SOIL SURVEY OF

Grant County, Minnesota

United States Department of Agriculture
Soil Conservation Service
In cooperation with
Minnesota Agricultural Experiment Station

This is a publication of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and agencies of the States, usually the Agricultural Experiment Stations. In some surveys, other Federal and local agencies also contribute. The Soil Conservation Service has leadership for the Federal part of the National Cooperative Soil Survey. In line with Department of Agriculture policies, benefits of this program are available to all who need the information, regardless of race, color, national origin, sex, religion, marital status, or age.

Major fieldwork for this soil survey was completed in the period 1970–73. Soil names and descriptions were approved in 1973. Unless otherwise indicated, statements in the publication refer to conditions in the county in 1973. This survey was made cooperatively by the Soil Conservation Service and the Minnesota Agricultural Experiment Station. It is part of the technical assistance furnished to the Grant County Soil and Water Conservation District.

Soil maps in this survey may be copied without permission, but any enlargement of these maps could cause misunderstanding of the detail of mapping and result in erroneous interpretations. Enlarged maps do not show small areas of contrasting soils that could have been shown at a larger mapping scale.

HOW TO USE THIS SOIL SURVEY

THIS SOIL SURVEY contains information that can be applied in managing farms, ranches, 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 Grant 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 mapping units of the county in numerical order and gives the capability classification, windbreak suitability group, recreation group, and pasture and hayland group in which the soil has been placed. It lists the page on which each soil is described and each interpretive group in which each 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 placed 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 the use and management of the soils from the soil descriptions and from the discussions of the capability units, the pasture and hayland groups, and the windbreak suitability groups.

Foresters and others can refer to the section "Windbreaks," where the soils of the county are grouped according to their suitability for trees.

Game managers, sportsmen, and others can find information about soils and wildlife in the section "Wildlife."

Engineers and builders can find, under "Engineering Uses of the Soils," tables that contain test data, 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 Grant 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 in the section "General Nature of the County."

Cover: Wheat, one of the leading small grains in Grant County, is being harvested on Hamerly soils in the central part of the county.

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SOIL SURVEY OF GRANT COUNTY, MINNESOTA

BY DONALD E. DEMARTELAERE, SOIL CONSERVATION SERVICE

FIELD SURVEY BY DONALD E. DEMARTELAERE, JOHN C. HARRIES, RAYMOND T. DIEDRICK, DAVID J. WESTER, CHARLES E. CARR, AND ALLAN G. GIENCKE, SOIL SCIENTISTS, SOIL CONSERVATION SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE, IN COOPERATION WITH THE UNIVERSITY OF MINNESOTA AGRICULTURAL EXPERIMENT STATION

GRANT COUNTY is in the west-central part of Minnesota (fig. 1). It has a total land area of 356,480 acres. Elbow Lake, in the central part of the county, is the county seat. About 95 percent of the land area is farmed. Most of the farm income comes from livestock products and from grain grown for cash. Corn, soybeans, sunflowers, oats, wheat, barley, flax, and alfalfa are the main crops. The county is on the northern border of the corn belt.

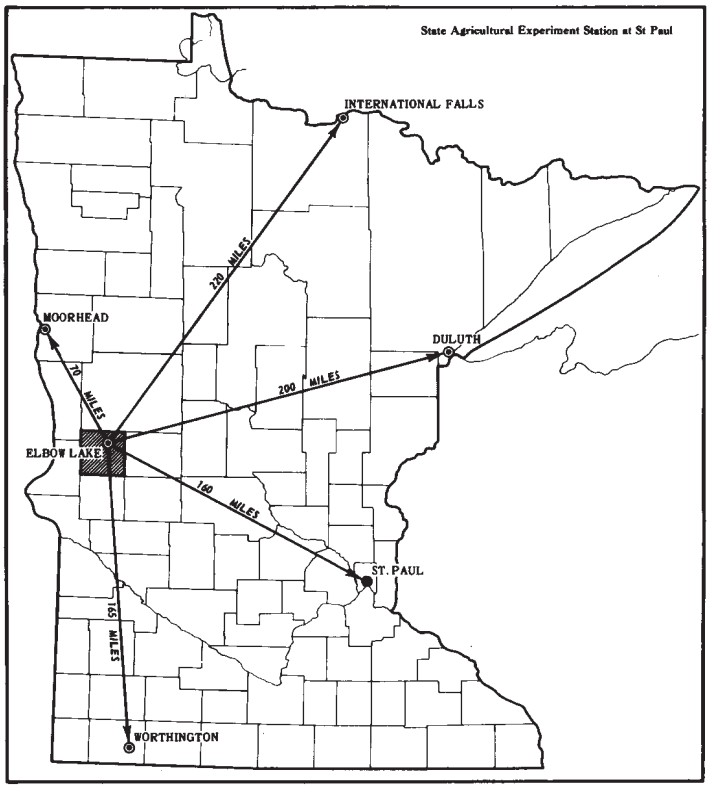

Figure 1.—**Location of Grant County in Minnesota.**

How This Survey Was Made

Soil scientists made this survey to learn what kinds of soil are in Grant County, where they are located, and how they can be used. The soil scientists went into the county knowing they would probably find many soils they had already seen and possibly some unfamiliar soils. 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* is the category of soil classification most used in a local survey.

Soils that have identical or nearly identical profiles 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 geographic feature near the place where a soil of that series was first observed and mapped. Barnes and Roliss, for example, are the names of two soil series. All the soils in the United States that have the same series name are essentially alike in the characteristics that affect their behavior in the undisturbed landscape.

Soils of one series can differ in texture of the surface layer and in slope, stoniness, or some other characteristic that affects use of the soils. On the basis of such differences, soil series are divided into phases. For example, Sioux loamy coarse sand, 0 to 6 percent slopes, is one of several phases in the Sioux 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, however, because it is not practical to show on such a map all the small, scattered bits of soil of some 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. Such mapping units are shown on the soil map of Grant County as soil complexes.

A soil complex consists of areas of two or more soils, so intricately mixed or so small 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. Generally, the name of a soil complex consists of the names of the dominant soils, joined by a hyphen. Barnes-Langhei loams, 3 to 6 percent slopes, is an example.

In most areas surveyed there are places where the soil material is so rocky, so shallow, so severely eroded, or so variable that they have not been classified by soil series. These places are shown on the soil map and are described in the survey, but they are called land types and are given descriptive names. Marsh is a land type in this survey.

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

Soil scientists observe how soils behave when used as a growing place for native and cultivated plants and as material for structures, foundations for structures, or covering for structures. They relate this behavior to properties of the soils. For example, they observe that filter fields for onsite disposal of sewage fail on a given kind of soil, and they relate this to the slow permeability of the soil or to its high water table. They see that streets, road pavements, and foundations for houses are cracked on a particular soil, and they relate this failure to the high shrink-swell potential of the soil material. Thus, they use observation and knowledge of soil properties, together with available research data, to predict limitations or suitability of soils for present and potential uses.

After data have been collected and tested for the key, or benchmark, soils in a survey area, the soil scientists set up trial groups of soils. They test these groups further by study and by consultation with farmers, agronomists, engineers, and others. They then 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 Grant County. A soil association is a landscape that has a distinctive pattern of soils in defined proportions. It typically consists of one or more major soils and at least one minor soil, and it is named for the major soils. The soils in an association can occur in other associations, but in different patterns.

A map showing soil associations is useful to people who want a general idea of the soils in a survey area, who want to compare different parts of that area, or who want to locate large tracts that are suitable for a certain kind of land use. Such a map is also a useful general guide for broad planning of recreational facilities and community developments and such engineering works as transportation corridors. However, it is not a suitable map for detailed planning of management of a farm or field or for selecting the exact location of a road or building or other structure, because the soils within an association generally vary in slope, depth, stoniness, drainage, and other characteristics that affect their management.

The soil associations in this survey area have been grouped into three general kinds of landscape for broad interpretative purposes. Each of the broad groups and the soil associations in each group are described on the following pages.

The names, descriptions, and delineations of the soils in this published soil survey do not always agree or join fully with soil maps of adjoining counties published at an earlier date. Differences are the result of better knowledge about soils or modification and refinements in soil series concepts. In addition, the correlation of a recognized soil is based upon the acreage of that soil and its dissimilarity to adjacent soils in the survey area. Frequently it is more feasible to include soils of small extent with smaller soils if management and response are much the same, rather than to map them separately. The soil descriptions reflect these combinations. Other differences are brought about by the predominance of different soils in taxonomic units made up of two or three series. Still another difference may be caused by the range in slope allowed in the mapping unit for each survey.

Neutral to Moderately Alkaline Soils of the Lake Plain

These are neutral to moderately alkaline, nearly level, very poorly drained to moderately well drained loamy soils. Nearly all areas are cultivated. Corn, soybeans, sunflowers, small grains, and hay grow well.

1. Wheatville-Grimstad association

Somewhat poorly drained and moderately well drained, nearly level soils that formed in loamy and sandy ma-

terial overlying waterworked, calcareous loamy and clayey material

The soils in this association are nearly level and are on a lake plain. Many small, shallow depressions are present throughout the area.

The association makes up about 2 percent of the county. It is about 35 percent Wheatville soils, 30 percent Grimstad soils, and 35 percent minor soils.

The Wheatville soils are somewhat poorly drained and moderately well drained. They have a surface layer of black, calcareous very fine sandy loam. The top part of the underlying material is calcareous very fine sandy loam that grades to loamy very fine sand. It is underlain by calcareous silty clay.

The Grimstad soils are somewhat poorly drained and moderately well drained. They have a surface layer of black, calcareous very fine sandy loam. The top part of the underlying material is calcareous loamy fine sand underlain by calcareous clay loam.

The minor soils in this association are in the Rockwell, Hecla, Kittson variant, Towner, and other series. Kittson variant and Rockwell soils are very poorly drained and poorly drained and are in the shallow depressions. Hecla and Towner soils are moderately well drained and are nearly level.

Most of the soils of this association are used for cultivated crops. Small grains, sunflowers, corn, and soybeans are the main crops. Cash cropping is the main farming enterprise.

The soils have a high potential for farming. Soil blowing and wetness are the main limitations that affect use and management of the soils in this association. Most of them have a high content of lime.

2. *Roliss-Towner association*

Poorly drained, very poorly drained, and moderately well drained, nearly level soils that formed in loamy and sandy waterworked material and in the underlying calcareous loamy glacial till

The soils in this association are nearly level. They occupy the glacial lake basin. Broad, nearly level areas dominate the landscape. Many shallow depressions and slight rises that are better drained than the depressions are in these areas.

The association makes up about 18 percent of the county. It is about 45 percent Roliss soils, 15 percent Towner soils, and 40 percent minor soils.

The Roliss soils are very poorly drained and poorly drained. The surface layer is black loam. The subsoil is olive-gray loam. The underlying material is calcareous, grayish-brown clay loam. Roliss soils are nearly level and are in slightly concave areas in the lake basin.

The Towner soils are moderately well drained. They have a surface layer of black fine sandy loam. The subsoil is very dark grayish-brown and light olive-brown loamy fine sand. The upper part of the underlying material is light brownish-gray and gray loam, and the lower part is light olive-brown clay loam. Towner soils are on slight rises and beach ridges in the glacial lake basin.

The minor soils in this association are in the Kittson, Grimstad, Vallers, and other series. Kittson soils are nearly level and are somewhat poorly drained to moderately well drained. Grimstad soils are nearly level to slightly convex. They are somewhat poorly drained to moderately well drained and are calcareous. Vallers soils are nearly level, poorly drained, and calcareous.

Nearly all the soils of this association are used for cultivated crops. Small grains and sunflowers are the most common crops, but some corn and soybeans are grown. Cash cropping is the main farming enterprise.

The soils have a high potential for farming. The main management needs are drainage, controlling erosion, conservation of misture, and improvement and maintenance of fertility and tilth.

Neutral to Mildly Alkaline Soils of the Outwash Plains and Beach Ridges

These are neutral to mildly alkaline, nearly level to steep, somewhat excessively drained to excessively drained loamy and sandy soils underlain by gravelly outwash. They generally are droughty and poorly suited to crops. Some areas can be irrigated.

3. *Arvilla-Sioux association*

Somewhat excessively drained and excessively drained, nearly level to steep soils that formed in loamy and sandy material over gravelly outwash

The soils in this association are mainly nearly level to rolling, but they are steep in places around sloughs, potholes, and drainageways (fig. 2). They are in the Pomme de Terre River valley, on beach ridges of the glacial lake, and in other small areas scattered throughout the county. The Pomme de Terre River valley has steep walls and is 40 to 80 feet below the uplands. The beach ridges rise 5 to 20 feet above the surrounding land. The river valley consists of stream terraces that lie above the present river channel. In many places the soils on these terraces are nearly level and smooth; in some places they are undulating to rolling.

The association makes up about 5 percent of the county. It is about 30 percent Arvilla soils, 30 percent Sioux soils, and 40 percent minor soils.

The Arvilla soils are somewhat excessively drained. They have a surface layer of black sandy loam. The upper part of the subsoil is very dark grayish-brown and dark grayish-brown coarse sandy loam. The lower part is dark grayish-brown gravelly loamy coarse sand. The underlying material is pale brown gravelly coarse sand. This soil is nearly level to undulating.

The Sioux soils are excessively drained. They have a surface layer of black loamy coarse sand. The underlying material is gravelly coarse sand. Sioux soils in this association are undulating to steep.

The minor soils in this association are in the Lamoure, Forada, Arveson, Maddock, and other series and Alluvial land, frequently flooded, and Marsh. Lamoure soils are poorly drained and very poorly drained and are on bottom lands adjacent to streams and drainageways. Alluvial land, frequently flooded, is adjacent to streams. It is either submerged or is covered with wetland grasses, reeds, and sedges. Forada soils are very poorly drained and poorly drained,

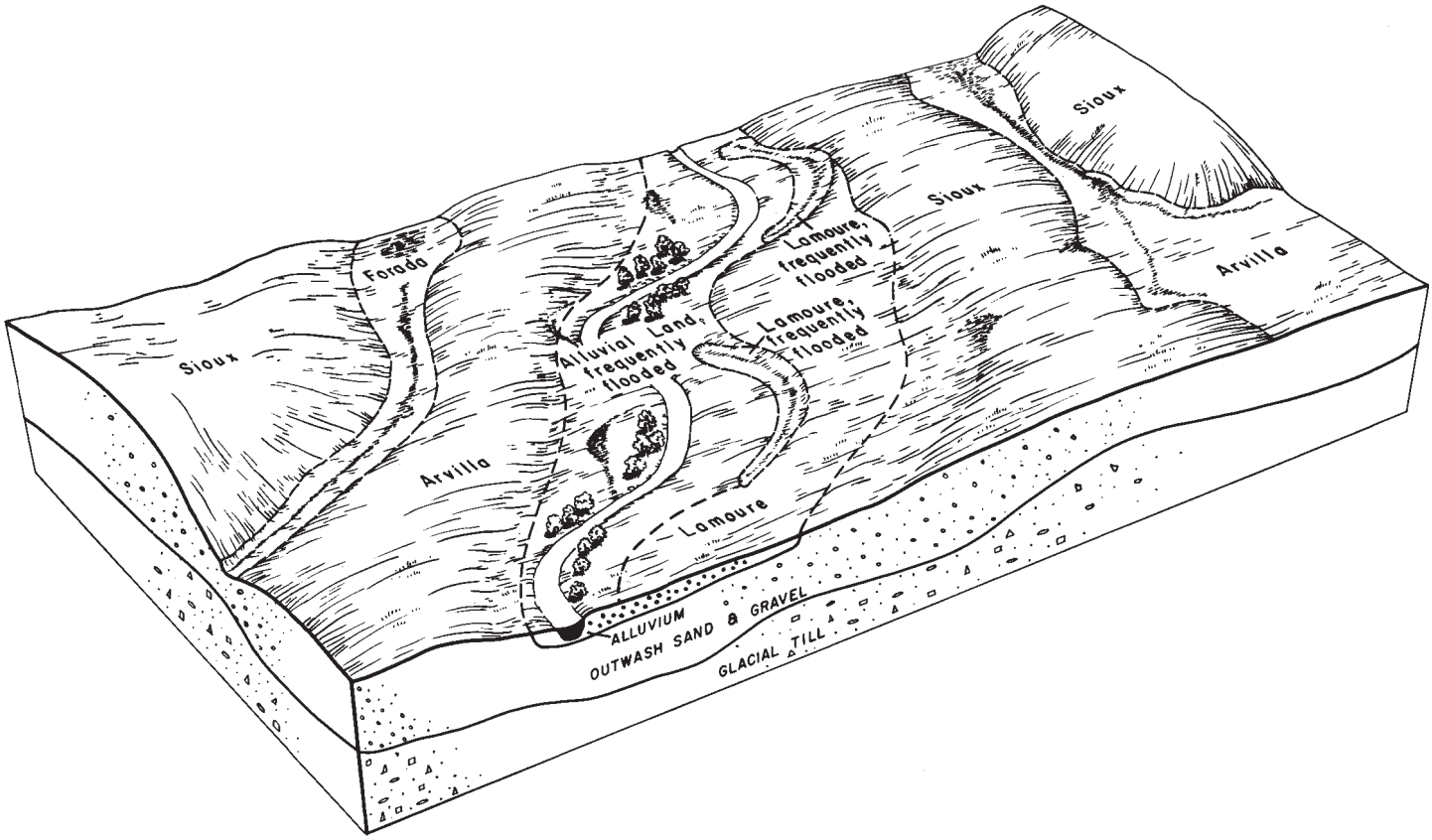

Figure 2.—**Typical pattern of soils in the Arvilla-Sioux association.**

nearly level soils of stream terraces, outwash plains, and glacial lake beaches. Arveson soils are calcareous and are poorly drained and very poorly drained. They are nearly level and are along glacial lake beaches. Maddock soils are well drained, are undulating to rolling, and are on uplands and stream terraces.

Arvilla soils in this association are mainly under cultivation. A few areas are in pasture. Sioux soils are mainly used for pasture and wildlife habitat. The soils of this association are subject to drought and erosion. Cash cropping, dairying, and beef raising are the main farming enterprises.

The soils have a medium potential for farming. Small grains or early-maturing crops are best suited because they make best use of limited moisture. Arvilla soils and some Sioux soils are suited to irrigation. The soils in this association provide most of the sand and gravel used in the county.

Neutral to Moderately Alkaline Soils of the Uplands

These are neutral to moderately alkaline, nearly level to steep, poorly drained to somewhat excessively drained loamy and silty soils. Nearly all areas are cultivated. A few areas are used for pasture. Corn, soybeans, sunflowers, small grains, and hay grow well.

4. Hamerly-McIntosh association

Somewhat poorly drained to moderately well drained, nearly level soils that formed in calcareous loamy glacial till and silty sediment over loamy glacial till

The soils in this association are nearly level but not smooth. The surface has a knobby or choppy appearance and is pitted with depressions and dissected by drainageways. Many marshes and a few shallow lakes are present.

The association makes up about 2 percent of the county. It is about 35 percent Hamerly soils, 30 percent McIntosh soils, and 35 percent minor soils.

The Hamerly soils are somewhat poorly drained to moderately well drained and calcareous. They have a surface layer of black clay loam. The underlying material is clay loam glacial till.

The McIntosh soils are somewhat poorly drained to moderately well drained and calcareous. They have a surface layer of black silt loam. The upper 15 inches of the underlying material is silt loam. Below this is clay loam glacial till.

The minor soils in this association are in the Aazdahl, Flom, Vallers, Quam, and Parnell series. Aazdahl soils are on broad, smooth appearing areas. Flom, Quam, and Parnell soils are in swales, drainageways, and low, concave areas. Vallers soils are on rises and around some low, wet areas.

Most of the soils of this association are cultivated. Small grains, corn, soybeans, and sunflowers are the main crops. Areas that are too wet to cultivate are used for wildlife habitat or pasture. Cash grain is the predominant form of farming, but a few livestock enterprises are scattered throughout the area.

This association has a high potential for farming. Soil blowing is a hazard on unprotected areas. The high lime content of the Hamerly and McIntosh causes a nutrient imbalance, which can limit the types of crops grown or reduce yields. Wetness in depressions and drainageways is a limitation.

5. *Formdale-Aazdahl association*

Well drained and moderately well drained, nearly level to rolling soils that formed in calcareous loamy glacial till

The soils in this association are nearly level to rolling (fig. 3). Slopes generally are short and complex, but in a few areas they are uniform. A few lakes and many marshes and potholes are present. Slopes around these areas are steeper.

The association makes up about 28 percent of the county. It is about 30 percent Formdale soils, 30 percent Aazdahl soils, and 40 percent minor soils.

The Formdale soils are well drained. They have a surface layer of black clay loam. The subsoil is dark-brown clay loam. The underlying material is light olive-brown, calcareous clay loam. Formdale soils generally lie higher on the landscape than Aazdahl soils and the minor soils.

The Aazdahl soils are moderately well drained. They have a surface layer of black clay loam. The subsoil is dark grayish-brown clay loam. The underlying material is grayish-brown and light olive-brown clay loam. This nearly level soil is in small to large, broad, irregularly shaped areas adjacent to areas of Formdale soils.

The minor soils in this association are in the Hamerly, Vallers, Flom, Quam, Parnell, and Langhei series. Hamerly and Vallers soils are nearly level, calcareous, and moderately well drained to poorly drained. They are in areas and rims around smaller, shallower depressions. Flom soils are nearly level and poorly drained and are in lower areas, shallow depressions, and drainageways. Quam and Parnell soils are very poorly drained and are in potholes and deeper depressions. Langhei soils are somewhat excessively drained and calcareous. They are on knobs and knolls.

Most of the soils of this association are used for crops. Small grains, along with some corn, soybeans, and sunflowers, are the main crops. Cash cropping and beef feeding are the main farming enterprises.

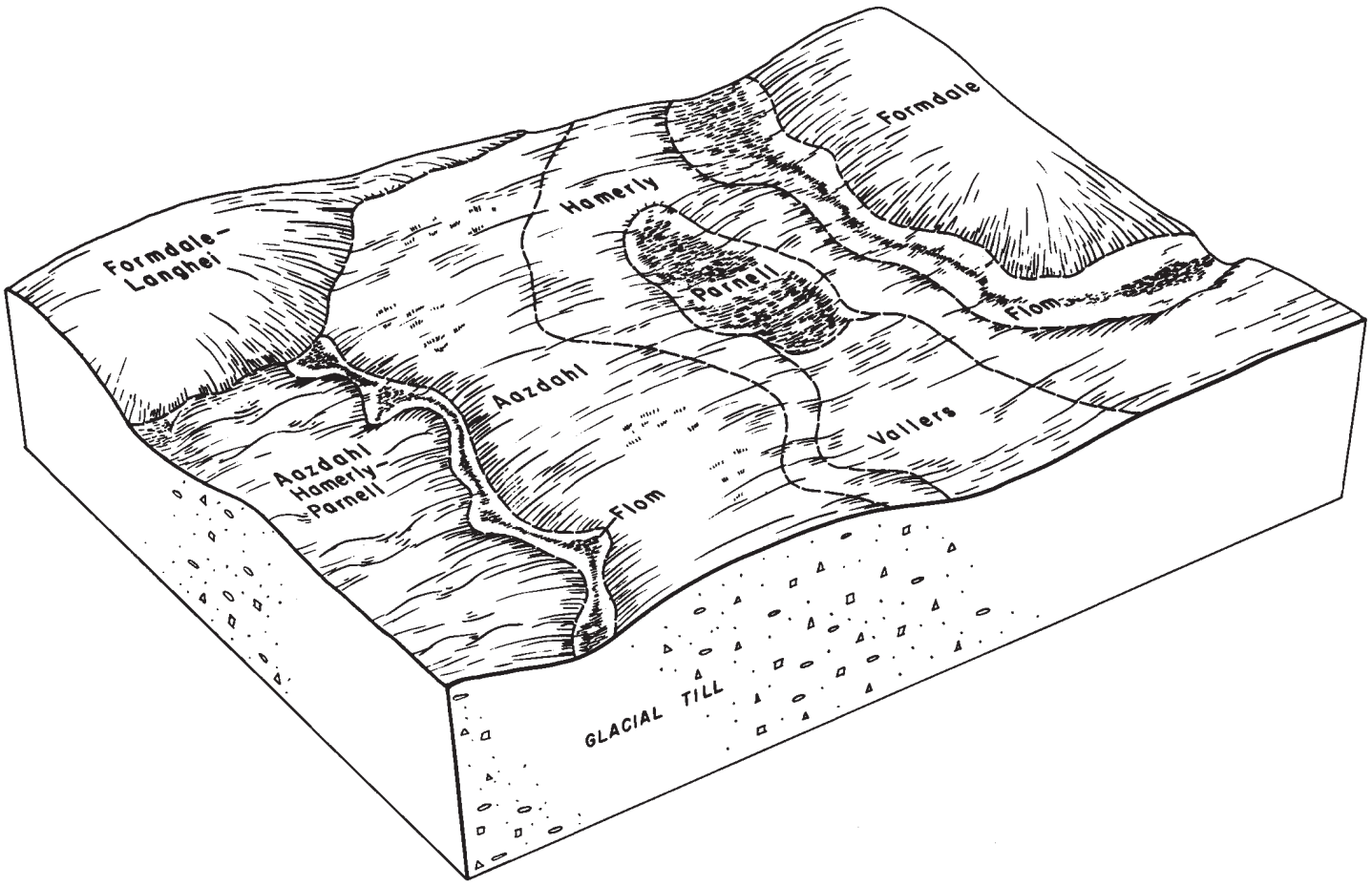

Figure 3.—**Typical pattern of soils in the Formdale-Aazdahl association.**

These soils are some of the best in the county for farming, and they have a high potential for farming. The management needs in this association are erosion control and improving and maintaining tilth and fertility. Drainage is needed on the poorly drained and very poorly drained minor soils.

6. *Hamerly-Aazdahl-Flom association*

Moderately well drained to poorly drained, nearly level soils that formed in calcareous loamy glacial till

The soils in this association are mainly nearly level, but in many places swells and swales are present (fig. 4). Many depressions, potholes, drainageways, and marshes and a few shallow lakes are in this association. Differences in relief are slight. Runoff collects in the many depressions and marshes.

The association makes up about 15 percent of the county. It is about 30 percent Hamerly soils, 20 percent Aazdahl soils, 20 percent Flom soils, and 30 percent minor soils.

The Hamerly soils are somewhat poorly drained and moderately well drained and are calcareous. They have a surface layer of black clay loam. The underlying material of glacial till is clay loam. Hamerly soils are on the crests of many slopes and are adjacent to potholes, depressions, and drainageways. The topography in areas of Hamerly soils appears choppy or knobbly and is pitted with depressions and drainageways.

The Aazdahl soils are moderately well drained. They have a surface layer of noncalcareous black clay loam. The subsoil is dark grayish-brown clay loam. The underlying material is grayish-brown and light olive-brown clay loam. Aazdahl soils have smooth-appearing, slightly convex slopes.

The Flom soils are poorly drained and are noncalcareous in the surface layer. They have a surface layer of black silty clay loam. The subsoil is dark grayish-brown clay loam. The underlying material is calcareous clay loam glacial till. Flom soils are in shallow depressions, drainageways, and broad flats.

The minor soils in this association are in the Vallers, Parnell, Quam and Formdale series. Vallers soils are on rims and low rises around and between depressions. Parnell and Quam soils are in deep depressions and potholes. Formdale soils are in relatively high, well-drained areas. This association also includes an area of the clayey Sinai soils immediately west of the Pomme de Terre River in the southern part of the county. Many marshes and shallow lakes are scattered over the landscape.

Most of the soils of this association are used for cultivated crops, but undrained, wet areas are used for pasture and wildlife. Small grains, corn, soybeans,

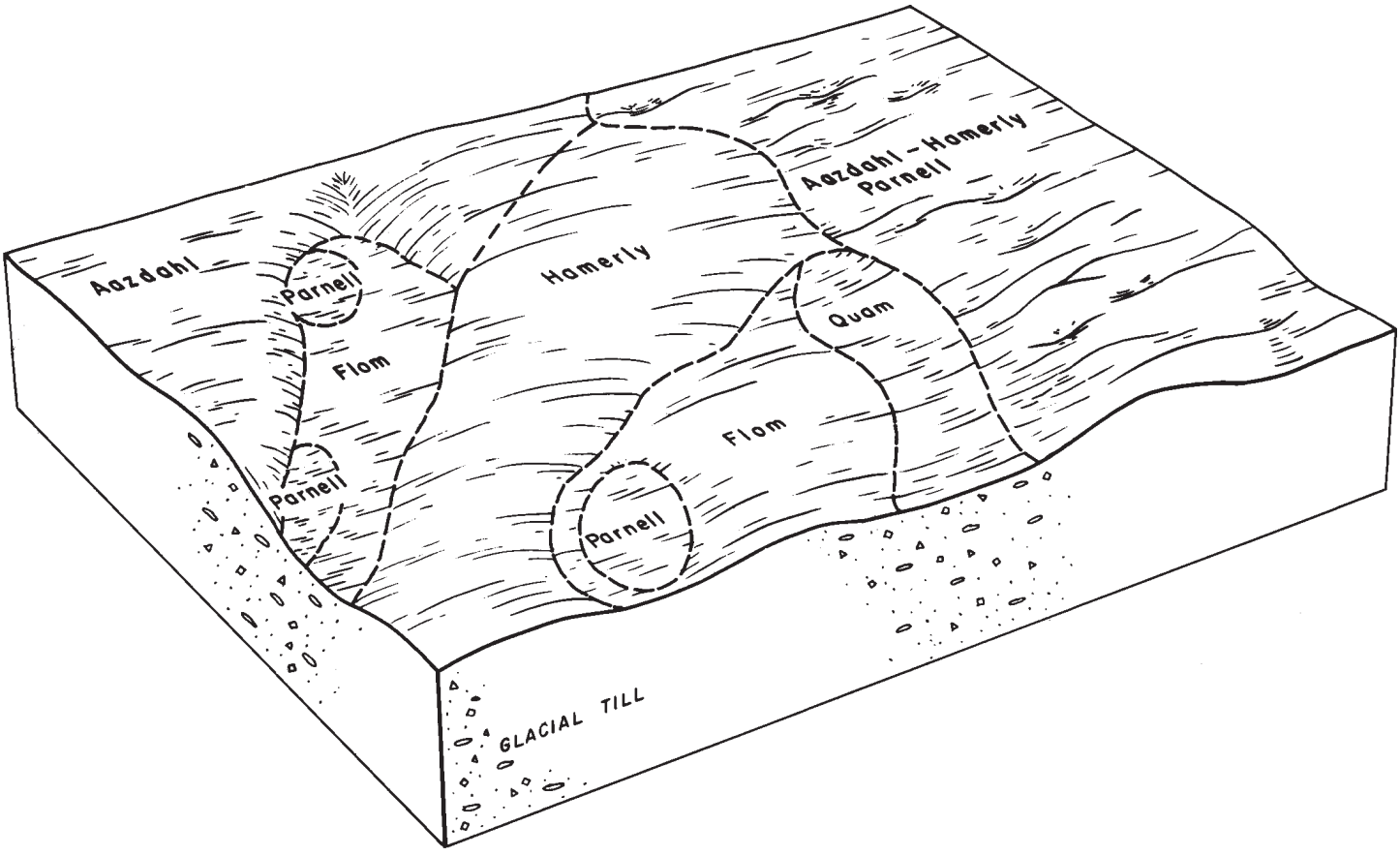

Figure 4.—**Typical pattern of soils in the Hamerly-Aazdahl-Flom association.**

and sunflowers are the main crops. Cash grain is the predominant form of farming, but some livestock is also raised.

The soils have a high potential for farming. Wetness is the main concern in management. Soil blowing is a hazard in some unprotected areas. The high lime content of Hamerly soils causes a nutrient imbalance, which can limit the types of crops grown or reduce yields.

7. *Barnes-Svea association*

Well drained and moderately well drained, nearly level to undulating soils that formed in calcareous loamy glacial till

The soils in this association are nearly level to undulating. Depressions, potholes, and drainageways are present in places. Some small shallow lakes and marshes and a few steeper soils are in this association.

The association makes up about 8 percent of the county. It is about 35 percent Barnes soils, 30 percent Svea soils, and 35 percent minor soils.

The Barnes soils are well drained and are noncalcareous in the surface layer. They have a surface layer of black loam. The subsoil is dark grayish-brown loam. The underlying material is calcareous, light olive-brown loam. The undulating part of this association consists of Barnes soils.

The Svea soils are moderately well drained. They have a surface layer of black loam. The subsoil is very dark brown and dark-brown loam. The underlying material is calcareous loam glacial till. Svea soils are nearly level.

The minor soils in this association are in the Langhei, Hamerly, Flom, Parnell, and Quam series. Langhei soils are in more sloping areas and on knolls that have convex slopes. Hamerly soils are on slight rises between depressions. Parnell and Quam soils are mainly in depressions and potholes, and Flom soils are dominantly in drainageways and shallow depressions.

Most of the soils of this association are cultivated. Corn, soybeans, and small grains are the main crops, but some areas of steeper soils and wet areas are used for pasture. Farming is divided among dairy farms, beef cattle operations, and cash-grain operations.

The soils have a high potential for farming. The association includes some of the best farm land in the county. Wetness is the main concern in management. Soil blowing is a hazard on unprotected, nearly level soils.

8. *Langhei-Barnes-Formdale association*

Somewhat excessively drained and well-drained, undulating to very steep soils that formed in calcareous loamy glacial till

The soils in this association are undulating to very steep. Depressions, potholes, and drainageways are present in places. Many of the steeper slopes are dissected by waterways. The undulating slopes generally are short and complex and extend in many directions. The steep slopes generally are long and in one direction. Some small, shallow lakes and marshes and one large lake are in this association.

The association makes up about 22 percent of the county. It is about 40 percent Langhei soils, 15 percent Barnes soils, 15 percent Formdale soils, and 30 percent minor soils.

The Langhei soils are somewhat excessively drained and calcareous. The surface layer is calcareous, dark grayish-brown loam. In places it has been completely removed by erosion, and the light-colored underlying material is exposed. In areas of Langhei soils associated with Formdale soils, the underlying material is loam glacial till and clay loam. Langhei soils are on the crests of most slopes in this association.

The Barnes soils are well drained. They have a surface layer of noncalcareous, black loam. The subsoil is dark-brown loam. The underlying material of glacial till is calcareous loam. Slope is less steep and more uniform in areas of Barnes soils than it is in other areas.

The Formdale soils are well drained. They have a surface layer of black clay loam and a subsoil of dark-brown clay loam. The underlying material is olive-brown, calcareous clay loam. Formdale soils are on the less steep parts of the slopes.

The minor soils in this association are in the Darnen, Flom, Svea, Hamerly, and Quam series. Svea and Hamerly soils are nearly level and are somewhat poorly drained to moderately well drained. Darnen soils are moderately well drained. They are at the bases of the steeper slopes. Quam soils are in the larger depressions.

Most of the soils of this association are cultivated. Where cultivated crops can be grown, small grains dominate. Corn and soybeans are also grown. Much of the area that is too steep for cultivated crops is used for pasture or wildlife habitat. Dairying, beef feeding, raising hogs, and cash crops are the main farming enterprises.

Farming potential varies, depending on the steepness of slopes. Water erosion is the major concern in management. The calcareousness of the Langhei soil is a concern, because it requires specific management and often limits the type of crops that can be grown.

Descriptions of the Soils

This section describes the soil series and mapping units in Grant County. Each soil series is described in detail, and then, briefly, each mapping unit in that series is described. Unless it is specifically mentioned otherwise, it is to be assumed that what is stated about the soil series holds true for the mapping units in that series. Thus, to get full information about any one mapping unit, it is necessary to read both the description of the mapping unit and the description of the soil series to which it belongs.

An important part of the description of each soil series is the soil profile, *i.e.*, the sequence of layers from the surface downward to rock or other underlying material. Each series contains two descriptions of this profile. The first is brief and in terms familiar to the layman. The second is much more detailed and is for those who need to make thorough and precise studies of soils. Color terms apply to moist soil unless otherwise stated. The profile described in the series is

representative of mapping units in that series. If the profile of a given mapping unit is different from the one described as representative of the series, these differences are stated in the description of the mapping unit, or they are differences that are apparent in the name of the mapping unit.

As mentioned in the section "How This Survey Was Made," not all mapping units are members of a soil series. Alluvial land, frequently flooded, for example, does not belong to a soil series, but it is listed in alphabetic order along with the soil series.

Preceding the name of each mapping unit is the symbol that identifies the mapping unit on the detailed soil map. Listed at the end of the description of each mapping unit are the capability unit, windbreak suitability group, recreation group, and pasture and hayland group in which the mapping unit has been placed. The page for the description of each of these interpretive groups can be found by referring to the "Guide to Mapping Units" at the back of this survey.

The approximate acreage and proportionate extent of each mapping unit are shown in table 1. Many of the terms used in describing soils can be found in the Glossary at the end of this survey, and more detailed information about the terminology and methods of soil mapping can be obtained from the Soil Survey Manual (*4*).[1]

The names, descriptions, and delineations of soils in the published soil survey do not in all places agree or join fully with those on soil maps of adjoining counties. Differences are the result of better knowledge of soils or of modifications and refinements in soil series concepts. In addition, the correlation of a recognized soil is based upon the acreage of that soil and its dissimilarity to adjacent soils within the survey area. It is frequently more feasible to include soils of small extent with similar soils where management and response are much the same rather than to map them separately. The soil descriptions reflect these combinations. Other differences are brought about by the dominance of different soils in mapping units made up of soils in two or three series. Still another difference can be the result of the range in slope allowed within the mapping unit for each survey.

Aazdahl Series

The Aazdahl series consists of nearly level, moderately well drained soils that formed in calcareous loamy glacial till.

In a representative profile the surface layer is black clay loam about 14 inches thick. The subsoil is dark grayish-brown, friable clay loam about 6 inches thick. The underlying material is clay loam. The upper 16 inches of this layer is grayish brown, and the lower part is light olive brown.

Aazdahl soils have high natural fertility, high organic-matter content, and moderate to high available water capacity. Permeability is moderate. The surface layer is neutral. It is fairly easy to work.

Aazdahl soils are used mainly for cultivated crops. They are suited to all crops commonly grown in the county.

Representative profile of Aazdahl clay loam, 1 to 3 percent slopes, 10 feet south and 10 feet west of the northeast corner of sec. 28, T. 128 N., R. 43 W.:

A1—0 to 14 inches, black (10YR 2/1) clay loam; moderate, fine, granular structure; friable; many roots; about 2 percent coarse fragments; neutral; gradual, smooth boundary.

B2—14 to 20 inches, dark grayish brown (2.5Y 4/2) clay loam; weak, fine, subangular blocky structure; friable; many roots; about 5 percent coarse fragments; neutral; abrupt, wavy boundary.

C1ca—20 to 36 inches, grayish brown (2.5Y 5/2) clay loam; weak, medium, subangular blocky structure; friable; about 5 percent coarse fragments; strong effervescence; moderately alkaline; gradual, wavy boundary.

C2—36 to 60 inches, light olive brown (2.5Y 5/4) clay loam; common, fine, prominent, yellowish brown (10YR 5/6) and few, fine, prominent, gray (5Y 5/1) mottles; structureless; about 5 percent coarse fragments; strong effervescence; moderately alkaline.

Depth to free carbonates ranges from 16 to 26 inches. The A horizon generally is black, but in places in its lower part, it is very dark gray. It generally is clay loam, but it is silty clay loam in places. The combined thickness of the Ap and A1 horizons ranges from 10 to 14 inches. The B horizon generally is very dark grayish brown and dark grayish brown. It generally is clay loam, but it is silty clay loam in places. The B horizon is 2 to 10 inches thick. The Cca horizon generally is light olive brown, light yellowish brown, and grayish brown. It is 6 to 20 inches thick. The calcium carbonate equivalent ranges from 18 to 30 percent. The C2 horizon generally is light olive brown or light yellowish brown. Mottles range from few to many and are distinct or prominent. The calcium carbonate equivalent ranges from 12 to 20 percent.

Aazdahl soils are associated with Formdale and Flom soils and are similar to Svea soils. They have a thicker A horizon and are wetter than Formdale soils. They are better drained than Flom soils and have a higher content of clay and silt than Svea soils.

26—Aazdahl clay loam, 1 to 3 percent slopes. This nearly level soil is in small to very large, broad, irregularly shaped areas. The large, broad areas normally have many small depressions. Slopes are plane and slightly convex. This soil has the profile described as representative of the series.

Included with this soil in mapping are small areas of Formdale and Hamerly soils that are more sloping than this soil, areas of Flom soils at lower elevations, and some areas of soils that have a surface layer that is thicker than the one in the profile described as representative of the series. Also included are areas of Quam and Parnell soils in small depressions, ½ acre to 3 acres in size, that are shown on the detailed soil map by a spot symbol.

This Aazdahl soil is productive and has few limitations. It is used for cultivated crops. It is suited to all crops commonly grown in the county. Capability unit I–1; windbreak suitability group 1; recreation group 1; pasture and hayland group 1.

900—Aazdahl-Hamerly-Parnell complex, 0 to 2 percent slopes. This mapping unit consists of nearly level soils in quite large areas on the till plains west of the Pomme de Terre River. Depressions and draws are scattered throughout the area and give it a bumpy appearance. Although the relative composition of this complex is variable, the Aazdahl soil makes

[1] Italic numbers in parentheses refer to Literature Cited, p. 84.

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

Soil	Acres	Percent	Soil	Acres	Percent
Aazdahl clay loam, 1 to 3 percent slopes	26,156	7.3	Langhei-Formdale clay loams, 6 to 12 percent slopes, eroded	13,565	3.8
Aazdahl-Hamerly-Parnell complex, 0 to 2 percent slopes	19,249	5.4	Langhei-Formdale clay loams, 12 to 18 percent slopes, eroded	2,190	.6
Alluvial land, frequently flooded	1,040	.3	Maddock loamy sand, 1 to 6 percent slopes	935	.3
Arveson fine sandy loam	680	.2	Maddock loamy sand, 6 to 18 percent slopes	730	.2
Arvilla sandy loam, 0 to 2 percent slopes	6,100	1.7	Marsh	13,005	3.7
Arvilla sandy loam, 2 to 6 percent slopes	4,680	1.3	McIntosh silt loam, 0 to 2 percent slopes	2,090	.6
Barnes loam, 2 to 5 percent slopes	8,605	2.4	Oldham silty clay loam	4,695	1.3
Barnes-Langhei loams, 3 to 6 percent slopes	11,165	3.1	Parnell silty clay loam	4,070	1.1
Barnes-Svea loams, 1 to 3 percent slopes	625	.2	Quam silty clay loam	4,905	1.4
Bearden silt loam, 0 to 2 percent slopes	490	.1	Rockwell loam	6,365	1.8
Darnen loam, 1 to 4 percent slopes	770	.2	Rockwell-Vallers complex	1,120	.3
Fargo silty clay	1,320	.4	Roliss loam	18,536	5.2
Flom silty clay loam	7,445	2.1	Roliss complex	17,824	5.0
Forada sandy loam	530	.1	Roliss-Vallers complex	3,445	1.0
Fordville loam, 0 to 2 percent slopes	825	.2	Rothsay silt loam, 2 to 6 percent slopes	750	.2
Formdale clay loam, 2 to 5 percent slopes	23,784	6.7	Sinai silty clay, 1 to 6 percent slopes	360	.1
Formdale-Aazdahl-Flom complex, 1 to 4 percent slopes	21,883	6.2	Sinai silty clay, 6 to 12 percent slopes	200	.1
Formdale-Langhei clay loams, 3 to 6 percent slopes	15,734	4.4	Sioux gravelly loamy coarse sand, 12 to 35 percent slopes	320	.1
Glyndon silt loam, 0 to 2 percent slopes	650	.2	Sioux loamy coarse sand, 0 to 6 percent slopes	3,550	1.0
Grimstad-Towner complex, 0 to 2 percent slopes	4,060	1.1	Sioux loamy coarse sand, 6 to 12 percent slopes	2,780	.8
Hamerly clay loam, 1 to 3 percent slopes	11,307	3.2	Svea loam, 1 to 3 percent slopes	5,705	1.6
Hamerly-Parnell complex, 0 to 3 percent slopes	3,755	1.1	Svea-Hamerly loams, 1 to 3 percent slopes	4,890	1.4
Hecla loamy fine sand, 0 to 2 percent slopes	565	.2	Sverdrup sandy loam, 2 to 6 percent slopes	3,530	1.0
Kittson very fine sandy loam, 0 to 2 percent slopes	5,590	1.6	Towner fine sandy loam, 0 to 2 percent slopes	8,150	2.3
Kittson fine sandy loam, gray subsoil variant	2,250	.6	Ulen loamy fine sand, 0 to 2 percent slopes	510	.1
Lake beaches	480	.1	Urness mucky silt loam	2,860	.8
Lamoure silt loam	3,445	1.0	Vallers clay loam	15,160	4.3
Lamoure silt loam, frequently flooded	890	.2	Vallers clay loam, firm subsoil	1,845	.5
Langhei loam, 18 to 35 percent slopes	2,295	.6	Waukon loam, 4 to 12 percent slopes	350	.1
Langhei-Barnes loams, 6 to 12 percent slopes, eroded	11,407	3.2	Waukon loam, 12 to 24 percent slopes	415	.1
Langhei-Barnes loams, 12 to 18 percent slopes, eroded	6,470	1.8	Wheatville very fine sandy loam, 0 to 2 percent slopes	2,540	.7
			Gravel pits	775	.2
			Water	4,070	1.1
			Total	356,480	100.0

up 30 to 50 percent of most areas, the Hamerly soil 20 to 40 percent, and the Parnell soil 10 to 20 percent. The Parnell soil is in depressions and waterways, the Hamerly soil is on small rises around and between depressions, and the Aazdahl soil is in broad, nearly level areas that have plane to slightly convex slopes.

Included with these soils in mapping are small areas of Formdale soils that are steeper than these soils and small areas of Vallers soils on the rims around the depressions. Also included in some places are areas of Flom soils in drainageways.

These soils are used for cultivated crops. They are suited to all crops commonly grown in the county. Excess lime near the surface of the Hamerly soil causes an imbalance of nutrients that can be improved by fertilization. The Parnell soil is wet and requires improved drainage.

The main management needs are controlling erosion and improving drainage, fertility, and tilth. Capability unit IIe–2; Aazdahl part in windbreak suitability group 1, Hamerly part in windbreak suitability group 2, Parnell part in windbreak suitability group 7; Aazdahl and Hamerly parts in recreation group 1, Parnell part in recreation group 4; Aazdahl and Hamerly parts in pasture and hayland group 1, Parnell part in pasture and hayland group 6.

Alluvial Land, Frequently Flooded

1002—Alluvial land, frequently flooded. This land type consists of nearly level, dark-colored loamy and sandy material recently deposited by rivers and streams. It is in areas adjacent to streams and rivers and lies 1 to 3 feet higher than the adjacent streams. Some areas are dissected by stream channels. Areas of this land type are frequently flooded during periods of excessive rainfall. Slopes range from 0 to 2 percent.

This land type consists of stratified material that ranges in texture from coarse sand to silty clay loam but generally is loam or silt loam. It varies considerably within short distances. In places it has a thin mucky surface layer. The surface layer ranges from neutral to moderately alkaline. Most areas are poorly drained, but some are very poorly drained or moderately well drained. Deposits are so recent that a soil profile has not formed, although the material is mottled in places. Because of the low-lying position, the water

table is at a depth of 1 to 3 feet during a large part of the growing season.

This land type is better suited to pasture, woodland, or wetland wildlife than to other uses. Pastured areas often become hummocky. A few slightly better drained areas are cultivated. Capability unit VIw–1; windbreak suitability group 7; recreation group 4; pasture and hayland group 5.

Arveson Series

The Arveson series consists of very poorly drained and poorly drained, calcareous, level to slightly depressional soils. These soils formed in calcareous loamy material underlain by calcareous sandy outwash material.

In a representative profile the surface layer is about 21 inches thick. The upper 7 inches of this layer is black fine sandy loam, and the lower 14 inches is very dark gray fine sandy loam. The underlying material is fine sand. The upper part is light gray, and the lower part is light brownish gray.

Arveson soils have high organic-matter content, medium natural fertility, and moderate available water capacity. Permeability is moderately rapid. The surface layer is moderately alkaline.

The high content of lime of these soils causes an imbalance of available plant nutrients. Because Arveson soils have a high water table, they are not well suited to cultivated crops. Drainage is needed for continuous growth of crops, and most areas are drained. Undrained areas are used for pasture and wildlife habitat.

Representative profile of Arveson fine sandy loam, 195 feet north and 595 feet west of the southeast corner of sec. 12, T. 128 N., R. 44 W.:

Ap—0 to 7 inches, black (10YR 2/1) fine sandy loam; weak, medium, subangular blocky structure parting to weak, very fine, granular; friable; strong effervescence; moderately alkaline; abrupt, smooth boundary.

A1ca—7 to 21 inches, very dark gray (10YR 3/1) fine sandy loam; weak, medium, subangular blocky structure parting to weak, very fine, granular; friable; violent effervescence; moderately alkaline; gradual, wavy boundary.

IIC1—21 to 34 inches, light gray (2.5Y 7/2) fine sand; few, medium, distinct, pale yellow (5Y 7/4) mottles; single grained; loose; slight effervescence; mildly alkaline; clear, wavy boundary.

IIC2—34 to 60 inches, light brownish gray (2.5Y 6/2) fine sand; single grained; loose; slight effervescence; mildly alkaline.

The Ap horizon is 6 to 10 inches thick, and the A1ca horizon is 8 to 16 inches thick. The Ap horizon is loam in places. Depth to underlying sand or fine sand ranges from 16 to 24 inches.

Arveson soils are associated with Rockwell and Ulen soils. They do not have a clay loam substratum, unlike Rockwell soils. They are wetter than Ulen soils.

61—Arveson fine sandy loam (0 to 2 percent slopes). This nearly level and slightly concave soil is in areas that vary in size and shape. The landscape associated with this soil has a microrelief of shallow swales and some irregularly shaped depressions.

Included with this soil in mapping are small areas of Ulen and Rockwell soils. Also included are areas of soils that have a surface layer of loamy fine sand.

Most areas of this soil are used for cultivated crops. If adequate drainage is used, the soil is suited to all the crops commonly grown in the county. Excess lime near the surface causes an imbalance of nutrients that can be improved by fertilization. Soil blowing is a hazard on fields left unprotected during winter and spring.

The main management needs are controlling erosion and improving and maintaining drainage and fertility. Capability unit IIIw–2; windbreak suitability group 4; recreation group 4; pasture and hayland group 4.

Arvilla Series

The Arvilla series consists of somewhat excessively drained, nearly level to undulating soils that formed in loamy material underlain by gravelly outwash at a depth of 1 foot to 2 feet. Most areas are in river valleys and on beach ridges.

In a representative profile the surface layer is black sandy loam about 5 inches thick. The subsoil is about 15 inches thick. The upper 7 inches of this layer is very dark grayish-brown and dark grayish-brown, friable coarse sandy loam, and the lower 8 inches is dark grayish-brown, loose gravelly loamy coarse sand. The underlying material is mixed pale-brown, light yellowish-brown, and light-gray gravelly coarse sand.

Arvilla soils have low available water capacity, medium natural fertility, and moderate organic-matter content. The surface layer is neutral. Rooting depth is shallow. Permeability is rapid.

Gravel pits have been opened on these soils and are a good source of sand and gravel. In most years, droughtiness is a hazard on these soils and restricts the growth of crops.

Representative profile of Arvilla sandy loam, 2 to 6 percent slopes, 900 feet east and 300 feet north of the southwest corner of sec. 7, T. 129 N., R. 41 W.:

A1—0 to 5 inches, black (10YR 2/1) sandy loam; weak, very fine, granular structure; friable; many roots; many bleached sand grains; neutral; clear, smooth boundary.

B1—5 to 8 inches, very dark grayish brown (10YR 3/2) coarse sandy loam; weak, medium, subangular blocky structure; friable; many roots; neutral; gradual, smooth boundary.

B21—8 to 12 inches, dark grayish brown (10YR 4/2) coarse sandy loam; weak, medium, subangular blocky structure; friable; many roots; neutral; abrupt, wavy boundary.

IIB22—12 to 20 inches, dark grayish brown (10YR 4/2) gravelly loamy coarse sand; single grained; loose; slight effervescence; mildly alkaline; abrupt, wavy boundary.

IIC—20 to 60 inches, pale brown (10YR 6/3), light yellowish brown (10YR 6/4), and light gray (10YR 7/2) gravelly coarse sand; single grained; loose; limy coatings on underside of pebbles in upper part; strong effervescence; mildly alkaline.

Thickness of the solum and depth to gravelly coarse sand or coarser textured material both range from about 14 to 22 inches. The A horizon generally is black or very dark gray. It generally is sandy loam, but it is loam in places. The A horizon is 5 to 10 inches thick. The B horizon generally is brown, dark brown, dark grayish brown, and very dark grayish brown. The B21 horizon generally is sandy loam, coarse sandy loam, or loam, and the IIB22 horizon is gravelly loamy coarse sand or loamy coarse sand. The B horizon is 7 to 16 inches thick. The IIC horizon is gravelly

coarse sand; the content of gravel ranges from 15 to 50 percent.

In many areas in the county Arvilla soils have more than 35 percent gravel in the IIC horizon and more organic matter in the B horizon. These Arvilla soils are thus outside the defined range of the series. This difference does not significantly affect their use and management.

Arvilla soils are associated with Sioux and Fordville soils and are similar to Sverdrup soils. They have a thicker solum than Sioux soils. They are underlain by gravelly coarse sand, and Sverdrup soils are underlain by sand. Arvilla soils are shallower to gravelly coarse sand than Fordville soils.

341—Arvilla sandy loam, 0 to 2 percent slopes. This nearly level soil is on outwash plains, river terraces, glacial beach ridges, and uplands. Areas are irregular in size and shape. This soil has a profile that is deeper to gravelly coarse sand than the one described as representative of the series.

Included with this soil in mapping are a few areas of soils that have the brownish subsoil exposed and some areas of soils in which gravel is underlain by glacial till at a depth of only a few feet. Also included are small areas of Forada soils in draws, Fordville soils in slightly concave positions, and small areas of Sioux soils.

Nearly all of this soil is used for cultivated crops, but a few areas are used for pasture. The soil is suited to all crops commonly grown in the county, but it is better suited to early-maturing crops than to other varieties because of the hazard of drought. Growth of corn and soybeans cannot be predicted; these crops often fail if no rain falls for a period of one or two weeks. If the soil is left unprotected, soil blowing is a hazard during spring and winter. This soil is suited to irrigation of field and vegetable crops.

The main management needs are controlling erosion, improving fertility, and conserving moisture. Capability unit IIIs–1; windbreak suitability group 6; recreation group 1; pasture and hayland group 7.

341B—Arvilla sandy loam, 2 to 6 percent slopes. This undulating soil is on outwash plains, stream terraces, glacial beach ridges, and uplands. Areas are variable in size and shape. The slopes are short and irregular. Narrow drainageways and depressions are scattered throughout. This soil has the profile described as representative of the series.

Included with this soil in mapping are a few areas of soils that have the brownish subsoil exposed and a few small areas of Sioux soils. Also included are small areas of Fordville soils near foot slopes, small areas of soils that are less sloping, small areas of soils that have stronger slopes, and areas of soils that have a loam surface layer.

This soil is used for cultivated crops and pasture. It is suited to all crops commonly grown in the county, but it is better suited to early-maturing crops than to other varieties because of the hazard of drought. This soil is suited to irrigation of field and vegetable crops. Water runs off at a medium rate, and the hazard of erosion is moderate.

The main management needs are controlling erosion, improving fertility, and conserving moisture. Capability unit IIIs–2; windbreak suitability group 6; recreation group 1; pasture and hayland group 7.

Barnes Series

The Barnes series consists of well-drained, undulating to hilly soils that formed in calcareous loam glacial till.

In a representative profile the surface layer is black loam about 8 inches thick. The subsoil is dark-brown, friable loam about 8 inches thick. The underlying material is light olive-brown loam.

Barnes soils have high natural fertility, high available water capacity, and high organic-matter content. Permeability is moderate. The surface layer is neutral.

These soils are friable and are easy to till. If adequate fertilization and erosion-control practices are used, Barnes soils are well suited to all crops commonly grown in the county.

Representative profile of Barnes loam, in an area of Barnes-Langhei loams, 3 to 6 percent slopes, 550 feet east and 85 feet south of the northwest corner of sec. 4, T. 127 N., R. 41 W.:

Ap—0 to 8 inches, black (10YR 2/1) loam; very dark brown (10YR 2/2, crushed); weak, fine, subangular blocky structure; friable; neutral; abrupt, smooth boundary.

B2—8 to 16 inches, dark brown (10YR 4/3) loam; dark grayish brown (10YR 4/2) coatings on faces of peds; moderate, fine, prismatic structure parting to moderate, fine, subangular blocky; friable; about 1 percent coarse fragments; neutral; clear, smooth boundary.

C1ca—16 to 28 inches, light olive brown (2.5Y 5/4) loam; weak, fine, subangular blocky structure; friable; few threads of lime; about 3 percent coarse fragments; strong effervescence; mildly alkaline; gradual, wavy boundary.

C2—28 to 60 inches, light olive brown (2.5Y 5/4) loam; few, fine, faint, brown (10YR 5/3) and gray mottles; weak, fine, subangular blocky structure; friable; about 3 percent coarse fragments; strong effervescence; mildly alkaline.

Depth to free carbonates ranges from 10 to 20 inches and varies within short horizontal distances. The A horizon generally is black. In areas where the soil is eroded, it is very dark gray or very dark grayish brown. The A horizon is 5 to 9 inches thick. The B horizon generally is dark brown, dark grayish brown, dark yellowish brown, and brown. It is 3 to 11 inches thick. In places a few thin, patchy clay films are on the faces of peds. The C horizon generally is light olive brown, light yellowish brown, and light brownish gray. The calcium carbonate equivalent ranges from 10 to 25 percent in the C horizon and higher in the Cca horizon. The content of coarse fragments ranges from 2 to 10 percent.

Barnes soils are associated with Langhei, Svea, and Flom soils and are similar to Formdale soils. They have a thicker, darker colored surface layer than Langhei soils and are better drained and have a thinner A horizon than Svea and Flom soils. They contain less clay and more sand than Formdale soils.

33B—Barnes loam, 2 to 5 percent slopes. This undulating soil is on side slopes in areas that vary in size and shape. The slopes are mainly 50 to 200 feet long, have concave and convex relief, and are complex, but in a few places they are more uniform.

Included with this soil in mapping are small areas of soils that have a surface layer and subsoil of silt loam or sandy loam and areas of soils that have the brownish subsoil exposed. Also included are spots of sandy and gravelly soils, eroded soils, small areas of soils that are less sloping than this Barnes soil, and small areas of soils that are more strongly sloping.

Many of these areas are indicated by spot symbols. Also included are small areas of Langhei soils on knobs and knolls, Svea or Darnen soils in slightly concave positions and drainageways, Quam and Parnell soils in small depressions, and Flom soils in drainageways and shallow depressions. Many areas of Flom, Quam, and Parnell soils are indicated on the soil maps by spot symbols.

This soil is well suited to all crops commonly grown in the county. Corn, soybeans, and small grains are the principal crops. Water runs off at a medium rate, and the hazard of erosion is moderate.

The main management needs are controlling erosion, maintaining and improving fertility and tilth, and conserving moisture. Capability unit IIe–1; windbreak suitability group 1; recreation group 1; pasture and hayland group 1.

903B—Barnes-Langhei loams, 3 to 6 percent slopes. This mapping unit consists of undulating areas of intermingled Barnes and Langhei soils (fig. 5). The Barnes soil makes up 60 to 80 percent of the area, and the Langhei soil makes up 20 to 40 percent. The Barnes soil is on the less convex parts of the landscape, and the Langhei soils are on more convex parts. The Langhei soil has a surface layer that is light gray when dry. In most areas the slopes are complex, but in some they are more uniform and in one direction. The slopes are 50 to 200 feet long. The Barnes soil has the profile described as representative of its series.

Included with these soils in mapping are areas in which the light olive-brown underlying material of the Langhei soil and the dark-brown subsoil of the Barnes soil are exposed. Also included are small areas of Svea soils on slightly concave positions, Darnen soils on toe slopes, Flom soils on the lower parts of waterways, small areas of soils that are steeper than these Barnes-Langhei loams, and areas of gravelly and sandy soils. Many small areas of Flom, Quam, and Parnell soils, ½ acre to 3 acres in size, are indicated on the soil maps by spot symbols. Also included are some areas of Barnes soil that have a silt loam surface layer and areas of a soil that are similar to the Langhei soil but that have a deeper and darker surface layer.

Most areas of this soil are used for the cultivated crops commonly grown in the county. The Langhei soil is less productive than the Barnes soil because it has

Figure 5.—Barnes-Langhei loams, 3 to 6 percent slopes, on a ridgetop. The dark areas are Barnes soils, and the light areas are Langhei soils.

lower natural fertility. Water runs off at a medium rate, and the hazard of erosion is moderate.

The main management needs are controlling erosion, improving fertility and tilth, and conserving moisture. Capability unit IIe–1; Barnes part in windbreak suitability group 1, Langhei part in windbreak suitability group 2; recreation group 1; pasture and hayland group 1.

907B—Barnes-Svea loams, 1 to 3 percent slopes. This mapping unit consists of soils that are nearly level to gently sloping. The Barnes and Svea soils each makes up about 40 to 60 percent of each area. The Barnes soil is on the more sloping, convex parts of the slopes in the landscape, and the Svea soil is on the nearly level to slightly concave parts.

Included with these soils in mapping are small areas of Flom soils in drainageways, Parnell and Quam soils in depressions, and Vallers and Hamerly soils around the edges of depressions. Many small depressions, waterways, and calcareous spots are indicated on the soil maps by spot symbols. Also included are small areas of soils that have a surface layer of silt loam and areas of soils that have a surface layer and subsoil of sandy loam.

These soils are used for cultivated crops and pasture and are well suited to all crops commonly grown in the county. The main management needs are improving fertility and tilth and controlling erosion. Capability unit I–1; windbreak suitability group 1; recreation group 1; pasture and hayland group 1.

Bearden Series

The Bearden series consists of nearly level, somewhat poorly drained, calcareous soils that formed in silty lacustrine sediment.

In a representative profile the surface layer is silt loam about 14 inches thick. The upper 8 inches is black and the lower 6 inches is dark gray. The underlying material is silt loam. The upper 8 inches of this layer is light brownish gray, and the lower part is light olive brown.

Bearden soils have high organic-matter content, very high available water capacity, and medium natural fertility. Permeability is moderate to moderately slow. The surface layer is moderately alkaline.

The high content of lime of these soils causes an imbalance of available plant nutrients. These soils are well suited to all crops commonly grown in the county, and nearly all areas are cultivated. Bearden soils are free of stones and boulders that can interfere with tillage.

Representative profile of Bearden silt loam, 0 to 2 percent slopes, 115 feet south and 1,725 feet west of the northeast corner of sec. 27, T. 129 N., R. 44 W.:

Ap—0 to 8 inches, black (10YR 2/1) silt loam; weak, very fine, granular structure; friable; strong effervescence; moderately alkaline; abrupt, smooth boundary.

ACca—8 to 14 inches, dark gray (10YR 4/1) silt loam; weak, very fine, granular structure; friable; violent effervescence; moderately alkaline; clear, wavy boundary.

C1ca—14 to 22 inches, light brownish gray (2.5Y 6/2) silt loam; weak, fine, subangular blocky structure; friable; violent effervescence; moderately alkaline; clear, wavy boundary.

C2—22 to 31 inches, light olive brown (2.5Y 5/4) silt loam; weak, fine, subangular blocky structure; friable; violent effervescence; moderately alkaline; gradual, wavy boundary.

C3—31 to 60 inches, light olive brown (2.5Y 5/4) silt loam; few, fine, distinct, yellowish brown (10YR 5/6) mottles and common, medium, prominent, gray (5Y 6/1) mottles; weak, fine, subangular blocky structure; friable; common gypsum crystals; strong effervescence; moderately alkaline.

The A and C horizons range from silt loam to silty clay loam. The combined thickness of the Ap and ACca horizons ranges from 8 to 16 inches.

Bearden soils are associated with McIntosh, Glyndon, and Wheatville soils. They are silty throughout, and McIntosh soils are underlain by clay loam glacial till. Bearden soils have neither the coarse silty substratum typical of Glyndon soils nor the clayey substratum typical of Wheatville soils.

67—Bearden silt loam, 0 to 2 percent slopes. This nearly level soil is the only Bearden soil mapped in the county. Areas range from 5 to 40 acres in size. Many small, wet depressions are present in some areas.

Included with this soil in mapping are small areas of McIntosh soils that have clay loam glacial till above a depth of 40 inches. Also included are small wet spots and a few areas of soils that have a noncalcareous surface layer.

Nearly all areas of this soil are used for cultivated crops. Small grains, corn, sunflowers, and soybeans are the most common crops. A small acreage is used for hay and pasture. If the soil is left unprotected, soil blowing is a hazard in spring and winter. The high content of lime causes an imbalance of plant nutrients.

The main management needs are improving fertilty and controlling erosion. Capability unit IIs–2; windbreak suitability group 2; recreation group 1; pasture and hayland group 1.

Darnen Series

The Darnen series consists of moderately well drained, nearly level to gently sloping soils that formed in loamy colluvial material at the bottoms of steep slopes and on fans at the ends of drainageways. These soils are mainly along river valley walls, but in places areas are on uplands.

In a representative profile the surface layer is loam about 28 inches thick. The upper 24 inches is black, and the lower 4 inches is very dark grayish brown. The subsoil is friable clay loam about 17 inches thick. The upper 6 inches is dark grayish brown, and the lower 11 inches is olive brown. The underlying material is light olive-brown clay loam.

Darnen soils have high natural fertility, high organic-matter content, and high to very high available water capacity. The surface layer is neutral. Permeability is moderate.

Darnen soils are free of stones and are easy to work. They are well suited to all crops grown in the county.

Representative profile of Darnen loam, 1 to 4 percent slopes, 320 feet south and 2,820 feet east of the northwest corner of sec. 14, T. 129 N., R. 43 W.:

Ap—0 to 8 inches, black (10YR 2/1) loam; weak, very fine, subangular blocky structure parting to weak, very

fine, granular; very friable; neutral; abrupt, smooth boundary.

A12—8 to 24 inches, black (10YR 2/1) loam grading with depth to very dark brown (10YR 2/2); weak, very fine, subangular blocky structure parting to weak, very fine, granular; very friable; neutral; clear, wavy boundary.

A3—24 to 28 inches, very dark grayish brown (10YR 3/2) loam; weak, very fine, subangular blocky structure parting to weak, very fine, granular; friable; neutral; clear, wavy boundary.

B1—28 to 34 inches, dark grayish brown (2.5Y 4/2) clay loam; moderate, fine, subangular blocky structure parting to weak, fine, granular; friable; about 1 percent coarse fragments; neutral; gradual, wavy boundary.

B2—34 to 42 inches, olive brown (2.5Y 4/4) clay loam; moderate, fine, subangular blocky structure; friable; about 1 percent coarse fragments; neutral; clear, wavy boundary.

B3ca—42 to 45 inches, light olive brown (2.5Y 5/4) clay loam; weak, fine, subangular blocky structure; very friable; about 2 percent coarse fragments; strong effervescence; mildly alkaline; clear, wavy boundary.

C—45 to 60 inches, light olive brown (2.5Y 5/6) clay loam; weak, fine, subangular blocky structure; friable; about 3 percent coarse fragments; strong effervescence; mildly alkaline.

Thickness of the solum ranges from 30 to 50 inches. The A horizon generally is silt loam or loam 20 to 40 inches thick. It has weak or moderate, granular structure. Structure in the lower parts of some profiles is subangular blocky. The B horizon generally is very dark grayish brown, dark grayish brown, dark brown, light olive brown, and olive brown. It generally is loam or clay loam 6 to 18 inches thick.

Darnen soils are associated with Langhei, Barnes, and Formdale soils. They have a thicker A horizon than any of these soils.

494B—Darnen loam, 1 to 4 percent slopes. This soil generally is in long, narrow areas at the foot of stronger slopes. A few areas are delta shaped and are at the mouths of waterways. In places the black surface layer is thicker than normal. Included with this soil in mapping are small areas of Barnes, Svea, and Flom soils.

Many areas of this soil are used for permanent pasture, because the areas are not readily accessible or are too small to cultivate separately. Farmed areas are used for all the cultivated crops commonly grown in the county. This soil is well suited to all crops. Capability unit I–1; windbreak suitability group 1; recreation group 1; pasture and hayland group 1.

Fargo Series

The Fargo series consists of poorly drained, nearly level soils that formed in calcareous, clayey lacustrine material.

In a representative profile the surface layer is black silty clay about 13 inches thick. The subsoil is light brownish-gray, very sticky silty clay about 5 inches thick. The underlying material is silty clay. The upper 9 inches of this layer is olive gray, and the lower part is light olive gray.

Fargo soils have high natural fertility, high organic-matter content, and moderate to high available water capacity. Permeability is slow. The surface layer is neutral.

These soils are suited to all crops commonly grown in the county. Nearly all Fargo soils are cultivated.

Representative profile of Fargo silty clay, 1,980 feet north and 600 feet west of the southeast corner of sec. 20, T. 129 N., R. 44 W.:

Ap—0 to 6 inches, black (N 2/0) silty clay; weak, fine, granular structure; very sticky; neutral; abrupt, smooth boundary.

A12—6 to 13 inches, black (N 2/0) silty clay; weak, fine, granular structure; very sticky; neutral; clear, irregular boundary.

B2—13 to 18 inches, light brownish gray (2.5Y 6/2) silty clay; moderate, fine, subangular blocky structure; very sticky; few tongues of black material extend into this horizon; slight effervescence; mildly alkaline; clear, wavy boundary.

C1ca—18 to 27 inches, olive gray (5Y 5/2) silty clay; moderate, very fine, subangular blocky structure; very sticky; few masses of gypsum crystals; strong effervescence; moderately alkaline; gradual, wavy boundary.

C2—27 to 33 inches, light olive gray (5Y 6/2) silty clay; weak, very fine, subangular blocky structure; very sticky; few masses of gypsum crystals; strong effervescence; mildly alkaline; gradual, wavy boundary.

C3g—33 to 60 inches, light olive gray (5Y 6/2) silty clay; common, fine, prominent, olive yellow (2.5Y 6/6) mottles; weak, very fine, subangular blocky structure; very sticky; common masses of gypsum crystals; strong effervescence; mildly alkaline.

Thickness of the solum ranges from 16 to 24 inches. The A horizon ranges from silty clay to clay. It is 8 to 20 inches thick. Lacustrine lake sediment ranges from 40 to more than 60 inches in thickness.

Fargo soils are associated with Roliss soils. They contain more clay than Roliss soils.

57—Fargo silty clay (0 to 1 percent slopes). This nearly level soil is on a smooth lake plain that has a few slight rises and shallow depressions. Areas are variable in size and shape.

Included with this soil in mapping are areas of soils that have a calcareous surface layer, areas of soils that are underlain by clay loam at a depth of 36 to 42 inches, and areas of soils that have more sand in the upper part of the profile than this Fargo soil. Also included are small areas of Roliss and Wheatville soils.

Most areas of this soil are used for cultivated crops. It is suited to all crops commonly grown in the county.

The main management needs are improving drainage, fertility, and tilth and controlling erosion. Capability unit IIw–1; windbreak suitability group 3; recreation group 4; pasture and hayland group 3.

Flom Series

The Flom series consists of poorly drained and somewhat poorly drained, nearly level soils in shallow depressions, drainageways, swales, and flats. These soils formed in calcareous loamy glacial till.

In a representative profile the surface layer is black silty clay loam about 17 inches thick. The subsoil is dark grayish-brown, firm clay loam about 4 inches thick. The underlying material is loam. The upper 10 inches of this layer is grayish brown, and the lower part is light olive brown.

Flom soils have high available water capacity, high natural fertility, and high organic-matter content. The surface layer is neutral. Permeability is moderately slow.

If adequate drainage, fertilization, and management practices are used, Flom soils are suited to the crops commonly grown in the county.

Representative profile of Flom silty clay loam, 125 feet north and 5 feet west of the southeast corner of sec. 28, T. 127 N., R. 41 W.:

A1—0 to 17 inches, black (10YR 2/1) silty clay loam; weak, fine, subangular blocky structure; friable; neutral; clear, wavy boundary.

B2g—17 to 21 inches, dark grayish brown (2.5Y 4/2) clay loam; few, fine, distinct, yellowish brown (10YR 5/4) mottles and common, fine, faint, light gray (2.5Y 7/2) mottles; moderate, medium, subangular blocky structure; firm; about 1 percent coarse fragments; neutral; gradual, wavy boundary.

C1gca—21 to 31 inches, grayish brown (2.5Y 5/2) loam; weak, fine, subangular blocky structure; friable; about 3 percent coarse fragments; violent effervescence; moderately alkaline; gradual, wavy boundary.

C2—31 to 60 inches, light olive brown (2.5Y 5/4) loam; common, medium, prominent, yellowish brown (10YR 5/4) mottles and common, fine, distinct, light gray (2.5Y 7/2) mottles; weak, fine, subangular blocky structure; friable; common fine spots of lime; about 3 percent coarse fragments; strong effervescence; mildly alkaline.

Depth to free carbonates ranges from 16 to 30 inches. The A horizon is clay loam or silty clay loam 12 to 20 inches thick. It has a granular or subangular blocky structure. Reaction ranges from neutral to mildly alkaline. The B horizon is olive gray, dark grayish brown or grayish brown. It is silty clay loam or clay loam 4 to 10 inches thick. The number, size, color, and distinctness of the mottles vary and depend on the depth to the water table and the location of the soil in the landscape. The C horizon is loam or clay loam.

Flom soils are associated with Formdale, Barnes, Aazdahl, and Svea soils. They are in lower positions than these soils and have a grayer B horizon than any of these soils except Aazdahl soils.

36—Flom silty clay loam (0 to 2 percent slopes). This nearly level to slightly concave soil is in swales, natural draws, shallow depressions, and lower areas on the morainic uplands and till plains. Areas range from 3 to 20 acres in size. In some areas the subsoil is more clayey than is defined in the range for the Flom series.

Included with this soil in mapping are small areas of soils that have a surface layer more than 20 inches thick and areas of soils that have a calcareous surface layer. Also included in Roseville township are areas of soils that are silty clay to clay throughout the profile and small areas of Aazdahl, Svea, Vallers, Quam and Parnell soils.

Unless the soil is drained, it generally is not well suited to cultivation. If adequately drained, it is suited to all crops grown in the county. Open ditches provide adequate drainage in most years, but a tile system is needed for complete drainage.

The main management needs are drainage and improving fertility and tilth. Capability unit IIw–1; windbreak suitability group 3; recreation group 4; pasture and hayland group 3.

Forada Series

The Forada series consists of very poorly drained and poorly drained, nearly level soils that formed in loamy material underlain by calcareous gravelly outwash at a depth of 22 to 40 inches.

In a representative profile the surface layer is about 15 inches thick. The upper part is black sandy loam, and the lower part is black sandy clay loam. The subsoil is about 11 inches thick. The upper 8 inches is very dark grayish-brown sandy clay loam, and the lower 3 inches is olive gravelly sandy loam. The underlying material is olive-gray gravelly coarse sand.

Forada soils have high natural fertility, low to moderate available water capacity, and high organic-matter content. Permeability is moderate in the upper part and rapid in the underlying material. The surface layer is mildly alkaline.

If adequately drained, Forada soils are suited to all crops commonly grown in the county.

Representative profile of Forada sandy loam, 500 feet south and 600 feet west of the northeast corner of sec. 30, T. 128 N., R. 41 W.:

Ap—0 to 8 inches, black (10YR 2/1) sandy loam; weak, fine, subangular blocky structure; very friable; mildly alkaline; abrupt, smooth boundary.

A12—8 to 15 inches, black (10YR 2/1) sandy clay loam; weak, fine, subangular blocky structure; very friable; mildly alkaline; abrupt, wavy boundary.

B2g—15 to 23 inches, very dark grayish brown (10YR 3/2) sandy clay loam; few, fine, faint, strong brown (7.5YR 5/8) mottles; moderate; medium, subangular blocky structure; friable; mildly alkaline; clear, wavy boundary.

B3—23 to 26 inches, olive (5Y 5/4) gravelly sandy loam; common, medium, distinct, yellowish brown (10YR 5/6) mottles; moderate, very fine, subangular blocky structure; very friable; mildly alkaline; clear, wavy boundary.

IIC—26 to 60 inches, olive gray (5Y 4/2) gravelly coarse sand; single grained; loose; strong effervescence; mildly alkaline.

Thickness of solum, depth to gravelly coarse sand, and depth to free carbonates all range from 22 to 40 inches. The A horizon generally is black, but it is very dark gray in places. It is loam, sandy clay loam, or sandy loam 12 to 18 inches thick. The B horizon generally is sandy loam, but subhorizons in places are sandy clay loam or loam that has faint to prominent mottles throughout. Structure of the subhorizons is weak or moderate, subangular blocky. The IIC horizon is sand, coarse sand, or gravelly coarse sand.

In many areas in the county, Forada soils have more clay, less sand, and more silt in the solum and slower permeability than defined in the range of the series. These differences do not significantly affect their use and management.

Forada soils are associated with Arvilla and Fordville soils. They are more poorly drained and at lower elevations than these soils.

375—Forada sandy loam (0 to 2 percent slopes). This nearly level soil is on outwash plains, stream terraces, glacial lake beaches, and uplands. Areas are irregularly shaped and variable in size and are on plane to slightly concave slopes. In a few areas the surface layer is calcareous.

Included with this soil in mapping are small areas of Arvilla soils. Also included are small areas of soils that have gravelly coarse sand at a depth of more than 40 inches.

This soil cannot be cropped successfully each year unless it is adequately drained. Drainage systems are difficult to maintain because the underlying gravelly coarse sand tends to cave in. Nearly all areas of this soil are used for cultivated crops. Undrained or in-

adequately drained areas are used for pasture. This soil is suited to all crops commonly grown in the county.

The main management needs are improving drainage, fertility, and tilth. Capability unit IIw–3; windbreak suitability group 3; recreation group 4; pasture and hayland group 3.

Fordville Series

The Fordville series consists of well-drained, nearly level soils that formed in loamy material underlain by gravelly outwash at a depth of 2 to 3½ feet. These soils are mainly in river valleys.

In a representative profile the surface layer is black loam about 12 inches thick. The subsoil is about 18 inches thick. The upper 8 inches of this layer is friable, dark-brown and brown loam, and the lower 10 inches is friable, yellowish-brown gravelly loam. The underlying material is yellowish-brown gravelly coarse sand.

Fordville soils have high natural fertility, high organic-matter content, and low to moderate available water capacity. Permeability is moderate in the surface layer and subsoil and rapid in the underlying material. The surface layer is neutral.

These soils are free of stones and easy to cultivate. A good seedbed can be prepared easily. Nearly all areas of Fordville soils are used for cultivated crops.

Representative profile of Fordville loam, 0 to 2 percent slopes 2,350 feet east and 1,200 feet south of the northwest corner of sec. 19, T. 129 N., R. 41 W.:

Ap—0 to 6 inches, black (10YR 2/1) loam; weak, fine, subangular blocky structure; very friable; neutral; abrupt, smooth boundary.

A12—6 to 12 inches, black (10YR 2/1) loam; weak, fine, subangular blocky structure; very friable; neutral; abrupt, smooth boundary.

B21—12 to 17 inches, dark brown (10YR 3/3) loam; very dark grayish brown (10YR 3/2) coatings on faces of peds; moderate, medium, prismatic structure parting to weak, fine, subangular blocky; friable; neutral; clear, wavy boundary.

B22—17 to 20 inches, brown (10YR 4/3) loam; moderate, medium, prismatic structure parting to weak, fine, subangular blocky; friable; neutral; clear, wavy boundary.

IIB3ca—20 to 30 inches, yellowish brown (10YR 5/4) gravelly loam; massive; friable; about 15 percent gravel; strong effervescence; mildly alkaline; clear, wavy boundary.

IIC—30 to 60 inches, yellowish brown (10YR 5/6) gravelly coarse sand; single grained; loose; limy coatings on undersides of pebbles in upper part; strong effervescence; mildly alkaline.

Depth to gravelly coarse sand is 20 to 36 inches. Thickness of the A horizon is 12 to 22 inches. The A horizon generally is black, but in places it is very dark gray. It generally is loam, but it is clay loam in places. The B horizon is brown, dark brown, very dark grayish brown, and yellowish brown. It is mainly loam or clay loam, but it commonly grades to gravelly loam or sandy loam with increasing depth.

Fordville soils are associated with Arvilla soils. They have a thicker solum than Arvilla soils.

339—Fordville loam, 0 to 2 percent slopes. This nearly level soil is on outwash plains and stream terraces. It is adjacent to areas of the droughty Arvilla soils. A few small areas are on uplands and are adjacent to areas of Barnes soils. In places the depth to gravelly coarse sand is more than 40 inches. In a few areas the soil is moderately well drained. In some areas the subsoil is clay loam.

Included with this soil in mapping are small areas of Arvilla soils. Also included are a few areas of gently sloping soils.

This soil is suited to all crops commonly grown in the county. Most areas of this soil are cultivated. A small acreage is in pasture. This soil has a slight hazard of drought because of the low to moderate available water capacity, but it is suited to irrigation of field and vegetable crops. A good seedbed can be prepared easily. Soil blowing is a hazard on this soil.

The main management needs are controlling erosion, conserving moisture, and maintaining fertility. Capability unit IIs–1; windbreak suitability group 5; recreation group 1; pasture and hayland group 1.

Formdale Series

The Formdale series consists of well-drained, undulating to hilly soils that formed in calcareous loamy glacial till.

In a representative profile the surface layer is black clay loam about 9 inches thick. The subsoil is dark-brown and dark yellowish-brown, friable clay loam about 7 inches thick. The underlying material is clay loam. The upper 18 inches of this layer is yellowish brown, and the lower part is light olive brown.

Formdale soils have high natural fertility, moderate to high available water capacity, and high organic-matter content. Permeability is moderately slow. The surface layer is neutral.

These soils are well suited to all crops commonly grown in the county. Most areas of Formdale soils are cultivated.

Representative profile of Formdale clay loam, 2 to 5 percent slopes, 1,500 feet west and 150 feet north of the southeast corner of sec. 33, T. 127 N., R. 42 W.:

Ap—0 to 9 inches, black (10YR 2/1) clay loam; weak, very fine, granular structure; friable; about 2 percent coarse fragments; neutral; abrupt, smooth boundary.

B21—9 to 13 inches, dark brown (10YR 3/3) clay loam; weak, coarse, prismatic structure parting to moderate, medium, subangular blocky; friable; about 2 percent coarse fragments; neutral; clear, wavy boundary.

B22—13 to 16 inches, dark yellowish brown (10YR 4/4) clay loam; weak, coarse, prismatic structure parting to moderate, medium, subangular blocky; friable; about 2 percent coarse fragments; slight effervescence; mildly alkaline; clear, wavy boundary.

C1ca—16 to 34 inches, yellowish brown (10YR 5/4) clay loam; weak, fine, subangular blocky structure very friable; about 5 percent coarse fragments; many fine, soft, light gray (10YR 7/1) limy masses; violent effervescence; moderately alkaline; gradual, wavy boundary.

C2—34 to 60 inches, light olive brown (2.5Y 5/4) clay loam; few, fine, distinct, yellowish brown (10YR 5/6) mottles throughout; many, fine, distinct, gray (5Y 6/1) mottles in the lower part; weak, medium and thick, platy structure parting to weak, very fine and fine, angular blocky; friable; about 5 percent coarse fragments; strong effervescence; moderately alkaline.

Thickness of the solum ranges from 8 to 20 inches. The A horizon is clay loam, but it is silty clay loam in places. It generally is black, but it is very dark gray in places. In

some profiles, the lower part of the A horizon is very dark grayish brown or very dark brown. The B horizon generally is clay loam, but it is silty clay loam in places. It generally is dark brown, dark yellowish brown, or brown, but in some profiles the lower part of the B horizon is olive brown. Primary structure is generally weak or moderate, prismatic. Secondary structure is generally weak or moderate, subangular blocky. However, it does not have the prismatic primary structure where the B horizon is near the thinner limit as defined in the range for the series. The C horizon generally is clay loam, but it is loam, silt loam, or silty clay loam in places.

Formdale soils are associated with Langhei and Aazdahl soils. They have a thicker solum than Langhei soils and are better drained than Aazdahl soils.

171B—Formdale clay loam, 2 to 5 percent slopes. This undulating soil is on till plains. It generally is higher than areas of the moderately well drained Aazdahl soils. The slopes are convex and are 50 to 200 feet long. In some places the slopes are fairly uniform and in one direction, but in other places they are undulating in many directions. In some cultivated areas this soil is moderately eroded and has the original surface layer mixed with the subsoil, resulting in a brownish color. In a few areas in Roseville township, this soil has a surface layer and subsoil of silty clay or clay. This soil has the profile described as representative of the series.

Included with this soil in mapping are small areas of Aazdahl soils in slightly convex areas, Darnen soils on concave slopes, Langhei soils on the more convex exposed knobs, and Parnell and Flom soils in drainageways and depressions. Also included are areas of soils that have fewer and steeper slopes and eroded and sandy spots.

This soil is used for cultivated crops. A few areas are in pasture. The soil is suited to all crops commonly grown in the county. Water runs off at a medium rate, causing a moderate hazard of erosion.

The main management needs are controlling erosion, improving tilth, and maintaining fertility. Capability unit IIe–1; windbreak suitability group 1; recreation group 1; pasture and hayland group 1.

912B—Formdale-Aazdahl-Flom complex, 1 to 4 percent slopes. This complex consists of nearly level to gently sloping soils. The topography is bumpy and has many slight depressions and small rises. The Formdale soil makes up 30 to 60 percent of the area, the Aazdahl soil makes up 20 to 40 percent, and the Flom soil makes up 15 to 30 percent. The Formdale soil is on the more convex parts of slopes, the Flom soil is in drainageways and depressions, and the Aazdahl soil is in slightly convex to nearly level areas between depressions and rises of the Formdale soil.

Included with these soils in mapping are small areas of Hamerly and Vallers soils on slight rises and at the edges of depressions and Parnell soils in depressions.

These soils are used for cultivated crops and pasture. They are suited to all crops commonly grown in the county.

The main management needs are improving fertility and tilth, controlling erosion, and improving drainage. Capability unit IIe–1; Formdale and Aazdahl parts in windbreak suitability group 1, Flom part in windbreak suitability group 3; Formdale and Aazdahl parts in recreation group 1, Flom part in recreation group 4; Formdale and Aazdahl parts in pasture and hayland group 1, Flom part in pasture and hayland group 3.

931B—Formdale-Langhei clay loams, 3 to 6 percent slopes. This mapping unit consists of intermingled areas of undulating Formdale and Langhei soils. The Formdale soil makes up 60 to 80 percent of the areas, and the Langhei soil makes up 20 to 40 percent. The Formdale soil is on the less convex parts of the slopes, and the Langhei soil is on the more convex and exposed parts of the slopes. The surface layer of the Langhei soil is light gray when dry, and the surface layer of the Formdale soil is black. The slopes are 50 to 200 feet long. In most areas they are complex, but in some they are more uniform and slope in one direction. The Langhei soil in this mapping unit is mainly clay loam throughout the profile.

Included with these soils in mapping are areas of soils in which the light olive-brown underlying material of the Langhei soil and the dark-brown subsoil of the Formdale soil are exposed. Also included are small areas of Aazdahl soils on slightly concave positions, Darnen soils on toe slopes, Flom soils in drainageways, and small areas of gravelly and sandy soils and soils that are steeper than Formdale and Langhei soils. Many small areas, ½ acre to 3 acres in size, of Flom, Quam, and Parnell soils are indicated on the soil maps by spot symbols.

Most areas of this mapping unit are used for the cultivated crops commonly grown in the county. The Langhei soil is less productive than the Formdale soil because it has lower natural fertility. Water runs off at a medium rate, and the hazard of erosion is moderate.

The main management needs are controlling erosion, improving fertility and tilth, and conserving moisture. Capability unit IIe–1; Formdale part in windbreak suitability group 1, Langhei part in windbreak suitability group 2; recreation group 1; pasture and hayland group 1.

Glyndon Series

The Glyndon series consists of somewhat poorly drained to moderately well drained, nearly level, calcareous soils. These soils formed in silty sediment that ranges from about 1½ to 3 feet thick and is underlain by lacustrine material.

In a representative profile the surface layer is black silt loam about 10 inches thick. The upper 13 inches of the underlying material is grayish-brown and gray silt loam. The next 5 inches of this layer is light yellowish-brown very fine sandy loam, and the lower part is light olive-brown very fine sand.

Glyndon soils have medium natural fertility, high available water capacity, and high organic-matter content. Permeability is moderate. The surface layer is moderately alkaline.

The high content of lime of these soils causes an imbalance of available plant nutrients. Nearly all areas of Glyndon soils are used for cultivated crops.

Representative profile of Glyndon silt loam, 0 to 2 percent slopes, 540 feet south and 1,500 feet east of the northwest corner of sec. 6, T. 129 N., R. 44 W.:

Ap—0 to 7 inches, black (10YR 2/1) silt loam; few masses of grayish brown (10YR 5/2); weak, very fine, granular structure; friable; strong effervescence; moderately alkaline; clear, wavy boundary.

A12—7 to 10 inches, black (10YR 2/1) silt loam; few spots of grayish brown (10YR 5/2); weak, very fine, granular structure; friable; strong effervescence; moderately alkaline; clear, wavy boundary.

C1ca—10 to 16 inches, grayish brown (10YR 5/2) silt loam; few masses of gray (10YR 6/1); weak, very fine, subangular blocky structure; friable; violent effervescence; moderately alkaline; clear, wavy boundary.

C2ca—16 to 23 inches, gray (10YR 6/1) silt loam; weak, fine, subangular structure; friable; violent effervescence; moderately alkaline; gradual, wavy boundary.

IIC3—23 to 28 inches, light yellowish brown (2.5Y 6/4) very fine sandy loam; single grained; loose; strong effervescence; moderately alkaline; gradual, wavy boundary.

IIC4—28 to 60 inches, light olive brown (2.5Y 5/4) very fine sand; common, fine, distinct, yellowish brown (10YR 5/6) mottles; single grained; loose; few reddish manganese concretions; strong effervescence; moderately alkaline.

The A horizon generally is black or very dark gray silt loam or loam. In some places there is an Aca horizon that is very dark gray. The A horizon is 7 to 16 inches thick. Depth to the underlying very fine sand or loamy very fine sand ranges from 18 to 36 inches, but it generally is about 30 inches.

Glyndon soils are associated with Wheatville and Bearden soils. They have neither the silty substratum typical of Bearden nor the clayey substratum typical of Wheatville soils.

60—Glyndon silt loam, 0 to 2 percent slopes. This nearly level soil is in the glacial lake basin. A few areas are along beach ridges. Areas have a smooth appearance when cultivated. Slopes are nearly level to slightly convex.

Included with this soil in mapping are small areas of Wheatville and Bearden soils. Also included are some areas of soils that have a zone of lime accumulation at the surface and a few areas of soils that have clay loam glacial till above a depth of 40 inches.

Nearly all areas of this soil are cultivated. The soil is suited to all crops commonly grown in the county, but most areas are used for small grains and sunflowers. Soil blowing is a hazard on unprotected fields during winter and early spring. This soil has a high content of lime, resulting in an imbalance of nutrients.

The main management needs are controlling soil blowing and overcoming the high lime conditions. Capability unit IIs–2; windbreak suitability group 2; recreation group 1; pasture and hayland group 1.

Grimstad Series

The Grimstad series consists of somewhat poorly drained to moderately well drained, nearly level, calcareous soils that formed in stratified loamy and sandy material underlain by loamy material.

In a representative profile the surface layer is very fine sandy loam about 15 inches thick. The upper 9 inches is black, and the lower 6 inches is dark grayish brown. The upper 11 inches of the underlying material is light brownish-gray and light yellowish-brown loamy fine sand, the next 5 inches of this layer is grayish-brown clay loam, and the lower part is light olive-brown clay loam.

Grimstad soils have medium natural fertility, high organic-matter content, and moderate to high available water capacity. Permeability is moderate. The surface layer is moderately alkaline.

The upper part of the profile of these soils has a high content of lime that causes an imbalance of plant nutrients. Most areas of Grimstad soils are used for cultivated crops.

Representative profile of Grimstad very fine sandy loam in an area of Grimstad-Towner complex, 0 to 2 percent slopes, 850 feet east and 1,020 feet north of the southwest corner of sec. 19, T. 130 N., R. 44 W.:

Ap—0 to 9 inches, black (10YR 2/1) very fine sandy loam; weak, very fine, granular structure; friable; violent effervescence; moderately alkaline; abrupt, smooth boundary.

A12ca—9 to 15 inches, dark grayish brown (10YR 4/2) very fine sandy loam; weak, very fine, granular structure; friable; violent effervescence; moderately alkaline; clear, wavy boundary.

C1ca—15 to 18 inches, light brownish gray (10YR 6/2) loamy fine sand; weak, very fine granular structure; few spots of dark grayish brown (10YR 4/2); friable; violent effervescence; moderately alkaline; clear, wavy boundary.

C2ca—18 to 21 inches, light yellowish brown (2.5Y 6/4) loamy sand; single grained; loose; violent effervescence; moderately alkaline; abrupt, wavy boundary.

C3—21 to 26 inches, light yellowish brown (2.5Y 6/4) loamy fine sand; single grained; loose; slight effervescence; mildly alkaline; abrupt, wavy boundary.

IIC4—26 to 31 inches, grayish brown (2.5Y 5/2) clay loam; few, faint, light olive brown (2.5Y 5/6) mottles; weak, very fine, subangular blocky structure; friable; about 5 percent coarse fragments; strong effervescence; moderately alkaline; gradual, wavy boundary.

IIC5—31 to 60 inches, light olive brown (2.5Y 5/4) clay loam; common, fine, distinct, yellowish brown (10YR 5/6) and common, fine, distinct, gray (5Y 5/1) mottles; weak, very fine, subangular blocky structure; firm; about 5 percent coarse fragments; strong effervescence; moderately alkaline.

The A horizon is 8 to 16 inches thick. It is fine sandy loam, very fine sandy loam, sandy loam, or loam. The C horizon is loamy fine sand, loamy sand, or loamy very fine sand, but in places the upper part is fine sandy loam or sandy loam. In places the A horizon contains gypsum crystals. The IIC horizon is loam or clay loam. It is at a depth of 20 to 40 inches. In some profiles, a thin pebble band is at the top of the IIC horizon.

Grimstad soils are associated with Rockwell and Towner soils. They are better drained and have more brownish underlying material than Rockwell soils. They have more lime near the surface than Towner soils.

914—Grimstad-Towner complex, 0 to 2 percent slopes. This complex is in areas that range from 4 to 120 acres in size. The topography is level to nearly level in the glacial lake plain, and changes in elevation are slight. The surface layer has a smooth, brindled appearance. The Grimstad soil and the Towner soil each makes up 40 to 60 percent of the complex. The Grimstad soil has the profile described as representative of its series. The profile of the Towner soil differs from the profile described as representative of its series in being mildly alkaline in the surface layer.

Included with this complex in mapping are small areas of Rockwell and Kittson variant soils. Also included are some small areas of soils that have underlying loam or clay loam material at a depth of more than 40 inches.

Most areas of this complex are used for the cultivated crops commonly grown in the county. Small grains are the most common crop, but some row crops, such as sunflowers, soybeans, and corn, are also grown. The Grimstad soil has a high content of lime that causes an imbalance of nutrients. Soil blowing is a serious hazard in winter and early spring if the soil is left unprotected.

The main management needs are controlling erosion, improving fertility, and maintaining tilth. Capability unit IIIs–3; Grimstad part in windbreak suitability group 2, Towner part in windbreak suitability group 5; recreation group 1; pasture and hayland group 1.

Hamerly Series

The Hamerly series consists of somewhat poorly drained to moderately well drained, nearly level, calcareous soils that formed in loamy glacial till.

In a representative profile the surface layer is clay loam about 19 inches thick. The upper 8 inches of this layer is black, the middle 4 inches is very dark gray, and the lower 7 inches is dark gray. The underlying material is clay loam. The upper 7 inches of this layer is grayish brown, the next 4 inches is light olive brown, and the lower part is light brownish gray.

Hamerly soils have medium natural fertility, high organic-matter content, and moderate to high available water capacity. Permeability is moderately slow. The surface layer is moderately alkaline.

The upper part of the profile of these soils has a high content of lime that causes an imbalance of plant nutrients. Nearly all areas of Hamerly soils are used for cultivated crops.

Representative profile of Hamerly clay loam, in an area of Hamerly-Parnell complex, 0 to 3 percent slopes, 550 feet west and 21 feet south of the northeast corner of sec. 4, T. 128 N., R. 24 W.:

Ap—0 to 8 inches, black (10YR 2/1) clay loam; moderate, fine, subangular blocky structure parting to moderate, medium, granular; friable; strong effervescence; moderately alkaline; abrupt, smooth boundary.

A12—8 to 12 inches, very dark gray (10YR 3/1) clay loam; moderate, fine, subangular blocky structure parting to moderate, medium, granular; friable; violent effervescence; moderately alkaline; gradual, wavy boundary.

A13—12 to 19 inches, dark gray (10YR 4/1) clay loam; weak, fine, subangular blocky structure; friable; violent effervescence; moderately alkaline; gradual, wavy boundary.

C1ca—19 to 26 inches, grayish brown (2.5Y 5/2, crushed) clay loam; weak, very fine, subangular blocky structure; friable; about 3 percent coarse fragments; strong effervescence; moderately alkaline; clear, wavy boundary.

C2—26 to 30 inches, light olive brown (2.5Y 5/4) clay loam; weak, very fine, subangular blocky structure; friable; about 3 percent coarse fragments; strong effervescence; mildly alkaline; gradual, wavy boundary.

C3—30 to 60 inches, light brownish gray (2.5Y 6/2 clay loam; common, fine, prominent, yellowish brown (10YR 5/6) mottles; weak, very fine, subangular blocky structure; friable; about 3 percent coarse fragments; few lime concretions; strong effervescence; mildly alkaline.

Texture ranges from loam to clay loam throughout. Hamerly soils associated with Barnes and Svea soils generally are loam throughout, and Hamerly soils associated with Aazdahl and related soils are mainly clay loam throughout. The Ap horizon is 6 to 10 inches thick, and the A1ca horizon is 4 to 10 inches thick. In some profiles, the C horizon contains gypsum crystals. Hamerly soils are mildly or moderately alkaline.

Hamerly soils are associated with Barnes, Formdale, and Vallers soils. They are calcareous throughout and moderately well drained, and Barnes and Formdale soils are not calcareous in the solum and are well drained. Hamerly soils are better drained than Vallers soils.

184—Hamerly clay loam, 1 to 3 percent slopes. This nearly level soil is on convex swells and low rises on depressional till plains and morainic uplands. On the crests of higher swells, the surface layer is thinner than it is in other places. The Hamerly soils associated with Barnes soils are loam, and those associated with Formdale soils are clay loam.

Included with this soil in mapping are small areas of Formdale, Barnes, Aazdahl, and Svea soils on small rises and convex swells. Also included are areas of Flom, Quam, and Parnell soils in drainageways and depressions. Many of these areas, which are ½ acre to 3 acres in size, are indicated on the soil maps by a spot symbol. Also included are a few small areas of soils that have a surface layer and subsoil of sandy loam, silt loam, or silty clay loam.

Most areas of this soil are used for cultivated crops. A few areas are used for hay and pasture. This soil is suited to all crops commonly grown in the county. Excess lime near the surface causes an imbalance of nutrients.

The main management needs are improving fertility and tilth and controlling erosion. Capability unit IIs–2; windbreak suitability group 2; recreation group 1; pasture and hayland group 1.

922—Hamerly-Parnell complex, 0 to 3 percent slopes. This mapping unit consists of nearly level soils on ground moraines. It occupies swells and rises in depressional areas. Differences in elevation are slight. The Hamerly soil makes up 60 to 80 percent of the complex, and the Parnell soil makes up 20 to 40 percent. The Hamerly clay loam is on the convex swells and low rises, and the Parnell silty clay loam is in the depressions and drainageways. The Parnell soil has the profile described as representative of its series.

Included with these soils in mapping are small areas of Aazdahl, Svea, Flom, and Vallers soils. Also included are small areas of soils that are more sloping than those soils and areas of soils that have a surface layer and subsoil of silt loam.

These soils are used for cultivated crops and pasture and are suited to all crops commonly grown in the county. Excess lime in the surface layer of the Hamerly soil causes an imbalance of nutrients. The Parnell soil is in depressions and holds water or becomes too wet to bear machinery in spring or after rains.

The main management need is improving fertility, tilth, and drainage. Capability unit IIe–2; Hamerly part in windbreak suitability group 2, Parnell part in windbreak suitability group 7; Hamerly part in recreation group 1, Parnell part in recreation group 4; Hamerly part in pasture and hayland group 1, Parnell part in pasture and hayland group 6.

Hecla Series

The Hecla series consists of moderately well drained, nearly level soils that formed in sandy material such as the material in beach ridges.

In a representative profile the surface layer is loamy fine sand about 15 inches thick. The upper part is black, and the lower part is very dark grayish brown. The subsoil is loose fine sand about 11 inches thick. The upper 8 inches is dark brown, and the lower 3 inches is grayish brown and dark grayish brown. The underlying material is pale-olive fine sand.

Hecla soils have low natural fertility, moderate organic-matter content, and low available water capacity. The surface layer is neutral. Permeability is rapid.

Nearly all areas of Hecla soils are used for cultivated crops, but some areas are planted to grass and are used for pasture.

Representative profile of Hecla loamy fine sand, 0 to 2 percent slopes, 2,620 feet north and 1,250 feet east of the southwest corner of sec. 17, T. 127 N., R. 44 W.:

Ap—0 to 9 inches, black (10YR 2/1) loamy fine sand, weak, fine, granular structure; loose; neutral; abrupt, wavy boundary.

A1—9 to 15 inches, very dark grayish brown (10YR 3/2) loamy fine sand; weak, very fine, granular structure; loose; neutral; gradual, wavy boundary.

B2—15 to 23 inches, dark brown (10YR 3/3) fine sand; single grained; loose; neutral; clear, wavy boundary.

B3—23 to 26 inches, grayish brown (2.5Y 5/2) and dark grayish brown (10YR 4/2) fine sand; single grained; loose; strong effervescence; mildly alkaline; clear, wavy boundary.

C1—26 to 60 inches, pale olive (5Y 6/3) fine sand; common, fine, prominent, yellowish brown (10YR 5/4) mottles and common, medium, prominent, very dark grayish brown (10YR 3/2) mottles; single grained; loose; strong effervescence; mildly alkaline.

The A horizon generally is very dark gray or black, but in some eroded areas it is very dark brown or very dark grayish brown. It is loamy fine sand or fine sand 10 to 20 inches thick. The B horizon generally is very dark grayish brown, grayish brown, dark brown, yellowish brown, olive brown, and light olive brown. The C horizon is fine sand or sand and has faint or distinct mottles.

Hecla soils are associated with Towner and Maddock soils. They do not have a clay loam IIC horizon, unlike Towner soils. They have mottles within a depth of 40 inches, unlike Maddock soils.

366—Hecla loamy fine sand, 0 to 2 percent slopes. This nearly level soil in some areas is on a combination of slightly concave and convex topography. In other areas it is a slight rise within areas of other soils. Areas of this soil are variable in size and shape.

Included with this soil in mapping are small areas of Ulen, Arveson, and Towner soils.

Most areas of this soil are cultivated. Early-maturing crops, such as small grains, are best suited to this soil because of the hazard of drought. If this soil is left unprotected, soil blowing is a hazard during winter and early spring.

The main management needs are controlling erosion, conserving moisture, and improving fertility. Capability unit IVs–2; windbreak suitability group 5; recreation group 3; pasture and hayland group 7.

Kittson Series

The Kittson series consists of somewhat poorly drained to moderately well drained, nearly level soils that formed in calcareous loamy glacial till.

In a representative profile the surface layer is very fine sandy loam about 10 inches thick. The upper part is black, and the lower part is very dark brown. The subsoil is friable, dark grayish-brown very fine sandy loam about 7 inches thick. The underlying material is clay loam. The upper part of this layer is grayish brown, and the lower part is light olive brown.

Kittson soils have high natural fertility, high organic-matter content, and moderate to high available water capacity. Permeability is moderately slow. The surface layer is neutral.

Nearly all areas of these soils are cultivated, but a few areas are in pasture. Kittson soils are suited to all crops commonly grown in the county.

Representative profile of Kittson very fine sandy loam, 0 to 2 percent slopes, 600 feet north and 600 feet east of the southwest corner of sec. 31, T. 128 N., R. 44 W.:

Ap—0 to 6 inches, black (10YR 2/1) very fine sandy loam; weak, very fine, granular structure; friable; neutral; abrupt, smooth boundary.

A12—6 to 10 inches, very dark brown (10YR 2/2) very fine sandy loam; weak, fine, granular structure; friable; neutral; abrupt, wavy boundary.

B2—10 to 17 inches, dark grayish brown (10YR 4/2) very fine sandy loam; weak, fine, subangular blocky structure; friable; mildly alkaline; abrupt, wavy boundary.

IIC1ca—17 to 38 inches, grayish brown (2.5Y 5/2) clay loam; few, fine, faint, light olive brown (2.5Y 5/6) mottles; weak, very fine, subangular blocky structure; very firm; about 3 percent coarse fragments; strong effervescence; mildly alkaline; abrupt, wavy boundary.

IIC2—38 to 60 inches, light olive brown (2.5Y 5/4) clay loam; common, fine, distinct, yellowish brown (10YR 5/6) mottles and many, medium, prominent, gray (5Y 5/1) mottles; weak, fine, subangular blocky structure; very firm; few iron and manganese concretions; about 3 percent coarse fragments; strong effervescence; mildly alkaline.

The A horizon generally is black, but it is very dark gray or very dark brown in places. It is loam, very fine sandy loam, sandy loam, or fine sandy loam 9 to 14 inches thick. The B horizon is dark grayish brown, dark brown, and dark gray. It is very fine sandy loam, loam, or sandy clay loam. The IIC horizon is loam or clay loam. In some profiles, a coarse-textured layer as much as 6 inches thick is above the IIC horizon.

Kittson soils are associated with Roliss and Towner soils. They do not have the sandy layer typical of Towner soils. They are better drained than Roliss soils.

58—Kittson very fine sandy loam, 0 to 2 percent slopes. This nearly level soil is on slight rises and slightly lower areas. Areas range from 5 to 160 acres in size. The soil is on a lake plain and nearby interbeach areas that commonly are coarser textured than the lake plain.

Included with this soil in mapping are a few small areas of soils that have a calcareous surface layer. Also included are small areas of Roliss, Kittson variant, and Towner soils.

Most areas of this soil are used for cultivated crops.

A few areas are used for hay and pasture. Small grains are the most common crops, but row crops, such as corn, soybeans, and sunflowers, are also grown. This soil is suited to all crops commonly grown in the county.

The main management need is maintaining fertility and tilth. Capability unit I–1; windbreak suitability group 1; recreation group 1; pasture and hayland group 1.

Kittson Variant

The Kittson variant consists of very poorly drained and poorly drained, nearly level soils in the glacial lake basin. These soils formed in loamy material underlain by calcareous loamy glacial till.

In a representative profile the surface layer is black fine sandy loam about 10 inches thick. The subsoil is very dark grayish-brown, very friable fine sandy loam about 11 inches thick. The underlying material is olive-gray clay loam.

The Kittson variant soils have medium natural fertility, moderate to high available water capacity, and high organic-matter content. Permeability is moderately slow. The surface layer is mildly alkaline.

Areas of the Kittson variant soils are used for cultivated crops and pasture.

Representative profile of Kittson fine sandy loam, gray subsoil variant, 385 feet north and 2,575 feet west of the southeast corner of sec. 10, T. 128 N., R. 44 W.:

A11—0 to 5 inches, black (10YR 2/1) fine sandy loam; moderate, fine, granular structure; very friable; mildly alkaline; abrupt, smooth boundary.

A12—5 to 10 inches, black (10YR 2/1) fine sandy loam; weak, medium and coarse, prismatic structure parting to moderate, fine, granular; very friable; mildly alkaline; clear, wavy boundary.

B21—10 to 15 inches, very dark grayish brown (10YR 3/2) fine sandy loam; weak, medium and coarse, subangular blocky structure; very friable; mildly alkaline; clear, wavy boundary.

B22—15 to 21 inches, very dark grayish brown (2.5Y 3/2) fine sandy loam; few, fine, faint, light olive brown (2.5Y 5/4) mottles; weak, coarse, prismatic structure parting to weak, medium, subangular blocky; very friable; mildly alkaline; abrupt, wavy boundary.

IIC1g—21 to 36 inches, olive gray (5Y 5/2) clay loam; common, fine, prominent, yellowish brown (10YR 5/6) mottles; weak, fine, subangular blocky structure; friable; about 3 percent coarse fragments; strong effervescence; mildly alkaline; gradual, wavy boundary.

IIC2g—36 to 60 inches, olive gray (5Y 5/2) clay loam; few, fine, prominent, yellowish brown (10YR 5/6) mottles; massive; firm; about 3 percent coarse fragments; strong effervescence; mildly alkaline.

Depth to free carbonates ranges from 16 to 30 inches. The A horizon generally is black, but it is very dark gray in places. It is sandy loam or fine sandy loam 8 to 18 inches thick. The B2 horizon is very dark grayish brown or dark grayish brown. It is loamy fine sand, loamy sand, sand, or fine sandy loam. The loam or clay loam IIC horizon is at a depth of 20 to 30 inches.

Kittson variant soils are associated with Rockwell, Arveson, and Towner soils. They have a noncalcareous A horizon, and Rockwell and Arveson soils have a calcareous A horizon. They are more poorly drained than Towner soils.

V58—Kittson fine sandy loam, gray subsoil variant (0 to 2 percent slopes). This nearly level soil is in the glacial lake basin. It is in slightly depressional areas that range from 5 to 30 acres in size. This soil is adjacent to or surrounded by better drained soils.

Included with this soil in mapping are small areas of Rockwell, Roliss, and Towner soils. Also included are small areas of soils that have a calcareous surface layer and a few areas of soils that have a coarse-textured layer less than 6 inches thick.

This soil is used for cultivated crops, pasture, and hayland. If it is adequately drained, it is suited to all crops commonly grown in the county.

The main management needs are maintaining and improving drainage. Capability unit IIIw–2; windbreak suitability group 3; recreation group 4; pasture and hayland group 4.

Lake Beaches

1032—Lake beaches (0 to 2 percent slopes). This mapping unit consists of soils around the borders of lakes and the edges of large ponds. It consists of mixed sandy or loamy soil material. In some areas stones are on the surface. In most areas the soil is nearly level, but in some it has short slopes and is steeper. Natural drainage is poor to very poor in level areas, but drainage is better where the slopes are steeper.

If the lakes are dry or have been drained, Lake beaches can be farmed in the same manner as surrounding areas. Natural fertility is low to medium, and available water capacity is variable, depending on the soil material.

Most areas of Lake beaches are used for pasture and wildlife. Capability unit IIIw–2; windbreak suitability group 7; recreation group 4; pasture and hayland group 6.

Lamoure Series

The Lamoure series consists of very poorly drained and poorly drained, nearly level, calcareous soils that formed in loamy alluvium along rivers and creeks.

In a representative profile the surface layer is about 32 inches thick. The upper part is black silt loam about 19 inches thick, and the lower part is black silty clay loam about 13 inches thick. The subsoil is very dark gray, slightly sticky silty clay loam about 11 inches thick. The underlying material is olive gray sandy loam.

Lamoure soils have medium natural fertility, high organic-matter content, and high to very high available water capacity. Permeability is moderate. The surface layer is moderately alkaline.

These soils are used mainly for pasture and wildlife habitat, but a few areas are cultivated.

Representative profile of Lamoure silt loam, 2,640 feet east and 250 feet north of the southwest corner of sec. 11, T. 129 N., R. 43 W.:

A11—0 to 19 inches, black (N 2/0) silt loam; weak, very fine, granular structure; friable; few concretions of lime; strong effervescence; moderately alkaline; abrupt, wavy boundary.

A12—19 to 32 inches, black (10YR 2/1) silty clay loam; weak, fine, granular structure; slightly sticky; strong effervescence; moderately alkaline; gradual, wavy boundary.

B2g—32 to 43 inches, very dark gray (5Y 3/1) silty clay loam; common, fine, distinct, brown (7.5YR 4/4) mottles; weak, fine, subangular blocky structure; slightly sticky; strong effervescence; mildly alkaline; gradual, wavy boundary.

IICg—43 to 60 inches, olive gray (5Y 5/2) sandy loam; common, fine, prominent, yellowish brown (10YR 5/6) mottles; single grained; slightly sticky; slight effervescence; mildly alkaline.

Thickness of the solum ranges from 24 to 45 inches. Depth to lime ranges from 0 to 8 inches. The A horizon is silt loam or silty clay loam. The B horizon is silt loam or silty clay loam. The C horizon is sandy loam, loam, silt loam, or silty clay loam. In some profiles gravelly coarse sand is below a depth of 40 inches.

Lamoure soils are associated with Alluvial land, frequently flooded, but are at higher elevations.

418—Lamoure silt loam (0 to 1 percent slopes). This nearly level soil is on bottom lands. Areas are long, and some are quite narrow. They are adjacent to Lamoure silt loam, frequently flooded, and Alluvial land, frequently flooded. In some spots the limy alluvium is covered with nonlimy, dark-colored sediment. In a few areas the soils are underlain by gravelly coarse sand at a depth as shallow as 36 to 40 inches. This soil has the profile described as representative of the series.

Included with this soil in mapping are small areas of Lamoure silt loam, frequently flooded, in abandoned stream channels, and Alluvial land, frequently flooded, adjacent to streams.

A few slightly higher lying areas of this soil from which water runs off better are used for the cultivated crops commonly grown in the county. A few areas cannot be adequately drained because suitable outlets are lacking. These areas are used for hay, pasture, and wetland wildlife.

The main management need is improving drainage, fertility, and tilth. Capability unit IIw–2; windbreak suitability group 4; recreation group 4; pasture and hayland group 5.

359—Lamoure silt loam, frequently flooded (0 to 1 percent slopes). This very poorly drained soil is in low-lying areas and abandoned river channels. It is adjacent to areas of Lamoure soils and Alluvial land, frequently flooded. The profile of this soil differs from the one described as representative of the series by having a thicker surface layer.

Included with this soil in mapping are small areas of other Lamoure soils and areas of soils that have a mucky surface layer.

This soil is likely to be flooded early in spring and after heavy rains in summer. The soil is generally not drained because adequate outlets are lacking. This soil is better suited to pasture and wildlife than to other uses. Capability unit VIw–1; windbreak suitability group 7; recreation group 4; pasture and hayland group 5.

Langhei Series

The Langhei series consists of somewhat excessively drained, undulating to very steep soils that formed in calcareous loamy glacial till.

In a representative profile the surface layer is dark grayish-brown loam about 5 inches thick. The underlying material is loam. The upper part of this layer is grayish brown, and the lower part is light olive brown.

Langhei soils have low natural fertility, moderate organic-matter content, and high available water capacity. Permeability is moderate. The surface layer is moderately alkaline.

The high lime content of these soils affects the availability of certain nutrients. If fertilization and erosion-control practices are used, Langhei soils are suited to the crops commonly grown in the county.

Representative profile of Langhei loam, in an area of Langhei-Barnes loams, 6 to 12 percent slopes, eroded, 1,300 feet west and 200 feet north of the southeast corner of sec. 36, T. 130 N., R. 41 W.:

Ap—0 to 5 inches, dark grayish brown (10YR 4/2) loam; light gray (10YR 7/1) dry; weak, very fine, granular structure; friable; strong effervescence; moderately alkaline; abrupt, smooth boundary.

C1ca—5 to 11 inches, grayish brown (2.5Y 5/2) loam; weak, fine, subangular blocky structure; friable; about 5 percent coarse fragments; violent effervescence; moderately alkaline; clear, wavy boundary.

C2—11 to 60 inches, light olive brown (2.5Y 5/6) loam; weak, fine and very fine, subangular blocky structure; few light gray (10YR 7/1) threads of lime; friable; about 5 percent coarse fragments; strong effervescence; mildly alkaline.

The A horizon is loam or clay loam. Reaction ranges from slightly acid to strongly acid. The Ap horizon is dark gray, dark grayish brown, or grayish brown. In places in some uncultivated areas the A1 horizon is as thick as 4 inches and is black or very dark gray. The C horizon is loam or clay loam.

Langhei soils are associated with Barnes, Formdale, Aazdahl, and Svea soils. They have a thinner A horizon, a lighter colored Ap horizon, and better natural drainage than any of these soils.

220E—Langhei loam, 18 to 35 percent slopes. This steep soil is on bluffs, along streams and drainageways, and around the borders of ponds and lakes. Waterways dissect the area, making cross slopes very irregular. The slopes are 100 to 300 feet long. This soil has a thinner profile than the one described as representative of the series.

Included with this soil in mapping are small areas of Barnes and Darnen soils. The Darnen soil is on toe slopes and in drainageways. Also included are areas of less sloping soils and areas of gravelly soils.

In most areas of this soil the vegetation is grass. Because of steep slopes this soil is better suited to grassland than to other uses. Water runs off very rapidly. Overgrazing is a hazard because of the resulting erosion.

The main management needs are controlling erosion and maintaining an adequate cover of grass. Capability unit VIIe–1; windbreak suitability group 2; recreation group 1; pasture and hayland group 2.

942C2—Langhei-Barnes loams, 6 to 12 percent slopes, eroded. This mapping unit consists of soils that have complex, rolling slopes. The Langhei soil makes up 50 to 80 percent of the areas, and Barnes soil makes up 20 to 50 percent. The Langhei soil formed on the steeper and more convex parts of the slopes in the landscape. The transition from the Langhei to the Barnes soil, which formed on the less convex parts of the slopes, is gradual. The Langhei soil has the profile described as representative of its series. The Barnes

soil has a thinner profile than the one described as representative of its series. The soils are moderately eroded in most places, and as a result the surface layer has been mixed with the subsoil by tillage.

Included with these soils in mapping are small areas of soils that are only slightly eroded and that have a darker colored surface layer than these soils. Also included are areas of Darnen soils in concave positions, small areas of more strongly sloping soils, small areas of less sloping soils, small areas of sandy soils, and small areas of a gravelly soil. A few small areas of soils that have a silty surface layer and subsoil and a few areas mapped that are more than 50 percent Barnes soil are also included.

Nearly all areas of this mapping unit are used for cultivated crops. These soils are suited to all crops commonly grown in the county. A few areas are used for hay and pasture. The Langhei soil is less productive than the Barnes soil, because the high content of lime causes a nutrient imbalance. Water runs off at a medium to rapid rate. The hazard of erosion is moderately severe.

The main management needs are controlling erosion, improving fertility and tilth, and conserving moisture. Capability unit IIIe–1; Langhei part in windbreak suitability group 2, Barnes part in windbreak suitability group 1; recreation group 1; pasture and hayland group 1.

942D2—Langhei-Barnes loams, 12 to 18 percent slopes, eroded. This complex consists of hilly soils on uplands and along valley walls of rivers and drainageways (fig. 6). The Langhei soil makes up 60 to 80 percent of the area, and the Barnes soil makes up 20 to 40 percent. The Langhei soil is on the more convex parts of the slopes, and the Barnes soil is on the less convex parts. The Barnes and Langhei soils, in most places, have profiles that are thinner than the ones described as representative of their respective series. On many eroded hillsides are large yellowish spots where the material that generally underlies the

Figure 6.—**Typical landscape of Langhei-Barnes loams, 12 to 18 percent slopes, eroded. The lighter colored Langhei soil is steeper than the darker colored Barnes soil.**

soils has been exposed. The fringes of these spots are brown because the subsoil of the Barnes soil has been exposed. The slopes range from 100 to 250 feet in length in many places. They are uniform in some places, but in others they are dissected by small, sharp drainageways.

Included with these soils in mapping are small areas of soils that are only slightly eroded. Also included are small areas of soils that are more sloping than these soils, small areas that are less sloping, and areas of gravelly soils. Small areas of Darnen and Svea soils on the concave foot slopes and Flom, Quam, and Parnell soils in drainageways and depressions are also included.

These soils are used for cultivated crops and pasture. They are suited to all crops commonly grown in the county. Water runs off rapidly, and the hazard of erosion is severe if clean-tilled crops are grown. Because of the rapid runoff, the amount of water available for plant growth is reduced.

The main management needs are controlling erosion, improving fertility and tilth, and conserving moisture. Capability unit IVe–1; Langhei part in windbreak suitability group 2, Barnes part in windbreak suitability group 1; recreation group 1; pasture and hayland group 1.

943C2—Langhei-Formdale clay loams, 6 to 12 percent slopes, eroded. This mapping unit consists of soils on the till plain. Many sloughs and waterways are in the areas. The Langhei soil makes up 50 to 70 percent of an area, and the Formdale soil makes up 30 to 50 percent. The Langhei soil is on the more convex parts of the slopes in the landscape, and the Formdale soil is on the less convex parts. In most places the Formdale soil has a combined surface layer and subsoil that is thinner than the combined surface layer and subsoil in the profile described as representative of the series. The Langhei soil is generally clay loam throughout the profile. In many areas the slopes are irregular and slope in several directions, but in some areas slopes are more uniform and are 150 to 250 feet long.

Included with these soils in mapping are small areas of Darnen soils on toe slopes, Aazdahl and Flom soils in drainageways and slight depressions, and Parnell soils in deeper depressions. Many areas of Flom and Parnell soils are indicated by spot symbols. In Roseville township are a few areas of soils that have a clayey surface layer and subsoil.

These soils are used mainly for cultivated crops, but a few areas are used for pasture. The soils are suited to all crops commonly grown in the county. Water runs off at a medium to rapid rate, and the hazard of erosion is moderately severe.

The main management needs are controlling erosion and improving fertility and tilth. Capability unit IIIe–1; Langhei part in windbreak suitability group 2, Formdale part in windbreak suitability group 1; recreation group 1; pasture and hayland group 1.

943D2—Langhei-Formdale clay loams, 12 to 18 percent slopes, eroded. This mapping unit consists of hilly soils on uplands and along valley walls of rivers and drainageways west of the Pomme de Terre River. The Langhei soil makes up about 50 to 70 percent of the areas, and the Formdale soil makes up 30 to 50 percent. The Langhei soil is on the most convex parts of the slopes in the landscape, and the Formdale soil is on the less convex parts. In most places the Formdale soil has a profile thinner than the one described as representative of the series. The Langhei soil is generally clay loam throughout the profile. On many eroded hillsides are large yellowish spots where the material that generally underlies the soils has been exposed. The fringes of these spots are brown because the subsoil of the Formdale soil has been exposed. The slopes range from 100 to 250 feet in length in many places. They are uniform but, in places, are dissected by small, sharp drainageways.

Included with these soils in mapping are small areas of soils that are only slightly eroded, small areas of soils that are more strongly sloping than these soils, and small areas of soils that are less sloping. Also included are areas of gravelly soils, small areas of Darnen and Aazdahl soils on toe slopes, and small areas of Flom, Quam, and Parnell soils in drainageways and depressions.

These soils are used for cultivated crops and pasture. They are suited to all crops commonly grown in the county. Water runs off rapidly, however, and the hazard of erosion is severe. Because of the rapid runoff, the amount of water available for plant growth is reduced.

The main management needs are controlling erosion, improving fertility and tilth, and conserving moisture. Capability unit IVe–1; Langhei part in windbreak suitability group 2, Formdale part in windbreak suitability group 1; recreation group 1; pasture and hayland group 1.

Maddock Series

The Maddock series consists of deep, well-drained, nearly level to hilly soils that formed in sandy material.

In a representative profile the surface layer is very dark brown loamy sand about 12 inches thick. The subsoil is friable, dark grayish-brown fine sand about 8 inches thick. The underlying material is fine sand. The upper part of this layer is brown, and the lower part is pale brown.

Maddock soils have low natural fertility, low available water capacity, and moderate organic-matter content. Permeability is rapid. The surface is neutral.

Nearly all areas of these soils are used for crops. Maddock soils are droughty and are subject to severe soil blowing in unprotected areas.

Representative profile of Maddock loamy sand, 1 to 6 percent slopes, 1,300 feet east and 60 feet north of the southwest corner of sec. 15, T. 129 N., R. 41 W.:

Ap—0 to 12 inches, very dark brown (10YR 2/2) loamy sand; weak, very fine, subangular blocky structure; friable; neutral; gradual, wavy boundary.

B2—12 to 20 inches, dark grayish brown (10YR 4/2) fine sand; weak, fine, subangular blocky structure; friable; neutral; gradual, wavy boundary.

C1—20 to 30 inches, brown (10YR 5/3) fine sand; single grained; loose; slight effervescence; mildly alkaline; gradual, wavy boundary.

C2—30 to 60 inches, pale brown (10YR 6/3) fine sand;

single grained; loose; strong effervescence; mildly alkaline.

Depth to carbonates ranges from 20 to 50 inches. The A horizon generally is black, very dark brown, and very dark gray. It is loamy sand or loamy fine sand 10 to 14 inches thick. Reaction is slightly acid to neutral. The B horizon is dark grayish brown, grayish brown, dark brown, or brown. Reaction is slightly acid to neutral.

Maddock soils are associated with Sverdrup and Arvilla soils. They have a coarser textured and thinner solum than Sverdrup soils. They are underlain by fine sand, and Arvilla soils are underlain by gravelly coarse sand.

45B—Maddock loamy sand, 1 to 6 percent slopes. This nearly level to gently sloping soil is on outwash plains and upland areas. Many of the areas are adjacent to Arvilla, Sioux, and Sverdrup soils on river terraces and outwash plains and to Barnes or Sverdrup soils on uplands. The slopes generally are short. This soil has the profile described as representative of the series. In some places the soil is calcareous at or near the surface, resulting in a grayish appearance in freshly plowed fields.

Included with this soil in mapping are small areas of Sverdrup soils, small areas of soils that are more strongly sloping than this Maddock soil, and a few areas of moderately eroded soil. Also included are small areas of soils that are underlain by loamy or silty material above a depth of 40 inches.

Nearly all areas of this soil are used for crops, but some areas are used for pasture or wildlife. This soil is suited to all crops commonly grown in the county. Droughtiness is a serious limitation, and it affects crops in most years. The hazard of soil blowing is severe on unprotected fields during winter and spring.

The main management needs are controlling erosion, conserving moisture, and maintaining fertility. Capability unit IVs–2; windbreak suitability group 6; recreation group 3; pasture and hayland group 7.

45C—Maddock loamy sand, 6 to 18 percent slopes. This sloping to moderately steep soil is on outwash plains and upland areas, generally around the edges of sloughs and along waterways. Many of the areas are adjacent to Arvilla, Sioux, and Sverdrup soils on river terraces and outwash areas. The profile of this soil differs from the one described as representative of the series by having a thinner surface layer.

Included with this soil in mapping are small areas of soils that have slopes lesser or greater than this soil, small areas of Sverdrup soils, and a few areas of eroded soils.

This soil is used mainly for pasture and wildlife. Some areas are used for crops. The soil is poorly suited to the crops commonly grown in the county. Droughtiness is a serious limitation, and it affects crops in most years. Water runs off at a medium to rapid rate, and the hazard of erosion is moderately severe.

The main management needs are controlling erosion, conserving moisture, and improving fertility. Capability unit VIs–1; windbreak suitability group 6; recreation group 3; pasture and hayland group 7.

Marsh

1053—Marsh (0 to 1 percent slopes). This land type consists of undrained, closed depressions and ponds that generally impound 1 to 3 feet of water, except in dry years. Cattails, reeds, sedges, and other water-dependent plants grow in scattered places along shores and in open water. The soils in these areas have not been identified, but the soil material is clay loam, silty clay loam, silt loam, mucky silt loam, or mucky silty clay loam.

Marsh has good potential for wetland wildlife habitat. It provides nesting, mating, and escape areas for waterfowl, furbearers, and upland wildlife. Many of these areas can be improved for wildlife habitat by controlling the water level, by increasing the resting and courting areas for ducks, and by fencing out livestock.

Many of these areas are impracticable to drain, because they lack adequate outlets. Capability unit VIIIw–1; windbreak suitability group 7; recreation group 4; pasture and hayland group 8.

McIntosh Series

The McIntosh series consists of somewhat poorly drained to moderately well drained, nearly level, calcareous soils that formed in silty sediment underlain by loamy glacial till.

In a representative profile the surface layer is silt loam about 12 inches thick. The upper 9 inches is black, and the lower 3 inches is grayish brown. The underlying material is stratified. The upper 5 inches of this layer is pale-brown silt loam, the middle 10 inches is light olive-brown silt loam, and the lower part is light olive-brown clay loam.

McIntosh soils have medium natural fertility, high organic-matter content, and high available water capacity. Permeability is moderately slow. The surface layer is moderately alkaline.

These soils are well suited to crops if they are properly managed. Most areas of McIntosh soils are cultivated.

Representative profile of McIntosh silt loam, 0 to 2 percent slopes, 1,000 feet south and 180 feet east of the northwest corner of sec. 35, T. 127 N., R. 44 W.:

Ap—0 to 9 inches, black (10YR 2/1) silt loam; weak, very fine, granular structure; very friable; strong effervescence; moderately alkaline; abrupt, smooth boundary.

A12ca—9 to 12 inches, grayish brown (10YR 5/2) silt loam; few black (10YR 2/1) threads; weak, very fine, granular structure; very friable; violent effervescence; moderately alkaline; clear, wavy boundary.

C1ca—12 to 17 inches, pale brown (10YR 6/3) silt loam; weak, very fine subangular blocky structure; very friable; violent effervescence; moderately alkaline; clear, wavy boundary.

C2—17 to 27 inches, light olive brown (2.5Y 5/4) silt loam; weak, very fine, subangular blocky structure; very friable; strong effervescence; mildly alkaline; abrupt, wavy boundary.

IIC3—27 to 60 inches, light olive brown (2.5Y 5/4) clay loam; common, fine, distinct, yellowish brown (10YR 5/6) and light gray (5Y 7/1) mottles; structureless; friable; about 2 percent coarse fragments; strong effervescence; mildly alkaline.

Thickness of the silty mantle ranges from 24 to 40 inches and varies within short distances. Some profiles contain variable amounts of gypsum crystals. In some profiles, a pebble band is at the contact area between the silt and the

underlying till. The A horizon generally is silt loam, but it is silty clay loam in places. The Ap horizon is black or very dark gray. The IIC horizon is loam or clay loam.

McIntosh soils are similar to Hamerly soils, but they have more silt in the surface and subsurface layers. They are better drained than Vallers soils.

108—McIntosh silt loam, 0 to 2 percent slopes. This nearly level soil is in irregularly shaped areas on the glacial lake plain and the till plain. Areas are bumpy, characterized by shallow depressions and slight rises.

Included with this soil in mapping are small areas of Hamerly and Bearden soils, small areas of soils that have a noncalcareous surface layer, and a few areas of soils that are poorly drained.

Most areas of this soil are used for cultivated crops. It is suited to all crops commonly grown in the county. If this soil is left unprotected, soil blowing is a hazard in winter and spring. The high content of lime causes an imbalance of nutrients.

The main management needs are controlling erosion and improving fertility. Capability unit IIs–2; windbreak suitability group 2; recreation group 1; pasture and hayland group 1.

Oldham Series

The Oldham series consists of very poorly drained, nearly level, calcareous soils in sloughs, potholes, and depressions. These soils formed in silty, water-sorted sediment derived from local drift. The native vegetation consists of marsh grass, cattails, sedges, and reeds.

In a representative profile the surface layer is black silty clay loam about 39 inches thick. The underlying material is very dark gray silty clay loam.

Oldham soils have high natural fertility, high organic-matter content, and high to very high available water capacity. Permeability is slow. The surface layer is mildly alkaline.

If these soils are to be cultivated, drainage is needed to remove excess surface water. Undrained areas can provide good habitat for wetland wildlife.

Representative profile of Oldham silty clay loam, 800 feet west and 250 feet north of the southeast corner of sec. 8, T. 130 N., R. 43 W.:

Ap—0 to 9 inches, black (N 2/0) silty clay loam; weak, fine, granular structure; slightly sticky; about 1 percent snail shells; strong effervescence; mildly alkaline; abrupt, wavy boundary.

A12—9 to 25 inches, black (N 2/0) silty clay loam; weak, very fine, subangular blocky structure; sticky; about 1 percent snail shells; strong effervescence; mildly alkaline; gradual, wavy boundary.

A13—25 to 39 inches, black (N 2/0) silty clay loam; weak, very fine, subangular blocky structure; sticky; about 1 percent snail shells; slight effervescence; mildly alkaline; gradual, wavy boundary.

C—39 to 60 inches, very dark gray (5Y 3/1) silty clay loam; weak, fine, subangular blocky structure; sticky; about 1 percent snail shells; strong effervescence; mildly alkaline.

Snail shells commonly are throughout the profile. A thin layer of muck 2 to 6 inches thick covers the A horizon in a few areas. The A horizon is black or very dark gray. It is silty clay loam or light silty clay 24 to 50 inches thick.

The Oldham soils as mapped are very poorly drained and are outside the defined range of the series. This difference does not significantly affect their use and management.

Oldham soils are similar to Quam, Parnell, and Urness soils. They are more alkaline than Quam and Parnell soils and have a lower organic-matter content in the surface layer than Urness soils.

276—Oldham silty clay loam (0 to 1 percent slopes). This nearly level soil is in deep depressions and small lake basins. Areas are variable in size and are generally circular and oblong in shape. This soil is flooded in spring; most areas are flooded occasionally throughout the year. Some areas dry by midsummer, but many are wet all year.

Included with this soil in mapping are small areas of Urness, Quam, and Vallers soils. Also included are areas of soils that have a dark-colored layer more than 60 inches thick; a few areas of soils that are underlain by sand at a depth of less than 40 inches, mainly near the beach ridges in the western part of the county; and a few areas of soils that have 2 to 6 inches of muck over the A horizon.

When undrained, this soil is covered with marsh vegetation that consists of sedges, reeds, rushes, or willows. The undrained areas have good potential for wetland wildlife habitat. They provide food, cover, and nesting for waterfowl, furbearers, and upland wildlife. Many of these areas can be improved for wildlife habitat by exposing or creating additional open water.

When drained this soil is used for crops, pasture, and hay, depending on the kind of drainage system installed. If adequately drained, this soil is suited to all crops grown in the county. Small grains tend to lodge, and corn and soybeans may not reach maturity every year. This soil can be drained by open ditch or tile.

The main management needs are drainage and maintaining fertility. Capability unit IIIw–1; windbreak suitability group 7; recreation group 4; pasture and hayland group 6.

Parnell Series

The Parnell series consists of very poorly drained, nearly level soils in deep potholes and sloughs. These soils formed in water-sorted silty and clayey sediment derived from local drift. The native vegetation consists of marsh grass, cattails, reeds, and sedges.

In a representative profile the surface layer is silty clay loam about 19 inches thick. The upper 14 inches is black, and the lower 5 inches is very dark gray. The subsoil is firm silty clay about 22 inches thick. The upper 17 inches is black, and the lower 5 inches is very dark gray. The underlying material is olive silty clay loam.

Parnell soils have high natural fertility, high organic-matter content, and high available water capacity. Permeability is slow. The surface layer is neutral.

If adequately drained, Parnell soils are suited to cultivated crops. Undrained areas can provide good habitat for wetland wildlife.

Representative profile of Parnell silty clay loam, in an area of Hamerly-Parnell complex, 0 to 3 percent slopes, 2,290 feet north and 265 feet east of the southwest corner of sec. 9, T. 128 N., R. 44 W.:

Ap—0 to 9 inches, black (10YR 2/1) silty clay loam; weak, fine, subangular blocky structure; friable; neutral; abrupt, smooth boundary.

A12—9 to 14 inches, black (10YR 2/1) silty clay loam; weak, fine, subangular blocky structure; friable; neutral; abrupt, smooth boundary.
A13—14 to 19 inches, very dark gray (10YR 3/1) silty clay loam; weak, fine, subangular blocky structure; friable; neutral; clear, wavy boundary.
B2tg—19 to 36 inches, black (10YR 2/1) silty clay; strong, very fine, angular blocky structure; firm; many, medium, continuous, black (10YR 2/1) clay films on vertical faces of peds; neutral; gradual, wavy boundary.
B3tg—36 to 41 inches, very dark gray (10YR 3/1, rubbed) silty clay; strong, very fine, angular blocky structure; firm; many, thin, patchy, black (10YR 2/1) clay films on faces of peds; slight effervescence; mildly alkaline; clear, wavy boundary.
C—41 to 60 inches, olive (5Y 5/3) silty clay loam; few, fine, distinct, light olive brown (2.5Y 5/6) mottles; massive; friable; about 2 percent coarse fragments; strong effervescence; mildly alkaline.

The A horizon is silt loam or silty clay loam 8 to 30 inches thick. It is black or very dark gray. The B horizon is black, very dark gray, dark olive gray, or olive gray. It is silty clay loam, silty clay, or clay. Depth to the underlying glacial till ranges from 40 to more than 60 inches.

Parnell soils are similar to Quam, Urness, and Flom soils. They are noncalcareous in the solum, and Urness soils are calcareous. Parnell soils have a B horizon that has an accumulation of translocated clay, unlike Quam and Flom soils.

34—Parnell silty clay loam (0 to 1 percent slopes). This nearly level soil occupies small to medium-sized depressions, mainly in till plain areas. Most areas are circular or oblong.

Included with this soil in mapping are small areas of Oldham soils in depressions and Vallers soils on narrow rims around depressions. In a few areas, the soil is underlain by sand above a depth of 40 inches, has a surface layer of silty clay, or has a mucky surface layer as much as 6 inches thick.

When undrained, this soil is covered with marsh vegetation consisting of sedges, reeds, rushes, and willows. Undrained areas have good potential for wetland wildlife habitat. They provide food, cover, and nesting for waterfowl, furbearers, and upland wildlife.

When drained, this soil is used for crops, pasture, and hay. It is suited to all cultivated crops commonly grown in the county, but small grains tend to lodge, and corn and soybeans may not reach maturity every year.

The main management needs are drainage and maintaining fertility and tilth. Capability unit IIIw–1; windbreak suitability group 7; recreation group 4; pasture and hayland group 6.

Quam Series

The Quam series consists of very poorly drained, nearly level soils in sloughs, potholes, and depressions. These soils formed under marsh grasses and cattails in water-sorted silty sediment derived from local drift.

In a representative profile the surface layer is black silty clay loam about 39 inches thick. The underlying material is black silty clay loam.

Quam soils have high natural fertility, high organic-matter content, and high to very high available water capacity. Permeability is moderately slow. The surface layer is neutral.

Drainage is needed if these soils are to be used for crops. Undrained areas can provide good habitat for wetland wildlife.

Representative profile of Quam silty clay loam, 50 feet west and 200 feet north of the southeast corner of sec. 33, T. 128 N., R. 41 W.:

Ap—0 to 7 inches, black (5Y 2/1) silty clay loam; weak, very fine, granular structure; friable; neutral; abrupt, smooth boundary.
A12—7 to 17 inches, black (N 2/0) silty clay loam; weak, very fine, granular structure; friable; neutral; gradual, wavy boundary.
A13—17 to 29 inches, black (N 2/0) silty clay loam; few, fine, distinct, dark brown (7.5YR 3/2) mottles; weak, fine, subangular blocky structure; slightly sticky; neutral; gradual, wavy boundary.
A14—29 to 39 inches, black (N 2/0) silty clay loam; few, fine, distinct, dark brown (7.5YR 3/2) mottles; weak, fine, subangular blocky structure; slightly sticky; slight effervescence; mildly alkaline; gradual, wavy boundary.
C—39 to 60 inches, black (10YR 2/1) silty clay loam; few, fine, distinct, dark brown (7.5YR 3/2) mottles; massive; slightly sticky; slight effervescence; mildly alkaline.

Depth to free carbonates ranges from 30 to 60 inches. The A horizon generally is 30 to 60 inches thick, but it ranges from 24 to 80 inches in thickness. The A horizon is black or very dark gray. It generally is silty clay loam or silt loam throughout, but it contains thin subhorizons of loam or clay loam in places. The C horizon is loam, clay loam, or silty clay loam.

Quam soils are associated with Formdale, Barnes, and Flom soils. They are more poorly drained and have a thicker A horizon than any of these soils.

344—Quam silty clay loam (0 to 1 percent slopes). This nearly level, depressional soil occupies large, deep potholes and sloughs, mainly in the morainic upland and till plain areas. Areas range from 10 to more than 30 acres in size. The surrounding slopes generally rise 20 to 50 feet above the bottoms of the depressions. In a few areas, mainly in Roseville township, the soil is silty clay. In some areas a mucky layer as much as 6 inches thick is on the surface.

Included with this soil in mapping are small areas of Urness and Oldham soils. Also included are small areas of Vallers soils on a calcareous rim around the depressions.

When undrained, this soil is covered with marsh vegetation consisting of sedges, reeds, rushes, and willows. The undrained areas have good potential for wetland wildlife habitat. They provide food, cover, and nesting for waterfowl, furbearers, and upland wildlife. When drained, this soil is used for crops, pasture, and hay, depending on the drainage system installed. If adequately drained, this soil is suited to all crops commonly grown in the county. Small grains have a tendency to lodge, and corn and soybeans may not reach maturity every year because of the low-lying position of this soil.

The main management needs are drainage and maintaining fertility and tilth. Capability unit IIIw–1; windbreak suitability group 7; recreation group 4; pasture and hayland group 6.

Rockwell Series

The Rockwell series consists of very poorly drained and poorly drained, nearly level, calcareous soils that

formed in layers of loamy and sandy material underlain by loamy glacial till.

In a representative profile the surface layer is about 24 inches thick. The upper 13 inches is black loam, and the lower 11 inches is very dark gray sandy loam. The underlying material is stratified. The upper 6 inches of this layer is gray fine sand, the next 5 inches is grayish-brown fine sand, and lower part is olive-gray clay loam.

Rockwell soils have medium natural fertility, high organic-matter content, and moderate to high available water capacity. Permeability is moderate to moderately slow. The surface layer is moderately alkaline.

If adequate drainage is used, Rockwell soils are suited to all crops grown in the county. Most areas of Rockwell soils are cultivated.

Representative profile of Rockwell loam, 2,140 feet south and 1,000 feet west of the northeast corner of sec. 12, T. 128 N., R. 44 W.:

Ap—0 to 8 inches, black (10YR 2/1) loam; weak, fine, granular structure; friable; strong effervescence; moderately alkaline; clear, smooth boundary.

A12ca—8 to 13 inches, black (10YR 2/1) loam; weak, fine, granular structure; friable; strong effervescence; moderately alkaline; clear, smooth boundary.

A13ca—13 to 24 inches, very dark gray (10YR 3/1) sandy loam; weak, fine, granular structure; very friable; common gypsum crystals; strong effervescence; moderately alkaline; gradual, wavy boundary.

C1ca—24 to 30 inches, gray (5Y 5/1) fine sand; few, fine, distinct, light olive brown (2.5Y 5/6) mottles; single grained; loose; violent effervescence; moderately alkaline; clear, wavy boundary.

C2—30 to 35 inches, grayish brown (2.5Y 5/2) fine sand; few, fine, distinct, yellowish brown (10YR 5/6) mottles; single grained; loose; few dark brown manganese concretions; slight effervescence; mildly alkaline; abrupt, wavy boundary.

IIC3g—35 to 60 inches, olive gray (5Y 5/2) clay loam; common fine, distinct, yellowish brown (10YR 5/6) mottles; structureless; firm; common gypsum crystals; about 3 percent coarse fragments; strong effervescence; mildly alkaline.

The A horizon is loam, sandy loam, or fine sandy loam 7 to 24 inches thick. The C1ca and C2 horizons are fine sand, loamy fine sand, loamy sand, or sand. The loamy and sandy layers generally range from 20 to 40 inches thick but typically are 30 to 35 inches thick. The lower part of many profiles contains gypsum crystals. The IIC horizon is loam or clay loam.

Rockwell soils are associated with Grimstad, Roliss, and Kittson variant soils. They are more poorly drained and are grayer in the underlying material than Grimstad soils. They have a zone of lime accumulation at a depth of less than 16 inches, and Roliss and Kittson variant soils, have no such horizon above that depth.

63—Rockwell loam (0 to 2 percent slopes). This nearly level to slightly concave soil is on the lake plain and in areas adjacent to lake beaches on till plains. Areas range from 10 to 50 acres in size. The surface layer is commonly black, but variations of black and mottled very dark gray also occur. In Gorton township in a few areas, a gravelly layer is in the upper part of the profile. This soil has the profile described as representative of the series.

Included with this soil in mapping are small areas of Grimstad, Arveson, Kittson variant, Roliss, and Vallers soils. Also included are a few areas of soils that have a surface layer of loamy fine sand.

Most areas of this soil are used for cultivated crops. It is suited to all crops commonly grown in the county. Small grains are the most common crops, but row crops such as sunflowers, soybeans, and corn are also grown. A few areas are used for hay and pasture. Drainage is needed to insure good crop growth each year.

The main management need is improving drainage, fertility, and tilth. Capability unit IIw–3; windbreak suitability group 4; recreation group 4; pasture and hayland group 3.

970—Rockwell-Vallers complex (0 to 2 percent slopes). This mapping unit consists of nearly level soils in areas that range from 20 to 40 acres in size. Areas are variable in shape and lie along either side of the easternmost beach ridge. These soils are in a pattern too complex to map separately, and they each make up from 40 to 60 percent of the complex.

Included with this complex in mapping are small areas of Roliss, Flom, Towner, Kittson variant, Grimstad, and Arveson soils.

Nearly all areas of this complex are used for cultivated crops. If adequate drainage is used, the soils are suited to all crops commonly grown in the county. A small acreage is used for hay and pasture.

The main management need is improving drainage, fertility, and tilth. Capability unit IIw–3; windbreak suitability group 4; recreation group 4; pasture and hayland group 3.

Roliss Series

The Roliss series consists of very poorly drained and poorly drained, nearly level soils that are mostly calcareous throughout. These soils formed in loamy glacial till.

In a representative profile the surface layer is black loam about 11 inches thick. The subsoil is friable, olive-gray loam about 5 inches thick. The underlying material is grayish-brown clay loam.

Roliss soils have high natural fertility, high organic-matter content, and moderate to high available water capacity. Permeability is moderately slow. The surface layer is mildly alkaline.

Nearly all areas of Roliss soils are cultivated. A few areas are used for hay, pasture, and wildlife habitat.

Representative profile of Roliss loam, in an area of Roliss complex, 1,175 feet east and 375 feet north of the southwest corner of sec. 20, T. 130 N., R. 44 W.:

Ap—0 to 8 inches, black (10YR 2/1) loam; weak, very fine, granular structure; friable; few masses of lime; slight effervescence; mildly alkaline; abrupt, smooth boundary.

A12—8 to 11 inches, black (10YR 2/1) loam; weak, very fine, granular structure; friable; few masses of lime; mildly alkaline; slight effervescence; clear, wavy boundary.

B2g—11 to 16 inches, olive gray (5Y 5/2) loam; few, fine, distinct, yellowish brown (10YR 5/6) mottles; weak, fine, subangular blocky structure; friable; about 1 percent coarse fragments; few masses of gypsum; slight effervescence; mildly alkaline; gradual, wavy boundary.

IIC1ca—16 to 24 inches, grayish brown (2.5Y 5/2) clay loam; few, fine, distinct, yellowish brown (10YR 5/6) and light olive brown (2.5Y 5/4) mottles; weak, very fine, subangular blocky structure; fri-

able; about 3 percent coarse fragments; few masses of gypsum; strong effervescence; mildly alkaline; gradual, wavy boundary.

C2—24 to 60 inches, grayish brown (2.5Y 5/2) clay loam; common, fine, distinct, yellowish brown (10YR 5/6) and light olive brown (2.5Y 5/4) mottles and common, medium, distinct, gray (5Y 5/1) mottles; weak, very fine, subangular blocky structure; firm; about 3 percent coarse fragments; few masses of gypsum; strong effervescence; mildly alkaline.

Depth to free carbonates ranges from 0 to 10 inches. The A horizon is generally black. In the lower parts of some profiles, it is very dark gray or very dark grayish brown. The A horizon typically is clay loam or loam, but it is silty clay loam, sandy loam, and sandy clay loam in places. The A horizon is 7 to 15 inches thick. The B2g horizon is similar in texture to the A horizon and is 4 to 6 inches thick. It is olive gray, dark grayish brown, very dark grayish brown, and grayish brown. It has distinct or prominent mottles. Reaction ranges from neutral to mildly alkaline. In some profiles, the B horizon has a coarse-textured layer as thick as 5 inches. The C horizon is loam or clay loam.

Roliss soils are associated with Kittson and Vallers soils. They are more poorly drained than Kittson soils and do not have a zone of lime accumulation above a depth of 16 inches, unlike Vallers soils.

582—Roliss loam (0 to 1 percent slopes). This nearly level and slightly concave soil is in the lake basin. It commonly is associated with an interbeach landscape where soil material changes within short distances and relief is variable. Areas are variable in size and range from 50 to more than 1,000 acres.

Included with this soil in mapping are areas of Vallers soils on rims around shallow depressions, Rockwell and Kittson variant soils in slightly concave positions, and Kittson and Towner soils on slight rises.

Most areas of this soil are used for crops. Some areas are in hay and pasture. This soil needs drainage to insure crop production each year. It is suited to all crops commonly grown in the county. Small grains are the most common crops, but row crops such as corn, soybeans, and sunflowers are also grown.

The main management needs are improving drainage and maintaining fertility and tilth. Capability unit IIw–1; windbreak suitability group 3; recreation group 4; pasture and hayland group 3.

971—Roliss complex (0 to 1 percent slopes). This complex occupies areas that range in size from 100 to 1,000 acres. The Roliss loam makes up 70 to 80 percent of this complex, and soils in depressions make up 20 to 30 percent. The nearly level landscape is dotted with many shallow swales and depressions. These depressions range from a few inches to 2 feet in depth. The soils in the depressions have a surface layer of loam or silt loam. The subsoil is clay loam or sandy clay loam. The underlying material is firm, calcareous loam or clay loam glacial till. The Roliss soil in this complex has the profile described as representative of its series.

Included with this complex in mapping are small areas of Vallers soils on rims around and between small depressions and Kittson and Towner soils on slight rises.

Nearly all areas of this complex are used for cultivated crops. The soils are suited to all crops commonly grown in the county. A small acreage is used for hay and pasture. In order to insure crop production each year, this soil needs drainage, especially in the small depressions. Water collects in these depressions in spring and after heavy rains.

The main management needs are improving drainage, maintaining fertility and tilth, and controlling erosion. Capability unit IIw–1; windbreak suitability group 3; recreation group 4; pasture and hayland group 3.

972—Roliss-Vallers complex (0 to 1 percent slopes). This mapping unit consists of nearly level soils on the lake plain. It is commonly associated with an interbeach landscape in which soil material changes within short distances and relief is variable. Roliss loam and Vallers clay loam each makes up 40 to 60 percent of the complex. The Roliss loam is in slightly concave to nearly level areas, and the Vallers clay loam is in nearly level to slightly elevated areas around and between the slightly concave areas. The Vallers clay loam is calcareous.

Included with these soils in mapping are small areas of Rockwell, Kittson variant, and Kittson soils.

Most areas of this complex are used for crops. A few areas are used for hay and pasture. The soils need drainage to insure crop production each year. They are suited to all crops commonly grown in the county. Small grains are the most common crops, but row crops such as corn, soybeans, and sunflowers are also grown.

The main management needs are improving drainage and maintaining fertility and tilth. Capability unit IIw–2; Roliss part in windbreak suitability group 3, Vallers part in windbreak suitability group 4; recreation group 4; pasture and hayland group 3.

Rothsay Series

The Rothsay series consists of well-drained, undulating soils that formed in calcareous silty material. These soils are free of stones.

In a representative profile the surface layer is silt loam about 15 inches thick. The upper 8 inches is black, and the lower 7 inches is very dark grayish-brown. The subsoil is friable, dark-brown silt loam about 11 inches thick. The underlying material is silt loam. The upper 14 inches of this layer is yellowish-brown, and the lower part is light olive brown.

Rothsay soils have high natural fertility, high organic-matter content, and very high available water capacity. Permeability is moderate. The surface layer is neutral.

These soils can be worked easily and are suited to all crops commonly grown in the county. The hazard of soil blowing is severe in unprotected areas.

Representative profile of Rothsay silt loam, 2 to 6 percent slopes, 400 feet south and 200 feet west of the northeast corner of sec. 24, T. 130 N., R. 41 W.:

Ap—0 to 8 inches, black (10YR 2/1) silt loam; weak, very fine, granular structure; friable; neutral; abrupt, smooth boundary.

A1—8 to 15 inches, very dark grayish brown (10YR 3/2) silt loam; weak, very fine, granular structure; friable; neutral; gradual, wavy boundary.

B2—15 to 26 inches, dark brown (10YR 4/3) silt loam; weak, fine, subangular blocky structure; friable; neutral; abrupt, wavy boundary.

C1—26 to 40 inches, yellowish brown (10YR 5/4) silt loam;

structureless; friable; strong effervescence; mildly alkaline; gradual, wavy boundary.

C2—40 to 60 inches, light olive brown (2.5Y 5/4) silt loam; common, fine, distinct, dark brown (7.5YR 3/2) mottles; structureless; friable; strong effervescence; mildly alkaline.

Thickness of the solum ranges from 16 to 30 inches. Depth to free carbonates ranges from 14 to 28 inches. The A horizon is black, very dark gray, or very dark grayish brown. Reaction is neutral to mildly alkaline. The B horizon is dark grayish brown, brown, dark brown, grayish brown, and yellowish brown. Reaction is neutral to mildly alkaline.

Rothsay soils are associated with Barnes soils. They have less sand and more silt throughout the profile than Barnes soils.

290B—Rothsay silt loam, 2 to 6 percent slopes. This undulating soil is mainly in the vicinity of Pelican Lake. Areas range from 5 to 20 acres in size.

Included with this soil in mapping are small areas of Barnes, Langhei, Flom, and Darnen soils. Also included are small areas of soils that are less sloping than this soil, small areas of soils that are more strongly sloping than this soil, and small areas of moderately eroded soils that appear brownish after plowing.

This soil is used for cultivated crops, pasture, and woodland. It is suited to all crops commonly grown in the county. Small grains, corn, and soybeans are the main crops. Water runs off at a medium rate, and the hazard of erosion is moderate.

The main management needs are controlling erosion and improving fertility and tilth. Capability unit IIe–1; windbreak suitability group 1; recreation group 1; pasture and hayland group 1.

Sinai Series

The Sinai series consists of moderately well drained and well drained, undulating to rolling soils that formed in calcareous clayey glacial lacustrine material.

In a representative profile the surface layer is black to very dark brown silty clay about 19 inches thick. The subsoil is firm, dark grayish-brown silty clay about 6 inches thick. The underlying material is silty clay. The upper 9 inches of this layer is olive brown, and the lower part is light olive brown.

Sinai soils have high natural fertility, high organic-matter content, and moderate to high available water capacity. Permeability is slow to very slow. The surface layer is mildly alkaline.

Sinai soils are difficult to work unless high content of organic matter is maintained and good management practices are used to prevent excessive compaction.

Representative profile of Sinai silty clay, 1 to 6 percent slopes, 185 feet north and 85 feet west of the southeast corner of sec. 36, T. 127 N., R. 42 W.:

A1—0 to 16 inches, black (10YR 2/1) silty clay; moderate, fine, subangular blocky structure parting to moderate, fine, granular; friable; mildly alkaline; clear, wavy boundary.

A3—16 to 19 inches, very dark brown (10YR 2/2) silty clay; moderate, fine, subangular blocky structure parting to moderate, fine, granular; friable; mildly alkaline; clear, wavy boundary.

B2—19 to 22 inches, dark grayish brown (10YR 4/2) silty clay; moderate, medium and coarse, prismatic structure parting to moderate, fine, subangular blocky; firm; neutral; gradual, wavy boundary.

B3—22 to 25 inches, dark grayish brown (2.5Y 4/2) silty clay; moderate, fine, subangular blocky structure; firm; neutral; abrupt, wavy boundary.

C1—25 to 34 inches, olive brown (2.5Y 4/4) silty clay; common, fine, distinct, yellowish brown (10YR 5/6) mottles; structureless; firm; few yellowish red concretions of iron oxide and many gray (2.5Y 5/1) concretions of lime; strong effervescence; mildly alkaline; clear, wavy boundary.

C2—34 to 60 inches, light olive brown (2.5Y 5/4) silty clay; common, fine, distinct, yellowish brown (10YR 5/6) mottles; structureless; firm; many yellowish red concretions of iron oxide and many gray (2.5Y 5/1) concretions of lime; strong effervescence; mildly alkaline.

The A horizon is silty clay or silty clay loam 16 to 24 inches thick. The B horizon is silty clay, clay, or silty clay loam. Tongues of material from the A horizon extend into the B horizon in some areas. Depth to the C horizon ranges from 17 to 30 inches. The C horizon is silty clay or silty clay loam.

Sinai soils are associated with Langhei and Formdale soils. They have more clay in the profile than Langhei and Formdale soils.

212B—Sinai silty clay, 1 to 6 percent slopes. This gently sloping and undulating soil is in glaciolacustrine areas. Slopes are fairly uniform and are 100 to 300 feet long. This soil has the profile described as representative of the series.

Included with this soil in mapping are small areas of soils that resemble Formdale soils and areas of soils that are lighter colored and are calcareous to the surface. Also included are small areas of soils that are more sloping than this soil, areas of moderately eroded soils, and areas of poorly drained and very poorly drained soils in small depressions and drainageways, some of which are indicated on the soil maps by spot symbols.

Nearly all areas of this soil are used for cultivated crops. A small acreage is in pasture. This soil is suited to all crops commonly grown in the county. Water runs off at a medium rate, and the hazard of erosion is moderate. This soil is sticky when wet and hard when dry.

The main management needs are controlling erosion and improving fertility and tilth. Capability unit IIe–1; windbreak suitability group 1; recreation group 2; pasture and hayland group 1.

212C—Sinai silty clay, 6 to 12 percent slopes. This sloping and rolling soil is in areas along waterways and around depressions. Slopes are fairly long and uniform, and many are in one direction. They are 100 to 250 feet long. This soil has a thinner solum than the one described as representative of the series.

Included with this soil in mapping are small areas of soils that resemble Formdale soils and small areas of poorly drained and very poorly drained soils in drainageways and depressions, some of which are indicated on the soil maps by spot symbols. Also included are small areas of soils that are less sloping than this soil and small areas of soils that are more strongly sloping than this soil. Another included soil, on the upper, convex part of the slope, is calcareous to the surface and lighter colored than this soil. A few mapped areas are as much as 40 percent of this included calcareous soil.

This soil is used for cultivated crops and pasture. It is suited to all crops commonly grown in the county. Water runs off at a medium to rapid rate, and the hazard of erosion is moderate. This soil is sticky when wet and hard when dry.

The main management needs are controlling erosion and improving fertility and tilth. Capability unit IIIe–1; windbreak suitability group 1; recreation group 2; pasture and hayland group 1.

Sioux Series

The Sioux series consists of excessively drained, nearly level to steep soils that are very shallow over calcareous gravelly outwash.

In a representative profile the surface layer is black loamy coarse sand about 9 inches thick. The underlying material is dark yellowish-brown, yellowish-brown, and pale-brown gravelly coarse sand.

Sioux soils have low natural fertility, low organic-matter content, and very low available water capacity. Permeability is rapid. The surface layer is mildly alkaline.

These soils are droughty and are poorly suited to crops. Sioux soils are a good source of sand and gravel.

Representative profile of Sioux loamy coarse sand, 6 to 12 percent slopes, 630 feet west and 1,025 feet north of the southeast corner of sec. 1, T. 129 N., R. 42 W.:

Ap—0 to 9 inches, black (10YR 2/1) loamy coarse sand; single grained; friable; many roots; slight effervescence; mildly alkaline; abrupt, smooth boundary.

C—9 to 60 inches, dark yellowish-brown (10YR 4/4), yellowish-brown (10YR 5/4), and pale-brown (10YR 6/3) gravelly coarse sand; single grained; loose; few roots; limy coatings on undersides of pebbles in upper part; strong effervescence; mildly alkaline.

The A horizon generally is loamy coarse sand, gravelly loamy coarse sand, or loamy sand, but it is sandy loam in places. It is 7 to 12 inches thick. The C horizon is calcareous gravelly coarse sand, stratified coarse sand, or sand and gravel.

Sioux soils in this county are outside the defined range of the series because they have a thinner or coarser textured A horizon. This difference does not affect their use and management.

Sioux soils are associated with Arvilla soils. They are shallower to gravelly coarse sand than Arvilla soils.

402D—Sioux gravelly loamy coarse sand, 12 to 35 percent slopes. This hilly to steep soil is along drainageways and streams and around depressions. Most areas are escarpments on outwash terraces. The profile of this soil differs from the one described as representative of the series by having a surface layer of gravelly loamy coarse sand.

Included with this soil in mapping are small areas of Sioux loamy coarse sand and Arvilla soils. Also included are small areas of soils that have lesser and greater slopes than this soil and areas of sandy soil.

Most areas of this soil are in grass. The soil is too steep and droughty for cultivated crops. Production of grass is low. The hazard of erosion is severe.

The main management need is controlling erosion and moisture. Capability unit VIIs–1; windbreak suitability group 6; recreation group 3; pasture and hayland group 8.

402B—Sioux loamy coarse sand, 0 to 6 percent slopes. This nearly level and undulating soil is on beach ridges, outwash terraces, and uplands. It borders outwash areas of Arvilla and Fordville soils. The profile of this soil is slightly deeper to gravelly coarse sand than the profile described as representative of the series. The surface layer is sandy loam in some areas.

Included with this soil in mapping are small areas of Sioux gravelly loamy coarse sand and Arvilla soils. Also included are small areas of soils that have steeper slopes than this soil and areas of sandy soils.

This soil is used for cultivated crops, pasture, and hayland. It is poorly suited to the crops commonly grown in the county because of the severe hazard of drought.

The main management needs are controlling erosion and conserving moisture. Capability unit IVs–1; windbreak suitability group 6; recreation group 3; pasture and hayland group 7.

402C—Sioux loamy coarse sand, 6 to 12 percent slopes. This rolling soil is on stream terraces and uplands among areas of Arvilla and Barnes soils. It also is along drainageways and around depressions. This soil has the profile described as representative of the series.

Included with this soil in mapping are small areas of Sioux gravelly loamy coarse sand and Arvilla soils. Also included are areas of soils that have lesser and greater slopes than this soil and areas of sandy soils.

This soil is used for cultivated crops, pasture, and hay. It is poorly suited to the crops commonly grown in the county because of the severe hazard of drought.

The main management needs are controlling erosion and conserving moisture. Capability unit IVs–1; windbreak suitability group 6; recreation group 3; pasture and hayland group 7.

Svea Series

The Svea series consists of moderately well drained, nearly level soils that formed in loamy glacial till.

In a representative profile the surface layer is black loam about 15 inches thick. The subsoil is friable loam about 9 inches thick. The upper part is very dark brown, and the lower part is dark brown. The underlying material is loam. The upper 16 inches of this layer is brown and pale brown, and the lower part is light olive brown.

Svea soils have high natural fertility, high organic-matter content, and high available water capacity. Permeability is moderate in the upper part and moderately slow in the underlying material. The surface layer is neutral.

These soils are used mainly for cultivated crops. Svea soils are suited to all crops commonly grown in the county.

Representative profile of Svea loam, 1 to 3 percent slopes, 2,200 feet east and 850 feet north of the southeast corner of sec. 4, T. 127 N., R. 41 W.:

A11—0 to 10 inches, black (10YR 2/1) loam; weak, very fine, subangular blocky structure; friable; neutral; gradual, smooth boundary.
A12—10 to 15 inches, black (10YR 2/1) loam, very dark brown (10YR 2/2) rubbed; weak, very fine, subangular blocky structure; friable; neutral; gradual, smooth boundary.
B21—15 to 18 inches, very dark brown (10YR 2/2) loam; moderate, medium, prismatic structure parting to weak, fine, subangular blocky; friable; neutral; gradual, irregular boundary.
B22—18 to 24 inches, dark brown (10YR 4/3) loam; weak, fine, subangular blocky structure; friable; about 1 percent coarse fragments; neutral; clear, wavy boundary.
C1ca—24 to 32 inches, brown (10YR 5/3) loam, pale brown (10YR 6/3) when rubbed; weak, fine, subangular blocky structure; friable; about 3 percent coarse fragments; violent effervescence; moderately alkaline; clear, wavy boundary.
C2ca—32 to 40 inches, pale brown (10YR 6/3) loam; many, fine, distinct, yellowish brown (10YR 5/8) and light olive gray (5Y 6/2) mottles; weak, fine, subangular blocky structure; friable; about 3 percent coarse fragments; violent effervescence; moderately alkaline; gradual, wavy boundary.
C3—40 to 60 inches, light olive brown (2.5Y 5/4) loam; many, fine, prominent, yellowish brown (10YR 5/8) and light olive gray (5Y 6/2) mottles; weak, fine, subangular blocky structure; friable; about 3 percent coarse fragments; violent effervescence; mildly alkaline.

Depth to free lime ranges from about 18 to 30 inches. The combined thickness of the A horizons ranges from 12 to 20 inches. The A horizon is loam or silt loam. The B horizon is 6 to 15 inches thick. It is brown, dark brown, dark grayish brown, or olive brown.

Svea soils are associated with Barnes and Flom soils. They are slightly wetter and have a thicker solum than Barnes soils and are better drained than Flom soils.

70—Svea loam, 1 to 3 percent slopes. This nearly level to gently sloping soil is on morainic uplands and till plains. Areas are irregularly shaped and are among areas of Barnes soils and adjacent to but at slightly higher elevations than areas of Flom soils. This soil has the profile described as representative of the series.

Included with this soil in mapping are small areas of the calcareous Hamerly and Vallers soils and small areas of Flom, Barnes, and Darnen, soils. Also included are small areas of soils that have a solum less than 16 inches thick.

This soil is productive and has a few limitations. It is suited to all crops commonly grown in the county. Most areas are cultivated.

The main management need is maintaining fertility and tilth. Capability unit I–1; windbreak suitability group 1; recreation group 1; pasture and hayland group 1.

962—Svea-Hamerly loams, 1 to 3 percent slopes. This mapping unit consists of nearly level soils on till plains and morainic uplands. It is among areas of Barnes and Svea soils. The Svea and Hamerly soils each makes up 40 to 60 percent of the complex. The Hamerly soil in this complex has a loam profile rather than the clay loam profile described as representative of the Hamerly series.

Included with these soils in mapping are small areas of Vallers soils on rims around depressions, Barnes soils on rises, Flom soils in drainageways, and Parnell soils in depressions.

These soils are used for cultivated crops. They are suited to all crops commonly grown in the county. Excess lime near the surface of the Hamerly soil causes a nutrient imbalance that can be improved with fertilization.

The main management need is improving fertility, tilth, and drainage. Capability unit IIs–2; Svea part in windbreak suitability group 1, Hamerly part in windbreak suitability group 2; recreation group 1; pasture and hayland group 1.

Sverdrup Series

The Sverdrup series consists of somewhat excessively drained, undulating soils that formed in loamy material underlain by sand.

In a representative profile the surface layer is very dark brown sandy loam about 10 inches thick. The subsoil is about 14 inches thick. The upper 5 inches of this layer is dark yellowish-brown, friable sandy loam, and the lower 9 inches is dark yellowish-brown, friable loamy sand. The underlying material is sand. The upper 4 inches is dark yellowish brown, and the lower part is grayish brown.

Sverdrup soils have medium natural fertility, moderate organic-matter content, and low available water capacity. Permeability is moderately rapid. The surface layer is neutral.

Because Sverdrup soils are droughty, they are better suited to crops that mature earlier and have lower moisture requirements than other crops.

Representative profile of Sverdrup sandy loam, 2 to 6 percent slopes, 1,130 feet north and 1,200 feet west of the southeast corner of sec. 9, T. 130 N., R. 41 W.:

Ap—0 to 10 inches, very dark brown (10YR 2/2) sandy loam; weak, fine, granular structure; friable; neutral; abrupt, smooth boundary.
B21—10 to 15 inches, dark yellowish brown (10YR 4/4) sandy loam; weak, fine and medium, subangular blocky structure; friable; neutral; abrupt, wavy boundary.
B22—15 to 24 inches, dark yellowish brown (10YR 4/4) loamy sand; weak, medium, subangular blocky structure; friable; neutral; gradual, wavy boundary.
IIC1—24 to 28 inches, dark yellowish brown (10YR 4/4) sand; single grained; loose; neutral; abrupt, wavy boundary.
IIC2—28 to 60 inches, grayish brown (10YR 5/2) sand; single grained; loose; strong effervescence; mildly alkaline.

Thickness of the solum ranges from 20 to 30 inches. Depth to free carbonates generally ranges from 24 to 36 inches, but the extreme range is 15 to 40 inches. The A horizon is black, very dark brown, and very dark gray. It generally is sandy loam, but it is loam in places. The A horizon is 8 to 16 inches thick. The B horizon is dark brown, yellowish brown, or dark yellowish brown. The C horizon is sand or fine sand.

Sverdrup soils are associated with Maddock and Arvilla soils. They are underlain by fine sand or sand, and Arvilla soils are underlain by gravelly coarse sand. They have a finer textured and thicker solum than Maddock soils.

127B—Sverdrup sandy loam, 2 to 6 percent slopes. This undulating soil is on outwash terraces and uplands. Areas are generally mixed or associated with areas of upland till or other outwash soils. Some areas

are in isolated upland areas of sandy outwash that have complex slopes.

Included with this soil in mapping are small areas of Maddock, Arvilla, and Sioux soils. Also included are small areas of more sloping soils.

Nearly all areas of this soil are used for cultivated crops. A few areas are in pasture. This soil is suited to all crops commonly grown in the county. It is better suited to early-maturing crops than to other crops because of the hazard of drought. In most areas this soil is suited to irrigation of field and vegetable crops.

The main management needs are controlling erosion, conserving moisture, and maintaining fertility. Capability unit IIIs–2; windbreak suitability group 5; recreation group 1; pasture and hayland group 7.

Towner Series

The Towner series consists of moderately well drained, nearly level soils that formed in stratified loamy and sandy material underlain by loamy glacial till.

In a representative profile the surface layer is black fine sandy loam about 9 inches thick. The subsoil is about 17 inches thick. The upper 9 inches is very friable, very dark grayish-brown loamy fine sand, and the lower 8 inches is light olive-brown, loose loamy fine sand. The upper 10 inches of the underlying material is light brownish-gray loam, the next 8 inches is gray loam, and the lower part is light olive-brown clay loam.

Towner soils have medium natural fertility, moderate to high organic-matter content, and moderate to high available water capacity. Permeability is moderately rapid in the upper part and moderately slow in the underlying material. The surface layer is neutral.

Most areas of these soils are used for crops. Towner soils have a moderate to severe hazard of drought.

Representative profile of Towner fine sandy loam, 0 to 2 percent slopes, 1,950 feet east and 250 feet south of the northwest corner of sec. 15, T. 128 N., R. 44 W.:

Ap—0 to 9 inches, black (10YR 2/1) fine sandy loam; weak, very fine, granular structure; friable; many roots; neutral; abrupt, smooth boundary.

B21—9 to 18 inches, very dark grayish brown (10YR 3/2) loamy fine sand; single grained; very friable; slight effervescence; mildly alkaline; gradual, wavy boundary.

B22—18 to 26 inches, light olive brown (2.5Y 5/4) loamy fine sand; single grained; loose; slight effervescence; mildly alkaline; abrupt, wavy boundary.

IIC1—26 to 36 inches, light brownish gray (2.5Y 6/2) loam; few, fine, distinct, yellowish-brown (10YR 5/6) mottles; few light-gray (10YR 7/1) spots of lime; weak, fine, subangular blocky structure; friable; about 5 percent coarse fragments; strong effervescence; mildly alkaline; gradual, wavy boundary.

IIC2—36 to 44 inches, gray (5Y 5/1) loam; common, fine, prominent, strong brown (7.5YR 5/6) mottles; weak, fine, subangular blocky structure; friable; about 5 percent coarse fragments; strong effervescence; mildly alkaline; gradual, wavy boundary.

IIC3—44 to 60 inches, light olive brown (2.5Y 5/4) clay loam; few, fine, distinct, yellowish brown (10YR 5/6) mottles and common, medium, distinct, gray (5Y 5/1) mottles; structureless; firm; about 5 percent coarse fragments; strong effervescence; mildly alkaline.

Thickness of the solum ranges from 20 to 40 inches. The A horizon is black or very dark gray. It is sandy loam, fine sandy loam, loamy sand, or loamy fine sand. The B horizon is dark grayish brown, very dark grayish brown, grayish brown, olive brown, or light olive brown. It is fine sandy loam or loamy fine sand. The IIC horizon generally is clay loam, but it is silty clay loam and loam in places.

Towner soils are associated with Grimstad and Kittson soils. They have less silt and clay in the A horizon than Kittson soils. They have a noncalcareous A horizon, and Grimstad soils have a calcareous A horizon.

330—Towner fine sandy loam, 0 to 2 percent slopes. This nearly level soil is on slightly uneven landscapes that have alternate concave and convex areas. Some areas are elongated and are slightly higher than the surrounding landscape. A few areas are calcareous to the surface, and a few areas have a surface layer of loamy fine sand.

Included with this soil in mapping are small areas of Hecla and Grimstad soils. Also included are areas of soils that have a dark-colored A horizon less than 16 inches thick.

In most areas this soil is used for cultivated crops. Small grains are the most common crops, but row crops such as corn, soybeans, and sunflowers are also grown. A few areas are used for hay and pasture. This soil is subject to soil blowing if left unprotected during winter and early spring.

The main management needs are controlling erosion, conserving moisture, and improving fertility. Capability unit IIIs–3; windbreak suitability group 5; recreation group 1; pasture and hayland group 1.

Ulen Series

The Ulen series consists of somewhat poorly drained and moderately well drained, calcareous, nearly level soils that formed in calcareous sandy material.

In a representative profile the surface layer is very dark gray loamy fine sand about 16 inches thick. The subsoil is loose, grayish-brown fine sand about 6 inches thick. The underlying material is brownish-yellow fine sand.

Ulen soils have low natural fertility, low available water capacity, and moderate organic-matter content. Permeability is rapid. The surface layer is moderately alkaline.

Because these soils are droughty, they are better suited to crops that mature earlier and have lower moisture requirements than other crops. Some areas of Ulen soils are in pasture.

Representative profile of Ulen loamy fine sand, 0 to 2 percent slopes, 2,600 feet west and 210 feet south of the northeast corner of sec. 14, T. 128 N., R. 44 W.:

Ap—0 to 9 inches, very dark gray (10YR 3/1) loamy fine sand; weak, very fine, granular structure; friable; strong effervescence; moderately alkaline; abrupt, smooth boundary.

A3ca—9 to 16 inches, very dark gray (10YR 3/1) loamy fine sand; weak, very fine, granular structure; friable; violent effervescence; mildly alkaline; clear, wavy boundary.

B2ca—16 to 22 inches, grayish brown (2.5Y 5/2) fine sand; single grained; loose; violent effervescence; moderately alkaline; gradual, wavy boundary.

C—22 to 60 inches, brownish yellow (10YR 6/8) fine sand;

few, fine, distinct, gray (5Y 5/1) mottles; single grained; loose; slight effervescence; mildly alkaline.

The A horizon is black, dark gray, very dark gray, very dark brown, or very dark grayish brown. It typically is fine sandy loam or loamy fine sand, but it is very fine sandy loam and loamy very fine sand in places. The B2ca horizon is fine sand or loamy fine sand. The C horizon is fine sand, but it is sand, loamy sand, and loamy fine sand in places.

Ulen soils are associated with Grimstad, Arveson, and Hecla soils. Ulen soils do not have a fine-textured IIC horizon above a depth of 40 inches, and Grimstad soils do. They are better drained than Arveson soils. They have a calcareous A horizon, and Hecla soils do not.

64—Ulen loamy fine sand, 0 to 2 percent slopes. This nearly level soil is in lake basins and on ground moraines adjacent to beach ridges. The topography is slightly convex and has alternate higher and lower areas.

Included with this soil in mapping are small areas of Grimstad, Arveson, and Hecla soils. Also included are small areas of soils that have a surface layer of fine sandy loam.

In most areas this soil is used for crops. In a few areas it is used for hay and pasture. Small grains are the most common crops, but row crops such as corn, soybeans, and sunflowers are also grown. This soil is subject to soil blowing if left unprotected during winter and early spring. It has a moderate hazard of drought.

The main management needs are controlling erosion, conserving moisture, and improving fertility. Capability unit IIIs–4; windbreak suitability group 2; recreation group 3; pasture and hayland group 7.

Urness Series

The Urness series consists of very poorly drained, calcareous, nearly level soils that formed in silty postglacial lake sediment.

In a representative profile the surface layer is about 47 inches thick. The upper 28 inches is black mucky silt loam, and the lower 19 inches is black silty clay loam. The underlying material is very dark gray silty clay loam.

Urness soils have medium natural fertility, very high organic-matter content, and very high available water capacity. Permeability is moderately slow. The surface layer is moderately alkaline.

If adequate drainage is used, Urness soils are suited to all crops commonly grown in the county. Undrained areas can provide good habitat for wetland wildlife.

Representative profile of Urness mucky silt loam, 1,200 feet south and 200 feet west of the northeast corner of sec. 2, T. 130 N., R. 43 W.:

Lcop—0 to 8 inches, black (10YR 2/1) mucky silt loam; weak, very fine, granular structure; strong effervescence; moderately alkaline; abrupt, smooth boundary.

Lco2—8 to 18 inches, black (10YR 2/1) mucky silt loam; few, fine, distinct, dark brown (7.5YR 3/2) mottles; weak, very fine, granular structure; friable; 2 to 3 percent snail shells; moderately alkaline; gradual, wavy boundary.

Lco3—18 to 28 inches, black (N 2/0) mucky silt loam; weak, fine, subangular blocky structure; friable; 2 to 3 percent snail shells; slight effervescence; mildly alkaline; abrupt, wavy boundary.

Lco4—28 to 47 inches, black (N 2/0) silty clay loam; structureless; friable; 2 to 3 percent snail shells; slight effervescence; mildly alkaline; abrupt, wavy boundary.

IIC—47 to 60 inches, very dark gray (5Y 3/1) silty clay loam; structureless; sticky; strong effervescence; mildly alkaline.

The Lco horizon is generally black, but it is very dark gray in places. It is silty clay loam or silt loam and contains 10 to 30 percent organic matter. It is 30 to 60 inches or more thick. Coarse fragments consisting almost entirely of snail shells make up 1 to 20 percent of the Lco horizon. The IIC horizon is clay loam, silty clay loam, or loam.

Urness soils are similar to Quam and Parnell soils. They have a higher organic-matter content than these soils. They also contain free lime throughout and numerous fragments of snail shells throughout the solum, unlike Quam and Parnell soils.

335—Urness mucky silt loam (0 to 2 percent slopes). This nearly level soil is on old lake beds and in large depressions. Areas are circular or oblong. Some are quite large.

Included with this soil in mapping are small areas of Oldham, Quam, and Vallers soils. Also included are small areas of soils that have a mucky surface layer.

If undrained, this soil is covered with marsh vegetation of sedges, reeds, rushes, and willows. Undrained areas provide habitat for wetland wildlife. If adequately drained, the soil is suited to all crops commonly grown in the county. Small grains, however, tend to lodge, and corn and soybeans often do not reach maturity because of early frost. Corn for silage is well suited to this soil.

The main management needs are maintaining drainage and fertility and controlling soil blowing. Capability unit IIIw–1; windbreak suitability group 7; recreation group 4; pasture and hayland group 6.

Vallers Series

The Vallers series consists of poorly drained, nearly level soils that formed in calcareous loamy glacial till.

In a representative profile the surface layer is black clay loam about 14 inches thick. The underlying material is grayish brown. The upper 11 inches is clay loam, and the lower part is loam.

Vallers soils have high organic-matter content, high available water capacity, and medium natural fertility. Permeability is moderately slow. The surface layer is moderately alkaline.

If proper management practices, fertilization, and drainage are used, Vallers soils are suited to all crops commonly grown in the county.

Representative profile of Vallers clay loam, 190 feet south and 200 feet west of the northeast corner of sec. 16, T. 128 N., R. 43 W.:

Ap—0 to 8 inches, black (10YR 2/1) clay loam; weak, fine, subangular blocky structure; very friable; strong effervescence; moderately alkaline; abrupt, smooth boundary.

Algca—8 to 14 inches, black (10YR 2/1) mixed with some grayish brown (2.5Y 5/2) clay loam; very dark gray (10YR 3/1) when rubbed; weak, fine, subangular blocky structure; very friable; violent effervescence; moderately alkaline; clear, wavy boundary.

Clgca—14 to 25 inches, grayish brown (2.5Y 5/2) clay loam; many, fine, faint, olive yellow (2.5Y 6/6) mottles; weak, fine, subangular blocky structure; friable; about 2 percent coarse fragments; common

concretions of lime; violent effervescence; moderately alkaline; clear, wavy boundary.

C2g—25 to 33 inches, grayish brown (2.5Y 5/2) loam; many, medium, faint, olive yellow (2.5Y 6/6) mottles; massive; friable; about 3 percent coarse fragments; strong effervescence; mildly alkaline; clear, wavy boundary.

C3g—33 to 50 inches, grayish brown (2.5Y 5/2) loam; many, medium, distinct, yellowish brown (10YR 5/6) mottles; massive; friable; about 3 percent coarse fragments; few concretions of lime; strong effervescence; mildly alkaline.

The A horizon typically is clay loam or silty clay loam, but it is silt loam and loam in places. It is 8 to 16 inches thick. In some profiles, the lower part of the A horizon is mottled. The C horizon is dark gray, gray, light brownish gray, grayish brown, dark grayish brown, olive, gray, or light olive gray. Mottles range from few and faint to many and prominent. In some profiles, the C horizon contains masses of gypsum crystals. Below a depth of 20 inches, the C horizon is friable or firm. A firm subsoil phase of the Vallers series is recognized in the western part of the county.

Vallers soils are associated with Aazdahl, Svea, Flom, Quam, and Parnell soils. They are more poorly drained than Aazdahl and Svea soils. They have a calcareous A horizon, unlike any of these soils.

236—Vallers clay loam (0 to 2 percent slopes). This nearly level soil is on till plains and morainic uplands. Areas are 5 to 30 acres in size. The topography consists of shallow swales, drainageways, and low, nearly level areas. Some areas are on the rims of very poorly drained potholes, and others occur as nearly level flats that have small depressions. This soil has the profile described as representative of the series. In some areas the soil has gravelly bands, in other areas it has less mottling, and in a few areas it lacks the distinct horizon of lime accumulation.

Included with this soil in mapping are small areas of Hamerly, Flom, and Parnell soils. Also included are areas of soils that have a surface layer and subsoil of silt loam more than 24 inches thick.

If adequately drained, this soil is suited to all crops commonly grown in the county. Drainage can be improved by open ditches or tiles. High lime conditions result in a nutrient imbalance that can be improved by proper fertilization.

The main management need is improving drainage, fertility, and tilth. Capability unit IIw–2; windbreak suitability group 4; recreation group 4; pasture and hayland group 3.

419—Vallers clay loam, firm subsoil (0 to 2 percent slopes). This nearly level soil is in the lake basin. Areas are as large as 100 acres. The landscape consists of shallow swales, depressions, and nearly level, slightly higher areas. The profile of this soil differs from the one described as representative of the series by having firm till at a depth of 20 to 40 inches. In a few areas this soil is high in soluble salts. These areas can be recognized during the growing season by very stunted crop growth. One of these areas is in sections 27 and 28 of Lawrence Township.

Included with this soil in mapping are small areas of Roliss, Rockwell, and Kittson soils. Also included are small areas of very poorly drained soils in depressions.

If adequate drainage is used, most areas of this soil can be used for cultivated crops. Small grains are the most common crops, but row crops such as corn, soybeans, and sunflowers are also grown. A few areas are in grass or used for pasture. The high lime condition causes an imbalance of nutrients that can be improved with proper fertilization.

The main management need is improving fertility, drainage, and tilth. Capability unit IIw–2; windbreak suitability group 4; recreation group 4; pasture and hayland group 3.

Waukon Series

The Waukon series consists of well-drained, undulating to steep soils that formed in calcareous loamy glacial till.

In a representative profile the surface layer is very dark brown loam about 6 inches thick. The subsurface layer is dark grayish-brown loam about 3 inches thick. The subsoil is friable clay loam about 18 inches thick. The upper 13 inches is dark brown, and the lower 5 inches is olive brown. The underlying material is light olive-brown loam.

Waukon soils have high natural fertility, high available water capacity, and moderate organic-matter content. Permeability is moderate. The surface layer is neutral.

Waukon soils are used for crops, pasture, and woodland.

Representative profile of Waukon loam, 12 to 24 percent slopes, 1,200 feet west and 3,050 feet north of the southeast corner of sec. 6, T. 129 N., R. 41 W.:

A1—0 to 6 inches, very dark brown (10YR 2/2) loam; moderate, very fine, subangular blocky structure; very friable; neutral; abrupt, wavy boundary.

A2—6 to 9 inches, dark grayish brown (10YR 4/2) loam; weak, thin, platy structure parting to weak, very fine, granular; very friable; neutral; clear, wavy boundary.

B1—9 to 15 inches, dark brown (10YR 4/3) clay loam; moderate, fine, subangular blocky structure; friable; neutral; gradual, wavy boundary.

B2t—15 to 22 inches, dark brown (10YR 4/3) clay loam; moderate, fine and very fine, subangular blocky structure; friable; many thick, very dark grayish brown (10YR 3/2) clay films on faces of peds; about 5 percent coarse fragments; neutral; gradual, wavy boundary.

B3t—22 to 27 inches, olive brown (2.5Y 4/4) clay loam; moderate, very fine, subangular blocky structure; friable; few very dark brown (10YR 2/2) clay films in old root channels; about 5 percent coarse fragments; neutral; clear, wavy boundary.

C—27 to 60 inches, light olive brown (2.5Y 5/4) loam; massive; friable; few, medium, distinct, gray (N 6/0) concretions of lime and few strong brown concretions of iron; about 3 percent coarse fragments; strong effervescence; mildly alkaline.

Thickness of the solum ranges from 18 to 40 inches. Depth to free carbonates ranges from 18 to 36 inches. The A horizon generally is dark grayish brown, very dark brown, or very dark gray, but in places it is black. It is generally loam, but it is sandy loam in places. The A2 horizon commonly has no cultivated areas. The B horizon is brown, olive brown, dark brown, dark yellowish brown, or yellowish brown. It is clay loam or sandy clay loam, and contains clay films that range from thin and patchy to thick and continuous. The C horizon is loam, sandy loam, or clay loam.

Waukon soils are associated with Flom and Quam soils. They are better drained than these soils.

38C—Waukon loam, 4 to 12 percent slopes. This undulating to rolling soil is on upland moraines. Areas vary in size. Most have complex, choppy topography. The slopes are 50 to 200 feet long. The profile of this soil is similar to the one described as representative of the series, but its solum is thicker. In some cultivated areas the soils have lost a portion of the surface layer through erosion.

Included with this soil in mapping are small areas of Langhei, Barnes, Darnen, Flom, Parnell, and Quam soils. Also included are small areas of soils that are less sloping than this soil, areas of soils that are more sloping than this soil, sandy spots, and areas of eroded soils.

This soil is used for cultivated crops, pasture, and woodland. It is suited to all crops commonly grown in the county. Water runs off at a medium to rapid rate, and the hazard of erosion is moderately severe.

The main management need is controlling erosion, improving fertility and tilth, and conserving moisture. Capability unit IIIe–1; windbreak suitability group 1; recreation group 1; pasture and hayland group 1.

38D—Waukon loam, 12 to 24 percent slopes. This hilly soil is on upland moraines along draws and waterways and around marshes and sloughs. Areas vary in size and shape. The slopes are irregular and are commonly dissected by draws. They are 100 to 200 feet long. This soil has the profile described as representative of the series.

Included with this soil in mapping are small areas of Langhei, Flom, and Darnen soils.

This soil is used for crops, woodland, and pasture. Except for some steep areas, it is suited to all crops commonly grown in the county. Water runs off at a rapid to very rapid rate, and the hazard of erosion is severe to very severe.

The main management needs are controlling erosion and conserving moisture. Capability unit IVe–1; windbreak suitability group 1; recreation group 1; pasture and hayland group 1.

Wheatville Series

The Wheatville series consists of somewhat poorly drained and moderately well drained, nearly level, calcareous soils in lake basins. These soils formed in loamy material over sandy material underlain by clayey material.

In a representative profile the surface layer is black very fine sandy loam about 13 inches thick. The underlying material is stratified. The upper 7 inches of this layer is light brownish-gray and grayish-brown very fine sandy loam, the next 9 inches is light olive-brown loamy very fine sand, and the lower part is gray silty clay.

Wheatville soils have medium natural fertility, high organic-matter content, and moderate to high available water capacity. Permeability is moderately rapid in the loamy material and slow in the clayey material. The surface layer is moderately alkaline.

Nearly all areas of these soils are cultivated. Wheatville soils are suited to all crops commonly grown in the county.

Representative profile of Wheatville very fine sandy loam, 0 to 2 percent slopes, 2,600 feet north and 850 feet west of the southeast corner of sec. 18, T. 129 N., R. 44 W.:

Ap—0 to 7 inches, black (10YR 2/1) very fine sandy loam; weak, fine, granular structure; friable; few threads of gypsum; strong effervescence; moderately alkaline; abrupt, smooth boundary.

A12ca—7 to 13 inches, black (10YR 2/1) very fine sandy loam; weak, fine, granular structure; friable; strong effervescence; moderately alkaline; gradual, wavy boundary.

C1ca—13 to 17 inches, light brownish gray (2.5Y 6/2) very fine sandy loam; structureless; friable; violent effervescence; moderately alkaline; clear, wavy boundary.

C2ca—17 to 20 inches, grayish brown (2.5Y 5/2) very fine sandy loam; structureless; friable; strong effervescence; moderately alkaline; gradual, wavy boundary.

C3—20 to 29 inches, light olive brown (2.5Y 5/4) loamy very fine sand; common, fine, distinct, yellowish brown (10YR 5/6) mottles; single grained; loose; slight effervescence; mildly alkaline; abrupt, wavy boundary.

IIC4—29 to 60 inches, gray (5Y 5/1) silty clay; common, fine, prominent, yellowish brown (10YR 5/6) and dark brown (7.5YR 3/2) mottles; weak, fine, subangular blocky structure; firm; few gypsum crystals; strong effervescence; mildly alkaline.

The A horizon is black or very dark gray. It generally is very fine sandy loam, but it is loam or silt loam in places. The Cca horizons are dark gray, grayish brown, dark grayish brown, gray, and light brownish gray. They generally are very fine sandy loam or loamy very fine sand. Faint mottles are in some profiles, but no distinct mottles are within a depth of 20 inches. The C horizons are strongly to violently effervescent. The C3 horizon is light brownish gray, light yellowish brown, and light olive brown. It is slightly to strongly effervescent. Faint to distinct mottles are below a depth of 20 inches. The C3 horizon is loamy very fine sand or very fine sandy loam. Depth to the IIC horizon ranges from 20 to 40 inches. Reaction is mildly alkaline to moderately alkaline throughout the profile.

Wheatville soils are associated with Bearden and Glyndon soils. They have a clayey IIC horizon, unlike Glyndon soils. They have a sandy layer below the surface and are underlain by clayey material, unlike Bearden soils.

343—Wheatville very fine sandy loam, 0 to 2 percent slopes. This nearly level soil is in the lake basin. Areas vary in size. Some are quite large.

Included with this soil in mapping are small areas of Glyndon and Bearden soils and a poorly drained soil.

Nearly all areas of this soil are cultivated. Small grains are most common, but some row crops such as corn, soybeans, and sunflowers are also raised. Some legumes are grown as a green manure crop. A few areas are used for hay or pasture. Soil blowing is a hazard on unprotected fields during winter and early spring. This soil has a high content of lime which causes an imbalance of nutrients.

The main management needs are controlling soil blowing and improving fertility and tilth. Capability unit IIs–2; windbreak suitability group 2; recreation group 1; pasture and hayland group 1.

Use and Management of the Soils

Management of soils used for crops is discussed in this section. The capability groupings are explained, and the soils of the county are grouped according to their suitability for crops and pasture. Yield predic-

tions are given for the common crops. Also discussed in this section is the use of the soil for windbreaks, wildlife, recreation, and engineering.

Cropland

Grant County is mainly a grain farming area, but some farmers raise beef cattle or hogs or run dairy operations. Corn, soybeans, sunflowers, oats, barley, and wheat are the main crops. Small acreages of flax, alfalfa, and sugar beets are also grown. The acreage of sunflowers, most of which is in the western part of the county, is increasing. Approximately 92 percent of the land is used for crops, and 3 percent is used for pasture. The soils range from marginal cropland to highly productive land. Good management practices can increase yields.

Water erosion is a hazard on sloping soils. Terracing, contour farming, minimum tillage, crop residue management, and stripcropping reduce runoff and help to control erosion. The return of crop residue to the soil increases the infiltration rate, which increases the amount of water available for plant growth. It also maintains a high content of organic matter, a high level of fertility, and improved tilth.

Soil blowing occurs throughout the county. It is most serious on sandy and gravelly soils along the the Pomme de Terre and Chippewa Rivers and the basin of glacial Lake Agassiz. Stripcropping, minimum tillage, stubble mulching, field shelterbelts, and crop residue management help to control soil blowing.

Most soil blowing occurs where soils are left bare in winter and spring. Fields plowed in fall should be left rough to expose crop residue and protect the soil. Plowing in fall is more suitable on the poorly drained soils, because they are difficult to work in spring when they are wet.

Wetness is a hazard on most of the level and depressional soils. Open ditches are commonly used to remove surface water from low areas and closed depressions and to provide outlets for tile drainage systems. Tile drainage systems can be installed in most of the soils. Root development is good in soils that are adequately drained because the movement of air and water is not restricted. Soils that are adequately drained generally warm earlier in spring.

Moisture deficiencies occur in most years in the well drained and excessively drained soils of Grant County. The somewhat excessively drained gravelly soils are irrigated, and it is expected that the irrigated acreage in the county will increase in the future. Use of irrigation will make practicable a greater variety of crops, especially on soils that have low available water capacity and that otherwise are best suited to early-maturing crops. Crop yields can be stabilized on the deep, well-drained soils by use of irrigation during the dry periods that occur in most years.

Most of the soils in the outwash areas are suited to irrigation. Although the outwash areas are underlain by a water supply, the amount of water needed for irrigation might not always be available. Test well borings are needed, therefore, to determine the adequacy of the water supply. Most potential areas for irrigation are along the Pomme de Terre River and small areas in the eastern part of the county.

Irrigation farming often requires that large fields be planted entirely to one crop. These fields are often left unprotected for long periods and are therefore susceptible to soil blowing. Practices such as planting winter cover crops or establishing field windbreaks help to control this erosion. Erosion is a hazard on sloping soils under irrigation management, and proper distribution of water is difficult to assure. The choice of a proper irrigation system can minimize the disadvantages of irrigating sloping soils.

Tilling too frequently or when soils are too wet or too dry damages the structure of the soils. Frequent tillage makes the surface layer powdery so that water is not readily absorbed. Tilling when the soil does not contain the proper amount of moisture makes the surface layer cloddy and unsuitable as a seedbed. The soils should be tilled only enough to prepare a good seedbed and control the growth of weeds. Plowing in fall is a common practice, but as previously stated, fall-plowed fields should be left rough in order to reduce erosion.

Fertilizer application increases crop yields on most of the soils in Grant County. The amount of fertilizer applied should be based on the results of soil tests. It varies, depending on the type of soil, past management, and the nutrient demand of the crops to be grown.

Capability grouping

Capability grouping shows, in a general way, the suitability of soils for most kinds of field crops. The soils are grouped according to their limitations when they are 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 and generally expensive land-forming 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 that require special management.

Those familiar with the capability classification can infer from it much more about the behavior of soils when they are 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 forest trees, or for engineering.

In the capability system, all 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 require moderate conservation practices.

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

Class IV soils have very severe limitations that reduce the choice of plants or 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 Grant County)

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

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

Class VIII soils and landforms have limitations that preclude their use for commercial plants and limit their use to recreation, wildlife, water supply, or to esthetic purposes.

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 plant 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, although 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–3. Thus, in one symbol, the Roman numeral designates the capability class, or degree of limitations; 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.

In the following pages the capability units in Grant County are described, and suggestions for the use and management of the soils are given.

CAPABILITY UNIT I–1

This unit consists of somewhat poorly drained to well-drained, nearly level to undulating, medium-textured and moderately fine textured soils.

These soils have moderate to very high available water capacity, high natural fertility, and high content of organic matter. Permeability and infiltration are moderate to moderately slow. The root zone is deep. Most of these soils are easily tilled and readily permeable to roots, air, and water and have no major limitation to use. The soils are subject to slight soil blowing on fields left unprotected in winter and spring, but under proper management soil loss can be kept to a minimum.

All crops suited to the climate of the county can be grown on these soils. Corn, soybeans, oats, wheat, barley, and alfalfa are the main crops, but small acreages of flax, sunflowers, and sugar beets are also grown. These soils are among the most productive in the county. In areas where these soils are used mainly for row crops, practices are needed to maintain optimum infiltration and permeability. Among such practices are minimum tillage, tilling the soils only when they contain the proper amount of moisture, stubble mulching, and managing all crop residue.

CAPABILITY UNIT IIe–1

This unit consists of moderately well drained to somewhat excessively drained, nearly level to undulating, fine- to medium-textured soils.

These soils have moderate to very high available water capacity and low to high natural fertility. Permeability and infiltration are moderately rapid to very slow. The root zone is deep. In some small areas the soils are poorly drained or very poorly drained. The root zone in these areas is limited by the depth to the water table. Most of these soils are easily tilled and are readily permeable to roots, air, and water. These soils are subject to further soil blowing unless properly managed. Erosion is most likely late in spring if the soil is not protected from rain and wind.

All crops suited to the climate of the county can be grown on these soils. Corn, soybeans, oats, wheat, barley, and alfalfa are the main crops, but small acreages of flax and sunflowers are also grown. Crop growth varies because of different surface texture, varying thickness of the surface layer, and content of lime in the soil. To control runoff and erosion, contour tillage, contour stripcropping, terracing, waterways, minimum tillage, and stubble mulching are used. Returning crop residue to the soil, fertilizing properly, and adding manure help to maintain the content of organic matter and tilth. Under a high level of management, these soils can be farmed more intensively to row crops.

CAPABILITY UNIT IIe–2

This unit consists of very poorly drained to moderately well drained, nearly level, medium-textured soils.

These soils have moderate to high available water capacity, medium to high natural fertility, and high content of organic matter. One of the soils has medium natural fertility because of its high content of lime. This causes an imbalance of plant nutrients. Permeability is moderately slow to slow. The root zone is deep in all but the very poorly drained soils, in which roots are limited by depth to the water table. Most of these soils are easily tilled and are permeable to roots and air, but the very poorly drained soil, which is in depressions, is not. If these depressions are not drained, water ponds for a few days to a few weeks in spring

and after heavy rains. This hinders farming in spring and can drown a crop if heavy rain falls after planting. Soil blowing is a hazard on fields left bare in winter and spring.

Most crops suited to the climate of the county can be grown on these soils. Corn, oats, wheat, and barley are the main crops, but small acreages of flax, sunflowers, and sugar beets are also grown. The main limitation to crop production is the degree of fertility relative to the high content of lime and the wetness of the very poorly drained soil in depressions. Management practices that include minimum tillage and stubble mulching are needed to control erosion. Returning crop residue to the soil, fertilizing properly, and adding manure help to maintain the content of organic matter, tilth, and fertility. Depressions need drainage.

CAPABILITY UNIT IIw–1

This unit consists of very poorly drained and poorly drained, nearly level, fine- to medium-textured soils.

These soils have moderate to high available water capacity, high fertility, and high content of organic matter. Permeability is moderately slow to slow. The root zone is limited by depth to the water table.

All crops suited to the climate of the county can be grown on these soils. Corn, soybeans, barley, oats, wheat, and sunflowers are the main crops, but small acreages of sugar beets are also grown. Wetness is the main management concern on these soils. Practices that promote movement of air and water into and through the soil are needed. These practices include minimum tillage, stubble mulching (fig. 7), field operations, returning crop residue to the soil, and fertilizing properly to improve tilth, fertility, and drainage. If these soils are plowed in the fall, a good seedbed can be obtained in spring. If these soils are plowed when too wet, hard clods form, and compaction is likely. Soil blowing is a hazard on fields left bare in winter and spring.

CAPABILITY UNIT IIw–2

This unit consists of poorly drained to very poorly drained, nearly level, medium-textured to moderately fine textured, calcareous soils.

Figure 7.—**Stubble mulching on Roliss loam, capability unit IIw–1.**

These soils have high to very high available water capacity, medium to high natural fertility, and high content of organic matter. Permeability is moderate to moderately slow, and infiltration is slow. The root zone is limited by depth to the water table. In most of these soils a high content of lime causes an imbalance of plant nutrients. Special attention should be given to the level of available phosphorus and potassium. In a few areas, the soils have a neutral surface layer.

All crops suited to the climate of the county can be grown on these soils. Corn, oats, soybeans, wheat, and barley are the main crops, but small acreages of sunflowers, flax, and sugar beets are also grown. Wetness is the main management concern on these soils. Practices that promote movement of air and water into and through the soil are needed. These practices include minimum tillage, timely field operations, returning all crop residue to the soil, growing legumes and grasses, and fertilizing properly to help maintain tilth. Ditches help to remove surface water early and permit cropping of the soil. Tile drainage is needed to provide an adequate root zone. If these soils are plowed in fall, a good seedbed can be obtained in spring. Soil blowing is a hazard on fields left bare in winter and spring.

CAPABILITY UNIT IIw–3

This unit consists of very poorly drained and poorly drained, nearly level, moderately coarse textured to moderately fine textured soils.

These soils have low to high available water capacity, medium to high natural fertility, and high content of organic matter. Permeability is moderately slow to rapid, and infiltration is moderate. In most of these soils a high content of lime causes an imbalance of plant nutrients. In some areas the soils are gravelly coarse sand at a depth of 22 to 40 inches.

All crops suited to the climate of the county can be grown in these soils. Corn, oats, soybeans, barley, and wheat are the main crops, but small acreages of flax, sunflowers, and sugar beets are also grown. Wetness is the main management concern on these soils. Practices that promote movement of air and water into and through the soil are needed. These practices include minimum tillage, timely field operations, returning all crop residue to the soil, and fertilizing properly to help improve and maintain tilth, fertility, and content of organic matter, and to improve drainage. Some soils have been drained by surface ditches. In soils underlain by sand and gravel, tile drainage is difficult. Plugging with sand is a hazard after tile has been installed. Soil blowing is a hazard on fields left bare in winter and spring.

CAPABILITY UNIT IIs–1

This unit consists only of Fordville loam, 0 to 2 percent slopes. It is a nearly level, medium-textured soil underlain by coarse-textured material.

This soil has low to moderate available water capacity, high natural fertility, and high content of organic matter. Permeability is moderate in the upper part of the soil and rapid below, and infiltration is moderate. The root zone is moderately deep. This soil is easily tilled and is readily permeable to roots, air, and water. It can be droughty during long, dry periods. Soil blowing is a hazard on fields left unprotected in winter and spring.

Corn, soybeans, and small grains are the main crops. To control erosion and conserve moisture, minimum tillage, stubble mulching, fertilizing properly, and returning all crop residue to the soil are needed.

CAPABILITY UNIT IIs–2

This unit consists of somewhat poorly drained and moderately well drained, nearly level, moderately fine textured to medium-textured, calcareous soils.

These soils have moderate to very high available water capacity and high content of organic matter. Most of these soils have medium fertility because of a high content of lime. This causes an imbalance of plant nutrients. Permeability is moderately rapid to slow, and infiltration is moderate. The root zone is deep. Some soils have a neutral surface layer. The soils in this unit are easily tilled and are permeable to roots and air. Soil blowing is a hazard on fields left bare in winter and spring.

Most crops suited to the climate of the county can be grown on these soils. Corn, oats, wheat, barley, and soybeans are the main crops, but small acreages of flax, sunflowers, and sugar beets are also grown. The main limitation to crop production is the degree of fertility relative to the high content of lime. The high pH of these soils reduces the availability of phosphorus. The high content of lime also causes the soil granules to break down into smaller particles that are easily blown by wind. Management practices that include minimum tillage and stubble mulching are needed to control erosion. Returning crop residue to the soil, fertilizing properly, and adding manure help to maintain the content of organic matter, tilth, and fertility.

CAPABILITY UNIT IIIe–1

This unit consists of well-drained to somewhat excessively drained, medium- to fine-textured, rolling soils.

These soils have moderate to high available water capacity, low to high natural fertility, and moderate to high content of organic matter. Permeability and infiltration are moderate to very slow. In many areas the soils are eroded, and the hazard of additional erosion is moderately severe. Erosion is most likely to occur if the soil is bare and is thus unprotected from rain. In some areas a high content of lime causes an imbalance of plant nutrients. In places the soils are clayey and more difficult to till.

All crops suited to the climate of the county can be grown on these soils. Corn, oats, soybeans, barley, wheat, and alfalfa are the main crops, but small acreages of flax are also grown. Crop production is generally lower on the eroded slopes because of the lower content of organic matter and the high content of lime. Erosion and runoff are the main management concerns on these soils. To control erosion and runoff, contour stripcropping (fig. 8), terracing, contour tillage, waterways, minimum tillage, and stubble mulching are used. On terraced or strip-cropped soils, row

Figure 8.—**Contour stripcropping on Langhei-Barnes loams, 6 to 12 percent slopes, eroded, capability unit IIIe-1.**

crops can also be planted. Returning crop residue to the soils, fertilizing properly, and adding manure help to maintain content of organic matter and tilth. The soils in this unit are generally plowed in the fall and left rough to catch snow and reduce the amount of soil blowing.

CAPABILITY UNIT IIIw-1

This unit consists of very poorly drained, nearly level, medium-textured to moderately fine textured soils.

These soils have high to very high available water capacity, medium to high natural fertility, and high to very high content of organic matter. Permeability and infiltration are moderately slow to slow. Some of the soils are mildly alkaline to moderately alkaline. The root zone is limited by depth to the water table.

Most crops suited to the climate of the county can be grown on these soils. Corn, soybeans, sunflowers, and small grains are the main crops. Where small grains are grown, lodging is generally a severe hazard. Wetness is the main limitation to farming, and the soils must be drained to be cropped. Where these soils are not drained, the water table generally is at or near the surface. Water ponds in some of these undrained areas for several weeks late in spring and in some areas throughout the year. These soils can be used for stockwater ponds (fig. 9). Most areas are drained by open ditches that remove surface water. Shallow ditches that drain closed depressions should be sodded where gullying is a hazard. Tile drainage is needed to provide adequate internal drainage. This lowers the water table, provides an adequate root zone, and allows the soil to warm earlier in spring.

CAPABILITY UNIT IIIw-2

This unit consists of poorly drained to very poorly drained, nearly level, moderately coarse textured soils underlain by coarse-textured to moderately fine textured material.

These soils have moderate to high available water capacity, medium natural fertility, and high content of organic matter. Permeability is moderately rapid in the upper part and rapid to moderately slow in the underlying material. The root zone is limited by depth to the water table.

All crops suited to the climate of the county can be grown on these soils. Corn, soybeans, wheat, barley, oats, and sunflowers are the main crops. Drainage is the main management concern on these soils. Practices that include drainage, minimum tillage, timely field operations, returning all crop residue to the soil, and

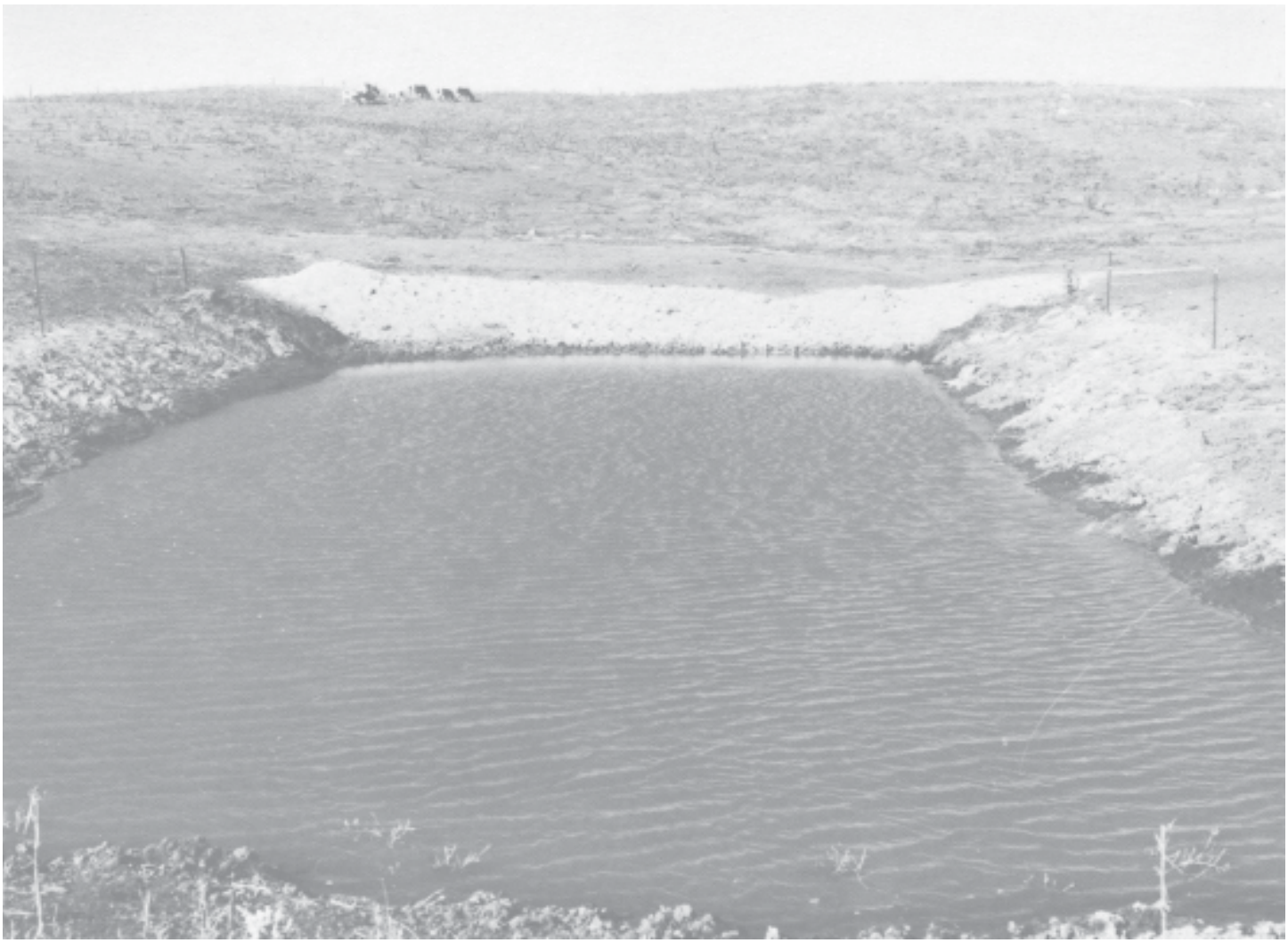

Figure 9.—**Stockwater pond on Quam silty clay loam, capability unit IIIw–1.**

fertilizing properly all help to maintain content of organic matter, good tilth, and fertility. Excess water limits the use of these soils. Water is commonly ponded in spring and occasionally throughout the year. Some areas have been drained by surface ditches. In soils in which the underlying material is rapidly permeable, tile drainage is difficult because of coarse texture. Plugging with sand is a hazard after tile has been installed. These soils are often plowed in fall and left rough in winter and spring to catch snow and reduce the amount of soil blowing. Disking rather than plowing these soils leaves a rough surface that reduces soil blowing. Stubble mulching, wind stripcropping, and field windbreaks also help to control soil blowing. Some areas of these soils are in permanent pasture. Undrained areas are marshy and are seasonally ponded. All of these soils are good sites for stockwater ponds.

CAPABILITY UNIT IIIs–1

This unit consists only of Arvilla sandy loam, 0 to 2 percent slopes. It is a somewhat excessively drained, moderately coarse textured soil underlain by coarse-textured material.

This soil has low available water capacity, medium natural fertility, and moderate content of organic matter. Permeability is rapid, and infiltration is moderate. The root zone is shallow. Droughtiness is the main hazard on this soil.

All crops suited to the climate of the county can be grown on this soil, but early-maturing crops that make the best use of limited moisture are best suited. This soil is easily tilled but is subjected to droughtiness and erosion. It warms early in spring and responds well to irrigation and fertilizer. This soil needs to be managed to control erosion and conserve moisture. Stubble mulching, minimum tillage, wind stripcropping, and field windbreaks control soil blowing and reduce evaporation and transpiration of soil and plants. Returning all crop residue to the soil and adding manure help to maintain content of organic matter, fertility, and tilth and reduce erosion. Spring plowing and wheel-track planting also help to control erosion.

CAPABILITY UNIT IIIs–2

This unit consists of somewhat excessively drained, moderately coarse textured, undulating soils underlain by coarse-textured material.

These soils have low available water capacity, medium natural fertility, and moderate content of organic matter. Permeability and infiltration are rapid. The root zone is shallow to deep. Droughtiness is the main hazard on these soils.

All crops suited to the climate of the county can be grown on these soils, but early-maturing crops that make the best use of the limited available moisture are best suited. These soils are easily tilled but are droughty and subject to erosion. They warm early in spring and respond well to irrigation and fertilizer. These soils need to be managed to control erosion and conserve moisture. Stubble mulching, minimum tillage, wind stripcropping, and field windbreaks control soil blowing and reduce evaporation of soil and transpiration from plants. Returning all crop residue to the soil, adding manure, spring plowing, and wheel-track planting help to control erosion.

CAPABILITY UNIT IIIs–3

This unit consists of somewhat poorly drained to moderately well drained, nearly level, moderately coarse textured soils underlain by fine-textured material.

These soils have moderate to high available water capacity, medium fertility, and moderate to high content of organic matter. Permeability is rapid to slow, and infiltration is moderate. The root zone is deep. Soil blowing is the main hazard on these soils.

All crops suited to the climate of the county can be grown on these soils. Sunflowers, wheat, oats, and barley are the main crops, but small acreages of flax, corn, and soybeans are also grown. These soils are easily tilled but are subject to soil blowing and droughtiness during long dry periods. These soils need to be managed to control erosion and conserve moisture. Stubble mulching, minimum tillage, wind stripcropping, and field windbreaks control soil blowing and reduce evaporation of soil and transpiration from plants. Returning all crop residue to the soil and adding manure help to maintain content of organic matter, fertility, and tilth and reduce erosion. Plowing in spring and wheel-track planting also help to control erosion.

CAPABILITY UNIT IIIs–4

This unit consists only of Ulen loamy fine sand, 0 to 2 percent slopes. It is somewhat poorly drained to moderately well drained, nearly level, coarse-textured soil.

This soil has low available water capacity, low natural fertility, and moderate content of organic matter. Permeability and infiltration are rapid. The high content of lime and the low content of available water contribute to the low natural fertility. The high content of lime causes an imbalance of plant nutrients and keeps little phosphorus available for plants. The root zone is deep. This soil is easily tilled and is readily permeable to roots, air, and water. Soil blowing is a severe hazard on fields left unprotected in winter and spring. Droughtiness is a hazard, and this soil is generally deficient of moisture by mid-summer.

All crops suited to the climate of the county can be grown on this soil, but early-maturing crops that make the best use of the limited available moisture are best suited. This soil is generally plowed in spring. Fields plowed in fall are left rough to prevent soil blowing in winter and spring. Disking rather than plowing, stubble mulching, wind stripcropping, and field shelterbelts also help to control soil blowing. Returning crop residue to the soil helps to maintain content of organic matter and good tilth.

CAPABILITY UNIT IVe–1

This unit consists of well-drained to somewhat excessively drained, moderately steep to steep, medium-textured to moderately fine textured soils.

These soils have high available water capacity, low to high natural fertility, and moderate to high content of organic matter. Permeability and infiltration are moderate to moderately slow. Some areas of soils have a surface layer that has a high content of lime. The root zone is deep.

All crops suited to the climate of the county can be grown on these soils. Corn, soybeans, and small grains are the main crops. Water erosion and runoff are the main management concerns on these soils. Practices that include stubble mulching, mulch planting, minimum tillage, cropping systems, and contour stripcropping help to control erosion and conserve moisture. Returning crop residue to the soil, fertilizing properly, and adding manure help to maintain content of organic matter, good tilth, and fertility. Contour tillage is difficult because the slopes are short, irregular, and steep, but its use should be considered where the slopes are suitable. Sodded waterways are needed wherever water collects and causes a hazard of gullying. Much of the rain that falls on these soils runs off, so plants often lack sufficient moisture. Droughtiness is often a hazard late in July and in August.

CAPABILITY UNIT IVs–1

This unit consists of excessively drained, nearly level to rolling, coarse-textured soils.

These soils have very low available water capacity, low content of organic matter, and low natural fertility. Permeability and infiltration are rapid. The root zone is very shallow. These soils are easily tilled and are rapidly permeable to roots, air, and water. Droughtiness and low fertility are severe hazards to farming these soils, and moisture is depleted by late June. Erosion is a hazard on the more rolling slopes.

All crops suited to the climate of the county can be grown on these soils. Corn, soybeans, small grains, legumes, and grasses are the main crops. Early-maturing crops that make the best use of the limited moisture supply are best suited. Crop production is so low that these soils are best suited to grasslands. Practices that include stubble mulching, minimum tillage, stripcropping, and field windbreaks help to control erosion and conserve moisture. Returning crop residue to the soil helps to maintain content of organic matter and tilth. Very low available water capacity, low fertility, and erosion make these soils marginal for irrigation.

CAPABILITY UNIT IVs–2

This unit consists of moderately well drained to well drained, nearly level to gently sloping, coarse-textured soils.

These soils have low available water capacity and natural fertility and moderate content of organic matter. Permeability and infiltration are rapid. The root zone is deep.

All crops suited to the climate of the county can be grown on these soils. Corn, soybeans, and small grains are the main crops. Early-maturing crops that make the best use of the limited moisture supply are best suited. Droughtiness and erosion are the main management concerns on these soils. Practices that include stubble mulching, cropping systems, minimum tillage, wind stripcropping, and field windbreaks help to control erosion and conserve soil moisture. Returning crop residue to the soil and using green manure crops help to maintain the content of organic matter and good tilth. Droughtiness is a severe limitation, and the soils generally are deficient of moisture by mid July. Soil blowing is a severe hazard on soils left bare in winter and spring, and fields generally are plowed in spring to protect them from this hazard. Low available water capacity and low fertility make these soils marginally suitable for irrigation.

CAPABILITY UNIT VIw–1

This unit consists of very poorly drained, nearly level, medium-textured to moderately fine textured soils.

These soils have medium to very high available water capacity, natural fertility, and content of organic matter. Permeability and infiltration are moderate to moderately slow. This wide variation in soil condition results from the wide range in soil texture, from moderately coarse to moderately fine. Flooding is the main hazard on these soils.

These frequently flooded soils are next to or near streams. They are best suited to permanent vegetation. They are flooded too frequently to be safely cultivated or are so cut up by old stream meanders that it is not practical to cultivate them. Suitable outlets for drainage are lacking because mapped areas are so close to streams. When these soils are used for pasture, it is important that weeds and brush be controlled. If the soils are grazed when too wet, they become hummocky and less valuable as pasture.

CAPABILITY UNIT VIs–1

This unit consists only of Maddock loamy sand, 6 to 18 percent slopes. It is a well-drained, sloping to moderately steep, coarse-textured soil.

This soil has low available water capacity and natural fertility and moderate content of organic matter. Permeability and infiltration are rapid. The root zone is deep.

This soil is suited to hay, pasture, and wildlife habitat. It is too droughty and erodible for cultivated crops. In some places farmed areas are best suited to permanent vegetation. This soil is loose and rapidly permeable to roots, air, and water. It is so erodible that it is best suited to permanent grasses; fertilization insures good grass production. Droughtiness is a very severe hazard, and this soil is generally deficient of moisture. Soil blowing is a hazard because the soil is so loose. Special care must be taken to prevent overgrazing.

CAPABILITY UNIT VIIe–1

This unit consists only of Langhei loam, 18 to 35 percent slopes. It is a somewhat excessively drained, steep, medium-textured, calcareous soil.

This soil has high available water capacity, low natural fertility, and moderate content of organic matter. Permeability and infiltration are moderate, but because runoff is very rapid, the amount of water that enters the soil is greatly reduced. The hazard of erosion is very severe.

This soil is not suited to cultivated crops, and areas now under cultivation are better suited to permanent vegetation. If this soil is used for pasture, a good cover of plants can be maintained to control erosion. Water erosion is a serious hazard on this soil. Because slopes in most areas are steep and most rain runs off, the soil is never saturated. Gullies can be shaped and seeded to grass for use as waterways.

CAPABILITY UNIT VIIs–1

This unit consists only of Sioux gravelly loamy coarse sand, 12 to 35 percent slopes. It is an excessively drained, moderately steep to steep, coarse-textured soil.

This soil has very low available water capacity, low content of organic matter, and low natural fertility. Permeability and infiltration are rapid. The root zone is very shallow. This soil is loose and rapidly permeable to roots, air, and water. Droughtiness is a severe hazard, and this soil is generally deficient of moisture. Soil blowing is a hazard because the soil is so loose. The hazards of erosion and occasional gullying are severe. This soil is a good source of sand and gravel (fig. 10).

This soil is so highly erodible and unproductive that it is best suited to permanent grass. Care must be taken to prevent overgrazing through rotation and restriction of grazing. Control of weeds helps maintain good grass cover.

CAPABILITY UNIT VIIIw–1

This unit consists of Marsh. This land type occurs along the edges of some lakes, ponds, and streams and in depressions. The water level fluctuates, depending on the season. Some areas cannot be drained because they lack outlets or because ground water keeps the area seepy. Vegetation consists of cattails, rushes, sedges, willows, and other water-tolerant plants. Because the areas are wet, the soil material has not been identified. In places during long, dry periods, the edges of the marsh can be cut for wild hay.

Areas of Marsh are not suited to crops or pasture but can provide good habitat for waterfowl, muskrat, mink, and upland game (fig. 11). The areas can be improved for wildlife by providing level ditches, made by blasting or digging, for controlling the level of water.

Figure 10.—**Gravel pit on Sioux gravelly loamy coarse sand, 12 to 35 percent slopes.**

Predicted yields

In table 2, predicted long-term average yields are listed for the main crops grown under improved management in Grant County. The table provides guidelines to potential crop yields on various soils. These yields are based on records and observations of the Soil Conservation Service, the Extension Service, and the University of Minnesota, and on interviews with farmers of the county.

Yields are not given for soils that are not considered suitable for a particular crop. The major crops can be grown on such soils, but because the soils are droughty, steep, severely eroded, or poorly drained, the crops are not likely to be successful.

The yield figures represent an average to be expected under improved management. The requirements of good management vary according to the soil, but under this level of management, crops suited to the soils are grown in a suitable cropping system. Surface and internal drainage provide the best growing conditions. Commercial fertilizers and manure are applied, proper tillage methods are used, and all organic matter is returned to the soils. Weeds, insects, and diseases are adequately controlled. The productivity and workability of the soils are maintained or improved, water erosion and soil blowing are adequately controlled, and plant nutrients and soil moisture are conserved.

Under pastureland management, it is assumed that rotation pasture consists of suitable legumes and grasses. Permanent pasture, under average management, consists mainly of native grass. Under improved management in which permanent pasture is renovated at intervals, a mixture of suitable grasses and legumes is the main cover. Good management for pasture includes fertilization according to soil tests and forage needs. Pastures are properly managed, weeds and brush are adequately controlled, and drainage is adequate for the forage species grown.

Yields in table 2 are obtainable using present farming practices and varieties of crops. As agricultural technology advances, increased yields per acre might be obtained. It is also possible that plant diseases and pests might cause average yields to be less than those predicted here.

Windbreaks [2]

This section gives general facts about trees and shrubs that are suggested for use in field and farmstead windbreak plantings. It shows the principal trees and discusses the soil properties that affect the growth of trees. Table 3 shows the productivity of the soils,

[2] Prepared with the assistance of JOHN HULTGREN, woodland conservationist, Soil Conservation Service.

Figure 11.—This area of Marsh provides good habitat for wildlife. Note the open water, cattails, and reeds.

TABLE 2.—*Predicted average yields per acre of the principal crops under improved management*

[Figures indicate yields that can be expected under improved management. Absence of figures indicates that the crop is not suited or that it is not commonly grown on the soil]

Mapping unit	Corn for grain	Corn for silage	Soybeans	Oats	Wheat	Barley	Sunflowers	Rotation hay	Rotation pasture	Permanent pasture
	Bu	*Tons*	*Bu*	*Bu*	*Bu*	*Bu*	*Lbs*	*Tons*	*AUM* [1]	*AUM*
Aazdahl clay loam, 1 to 3 percent slopes	80	16	30	80	50	55	1,400	4.0	6	3
Aazdahl-Hamerly-Parnell complex, 0 to 2 percent slopes	70	14	28	75	30	45	1,200	3.5	6	3
Alluvial land, frequently flooded										3
Arveson fine sandy loam	50	10	18	55	30	35	1,200	3.0	5	3
Arvilla sandy loam, 0 to 2 percent slopes	50	10	18	50	20	28		2.5	4	2
Arvilla sandy loam, 2 to 6 percent slopes	50	10	16	50	20	28		2.5	4	2
Barnes loam, 2 to 5 percent slopes	75	15	28	80	40	50		4.0	6	3
Barnes-Langhei loams, 3 to 6 percent slopes	60	12	26	65	30	40		3.5	6	3
Barnes-Svea loams, 1 to 3 percent slopes	75	15	30	80	45	50		4.0	6	3
Bearden silt loam, 0 to 2 percent slopes	65	13	26	70	45	45	1,400	4.5	5	3
Darnen loam, 1 to 4 percent slopes	80	16	35	80	45	55		4.5	6	3
Fargo silty clay	60	12	24	75	45	55	1,400	4.0	6	3
Flom silty clay loam	80	16	30	80	40	55	1,600	4.0	6	3
Forada sandy loam	50	10	18	50	25	35		3.0	5	3
Fordville loam, 0 to 2 percent slopes	55	13	24	60	35	45		3.5	6	3
Formdale clay loam, 2 to 5 percent slopes	75	15	28	80	40	50	1,400	4.0	6	3
Formdale-Aazdahl-Flom complex, 1 to 4 percent slopes	70	14	26	75	35	50	1,400	4.0	6	3

TABLE 2.—*Predicted average yields per acre of the principal crops under improved management*—Continued

Mapping unit	Corn for grain	Corn for silage	Soybeans	Oats	Wheat	Barley	Sunflowers	Rotation hay	Rotation pasture	Permanent pasture
	Bu	*Tons*	*Bu*	*Bu*	*Bu*	*Bu*	*Lbs*	*Tons*	*AUM* [1]	*AUM*
Formdale-Langhei clay loams, 3 to 6 percent slopes	60	12	26	65	30	40	1,300	3.5	5	3
Glyndon silt loam, 0 to 2 percent slopes	70	14	25	70	40	50	1,400	4.0	6	3
Grimstad-Towner complex, 0 to 2 percent slopes	65	13	23	65	35	45	1,300	4.0	6	3
Hamerly clay loam, 1 to 3 percent slopes	70	14	25	70	45	55	1,300	4.0	6	3
Hamerly-Parnell complex, 0 to 3 percent slopes	70	14	28	75	40	55	1,300	4.0	6	3
Hecla loamy fine sand, 0 to 2 percent slopes	45	9	15	45	20	30	1,000	2.5	4	2
Kittson very fine sandy loam, 0 to 2 percent slopes	70	14	28	75	45	55	1,400	4.0	6	3
Kittson fine sandy loam, gray subsoil variant	55	8	14	65	35	40	1,200	2.5	5	3
Lake beaches										2
Lamoure silt loam	60	16	25	70	35	50		3.5	6	3
Lamoure silt loam, frequently flooded										3
Langhei loam, 18 to 35 percent slopes									4	3
Langhei-Barnes loams, 6 to 12 percent slopes, eroded	50	12	20	55	35	40		3.5	6	3
Langhei-Barnes loams, 12 to 18 percent slopes, eroded	40	8	12	45	25	30		3.0	5	3
Langhei-Formdale clay loams, 6 to 12 percent slopes, eroded	50	12	20	55	35	40		3.5	6	3
Langhei-Formdale clay loams, 12 to 18 percent slopes, eroded	40	8	12	45	25	30		3.0	5	3
Maddock loamy sand, 1 to 6 percent slopes	25	5	12	35	20	25		2.5	3	1
Maddock loamy sand, 6 to 18 percent slopes								2.0	3	1
Marsh										
McIntosh silt loam, 0 to 2 percent slopes	70	14	20	70	45	55	1,300	4.0	6	3
Oldham silty clay loam	80	16	30	70	30	40		4.0	6	3
Parnell silty clay loam	80	16	30	70	30	40	1,300	4.0	6	3
Quam silty clay loam	80	16	30	70	30	35	1,300	4.0	6	3
Rockwell loam	60	12	28	70	40	50	1,400	4.0	6	3
Rockwell-Vallers complex	65	13	28	70	40	55	1,400	3.5	6	3
Roliss loam	80	16	30	80	50	55	1,500	4.0	5	3
Roliss complex	75	16	30	70	45	55	1,500	3.0	5	3
Roliss-Vallers complex	80	16	30	70	40	55	1,500	3.0	5	3
Rothsay silt loam, 2 to 6 percent slopes	75	15	28	80	45	55		4.5	6	4
Sinai silty clay, 1 to 6 percent slopes	70	12	26	70	35	45	1,300	4.0	6	3
Sinai silty clay, 6 to 12 percent slopes	60	12	26	60	30	40	1,300	4.0	6	3
Sioux gravelly loamy coarse sand, 12 to 35 percent slopes										1
Sioux loamy coarse sand, 0 to 6 percent slopes	30	6	12	30		30		2.0	3	1
Sioux loamy coarse sand, 6 to 12 percent slopes	20	4	10	20		25		1.5	2	1
Svea loam, 1 to 3 percent slopes	80	11	30	80	50	55		4.0	6	3
Svea-Hamerly loams, 1 to 3 percent slopes	75	15	28	80	50	55		4.0	6	3
Sverdrup sandy loam, 2 to 6 percent slopes	50	10	15	50	20	30	1,300	2.5	4	2
Towner fine sandy loam, 0 to 2 percent slopes	60	11	24	65	30	45	1,500	3.0	5	3
Ulen loamy fine sand, 0 to 2 percent slopes	55	11	18	55	30	40	1,300	2.5	4	2
Urness mucky silt loam	70	14	25	60	30	40		4.5	5	4
Vallers clay loam	80	16	30	70	35	45	1,300	4.0	6	3
Vallers clay loam, firm subsoil	60	13	24	58	30	35	1,200	3.5	5	2
Waukon loam, 4 to 12 percent slopes	60	12	21	75	35	50		4.0	6	3
Waukon loam, 12 to 24 percent slopes	50	10	16	50	30	35		3.0	5	3
Wheatville very fine sandy loam, 0 to 2 percent slopes	60	11	24	70	40	50	1,400	4.0	5	3

[1] AUM means animal-unit-months, the length of time that one animal unit (one cow, horse, or mule or five sheep or goats) can graze 1 acre without injuring the pasture.

TABLE 3.—*Height of trees and shrubs, by windbreak suitability group*

[Expected heights, in feet, are given for trees at age 20. Dashes indicate trees are generally not suited]

CONIFEROUS TREES

Windbreak suitability group	Eastern redcedar	Northern white-cedar	Jack pine	Red pine	Ponderosa pine	Eastern white pine	Blue spruce	White spruce and Black Hills spruce
1	19	20	28	28	28	28	22	22
2	17	13	----	----	20	----	18	----
3	10	15	----	----	----	25	20	20
4	15	10	----	----	----	----	----	----
5	15	----	20	20	20	20	----	----
6	15	----	15	10	15	10	----	----
7	----	----	----	----	----	----	----	----

DECIDUOUS TREES

Windbreak suitability group	Green ash	American elm	Siberian elm	Hackberry	Silver maple	Eastern cottonwood	White willow and laurel-leaved willow
1	35	36	45	34	47	60	32
2	32	32	35	25	----	60	25
3	30	32	40	25	45	60	35
4	28	30	40	----	----	60	35
5	----	----	25	18	----	35	----
6	----	----	----	18	----	----	----
7	----	----	----	----	----	----	----

SMALL TREES AND SHRUBS

Windbreak suitability group	Siberian peashrub	Buffaloberry	Siberian crabapple	Tatarian honeysuckle	Lilac	Ginnala maple	Russian-olive	American plum	Purple osier	Dogwood
1	10	15	20	12	12	25	30	16	17	15
2	10	15	18	12	10	----	25	15	13	12
3	10	----	18	12	10	15	24	10	14	15
4	8	----	----	10	----	----	25	15	25	15
5	8	12	12	10	10	----	15	7	7	----
6	7	12	12	10	6	----	10	----	----	----
7	----	----	----	----	----	----	----	----	----	----

by windbreak suitability group, for several tree and shrub species.

Trees and shrubs are planted extensively for windbreaks in Grant County.

Field windbreaks (fig. 12) are necessary to retard soil blowing, distribute and control snow, and reduce crop damage and moisture loss. They are not recommended on sloping areas that are subject to water erosion caused by snowmelt.

Farmstead windbreaks (fig. 13) are established to reduce soil erosion, block out severe winds, improve human comfort, protect livestock, control snow drifting, and provide food and cover for wildlife. They help to improve the esthetics of the farmstead, reduce dust and wind damage, and make outdoor activity more enjoyable.

The soils of Grant County have been placed in windbreak suitability groups for windbreak use. Each group consists of soils that have similar characteristics that affect tree and shrub growth. These groups are described in the following paragraphs.

WINDBREAK SUITABILITY GROUP 1

This group consists of deep, medium-textured to fine-textured, somewhat poorly drained to well-drained soils. Natural fertility is high, and content of organic matter is moderate to high. The soil is neutral to mildly alkaline in the surface layer and mildly alkaline to moderately alkaline in the underlying material. Available water capacity is moderate to very high, and permeability is moderate to very slow. The soils in this group are among the most productive in the county.

WINDBREAK SUITABILITY GROUP 2

This group consists of deep, medium-textured, moderately coarse textured, and coarse textured, somewhat poorly drained to somewhat excessively drained soils that have a high content of lime. Natural fertility is low to medium, and content of organic matter is moderate to high. The soil is moderately alkaline in the surface layer. Available water capacity is low to very high, and permeability is rapid to slow.

The soils in this group have a restricted root zone because of the high content of lime. This excess lime affects the growth of many tree and shrub species by interfering with the uptake of plant nutrients. The original vegetation was native grasses. Woody plant-

Figure 12.—**One-row field windbreak of dropmore elm on Roliss loam.**

ings can be made for windbreaks, wildlife, and watershed protection.

WINDBREAK SUITABILITY GROUP 3

This group consists of fine textured, moderately fine textured, and medium-textured, poorly drained to very poorly drained soils in nearly level to slightly depressional areas. Natural fertility is medium to high, and content of organic matter is high. The soil is neutral to mildly alkaline in the surface layer and mildly alkaline in the underlying material. Available water capacity is low to high, and permeability is rapid to slow.

The root zone in these soils is limited by depth to the water table. The seasonal water table is at a depth of 1 to 5 feet in these occasionally flooded soils. If undrained and unprotected from flooding, these soils are too wet to be suited to many tree and shrub species.

WINDBREAK SUITABILITY GROUP 4

This group consists of medium textured to moderately fine textured, very poorly drained to poorly drained, calcareous soils. These soils are in nearly level and slightly depressional areas, and some are on bottom lands along streams and drainageways. Natural fertility is medium. The soil is moderately alkaline. Available water capacity is moderate to very high, and permeability is moderately rapid to moderately slow.

The seasonal water table is mainly at a depth of 0 to 3 feet. Undrained areas are generally too wet to be suited to most tree species. Seedling mortality is moderate to severe. Drained areas provide more favorable conditions for trees. Excess lime, however, affects the growth and survival of many trees and shrubs.

WINDBREAK SUITABILITY GROUP 5

This group consists of moderately well drained to somewhat excessively drained soils. These soils are moderately droughty to droughty and are underlain by sand, gravel, or loamy material. Natural fertility is low to medium, and content of organic matter is moderate to high. The soil is neutral in the surface layer and becomes more alkaline with depth. Available water capacity is low to high, and permeability is moderately rapid to rapid.

The root zone is restricted to depth of gravelly coarse sand or sand in some soils and is unrestricted

Figure 13.—One-year-old farmstead windbreak of honeysuckle, dropmore elm, chokecherry, silver maple, green ash, flowering crabapple, and blue spruce. The soil is a Formdale clay loam.

in other soils. Droughtiness and damage caused by soil blowing are hazards to new plants.

WINDBREAK SUITABILITY GROUP 6

This group consists of droughty soils that have a substratum of gravelly coarse sand or sand within a depth of 6 to 20 inches. Natural fertility is medium to low, and content of organic matter is low to moderate. The soil is neutral to mildly alkaline in the surface layer and mildly alkaline in the substratum. Available water capacity is low to very low, and permeability is rapid.

Pocket gophers can be a concern in planted areas. The hazards of soil blowing and water erosion are severe.

WINDBREAK SUITABILITY GROUP 7

This group consists of medium-textured to fine-textured soils. These are mainly very poorly drained soils, but soils in a few small areas are better drained. Available water capacity is high to very high, and permeability is moderate to slow. The seasonal water table is high, and the root zone is limited by its depth. In some soils fertility is medium to high and content of organic matter is high to very high. Reaction is neutral in the surface layer of some soils and mildly alkaline or moderately alkaline in others.

Some soils are in depressions, potholes, and sloughs, and another is on bottom lands adjacent to major streams. If the soils are adequately drained, species suitable for planting are similar to those in groups 3 and 4. Undrained soils, soils unprotected from flooding, and soils covered with water for long periods are not generally suited to trees or shrubs.

Wildlife [3]

The condition of wildlife habitat in the county is related to soil, climate, and land use. Most of the soils of the lake plain are under intensive farm use. Nesting areas and woody cover are limited to odd areas, farmsteads, road ditches, and field windbreaks. Wildlife populations are considerably lower on the lake plain than in other parts of the county.

Soils of the outwash plains and beach ridges are characterized by level to rolling terrain and some marshes, small lakes, and streams throughout the area. Because of the coarse texture of the soils, habitat variety and extent are somewhat limited. Some waterfowl and furbearers live around the larger marshes. Deer populations are mainly associated with wooded

[3] Prepared with the assistance of ALLEN R. VAUGHN and JOHN W. BEDISH, biologists, Soil Conservation Service.

stream courses. Pheasants and other upland game species are somewhat limited as a result of less favorable habitat conditions.

Soils of the uplands support a variety of habitat conditions, including upland grass and legume areas and wet meadow and sedge areas. Oak woods are interspersed throughout the uplands and are adjacent to the many lakes in these areas. Approximately 92 percent of the land is in row crops, pasture, hay, and small grains. Nesting and winter cover are limited in the Hamerly-McIntosh association because of intensive farming. The upland areas generally support good wildlife habitat. Although habitat for pheasants is abundant, their populations vary from year to year because of severe winters. These upland areas are in the high-density pheasant range of Minnesota. White-tailed deer are common, mainly in wooded areas. Although these areas are not within good ruffed grouse range, a few ruffed grouse live in them.

Soils directly affect the kind and amount of vegetation that is available to wildlife as food and cover, and they affect the development of water impoundments. The kind and amount of wildlife that populate an area depend largely on the amount and distribution of food, cover, and water. If any one of these elements is missing, inadequate, or inaccessible, wildlife is either scarce or does not inhabit the area.

If the soils are potentially suited, wildlife habitat can be created or improved by planting appropriate vegetation, by properly managing existing plant cover, and by fostering natural establishment of desirable plants.

In table 4 the soil associations in the county are rated according to their potential to support the main kinds of wildlife habitat in the area.

The potential of the soil is rated good, fair, poor, or very poor. A rating of *good* means that the element of wildlife habitat or the kind of habitat is easily created, improved, or maintained. Few or no limitations affect management, and satisfactory results can be expected if the soil is used for the designated purpose. A rating of *fair* means that the element of wildlife habitat or kind of habitat can be created, improved, or maintained in most places. Moderate intensity of management and fairly frequent attention are required for satisfactory results. A rating of *poor* means that limitations are severe for the designated element of wildlife habitat or kind of habitat. Habitat can be created, improved, or maintained in most places, but management is difficult and requires intensive effort. A rating of *very poor* means that restrictions for the element of wildlife habitat or kind of habitat are very severe. Unsatisfactory results can be expected, and wildlife habitat is impractical or even impossible to create, improve, or maintain on soils that have such a rating.

The elements of wildlife habitat are briefly described in the following paragraphs.

Grain and seed crops are seed-producing annuals used by wildlife. Examples are corn, sorghum, wheat, oats, barley, millet, buckwheat, soybeans, and sunflowers. The main soil properties that affect the growth of grain and seed crops are depth of the root zone, texture of the surface layer, available water capacity, wetness, slope, surface stoniness, and the hazard of flooding. Temperature and moisture of the soil are also considerations.

Domestic grasses and legumes are domestic perennial grasses and herbaceous legumes that are planted for wildlife food and cover. Examples are fescue, bluegrass, reed canarygrass, switchgrass, bromegrass, timothy, orchardgrass, clover, alfalfa, trefoil, and crownvetch. The main soil properties that affect the growth of grasses and legumes are depth of the root zone, textures of the surface layer, available water capacity, wetness, surface stoniness, hazard of flooding, and slope. Temperature and moisture of the soil are also considerations.

Wild herbaceous plants are native or naturally established herbaceous grasses and forbs, including weeds, that provide food and cover for wildlife. Examples are bluestem, indiangrass, goldenrod, beggarweed, smartweed, barnyardgrass, wheatgrass, sweet-clover, and grama. The main soil properties that affect the growth of these plants are thickness of the soil, texture of the surface layer, available water capacity, wetness, surface stoniness, and hazard of flooding. Temperature and moisture of the soil are also considerations.

Hardwood plants (trees and the associated woody understory) provide cover for wildlife and produce nuts or other fruit, buds, catkins, twigs, bark, or foliage that wildlife eat. The plants generally regenerate naturally, but can be planted (fig. 14). Examples of native plants are oak, aspen, cherry, apple, hawthorn, dogwood, plum, sumac, hazelnut, blackberry, grape, viburnum, blueberry, birch, and maple. Examples of fruit-producing shrubs that are commercially available and suitable for planting on soils rated good are Russian-olive, autumn-olive, and crabapple. The main soil properties that affect growth of hardwood trees and shrubs are depth of the root zone, available water capacity, and wetness.

Coniferous plants are cone-bearing trees, shrubs, or ground cover that furnish habitat or supply food in the form of browse, seeds, or fruitlike cones. They are commonly established through natural processes but can be planted or transplanted. Examples are pine, spruce, fir, cedar, and juniper. The main soil properties that affect the growth of coniferous plants are depth of the root zone, available water capacity, and wetness.

Wetland plants are annual and perennial wild herbaceous plants that grow on moist or wet sites, exclusive of submerged or floating aquatics. They produce food or cover for wildlife that use wetland as habitat. Examples of wetland plants are smartweed, wild millet, rushes, sedges, reeds, wild rice, saltgrass, cordgrass, and cattail. The main soil properties that affect wetland plants are texture of the surface layer, wetness, reaction, salinity, slope, and surface stoniness.

Shallow water areas are bodies of surface water that have an average depth of less than 5 feet and that are useful to wildlife. They can be naturally wet areas, or they can be created by dams or levees or by waterfowl feeding areas, wildlife watering developments, beaver ponds, and other wildlife ponds. The main soil properties that affect shallow water areas are depth to bed-

TABLE 4.—*Potential of the soils for*

Soil association	Elements of wildlife habitat			
	Grain and seed crops	Domestic grasses and legumes	Wild herbaceous plants	Hardwood plants
Wheatville-Grimstad	Fair to good	Good	Fair to good	Fair
Roliss-Towner	Fair to good	Good	Fair to good	Fair
Arvilla-Sioux	Fair to very poor	Poor to good	Fair	Very poor to fair
Hamerly-McIntosh	Good	Good	Good	Fair
Formdale-Aazdahl	Fair to good	Good	Good	Good
Hamerly-Aazdahl-Flom	Good	Good	Good	Fair to good
Barnes-Svea	Fair to poor	Good to fair	Good	Good
Langhei-Barnes-Formdale	Poor to fair	Poor to good	Fair to good	Fair to good

rock, wetness, surface stoniness, slope, and permeability. The availability of a dependable water supply is important if water areas are to be developed.

The kinds of wildlife habitat are briefly described in the following paragraphs.

Open land habitat consists of cropland, pastures, meadows, and areas that are overgrown with grasses, herbs, shrubs, and vines. These areas produce grain and seed crops, grasses and legumes, and wild herbaceous plants. The kinds of wildlife attracted to these areas include pheasant, meadowlark, field sparrow, killdeer, cottontail rabbit, red fox, and woodchuck.

Woodland habitat consists of hardwoods or conifers or a mixture of both, and associated grasses, legumes, and wild herbaceous plants. Examples of wildlife attracted to this habitat are ruffed grouse, woodcock,

***Figure 14.*—These Russian-olive and hybrid elm trees were planted on an Aazdahl soil to provide food and cover for wildlife.**

wildlife habitat, by soil association

Elements of wildlife habitat—Continued			Kinds of wildlife		
Coniferous plants	Wetland plants	Shallow-water areas	Open land	Woodland	Wetland
Poor to fair	Poor to fair	Poor to fair	Fair to good	Fair	Poor to fair.
Fair	Fair to good	Poor to good	Good	Fair	Poor to good.
Fair to very poor	Very poor	Very poor	Poor to fair	Poor	Very poor.
Fair	Fair	Fair to poor	Good	Fair	Fair to poor.
Fair to good	Poor	Poor to fair	Good	Fair	Poor.
Fair to good	Poor to good	Poor to good	Good	Fair	Poor to good.
Fair to good	Poor to very poor	Poor to very poor	Good to fair	Fair	Poor to very poor.
Fair	Poor to very good	Very poor to fair	Poor to good	Fair	Very poor to poor.

thrushes, vireos, woodpeckers, tree squirrels, fox, raccoon, deer, and black bear.

Wetland habitat consists of water-tolerant plants in open, marshy, or swampy shallow areas. Examples of wildlife attracted to this habitat are ducks, geese, herons, shorebirds, rails, kingfishers, muskrats, mink, and beaver.

Pasture and Hayland

For pasture and hayland use, the soils of Grant County were placed in seven groups.

Table 5 shows predicted long-term average yields for forage crops grown in Grant County under an improved level of management. It provides guidelines to crop-yield potential of various soil groups. Yields are not given for forages that are not considered suitable for a particular group of soils. The yield figures represent an average expected over a period of 10 years. They do not take into account past management on a particular form.

The requirements of good management vary according to the soil group. Under an improved level of management, grasses and legumes suited to the soil are grown; fertilizer and manure are applied; surface and interval drainage provide the best growing conditions; grazing is rotated or seasonal; and weeds and brush are controlled.

An important consideration is the plant resource management essential for satisfactory production. Plant resource management includes fertilizing to meet the fertility requirements of the specific plants being grown, adaptation of plants to soils and climatic conditions, weed and brush control, and livestock management that properly utilizes the forage produced. Each of the soil groups may have special management requirements based on soils, climatic conditions, or plant resources to be utilized. For additional information, see the pasture and hayland groups in the following paragraphs and the information in table 5.

PASTURE AND HAYLAND GROUP 1

This group consists of somewhat poorly drained to somewhat excessively drained, moderately coarse textured to fine-textured, nearly level to hilly soils. These soils generally have medium to high natural fertility and moderate to very high available water capacity. Reaction ranges from neutral to moderately alkaline. Management needs include fertilization, control of grazing, and weed control.

PASTURE AND HAYLAND GROUP 2

This group consists of somewhat excessively drained, medium-textured to moderately fine textured, steep to very steep soils. These soils have low natural fertility, high available water capacity, and moderate content of organic matter. Reaction is moderately alkaline. The main management needs are controlling erosion, fertilization, control of grazing, and weed control.

PASTURE AND HAYLAND GROUP 3

This group consists of poorly drained to very poorly drained, moderately coarse textured to fine-textured, nearly level soils. These soils have medium to high natural fertility, low to high available water capacity, and high content of organic matter. These soils are subject to moderate to occasional flooding. The main management needs are pasture and hayland planting, fertilization, control of grazing, and weed control. The seasonal water table is at a depth of 1 to 6 feet and is a factor in management.

PASTURE AND HAYLAND GROUP 4

This group consists of poorly drained to very poorly drained, coarse textured and moderately coarse textured, nearly level soils that are underlain by coarse-textured or fine-textured material. These soils have medium natural fertility, moderate to high available water capacity, and high content of organic matter. The main management needs are proper pasture or hayland planting, fertilization, control of grazing, weed control, and drainage. The seasonal high water table is at a depth of 1 to 6 feet.

PASTURE AND HAYLAND GROUP 5

This group consists of poorly drained to very poorly drained, moderately textured to moderately fine textured, nearly level soils that are subject to flooding. These soils have medium natural fertility and high to very high available water capacity. The main management needs are proper pasture planting, fertilization, control of grazing, weed control, and delaying grazing until the soil becomes firm. The hazard of flooding and the seasonal high water table are significant factors in management of these soils.

TABLE 5.—*Predicted yields per acre of forage crops under improved management, by pasture and hayland groups*

[Absence of a figure indicates that crops are not suited to or are not commonly grown on soils in the pasture and hayland group. AUM means animal-unit-months, the length of time that one animal unit (one cow, horse, or mule, or five sheep or goats) can graze 1 acre without injuring the pasture]

COOL-SEASON GRASSES

Pasture and hayland group	Smooth bromegrass		Intermediate wheatgrass		Reed canarygrass		Orchardgrass [1]		Kentucky bluegrass		Timothy		Green needlegrass		Redtop		Garrison creeping foxtail	
	Tons	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*
1	3.5	5.2	3.5	5.2	3.5	5.2	3.5	5.2	2.0	3.0	2.5	3.7	2.5	3.7	---	---	---	---
2	2.0	3.0	2.5	3.7	---	---	2.0	3.0	1.5	2.2	---	---	2.0	3.0	---	---	---	---
3	3.5	5.2	3.5	5.2	4.0	6.0	3.5	5.2	2.5	3.7	3.5	5.2	2.5	3.7	2.5	3.7	3.5	5.2
4	3.0	4.5	---	---	4.0	6.0	---	---	2.5	3.7	3.0	4.5	---	---	2.0	3.0	---	---
5	---	---	---	---	4.0	6.0	---	---	2.5	3.7	---	---	---	---	---	---	3.5	5.2
6	2.5	3.7	---	---	3.0	4.5	2.5	3.7	2.0	2.5	2.8	4.0	---	---	2.0	2.5	2.8	4.0
7	2.5	3.7	2.5	3.7	---	---	---	---	1.0	1.5	---	---	---	---	---	---	---	4.0
8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

WARM-SEASON GRASSES AND LEGUMES

Pasture and hayland group	Warm-season grasses [2]										Legumes									
	Big bluestem		Indiangrass		Little bluestem		Switchgrass		Sideoats grama		Alfalfa		Birdsfoot trefoil		Red clover		Alsike		Ladino	
	Tons	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*	*Tons*	*AUM*
1	---	3.0	---	2.5	---	2.0	---	3.0	---	2.0	3.5	5.2	3.0	4.5	2.5	3.7	---	---	---	---
2	---	2.0	---	---	---	1.5	---	---	---	1.5	2.5	3.7	2.0	3.0	2.0	3.0	---	---	---	---
3	---	3.5	---	3.0	---	---	---	3.5	3.5	5.2	3.5	5.2	3.5	5.2	3.0	4.5	2.0	3.0	2.5	3.7
4	---	---	---	---	---	---	---	---	---	---	---	---	2.5	3.7	---	---	2.0	3.0	2.0	3.0
5	---	---	---	---	---	---	---	---	---	---	---	---	3.0	4.5	---	---	2.2	3.5	2.7	4.0
6	---	2.8	---	2.5	---	---	---	2.8	---	---	2.8	4.0	2.8	4.0	2.5	3.7	1.5	2.2	2.0	3.0
7	---	2.0	---	---	---	1.5	---	---	---	1.5	2.5	3.7	---	3.0	---	---	---	---	---	---
8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

[1] May not be winterhardy. Should only be used as part of a mixture.
[2] Warm-season grasses generally not harvested.

PASTURE AND HAYLAND GROUP 6

This group consists of very poorly drained, moderately fine textured to fine textured, depressional soils. These soils have moderate to very high available water capacity and generally high natural fertility. The seasonal high water table is at or near the surface. These soils are ponded for long periods unless they are drained. The main management needs are proper hayland or pasture planting, fertilization, weed control, drainage, and delaying grazing until the soil becomes firm.

PASTURE AND HAYLAND GROUP 7

This group consists of somewhat poorly drained to excessively drained, moderately coarse textured and coarse textured, nearly level to sloping or rolling soils underlain by coarse-textured material. These soils have low to medium natural fertility and low to very low available water capacity. These soils are droughty. The main management needs are proper pasture or hayland planting, fertilization, control of grazing, weed control, and conserving moisture.

PASTURE AND HAYLAND GROUP 8

This group consists of coarse-textured, steep to very steep soils and Marsh. The coarse-textured soils are droughty, and Marsh is too wet or flooded. These properties severely restrict forage production. For most areas, onsite investigation is needed.

Recreational Development

Knowledge of soils is necessary in planning, developing, and maintaining areas used for recreation. In table 6 the soils of Grant County are rated according to limitations that affect their suitability for camp areas, playgrounds, picnic areas, and paths and trails (fig. 15).

In table 6 the soils are rated as having slight, moderate, or severe limitations for the specified uses. For all of these ratings, it is assumed that a good cover of vegetation can be established and maintained. A limitation of *slight* means that soil properties generally are favorable and limitations are so minor that they can easily be overcome. A *moderate* limitation

Figure 15.—**Picnic area on Arvilla sandy loam, 2 to 6 percent slopes, near the outlet of Pomme de Terre Lake.**

can be overcome or modified by planning, design, or special maintenance. A *severe* limitation means that costly soil reclamation, special design, intense maintenance, or a combination of these, is required.

Camp areas are used intensively for tents and small camp trailers and the accompanying activities of outdoor living. Little preparation of the site is required other than shaping and leveling for tent and parking areas. Camp areas are subject to heavy foot traffic and limited vehicular traffic. The soils that are best suited to this use have gentle slopes, good drainage, a surface that is free of rocks and coarse fragments, freedom from flooding during periods of heavy use, and a surface that is firm after rain but not dusty when dry.

Picnic areas are attractive natural or landscaped tracts used primarily for preparing meals and eating outdoors. These areas are subject to heavy foot traffic. Most of the vehicular traffic, however, is confined to access roads. The soils that are best suited to this use are firm when wet but not dusty when dry, are free of flooding during periods of use, and do not have slopes or stoniness that greatly increases the cost of leveling sites or of building access roads.

Playgrounds are areas used intensively for baseball, football, badminton, and similar organized games. Soils suitable for this use need to withstand intensive foot traffic. The best soils have a nearly level surface that is free of coarse fragments and outcrops of rock, good drainage, freedom from flooding during periods of heavy use, and a surface that is firm after rain but not dusty when dry. If grading and leveling are required, depth to rock is important.

Paths and trails are used for local and cross-country travel by foot or horseback. Design and layout should require little or no cutting and filling. The soils that are best suited to this use are at least moderately well drained, are firm when wet but not dusty when dry,

TABLE 6.—*Limitations of the soils for recreational uses, by recreation group*

Recreation group	Camp areas	Picnic areas	Playgrounds	Paths and trails
1	Slight where slopes are 0 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Slight where slopes are 0 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Slight where slopes are 0 to 2 percent. Moderate where slopes are 2 to 6 percent. Severe where slopes are more than 6 percent.	Slight where slopes are 0 to 18 percent. Moderate where slopes are 18 to 25 percent. Severe where slopes are more than 25 percent.
2	Moderate: too clayey	Moderate: too clayey	Moderate where slopes are 0 to 6 percent: too clayey. Severe where slopes are more than 6 percent.	Moderate: too clayey.
[1] 3	Moderate where slopes are 0 to 12 percent: too sandy. Severe where slopes are more than 12 percent.	Moderate where slopes are 0 to 12 percent: too sandy. Severe where slopes are more than 12 percent.	Moderate where slopes are 0 to 6 percent: too sandy. Severe where slopes are more than 6 percent.	Moderate where slopes are 0 to 25 percent: too sandy. Severe where slopes are more than 25 percent.
4	Severe: wet	Severe: wet	Severe: wet	Severe: wet.

[1] The soils of the Sioux series have severe limitations for all uses because they are too sandy.

are flooded not more than once during periods of use, have slopes of less than 15 percent, and have few or no rocks or stones on the surface.

RECREATION GROUP 1

This group consists of excessively drained to somewhat poorly drained, moderately coarse textured and moderately fine textured soils. The water table is generally below a depth of 3 feet. Soils in this group are well suited to recreational uses and have no limitations except those caused by slope, which ranges from 0 to more than 25 percent.

RECREATION GROUP 2

This group consists of well drained and moderately well drained, fine-textured soils. The water table is generally below a depth of 3 feet. Texture and slope are the limiting soil characteristics. Slope ranges from 1 to 12 percent.

RECREATION GROUP 3

This group consists of excessively drained to somewhat poorly drained, coarse-textured soils. The water table is below a depth of 20 inches during periods of use and is generally below a depth of 60 inches. The sandy nature of these soils limits most recreational uses. Slope ranges from 0 to more than 25 percent.

RECREATION GROUP 4

This group consists of poorly drained and very poorly drained soils. The high water table is the most limiting soil characteristic. It is above a depth of 20 inches at some time during periods of use. Texture ranges from sandy loam to silty clay. Some soils are subject to a hazard of flooding. Slope ranges from 0 to 2 percent.

Engineering Uses of the Soils [4]

This section is useful to those who need information about soils used as structural material or as foundation material upon which structures are built. Among those who can benefit from this section are planning commissions, town and city managers, land developers, engineers, contractors, and farmers.

Among properties of soils very important in engineering are permeability, strength, compaction characteristics, soil drainage condition, shrink-swell potential, grain size, plasticity, and reaction. Also important are depth to the water table, depth to bedrock, and slope. These properties, in varying degrees and combinations, affect construction and maintenance of roads, airports, pipelines, foundations for small buildings, irrigation systems, ponds and small dams, and systems for disposal of sewage and refuse.

Information in this section of the soil survey can be helpful to those who—

1. Select potential residential, industrial, commercial, and recreational areas.
2. Evaluate alternate routes for roads, highways, pipelines, and underground cables.
3. Seek sources of gravel, sand, or clay.
4. Plan farm drainage systems, irrigation systems, ponds, terraces, and other structures for controlling water and conserving soil.
5. Correlate performance of structures already built with properties of the kinds of soil on which they are built, for the purpose of predicting performance of structures on the same or similar kinds of soil in other locations.

[4] ALVA E. BROYLES, engineer, Soil Conservation Service, assisted in the preparation of this section.

6. Predict the trafficability of soils for cross-country movement of vehicles and construction equipment.
7. Develop preliminary estimates pertinent to construction in a particular area.

Most of the information in this section is presented in tables 7, 8, and 9, which show, respectively, several estimated soil properties significant in engineering; interpretations for various engineering uses; and results of engineering laboratory tests on soil samples.

This information, along with the soil map and other parts of this publication, can be used to make interpretations in addition to those given in table 8, and it can also be used to make other useful maps.

This information, however, does not eliminate the need for further investigation at sites selected for engineering works, especially works that involve heavy loads or that require excavations to depths greater than those shown in the tables (generally, depths greater than 6 feet). Moreover, inspection of sites, especially the small ones, is needed because many delineated areas of a given mapping unit may contain small areas of other kinds of soil that have strongly contrasting properties and different suitabilities or limitations for soil engineering.

Some of the terms used in this soil survey have special meaning to soil scientists but are not known to all engineers. The Glossary defines many of these terms commonly used in soil science.

Engineering classification systems

The two systems most commonly used in classifying samples of soils for engineering are the Unified system (*2*) used by the SCS engineers, the Department of Defense, and others, and the AASHTO system adopted by the American Association of State Highway and Transportation Officials (*1*).

The Unified system is used to classify soils according to engineering uses for building material or for the support of structures other than highways. Soils are classified according to particle-size distribution, plasticity index, liquid limit, and organic-matter content. Soils are grouped into 15 classes. Eight classes of coarse-grained soils are subdivided on the basis of gravel and sand content. These are identified as GW, GP, GM, GC, SW, SP, SM, and SC. Six classes of fine-grained soils are subdivided on the basis of the plasticity index. Nonplastic classes are ML, MH, OL, and OH; plastic classes are CL and CH. One class of highly organic soils is identified as Pt. Soils on the borderline between two classes are designated by symbols for both classes; for example, CL–ML.

The AASHTO system is used to classify soils according to the properties that affect their use in highway construction and maintenance. In this system, a soil is placed in one of seven basic groups ranging from A–1 through A–7 on the basis of grain-size distribution, liquid limit, and plasticity index. In group A–1 are gravelly soils that have high bearing strength, or the best soils for subgrade (foundation). At the other extreme, in group A–7, are clay soils that have low strength when wet and that are the poorest soils for subgrade. Where laboratory data are available to justify a further breakdown, the A–1, A–2, and A–7 groups are divided as follows: A–1–a, A–1–b, A–2–4, A–2–5, A–2–6, A–2–7, A–7–5, and A–7–6.

USDA texture is determined by the relative proportions of sand, silt, and clay in soil material that is less than 2 millimeters in diameter. "Sand," "silt," "clay," and some of the other terms used in the USDA textural classification are defined in the Glossary. Stones, cobbles, and gravel are used as textural modifiers where they are present in the soil.

Estimated soil properties significant in engineering

Several estimated soil properties significant in engineering are given in table 7. These estimates are made for typical profiles, by layers that are sufficiently different to have different significance for soil engineering. The estimates are based on field observations made in the course of mapping, on test data for these and similar soils, and on experience with the same kinds of soil in other counties. Following are explanations of some of the columns in table 7.

Depth to seasonal high water table is the distance from the surface of the soil to the highest level that ground water reaches in the soil in most years.

USDA texture is described in the standard terms used by the Department of Agriculture. These terms take into account relative percentages of sand, silt, and clay in soil material that is less than 2 millimeters in diameter. "Loam," for example, is soil material that contains 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If the soil contains gravel or other particles coarser than sand, an appropriate modifier is added, for example, "gravelly loamy sand." "Sand," "silt," "clay," and some of the other terms used in USDA textural classification are defined in the Glossary of this soil survey.

Liquid limit and *plasticity index* indicate the effect of water on the strength and consistence of soil material. As the moisture content of a clayey soil increases from a dry state, the material changes from a semisolid to a plastic state. If the moisture content further increases, the material changes from a plastic to a liquid state. The *plastic* limit is the moisture content at which the soil material changes from a semisolid to a plastic state; and the *liquid limit*, from a plastic to a liquid state. The *plasticity index* is the numerical difference between the liquid limit and the plastic limit. It indicates the range of moisture content within which a soil material is plastic. Liquid limit and plasticity index are estimated in table 7, but in table 9 the data on liquid limit and plasticity index are based on tests of soil samples.

Permeability is that quality of a soil that enables it to transmit water or air. It is estimated on the basis of those soil characteristics observed in the field, particularly structure and texture. The estimates in table 7 do not take into account lateral seepage or such transient soil features as plowpans and surface crusts.

Available water capacity is the ability of soils to hold water for use by most plants. It is commonly defined as the difference between the amount of water in the soil at field capacity and the amount of water at the wilting point of most crops.

Reaction is the degree of acidity or alkalinity of a

TABLE 7.—*Estimated soil*

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

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	USDA texture	Classification		Coarse fraction greater than 3 inches
				Unified	AASHTO	
	Feet	*Inches*				*Percent*
*Aazdahl: 26, 900	3–5	0–14	Clay loam	OL	A–6, A–7	0
		14–60	Clay loam	CL–ML, CL	A–6, A–7	0
For Hamerly and Parnell parts of 900, see those series.						
Alluvial land, frequently flooded: 1002.						
Too variable to rate.						
Arveson: 61	1–3	0–21	Fine sandy loam	SM	A–4	0
		21–60	Fine sand	SM	A–2 or A–3	0
Arvilla: 341, 341B	>6	0–12	Sandy loam	SM	A–2, A–4	0
		12–20	Gravelly loamy coarse sand	SM	A–2	0
		20–60	Gravelly coarse sand	GP, SP, SM	A–1	0
*Barnes: 33B, 903B, 907B	>6	0–8	Loam	OL	A–6	0
		8–60	Loam	CL	A–6	0
For Langhei part of 903B and Svea part of 907B, see those series.						
Bearden: 67	3–5	0–14	Silt loam	CL	A–6	0
		14–60	Silt loam	CL	A–6	0
Darnen: 494B	>6	0–28	Loam	OL	A–4	0
		28–60	Clay loam	CL	A–6, A–7	0
Fargo: 57	3–5	0–18	Silty clay	CH	A–7	0
		18–60	Silty clay	CH	A–7	0
Flom: 36	1–3	0–17	Silty clay loam	OL	A–7	0
		17–21	Clay loam	CL	A–7	0
		21–60	Loam	CL	A–6, A–7	0
Forada: 375	1–3	0–8	Sandy loam	SM	A–4	0
		8–26	Sandy clay loam	SC	A–6	0
		26–60	Gravelly coarse sand	SP, GP	A–1	0
Fordville: 339	>6	0–12	Loam	OL	A–4	0
		12–20	Loam	ML	A–4	0
		20–30	Gravelly loam	ML	A–4	0
		30–60	Gravelly coarse sand	SP, GP, SM	A–1	0
*Formdale: 171B, 912B, 931B	>6	0–9	Clay loam	OL	A–6, A–7	0
		9–60	Clay loam	CL	A–6, A–7	0
For Aazdahl and Flom parts of 912B and Langhei part of 931B, see those series.						
Glyndon: 60	2.5–6	0–10	Silt loam	OL	A–4	0
		10–23	Silt loam	ML	A–4	0
		23–60	Very fine sand	SM, ML	A–4	0
*Grimstad: 914	3–5	0–15	Very fine sandy loam	ML	A–4	0
		15–26	Loamy fine sand	SM	A–2	0
For Towner part, see Towner series.		26–60	Clay loam	CL	A–6	0
*Hamerly: 184, 922	3–5	0–8	Clay loam	OL	A–6	0–3
		8–60	Clay loam	CL	A–6, A–7	0–3
For Parnell part of 922, see Parnell series.						
Hecla: 366	3–5	0–15	Loamy fine sand	SM	A–2	0
		15–60	Fine sand	SM, SP–SM	A–2, A–3	0
Kittson: 58	2.5–5	0–17	Very fine sandy loam	OL, CL–ML, ML	A–4	0
		17–60	Clay loam	CL	A–6, A–7	0

properties significant in engineering

soils in such mapping units may have different properties and limitations, and for this reason it is necessary to follow carefully the indicates that no estimate was made. The symbol > means greater than; the symbol < means less than]

Percentage less than 3 inches passing sieve—				Liquid limit	Plasticity index	Permeability	Available water capacity	Reaction	Shrink-swell potential	Corrosivity to—	
No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 40 (0.42 mm)	No. 200 (0.074 mm)							Uncoated steel	Concrete
				Percent		*Inches per hour*	*Inches per inch of soil*	*pH*			
95–100	95–100	85–100	70–85	35–50	11–23	0.2–0.6	0.17–0.19	6.6–7.3	Moderate	Moderate	Low.
95–100	90–100	85–100	70–85	30–50	11–30	0.2–0.6	0.14–0.19	6.6–8.4	Moderate	Moderate	Low.
100	95–100	70–85	36–50	10–23	[1] NP–4	2.0–6.0	0.16–0.18	7.9–8.4	Low	High	Low.
100	95–100	70–80	5–35		NP	2.0–6.0	0.07–0.09	7.4–7.8	Low	High	Low.
95–100	95–100	60–70	30–45	10–20	NP–4	2.0–6.0	0.13–0.15	6.6–7.3	Low	Low	Low.
75–95	60–75	50–65	20–35		NP	6.0–20.0	0.05–0.08	7.4–7.8	Low	Low	Low.
35–70	30–60	15–35	2–25		NP	6.0–20.0	0.02–0.04	7.4–7.8	Low	Low	Low.
95–100	95–100	85–95	60–75	20–40	5–20	0.6–2.0	0.20–0.22	6.6–7.3	Low	Low	Low.
95–100	90–100	85–95	60–75	25–40	11–25	0.2–2.0	0.17–0.19	6.6–8.4	Moderate	Low	Low.
100	100	90–100	75–95	20–40	11–30	0.6–2.0	0.22–0.24	7.9–8.4	Moderate	High	Low.
100	100	90–100	75–95	20–40	11–30	0.2–2.0	0.20–0.22	7.9–8.4	Moderate	High	Low.
100	100	85–95	60–85	20–40	3–10	0.6–2.0	0.20–0.22	6.6–7.3	Low	High	Low.
95–100	95–100	80–95	70–80	30–50	11–25	0.6–2.0	0.14–0.19	6.6–7.8	Moderate	High	Low.
100	100	95–100	90–95	50–75	25–45	0.06–0.2	0.18–0.22	6.6–7.8	High	High	Low.
100	100	95–100	90–95	50–75	25–45	0.06–0.2	0.11–0.16	7.9–8.4	High	High	Low.
98–100	95–100	95–100	80–90	41–50	11–23	0.2–0.6	0.18–0.22	6.6–7.3	Moderate	High	Low.
98–100	95–100	90–100	70–80	41–50	15–30	0.2–0.6	0.15–0.19	6.6–7.3	Moderate	High	Low.
98–100	95–100	85–95	65–80	30–50	11–30	0.2–0.6	0.17–0.19	7.4–8.4	Moderate	High	Low.
90–100	90–100	60–80	36–50	15–30	NP–4	2.0–6.0	0.13–0.15	7.4–7.8	Low	High	Low.
90–100	90–100	75–85	36–50	20–40	11–20	0.6–2.0	0.16–0.20	7.4–7.8	Low	High	Low.
30–60	25–50	10–30	2–5		NP	6.0–20.0	0.02–0.04	7.4–7.8	Low	High	Low.
100	100	85–95	60–85	20–40	3–10	0.6–2.0	0.20–0.22	6.6–7.3	Moderate	Low	Low.
95–100	95–100	80–90	60–80	20–40	3–10	0.6–2.0	0.17–0.19	6.6–7.3	Moderate	Low	Low.
70–85	65–80	55–75	50–60	20–35	1–10	0.6–2.0	0.12–0.14	7.9–8.4	Low	Low	Low.
35–70	20–50	10–30	2–25		NP	6.0–20.0	0.02–0.04	7.9–8.4	Low	Low	Low.
95–100	95–100	85–100	70–85	35–50	10–23	0.2–0.6	0.17–0.19	6.6–7.3	Moderate	Moderate	Low.
95–100	95–100	85–100	70–85	30–50	11–30	0.2–0.6	0.14–0.16	6.6–8.4	Moderate	Moderate	Low.
100	100	90–100	70–90	25–40	2–10	0.6–2.0	0.22–0.24	7.9–8.4	Low	High	Low.
100	100	90–100	70–90	20–40	2–10	0.6–2.0	0.20–0.22	7.9–8.4	Low	High	Low.
100	100	75–90	35–60	10–30	0–10	2.0–6.0	0.15–0.17	7.9–8.4	Low	High	Low.
100	100	85–95	50–65	20–35	2–10	2.0–6.0	0.17–0.19	7.9–8.4	Low	High	Low.
100	95–100	70–80	15–35	0–10	0–4	2.0–6.0	0.09–0.11	7.4–8.4	Low	High	Low.
95–100	95–100	85–90	55–80	30–40	11–25	0.6–2.0	0.14–0.16	7.4–8.4	Moderate	High	Low.
95–100	90–100	85–95	65–80	20–40	11–20	0.2–2.0	0.17–0.19	7.9–8.4	Moderate	High	Low.
95–100	90–100	85–95	65–80	25–45	15–25	0.2–0.6	0.14–0.16	7.4–8.4	Moderate	High	Low.
100	100	75–90	12–25		NP	6.0–20.0	0.11–0.15	6.6–7.3	Low	High	Low.
100	100	70–80	5–20		NP	6.0–20.0	0.05–0.08	6.6–7.8	Low	High	Low.
100	100	85–96	50–65	15–30	2–10	2.0–6.0	0.15–0.19	6.6–7.8	Low	High	Low.
95–100	94–100	85–95	70–80	30–50	15–30	0.2–0.6	0.14–0.16	7.4–7.8	Moderate	High	Low.

TABLE 7.—*Estimated soil*

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	USDA texture	Classification		Coarse fraction greater than 3 inches
				Unified	AASHTO	
	Feet	*Inches*				*Percent*
Kittson variant: V58	1–3	0–21	Fine sandy loam	SM	A–4	0
		21–60	Clay loam	CL	A–6	0
Lake beaches: 1032. Too variable to rate.						
Lamoure: 418, 359	1–5	0–19	Silt loam	OL	A–4	0
		19–43	Silty clay loam	CL	A–7	0
		43–60	Sandy loam	SM	A–2 or A–4	0
*Langhei: 220E, 942C2, 942D2, 943C2, 943D2. For Barnes parts of 942C2 and 942D2 and Formdale parts of 943C2 and 943D2, see those series.	>6	0–5	Loam	CL	A–6	0
		5–60	Loam	CL	A–6	0
Maddock: 45B, 45C	>6	0–12	Loamy sand	SM	A–2	0
		12–60	Fine sand	SM, SP–SM	A–2, A–3	0
Marsh: 1053. No classification possible. Onsite inspection needed.						
McIntosh: 108	3–5	0–9	Silt loam	OL	A–4	0
		9–27	Silt loam	ML	A–4	0
		27–60	Clay loam	CL	A–6, A–7	0
Oldham: 276	0–4	0–39	Silty clay loam	OL	A–7	0
		39–60	Silty clay loam	CL	A–7	0
Parnell: 34	0–2	0–19	Silty clay loam	OH	A–7	0
		19–41	Silty clay	CH	A–7	0
		41–60	Silty clay loam	CL	A–7	0
Quam: 344	0–2	0–17	Silty clay loam	OL	A–7	0
		17–60	Silty clay loam	CL	A–7	0
*Rockwell: 63, 970 For Vallers part of 970, see Vallers series.	0–3	0–13	Loam	OL	A–4	0
		13–24	Sandy loam	SM	A–4	0
		24–35	Fine sand	SM	A–2	0
		35–60	Clay loam	CL	A–6	0
*Roliss: 582, 971, 972 For Vallers part of 972, see Vallers series.	1–3	0–11	Loam	OL	A–6	0
		11–16	Loam	CL	A–6	0
		16–60	Clay loam	CL	A–7	0
Rothsay: 290B	>6	0–15	Silt loam	ML	A–4	0
		15–60	Silt loam	ML	A–4	0
Sioux: 212B, 212C	>6	0–16	Silty clay	OH, MH	A–7	0
		16–60	Silty clay	MH	A–7	0
Sioux: 402B, 402C, 402D	>6	0–9	Loamy coarse sand	SM	A–2	0
		9–60	Gravelly coarse sand	SP–SM, GM, SM	A–1	0
*Svea: 70, 962 For Hamerly part of 962, see Hamerly series.	3–6	0–15	Loam	OL	A–6	0
		15–60	Loam	CL	A–6	0
Sverdrup: 127B	>6	0–15	Sandy loam	SM	A–4	0
		15–24	Loamy sand	SM	A–2	0
		24–60	Sand	SM–SP, SP	A–3	0
Towner: 330	3–5	0–9	Fine sandy loam	SM	A–4	0
		9–26	Loamy fine sand	SM	A–2	0

properties significant in engineering—Continued

Percentage less than 3 inches passing sieve—				Liquid limit	Plasticity index	Permeability	Available water capacity	Reaction	Shrink-swell potential	Corrosivity to—	
No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 40 0.42 mm)	No. 200 (0.074 mm)							Uncoated steel	Concrete
				Percent		*Inches per hour*	*Inches per inch of soil*	*pH*			
100	100	70–80	36–50	15–25	1–4	2.0–6.0	0.15–0.18	7.4–7.8	Low	High	Low.
95–100	95–100	90–100	65–80	20–40	11–25	0.2–0.6	0.14–0.16	7.4–7.8	Moderate	High	Low.
100	100	90–100	75–95	25–40	3–10	0.6–2.0	0.20–0.22	7.9–8.4	Moderate	High	Low.
100	100	90–100	70–80	41–50	15–35	0.6–2.0	0.16–0.22	7.9–8.4	Moderate	High	Low.
100	95–100	60–70	30–40	10–25	2–4	2.0–6.0	0.11–0.13	7.4–7.8	Low	High	Low.
95–100	90–100	80–90	60–75	20–40	11–20	0.6–2.0	0.20–0.22	7.9–8.4	Moderate	Low	Low.
95–100	90–100	80–90	60–75	30–40	11–25	0.6–2.0	0.17–0.19	7.4–8.4	Moderate	Low	Low.
100	100	65–95	15–35	-------	NP	6.0–20.0	0.10–0.12	6.6–7.3	Low	Moderate	Low.
100	95–100	70–100	5–35	-------	NP	6.0–20.0	0.05–0.08	6.6–8.4	Low	Moderate	Low.
100	100	90–100	70–90	20–40	5–10	0.6–2.0	0.22–0.24	7.9–8.4	Low	High	Low.
100	100	90–100	70–90	20–40	2–10	0.6–2.0	0.20–0.22	7.4–8.4	Low	High	Low.
95–100	95–100	85–95	70–80	30–50	15–30	0.2–0.6	0.14–0.16	7.4–7.8	Moderate	High	Low.
100	100	95–100	85–95	41–50	15–23	0.06–0.2	0.18–0.22	7.4–8.4	High	High	Low.
100	95–100	90–100	80–90	41–50	15–35	0.06–0.2	0.16–0.19	7.9–8.4	High	High	Low.
100	100	95–100	85–95	50–70	15–35	0.2–0.6	0.18–0.22	6.6–7.3	High	High	Low.
100	100	95–100	90–95	50–80	30–50	0.06–0.2	0.13–0.16	6.6–7.8	High	High	Low.
95–100	95–100	85–95	80–90	41–50	15–35	0.06–0.2	0.16–0.19	7.4–7.8	High	High	Low.
100	100	95–100	85–95	41–50	11–20	0.2–0.6	0.18–0.22	6.6–7.3	High	High	Low.
100	95–100	90–100	80–90	41–50	11–20	0.2–0.6	0.16–0.22	6.6–7.8	High	High	Low.
100	100	85–95	60–75	20–40	1–10	0.6–2.0	0.20–0.22	7.9–8.4	Low	High	Low.
100	100	60–70	36–50	15–30	NP–4	2.0–6.0	0.13–0.15	7.9–8.4	Low	High	Low.
100	100	70–80	15–30	-------	NP	6.0–20.0	0.05–0.08	7.4–8.4	Low	High	Low.
95–100	95–100	85–100	65–90	20–40	11–20	0.2–0.6	0.14–0.16	7.4–7.8	Moderate	High	Low.
95–100	95–100	80–95	60–75	20–40	11–20	0.6–2.0	0.20–0.22	7.4–7.8	Moderate	High	Low.
95–100	95–100	80–90	65–80	20–40	11–25	0.6–2.0	0.17–0.19	7.4–7.8	Moderate	High	Low.
95–100	95–100	80–90	70–85	41–50	15–30	0.2–0.6	0.14–0.16	7.4–7.8	Moderate	High	Low.
100	100	90–100	70–90	20–40	4–10	0.6–2.0	0.22–0.24	6.6–7.3	Low	Low	Low.
100	100	90–100	70–90	20–40	3–10	0.6–2.0	0.20–0.22	6.6–7.8	Low	Low	Low.
100	100	95–100	90–95	50–70	20–35	<0.06–0.2	0.14–0.17	7.4–7.8	High	High	Low.
100	100	95–100	90–95	50–70	15–35	<0.06–0.2	0.11–0.16	6.6–7.8	High	High	Low.
80–90	60–80	30–40	15–30	-------	NP	6.0–20.0	0.6–0.10	7.4–7.8	Low	Low	Low.
35–70	20–50	10–30	5–25	-------	NP	6.0–20.0	0.02–0.04	7.9–8.4	Low	Low	Low.
95–100	95–100	85–95	60–75	20–40	11–20	0.6–2.0	0.20–0.22	6.6–7.3	Low	High	Low.
95–100	95–100	85–95	60–80	20–40	11–25	0.2–0.6	0.17–0.19	6.6–8.4	Moderate	High	Low.
100	100	60–70	35–50	10–20	NP–4	2.0–6.0	0.12–0.15	6.6–7.3	Low	Low	Low.
100	95–100	50–75	15–30	-------	NP	6.0–20.0	0.09–0.11	6.6–7.3	Low	Low	Low.
100	95–100	50–60	2–10	-------	NP	6.0–20.0	0.05–0.07	7.4–7.8	Low	Low	Low.
100	100	60–85	36–45	-------	NP	2.0–6.0	0.16–0.18	6.6–7.3	Low	High	Low.
100	100	50–80	20–35	-------	NP	6.0–20.0	0.10–0.12	6.6–7.8	Low	High	Low.

TABLE 7.—*Estimated soil*

Soil series and map symbols	Depth to seasonal high water table	Depth from surface	USDA texture	Classification		Coarse fraction greater than 3 inches
				Unified	AASHTO	
	Feet	*Inches*				*Percent*
		26–44	Loam	ML	A–4	0–2
		44–60	Clay loam	CL	A–6, A–7	0–2
Ulen: 64	2–4	0–16	Loamy fine sand	SM	A–4	0
		16–60	Fine sand	SM, SP–SM	A–2, A–3	0
Urness: 335	0–3	0–28	Mucky silt loam	OL	A–4	0
		28–60	Silty clay loam	CL	A–7	0
Vallers: 236, 419	1–3	0–8	Clay loam	OL	A–6, A–7	0
		8–25	Clay loam	CL	A–6	0
		25–60	Loam	CL	A–6	0
Waukon: 38C, 38D	>6	0–9	Loam	CL–ML, OL, CL	A–6	0
		9–27	Clay loam	CL	A–6, A–7	0
		27–60	Loam	CL	A–6	0
Wheatville: 343	2.5–5	0–13	Very fine sandy loam	OL, ML	A–4	0
		13–20	Very fine sandy loam	ML	A–4	0
		20–29	Loamy very fine sand	ML	A–4	0
		29–60	Silty clay	CH	A–7	0

[1] NP=nonplastic.

TABLE 8.—*Interpretations of*

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

Soil series and map symbols	Degree and kind of limitation for—						Suitability as source of—
	Septic tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings with basements	Sanitary landfill	Local roads and streets	Road fill
*Aazdahl: 26, 900. For Hamerly and Parnell parts of 900, see those series.	Severe: moderately slow permeability.	Moderate: seasonal high water table.	Moderate: moderately well drained; clay loam.	Moderate: moderate shrink-swell potential; moderately well drained.	Severe: seasonal high water table.	Severe: high frost-action potential.	Poor: high frost-action potential.
Alluvial land, frequently flooded: 1002.	Severe: hazard of flooding; seasonal high water table.	Severe: hazard of flooding; seasonal high water table.	Severe: hazard of flooding; seasonal high water table.	Severe: hazard of flooding; seasonal high water table.	Severe: subject to frequent flooding; seasonal high water table.	Severe: hazard of flooding.	Poor: poorly drained; variable material.
Arveson: 61	Severe: seasonal high water table; hazard of pollution.	Severe: moderately rapid permeability; high water table.	Severe: very poorly drained to poorly drained; high water table.	Severe: very poorly drained to poorly drained; high water table.	Severe: very poorly drained to poorly drained; moderately rapid permeability.	Severe: very poorly drained to poorly drained; high frost-action potential.	Poor: very poorly drained to poorly drained; high frost-action potential.

properties significant in engineering—Continued

Percentage less than 3 inches passing sieve—				Liquid limit	Plasticity index	Permeability	Available water capacity	Reaction	Shrink-swell potential	Corrosivity to—	
No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 40 0.42 mm)	No. 200 (0.074 mm)							Uncoated steel	Concrete
				Percent		*Inches per hour*	*Inches per inch of soil*	*pH*			
92–100	95–100	80–95	60–75	20–40	2–10	0.6–2.0	0.17–0.19	7.9–8.4	Low	High	Low.
92–100	95–100	85–95	65–80	30–50	11–30	0.2–0.6	0.14–0.16	7.9–8.4	Moderate	High	Low.
100	100	80–95	36–50	0–10	0–4	6.0–20.0	0.10–0.12	7.4–8.4	Low	Low	Low.
100	95–100	70–80	5–35		NP	6.0–20.0	0.05–0.08	7.4–8.4	Low	Low	Low.
100	100	90–100	70–90	20–40	5–10	0.6–2.0	0.22–0.24	7.4–8.4	Moderate	High	Low.
95–100	95–100	85–100	80–90	41–50	15–30	0.2–0.6	0.16–0.19	7.4–7.8	Moderate	High	Low.
95–100	95–100	95–100	65–80	30–50	11–20	0.2–0.6	0.17–0.19	7.9–8.4	Moderate	High	Low.
95–100	90–100	90–100	65–80	20–40	11–20	0.2–0.6	0.14–0.19	7.9–8.4	Moderate	High	Low.
95–100	90–100	85–100	60–80	20–40	11–20	0.2–0.6	0.17–0.19	7.4–7.8	Low	High	Low.
95–100	90–100	85–95	60–75	20–40	11–20	0.6–2.0	0.20–0.22	6.6–7.3	Moderate	Low	Low.
95–100	90–100	85–95	60–80	30–50	15–30	0.6–2.0	0.15–0.19	6.6–7.3	Moderate	Low	Low.
95–100	90–100	85–95	50–75	20–40	11–20	0.6–2.0	0.17–0.19	7.4–7.8	Moderate	Low	Low.
100	100	85–95	50–65	20–40	4–10	2.0–6.0	0.17–0.22	7.9–8.4	Low	High	Low.
100	100	85–95	50–65	15–35	4–10	2.0–6.0	0.15–0.19	7.9–8.4	Low	High	Low.
100	100	90–95	50–70	15–30	4–10	2.0–6.0	0.12–0.14	7.9–8.4	Low	High	Low.
100	100	95–100	90–95	50–70	23–40	0.06–0.2	0.11–0.15	7.4–7.8	High	High	Low.

engineering properties of the soils

The soils in such mapping units may have different properties and limitations, and for this reason it is necessary to follow series that appear in the first column of this table]

Suitability as source of—Cont.		Soil features affecting—					
Sand and gravel	Topsoil	Pond reservoir areas	Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways
Not suitable	Fair: clay loam surface layer.	Favorable: seasonal high water table at a depth of 3 to 5 feet.	Fair compaction characteristics; medium compressibility; medium to low shear strength.	Not needed	Moderately slow permeability; moderately well drained; high available water capacity.	Not needed: nearly level.	Favorable for establishment.
Variable material; each site needs checking.	Poor: poorly drained.	Seasonal high water table; variable material.	Variable material; each site needs checking.	Subject to frequent flooding; outlets difficult to obtain; high water table.	Subject to frequent flooding; seasonal high water table.	Not needed: nearly level.	Not needed: nearly level.
Fair for sand: fine sand. Unsuitable for gravel.	Poor: very poorly drained to poorly drained.	Water table at a depth of 1 to 3 feet; moderately rapid permeability.	Underlying material has high permeability when compacted; medium to high susceptibility to piping.	High water table.	Very poorly drained to poorly drained; moderate available water capacity.	Not needed: nearly level.	Not needed: nearly level.

TABLE 8.—*Interpretations of*

Soil series and map symbols	Degree and kind of limitation for—						Suitability as source of—
	Septic tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings with basements	Sanitary landfill	Local roads and streets	Road fill
Arvilla: 341, 341B.	Slight: hazard of pollution.	Severe: rapid permeability in underlying material; poor reservoir material.	Severe: gravelly coarse sand substratum; poor stability.	Slight	Severe: rapid permeability in underlying material.	Slight	Good
*Barnes: 33B, 903B, 907B. For Langhei part of 903B and Svea part of 907B, see those series.	Moderate where slopes are 2 to 12 percent: moderate permeability. Severe where slopes are more than 12 percent.	Moderate where slopes are less than 6 percent: moderate permeability. Severe where slopes are more than 6 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Moderate where slopes are less than 12 percent: moderate shrink-swell potential. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 12 percent. Moderate where slopes are 12 to 18 percent.	Moderate where slopes are 2 to 12 percent. Severe where slopes are 12 to 18 percent.	Fair: low strength, frost-action potential.
Bearden: 67	Moderate: seasonal high water table.	Moderate: moderate to moderately slow permeability; seasonal high water table.	Severe: somewhat poorly drained.	Severe: somewhat poorly drained.	Moderate: seasonal high water table.	Severe: high frost-action potential.	Poor: high frost-action potential.
Darnen: 494B	Slight	Moderate where slopes are 2 to 6 percent: moderate permeability; hazard of seepage.	Slight	Moderate: moderate shrink-swell potential.	Slight: soil found only in small areas.	Severe: too clayey.	Severe: too clayey.
Fargo: 57	Severe: slow permeability; subject to frequent flooding.	Slight	Severe: poorly drained; silty clay.	Severe: poorly drained; high shrink-swell potential; seasonal high water table.	Severe: seasonal high water table; silty clay.	Severe: high shrink-swell potential; high frost-action potential.	Poor: high shrink-swell potential; high frost-action potential; poorly drained.
Flom: 36	Severe: seasonal high water table; moderately slow permeability.	Severe: seasonal high water table.	Severe: poorly drained; seasonal high water table.	Severe: poorly drained; seasonal high water table.	Severe: poorly drained; seasonal high water table.	Severe: poorly drained; high frost-action potential.	Poor: poorly drained; high frost-action potential.
Forada: 375	Severe: seasonal high water table; hazard of pollution.	Severe: high water table; hazard of pollution.	Severe: very poorly drained and poorly drained; poor stability.	Severe: very poorly drained and poorly drained; seasonal high water table.	Severe: rapid permeability in underlying material; very poorly drained and poorly drained.	Severe: very poorly drained and poorly drained.	Poor: very poorly drained and poorly drained; high frost-action potential.

engineering properties of the soils—Continued

Suitability as source of—Cont.		Soil features affecting—					
Sand and gravel	Topsoil	Pond reservoir areas	Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways
Good: needs screening. (Sand and gravel are mixed.)	Fair: surface layer less than 16 inches thick.	Rapid permeability in underlying material.	Underlying material has high permeability when compacted; susceptibility to piping.	Not needed: somewhat excessively drained.	Low available water capacity; shallow root zone; rapid intake rate.	Shallow; gravelly coarse sand below a depth of 1 to 2 feet; erodes easily.	Shallow; gravelly coarse sand below a depth of 1 to 2 feet; difficult to vegetate.
Not suitable	Fair: surface layer 8 to 16 inches thick.	Moderate permeability; slope.	Medium to low shear strength; medium compressibility.	Not needed: well drained.	Features favorable; slope.	Features favorable; slope.	Features favorable; slope.
Not suitable	Fair: surface layer less than 16 inches thick.	Moderate to moderately slow permeability; hazard of seepage.	Medium to low shear strength.	Outlets difficult to obtain.	Somewhat poorly drained; moderately alkaline.	Not needed: nearly level.	Not needed: nearly level.
Not suitable	Good	Moderate permeability; hazard of seepage.	Medium to low shear strength; medium compressibility.	Not needed: moderately well drained to well drained.	Features favorable.	Features favorable.	Features favorable.
Not suitable	Poor: silty clay; poorly drained.	Favorable: extensive diking needed.	High compressibility; fair to poor compaction characteristics; low shear strength.	Slow permeability; high water table.	Slow permeability; poorly drained.	Not needed: nearly level.	Not needed: nearly level.
Not suitable	Poor: poorly drained.	Favorable	Medium to low shear strength; medium compressibility.	Moderately slow permeability; high water table.	Poorly drained	Not needed: nearly level.	Not needed: nearly level.
Good: sand and gravel are mixed; hazard of wetness.	Poor: very poorly drained and poorly drained.	Water table at a depth of 1 to 3 feet; rapid permeability in underlying material.	Underlying material has high permeability when compacted; susceptibility to piping; erodes easily.	Sand and gravel subsoil at a depth of 2 to 3 feet; high water table.	Poorly drained and very poorly drained; high water table.	Not needed: nearly level.	Not needed: nearly level.

TABLE 8.—*Interpretations of*

Soil series and map symbols	Degree and kind of limitation for—						Suitability as source of—
	Septic tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings with basements	Sanitary landfill	Local roads and streets	Road fill
Fordville: 339	Slight: hazard of pollution.	Severe: rapid permeability in substratum; hazard of pollution.	Severe: poor stability.	Slight	Severe: rapid permeability; hazard of pollution.	Slight	Good: gravelly coarse sand at a depth of 2 to 3 feet.
*Formdale: 171B, 912B, 931B. For Aazdahl and Flom parts of 912B and Langhei part of 931B, see those series.	Severe: moderately slow permeability.	Moderate where slopes are 2 to 6 percent. Severe where slopes are more than 6 percent.	Moderate where slopes are less than 12 percent: clay loam. Severe where slopes are more than 12 percent.	Moderate: moderate shrink-swell potential. Severe: where slopes are more than 12 percent.	Moderate: clay loam.	Severe: low strength.	Poor: low strength.
Glyndon: 60	Moderate: seasonal high water table; hazard of pollution.	Severe: rapid permeability; hazard of pollution.	Severe: poor stability; somewhat poorly drained to moderately well drained.	Moderate: somewhat poorly drained to moderately well drained; seasonal high water table.	Severe: rapid permeability in substratum.	Severe: high frost-action potential.	Poor: high frost-action potential.
*Grimstad: 914 For Towner part, see Towner series.	Moderate: seasonal high water table; moderate permeability in substratum.	Moderate: hazard of seepage; layer of sand.	Moderate: somewhat poorly drained to moderately well drained; seasonal high water table.	Moderate: somewhat poorly drained to moderately well drained; seasonal high water table; moderate shrink-swell potential.	Moderate: seasonal high water table; layer of sand.	Severe: high frost-action potential.	Poor: low shear strength; high frost-action potential.
*Hamerly: 184, 922. For Parnell part of 922, see Parnell series.	Severe: moderately slow permeability.	Moderate: seasonal high water table.	Severe: somewhat poorly drained to moderately well drained.	Severe: somewhat poorly drained to moderately well drained; seasonal high water table.	Severe: seasonal high water table.	Severe: high frost-action potential.	Poor: high frost-action potential.
Hecla: 366	Moderate: seasonal high water table; hazard of pollution.	Severe: rapid permeability.	Severe: sand in substratum; poor stability.	Moderate: seasonal high water table; moderately well drained.	Severe: rapid permeability; hazard of seepage.	Moderate: moderate frost-action potential.	Fair: moderate frost-action potential.

engineering properties of the soils—Continued

Suitability as source of—Cont.		Soil features affecting—					
Sand and gravel	Topsoil	Pond reservoir areas	Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways
Good: mixed sand and gravel at a depth of 2 to 3 feet.	Good	Rapid permeability at a depth of 2 to 3 feet; hazard of seepage.	Upper layers have low shear strength; high permeability in underlying material; medium compacted shear strength; erodes easily.	Not needed: well drained.	Low to moderate available water capacity; sand and gravel at a depth of 2 to 3 feet.	Not needed: nearly level.	Not needed: nearly level.
Not suitable	Fair where slopes are less than 12 percent: clay loam surface layer. Poor where slopes are more than 12 percent.	Favorable	Medium to low shear strength; medium compressibility.	Not needed: well drained.	Moderately slow permeability; complex slopes.	Clay loam; moderately slow permeability; complex slopes.	Features favorable.
Poor: underlying material is very fine sand.	Fair: thin surface layer; high lime content.	Hazard of seepage.	Medium to high susceptibility to piping; erodes easily.	Not needed	Somewhat poorly drained to moderately well drained; high available water capacity; high lime content.	Not needed: nearly level.	Not needed: nearly level.
Fair for sand: layer of sand. Unsuitable for gravel.	Fair: surface layer less than 16 inches thick.	Layer of sand; moderately rapid permeability in upper part; moderate permeability in substratum.	Medium compressibility; medium compacted shear strength; upper layers erode easily.	Not needed	Moderate to high available water capacity; rapid intake rate; high lime content in surface layer.	Not needed: nearly level.	Not needed: erodes easily.
Not suitable	Fair: surface layer less than 16 inches thick.	Favorable	Medium compacted shear strength; medium compressibility.	Not needed	Slow intake rate; moderately slow permeability.	Not needed: nearly level.	Excess lime.
Good for fine sand. Unsuitable for gravel.	Poor: loamy fine sand surface layer.	Rapid permeability; hazard of seepage.	Medium to high permeability when compacted; medium to high susceptibility to piping; erodes easily.	Not needed	Moderately well drained; low available water capacity; rapid permeability.	Not needed: nearly level.	Droughty; erodes easily.

TABLE 8.—*Interpretations of*

Soil series and map symbols	Degree and kind of limitation for—						Suitability as source of—
	Septic tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings with basements	Sanitary landfill	Local roads and streets	Road fill
Kittson: 58	Moderate: moderately slow permeability; seasonal high water table.	Moderate: somewhat poorly drained to moderately well drained; seasonal high water table.	Moderate: somewhat poorly drained to moderately well drained.	Moderate: somewhat poorly drained to moderately well drained; moderate shrink-swell potential.	Moderate: seasonal high water table.	Severe: high frost-action potential.	Poor: high frost-action potential.
Kittson variant: V58.	Severe: very poorly drained to poorly drained; seasonal high water table; moderately slow permeability.	Severe: very poorly drained to poorly drained; seasonal high water table.	Severe: very poorly drained to poorly drained; seasonal high water table.	Severe: very poorly drained to poorly drained; seasonal high water table.	Severe: very poorly drained to poorly drained; seasonal high water table.	Severe: very poorly drained to poorly drained; seasonal high water table; high frost-action potential.	Poor: very poorly drained to poorly drained; low shear strength in upper 2 to 3 feet; high frost-action potential.
Lake beaches: 1032.	Severe: seasonal high water table.	Severe: seasonal high water table.	Severe: seasonal high water table.	Severe: seasonal high water table.	Severe: seasonal high water table.	Severe: seasonal high water table.	Variable
Lamoure: 418, 359.	Severe: seasonal high water table; subject to flooding.	Severe: seasonal high water table; subject to flooding.	Severe: poorly drained; seasonal high water table.	Severe: poorly drained; seasonal high water table; subject to flooding.	Severe: poorly drained; seasonal high water table; subject to flooding.	Severe: poorly drained; high frost-action potential; subject to flooding.	Poor: poorly drained; high frost-action potential.
*Langhei: 220E, 942C2, 942D2, 943C2, 943D2. For Barnes parts of 942C2 and 942D2 and Formdale parts of 943C2 and 943D2, see those series.	Moderate where slopes are less than 12 percent: moderate permeability. Severe where slopes are more than 12 percent.	Moderate where slopes are less than 6 percent: moderate permeability. Severe where slopes are more than 6 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Moderate where slopes are less than 12 percent: moderate shrink-swell potential. Severe where slopes are more than 12 percent.	Slight where slopes are 2 to 12 percent. Moderate where slopes are 12 to 25 percent. Severe where slopes are more than 25 percent.	Moderate: moderate shrink-swell potential; moderate frost-action potential.	Fair where slopes are less than 25 percent: moderate shrink-swell potential; moderate frost-action potential. Poor where slopes are more than 25 percent.
Maddock: 45B, 45C.	Slight where slopes are less than 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent: hazard of pollution.	Severe: rapid permeability.	Severe: fine sand substratum; poor stability.	Slight where slopes are less than 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Severe: rapid permeability; hazard of pollution.	Slight where slopes are less than 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Good where slopes are less than 12 percent. Fair where slopes are more than 12 percent.

engineering properties of the soils—Continued

Suitability as source of—Cont.		Soil features affecting—					
Sand and gravel	Topsoil	Pond reservoir areas	Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways
Not suitable	Fair: surface layer less than 16 inches thick.	Favorable	Medium compressibility; medium to low shear strength.	Not needed	Somewhat poorly drained to moderately well drained; moderately slow permeability.	Not needed: nearly level.	Favorable.
Not suitable	Poor: very poorly drained to poorly drained.	Moderately rapid permeability in upper 2 to 3 feet; hazard of seepage.	Medium compressibility; medium to low shear strength.	Seasonal high water table; poor outlets.	Very poorly drained to poorly drained; moderate to high available water capacity.	Not needed: nearly level.	Not needed: nearly level.
Variable	Variable	Variable	Variable	Variable	Variable	Variable	Variable.
Not suitable	Poor: poorly drained.	Favorable: broad, level areas need extensive diking.	Medium to low shear strength; medium compressibility.	Seasonal high water table; subject to flooding; availability of outlets.	Poorly drained; seasonal high water table.	Not needed: nearly level.	Not needed: nearly level.
Not suitable	Poor: surface layer less than 8 inches thick.	Moderate permeability; slope is a limiting factor in places.	Medium compressibility; medium to low shear strength.	Not needed: somewhat excessively drained.	Moderately alkaline; complex slopes of 2 to 35 percent.	Complex slopes of 2 to 35 percent; high lime content restricts revegetation in places	Complex slopes of 2 to 35 percent; high lime content restricts revegetation in places.
Good for fine sand. Unsuitable for gravel.	Poor: loamy sand.	Rapid permeability; hazard of seepage.	Medium to low permeability when compacted; medium to high susceptibility to piping; erodes easily.	Not needed: well drained.	Low available water capacity; rapid permeability; erodes easily.	Erodes easily.	Low available water capacity; erodes easily.

TABLE 8.—*Interpretations of*

Soil series and map symbols	Degree and kind of limitation for—						Suitability as source of—
	Septic tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings with basements	Sanitary landfill	Local roads and streets	Road fill
Marsh: 1053	Severe: very poorly drained; water table at or near the surface; subject to flooding.	Severe: very poorly drained; water table at or near the surface; subject to flooding.	Severe: very poorly drained; water table at or near the surface; subject to flooding.	Severe: very poorly drained; water table at or near the surface; subject to flooding.	Severe: very poorly drained; water table at or near the surface; subject to flooding.	Severe: very poorly drained; subject to flooding.	Poor: variable material; very poorly drained.
McIntosh: 108	Severe: moderately slow permeability in substratum.	Moderate: seasonal high water table; hazard of seepage in upper layers.	Moderate: somewhat poorly drained to moderately well drained; seasonal high water table.	Moderate: somewhat poorly drained to moderately well drained; moderate shrink-swell potential; seasonal high water table.	Moderate: seasonal high water table.	Severe: high frost-action potential.	Poor: high frost-action potential; low shear strength.
Oldham: 276	Severe: slow permeability; seasonal high water table; subject to flooding.	Severe: seasonal high water table; subject to flooding.	Severe: very poorly drained; seasonal high water table.	Severe: very poorly drained; seasonal high water table; high shrink-swell potential.	Severe: very poorly drained; seasonal high water table; subject to flooding.	Severe: high shrink-swell potential; high frost-action potential.	Poor: very poorly drained; high frost-action potential; high shrink-swell potential.
Parnell: 34	Severe: slow permeability; seasonal high water table; subject to flooding.	Severe: seasonal high water table; subject to flooding.	Severe: very poorly drained; seasonal high water table.	Severe: very poorly drained; seasonal high water table; high shrink-swell potential; subject to flooding.	Severe: very poorly drained; seasonal high water table; subject to flooding.	Severe: high shrink-swell potential; high frost-action potential; seasonal high water table.	Poor: very poorly drained; high shrink-swell potential; high frost-action potential.
Quam: 344	Severe: moderately slow permeability; seasonal high water table; subject to flooding.	Severe: seasonal high water table; subject to flooding.	Severe: very poorly drained; seasonal high water table; subject to flooding.	Severe: very poorly drained; seasonal high water table; high shrink-swell potential; subject to flooding.	Severe: very poorly drained; seasonal high water table.	Severe: high shrink-swell potential; high frost-action potential; subject to flooding; low shear strength.	Poor: high frost-action potential; very poorly drained; high shrink-swell potential.
*Rockwell: 63, 970. For Vallers part of 970, see Vallers series.	Severe: moderately slow permeability in substratum; seasonal high water table.	Severe: seasonal high water table; hazard of seepage.	Severe: very poorly drained and poorly drained; seasonal high water table.	Severe: very poorly drained and poorly drained; seasonal high water table.	Severe: very poorly drained and poorly drained; seasonal high water table.	Severe: very poorly drained and poorly drained; high frost-action potential.	Poor: high frost-action potential; very poorly drained and poorly drained.

engineering properties of the soils—Continued

Suitability as source of—Cont.		Soil features affecting—					
Sand and gravel	Topsoil	Pond reservoir areas	Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways
Not suitable	Not suitable	Favorable	Variable material.	Variable material; water table at or near the surface; outlets may be difficult to obtain.	Very poorly drained.	Not needed: nearly level.	Not needed: nearly level.
Not suitable	Fair: surface layer less than 16 inches thick; high lime content.	Favorable	Medium compressibility; medium to low shear strength.	High frost-action potential; poor outlets.	High lime content; slow intake rate.	Not needed: nearly level.	High lime content; nearly level.
Not suitable	Poor: very poorly drained; too clayey.	Favorable	High compressibility; low shear strength; fair to poor compaction characteristics.	Slow permeability; seasonal high water table; high frost-action potential.	Very poorly drained.	Not needed: nearly level.	Not needed: nearly level.
Not suitable	Poor: very poorly drained.	Favorable	High compressibility; fair to poor compaction characteristics; medium to low shear strength.	Slow permeability; seasonal high water table; high frost-action potential.	Very poorly drained.	Not needed: nearly level.	Not needed: nearly level.
Not suitable	Poor: very poorly drained.	Favorable	Low shear strength; high compressibility.	Moderately slow permeability; high frost-action potential.	Very poorly drained.	Not needed: nearly level.	Not needed: nearly level.
Not suitable	Poor: very poorly drained and poorly drained.	Favorable: may need extensive diking.	Medium to low shear strength; medium to high susceptibility to piping; erodes easily.	Very poorly drained and poorly drained; poor outlets	Very poorly drained and poorly drained; excess lime; erodes easily.	Not needed: nearly level.	Not needed: nearly level; erodes easily.

TABLE 8.—*Interpretations of*

Soil series and map symbols	Degree and kind of limitation for—						Suitability as source of—
	Septic tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings with basements	Sanitary landfill	Local roads and streets	Road fill
*Roliss: 582, 971, 972. For Vallers part of 972, see Vallers series.	Severe: seasonal high water table; moderately slow permeability.	Severe: seasonal high water table.	Severe: very poorly drained and poorly drained; seasonal high water table.	Severe: very poorly drained and poorly drained; seasonal high water table.	Severe: very poorly drained and poorly drained; seasonal high water table.	Severe: high frost-action potential; very poorly drained and poorly drained.	Poor: high frost-action potential; very poorly drained and poorly drained; moderate shear strength.
Rothsay: 290B	Slight	Moderate: moderate permeability; hazard of seepage.	Slight	Moderate: medium to low shear strength.	Severe: hazard of seepage.	Severe: high frost-action potential; medium to low shear strength.	Poor: high frost-action potential; medium to low shear strength.
Sinai: 212B, 212C.	Severe: very slow permeability.	Slight where slopes are less than 2 percent. Moderate where slopes are 2 to 6 percent. Severe where slopes are more than 6 percent.	Severe: silty clay.	Severe: high shrink-swell potential.	Severe: silty clay.	Severe: high shrink-swell potential; low shear strength.	Poor: high shrink-swell potential; low shear strength.
Sioux: 402B, 402C, 402D.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent: hazard of pollution.	Severe: rapid permeability; poor material for reservoir sites.	Severe: gravelly coarse sand substratum; poor stability.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Severe: rapid permeability; hazard of pollution.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are more than 12 percent.	Good where slopes are 2 to 12 percent. Fair where slopes are 12 to 25 percent. Poor where slopes are more than 25 percent.
*Svea: 70, 962 For Hamerly part of 962, see Hamerly series.	Moderate: moderate permeability.	Moderate: moderate permeability.	Moderate: moderately well drained.	Moderate: moderately well drained; moderate shrink-swell potential.	Slight	Moderate: moderate shrink-swell potential; moderate frost-action potential.	Fair: moderate shrink-swell potential; moderate frost-action potential.
Sverdrup: 127B	Slight: hazard of pollution.	Severe: rapid permeability in substratum; hazard of seepage.	Severe: sand substratum; poor stability.	Slight	Severe: rapid permeability; hazard of pollution.	Slight	Good

engineering properties of the soils—Continued

Suitability as source of—Cont.		Soil features affecting—					
Sand and gravel	Topsoil	Pond reservoir areas	Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways
Not suitable	Poor: very poorly drained and poorly drained.	Favorable: may need extensive diking.	Medium to low shear strength; medium compressibility; susceptibility to piping.	Moderately slow permeability; seasonal high water table; high frost-action potential.	Very poorly drained and poorly drained; seasonal high water table.	Not needed: nearly level.	Not needed: nearly level.
Not suitable	Fair: surface layer less than 16 inches thick.	Moderate permeability; hazard of seepage.	Fair to poor compaction characteristics; high susceptibility to piping; medium to low shear strength.	Not needed: well drained.	Favorable	Favorable	Silt loam; features favorable.
Not suitable	Poor: silty clay.	Favorable	High compressibility; poor to fair compaction characteristics; low shear strength.	Very slow permeability.	Very slow permeability; slow intake rate.	Very slow permeability.	Favorable.
Good: needs screening. (Sand and gravel are mixed.)	Poor: thin layer of material; too sandy.	Rapid permeability; hazard of seepage.	Medium to high permeability when compacted; hazard of seepage.	Not needed: excessively drained.	Very low available water capacity; rapid permeability; complex slopes.	Complex slopes; rapid permeability.	Droughty; erodes easily; steep slope.
Not suitable	Good	Moderate permeability; hazard of seepage.	Medium compressibility; medium to low shear strength.	Not needed	Favorable	Outlets difficult to establish in places.	Features favorable.
Good for sand. Unsuitable for gravel.	Fair: surface layer less than 16 inches thick.	Rapid permeability in substratum; hazard of seepage.	High permeability when compacted; medium to high susceptibility to piping.	Not needed: somewhat excessively drained.	Low available water capacity; sand below a depth of 2 feet; rapid intake rate.	Sand below a depth of 2 feet; erodes easily.	Erodes easily.

TABLE 8.—*Interpretations of*

Soil series and map symbols	Degree and kind of limitation for—						Suitability as source of—
	Septic tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings with basements	Sanitary landfill	Local roads and streets	Road fill
Towner: 330	Severe: moderately slow permeability in substratum; seasonal high water table.	Moderate: seasonal high water table; layer of sand.	Moderate: moderately well drained; seasonal high water table.	Moderate: moderately well drained: seasonal high water table.	Moderate: seasonal high water table; hazard of pollution.	Moderate: moderate shrink-swell potential; moderate frost-action potential.	Fair: moderate to high shrink-swell potential; moderate frost-action potential.
Ulen: 64	Moderate: seasonal high water table; hazard of pollution.	Severe: rapid permeability; poor material for reservoir sites; hazard of pollution.	Severe: fine sand substratum; poor stability.	Moderate: moderately well drained to somewhat poorly drained; seasonal high water table.	Severe: rapid permeability; seasonal high water table; hazard of pollution.	Moderate: moderate frost-action potential.	Good
Urness: 335	Severe: moderately slow permeability; seasonal high water table; subject to flooding.	Severe: seasonal high water table; high organic-matter content; subject to flooding.	Severe: very poorly drained; seasonal high water table; subject to flooding.	Severe: very poorly drained; seasonal high water table; low shear strength.	Severe: very poorly drained; seasonal high water table; subject to flooding.	Severe: very poorly drained; high frost-action potential; low shear strength; subject to flooding; excess humus.	Poor: high frost-action potential; very poorly drained; low shear strength.
Vallers: 236, 419.	Severe: moderately slow permeability; seasonal high water table.	Severe: seasonal high water table.	Severe: poorly drained; seasonal high water table.	Severe: poorly drained; seasonal high water table.	Severe: poorly drained; seasonal high water table.	Severe: poorly drained; high frost-action potential.	Poor: high frost-action potential; poorly drained.
Waukon: 38C, 38D.	Moderate where slopes are 2 to 12 percent. Severe where slopes are 12 to 18 percent.	Moderate where slopes are less than 6 percent: moderate permeability. Severe where slopes are more than 6 percent.	Slight where slopes are 2 to 6 percent. Moderate where slopes are 6 to 12 percent. Severe where slopes are 12 to 18 percent.	Moderate where slopes are less than 12 percent: moderate shrink-swell potential; medium to low shear strength. Severe where slopes are 12 to 18 percent.	Slight where slopes are 2 to 12 percent. Moderate where slopes are 12 to 18 percent.	Moderate where slopes are less than 12 percent: moderate shrink-swell potential; moderate frost-action potential. Severe where slopes are more than 12 percent.	Fair: moderate shrink-swell potential; moderate frost-action potential.
Wheatville: 343.	Severe: slow permeability in substratum; seasonal high water table.	Slight: moderately rapid permeability in upper 2 to 3 feet.	Moderate: somewhat poorly drained and moderately well drained; seasonal high water table.	Severe: high shrink-swell potential; seasonal high water table.	Severe: seasonal high water table; silty clay substratum.	Severe: high frost-action potential; high shrink-swell potential in underlying material.	Poor: high shrink-swell potential; high frost-action potential.

engineering properties of the soils—Continued

Suitability as source of—Cont.		Soil features affecting—					
Sand and gravel	Topsoil	Pond reservoir areas	Embankments, dikes, and levees	Drainage of cropland and pasture	Irrigation	Terraces and diversions	Waterways
Not suitable	Fair: surface layer less than 16 inches thick.	Layer of sand; hazard of seepage.	Medium compressibility; medium to low shear strength; layer of sand.	Not needed	Erodes easily; rapid intake rate.	Erodes easily.	Not needed: nearly level.
Good for fine sand. Unsuitable for gravel.	Poor: too sandy; excess lime.	Rapid permeability; hazard of seepage.	High permeability when compacted; medium to high susceptibility to piping.	Not needed	Low available water capacity; sand substratum; rapid intake rate; rapid permeability.	Not needed: nearly level.	Not needed: nearly level.
Not suitable	Poor: very poorly drained.	Favorable	High compressibility; low shear strength; medium to high susceptibility to piping; excess humus.	Moderately slow permeability; seasonal high water table; high frost-action potential.	Very poorly drained.	Not needed: nearly level.	Not needed: nearly level.
Not suitable	Poor: poorly drained; excess lime.	Favorable	Medium to low shear strength; medium compressibility; low to medium susceptibility to piping.	Moderately slow permeability; seasonal high water table; poor outlets.	Poorly drained; moderately slow permeability; excess lime; slow intake rate.	Not needed: nearly level.	Not needed: nearly level.
Not suitable	Fair where slopes are less than 12 percent: surface layer less than 16 inches thick. Poor where slopes are more than 12 percent.	Moderate permeability; storage area limited by slope.	Medium to low shear strength; medium compressibility.	Not needed: well drained.	Complex and steep slopes.	Complex slopes.	Favorable; steep in places.
Not suitable	Fair: surface layer less than 16 inches thick; excess lime.	Favorable: broad, level areas need extensive diking.	Fair to poor compaction characteristics; high compressibility; medium to low shear strength.	Not needed	Slow permeability in substratum; excess lime; layer of sand.	Not needed: nearly level.	Not needed: nearly level.

TABLE 9.—*Engineering*

Soil name and location	Parent material	Minnesota report number	Depth from surface	Moisture density [1]—	
				Maximum dry density	Optimum moisture
			Inches	*Pounds per cubic foot*	*Percent*
Aazdahl clay loam: NW¼NW¼NW¼ sec. 27, T. 128 N., R. 43 W. (Modal)	Calcareous glacial till.	354	0–10	93	25
		355	17–22	101	20
		356	28–60	105	20
Formdale clay loam: NW¼NW¼SW¼ sec. 36, T. 128 N., R. 42 W. (Modal)	Calcareous glacial till.	360	0–9	96	22
		361	9–14	97	23
		362	18–60	108	18
Kittson very fine sandy loam: SW¼SW¼ sec. 31, T. 128 N., R. 44 W. (Modal)	Calcareous glacial till.	369	0–6	107	17
		370	10–17	114	14
		371	38–60	106	19
Vallers clay loam: SW¼ sec. 16, T. 128 N., R. 42 W. (Modal)	Calcareous glacial till.	366	0–7	95	24
		367	12–15	108	17
		368	18–60	108	18

[1] Based on AASHTO Designation T–99–57, method C (*1*).

[2] Mechanical analyses according to the AASHTO Designation T88–57 (*1*). Results by this procedure frequently may differ somewhat from results obtained by the soil survey procedure of the Soil Conservation Service (SCS). In the AASHTO procedure, the fine material is analyzed by the hydrometer method and the various grain-sized fractions are calculated on the basis of all the material, including that coarser than 2 millimeters in diameter. In the SCS soil survey procedure, the fine material is analyzed by the pipette method and the material coarser than 2 millimeters in diameter is excluded from calculations of grain-sized fractions. The mechanical analysis data used in this table are not suitable for naming textural classes of soils.

soil, expressed in pH value. The pH value and terms used to describe soil reaction are explained in the Glossary.

Shrink-swell potential is the relative change in volume expected in soil material caused by changes in moisture content, that is, the extent to which the soil shrinks as it dries out or swells when it gets wet. The extent of shrinking and swelling causes much damage to building foundations, roads, and other structures. A *high* shrink-swell potential indicates a hazard to maintenance of structures built in, on, or with material that has this rating.

Corrosivity pertains to potential soil-induced chemical action that dissolves or weakens uncoated steel or concrete. The rate of corrosion of uncoated steel is related to soil properties such as drainage, texture, total acidity, and electrical conductivity of the soil material. Corrosivity for concrete is influenced mainly by the content of sodium or magnesium sulfate, but also by soil texture and acidity. Installations of uncoated steel that intersect soil boundaries or soil horizons are more susceptible to corrosion than installations entirely in one kind of soil or in one soil horizon. A corrosivity rating of *low* means that there is a low probability of soil-induced corrosion damage. A rating of *high* means that there is such a high probability of damage that protective measures for steel and more resistant concrete should be used to avoid or minimize damage.

Engineering interpretations

The estimated interpretations in table 8 are based on the engineering properties of soils shown in table 7, on test data for soils in this survey area and others nearby or adjoining, and on the experience of engineers and soil scientists with the soils of Grant County. In table 8, ratings are used to summarize limitations or suitability of the soils for all listed purposes other than for drainage of cropland and pasture; irrigation; pond reservoir areas, embankments, dikes, and levees; terraces and diversions; and waterways. For these particular uses, table 8 lists those soil features not to be overlooked in planning, installation, and maintenance.

Soil limitations are indicated by the ratings slight, moderate, and severe. *Slight* means that properties generally are favorable for the rated use, that is, limitations are minor and easily overcome. *Moderate* means that some properties are unfavorable but can be overcome or modified by special planning and design. *Severe* means that properties are so unfavorable and so difficult to correct or overcome as to require major soil reclamation, special design, or intensive maintenance. For some uses, the rating of severe is divided to obtain ratings of severe and very severe. *Very severe* means that one or more of the properties are so unfavorable for a particular use that overcoming the limitations is most difficult, costly, and commonly not practical for the rated use.

Soil suitability is rated by the terms *good, fair,* and *poor,* which have, respectively, meanings approximately parallel to the terms slight, moderate, and severe.

Following are explanations of some of the columns in table 8.

Septic tank absorption fields are subsurface systems of tile or perforated pipe that distribute effluent from a septic tank into natural soil. The soil material be-

test data

Mechanical analysis[2]								Liquid limit	Plasticity index	Classification	
Percentage less than 3 inches passing sieve—					Percentage smaller than—						
⅜-inch	No. 4 (4.7 mm)	No. 10 (2.0 mm)	No. 40 (0.42 mm)	No. 200 (0.074 mm)	0.05 mm	0.005 mm	0.002 mm			AASHTO	Unified
								Percent			
		100	96	77	69	34	24	43	14	A–7–6	OL
100	99	99	95	76	69	39	32	42	23	A–7–6	CL
[3]98	97	95	89	72	66	32	22	32	11	A–6	CL–ML
100	99	99	95	74	68	37	28	44	14	A–7–5	OL
	100	99	96	81	75	41	31	47	23	A–7–6	CL
[4]99	97	96	92	73	68	34	27	33	14	A–6	CL
100	99	99	95	64	35	21	17	29	10	A–4	OL
	100	99	96	60	23	18	17	24	2	A–4	CL–ML
[4]98	97	94	90	72	65	43	33	44	25	A–7–6	CL
100	99	99	95	77	74	40	32	47	18	A–7–6	OL
[4]99	99	98	94	71	66	40	32	33	16	A–6	CL
100	99	98	94	80	71	37	29	32	14	A–6	CL

[3] 100 percent passes 1-inch sieve, and 99 percent passes ¾-inch sieve.
[4] 100 percent passes ¾-inch sieve.

tween depths of 18 inches and 6 feet is evaluated. The properties considered are those that affect both absorption of effluent and construction and operation of the system. Properties that affect absorption are permeability, depth to water table or rock, and susceptibility to flooding. Slope affects difficulty of layout and construction and also the hazard of soil erosion, lateral seepage, and downslope flow of effluent. Large rocks or boulders increase construction costs.

Sewage lagoons are shallow ponds constructed to hold sewage within a depth of 2 to 5 feet long enough for bacteria to decompose the solids. A lagoon has a nearly level floor, and its sides, or embankments, are made of compacted soil material. The assumption is made that the embankment is compacted to medium density and the pond is protected from flooding. Properties considered are those that affect the pond floor and the embankment. Those that affect the pond floor are permeability, content of organic matter, slope, and, if the floor needs to be leveled, depth to bedrock. The properties that affect the embankment are the engineering properties of the embankment material as interpreted from the Unified Soil Classification and the number of stones, if any, that influence ease of excavation and compaction of the embankment material.

Shallow excavations are those that require digging or trenching to a depth of less than 6 feet, for example, excavations for pipelines, sewer lines, phone and power transmission lines, basements, open ditches, and cemetaries. Desirable properties are good workability, moderate resistance to sloughing, gentle slopes, absence of rock outcrops or big stones, and freedom from flooding or a high water table.

Dwellings with basements, as rated in table 8, are not more than three stories high and are supported by foundation footings placed in undisturbed soil. The features that affect the rating of a soil for dwellings are those that relate to capacity to support load and resist settlement under load and those that relate to ease of excavation. Properties that affect the capacity of the soil to support load are wetness, susceptibility to flooding, density, plasticity, texture, and shrink-swell potential. Those that affect excavation are wetness, slope, depth to bedrock, and content of stones and rocks.

Sanitary landfill is a method of disposing of refuse in dug trenches. The waste is spread in thin layers, compacted, and covered with soil throughout the disposal period. Landfill areas are subject to heavy vehicular traffic. Some properties that affect suitability for landfill are ease of excavation, hazard of polluting ground water, and trafficability. The soils that are best suited have moderately slow permeability, withstand heavy traffic, and are friable and easy to excavate. Unless otherwise stated, the ratings in table 8 apply only to a depth of about 6 feet, and therefore limitation ratings of *slight* or *moderate* may not be valid if trenches are to be much deeper than that. For some soils, reliable predictions can be made to a depth of 10 or 15 feet; nevertheless every site should be investigated before it is selected.

Local roads and streets, as rated in table 8, have an all-weather surface expected to carry automobile traffic all year. They have a subgrade of underlying soil material; a base consisting of gravel, crushed rock, or soil material stabilized with lime or cement; and a

flexible or rigid surface, commonly asphalt or concrete. These roads are graded to shed water and have ordinary provisions for drainage. They are built mainly from soil at hand, and most cuts and fills are less than 6 feet deep.

Soil properties that most affect design and construction of roads and streets are load-supporting capacity and stability of the subgrade and the workability and quantity of cut and fill material available. The AASHTO and Unified classifications of the material, as well as the shrink-swell potential, indicate traffic-supporting capacity. Wetness and flooding affect stability. Slope, depth to hard rock, content of stones and rocks, and wetness affect ease of excavation and the amount of cut and fill material needed to reach an even grade.

Road fill is soil material used in embankments for roads. The suitability ratings reflect the predicted performance of soil after it has been placed in an embankment that has been properly compacted and provided with adequate drainage and the relative ease of excavating the material at borrow areas.

Sand and gravel are used in great quantities in many kinds of construction. The ratings in table 8 provide guidance in looking for probable sources. A soil rated as a *good* or *fair* source of sand or gravel generally has a layer at least 3 feet thick, the top of which is within a depth of 6 feet from the surface. The ratings do not take into account thickness of overburden, location of the water table, or other factors that affect mining of the materials; nor do the ratings indicate quality of the deposit.

Topsoil is used for topdressing an area where vegetation is to be established and maintained. Suitability is affected mainly by ease of working and spreading the material, as for preparing a seedbed; natural fertility of the material, or the response of plants when fertilizer is applied; and absence of substances toxic to plants. Texture of the material and its content of stone fragments are characteristics that affect suitability, but also considered in the ratings is damage that results at the area from where topsoil is taken.

Pond reservoir areas hold water behind a dam or embankment. Soils suitable for pond reservoir areas have low seepage, which is related to permeability of the soil and depth to fractured or permeable bedrock or other permeable material.

Embankments, dikes, and levees require material that is resistant to seepage and piping and that has favorable stability, shrink-swell potential, shear strength, and compactibility. Stones or organic material are among the unfavorable features.

Drainage of cropland and pasture is affected by properties such as permeability, texture, and structure; depth to claypan, rock, or other layers that affect rate of water movement; depth to the water table; slope and stability of ditchbanks; susceptibility to stream overflow; salinity or alkalinity; and availability of outlets for drainage.

Irrigation is affected by features such as slope; susceptibility to stream overflow, water erosion, or soil blowing; texture; content of stones; accumulation of salts and alkali; depth of root zone; rate of water intake at the surface; permeability of soil layers below the surface layer and in fragipans or other layers that restrict movement of water; amount of water held available to plants; and need for drainage or depth to water table or bedrock.

Terraces and diversions are embankments, or ridges, that are constructed across the slope to intercept runoff so that it soaks into the soil or flows to a prepared outlet. Features that affect suitability of a soil for terraces are uniformity and steepness of slope; depth to bedrock or other unfavorable material; presence of stones; permeability; and resistance to water erosion, soil slipping, and soil blowing. A soil suitable for terraces and diversions provides outlets for runoff and is not difficult to vegetate.

Waterways are used to allow water to flow in defined channels across the land without causing erosion. Features considered for waterways are those that affect the establishment, growth, and maintenance of plant cover.

Engineering test data

Table 9 contains engineering test data for some of the major soil series in Grant County. Test were made to help evaluate the soils for engineering purposes. The engineering classifications given are based on data obtained by mechanical analyses and by tests designed to determine liquid limits and plastic limits. The mechanical analyses were made by combined sieve and hydrometer methods.

Compaction (or moisture-density) data are important in earthwork. If material is compacted at a successively higher moisture content, assuming that the compactive effort remains constant, the density of the compacted material increases until the *optimum moisture content* is reached. After that, density decreases with increasing moisture. The highest dry density obtained in the compactive test is called *maximum dry density*. As a rule, maximum strength of earthwork is obtained if the soil is compacted to the maximum dry density.

Tests to determine liquid limit and plastic limit measure the effect of water on the consistence of soil material, as has been explained for table 7.

Formation and Classification of the Soils

This section consists of two main parts. The first part explains the effects of the factors of soil formation on the formation of soils in Grant County. The second part explains the system of soil classification currently used and places each series in the classes of that system.

Factors of Soil Formation

Soil is produced by soil-forming processes acting on material deposited or accumulated by geologic agencies. The characteristics of the soil at any given point are determined by the physical and mineral composition of the parent material; the climate under which the soil material has accumulated and existed since accumulation; the plant and animal life on and in the soil; the relief, or lay of the land; and the length of

time the forces of soil formation have acted on the material.

Climate and plant and animal life, mainly plant life, 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 developed and, in extreme cases, determines it almost entirely. Time is needed for the development of parent material into a soil profile. The length of time required may vary greatly, but some time is always needed for differentiation of horizons. Generally, a long time is required for the development of distinct horizons.

The factors of soil formation are so closely interrelated in their effects on the soil 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 formation are not known.

Parent material

The soils in Grant County formed in glacial drift and modified glacial drift from the Des Moines Lobe of the Late Wisconsin Glaciation. The Lobe covered Grant County about 10,000 years ago. As it receded northward, meltwater from it formed great glacial Lake Agassiz, which covered large parts of northwestern Minnesota, eastern North Dakota and south-central Canada. Lake Agassiz occupied approximately the western third of Grant County. A part of its basin in Minnesota is called the Red River Valley.

Glacial Till.—Most of Grant County is covered by glacial till or water-modified glacial till. The eastern fourth of the county is mainly loam till. The soils are a mixture of sand, silt, and clay. Small pebbles and stones are throughout the profile. The main loamy glacial till soils are the Barnes, Langhei, Svea, Flom, and Vallers soils. The Rothsay soils, which formed from deep wind-blown silts, are in a small area around Pelican Lake. In the middle part of the county, the soils formed mainly from clay loam glacial till, which differs from the loam glacial till in that it has more clay and silt and less sand. The main soils that formed in clay loam glacial till are Formdale and Aazdahl soils. A small area of Sinai soils, which formed in clay till, is in the southeastern part of Roseville Township. In the western fourth of the county, the soils formed in waterworked clay loam glacial till. In this area the meltwater of the glacier formed glacial Lake Agassiz, so now a thin mantle of water-sorted sediment commonly overlies the till. The main soils in this area are Roliss, Kittson, Grimstad, and Towner soils.

Outwash.—Outwash is glacial drift that has been sorted and deposited by moving water. The main area of outwash is in the valleys along the Pomme de Terre and Chippewa Rivers, and some small areas are in the eastern fourth of the county and on Herman Beach, the outer beach at the eastern edge of the basin of glacial Lake Agassiz. The outwash soils consist of sandy or loamy material underlain by sand and gravel. The main outwash soils are the Arvilla and Sioux soils.

Alluvium and Colluvium.—Alluvium was deposited in areas adjacent to rivers and streams. These deposits are relatively recent, and the soils show little development. Lamoure silt loam is an alluvial soil. Colluvium has accumulated at the bases of slopes and alluvial fans from material that eroded from higher slopes. The dark-colored surface soil is thicker than the soils on the slopes. Darnen soils formed in colluvium.

Lacustrine Sediment.—Lacustrine sediment was deposited in a few areas in glacial Lake Agassiz. This soil material is dominantly silt loam and silty clay. The main soils that formed in lacustrine deposits are the Bearden and Fargo soils.

Climate

Climate is a major factor in determining the kinds of soils that form in different kinds of parent material. It determines the vegetation and influences the rate and intensity of the physical, chemical, and biological relationships in the soil profile, chiefly through the effects of precipitation and temperature. In turn, the effects of climate and vegetation vary according to topography and the length of time the parent material has been in place.

The amount of water that filters through the soil at a given point depends on the amount and intensity of rainfall, relative humidity, length of the frost-free period, permeability, and physiography. Water dissolves minerals, supports biological activity, and transports mineral and organic residue through the profile. Temperature affects the kinds and growth of organisms and the speed of physical and chemical reactions in the soil.

Plant and animal life

Plants, animals, bacteria, and other organisms are active in soil-forming processes. The changes they produce depend mainly on their life cycles. The kinds of plants and animals that live on and in the soil are affected, in turn, by the climate, the parent material, relief, and age of the soil. Bacteria, fungi, earthworms, and other forms of animal life help in the breakdown of parent material and in the decomposition of organic matter. Vegetation affects soil formation by leaving residue in the soil and by transferring plant nutrients from the subsoil to the surface horizon.

The formation of the soils in Grant County has been mainly affected by prairie grasses. Soils that formed under prairie have a dark-colored surface that is high in content of organic matter. Barnes soils are an example of soils that formed under prairie. In the northeastern part of the county, a small area of soils was affected by forests. These soils have a moderately dark colored surface layer and a subsoil that is finer textured than the surface layer or the parent material. Waukon soils are an example of soils that formed under forests.

Relief

Relief, through its effect on drainage, aeration, and erosion, is an important factor in the formation of soils. Maximum profile development takes place in well-drained, gently sloping soils.

Runoff from steep soils and from soils on knolls is more rapid than from more nearly level soils. Much

of the steep soil material is likely to be washed away before a soil profile can develop. Since less water percolates through steep soils, the profile is likely to be less well developed than that of more level soils. Langhei soils are an example.

On lower slopes and more level land, runoff is less rapid, and more water percolates through the soil, which allows for greater soil developments. These soils have a thick, black A horizon, a brownish B horizon, and a greater depth to lime. Barnes soils are an example.

Soils that formed in depressional areas have a thick, dark-colored surface layer because they have a high content of organic matter. These soils generally receive more water than can percolate through them. The color and mottling of these soils are affected by poor drainage. Parnell and Flom soils are examples.

Some calcareous soils that formed in nearly level to gently undulating areas have a water table within a few feet of the surface. They have a thin, black, calcareous surface layer underlain by a thick, grayish, strongly calcareous layer. As these soils formed, moisture evaporated from the ground surface, concentrating lime in the surface layer. Hamerly soils are an example.

Time

All the soils of Grant County are young. Many of them started forming after the last glacier receded. Soils that formed in glacial till developed in a relatively short time because most of the material deposited by the glacier consisted of reworked drift carried by earlier glaciers, and the weathering of minerals had begun at the time of deposition.

Most soils that formed in glacial drift have distinct A, B, and C horizons. The development of horizons is less distinct in the poorly drained soils because high or fluctuating water has modified the effect of time. Soils on bottom lands near rivers and small streams show little development because the material is very young.

Classification of Soils

Soils are classified so that their significant characteristics can more easily be remembered. Classification is used to assemble knowledge about the soils, to see their relationship to one another and to the whole environment, and to develop principles that help in understanding their behavior and their response to manipulation. Through classification and the use of soil maps, knowledge of soils can be applied to specific fields and other tracts of land.

The narrow categories of classification, such as those used in detailed soil surveys, help in organizing and applying knowledge about soils in managing farms, fields, and woodlands; in developing rural areas; in engineering work; and in many other ways. Soils are placed in broad classes to facilitate study and comparison in large areas such as countries and continents.

The system of soil classification currently used was adopted by the National Cooperative Soil Survey in 1965. Because this system is under continual study, readers interested in developments in the current system should research the latest literature available (*3, 5*).

The current system of classification has six categories. Beginning with the broadest, the categories are order, suborder, great group, subgroup, family, and series. In this system, the criteria used as a basis for classification are soil properties that are observable and measurable. The properties are chosen, however, so that the soils of similar genesis, or mode of origin, are grouped together. In table 10, the soil series of Grant County are placed in the categories of the current system. Classes of the current system are briefly defined in the following paragraphs.

ORDER. Ten orders are recognized. The properties used to differentiate among orders are those that tend to give broad climatic groupings of soils. The two exceptions to this are the Entisols and Histosols, which occur in many different climates.

SUBORDER. Each order is subdivided into suborders that are based mainly on the characteristics that seem to produce classes with the greatest genetic similarity. The suborders narrow the broad climatic range of the orders. The properties used to separate suborders are mainly those that reflect either the presence or absence of waterlogging or soil differences resulting from the climate or vegetation.

GREAT GROUP. Suborders are separated into great groups on the basis of uniformity in the kinds and sequence of major soil horizons and features. Separations are made on the basis of horizons in which clay, iron, or humus has accumulated; horizons that have pans that interfere with growth or roots, movement of water, or both; and thick, dark-colored surface horizons. The features involved are the self-mulching properties of clay, soil temperature, major differences in chemical composition (mainly calcium, magnesium, sodium, and potassium), dark-red and dark-brown colors associated with basic rocks, and the like.

SUBGROUP. Great groups are subdivided into subgroups, one that represents the central (typic) segment of the group and others, called intergrades, that have properties of the group and one or more properties of another great group, suborder, or order. Subgroups are also made in those instances where properties intergrade outside the range of any other great group, suborder, or order.

FAMILY. Families are separated within a subgroup mainly on the basis of properties important to the growth of plants or on the behavior of soils when used for engineering. Among the properties considered are texture, mineralogy, reaction, soil temperature, permeability, thickness of horizons, and consistence.

General Nature of the County

This section explains the history, transportation, and markets; relief and drainage; geology; farming; and climate of Grant County.

History, Transportation, and Markets

No permanent settlers arrived in Grant County until the late 1860's. The people were mainly trappers and

TABLE 10.—*Classification of soil series*

Series	Family	Subgroup	Order
Aazdahl	Fine-loamy, mixed	Aquic Haploborolls	Mollisols.
Alluvial land, frequently flooded.	Sandy and loamy, frigid	Fluvaquents and Udifluvents	Entisols.
Arveson	Coarse-loamy, frigid	Typic Calciaquolls	Mollisols.
Arvilla [1]	Sandy, mixed	Udic Haploborolls	Mollisols.
Barnes	Fine-loamy, mixed	Udic Haploborolls	Mollisols.
Bearden	Fine-silty, frigid	Aeric Calciaquolls	Mollisols.
Darnen	Fine-loamy, mixed	Pachic Udic Haploborolls	Mollisols.
Fargo	Fine, montmorillonitic, frigid	Vertic Haploborolls	Mollisols.
Flom	Fine-loamy, mixed, frigid	Typic Haplaquolls	Mollisols.
Forada [2]	Coarse-loamy, mixed, frigid	Typic Haplaquolls	Mollisols.
Fordville	Fine-loamy over sandy or sandy-skeletal, mixed.	Pachic Udic Haploborolls	Mollisols.
Formdale	Fine-loamy, mixed	Udic Haploborolls	Mollisols.
Glyndon	Coarse-silty, frigid	Aeric Calciaquolls	Mollisols.
Grimstad	Sandy over loamy, frigid	Aquic Haploborolls	Mollisols.
Hamerly	Fine-loamy, frigid	Aeric Calciaquolls	Mollisols.
Hecla	Sandy, mixed	Aquic Haploborolls	Mollisols.
Kittson	Fine-loamy, mixed	Aquic Haploborolls	Mollisols.
Kittson variant	Fine-loamy, mixed	Typic Haplaquolls	Mollisols.
Lamoure [3]	Fine-silty, mixed (calcareous), frigid	Cumulic Haplaquolls	Mollisols.
Langhei	Fine-loamy, mixed (calcareous), frigid	Typic Udorthents	Entisols.
Maddock	Sandy, mixed	Udorthentic Haploborolls	Mollisols.
Marsh	Loamy and clayey	Aquents and Aquolls	Mollisols.
McIntosh	Fine-silty, frigid	Aeric Calciaquolls	Mollisols.
Oldham [4]	Fine, montmorillonitic (calcareous), frigid.	Cumulic Haplaquolls	Mollisols.
Parnell	Fine, montmorillonitic, frigid	Typic Argiaquolls	Mollisols.
Quam	Fine-silty, mixed, frigid	Cumulic Haplaquolls	Mollisols.
Rockwell	Coarse-loamy, frigid	Typic Calciaquolls	Mollisols.
Roliss	Fine-loamy, mixed (calcareous), frigid	Typic Haplaquolls	Mollisols.
Rothsay	Coarse-silty, mixed	Udic Haploborolls	Mollisols.
Sinai	Fine, montmorillonitic	Pachic Udic Haploborolls	Mollisols.
Sioux [5]	Sandy-skeletal, mixed	Udorthentic Haploborolls	Mollisols.
Svea	Fine-loamy, mixed	Pachic Udic Haploborolls	Mollisols.
Sverdrup	Sandy, mixed	Udic Haploborolls	Mollisols.
Towner	Sandy over loamy, mixed	Pachic Udic Haploborolls	Mollisols.
Ulen	Sandy, mixed	Aeric Calciaquolls	Mollisols.
Urness	Fine-silty, mixed (calcareous), frigid	Mollic Fluvaquents	Entisols.
Vallers	Fine-loamy, frigid	Typic Calciaquolls	Mollisols.
Waukon	Fine-loamy, mixed	Mollic Eutroboralfs	Alfisols.
Wheatville	Coarse-silty over clayey, frigid	Aeric Calciaquolls	Mollisols.

[1] Some Arvilla soils in Grant County are taxadjuncts to the Arvilla series because they have more gravel and less sand in the IIC horizon and a thicker mollic epipedon than is defined in the range for the series.

[2] Forada soils in Grant County are taxadjuncts to the Forada series because they contain more clay and less sand and silt than is defined in the range for the series.

[3] Lamoure soils in Grant County are taxadjuncts to the Lamoure series because some soils in the series are very poorly drained and therefore outside of the range defined for the series.

[4] Oldham soils in Grant County are taxadjuncts to the Oldham series because some soils in the series are very poorly drained and therefore outside of the range defined for the series.

[5] Sioux soils in Grant County are taxadjuncts to the Sioux series because they have a thinner or coarser textured A horizon than is defined in the range for the series.

hunters, and farmers arrived a few years later. The eastern part of the county was the first to be settled. Grant County, formally organized on March 8, 1868, was named after General Ulysses S. Grant, who was elected president of the United States that year. The county seat was established at a site which later became the village of Elbow Lake, and the first court house was erected there in 1878.

Grant County is served by two railroads, the Burlington Northern and the Soo Line. Public highways are well maintained. Among them are Interstate 94, which runs diagonally across the northeastern corner of the county, U.S. Highway 59, Minnesota State Highways 9, 27, 54, 55, 78, and 79, and several blacktop county roads. Good gravelled roads maintained by the county and townships serve most of the farms.

Trading centers are located throughout the county. Grain elevators are located at the trading centers. Marketing facilities are good.

Relief and Drainage

Grant County has three distinct types of topography. The western fourth of the county, known locally as the "flats," is nearly level. The northeastern and extreme eastern parts of the county are the most hilly, having slopes that range from 2 percent to more than 18 percent. The rest of the county is nearly level to

undulating, except for the slopes at the sides of the Chippewa, Pomme de Terre, and the Mustinka River Valleys.

The elevation of Grant County varies from about 1,000 to approximately 1,350 feet above sea level. The highest elevations are in the eastern part of the county, and the lowest elevations are in the western part.

Grant County drains partly to the north and partly to the south. The western half of the county is drained by the Mustinka River, which empties into Lake Traverse; by Five Mile Creek, which empties into the Mustinka River; and by the Rabbit River, which empties into the Bois de Sioux River. The outlet of Lake Traverse is the Bois de Sioux River, which is a tributary of the north-flowing Red River of the North. The eastern part of the county is in the Mississippi River basin. It is drained by the Chippewa and Pomme de Terre Rivers, which flow south to the Minnesota River, a tributary of the Mississippi River.

Geology

Grant County is covered by a glacial drift and modified glacial drift of the Late Wisconsin Glaciation. The glacial ice covered the county about 10,000 years ago. When it receded it left a thick mantle of glacial drift ranging from 100 to 250 feet in thickness. Beneath the drift is limestone bedrock underlain by Archaen rocks such as granite, feldspar, quartzite, and mica schist.

The western fourth of the county lies in the relatively flat Red River Valley. This is most widely believed to be the bed of glacial Lake Agassiz. As the glacier melted and receded northward, the meltwater formed Lake Agassiz between the ice front and the higher land to the south. The ice front acted as a dam and did not allow the water to drain northward, and a lake formed. The lake eventually became large enough to spill over its southern shore and discharge southward through the valley of the present Minnesota River and the Mississippi basin. Eventually the glacier receded far enough that drainage to the north resumed, and Lake Agassiz completely disappeared, leaving the broad, flat lake plain that exists today.

The soil in the Chippewa, Pomme de Terre, and Mustinka River valleys was deposited by flowing water. These rivers once drained melting icefields as the glacier receded, and consequently the rivers were once many times larger than they are now. The valleys where the three rivers now flow were cut when the rivers were at their larger stage. The Chippewa, Pomme de Terre, and Mustinka Rivers, as they exist today, have cut only about 5 feet of their present channels.

The Pomme de Terre and Mustinka valleys range from ¼ to 1 mile wide and from 50 to 100 feet deep. The Pomme de Terre valley was once deeper than it is now. Tributaries carried material into the valley and filled some places more than others. Pomme de Terre and Little Pomme de Terre Lakes are depressions in the original valley floor that were not filled in.

The beaches formed by Lake Agassiz can still be seen. The uppermost beach, known as the Herman Beach, extends from north to south through the western part of Grant County about 4 to 6 miles east of the county line. It is 3 to 10 feet above the land to the east and 10 to 20 feet above the land to the west. A second beach, known as Norcross Beach, is almost parallel to Herman Beach but is 1 to 3 miles west of it. The crest of Norcross Beach averages about 10 feet lower in elevation than Herman Beach, and Norcross Beach is not so pronounced on the landscape. Both beaches consist of sand and gravel ridges 150 to 1,600 feet wide.

The land east of Herman Beach is glacial till ground moraine, except for the northwestern part of the county and the valleys of major streams. However, the glacial till between Herman Beach and the Pomme de Terre River is somewhat modified. Silt deposits indicate that the waters of Lake Agassiz may once have been higher than and east of Herman Beach. Shallowness of the water at this higher level and the relatively short period that it was held at this level may explain the lack of a definite beach.

The northeastern part of the county is part of a terminal moraine known as the Alexandria moraine complex. The most hilly land in Grant County is in the terminal moraine area.

Farming

Grant County is generally rural. In 1970 there were 751 farms in the county, and the average size was 400 acres. The trend during the past three decades has been a decrease in the number of farms in the county and an increase in the average size of farms. The amount of land in farms is relatively constant at 92 to 95 percent of the total land in the county.

The first farmers to arrive in Grant County came in the 1870's. They found the prairie soil difficult to break. Once broken, however, the soil was very productive. Small grains were the first crops raised. Wheat immediately became the main crop, but some oats, barley, and rye were also grown. Many of the crops planted by the early settlers were lost to prairie fires, grasshoppers, hail, and other hazards. Wheat continued to dominate agriculture in Grant County until the turn of the century, when farming became more diversified. In the early 1900's artificial drainage was initiated in the nearly level western part of the county, and farmers began to settle that area. Some livestock was brought into the county mainly for personal use.

For the past decade oats has been the leading small grain, but in 1971 wheat production greatly increased, and its production now nearly equals that of oats. Corn, soybeans, barley, and flax are other important crops. Sunflowers and sugar beets are the latest crops to be introduced, and the acreage planted to these crops is increasing. A small amount of hay is also grown.

Livestock raising ranks second to cash-grain farming in Grant County. Dairy cows, beef cattle, and hogs are the main livestock enterprises.

Climate

Grant County lies near the western border of central Minnesota. The terrain varies from gently rolling to nearly level plains, but small areas on moraines and outwash terraces have fairly steep slopes. Local relief

generally ranges from a few feet to 30 or 40 feet. The difference in elevation between the highest and lowest points in the county is approximately 400 feet.

The climate is continental, with warm summers and cold winters. The area is subject to frequent outbreaks of continental polar air throughout the year, with occasional Arctic outbreaks in winter. The following paragraphs are based on data from Fergus Falls, Minnesota, for the period 1941–70, unless stated otherwise.

The county is near the center of the great land mass of North America, and this is probably the main factor in determining its climate. This large land mass is heated by a summer sun that shines for many hours a day at this high altitude, producing warm summers. Because of the location of this land mass, weather systems pass through frequently in both winter and summer.

The average daily maximum summer temperatures (table 11) range from the high 70's to the low 80's. The minimum average daily summer temperatures range from the low to high 50's. The average July temperature is nearly as warm as temperatures at stations 200 miles to the south, although temperatures of 100° F are not common. Such temperatures have occurred only 12 times in the last 33 years. The highest temperature on record, 110° F, occurred on July 16, 1936. Warm, humid periods last only a short time before cooler, drier air tempers the heat and lowers the humidity. Southerly flows bring warm, moist air from the Gulf of Mexico into the area in summer and provide the county with about 75 percent of its annual precipitation. This precipitation falls between April and September, which coincides with the growing season for row crops. The average annual precipitation for the county is approximately 24 inches. Annual precipitation has varied from 14.05 inches in 1910 to 38.10 inches in 1896. The greatest total daily precipitation (5.62 inches) occurred on June 25, 1923. The greatest monthly precipitation (10.21 inches) occurred in June 1923.

Winters are quite cold, with average daily maximum temperatures ranging from the high teens to the mid twenties. Average daily minimum temperatures range from approximately 7° F in December to −1° in January. Daily minimum temperatures fall below 0° on an average of 46 days a year because of outbreaks of cold Canadian air. The coldest temperature on record, −42° F, occurred on February 16, 1936. February 1936 is also the coldest month on record, with an average temperature of −8.4° F. The average annual snowfall is approximately 44 inches, with snow cover of 1 inch or more reported on an average of 107 days a year. The first measurable snowfall is in late October about 1 year in 3, and the last snowfall is in April.

Measurable precipitation (0.01 inch or more) can be expected on an average of 96 days a year, 49 of which generally have 0.1 inch or more, and 4 of which have 1 inch or more. An average of 25 thunderstorms can be expected each year. On occasion, hail and damaging winds accompany the thunderstorms. The average length of the growing season is 142 days. The last spring freeze occurs on about May 10, and the first fall freeze occurs on about September 29 (table 12).

TABLE 11.—*Temperature and precipitation*

[Data from Fergus Falls, Minnesota. Period of record, 1941–70]

Month	Temperature				Precipitation				
			Two years in 10 will have at least 4 days with—			One year in 10 will have—			
	Average daily maximum	Average daily minimum	Maximum temperature equal to or higher than—	Minimum temperature equal to or lower than—	Average monthly total	Less than—	More than—	Days with snow cover	Average depth of snow on days with snow cover
	°F	°F	°F	°F	*Inches*	*Inches*	*Inches*	*Number*	*Inches*
January	17.7	−1.3	37	−24	0.77	0.18	1.42	28	7
February	23.6	3.1	39	−18	.60	.15	1.05	27	7
March	35.7	16.8	56	−5	1.12	.46	1.86	19	6
April	54.4	32.5	74	20	2.60	1.08	3.89	2	2
May	68.1	44.1	84	31	2.99	1.23	5.18	-------	-------
June	77.1	54.2	90	42	4.68	2.19	6.39	-------	-------
July	83.1	59.3	93	49	3.32	.83	5.08	-------	-------
August	81.9	57.9	93	47	3.05	1.37	4.71	-------	-------
September	70.5	47.4	87	33	2.24	.79	3.64	-------	-------
October	59.1	37.1	76	24	1.42	.43	2.68	(1)	1
November	37.9	21.7	55	2	.87	.28	1.65	7	2
December	23.7	6.4	40	−14	.90	.18	1.50	24	4
Year	52.7	31.6	[2] 96	[3] −27	24.56	19.92	29.03	107	6

[1] Less than half a day.

[2] Average annual highest temperature.

[3] Average annual lowest temperature.

TABLE 12.—*Probabilities of last freezing temperatures in spring and first in fall*

[Data from Fergus Falls, Minnesota. Period of record, 1941–70]

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 18	May 3	May 5	May 15	May 25
2 years in 10 later than	April 12	April 27	April 30	May 10	May 20
5 years in 10 later than	April 2	April 15	April 21	May 1	May 10
Fall:					
1 year in 10 earlier than	October 26	October 19	October 3	September 27	September 14
2 years in 10 earlier than	October 31	October 23	October 10	October 1	September 19
5 years in 10 earlier than	November 9	October 31	October 19	October 10	September 29

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Glossary

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.

Brindle. Soil that has a surface with dark streaks and spots on a gray background. This is usually caused by free calcium carbonate and small depressions.

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.

Claypan. A compact, slowly permeable soil horizon that contains more clay than the horizons above and below it. A claypan is commonly hard when dry and plastic or stiff when wet.

Colluvium. Soil material, rock fragments, or both, moved by creep, slide, or local wash and deposited at the base of steep slopes.

Complex, soil. A mapping unit consisting of different kinds of soils that occur in such small individual areas or in such an intricate pattern that they cannot be shown separately on a publishable soil map.

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.

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 available water 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 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.

Drift (geology). Material of any sort deposited by geologic processes in one place after having been removed from another; includes drift materials deposited by glaciers and by streams and lakes associated with them.

Erosion. The wearing away of the land surface by wind (sandblast), running water, and other geological agents.

Fertility, soil. The quality of a soil that enables it to provide

compounds, in adequate amounts and in proper balance, for the growth of specified plants, when other growth factors such as light, moisture, temperature, and the physical condition of the soil are favorable.

Glacial drift (geology). Rock material transported by glacial ice and then deposited; also includes the assorted and unassorted material deposited by streams flowing from glaciers.

Glacial outwash (geology). Cross-bedded gravel, sand and silt deposited by meltwater as it flowed from glacial ice.

Glacial till (geology). Unassorted, nonstratified glacial drift that consists of clay, silt, sand, and boulders transported and deposited by glacial ice.

Ground moraine (geology). Glacial till accumulated beneath the advancing ice and deposited from it during its dissolution, rather than aggregated in a thickened belt at the ice edge; the deposit is relatively thin and characteristically forms an undulating plain with gently sloping swells, sags, and closed depressions.

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 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.

Lacustrine deposit (geology). Material deposited in lake water and exposed by lowering of the water level or elevation of the land.

Leaching. The removal of soluble materials from soils or other material by percolating water.

Lime. Chemically, lime is calcium oxide (CaO), but its meaning has been extended to include all limestone-derived materials applied to neutralize acid soils. Agricultural lime can be obtained as ground limestone, hydrated lime, or burned lime, with or without magnesium minerals. Basic slag, oystershells, and marl also contain calcium.

Loess. Fine-grained material, dominantly of silt-sized particles, that has been deposited by wind.

Made land. Areas filled artificially with earth or trash, or both.

Morphology, soil. The physical makeup of the soil, including the the texture, structure, porosity, consistence, color, and other physical mineral, and biological properties of the various horizons, and their thickness and arrangement in the soil profile.

Mottling, soil. 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.

Muck. An organic soil consisting of fairly well decomposed organic material that is relatively high in mineral content, finely divided, and dark in color.

Munsell notation. A system for designating color by degrees of the three simple variables—hue, value, and chroma. For example, a notation of 10YR 6/4 is a color with a hue of 10YR, a value of 6, and a chroma of 4.

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.

Percolation. The downward movement of water through the soil.

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 nor 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 strong 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

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.

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 characteristic of the soil are largely confined to the solum.

Stratified. Composed of, or arranged in, strata, or layers, such as stratified alluvium. The term is confined to geological material. Layers in soils that result from the processes of soil formation are called horizons, those inherited from the parent material are called strata.

Structure, soil. The arrangement of primary soil particles into compound particles or clusters that are separated 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 grained* (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 soil. The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, about 5 to 8 inches in thickness. The plowed layer.

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 noncapillarly porosity and stable, granular structure. A soil in poor tilth is nonfriable, hard, nonaggregated, and difficult to till.

Variant, soil. A soil having properties sufficiently different from those of other known soils to suggest establishing a new soil series, but a soil of such limited known area that creation of a new series is not believed to be justified.

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.

GUIDE TO MAPPING UNITS

For a full description of a mapping unit, read both the description of the mapping unit and the description of the soil series to which the mapping unit belongs.

Map symbol	Mapping unit	Page	Capability unit	Page	Windbreak suitability group	Recreation group	Pasture and hayland group
26	Aazdahl clay loam, 1 to 3 percent slopes	8	I-1	38	1	1	1
33B	Barnes loam, 2 to 5 percent slopes	11	IIe-1	38	1	1	1
34	Parnell silty clay loam	27	IIIw-1	41	7	4	6
36	Flom silty clay loam	15	IIw-1	39	3	4	3
38C	Waukon loam, 4 to 12 percent slopes	36	IIIe-1	40	1	1	1
38D	Waukon loam, 12 to 24 percent slopes	36	IVe-1	43	1	1	1
45B	Maddock loamy sand, 1 to 6 percent slopes	25	IVs-2	44	6	3	7
45C	Maddock loamy sand, 6 to 18 percent slopes	25	VIs-1	44	6	3	7
57	Fargo silty clay	14	IIw-1	39	3	4	3
58	Kittson very fine sandy loam, 0 to 2 percent slopes	20	I-1	38	1	1	1
V58	Kittson fine sandy loam, gray subsoil variant	21	IIIw-2	41	3	4	4
60	Glyndon silt loam, 0 to 2 percent slopes	18	IIs-2	40	2	1	1
61	Arveson fine sandy loam	10	IIIw-2	41	4	4	4
63	Rockwell loam	28	IIw-3	40	4	4	3
64	Ulen loamy fine sand, 0 to 2 percent slopes	34	IIIs-4	43	2	3	7
67	Bearden silt loam, 0 to 2 percent slopes	13	IIs-2	40	2	1	1
70	Svea loam, 1 to 3 percent slopes	32	I-1	38	1	1	1
108	McIntosh silt loam, 0 to 2 percent slopes	26	IIs-2	40	2	1	1
127B	Sverdrup sandy loam, 2 to 6 percent slopes	32	IIIs-2	43	5	1	7
171B	Formdale clay loam, 2 to 5 percent slopes	17	IIe-1	38	1	1	1
184	Hamerly clay loam, 1 to 3 percent slopes	19	IIs-2	40	2	1	1
212B	Sinai silty clay, 1 to 6 percent slopes	30	IIe-1	38	1	2	1
212C	Sinai silty clay, 6 to 12 percent slopes	30	IIIe-1	40	1	2	1
220E	Langhei loam, 18 to 35 percent slopes	22	VIIe-1	44	2	1	2
236	Vallers clay loam	35	IIw-2	39	4	4	3
276	Oldham silty clay loam	26	IIIw-1	41	7	4	6
290B	Rothsay silt loam, 2 to 6 percent slopes	30	IIe-1	38	1	1	1
330	Towner fine sandy loam, 0 to 2 percent slopes	33	IIIs-3	43	5	1	1
335	Urness mucky silt loam	34	IIIw-1	41	7	4	6
339	Fordville loam, 0 to 2 percent slopes	16	IIs-1	40	5	1	1
341	Arvilla sandy loam, 0 to 2 percent slopes	11	IIIs-1	42	6	1	7
341B	Arvilla sandy loam, 2 to 6 percent slopes	11	IIIs-2	43	6	1	7
343	Wheatville very fine sandy loam, 0 to 2 percent slopes	36	IIs-2	40	2	1	1
344	Quam silty clay loam	27	IIIw-1	41	7	4	6
359	Lamoure silt loam, frequently flooded	22	VIw-1	44	7	4	5
366	Hecla loamy fine sand, 0 to 2 percent slopes	20	IVs-2	44	5	3	7
375	Forada sandy loam	15	IIw-3	40	3	4	3
402B	Sioux loamy coarse sand, 0 to 6 percent slopes	31	IVs-1	43	6	3	7
402C	Sioux loamy coarse sand, 6 to 12 percent slopes	31	IVs-1	43	6	3	7
402D	Sioux gravelly loamy coarse sand, 12 to 35 percent slopes	31	VIIs-1	44	6	3	8
418	Lamoure silt loam	22	IIw-2	39	4	4	5
419	Vallers clay loam, firm subsoil	35	IIw-2	39	4	4	3
494B	Darnen loam, 1 to 4 percent slopes	14	I-1	38	1	1	1
582	Roliss loam	29	IIw-1	39	3	4	3
900	Aazdahl-Hamerly-Parnell complex, 0 to 2 percent slopes	8	IIe-2	38	---	---	---
	Aazdahl part	--	------	--	1	1	1
	Hamerly part	--	------	--	2	1	1
	Parnell part	--	------	--	7	4	6

GUIDE TO MAPPING UNITS--Continued

Map symbol	Mapping unit	Page	Capability unit	Page	Windbreak suitability group	Recreation group	Pasture and hayland group
903B	Barnes-Langhei loams, 3 to 6 percent slopes---	12	IIe-1	38	---	1	1
	Barnes part----------	--	------	--	1	---	---
	Langhei part----------	--	------	--	2	---	---
907B	Barnes-Svea loams, 1 to 3 percent slopes------	13	I-1	38	1	1	1
912B	Formdale-Aazdahl-Flom complex, 1 to 4 percent slopes----------	17	IIe-1	38	---	---	---
	Formdale part----------	--	------	--	1	1	1
	Aazdahl part----------	--	------	--	1	1	1
	Flom part----------	--	------	--	3	4	3
914	Grimstad-Towner complex, 0 to 2 percent slopes----------	18	IIIs-3	43	---	1	1
	Grimstad part----------	--	------	--	2	---	---
	Towner part----------	--	------	--	5	---	---
922	Hamerly-Parnell complex, 0 to 3 percent slopes----------	19	IIe-2	38	---	---	---
	Hamerly part----------	--	------	--	2	1	1
	Parnell part----------	--	------	--	7	4	6
931B	Formdale-Langhei clay loams, 3 to 6 percent slopes----------	17	IIe-1	38	---	1	1
	Formdale part----------	--	------	--	1	---	---
	Langhei part----------	--	------	--	2	---	---
942C2	Langhei-Barnes loams, 6 to 12 percent slopes, eroded----------	22	IIIe-1	40	---	1	1
	Langhei part----------	--	------	--	2	---	---
	Barnes part----------	--	------	--	1	---	---
942D2	Langhei-Barnes loams, 12 to 18 percent slopes, eroded----------	23	IVe-1	43	---	1	1
	Langhei part----------	--	------	--	2	---	---
	Barnes part----------	--	------	--	1	---	---
943C2	Langhei-Formdale clay loams, 6 to 12 percent slopes, eroded----------	24	IIIe-1	40	---	1	1
	Langhei part----------	--	------	--	2	---	---
	Formdale part----------	--	------	--	1	---	---
943D2	Langhei-Formdale clay loams, 12 to 18 percent slopes, eroded----------	24	IVe-1	43	---	1	1
	Langhei part----------	--	------	--	2	---	---
	Formdale part----------	--	------	--	1	---	---
962	Svea-Hamerly loams, 1 to 3 percent slopes-----	32	IIs-2	40	---	1	1
	Svea part----------	--	------	--	1	---	---
	Hamerly part----------	--	------	--	2	---	---
970	Rockwell-Vallers complex----------	28	IIw-3	40	4	4	3
971	Roliss complex----------	29	IIw-1	39	3	4	3
972	Roliss-Vallers complex----------	29	IIw-2	39	---	4	3
	Roliss part----------	--	------	--	3	---	---
	Vallers part----------	--	------	--	4	---	---
1002	Alluvial land, frequently flooded----------	9	VIw-1	44	7	4	5
1032	Lake beaches----------	21	IIIw-2	41	7	4	6
1053	Marsh----------	25	VIIIw-1	44	7	4	8

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