very friable; abundant fibrous roots; some black (10YR 2/1) organic coatings on peds; medium acid; gradual, smooth boundary.

A12—4 to 14 inches, very dark brown (10YR 2/2) silt loam; weak, fine, prismatic structure breaking to weak, fine, granular; friable; abundant fibrous roots; some black (10YR 2/1) organic coatings on peds; slightly acid; diffuse, smooth boundary.

A13—14 to 22 inches, very dark brown (10YR 2/2) silt loam; weak, medium, prismatic structure breaking to weak, fine, granular; friable; many fine roots; many fine and medium pores; numerous wormholes and some casts; neutral; diffuse, smooth boundary.

A3—22 to 31 inches, very dark grayish-brown (10YR 3/2) silt loam; weak, medium, prismatic structure breaking to weak, fine, granular; friable; very dark brown (10YR 2/2) coatings on peds; few fine roots; many fine and medium pores; many wormholes and few worm casts; neutral; diffuse, smooth boundary.

B1—31 to 42 inches, dark-brown (10YR 3/3) silt loam; weak, fine subangular blocky structure breaking to weak, fine, granular; friable; very dark grayish-brown (10YR 3/2) coatings on peds; many fine and medium pores; many wormholes and very dark brown (10YR 2/2) worm casts; neutral; gradual, smooth boundary.

B2—42 to 56 inches, brown (10YR 4/3) silt loam; moderate, fine to medium, subangular blocky structure; friable; dark brown (10YR 3/3) ped faces; many fine and medium pores; few fine roots; distinct grayish-brown (10YR 5/2, dry) or very dark grayish-brown (10YR 3/2, moist) silt coatings on all peds; neutral.

The surface layer ranges from about 24 to 36 inches in thickness and from black to very dark grayish brown in color.

The subsoil is dark brown or brown within a depth of 40 inches, but darkened organic coatings mask higher chroma ped interiors to a depth below 40 inches in most places. The subsoil is 12 to 24 inches thick. The combined thickness of the surface layer and the subsoil ranges from 36 to 60 inches.

In the steepest soils, the substratum, not shown in the representative profile, is calcareous at a depth below 36 inches in places. It is brown or yellowish brown.

Napier soils are typically silt loam throughout, but thin zones of light silty clay loam are present in places. Napier soils are typically slightly acid or neutral but range to medium acid in the upper part of the surface layer.

Napier soils formed in parent material similar to that of Judson and Kennebec soils and are similar in texture and drainage to Monona soils. They are similar to Judson soils but have less clay throughout. They have a thicker dark-colored surface layer than Monona soils. Napier soils differ from Kennebec soils in having browner colors at a depth below about 30 inches.

**Napier silt loam, 2 to 5 percent slopes** (NbB).—This soil has the profile described as representative for the series. It is on foot slopes at the base of steeper slopes, occupied mainly by Monona soils, on fans at the outlets of upland drainageways, and on flood plains of small streams.

This soil is generally cultivated and is well suited to row crops. It is susceptible to slight sheet and gully erosion. The areas on the flood plain are susceptible to flooding and deposition. Tilth and physical characteristics are good. (Capability unit IIe-2)

**Napier silt loam, 5 to 9 percent slopes** (NbC).—This soil has a profile similar to that described as representative for the series, but in places the surface layer is a little thinner. It is on foot slopes at the base of steeper slopes occupied by Monona and Ida soils and on fans at the outlets of upland drainageways.

This soil is generally cultivated. If the associated soils on nearby hillsides are steep, this soil is managed along with those soils as pasture. It is suited to row crops if sheet and gully erosion are controlled. In places water flowing across this soil causes gullies and siltation downslope. Tilth and physical characteristics are good. (Capability unit IIIe-6)

**Napier silt loam, 9 to 14 percent slopes** (NbD).—This soil has a profile similar to that described as representative for the series, but in many places the surface layer is a few inches thinner. This soil is on foot slopes at the base of steeper slopes generally occupied by Monona and Ida soils.

This soil is cultivated in many places. Many areas of the associated soils on nearby hillsides are steep, and in such places this soil is managed along with those soils as pasture. It is susceptible to sheet and gully erosion, but it is suited to row crops if erosion is controlled. It is also well suited to small grains and hay and pasture. In places water flowing across this soil causes gullies and siltation downslope. Tilth and physical conditions are good. (Capability unit IIIe-6)

**Napier-Gullied land complex, 2 to 10 percent slopes** (NgC).—This complex consists primarily of Napier soils, but included in mapping were small areas of Kennebec and Nodaway soils. It is generally downslope from strongly sloping to steep Monona or Ida soils, but in places it is downslope from Napier-Kennebec-Nodaway silt loams.

This complex is along narrow drainageways and minor streams where deep gullies are a major feature. The gullies occupy half or more of any given area. The gully banks are generally steep and overgrown with trees and brush.

This complex is not suited to cultivation. The areas are small, and in places they are isolated. They are crossed by stream channels and are subject to flooding. Gullies are numerous. The areas are generally used for pasture or are idle. Some areas are suitable for wildlife habitat. (Capability unit VIIe-1)

**Napier-Kennebec-Nodaway silt loams, 2 to 5 percent slopes** (NkB).—This complex consists of about 35 to 45 percent Napier soils, 35 to 40 percent Kennebec soils, and 20 to 25 percent Nodaway soils. Included in mapping were a few areas of Colo soils.

This complex is primarily in long, narrow areas along narrow drainageways and minor streams in the Monona-Marshall and Monona-Ida associations. It occupies a large acreage. Typical areas have a main stem in the valleys and fingers extending into side-valley drains. Many areas have a waterway that can be crossed with machinery, but some are gullied. Most areas are large.

Most of this complex is cultivated. It is suited to row crops but is subject to flooding and susceptible to severe gully erosion. Some areas tend to remain wet after flooding. Tilth and physical characteristics are good. (Capability unit IIe-2)

**Napier-Kennebec-Nodaway silt loams, 5 to 9 percent slopes** (NkC).—This complex consists of about 60 to 70 percent Napier soils, 18 to 25 percent Kennebec soils, and 12 to 18 percent Nodaway soils. These soils are primarily in long, narrow areas along narrow drainageways and minor streams in the Monona-Marshall and Monona-Ida associations. Typical areas have a main stem in the valley and fingers extending up the side-valley drains. Some areas have a waterway that can be crossed with farm machinery. Others have gullies.

Many areas of this complex are cultivated, but the cropping pattern is generally determined by the associated soils. If nearby hillsides are steep and used for pasture, this complex is also used for pasture. Areas that have meandering streams or gullies are generally used for pasture. They are suited to row crops but are susceptible to gully erosion, and lower lying areas are subject to flooding. Tilth and physical characteristics are good. (Capability unit IIIe-6)

## Nodaway Series

The Nodaway series consists of moderately well drained, nearly level, stratified soils. These soils formed under prairie vegetation in recently deposited alluvium.

Nodaway soils are on flood plains and are generally near stream channels. They are also in narrow drainageways in a complex with Judson and Colo soils in the Marshall soil association and with Napier and Kennebec soils in the Monona-Ida and Monona-Marshall soil associations.

In a representative profile, the surface layer is very dark grayish-brown silt loam about 9 inches thick. Below this, to a depth of about 48 inches, is stratified, dark grayish-brown, brown, and very dark gray, friable loam to silt loam that contains strata of silty clay loam to silty clay and sandy loam. Below this is very dark gray and brown, friable silt loam.

Nodaway soils have high available water capacity and are moderately permeable. They are typically neutral throughout. Their organic-matter content is low. Available nitrogen is low, available phosphorus is low or medium, and available potassium is medium.

Most areas of Nodaway soils are cultivated. They are subject to flooding and receive deposition.

Representative profile of Nodaway silt loam, on the flood plain of the Boyer River, 380 feet west and 220 feet north of the southeast corner of NE$\frac{1}{4}$ sec. 16, T. 83 N., R. 39 W.

Ap—0 to 9 inches, very dark grayish-brown (10YR 3/2) silt loam; weak, fine, subangular blocky structure breaking to fine, granular; friable; many fine to medium roots; many worm casts; neutral; clear, smooth boundary.

C1—9 to 24 inches, stratified material of mixed color and texture; 60 percent dark grayish-brown (10YR 4/2) loam to silt loam, 20 percent very dark gray (10YR 3/1) silty clay loam to silty clay, and 20 percent brown (10YR 5/3) sandy loam; weak, fine subangular blocky structure breaking to fine, granular; friable; few worm casts; a few thin lenses of fine sand; neutral; gradual, smooth boundary.

C2—24 to 48 inches, colors and textures as in the C1 horizon; few, faint mottles of brown; many worm casts; stratification not so distinct as in the C1 horizon; neutral; gradual, smooth boundary.

C3—48 to 70 inches, mixed colors, 80 percent very dark gray (10YR 3/1) silt loam and 20 percent brown (10YR 5/3) silt loam; friable; stratification less distinct than in the C2 horizon; sand content higher than in the Ap, C1, and C2 horizons; neutral.

The plow layer, or surface layer in unplowed areas, is typically very dark grayish brown, but it is very dark gray or dark grayish brown in some places. The stratified substratum is typically dark grayish brown, but strata range from very dark gray to brown. It is typically silt loam, but thin strata of loam, silty clay loam, sandy loam, or fine sand occur in places. Mottles are present in many places, especially in areas where this soil is in narrow bottom lands that are frequently flooded. Mottles range from strong brown to grayish brown. Buried, dark-colored soils are present at depths greater than 36 inches in places, especially in narrow drainageways and near the heads of drainageways.

Nodaway soils have a thinner surface layer than Kennebec, Napier, Colo, and Judson soils and have distinct stratification that is lacking in those soils. Nodaway soils are not so fine textured as Colo or Judson soils. All of these soils formed in alluvium.

**Nodaway silt loam** (0 to 2 percent slopes) (No).—This soil is on bottom lands and in most places is adjacent to stream channels.

Most of this soil is cultivated, and row crops are well suited. It is susceptible to flooding and surface deposition, but the flooding generally occurs before crops are planted or is of short duration. Tillage is delayed at times, and crops are sometimes damaged. In most years, however, the damage is slight. Tilth is generally good. (Capability unit I–2)

## Salida Series

The Salida series consists of excessively drained soils that formed under prairie vegetation in calcareous, stratified, sandy and gravelly glacial sediments.

Salida soils are on convex side slopes, on the noses of narrow ridges, and on knobs on side slopes. They are also on the tops and sides of narrow ridges. They are mainly on uplands along the Boyer River and near the mouths of larger creeks that flow into the River. Slopes are 9 to 25 percent.

In a representative profile, the surface layer is very dark grayish brown and about 16 inches thick. The upper part is gravelly loam, and the lower part is gravelly sand. Below this is dark yellowish-brown and very pale brown, loose gravelly sand.

Salida soils have very low available water capacity and are very rapidly permeable. In many places they are neutral or slightly acid in the upper part of the surface layer and neutral in the lower part, but in other places they are mildly or moderately alkaline in this layer and calcareous at or near the surface. Their organic-matter content is low. Available nitrogen is very low or low, available phosphorus is very low, and available potassium is low or medium.

Most areas of Salida soils are in permanent pasture, but a few are cultivated. Salida soils are subject to erosion and are droughty. The gravelly surface layer hinders cultivation.

Representative profile of Salida gravelly loam, 14 to 25 percent slopes, moderately eroded, on a south-facing slope 130 feet east and 275 feet north of the southwest corner of SW$\frac{1}{4}$NW$\frac{1}{4}$ sec. 5, T. 85 N., R. 37 W.

A11—0 to 8 inches, very dark grayish-brown (10YR 3/2) gravelly loam; weak, medium, subangular blocky structure breaking to fine, granular; very friable; slightly acid; clear, wavy boundary.

A12—8 to 16 inches, very dark grayish-brown (10YR 3/2) gravelly sand; single grain; loose; pebbles as much as 3 inches in diameter; roots concentrated in this horizon; neutral; clear, wavy boundary.

C1—16 to 25 inches, dark yellowish-brown (10YR 4/4) gravelly sand; single grain; loose; less gravel than in A12 horizon; moderately alkaline; calcareous; diffuse boundary.

C2—25 to 50 inches, very pale brown (10YR 7/4) gravelly sand; single grain; loose; some cobblestones as much as 7 inches in diameter; moderately alkaline; calcareous.

The surface layer ranges from 7 to 18 inches in thickness and from very dark brown to very dark grayish brown and dark brown in color. It is gravelly loam or gravelly sandy loam. In places a thin subsoil of leached gravelly loamy sand or gravelly sand is present. In other places the surface layer is directly underlain by the substratum.

The substratum is moderately alkaline and calcareous and ranges from dark brown to very pale brown. It is generally gravelly sand, but the proportion and size of the particles are variable. The gravel is mostly fine or medium in size, but in some areas cobblestones are 5 inches or more in diameter.

Salida soils range from slightly acid to moderately alkaline in the surface layer.

Salida soils differ from Sparta and Chute soils in having more gravel-size material in the profile, and they are calcareous nearer the surface than Sparta soils. All the soils formed in coarse-textured materials.

**Salida gravelly loam, 9 to 14 percent slopes, moderately eroded** (SaD2).—This soil has a profile similar to that described as representative for the series, except that in many places the surface layer is thinner. It is on the noses of narrow ridges and on narrow ridgetops. Included in mapping was about 90 acres of moderately eroded and severely eroded Salida soils that have slopes of 5 to 9 percent. Also included were some areas that are severely eroded and have a surface layer less than 3 inches thick. The severely eroded areas are shown on the soil map by a symbol. Sand and gravel have been removed from some areas, but the quality is variable. Most areas of this soil are small.

Many areas of this soil are presently in permanent pasture. Some areas are cultivated. The gravelly surface layer makes tillage difficult. This soil is better suited to hay or pasture than to crops. If rainfall is not properly distributed, crops are damaged by drought because of the low water-holding capacity. (Capability unit IVs-1)

**Salida gravelly loam, 14 to 25 percent slopes, moderately eroded** (SaF2).—This soil has the profile described as representative for the series; in many places, however, the surface layer is thinner. This soil is on convex side slopes and knobs along the Boyer River and near the mouths of larger creeks that flow into the Boyer River. Included in mapping was about 40 acres of Salida soils on 25 to 35 percent slopes and some areas that are severely eroded and have a very thin surface layer. The severely eroded areas are shown on the soil map by a symbol. Sand and gravel have been removed from many areas, but the quality is variable. Most areas of this soil are small.

This soil is not suited to cultivation because of the gravelly surface layer and rough, moderately steep and steep slopes. It is generally in permanent pasture. Enough tillage for pasture renovation is possible in some areas. Vegetation is generally sparse because of the low water-holding capacity, depending on rainfall distribution. (Capability unit VIIs-1)

## Shelby Series

The Shelby series consists of moderately well drained soils that formed under prairie vegetation in glacial till.

Shelby soils are on convex side slopes adjacent to drainageways and major stream valleys. Most areas are on uplands along the Boyer River and its tributaries. Spots of Shelby soils are exposed on noses of loess-mantled ridges, at shoulders of slopes, and in other eroded areas. Slopes range from 5 to 35 percent.

In a representative profile, the surface layer is very dark brown loam about 7 inches thick. The subsoil is yellowish-brown, friable or firm clay loam to a depth of about 34 inches. The substratum is yellowish-brown, calcareous, firm clay that has mottles of grayish brown and brown.

Shelby soils have high available water capacity and are moderately slowly permeable. They are typically neutral or slightly acid in the surface layer and slightly acid in the subsoil. Their organic-matter content is low. Available nitrogen is low, available phosphorus is very low or low, and available potassium is low or medium.

Many areas of the moderately sloping to moderately steep Shelby soils are cultivated, but some areas are in permanent pasture. Steep areas are in permanent pasture. Shelby soils are susceptible to sheet and gully erosion.

Representative profile of Shelby loam, 14 to 18 percent slopes, moderately eroded, in a northeast-facing area, 840 feet west and 60 feet north of the southeast corner of NW¼NE¼ sec. 35, T. 83 N., R. 39 W.

A1—0 to 7 inches, very dark brown (10YR 2/2) loam; weak to moderate, medium, subangular blocky structure breaking to fine, subangular blocky and granular; many fine roots; friable; neutral; clear, smooth boundary.

B1—7 to 13 inches, 60 percent yellowish-brown (10YR 5/4) and 40 percent dark yellowish-brown (10YR 4/4) clay loam; weak to moderate, fine and medium, subangular blocky structure breaking to fine, subangular blocky; friable; slightly acid; gradual, smooth boundary.

B2t—13 to 19 inches, yellowish-brown (10YR 5/4) clay loam; weak, medium, subangular blocky structure breaking to fine, subangular blocky; friable; dark yellowish-brown (10YR 4/4) faces on peds; few, thin, discontinuous clay films; slightly acid; gradual, smooth boundary.

B3—19 to 34 inches, yellowish-brown (10YR 5/4) clay loam; weak, medium, subangular blocky structure; firm; slightly acid; clear, smooth boundary.

C1—34 to 60 inches, yellowish-brown (10YR 5/4) clay loam; common, medium, distinct mottles of grayish brown (2.5YR 5/2) and brown (7.5YR 4/4); massive; firm; calcareous; many, soft, white, calcium carbonate accumulations; a zone of calcium carbonate accumulation between 40 and 42 inches; mildly alkaline.

The surface layer ranges from very dark brown to very dark grayish brown or very dark gray in color, except in severely eroded areas. Its thickness ranges from 3 inches or less in severely eroded areas to about 12 inches. Its texture is dominantly loam, but it is clay loam in the severely eroded areas.

The subsoil is 20 to 40 inches thick in most places. It grades from dark brown or dark yellowish brown in the upper part to dark yellowish brown or yellowish brown in the rest. Mottles, dominantly strong brown, olive gray, and grayish brown, are present in many places.

The substratum typically has matrix colors of dark yellowish brown, yellowish brown, or light olive brown. Mottles increase in size and number in the substratum, especially those of a grayish color.

Shelby soils are typically calcareous at depths between 30 and 60 inches. They range from neutral to medium acid in the surface layer and are slightly acid or medium acid in the subsoil.

Severely eroded Shelby soils have a surface layer that is thinner and lighter colored than is defined as the range for the series. These differences do not significantly alter their usefulness or behavior.

Shelby soils have less clay, lack reddish colors in the subsoil, and do not have so firm a subsoil as Adair soils. They are not calcareous at or near the surface, as are Steinauer soils. Shelby, Adair, and Steinauer soils formed in glacial till.

**Shelby loam, 5 to 9 percent slopes, moderately eroded** (ShC2).—In most places this soil has a very dark brown or very dark grayish-brown plow layer. In some places it is leached more deeply than the soil that has the profile described as representative for the series. Included in mapping were some severely eroded areas where the surface layer is very thin, and the yellowish-brown or dark yellowish-brown subsoil is exposed in places. This soil is on eroded noses of narrow ridges, at shoulders of slopes, and in other moderately sloping areas. It is generally downslope from Monona or Marshall soils. It is upslope from soils of the drainageways and bottom lands. Most areas of this soil are small.

This soil is generally cultivated and is managed with the surrounding soils. It is susceptible to sheet and gully erosion, but it is suited to row crops if erosion is controlled. Tilth is generally fair or poor, and the surface layer tends to crust and dry out cloddy and hard after rain. (Capability unit IIIe-5)

**Shelby loam, 9 to 14 percent slopes, moderately eroded** (ShD2).—In most places this soil has a very dark grayish-brown plow layer. In places it is leached more deeply than the soil that has the profile described as representative of the series. Included in mapping were some areas that have a black to very dark grayish-brown surface layer about 7 to 10 inches thick. This soil is on noses of narrow ridges, on shoulders of slopes, and on side slopes. It is mainly downslope from Monona or Marshall soils, but on the side slopes, in places, it is downslope from Adair soils. It is upslope from soils of the drainageways or bottom lands.

Many areas are cultivated, but some are in permanent pasture. This soil is susceptible to sheet and gully erosion, but it is suited to row crops if erosion is controlled. It is also well suited to hay and pasture. Tilth is generally fair or poor, and the soil tends to crust and dry out hard and cloddy after rain. (Capability unit IIIe-5)

**Shelby loam, 14 to 18 percent slopes, moderately eroded** (ShE2).—This soil has the profile described as representative for the series. Included in mapping were a few areas that have a very dark brown or very dark grayish-brown surface layer about 7 to 10 inches thick. This soil is on eroded shoulders of slopes and on side slopes. It is generally downslope from Monona or Marshall soils, but in places is downslope from Adair soils. It is upslope from soils of the drainageways or bottom lands.

Some areas are cultivated, but most are in hay or permanent pasture. The soil is susceptible to sheet and gully erosion. It is better suited to hay and pasture than to row crops. Farm machinery can be operated in most areas to renovate permanent pasture. A crop of corn is sometimes grown when stands of hay need to be plowed and reseeded or when pastures need renovating. The organic-matter content is typically low, and tilth is fair or poor. (Capability unit IVe-3)

**Shelby loam, 18 to 25 percent slopes, moderately eroded** (ShF2).—This soil has a dark-brown or very dark grayish-brown surface layer that, in most places, is 3 to 7 inches thick. In most places it is not leached so deeply as Shelby soils on lesser slopes, and in many places the calcareous substratum is at a depth of about 30 inches. It is on side slopes, mainly adjacent to the Boyer River and its tributaries. It is generally downslope from Marshall or Monona soils and is upslope from soils of the drainageways or bottom lands. Included in mapping was about 45 acres of soils that have a grayish-brown subsurface layer and a somewhat more clayey subsoil.

This soil is too steep and too eroded to be cultivated. In most places it is better suited to permanent pasture than to other uses. Most areas are presently used for permanent pasture. In areas that are not too gullied or steep, farm machinery can be used to renovate and reseed pastures. (Capability unit VIe-2)

**Shelby cobbly loam, 14 to 35 percent slopes** (SIF).—This soil has a surface layer of very dark grayish-brown cobbly loam that is less than 3 inches thick in most places. The subsoil is brown to yellowish-brown gravelly to cobbly clay loam that is mixed into the surface layer or is exposed in places. The substratum is yellowish-brown to brownish-yellow gravelly clay loam or clay loam. This soil formed in glacial till that has a high content of medium to coarse gravel and small cobblestones. The gravel and cobblestones are concentrated on the surface and decrease with depth.

This soil consists primarily of eroded, convex areas along the Boyer River and near the mouths of the major creeks that flow into the river. It is associated with Marshall, Monona, Salida, and Shelby soils. It contains much more gravel and cobblestones than other Shelby soils (fig. 10). It has a clay loam matrix, which is lacking in the Salida soils. Included in mapping were a few areas where the slope is 9 to 14 percent.

This soil is not suited to cultivation. It is primarily in permanent pasture. Pasture renovation is possible in

*Figure 10.*—**Area of Shelby cobbly loam in permanent pasture. In the field lane (foreground) are many cobblestones and pebbles.**

some areas, but tillage is difficult because of the cobblestones on the surface. Some areas of this soil can be used as wildlife habitat. (Capability unit VIIe-1)

**Shelby soils, 9 to 14 percent slopes, severely eroded** (SoD3).—These soils typically have a dark-brown or brown, clay loam or loam plow layer. The yellowish-brown subsoil is exposed in many places. The soils are on severely eroded noses of narrow ridges, on the shoulders of slopes, and on side slopes. They are generally downslope from Monona or Marshall soils. They are upslope from soils of the drainageways and bottom lands. Most areas are small.

These soils are generally cultivated and are managed with associated soils that are better suited to cultivation. They are susceptible to sheet and gully erosion, but they are suited to row crops if erosion is controlled. They are better suited to hay or pasture than to row crops. Tilth is poor, and the soils are difficult to till because most of the friable topsoil is gone. These soils crust, and this hinders seedling emergence. (Capability unit IVe-3)

**Shelby soils, 14 to 18 percent slopes, severely eroded** (SoE3).—These soils typically have a dark-brown or brown surface layer 3 inches or less in thickness. The subsoil is yellowish-brown clay loam or loam; it is exposed in places. These soils are on eroded shoulders of slopes and on side slopes. They are generally downslope from Monona or Marshall soils. They are upslope from soils of the drainageways and bottom lands.

These soils are moderately steep and are too eroded for cultivation. Many areas, however, have been cultivated in the past. The soils are suited to hay and pasture, and most areas are now in pasture. The carrying capacity of many existing permanent pastures can be increased by renovation and planting suitable grasses and legumes. Farm machinery can be used in most places, except where the areas are extremely rough or gullied. Tilth and physical characteristics are poor. (Capability unit VIe–2)

**Shelby soils, 18 to 25 percent slopes, severely eroded** (SoF3).—These soils typically have a surface layer of dark-brown or brown clay loam or loam less than 3 inches thick. The yellowish-brown subsoil is exposed in many places. These soils are not generally leached so deeply as Shelby soils on lesser slopes. In many places the calcareous substratum is at a depth of about 30 inches. The soils are on side slopes, mainly along the Boyer River and its tributaries. Included in mapping was about 20 acres of soils that are calcareous at or near the surface and about 20 acres of soils that have a grayish subsurface layer and a more clayey subsoil. Also included was about 40 acres of Adair soils. These areas are shown on the soil map by a symbol. Most areas of these soils are small.

These soils are not suited to cultivation because they are steep and severely eroded. Most areas are in permanent pasture. In areas where farm machinery can be operated, the carrying capacity of many pastures is increased by renovation and the seeding of suitable grasses and legumes. Some areas of these soils are suitable for wildlife habitat. (Capability unit VIe-2)

**Shelby soils, 25 to 35 percent slopes, severely eroded** (SoG3).—These soils typically have a surface layer of dark-brown or brown clay loam or loam about 3 inches thick. The yellowish-brown subsoil is exposed in many places. These soils are not generally leached so deeply as other Shelby soils. They are calcareous in many places at a depth of about 30 inches. Included in mapping were some areas that have a surface layer that is very dark brown or very dark grayish brown and 3 to 10 inches thick. These steep soils are on side slopes, mainly along the Boyer River. Most areas are small.

These soils are not suited to cultivation, because they are steep and severely eroded. They are suited to permanent pasture and to wildlife habitat. Most areas are in permanent pasture. The slope makes renovation of these pastures difficult. (Capability unit VIIe-1)

## Sparta Series

The Sparta series consists of excessively drained soils that formed under prairie vegetation in loose, wind-deposited fine sands.

Sparta soils are on crests of ridges and convex side slopes. They are on uplands, mainly near the Boyer River or near the mouths of its major tributaries. In places they are in very small areas surrounded by other soils. Slopes are 5 to 20 percent.

In a representative profile, the surface layer is very dark grayish-brown fine sandy loam about 6 inches thick. The upper part of the subsoil is dark-brown and yellowish-brown, very friable to loose loamy fine sand to a depth of about 14 inches. The lower part, to a depth of about 27 inches, is light yellowish-brown to brownish-yellow, loose fine sand. Below this, the substratum is very pale brown to yellow, loose sand.

Sparta soils have very low available water capacity and are rapidly or very rapidly permeable. They are medium acid in the surface layer and upper part of the subsoil. Their organic-matter content is low. Available nitrogen and phosphorus are very low, and available potassium is low.

Most areas of Sparta soils are used for hay or pasture. They are very droughty and are susceptible to water erosion and to soil blowing.

Representative profile of Sparta fine sandy loam, 9 to 14 percent slopes, moderately eroded, in a northwest-facing area, 500 feet south and 250 feet west of the northeast corner of the SW¼SW¼ sec. 15, T. 83 N., R. 39 W.

Ap—0 to 6 inches, very dark grayish-brown (10YR 3/2) fine sandy loam; weak, fine to medium, subangular blocky structure breaking to fine, granular; friable; many fine roots; medium acid; clear, smooth boundary.

B2—6 to 14 inches, 60 percent dark-brown (10YR 3/3) and 40 percent yellowish-brown (10YR 5/4) loamy fine sand; very weak, subangular blocky structure to single grain; very friable to loose; many fine roots; medium acid; clear, smooth boundary.

B3—14 to 27 inches, light yellowish-brown (10YR 6/4) to brownish-yellow (10YR 6/6) fine sand; single grain; loose; few roots; neutral; diffuse, smooth boundary.

C1—27 to 48 inches, very pale brown (10YR 7/4) to yellow (10YR 7/6) fine sand; single grain; loose; moderately alkaline; weakly calcareous; diffuse, smooth boundary.

C2—48 to 70 inches, yellow (10YR 8/6) fine and medium sand; single grain; loose; moderately alkaline; weakly calcareous.

The surface layer ranges from fine sandy loam to loamy fine sand and from 2 to 10 inches in thickness. It is typically very dark brown, very dark gray, very dark grayish brown, or dark brown.

The subsoil ranges from 18 to about 40 inches in thickness and from fine sandy loam to loamy fine sand and fine sand. The fine sandy loam does not extend to a depth greater than 18 inches. It ranges from dark brown to brownish yellow.

The yellowish-brown to very pale brown or yellow substratum is typically fine sand or loamy fine sand.

Sparta soils range from slightly acid to medium acid in the surface layer and from neutral to medium acid in the subsoil. The substratum ranges from slightly acid to moderately alkaline. The depth to calcareous material ranges from about 24 inches to 40 inches or more.

Sparta soils have a thinner surface layer and are not so acid in the subsoil and substratum as the defined range for the series. These differences do not significantly alter their usefulness or behavior.

Sparta soils are not calcareous at or near the surface, as are Chute soils. These soils formed in similar materials.

**Sparta fine sandy loam, 5 to 9 percent slopes, moderately eroded** (SpC2).—This soil is on crests of ridges and convex side slopes. It is generally surrounded by Marshall and Monona soils. Included in mapping were some areas where the surface layer is as much as 10 inches thick. Also included were some severely eroded areas where the surface or plow layer is mostly subsoil material and is dark brown to dark yellowish brown. In some places the surface layer is loamy fine sand. In many places, this soil is leached to a depth of 40 inches or more. Most areas of this soil are small.

Most of this soil is cultivated. It is better suited to hay or pasture than to row crops, but small areas are generally managed with surrounding soils. It is droughty and susceptible to water erosion and soil blowing. (Capability unit IVs-1)

**Sparta fine sandy loam, 9 to 14 percent slopes, moderately eroded** (SpD2).—This soil has the profile described as representative for the series. Included in mapping were some severely eroded areas where the surface layer is very thin or where the plow layer is mostly subsoil material and is dark brown to dark yellowish brown. In some places the surface layer is loamy fine sand. In many places this soil is leached to a depth of 40 inches or more. This soil is generally on side slopes. In places it is upslope from and adjacent to Shelby or Napier soils. Most areas are small and are surrounded by Marshall or Monona soils.

This soil is not suited to row crops, but small areas in cultivated fields are managed with the surrounding soils. The larger areas are generally used for hay or pasture. It is droughty and is susceptible to erosion and soil blowing. (Capability unit VIs-1)

**Sparta fine sandy loam, 14 to 20 percent slopes, moderately eroded** (SpE2).—This soil is generally on side slopes. It has a profile similar to that described as representative for the series. In severely eroded areas, however, the surface layer is thinner and brown, and the yellowish-brown subsoil is exposed on the surface in many places. These places are shown on the soil map by a symbol. In many places this soil is leached to a depth of 40 inches or more. Included in mapping were a very few areas where the slope is as much as 40 percent. Most areas of this soil are small and are surrounded by Marshall or Monona soils.

This soil is generally used for hay and pasture. It is not suited to row crops. It is droughty and susceptible to severe sheet and gully erosion and to soil blowing. (Capability unit VIIs-1)

## Steinauer Series

The Steinauer series consists of well-drained soils that formed under prairie vegetation in calcareous glacial till.

Steinauer soils are on convex slopes, dominantly on uplands along the major stream valley. Slopes range from 9 to 18 percent.

In a representative profile, the surface layer is very dark grayish-brown clay loam about 7 inches thick. Below this is yellowish-brown to brownish-yellow, firm clay loam that contains mottles of strong brown, yellowish brown, light gray, and light brownish gray.

Steinauer soils have high available water capacity and are moderately slowly permeable. They are moderately alkaline and calcareous throughout. Their organic-matter content is low. Available nitrogen and phosphorus are very low, and available potassium is medium.

Steinauer soils are mainly in permanent pasture, but some strongly sloping areas are cultivated along with surrounding soils. Runoff is rapid, especially on steeper slopes, and the soils are susceptible to sheet and gully erosion.

Representative profile of Steinauer clay loam, 9 to 14 percent slopes, severely eroded, in a west-facing area, 619 feet north and 508 feet west of the southeast corner of the SW¼SE¼ sec. 16, T. 84 N., R. 39 W.

Ap—0 to 7 inches, very dark grayish-brown (10YR 3/2) light clay loam; moderate, medium, subangular blocky structure breaking to fine, subangular blocky; firm; many fine and medium roots; many worm casts; moderately alkaline; strongly calcareous; clear, smooth boundary.

C1—7 to 16 inches, 70 percent yellowish-brown (10YR 5/4) and 30 percent very dark grayish-brown (10YR 3/2) clay loam; weak, medium, subangular blocky structure; firm; many medium and fine roots; many worm casts; few, medium, calcareous nodules; moderately alkaline; strongly calcareous; diffuse, smooth boundary.

C2—16 to 29 inches, light yellowish-brown (10YR 6/4) to brownish-yellow (10YR 6/6) clay loam; many, coarse to fine, distinct mottles of light gray (N 6/0) to light brownish gray (2.5Y 6/2) and few, fine, faint mottles of yellowish brown (10YR 5/8); weak, medium, subangular blocky structure breaking to fine, subangular blocky; firm; few fine to medium roots; few worm casts; many lime concretions; moderately alkaline; strongly calcareous; diffuse, smooth boundary.

C3—29 to 70 inches, light yellowish-brown (10YR 6/4) heavy clay loam, yellowish brown (10YR 5/8) when crushed; many, coarse to fine, distinct mottles of light gray (N 6/0) to light brownish gray (2.5Y 6/2) and few, fine, faint mottles of yellowish brown (10YR 5/8); weak, medium, subangular blocky structure breaking to fine, subangular blocky; firm; many lime concretions; moderately alkaline; strongly calcareous.

The surface layer ranges from very dark grayish brown to dark yellowish brown and is as much as 8 inches in thickness. The surface layer is typically a mixture of the original surface layer and the subsoil. The substratum ranges from dark yellowish brown to light brownish yellow and contains mottles that range from strong brown, yellowish brown, or dark brown to olive gray.

Steinauer soils are typically calcareous at or near the surface and are moderately alkaline, but the range includes those soils that are neutral in the surface layer.

Steinauer and Shelby soils formed in similar parent material. Steinauer and Salida soils are similar in that they are calcareous at or near the surface. Steinauer soils are calcareous at or near the surface, but Shelby soils are typically leached to a depth of 30 inches or more. Steinauer soils are less sandy and gravelly than Salida soils.

**Steinauer clay loam, 9 to 14 percent slopes, severely eroded** (SrD3).—This soil has the profile described as representative for the series. In many areas, however, the surface layer is lighter colored or thinner. It is on convex side slopes. Most areas of this soil are very small.

This soil is poorly suited to cultivation because of the thin, rocky surface layer and the hazard of erosion. It is generally not cultivated, but small areas are sometimes managed along with the surrounding soils. It is better suited to small grain, hay, or pasture than to row crops. The organic-matter content is low, and tilth is poor. (Capability unit IVe-3)

**Steinauer clay loam, 14 to 18 percent slopes, severely eroded** (SrE3).—This soil has a profile similar to that described as representative for the series, except that in most places the surface layer is lighter colored or thinner. It is on convex side slopes, mostly along the Boyer River and its tributaries. This soil occupies only a small acreage.

This soil is not suited to cultivation because of the slope, the extent of erosion and the severe hazard of further erosion, and the high content of lime. Most areas are in permanent pasture. Renovating pasture and seeding to suitable grasses and legumes improves the carrying capacity of many pastures. Farm machinery can be used in most areas, but some areas are so rough and gullied that operating machinery is very hazardous. (Capability unit VIe-2)

## Zook Series

The Zook series consists of poorly drained soils that formed under water-tolerant prairie grasses in fine-textured, silty alluvium.

Zook soils are nearly level. They are mainly along streams in the eastern part of the county, generally on broad flood plains at a slightly lower elevation and some distance from the stream channel.

In a representative profile, the surface layer is black and is about 27 inches thick. The upper 12 inches is silty clay loam and the lower 15 inches is silty clay. The subsoil extends to a depth of about 50 inches. It is very dark gray, firm silty clay to a depth of about 40 inches and is dark gray below. The substratum is dark-gray, firm silty clay and has a few yellowish and light-gray mottles.

These soils have high available water capacity and are slowly permeable. They are typically slightly acid throughout. Their organic-matter content is high. Surface drainage is generally poor, and the soils pond in places. Available nitrogen is low or medium, available phosphorus is low or very low, and available potassium is low or medium.

Zook soils are mainly cultivated, but some areas are in permanent pasture. They are wet, some areas tend to pond, and most areas are subject to flooding.

Representative profile of Zook silty clay loam, on a flood plain, 80 feet west and 1,200 feet north of the southeast corner of NE¼ sec. 21, T. 82 N., R. 37 W.

A11—0 to 7 inches, black (10YR 2/1) silty clay loam; moderate, medium, subangular blocky structure breaking to fine, subangular blocky and granular; friable; abundant fine and medium roots; abundant wormholes and worm casts; slightly acid; abrupt, smooth boundary.

A12—7 to 12 inches, black (N 2/0) heavy silty clay loam; black (10YR 2/1) when crushed; strong, medium to fine, subangular blocky structure breaking to very fine, subangular blocky and fine, crumb structure; firm; abundant fine roots and worm casts; slightly acid; clear, smooth boundary.

A3—12 to 27 inches, black (N 2/0) silty clay, black (10YR 2/1) when crushed; moderate, medium to fine, subangular blocky structure breaking to very fine, subangular blocky and fine, granular; firm; many fine roots and worm casts; shiny coats on peds; slightly acid; gradual, smooth boundary.

B2g—27 to 40 inches, very dark gray (10YR 3/1) silty clay; strong, medium, prismatic structure breaking to fine, prismatic and fine, angular blocky; firm; shiny coats on peds; slightly acid; gradual, smooth boundary.

B3g—40 to 50 inches, dark-gray (10YR 4/1) silty clay; strong, coarse, prismatic structure breaking to fine, prismatic and fine, angular blocky; firm; water table begins in this horizon; slightly acid; diffuse, smooth boundary.

Cg—50 to 76 inches, dark-gray (10YR 4/1) silty clay; few faint mottles of yellow and light gray; massive; firm; slightly acid.

The surface layer ranges from 24 to 36 inches in thickness and is black or very dark gray. Zook soils that have recent overwash, however, have 6 to 15 inches of very dark grayish-brown or dark grayish-grown silt loam covering the surface. The surface layer is silty clay loam to a depth of as much as 18 inches in places.

The rest of the profile is typically silty clay, but it is very heavy silty clay loam in places. The subsoil is black or very dark gray to a depth of 36 inches or more and typically grades to dark gray as depth increases. Where mottles occur, they are typically at a depth below 3 feet. The structure is moderate or strong, and the consistence is firm or very firm below the plow layer. Zook soils are neutral to medium acid in the surface layer.

Zook soils are finer textured than Colo soils at a depth below about 12 inches. They are finer textured and darker colored than Kennebec, Nodaway, or Judson soils. They are not stratified, as are Nodaway soils. All of these soils formed in alluvium.

**Zook silt loam, overwash** (0 to 2 percent slopes) (Zo).—This soil is similar to Zook silty clay loam, but the dark-colored surface layer is covered with 6 to 15 inches of recent alluvium that is very dark grayish-brown, stratified silt loam. It is generally in areas where the upland has more relief and there is more erosion than in other areas. Areas of this soil are small and are generally adjacent to areas of Nodaway, Colo, or Judson soils.

This soil is generally cultivated. It is well suited to row crops, but it is wet, subject to flooding, and receives runoff, which deposits overwash. Some of the most frequently flooded areas are used for pasture. Tilth is generally good. (Capability unit IIw-1)

**Zook silty clay loam** (0 to 2 percent slopes) (Zs).—This soil has the profile described as representative for the series. About one-third of the acreage is silty clay throughout. In most places this soil is adjacent to Judson or Colo soils.

This soil is well suited to row crops, but it is wet and some areas tend to pond after rain. At times the soil is flooded by stream overflow. This soil tends to dry out cloddy and hard if plowed when wet. Most tillage is done in the fall so that freezing and thawing can improve tilth, and so that tillage can be delayed in spring until moisture conditions are more favorable. (Capability unit IIw-1)

# *Use and Management of the Soils*

This section discusses the use of the soils for crops and pasture. It describes the system of capability classification used by the Soil Conservation Service and discusses the management of soils by capability units. Predicted yields for major crops are given, and the use of the soils for wildlife, recreation, and engineering are discussed.

## Use of the Soils for Crops and Pasture

In Crawford County about 275,000 acres, or about 60 percent of the county, is used for crops. About 109,000 acres, or about 21 percent of the county, is used for pasture.

Corn, soybeans, and legumes and legume-grass hay are the main crops, but oats, sorghums, and popcorn are also grown.

Most pastures are in permanent bluegrass. Some have been renovated, and such plants as birdsfoot trefoil have been introduced. Other pasture plants are bromegrass, orchardgrass, and grass-legume mixtures, such as alfalfa-bromegrass.

Many soils in the county, including Dow, Ida, Marshall, Monona, and Shelby soils, are subject to sheet erosion and gullying. Regular, level terraces; grassed backslope terraces; and, in places, diversion terraces are used for erosion control. Contour tillage is also a common erosion control practice.

Gully control structures, farm ponds, and grassed waterways are used to control gullying in drainageways. The farm ponds furnish water for recreation and livestock.

Drain tiles are used to reduce wetness in such soils as Colo and Zook soils or areas of the Judson-Colo-Nodaway complex. In some places levees have been constructed to protect soils of the bottom lands from flooding, and in many places in the county, streams have been straightened to reduce the hazard of flooding.

### *Capability grouping*

Capability grouping shows, in a general way, the suitability of soils for most kinds of field crops. The groups are made according to the limitations of the soils when used for field crops, the risk of damage when they are used, and the way they respond to treatment. The grouping does not take into account major and generally expensive landforming that would change slope, depth, or other characteristics of the soils; does not take into consideration possible but unlikely major reclamation projects; and does not apply to rice, cranberries, horticultural crops, or other crops requiring special management.

Those familiar with the capability classification can infer from it much about the behavior of soils when used for other purposes, but this classification is not a substitute for interpretations designed to show suitability and limitations of groups of soils for range, for woodland, or for engineering.

In the capability system, all kinds of soils are grouped at three levels: the capability class, subclass, and unit. These are discussed in the following paragraphs.

Capability Classes, the broadest groups, are designated by Roman numerals I through VIII. The numerals indicate progressively greater limitations and narrower choices for practical use, defined as follows:

Class I soils have few limitations that restrict their use.

Class II soils have moderate limitations that reduce the choice of plants or that require moderate conservation practices.

Class III soils have severe limitations that reduce the choice of plants, require special conservation practices, or both.

Class IV soils have very severe limitations that reduce the choice of plants, require very careful management, or both.

Class V soils are not likely to erode but have other limitations, impractical to remove, that limit their use largely to pasture, range, woodland, or wildlife. (None in this county)

Class VI soils have severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range, woodland, or wildlife.

Class VII soils have very severe limitations that make them unsuited to cultivation and that restrict their use largely to pasture or range, woodland, or wildlife.

Class VIII soils and landforms have limitations that preclude their use for commercial plants and restrict their use to recreation, wildlife, or water supply, or to esthetic purposes. (None in this county)

Capability Subclasses are soil groups within one class; they are designated by adding a small letter, *e*, *w*, *s*, or *c*, to the class numeral, for example, IIe. The letter *e* shows that the main limitation is risk of erosion unless close-growing cover is maintained; *w* shows that water in or on the soil interferes with plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); *s* shows that the soil is limited mainly because it is shallow, droughty, or stony; and *c*, used in only some parts of the United States, shows that the chief limitation is climate that is too cold or too dry.

In class I there are no subclasses, because the soils of this class have few limitations. Class V can contain, at the most, only the subclasses indicated by *w*, *s*, and *c*, because the soils in class V are subject to little or no erosion though they have other limitations that restrict their use largely to pasture, range, woodland, wildlife, or recreation.

Capability Units are soil groups within the subclasses. The soils in one capability unit are enough alike to be suited to the same crops and pasture plants, to require similar management, and to have similar productivity and other responses to management. Thus, the capability unit is a convenient grouping for making many statements about management of soils. Capability units are generally designated by adding an Arabic numeral to the subclass symbol, for example, IIe-2 or IIIe-6. Thus, in one symbol, the Roman numeral designates the capability class, or degree of limitation; the small letter indicates the subclass, or kind of limitation, as defined in the foregoing paragraph; and the Arabic numeral specifically identifies the capability unit within each subclass.

### *Management by capability units*

In the following pages each of the capability units in Crawford County is described, and suggestions for use and management of the soils are briefly discussed. The names of soil series represented are mentioned in the description of each capability unit, but this does not mean that all soils of a given series are in the unit. The capability classification is given in the "Guide to Mapping Units."

#### CAPABILITY UNIT I-1

This unit consists of well-drained, nearly level soils of the Marshall and Monona series. Most areas of the Monona soil are on high benches, but some are on uplands on broad divides. Most areas of the Marshall soil are on upland divides, and only a few acres are on benches.

All of these soils have a surface layer of friable silty clay loam or silt loam. The subsoil is friable silt loam or silty clay loam.

The soils of this capability unit have high available water capacity and moderate permeability. They are typically low or medium in available nitrogen and available phosphorus, and medium or high in available potassium. The organic-matter content is generally about medium.

Tilth is good, and these soils are well aerated. Erosion is ordinarily not a hazard on these soils, because the soils are nearly level and good permeability retards runoff. If used intensively for row crops, the most sloping areas are subject to some erosion in places. Wetness is not a hazard.

Most areas of these soils are cultivated. Corn and soybeans are the major crops, but oats, alfalfa, and other hay crops are also grown. The soils can be used for row crops often.

These soils are well suited to intensive farming. High plant populations, high rates of fertilization, and chemical control of weeds and insects are likely to result in favorable returns.

Crops respond well to fertilizer. Nitrogen and phosphorus are likely to be lacking. Small amounts of potassium in starter fertilizer are beneficial to corn. These soils are typically slightly acid in the surface layer, and some areas need lime, especially if legumes are grown.

#### CAPABILITY UNIT I-2

This unit consists of moderately well drained and well drained soils of the Judson, Kennebec, and Nodaway series. These soils are on low foot slopes or alluvial fans and bottom lands. Some individual areas of these soils on flood plains of major streams are large, but generally the areas in the upland valleys and on foot slopes are long and narrow.

Most of these soils have a thick surface layer of friable silt loam or silty clay loam, but the Nodaway soil has a thin surface layer that has been darkened by organic matter. The soils are silt loam to silty clay loam below the surface layer.

The soils of this capability unit have very high or high available water capacity. They are typically medium or low in available nitrogen and available phosphorus and medium in available potassium. Organic-matter content is high in the Judson and Kennebec soils, but it is low in the Nodaway soil.

Tilth is good, and these soils are well aerated. Erosion is not a hazard on these soils. The soils are subject to flooding, but the flooding generally occurs before crops are planted or is of short duration. Tillage is delayed at times or some crop damage occurs in places, but in most years crops can be grown and damage is only slight. The Judson soil is on foot slopes, and in places terraces or diversions are needed to protect the soil from runoff. Straightening of major streams and construction of dikes reduce the hazard of flooding. Wetness is generally not a hazard, because these soils slope enough to prevent ponding and are permeable enough to readily absorb any water that does not run off. These soils remain wet slightly longer than associated upland soils, but not as long as more poorly drained soils of the bottom lands.

Most areas of these soils are cultivated. Corn and soybeans are the major crops, but oats, alfalfa, and other hay crops are also grown. The soils are suited to row crops most of the time. Areas adjacent to the stream are generally maintained in pasture, especially if the stream is meandering.

These soils are especially suited to intensive management. They generally have water available for plants throughout the season, and high plant populations, high rates of fertilization, and chemical control of weeds and insects are likely to result in favorable returns.

Crops respond well to fertilizer. Nitrogen and phosphorus are likely to be lacking. Some potassium is often beneficial. These soils are neutral to medium acid, and some areas need lime.

#### CAPABILITY UNIT IIe-1

This unit consists of well-drained soils of the Marshall and Monona series. These soils are mainly on ridgetops and side slopes, but some of the Marshall soils are on benches. Some of the soils are moderately eroded. Slopes are 2 to 5 percent.

These soils have a surface layer and subsoil of friable silt loam or silty clay loam.

The soils of this capability unit have high available water capacity and moderate permeability. They are typically low or medium in available nitrogen and available phosphorus and medium or high in available potassium. Organic-matter content is generally about medium, but it is lower in the moderately eroded soils.

Tilth is fair or good, and these soils are well aerated. Soils in this unit are subject to erosion.

Most areas of these soils are cultivated. Corn and soybeans are the major crops, but oats, alfalfa, and other hay crops are also grown. The soils are suited to row crops most of the time if erosion is controlled and management is good. Contour tillage and terraces are the practices most used to control erosion (fig. 11).

Crops respond well to fertilizer. Nitrogen and phosphorus are likely to be lacking. Small amounts of potassium in starter fertilizer are generally beneficial to corn. These soils are typically slightly acid in the surace layer, and some areas need lime, especially if legumes are grown.

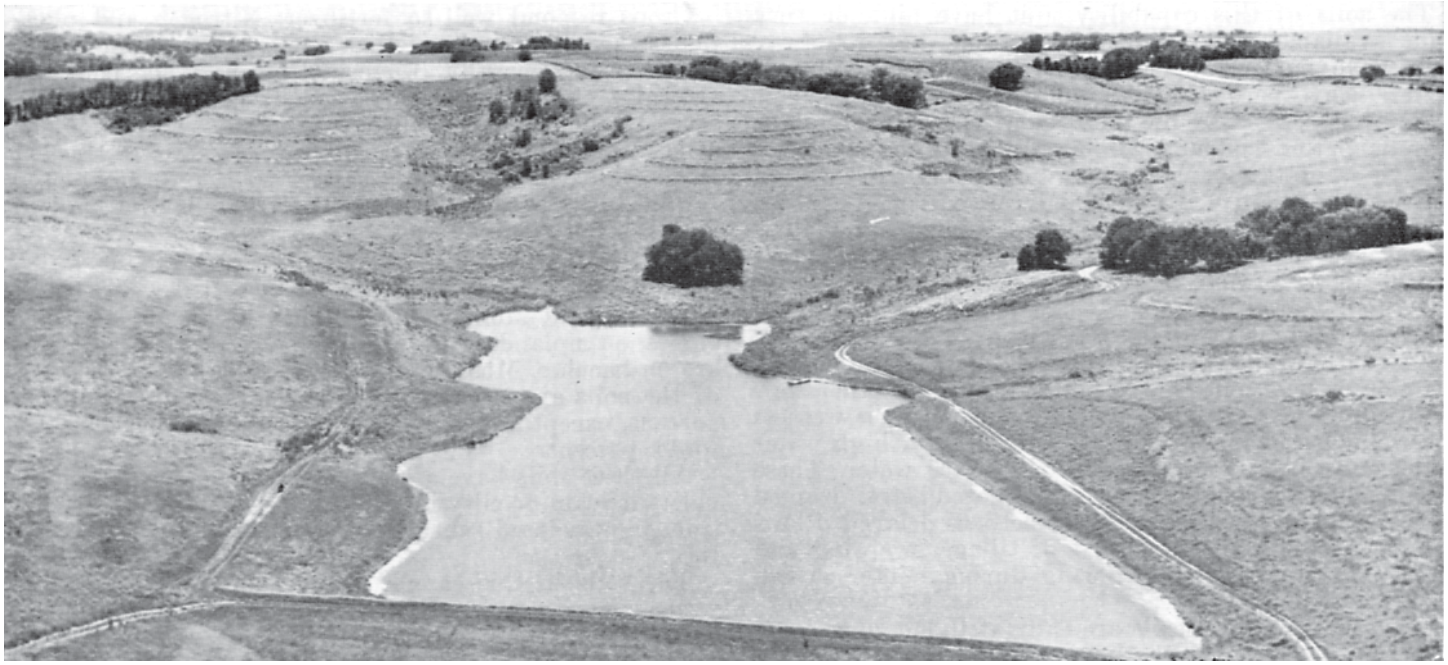

*Figure 11.*—**An area of Monona soils, which are in capability unit IIe-1. Terraces and grass protect the slopes above the structure from further erosion.**

#### CAPABILITY UNIT IIe-2

This unit consists of well drained and moderately well drained soils of the Judson and Napier series. Also in this capability unit are the Napier-Kennebec-Nodaway silt loams. All the soils have slopes of 2 to 6 percent and are in narrow upland valleys and on foot slopes. The Judson and Napier soils are in narrow strips, mainly at the foot of slopes occupied by Marshall or Monona soils, and the Napier-Kennebec-Nodaway silt loams are in long, narrow areas along upland valleys and small drainageways. In most places they are managed along with the adjacent soils.

Most of the soils have a thick surface layer of friable silt loam or silty clay loam. Nodaway soils, however, have a thin surface layer. The subsoil is silt loam or silty clay loam.

The soils of this capability unit have very high or high available water capacity and moderate permeability. The organic-matter content is generally high, but it is low in the Nodaway soils. The soils are typically medium or low in available nitrogen and available phosphorus and medium or high in available potassium.

Tilth is good. Soils in this capability unit are slightly susceptible to erosion. Many areas are subject to occasional flooding from streams or to runoff from upslope that causes gullying in places. Napier-Kennebec-Nodaway silt loams remain slightly wet in places after flooding, but supplemental drainage is seldom used, and tillage is not delayed for long. Contour tillage, terraces, and diversions are used to control erosion. Diversion or basin terraces are used to intercept runoff from adjacent slopes and thus prevent gullying, erosion, and siltation caused by water running across these soils. Some areas of the Napier-Kennebec-Nodaway silt loams have gullies that are encroaching into the cropland. In places special retention structures have been used to slow the rate of cutting, to trap sediments, and to prevent further damage (see fig. 11). In many places in soils of this unit, the noncrossable gullies can be shaped and seeded for grassed waterways.

Most areas of these soils are cultivated. Corn and soybeans are the major crops, but oats, alfalfa, and other hay crops are also grown. A few inaccessible areas are used for pasture. The soils are suited to row crops most of the time if erosion is controlled and management is good.

Crops respond well to fertilizer. Nitrogen and phosphorus are likely to be lacking. Small amounts of potassium in starter fertilizer are likely to be beneficial to corn. These soils range from neutral to medium acid in the surface layer, and lime is needed in some places.

#### CAPABILITY UNIT IIw-1

This unit consists of poorly drained soils of the Colo and Zook series. These soils are nearly level and are on bottom lands. Also in this capability unit is the Judson-Colo-Nodaway complex, 2 to 6 percent slopes. The Judson and Nodaway soils are moderately well drained or well drained. The Judson-Colo-Nodaway complex is in long, narrow areas along small streams and drainageways. The Zook soils are in large areas along major streams. The Colo soil is mainly in large areas along major streams but is also in small areas along upland drainageways.

Most of these soils have a thick surface layer of friable silty clay loam, but the Nodaway soil has a thin surface layer of silt loam. Most soils have a subsoil of silty clay loam, but the Zook soil has a silty clay subsoil, and the Nodaway soil is silt loam throughout.

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The soils of this capability unit have high or very high available water capacity. Judson and Nodaway soils have moderate permeability, Colo soil has moderately slow permeability, and Zook soils have slow permeability because of their silty clay texture. The organic-matter content is high, except for the Nodaway soil. Soils of this capability unit typically are medium or low in available nitrogen and range from very low to medium in available phosphorus. They are mainly about medium in available potassium, but some areas of Zook soils are low in available potassium.

Tilth is generally good, but some of these soils become cloddy and hard if worked when wet. The sloping areas of the Judson-Colo-Nodaway complex are subject to some erosion, but this is not a hazard on other soils in the unit. The main concern of management is wetness caused by the moderately slow permeability, high water table, and flooding or ponding of surface water. These soils remain wet longer than the associated better drained soils, and tillage or planting is sometimes delayed. Plowing in fall helps the timeliness of tillage in spring and allows the freezing and thawing during winter to improve tilth.

Most areas of these soils are cultivated, but some areas that are inaccessible, that are cut up by meandering streams, or that are associated with soils not suited to cultivation are in pasture. These soils are suited to row crops most of the time if adequate drainage is provided. Corn and soybeans are the major crops, but oats, alfalfa, and other hay crops are also grown. Surface drains and tile are used to drain the soils, but tile drains do not function as well in Zook soils as in more permeable soils in this capability unit. Proper spacing and placement of drain tiles are very important.

Crops respond well to fertilizer if drainage is adequate. Nitrogen and phosphorus are needed in larger amounts than potassium, but some potassium is needed in most places. These soils are neutral to medium acid in the surface layer, and some areas need lime.

#### CAPABILITY UNIT IIIe-1

This unit consists of well-drained soils of the Marshall and Monona series. These soils have slopes of 5 to 9 percent. They are on ridgetops and side slopes mainly on uplands, but some areas of Marshall soils are on benches. One of the Monona soils is severely eroded.

All of these soils have a surface layer and subsoil of friable silty clay loam or silt loam.

The soils of this capability unit have high available water capacity and moderate permeability. The organic-matter content is typically low in the moderately or severely eroded soils and medium in the slightly eroded soils. These soils are typically low or medium in available nitrogen and available phosphorus and medium or high in available potassium.

Tilth is good or fair in most places. These soils are susceptible to sheet erosion and gullying.

Most areas of these soils are cultivated. They can be used for row crops much of the time if erosion is controlled and if management is good. Corn and soybeans are the major crops, but more oats, alfalfa, and other hay crops are grown than on less sloping soils. Terraces and contour tillage are the practices most used to help control erosion. Grassed waterways are needed in places.

Crops respond well to fertilizer. Nitrogen and phosphorus are likely to be needed. Some potassium in starter fertilizer is generally beneficial to corn. The soils are typically slightly acid in the surface layer, and some areas need lime, especially if legumes are grown. These soils, especially those that are severely eroded, benefit from additions of organic matter in the form of crop residue, barnyard manure, and green manure plowed under.

#### CAPABILITY UNIT IIIe-2

This unit consists of well-drained soils of the Knox, Marshall, and Monona series. They are mainly on side slopes on uplands, but a few areas of Marshall soils are on benches. Most areas of these soils are large. Some of the soils are severely eroded. The slopes are 9 to 14 percent, except for the Knox soil, which ranges from 5 to 14 percent.

All these soils have a surface layer and subsoil of friable silt loam or silty clay loam. The Knox soils have a thin, light-colored subsurface layer that has platy structure.

The soils in this capability unit have high available water capacity and moderate permeability. The organic-matter content ranges from medium on slightly eroded soils to low on the severely eroded ones. These soils are typically low or medium in available nitrogen and available phosphorus and medium or high in available potassium.

Tilth is fair or good in most places, but it is poor in many places in the severely eroded soils. These soils are susceptible to severe sheet erosion and gullying. Runoff is more rapid under similar management than on the similar, but less sloping soils of capability unit IIIe-1.

Many areas of these soils are cultivated. The rest is mainly in permanent pasture, and these areas are mostly small and are associated with steeper soils. These soils can be used for row crops part of the time if erosion is controlled. Corn, oats, alfalfa, and other hay crops are grown. Some soybeans are grown, but they are not generally grown on this sloping soil. Terraces (fig. 12) and contour tillage are the practices most used to help control erosion. Some hillside gullies need to be shaped and seeded for grassed waterways. Most areas of the Knox soil have stands of trees, but they are managed for pasture rather than for woodland. If cleared, they can be managed like other soils in the unit. Uncleared areas can also be managed for woodland, but they should be protected from grazing. These areas also have good potential for development as recreation areas or wildlife habitat.

Crops respond well to fertilizer. Nitrogen and phosphorus are likely to be lacking. Potassium in starter fertilizer is generally beneficial to corn. The soils are slightly acid to medium acid in the surface layer, and some areas need lime. These soils, especially those that are severely eroded, benefit from additions of organic matter in the form of crop residue, barnyard manure, or green manure plowed under.

#### CAPABILITY UNIT IIIe-3

This unit consists of well-drained soils of the Dow, Ida, and Monona series. These soils have slopes of 5 to 9 percent and are on uplands. They are mainly on nar-

*Figure 12.*—**Grassed backslope terraces on Monona silt loam, 9 to 14 percent slopes, moderately eroded. This soil is in capability unit IIIe–2.**

row ridges and side slopes. Some areas of Ida soils are severely eroded.

All these soils have a surface layer of friable silt loam and are silt loam below. Ida and Dow soils are calcareous at or near the surface, but Monona soils are leached to a depth of 2 feet or more.

The soils of this capability unit have high available water capacity and moderate permeability. The organic-matter content is low or very low. Ida and Dow soils are typically very low in available nitrogen and available phosphorus and are medium or high in available potassium. The Monona soil is typically low in available nitrogen and available phosphorus and is high in available potassium.

Tilth is fair or good. Some of the soils, especially the severely eroded soils, tend to crust when they dry out after rain. Soils in this capability unit are susceptible to severe sheet erosion and gullying.

Most areas of these soils are cultivated. Some of the steeper areas are used for pasture. Corn, soybeans, small grains, alfalfa, and other hay crops are grown. These soils can be used for row crops most of the time if erosion is controlled and management is good. Terraces and contour tillage are the practices most used to help control erosion.

Crops respond well to fertilizer, and a good fertility maintenance program is important. Phosphorus, which is especially important for meadows, is very low in Dow and Ida soils. Some potassium in starter fertilizer is generally beneficial to corn. Except for the Monona soil, these soils are calcareous and do not need lime. They benefit from additions of organic matter in the form of crop residue, barnyard manure, and green manure plowed under. Organic matter improves tilth and the ability of the soils to absorb water.

#### CAPABILITY UNIT IIIe–4

This unit consists of well-drained soils of the Dow, Ida, and Monona series. The soils have slopes of 9 to 14 percent and are on uplands. They are mainly on side slopes, but some areas are on ridges. Several of the soils are severely eroded.

All these soils have a surface layer of friable silt loam and are silt loam below. Ida and Dow soils are calcareous at or near the surface, but Monona soils are leached to a depth of about 2 feet or more.

The soils of this capability unit have high available water capacity and moderate permeability. The organic-matter content is very low or low. Ida and Dow soils are typically very low in available nitrogen and available phosphorus and medium or high in available potassium. Monona soils are typically low in available nitrogen and available phosphorus and high in available potassium.

Tilth is generally fair. The eroded soils tend to form a crust when they dry out after rains. Soils in this capability unit are susceptible to severe sheet and gully erosion.

Most areas are cultivated, but some areas are in permanent pasture. These soils can be used for row crops part of the time if erosion is controlled and management is good. Corn, oats, alfalfa, and other hay and pasture crops are grown. Some soybeans are grown, but the acreage is not extensive. Terraces and contour tillage are the practices most used to control erosion. Some hillside guillies need to be shaped and seeded for grassed waterways.

Crops respond well to fertilizer if moisture is adequate. Available nitrogen and phosphorus are needed in most of the soils, and potassium in starter fertilizer is beneficial to corn. Phosphorus is especially important if these soils are used for pasture. Except for some areas of the Monona part of Dow-Monona silt loams, the soils are calcareous and do not need lime. These soils benefit from additions of organic matter in the form of crop residue, barnyard manure, and green manure plowed under. Organic matter improves tilth and the ability of the soils to absorb water.

#### CAPABILITY UNIT IIIe-5

This unit consists of moderately well drained soils of the Shelby series. These soils have slopes of 5 to 14 percent and are mainly on eroded noses of ridges, on the shoulders of slopes, and on convex side slopes on uplands.

These soils have a surface layer of friable loam and a subsoil of clay loam. The substratum is firm.

The soils in this capability unit have high available water capacity and moderately slow permeability. The organic-matter content is typically low. These soils are typically low in available nitrogen, very low or low in available phosphorus, and low or medium in available potassium.

Tilth is poor or fair. The surface layer tends to dry out cloddy and hard, especially if cultivated when it is too wet. These soils are susceptible to severe sheet and gully erosion. A few steeper areas have small wet spots where water seeps out of the hillsides, but wetness is not generally a management problem. Although the soils have high available water capacity, enough water runs off the steeper soils to cause them to be droughty in dry periods. Some areas have stones and boulders that hinder tillage.

Most areas of these soils are cultivated, but some of the steeper areas are in permanent pasture. These soils can be used for row crops part of the time if erosion is controlled and if management is good. Corn, oats, alfalfa, and other hay and pasture crops are grown. Soybeans are not generally grown on these sloping soils. Contour tillage and graded terraces are practices most used to control erosion. Some hillside gullies need to be shaped and seeded for grassed waterways.

Crops respond well to fertilizer if moisture is adequate and other management is good. These soils are likely to need all the major nutrients in varying amounts, depending on the crop grown. Many areas need lime. These soils, especially those that are severely eroded, benefit from additions of organic matter in the form of crop residue, barnyard manure, or green manure plowed under. Organic matter helps improve tilth and the ability of the soils to absorb and hold water.

#### CAPABILITY UNIT IIIe-6

This unit consists of well-drained soils of the Napier series and moderately well drained soils of the Kennebec and Nodaway series. The Napier soils are at the foot of upland slopes and along upland drainageways. The complex mapped as Napier-Kennebec-Nodway silt loams is along minor streams and upland drainageways. All of the soils have slopes of 5 to 14 percent.

These soils have a thick surface layer of friable silt loam or silty clay loam and a friable subsoil of similar texture. An exception is the Nodaway soil, which has a thin surface layer darkened by organic matter.

The soils of this capability unit have very high or high available water capacity and moderate permeability. The organic-matter content is generally high, but it is low in Nodaway soils. These soils are medium or low in available nitrogen and available phosphorus and medium or high in available potassium.

Tilth is good. These soils are susceptible to sheet and gully erosion and to flooding from streams. They are also subject to runoff from upslope that causes erosion and siltation. Wetness generally is not a hazard, because these soils have enough slope and are permeable enough that water does not stand for long. However, some areas are wet slightly longer than associated soils on uplands. Occasionally, flooding washes out seed or young crops in the area next to the waterway. In places large guillies have formed.

Many areas of these soils are cultivated, but some steeper areas or areas that have meandering streams or gullies are often used for permanent pasture. These soils are suited to row crops much of the time if erosion is controlled. Corn, soybeans, oats, alfalfa, and other forage crops are grown. Areas that have slopes of more than about 9 percent need to be used for close-growing crops more of the time than less sloping areas. Contour tillage, terraces, and diversions are used to control erosion. Diversion or basin terraces at the upper edge of these soils protect them from runoff that causes rilling, gullying, and siltation. In many places noncrossable gullies can be shaped and seeded for grassed waterways. In places special retention structures have been used to slow the rate of gullying, to trap sediment, and to prevent further damage.

Crops respond well to fertilizer. Nitrogen and phosphorus are likely to be needed, but potassium in starter fertilizer is beneficial in places, especially to corn. The soils range from neutral to slightly acid or medium acid in the surface layer, and some areas need lime.

#### CAPABILITY UNIT IVe-1

This unit consists of well-drained soils of the Knox, Marshall, and Monona series. The soils have slopes of 14 to 20 percent and are generally on convex side slopes on uplands. Some of the soils are severely eroded.

All of these soils have a surface layer and subsoil of friable silt loam or silty clay loam. The Knox soil has a thin subsurface layer that has platy structure.

The soils of this capability unit are typically very low or low in available nitrogen, very low to medium in available phosphorus, and medium or high in available potassium. The organic-matter content is mostly low, especially in the severely eroded soils.

Tilth is typically fair in cultivated areas but is poor in some severely eroded areas. These soils are susceptible to severe sheet and gully erosion. Because of rapid runoff, these soils tend to be more droughty than similar but less sloping soils.

Many areas of these soils are cultivated, but hay or pasture crops are grown much of the time. The soils are well suited to these crops and are suited to an occasional row crop if erosion is controlled (fig. 13). Some areas are in permanent pasture. These soils are commonly in hay or pasture most of the time, and a row

*Figure 13.*—**Grassed backslope terraces on a Monona soil of about 15 percent slope. This soil is in capability unit IVe–1.**

crop is grown when the stands of legumes and grasses become poor and need to be plowed and reseeded. Corn is the major row crop; soybeans are seldom grown. Terraces or contour tillage are practices used to control erosion. In some places gullied waterways need to be shaped before terraces are built (fig. 14). Most areas of the Knox soil are wooded, but they are generally managed as pasture rather than woodland. Some areas can be used for recreation or wildlife habitat. Few areas are managed for production of timber products. If managed for woodland, they ought to be protected from grazing.

Crops respond well to fertilizer if moisture is adequate. Phosphorus is especially beneficial if these soils are used for pasture. The soils are typically slightly acid or medium acid in the surface layer, and many areas need lime. These soils, especially those that are severely eroded, benefit from additions of organic matter in the form of crop residue, barnyard manure, or green manure plowed under. Organic matter improves tilth and the ability of the soils to absorb and hold water.

*Figure 14.*—**Gullied Monona soils, which are used for permanent pasture. These soils are in capability unit IVe–1.**

#### CAPABILITY UNIT IVe–2

This unit consists of well-drained soils of the Dow, Ida, and Monona series. Most of these soils are on convex side slopes. Slopes are 14 to 20 percent. Most of these soils are severely eroded.

These soils have a surface layer of friable silt loam and are silt loam below. Ida and Dow soils are calcareous at or near the surface, but Monona soils are leached to a depth of 2 feet or more.

The soils of this capability unit have high available water capacity and moderate permeability. The organic-matter content is very low or low. The Dow and Ida soils are typically very low in available nitrogen and available phosphorus and medium or high in available potassium. Monona soils are typically low in available nitrogen and available phosphorus and high in available potassium.

Tilth is generally fair. Some of the soils tend to form a crust when they dry out after rains. These soils are susceptible to severe sheet and gully erosion. Runoff is rapid, and these soils tend to be more droughty than similar but less sloping soils.

Many areas of these soils are cultivated, but hay and pasture crops are grown much of the time. These soils are well suited to hay and pasture crops. Some areas are in permanent pasture. These soils are commonly used for hay or pasture most of the time, and a row crop is grown when stands of legumes and grasses become poor and need to be plowed and reseeded. Terraces or contour tillage are practices used to control erosion. In places, gullied waterways need to be shaped before terraces are built.

Crops respond fairly well to fertilizer if moisture is adequate. Nitrogen and phosphorus are very low in most of the soils, and phosphorus is needed if these soils are used for pasture. Only the Monona soils are not calcareous at or near the surface; consequently, lime is needed only in areas of these soils. The soils of this capability unit benefit from additions of organic matter in the form of crop residue, barnyard manure, or green manure plowed under. Organic matter improves tilth and the ability of the soils to absorb and hold water.

#### CAPABILITY UNIT IVe-3

This unit consists of well drained and moderately well drained soils of the Shelby and Steinauer series. These soils have slopes of 9 to 18 percent and are mainly on side slopes. Most of the soils are severely eroded.

All of these soils have a surface layer of friable or firm loam or clay loam. The subsoil and substratum are clay loam and are typically firm. The Steinauer soil is calcareous at or near the surface.

The soils in this capability unit have high available water capacity and moderately slow permeability. The organic-matter content is low. The soils are typically very low or low in available nitrogen and available phosphorus and low or medium in available potassium.

Tilth is poor in most places, and the surface layer tends to dry out cloddy and hard if tilled when wet. These soils are susceptible to severe sheet and gully erosion, and gullies are present in places. In few places there are small wet spots where water seeps out of the hillsides, but wetness is not generally a management problem. Although the soils have high available water capacity, enough water runs off to cause the soils to be droughty in dry periods. Stones and boulders interfere with tillage in places.

Many areas are or have been cultivated, but many are in permanent pasture. The Steinauer soil is mostly in permanent pasture. Hay and pasture crops are grown much of the time in cultivated areas. These soils are better suited to these crops than to row crops. It is a common practice to leave these soils in hay or pasture most of the time and to plant a crop of corn only when stands of legumes and grasses need to be plowed and reseeded. Soybeans are seldom grown. The Steinauer soil is alkaline and does not need lime, but lime is needed in many areas of Shelby soils. Farm machinery can be operated on most areas to renovate permanent pastures. Terraces are not generally built on the steeper soils, but graded terraces are built on others. Terracing soils upslope, which are better suited, helps control runoff and erosion on these soils.

Crop response to fertilizer is generally only fair because of poor tilth and severe erosion.

#### CAPABILITY UNIT IVs-1

This unit consists of sandy and gravelly, excessively drained soils of the Salida and Sparta series. The soils have slopes of 5 to 14 percent and are on uplands.

The Sparta soil has a surface layer of fine sandy loam and are loamy fine sand or fine sand below. The Salida soil has a surface layer of gravelly loam and is typically gravelly sand below.

The soils in this capability unit have very low available water capacity and rapid or very rapid permeability. The organic-matter content is low. The soils are very low or low in available nitrogen, very low in available phosphorus, and low or medium in available potassium.

The Sparta soil is easy to till, but the Salida soil is difficult to till because it is so gravelly. These soils are droughty and are susceptible to erosion. Soil blowing is a hazard on the Sparta soil, and at times blowing sand injures young plants.

These soils are not well suited to cultivated crops, because they are droughty. Some areas surrounded by better soils are cultivated. They are better suited to hay and pasture than to row crops. If row crops are grown, they should be on the contour. Mulch tillage helps to control erosion and soil blowing on the Sparta soil and helps to prevent damage to young crops. Terraces are seldom built because of the difficulties in construction and maintenance and because these soils are so permeable that the amount of runoff is small. Some areas of the Salida soil are so gravelly and cobbly that they should be left in permanent pasture.

Crop response to fertilizer is poor in most years because of inadequate moisture, and large amounts are not generally practical. The Salida soil does not need lime. The Sparta soil is typically medium acid in the surface layer, and many areas need lime.

#### CAPABILITY UNIT VIe-1

This unit consists of soils of the Ida, Knox, and Monona series. These soils have slopes of 20 to 30 percent and are on uplands. They are mainly on convex side slopes.

Most of these soils have a surface layer of friable silt loam and are silt loam below. The Knox soil has a thin subsurface layer that has platy structure; the subsoil is silty clay loam.

The soils of this capability unit have high available water capacity and moderate permeability. The organic-matter content is low, especially on the severely eroded soils.

These soils are susceptible to severe erosion. Runoff is rapid. Gullies are present in some places. Regular terraces are not practical, because the soil is steep, but basin or diversion terraces can be used in some places to help control runoff on soils downslope or in valleys.

Most of these soils are in permanent pasture. Hay or small grains are grown in a few areas, but pasture is a better use. Farm equipment can be used in many areas to renovate permanent pasture and establish more productive grasses and legumes, but using farm machinery on these steep soils is hazardous. Alfalfa and bromegrass are among the plants generally used in pasture renovation. Control of grazing is an important management practice on these soils.

The Knox soil generally has stands of trees, but it is mainly used for permanent pasture. Few areas are managed for the timber products they produce. If managed as timber, they should be protected from grazing. These areas can be used for recreation and as wildlife habitat.

Addition of fertilizer is generally beneficial in areas used for pasture. Phosphorus is needed, and if the stand of legumes is thin or lacking, nitrogen is also generally needed. The Ida soil does not need lime, but the other soils need lime in places.

#### CAPABILITY UNIT VIe-2

This unit consists of well-drained to somewhat poorly drained soils of the Adair, Shelby, and Steinauer series. These soils are mainly on side slopes on uplands. The Shelby and Steinauer soils have slopes of 14 to 25 percent, but the Adair soil has slopes of 9 to 14 percent. Most of the soils are severely eroded.

All of these soils have a surface layer of loam or clay loam. The subsoil and substratum in most of the soils are firm clay loam. The Adair soil typically has a firm layer of clay in the subsoil, but it is clay loam in the rest of the subsoil and substratum.

The soils of this capability unit have high available water capacity. The Shelby and Steinauer soils have moderately slow permeability, and the Adair soil has slow permeability in the clay layer. The organic-matter content is low.

Tilth is poor. These soils tend to dry out cloddy and hard if tilled when wet. Most areas of these soils are severely eroded and are susceptible to further erosion and gullying. Even though they have high available water capacity, enough water runs off that they are often droughty in dry periods. The poor tilth and low organic-matter content of the surface layer causes runoff to be more rapid than on most other similarly sloping soils. The upper edge of areas of the Adair soil tends to be seasonally seepy and wet. Some areas have hillside gullies that need to be shaped and seeded for waterways.

These soils are not suited to cultivation because of slope, the hazard of further erosion, low fertility, and poor tilth of the surface layer. Some areas are or have been cultivated, but most areas are now in permanent pasture. Many small areas are cultivated and are managed with adjacent soils that are better suited to cultivation. It is possible to operate farm machinery on many areas for renovation of pasture and seeding of grasses and legumes to improve carrying capacity. A few areas are too rocky to prepare a seedbed, however. The control of grazing is an important management practice that increases productivity and limits further erosion. Alfalfa and bromegrass are among the plants generally used in pasture renovation.

The response of pasture plants to fertilizer is fair to good. The Steinauer soil is calcareous and does not need lime. Shelby and Adair soils need lime in places.

#### CAPABILITY UNIT VIs-1

This unit consists of excessively drained soils of the Chute and Sparta series. These soils have slopes of 6 to 14 percent and are on uplands. They are mainly on ridgetops and on convex side slopes.

These soils have a surface layer of very friable fine sandy loam and are loamy fine sand or sand below.

The soils in this capability unit have very low available water capacity and rapid or very rapid permeability. The natural fertility and organic-matter content are low.

These soils are very droughty. They are susceptible to some soil blowing, and in places blowing sand injures young plants on these and surrounding soils. They absorb rainfall readily, but they are susceptible to some sheet erosion and gullying. They dry out quickly and can be worked soon after rains. They warm up quickly in spring.

Many areas of these soils are small, and they generally are managed as cropland along with soils that are better suited to cultivation. Other areas are in hay or pasture. These soils are better suited to hay and pasture than to row crops because they are droughty and subject to soil blowing and water erosion. Row crops are not well suited. If used for pasture, control of grazing is important to maintain a vegetative cover. Tillage that leaves mulch on the surface or additions of strawy manure or other mulches are generally beneficial and prevent erosion and damage to new seedings from blowing sand. Terraces on these soils are not stable. In places terracing soils upslope helps reduce runoff onto these soils and reduces the hazard of water erosion.

Crop response to fertilizer is poor in most years, and the soils are so droughty that large amounts are not generally feasible. The Chute soil is calcareous and does not need lime. The Sparta soil is typically medium acid in the surface layer, and many areas need lime.

#### CAPABILITY UNIT VIIe-1

This unit consists of well-drained to somewhat poorly drained soils of the Adair, Monona, and Shelby series. Also in this capability unit is one of the soils of the Napier-Gullied land complex. These soils are on uplands. They are mainly on side slopes, but the Napier-Gullied land complex is in upland drainageway and along small streams. Most of the soils have slopes that range from 14 to 40 percent, but the Napier-Gullied land complex has slopes of 2 to 10 percent. Most of the soils are severely eroded.

These soils have a surface layer of silt loam, loam, or clay loam. Monona and Napier soils have a subsoil of silt loam, and the Shelby soils have a subsoil of clay loam. The Shelby cobbly loam soil has many cobblestones and stones in the profile. The Adair soil typically has a thin clay layer in the subsoil.

The soils of this unit have high or very high available water capacity. Monona and Napier soils have moderate permeability, Shelby soils have moderately slow permeability, and the Adair soil has slow permeability in the clay layer.

Although the soils have high or very high available water capacity, water runs off so rapidly because of slow infiltration that some of these soils are droughty most of the time.

Steep slopes, cobblestones and rockiness, a severely eroded surface layer, gullying, and the hazard of further erosion restrict these soils to permanent vegetation. Most areas are in permanent pasture. A few areas have stands of trees. The soils are generally too steep, rocky, or gullied to operate conventional farm machinery, so few pastures can be renovated unless special equipment is used. Control of grazing is important in managing pasture on these soils. Overgrazing results in lower production of forage and increased sheet erosion and gullying. Timbered areas to be managed as woodland should not be grazed. These soils can be used for recreation or wildlife habitat.

#### CAPABILITY UNIT VIIs-1

This unit consists of soils of the Chute, Salida, and Sparta series. These soils have slopes of 12 to 25 percent and are on uplands.

The Chute and Sparta soils have a surface layer of fine sandy loam and are loamy fine sand or fine sand below. The Salida soil has a thin surface layer of gravelly loam and is typically gravelly sand below.

The soils of this capability unit have very low available water capacity and rapid or very rapid permeability. The organic-matter content is very low.

These soils are very droughty. Because much of the rain infiltrates fairly rapidly, runoff is not great, but some sheet erosion and gullying occurs. Where vegetation is sparse, soil blowing is a hazard. Terraces are seldom built on these soils because of the problem in construction and maintenance, and because the amount of runoff is not great. The Salida soil is so gravelly that in places it is not tillable.

These soils are not suited to cultivation. Most areas are used for permanent pasture. Pasture renovation and reseeding are possible on many areas, but are not possible in places on the steepest soils and on the more gravelly areas of the Salida soil.

The response of pasture plants to fertilizer is poor because the moisture supply is low unless rainfall is above average. Large amounts are not feasible. Control of grazing is important to maintain a vegetative cover and to control erosion. These soils can be used for recreation areas or wildlife habitat.

## Predicted yields

In table 2 the average yields per acre of the principal crops are predicted for soils of the county under a high level of management. Under this level of management, seedbed preparation, planting, and tillage practices provide for adequate stands of suitable varieties; erosion is controlled; the organic-matter content and tilth are maintained; the level of fertility for each crop is maintained, as indicated by soil tests and field trials; the water level in wet soils is controlled; excellent weed and pest control are provided; and operations are timely.

Many available sources of information were used to make these estimates, including data from the federal census, the Iowa farm census, data from experiemental farms and cooperative experiments with farmers, and from on-farm experience by soil scientists, extension workers, and others.

The yield predictions are meant to serve as guides. They are only approximate values and should be so considered. Of more value than actual yield figures to many users is the comparative yields among soils. These relationships are likely to remain consistent over a period of years, but actual yields have been increasing in recent years. If they continue to increase as expected, predicted yields in this table will be outdated in a few years.

TABLE 2.—*Predicted average yields per acre of principal crops under a high level of management*

| Soil | Corn | Soybeans | Oats | Alfalfa-bromegrass hay | Bromegrass pasture |
|---|---|---|---|---|---|
| | *Bu.* | *Bu.* | *Bu.* | *Tons* | *A.U.D.*[1] |
| Adair soils, 9 to 14 percent slopes, severely eroded | | | 35 | 2.0 | 93 |
| Adair soils, 14 to 18 percent slopes, severely eroded | | | | 1.5 | 70 |
| Chute fine sandy loam, 6 to 12 percent slopes, severely eroded | | | 29 | 1.0 | 48 |
| Chute fine sandy loam, 12 to 20 percent slopes, severely eroded | | | | | 40 |
| Colo silt loam, overwash | 104 | 40 | 73 | 4.0 | 187 |
| Colo silty clay loam | 101 | 38 | 71 | 3.8 | 182 |
| Dow silt loam, 5 to 9 percent slopes, moderately eroded | 78 | 30 | 55 | 3.0 | 140 |
| Dow silt loam, 9 to 14 percent slopes, moderately eroded | 69 | 26 | 47 | 2.6 | 124 |
| Dow-Ida silt loams, 9 to 14 percent slopes, severely eroded | 65 | 25 | 45 | 2.5 | 117 |
| Dow-Ida silt loams, 14 to 20 percent slopes, severely eroded | 50 | | 35 | 1.9 | 90 |
| Dow-Monona silt loams, 5 to 9 percent slopes, moderately eroded | 80 | 30 | 56 | 3.0 | 144 |
| Dow-Monona silt loams, 9 to 14 percent slopes, moderately eroded | 71 | 28 | 50 | 2.8 | 128 |
| Dow-Monona silt loams, 9 to 14 percent slopes, severely eroded | 65 | 25 | 46 | 2.5 | 117 |
| Dow-Monona silt loams, 14 to 20 percent slopes, moderately eroded | 56 | | 39 | 2.1 | 101 |
| Dow-Monona silt loams, 14 to 20 percent slopes, severely eroded | 50 | | | 1.9 | 90 |
| Ida silt loam, 5 to 9 percent slopes | 83 | 32 | 58 | 3.2 | 149 |
| Ida silt loam, 5 to 9 percent slopes, severely eroded | 77 | 29 | 54 | 2.9 | 139 |
| Ida silt loam, 9 to 14 percent slopes | 74 | 28 | 52 | 2.8 | 135 |
| Ida silt loam, 9 to 14 percent slopes, severely eroded | 68 | 26 | 48 | 2.6 | 122 |
| Ida silt loam, 14 to 20 percent slopes, severely eroded | 53 | | 37 | 2.0 | 95 |
| Ida silt loam, 20 to 30 percent slopes, severely eroded | | | | | 70 |
| Judson silty clay loam, 0 to 2 percent slopes | 110 | 42 | 77 | 4.2 | 198 |
| Judson silty clay loam, 2 to 6 percent slopes | 108 | 41 | 76 | 4.1 | 194 |
| Judson-Colo-Nodaway complex, 2 to 6 percent slopes | 105 | 40 | 74 | 4.0 | 189 |
| Kennebec silt loam | 111 | 42 | 78 | 4.2 | 200 |
| Kennebec silt loam, overwash | 111 | 42 | 78 | 4.2 | 200 |

See footnote at end of table.

TABLE 2.—*Predicted average yields per acre of principal crops under a high level of management*—Continued

| Soil | Corn | Soy-beans | Oats | Alfalfa-brome-grass hay | Brome-grass pasture |
|---|---|---|---|---|---|
| | *Bu.* | *Bu.* | *Bu.* | *Tons* | *A.U.D.*[1] |
| Knox silt loam, 5 to 14 percent slopes | 84 | 32 | 59 | 3.2 | 151 |
| Knox silt loam, 14 to 20 percent slopes | --- | --- | --- | 2.6 | 124 |
| Knox silt loam, 20 to 30 percent slopes | --- | --- | --- | --- | [2] 70 |
| Marshall silty clay loam, 0 to 2 percent slopes | 103 | 39 | 72 | 3.9 | 185 |
| Marshall silty clay loam, 2 to 5 percent slopes | 101 | 38 | 71 | 3.8 | 182 |
| Marshall silty clay loam, 2 to 5 percent slopes, moderately eroded | 98 | 37 | 69 | 3.7 | 176 |
| Marshall silty clay loam, 5 to 9 percent slopes | 96 | 36 | 67 | 3.6 | 173 |
| Marshall silty clay loam, 5 to 9 percent slopes, moderately eroded | 93 | 35 | 65 | 3.5 | 167 |
| Marshall silty clay loam, 9 to 14 percent slopes | 87 | 33 | 61 | 3.3 | 157 |
| Marshall silty clay loam, 9 to 14 percent slopes, moderately eroded | 84 | 32 | 59 | 3.2 | 151 |
| Marshall silty clay loam, 9 to 14 percent slopes, severely eroded | 78 | 30 | 55 | 3.0 | 140 |
| Marshall silty clay loam, 14 to 20 percent slopes, moderately eroded | 69 | --- | 48 | 2.6 | 124 |
| Marshall silty clay loam, 14 to 20 percent slopes, severely eroded | 63 | --- | 44 | 2.4 | 113 |
| Monona silt loam, 0 to 2 percent slopes | 100 | 38 | 70 | 3.8 | 180 |
| Monona silt loam, 2 to 5 percent slopes | 98 | 37 | 69 | 3.7 | 176 |
| Monona silt loam, 2 to 5 percent slopes, moderately eroded | 95 | 36 | 67 | 3.6 | 171 |
| Monona silt loam, 5 to 9 percent slopes | 93 | 35 | 65 | 3.5 | 167 |
| Monona silt loam, 5 to 9 percent slopes, moderately eroded | 90 | 34 | 63 | 3.4 | 162 |
| Monona silt loam, 5 to 9 percent slopes, severely eroded | 84 | 32 | 59 | 3.2 | 151 |
| Monona silt loam, 9 to 14 percent slopes | 84 | 32 | 59 | 3.2 | 151 |
| Monona silt loam, 9 to 14 percent slopes, moderately eroded | 81 | 31 | 57 | 3.1 | 146 |
| Monona silt loam, 9 to 14 percent slopes, severely eroded | 75 | 28 | 53 | 2.8 | 135 |
| Monona silt loam, 14 to 20 percent slopes, moderately eroded | 66 | --- | 46 | 2.5 | 119 |
| Monona silt loam, 14 to 20 percent slopes, severely eroded | 60 | --- | 42 | 2.3 | 108 |
| Monona silt loam, 20 to 30 percent slopes, moderately eroded | --- | --- | --- | --- | 85 |
| Monona silt loam, 20 to 30 percent slopes, severely eroded | --- | --- | --- | --- | 80 |
| Monona silt loam, 30 to 40 percent slopes, severely eroded | --- | --- | --- | --- | [2] 50 |
| Napier silt loam, 2 to 5 percent slopes | 105 | 40 | 74 | 4.0 | 189 |
| Napier silt loam, 5 to 9 percent slopes | 100 | 38 | 70 | 3.8 | 180 |
| Napier silt loam, 9 to 14 percent slopes | 91 | 35 | 64 | 3.5 | 164 |
| Napier-Gullied land complex, 2 to 10 percent slopes | --- | --- | --- | --- | 70 |
| Napier-Kennebec-Nodaway silt loams, 2 to 5 percent slopes | 105 | 40 | 74 | 4.0 | 189 |
| Napier-Kennebec-Nodaway silt loams, 5 to 9 percent slopes | 100 | 38 | 70 | 3.8 | 180 |
| Nodaway silt loam | 103 | 39 | 72 | 3.9 | 185 |
| Salida gravelly loam, 9 to 14 percent slopes, moderately eroded | 35 | --- | 24 | 1.3 | 63 |
| Salida gravelly loam, 14 to 25 percent slopes, moderately eroded | --- | --- | --- | --- | [2] 25 |
| Shelby loam, 5 to 9 percent slopes, moderately eroded | 86 | 33 | 60 | 3.3 | 155 |
| Shelby loam, 9 to 14 percent slopes, moderately eroded | 76 | 29 | 53 | 2.9 | 137 |
| Shelby loam, 14 to 18 percent slopes, moderately eroded | 61 | --- | 43 | 2.3 | 110 |
| Shelby loam, 18 to 25 percent slopes, moderately eroded | --- | --- | --- | --- | [2] 60 |
| Shelby cobbly loam, 14 to 35 percent slopes | --- | --- | --- | --- | [2] 40 |
| Shelby soils, 9 to 14 percent slopes, severely eroded | 70 | --- | 49 | 2.7 | 126 |
| Shelby soils, 14 to 18 percent slopes, severely eroded | --- | --- | --- | 2.0 | 95 |
| Shelby soils, 18 to 25 percent slopes, severely eroded | --- | --- | --- | --- | [2] 55 |
| Shelby soils, 25 to 35 percent slopes, severely eroded | --- | --- | --- | --- | [2] 45 |
| Sparta fine sandy loam, 5 to 9 percent slopes, moderately eroded | 35 | --- | 24 | 1.3 | 64 |
| Sparta fine sandy loam, 9 to 14 percent slopes, moderately eroded | --- | --- | 22 | 1.1 | 54 |
| Sparta fine sandy loam, 14 to 20 percent slopes, moderately eroded | --- | --- | --- | .9 | 44 |
| Steinauer clay loam, 9 to 14 percent slopes, severely eroded | 58 | --- | 40 | 2.2 | 104 |
| Steinauer clay loam, 14 to 18 percent slopes, severely eroded | --- | --- | --- | 1.8 | 85 |
| Zook silt loam, overwash | 96 | 36 | 67 | 3.6 | 173 |
| Zook silty clay loam | 93 | 35 | 65 | 3.5 | 167 |

[1] A.U.D. stands for animal-unit-days, which is defined as the number of animal units per acre multiplied by the number of days the pasture is grazed during a single season without injury to the sod. One animal unit is one cow, steer, or horse; five hogs, or seven sheep.
[2] This yield is for permanent bluegrass pasture instead of bromegrass pasture.

## Use of the Soils for Wildlife and Recreation

The kinds and amounts of wildlife that can be produced and maintained in the county are largely determined by the kinds and amounts of vegetation. Wildlife is influenced by topography and by such soil characteristics as fertility. Fertile soils are capable of greater production than infertile ones. Topography affects wildlife through its effect on use of soils. Extremely rough, irregular areas present hazards to livestock and are unsuited to crop production in places. In such areas the undistributed vegetation is commonly suited to wildlife use. If suitable vegetation is in such areas, it can often be developed to improve conditions for desirable kinds of wildlife.

Wetness and water-holding capacity of the soils are

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important in selecting sites for ponds for fish and in maintaining aquatic or semiaquatic habitat for waterfowl or some species of furbearing animals.

The wildlife resources of Crawford County are important, primarily for the opportunities they provide for recreation. Many species of wildlife, however, are also beneficial in the control of undesirable insects and rodents. Many species of birds are very beneficial because they eat harmful insects. Hawks, owls, and other predatory birds help keep undesirable rodents within tolerable numbers, as do shrews, skunks, foxes, and snakes.

Pheasants, cottontail rabbits, squirrels, and deer provide much of the recreational hunting in the county. Pheasants and rabbits are distributed fairly uniformly throughout the county. Squirrels and deer are most numerous in the Kennebec-Nodaway-Colo association and in the parts of other associations that border it. Here, the growth of trees, food supply, and cover favor these species. Opossum, raccoons, weasels, badgers, foxes, and skunks are present in varying numbers throughout the county. Muskrat and mink, which are the most important furbearers in the county, are along both large and small streams throughout the county.

Streams and farm ponds that have been stocked provide fishing. Farm ponds can provide excellent fishing if properly managed. Steinauer and Shelby soils are well suited to construction of farm ponds as far as soil materials are concerned and are generally in places where sites suitable for farm ponds are available. All associations in the county have sites suitable for ponds.

In a number of areas in Crawford County, soils, topography, and vegetation favor the development of facilities for outdoor recreation (fig. 15). Wooded areas occupied by Knox and other moderately sloping to steep soils along the larger streams, such as the Boyer River, offer the greatest potential for the development of parks that provide recreation in the form of hiking trails, trails for horseback riding, nature study, picnicking, and camping.

Many areas that cannot be used economically to produce other crops are well suited to the production of useful wildlife. Small, odd areas of low value for other purposes can be set aside and developed specifically for the use of wildlife. Areas of Salida, Steinauer, Shelby, and very steep Ida or Monona soils commonly fit this category. Small, steep, eroded, or gravelly areas in crop fields, gravel pits, railroad rights-of-way, or bits of land cut off from the rest of the fields by a stream or gully are all suitable for developing wildlife habitat. Soils that are suitable for use as cropland, pasture, or woodland can also produce wildlife habitat.

## Engineering Uses of the Soils

Some soil properties are of special interest to engineers because they affect the construction and maintenance of roads, airports, pipelines, facilities for storing water, erosion control structures, irrigation systems, drainage systems, building foundations, and sewage disposal systems. Among the properties most important in engineering are permeability to water, shear strength, compaction characteristics, soil drainage, shrink-swell potential, grain size, plasticity, and reaction. Depth to the water table, depth to bedrock, and topography are also important.

The information in this survey can be used by engineers to—

1. Make soil and land use studies that aid in selecting and developing industrial, business, residential, and recreational sites.
2. Make preliminary estimates of the engineering properties of soils that help in the planning of farm drainage systems, farm ponds, irrigation systems, terraces, waterways, and diversion terraces.

***Figure 15.*—The beach area at Nelson Park, about 5 miles west of Dow City.**

3. Make preliminary evaluations of soil and ground conditions that aid in selecting highway and airport locations and in planning detailed investigations at the selected locations.
4. Locate probable sources of gravel, sand, or other construction materials.
5. Correlate performance of engineering structures with soil mapping units to develop information for planning that is useful in designing and maintaining specified engineering practices and structures.
6. Determine the suitability of soil mapping units for cross-country movement of vehicles and construction equipment.
7. Supplement information obtained from other published maps and reports and aerial photographs to make maps and reports that can be used readily by engineers.
8. Develop other preliminary estimates for construction purposes pertinent to the particular area.

The engineering interpretations reported here can be useful for many purposes. At many construction sites, however, there are major variations in the soil within the depth of proposed excavation, and several soil units occur within short distances. These interpretations therefore do not eliminate the need for sampling and testing at the site of specific engineering works that involve heavy loads, or where the excavations are deeper than the depth of the layers here reported. Even in these situations, however, the soil map and descriptions of soils are useful for planning more detailed field investigations and for suggesting the kinds of problems that are expected. With this information, the engineer can concentrate on the soils more important for his purpose and reduce the cost of an adequate soil investigation.

Information regarding the behavior and properties of the soils in Crawford County can be obtained from the detailed soil map at the back of the survey and from tables 3 and 4 in this section. The information in the tables was obtained and evaluated from field experience, field performance of the soils, and the results of tests from similar soils in nearby counties.

Some terms used by the soil scientist have special meaning in soil science, and some have a different meaning to engineers. Many of these terms are defined in the Glossary at the back of this survey.

### *Engineering classification systems*

Most highway engineers classify soil material according to the system approved by the American Association of State Highway Officials (AASHO) (*1*). In this system, soil materials are placed in seven principal groups based on field performance. The groups range from A–1, consisting of gravelly and coarse sandy soils of high bearing capacity, to A–7, consisting of clayey soils that have low strength when wet.

Some engineers prefer to use the Unified Soil Classification System developed by the U.S. Department of Defense (*25*). This system is based on the texture and plasticity of soils and the performance of soils as material for engineering works. In this system, soil materials are classified as coarse-grained (eight classes), fine-grained (six classes), or highly organic (one class). An approximate classification can be made in the field. The soil series in Crawford County have been classified by the AASHO and Unified systems in table 3.

### *Engineering properties*

The soil series in Crawford County are listed and estimates of the behavior of each soil are given in table 3. The data in table 3 are based on test data from similar soils in nearby counties, on experience with them in those counties, and on information in other parts of the survey.

Permeability is estimated for each soil as it occurs in place. The estimates were based on soil structure and porosity and were compared to undisturbed cores of similar soil material.

The available water capacity is expressed in this table in inches per inch of soil depth. It is the approximate amount of water available to plants in the soil when it is wet to field capacity. When the soil is air-dry, this amount of water wets the material described to a depth of 1 inch without deeper penetration.

Reaction, or pH value, given in table 3, is the degree of acidity or alkalinity of a soil. The pH value of a neutral soil is 7.0, of an acid soil is less than 7.0, and an alkaline soil is more than 7.0.

The shrink-swell potential indicates the change in volume that occurs with a change in moisture content. It is estimated primarily on the basis of the kind and amount of clay in a soil.

Soils in Crawford County are so deep over bedrock that bedrock does not generally affect their use, so no column for depth to bedrock was included in table 3.

### *Engineering interpretations*

In table 4 the soils in each series are rated for their suitability for use as topsoil, sand, gravel, and road fill. The suitability of the soil material for road fill depends largely on the density that can be obtained by compacting the material. Density affects the rigidity, flexibility, and load-bearing properties of the soil as subgrade fill for paved roads and as surfacing material for unpaved roads. Shrink-swell potential is also a factor in evaluating material for road fill.

Soil features affecting the use of soils for highway location, foundations for low buildings, farm ponds, agricultural drainage, irrigation, terraces and diversions, and grassed waterways are given in table 4. Features that have an adverse effect on these practices generally are listed, but beneficial features are listed for some practices. Special features affecting highway construction are discussed elsewhere in this section. For foundations for low buildings, the soils are rated for bearing capacity, compressibility, height of the water table, and other important features. These features vary widely. Engineers and others should not apply specific values to the estimates given for bearing capacity.

Also rated in table 4 is the degree of limitation of each soil series for septic tank disposal fields and sewage lagoons. For septic tank disposal fields, the soils are rated for their ability to absorb sewage effluent over a long period. Before a septic tank and field are installed, however, a percolation test should be made at the site. In some places a sewage system that is close to a well or stream contaminates the water.

### *Soil features affecting highway work* [3]

Many of the soils in Crawford County formed in loess several feet to many feet thick over glacial till of Kansan age. On the tops of ridges on uplands in the western part of the county, the loess is as much as 55 feet thick in places. On some of the most sloping soils, the loess thins out to the point where it is entirely lacking, and the underlying glacial till forms the parent material.

The soils derived from loess, such as Monona, Ida, and Marshall soils, are typically A–6 to A–7–6, ML–CL or CL that have medium group index numbers. These soils tend to erode easily if runoff concentrates. Sodding, paving, or check dams are needed in gutters and ditches in places to prevent excessive erosion.

In the soils derived from loess, the seasonally high water table is generally above the glacial till-loess interface. On deep cuts the seepage from this zone needs to be intercepted by subdrains in places to improve slope stability. In these areas, the in-place density of the loess is relatively low, and the soil has a high moisture content. This causes instability in embankments unless moisture-density control is exercised to permit compaction to good density. Because of their high in-place density, the Kansan glacial till soils generally do not have an excessively high moisture content and are more easily compacted. The Kansan glacial till below the loess is heterogeneous and of fair to poor quality. On the nearly level to gently rolling soils on uplands, under the mantle of loess, is the remains of the original Kansan till plain. Here the upper layer of the Kansan till is very plastic clay, A–7–6 (19–20), that is unstable for highway subgrade because of expansiveness, and it should not be used within 5 feet of finished grade. On slopes toward drainageways, where the loess thins out, this plastic clay crops out, and the Adair soils formed in this material. In road cuts the clay should be removed to a depth of 2 feet and replaced with a good glacial till or granular soil backfill.

[3] By Donald A. Anderson, soils engineer, Iowa State Highway Commission. Mr. Anderson also helped prepare tables 3 and 4.

TABLE 3.—*Estimated soil properties*

[An asterisk in the first column indicates that at least one mapping unit in this series is made up of two or more kinds of soil. The soils for referring to other series that appear in the first

| Soil series and map symbols | Depth to seasonal high water table | Depth from surface | Classification: USDA texture | Classification: Unified |
|---|---|---|---|---|
| | *Feet* | *Inches* | | |
| Adair: AdD3, AdE3 | (2) | 0–7 | Clay loam | CL |
| | | 7–34 | Clay loam or clay | CL or CH |
| | | 34–60 | Clay loam | CL |
| Chute: ChD3, ChE3 | >5 | 0–9 | Fine sandy loam and loamy fine sand. | SM |
| | | 9–72 | Fine sand | SM or SP–SM |
| Colo: [3] | | | | |
| Co | 1–3 | 0–12 | Silt loam | ML or CL |
| | | 12–36 | Silty clay loam | OH or CH or CL |
| | | 36–60 | Silty clay loam | CH or CL |
| Cs | 1–3 | 0–37 | Silty clay loam | OH or CH or CL |
| | | 37–60 | Silty clay loam | CH or CL |
| *Dow: DoC2, DoD2, DsD3, DsE3, DwC2, DwD2, DwD3, DwE2, DwE3. For Ida part of DsD3 and DsE3, see Ida series; for Monona part of DwC2, DwD2, DwD3, DwE2, and DwE3, see Monona series. | >5 | 0–40 | Silt loam | ML–CL or CL |
| Gullied land. Properties variable. Mapped only with Napier soils. | | | | |
| Ida: IdC, IdC3, IdD, IdD3, IdE3, IdF3 | >5 | 0–40 | Silt loam | ML-CL or CL |
| *Judson: JdA, JdB, JnB. For Colo and Nodaway parts of JnB, see Colo and Nodaway series. | >5 | 0–32 | Silty clay loam | CL or OL |
| | | 32–70 | Silty clay loam | CL |

See footnotes at end of table.

Below the clay layer, outcropping on lower slopes, is Kansan till that is heterogeneous but primarily an A–6 or A–7 (CL) soil. The Shelby and Steinauer soils formed in the till. Where this soil is along grading projects, it is normally placed in the upper subgrade through unstable areas. Pockets and lenses of sand and gravel are commonly interspersed throughout the till, and many are water bearing. Where the road grade is only a few feet above such a deposit, and loess or silty till is over it, frost heaving is likely to develop unless the deposit is drained or the soil above it is replaced with granular backfill or a good clay till.

The bedrock in Crawford County is so deeply buried that no soils that formed in bedrock are exposed.

The bottom-land soils formed in relatively deep recent alluvium washed from uplands. The Colo, Zook, Judson, Napier, and Kennebec soils have a thick, organic topsoil and may consolidate erratically under an embankment load in places. The Colo and Zook soils are A–7 (CH) and have low in-place density and high moisture content, and embankments more than 15 feet in height should be carefully analyzed to be sure there is sufficient strength in the thick foundation soils to support them. Roadway embankments through bottom lands should be constructed on a continuous embankment that extends above the level reached by frequent floods. In places the Nodaway soils have lenses of fine sand, and if an embankment is constructed only a few feet above the water table in these soils, frost heaving results unless proper drainage is established or materials not susceptible to frost action are used in the subgrade.

Ratings are given in table 4 to show the suitability of the soils of Crawford County as a source of topsoil to promote the growth of vegetation on embankments, on cut slopes, and in ditches. The ratings also show the suitability of the soils as a source of borrow for road construction. Organic topsoils are generally unsuitable for use on shoulders of highways that are to support limited traffic during wet periods.

*significant in engineering*

in such mapping units may have different properties and limitations, and for this reason it is necessary to follow carefully the instructions column of this table. The symbol > means more than]

| Classification—Con. | Percentage passing sieve— | | | Permeability | Available water capacity [1] | Reaction | Shrink-swell potential |
|---|---|---|---|---|---|---|---|
| AASHO | No. 4 (4.7 mm.) | No. 10 (2.0 mm.) | No. 200 (0.074 mm.) | | | | |
| | | | | *Inches per hour* | *Inches per inch of soil* | *pH value* | |
| A-6(8-12) | 95-100 | 80-95 | 60-80 | 0. 2-0. 63 | 0. 17 | 5. 6-6. 0 | Moderate. |
| A-7-6(15-20) | 95-100 | 80-95 | 55-80 | 0. 06-0. 20 | . 15 | 6. 1-6. 5 | High. |
| A-6(8-12) or A-7-6(10-14) | 95-100 | 80-95 | 55-80 | 0. 2-0. 63 | . 16 | 6. 1-7. 3 | Moderate. |
| A-2-4(0) or A-4(0-2) | ---------- | 100 | 20-40 | 6. 3-20. 0 | . 08 | 7. 4-7. 8 | Low. |
| A-3(0) or A-2-4(0) | ---------- | 100 | 8-20 | 6. 3-20. 0+ | . 04 | 7. 8-8. 4 | Low. |
| A-4(4-8) or A-6(6-10) | 100 | 95-100 | 90-100 | 0. 63-2. 0 | . 19 | 6. 6-7. 3 | Moderate. |
| A-7-5 or A-7-6 (14-20) | 100 | 100 | 90-100 | 0. 2-0. 63 | . 21 | 6. 1-7. 3 | High. |
| A-7-6(14-20) | 100 | 100 | 85-100 | 0. 2-0. 63 | . 19 | 6. 6-7. 3 | High. |
| A-7-5 or A-7-6 (14-20) | 100 | 100 | 90-100 | 0. 2-0. 63 | . 21 | 6. 1-7. 3 | High. |
| A-7-6(14-20) | 100 | 100 | 85-100 | 0. 2-0. 63 | . 19 | 6. 6-7. 3 | High. |
| A-4(4-8) or A-6 (8-10) | ---------- | 100 | 95-100 | 0. 63-2. 0 | . 18 | 7. 8-8. 4 | Low. |
| A-4(6-8) or A-6(8-10) | ---------- | 100 | 95-100 | 0. 63-2. 0 | . 18 | 7. 8-8. 4 | Low. |
| A-6(8-12) or A-7-6(10-14) | ---------- | 100 | 90-100 | 0. 63-2. 0 | . 22 | 5. 6-6. 0 | Moderate. |
| A-6(8-12) or A-7-6(10-12) | ---------- | 100 | 90-100 | 0. 63-2. 0 | . 19 | 6. 1-6. 5 | Moderate. |

TABLE 3.—*Estimated soil properties*

| Soil series and map symbols | Depth to seasonal high water table | Depth from surface | Classification: USDA texture | Classification: Unified |
|---|---|---|---|---|
| | *Feet* | *Inches* | | |
| Kennebec:[3] Kb, Kc | 3–5 | 0–41 | Silt loam | OL or CL or ML-CL |
| | | 41–58 | Silt loam | CL |
| Knox: KnD, KnE, KnF | >5 | 0–16 | Silt loam | ML-CL or CL |
| | | 16–52 | Silty clay loam | ML-CL or CL |
| | | 52–60 | Silt loam | ML-CL or CL |
| Marshall: MaA, MaB, MaB2, MaC, MaC2, MaD, MaD2, MaD3, MaE2, MaE3. | >5 | 0–20 | Silty clay loam | ML-CL or CL |
| | | 20–37 | Silty clay loam | ML-CL or CL |
| | | 37–94 | Silt loam | ML-CL or CL |
| Monona: MoA, MoB, MoB2, MoC, MoC2, MoC3, MoD, MoD2, MoD3, MoE2, MoE3, MoF2, MoF3, MoG3. | >5 | 0–21 | Silt loam | ML-CL or CL |
| | | 21–89 | Silt loam | ML-CL or CL |
| *Napier: NbB, NbC, NbD, NgC, NkB, NkC. For Kennebec and Nodaway parts of NkB and NkC, see Kennebec and Nodaway series. | >5 | 0–31 | Silt loam | OL or CL |
| | | 31–56 | Silt loam | ML-CL or CL |
| Nodaway:[3] No | 3–5 | 0–70 | Silt loam and loam to silt loam | ML-CL or CL |
| Salida: SaD2, SaF2 | >5 | 0–8 | Gravelly loam | SM-SC or SM |
| | | 8–50 | Gravelly sand | SP-SM or SM |
| Shelby: ShC2, ShD2, ShE2, ShF2,[4] SlF, SoD3, SoE3, SoF3, SoG3. | >5 | 0–13 | Loam or clay loam | CL |
| | | 13–60 | Clay loam | CL |
| Sparta: SpC2, SpD2, SpE2 | >5 | 0–14 | Fine sandy loam and loamy fine sand. | SM |
| | | 14–70 | Fine sand | SM or SP–SM |
| Steinauer: SrD3, SrE3 | >5 | 0–70 | Clay loam | CL |
| Zook:[3] | | | | |
| Zo | 1–3 | 0–12 | Silty clay loam | OH or CH |
| | | 12–70 | Silty clay | CH |
| Zs | 1–3 | 0–12 | Silt loam | ML–CL or CL |
| | | 12–24 | Silty clay loam | OH or CH |
| | | 24–70 | Silty clay | CH |

[1] Available water capacity ranges from 0.02 of an inch below to 0.02 of an inch above the figure shown in this column.
[2] Soils seasonally wet because of seepage from more permeable soils upslope.
[3] Soils subject to flooding.

*significant in engineering*—Continued

| Classification—Con. | Percentage passing sieve— | | | Permeability | Available water capacity [1] | Reaction | Shrink-swell potential |
|---|---|---|---|---|---|---|---|
| AASHO | No. 4 (4.7 mm.) | No. 10 (2.0 mm.) | No. 200 (0.074 mm.) | | | | |
| | | | | *Inches per hour* | *Inches per inch of soil* | *pH value* | |
| A-6(8-12) or A-7-6(10-14) | ---------- | 100 | 90-100 | 0. 63-2. 0 | . 22 | 6. 1-6. 5 | Moderate. |
| A-6(8-12) or A-7-6(10-14) | ---------- | 100 | 90-100 | 0. 63-2. 0 | . 19 | 6. 1-6. 5 | Moderate. |
| A-6(10-13) | 100 | 100 | 95-100 | 0. 63-2. 0 | . 21 | 5. 6-6. 0 | Moderate. |
| A-7-6(12-16) | 100 | 100 | 95-100 | 0. 63-2. 0 | . 19 | 5. 6-6. 5 | Moderate. |
| A-6(10-13) | 100 | 100 | 95-100 | 0. 63-2. 0 | . 18 | 6. 1-6. 5 | Moderate. |
| A-7-6(10-14) | ---------- | 100 | 95-100 | 0. 63-2. 0 | . 21 | 6. 1-6. 5 | Moderate. |
| A-7-6(12-18) | ---------- | 100 | 95-100 | 0. 63-2. 0 | . 19 | 6. 1-6. 5 | Moderate or high. |
| A-7-6(10-14) | ---------- | 100 | 95-100 | 0. 63-2. 0 | . 18 | 6. 1-7. 3 | Moderate. |
| A-7-6(10-14) | ---------- | 100 | 95-100 | 0. 63-2. 0 | . 21 | 6. 1-6. 5 | Moderate. |
| A-6(8-12) or A-7-6(10-14) | ---------- | 100 | 95-100 | 0. 63-2. 0 | . 19 | 6. 6-7. 3 | Moderate. |
| A-6(8-12) or A-7-6(10-13) | ---------- | 100 | 95-100 | 0. 63-2. 0 | . 23 | 5. 6-7. 3 | Moderate. |
| A-6(8-12) or A-7-6(10-13) | ---------- | 100 | 95-100 | 0. 63-2. 0 | . 21 | 6. 6-7. 3 | Moderate. |
| A-6(6-10) or A-7-6(10-12) | 100 | 100 | 90-100 | 0. 63-2. 0 | . 19 | 6. 6-7. 3 | Moderate. |
| A-2-4(0) | 80-90 | 70-80 | 20-30 | 2. 0-6. 3 | . 10 | 6. 1-6. 5 | Low. |
| A-2-4(0) or A-1-b(0) | 75-90 | 50-70 | 5-20 | >20. 0 | . 03 | 7. 4-8. 4 | Very low. |
| A-6(8-14) | 85-95 | 80-90 | 50-65 | 0. 2-0. 63 | . 18 | 6. 1-6. 5 | Moderate. |
| A-6(8-14) or A-7-6(12-16) | 85-95 | 80-90 | 50-65 | 0. 2-0. 63 | . 16 | 6. 1-7. 8 | Moderate. |
| A-2-4(0) or A-4(0-2) | 100 | 100 | 20-40 | 6. 3-20. 0 | . 08 | 5. 6-6. 0 | Low. |
| A-2-4(0) or A-3(0) | 100 | 100 | 8-20 | 6. 3-20. 0 | . 04 | 6. 6-8. 4 | Low. |
| A-6(8-14) or A-7-6(12-16) | 90-100 | 80-95 | 55-75 | 0. 2-0. 63 | . 16 | 7. 9-8. 4 | Moderate. |
| A-7-6(16-20) or A-7-5(16-20) | ---------- | 100 | 90-100 | 0. 06-0. 20 | . 19 | 6. 1-6. 5 | High. |
| A-7-6(16-20) | ---------- | 100 | 90-100 | 0. 06-0. 20 | . 17 | 6. 1-6. 5 | High. |
| A-4(8) to A-6(10) | 100 | 95-100 | 90-100 | 0. 63-2. 0 | . 19 | 6. 6-7. 3 | Moderate. |
| A-7-6(16-20) or A-7-5(16-20) | ---------- | 100 | 90-100 | 0. 06-0. 20 | . 19 | 6. 1-6. 5 | High. |
| A-7-6(16-20) | ---------- | 100 | 90-100 | 0. 06-0. 20 | . 17 | 6. 1-6. 5 | High. |

[4] The Shelby cobbly loam soil contains variable amounts, but generally many more cobblestones and stones in the surface layer and throughout than other Shelby soils.

TABLE 4.—*Engineering*

[An asterisk in the first column indicates that at least one mapping unit in this series is made up of two or more kinds of soil. The soils in such mapping units may have different

| Soil series and map symbols | Suitability as source of— | | | | Soil features affecting— | |
|---|---|---|---|---|---|---|
| | Topsoil | Sand | Gravel | Road fill | Highway location | Foundations for low buildings [1] |
| Adair: AdD3, AdE3 | Poor: generally low organic-matter content. | Not suitable | Not suitable | Very poor: subsoil is highly elastic and has high shrink-swell potential; substratum compacts readily to high density. | Strongly sloping and moderately steep; seepage can be expected in cuts. | Slight compressibility; seepy and wet in places; high shrink-swell potential. |
| Chute: ChD3, ChE3 | Poor: thin layer of suitable material; low fertility and organic-matter content. | Fair: poorly graded; fine grained. | Not suitable; lacks gravel. | Good: slight compressibility; low shrink-swell potential; slopes are erodible unless dressed with topsoil. | Moderately sloping to moderately steep; erodible; loose sand can hinder excavation; difficult to vegetate. | Fairly good bearing capacity and shear strength; slight compressibility; low shrink-swell potential; poor resistance to piping. |
| Colo: Co, Cs | Good to fair in Co: silt loam surface overwash. Fair in Cs: moderately fine textured. | Not suitable | Not suitable | Very poor: high organic-matter content to a depth of 3 feet or more; seasonal high water table; poor bearing capacity and shear strength. | Seasonal high water table; subject to flooding; poor foundation for high fills. | Seasonal high water table; poor bearing capacity; high compressibility; subject to flooding. |
| *Dow: DoC2, DoD2, DsD3, DsE3, DwC2, DwD2, DwD3, DwE2, DwE3. For Ida part of DsD3 and DsE3, see Ida series; for Monona part of DwC2, DwD2, DwD3, DwE2, and DwE3, see Monona series. | Fair: low organic-matter content and fertility. | Not suitable | Not suitable | Fair: fair or poor bearing capacity and shear strength; medium compressibility; satisfactory compaction only within a narrow range of moisture content. | Moderately sloping to moderately steep; very erodible. | Fair or poor bearing capacity; medium compressibility; low shrink-swell potential; poor resistance to liquefaction and piping. |
| Gullied land. Properties too variable to interpret. Mapped only with Napier soils. | | | | | | |
| Ida: IdC, IdC3, IdD, IdD3, IdE3, IdF3 | Fair: low organic-matter content and fertility. | Not suitable | Not suitable | Fair: fair or poor bearing capacity and shear strength; satisfactory compaction only within a narrow range of moisture content; low shrink-swell potential. | Moderately sloping to steep; erodible | Fair or poor bearing capacity; medium compressibilty; low shrink-swell potential; poor resistance to liquefaction and piping. |
| * Judson: JdA, JdB, JnB. For Colo and Nodaway parts of unit JnB, see those series; | Good: thick layer of suitable material; high organic-matter content. | Not suitable | Not suitable | Poor: high organic-matter content to a depth of 2 to 3 feet; high compressibility; difficult to compact. | High organic-matter content; some areas subject to local runoff concentration and flooding; low borrow potential. | Fair bearing capacity; high compressibility; some areas subject to local runoff concentration and flooding. |

See footnotes at end of table.

*interpretations*

properties and limitations, and for this reason it is necessary to follow carefully the instructions for referring to other series that appear in the first column of this table]

| Soil features affecting—Continued | | | | | | Degree of limitation for— | |
|---|---|---|---|---|---|---|---|
| Farm ponds | | Agricultural drainage | Irrigation | Terraces and diversions | Grassed waterways | Septic tank disposal fields | Sewage lagoons |
| Reservoir area | Embankment | | | | | | |
| Very slow permeability if compacted; easily compacted. | Fair or good stability; impervious when compacted; high shrink-swell potential in subsoil, moderate below; good for impervious cores. | Seasonally wet because of seepage; tile placed upslope helps to reduce wetness by intercepting runoff. | High available water capacity; slow permeability; strongly sloping or moderately steep. | Subsoil unfavorable for crops and difficult to vegetate; terrace channels likely to be seepy and wet. | Seepy and wet; subsoil unfavorable for crops; difficult to vegetate. | Severe where slopes are more than 9 percent; slow permeability. | Severe where slopes are more than 9 percent. |
| Rapid or very rapid permeability; too porous to hold water. | Pervious when compacted; low shrink-swell potential; poor resistance to piping; erodible. | Not needed; excessively drained. | Very low available water capacity; very rapid intake rate; erodible. | Erodible; difficult to build, maintain, and vegetate. | Very low available water capacity; vegetation is difficult to start; erodible. | Moderate where slopes are 5 to 9 percent; severe where slopes are more than 9 percent; poor filtering material; risk of pollution. | Severe: rapid or very rapid permeability. |
| Uncompacted material has moderately slow permeability; high organic-matter content. | High organic-matter content to a depth of 3 feet or more; poor compaction characteristics; high shrink-swell potential. | Seasonal high water table; subject to flooding; moderately slow permeability. | High available water capacity; medium intake rate; seasonal high water table; subject to flooding. | Terraces not needed; nearly level bottom land. | Seasonal high water table and wetness; features affecting construction and vegetation favorable; not needed in most areas. | Severe: seasonal high water table; subject to flooding; moderately slow permeability. | Moderate: subject to flooding; high in organic-matter content. |
| Uncompacted material has moderate permeability. | Fair or poor stability; difficult to compact to high density; poor resistance to liquefaction and piping; erodible. | Not needed; well drained. | High available water capacity; erodible; moderately sloping to moderately steep. | Soil features favorable for construction; low fertility hinders vegetation. | Erodible; low fertility hinders vegetation. | Moderate where slopes are 5 to 9 percent; severe where slopes are more than 9 percent; moderate permeability. | Moderate where slopes are less than 9 percent; severe where slopes are more than 9 percent; moderate permeability. |
| Uncompacted material has moderate permeability. | Fair or poor stability; difficult to compact to high density; poor resistance to liquefaction and piping; erodible. | Not needed; well drained. | High available water capacity; erodible; moderately sloping to steep. | Features favorable for construction; low fertility hinders vegetation. | Erodible; low fertility hinders vegetation. | Moderate where slopes are 5 to 9 percent; severe where slopes are more than 9 percent; moderate permeability. | Moderate where slopes are less than 9 percent; severe where slopes are more than 9 percent; moderate permeability. |
| Uncompacted material has moderate permeability. | Fair stability; high compressibility; high in organic-matter content; difficult to compact. | Generally not needed; moderate permeability. | High available water capacity; medium intake rate. | Soil features favorable. | Soil features favorable. | Slight: moderate permeability; some areas subject to local runoff concentrations and flooding. | Moderate or severe: some areas subject to local runoff concentrations and flooding; high in organic-matter content; moderate permeability. |

TABLE 4.—*Engineering*

| Soil series and map symbols | Suitability as source of— | | | | Soil features affecting— | |
|---|---|---|---|---|---|---|
| | Topsoil | Sand | Gravel | Road fill | Highway location | Foundations for low buildings [1] |
| Kennebec: Kb, Kc | Good: thick layer of suitable material; high organic-matter content. | Not suitable | Not suitable | Poor: high organic-matter content to a depth of about 3 feet; high compressibilty; difficult to compact. | Nearly level; high organic-matter content; subject to flooding; poor foundation for high fills. | Poor bearing capacity; high compressibility; subject to flooding. |
| Knox: KnD, KnE, KnF | Fair: thin layer of suitable material; high organic-matter content. | Not suitable | Not suitable | Fair: fair or poor bearing capacity and shear strength; fair workability and compaction characteristics. | Moderately sloping to steep; seepage can be expected in some deep cuts. | Fair or poor bearing capacity; medium or high compressibility; moderate shrink-swell potential. |
| Marshall: MaA, MaB, MaB2, MaC, MaC2, MaD, MaD2, MaD3, MaE2, MaE3. | Fair: low organic-matter content in severely eroded soils. | Not suitable except in areas of benches where soils are underlain by sand and gravel. | Not suitable except in areas of benches where soils are underlain by sand and gravel. | Fair: fair or poor bearing capacity and shear strength; fair workability and compaction characteristics; moderate or high shrink-swell potential. | Nearly level to moderately steep; high seepage can be expected in some cuts. | Fair or poor bearing capacity and shear strength; medium or high compressibility; moderate or high shrink-swell potential. |
| Monona: MoA, MoB, MoB2, MoC, MoC2, MoC3, MoD, MoD2, MoD3, MoE2, MoE3, MoF2, MoF3, MoG3. | Good: low organic-matter content in severely eroded soils; thin surface layer in many soils. | Not suitable except in areas of benches where soils are underlain by sand and gravel. | Not suitable except in areas of benches where soils are underlain by sand and gravel. | Fair: fair or poor bearing capacity and shear strength; fair workability and compaction characteristics; moderate shrink-swell potential. | Nearly level to steep; erodible in gutters and on exposed slopes. | Fair or poor bearing capacity and shear strength; medium compressibility; fair or poor resistance to liquefaction and piping. |
| *Napier: NbB, NbC, NbD, NgC, NkB, NkC. For the Kennebec and Nodaway parts of NkB and NkC see those series. | Good: thick layer of suitable material; high organic-matter content. | Not suitable | Not suitable | Poor: high organic-matter content to a depth of 2 feet or more; high compressibility; difficult to compact. | High organic-matter content; some areas subject to local runoff concentration and flooding. | Poor bearing capacity; high compressibility; some areas subject to local runoff concentration and flooding. |
| Nodaway: No | Good: low organic-matter content below surface layer. | Not suitable | Not suitable | Poor: fair or poor bearing capacity and shear strength; difficult to compact. | Nearly level; subject to flooding. | Fair or poor bearing capacity; high compressibility; subject to flooding; high water table in places. |

See footnotes at end of table.

*interpretations*—Continued

| Soil features affecting—Continued | | | | | | Degree of limitation for— | |
|---|---|---|---|---|---|---|---|
| Farm ponds | | Agricultural drainage | Irrigation | Terraces and diversions | Grassed waterways | Septic tank disposal fields | Sewage lagoons |
| Reservoir area | Embankment | | | | | | |
| Generally no sites suitable for farm ponds; high organic-matter content; uncompacted material has moderate permeability. | High in organic-matter content; difficult to compact; high compressibility. | Most areas do not need drainage; subject to flooding; moderate permeability. | High available water capacity; medium intake rate; subject to flooding. | Terraces not needed; soil features favorable for diversions. | Generally not needed; soil features favorable. | Moderate or severe: moderately permeable; subject to flooding; high water table in places. | Moderate or severe: subject to flooding; high in organic-matter content; moderate permeability. |
| Uncompacted material has moderate permeability. | Fair stability; fair workability and compaction characteristics; moderate shrink-swell potential. | Not needed; well drained. | High available water capacity; medium intake rate; moderately sloping to steep; erodible. | Soil features favorable. | Soil features favorable. | Moderate where slopes are 5 to 9 percent; severe where slopes are more than 9 percent; moderate permeability. | Moderate where slopes are less than 9 percent; severe where slopes are more than 9 percent; moderate permeability. |
| Uncompacted material has moderate permeability. | Fair stability; fair workability and compaction characteristics; moderate or high shrink-swell potential. | Not needed; well drained. | High available water capacity; medium intake rate; erodible on sloping soils. | Soil features favorable. | Soil features favorable. | Slight where slopes are less than 5 percent; moderate where slopes are 5 to 9 percent; severe where slopes are more than 9 percent; moderate permeability. | Moderate where slopes are less than 9 percent; severe where slopes are more than 9 percent; moderate permeability. |
| Uncompacted material has moderate permeability. | Fair stability; fair workability and compaction characteristics; fair or poor resistance to liquefaction and piping. | Not needed; well drained. | High available water capacity; subject to runoff and erodibility on sloping soils; medium intake rate. | Soil features favorable. | Soil features favorable. | Slight where slopes are less than 5 percent; moderate where slopes are 5 to 9 percent; severe where slopes are more than 9 percent; moderate permeability. | Moderate where slopes are less than 9 percent; severe where slopes are more than 9 percent; moderate permeability. |
| Uncompacted material has moderate permeability. | High in organic-matter content to a depth of 2 feet or more; difficult to compact; high compressibility. | Not needed; well drained. | High available water capacity; medium intake rate; subject to local runoff concentrations and flooding, erodibility, and gullying in places. | Soil features favorable. | Soil features favorable. | Slight where slopes are less than 5 percent; moderate where slopes are 5 to 9 percent; severe where slopes are 9 percent; subject to short-duration runoff concentrations and flooding. | Moderate or severe where slopes are less than 9 percent; severe where slopes are more than 9 percent; high in organic-matter content; moderate permeability; some areas subject to local runoff concentrations and flooding. |
| Uncompacted material has moderate permeability; generally no sites suitable for farm ponds. | Poor stability at high moisture content; difficult to compact. | Subject to flooding.. | High available water capacity; subject to flooding; medium intake rate. | Terraces not needed; nearly level bottom land. | Generally not needed; soil features favorable. | Severe: subject to flooding. | Severe: subject to flooding; moderate permeability. |

TABLE 4.—*Engineering*

| Soil series and map symbols | Suitability as source of— | | | | Soil features affecting— | |
|---|---|---|---|---|---|---|
| | Topsoil | Sand | Gravel | Road fill | Highway location | Foundations for low buildings[1] |
| Salida: SaD2, SaF2 | Very poor: gravelly; low fertility. | Fair to good: fairly well graded mixtures of sand and gravel; considerable fines in some areas. | Fair to good: fairly well graded mixtures of sand and gravel; considerable fines in some areas. | Good: good bearing capacity; low shrink-swell potential; slight compressibility. | Undulating; good source of subgrade material. | Good bearing capacity and shear strength; low shrink-swell potential. |
| Shelby: ShC2, ShD2, ShE2, ShF2,[2] SlF, SoD3, SoE3, SoF3, SoG3. | Fair: some cobblestones and stones in places. | Not suitable | Not suitable | Good: fair or good bearing capacity; good workability and compaction characteristics; slight compressibility. | Moderately sloping to steep; seepage can be expected in some cuts; good borrow potential for subgrade soil. | Fair or good bearing capacity and shear strength; slight compressibility. |
| Sparta: SpC2, SpD2, SpE2 | Poor: thin layer of suitable material; low organic-matter content and fertility. | Good: fine grained; poorly graded. | Not suitable: lacks gravel. | Good: slight compressibility; low shrink-swell potential; slopes are erodible unless dressed with topsoil. | Moderately sloping to moderately steep; loose sand may hinder excavation; difficult to vegetate. | Fairly good bearing capacity and shear strength; slight compressibility; low shrink-swell potential; poor resistance to piping. |
| Steinauer: SrD3, SrE3 | Poor: low organic-matter content and fertility; cobbly and gravelly in places. | Not suitable | Not suitable | Good: good bearing capacity; slight compressibility; good workability and compaction characteristics. | Strongly sloping and moderately steep; seepage can be expected in some cuts; good borrow potential for subgrade. | Good bearing capacity; slight compressibility. |
| Zook: Zo, Zs | Fair to poor in Zs: silty clay loam texture; fair or good in silt loam overwash part of Zo; fair or poor below. | Not suitable | Not suitable | Very poor: poor bearing capacity; high shrink-swell potential; high organic-matter content to a depth of 3 feet or more. | Highly plastic; high organic-matter content; seasonal high water table; subject to flooding; poor foundation for high fills. | Poor bearing capacity; high shrink-swell potential; seasonal high water table; subject to flooding. |

[1] Engineers and others should not apply specific values to the estimates given for bearing capacity of soils.

*interpretations*—Continued

| Soil features affecting—Continued | | | | | | Degree of limitation for— | |
|---|---|---|---|---|---|---|---|
| Farm ponds | | Agricultural drainage | Irrigation | Terraces and diversions | Grassed waterways | Septic tank disposal fields | Sewage lagoons |
| Reservoir area | Embankment | | | | | | |
| Substratum too porous to prevent excessive seepage. | Good stability; good compaction; slight compressibility; somewhat pervious; fair to poor resistance to piping; stones and boulders in places. | Not needed; excessively drained. | Rapid water intake rate; very low available water capacity; sloping; poor farming potential. | Shallow to sand and gravel; erodible and difficult to vegetate. | Shallow to sand and gravel; difficult to vegetate. | Severe: slope; very rapid permeability; danger of pollution. | Severe: very rapid permeability. |
| Uncompacted material has moderately slow permeability; suitable sites likely for farm ponds. | Fair or good stability; good workability and compaction characteristics; suitable for cores. | Generally not needed; moderately well drained; seepy areas in places. | High available water capacity; moderately sloping to steep; subject to runoff and erosion. | Soil features favorable for construction, except for stones and boulders; subsoil is firm and low in fertility. | Soil features favorable for construction, except for stones and boulders; subsoil is firm and low in fertility. | Severe: slope; moderately slow permeability. | Moderate where slopes are less than 9 percent; severe where slopes are more than 9 percent; moderately slow permeability. |
| Rapid or very rapid permeability; too porous to hold water. | Pervious when compacted; poor resistance to piping; erodible; low shrink-swell potential. | Not needed; excessively drained. | Very low available water capacity; erodible; very rapid intake rate. | Erodible; difficult to maintain and and vegetate. | Erodible; difficult to vegetate; very low available water capacity. | Moderate where slopes are 5 to 9 percent; severe where slopes are more than 9 percent; rapid or very rapid permeability; risk of pollution. | Severe: rapid or very rapid permeability. |
| Uncompacted material has moderately slow permeability; pockets of sand and gravel in places. | Fair or good stability; good workability and compaction characteristics; suitable for cores. | Not needed; well drained. | High available water capacity; strongly sloping and moderately steep; subject to runoff and erosion. | Irregular short slopes; soil features generally favorable for construction but some stones; low fertility; difficult to vegetate. | Erodible; difficult to vegetate. | Severe: slope; moderately slow permeability. | Severe: slopes more than 9 percent; moderately slow permeability. |
| Soil features favorable; generally no sites suitable for farm ponds. | Fair stability; high shrink-swell potential; high organic-matter content. | Seasonal high water table; slowly permeable. | High available water capacity; slowly permeable. | Not needed; nearly level bottom land. | Not needed in most areas; seasonal high water table and wetness. | Severe: slowly permeable; seasonal high water table. | Moderate or severe depending on degree of flooding; high in organic-matter content; slow permeability. |

[2] The Shelby cobbly loam contains variable amounts, but in most places many stones, boulders, and cobblestones occur throughout, which complicates its use for almost any engineering work.

# *Formation and Classification of the Soils*

This section consists of three main parts. In the first part, the factors of soil formation are discussed as they relate to the formation of the soils in the county. The second part discusses the processes of horizon differentiation. In the third part, each soil series represented in the county is placed in its respective family, subgroup, and order according to the current system for classifying soils.

## Factors of Soil Formation

Soil is produced by soil-forming processes acting on materials deposited or accumulated by geologic agents. The characteristics of the soil at any given point are determined by (1) the physical and mineralogical composition of the parent material, (2) the climate under which the soil material has accumulated and existed since accumulation, (3) the plant and animal life on and in the soil, (4) the relief, or lay of the land, and (5) the length of time the forces of soil formation have acted on the soil material.

Climate and plant and animal life, chiefly plants, are active factors of soil formation. They act on the parent material that has accumulated through the weathering of rocks and slowly change it to a natural body that has genetically related horizons. The effects of climate and plant and animal life are conditioned by relief. The parent material also affects the kind of soil profile that is formed and, in extreme cases, determines it almost entirely. Finally, time is needed for changing the parent material into a soil profile. It may be much or little, but some time is always required for differentiation of soil horizons. Generally, a long time is required for the development of distinct horizons.

The factors of soil formation are so closely interrelated that few generalizations can be made regarding the effect of any one factor unless conditions are specified for the other four. Many of the processes of soil development are unknown.

### *Parent material*

The soils of Crawford County formed in loess, glacial till, alluvium, and eolian sands. The bedrock in the county is so deep that it has had little or no influence on the soils. Figures 16 and 17 show a cross section of the soil-parent material relationship.

The several parent materials are discussed briefly in the following paragraphs.

LOESS.—Most of the soils in Crawford County formed in loess, which is a yellowish-brown, wind-deposited material that consists largely of silt particles but has smaller amounts of clay and sand. There are no pebbles or stones, but there are numerous lime concentrations that have formed since the loess was deposited. It is assumed that the loess was calcareous when deposited.

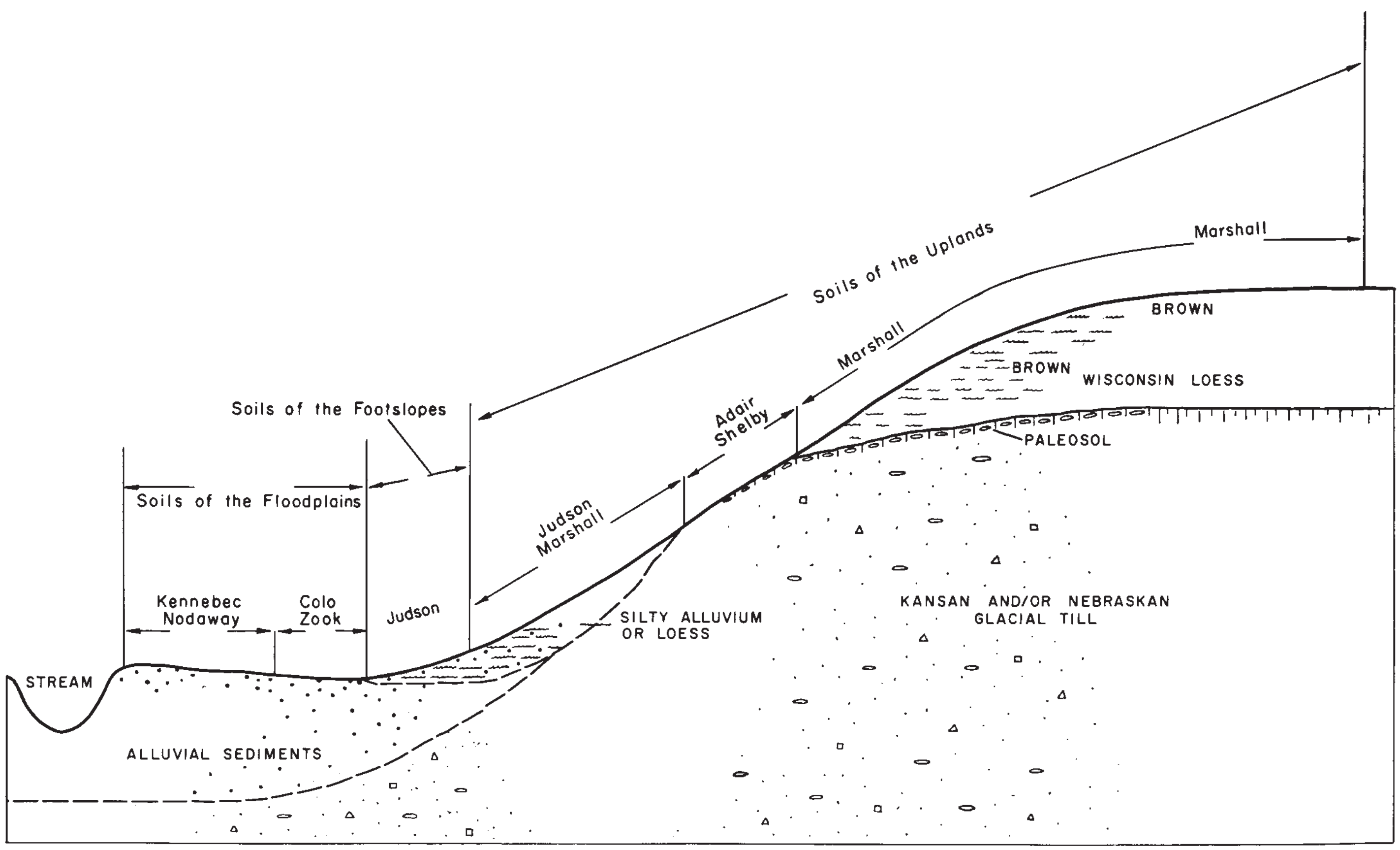


***Figure 16.*—Relationship of parent material to the soils in the eastern part of Crawford County.**

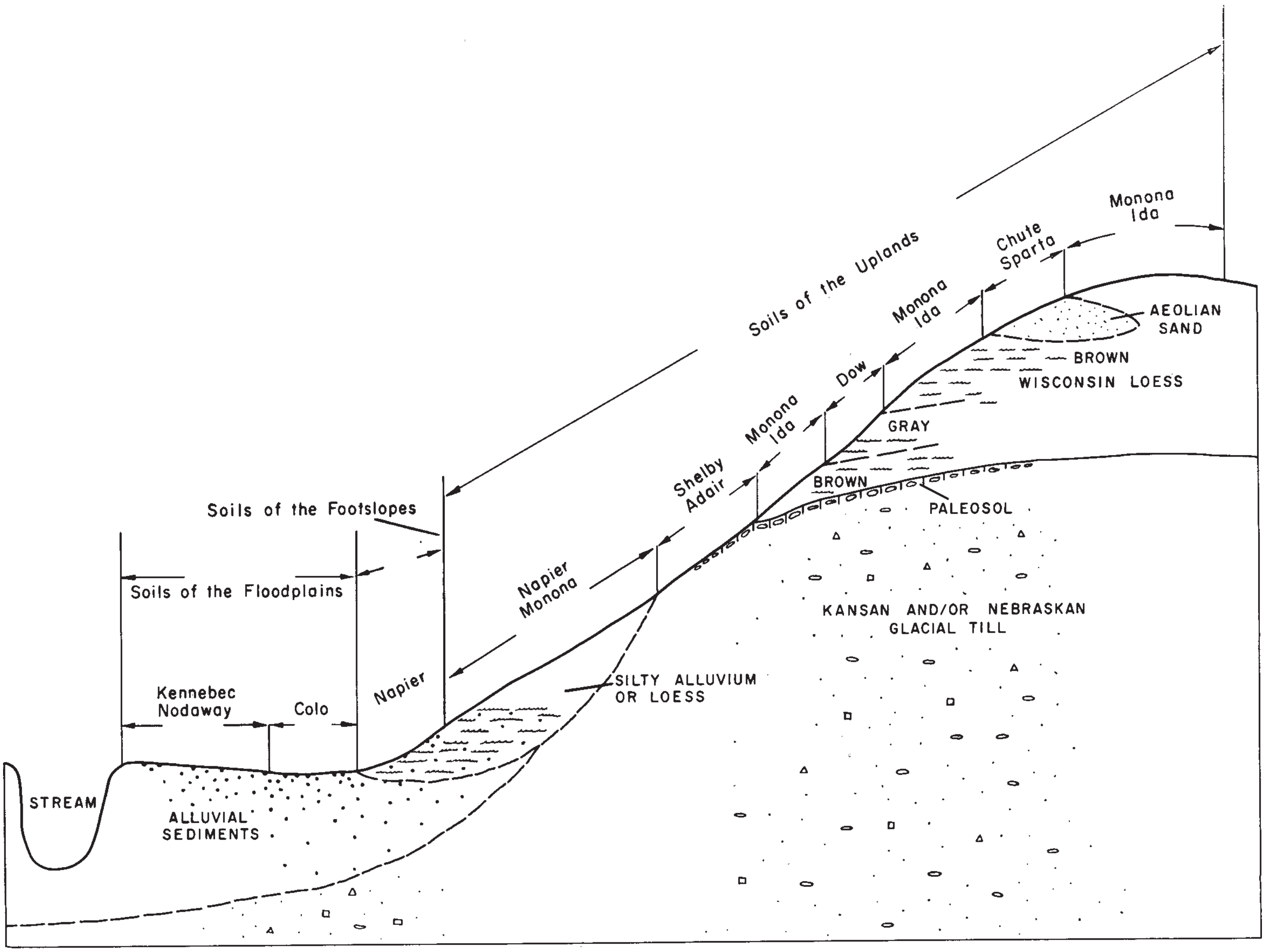


***Figure 17.*—Relationship of parent material to the soils in the western part of Crawford County.**

Most of the upland is occupied by soils that formed in loess. The most extensive soils are those of the Monona, Ida, and Marshall series. Also formed in loess were soils of the Knox and Dow series. Dow series formed in deoxidized and unleached, grayish loess.

The loess is thickest in the western part of the county in the Monona-Ida association. Here the loess is as thick as about 55 feet on the most stable parts of the landscape. The loess thins out in a northeasterly direction and is about 15 to 20 feet thick on stable divides in the northeastern part of the county. It thins out on the side slopes, and in places geologic erosion has removed the loess and glacial till is exposed.

Soils formed in loess provide a good, unrestricted root zone for plants, have high available water capacity, and are generally well aerated.

Glacial till.—Glacial till is the parent material for only a few soils in the county. There are thick glacial till deposits throughout the uplands, but most are covered by loess. The main areas of glacial till exposed in Crawford County are on hillsides along the Boyer River valley and its main tributaries where the loess has been removed by erosion. The acreage occupied by soils derived from glacial till is small.

Crawford County has been subjected to two major glaciations, namely the Nebraskan and the Kansan (*27*). The Nebraskan till is the older and is overlain by the younger Kansan till, which is generally the one that is exposed. The unweathered till is firm, calcareous clay loam. It contains pebbles, boulders, and sand, as well as silt and clay. The till is a heterogeneous mixture that shows little evidence of sorting or stratification. The mineral composition of its components is also heterogeneous and is similar to that of particles of unweathered loess (*10*). Adair, Shelby, and Steinauer soils formed in glacial till.

Soil formation took place on the Kansan till plain during the Yarmouth and Sangamon interglacial stages, before loess was deposited. In nearly level areas the soils were strongly weathered and had a gray clay subsoil called "gumbotil" (*8*, *9*). The gumbotil is several feet thick and is very slowly permeable. It formed during the Yarmouth and Sangamon interglacial stages. Widespread surface erosion has removed paleosols formed in the gumbotil and exposed the less weathered Kansan till and older deposits. The surface is characterized generally by a stone line or subjacent sediment and is surmounted by pedisediment (*13*, *14*). A paleosol formed in the pedisediment stone line and generally in subjacent till. This soil formed during the Sangamon interglacial stage. It was less strongly weathered, more reddish, and not so thick as the Yarmouth-Sangamon paleosol.

Geologic erosion has removed the loess from some slopes in Crawford County and exposed the paleosols. In other places erosion has removed all of the paleosol and has exposed till that is only slightly weathered at the surface. The Adair soils formed where the less strongly weathered reddish paleosols crop out. The strongly weathered gray paleosols of the Yarmouth and Sangamon stages do not crop out to any extent in Crawford County. Shelby and Steinauer soils formed in Kansan till where the overlying paleosols have been removed by geologic erosion.

Alluvium.—Alluvium is the second most important parent material in the county. It consists of sediments deposited along streams and upland drainageways. In Crawford County the texture of the alluvium is mostly silt loam, silty clay loam, or silty clay. Some of the alluvial material has been transported only a short distance, and is called local alluvium. Such alluvium retains many of the characteristics of the soils from which it has eroded. Judson and Napier soils, for example, generally are at the base of slopes below soils formed in loess. They are similar in texture to the soils upslope.

Nodaway soils formed in alluvium that has been partly deposited since the county was settled. It is stratified and is generally near the present stream channel. The Kennebec, Colo, and Zook soils, which are listed in order of increasingly finer texture, formed in alluvium consisting of local sediment washed from nearby uplands and intermixed with sediment washed from greater distances. These soils are older and darker colored than the Nodaway soils. Kennebec soils are generally near streams, and in many places Colo soils are also near streams. Zook soils are generally farther from stream channels in nearly level to somewhat depressed areas where finer textured sediments have been deposited.

Alluvial materials that are mostly sand and gravel are on benches, mainly along the Boyer River. They consist mostly of outwash from retreating glaciers (*3*), but they generally have a loess mantle. The Marshall and Monona soils formed in this loess on benches. In places pits have been dug and the sand and gravel are being used for surfacing roads or for other uses. Salida soils are the only soils in the county that formed in these coarse materials. They are mainly on valley side slopes and points of narrow ridges along the Boyer River and near the mouths of some of its larger tributaries. Here, the loess has been removed, and the coarse sediments in which Salida soils formed are exposed.

Eolian sand.—This is a minor parent material in the county. It was deposited by wind, mainly on north- and west-facing slopes along the Boyer River and along the lower reaches of its major tributaries in the southwestern part of the county. Sandy sediments in the stream valleys were probably the source of these sands. They were blown up onto slopes along the streams.

Chute and Sparta soils formed in this parent material. Individual areas are typically small. Chute soils are calcareous, and Sparta soils have been leached and are slightly acid or medium acid in the surface layer. They are droughty and low in fertility.

Eolian sand consists chiefly of quartz, which is very resistant to weathering. It has not been altered much since it was deposited. Soils formed in it have a high content of sand and a low content of clay.

### *Climate*

Crawford County soils, according to recent evidence, formed under variable climatic conditions. In the post-Cary graciation period, from about 13,000 to 10,500 years ago, the climate was cool and the vegetation was dominantly conifers (*26*). During the period from 10,500 to 8,000 years ago, there was a warming trend and a change in vegetation from conifers to mixed forest. Hardwood species were prominent. Beginning about 8,000 years ago, the climate became warmer and drier. Herbaceous prairie fauna became dominant and continued to be so to the present time. A late change in postglacial climate from relatively dry prairie to more humid conditions may have begun about 3,000 years ago. (*11*). The present climate is midcontinental subhumid.

Nearly uniform climate prevails throughout the county, and differences in general climate have not caused major differences in the soils. The influence of the general climate is modified by local conditions. For example, north- and east-facing slopes tend to be cooler and more moist than south-facing slopes, and in this climatic region, natural stands of trees are more likely to grow. Knox soils formed under trees and grass and are mainly on north- and east-facing slopes. A low-lying, poorly drained soil, such as a Zook soil, tends to be cooler and wetter than most areas around it.

Weathering of the parent material by water and air is activated by changes in temperature. As a result of weathering, changes caused by both physical and chemical actions take place. Rainfall has influenced the formation of the soils through its effect on the amount of leaching in soils and on kinds of plants that grow. Some variations in plant and animal life are caused by variations in temperature or by the action of other climatic forces on the soil material. To that extent, climate influences changes in soils that are brought about by differences in plant and animal populations.

### *Plant and animal life*

A number of kinds of living organisms are important in soil formation. The activities of burrowing animals, worms, crayfish, and micro-organisms, for example, are reflected in soil properties. But differences in the kind of vegetation commonly cause the most marked differences among soils (*12*).

In Crawford County tall prairie grasses were the dominant vegetation at the time of settlement (*5*). The trees were mainly on slopes that border the Boyer River but were also along some of the tributary streams. They are likely to be on north- and east-facing slopes.

Soils formed under prairie vegetation typically have a thicker, darker colored surface layer than soils formed under trees, because grasses have many roots and tops that have decayed or are in the soil. Under trees, the organic matter, derived principally from leaves, was deposited mainly on the surface of the soil. Soils that formed under trees generally are more acid than those formed under grass. Marshall and Monona soils are typical of those soils that formed under prairie vegetation. Soils, such as Knox soils, however, have properties that are intermediate between soils formed entirely under trees and those formed under grass. It is believed that Knox soils first developed under prairie grasses and then later trees encroached. Knox soils are the only ones in the county that have been markedly influenced by trees.

Man has had marked influence on soils because of the changes that have taken place in them as a result of his use. Changes caused by water erosion are generally the most apparent. On many of the cultivated soils in the county, part or all of the original surface layer has been lost through sheet erosion. In some places gullies have formed. Tillage alters the structure of the surface layer of the soil. Less obvious are chemical changes brought about by additions of lime and fertilizer and changes in microbial activity and organic-matter content that result from removing the native vegetation and substituting crops.

### *Relief*

Relief ranges from nearly level to steep in Crawford County. It is an important factor in soil formation because of its effect on drainage, runoff, the height of the water table, and erosion. A difference in topography is the basic reason for the differing soil properties of some of the soils in the county.

Even though soils formed in the same parent material, the influence of relief is seen in the color, thickness of the solum, and horizonation of the soils. Ida and Monona soils are examples of soils that formed in similar parent material but that differ in characteristics mainly because of relief. Most of the well-drained Monona soils are on slopes where some of the water runs off. Most of the Ida soils, however, are steeper, more of the water runs off, and erosion has occurred at such a rate that little soil formation has taken place. This accounts for the fact that Monona soils have a thicker, darker colored surface layer than Ida soils and are leached of carbonates, and Ida soils are calcareous at or near the surface. Also, slope affects runoff that, in turn, affects the amount of moisture available for plants. The lack of available moisture restricts plant growth on some of the steeper Ida, Monona, and Shelby soils. This accounts for the difference in the thickness and organic-matter content of the surface layer of these soils and less sloping soils in the same and other series.

Relief affects the color of the B horizon through its effect on drainage and soil aeration. The subsoil of a soil that has good drainage generally is brown because iron compounds are well distributed throughout the horizon and are oxidized. On the other hand, the subsoil of soils that have restricted drainage is generally grayish and mottled. Monona soils are examples of soils that are well drained. Colo soils are poorly drained.

### *Time*

The passage of time enables the factors of relief, climate, and plant and animal life to bring about changes in the parent material. Very similar kinds of soils form from widely different kinds of parent material if other factors continue to be active over long periods of time. But soil formation is generally interrupted by geologic events that expose new parent material.

New parent material has been added to the upland at least three times (*21*). The bedrock has been covered by glacial drift from two different glaciers. Then the present surface material, the loess, was deposited. As a result, soils have been buried and further development of these soils has stopped (*13*).

Adair soils are very old and formed in Kansan till that probably weathered for more than 115,000 years before they were covered by loess (*9*). More recently, the material has been exposed to weathering again when the loess was removed by erosion.

The radiocarbon technique for determining the age of carbonaceous material found in loess and till has been useful in dating soils formed partly in Wisconsin age (*16*, *17*). Loess deposition began about 25,000 years ago and continued to about 14,000 years ago. Based on these dates, the age of nearly level loess soils on stable divides is about 14,000 years. In Crawford County these stable areas include nearly level Marshall and Monona soils and most of the gently sloping divides occupied by these soils.

In much of Iowa, including Crawford County, geologic erosion has beveled, and in places removed, material on side slopes and deposited new sediments downslope (*15*). The surface of nearly level upland divides is older than the slopes that bevel and ascend to the divides. Thus, the side slopes are less than 14,000 years old. The base of the local alluvium in some stream valleys is less than 1,800 years old (*4*). Because the sediments from the side slopes accumulated to form the alluvium, the surfaces of the side slopes in these areas are also less than 1,800 years old. Some of the soils that formed in these and similar areas of alluvium include Napier, Kennebec, Colo, and Judson soils. The Nodaway soils formed in alluvium, some of which was deposited since settlement by man.

The percentages of land surfaces that are about 14,000 years old and less than 14,000 years old can be obtained by extrapolating soil data by landscapes in counties that have completed soil surveys (*6*). In Crawford County, only about 9 percent of the soils are as old or older than 14,000 years. About 91 percent are younger than 14,000 years.

## Processes of Horizon Differentiation

Horizon differentiation occurs because of four basic kinds of changes. These are additions, removals, transfers, and transformations in the soil system (*19*). Each of these four kinds of changes affect many substances that make up soil. For example, there are additions, removals, transfers, or transformations of organic matter, soluble salts, carbonates, sesquioxides, or silicate clay minerals.

In general, these processes tend to promote horizon differentiation, but some tend to offset or retard it. These processes, and the changes brought about, proceed simultaneously in soils, and the ultimate nature of the profile is governed by the balance of these changes within the profile.

Addition of organic matter is an early step in the process of horizon differentiation in most soils. In some soils in Crawford County the darkened surface layer is the only soil feature that reflects to any degree the basic processes mentioned above. The Ida and Steinauer soils are examples.

The process of removal of substances from parts of the soil profile is very important in the differentiation of soil horizons in Crawford County. This process accounts for some of the most obvious differences between a number of soils in the county. The movement of calcium carbonates downward in the soil material as a result of leaching is an example. In soils such as Ida and Steinauer soils, little calcium carbonate has been removed, so they are calcareous at or near the surface. In many places there are lime concretions on the surface. No B horizon has developed in these soils. Soil scientists consider that in Monona and Shelby soils, calcium carbonate has been removed by leaching from the upper parts of their profiles. This removal, along with other processes, has resulted in the differentiation of a B horizon in these soils. The Monona and Ida soils formed in calcareous loess, and Shelby and Steinauer soils formed in glacial till.

A number of kinds of transfers of substances from one horizon to another are evident in the soils of Crawford County. Phosphorus is removed from the subsoil by plant roots and transferred to parts of the plant growing above the ground. Then it is added to the surface layer in the plant residue.

The translocation of clay minerals is an important process in horizon differentiation. The clay minerals are carried downward from the A horizon in suspension in percolating water. They accumulate in the B horizon in pores and root channels and as clay films on ped faces. In Crawford County only Adair, Shelby, and Knox soils show much evidence of this process. In other soils, the clay content of the A and B horizons is not markedly different and other evidence of clay movement is minimal. Another kind of transfer that is minimal in most soils, but occurs to some extent in very clayey soils, is that brought about by shrinking and swelling. This causes cracks to form and the incorporation of some materials from the surface layer into lower parts of the profile. Zook soils are the only ones in Crawford County that have much potential for these kinds of physical transfers.

Transformations are physical and chemical. For example, soil particles are weathered to smaller sizes. This process is called gleying and involves the saturation of soil with water for long periods of time in the presence of organic matter. It is characterized by the presence of ferrous iron and of gray colors. Gleying is associated with poorly drained and very poorly drained soils.

Still another kind of transformation is the weathering of the primary apatite mineral present in soil parent materials to secondary phosphorus compounds. According to theory, the pH must decline to about 7 before appreciable amounts of this weathering take place (*7*, *18*). This is important in Crawford County because it helps explain the difference in available phosphorus levels between soils formed in similar calcareous parent materials. For example, Ida soils, which are calcareous, are very low in available phosphorus. In Monona soils, which have been leached and are about neutral, the available phosphorus, although low, is in better supply than in Ida soils.

## Classification of the Soils

Two systems of classifying soils have been used in the United States in recent years. The older system was adopted in 1938 (*2*) and later revised (*22*). The system currently used was adopted for general use by the National Cooperative Soil Survey in 1965 and supplemented in March 1967 and September 1968 (*24*). This system is under continual study, and readers interested in the development of the system should refer to the latest literature available.

The current system of classification defines classes in terms of observable or measurable properties of soils (*20*). It has six categories. Beginning with the most inclusive, the categories are the order, suborder, great group, subgroup, family, and series. The placement of some soil series, particularly in families, may change as more precise information becomes available. Because they do not fit in a series that has been recognized, some of the soils in this county have been placed in a series that they strongly resemble and from which they differ only in ways that do not significantly affect their usefulness or behavior. These soils are called taxadjuncts to the series for which they are named.

Table 5 shows the classification of the soil series in Crawford County according to the current system. Following are brief descriptions of the six categories.

ORDER.—Soils are grouped into orders according to properties that seem to have resulted from the processes acting to about the same degree on the parent material. Ten soil orders are recognized in the current system: Entisols, Vertisols, Inceptisols, Aridisols, Mollisols, Spodosols, Alfisols, Ultisols, Oxisols, and Histosols. The properties used to differentiate the soil orders are those that tend to give broad climatic groupings of soils. Two exceptions, Entisols and Histosols, are in many different climates. Three of the ten soil orders occur in this county: Entisols, Mollisols, and Alfisols.

Entisols are recent soils in which there has been little, if any, horizon development. This order is represented in Crawford County by soils of the Chute, Dow, Ida, Nodaway, and Steinauer series.

Mollisols have a thick, dark-colored surface layer and base saturation of more than 50 percent. This order is represented by soils of the Adair, Colo, Judson, Kennebec, Marshall, Monona, Napier, Salida, Shelby, Sparta, and Zook series.

Alfisols have a clay-enriched B horizon and a base saturation of more than 35 percent. This order is represented by soils of the Knox series.

SUBORDER.—Each order is divided into suborders, primarily on the basis of soil characteristics that seem to produce classes having the greatest genetic similarity. The soil properties used are mainly those that reflect either the presence or absence of waterlogging or differences in climate or vegetation. The climatic range of the suborders is narrower than that of the orders.

TABLE 5.—*Classification of soil series by higher categories*

| Series | Family | Subgroup | Order |
|---|---|---|---|
| Adair [1] | Fine, montmorillonitic, mesic | Aquic Argiudolls | Mollisols. |
| Chute | Mixed, mesic | Typic Udipsamments | Entisols. |
| Colo | Fine-silty, mixed, noncalcareous, mesic | Cumulic Haplaquolls | Entisols. |
| Dow | Fine-silty, mixed, calcareous, mesic | Typic Udorthents | Entisols. |
| Ida | Fine-silty, mixed, calcareous, mesic | Typic Udorthents | Entisols. |
| Judson | Fine-silty, mixed, mesic | Cumulic Hapludolls | Mollisols. |
| Kennebec | Fine-silty, mixed, mesic | Cumulic Hapludolls | Mollisols. |
| Knox | Fine-silty, mixed, mesic | Mollic Hapludalfs | Alfisols. |
| Marshall [1] | Fine-silty, mixed, mesic | Typic Hapludolls | Mollisols. |
| Monona [1] | Fine-silty, mixed, mesic | Typic Hapludolls | Mollisols. |
| Napier | Fine-silty, mixed, mesic | Cumulic Hapludolls | Mollisols. |
| Nodaway | Fine-silty, mixed, nonacid, mesic | Typic Udifluvents | Entisols. |
| Salida | Sandy-skeletal, mixed, mesic | Entic Hapludolls | Mollisols. |
| Shelby [1] | Fine-loamy, mixed, mesic | Typic Argiudolls | Mollisols. |
| Sparta [1] | Sandy, mixed, mesic | Entic Hapludolls | Mollisols. |
| Steinauer | Fine-loamy, mixed, calcareous, mesic | Typic Udorthents | Entisols. |
| Zook | Fine, montmorillonitic, noncalcareous, mesic. | Cumulic Haplaquolls | Mollisols. |

[1] In this county these soils are taxadjuncts to the series for which they are named because of the following characteristics: Adair soils and severely eroded units of Marshall, Monona, and Shelby soils have a surface horizon that is thinner or lighter colored, or both, than is defined as the range for the series. Sparta soils have a surface horizon that is thinner and a subsoil that is more acid than is defined as the range for the series.

GREAT GROUP.—Each suborder is divided into great groups on the basis of uniformity in the kinds and sequence of major horizons and soil features. The horizons considered are those in which clay, iron, or humus has accumulated and those that have pans that interfere with the growth of roots or the movement of water. The features considered are the self-mulching properties of clays, soil temperature, chemical composition (mainly calcium, magnesium, sodium, and potassium), and the like.

SUBGROUP.—Each great group is divided into subgroups, one representing the central (typic) segment of the group, and other groups, called intergrades, that have properties of one great group and also one or more properties of another great group, suborder, or order. Subgroups are also made in those instances where soil properties intergrade outside the range of any other great group, suborder, or order.

FAMILY.—Families are established within a subgroup, primarily on the basis of properties that affect the growth of plants or the behavior of soils when used for engineering purposes. Among the properties considered are texture, mineralogy, reaction, soil temperature, permeability, thickness of horizons, and consistence.

SERIES.—The series is a group of soils that have major horizons that, except for texture of the surface layer, are similar in important characteristics and in arrangement in the profile.

## *General Nature of the County*

This section discusses the early history and settlement, transportation, climate, topography, and farming of the county.

The area that includes Crawford County was ceded to the United States in 1830 by a treaty with the Sac, Fox, and other Indian tribes. Settlers began moving into the area, and by 1850 most of the timbered land had been claimed; then the prairie lands were settled.

The boundaries of Crawford County were defined by the State Legislature in 1851 and enlarged by one tier of townships on the west in 1865. Denison became the county seat in 1865.

The Rural Electric Cooperative was organized in 1936, and this aided in the development of farming in Crawford County.

State and U.S. highways provide routes for auto traffic and for transporting farm products to market. The asphalt and graveled county roads enable farmers to come to the trading centers throughout the year. Railroads cross the county in both east-west and north-south directions and serve many of the towns in the county. The first railroad tracks in the county were laid in 1867. Bus transportation is available in many parts of the county, and motor freight lines serve most of the trading centers.

### Climate [4]

Crawford County, in west-central Iowa, is mostly within the Boyer River drainage system, which slopes southwestward. The Nishnabotna River traverses the extreme southeastern part of the county, and the Soldier River drains the northwestern townships.

The climate at Denison, near the mouth of the fork of the Boyer River, is representative of the county, because elevational changes in the county are relatively small. The most noticeable climatic variations involve minimum temperatures, most marked in calm, clear parts of air masses and the warm-season showers.

Annual precipitation, averaging 28 to 29 inches, increases slightly from northwest to southeast. About 75 percent of the annual precipitation falls during the warm part of the year, April through September. About 20 days per year have half an inch or more of rainfall. This

[4] By PAUL J. WAITE, climatologist for Iowa, National Weather Service, U.S. Department of Commerce.

rain falls mostly during the warm part of the year when the ground is unfrozen and has been tilled. The hazard of erosion, most severe in the western townships, reaches maximum late in the spring and early in summer. Heavy showers are most frequent in May and June, before most crops establish adequate ground cover and root systems. Because most showers cover only a few miles, rainfall variations are generally very marked, even though seasonal totals tend to obscure the variations. About 10 percent of the annual precipitation falls as snow. Snowfall averages about 25 inches a year and falls mainly from November through March.

At crop planting time there is preferably ample subsoil moisture and the surface layers are relatively dry. Well-spaced, gentle showers thereafter throughout the growing season are desirable. Variations from the desired pattern are frequent, however, and on occasion extreme. May and June are normally the rainiest months. Dry periods are most likely in late July and August. Except in the early growth stages, corn requires about an inch of moisture per week for optimum growth. The probability of an inch of rainfall per week in June is about two in five and decreases to about one in four during most of July and August. Ample subsoil water supplies each spring at planting time are important, because rainfall is rarely abundant enough to supply the crop needs throughout the season. Most soils in the county have high available water capacity; however, some soils have rapid runoff, and these soils are seldom at capacity.

On calm, clear nights, minimum temperatures vary as much as 10° F. or more between the warmer urban and upland localities and the rural lowland areas into which cold air drains. Optimum crop growth is normally limited by temperatures of 90° or higher. These temperatures occur on an average of 20 to 25 days per year. The evapotranspiration on these days generally causes plant stress that limits growth and development.

Tables 6 and 7 give temperature and precipitation data recorded at Denison.

## Farming

This section discusses farming in Crawford County. Unless otherwise stated, the data given are from the 1967 Iowa Annual Farm Census, published by the Iowa Department of Agriculture, Division of Agricultural Statistics.

Farming is the main enterprise in Crawford County. The farming is diversified and includes crop production and livestock raising. About 97 percent of the county, or 446,753 acres, is in farms. The average size of the farms is 248 acres. In 1967 only 49.9 percent of the area was farmed by the owners; the rest was operated by tenants. The trend for a number of years has been for the farm population and the number of farms to decrease, and for the size of the farms to increase.

Corn is the most extensive crop grown. Most of the corn is fed to livestock on the farms, and the rest is sold. Other crops grown include soybeans, oats, hay, wheat, sorghum, and popcorn. The acreage in wheat and sorghum is very small. Oats and hay are grown mostly in rotation with corn and soybeans. Hay crops are primarily mixtures of alfalfa and grasses. The permanent pastures are generally unimproved, and the vegetation is primarily Kentucky bluegrass. Renovated pastures consist mostly of grass-legume mixtures, and bromegrass or orchardgrass and alfalfa or red clover are common.

In recent years, the acreage in corn has decreased slightly, while the acreage in soybeans has greatly increased. The acreage in oats and hay has also decreased.

TABLE 6.—*Temperature and precipitation data*

[Data from the station at Denison, elevation 1,401 feet; based on records for the period 1931–60]

| Month | Temperature | | | | Precipitation | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Average daily maximum | Average daily minimum | Average yearly | | Average total | One year in 10 will have— | | Average days with snow cover 1 inch or more | Average depth of snow on days with snow cover 1 inch or more |
| | | | Average highest | Average lowest | | Less than— | More than— | | |
| | ° F. | ° F. | ° F. | ° F. | Inches | Inches | Inches | Number | Inches |
| January | 30 | 10 | 49 | −16 | 0.75 | 0.12 | 1.60 | 18 | 3 |
| February | 33 | 13 | 53 | −12 | .92 | .18 | 1.92 | 15 | 3 |
| March | 45 | 24 | 71 | 2 | 1.42 | .41 | 2.72 | 8 | 3 |
| April | 61 | 37 | 82 | 20 | 2.59 | .80 | 4.80 | (1) | 1 |
| May | 72 | 48 | 88 | 32 | 3.96 | 1.78 | 6.73 | | |
| June | 80 | 58 | 93 | 43 | 4.60 | 2.22 | 7.97 | | |
| July | 86 | 63 | 97 | 50 | 3.60 | 1.43 | 6.10 | | |
| August | 84 | 61 | 96 | 46 | 3.65 | 1.70 | 6.69 | | |
| September | 76 | 52 | 91 | 32 | 3.12 | .77 | 6.00 | | |
| October | 65 | 41 | 83 | 21 | 2.02 | .45 | 3.89 | | |
| November | 47 | 26 | 68 | 5 | 1.24 | .12 | 2.52 | 4 | 3 |
| December | 34 | 15 | 53 | −8 | .75 | .14 | 1.51 | 7 | 2 |
| Year | 59 | 37 | | | 28.62 | | | 52 | 3 |

[1] Less than half a day.

TABLE 7.—*Probabilities of freezing temperatures in spring and fall*

[All data from Denison, elevation 1,401 feet, based on records for the period 1931–60]

| Probability | Dates for given probability and temperature | | | | |
|---|---|---|---|---|---|
| | 16° F. or lower | 20° F. or lower | 24° F. or lower | 28° F. or lower | 32° F. or lower |
| Spring | | | | | |
| 1 year in 10 later than | April 8 | April 14 | April 24 | May 9 | May 17 |
| 2 years in 10 later than | April 3 | April 9 | April 20 | May 4 | May 12 |
| 5 years in 10 later than | March 25 | March 31 | April 11 | April 24 | May 3 |
| Fall: | | | | | |
| 1 year in 10 earlier than | October 23 | October 18 | October 9 | October 3 | September 22 |
| 2 years in 10 earlier than | October 29 | October 23 | October 15 | October 8 | September 26 |
| 5 years in 10 earlier than | November 8 | November 2 | October 25 | October 17 | October 4 |

The yields of crops have been steadily increasing because of the use of more fertilizer and lime, more productive facilities, better erosion control, and improved management. The acreage of crops in Crawford County in 1967 was as follows: Corn, 148,312; oats, 33,400; soybeans, 37,932; popcorn, 6,284; all hay, 46,556; and all pasture, 108,742.

The feeding of beef cattle and hogs is the most important livestock enterprise. Many of the beef cattle are bought out of the State and trucked into the county for feeding. Hogs are mostly farrowed and fed on the same farm, but some feeder pigs are brought in. The beef cattle and hogs are marketed at the packing plants in Denison and at other marketing centers, including Omaha and Sioux City.

The numbers of beef cattle, hogs, and lambs fed in the county are increasing. Dairy cows and heifers on hand are decreasing, but beef cows and heifers on hand are increasing. The production of chickens has decreased; turkey production has been variable, but the general trend is to increased numbers.

The numbers of the principal kinds of livestock raised and sold or on hand in 1967 were as follows: grain-fed cattle marketed, 72,098; grain-fed sheep and lambs marketed, 19,616; sows farrowed, 39,897; milk cows, 6,538; beef cows, 19,004; hens and pullets of laying age, 213,770; commercial broilers produced, 2,700; and turkeys raised, 26,031.

## Topography

Crawford County is part of a large upland plain that slopes generally to the southwest and drains into the Missouri River. The once relatively smooth plain has been incised by streams, and the topography varies from nearly level to steep. Generally, the surface of the upland is characterized by rounded ridges and smooth slopes to the stream channels. Some areas are quite hilly and have steep slopes to the streams. The most hilly and sharply dissected areas are in the southwestern part of the county. The eastern part of the county has more uniform topography and is generally gently rolling. Stream channels are not so deeply incised, and erosion has not been so severe as in the rougher areas of the county.

The county has a well-developed natural drainage system, and streams and intermittent drainageways extend into all parts. Eventually, all of the drainage goes into the Missouri River. The Boyer River and its tributaries are the primary drainage system that extends from the northeastern to the southwestern part of the county. Some of the larger tributaries of the Boyer River are Buffalo, Otter, Tucker, Trinkle, and Beaman Creeks. Soldier, Middle Soldier, and East Soldier Rivers and Beaver Creek are the principal streams in the northwestern part of the county. Willow, Middle Willow, and South Willow Creeks drain the southwestern part of the county and flow generally parallel to the Boyer River. The Nishnabotna River and its tributaries drain the southeastern part of the county. The channels of the Boyer, Soldier, and Nishnabotna Rivers have been straightened and enlarged, which largely eliminates damage from floods. In some places artificial drainage channels have been constructed at the junction of the creeks with the major stream to reduce flooding.

The soils on uplands in the county are mainly well drained. Colo and Zook soils in the bottom lands are poorly drained. In places artificial drainage is needed to achieve the most intensive use of these soils.

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## Glossary

**Alluvial fan.** A fan-shaped deposit of sand, gravel, and fine material dropped by a stream where its gradient lessens abruptly.

**Alluvium.** Soil material, such as sand, silt, or clay, that has been deposited on land by streams.

**Available water capacity** (also termed available moisture capacity). The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field capacity and the amount at wilting point. It is commonly expressed as inches of water per inch of soil.

**Calcareous soil.** A soil containing enough calcium carbonate (often with magnesium carbonate) to effervesce (fizz) visibly when treated with cold, dilute hydrochloric acid.

**Clay.** As a soil separate, the mineral soil particles less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

**Clay film.** A thin coating of clay on the surface of a soil aggregate. Synonyms: clay coat, clay skin.

**Concretions.** Grains, pellets, or nodules of various sizes, shapes, and colors consisting of concentrations of compounds, or of soil grains cemented together. The composition of some concretions is unlike that of the surrounding soil. Calcium carbonate and iron oxide are examples of material commonly found in concretions.

**Consistence, soil.** The feel of the soil and the ease with which a lump can be crushed by the fingers. Terms commonly used to describe consistence are—

*Loose.*—Noncoherent when dry or moist; does not hold together in a mass.

*Friable.*—When moist, crushes easily under gentle pressure between thumb and forefinger and can be pressed together into a lump.

*Firm.*—When moist, crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.

*Plastic.*—When wet, readily deformed by moderate pressure but can be pressed into a lump; will form a "wire" when rolled between thumb and forefinger.

*Sticky.*—When wet, adheres to other material, and tends to stretch somewhat and pull apart, rather than to pull free from other material.

*Hard.*—When dry, moderately resistant to pressure; can be broken with difficulty between thumb and forefinger.

*Soft.*—When dry, breaks into powder or individual grains under very slight pressure.

*Cemented.*—Hard and brittle; little affected by moistening.

**Contour farming.** Plowing, cultivating, planting, and harvesting in rows that are at right angles to the natural direction of the slope or that are parallel to terrace grade.

**Drainage class** (natural). Refers to the conditions of frequency and duration of periods of saturation or partial saturation that existed during the development of the soil, as opposed to altered drainage, which is commonly the result of artificial drainage or irrigation but may be caused by the sudden deepening of channels or the blocking of drainage outlets. Seven different classes of natural soil drainage are recognized.

*Excessively drained* soils are commonly very porous and rapidly permeable and have a low water-holding capacity.

*Somewhat excessively drained* soils are also very permeable and are free from mottling throughout their profile.

*Well-drained* soils are nearly free from mottling and are commonly of intermediate texture.

*Moderately well drained* soils commonly have a slowly permeable layer in or immediately beneath the solum. They have uniform color in the A and upper B horizons and have mottling in the lower B and the C horizons.

*Somewhat poorly drained* soils are wet for significant periods but not all the time, and some soils commonly have mottling at a depth below 6 to 16 inches.

*Poorly drained* soils are wet for long periods and are light gray and generally mottled from the surface downward, although mottling may be absent or nearly so in some soils.

*Very poorly drained* soils are wet nearly all the time. They have a dark-gray or black surface layer and are gray or light gray, with or without mottling, in the deeper parts of the profile.

**First bottom.** The normal flood plain of a stream, subject to frequent or occasional flooding.

**Flood plain.** Nearly level land, consisting of stream sediments, that borders a stream and is subject to flooding unless protected artificially.

**Horizon, soil.** A layer of soil, approximately parallel to the surface, that has distinct characteristics produced by soil-forming processes. These are the major horizons:

*O horizon.*—The layer of organic matter on the surface of a mineral soil. This layer consists of decaying plant residues.

*A horizon.*—The mineral horizon at the surface or just below an O horizon. This horizon is the one in which living organisms are most active and therefore is marked by the accumulation of humus. The horizon may have lost one or more of soluble salts, clay, and sesquioxides (iron and aluminum oxides).

*B horizon.*—The mineral horizon below an A horizon. The B horizon is in part a layer of change from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics caused (1) by accumulation of clay, sesquioxides, humus, or some combination of these; (2) by prismatic or blocky structure; (3) by redder or stronger colors than the A horizon; or (4) by some combination of these. Combined A and B horizons are usually called the solum, or true soil. If a soil lacks a B horizon, the A horizon alone is the solum.

*C horizon.*—The weathered rock material immediately beneath the solum. In most soils this material is presumed to be like that from which the overlying horizons were formed. If the material is known to be different from that in the solum, a Roman numeral precedes the letter C.

*R layer.*—Consolidated rock beneath the soil. The rock usually underlies a C horizon but may be immediately beneath an A or B horizon.

**Leaching.** The removal of soluble materials from soils or other material by percolating water.

**Mottled.** Irregularly marked with spots of different colors that vary in number and size. Mottling in soils usually indicates poor aeration and lack of drainage. Descriptive terms are as follows: Abundance—*few, common,* and *many;* size—*fine, medium,* and *coarse;* and contrast—*faint, distinct,* and *prominent.* The size measurements are these: *fine,* less than 5 millimeters (about 0.2 inch) in diameter along the greatest dimension; *medium,* ranging from 5 millimeters to 15 millimeters (about 0.2 to 0.6 inch) in diameter along the greatest dimension; and *coarse,* more than 15 millimeters (about 0.6 inch) in diameter along the greatest dimension.

**Organic matter.** A general term applied to a soil or a soil horizon that consists primarily of organic matter, such as peat soils, muck soils, and peaty soil layers. In chemistry, organic refers to the compounds of carbon.

**Parent material.** Disintegrated and partly weathered rock from which soil has formed.

**Ped.** An individual natural soil aggregate, such as a crumb, a prism, or a block, in contrast to a clod.

**Pedisediment.** A sediment that covers a pediment rather thinly. A pediment is an erosional surface that lies at the foot of a receded slope, is underlain by rocks or sediment of the upland, is barren or mantled with alluvium, and displays a longitudinal profile, normally concave upward.

**Permeability.** The quality that enables the soil to transmit water or air. Terms used to describe permeability are as follows: *very slow, slow, moderately slow, moderate, moderately rapid, rapid,* and *very rapid.*

**Profile, soil.** A vertical section of the soil through all its horizons and extending into the parent material.

**Reaction, soil.** The degree of acidity or alkalinity of a soil, expressed in pH values. A soil that tests to pH 7.0 is precisely neutral in reaction because it is neither acid or alkaline. An acid, or "sour", soil is one that gives an acid reaction; an alkaline soil is one that is alkaline in reaction. In words, the degrees of acidity or alkalinity are expressed thus:

| | *pH* | | *pH* |
|---|---|---|---|
| Extremely acid | Below 4.5 | Neutral | 6.6 to 7.3 |
| Very strongly acid | 4.5 to 5.0 | Mildly alkaline | 7.4 to 7.8 |
| Strongly acid | 5.1 to 5.5 | Moderately alkaline | 7.9 to 8.4 |
| Medium acid | 5.6 to 6.0 | Strongly alkaline | 8.5 to 9.0 |
| Slightly acid | 6.1 to 6.5 | Very strongly alkaline | 9.1 and higher |

**Runoff** (hydraulics). The part of the precipitation upon a drainage area that is discharged from the area in stream channels. The water that flows off the land surface without sinking in is called surface runoff; that which enters the ground before reaching surface streams is called ground-water runoff or seepage flow from ground water.

**Sand.** Individual rock or mineral fragments in a soil that range in diameter from 0.05 to 2.0 millimeters. Most sand grains consist of quartz, but they may be of any mineral composition. The textural class name of any soil that contains 85 percent or more sand and not more than 10 percent clay.

**Second bottom.** The first terrace above the normal flood plain of a stream.

**Series, soil.** A group of soils developed from a particular type of parent material and having genetic horizons that, except for texture of the surface layer, are similar in differentiating characteristics and in arrangement in the profile.

**Silt.** Individual mineral particles in a soil that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). Soil of the silt textural class is 80 percent or more silt and less than 12 percent clay.

**Soil.** A natural, three-dimensional body on the earth's surface that supports plants and that has properties resulting from the integrated effect of climate and living matter acting on earthy parent material, as conditioned by relief over periods of time.

**Solum.** The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in mature soil includes the A and B horizons. Generally, the characteristics of the material in these horizons are unlike those of the underlying material. The living roots and other plant and animal life characteristics of the soil are largely confined to the solum.

**Structure, soil.** The arrangement of primary soil particles into compound particles or clusters that are separate from adjoining aggregates and have properties unlike those of an equal mass of unaggregated primary soil particles. The principal forms of soil structure are—*platy* (laminated), *prismatic* (vertical axis of aggregates longer than horizontal), *columnar* (prisms with rounded tops), *blocky* (angular or subangular), and *granular. Structureless* soils are either *single grain* (each grain by itself, as in dune sand) or *massive* (the particles adhering together without any regular cleavage, as in many claypans and hardpans).

**Subsoil.** Technically, the B horizon; roughly, the part of the solum below plow depth.

**Substratum.** Technically, the part of the soil below the solum.

**Surface layer.** A term used in nontechnical soil descriptions for one or more layers above the subsoil. Includes A horizon and part of B horizon; has no depth limit.

**Terrace.** An embankment, or ridge, constructed across sloping soils on the contour or at a slight angle to the contour. The terrace intercepts surface runoff so that it may soak into the soil or flow slowly to a prepared outlet without harm. Terraces in fields are generally built so they can be farmed. Terraces intended mainly for drainage have a deep channel that is maintained in permanent sod.

**Terrace** (geological). An old alluvial plain, ordinarily flat or undulating, bordering a river, lake, or the sea. Stream terraces are frequently called second bottoms, as contrasted to flood plains, and are seldom subject to overflow. Marine terraces were deposited by the sea and are generally wide.

**Texture, soil.** The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportion of fine particles, are *sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay,* and *clay.* The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse," "fine," or "very fine."

**Tilth, soil.** The condition of the soil in relation to the growth of plants, especially soil structure. Good tilth refers to the friable state and is associated with high noncapillary porosity and stable, granular structure. A soil in poor tilth is nonfriable, hard, nonaggregated, and difficult to till.

**Water table.** The highest part of the soil or underlying rock material that is wholly saturated with water. In some places an upper, or perched, water table may be separated from a lower one by a dry zone.

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