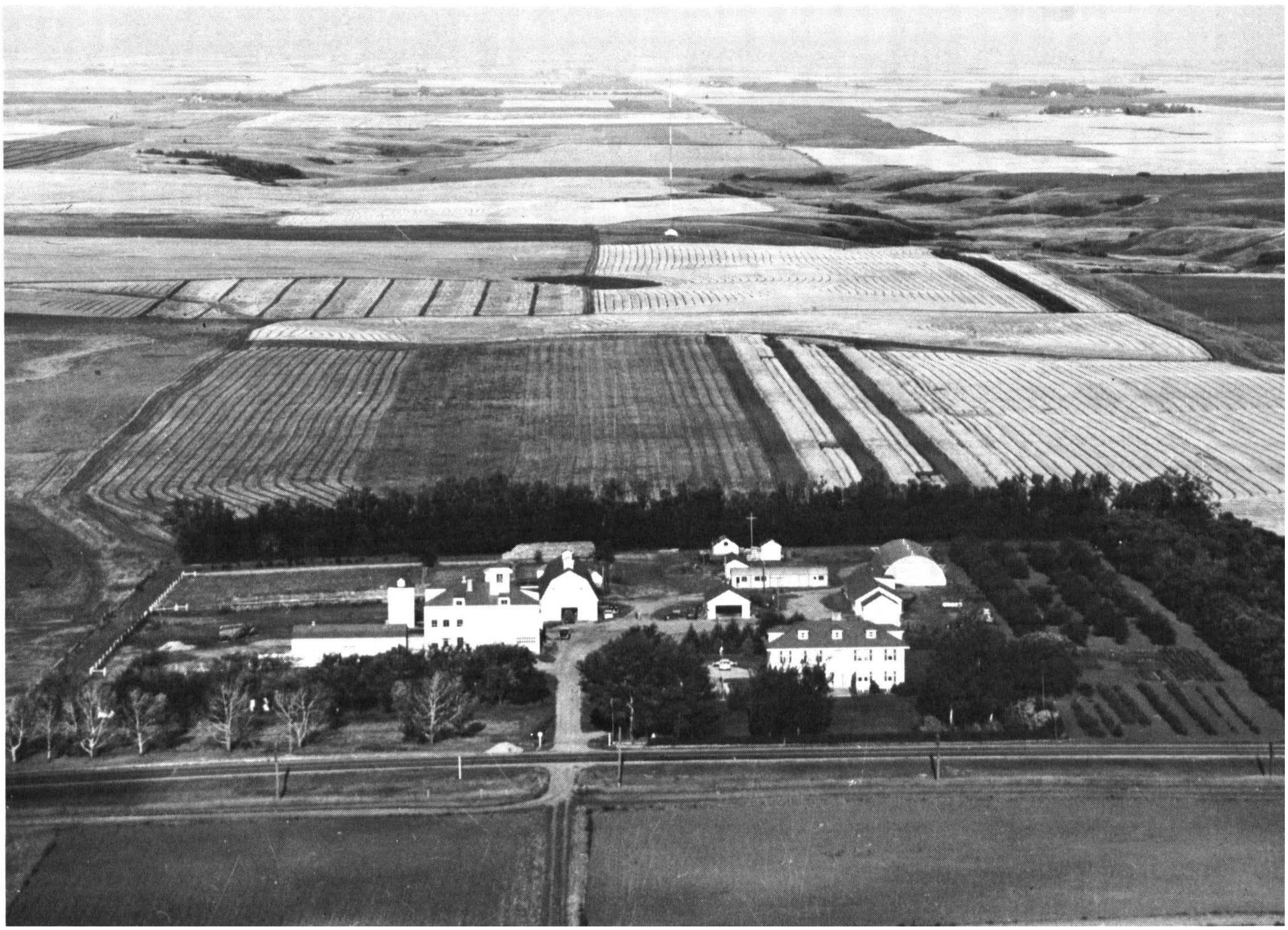
SOIL SURVEY OF

Ward County, North Dakota



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

Issued 1974

Major fieldwork for this soil survey was done in the period 1956-64. Soil names and descriptions were approved in 1970. Unless otherwise indicated, statements in the publication refer to conditions in the county in 1966. This survey was made cooperatively by the Soil Conservation Service and the North Dakota Agricultural Experiment Station. It is part of the technical assistance furnished to the Ward County Soil and Water Conservation District.

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

HOW TO USE THIS SOIL SURVEY

THIS SOIL SURVEY contains information that can be applied in managing farms, 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 Ward County are shown on the detailed map at the back of this publication. This map consists of many sheets made from aerial photographs. Each sheet is numbered to correspond with a number on the Index to Map Sheets.

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

Finding and Using Information

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

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

Farmers and those who work with farmers can learn about use and management of the soils from the soil descriptions and from the discussions of the capability units, the range sites, and the windbreak groups.

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

Ranchers and others can find, under "Range Management," groupings of the soils according to their suitability for range, and also the names of many of the plants that grow on each range site.

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 Ward 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: Area of Williams-Bowbells association along U.S. Highway No. 83. In foreground is the North Central Experiment Station, which is south of Minot. In background is a broad area of predominantly nearly level to gently sloping Williams soils but on the coulee breaks are steep Max and Zahl soils.

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Issued 1974

SOIL SURVEY OF WARD COUNTY, NORTH DAKOTA

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

WARD COUNTY, in north-central North Dakota (fig. 1), has an area of 1,310,720 acres. Minot is the county seat and principal city.

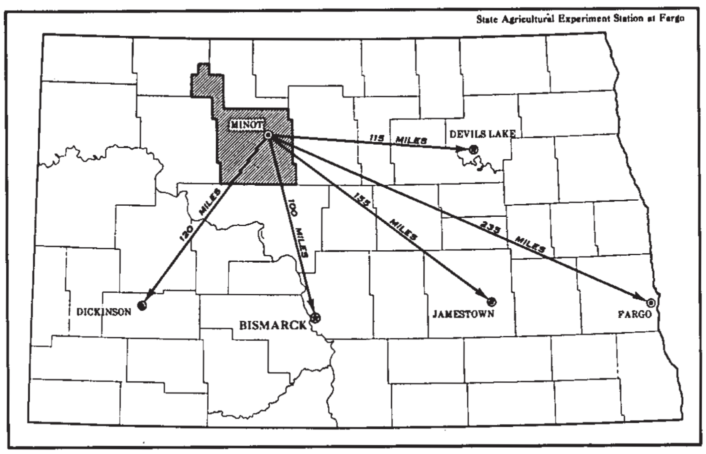

Figure 1.—Location of Ward County in North Dakota.

Physiographically, the county consists of nearly level till plains, rolling morainic hills, and the deeply entrenched valleys of the Des Lacs and Souris Rivers. The subhumid, continental climate has wide seasonal and day-to-day variations in temperature and rainfall. About two-thirds of the acreage in the county is in crops, and nearly one-third is still in native grass. Natural woodlands occur only in the coulees and on river bottoms and have no commercial value for lumber.

Ward County is an important producer of wheat, barley, and flax, as well as beef and dairy cattle. Oats, rye, corn, alfalfa, and tame grass are also commonly grown. Native grasses are used for both hay and pasture. Most areas of the county can be reached by paved State or Federal roads and well-maintained, graveled county roads.

How This Survey Was Made

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

The soil scientists made comparisons among the profiles they studied, and they compared these profiles with those in counties nearby and in places more distant. They classified and named the soils according to nationwide, uniform procedures. The *soil series* and the *soil phase* are the categories of soil classification most used in a local survey (*11*)[1].

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

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

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

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

[1] Italic or underlined numbers in parentheses refer to Literature Cited, p. 91.

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. Two such kinds of mapping units are shown on the soil map of Ward County: soil complexes and undifferentiated groups.

A soil complex consists of areas of two or more soils, so intricately mixed or so small in size that they cannot be shown separately on the soil map. Each area of a complex contains some of each of the two or more dominant soils, and the pattern and relative proportions are about the same in all areas. Generally, the name of a soil complex consists of the names of the dominant soils, joined by a hyphen. Bowbells-Williams complex, nearly level, is an example.

An undifferentiated group is made up of two or more soils that could be delineated individually but are shown as one unit because, for the purpose of the soil survey, there is little value in separating them. The pattern and proportion of soils are not uniform. An area shown on the map may be made up of only one of the dominant soils, or of two or more. Harriet and Vallers soils, strongly saline, is an undifferentiated soil group in this county.

In most areas surveyed there are places where the soil material is so rocky, so shallow, so severely eroded, or so variable that it has 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. Alluvial land is a land type in this county.

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 kinds 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 kinds of soil. Yields under defined management are estimated 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 a high water table. They see that streets, road pavements, and foundations for houses are cracked on a named kind of 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 by further 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 Ward County. A soil association is a landscape that has a distinctive proportional pattern of soils. It normally consists of one or more major soils and at least one minor soil, and it is named for the major soils. The soils in one association may occur in another, but in a different pattern.

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

The soil associations in Ward County are discussed in the following pages.

The terms for texture used in the title for several of the associations apply to the texture of the surface layer. For example, in the title of association 1, the word "loamy" refers to the texture of the surface layer.

1. Barnes-Svea association

Well drained and moderately well drained, nearly level, black loamy soils formed in glacial till

This soil association consists of nearly level soils on till plains in the northern part of Ward County. The landscape includes many shallow depressions but few natural watercourses.

This association makes up 18 percent of the county. Barnes soils make up about 65 percent of the association, and Svea soils about 15 percent. Minor soils make up the remaining 20 percent. Of these, Hamerly soils make up about 10 percent; Tonka soils, 5 percent; and Parnell soils, 5 percent.

Barnes soils are well drained. They have a surface layer of black loam and a subsoil of dark-brown loam. The underlying material is dark grayish-brown, calcareous loam glacial till.

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

Barnes soils are in convex positions and the Svea soils in concave positions on the landscape.

Minor soils are those of the Tonka, Parnell, and Hamerly series. Many small areas of Tonka and Parnell soils are in depressions where runoff water ponds. Areas of Hamerly soils are adjacent to these depressions, and they have a perched seasonal water table. The glacial till underlying Hamerly soils is firm and compact and has moderately slow permeability.

Most of this association is cultivated. Wheat, barley, flax, and oats are the main crops. A 2- or 3-year rotation that includes 1 year of cultivated summer fallow is used. Cash-grain farming is the main enterprise. The Barnes and Svea soils are generally tillable, but the associated soils are sometimes too wet to till or seed. Because these areas are scattered throughout the association, they interfere with field patterns, field windbreak plantings, and weed control. Only a small acreage has been improved by use of surface drainage ditches.

2. Barnes association

Well drained, gently sloping, loamy soils formed in glacial till

This soil association consists of well-drained, gently sloping soils on till plains along the main drainageways in the northeastern part of Ward County. These drainageways are low-gradient, intermittent streams that are entrenched in the till plain. Local relief ranges from 5 to about 25 feet.

This association makes up about 5 percent of the county. Barnes soils make up about 75 percent of the association. Minor soils make up the remaining 25 percent. Of these, Svea soils make up 15 percent, and other soils, 10 percent.

Barnes soils are well drained. They have a surface layer of black loam and a subsoil of dark-brown loam. The underlying material is dark grayish-brown, calcareous loam glacial till. These soils occupy slightly convex slopes along drainageways.

Minor soils are those of the Svea, Buse, Colvin, and Lamoure series. Svea soils are on foot slopes along drainageways and are thicker to the underlying glacial till than Barnes soils. Buse soils are well drained and are on slope breaks. Colvin and Lamoure soils are on bottom lands along drainageways and are calcareous and wet because of a high water table.

Most of this association is cultivated, except for the wet areas in drainageways. Wheat, barley, flax, and oats are grown as cash-grain crops. Water erosion is a concern of management, but gullying is not common. Contour tillage is used, but contour stripcropping is not.

3. Colvin-Vallers-Lamoure association

Poorly drained, level, loamy soils formed in alluvium and glacial till

This soil association is in small glacial lake basins marked by sloughs, marshes, and small lakes.

This association makes up about 2 percent of the county. Colvin soils make up about 35 percent of the association; Vallers soils, about 25 percent; Lamoure soils, about 15 percent; and minor soils, about 25 percent.

Colvin soils are deep and poorly drained. They have a surface layer of black silt loam that is underlain by very dark gray and olive silt loam that contains a large amount of lime. Below this, underlying material is olive-brown and gray silt loam and silty clay loam.

Vallers soils are deep and poorly drained. They have a surface layer of dark-gray loam that is underlain by olive-gray loam that contains a large amount of lime.

Lamoure soils are deep and poorly drained. They have a surface layer of black silty clay loam that is underlain by silty clay loam that is very dark gray in the upper part and gray and olive gray in the lower part.

Colvin and Lamoure soils are on bottoms of drainageways and in lake basins. Vallers soils are in depressions on the glacial till plain. All of these soils are wet and calcareous and have varying degrees of salinity.

Minor soils are those of the Renshaw, Lehr, Divide, Benoit, Hamerly, and Parnell series.

Most of this association is in native grass and is used for pasture and hay. A few areas have been drained and are cultivated. Some areas of the minor soils are also cultivated.

4. Barnes-Egeland-Emrick association

Well drained and moderately well drained, level to undulating, loamy and moderately sandy soils formed in water-sorted glacial till and outwash

This soil association consists of soils on a uniform landscape that has some shallow depressions. The areas are northeast and southwest of Surrey.

This association makes up about 1.5 percent of the county. Barnes soils make up about 40 percent of the association; Egeland soils, 20 percent; Emrick soils, 15 percent; and minor soils, the remaining 25 percent.

Barnes soils are well drained. They have a surface layer of black silt loam and a subsoil of dark-brown loam. The underlying material is dark grayish-brown and olive, firm, calcareous loam glacial till.

Egeland soils are well drained. They have a surface layer of very dark gray fine sandy loam and a subsoil of very dark grayish-brown sandy loam. The underlying material is light olive-brown fine sandy loam.

Emrick soils are moderately well drained. They have a surface layer of black loam and a subsoil of friable, very dark grayish-brown loam. The underlying material is olive-brown loam high in lime. Below this, at depths ranging from 3 to 5 feet, is firm glacial till that has slow permeability.

Minor soils are those of the Heimdal, Svea, and Embden series.

Most of this association is cultivated. Wheat, barley, flax, oats, rye, and alfalfa are the main crops. Soil blowing is a hazard on the Egeland soils. Stubble-mulch tillage, wind stripcropping, and pattern field windbreaks help to control soil blowing in some areas.

5. Manning-Lihen association

Well-drained, nearly level to undulating, moderately sandy soils formed in glacial outwash

This soil association consists of soils on smooth, uniform, outwash plains.

This association makes up about 3 percent of the county. Manning soils make up about 40 percent of the association; Lihen soils, about 30 percent; and minor soils, about 30 percent.

Manning soils are well drained. They have a surface layer of very dark brown sandy loam and a subsoil of very dark grayish-brown and dark-brown, friable sandy loam. The underlying material is loose coarse sand and gravel that limits rooting depth and available water capacity.

Lihen soils are well drained. They have a surface layer of very dark brown fine sandy loam and a subsoil of very dark grayish-brown, friable fine sandy loam. The underlying material is loamy sand or stratified loamy sand and fine sand.

Minor soils are those of the Telfer, Lehr, Wabek, and Benoit series.

Most of this association has been cropland, but many areas are now seeded to grass. The soils are droughty, and fertility is low. Soil blowing is a hazard, and cover crops, stubble-mulch tillage, stripcropping, and field windbreaks are used to control this.

6. Max-Williams association

Well-drained, rolling to strongly sloping, loamy soils formed in glacial till

This soil association consists of rolling soils on a morainic till plain that contains hundreds of small, closed basins. Local relief ranges from 25 to more than 50 feet. Slopes generally range from 6 to 12 percent. Slope segments are commonly less than 300 feet in length.

This association makes up about 10 percent of the county. Max soils make up about 40 percent of the association, and Williams soils about 30 percent. Minor soils make up the remaining 30 percent. Of these, Zahl soils make up 10 percent; Bowbells soils, 10 percent; and Parnell soils, 10 percent.

Max soils are well drained. They have a surface layer of very dark brown loam and a thin subsoil of very dark grayish-brown loam. The underlying material is calcareous, olive-brown loam glacial till.

Williams soils are well drained. They have a surface layer of very dark brown loam and a subsoil of dark-brown clay loam that is thicker than that of the Max soils. The underlying material is calcareous, olive-brown loam glacial till.

Max soils have more convex slopes, and Williams soils have slightly convex and plane slopes.

Minor soils are those of the Zahl, Bowbells, and Parnell series. Zahl soils are on sharp slope breaks, Bowbells soils are in swales, and Parnell soils are in depressions where runoff water ponds.

Most of this association is cultivated, but nearly a fourth is used for hay and pasture. Wheat, barley, flax, oats, crested wheatgrass, alfalfa, and native hay are the common crops. Gullying is not severe, but rill and sheet erosion transport much topsoil from hilltop to swale. This erosion is accelerated by the current practice of summer fallowing one-third to one-half of the cultivated areas.

7. Max-Zahl association

Well-drained, hilly, loamy soils formed in glacial till

This soil association (fig. 2) is on the hilly parts of the glacial moraine. Slopes range from 10 to 25 percent. Local relief is commonly 50 to 100 feet. These hilly soils surround potholes, sloughs, and small lakes, and therefore drainageways are short and terminate locally.

Figure 2.—An area of hilly Max-Zahl soil association, which is in the morainic hills in the southwestern part of the county.

This association makes up about 10 percent of the county. Max soils make up about 40 percent of the association, and Zahl soils 20 percent. Minor soils make up the remaining 40 percent. Of these, Bowbells soils make up 15 percent; Williams soils, 15 percent; and Parnell soils, 10 percent.

Max soils are well drained. They have a surface layer of very dark brown loam and a subsoil of very dark grayish-brown loam. The underlying material is highly calcareous, olive-brown loam glacial till.

Zahl soils are excessively drained. They have a thin surface layer of very dark gray loam that is underlain by calcareous, dark grayish-brown loam. The underlying material is highly calcareous, olive-brown loam glacial till.

Max soils are dominant on the smooth convex side slopes, and Zahl soils are on the ridgetops and slope breaks.

The minor soils are those of the Bowbells, Williams, and Parnell series. Bowbells soils are on foot slopes, Williams soils are on slightly convex and plane positions, and Parnell soils are in depressions where runoff water ponds.

Most of this association is in native grass. This grassland forms the nucleus for the beef cattle ranches in the county. The native grass in the sloughs and swales produces most of the harvested forage.

8. Nutley-Sinai association

Well drained and moderately well drained, level to gently sloping, clayey soils formed in glacial lacustrine sediment

This soil association is on smooth glacial lake plains and uplands and is surrounded by morainic hills. The soils in this association generally are gently sloping, and slopes generally are long. The lake plains are mantled by clayey sediment that settled out in the ice-walled lakes that once occupied these areas.

This association makes up 1.5 percent of the county. Nutley soils make up about 40 percent of the association; Sinai soils, 40 percent; and minor soils, the remaining 20 percent.

Nutley soils are well drained. They have a surface layer of very dark gray silty clay and a subsoil of very dark grayish-brown silty clay. The underlying material is calcareous, firm, clayey glacial lacustrine sediment.

Sinai soils are moderately well drained. They have a surface layer of black silty clay and a thick subsoil of very dark gray silty clay. The underlying material is calcareous, firm, clayey glacial lacustrine sediment.

Nutley soils have convex slopes, and Sinai soils have plane and concave slopes.

Minor soils are those of the Williams, Max, Zahl, and Parnell series. Areas of these soils adjoin or are within areas of the major soils.

Nearly all the acreage in major soils is cultivated. Wheat and barley are commonly grown in a 2-year rotation that includes summer fallow. Soil blowing is a hazard in winter and spring on open-fallow fields because these clayey soils granulate into sand-size particles that blow readily.

9. Wabek association

Excessively drained, rolling and hilly, moderately sandy soils formed in glacial outwash

This soil association occupies glacial outwash ridges and hills. Stones and gravel cap the ridges and are exposed in road cuts.

This association makes up about 2 percent of the county. Wabek soils make up about 60 percent of this association, and minor soils the remaining 40 percent.

Wabek soils are excessively drained. They have a surface layer of very dark grayish-brown gravelly sandy loam that is underlain by coarse sand and gravel.

Minor soils are those of the Manning, Max, and Zahl series.

Most of this association is used for pasture. This association is not widely cultivated. Most areas that were once plowed have been seeded to grass, because the soils are not suitable for cultivated crops. This association is an excellent source of gravel and of stones for crushing.

10. Williams-Bowbells association

Well-drained and moderately well drained, nearly level, very dark brown loamy soils formed in glacial till

This association consists of nearly level soils on till plains in the central and southwestern parts of Ward County.

This association makes up about 25 percent of the county. Williams soils make up about 60 percent of the association, and Bowbells soils 30 percent. Minor soils make up the remaining 10 percent. Of these, Tonka soils make up 7 percent and Parnell soils, 3 percent.

Williams soils are well drained. They have a surface layer of very dark brown loam and a subsoil of dark-brown clay loam. Friable, calcareous till begins at a depth ranging from 10 to 16 inches. Firm dense till is below a depth of about 36 inches.

Bowbells soils are moderately well drained. They have a surface layer of very dark brown loam and a subsoil of very dark grayish-brown clay loam. Firm loam glacial till is below a depth of about 36 inches. The Bowbells soils have a thicker subsoil than the Williams soils.

Minor soils are those of the Tonka and Parnell series. Many areas of Tonka soils are in shallow depressions where runoff water ponds because of the poorly developed surface drainage pattern.

Most of this association is cultivated. Wheat, barley, flax, and oats are the main crops. Cash-grain crops are the main enterprise. Some areas have numerous depressions. Other areas have been completely drained by use of surface ditches. A general slope of 20 to 30 feet per mile to the northeast, along with many entrenched coulees and waterways, facilitates the natural and artificial drainage of the central till plain along the valleys of the Souris and Des Lacs Rivers. Williams soils that have some of the subsoil mixed into the plow layer are resistant to soil blowing, but tillage, rainfall dispersion, and winter weathering cause a hazard of soil blowing in areas of unprotected fields.

11. Williams-Niobell association

Well-drained, nearly level, loamy soils formed in glacial till

This association consists of nearly level soils on till plains in the northwestern part of Ward County near Niobe.

This association makes up less than 1 percent of the county. Williams soils make up about 60 percent of the association, and Niobell soils 30 percent. Minor soils of the Noonan series make up the remaining 10 percent.

Williams soils are well drained. They have a surface layer of very dark brown loam and a subsoil of dark-brown clay loam. They are underlain by calcareous loam glacial till.

Niobell soils are moderately well drained. They have a surface layer of dark-brown loam and a leached subsurface layer of dark grayish-brown loam. They have a subsoil of firm clay loam that has moderately slow permeability. The underlying material is saline-alkali till.

Minor soils are those of the Noonan series. These soils are shallower to saline-alkali till than Niobell soils. Noonan soils have a strongly alkaline subsoil and strongly saline-alkali underlying material that is within a depth of 12 to 18 inches.

Most of this association is cultivated, but the droughtiness of the Niobell and Noonan soils causes the growth of small grains and alfalfa to be spotty and variable.

12. Williams association

Well-drained, undulating, loamy soils formed in glacial till

This soil association consists of undulating soils that have 10 to 24 feet of local relief. Areas of this soil association have more local relief than those of the Williams-Bowbells association but less than those of the Max-Williams association. Slopes generally are 3 to 7 percent and are dominantly 200 to 300 feet long. Most areas drain into local enclosed depressions or sloughs, but some areas are along drainageways.

This association makes up about 11 percent of the county. Williams soils make up about 65 percent of the association. Minor soils make up the remaining 35 percent. Of these, Bowbells soils make up 15 percent; Hamerly soils, 10 percent; and Parnell soils, 10 percent.

Williams soils are well drained. They have a surface layer of very dark brown loam and a subsoil of dark-brown clay loam. The underlying material is calcareous loam glacial till. These soils have moderately convex slopes.

Minor soils are those of the Bowbells, Hamerly, and Parnell series. Bowbells soils are moderately well drained. They have a darker colored profile than that of the Williams soils. These soils have slightly concave slopes. Hamerly soils are moderately well drained. They have a calcareous, very dark gray surface layer and a highly calcareous subsoil. These soils have a seasonal perched water table and are adjacent to the poorly drained Parnell soils in depressions.

Much of this association is cultivated, except for areas of Parnell soils that are in sloughs and that usually are too wet. Field boundaries adjoin the slough areas that are used for native hay. Wheat, barley, flax, and oats are the main crops. Cash-grain crops and beef cattle are the main enterprises.

13. Zahl-Max-Williams-Velva association.

Well-drained, level to steep, loamy soils formed in glacial till and well-drained, level, loamy soils formed in alluvium

This association consists mainly of soils in the breaks along the valleys of the Souris and Des Lacs Rivers. Zahl and Max soils are steep. Zahl soils are on the upper parts of convex slope breaks, and Max soils are in the lower, plane positions. Williams soils are on uplands and are level to undulating. Slopes generally range from 20 to 60 percent and are dominantly 400 to 500 feet long. Local relief is more than 200 feet in many places. Velva soils are nearly level and are on bottom lands that are one-half to 1 mile wide.

This association makes up about 10 percent of the county. Zahl soils make up about 35 percent of the association; Max soils, 30 percent; Williams soils, 20 percent; and Velva soils, the remaining 15 percent.

Zahl soils are well drained. They have a thin surface layer of very dark grayish-brown loam that is underlain by dark grayish-brown, calcareous loam. The underlying material is olive-brown, highly calcareous loam glacial till.

Max soils are well drained. They have a surface layer of very dark brown loam and a subsoil of very dark grayish-brown loam. The underlying material is olive-brown, highly calcareous loam glacial till.

Williams soils are well drained. They have a surface layer of very dark brown loam and a subsoil of dark-brown clay loam. The underlying material is calcareous loam glacial till.

Velva soils are well drained. They have a surface layer of very dark brown loam and a friable, very dark grayish-brown subsoil. The underlying material is stratified loamy alluvium.

Most areas of Williams and Velva soils are cultivated, but the areas of Zahl and Max soils are not. Mixed cash-grain crops and livestock are the main enterprises. Much of this association is used for pasture, including the areas that are in the Des Lacs and the Upper Souris National Wildlife Refuges. Some areas are idle because of their limited size, their shape, and lack of water for livestock. Only seriously overgrazed pastures and areas where vegetation and topsoil are removed by construction and not replaced are subject to erosion. Control of runoff and adequate outlets are needed in areas used for urban development.

Descriptions of the Soils

This section describes the soil series and mapping units in Ward County. Each soil series is described in detail, and then each mapping unit in that series is briefly 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 this 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; that is, 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.

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

In the detailed descriptions of representative profiles, references to color apply to dry soil, except as otherwise noted. In all other places in the description of the series and the mapping units, references to color apply to moist soil, unless otherwise noted.

As mentioned in the section "How This Survey Was Made," not all mapping units are members of a soil series. Mine pits and dumps, for example, do not belong to a soil series, but nevertheless they are listed in alphabetic order along with the soil series.

Following the name of each mapping unit is a symbol of parentheses. This symbol identifies the mapping unit on the detailed soil map. Listed at the end of each description of a mapping unit is a capability unit, range site, and windbreak group in which the mapping unit has been placed. The page for the description of each capability unit, range site, and windbreak group can be learned by referring to the "Guide to Mapping Units" at the back of this survey.

The 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, and more detailed information about the terminology and methods of soil mapping can be obtained from the Soil Survey Manual (*11*).

Alluvial Land

Alluvial land (0 to 6 percent slopes) (Ad) consists of a mixture of soils and soil material. It is on narrow bottom lands along channeled, intermittent drainageways. Deep, meandering stream channels have cut the areas into many small irregular parts.

Included with this land type in mapping were small areas of Lamoure, Svea, Velva, and other soils. Some included areas consist of recently deposited, loamy alluvium.

This land type is flooded for a short time when streams overflow, commonly during the spring thaw. Otherwise, surface water runs off and drainage is not a limitation. Gullying or channel cutting occurs in places.

This land type is well suited to grass and trees. Most areas are used for pasture. Some small areas are used for hay. The control of erosion and the maintenance of desirable grass species are a part of good management. Capability unit VIe-Si; windbreak group 1; Silty range site.

Arveson Series

The Arveson series consists of deep, level, poorly drained soils that formed in sandy material. These soils are in slight depressions on outwash plains.

In a representative profile, the surface layer is black fine sandy loam about 7 inches thick. The underlying material, to a depth of 30 inches, is very dark gray and gray friable fine sandy loam that is high in lime. Below this, it is olive-gray loamy sand that grades, at a depth of about 48 inches, to grayish-brown coarse sand.

Permeability is moderately rapid. The available water capacity is moderate. Organic-matter content is moderate, and fertility is medium. These soils have a water table near the surface much of the time.

Most areas of Arveson soils are in grass.

Representative profile of Arveson fine sandy loam, in a large, flat, depressional area of native grasses, 1,200 feet west and 120 feet north of the southeast corner of sec. 16, T. 156 N., R. 81 W.

A1—0 to 7 inches, very dark gray (10YR 3/1) fine sandy loam, black (10YR 2/1) moist; moderate, fine, crumb structure; soft when dry, very friable when moist, and slightly sticky but nonplastic when wet; many roots; mildly alkaline; slight effervescence; clear, irregular boundary; many tongues of this horizon extend into the ACca horizon.

ACca—7 to 15 inches, gray (2.5Y 5/1) fine sandy loam, very dark gray (2.5Y 3/1) moist; weak, fine, crumb structure; friable when moist, slightly sticky but nonplastic when wet; common roots; much disseminated lime; moderately plastic; alkaline; violent effervescence; clear, irregular boundary.

C1ca—15 to 30 inches, light-gray (N 7/0) fine sandy loam, gray (N 6/0) moist; massive; friable when moist, slightly sticky and slightly plastic when wet; few roots; much disseminated lime; moderately alkaline; violent effervescence; gradual boundary.

C2—30 to 48 inches, light-gray (5Y 7/2) loamy sand, olive gray (5Y 5/2) moist; single grain; loose; slight effervescence; gradual boundary.

IIC3—48 to 60 inches, light brownish-gray (2.5Y 6/2) coarse sand, grayish brown (2.5Y 5/2) moist; single grain; loose; slight effervescence.

The A1 horizon ranges from 5 to 15 inches in thickness and has slight to strong effervescence. It is very dark gray or black in color and is fine sandy loam or loam in texture. The ACca horizon is dark gray or very dark gray in color and has tongues that extend into the Cca horizon. The Cca horizon ranges from 10 to 20 inches in thickness. The C horizon is loamy sand, loamy fine sand, coarse sand, sandy loam, or fine sandy loam in texture.

Arveson soils are associated with Embden, Lihen, and Manning soils. They have a Cca horizon underlying the A1 horizon within a depth of 16 inches and are wetter than the Embden, Lihen, and Man-

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

Soil	Area	Extent
	Acres	Percent
Alluvial land	9,208	0.7
Arveson fine sandy loam	905	.1
Arvilla sandy loam, nearly level	2,262	.2
Arvilla sandy loam, gently sloping	661	.1
Barnes loam, level	115,254	8.8
Barnes loam, gently undulating	16,893	1.3
Barnes loam, gently sloping	30,931	2.4
Barnes loam, sloping	5,579	.4
Barnes loam, strongly sloping	1,153	.1
Barnes-Buse loams, undulating	4,025	.3
Barnes-Hamerly loams, undulating	6,071	.5
Barnes-Svea loams, nearly level	57,985	4.4
Barnes-Tonka loams, gently undulating	4,537	.3
Benoit loam	2,354	.2
Bowbells loam, gently sloping	16,467	1.3
Bowbells-Parnell complex	10,611	.8
Bowbells-Tonka loams	33,321	2.5
Bowbells-Williams complex, nearly level	4,738	.4
Buse loam, hilly	731	.1
Buse-Barnes loams, rolling	1,664	.1
Buse-Barnes loams, hilly	881	.1
Colvin silt loam	734	.1
Colvin silty clay loam, very poorly drained	4,396	.3
Divide loam	951	.1
Egeland fine sandy loam, undulating	1,949	.1
Egeland fine sandy loam, till substratum, nearly level	2,218	.2
Embden fine sandy loam	1,712	.1
Emrick-Heimdal loams, level	4,640	.4
Fargo silty clay	736	.1
Freshwater marsh	8,817	.7
Gravel pits	1,062	.1
Hamerly loam	15,355	1.2
Harriet complex	799	.1
Harriet and Vallers soils, strongly saline	4,391	.3
Hegne silty clay	784	.1
Heil soils	520	(1/)
Heimdal loam, undulating	2,184	.2
Lamoure and Colvin soils	4,577	.3
Lehr loam, nearly level	2,843	.2
Lehr loam, undulating	243	(1/)
Lihen-Telfer fine sandy loams, nearly level	3,764	.3
Lihen-Telfer fine sandy loams, undulating	3,800	.3
Lihen-Telfer fine sandy loams, till substratum, nearly level	1,266	.1
Lihen-Telfer fine sandy loams, till substratum, undulating	783	.1
Lihen-Telfer loamy fine sands, undulating	580	(1/)
Loamy lake beaches	2,849	.2
Ludden silty clay loam	1,012	.1
Ludden clay	2,414	.2
Ludden clay, depressional	314	(1/)
Makoti silty clay loam, level	3,082	.2
Manning sandy loam, nearly level	4,527	.3
Manning sandy loam, undulating	11,244	.9
Manning-Wabek sandy loams, rolling	1,146	.1
Max-Bowbells-Zahl loams, hilly	61,834	4.7
Max-Williams loams, undulating	5,990	0.5
Max-Williams loams, rolling	76,578	5.8
Max-Williams loams, strongly sloping	10,753	.8
Max-Zahl stony loams, rolling	1,559	.1
Max-Zahl loams, rolling	17,113	1.3
Mine pits and dumps	1,409	.1
Noonan-Miranda complex	454	(1/)
Noonan-Niobell loams	2,531	.2
Nutley silty clay, gently sloping	4,241	.3
Nutley-Sinai silty clays, nearly level	2,930	.2
Overly silty clay loam, mottled variant	370	(1/)
Parnell silty clay loam	39,915	3.0
Parnell soils, very poorly drained	16,224	1.2
Renshaw loam, nearly level	1,106	.1
Roseglen-Tansem silt loams, level	3,343	.3
Salt water marsh	1,936	.2
Seroco fine sand, hummocky	105	(1/)
Sinai silty clay loam, gently sloping	3,821	.3
Sinai silty clay, level	2,600	.2
Sioux soils, undulating	1,397	.1
Svea loam, level	3,617	.3
Svea loam, gently sloping	883	.1
Svea loam, fans, nearly level	2,314	.2
Svea loam, fans, gently sloping	6,578	.5
Svea-Hamerly-Tonka loams	2,717	.2
Svea-Lamoure complex	1,950	.1
Svea-Tonka loams	13,741	1.0
Telfer-Lihen loamy fine sands, rolling	1,495	.1
Tonka silt loam	16,275	1.2
Vallers loam, saline	6,914	.5
Velva fine sandy loam	3,157	.2
Velva loam	10,895	.8
Velva loam, alkali variant	835	.1
Wabek soils, undulating	5,910	.5
Wabek soils, hilly	6,876	.5
Wabek, Max, and Zahl stony loams, rolling	13,324	1.0
Williams loam, level	191,309	14.6
Williams loam, gently undulating	55,045	4.2
Williams loam, undulating	97,033	7.4
Williams loam, sloping	4,458	.3
Williams clay loam, level	2,188	.2
Williams clay loam, undulating	12,280	.9
Williams clay loam, rolling	7,583	.6
Williams clay loam, strongly sloping	1,151	.1
Williams-Bowbells-Tonka loams, level	31,699	2.4
Williams-Hamerly loams, undulating	2,043	.2
Williams-Niobell loams, level	6,976	.5
Zahl loam, hilly	24,200	1.8
Zahl-Max loams, rolling	4,764	.4
Zahl-Max loams, hilly	28,459	2.2
Zahl-Max loams, steep	54,063	4.1
Zahl-Miranda loams, hilly	1,490	.1
Water	10,386	.8
Total	1,310,720	100.0

1/ Less than 0.05 percent.

ning soils. Arveson soils have a profile similar to that of the Benoit, Colvin, and Vallers soils, but they contain more fine sand and less clay throughout.

Arveson fine sandy loam (0 to 2 percent slopes) (Af).—This soil is in low areas on sandy outwash plains. The areas are small in size.

Included with this soil in mapping were a few wet areas.

The water table is near the surface part of the time and is commonly within a depth of 2 to 3 feet the rest of the time.

This soil is well suited to grass. It is not suited to crops. Most areas are used for pasture or hay. Maintaining desirable species is the main concern of management. Controlling soil blowing is necessary if this soil is cultivated. Capability unit IVwe-3; windbreak group 2; Subirrigated range site.

Arvilla Series

The Arvilla series consists of level and gently sloping, somewhat excessively drained soils that formed in moderately sandy material that is underlain by sand and gravel at a depth of 12 to 24 inches. These soils are on outwash plains.

In a representative profile, the surface layer is very dark brown sandy loam about 5 inches thick. The subsoil is about 11 inches thick. It is dark-brown, friable sandy loam in the upper part and dark-brown, loose loamy sand in the lower part. The underlying material is dark grayish-brown, loose coarse sand and gravel.

Permeability is rapid in the upper 16 inches and is very rapid below that depth. The available water capacity is low. Organic-matter content is moderately low, and fertility is low. These soils are droughty, and crop growth is usually poor.

Some areas of Arvilla soils are used for crops, but many areas have been seeded to grass.

Representative profile of Arvilla sandy loam, nearly level, in a field of tame grasses, 158 feet north and 100 feet east of the southwest corner of sec. 2, T. 155 N., R. 81 W.

Ap—0 to 5 inches, dark-gray (10YR 4/1) sandy loam, very dark brown (10YR 2/2) moist; weak, fine, crumb structure; soft when dry, very friable when moist, nonsticky and nonplastic when wet; many roots; neutral; clear, smooth tillage boundary.

B2—5 to 12 inches, dark grayish-brown (10YR 4/2) sandy loam, dark brown (10YR 3/3) moist; weak, coarse, prismatic structure; slightly hard when dry, friable when moist, nonsticky and nonplastic when wet; common roots; neutral; clear, wavy boundary.

B3—12 to 16 inches, dark grayish-brown (10YR 4/2) loamy sand, dark brown (10YR 3/3) moist; single grain; loose; few roots; neutral; abrupt, wavy boundary.

IIC1—16 to 36 inches, light brownish-gray (2.5Y 6/2) coarse sand and gravel, dark grayish brown (2.5Y 4/2) moist; single grain; loose; very few roots; lime coatings on bottom of pebbles; moderately alkaline; slight effervescence; gradual boundary.

IIC2—36 to 60 inches, light brownish-gray (2.5Y 6/2) gravel; dark grayish brown (2.5Y 4/2) moist; single grain; loose; moderately alkaline.

The solum ranges from 12 to 24 inches in thickness. The A1 horizon ranges from 4 to 8 inches in thickness, is very dark brown or black in color, and is sandy loam or loam in texture. The B horizon ranges from 5 to 12 inches in thickness, is dark brown, very dark grayish brown, or dark grayish brown in color, and is sandy loam or fine sandy loam in texture. The C horizon is grayish-brown or dark grayish-brown sand and gravel.

Arvilla soils are associated with Divide and Renshaw soils, but they contain more sand and less clay. They are better drained than the Divide soils. They are associated with the Sioux soils, but they have a thicker profile that has coarse material at a greater depth.

Arvilla sandy loam, nearly level (0 to 3 percent slopes) (ArA).—This soil is in smooth areas of outwash plains. It has the profile described as representative for the series.

Included with this soil in mapping were small areas of Sioux gravelly sandy loam. Also included were a few areas of soils that have slopes of more than 3 percent. The slopes in these areas are short.

Soil blowing is a severe hazard, and the low available water capacity is a limitation.

This soil is suited to crops and grass, but it is not well suited to trees. Most areas are cultivated. Some areas are used for hay and pasture. Conserving moisture, maintaining fertility, and controlling soil blowing are serious concerns of management. Capability unit IIIes-3; windbreak group 6; Sandy range site.

Arvilla sandy loam, gently sloping (3 to 6 percent slopes) (ArB).—This soil is on side slopes and low hills on outwash plains.

Included with this soil in mapping were small areas of Sioux gravelly sandy loam that make up 10 to 15 percent of the area.

Soil blowing is a severe hazard, and about half of the areas are moderately eroded.

This soil is suited to grass and crops. Most areas are cultivated. Controlling soil blowing and conserving moisture are special concerns of management. Capability unit IIIes-3; windbreak group 6; Sandy range site.

Barnes Series

The Barnes series consists of deep, level to hilly, well-drained soils that formed in loamy glacial till. These soils are on upland till plains. Slopes range from 0 to 15 percent and are plane or convex.

In a representative profile, the surface layer is black loam about 4 inches thick. The subsoil is dark-brown friable loam about 10 inches thick. The underlying material, to a depth of about 42 inches, is dark grayish-brown friable loam glacial till that contains a large amount of lime. Below this, it is olive, firm loam glacial till that contains a moderate amount of lime.

Permeability is moderate to a depth of about 42 inches and is moderately slow below that depth. The available water capacity is high. Organic-matter content is moderate, and fertility is high.

Most areas of Barnes soils are used for crops. These soils are well suited to small grains, grass, legumes, and trees.

Representative profile of Barnes loam, gently sloping, in a pasture of native grass, 1,050 feet east and 300 feet south of the northwest corner of sec. 1, T. 155 N., R. 82 W.

A1—0 to 4 inches, dark-gray (10YR 4/1) loam, black (10YR 2/1) moist; strong, very fine, granular structure; friable when moist; many roots; neutral; clear, irregular boundary, but fine tongues of material from this horizon extend to a depth of 12 inches.

B2—4 to 14 inches, grayish-brown (10YR 5/2) loam, dark brown (10YR 4/3) moist; moderate, medium, prismatic structure; friable when moist; very dark grayish-brown (10YR 3/2), moist, organic-stained clay films on faces of peds; many roots; neutral; clear, wavy boundary.

C1ca—14 to 42 inches, light brownish-gray (10YR 6/2) loam, dark grayish brown (2.5Y 4/2) moist; weak, subangular blocky structure; friable when moist; common roots and root pores; many, prominent, white lime nodules; highly calcareous; gradual boundary.

C2—42 to 66 inches, pale-olive (5Y 6/3) loam, olive (5Y 4/3) moist; massive; firm when moist; moderately calcareous.

The solum ranges from 8 to 18 inches in thickness to lime. Some pebbles and cobblestones are throughout the profile. The A horizon ranges from 4 to 8 inches in thickness. In grassland it is dark gray or very dark gray when dry and is black when moist. In cultivated fields where some material from the B horizon has been mixed with the A horizon by tillage, it is very dark brown or very dark grayish brown when moist. The B horizon ranges from 4 to 12 inches in thickness. It is brown, dark grayish brown, or grayish brown when dry and dark brown or dark grayish brown when moist. The C horizon is light yellowish brown, light brownish gray, light olive brown, pale olive, or olive when dry, or is mixtures of these colors. It has a large amount of lime diffused or has few to many soft lime masses in the upper part.

Barnes soils are associated with Buse, Hamerly, and Svea soils. Barnes soils have a B horizon that Buse soils lack. They are better drained and have a thinner surface layer and subsoil than Svea soils. They are better drained than Hamerly soils and have a lime-free surface layer and subsoil. Barnes soils are associated with poorly drained Tonka and Parnell soils in places, but Barnes soils have a thinner surface layer and are shallower to lime.

Barnes loam, level (0 to 2 percent slopes) (BaA).—This soil is in the smoother areas of the till plain. The profile is similar to the one described as representative for the series, but the surface layer is thicker.

Included with this soil in mapping were small areas of Svea loam that make up less than 10 to 15 percent of the area. Also included in a few small areas where Tonka silt loam is in small depressions.

Surface runoff is slow, and the hazard of erosion is slight.

This soil is well suited to wheat and other crops commonly grown in the county. Most areas are cultivated. This soil is also well suited to grass and trees. Conserving moisture and maintaining fertility are the main concerns of management. Capability unit IIc-6; windbreak group 3; Silty range site.

Barnes loam, gently undulating (2 to 4 percent slopes) (BaB).—This soil is on low knolls, ridges, and slopes on the till plain and along drainageways. The areas are irregular in shape. The profile is similar to the one described as representative for the series, except that there are variations in the thickness of the surface layer and subsoil within short distances.

Included with this soil in mapping were small areas of soils that have a lighter colored surface layer and some areas of soils that contain more stones and pebbles in the surface layer. Also included were small areas of soils that have slopes of more than 4 percent. The slopes in these areas are short.

Surface runoff is slow or medium, and the hazard of erosion is slight.

This soil is well suited to crops, and most areas are cultivated. Conserving moisture and maintaining fertility are the main concerns of management, and controlling erosion is a secondary concern. Capability unit IIe-6; windbreak group 3; Silty range site.

Barnes loam, gently sloping (4 to 6 percent slopes) (BaC).—This soil is on smooth slopes that grade from uplands toward the drainageways. The areas are irregular in shape. This soil has the profile described as representative for the series.

Included with this soil in mapping were small areas of soils that have slopes of less than 4 percent and some that have slopes of more than 6 percent. Also included were a few small areas of Buse loam. Also included in some cultivated areas were areas of soils that have a lighter colored surface layer.

Surface runoff is medium, and the hazard of erosion is moderate.

This soil is suited to wheat and other crops commonly grown in the county. It is also suited to grass and trees. Conserving moisture, maintaining fertility, and controlling erosion are a necessary part of good management. Capability unit IIe-6; windbreak group 3; Silty range site.

Barnes loam, sloping (6 to 9 percent slopes) (BaD).—This soil is on upland slopes that grade toward the drainageways. The areas are irregular in shape. The profile is similar to the one described as representative for the series, except that there are variations in the thickness of the surface layer and subsoil. The surface layer and subsoil are thinnest in the more strongly sloping areas on the upper parts of slopes and thicker on the lower parts. The present surface layer is browner than the original surface layer where the subsoil has been mixed into the plow layer.

Included with the soil in mapping were small areas of soils that have slopes of less than 6 percent or more than 9 percent. The slopes in these areas are short. Also included were small areas of Buse loam that make up 10 to 15 percent of the area.

Runoff is moderate or rapid, and the hazard of erosion is severe. Small gullies are in cultivated fields in places.

This soil is suited to crops, grass, and trees. Controlling erosion is a serious concern of management, but conserving moisture and maintaining fertility are also concerns. Capability unit IIIe-6; windbreak group 3; Silty range site.

Barnes loam, strongly sloping (9 to 12 percent slopes) (BaE).—This soil is on side slopes that grade from uplands into the drainageways. The areas are irregular in shape.

Included with this soil in mapping were many areas of soils in cultivated fields that have a lighter colored surface layer. Also included were small areas of soils that have slopes of less than 9 percent or more than 12 percent. The slopes in these areas are short. Also included were small areas of Buse loam that make up 10 to 15 percent of the area.

Surface runoff is rapid, and the hazard of erosion is severe.

This soil is suited to crops, but it is better suited to grass. Controlling rill and gully erosion is a serious concern of management, but conserving moisture and maintaining fertility are also concerns. Capability unit IVe-6; windbreak group 3; Silty range site.

Barnes-Buse loams, undulating (3 to 6 percent slopes) (BbB).—This complex is on crests of low knolls and ridges. The areas are irregular in shape. Barnes loam makes up about 50 to 60 percent of the complex, and Buse loam 40 to 50 percent. The Buse soil is slightly lighter colored than the Barnes soil, and it is on the crests of ridges and slope breaks above the Barnes soil.

The profile of the Barnes soil in this complex is similar to the one described as representative for the Barnes series, except that the surface layer and subsoil are thinner and lighter colored. The profile of the Buse soil is similar to the one described as representative for the Buse series, except that some of the limy underlying material has been mixed with the surface layer by tillage.

Surface runoff is medium or rapid, and the hazard of erosion is moderate.

The complex is suited to crops, grass, and trees. Crop growth is not so favorable as it is on Barnes loam, gently sloping. Controlling erosion, conserving moisture, and maintaining fertility are serious concerns of management. Capability unit IVe-4L; Barnes part in windbreak group 3, Buse part in windbreak group 8; Barnes part in Silty range site, Buse part in Thin Silty range site.

Barnes-Hamerly loams, undulating (1 to 6 percent slopes) (BhB).—This complex is around and between depressions on the till plains. The areas are small in size and irregular in shape. Barnes loam makes up about 50 to 60 percent of the complex, and Hamerly loam about 25 to 50 percent. The remaining 5 to 15 percent of the complex is Parnell or Tonka soils.

Included with this complex in mapping were spots of soils where the underlying limy layer has been mixed with the original surface layer by tillage. The surface layer is lighter colored in these spots.

Runoff is slow or medium, and the hazard of erosion is slight or moderate. In cultivated fields water in the depressions and the high water table in the Hamerly soils are limitations.

This complex is suited to grass, hay, wheat, and other small grain. Controlling erosion, conserving moisture, maintaining fertility, and removing water from wet areas are concerns of management. Capability unit IIe-6; windbreak group 3; Silty range site.

Barnes-Svea loams, nearly level (0 to 3 percent slopes) (B1A).—This complex consists of level and irregularly sloping soils. The level areas are large in size. The slopes are generally less than 100 to 150 feet long, and the difference in relief is less than 5 feet between high and low areas. Barnes loam makes up about 50 to 70 percent of the complex, and Svea loam about 20 to 40 percent. The remaining 5 to 15 percent is Tonka silt loam. The Barnes soil is on the convex areas and the higher, level areas; the Svea soil is in the swales and in the lower, level areas; and the Tonka soil is in the lowest, level depressions.

Surface runoff is slow, and the hazard of erosion is slight. Some areas in the lower parts of depressions are ponded for a short time. Ponded water in low areas delays tillage, seeding, and harvesting in some years.

This complex is well suited to crops, grass, and trees. Most of the acreage is cultivated. Conserving moisture and maintaining fertility are the main concerns of management, but removing surface water from the low areas is a secondary concern. Capability unit IIc-6; Barnes part in windbreak group 3, Svea part in windbreak group 1; Silty range site.

Barnes-Tonka loams, gently undulating (0 to 5 percent slopes) (BmB).—This complex is characterized by irregular slopes that have about 10 feet relief and shallow depressions. It has slopes of 1 to 5 percent that are 150 to 200 feet long. Barnes loam makes up about 70 to 80 percent of this complex, and Tonka silt loam about 10 to 20 percent. The remaining 10 to 15 percent is Svea loam. The Barnes soil is on the convex, upper parts of the slopes, the Tonka soil is in the lowest depressions, and the Svea soil is between the Barnes and Tonka soils.

Included with this complex in mapping were a few small areas of Hamerly loam and Parnell silty clay loam.

Surface runoff is medium, and the hazard of erosion is slight.

This complex is well suited to small grains and other crops, grass, and trees. Conserving moisture, maintaining fertility, and controlling water in the low areas are the main concerns of management. Capability unit IIe-6; Barnes part in windbreak group 3, Tonka part in windbreak group 2; Barnes part in Silty range site, Tonka part in Wetland range site.

Benoit Series

The Benoit series consists of level, poorly drained soils that formed in loamy material that is underlain by sand and gravel at a depth of 15 to 25 inches. These soils are on glacial outwash plains. Slopes are level or concave.

In a representative profile, the surface layer is black loam about 6 inches thick. The underlying material, to a depth of about 25 inches, is gray and olive-gray loam that is high in lime. Below this, it is light olive-brown coarse sand and gravel.

Permeability is moderate to a depth of about 25 inches and very rapid below that depth. The available water capacity is moderate. Organic-matter content is moderate, and fertility is medium. These soils have a water table near the surface much of the time.

Most areas of Benoit soils are in grass.

Representative profile of Benoit loam, in a cultivated field, 2,450 feet east and 65 feet south of the northwest corner of sec. 17, T. 157 N., R. 81 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) loam, black (10YR 2/1) moist; moderate, fine, crumb structure; slightly hard when dry, friable when moist, slightly sticky and plastic when wet; mildly alkaline; strong effervescence; clear, irregular boundary, but tongues of this horizon extend to a depth of 16 inches.

C1ca—6 to 16 inches, light-gray (5Y 7/1) loam, gray (5Y 5/1) moist; moderate, fine, subangular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; much disseminated lime; moderately alkaline; violent effervescence; gradual boundary.

C2ca—16 to 25 inches, gray (5Y 6/1) loam, olive gray (5Y 5/2) moist; common light mottles of olive brown (2.5Y 5/6) moist; massive; hard when dry, friable when moist, sticky and plastic when wet; moderately alkaline; violent effervescence; abrupt, wavy boundary.

IIC3—25 to 60 inches, light yellowish-brown (2.5Y 6/4) coarse sand and gravel; light olive brown (2.5Y 5/4) moist; single grain; loose; slight effervescence.

The soil ranges from 15 to 25 inches in depth to sand and gravel. The A1 horizon ranges from 5 to 12 inches in thickness, is very dark gray or black in color, and is loam in texture. The Cca horizon ranges from 10 to 20 inches in thickness, is gray, olive gray, or dark gray in color, and is loam in texture. The IIC horizon is light olive-brown or grayish-brown sand and gravel.

Benoit soils are associated with Divide, Lehr, and Renshaw soils. They are not so well drained as Divide soils, and they are more poorly drained than Lehr and Renshaw soils.

Benoit loam (0 to 2 percent slopes) (Bn).—This soil is in low depressions and channels on glacial outwash plains. The areas are small in size and irregular in shape.

Included with this soil in mapping were a few small areas of very poorly drained Colvin soils.

This soil is well suited to grass and wetland vegetation. Some areas are cultivated, but wetness hinders farming operations. The water table at or near the surface is the main concern of management. Capability unit IVw-4L; windbreak group 2; Subirrigated range site.

Bowbells Series

The Bowbells series consists of deep, level and gently sloping, moderately well drained soils that formed in glacial till and local alluvium derived from the till. These soils are on upland till plains. Slopes range from 0 to 5 percent and are plane or concave.

In a representative profile, the surface layer is very dark brown loam about 6 inches thick. The subsoil is very dark grayish-brown, friable clay loam about 17 inches thick. The underlying material, to a depth of 36 inches, is friable, calcareous, light olive-brown loam. Below this, it is firm, olive-brown loam glacial till.

Permeability is moderate to a depth of about 36 inches and moderately slow below that depth. The available water capacity is high. Organic-matter content is high, and fertility is high. These soils receive additional moisture from snow accumulation and runoff from adjacent slopes.

Bowbells soils are well suited to cultivated crops; grass, and trees. Most areas are used for crops.

Representative profile of Bowbells loam, gently sloping, in an area of native grass, 2,040 feet south and 365 feet west of the northeast corner of sec. 32, T. 151 N., R. 85 W.

A1—0 to 6 inches, dark-gray (10YR 4/1) loam, very dark brown (10YR 2/2) moist; weak, medium, prismatic structure parting to strong, fine, granular structure; slightly hard when dry, friable when moist, slightly sticky and plastic when wet; many roots; neutral; clear, wavy boundary.

B2t—6 to 23 inches, dark grayish-brown (10YR 4/2) clay loam, very dark grayish brown (10YR 3/2) moist; moderate, medium, prismatic structure parting to strong, medium, angular blocky structure; very dark brown, moderate clay films on faces of peds in the upper part; hard when dry, friable when moist, sticky and plastic when wet; common roots; neutral; gradual boundary.

C1ca—23 to 36 inches, light brownish-gray (2.5Y 6/2) loam, light olive brown (2.5Y 5/3) moist; weak, medium, subangular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; common roots; much segregated lime; moderately alkaline; gradual boundary.

C2—36 to 60 inches, grayish-brown (2.5Y 5/2) loam, olive brown (2.5Y 4/3) moist; weak, fine, subangular blocky structure; firm when moist; few roots; moderately alkaline; slight effervescence.

The solum ranges from 20 to more than 30 inches in thickness. The A1 horizon ranges from 6 to 12 inches in thickness and is neutral or mildly alkaline. It is very dark brown or black in color and is loam or clay loam in texture. The B2t horizon ranges from 10 to 18 inches in thickness, is very dark grayish brown in color, and is clay loam or loam in texture. It has moderate or strong, prismatic structure parting to moderate or strong, angular or subangular blocky structure. The C horizon is light olive brown, olive brown, or grayish brown in color and is loam in texture. It has a large amount of lime in the upper part and a small amount in the lower part.

Bowbells soils are associated with Max and Williams soils. They have thicker A and B horizons and are deeper to lime than Max and Williams soils.

Bowbells loam, gently sloping (2 to 5 percent slopes) (BoB).—This soil is in swales and along drainageways on till plains and morainic hills. The areas are small. This soil has the profile described as representative for the series.

Included with this soil in mapping were a few areas of soils that are more strongly sloping.

Surface runoff is medium, and the hazard of erosion is slight. Soil material washed from higher areas accumulates on the surface in places.

This soil is well suited to crops, grass, and trees. Conserving moisture and maintaining fertility are the main concerns of management, but controlling erosion along swales is also a concern in places. Capability unit IIe-6; windbreak group 1; Silty range site.

Bowbells-Parnell complex (0 to 5 percent slopes) (Bp).—This complex consists of nearly level and gently sloping soils in swales and depressions on till plains. The areas are small in size. Bowbells loam makes up about 75 to 90 percent of the complex, and Parnell silty clay loam 10 to 25 percent. The Bowbells soil is on the concave side slopes and the upper parts of swales. The Parnell soil is in the deeper depressions.

Included with this complex in mapping were a few areas of Hamerly loam and Williams loam. Also included were a few areas where slopes are 5 to 9 percent. The slopes in these areas are short.

Surface runoff is medium, and the hazard of erosion is slight.

Part of the acreage is cultivated, and part is in native grass. The Bowbells soil is well suited to crops, grass, and trees. The Parnell soil is better suited to wetland grasses and wildlife habitat than to other uses. Controlling flooding caused by runoff in the lower areas and conserving moisture and maintaining fertility in the higher areas are the concerns of management in cultivated areas. Capability unit IIe-6; Bowbells part in windbreak group 1, Parnell part in windbreak group 2; Bowbells part in Silty range site, Parnell part in Wetland range site.

Bowbells-Tonka loams (0 to 2 percent slopes) (Br).—This complex consists of nearly level soils in shallow swales on the till plains. The areas are small and medium in size and irregular in shape. Bowbells loam makes up about 75 to 90 percent of the complex; and Tonka silt loam about 10 to 25 percent. The Bowbells soil is better drained and is on the higher parts of the swales and concave depressions, and the Tonka soil is in the low depressions that are flooded by water from adjacent areas part of the time.

Included with this complex in mapping were a few small areas of Hamerly loam around the rims of the depressions and of Parnell silty clay loam in the center of some depressions.

Surface runoff is slow, and the hazard of erosion is slight.

This complex is well suited to crops, grass, and trees. Wetness caused by runoff from higher lying soils is one of the main concerns of management. Conserving moisture and maintaining fertility are of less concern. Capability unit IIc-6; Bowbells part in windbreak group 1, Tonka part in windbreak group 2; Bowbells part in Silty range site, Tonka part in Wetland range site.

Bowbells-Williams complex, nearly level (0 to 3 percent slopes) (BtA).—This complex consists of mildly undulating soils in relatively smooth areas on till plains. The areas are large. Slopes are concave and convex, and there is only a few feet of relief. Bowbells loam makes up about 50 to 75 percent of the complex, and Williams loam about 25 to 50 percent. The Bowbells soil has concave slopes, and the Williams soil has convex slopes.

Included with this complex in mapping were a few small areas of Hamerly loam, Tonka silt loam, and Parnell silty clay loam.

Surface runoff is slow, and the hazard of erosion is slight.

This complex is well suited to crops, grass, and trees. Most areas are cultivated. Conserving moisture and maintaining fertility are the main concerns of management. Capability unit IIc-6; Bowbells part in windbreak group 1, Williams part in windbreak group 3; Silty range site.

Buse Series

The Buse series consists of deep, rolling and hilly, well-drained soils that formed in glacial till. These soils are on upland till plains. The slopes range from 6 to 20 percent and are convex.

In a representative profile, the surface layer is very dark grayish-brown loam about 6 inches thick. The underlying material is friable, calcareous loam glacial till. It is dark grayish brown to a depth of about 18 inches, and below this, it is olive brown.

Permeability is moderate to a depth of about 18 inches and is moderately slow below that depth. The available water capacity is high. Organic-matter content is moderately low, and fertility is medium.

Buse soils are better suited to grass and legumes than to other crops.

Representative profile of Buse loam, in an area of Buse-Barnes loams, rolling, on the crest of a knoll in a cultivated field, 2,160 feet west and 200 feet south of the northeast corner of sec. 33, T. 156 N., R. 83 W.

Ap—0 to 6 inches, grayish-brown (2.5Y 5/2) loam, very dark grayish brown (2.5Y 3/2) moist; moderate, fine, granular structure; friable when moist; moderately alkaline; strong effervescence; clear, smooth tillage boundary.

Clca—6 to 18 inches, light browish-gray (2.5Y 6/2) loam, dark grayish brown (2.5Y 4/2) moist; weak, medium, subangular blocky structure; friable when moist; many root pores; much segregated lime; moderately alkaline; violent effervescence; gradual boundary.

C2—18 to 60 inches, light brownish-gray (2.5Y 6/2) loam, olive brown (2.5Y 4/3) moist; weak, fine, subangular blocky structure; friable when moist; few root pores; moderately alkaline; strong effervescence in upper part and slight in lower part.

The A horizon ranges from 4 to 9 inches in thickness and is mildly alkaline or moderately alkaline. It is black in grassland and very dark gray or very dark grayish brown in cultivated areas. The C horizon is dark grayish brown, grayish brown, or olive brown in color and loam in texture. It has a large amount of lime in the upper part. Stones or boulders are throughout the profile, and in places many stones are in the A horizon.

Buse soils are associated with Barnes and Svea soils. They lack a B2 horizon and are not so deep to lime and glacial till as Barnes and Svea soils. They have a profile similar to that of the Zahl soils, but they have a black A1 horizon in grassland and are moist for a longer period of time.

Buse loam, hilly (9 to 15 percent slopes) (BuE).—This soil is on hilltops and slope breaks. The areas are small and irregularly shaped.

Included with this soil in mapping were a few small areas of Barnes loam and a few small areas of soils that are less sloping or more strongly sloping.

Surface runoff is rapid, and the hazard of erosion is severe.

This soil is better suited to grass than to other crops. Control of erosion is a serious concern of management if the soil is cultivated. Capability unit VIe-TSi; windbreak group 8; Thin Silty range site.

Buse-Barnes loams, rolling (6 to 9 percent slopes) (BvC).—This complex is on hilltops and crests of slopes. Buse loam makes up about 60 to 75 percent of the complex, and Barnes loam about 25 to 40 percent. The Buse soil is more strongly sloping and is on the upper part of slopes. The Barnes soil has plane slopes and is below areas of the Buse soil.

Buse loam in this complex has the profile described as representative for the Buse series. The profile of Barnes loam in this complex is similar to the one described as representative for the Barnes series, except that the surface layer and subsoil are thinner and lighter colored.

In cultivated fields the limy subsoil material is exposed at the surface. Tillage has mixed part of the subsoil and underlying material with the remaining surface layer in about 25 percent of the cultivated areas. Runoff is moderate or rapid, and erosion is a hazard.

Most areas of this complex are cultivated. Crop growth is not so favorable as it is on Barnes loam, level, or Barnes loam, gently sloping. Controlling erosion, maintaining fertility, and conserving moisture are serious concerns of management. Capability unit IVe-4L; Buse part in windbreak group 8, Barnes part in windbreak group 3; Buse part in Thin Silty range site, Barnes part in Silty range site.

Buse-Barnes loams, hilly (10 to 20 percent slopes) (BvE).—This complex is on sides and crests of slopes that break to the outwash valleys. Buse loam makes up about 50 to 75 percent of the complex, and Barnes loam about 25 to 40 percent. The rest of the complex is Svea loam. The Buse soil is more strongly sloping and has convex slopes. The Barnes soil has plane slopes and is below the Buse soil, and the Svea soil has concave slopes and is on fans and swales.

The profile of the Barnes soil is similar to the one described as representative for the Barnes series, except that it has a slightly thinner surface layer and subsoil.

Runoff is rapid, and the hazard of erosion is very severe.

This complex is better suited to grass than to other crops. Most of the acreage is in native grass. It is not suited to crops, because erosion is rapid if the soil is cultivated. Capability unit VIe-TSi; Buse part in windbreak group 8, Barnes part in windbreak group 3; Buse part in Thin Silty range site, Barnes part in Silty range site.

Colvin Series

The Colvin series consists of deep, level, poorly drained soils that formed in glacio-lacustrine material. These soils are on glacio-lacustrine plains and glacial outwash plains. Slopes are plane or slightly concave.

In a representative profile, the surface layer is black silt loam about 6 inches thick. The underlying material, to a depth of 40 inches, is friable silt loam that is high in lime. It is very dark gray in the upper part and olive and olive brown in the lower part. Below this, the underlying material is gray and olive-brown silty clay loam.

Permeability is moderate. The available water capacity is high. Organic-matter content is high, and fertility is high. These soils have a water table at or near the surface much of the time.

Most areas of Colvin soils are in grass.

Representative profile of Colvin silt loam, 30 feet north of the southwest corner of sec. 31, T. 157 N., R. 82 W.

A1—0 to 6 inches, very dark gray (10YR 3/1) silt loam, black (10YR 2/1) moist; strong, very fine, granular structure; friable when moist; many roots; much diffused lime; moderately alkaline; violent effervescence; clear, irregular boundary; tongues of this layer extend to a depth of 15 inches.

ACca—6 to 10 inches, gray (2.5Y 5/1) silt loam, very dark gray (2.5Y 3/1) moist; moderate, fine, subangular blocky structure; friable when moist; many roots; much disseminated lime; moderately alkaline; violent effervescence; clear, irregular boundary.

C1ca—10 to 28 inches, light-gray (5Y 7/1) silt loam, olive (5Y 5/3) moist; moderate, fine, subangular blocky structure; friable when moist, sticky and plastic when wet; common roots; much disseminated lime; moderately alkaline; violent effervescence; gradual, wavy boundary.

C2—28 to 40 inches, light yellowish-brown (2.5Y 6/3) silt loam, olive brown (2.5Y 4/3) moist; massive; friable when moist; few root pores; moderately alkaline; strong effervescence; gradual boundary.

IIC3—40 to 60 inches, light-gray and light olive-brown (5Y 6/1 and 2.5Y 5/6) silty clay loam, gray and olive brown (5Y 5/1 and 2.5Y 4/4) moist; laminated; firm when moist; moderately alkaline; slight effervescence.

The A1 horizon ranges from 6 to 15 inches in thickness, is very dark gray or black in color, and is silt loam or silty clay loam in texture. The Cca horizon ranges from 10 to 25 inches in thickness, is olive or dark gray in color, and is silt loam or silty clay loam in texture. It has a hue of 5Y, 2.5Y, or is N/O and contains a few mottles in places. The C horizon is silt loam or silty clay loam in texture to a depth of more than 40 inches. Coarser textured material is below a depth of 40 inches in places.

Colvin soils are associated with Lamoure soils. They have a Cca horizon at a shallower depth than the Lamoure soils. Colvin soils have a profile similar to those of the Arveson, Benoit, and Vallers soils. They have a solum that contains more silt and less sand than Arveson and Vallers soils. They do not have the substratum of sand and gravel that is in the Benoit soils.

Colvin silt loam (0 to 2 percent slopes) (Co).—This soil is in the lower parts of glacial lake basins, drainageways, and outwash channels. The areas are small. It has the profile described as representative for the series.

Included with this soil in mapping were a few areas of wetter soils.

Water is near the surface of this soil most of the time. This soil receives runoff and seepage from adjacent areas.

Most areas of this soil are in native grass. This soil is better suited to wetland grasses than to other uses. Capability unit IVw-4L; windbreak group 2; Subirrigated range site.

Colvin silty clay loam, very poorly drained (0 to 1 percent slopes) (Cv).—This soil is in the lowest parts of some glacial lake basins and drainageways on outwash plains. The areas are small. It has a profile similar to that described as representative for the series, except that the surface layer is silty clay loam and is a little thicker.

The water table is above the surface of this soil longer than on Colvin silt loam. It remains ponded in places throughout the growing season if rainfall is above normal.

This soil is not suited to cultivated crops, but it is well suited to grass and wetland vegetation. Capability unit Vw-WL; windbreak group 10; Wetland range site.

Divide Series

The Divide series consists of level, somewhat poorly drained soils that formed in loamy material underlain by sand and gravel at a depth of 15 to 30 inches. These soils are on outwash plains.

In a representative profile, the surface layer is black loam about 8 inches thick. The underlying material, to a depth of about 24 inches, is grayish-brown loam in the upper part and grayish-brown gravelly sandy loam in the lower part. Below this, it is olive-gray coarse sand and gravel.

Permeability is moderate to a depth of about 16 inches, moderately rapid to a depth of about 24 inches, and very rapid below that depth. The available water capacity is low. Organic-matter content is moderate, and fertility is medium. These soils have a seasonally high water table that is a slight limitation to their use for crops.

Most areas of Divide soils are used for crops.

Representative profile of Divide loam, on a level outwash plain in a cultivated field, 2,335 feet north and 115 feet west of the southeast corner of sec. 3, T. 155 N., R. 81 W.

Ap—0 to 8 inches, very dark gray (10YR 3/1) loam, black (10YR 2/1) moist; strong, fine, granular structure; friable when moist; many roots; moderately alkaline; strong effervescence; clear, smooth tillage boundary.

C1ca—8 to 16 inches, gray (2.5Y 5/1) loam, grayish brown (2.5Y 4/2) moist; weak, fine, subangular blocky structure; friable when moist; common roots; much disseminated lime; moderately alkaline; violent effervescence; clear, smooth boundary.

IIC2ca—16 to 24 inches, light-gray (5Y 6/1) gravelly sandy loam, grayish brown (2.5Y 5/2) moist; single grain; loose; few roots; lime coatings on pebbles; moderately alkaline; gradual boundary.

IIC3—24 to 60 inches, light olive-gray (5Y 6/2) coarse sand and gravel; olive gray (5Y 5/2) moist; single grain; loose; strong effervescence.

The soil ranges from 15 to 30 inches in depth to sand and gravel. The A1 horizon ranges from 5 to 12 inches in thickness, is very dark gray or black in color, and is loam in texture. The Cca horizon ranges from 8 to 18 inches in thickness. It is grayish-brown, dark-gray, or gray loam in the upper part and is coarse loam, sandy loam, or gravelly sandy loam in the lower part. The IIC horizon is olive-gray or olive-brown sand and gravel. In a few places, loam glacial till is below the sand and gravel at a depth ranging from 48 to 60 inches.

Divide soils are associated with Benoit, Lehr, and Renshaw soils. They are better drained than Benoit soils and are not so well drained as Lehr and Renshaw soils.

Divide loam (0 to 2 percent slopes) (Dd).—This soil is on outwash plains. The areas are small.

Included with this soil in mapping were a few small areas of Renshaw loam and Lehr loam.

A high water table may delay cultivation for a short time in spring and after above normal rainfall. Soil blowing and lack of moisture are moderate hazards.

This soil is suited to crops, grass, and trees. Conserving moisture, maintaining fertility, and controlling soil blowing are concerns of management. Capability unit IIIs-5; windbreak group 1; Silty range site.

Egeland Series

This series consists of deep, level to undulating, well-drained soils that formed in moderately coarse textured or coarse textured material. These soils are on outwash plains. Slopes range from 0 to 6 percent and are convex.

In a representative profile, the surface layer is very dark gray fine sandy loam about 6 inches thick. The subsoil is about 18 inches thick. It is very dark grayish-brown, very friable sandy loam in the upper part and brown, loose loamy sand in the lower part. The underlying material is light olive-brown fine sandy loam.

Permeability is moderately rapid. The available water capacity is moderate. Organic-matter content is moderate, and fertility is medium. Soil blowing is a hazard.

Egeland soils are suited to cultivated crops, grasses, and trees.

Representative profile of Egeland fine sandy loam, undulating, in a cultivated field, 2,600 feet south and 400 feet west of the northeast corner of sec. 11, T. 155 N., R. 81 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) fine sandy loam, very dark gray (10YR 3/1) moist; weak, very fine, granular structure; very friable when moist, nonsticky and nonplastic when wet; many roots; neutral; clear, smooth boundary.

B2—6 to 15 inches, dark grayish-brown (10YR 4/2) sandy loam, very dark grayish brown (10YR 3/2) moist; weak, coarse, prismatic structure; very friable when moist; many roots; neutral; clear, wavy boundary.

B3—15 to 24 inches, grayish-brown (10YR 5/2) loamy sand, brown (10YR 4/3) moist; single grain; loose; common roots; neutral; clear, wavy boundary.

C1ca—24 to 40 inches, light brownish-gray (2.5Y 6/2) fine sandy loam, light olive brown (2.5Y 5/3) moist; weak, fine, granular structure; very friable when moist; few roots; much lime flour; moderately alkaline; violent effervescence; gradual boundary.

C2—40 to 60 inches, pale-yellow (2.5Y 7/3) fine sandy loam, light olive brown (2.5Y 5/3) moist; massive; very friable when moist; moderately alkaline; slight effervescence.

The solum ranges from 16 to 24 inches in thickness. The A1 horizon ranges from 5 to 8 inches in thickness, is very dark gray or black in color, and is sandy loam or fine sandy loam in texture. The B2 horizon ranges from 8 to 16 inches in thickness, is very dark grayish brown or dark brown in color, and is sandy loam or fine sandy loam in texture. In some places loamy sand or loamy fine sand is in the lower part of the B horizon. The C horizon is olive brown or light olive brown in color and fine sandy loam or loamy fine sand in texture. In places loam-textured glacial till is within a depth of 48 inches.

Egeland soils are associated with Embden soils. They have a thinner A1 horizon and are not so deep to lime as Embden soils.

Egeland fine sandy loam, undulating (3 to 6 percent slopes) (EcB).—This soil is on outwash plains and glacial lake plains. The slopes are short and convex. This soil has the profile described as representative for the series.

Included with this soil in mapping were small areas of Embden fine sandy loam and Telfer loamy fine sand. Also included were a few areas of soils that are less sloping or more strongly sloping.

Soil blowing and lack of moisture are moderate hazards. Runoff is slow or moderate.

This soil is suited to crops, grass, and trees. It is better suited to winter rye and alfalfa than to other crops. Controlling soil blowing, conserving moisture, and maintaining fertility are a necessary part of good management. Capability unit IIIe-3; windbreak group 5; Sandy range site.

Egeland fine sandy loam, till substratum, nearly level (0 to 3 percent slopes) (EdA).—This soil is on the sand-mantled till plain adjacent to glacial lake plains and outwash plains. The areas are small, and slopes are convex. The profile of this soil is similar to that described as representative for the series, except that the underlying material is loam-textured glacial till at a depth ranging from 24 to 48 inches.

Soil blowing is the main hazard.

This soil is well suited to crops, grass, and trees. Controlling soil blowing, conserving moisture, and maintaining fertility are necessary for good management. Capability unit IIIe-3M; windbreak group 5; Sandy range site.

Embden Series

The Embden series consists of deep, level, moderately well drained soils that formed in moderately coarse textured or coarse textured material. These soils are on outwash plains. The slopes range from 0 to 2 percent. They are plane and slightly concave.

In a representative profile, the surface layer is black fine sandy loam about 16 inches thick. The subsoil is very dark brown and very dark grayish-brown friable fine sandy loam about 16 inches thick. The underlying material, to a depth of about 48 inches, is dark-gray fine sandy loam that is high in lime. Below this, it is olive-gray fine sandy loam.

Permeability is moderately rapid. The available water capacity is moderate. Organic-matter content is high, and fertility is medium. Soil blowing is a hazard.

Most areas of Embden soils are used for crops. These soils are well suited to small grains, grass, legumes, and trees.

Representative profile of Embden fine sandy loam, on a slightly concave flat, in a cultivated field, 2,340 feet east and 1,175 feet north of the southwest corner of sec. 22, T. 155 N., R. 82 W.

Ap—0 to 8 inches, dark-gray (10YR 4/1) fine sandy loam, black (10YR 2/1) moist; weak, very fine, crumb structure; soft when dry, very friable when moist, nonsticky and nonplastic when wet; neutral; clear, smooth boundary.

A12—8 to 16 inches, dark-gray (10YR 4/1) fine sandy loam, black (10YR 2/1) moist; weak, subangular blocky structure; very friable when moist; many root pores; neutral; gradual boundary.

B21—16 to 24 inches, dark grayish-brown (10YR 4/2) fine sandy loam, very dark brown (10YR 2/2) moist; weak, coarse, prismatic structure; friable when moist; common root pores; neutral; gradual boundary.

B22—24 to 32 inches, grayish-brown (10YR 5/2) fine sandy loam, very dark grayish brown (10YR 3/2) moist; coarse, prismatic structure; friable when moist; common root pores; neutral; clear, wavy boundary.

C1ca—32 to 48 inches, light-gray (2.5Y 7/1) fine sandy loam, dark gray (2.5Y 4/1) moist; massive; friable when moist; few root pores; diffuse lime; moderately alkaline; violent effervescence; gradual boundary.

C2—48 to 60 inches, gray (5Y 6/1) fine sandy loam, olive gray (5Y 5/2) moist; massive; friable when moist; slight effervescence.

The solum ranges from 20 to 36 inches in thickness. The A1 horizon ranges from 8 to 16 inches in thickness, is very dark gray or black in color, and is fine sandy loam or very fine sandy loam in texture. The B2 horizon ranges from 10 to 24 inches in thickness, is very dark brown or very dark grayish brown in color, and is fine sandy loam in texture. The C horizon is dark gray, olive gray, dark grayish brown, or olive brown in color and is fine sandy loam or loamy fine sand in texture. This horizon has a moderate to large amount of lime in the upper part and a small amount in the lower part.

Embden soils are associated with Egeland soils. They have a thicker A1 horizon and are deeper to lime than Egeland soils. They are similar to Emrick soils, but they contain more sand and less silt and very fine sand in the B and C horizons.

Embden fine sandy loam (0 to 2 percent slopes) (Em).—This soil is in plane and concave areas of glacial lake plains and outwash plains.

Included with this soil in mapping were small areas that have loam-textured glacial till in the substratum. Also included were a few small areas of Egeland fine sandy loam.

The hazard of soil blowing is moderate.

This soil is well suited to crops, grass, and trees. Most areas are cultivated. Controlling soil blowing is the main concern of management. Capability unit IIIe-3; windbreak group 1; Sandy range site.

Emrick Series

The Emrick series consists of deep, level, moderately well drained soils that formed in water-worked glacial till. These soils are on till plains. Slopes range from 0 to 2 percent and are plane or slightly concave.

In a representative profile, the surface layer is black loam about 7 inches thick. The subsoil is very dark grayish-brown friable loam about 10 inches thick. The underlying material, to a depth of about 36 inches, is olive-brown friable loam that is high in lime. Below this, it is olive, firm loam glacial till.

Permeability is moderate. The available water capacity is high. Organic-matter content is high, and fertility is high. These soils are susceptible to soil blowing.

Most areas of Emrick soils are used for crops. These soils are well suited to small grains, grass, legumes, and trees.

Representative profile of Emrick loam, in an area of Emrick-Heimdal loams, level, in a cultivated field, 1,560 feet east and 80 feet north of the southwest corner of sec. 1, T. 155 N., R. 81 W.

Ap—0 to 7 inches, dark-gray (10YR 4/1) loam, black (10YR 2/1) moist; moderate, fine, granular structure; friable when moist; neutral; clear, smooth boundary.

B2—7 to 17 inches, dark grayish-brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; weak, medium, prismatic structure parting to moderate, fine, subangular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; many root pores; neutral; clear, wavy boundary.

Cca—17 to 36 inches, light brownish-gray (2.5Y 6/2) loam, olive brown (2.5Y 4/3) moist; weak, fine, subangular blocky structure; friable when moist; common root pores; soft segregations of lime; moderately alkaline; violent effervescence; gradual boundary

C—36 to 60 inches, light olive-gray (5Y 6/2) loam, olive (5Y 4/3) moist; massive; firm when moist; slight effervescence.

The solum ranges from 16 to 30 inches in thickness. The A1 horizon ranges from 7 to 12 inches in thickness, is very dark gray or black in color, and is loam, silt loam, or very fine sandy loam in texture. The B2 horizon ranges from 8 to 20 inches in thickness, is very dark brown or very dark grayish brown in color, and is loam in texture. It has weak or moderate, prismatic and blocky structure. The Cca horizon is olive brown or grayish brown in color and is loam or a mixture of loam and fine sandy loam in texture. It has few to many soft lime masses. The horizon grades to firm, loam-textured till that contains more clay at a depth of about 30 to 48 inches.

Emrick soils are associated with Heimdal soils. Typically, they have a thicker A1 horizon and solum than Heimdal soils. They are similar to Svea soils, but they contain less clay and more silt and very fine sand in the B and C horizons.

Emrick-Heimdal loams, level (0 to 2 percent slopes) (ErA). This complex is characterized by shallow depressions and convex slopes that have less than 5 feet relief. The areas are in an intricate pattern. Emrick loam makes up about 60 percent of the complex and Heimdal loam, about 30 percent. The remaining 10 percent of the complex is Hamerly loam and small inclusions of Tonka silt loam. The Emrick soil is in level and concave areas, and the Heimdal soil is more sloping and is in areas that have convex slopes.

The Emrick soil has the profile described as representative for the Emrick series.

Soil blowing is the main hazard.

This complex is well suited to crops commonly grown in the county and grass and trees. Most areas are cultivated. Controlling soil blowing is a necessary part of good management, but conserving moisture and maintaining fertility are secondary concerns. Capability unit IIe-5; Emrick part in windbreak group 1, Heimdal part in windbreak group 3; Silty range site.

Fargo Series

The Fargo series consists of deep, level, poorly drained soils that formed in clayey glacial-lake sediment on lake plains.

In a representative profile, the surface layer is black silty clay about 6 inches thick. The subsoil is very dark gray firm silty clay about 12 inches thick. The underlying material, to a depth of about 36 inches, is dark-gray silty clay. Below this, it is olive silty clay.

Permeability is slow. The available water capacity is high. Organic-matter content is high, and fertility is high. These soils have slow or ponded surface drainage.

Fargo soils are suited to small grains if they are not too wet.

Representative profile of Fargo silty clay, in a field of grass on a level lake plain, 900 feet west and 100 feet south of the northeast corner of sec. 13, T. 160 N., R. 87 W.

Ap—0 to 6 inches, very dark gray (10YR 3/1) silt clay, black (10YR 2/1) moist; strong, very fine, granular structure; friable when moist, sticky and plastic when wet; many roots; mildly alkaline; clear, smooth boundary.

B2—6 to 18 inches, gray (10YR 5/1) silty clay, very dark gray (2.5Y 3/1) moist; moderate, medium, angular blocky structure; hard when dry, firm when moist, very sticky and very plastic when wet; many roots; mildly alkaline; clear, irregular boundary.

C1ca—18 to 36 inches, gray (5Y 6/1) silty clay, dark gray (5Y 4/1) moist; weak, medium, angular blocky structure; firm when moist; common roots; diffused lime and gypsum; moderately alkaline; strong effervescence; gradual boundary.

C2—36 to 60 inches, olive-gray (5Y 5/2) silty clay, olive (5Y 4/3) moist; massive; firm when moist; few roots; moderately alkaline; slight effervescence.

The A1 horizon ranges from 5 to 10 inches in thickness, is very dark gray or black in color, and is silty clay or silty clay loam in texture. The B2 horizon ranges from 8 to 18 inches in thickness, is very dark gray in color, and is silty clay or clay in texture. The C horizon is dark gray, olive, or olive gray in color and is silty clay or clay in texture. It has slight to strong effervescence and contains lime disseminated or in soft masses. In some places the C horizon contains gypsum crystals, and varving is evident.

Fargo soils are associated with Hegne and Overly soils. They have a B horizon, and have a Cca horizon at a greater depth than Hegne soils. They contain more clay throughout than Overly soils.

Fargo silty clay (0 to 1 percent slopes) (Fc).—This soil is in a few areas on glacial lake plains. The areas are large.

Included with this soil in mapping were a few small areas of Hegne silty clay.

Surface runoff is very slow. Water ponds on the surface for a few days after rain. In some years water from snow melting causes spring floods on this soil. Soil blowing is a severe hazard in spring and fall in summer-fallowed fields.

Most areas of this soil are used for crops if the soil is not too wet. It is suited to crops and grasses. Controlling soil blowing and removing surface water are the main concerns of management. Capability unit IIws-4; windbreak group 2; Clayey range site.

Freshwater Marsh

Freshwater marsh (Fw) is in deep, closed depressions on uplands and outwash plains and in basins and channels on stream flood plains. The underlying material in this land type is glacial till, local alluvium, postglacial stream alluvium, and lake sediment.

Included with this land type in mapping were the marshes in the Upper Souris National Wildlife Refuge.

This land type is covered by water most of the time. Cattails, sedges, and rushes grow along the margins where the water is shallow, and open water is in the center.

These areas are better suited to wildlife habitat than to other uses. Capability unit VIIIw; not placed in a windbreak group; not placed in a range site.

Gravel Pits

Gravel pits (Gp) are excavated areas from which the soil material has been removed to mine the underlying sand and gravel. This land type consists of irregularly shaped pits and dumps that are mostly barren. Sand, stones, and other waste material are exposed at the surface. This land type is in areas of Arvilla, Lehr, Manning, Sioux, or Wabek soils.

It is not suited to grass or other uses unless it is leveled and soil placed on it. Capability unit VIIIe; not placed in a windbreak group; not placed in a range site.

Hamerly Series

The Hamerly series consists of deep, level and undulating, moderately well drained soils that formed in glacial till. These soils are adjacent to intermittently ponded closed depressions. Slopes are 1 to 5 percent.

In a representative profile, the surface layer is very dark gray loam about 7 inches thick. The underlying material, to a depth of about 24 inches, is light yellowish-brown and olive friable loam that is high in lime. Below this, it is olive firm loam.

Permeability is moderately slow. The available water capacity is high. Organic-matter content is moderate, and fertility is high. These soils have a seasonally perched water table that delays tillage.

Hamerly soils are suited to small grains, grass, legumes, and trees.

Representative profile of Hamerly loam, on a slight rise between two depressions in a cultivated field, 550 feet south and 150 feet east of the northwest corner of sec. 32, T. 156 N., R. 83 W.

Ap—0 to 7 inches, gray (10YR 5/1) loam, very dark gray (10YR 3/1) moist; strong, fine, granular structure; friable when moist; moderately alkaline; strong effervescence; clear, smooth boundary.

C1ca—7 to 15 inches, light-gray (2.5Y 7/2) loam, light yellowish brown (2.5Y 6/3) moist; weak, fine, granular structure; hard when dry, friable when moist, sticky and plastic when wet; many root pores; disseminated lime; moderately alkaline; violent effervescence; gradual boundary.

C2ca—15 to 24 inches, light-gray (5Y 7/2) loam, olive (5Y 5/3) moist; weak, fine, subangular blocky structure; friable when moist; common root pores; moderately alkaline; violent effervescence; gradual boundary.

C3—24 to 60 inches, light olive-gray (5Y 6/1) loam, olive (5Y 4/3) moist; common, medium, prominent, light olive-brown mottles; massive; hard when dry, firm when moist, sticky and plastic when wet; moderately alkaline; strong effervescence.

The A horizon ranges from 5 to 10 inches in thickness, is very dark gray or black in color, and is loam in texture. It contains a small amount of lime in some places and a large amount in others. the Cca horizon ranges from 8 to 18 inches in thickness, is light yellowish brown, light olive brown, olive brown or olive in color, and loam or clay loam in texture. Most of the lime in this horizon is disseminated, but some is in small and large, soft accumulations. Gypsum and other salts are in the Cca horizon in places. The C1ca horizon is underlain by an olive or olive-brown C horizon that has few to many gray, light olive-brown, or yellowish-brown mottles.

Hamerly soils are associated with Barnes, Parnell, Svea, Tonka, Vallers, and Williams soils. Hamerly soils are more poorly drained than the Barnes, Svea, and Williams soils. They are better drained than the Vallers soils. They contain less clay throughout and are better drained than Parnell and Tonka soils.

Hamerly loam (0 to 5 percent slopes) (Hf).—This soil is in areas around rims of potholes and in low swales between them. The areas are small in size and irregular in shape.

Included with this soil in mapping were small areas of Parnell, Svea, Tonka, and Vallers soils. These inclusions make up 10 to 20 percent of the area.

Surface runoff is slow or medium. If these soils are cultivated, soil blowing and an increase in the amount of soluble salt in the surface layer are moderate hazards.

This soil is suited to crops, grass, and trees. Most areas are cultivated. Controlling soil blowing, removing surface water in low areas, preventing the increase of salts in the surface layer, and maintaining fertility are concerns of management. Capability unit IIe-4L; windbreak group 3; Silty range site.

Harriet Series

The Harriet series consists of deep, level, poorly drained soils that formed in saline-alkaline alluvium. These soils are on flood plains.

In a representative profile, the surface layer is very dark gray loam 1 inch thick. The subsoil is strongly alkaline, very dark brown and very dark grayish-brown, very firm clay loam about 9 inches thick. The underlying material is dark grayish-brown silt loam that grades, at a depth of about 16 inches, to olive loam. This underlying material is high in lime and other salts.

Permeability is slow. The available water capacity is low. Organic-matter content is moderate, and fertility is medium.

Harriet soils are better suited to grass than to crops. Management is difficult if these soils are used for crops.

Representative profile of Harriet loam, from an area of Harriet complex, in an area of native grass, 200 feet south and 100 feet west of the northeast corner of sec. 10, T. 154 N., R. 82 W.

A2—0 to 1 inch, gray (10YR 6/1) loam, very dark gray (10YR 3/1) moist; strong, very fine, granular structure; friable when moist; many roots; moderately alkaline; abrupt, smooth boundary.

B21t—1 to 4 inches, dark-gray (10YR 4/1) clay loam, very dark brown (10YR 2/2) moist; strong, fine, columnar structure; extremely hard when dry, very firm when moist, sticky and plastic when wet; common roots; strongly alkaline; clear, wavy boundary.

B22sa—4 to 10 inches, dark grayish-brown (10YR 4/2) clay loam, very dark grayish brown (10YR 3/2) moist; moderate, medium, prismatic structure parting to moderate, medium, angular blocky structure; very firm when moist; few roots; many fine white salt specks when dry; strongly alkaline; slight effervescence; clear, wavy boundary.

C1ca—10 to 16 inches, light brownish-gray (2.5Y 6/2) silt loam, dark grayish brown (2.5Y 4/2) moist; weak, medium, subangular blocky structure; friable when moist; few roots; strongly alkaline; violent effervescence; gradual boundary.

C2—16 to 60 inches, light olive-gray (5Y 6/2) loam; olive (5Y 4/3) moist; massive; friable; stratified in lower part; slight effervescence.

The solum ranges from 10 to 18 inches in thickness and is moderately alkaline or strongly alkaline. The A horizon ranges from 1 to 5 inches in thickness. In some places it is black in the upper part and very dark gray in the lower part. It is loam or silt loam in texture. The B2 horizon ranges from 6 to 16 inches in thickness, is very dark gray, very dark brown, or very dark grayish brown in color, and is clay loam in texture. It has moderate or strong, columnar or prismatic structure and firm or very firm consistence. It contains few to many salt crystals in the lower part. The C horizon is dark grayish-brown, dark-gray, or olive loam, silt loam, clay loam, or stratified layers of these.

Harriet soils are associated with Vallers and Velva soils. They contain more clay in the B horizon than Vallers soils. They are more poorly drained than Velva soils.

Harriet complex (0 to 2 percent slopes) (Hh).—This complex is on bottom lands along streams. The areas are small. Harriet loam and Harriet clay loam make up about 60 to 90 percent of the complex and Harriet loam, strongly saline or Harriet clay loam, strongly saline, make up about 10 to 25 percent. The Harriet loam in this complex has the profile described as representative for the series. A few small inclusions of Velva loam make up less than 15 percent of the complex.

Most areas of this complex are in native grass. These areas are used for pasture and hay. Controlling grazing to prevent the decrease in amount and kind of grass produced is the main concern of management. Capability unit VIs-Cp; windbreak group 9; Claypan range site.

Harriet and Vallers soils, strongly saline (0 to 2 percent slopes) (Hk).—This undifferentiated group is along drainageways and adjacent to sloughs and salt marshes. The areas are irregular in shape. Some areas are Harriet soils, some are Vallers soils, and some are both soils. Harriet soils are mainly along stream valleys, and Vallers soils commonly are in low areas around basins on till plains.

The profiles of these soils are similar to those described as representative for their respective series, except that both soils are shallower to underlying material and they contain more salts.

This undifferentiated group is not so well suited to grass as other soils that contain less salts. Most areas are in grass and are used for pasture. Maintaining desirable species of grass is the main concern of management. Capability unit VIs-SSb; windbreak group 9; Saline Subirrigated range site.

Hegne Series

The Hegne series consists of deep, level, poorly drained soils that formed in clayey glacial lake sediments on lake plains.

In a representative profile, the surface layer is very dark gray silty clay about 6 inches thick. The underlying material, to a depth of about 28 inches, is dark-gray firm silty clay that is high in lime. Below this, it is dark-gray clay.

Permeability is slow. The available water capacity is high. Organic-matter content is moderate, and fertility is high. These soils have slow surface drainage and are slightly saline in some places.

Hegne soils are suited to small grains if they are not too wet.

Representative profile of Hegne silty clay, on a level lake plain in a cultivated field, 1,580 feet east and 150 feet north of the southwest corner of sec. 6, T. 155 N., R. 87 W.

Ap—0 to 6 inches, dark-gray (2.5Y 4/1) silty clay, very dark gray (2.5Y 3/1) moist; strong, very fine, granular structure; friable when moist; moderately alkaline; strong effervescence; clear, smooth boundary.

Cca—6 to 28 inches, gray (2.5Y 6/1) silty clay, dark gray (2.5Y 4/1) moist; weak, coarse, prismatic structure parting to strong, fine, granular structure; hard when dry, firm when moist, very sticky and very plastic when wet; common root pores; much disseminated lime; moderately alkaline; violent effervescence; gradual boundary.

C—28 to 60 inches, light-gray (5Y 6/1) clay, dark gray (5Y 4/1) moist; massive; firm when moist; few root pores; moderately alkaline; strong effervescence.

The A1 horizon ranges from 5 to 12 inches in thickness and is slightly effervescent or strongly effervescent. It is very dark gray or black in color and silty clay or silty clay loam in texture. The Cca horizon ranges from 10 to 25 inches in thickness, is dark gray or gray in color, and silty clay or clay in texture. It has mainly disseminated lime, but a few soft accumulations are in places. The C horizon is dark gray or olive gray in color and clay or silty clay in texture. In places it has varving or strata of silty clay and clay.

Hegne soils are associated with Fargo, Makoti, Overly, and Sinai soils. They have a Cca horizon at a shallower depth and are more poorly drained than those soils.

Hegne silty clay (0 to 1 percent slopes) (Hr).—This soil is in low areas on lake plains. The areas are small.

Included with this soil in mapping were a few areas of soils that have a moderately saline surface layer.

Soil blowing is a severe hazard in summer-fallowed fields. Water ponds on the smooth surface after rain.

Most areas of this soil are cultivated. This soil is not well suited to crops or trees; it is better suited to grass, Removing surface water and controlling soil blowing are the main concerns of management. Capability unit IIws-4; windbreak group 2; Clayey range site.

Heil Series

The Heil series consists of deep, level, poorly drained soils that formed in clayey saline-alkaline lake sediments on lake plains.

In a representative profile, the surface layer is very dark gray silty clay loam about 6 inches thick. The subsoil is dark-gray firm silty clay about 4 inches thick. The underlying material is olive silty clay. It is strongly alkaline and high in soluble salts to a depth of about 30 inches.

Permeability is very slow. The available water capacity is low. Organic-matter content is moderate, and fertility is medium.

Heil soils are better suited to grass than to crops. Management is difficult if these soils are used for crops.

Representative profile of Heil silty clay loam, from an area of Heil soils on a level lake plain, in a cultivated field, 2,140 feet west and 50 feet north of the southeast corner of sec. 14, T. 151 N., R. 86 W.

Ap—0 to 6 inches, dark-gray (2.5Y 4/1) silty clay loam, very dark gray (2.5Y 3/1) moist; strong, very fine, granular structure; friable when moist; moderately alkaline; clear, smooth boundary.

B2t—6 to 10 inches, gray (2.5Y 5/1) silty clay, dark gray (2.5Y 4/1) moist; strong, medium, columnar structure parting to strong, fine, angular blocky structure; extremely hard when dry, firm when moist, very sticky and very plastic when wet; few root pores; strongly alkaline; clear, wavy boundary.

C1cacs—10 to 30 inches, light olive-gray (5Y 6/2) silty clay, olive (5Y 5/3) moist; firm when moist; few root pores; many gypsum crystals; strongly alkaline; strong effervescence; gradual boundary.

C2—30 to 60 inches, light olive-gray (5Y 6/2) silty clay, olive (5Y 5/3) moist; massive; firm when moist; lenses of silt and sand; moderately alkaline; slight effervescence.

The solum ranges from 10 to more than 20 inches in thickness. The A1 horizon or A1 and A2 horizons range from 1 to 6 inches in thickness, are very dark gray, dark gray, or black in color, and silt loam, silty clay loam, or silty clay in texture. The B2t horizon ranges from 4 to 18 inches in thickness, is dark gray or very dark gray in color, and is silty clay or clay in texture. It has strong, very coarse, coarse, or medium columnar structure. The C horizon is olive, light olive gray, or gray in color and silty clay in texture. It is strongly alkaline in the upper part and moderately alkaline in the lower part.

Heil soils are associated with Makoti soils. They contain more clay throughout and are more poorly drained than Makoti soils.

Heil soils (0 to 1 percent slopes) (Hs).—This mapping unit is on part of a large lake basin south of Ryder.

Water is ponded on the surface for part of the time.

This mapping unit is better suited to grass than to other uses, but some areas are cultivated. Maintaining a good cover of grass and keeping the more desirable species of grass are necessary to good management. Capability unit VIs-Cp; windbreak group 9; Claypan range site.

Heimdal Series

The Heimdal series consists of deep, undulating, well-drained soils that formed in water-worked glacial till. These soils are on till plains. Slopes range from 0 to 6 percent and are plane and convex.

In a representative profile, the surface layer is very dark brown loam about 6 inches thick. The upper part of the subsoil is very dark grayish-brown friable loam about 9 inches thick. The lower part of the subsoil is olive-brown very friable fine sandy loam. The underlying material, to a depth of about 45 inches, is olive-brown friable loam that is high in lime. Below this, it is olive firm loam.

Permeability is moderate to a depth of about 45 inches and is moderately slow below that depth. The available water capacity is high. Organic-matter content is moderate, and fertility is high. These soils are susceptible to soil blowing.

Heimdal soils are well suited to small grains, grass, legumes, and trees. Most areas are used for crops.

Representative profile of Heimdal loam, undulating, in a cultivated field, 1,835 feet north and 65 feet east of the southwest corner of sec. 24, T. 156 N., R. 81W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) loam, very dark brown (10YR 2/2) moist; moderate, very fine, granular structure; soft when dry, friable when moist, slightly sticky and slightly plastic when wet; neutral; clear, smooth boundary.

B21—6 to 15 inches, grayish-brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; weak, coarse, prismatic structure parting to weak, medium, subangular blocky structure; friable when moist, slightly sticky and slightly plastic when wet; many root pores; neutral; clear, wavy boundary.

B22—15 to 25 inches, light olive-brown (2.5Y 5/3) fine sandy loam, olive brown (2.5Y 4/3) moist; weak, fine, subangular blocky structure; very friable when moist; many root pores; neutral; clear, wavy boundary.

Cca—25 to 45 inches, light olive-gray (2.5Y 6/2) loam, olive brown (2.5Y 4/3) moist; weak, fine, subangular blocky structure; friable when moist; much segregated lime; moderately alkaline; strong effervescence; gradual boundary.

C2—45 to 60 inches, pale-olive (5Y 6/3) loam, olive (5Y 4/3) moist; massive; firm when moist; moderately alkaline; strong effervescence.

The solum ranges from 14 to about 25 inches in thickness. The A1 horizon ranges from 5 to 10 inches in thickness, is black or very dark gray in color, and is loam in texture. In cultivated areas it is very dark brown or very dark grayish brown in color. The B2 horizon ranges from 6 to 20 inches in thickness, is very dark grayish brown, dark grayish brown, or olive brown in color, and is loam, very fine sandy loam, or fine sandy loam in texture. The C horizon is olive-brown or olive in color, and loam in texture in the upper part. The upper part of this horizon is friable and contains a larger amount of lime; the lower part is firm and contains a small amount of lime.

Heimdal soils are associated with Emrick soils. Typically, they have a thinner A horizon and a browner B horizon than Emrick soils. They are similar to Barnes soils, but they contain less clay and more sand throughout.

Heimdal loam, undulating (3 to 6 percent slopes) (HtB).—This soil is on more sloping parts of the till plain. The areas are small and large in size, and slopes are convex and irregular.

Included with this soil in mapping were a few small areas of Buse loam and Emrick loam. Also included were areas of soil that have slopes of more than 6 percent and that make up about 10 percent of the area.

Runoff is medium, and soil blowing is a hazard.

This soil is well suited to crops, grass, and trees. Most areas are cultivated. Controlling soil blowing and runoff are a necessary part of good management. Capability unit IIe-5; windbreak group 3; Silty range site.

Lamoure Series

The Lamoure series consists of deep, level, poorly drained soils that formed in silty alluvium. These soils are on stream bottoms and have a high water table.

In a representative profile, the surface layer is black and very dark gray silty clay loam about 10 inches thick. The underlying material, to a depth of about 50 inches, is friable silty clay loam. It is very dark gray in the upper 10 inches, gray and high in lime in the next 20 inches, and olive gray in the lower 10 inches. Below a depth of about 50 inches is light olive-brown coarse sand and gravel.

Permeability is moderately slow. The available water capacity is high. The organic-matter content is high, and fertility is high. Lamoure soils have a water table near the surface much of the time.

Most areas are in grass.

Representative profile of Lamoure silty clay loam, from an area of Lamoure and Colvin soils, on a level channel bottom in native grass, 1,970 feet north and 50 feet west of the southeast corner of sec. 4, T. 156 N., R. 81 W.

A11—0 to 3 inches, very dark gray (10YR 3/1) silty clay loam, black (10YR 2/1) moist; strong, very fine, granular structure; friable when moist; many roots; mildly alkaline; slight effervescence; gradual boundary.

A12—3 to 10 inches, dark-gray (2.5Y 4/1) silty clay loam, very dark gray (2.5Y 3/1) moist; strong, very fine, granular structure; friable when moist; sticky and plastic when wet; many roots; moderately alkaline; strong effervescence; gradual, irregular boundary.

AC—10 to 20 inches, gray (2.5Y 5/1) silty clay loam, very dark gray (2.5Y 3/1) moist; moderate, fine, granular structure; hard when dry, friable when moist; sticky and plastic when wet; common roots; moderately alkaline; strong effervescence; gradual, irregular boundary.

C1ca—20 to 40 inches, light-gray (5Y 6/1) silty clay loam, gray (5Y 5/1) moist; weak, fine, subangular blocky structure; friable when moist; few roots; diffused lime; moderately alkaline; violent effervescence; gradual boundary.

C2—40 to 50 inches, light olive-gray (5Y 6/2) silty clay loam, olive gray (5Y 5/2) moist; massive; friable when moist; moderately alkaline; strong effervescence; abrupt, smooth boundary.

IIC3—50 to 60 inches, light olive-brown (2.5Y 5/3) coarse sand and gravel, olive brown (2.5Y 4/3) moist; single grain; loose; slight effervescence.

The A1 horizon ranges from 8 to 20 inches in thickness, is very dark gray or black in color, and is silty clay loam or silt loam in texture. It has a moderate or large amount of lime. The C horizon is gray, dark gray, olive brown or olive gray in color and silty clay loam or silt loam in texture. Stratified silt, sand, and clay are at a depth of more than 40 inches in places.

Lamoure soils are associated with Colvin soils. They have a thicker A1 horizon and contain less lime than Colvin soils.

Lamoure and Colvin soils (0 to 2 percent slopes) (Lc).—This undifferentiated group is along drainageways in outwash valleys. The areas are long and narrow. Some areas are Colvin silt loam or Colvin silty clay loam, some are Lamoure silty clay loam, and some are both soils. The Lamoure soil in this group has the profile described as representative for the Lamoure series.

Included with this soil in mapping were small areas of soils that have a moderately saline surface layer and a few areas of wetter soils.

A water table is at or near the surface most of the time. These soils are flooded for short periods by water from higher lying areas.

This group is well suited to grass, and most areas are in native grass. Conserving the native grass species to maintain a good stand of desirable species is a part of management. Capability unit IVw-4L; windbreak group 10; Subirrigated range site.

Lehr Series

The Lehr series consists of level and gently sloping, somewhat excessively drained soils that formed in loamy alluvium that is underlain by sand and gravel at a depth of 15 to 25 inches. These soils are on outwash plains. Slopes range from 0 to 6 percent. They are plane and convex.

In a representative profile, the surface layer is very dark brown loam about 7 inches thick. The subsoil is very dark grayish-brown friable loam about 9 inches thick. The underlying material, to a depth of about 30 inches, is grayish-brown gravelly coarse sandy loam that is high in lime. Below this, it is light olive-brown sand and gravel.

Permeability is moderately rapid to a depth of about 30 inches and very rapid below that depth. The available water capacity is low. Organic-matter content is moderate, and fertility is medium.

Lehr soils are better suited to small grains, grass, and legumes than to other uses. Most areas are used for crops.

Representative profile of Lehr loam, nearly level, on an outwash plain, in a cultivated field, 2,040 feet west and 2,040 feet north of the southeast corner of sec. 36, T. 151 N., R. 85 W.

Ap—0 to 7 inches, dark-gray (10YR 4/1) loam, very dark brown (10YR 2/2) moist; strong, fine, granular structure; friable when moist; neutral; clear, smooth boundary.

B2—7 to 16 inches, dark grayish-brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; weak, coarse, prismatic structure parting to moderate, medium, subangular blocky structure; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; common root pores; neutral; clear, wavy boundary.

IIC1ca—16 to 30 inches, light grayish-brown (10YR 6/2) gravelly coarse sandy loam, grayish brown (10YR 5/2) moist; massive and single grain; friable when moist; moderately alkaline; strong effervescence; gradual boundary.

IIC2—30 to 60 inches, light yellowish-brown (2.5Y 6/3) sand and gravel, light olive brown (2.5Y 5/4) moist; single grain; loose; slight effervescence.

The solum ranges from 15 to 25 inches in thickness to gravelly material. The A1 horizon ranges from 5 to 9 inches in thickness, is very dark brown or very dark grayish brown in color, and is loam in texture. The B2 horizon ranges from 7 to 16 inches in thickness, is dark brown, very dark grayish brown, or dark grayish brown in color, and is loam in texture. It has weak or moderate, prismatic structure. The IIC horizon is gravelly coarse sandy loam to sand and gravel. It has an accumulation of lime in the upper part.

Lehr soils are associated with Manning and Wabek soils. They contain more clay in the solum than Manning soils and they have a B horizon and a thicker solum than the Wabek soils.

Lehr loam, nearly level (0 to 3 percent slopes) (LeA).—This soil is on smooth outwash plains. The areas are small and large in size. This soil has the profile described as representative for the series.

Included with this soil in mapping were a few small areas of Manning sandy loam and Wabek gravelly loam. Also included was one large area of a soil that has a little thicker surface layer and subsoil.

The shallowness of the soil over gravel, the low available water capacity, and soil blowing are the main hazards.

This soil is suited to crops and grass, but is not well suited to trees. Most areas are cultivated. Controlling soil blowing, conserving moisture, and maintaining fertility are necessary to good management. Capability unit IIIs-5; windbreak group 6; Silty range site.

Lehr loam, undulating (3 to 6 percent slopes) (LeB).—This soil is on small hills and side slopes 100 to 300 feet long on outwash plains.

Included with this soil in mapping were a few small areas of Manning sandy loam and Wabek gravelly loam.

Runoff is medium, and soil blowing is a moderate hazard. The low available water capacity and the shallowness of the soil are also hazards.

This soil is suited to crops and grass, but it is less suited to trees. Most areas are cultivated. Controlling runoff and soil blowing, conserving moisture, and maintaining fertility are necessary to good management. Capability unit IIIs-5; windbreak group 6; Silty range site.

Lihen Series

The Lihen series consists of deep, level to rolling, well-drained soils that formed in sandy material. These soils are on outwash plains. Slopes range from 0 to 12 percent and are plane and concave.

In a representative profile, the surface layer is very dark brown fine sandy loam about 7 inches thick. The subsoil is about 23 inches thick. It is very dark grayish-brown friable fine sandy loam in the upper 13 inches and dark grayish-brown loamy fine sand in the lower 10 inches. The underlying material is light olive-brown stratified loamy fine sand and fine sandy loam.

Permeability is moderately rapid. The available water capacity is moderate. Organic-matter content is moderate, and fertility is medium. These soils are somewhat droughty and susceptible to soil blowing.

Lihen soils are suited to small grains, grass, legumes, and trees. Most areas are used for crops.

Representative profile of Lihen fine sandy loam, from an area of Lihen-Telfer fine sandy loams, nearly level, on a lake plain, in a cultivated field, 1,320 feet south and 150 feet west of the northeast corner of sec. 11, T. 151 N., R. 86 W.

Ap—0 to 7 inches, dark-gray (10YR 4/1) fine sandy loam, very dark brown (10YR 2/2) moist; weak, fine, crumb structure; soft when dry, very friable when moist, nonsticky and nonplastic when wet; many roots; neutral; clear, smooth boundary.

B2—7 to 20 inches, dark grayish-brown (10YR 4/2) fine sandy loam, very dark grayish brown (10YR 3/2) moist; weak, coarse, prismatic structure parting to weak, fine, subangular blocky structure; friable when moist; common roots; neutral; gradual boundary.

B3—20 to 30 inches, grayish-brown (10YR 5/2) loamy fine sand, dark grayish brown (10YR 4/2) moist; weak, coarse, prismatic structure parting to single grain; very friable when moist; neutral; clear, wavy boundary.

Cca—30 to 60 inches, light brownish-gray (2.5Y 6/2) fine sandy loam and loamy fine sand in stratified layers, light olive brown (2.5Y 5/4) moist; massive; very friable; many soft lime accumulations; moderately alkaline; strong effervescence.

The solum ranges from 20 to 40 inches in thickness. The A1 horizon ranges from 6 to 18 inches in thickness, is very dark brown or very dark grayish brown in color, and is fine sandy loam or loamy fine sand in texture. The B horizon ranges from very dark grayish brown to dark brown in color and is loamy fine sand in texture. In places it is fine sandy loam in the upper 6 to 15 inches. The C horizon is grayish brown or light olive brown in color and is fine sandy loam, loamy fine sand, loamy sand, or fine sand in texture. In some places gravel is at a depth of more than 36 inches.

Lihen soils are associated with Seroco and Telfer soils. They are dark colored to greater depth than Seroco or Telfer soils.

Lihen-Telfer fine sandy loams, nearly level (0 to 3 percent slopes) (LfA).—This complex is on outwash plains characterized by shallow swales and mild slopes. Lihen fine sandy loam makes up about 60 to 80 percent of the complex, and Telfer fine sandy loam about 20 to 40 percent. The Lihen soil has level and concave slopes, and the Telfer soil has convex slopes. The Lihen soil in this complex has the profile described as representative for the Lihen series.

Included with this complex in mapping were eroded spots that make up about one-fourth of the area. Soil blowing has removed part of the surface layer in these areas, and the remaining surface layer is thinner, lighter colored, or has more sand.

Soil blowing is a serious hazard.

This complex is suited to crops, grass, and trees. Most areas are cultivated. Controlling soil blowing is a serious concern of management. Conserving moisture and maintaining fertility are also necessary. Capability unit IIIe-3; windbreak group 7; Sandy range site.

Lihen-Telfer fine sandy loams, undulating (3 to 6 percent slopes) (LfB).—This complex is in areas characterized by irregular slopes and swales that have 5 to 15 feet relief. The slopes are 100 to 300 feet long. Lihen fine sandy loam makes up about 50 to 60 percent of this complex, and Telfer fine sandy loam about 40 to 50 percent. The Lihen soil is in swales and the lower parts of slopes, and the Telfer soil has stronger convex slopes.

Included with this complex in mapping were small areas of Telfer loamy fine sand and Manning sandy loam.

Soil blowing is a severe hazard. About one-third of the area has moderate erosion caused by soil blowing.

This complex is suited to crops, grass, and trees. Most areas are cultivated. Controlling soil blowing is a serious concern of management. Conserving moisture and maintaining fertility are also a necessary part of management. Capability unit IIIe-3; windbreak group 7; Sandy range site.

Lihen-Telfer fine sandy loams, till substratum, nearly level (0 to 3 percent slopes) (LhA).—This complex is in relatively smooth areas on sandy outwash-mantled till plains. The areas have about 5 feet relief. The Lihen fine sandy loam makes up about 70 to 80 percent of the complex, and the Telfer fine sandy loam about 20 to 30 percent. The Lihen soil is level or in the swales, and the Telfer soil is nearly level and has convex slopes.

The profiles of Lihen and Telfer soils are similar to those described as representative for their respective series, but loam-textured glacial till is at a depth of about 36 to 48 inches. Permeability is moderately slow in this glacial till.

Soil blowing is a severe hazard.

This complex is suited to crops, grass, and trees. Most areas are cultivated. Controlling soil blowing is a necessary part of management. Conserving moisture and maintaining fertility are lesser concerns. Capability unit IIIe-3M; windbreak group 7; Sandy range site.

Lihen-Telfer fine sandy loams, till substratum, undulating (3 to 6 percent slopes) (LhB).—This complex is on sand-mantled till plains that have irregular slopes and shallow swales. Lihen fine sandy loam makes up about 50 to 60 percent of the complex, and Telfer fine sandy loam makes up about 40 to 50 percent. The Lihen soil is in swales, and the more sloping Telfer soil has convex slopes.

The profiles of the Lihen and Telfer soils are similar to the ones described as representative for the series, but loam-textured glacial till is at a depth ranging from 24 to more than 48 inches. Permeability is moderately slow in this glacial till.

Included with this complex in mapping were spots that make up about one third of the area. In these areas soil blowing has removed part of the surface layer, and the remaining surface layer is thinner and lighter colored.

Soil blowing is a severe hazard.

This complex is suited to crops, grass, and trees. Most areas are cultivated. Controlling soil blowing, conserving moisture, and maintaining fertility are serious concerns of management. Controlling surface runoff is a lesser concern. Capability unit IIIe-3M; windbreak group 7; Sandy range site.

Lihen-Telfer loamy fine sands, undulating (0 to 6 percent slopes) (L1B).—This complex is on sandy outwash plains that have irregular short slopes 100 to 200 feet long and as much as 15 feet of relief. Lihen loamy fine sand makes up about half of the complex, and Telfer loamy fine sand makes up the rest. Lihen soil is level and in swales, and the Telfer soil is more strongly sloping and on convex-shaped hills.

The profile of the Lihen soil is similar to those described as representative for the Lihen series, but the surface layer is loamy fine sand. The Telfer soil has the profile described as representative for the Telfer series.

Included with this complex in mapping are eroded areas that make up about 50 percent of the complex and severely eroded areas that make up about 25 percent. In these areas the surface layer is thinner and lighter colored.

Soil blowing is a very severe hazard.

This complex is suited to crops, grass, and trees. Most areas have been cultivated, but some have returned to grass. Controlling soil blowing and maintaining fertility are serious concerns of management. Capability unit IVe-2; windbreak group 7; Sands range site.

Loamy Lake Beaches

Loamy lake beaches (Lo) are around the rims of intermittent lakes and sloughs. Slopes face toward the lake and have 1 to 10 percent gradient. They are less than 100 feet long. Mixtures of sand, silt, clay, gravel, and stones are in the surface layer. The underlying material is mainly firm, loam-textured glacial till. In a few places it is sorted sandy material.

These areas are flooded for a short time when lakes are full. Wave action sorts the material and cuts into the banks at other times.

This land type is suited to grass, but it is not suited to crops. Some areas are used for hay when the water is low. It is suited to wildlife habitat. Capability unit Vws; not placed in a windbreak group; not placed in a range site.

Ludden Series

The Ludden series consists of deep, level, poorly drained soils that formed in clayey alluvium. These soils are on bottom lands that are frequently flooded. Slopes are plane or concave.

In a representative profile, the surface layer is very dark gray clay about 8 inches thick. The underlying material, to a depth of about 18 inches, is very dark gray firm clay. Below this, it is very dark gray very firm clay that grades, at a depth of about 36 inches, to olive gray, very firm clay (fig. 3).

Permeability is slow. The available water capacity is high. Organic-matter content is moderate, and fertility is high. Surface runoff and internal drainage are slow.

Most areas of Ludden soils are in grass.

Representative profile of Ludden clay, on level bottom land in native grass, 1,440 feet east and 600 feet north of the southwest corner of sec. 10, T. 156 N., R. 84 W.

A11—0 to 1 inch, dark-gray (2.5Y 4/1) silty clay, very dark gray (2.5Y 3/1) moist; strong, very fine, granular structure; friable when moist, very sticky and very plastic when wet; many roots; neutral; abrupt, smooth boundary.

A12—1 to 8 inches, dark-gray (2.5Y 4/1) clay, very dark gray (2.5Y 3/1) moist; strong, very fine, angular blocky structure; firm when moist; many roots; mildly alkaline; slight effervescence; clear, irregular boundary; tongues of this horizon extend to a depth of 36 inches.

AC— 8 to 18 inches, dark-gray (5Y 4/1) clay, very dark gray (5Y 3/1) moist; weak, coarse, prismatic structure parting to weak, fine, angular blocky structure; hard when dry, firm when moist, very sticky and very plastic when wet; common roots; moderately alkaline; slight effervescence; gradual, irregular boundary.

C1cs—18 to 36 inches, dark-gray (5Y 4/1) clay, very dark gray (5Y 3/1) moist; massive; very firm when moist; few roots; accumulations of lime and gypsum; moderately alkaline; strong effervescence; gradual boundary.

C2cs—36 to 60 inches, gray (5Y 5/1) clay, olive gray (5Y 4/2) moist; massive; very firm when moist; many gypsum crystals; moderately alkaline; slight effervescence.

The A1 horizon ranges from 8 to 18 inches in thickness, but has tongues that extend to a depth of 36 inches. It is very dark gray or black in color and silty clay loam, silty clay, or clay in texture. The C horizon is very dark gray, olive gray, or dark gray in color and silty clay or clay in texture. It contains accumulations of lime and gypsum in places.

Ludden soils are associated with Velva soils. They contain more clay and less sand throughout than Velva soils. Ludden soils are similar to Fargo soils, but they have a much thicker, very dark gray surface layer and lack a B horizon.

Ludden silty clay loam (0 to 1 percent slopes) (Ls).—This soil is on flat bottom lands along smaller streams. The profile is similar to the one described as representative for the series, but the surface layer is silty clay loam and is thicker.

Included with this soil in mapping were a few small areas of Lamoure silty clay loam and Parnell silty clay loam.

Runoff is very slow. Water runs from higher areas and floods this soil for short periods.

This soil is suited to crops and grass. Most areas are cultivated. Controlling floods, surface water, and channel cutting are concerns of management. Capability unit IIws-4; windbreak group 2; Clayey range site.

Ludden clay (0 to 1 percent slopes) (Lt).—This soil is on flat bottom lands adjacent to the channel of the Souris River. It has the profile described as representative for the series.

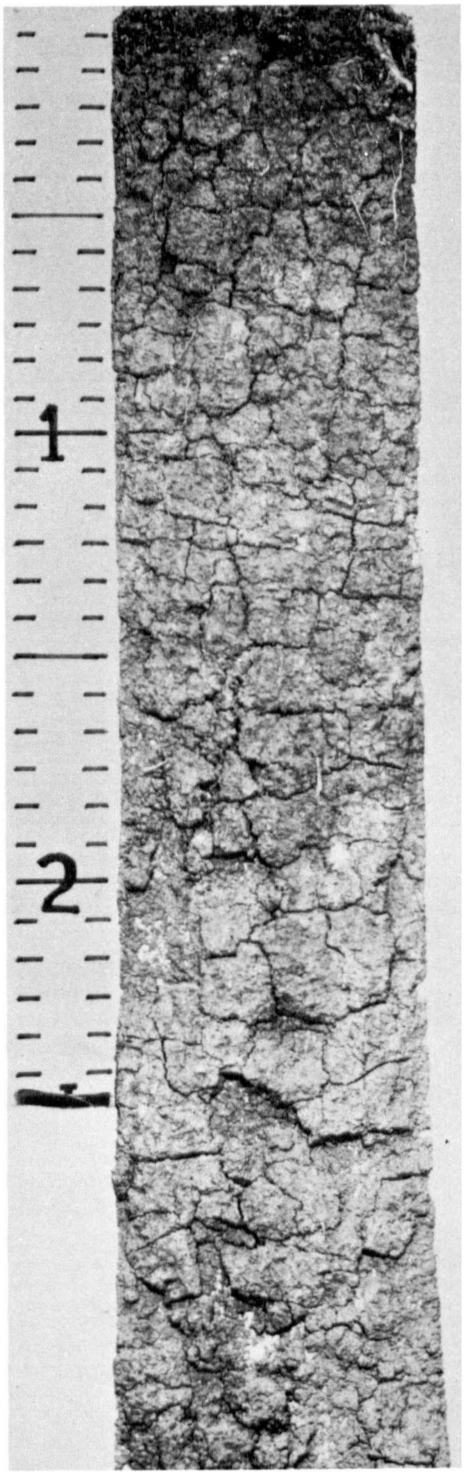

Figure 3.—Profile of Ludden clay. The cracks formed as the clayey material air dried. Deep cracks also formed on the surface of the field as the soil dried.

Surface runoff is very slow. The river overflows and floods these soils when snow melts rapidly and after heavy rains.

Most of this soil is in grass. A few ash and elm trees and shrubs are along the streambank. Dams have reduced flooding. Controlling floods, irrigation, and water spreading to increase the growth of grass are concerns of management. Capability unit IIws-4; windbreak group 2; Clayey range site.

Ludden clay, depressional (0 to 1 percent slopes) (Lu).—This soil is in depressions and old stream channels and on oxbows on bottom lands of the Des Lacs and Souris Rivers. The areas are small. The profile is similar to the one described as representative for the series, but the surface layer is thicker and has more organic matter.

This soil is usually flooded in spring.

This soil is suited to grasses and hay. It is too wet to use for crops. Slough sedge and rivergrass grow well on this soil. Capability unit Vw-WL; windbreak group 10; Wetland range site.

Makoti Series

The Makoti series consists of deep, level, moderately well drained soils that formed in moderately fine textured glacial lake sediment. These soils are on lake plains. Slopes are plane or concave.

In a representative profile, the surface layer is very dark gray silty clay loam about 6 inches thick. The subsoil is very dark grayish-brown friable silty clay loam about 9 inches thick. The underlying material, to a depth of about 42 inches, is light olive-brown friable silty clay loam that contains much lime. Below this, it is gray friable silty clay loam.

Permeability is moderately slow. The available water capacity is high. Organic-matter content is high, and fertility is high.

Makoti soils are well suited to small grains, grass, legumes, and trees. Most areas are used for crops.

Representative profile of Makoti silty clay loam, level, on a lake plain in a cultivated field, 1,287 feet west and 285 feet north of the southeast corner of sec. 12, T. 152 N., R. 86 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) silty clay loam, very dark gray (10YR 3/1) moist; strong, very fine, granular structure; friable when moist; neutral; clear, smooth boundary.

B2—6 to 15 inches, grayish-brown (2.5Y 5/2) silty clay loam, very dark grayish brown (2.5Y 3/2) moist; moderate, medium, prismatic structure parting to moderate, medium, angular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; many root pores; neutral; clear, irregular boundary.

C1ca—15 to 42 inches, light brownish-gray (2.5Y 6/2) silty clay loam, light olive brown (2.5Y 5/3) moist; friable when moist; common root pores; moderately alkaline; violent effervescence; gradual boundary.

C2—42 to 60 inches, light-gray (5Y 7/1) silty clay loam, gray (5Y 6/1) moist; common, medium, prominent, dark-brown mottles; massive but laminated; friable, moderately alkaline; slight effervescence.

The solum ranges from 12 to 24 inches in thickness. The A1 horizon ranges from 5 to 10 inches in thickness, is very dark gray, very dark brown, or very dark grayish brown in color, and is silt loam or silty clay loam in texture. The B2 horizon ranges from 5 to 12 inches in thickness, is very dark grayish brown or dark grayish brown in color, and is silt loam or silty clay loam in texture. It has weak or moderate, prismatic structure parting to angular or subangular blocky structure. The C horizon is light olive brown, olive, dark grayish brown, gray, or light gray in color and is laminated silt loam or silty clay loam in texture. It has a moderate or large amount of lime in the upper part and a small amount in the lower part.

Makoti soils are associated with Roseglen and Tansem soils. They contain less sand and more silt and clay than these soils.

Makoti silty clay loam, level (0 to 2 percent slopes) (MaA).—This soil is on smooth glacial lake plains.

Included with this soil in mapping were a few areas of soils that have a thicker and darker colored surface layer. Also included were a few small areas of Roseglen silt loam.

Surface runoff is slow, and the hazard of erosion is slight.

This soil is well suited to crops, grass, and trees. Most areas are cultivated. Conserving moisture and maintaining fertility are part of good management. Capability unit IIc-6; windbreak group 3; Silty range site.

Manning Series

The Manning series consists of level to rolling, well-drained soils that formed in moderately coarse textured material that is underlain by sand and gravel at a depth of 12 to 24 inches. These soils are on outwash plains. Slopes range from 0 to 10 percent and are plane and convex.

In a representative profile, the surface layer is very dark brown sandy loam about 7 inches thick. The subsoil is about 17 inches thick. It is very dark grayish-brown friable sandy loam in the upper part and dark-brown gravelly sandy loam in the lower part. The underlying material, to a depth of about 40 inches, is brown gravelly loamy coarse sand. Below this, it is light olive-brown coarse sand.

Permeability is moderately rapid to a depth of about 24 inches and is very rapid below that depth. The available water capacity is low. Organic-matter content is moderately low, and fertility is low.

Manning soils are suited to small grains, grass, and legumes. Some areas are used for cropland, but many areas have been seeded to grass. These soils are droughty and are generally poorly suited to crops.

Representative profile of Manning sandy loam, undulating, in a cultivated field, 1,120 feet south and 100 feet west of the northeast corner of sec. 11, T. 152 N., R. 85 W.

Ap—0 to 7 inches, dark-gray (10YR 4/1) sandy loam, very dark brown (10YR 2/2) moist; moderate, fine, crumb structure or single grain; very friable when moist, nonsticky and nonplastic when wet; neutral; clear, smooth boundary.

B2—7 to 15 inches, grayish-brown (10YR 5/2) sandy loam, very dark grayish brown (10YR 3/2) moist; weak, medium, prismatic structure parting to weak, medium, subangular blocky structure; friable when moist; many root pores; neutral; clear, smooth boundary.

B3—15 to 24 inches, dark grayish-brown (10YR 4/2) gravelly sandy loam; dark brown (10YR 3/3) moist; weak, fine, subangular blocky structure or single grain; very friable when moist; neutral; clear, wavy boundary.

IIC1ca—24 to 40 inches, light brownish-gray (10YR 6/2) gravelly loamy coarse sand, brown (10YR 4/3) moist; single grain; loose; lime coating the bottom of pebbles; moderately alkaline; strong effervescence; gradual boundary.

IIC2—40 to 60 inches, light-gray (2.5Y 7/2) coarse sand, light olive brown (2.5Y 5/3) moist; single grain; loose; slight effervescence.

The solum ranges from 12 to 24 inches in thickness. The A1 horizon ranges from 5 to 7 inches in thickness, is very dark brown or very dark grayish brown in color, and is sandy loam or fine sandy loam in texture. The B horizon ranges from 8 to 17 inches in thickness, is dark grayish brown, dark brown, or very dark grayish brown in color, and is sandy loam in texture. The lower part of this horizon is as much as 30 percent gravel. The IIC horizon is loamy coarse sand to sand and gravel.

Manning soils are associated with Lehr and Wabek soils. They contain more sand and less clay than Lehr soils, and they have a thicker solum and contain less gravel than Wabek soils.

Manning sandy loam, nearly level (0 to 3 percent slopes) (MgA).—This soil is on smooth outwash plains. The relief is less than 5 feet. The profile is similar to the one described as representative for the series, but some profiles have a thicker surface layer and subsoil.

Included with this soil in mapping were a few small areas of Lehr loam and Wabek gravelly loam. Also included were some areas of soils that have slopes of more than 3 percent. The slopes in these areas are short.

Shallowness of this soil to sand and gravel, low available water, and low fertility are severe limitations to use. Soil blowing is a severe hazard.

This soil is suited to crops and grass, but it is less suited to trees. Most areas are cultivated, but some have been seeded to grass. Conserving moisture, maintaining fertility, and controlling soil blowing are serious concerns of management. Capability unit IIIes-3; windbreak group 6; Sandy range site.

Manning sandy loam, undulating (3 to 6 percent slopes) (MgB).—This soil is in shallow swales and on hills that have 5 to 15 feet relief and convex slopes 150 to 250 feet long. The areas are irregular in shape. This soil has the profile described as representative for the series.

Included with this soil in mapping were areas of soils in swales that have a little thicker surface layer and subsoil. Also included were small areas of Lihen soils in swales and Wabek soils on the crests of some hills.

Soil blowing is a severe hazard, and about one-third of the acreage is moderately eroded. Low soil moisture is a limitation.

This soil is better suited to crops and grass than to other uses. It is poorly suited to trees. Most areas are cultivated, but some have been reseeded to grass. Controlling soil blowing, conserving moisture, and maintaining fertility are serious concerns of management. Capability unit IIIes-3; windbreak group 6; Sandy range site.

Manning-Wabek sandy loams, rolling (6 to 10 percent slopes) (MhC).—This complex is on irregular slopes, in swales, and on hills. The relief is 25 to 30 feet, and slopes are 200 to 300 feet long. Manning sandy loam makes up about 75 to 90 percent of the complex, and Wabek sandy loam about 10 to 25 percent. The Manning soil is on the sides of hills and in less sloping swales, and the Wabek soil is on crests of hills.

Soil blowing is a severe hazard. About one-half of this complex is moderately eroded. The eroded areas have a thinner and lighter colored surface layer. Low soil moisture is a limitation.

This complex is not so well suited to crops and grass as Manning sandy loam, level. Most areas are cultivated, or they have been cultivated but are now seeded to grass. Controlling soil blowing, conserving moisture, and maintaining fertility are serious concerns of management. Capability unit IVes-3; Manning part in windbreak group 6, Wabek part in windbreak group 10; Manning part in Sandy range site, Wabek part in Shallow to Gravel range site.

Max Series

The Max series consists of deep, undulating to steep, well-drained soils that formed in glacial till. These soils are on breaks of glacial moraines and valleys. Slopes range from 3 to 30 percent and are plane and convex.

In a representative profile, the surface layer is very dark brown loam about 5 inches thick. The subsoil is about 10 inches thick. It is very dark grayish-brown friable loam in the upper part and dark grayish-brown loam in the lower part. The underlying material is olive-brown loam that has much lime in the upper part.

Permeability is moderate to a depth of about 30 inches and is moderately slow below that depth. The available water capacity is high. Organic-matter content is moderate, and fertility is high.

Max soils are suited to small grains, grass, legumes, and trees. The hilly and steep areas are better suited to grass than to other uses.

Representative profile of Max loam, from an area of Max-Williams loams, rolling, in an area of native grass, 250 feet north and 65 feet east of the southwest corner of sec. 9, T. 152 N., R. 85 W.

A1—0 to 5 inches, dark-gray (10YR 4/1) loam, very dark brown (10YR 2/2) moist; strong, fine, granular structure; friable when moist; many roots; neutral; clear, irregular boundary; tongues of this horizon extend to a depth of 15 inches.

B2—5 to 10 inches, dark-gray (10YR 4/1) loam, very dark grayish brown (10YR 3/2) moist; moderate, medium, prismatic structure parting to moderate, medium, subangular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; many roots; neutral; clear, irregular boundary.

B3ca—10 to 15 inches, grayish-brown (2.5Y 5/2) loam, dark grayish brown (2.5Y 4/2) moist; weak, medium, prismatic structure parting to weak, medium, subangular blocky structure; friable when moist; common roots; moderately alkaline; strong effervescence; clear, wavy boundary.

C1ca—15 to 30 inches, light brownish-gray (2.5Y 6/2) loam, olive brown (2.5Y 4/3) moist; weak, medium, subangular blocky structure; friable when moist; common roots; soft lime masses; moderately alkaline; violent effervescence; gradual boundary.

C2—30 to 60 inches, light yellowish-brown (2.5Y 6/3) loam, olive brown (2.5Y 4/3) moist; massive; friable when moist; few roots; moderately alkaline; slight effervescence.

The solum ranges from 10 to 18 inches in thickness to lime. The A1 horizon ranges from 4 to 10 inches in thickness, is very dark brown or very dark grayish brown in color, and is loam or clay loam in texture. The B horizon ranges from 4 to 12 inches in thickness, is very dark grayish brown to grayish brown in color, and is loam or clay loam in texture. It contains some lime in the lower part. The C horizon is olive-brown or grayish-brown loam glacial till. This horizon contains an accumulation of lime in the upper part. Stones make up as much as 8 percent, by weight, throughout.

Max soils are associated with Bowbells, Williams, and Zahl soils. They have thinner A1 and B2 horizons than Bowbells and Williams soils. They have thicker A1 and B2 horizons than Zahl soils.

Max-Bowbells-Zahl loams, hilly (9 to 25 percent slopes) (M1E).—This complex has irregular slopes and is on hills, in swales, and in basins. Slopes are commonly 100 to 300 feet long, and relief is more than 50 feet. Max loam makes up about 50 to 75 percent of the complex; Bowbells loam, about 15 to 25 percent; and Zahl loam, about 10 to 20 percent. The Max soil is on the side slopes, the Bowbells soil is in swales and concave fans, and the Zahl soil is on the crests of hills and is more strongly sloping on parts of slopes.

Included with this complex in mapping were small areas of Hamerly, Parnell, Tonka, and Williams soils. Also included were areas of Max and Zahl stony loams.

Surface runoff is rapid, and the hazard of erosion is very severe.

This complex is better suited to grass than to other uses. Most areas are used for range and pasture. A few small areas are cultivated. Small areas of less sloping Bowbells and Max soils and areas of these soils that are in swales are suited to crops. Controlling runoff and maintaining a cover of grass are the main concerns of management. Capability unit VIe-Si; Max part in windbreak group 3, Bowbells part in windbreak group 1, Zahl part in windbreak group 8; Max and Bowbells parts in Silty range site, Zahl part in Thin Silty range site.

Max-Williams loams, undulating (3 to 6 percent slopes) (MmB).—This complex is characterized by areas of irregularly shaped, shallow swales, convex slopes, and low ridges. The low ridges have 5 to 15 feet relief and slopes that are 100 to 200 feet long. Max loam makes up about 40 to 60 percent of the complex, and Williams loam about 30 to 50 percent. The Max soil is on the tops of ridges and has stronger convex slopes. The Williams soil is in smoother areas and is less sloping.

Included with this complex in mapping were a few small areas of Lehr, Tansem, and Wabek soils. Included with the Max loam were small areas where Max soils have a sandy or gravelly surface layer.

Runoff is medium, and soil blowing is a hazard. The hazard of soil blowing is severe in the included areas of Max soils that have a sandy surface layer.

This complex is suited to crops, grass, and trees. Most areas are cultivated. Controlling soil blowing, conserving moisture, and maintaining fertility are part of good management. Capability unit IIe-6; windbreak group 3; Silty range site.

Max-Williams loams, rolling (6 to 9 percent slopes) (MmC).—This complex is characterized by irregular slopes, hills, swales, and potholes on the glacial moraine. Slopes are 200 to 300 feet long, and the relief is 10 to more than 25 feet. Max loam makes up 40 to 50 percent of the complex; Williams loam, 30 to 40 percent; and small areas of Bowbells loam, Parnell silty clay loam, and Zahl loam, the remainder. The Max soil is more strongly sloping and is on hills, and the Williams soil has smoother slopes.

The Max soil in this complex has the profile described as representative for the Max series.

Included with this complex in mapping are small areas of soils that contain stones and boulders.

Surface runoff is medium or rapid. Soil blowing is a hazard, mainly on hilltops.

This complex is suited to crops, grass, and trees. A large part is cultivated, and the remainder is in native grass. Controlling erosion, conserving moisture, and maintaining fertility are a necessary part of management. Removing stones and managing areas of short, complex slopes are also concerns. Capability unit IIIe-6; windbreak group 3; Silty range site.

Max-Williams loams, strongly sloping (9 to 12 percent slopes) (MmD).—This complex is on the sides and crests of slopes facing depressions and swales. Slopes are 300 to 400 feet long. Max loam makes up about 50 to 75 percent of the complex; and Williams loam, 15 to 25 percent; small areas of Zahl loam and Bowbells loam, the remainder.

Surface runoff is rapid, and the hazard of erosion is severe. Rills and gullies form after hard rains. About half the acreage is moderately eroded. The surface layer is thinner and lighter colored in these areas.

This complex is not so well suited to crops and trees as Max-Williams loams, undulating. It is suited to grass. Many areas are cultivated. Controlling surface runoff and erosion are serious concerns of management, but conserving moisture and maintaining fertility are also needed. Capability unit IVe-6; windbreak group 3; Silty range site.

Max-Zahl stony loams, rolling (6 to 12 percent slopes) (MnC).—This complex is on hills of the moraines and till plains. The areas are small, and the slopes are short and irregularly shaped. Stones and boulders are throughout the profile and generally are more numerous on the tops of knobs and ridges than in the lower areas. Max stony loam makes up about 60 to 80 percent of the complex, and Zahl stony loam about 20 to 40 percent.

Included with this complex in mapping were a few areas of Williams stony loam and Bowbells loam.

The acreage is in native grass and is not suited to crops. Controlling grazing to maintain the cover of grass is the main concern of management. The stones and boulders in this complex make the use of farm machinery impractical. Capability unit VIIs-Si; windbreak group 10; Max part in Silty range site, Zahl part in Thin Silty range site.

Max-Zahl loams, rolling (6 to 12 percent slopes) (MoC).—This complex is on hills and in depressions on till plains. Slopes are short, irregularly shaped, and 100 to 200 feet long. Relief is 10 to more than 25 feet. Max loam makes up about 50 to 60 percent of the complex; Zahl loam, about 15 to 25 percent; and Bowbells loam, about 10 to 15 percent. The Max soil is on the smoother slopes and smaller hills, the Zahl soil is on the crests of slopes and tops of hills, and the Bowbells soil is in swales and on the lower parts of concave slopes.

Included with this complex in mapping were small areas of Hamerly loam, Parnell silty clay loam, and Williams loam. Also included were a few areas of soils that contain more stones.

Surface runoff is rapid, and the hazard of erosion is severe. Some cultivated areas, mainly on the tops of hills and in more strongly sloping areas, are moderately eroded.

This complex is better suited to grass than to crops and trees. Most areas are in native grass, but some are cultivated. In cultivated areas, controlling erosion, conserving moisture, and maintaining fertility are serious concerns of management. In the areas of native grass, maintaining a good, vigorous grass cover is the main concern of management. Controlling erosion is a lesser concern. Capability unit IVe-6; Max part in windbreak group 3, Zahl part in windbreak group 8; Max part in Silty range site, Zahl part in Thin Silty range site.

Mine Pits and Dumps

Mine pits and dumps (Mp) are in areas where strip mining operations have removed soil material to a depth of 30 to 60 feet to uncover coal. The waste material has been dumped to form complex ridges that are more than 50 feet high. The areas are irregular in shape. The largest area is in the southeastern part of the county.

Included with this land type in mapping were a few areas of pits caused by cave-ins over abandoned underground mines.

Surface runoff from the steep areas and the spread of sediment are hazards.

This land type is suited to wildlife habitat and to grass. Reseeding, restoring fertility, and leveling the steep ridges are concerns of management (fig. 4). Capability unit VIIIe; not placed in a windbreak group; not placed in a range site.

Miranda Series

The Miranda series consists of deep, level, moderately well drained soils that formed in saline-alkaline glacial till.

In a representative profile, the surface layer is very dark gray loam about 2 inches thick. The subsoil is very dark grayish-brown firm clay loam about 6 inches thick. The underlying material, to a depth of about 24 inches, is strongly alkaline light olive-brown loam that contains much lime and gypsum. Below this, it is moderately alkaline olive loam that has a high content of gypsum.

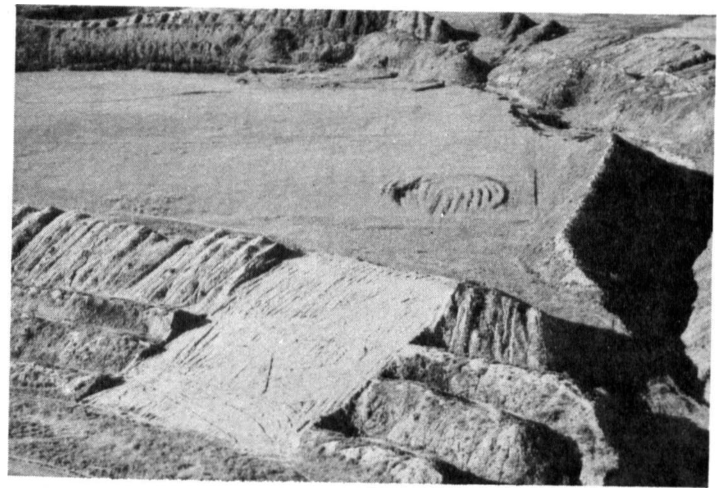

Figure 4.—Rough spoil banks and leveled spoil banks in an open pit where lignite is strip mined.

Permeability is very slow. The available water capacity is low. Organic-matter content is moderately low, and fertility is low.

Miranda soils are not well suited to crops. They are better suited to grass than to other uses. Management is difficult if these soils are cultivated.

Miranda soils in this county are mapped only in complexes with Noonan and Zahl soils.

Representative profile of Miranda loam, from an area of Noonan-Miranda complex, in native grassland, 300 feet south of the northwest corner of sec. 30, T. 155 N., R. 87 W.

A2—0 to 2 inches, light-gray (2.5Y 6/1) loam, very dark gray (2.5Y 3/1) moist; strong, very fine, granular structure; friable when moist; many roots; moderately alkaline; abrupt, smooth boundary.

B2t—2 to 5 inches, dark grayish-brown (2.5Y 4/2) clay loam, very dark grayish brown (2.5Y 3/2) moist; moderate, medium, columnar structure parting to strong, medium, angular blocky structure; extremely hard when dry, firm when moist, sticky and plastic when wet; common roots; moderately alkaline; clear, wavy boundary.

B3cs—5 to 8 inches, light brownish-gray (2.5Y 6/2) clay loam, dark grayish brown (2.5Y 4/2) moist; moderate, medium, prismatic structure; firm when moist; few roots; strongly alkaline; strong effervescence; gradual boundary.

C1cacs—8 to 24 inches, light yellowish-brown (2.5Y 6/3) loam; light olive brown (2.5Y 5/3) moist; massive; firm when moist; segregated lime and gypsum; strongly alkaline; violent effervescence; gradual boundary.

C2cs—24 to 60 inches, light olive-gray (5Y 6/2) loam, olive (5Y 4/3) moist; massive; firm; much gypsum; moderately alkaline; slight effervescence.

The solum ranges from 5 to 10 inches in thickness. The A horizon ranges from 1 to 4 inches in thickness and is mildly alkaline or moderately alkaline. It is dark gray or very dark gray in color and is loam or clay loam in texture. The B2t horizon is very dark gray or very dark grayish brown in color and is clay loam in texture. It has moderate or strong columnar structure and is moderately alkaline or strongly alkaline. The C horizon is olive, olive brown, light olive brown, or grayish brown in color and is loam or clay loam in texture. It has a moderate to large amount of salts and is strongly alkaline in the upper part.

Miranda soils are associated with Niobell and Noonan soils. They have a thinner solum and are shallower to salts and strongly alkaline layers. They are associated with Zahl soils in a few places. They contain more clay than the Zahl soils.

Niobell Series

The Niobell series consists of deep, nearly level, well-drained soils that formed in loamy glacial till on till plains.

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 neutral, firm, brown clay loam about 6 inches thick. The underlying material, to a depth of about 32 inches, is strongly alkaline light olive-brown clay loam that contains much lime and gypsum. Below this, it is moderately alkaline olive clay loam that contains much gypsum.

Permeability is moderately slow below the surface and subsurface layers. The available water capacity is moderate. Organic-matter content is moderate, and fertility is high. These soils have a claypan subsoil that limits rooting depth and moisture use.

Niobell soils are better suited to small grains, grass, and legumes than to other uses. Most areas are used for crops.

Niobell soils in this county are mapped only in complexes with the Noonan and Williams soils.

Representative profile of Niobell loam, from an area of Williams-Niobell loams, level, in a cultivated field, 2,607 feet east and 150 feet north of the southwest corner of sec. 26, T. 160 N., R. 89 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) loam, very dark brown (10YR 2/2) moist; strong, fine, granular structure; friable when moist; neutral; clear, smooth boundary.

A2—6 to 9 inches, light-gray (10YR 6/1) loam, dark grayish brown (10YR 4/2) moist; weak, thick, platy structure parting to weak, fine, granular structure; friable when moist; many root pores; neutral; abrupt, smooth boundary.

B2t—9 to 15 inches, grayish-brown (10YR 5/2) clay loam, brown (10YR 4/3) moist; dark-brown clay films; moderate, medium, prismatic structure parting to strong, medium, angular blocky structure; hard when dry, firm when moist, sticky and plastic when wet; few root pores; neutral; clear, wavy boundary.

C1cacs—15 to 32 inches, light brownish-gray (2.5Y 6/2) clay loam, light olive brown (2.5Y 5/3) moist; massive, dispersed; firm when moist; accumulations of lime and gypsum; strongly alkaline; strong effervescence; gradual boundary.

C2cs—32 to 60 inches, pale-olive (5Y 6/3) clay loam, olive (5Y 5/3) moist; massive; firm; much gypsum; moderately alkaline; slight effervescence.

The solum ranges from 15 to 24 inches in thickness. The A horizon ranges from 6 to 15 inches in thickness. The upper part of the A horizon is grayish brown or very dark brown loam or clay loam. The lower part is dark grayish-brown or grayish-brown loam. The B2t horizon ranges from 6 to 12 inches in thickness, is brown or dark grayish brown in color, and is clay loam in texture. It has moderate or strong prismatic structure that parts easily to strong angular blocky structure. The C horizon is light olive brown, olive, or grayish brown in color and is loam or clay loam glacial till. It contains lime and salt accumulations in the upper part.

Niobell soils are associated with Miranda and Noonan soils. They have a B2t horizon that has prismatic structure and neutral reaction that the Noonan soils lack. They have a thicker solum than Miranda soils. They are also associated with Bowbells, Max, and Williams soils, but they have an A2 horizon and a strongly alkaline C horizon that Williams soils lack.

Noonan Series

The Noonan series consists of deep, level, moderately well drained soils that formed in saline-alkaline material on till plains.

In a representative profile, the surface layer is very dark gray loam about 7 inches thick. The subsurface layer is dark-gray loam about 3 inches thick. The subsoil is strongly alkaline, very firm, olive-brown clay loam about 7 inches thick. The underlying material, to a depth of about 34 inches, is strongly alkaline olive-brown clay loam that contains much lime and gypsum. Below this, it is olive-gray clay loam that contains much gypsum.

Permeability is slow below the surface and subsurface layer. The available water capacity is low. Organic-matter content is moderate, and fertility is medium. These soils have a claypan subsoil that limits rooting depth and moisture use.

Noonan soils are better suited to grass than to other uses.

Representative profile of Noonan loam, from an area of Noonan-Niobell loams, in native grassland, 260 feet north and 105 feet east of the southwest corner of sec. 28, T. 160 N., R. 89 W.

A1—0 to 7 inches, gray (10YR 5/1) loam, very dark gray (10YR 3/1) moist; moderate, fine, granular structure; friable when moist; many roots; neutral; clear, smooth boundary.

A2—7 to 10 inches, light-gray (10YR 6/1) loam, dark gray (10YR 4/1) moist; weak, thin, platy structure parting to weak, fine, granular structure; friable when moist; common roots; neutral; abrupt, smooth boundary.

B2t—10 to 17 inches, grayish-brown (2.5Y 5/2) clay loam, olive brown (2.5Y 4/3) moist; very dark grayish-brown clay films; moderate, medium, columnar structure parting to strong, medium, angular blocky structure; extremely hard when dry, very firm when moist, very sticky and very plastic when wet; few roots; strongly alkaline; clear, wavy boundary.

C1cacs—17 to 34 inches, grayish-brown (2.5Y 5/2) clay loam, olive brown (2.5Y 4/3) moist; massive, dispersed; firm when moist, very sticky and very plastic when wet; few roots; many gypsum crystals; strongly alkaline; violent effervescence; gradual boundary.

C2cs—34 to 60 inches, light olive-gray (5Y 6/2) clay loam, olive gray (5Y 4/2) moist; massive; firm when moist; much gypsum; strongly alkaline; slight effervescence.

The solum ranges from 12 to 18 inches in thickness. The A1 horizon ranges from 5 to 10 inches in thickness, is very dark gray or very dark grayish brown in color, and is loam or clay loam in texture. The B2t horizon ranges from 6 to 12 inches in thickness, is olive brown, dark brown, dark grayish brown, or very dark grayish brown in color, and is clay loam in texture. It has moderate or strong columnar structure and is moderately alkaline or strongly alkaline. The C horizon is olive gray or olive brown in color and is loam or clay loam in texture. It contains a large amount of salts in the upper part.

Noonan soils are associated with Miranda and Niobell soils. They have strong columnar structure and are more alkaline in the B2t horizon than Niobell soils. They have a thicker A horizon and a thicker solum than the Miranda soils. Noonan soils are associated with Bowbells, Max, and Williams soils, but they differ from those soils in being strongly alkaline and in having a columnar B2t horizon.

Noonan-Miranda complex (0 to 2 percent slopes) (Nm).—This complex has smooth and plane or concave slopes. It is in areas of small depressions that are a few inches deep and generally 3 to 25 feet across. Noonan loam makes up about 40 to 60 percent of the complex; Miranda loam, about 25 to 40 percent; and Niobell loam, about 10 to 15 percent. The Noonan soil and the Niobell soil are in the higher areas, and the Miranda soil is in the depressions.

The Miranda soil has the profile described as representative for the Miranda series.

Runoff is slow, and the hazard of erosion is slight. Cultivated areas have many spots where the clayey subsoil has been mixed with the plow layer. These areas are soft and sticky when wet and extremely hard when dry.

Part of the acreage is cultivated, but most areas are in native grass. This complex is not suited to trees. Use of areas that have an extremely hard surface layer or are shallow to salts and maintaining the grasses are the main concerns of management. Capability unit VIs-Cp; windbreak group 9; Claypan range site.

Noonan-Niobell loams (0 to 2 percent slopes) (Nn).—This complex is on a smooth till plain. The areas are small and are irregular in shape. They have relief of less than 5 feet and some depressions that are a few inches deep. Noonan loam makes up about 30 to 40 percent of the complex, and Niobell loam about 30 to 40 percent. Small areas of included soils make up the rest.

The Noonan soil has the profile described as representative for the Noonan series.

Included with this complex in mapping were small areas of Bowbells loam, Miranda loam, and Williams loam.

Surface runoff is slow, and the hazard of erosion is slight. The clayey subsoil has been mixed with the plow layer in places.

This complex is suited to crops and grass. It is not well suited to trees. Most areas are cultivated. Maintaining tilth in the surface layer, conserving moisture, and maintaining fertility are the main concerns of management. Capability unit IIIs-6P; Noonan part in windbreak group 9, Niobell part in windbreak group 4; Noonan part in Claypan range site, Niobell part in Silty range site.

Nutley Series

The Nutley series consists of deep, level and gently sloping, well-drained soils that formed in clayey glacial lake sediment. These soils are on upland glacial lake plains. Slopes range from 0 to 5 percent and are plane and convex.

In a representative profile, the surface layer is very dark gray silty clay about 6 inches thick. The subsoil is very dark grayish-brown friable silty clay about 10 inches thick. The underlying material, to a depth of about 32 inches, is friable olive silty clay that contains much lime. Below this, it is firm olive silty clay.

Permeability is slow. The available water capacity is high. Organic-matter content is moderate, and fertility is high.

Nutley soils are well suited to small grains, grass, and legumes. Most areas are used for crops.

Representative profile of Nutley silty clay, gently sloping, in a cultivated field, 965 feet north and 150 feet east of the southwest corner of sec. 36, T. 154 N., R. 86 W.

Ap—0 to 6 inches, dark grayish-brown (2.5Y 4/2) silty clay, very dark gray (2.5Y 3/1) moist; strong, very fine, granular structure; friable when moist; mildly alkaline; slight effervescence; clear, smooth boundary.

B2—6 to 16 inches, dark grayish-brown (2.5Y 4/2) silty clay, very dark grayish brown (2.5Y 3/2) moist; moderate, fine, angular blocky structure parting to strong, fine, granular structure; friable when moist; very sticky and very plastic when wet; common root pores; moderately alkaline; strong effervescence; clear, irregular boundary.

C1ca—16 to 32 inches, light olive-gray (5Y 6/2) silty clay, olive (5Y 5/3) moist; weak, very fine, granular structure; friable when moist; weak, common root pores; diffuse and segregated lime; moderately alkaline; violent effervescence; gradual boundary.

C2—32 to 60 inches, olive-gray (5Y 5/2) silty clay, olive (5Y 4/3) moist; massive; firm; few root pores; moderately alkaline; slight effervescence.

The solum ranges from 14 to 20 inches in thickness. The A1 horizon ranges from 4 to 8 inches in thickness and is mildly alkaline or moderately alkaline. It is very dark gray or black in color and is silty clay or clay in texture. The B horizon is dark grayish brown or very dark grayish brown in color and is silty clay or clay in texture. It has slight or strong effervescence. This horizon has a wavy to very irregular, tongued boundary into the C horizon. The C horizon is olive, olive gray, or dark gray in color and silty clay or clay in texture. It is massive, or it has layers or varves of silt and clay.

Nutley soils are associated with Sinai and Williams soils. They have a thinner A horizon than Sinai soils, and they contain more clay throughout than Williams soils.

Nutley silty clay, gently sloping (2 to 5 percent slopes) (NtB).—This soil has convex, smooth slopes that are 300 to 500 feet long. It has the profile described as representative for the series.

Included with this soil in mapping were a few small areas of Williams clay loam and a few areas of soils that have slopes of less than 2 percent.

Surface runoff is medium, and the hazard of erosion is moderate. The soil forms granules easily when wetted and dried or when frozen and thawed.

This soil is well suited to crops, grass, and trees. Most areas are cultivated. Controlling soil blowing, conserving moisture, and maintaining fertility are a necessary part of good management. Capability unit IIe-4; windbreak group 4; Clayey range site.

Nutley-Sinai silty clays, nearly level (0 to 2 percent slopes) (NuA).—This complex is on the high lake plains in the moraine hills. Slopes are long and smooth. Nutley silty clay makes up about 75 to 80 percent of the complex, and Sinai silty clay about 20 to 25 percent. The Nutley soil is on the convex parts of slopes, and the Sinai soil is in the swales.

Surface runoff is slow, and the hazard of erosion is slight. The soil forms granules easily when wetted and dried or when frozen and thawed. Soil blowing is a hazard in summer-fallowed fields.

This complex is well suited to small grains, grass, and some trees. Most areas are cultivated. Conserving moisture, maintaining fertility, and controlling soil blowing are part of good management. Capability unit IIe-4; windbreak group 4; Clayey range site.

Overly Series, Mottled Variant

The Overly series, mottled variant, consists of deep, level, moderately well drained soils that formed in moderately fine textured glacial lacustrine sediment on lake plains. Slopes are plane.

In a representative profile, the surface layer is black silty clay loam about 7 inches thick. The subsoil is olive-brown firm silty clay loam about 9 inches thick. The underlying material, to a depth of about 36 inches, is friable gray silty clay loam that contains much lime. Below this, it is firm gray and olive silty clay loam.

Permeability is moderately slow. The available water capacity is high. Organic-matter content is high, and fertility is high.

Overly soils, mottled variant, are well suited to small grains, grass, legumes, and trees. Most areas are used for crops.

Representative profile of Overly silty clay loam, mottled variant, on a level lake plain, in a cultivated field, 315 feet south and 33 feet east of the northwest corner of sec. 1, T. 160 N., R. 87 W.

Ap—0 to 7 inches, dark-gray (10YR 4/1) silty clay loam, black (10YR 2/1) moist; strong, very fine, granular structure; friable when moist; many roots; neutral; clear, smooth boundary.

B2—7 to 16 inches, grayish-brown (2.5Y 5/2) silty clay loam, olive brown (2.5Y 4/3) moist; many, fine, prominent, yellowish-brown mottles; moderate, medium, prismatic structure parting to moderate, medium, subangular blocky structure; hard when dry, firm when moist; sticky and plastic when wet; common roots; neutral; clear, wavy boundary.

C1ca—16 to 36 inches, light-gray (5Y 6/1) silty clay loam, gray (5Y 5/1) moist; many, fine, prominent, light olive-brown mottles; weak, medium, subangular blocky structure; friable when moist; common roots; moderately alkaline; violent effervescence; gradual boundary.

C2—36 to 60 inches, light-gray and pale-olive (5Y 6/1 and 6/3) silty clay loam, gray and olive (5Y 5/1 and 5/3) moist; massive; firm; few roots; moderately alkaline; strong effervescence.

The solum ranges from 16 to 24 inches in thickness. The A1 horizon ranges from 6 to 10 inches in thickness, is black or very dark gray in color, and is silt loam or silty clay loam in texture. The B2 horizon ranges from 8 to 14 inches in thickness, is very dark grayish brown or olive brown in color, and is silty clay loam in texture. This horizon has few to many, fine or medium, faint to prominent, yellowish-brown mottles. The C horizon is gray or olive in color and is silty clay loam in texture.

Overly soils, mottled variant, are associated with Fargo and Hegne soils. They contain less clay and more silt throughout than those soils.

Overly silty clay loam, mottled variant (0 to 2 percent slopes) (Ov).—This soil is on the higher part of the lake plain about 12 miles northeast of Kenmare. Slopes are smooth.

Included with this soil in mapping were a few small areas of Fargo silty clay and Emrick loam.

The hazard of erosion is slight.

This soil is suited to crops, grass, and trees. Most areas are cultivated. Conserving moisture and maintaining fertility are the main concerns of management. Capability unit IIc-6; windbreak group 1; Silty range site.

Parnell Series

The Parnell series consists of deep, level, poorly drained soils that formed in fine-textured glacial alluvium. These soils are in deep closed depressions on till plains.

In a representative profile, the surface layer is black silty clay loam about 6 inches thick. The subsoil is black and very dark gray firm silty clay about 30 inches thick. The underlying material, to a depth of about 45 inches, is olive-gray silty clay. Below this, it is gray and olive-brown clay loam.

Permeability is slow, and runoff water ponds on the surface. The available water capacity is high. Organic-matter content is high, and fertility is high.

Unless drained, Parnell soils are seldom cultivated. They are well suited to grass.

Representative profile of Parnell silty clay loam, in a drained slough, in a cultivated field, 1,050 feet east and 650 feet north of the southwest corner of sec. 9, T. 157 N., R. 86 W.

Ap—0 to 6 inches, very dark gray (10YR 3/1) silty clay loam, black (10YR 2/1) moist; strong, fine, granular structure; friable when moist; many roots; neutral; clear, smooth boundary.

B2t—6 to 20 inches, dark-gray (2.5Y 4/1) silty clay, black (2.5Y 2/1) moist; many, fine, distinct, light olive-brown mottles; strong, fine, angular blocky structure; hard when dry, firm when moist, very sticky and very plastic when wet; many roots; neutral; gradual boundary.

B3—20 to 36 inches, dark-gray (2.5Y 4/1) silty clay, very dark gray (2.5Y 3/1) moist; few, medium, prominent, dark-brown mottles; massive; firm when moist; common roots; neutral; clear, irregular boundary.

C1g—36 to 45 inches, gray (5Y 6/1) silty clay, olive gray (5Y 5/2) moist; massive; firm; few roots; mildly alkaline; clear, wavy boundary.

IIC2—45 to 60 inches, light-gray and light olive-brown (5Y 6/1 and 2.5Y 5/6) clay loam, gray and olive brown (5Y 5/1 and 2.5Y 4/4) moist; massive; firm; moderately alkaline; slight effervescence.

The solum ranges from 30 to more than 40 inches in thickness. The A1 horizon ranges from 6 to 14 inches in thickness, is black in color, and is silty clay loam, silt loam, or silty clay in texture. The B horizon ranges from 20 to 36 inches in thickness and is silty clay or silty clay loam in texture. The upper part of the C horizon is olive-gray or gray silty clay. The lower part is gray or olive-brown clay loam or silty clay.

Parnell soils are associated with Max, Williams, and Zahl soils. They are more poorly drained and have a thicker A1 horizon than those soils. They are also associated with Tonka soils, but they lack the A2 horizon of those soils.

Parnell silty clay loam (0 to 1 percent slopes) (Pa).—This soil is in basins and depressions. It has the profile described as representative for the series.

Included with this soil in mapping were a few small areas of Tonka and Colvin soils.

This soil usually is ponded until midsummer or later. It is sometimes ponded all year after a series of wet seasons, but after a series of dry years it is ponded for only a few days following heavy rains.

Undrained areas are well suited to native grass. Most areas are used for hay, pasture, and wildlife. Managing wildlife habitat and grazing and developing permanent water are part of management. Capability unit IIIw-6; windbreak group 2; Wetland range site.

Parnell soils, very poorly drained (0 to 1 percent slopes) (Pe).—These soils are in the deeper basins and depressions (fig. 5). The profile is similar to the one described as representative for the series, but the surface layer is thicker and has more organic matter.

Included with these soils in mapping were small areas of loamy beaches.

These soils provide excellent habitat for waterfowl. They are not so well suited to grass as Parnell silty clay loam. They are used mainly for wildlife habitat and pasture. Capability unit Vw-WL; windbreak group 10; Wetland range site.

Renshaw Series

The Renshaw series consists of nearly level, somewhat excessively drained soils that formed in loamy alluvium that is underlain by sand and gravel at a depth of 12 to 24 inches. These soils are on outwash plains. Slopes range from 0 to 3 percent and are plane.

In a representative profile, the surface layer is very dark brown loam about 6 inches thick. The subsoil is dark-brown friable loam about 10 inches thick. The underlying material, to a depth of about 24 inches, is dark grayish-brown gravelly sandy loam. Below this, it is loose dark grayish-brown coarse sand and gravel.

Permeability is moderately rapid in the upper 16 inches and very rapid below that depth. The available water capacity is low. Organic-matter content is moderate, and fertility is medium.

These soils are suited to small grains, grass, and legumes. Most areas are used for crops.

Representative profile of Renshaw loam, nearly level, on an outwash plain, in a cultivated field, 150 feet north and 120 feet east of the southwest corner of sec. 34, T. 154 N., R. 81 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) loam, very dark brown (10YR 2/2) moist; moderate, fine, granular structure; friable when moist; many roots; neutral; clear, smooth boundary.

B2—6 to 16 inches, dark grayish-brown (10YR 4/2) loam, dark brown (10YR 3/3) moist; weak, medium prismatic structure parting to weak, medium, subangular blocky structure; friable when moist; common roots; neutral; clear, wavy boundary.

IIB3—16 to 24 inches, grayish-brown (2.5Y 5/2) gravelly sandy loam, dark grayish brown (2.5Y 4/2) moist; single grain; loose; few roots; mildly alkaline; slight effervescence; gradual boundary.

IIC—24 to 60 inches, light brownish-gray (2.5Y 6/2) coarse sand and gravel, dark grayish brown (2.5Y 4/2) moist; single grain; loose; moderately alkaline; slight effervescence.

The solum ranges from 12 to 24 inches in thickness to sand and gravel. The A horizon ranges from 4 to 8 inches in thickness. It is black in native grassland and very dark brown or very dark gray in cultivated areas. It is loam or sandy clay loam in texture. The B2 horizon is dark brown, dark grayish brown, or very dark grayish brown in color and loam in texture. It has weak or moderate prismatic structure parting

Figure 5.—Very poorly drained Parnell soils, which are too deeply ponded in many places for grass or sedge to survive. On adjacent hills is Zahl-Max loams, hilly.

easily to weak or moderate subangular blocky structure. The IIC horizon is a mixture of coarse sand and gravel.

Renshaw soils are associated with Arvilla, Divide, and Sioux soils. They contain more clay and less sand than Arvilla soils. They contain less lime and are better drained than Divide soils. They are deeper to gravel than Sioux soils.

Renshaw loam, nearly level (0 to 3 percent slopes) (ReA).—This soil is on smooth areas. The slopes are convex and plane.

Included with this soil in mapping were a few small areas of Arvilla and Divide soils.

The low moisture supply during the growing season is the main limitation. The hazard of erosion is slight or moderate.

This soil is suited to crops and grass. Most areas are cultivated. Conserving moisture, maintaining fertility, and controlling soil blowing are part of good management. Capability unit IIIs-5; windbreak group 6; Silty range site.

Roseglen Series

The Roseglen series consists of deep, level, moderately well drained soils that formed in silty glacial lake sediment on glacial lake plains. Slopes are plane and concave.

In a representative profile, the surface layer is very dark brown silt loam about 6 inches thick. The subsoil is very dark grayish-brown friable silt loam about 15 inches thick. The underlying material, to a depth of about 36 inches, is olive-brown silt loam that contains much lime. Below this, it is gray and olive-brown silt loam.

Permeability is moderate. The available water capacity is high. Organic-matter content is high, and fertility is high.

Roseglen soils are well suited to small grains, grasses, legumes, and trees. Most areas are used for crops.

Representative profile of Roseglen silt loam, from an area of Roseglen-Tansem silt loams, level, in a cultivated field, 2,510 feet west and 600 feet south of the northeast corner of sec. 14, T. 151 N., R. 86 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) silt loam, very dark brown (10YR 2/2) moist; moderate; fine, granular structure; friable when moist; neutral; clear, smooth boundary.

B2—6 to 21 inches, grayish-brown (2.5Y 5/2) silt loam, very dark grayish brown (2.5Y 3/2) moist; weak, medium, prismatic structure; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many root pores; neutral; clear, wavy boundary.

C1ca—21 to 36 inches, light-gray (2.5Y 7/1) silt loam, olive brown (2.5Y 4/3) moist; weak, fine, subangular blocky structure; friable when moist; common root pores; moderately alkaline; violent effervescence; gradual boundary.

C2—36 to 60 inches, light-gray and light yellowish-brown (2.5Y 6/1 and 6/4) silt loam, gray and olive brown (2.5Y 5/1 and 4/4) moist; massive; friable when moist; moderately alkaline; strong effervescence.

The solum ranges from 20 to 30 inches in thickness. The A1 horizon ranges from 5 to 10 inches in thickness, is very dark grayish brown or very dark brown in color, and is loam or silt loam in texture. The B2 horizon ranges from 10 to 20 inches in thickness, is very dark grayish brown in color, and is silt loam or loam in texture. It has weak or moderate prismatic structure that in places parts into subangular blocks. The C horizon is light olive brown, gray, olive brown, or mixtures of these and is silt loam or loam in texture. It has a large amount of disseminated and segregated lime in the upper part.

Roseglen soils are associated with Makoti and Tansem soils. They contain less clay and silt than Makoti soils. They have thicker A and B horizons than Tansem soils.

Roseglen-Tansem silt loams, level (0 to 2 percent slopes) (RtA).—This complex is in smooth areas on the higher parts of the glacial lake plains. Roseglen silt loam makes up about 60 to 75 percent of the complex, and Tansem silt loam about

25 to 40 percent. The Roseglen soil is in Concave areas, and the Tansem soil is in the higher, convex areas.

Included with this complex in mapping were a few small areas of Makoti silt loam.

Surface runoff is slow, and the hazard of erosion is slight.

This complex is well suited to crops, grass, and trees. Most areas are cultivated. Conserving moisture, maintaining fertility, and preventing soil blowing are parts of good management. Capability unit IIc-6; Roseglen part in windbreak group 1, Tansem part in windbreak group 3; Silty range site.

Salt Water Marsh

Salt water marsh (Sa) is in closed basins and on beachlines. This land type is flooded when runoff is above normal. Ground water from higher areas seeps into these areas and evaporates. This leaves salt on the surface.

The soil material is saline enough that only a few kinds of plants can grow. Salt water marsh is poorly suited to wildlife habitat. Capability unit VIIIs; not placed in a windbreak group; not placed in a range site.

Seroco Series

The Seroco series consists of deep, excessively drained soils that formed in sandy wind-worked outwash material.

In a representative profile, the surface layer is very dark grayish-brown fine sand about 4 inches thick. The underlying material, to a depth of about 12 inches, is dark grayish-brown fine sand. Below this, it is olive-brown and olive-gray loose fine sand.

Permeability is rapid. The available water capacity is very low. Organic-matter content is low, and fertility is low. These soils are droughty and very susceptible to soil blowing.

Seroco soils are better suited to grass than to other uses.

Representative profile of Seroco fine sand, hummocky, in a severely eroded area, 2,590 feet north and 500 feet east of the southwest corner of sec. 33, T. 151 N., R. 84 W.

A1—0 to 4 inches, dark grayish-brown (10YR 4/2) fine sand, very dark grayish brown (10YR 3/2) moist; single grain; loose; neutral; gradual boundary.

AC—4 to 12 inches, grayish-brown (10YR 5/2) fine sand, dark grayish brown (10YR 4/2) moist; single grain; loose; neutral; gradual boundary.

C1—12 to 30 inches, light yellowish-brown (2.5Y 6/3) fine sand, olive brown (2.5Y 4/3) moist; single grain; loose; neutral; gradual boundary.

C2—30 to 60 inches, light olive-gray (5Y 6/2) fine sand, olive gray (5Y 5/2) moist; single grain; loose; mildly alkaline; slight effervescence.

The A1 horizon ranges from 2 to 6 inches in thickness, is dark grayish brown or very dark grayish brown in color, and is fine sand or loamy fine sand in texture. The AC horizon is dark grayish brown or grayish brown in color. The C horizon is olive brown, grayish brown, or olive gray in color. The AC and C horizons are loamy fine sand, loamy sand, fine sand, or sand in texture.

Seroco soils are associated with Lihen and Telfer soils. They contain less organic matter and have a thinner A horizon than Lihen or Telfer soils.

Seroco fine sand, hummocky (SeC).—This soil is in the south-central part of the county.

Included with this soil in mapping were blowouts and dunes less than 10 feet high.

Soil blowing is a very severe hazard.

This soil is suited to grass. It is used for pasture. Control of soil blowing is a serious concern of management. Capability unit VIe-Sa; windbreak group 10; Sands range site.

Sinai Series

The Sinai series consists of deep, nearly level and gently sloping, moderately well drained soils that formed in clayey local alluvium. These soils are on glacial lake plains. Slopes range from 0 to 5 percent and are plane and concave.

In a representative profile, the surface layer is black silty clay loam about 7 inches thick. The subsoil is very dark gray firm silty clay about 20 inches thick. The underlying material is olive-gray silty clay.

Permeability is slow. The available water capacity is high. Organic-matter content is high, and fertility is high.

Sinai soils are well suited to small grains, grasses, legumes, and trees. Most areas are used for crops.

Representative profile of Sinai silty clay loam, gently sloping, in a cultivated field, 1,170 feet east and 35 feet south of the northwest corner of sec. 31, T. 151 N., R. 81 W.

Ap—0 to 7 inches, dark-gray (10YR 4/1) silty clay loam, black (10YR 2/1) moist; strong, very fine, granular structure; friable when moist; neutral; clear, smooth boundary.

B2—7 to 27 inches, gray (2.5Y 5/1) silty clay, very dark gray (2.5Y 3/1) moist; weak, medium, prismatic structure parting to strong, fine, angular blocky structure; hard when dry, firm when moist, very sticky and very plastic when wet; common root pores; neutral; clear, irregular boundary.

C—27 to 60 inches, light-gray (5Y 6/1) silty clay, olive gray (5Y 4/2) moist; massive; firm when moist; few root pores; moderately alkaline; slight effervescence.

The solum ranges from 20 to 30 inches in thickness. The A1 horizon ranges from 6 to 12 inches in thickness, is very dark gray or black in color, and is silty clay or silty clay loam in texture. The B2 horizon ranges from 10 to 24 inches in thickness, is very dark gray or very dark grayish brown in color, and is silty clay or clay in texture. The C horizon is olive gray or gray in color and is silty clay, or thinly laminated silty clay, silt, and clay.

Sinai soils are associated with Makoti and Nutley soils. They contain more clay than Makoti soils, and they have thicker A1 and B horizons than Nutley soils.

Sinai silty clay loam, gently sloping (2 to 5 percent slopes) (SgB).—This soil is in shallow swales and on foot slopes. It has the profile described as representative for the series.

Included with this soil in mapping were a few small areas of Sinai silty clay and Bowbells loam. Also included were a few areas of soils that are more strongly sloping or less sloping. Slopes are short in these areas.

Surface runoff is medium, and the hazard of erosion is moderate. Water running from higher areas causes gullies in places.

This soil is well suited to crops, grass, and trees. Most areas are cultivated. Controlling runoff, conserving moisture, and maintaining fertility are necessary in good management. Capability unit IIe-4; windbreak group 4; Clayey range site.

Sinai silty clay, level (0 to 2 percent slopes) (SnA).—This soil is in drainageways, in swales, and on foot slopes. The areas are small. The profile is similar to the one described as representative for the series, but the surface layer is silty clay.

Surface runoff is slow, and the hazard of erosion is slight. Water runs from higher areas across this soil and causes gullies in places.

This soil is well suited to crops, grass, and trees. Most areas are cultivated. Conserving moisture and maintaining fertility are a necessary part of good management. Controlling water from higher lying areas is a concern of management. Capability unit IIe-4; windbreak group 4; Clayey range site.

Sioux Series

The Sioux series consists of level and undulating, excessively drained soils that formed in sand and gravel outwash material on outwash plains. Slopes are plane and convex and are 1 to 6 percent. Sand and gravel is at a depth of 6 to 12 inches.

In a representative profile, the surface layer is black gravelly loam about 7 inches thick. The underlying material, to a depth of about 12 inches, is dark-brown gravelly sandy loam. Below this, it is grayish-brown loose coarse sand and gravel.

Permeability is very rapid below the surface layer. The available water capacity is very low. Organic-matter content is moderately low, and fertility is low. These soils are droughty.

Sioux soils are not well suited to crops. They are better suited to grass.

Representative profile of Sioux gravelly loam, from an area of Sioux soils, undulating, in a cultivated field, 1,620 feet north and 70 feet west of the southeast corner of sec. 1, T. 157 N., R. 82 W.

Ap—0 to 7 inches, dark-gray (10YR 4/1) gravelly loam, black (10YR 2/1) moist; weak, fine, granular structure and single grain; friable when moist; neutral; clear, smooth boundary.

IIAC--7 to 12 inches, dark grayish-brown (10YR 4/2) gravelly sandy loam, dark brown (10YR 3/3) moist; weak, fine, subangular blocky structure and single grain; very friable; neutral; clear, wavy boundary.

IIC—12 to 60 inches, light brownish-gray (2.5Y 6/2) coarse sand and gravel, grayish brown (2.5Y 5/2) moist; single grain; loose; lime coatings on bottom of pebbles; moderately alkaline; strong effervescence.

The soil ranges from 6 to 12 inches in depth to sand and gravel. The A horizon is very dark gray or black in color and is loam, gravelly loam, or gravelly sandy loam in texture. The C horizon is sand and gravel and is 20 to more than 60 percent gravel. In places, the C horizon consists of layers of gravel and sand.

Sioux soils are associated with Arvilla and Renshaw soils. They are not so thick to sand and gravel as Arvilla and Renshaw soils.

Sioux soils, undulating (1 to 6 percent slopes) (SoB).—These soils are on low ridges and hills. The areas are small.

Included with this soil in mapping were a few small areas of Arvilla and Renshaw soils and a few areas of soils that have slopes of more than 6 percent. Slopes are short in these areas.

Low fertility and very low available water capacity are severe limitations, and soil blowing is a severe hazard.

This soil is suited to grass. It is used for pasture. Some areas are mined for gravel. Regulating grazing to maintain desirable grasses is the main concern of management. Capability unit VIs-SwG; windbreak group 10; Shallow to Gravel range site.

Svea Series

The Svea series consists of deep, level and gently sloping, moderately well drained soils that formed in loamy glacial till. These soils are on foot slopes and in swales. Slopes are plane and concave and are 0 to 7 percent.

In a representative profile, the surface layer is black loam about 9 inches thick. The subsoil is about 16 inches thick. It is very dark brown friable loam in the upper part and olive-brown friable loam in the lower part. The underlying material, to a depth of about 42 inches, is friable olive loam that contains much lime. Below this, it is firm olive loam.

Permeability is moderate to a depth of about 24 inches and is moderately slow below that depth. The available water capacity is high. Organic-matter content is high, and fertility is high.

Svea soils are well suited to small grains, grass, legumes, and trees. Most areas are used for crops.

Representative profile of Svea loam, level, in a cultivated field, 630 feet south and 70 feet east of the northwest corner of sec. 15, T. 156 N., R. 83 W.

Ap—0 to 8 inches, dark-gray (10YR 4/1) loam, black (10YR 2/1) moist; strong, very fine, granular structure; friable when moist; neutral; clear, smooth boundary.

B21—8 to 16 inches, dark-gray (10YR 4/1) loam, very dark brown (10YR 2/2) moist; weak, medium, prismatic structure parting to weak, medium, angular blocky structure; slightly hard when dry, friable when moist, sticky and plastic when wet; many root pores; neutral; clear, wavy boundary.

B22—16 to 24 inches, grayish-brown (2.5Y 5/2) loam, olive brown (2.5Y 4/3) moist; moderate, medium, prismatic structure parting to moderate, medium, angular blocky structure; friable when moist; many root pores; neutral; clear, wavy boundary.

C1ca—24 to 42 inches, pale-olive (5Y 6/3) loam, olive (5Y 5/3) moist; weak, fine, subangular blocky structure; friable when moist; common root pores; much segregated lime; moderately alkaline; violent effervescence; gradual boundary.

C2—42 to 60 inches, pale-olive (5Y 6/3) loam, olive (5Y 4/3) moist; massive; firm when moist; few root pores; moderately alkaline; strong effervescence.

The solum ranges from 16 to more than 30 inches in thickness. The A1 horizon ranges from 6 to 16 inches in thickness, is black or very dark gray in color, and is loam or silt loam in texture. The B2 horizon ranges from 10 to 20 inches in thickness, is very dark brown, very dark grayish brown or olive brown in color, and is loam or clay loam in texture. It has weak or moderate prismatic structure. The C horizon is light olive brown, grayish brown, olive, or olive brown in color and is loam in texture. It has an accumulation of lime in the upper part, and some is segregated into few to many soft masses. In a few places thin strata of sandy loam, gravel, and clay loam are in the C horizon at a depth of more than 36 inches.

Svea soils are associated with Barnes, Hamerly, Lamoure, Tonka, and Parnell soils. Svea soils have a thicker solum than Barnes or Hamerly soils. They contain less clay in the B2 horizon and are better drained than Parnell or Tonka soils. They have a lime-free solum and contain more sand than Lamoure soils.

Svea loam, level (0 to 2 percent slopes) (SvA).—This soil is on level areas and in shallow swales. It has the profile described as representative for the series.

Included with this soil in mapping were small areas of Barnes and Hamerly soils.

Surface runoff is slow, and the hazard of erosion is slight.

This soil is well suited to crops, grass, and trees. Most areas are cultivated. Conserving moisture and maintaining fertility are the main concerns of management. Capability unit IIc-6; windbreak group 1; Silty range site.

Svea loam, gently sloping (2 to 5 percent slopes) (SvB).—This soil is on foot slopes and in swales. Slopes are 100 to 200 feet long.

Surface runoff is medium, and the hazard of erosion is moderate.

This soil is well suited to crops, grass, and trees. Most areas are cultivated. Conserving moisture, maintaining fertility, and controlling surface runoff are necessary for good management. Capability unit IIe-6; windbreak group 1; Silty range site.

Svea loam, fans, nearly level (0 to 3 percent slopes) (SwA).—This soil is on fans at the base of more strongly sloping areas in the valleys of the Souris and Des Lacs Rivers. The fans are 300 to 500 feet long. The profile is similar to the one described as representative for the series, but it has thin strata of sand in the underlying material in places and the soil material is more friable and permeable.

Surface runoff is slow, and the hazard of erosion is slight. Water from higher areas runs across this soil.

This soil is well suited to crops, grass, and trees. Most areas are cultivated. Conserving moisture, maintaining fertility, and controlling runoff are a necessary part of good management. Capability unit IIc-6; windbreak group 1; Silty range site.

Svea loam, fans, gently sloping (3 to 7 percent slopes) (SwB).—This soil is on long fans and on foot slopes at the base of steep areas in the valleys of the Souris and Des Lacs Rivers. The profile is similar to the one described as representative for the series, but it is more friable, more permeable, and has thin sandy strata in the underlying material in places.

Surface runoff is medium, and the hazard of erosion is moderate. Water from higher areas runs across this soil and causes gullies in places.

This soil is well suited to crops, grass, and trees. Controlling runoff is a serious concern of management, and conserving moisture and maintaining fertility are lesser concerns. Capability unit IIe-6; windbreak group 1; Silty range site.

Svea-Hamerly-Tonka loams (0 to 2 percent slopes) (Sx).—This complex is in irregular swales and on slopes that contain shallow depressions. Svea loam makes up about 50 to 70 percent of the complex; Hamerly loam, 15 to 25 percent; and Tonka silt loam, about 10 to 25 percent. The Svea soil is in the swales and on flat areas. The Tonka soil is in the shallow depressions. The Hamerly soil is on rims around the Tonka soil and through saddles between the depressions.

The depressional areas are flooded by runoff for a short time during thaws in spring and after heavy rains. The Tonka soil remains wet for a few weeks or throughout the growing season during unusually wet seasons.

This complex is suited to crops, grass, and trees. A large part is cultivated. Removing surface water is a special concern of management. Capability unit IIc-6; Svea part in windbreak group 1, Hamerly part in windbreak group 3, Tonka part in windbreak group 2; Svea and Hamerly parts in Silty range site, Tonka part in Wetland range site.

Svea-Lamoure complex (0 to 4 percent slopes) (Sy).—This complex is in shallow drainageways, including the narrow fan or foot slope and the flat bottom land at the base of the fan. The areas are long and narrow. Svea loam makes up about 50 to 75 percent of the complex, and Lamoure silt loam or Lamoure silty clay loam about 25 to 50 percent. The Lamoure soils are on the level bottom lands, and the Svea soil is on the fans and foot slopes.

Wetness on the Lamoure soils and flooding by runoff are the main hazards.

This complex is suited to crops, grass, and trees. It is used for cultivated crops, hay, and pasture. Removing surface water and controlling runoff from higher lying areas are special concerns of management. Capability unit IIe-6; Svea part in windbreak group 1, Lamoure part in windbreak group 2; Svea part in Silty range site, Lamoure part in Subirrigated range site.

Svea-Tonka loams (0 to 2 percent slopes) (Sz).—This complex is in swales and shallow drainageways that have small, oval depressions along them. Svea loam makes up about 75 to 90 percent of the complex, and Tonka silt loam about 10 to 25 percent. The Svea soil is in the upper parts of swales and around the depressions. The Tonka soil is in the small depressions.

The small depressions are flooded when the snow melts in spring and after heavy rains.

This complex is well suited to crops, grass, and trees. A large part is cultivated. Removing surface water is a part of good management. Capability unit IIc-6; Svea part in windbreak group 1, Tonka part in windbreak group 2; Svea part in Silty range site, Tonka part in Wetland range site.

Tansem Series

The Tansem series consists of deep, nearly level, well-drained soils that formed in silty glacial lake sediment on glacial lake plains. Slopes are plane and convex.

In a representative profile, the surface layer is very dark brown silt loam about 6 inches thick. The subsoil is dark-brown friable silt loam about 8 inches thick. The underlying material, to a depth of about 30 inches, is olive-brown silt loam that contains much lime. Below this, it is gray and olive-brown silt loam.

Permeability is moderate. The available water capacity is high. Organic-matter content is moderate, and fertility is high.

Tansem soils are well suited to small grains, grasses, legumes, and trees. Most areas are used for crops.

Tansem soils are mapped only in a complex with the Roseglen soils.

Representative profile of Tansem silt loam, from an area of Roseglen-Tansem silt loams, level, in a cultivated field, 2,510 feet west and 700 feet south of the northeast corner of sec. 14, T. 151 N., R. 86 W.

Ap—0 to 6 inches, dark-gray (10YR 4/1) silt loam, very dark brown (10YR 2/2) moist; moderate, very fine, granular structure; friable when moist; neutral; clear, smooth boundary.

B2—6 to 14 inches, dark grayish-brown (10YR 4/2) silt loam, dark brown (10YR 3/3) moist; weak, medium, prismatic structure parting to weak, medium, subangular blocky structure; slightly hard when dry, friable when moist; slightly sticky and slightly plastic when wet; many root pores; neutral; clear, wavy boundary.

C1ca—14 to 30 inches, grayish-brown (2.5Y 5/2) silt loam, olive brown (2.5Y 4/3) moist; weak, fine, subangular blocky structure; friable when moist; common root pores; soft accumulations of lime; moderately alkaline; violent effervescence; gradual boundary.

C2—30 to 60 inches, light-gray and light yellowish-brown (5Y 6/1 and 2.5Y 6/3) silt loam, gray and olive brown (5Y 5/1 and 2.5Y 4/4) moist; massive; friable; few root pores; moderately alkaline; strong effervescence.

The solum ranges from 12 to 18 inches in thickness to lime. The A1 horizon is very dark brown or very dark grayish brown in color and is loam or silt loam in texture. The B2 horizon is dark brown, dark grayish brown, or very dark grayish brown in color and is silt loam or loam in texture. It has weak or moderate prismatic structure parting to subangular blocky structure. The C horizon is olive brown, light olive brown, grayish brown, or gray in color and is silt loam in texture. It has an accumulation of lime in the upper part. The lower part is thinly laminated silt, loam, and very fine sand.

Tansem soils are associated with Makoti and Roseglen soils. They contain less clay than Makoti soils, and they have a thinner solum than Roseglen soils.

Telfer Series

The Telfer series consists of deep, level to rolling, somewhat excessively drained soils that formed in sandy outwash material on outwash plains. Slopes range from 0 to 12 percent and are plane and convex.

In a representative profile, the surface layer is very dark brown loamy fine sand about 6 inches thick. Below this is very dark grayish-brown very friable loamy fine sand about 9 inches thick. The underlying material, to a depth of about

30 inches, is dark grayish-brown loose loamy fine sand. Below this, it is olive-brown loose fine sand.

Permeability is rapid. The available water capacity is low. Organic-matter content is moderately low, and fertility is low. These soils are droughty and susceptible to soil blowing.

Telfer soils are suited to small grains, grasses, legumes, and trees. Most areas are used for crops, but many areas have been seeded to grass and legumes.

Representative profile of Telfer loamy fine sand, from an area of Lihen-Telfer loamy fine sands, undulating, in a cultivated field, 950 feet south and 50 feet east of the northwest corner of sec. 33, T. 151 N., R. 84 W.

Ap—0 to 6 inches, dark grayish-brown (10YR 4/2) loamy fine sand, very dark brown (10YR 2/2) moist; weak, fine, crumb structure and single grain; very friable when moist; many roots; neutral; clear, smooth boundary.

AC—6 to 15 inches, dark grayish-brown (10YR 4/2) loamy fine sand, very dark grayish brown (10YR 3/2) moist; weak, coarse, prismatic structure parting to single grain; soft when dry, very friable when moist, nonsticky and nonplastic when wet; many roots; neutral; gradual boundary.

C1—15 to 30 inches, grayish-brown (2.5Y 5/2) loamy fine sand, dark grayish brown (2.5Y 4/2) moist; single grain; loose; few roots; neutral; gradual boundary.

C2—30 to 60 inches, light brownish-gray (2.5Y 6/2) fine sand, olive brown (2.5Y 4/3) moist; single grain; loose; mildly alkaline; slight effervescence.

The A horizon ranges from 6 to 15 inches in thickness. It is very dark brown or very dark grayish brown in color and is loamy fine sand or fine sandy loam in texture. The C horizon is dark grayish brown, grayish brown, or olive brown in color and is loamy fine sand or fine sand in texture.

Telfer soils are associated with Lihen and Seroco soils. They are not dark colored to so great a depth as Lihen soils and are dark colored to a greater depth than Seroco soils.

Telfer-Lihen loamy fine sands, rolling (6 to 12 percent slopes) (TlC).—Areas of this complex are characterized by irregular slopes, concave foot slopes, and swales. Relief is 10 to 25 feet, and slopes are 200 to 300 feet long. Telfer soil makes up about 50 to 70 percent of the complex, and Lihen soil about 30 to 50 percent. The Telfer soil is on hills and convex side slopes. The Lihen soil is in swales and on concave foot slopes.

Included with this complex in mapping were some areas of soils that have a surface layer of fine sandy loam.

Soil blowing is a severe hazard. Loss of soil fertility and loss of moisture are moderate limitations. Cultivated fields are moderately eroded.

This complex is suited to crops, grass, and trees. About half the acreage is cultivated. The remainder is in native grassland. Conserving moisture, maintaining fertility, and controlling soil blowing are serious concerns of management. Capability unit IVes-3; windbreak group 7; Sands range site.

Tonka Series

The Tonka series consists of deep, level, poorly drained soils that formed in glacial alluvium. These soils are in shallow, closed depressions on till plains.

In a representative profile, the surface layer is very dark gray silt loam about 8 inches thick. The subsurface layer is dark-gray loam about 12 inches thick. The subsoil is about 28 inches thick. It is black firm clay loam in the upper 16 inches and olive clay loam in the lower 12 inches. The underlying material is olive loam.

Permeability is slow below the surface and subsurface layers, and runoff water ponds on the surface. The available water capacity is high. Organic-matter content is high, and fertility is high.

Tonka soils are well suited to grass. If drained, they are also suited to small grains, legumes, and trees. Most areas are used for crops.

Representative profile of Tonka silt loam, in a shallow depression, in a cultivated field, 2,430 feet east and 65 feet north of the southwest corner of sec. 25, T. 156 N., R. 85 W.

Ap–0 to 8 inches, gray (10YR 5/1) silt loam, very dark gray (10YR 3/1) moist; moderate, very fine, granular structure; friable when moist; neutral; clear, smooth boundary.

A2–8 to 20 inches, light-gray (2.5Y 6/1) loam, dark gray (2.5Y 4/1) moist; common, large, prominent, dark-brown mottles; weak, medium, platy structure parting to moderate, fine, granular structure; friable when moist; many root pores; slightly acid; abrupt, wavy boundary.

B21t–20 to 36 inches, dark-gray (2.5Y 4/1) clay loam, black (2.5Y 2/1) moist; moderate, medium, angular blocky structure; hard when dry, firm when moist, very sticky and very plastic when wet; common root pores; neutral; gradual boundary.

B22t–36 to 48 inches, olive-gray (5Y 5/2) clay loam, olive (5Y 4/3) moist; some very dark gray coatings; moderate, medium, angular blocky structure; firm when moist; few root pores; neutral; gradual boundary.

IIC–48 to 60 inches, light olive-gray (5Y 6/2) loam, olive (5Y 4/4) moist; massive; firm; mildly alkaline.

The solum ranges from 18 to more than 60 inches in thickness to lime. The A1 horizon ranges from 6 to 24 inches in thickness. It is very dark gray or black in color and is silt loam or silty clay loam in texture. The A2 horizon ranges from 4 to 16 inches in thickness, is dark gray or very dark gray in color, and is loam, silt loam, or very fine sandy loam in texture. This horizon contains few to many prominent mottles, and it has weak or moderate, thin to thick, platy structure. The B2t horizon ranges from 12 to 30 inches in thickness, is black, very dark gray, or olive in color, and is clay loam or light clay in texture. The C horizon is olive or olive gray in color, and is loam or clay loam in texture.

Tonka soils are associated with Barnes, Hamerly, Max, Parnell, and Williams soils. Tonka soils have poorer drainage and contain more clay in the B horizon than Barnes, Max, and Williams soils. They contain more clay than Hamerly soils. They have a platy A2 horizon, which is lacking in Parnell soils.

Tonka silt loam (0 to 1 percent slopes) (To).—This soil is in shallow depressions and potholes. The areas are small and oval.

Included with this soil in mapping were small areas of Parnell silty clay loam.

This soil is flooded by runoff from adjacent areas during thaws in spring and in wet periods. Ponding makes it impossible to grow crops in some years.

If drained, this soil is suited to small grain. It is less suited to corn, alfalfa, and trees. It is well suited to grass. Most areas are cultivated along with the adjacent soils. Removing surface water is the main concern of management. Capability unit IIw-6; windbreak group 2; Wetland range site.

Vallers Series

The Vallers series consists of deep, level, poorly drained soils that formed in loamy glacial till or till plains. Slopes are plane.

In a representative profile, the surface layer is very dark gray loam about 6 inches thick. The underlying material, to a depth of about 10 inches, is olive-gray friable loam that is high in lime. Below this, it is olive firm loam that has gray mottles.

Permeability is moderately slow, and runoff is slow. The available water capacity is high. Organic-matter content is moderate, and fertility is high. These soils are seasonally subirrigated and are moderately wet, but they are seldom ponded.

Some areas of Vallers soils are used for crops.

Representative profile of Vallers loam, saline, on a slight rise between two wet depressions, in native grassland, 1,560 feet west and 30 feet south of the northeast corner of sec. 22, T. 152 N., R. 85 W.

A1—0 to 6 inches, dark-gray (2.5Y 4/1) loam, very dark gray (2.5Y 3/1) moist; strong, very fine, granular structure; friable when moist; many roots; moderately alkaline; strong effervescence; clear, irregular boundary; tongues of this material extend to a depth of 10 inches.

Cca—6 to 10 inches, gray (5Y 5/1) loam, olive gray (5Y 4/2) moist; moderate, medium, subangular blocky structure parting to moderate, fine, granular structure; friable when moist; common roots; some salt; moderately alkaline; violent effervescence; clear, wavy boundary.

Ccs–10 to 60 inches, pale-olive (5Y 6/3) loam, olive (5Y 4/3) moist; many, small, prominent gray mottles; massive; firm; few roots: many gypsum crystals; moderately alkaline; strong effervescence.

The A1 horizon ranges from 3 to 10 inches in thickness. It is black or very dark gray in color and loam or clay loam in texture. The Cca horizon ranges from 3 to 12 inches in thickness, is olive or olive gray in color, and is loam or clay loam in texture. It has few to many salt crystals and soft lime accumulations. The Ccs horizon is olive or olive gray loam and contains some lime and few to many, small and large gypsum crystals.

Vallers soils are associated with Hamerly, Harriet, Parnell, and Tonka soils. They are wetter than Hamerly soils. They are not so strongly alkaline as Harriet soils. They have a thinner A horizon and contain more lime than Parnell and Tonka soils.

Vallers loam, saline (0 to 2 percent slopes) (Va).—This soil is in low areas around potholes and sloughs and in low swales. The areas are small.

Included with this soil in mapping were small areas of Colvin, Hamerly, and Parnell soils.

Salts are common in the surface layer. The water table is at or near the surface in spring and in wet periods.

Some of this soil is cultivated, but tillage is delayed because of wetness, and crops do not do well in the saline spots. This soil is not suited to trees. It is better suited to grasses than to other uses. Maintaining and seeding desirable species of grass are the main concerns of management. Capability unit IVw-4L; windbreak group 10; Subirrigated range site.

Velva Series

The Velva series consists of deep, level, well-drained soils that formed in stratified loamy alluvium on river bottom lands.

In a representative profile, the surface layer is very dark brown loam about 7 inches thick. The subsoil is very dark grayish-brown friable loam about 8 inches thick. The underlying material is grayish-brown and olive-gray very fine sandy loam that contains darker colored layers.

Permeability is moderate. The available water capacity is high. Organic-matter content is moderate, and fertility is high. Small areas along the rivers are frequently flooded, and nearly all areas of these soils were flooded in the spring of 1969.

Velva soils are well suited to small grains, grasses, legumes, and trees. Most large areas are used for crops.

Representative profile of Velva loam, in a cultivated field, 1,320 feet east and 1,100 feet south of the northwest corner of sec. 26, T. 157 N., R. 85 W.

Ap—0 to 7 inches, dark-gray (10YR 4/1) loam, very dark brown (10YR 2/2) moist; moderate, very fine, granular structure; friable when moist; many roots; neutral; clear, smooth boundary.

B—7 to 15 inches, dark grayish-brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; weak, coarse, prismatic structure parting to weak, fine, granular structure; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many roots; neutral; clear, smooth boundary.

Ab—15 to 18 inches, dark-gray (2.5Y 4/1) silt loam, black (2.5Y 2/1) moist; moderate, fine, granular structure; friable when moist; many roots; mildly alkaline; slight effervescence; clear, smooth boundary.

C1ca—18 to 45 inches, light-gray (2.5Y 7/2) very fine sandy loam, grayish brown (2.5Y 5/2) moist; weak, very fine, granular structure and single grain; very friable when moist; common roots; moderately alkaline; violent effervescence; gradual boundary.

C2—45 to 60 inches, light olive-gray (5Y 6/2) very fine sandy loam, olive gray (5Y 4/2) moist; massive and single grain; friable; few roots; moderately alkaline; strong effervescence.

The A1 horizon ranges from 5 to 10 inches in thickness. It is very dark brown or very dark grayish brown in color and is fine sandy loam, very fine sandy loam, loam, silt loam, or silty clay loam in texture. The underlying material is made up of layers of fine sandy loam, loam, silt loam, or very fine sandy loam. These layers are olive-gray, grayish brown, very dark grayish brown, dark gray, very dark brown, or black in color. The darker layers are a buried A horizon. Some layers have a moderate amount of soluble salts.

Velva soils are associated with Harriet, Ludden, and Svea soils. They are better drained and contain less clay than Harriet and Ludden soils. They have a thinner A1 horizon than Svea soils.

Velva fine sandy loam (0 to 3 percent slopes) (Ve).—This soil is in areas along meandering streams. The areas are irregular in shape. The profile is similar to that described as representative for the series, but the surface layer is fine sandy loam.

Included with this soil in mapping were a few areas of soils that have a surface layer of very fine sandy loam.

The streams overflow and flood this soil, generally during the spring thaw. Soil blowing is a moderate hazard.

Most of this soil is in native woodland, but in the valley of the Des Lacs River above Burlington the areas are in native grass. Some areas are cultivated. This soil is well suited to trees, grass, and crops. It is suited to recreation and wildlife habitat. Preventing damage from flooding and controlling soil blowing are the main concerns of management. Capability unit IIIe-3; windbreak group 1; Silty range site.

Velva loam (0 to 2 percent slopes) (Vh).—This nearly level soil is along the Des Lacs and Souris Rivers. It has the profile described as representative for the series (fig. 6).

Included with this soil in mapping were a few small areas of Velva silty clay loam.

Flooding occurs if a large amount of snow melts during the spring thaw or if there is heavy rain in summer.

This soil is well suited to crops, grass, and trees. A large part is cultivated, and some areas are irrigated. Conserving fertility and preventing damage from flooding are necessary for good management. Capability unit IIe-5; windbreak group 1; Silty range site.

Velva loam, alkali variant (0 to 2 percent slopes) (Vk).—This soil is on low fans and in the slightly lower areas of the bottom lands. The profile is similar to that described as representative for the series, but the subsoil and the underlying material are moderately alkaline and contain more soluble salts.

Included with this soil in mapping were a few small areas of Harriet soil.

A water table is commonly within a depth of 5 feet. Salts in the soil affect the growth of vegetation in places.

This soil is not well suited to crops and is not suited to trees. Most areas are in native grass that is used for pasture or hay. Maintaining desirable grass species is part of good management. Capability unit VIs-SSb; windbreak group 9; Saline Subirrigated range site.

Figure 6.—Profile of Velva loam.

Wabek Series

The Wabek series consists of level to hilly, excessively drained soils that formed in sand and gravel outwash material. These soils are on outwash plains. Slopes range from 1 to 20 percent and are plane and convex. Sandy and gravelly material is at a depth of 4 to 8 inches.

In a representative profile, the surface layer is very dark grayish-brown gravelly sandy loam about 6 inches thick. The underlying material, to a depth of about 12 inches, is dark grayish-brown loamy coarse sand. Below this, it is grayish-brown and olive-brown coarse sand and gravel.

Permeability is very rapid below the surface layer. The available water capacity is very low. Organic-matter content is moderately low and fertility is low. These soils are droughty.

Wabek soils are better suited to grassland than to other uses.

Representative profile of Wabek gravelly sandy loam, from an area of Wabek soils, undulating, in a cultivated field, 2,110 feet north and 200 feet east of the southwest corner of sec. 15, T. 151 N., R. 84 W.

Ap—0 to 6 inches, dark grayish-brown (10YR 4/2) gravelly sandy loam, very dark grayish brown (10YR 3/2) moist; weak, fine, granular structure and single grain; very friable when moist; many roots; neutral; clear, smooth boundary.

IIC1—6 to 12 inches, light brownish-gray (2.5Y 6/2) loamy coarse sand, dark grayish brown (2.5Y 4/2) moist; single grain; loose; few roots; neutral; gradual boundary.

IIC2ca—12 to 36 inches, light-gray (2.5Y 7/2) coarse sand and gravel, light brownish gray (2.5Y 6/2) moist; single grain; loose; lime coatings on bottom of pebbles; moderately alkaline; strong effervescence; gradual boundary.

IIC3—36 to 60 inches, light brownish-gray (2.5Y 6/2) coarse sand and gravel, olive brown (2.5Y 4/3) moist; single grain; loose; slight effervescence.

The A horizon ranges from 4 to 8 inches in thickness. It is very dark brown or very dark grayish brown in color and loam, gravelly loam, or gravelly sandy loam in texture. The IIC horizon consists of layers of light brownish-gray, dark grayish-brown, or olive-brown loamy coarse sand to sand and gravel.

Wabek soils are associated with Lehr and Manning soils. They are not so thick to sand and gravel as those soils.

Wabek soils, undulating (0 to 6 percent slopes) (WaB).—These soils are in low ridges and knolls. Relief is less than 15 feet, and slopes are 100 to 200 feet long. The Wabek gravelly sandy loam in this unit has the profile described as representative for the series.

Included with these soils in mapping were areas of soils that have a surface layer of gravelly loam, cobbly loam, sandy loam, and gravelly sandy loam. Also included were a few small areas of Manning and Lehr soils.

Available water capacity is very low, and fertility is low. The hazard of soil blowing is severe. These soils are poorly suited to crops and trees. Much of the acreage was once cultivated but is now seeded to grass. Establishing and maintaining a grass cover and controlling soil blowing are serious concerns of management. Capability unit VIs-SwG; windbreak group 10; Shallow to Gravel range site.

Wabek soils, hilly (6 to 20 percent slopes) (WaE).—These soils are on high ridges, knolls, and sides of hills. Relief is 15 to 50 feet, and slopes are 200 to 300 feet long. The profiles of these soils are similar to the ones described as representative for the series, but a few areas, mainly on the tops of hills, have a thinner surface layer that contains more gravel.

Very low available water capacity, the shallowness to sand and gravel, and low fertility are severe limitations. Soil blowing is a severe hazard.

These soils are suited to grass, poorly suited to crops, and unsuited to trees. Most areas are in grass, but about 2,000 acres is cultivated. Some areas are used as a source of gravel for roads. Maintaining desirable species of grass, maintaining a grass cover on the surface, controlling soil blowing, and conserving moisture are special concerns of management. Capability unit VIs-SwG; windbreak group 10; Shallow to Gravel range site.

Wabek, Max, and Zahl stony loams, rolling (3 to 20 percent slopes) (WeC).—This undifferentiated group is in an area of hills, knolls, ridges, side slopes, and small swales. It consists of Wabek gravelly loam in some areas, Max loam in some areas, Zahl loam in some areas, and two or all three of the soils in other areas. Relief is 5 to more than 50 feet. Included in mapping were small areas of Tonka silt loam, Bowbells loam, Parnell silty clay loam, Lehr loam, and other soils.

The profiles of the Wabek, Max, and Zahl soils are similar to the ones described as representative for their respective series, but the surface layer contains more stones (fig. 7).

Erosion is a hazard, and lack of moisture is a limitation.

This group is better suited to grass than to other uses. Most of the acreage is used for pasture. Maintaining desirable grass species and controlling erosion are part of good

Figure 7.—Profile of Wabek stony loam.

management. Capability unit VIIs-Si; windbreak group 10; Wabek part in Shallow to Gravel range site, Max part in Silty range site, Zahl part in Thin Silty range site.

Williams Series

The Williams series consists of deep, level to strongly sloping, well-drained soils that formed in loamy glacial till on glacial plains. Slopes range from 0 to 12 percent and are plane or convex.

In a representative profile, the surface layer is very dark brown loam about 6 inches thick. The subsoil is about 12 inches thick. It is dark-brown friable clay loam in the upper part and olive-brown clay loam in the lower part. The underlying material, to a depth of 30 inches, is friable loam that is high in lime. Below this, it is firm olive and gray loam.

Permeability is moderate to a depth of about 30 inches and is moderately slow below that depth. The available water capacity is high. Organic-matter content is moderate, and fertility is high.

Williams soils are well suited to small grains, grasses, legumes, and trees. Most areas are used for crops.

Representative profile of Williams loam, gently undulating, in a cultivated field, 125 feet south and 300 feet east of the northwest corner of sec. 33, T. 156 N., R. 85 W.

Ap–0 to 6 inches, dark-gray (10YR 4/1) loam, very dark brown (10YR 2/2) moist; strong, very fine, granular structure; friable when moist; neutral; clear, smooth boundary; fine tongues of this material extend to a depth of 12 inches.

B21t–6 to 12 inches, brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist; very dark grayish brown clay films; strong, medium, prismatic structure parting to moderate, medium, angular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; many root pores; neutral; gradual boundary.

B22t–12 to 18 inches, grayish-brown (2.5Y 5/2) clay loam, olive brown (2.5Y 4/3) moist; moderate, medium, prismatic structure parting to moderate, medium, angular blocky structure; friable when moist; many root pores; neutral; clear, wavy boundary.

C1ca–18 to 30 inches, grayish-brown (2.5Y 5/2) loam, olive brown (2.5Y 4/3) moist; weak, medium, subangular blocky structure; friable when moist; common root pores; much segregated lime; moderately alkaline; violent effervescence; gradual boundary.

C2–30 to 60 inches, pale-olive and light-gray (5Y 6/3 and 6/1) loam; olive and gray (5Y 4/3 and 5/1) moist; massive; firm when moist; moderately alkaline; strong effervescence.

The solum ranges from 10 to more than 20 inches in thickness. It has a few stones throughout. The A1 horizon ranges from 3 to 8 inches in thickness, is very dark brown or very dark grayish brown in color, and is loam or clay loam in texture. The B2t horizon ranges from 6 to 14 inches in thickness, is dark brown, dark grayish brown, or olive brown in color, and is clay loam or loam in texture. This horizon has moderate or strong prismatic structure parting to blocky structure, and it is friable or firm in consistence. The C horizon is dark grayish brown, olive brown, light olive brown, olive gray, olive, gray, or mixtures of these colors. It is loam or clay loam in texture and is friable or firm in consistence. The upper part has an accumulation of lime. The lime is either disseminated or in few to many soft accumulations.

Williams soils are associated with Bowbells, Max, and Zahl soils. They are dark colored to a lesser depth and have a thinner solum than Bowbells soils. They contain more clay in the B2t horizon than Max soils, and they have a thicker solum than Zahl soils.

Williams loam, level (0 to 2 percent slopes) (WlA).—This soil is on the smoother parts of the till plain where there are only a few swales or depressions. The profile is similar to that described as representative for the series, but the surface layer and subsoil are a little thicker.

Included with this soil in mapping were a few small areas of Bowbells loam and a few areas of soils that have more than 2 percent slopes.

Surface runoff is slow, and the hazard of erosion is slight.

This soil is well suited to crops, grass, and trees. Most areas are cultivated. Conserving moisture and maintaining fertility are a part of good management. Capability unit IIc-6; windbreak group 3; Silty range site.

Williams loam, gently undulating (2 to 4 percent slopes) (WlB).—This soil is in areas characterized by low knolls, ridges, and smooth slopes. Relief is 5 to 15 feet, and slopes are 200 to 300 feet long. This soil has the profile described as representative for the series.

Included with this soil in mapping were a few small areas of Max loam and a few areas of more strongly sloping soils.

Runoff is medium, and the hazard of erosion is slight.

This soil is well suited to crops, grass, and trees. Most areas are cultivated. Controlling runoff and soil blowing, conserving moisture, and maintaining fertility are a necessary part of good management. Capability unit IIe-6; windbreak group 3; Silty range site.

Williams loam, undulating (4 to 6 percent slopes) (WlC).—This soil is on irregular knolls, ridges, and side slopes around potholes, swales, and valley sides. Slopes are 200 to 300 feet long, and relief is 5 to more than 25 feet. The profile is similar to the one described as representative for the series, but the surface layer and subsoil are thinner in places.

Included with this soil in mapping were a few small areas of Bowbells loam, Max loam, Tonka silt loam, and Zahl loam. Also included and making up about 10 percent of the area were soils that have slopes of more than 6 percent. The slopes in these areas are short.

Runoff is medium, and the hazard of erosion is moderate.

This soil is suited to crops, grass, and trees. A large part is cultivated. Controlling erosion and runoff, conserving moisture, and maintaining fertility are part of good management. Capability unit IIe-6; windbreak group 3; Silty range site.

Williams loam, sloping (6 to 9 percent slopes) (WlD).—This soil is in areas along sides of drainageways. Slopes are 200 to 400 feet long. The areas are small and are irregular in shape. The profile is similar to that described as representative for the series, but the differences in the thickness of the surface layer and subsoil are greater. Tillage has mixed some of the subsoil with the remaining surface layer in places.

Runoff is medium or rapid, and the hazard of erosion is severe. Small gullies are in some swales.

This soil is suited to crops, grass, and trees. Most areas are cultivated. Controlling erosion, conserving moisture, and maintaining fertility are serious concerns of management. Capability unit IIIe-6; windbreak group 3; Silty range site.

Williams clay loam, level (0 to 3 percent slopes) (WmA).—This soil is on the smoother parts of the till plain, but there are small convex rises and a few shallow swales. The profile is similar to the one described as representative for the series, but the surface layer and underlying layers are clay loam, and the subsoil has more clay.

Included with this soil in mapping were a few small areas of Bowbells and Tonka soils.

Runoff is slow, and the hazard of erosion is slight.

This soil is well suited to crops, grass, and trees. Most areas are cultivated. Conserving moisture and maintaining fertility are a necessary part of good management. Capability unit IIc-6; windbreak group 3; Silty range site.

Williams clay loam, undulating (3 to 6 percent slopes) (WmB).—This soil is in areas characterized by low knolls, hills, ridges, and side slopes. Relief is about 15 feet, and slopes are 200 to 400 feet long. The profile is similar to the one described as representative for the series, but the surface layer and underlying layers are clay loam throughout.

Runoff is medium, and the hazard of erosion is moderate.

This soil is well suited to crops, grass, and trees. Most areas are cultivated. Controlling runoff and erosion, conserving moisture, and maintaining fertility are a necessary part of good management. Capability unit IIe-6; windbreak group 3; Silty range site.

Williams clay loam, rolling (6 to 9 percent slopes) (WmC).—This soil is on hills, side slopes, and ridges. Relief is 15 to 30 feet, and slopes are 300 to 400 feet long. The profile is similar to the one described as representative for the series, but the surface layer and underlying layers are clay loam.

Runoff is medium or rapid, and the hazard of erosion is severe.

This soil is suited to crops, grass, and trees. A large part of the acreage is cultivated. Controlling erosion and runoff are serious concerns of management, and conserving moisture and maintaining fertility are lesser concerns. Capability unit IIIe-6; windbreak group 3; Silty range site.

Williams clay loam, strongly sloping (9 to 12 percent slopes) (WmD).—This soil is along side slopes of drainageways. The areas are small and are irregular in shape. The profile is similar to the one described as representative for the series, but the texture is clay loam throughout. This soil has a thinner surface layer and subsoil than is typical of less sloping soils.

Included with this soil in mapping were a few small areas of Bowbells, Max, and Zahl loams.

Runoff is medium or rapid, and the hazard of erosion is severe. Many cultivated fields are moderately eroded.

This soil is not so well suited to crops and trees as the less sloping Williams soils. It is suited to grass. Part of the acreage is cultivated and part is in grass for hay and pasture. Controlling erosion and surface runoff, conserving moisture, and maintaining fertility are special concerns of management. Capability unit IVe-6; windbreak group 3; Silty range site.

Williams-Bowbells-Tonka loams, level (0 to 3 percent slopes) (WoA).—This complex is in areas of small, convex rises less than 5 feet high and many small swales and shallow, closed depressions. Williams loam makes up about 60 to 75 percent of the complex; Bowbells loam, about 15 to 20 percent; and Tonka silt loam, 10 to 20 percent. The Williams soil is on the convex rises, the Bowbells soil is in the small swales, and the Tonka soil is in the closed depressions.

Runoff is slow, and the hazard of erosion is slight. Water ponds in the shallow depressions during the spring thaw and after heavy rains.

This complex is suited to crops, grass, and trees. Most areas are cultivated, but some are in grass. Removing surface water and conserving fertility are the main concerns of management. Capability unit IIc-6; Williams part in windbreak group 3, Bowbells part in windbreak group 1, Tonka part in windbreak group 2; Williams and Bowbells parts in Silty range site, Tonka part in Wetland range site.

Williams-Hamerly loams, undulating (3 to 6 percent slopes) (WrB).—This complex is on side slopes and low rises surrounding deep depressions. Hamerly loam is around the deep depressions. Williams loam is at higher elevations above the Hamerly loam and surrounds both the depressions and Hamerly loam. Slopes are 50 to 100 feet long, and relief is 5 to 10 feet. Williams loam makes up about 50 to 75 percent of the complex, and Hamerly loam about 25 to 50 percent.

Runoff is medium, and the hazard of erosion is slight. Runoff ponds in the depressions for a few days during the spring thaw and after heavy rains.

This complex is suited to crops, grass, and trees. A large part of the acreage is cultivated, but some is in native grass. Wet areas that are ponded by runoff from higher areas are special concerns of management. Controlling erosion and runoff and conserving moisture are part of good management. Capability unit IIe-6; windbreak group 3; Silty range site.

Williams-Niobell loams, level (0 to 3 percent slopes) (WsA).—Williams loam makes up about 60 to 80 percent of this complex, and Niobell loam about 20 to 30 percent. The Niobell loam is intermixed in an irregular pattern with the Williams loam. The remainder of the complex consists of small areas of Bowbells and Noonan loams.

The profile of the Williams soil is similar to the one described as representative for the series, but the substratum is more alkaline in places.

Surface runoff is slow, and the hazard of erosion is slight. Lack of moisture on the Niobell soils is a limitation in dry seasons.

This complex is suited to crops and grass, but it is not so well suited to trees. A large part of the acreage is cultivated. Conserving moisture and maintaining fertility is part of good management. Controlling erosion is a lesser concern. Capability unit IIc-6; Williams part in windbreak group 3, Niobell part in windbreak group 4; Silty range site.

Zahl Series

The Zahl series consists of deep, rolling to steep, well-drained soils that formed in loamy glacial till. These soils are on glacial moraines and slope breaks. Slopes range from 6 to 60 percent and are convex.

In a representative profile, the surface layer is very dark gray and very dark brown loam about 6 inches thick. The underlying material, to a depth of about 15 inches, is dark grayish-brown friable loam that is high in lime. Below this, it is friable olive-brown loam that grades, at a depth of about 30 inches, to firm olive-gray loam.

Permeability is moderate to a depth of about 15 inches and moderately slow below that depth. The available water capacity is high. Organic-matter content is moderately low, and fertility is medium.

Zahl soils are better suited to grass and legumes than to crops.

Representative profile of Zahl loam, hilly, in native grassland, 2,340 feet east and 50 feet north of the southwest corner of sec. 34, T. 152 N., R. 83 W.

A11—0 to 3 inches, dark-gray (10YR 4/1) loam, very dark gray 10YR 3/1) moist; moderate, fine, granular structure; friable when moist; many roots; mildly alkaline; slight effervescence; clear, wavy boundary.

A12—3 to 6 inches, dark-gray (10YR 4/1) loam, very dark brown (10YR 2/2) moist; moderate, fine, granular structure; friable when moist; many roots; moderately alkaline; slight effervescence; clear, wavy boundary.

C1ca—6 to 15 inches, light brownish-gray (2.5Y 6/2) loam, dark grayish brown (2.5Y 4/2) moist; weak, fine, subangular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; common roots; much segregated lime; moderately alkaline; violent effervescence; gradual boundary.

C2—15 to 30 inches, grayish-brown (2.5Y 5/2) loam, olive brown (2.5Y 4/3) moist; massive; friable when moist; few roots; moderately alkaline; strong effervescence; gradual boundary.

C3—30 to 60 inches, light olive-gray (5Y 6/2) loam, olive gray (5Y 4/2) moist; massive; firm; moderately alkaline; strong effervescence.

The A horizon ranges from 3 to 8 inches in thickness. It is very dark gray, very dark brown, or very dark grayish brown in color and is loam or clay loam in texture. The upper part of the C horizon has an accumulation of lime. The lime is disseminated or in soft masses. The C horizon is loam or clay loam in texture. It is dark grayish brown or olive brown in the upper part and olive gray in the lower part. Very few to many stones are in the soil.

Zahl soils are associated with Bowbells, Max, and Williams soils and, in a few places, with Miranda soils. They do not have a B horizon and have a thinner A horizon and a thinner solum than the Bowbells, Max, and Williams soils. They are not so alkaline and lack the columnar Bt horizon typical of the Miranda soils.

Zahl loam, hilly (9 to 20 percent slopes) (ZaE).—This soil is on hilltops, ridges, and the upper parts of slope breaks. It has the profile (fig. 8) described as representative for the series.

Included with this soil in mapping were small areas of Max loam on smoother slopes.

Surface runoff is rapid, and the hazard of erosion is severe. In places in cultivated fields the underlying material has been mixed with the surface layer by plowing. These areas are lighter colored than is typical. Most are moderately eroded.

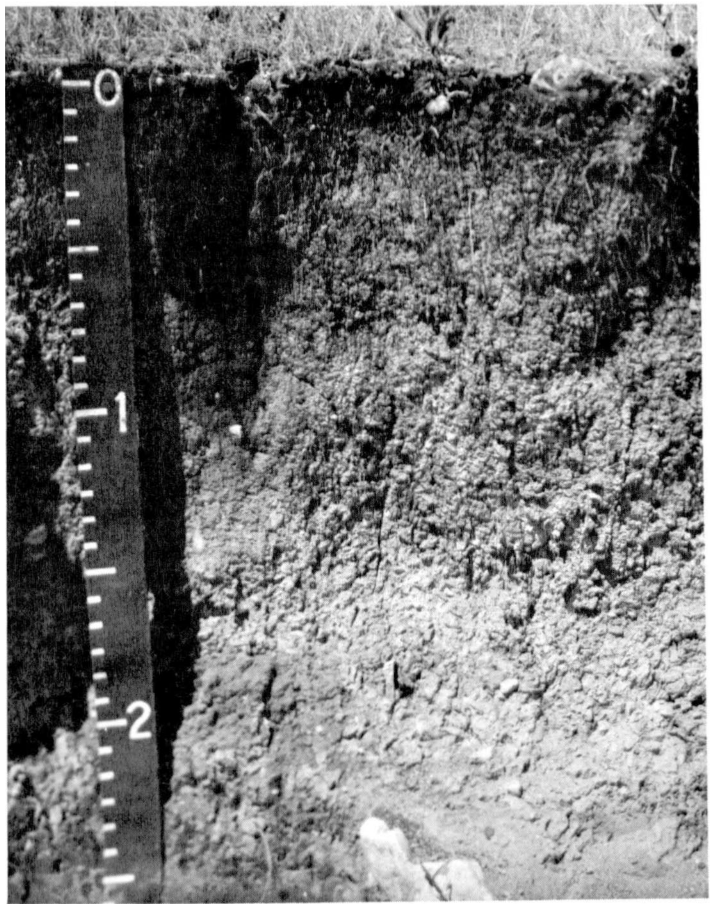

Figure 8.—Profile of Zahl loam in an area of native grassland. Only a thin dark-colored surface layer formed over the friable, calcareous, glacial till.

This soil is not suited to crops and trees. It is suited to grass. Controlling erosion, maintaining suitable species of grass, and keeping a grass cover are part of good management. Capability unit VIe-TSi; windbreak group 8; Thin Silty range site.

Zahl-Max loams, rolling (6 to 9 percent slopes) (ZmC).—This complex is on hilltops and slope breaks. Slopes are 100 to 200 feet long, and relief is 10 to more than 25 feet. Zahl loam makes up 50 to 75 percent of the complex, and Max loam about 25 to 50 percent. The Zahl soil is on hilltops and crests of side slopes, and the Max soil is on the smoother and lower parts of the side slopes.

Surface runoff is medium or rapid, and the hazard of erosion is severe. In cultivated fields some of the surface layer is removed, and the underlying material is mixed with the remaining surface layer by tillage.

This complex is not well suited to crops and trees. It is better suited to grass. Most areas are cultivated. Controlling erosion, conserving moisture, and maintaining fertility are serious concerns of management. Capability unit IVe-4L; Zahl part in windbreak group 8, Max part in windbreak group 3; Zahl part in Thin Silty range site, Max part in Silty range site.

Zahl-Max loams, hilly (12 to 25 percent slopes) (ZmE).—This complex is on hills in the moraines and steep valley sides. Slopes are 200 to 300 feet long and relief is 15 to more than 50 feet. Zahl loam makes up about 50 to 75 percent of the complex, and Max loam about 25 to 50 percent. The Zahl soil is on the upper side slopes and hilltops, and the Max soil is on foot slopes and smoother side slopes.

Included with this complex in mapping were small areas of Bowbells loam on the lower parts of foot slopes.

Surface runoff is rapid and the hazard of erosion is severe. The cultivated areas are moderately eroded.

This complex is better suited to grass than to other uses. Most areas are in grass, but a few small areas are cultivated. Controlling erosion and maintaining desirable grass species are the main concerns of management. Capability unit VIe-TSi; Zahl part in windbreak group 8, Max part in windbreak group 3; Zahl part in Thin Silty range site, Max part in Silty range site.

Zahl-Max loams, steep (20 to 60 percent slopes) (ZmF).—This complex is on the side slopes of the valleys of the Des Lacs and Souris Rivers and deep, side streams running into these valleys. Slopes are 400 to 500 feet long, and local relief is 50 to more than 200 feet. Zahl loam makes up about 50 to 75 percent of the complex, and Max loam about 25 to 50 percent. The Zahl soil is on hilltops and the upper parts of side slopes, and the Max soil is on the smoother, lower parts of the side slopes.

The profile of the Zahl loam is similar to the one described as representative for the series, but the surface layer is thinner in some areas, mainly on the highest part of the landscape.

Surface runoff is rapid, and the hazard of erosion is severe. A few areas have terraces or steps caused by grazing.

All of this complex is in native grassland and it is better suited to grass than to other uses. Shrubs are in a few areas. This complex is used for grazing. Maintaining a grass cover of desirable species and controlling erosion are the main concerns of management. Capability unit VIe-TSi; windbreak group 10; Zahl part in Thin Silty range site. Max part in Silty range site.

Zahl-Miranda loams, hilly (6 to 20 percent slopes) (ZnE).—This complex is on hills and side slopes, mainly on the downwind sides of salt lakes and marshes. Zahl loam makes up 50 to 75 percent of the complex, and Miranda loam about 25 to 50 percent. The Zahl soil is steeper and is on slope breaks and crests of hills. The Miranda soil is on side slopes, in small swales, and on foot slopes.

The profile of the Zahl soil in this complex is similar to the one described as representative for the Zahl series, but in places the surface layer contains salts.

When the salt lakes have dried, salts are blown from the lakebed and are deposited on the surface of this complex. This affects the growth of plants and increases the hazard of erosion.

This complex is not suited to crops or trees and is poorly suited to grass. All of it is used for range or pasture. Keeping an adequate cover of desirable plant species to control erosion is the main concern of management. Capability unit VIs-Cp; windbreak group 9; Zahl part in Thin Silty range site, Miranda part in Claypan range site.

Use and Management of the Soils

This section discusses the use and management of the soils as cropland, range, wildlife habitat, and as sites for windbreaks. It describes the relative suitability of soils for highway construction and other engineering uses. A table showing predicted yields under two levels of management is provided.

General Management of Cropland[2]

The main considerations in managing cultivated soil in Ward County are conserving moisture, controlling soil blowing and water erosion, and maintaining fertility.

In dryfarmed areas conserving moisture generally means reducing evaporation, limiting runoff, increasing infiltration, and controlling weeds. Among the effective measures that help to conserve moisture are stubble mulching, contour farming, stripcropping, field windbreaks, buffer strips, timely tillage, minimum tillage, use of crop residue, and application of fertilizer. Fallow also helps to control weeds and to build up the moisture content.

Among the measures that help to control erosion are cover crops, stripcropping, buffer strips, windbreaks, contour farming, diversions, waterways, minimum tillage, timely tillage, emergency tillage, and the use of crop residue. Generally, a combination of several measures is used.

Among the measures that help to maintain fertility are the application of chemical fertilizer, green manure, and barnyard manure and the inclusion in the cropping system of cover crops, grasses, and legumes, as well as the use of summer fallow. Control of erosion also helps to maintain fertility.

Drainage, removal of stones, and reduction of salinity are needed in places to offset the effects of unfavorable soil characteristics.

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

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

In the capability system, the kinds of soil 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. (None in Ward County).

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

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

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

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[2]By EDWARD R. WEIMER, agronomist, Soil Conservation Service.

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 habitat.

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

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

Class VIII soils and landforms have limitations that preclude their use for commercial plants and restrict their use to recreation, wildlife habitat, or 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, though they have other limitations that restrict their use largely to pasture, range, woodland, wildlife habitat, 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-4 or IIIe-6. Thus, in one symbol, the Roman numeral designates the capability class, or degree of limitation; the small letter indicates the subclass, or kind of limitation, as defined in the foregoing paragraph; and the Arabic numeral specifically identifies the capability unit within each subclass. Arabic numerals are also used to indicate the susceptibility to soil blowing; these range from 2, which is very high, to 6, which is slight. The letter P indicates the presence of a sodic claypan in the subsoil, and the letter L indicates that the soil is calcareous. Following the subclass designation in capability units in classes V, VI, and VII is an abbreviation of the name of the range site into which the major soils of this unit have been placed.

Management by capability units

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

CAPABILITY UNIT IIe-4

This unit consists of deep, nearly level and gently sloping soils of the Nutley and Sinai series. These soils have a surface layer of silty clay loam or silty clay and a subsoil of silty clay. Available water capacity is high, and fertility is high. These soils absorb water readily, but they have slow permeability when they are wet.

The soils of this unit are difficult to till when they are wet and are difficult to plow most of the time. They slack into fine granules when they are exposed to freezing and thawing in winter. This produces a good seedbed in spring on the fields that have been tilled in fall or have been fallowed in summer. It also leaves on the surface a fine granular material, which blows off easily.

Most areas of these soils are cultivated. The most common cropping system is an alternate rotation of summer fallow and wheat.

Soil blowing is a major hazard, but water erosion is also a hazard in areas of gently sloping soils because of high-intensity rain in summer. In areas used for crops, the main management practices are stubble mulching and the use of crop residue. Buffer strips, windbreaks, and stripcropping are also used. The use of manure and commercial fertilizer, as well as the planting of sweetclover in the rotation, helps to improve growth of crops and to improve the tilth of these soils.

CAPABILITY UNIT IIe-4L

The only soil in this unit is Hamerly loam, a deep soil that is limy at or near the surface. This soil has a surface layer of loam underlain by loam that contains a large amount of lime. Available water capacity is high, and fertility is high. A seasonal high water table contributes to the accumulation of lime. Small depressions are common.

The calcareous surface layer of this soil is well granulated and has good tilth, but it is susceptible to soil blowing. A temporary water table and salts in the substratum limit the use of this soil for deep-rooted crops. The soil warms up slowly in spring, and tillage and seeding are delayed by wetness. Summer fallow is of little benefit because the soil is frequently wet in spring. Surface evaporation on fallow soil tends to bring salts to the surface by capillary action.

Most areas of this soil are cultivated along with adjoining soils. This soil is suited to all locally grown crops.

Careful management of crop residue is needed to control erosion. The cropping system should reduce the use of fallow and increase the use of grass and legumes. A cropping system that includes the planting of sweetclover for hay or for a green-manure crop, and following this by late-season fallow, conserves moisture rather than wastes it. Rotational or permanent plantings of alfalfa and bromegrass and reed canarygrass in the depressions provide excellent hay crops. In areas used for crops, drainage of the small depressions, if feasible, lowers the temporary high water table and retards accumulation of lime in the surface layer. Crops respond well to applications of phosphate fertilizer.

CAPABILITY UNIT IIe-5

This unit consists of deep, level to undulating soils of the Emrick, Heimdal, and Velva series. These soils have a surface layer of coarse loam and a subsoil of loam. Available water capacity and fertility are high. Permeability is moderate.

The soils of this unit are easy to till, and they can be tilled early in spring. They form small clods, blocks, and crumbs if they are tilled when moist. These aggregates, however, are not stable when they are dry and are susceptible to soil blowing.

Most areas of these soils are cultivated. These soils are suited to all the crops, hay crops, and pasture plants commonly grown in the county. The most common cropping system is wheat, after summer fallow, and followed by barley, flax, or oats. In some years, corn is used in place of summer fallow.

Slight to moderate susceptibility to soil blowing is the chief limitation to use of these soils for crops, but the undulating soils are also susceptible to water erosion during periods of extensive runoff in spring and during rains. Soils that are summer fallowed are especially susceptible to erosion. Commonly used practices that help to control soil blowing and water erosion are stubble-mulch fallow and use of crop residue. Wind stripcropping or windbreaks are also used to reduce field size and to decrease the velocity of the wind at ground level. Fertilizer and weed control are needed for optimum crop growth.

CAPABILITY UNIT IIe-6

This unit consists of deep, gently sloping, gently undulating, and undulating soils of the Barnes, Bowbells, Max, Svea, and Williams series. Also included in this unit are the moderately well drained soils of the Hamerly series and the poorly drained soils of the Lamoure, Parnell, and Tonka series. These soils were mapped with the Barnes, Bowbells, Svea, or Williams soils. Most of these soils have a surface layer of loam or silt loam and a subsoil of loam or clay loam. Available water capacity and fertility are high. Permeability is generally moderate to moderately slow, but it is slow in the Parnell and Tonka soils.

The soils of this unit are easy to till. They form small clods, blocks, and crumbs if they are tilled when moist. These aggregates are stable when dry. This makes tilth easy to maintain and helps to reduce soil blowing.

Most areas of these soils are cultivated. They are suited to all the crops, hay crops, and pasture plants commonly grown in the county. The most common cropping system is wheat after summer fallow and following this by flax or barley the third year. In some years corn is used in place of summer fallow.

Moderate susceptibility to soil blowing and water erosion are the main hazards. Good use of crop residue and stubble-mulch fallow provides protection against soil blowing and water erosion. Wind stripcropping, windbreaks, and buffer strips are other practices used to help hold snow and reduce ground winds. Fertilizer is beneficial to grain and other crops. The use of manure or grass and legumes grown in rotation are additional measures used to improve these soils.

CAPABILITY UNIT IIw-6

The only soil in this unit is Tonka silt loam, a deep soil that is poorly drained. This soil is in depressions where runoff water collects. It has a surface layer of silt loam and a subsoil of clay loam. Available water capacity is high, and fertility is high. Permeability is slow.

This soil receives more runoff water than it can store. Water stands or ponds on the surface in spring and after heavy rains. This soil cannot be tilled or seeded until the water evaporates and the surface layer dries. When this soil is dry, it is easy to till, and tilth is easy to maintain. Salts have been leached deeply, so that crops grow well if excess water is removed.

Most areas of this soil are small and are farmed along with the surrounding soils. Because the soil dries out slowly, planting is delayed. If this soil is too wet to seed along with the rest of the field, it is seeded to flax or oats later in the season or is left idle. Some areas of this depressional soil are artificially drained. If drained, this soil is better suited to crops than the adjacent soils, and there is little difficulty in tilling, seeding, or harvesting crops in drained areas.

Wetness is the main limitation to the use of this soil. Appropriate management practices can help to reduce wetness in undrained areas. Sweetclover grown with a small-grain crop removes moisture from the subsoil, and other legumes and grass use large amounts of water. Tillage in fall reduces the amount of snow trapped and thus permits more rapid drying and warming in spring. Including grasses and legumes in the rotation helps to improve permeability. Reed canarygrass and bromegrass mixtures grown for forage are suited to this soil if adequately fertilized. Use of crop residue, stubble-mulch fallow, and contour tillage on adjacent fields help to reduce runoff onto this depressional soil.

CAPABILITY UNIT IIws-4

This unit consists of deep, level soils of the Fargo, Hegne, and Ludden series. The Fargo and Hegne soils have a surface layer and subsoil of silty clay. The Ludden soil has a surface layer of silty clay loam or clay and a subsoil of clay. Available water capacity and fertility are high. Permeability is slow.

The soils of this unit receive surplus runoff water. They are difficult to till, and tillage can be done only when the soils are at the right moisture content. If these soils are tilled when wet, the structure of the surface layer deteriorates and tends to puddle. When the surface layer dries, the soils are nearly impermeable to water, and seedlings cannot emerge. If tilled in fall, the clods on the surface slack into fine granules when exposed to freezing and thawing in winter. This produces a good seedbed in spring if the soils are not too wet.

Most areas of these soils are cultivated, but farming operations generally are delayed in spring because the extra moisture keeps the soil too cool for seeds to germinate. If seeding is delayed, flax or oats are generally grown. Corn is poorly suited to these soils, and alfalfa is winter-killed or is drowned out. Bromegrass and reed canarygrass are well suited.

Wetness and difficult tillage are the main limitations to the use of these soils. These soils are also susceptible to soil blowing if the surface layer is dry. Management practices include surface drainage, tillage in fall, and the use of grass and legumes in the rotation. Sweetclover, rye, and grass use moisture early in spring even if these soils are not tilled in spring. If outlets are available, drainage can be improved by constructing field drains. Practices commonly used to control erosion are stripcropping, stubble mulching, rough tillage, growing cover crops, establishing field windbreaks, and planting close-growing crops year after year.

CAPABILITY UNIT IIc-6

This unit consists of deep, nearly level soils of the Barnes, Bowbells, Makoti, Overly, Roseglen, Svea, Tansem, and Williams series. Also in this unit are the Hamerly, Niobell, and Tonka soils that were mapped with the Bowbells, Svea, or Williams soils. The soils of this unit have a surface layer of loam or silty clay loam and a subsoil of loam, clay loam, or silty clay loam. Available water capacity and fertility are high. Permeability is generally moderate to moderately slow, but it is slow in the Tonka soils.

These soils can absorb more moisture than they normally receive, even if they are summer fallowed. If management is good, most of the rainfall and snow moisture is absorbed. A considerable amount of moisture is lost by evaporation, especially if these soils are summer fallowed. Only small amounts of moisture or plant nutrients are lost by deep percolation. Organic-matter content is moderate to high, and these soils have a good reserve supply of plant nutrients. They are easily tilled and form small clods, blocks, and crumbs if tilled when moist. These aggregates are stable when dry. This makes tilth easy to maintain and helps to reduce soil blowing.

These soils are suited to all locally grown crops. The most common cropping system is a 3-year rotation of summer fallow, wheat, and barley or flax. In some years, corn is used in place of summer fallow. Grass and legumes generally are seeded on selected fields rather than kept in a regular crop rotation.

Lack of available moisture is the main limitation to the use of these soils. If these soils are used for crops, the main management practices are stubble mulching and use of crop residue along with timely and minimum tillage. Wind stripcropping, windbreaks, and buffer strips are valuable supplemental practices to hold snow and decrease ground winds. The use of commercial fertilizer along with the control of weeds is needed for optimum crop growth. Manure or grasses and legumes grown in rotation are additional measures used to improve these soils.

CAPABILITY UNIT IIIe-3

This unit consists of deep, nearly level and undulating soils of the Egeland, Embden, Lihen, Telfer, and Velva series. All of these soils, except the Telfer and Velva soils, have a surface layer of fine sandy loam and a subsoil of sandy loam or fine sandy loam. The Telfer soils have a subsoil of loamy fine sand, and the Velva soils have a subsoil of loam. Available water capacity generally is moderate, and fertility generally is medium, but available water capacity and fertility are low in the Telfer soils.

These soils are easy to till. If they are tilled when dry, however, the structure of the surface layer deteriorates, and susceptibility to soil blowing is increased. In years when precipitation is below normal, adequate moisture for the germination of seeds and for the growth of crops is lacking because of the limited available water capacity.

Most areas of these soils are cultivated. They are suited to all crops, hay crops, and pasture plants commonly grown in the county. The most common cropping system is a 3- or 4-year rotation of small grain and summer fallow. Corn is used in place of summer fallow to a limited extent.

The chief limitations to the use of these soils for crops are susceptibility to soil blowing and droughtiness caused by the limited available water capacity. Practices commonly used to control soil blowing are use of crop residue and stubble mulching. Wind stripcropping and windbreaks help to hold snow and decrease ground winds. Including cover crops and grass in the cropping system and the use of buffer strips also help to control erosion. Deep-rooted crops, such as alfalfa and sweetclover, are more resistant to short dry spells than most crops. Summer fallow should be used only to control weeds because the amount of moisture that can be stored is limited. Generally, tillage should be kept to the minimum needed to control weeds and to prepare a seedbed.

CAPABILITY UNIT IIIe-3M

This unit consists of deep, nearly level and undulating Egeland, Lihen, and Telfer soils that are underlain by loam glacial till at moderate depths. These soils have a surface layer of fine sandy loam and a subsoil of sandy loam or fine sandy loam. The underlying material is loam glacial till. Available water capacity is moderate in the surface layer and subsoil and high in the underlying material. Permeability is moderately rapid in the surface layer and subsoil and moderate to moderately slow in the underlying material.

These soils absorb moisture rapidly. The underlying material holds moisture better than the subsoil. This is beneficial to deep-rooted crops such as alfalfa and sweetclover. These soils are easy to till. If they are tilled when dry, however, the structure of the surface layer deteriorates, and susceptibility to soil blowing is increased. In years when precipitation is below normal, adequate moisture for the germination of seeds and for the growth of crops is lacking because of the limited available water capacity in the upper layers.

Most areas of these soils are cultivated. These soils are suited to all the crops, hay crops, and pasture plants commonly grown in the county. The most common cropping system is a 3- or 4-year rotation of small grain and summer fallow. Corn is used in place of summer fallow to a limited extent.

The chief limitation to use of these soils for crops is susceptibility to soil blowing. Practices commonly used to control soil blowing are use of crop residue and stubble mulching. Wind stripcropping and windbreaks are valuable supplements that help to hold snow and to decrease ground winds. Including cover crops and grass in the cropping system and the use of buffer strips also help to control erosion.

CAPABILITY UNIT IIIes-3

This unit consists of nearly level, gently sloping, and undulating soils of the Arvilla and Manning series. These soils have a surface layer and subsoil of sandy loam. They are shallow to moderately deep to underlying sand and gravel. Available water capacity and fertility are low. Permeability is rapid to moderately rapid in the surface layer and subsoil and very rapid in the underlying material.

These soils are easy to till, but soil structure is weak. If these soils are tilled when dry, the structure of the surface layer deteriorates, and the soils become more susceptible to soil blowing. Moderate erosion caused by soil blowing has reduced the organic-matter content and fertility of many areas of these soils.

Many areas of these soils are cultivated. The most common cropping system is a 3- or 4-year rotation of small grain and summer fallow. Rye is grown extensively. Native grassland areas are used for pasture.

The chief limitations to use of these soils for crops are susceptibility to soil blowing and droughtiness caused by the shallow root zone and the very low available water capacity of the substratum. Summer fallow is of little value because of the small quantity of water these soils can store. Commonly used practices that help to control soil blowing are stripcropping, stubble mulching, rough tillage, growing cover crops, continuous cropping, and establishing field windbreaks. Grass and legumes in a rotation help to maintain organic-matter content and soil structure.

CAPABILITY UNIT IIIe-6

This unit consists of deep, sloping and rolling soils of the Barnes, Max, and Williams series. These soils have a surface layer of loam and a subsoil of loam or clay loam. Available water capacity and fertility are high. Permeability is moderate in the upper part of these soils and moderately slow in the lower part.

These soils are easy to till, and they form small clods, blocks, and crumbs if tilled when moist. These aggregates are stable when dry. This makes tilth easy to maintain and helps to reduce soil blowing. Runoff is medium.

Most areas of these soils are cultivated. These soils are suited to all the crops, hay crops, and pasture plants commonly grown in the county. The most common cropping systems are a 2- or 3-year rotation of summer fallow and wheat, or summer fallow, wheat, and barley or flax. Little corn is grown, and grasses or legumes are not a part of most crop rotations.

Susceptibility to water erosion is the main hazard. Practices commonly used to conserve moisture and control erosion are use of crop residue and stubble-mulch fallow along with timely and minimum tillage. Contour or wind stripcropping, windbreaks, and buffer strips are supplemental practices used to help hold the snow and reduce ground winds. The use of manure or including grass and legumes in the rotation are additional measures used to improve these soils.

CAPABILITY UNIT IIIw-6

The only soil in this unit is Parnell silty clay loam, a deep, level soil. This soil has a surface layer of silty clay loam and a subsoil of silty clay. Available water capacity is high, and fertility is high. Permeability is slow.

This soil receives more runoff water than it can store, and it is subject to ponding. The additional water is runoff from surrounding soils. Tilth is easy to maintain on the well-granulated and crumb-structured surface layer if water is removed from the surface.

Most areas of this soil are in native wetland grasses and sedges. Undrained areas are well suited to water-tolerant grasses, and reed canarygrass or meadow foxtail are suitable species.

Wetness is the main limitation to the use of this soil. Appropriate management practices can help to reduce wetness in undrained areas. Grasses and legumes are needed in the crop rotation to use excess moisture and to maintain permeability and tilth. Sweetclover seeded with small grain is also beneficial. Summer fallow should be used as little as possible. Drained areas of this soil can be cultivated. Small areas within cultivated areas are tilled if they are not too wet from runoff in spring. Plowing drained areas in fall reduces the amount of snow trapped and allows the soil to warm up more rapidly in spring. Seeding and fertilizing areas used for tame grassland are good management practices.

CAPABILITY UNIT IIIs-5

This unit consists of nearly level and undulating soils of the Divide, Lehr, and Renshaw series. These soils have a surface layer and subsoil of loam. They are shallow to moderately deep to underlying sand and gravel. Available water capacity is low in the Divide and Lehr soils and moderate in the Renshaw soils. Fertility is medium. Permeability is moderate to moderately rapid in the surface layer and subsoil and very rapid in the underlying sand and gravel. The Divide soil has a high water table in spring but is droughty after the water table recedes because the space for water storage is limited.

These soils absorb water readily. If management is good, most of the rainfall and moisture from snow enters the soil. The available water capacity is not sufficient to make full use of summer fallow. These soils are easy to till. Tilth is easy to maintain, but the structure of the surface layer deteriorates when the soil is dry, and these soils are susceptible to soil blowing.

Most areas of these soils are cultivated. The most common cropping system is a 3- or 4-year rotation of small grain and summer fallow. In some years corn is used in place of summer fallow.

The chief limitations to use of these soils for crops are susceptibility to erosion and droughtiness caused by the shallow root zone and the very low available water capacity of the substratum. Summer fallow is of little value because of the small quantity of water these soils can store. Common practices that conserve moisture and control erosion are use of crop residue, stubble mulching, and timely or minimum tillage. Wind stripcropping, windbreaks, and buffer strips are valuable practices for helping to hold snow and reduce ground winds. Including corn in the rotation is a good substitute for summer fallow. Including grass and legumes in the crop rotation helps to maintain tilth and organic-matter content.

CAPABILITY UNIT IIIs-6P

This unit consists only of Noonan and Niobell soils. These are deep, nearly level soils that have a claypan subsoil. They have a surface layer of loam and a subsoil of clay loam. The Noonan soil has low available water capacity, medium fertility, and slow permeability. The Niobell soil has moderate available water capacity, high fertility, and moderately slow permeability.

These soils absorb and store a limited amount of moisture. Tilth is easy to maintain in most of the surface layer, except for slick spots where the sodium-dispersed subsoil has been plowed and mixed with the surface layer. The slow and moderately slow permeability of the subsoil make timely tillage of these soils difficult. The best seedbed is produced by tillage in fall or fallow because the clods on the surface slack when exposed to freezing and thawing in winter. Roots seldom use the moisture in the substratum because of salts and alkali. In wet years, the slick spots become wet and sticky and are commonly called gumbo spots. Crop growth is stunted and sparse on these spots and is variable throughout the field.

Most areas of these soils are cultivated. The most common cropping systems are a 2-year rotation of summer fallow and wheat or barley or a 3-year rotation of fallow, wheat, and barley or flax. These soils are poorly suited to corn.

The chief limitations to the use of these soils for crops are susceptibility to soil blowing and the restricted root zone caused by the claypan subsoil. The adverse effects of the restricted root zone are most severe in years when precipitation is below normal. Good use of crop residue and stubble-mulch fallow help to prevent soil blowing. Including grass and legumes in the crop rotation helps to maintain tilth. The roots of legumes open temporary channels through the claypan subsoil. Field windbreaks are generally unsatisfactory because of poor growth of trees.

CAPABILITY UNIT IVe-2

This unit consists only of Lihen and Telfer loamy fine sands, undulating. The Lihen soil has a surface layer of loamy fine sand and a subsoil of fine sandy loam. Available water capacity is moderate, and fertility is medium. Permeability is moderately rapid. The Telfer soil has a surface layer and subsoil of loamy fine sand. Available water capacity and fertility are low. Permeability is rapid.

The soils of this unit are easy to till, but the structure of the surface layer lacks durability. If these soils are tilled when dry, the structure deteriorates, and susceptibility to soil blowing is increased. Most areas that have been cultivated are moderately eroded.

Most areas of these soils are cultivated. Rye and other small grains are grown, but they are poorly suited. Some areas have been seeded to grass and alfalfa.

The chief limitations to the use of these soils for crops are high susceptibility to soil blowing and droughtiness caused by low available water capacity. Practices commonly used to control soil blowing and conserve moisture are use of crop residue, including grass and legumes in the crop rotation, and fertilizing.

CAPABILITY UNIT IVes-3

This unit consists of Lihen, Manning, Telfer, and Wabek soils. The Manning soil is moderately deep; the Wabek soil is very shallow to sand and gravel; the other soils are deep. These soils have a surface layer and subsoil of sandy loam. Available water capacity is low in the Manning soil and very low in the Wabek soil. Permeability is moderately rapid in the upper part of these soils and rapid in the lower part. The Telfer and Lihen soils have a surface layer and subsoil of loamy fine sand. Available water capacity is low in the Telfer soil and moderate in the Lihen soil. The surface layer of all of these soils absorbs moisture readily. These soils are droughty because of their moderate to very low available water capacity.

These soils are easy to till, but the soil structure is weak. Moderate and severe erosion caused by soil blowing has reduced the organic-matter content and fertility of these soils.

Most areas of these soils are cultivated or have been cultivated. These rolling soils are not suited to corn or other row crops. They are better suited to grass.

The chief limitations to the use of these soils for crops are high susceptibility to soil blowing and droughtiness caused by low available water capacity. Practices commonly used to control soil blowing and conserve moisture are use of crop residue, including grass and legumes in the crop rotation, and fertilizing. Fallowed soil can be used as a seedbed for fall-seeded rye. This provides a cover crop and timely use of moisture early in spring.

CAPABILITY UNIT IVe-4L

This unit consists of deep, undulating and rolling soils of the Barnes, Buse, Max, and Zahl series. These soils have a surface layer and subsoil of loam. Available water capacity is high, and fertility is medium to high. Permeability is moderate in the upper part of these soils and moderately slow in the lower part.

The soils of this unit are easy to till. They absorb water readily if protected by plants or mulch.

Most areas of these soils are cultivated. They are suited to all the crops, hay crops, and pasture plants commonly grown in the county.

Moderate susceptibility to soil blowing and water erosion are the chief limitations to use of these soils for crops. Most cultivated areas of these soils are moderately eroded. The main practices used to conserve moisture and control erosion are use of crop residue and stubble-mulch fallow. Adding manure or including grass and legumes in the rotation are additional measures used to improve these soils.

CAPABILITY UNIT IVe-6

This unit consists of deep, strongly sloping or rolling soils of the Barnes, Max, Williams, and Zahl series. These soils have a surface layer and subsoil of loam or clay loam. Available water capacity is high, and fertility is medium to high. Permeability is moderate in the upper part of these soils and moderately slow in the lower part.

These soils are easy to till, and tilth is easy to maintain because of the stable crumb and granular structure of the surface layer. Tillage up and down the slope increases susceptibility to water erosion, but tillage and seeding on the contour decreases surface runoff and erosion if a good mulch is maintained.

Many areas of these soils are cultivated. Where these soils are associated with steeper or stony soils, they are used for grass. These soils are poorly suited to corn or other row crops.

Moderate susceptibility to water erosion and slight susceptibility to soil blowing are the chief limitations to the use of these soils for crops. The main practices used to conserve moisture and control erosion are use of crop residue, stubble-mulch fallow, and contour tillage. The use of manure or including grass and legumes in the crop rotation are additional measures to improve these soils.

CAPABILITY UNIT IVwe-3

The only soil in this unit is Arveson fine sandy loam, a deep, poorly drained soil. This soil has a surface layer of fine sandy loam that is underlain by fine sandy loam that contains a large amount of lime. Available water capacity is moderate, and fertility is medium. Permeability is moderately rapid. This soil has a seasonal high water table.

This soil is easy to till when dry, but the high water table, slow runoff, and ponded water on the surface keep it too wet to cultivate for long periods of time.

Unless this soil is drained, it is better suited to grass than to other uses. If this soil is too wet to produce a suitable seedbed, it is left idle or is used for hay.

Wetness is the chief limitation to the use of this soil, but drained areas are susceptible to soil blowing.

CAPABILITY UNIT IVw-4L

This unit consists of deep, level soils of the Colvin, Lamoure, and Vallers series and the soil of the Benoit series that is moderately deep to sand and gravel. These soils are calcareous throughout and are poorly drained. They have a surface layer of loam, silt loam, or silty clay loam that is generally underlain by loam, silt loam, or silty clay loam that contains a large amount of lime. The Benoit soil is underlain by sand and gravel. Available water capacity generally is high, but it is moderate in the Benoit soil. Fertility is medium to high. Permeability generally is moderate to moderately slow, but it is moderately rapid in the underlying sand and gravel of the Benoit soil.

Most areas of these soils are in grass. A few small areas are cultivated. Cultivated areas are farmed with adjacent soils or, if they are too wet, are left idle. Unless these soils are drained, they are better suited to grass than to other uses.

Wetness is the chief limitation to the use of these soils for crops.

CAPABILITY UNIT Vw-WL

This unit consists of a very poorly drained phase of the Colvin and Parnell series and a depressional phase of the Ludden series. The Colvin soils have a surface layer and subsoil of silt loam, the Ludden soils have a surface layer and subsoil of clay, and the Parnell soils have a surface layer of silty clay loam and a subsoil of silty clay. Available water capacity and fertility are high. Permeability is moderate in the Colvin soils and slow in the Ludden and Parnell soils. Because these soils are in nearly level areas or in depressions, water ponds on the surface much of the time. A seasonal water table is at the surface or is within 5 feet of the surface during the wettest part of the year, and excess water is on or at the surface during much of the growing season.

These soils are not suitable for cultivation, but they are well suited to grass. They are used for hay, pasture, or wildlife habitat.

The chief limitation to the use of these soils for crops is wetness caused by the high water table and the ponding from runoff. In most places artificial drainage is impractical.

CAPABILITY UNIT Vws

This unit consists only of Loamy lake beaches. This land type is alternately wet and dry. It is low in fertility and is very stony or gravelly in some areas. Wave action from the adjoining areas of intermittent open water has removed the surface layer from many areas.

These soils are suitable for native pasture or for use as wildlife habitat. Some areas are used for hayland. The upland grasses die out during periods of ponding or flooding, and the wetland grasses die out during dry seasons.

CAPABILITY UNIT VIe-Si

This unit consists of soils of the Max, Bowbells, and Zahl series and Alluvial land. These soils have a surface layer of loam and a subsoil of loam or clay loam. Available water capacity and fertility are high. Permeability is moderate in the upper part of the Max and Bowbells soils and moderately slow in the lower part. Alluvial land is dissected by stream channels and is subject to occasional flooding. These soils absorb and hold moisture well if the surface protection is provided. Because these soils are steep, runoff is rapid on the Max, Bowbells, and Zahl soils. Runoff is slow on Alluvial land.

Most areas of these soils are in native grass.

The chief limitation to the use of these soils for crops is susceptibility of the steep areas to water erosion. In addition, Alluvial land, which is on channeled bottom lands, is nearly inaccessible to farm machinery. The main management practice is proper range use. Grazing should be regulated so that not more than half the annual growth of desirable plants is consumed. Control of brush is necessary in a few places.

CAPABILITY UNIT VIe-Sa

The only soil in this unit is Seroco fine sand, hummocky. This soil has a surface layer of fine sand that is underlain by fine sand. Available water capacity and fertility are low. Permeability is rapid.

This soil absorbs water readily but holds very little. It dries out quickly and is very droughty. Severe soil blowing has removed all of the surface layer in some areas, and in other areas the original surface layer has been buried. Establishing a good grass cover has been hindered by active soil blowing and the formation of dunes.

The low available water capacity and very high susceptibility to soil blowing if cultivated makes this soil suitable only for hay and pasture or for use as wildlife habitat. It is important to keep a good cover of plants in pastures. If the pasture is overgrazed, the native plants are replaced by those that are less desirable for grazing. Limited grazing and seeding with native grass species is needed to improve stands and to maintain a plant cover to prevent further soil blowing.

CAPABILITY UNIT VIe-TSl

This unit consists of deep, hilly and steep soils of the Barnes, Buse, Max, and Zahl series. These soils have a surface layer and subsoil of loam. Available water capacity is high, and fertility is medium. Permeability is moderate in the upper part of these soils and moderately slow in the lower part. Because these soils are hilly and steep, runoff is rapid. These soils are highly susceptible to water erosion. They absorb and hold moisture well if the surface is protected.

These soils are not suitable for cultivation.

A good protective cover is needed on these soils to control runoff and maintain plant growth. Proper range use is needed for maintenance or improvement of the range. In areas that are cut for roadways or urban development, all steep soils need to be sodded and all other areas should have black topsoil applied, seeded, and mulched.

CAPABILITY UNIT VIs-SSb

This unit consists of deep, strongly saline, poorly drained Harriet and Vallers soils and Velva loam, alkali variant. These soils are level or nearly level. They have a loam surface that is underlain by loam or clay loam that contains a large amount of salts. Available water capacity is low because of the presence of salts. Fertility is medium. These soils have moderate, moderately slow, or slow permeability. A seasonal water table is at the surface or is within a depth of 5 feet during the wet parts of the year. Runoff is slow.

Because these soils have strong salinity and poor natural drainage, they are used only for hay and pasture or as wildlife habitat.

Proper use of native grass areas and seeding of salt-tolerant grasses, such as tall wheatgrass, in areas used for crops are special management practices for these soils. Keeping a good cover of plants in the areas in pasture is also important. Range that is overused, even for short periods, deteriorates rapidly.

CAPABILITY UNIT VIs-Cp

This unit consists of deep soils of the Harriet, Heil, Miranda, Noonan, and Zahl series. The Zahl soil and one of the Miranda soils are hilly; the other soils are level and nearly level. All of these soils have a surface layer of loam or silty clay loam. Except for the Zahl soil, they have a dense claypan subsoil of clay loam or silty clay. Available water capacity is low to moderate, and fertility is low to medium. Permeability is slow or very slow in all of these soils, except for the Zahl soil. The Zahl soil does not have a claypan subsoil and has moderate permeability in the upper part and moderately slow permeability in the lower part.

The chief limitations to the use of these soils for crops are droughtiness caused by the shallow root zone and the salinity of the substratum. Because of the dense claypan only a few roots can penetrate the subsoil. As a result, these soils should be used only for hay and pasture or as wildlife habitat. It is important that a good cover of plants be maintained on pastures at all times. If the pastures are overgrazed, the few palatable grasses are replaced by weeds and by inland saltgrass. If overgrazing is severe, all the vegetation is destroyed, and the bare soils are then susceptible to soil blowing.

CAPABILITY UNIT VIs-SwG

This unit consists of undulating and hilly soils of the Sioux and Wabek series. These soils are very shallow to sand and gravel. They have a surface layer of loam, gravelly loam, cobbly loam, sandy loam, or gravelly sandy loam that is underlain by sand and gravel. Available water capacity is very low, and fertility is low. These soils are excessively drained and have very rapid permeability. These soils absorb moisture readily but hold very little.

The surface layer has good tilth, but this soil is susceptible to soil blowing.

The chief limitations to the use of these soils for crops are steepness in many places and droughtiness. Because of these limitations, these soils are better suited to grass than to other uses. Cultivated areas should be seeded back to native grass. Careful management is needed on range because the production of grass is low at optimum and the range is slow to recover from abuse.

CAPABILITY UNIT VIIs-Sl

This unit consists of rolling, stony soils of the Max, Wabek, and Zahl series. The Max and Zahl soils have a surface layer and subsoil of loam. Available water capacity is high, and fertility is medium to high. Permeability is moderate in the upper part of these soils and moderately slow in the lower part. The Wabek soils have a surface layer of loam that is underlain by sand and gravel. Available water capacity is low and fertility is low. Permeability is very rapid. On the surface of all these soils are stones, boulders, and pebbles.

The many stones on the surface are the chief limitation to the use of these soils for crops. Because of these stones, the soils are used only for pasture and as wildlife habitat. Because these soils cannot be tilled and reseeded by conventional methods, the natural vegetation must be carefully managed to maintain existing stands.

CAPABILITY UNIT VIIIs

This unit consists of Gravel pits and Mine pits and dumps. It is sparsely vegetated and has irregular topography. The strip mine material contains almost no organic matter and has no surface soil. The upper 1 or 2 inches is slacked and granulated into a suitable seedbed for grass, but the topography is too rough to seed with a drill.

This material would be better suited to the seeding of grass if some leveling or shaping were done, and it would be better suited to grazing and wildlife habitat if the spoil banks were leveled and access trails provided. Most of the pits and dumps are left idle and provide some wildlife habitat. Some areas are seeded to sweetclover, and a few areas are planted to trees.

Seeding of legumes or native grasses and using fertilizer expedites the revegetation of this land.

CAPABILITY UNIT VIIIw

The unit consists entirely of Freshwater marsh. This land is covered by water most of the time, and except in dry years when it is dry in places much of the summer, it is dry for only a short period late in summer.

Freshwater marsh has no agricultural value, but it provides food and cover for ducks and other wildlife.

Construction of shallow ditches to provide more permanent water is beneficial to wildlife habitat. The ditches and spoil banks also provide habitat for muskrats and mink.

CAPABILITY UNIT VIIIs

This unit consists entirely of Salt water marsh. It is made up of very strongly saline marshes and barren salt flats. The plants that grow are mainly salt-tolerant species, such as alkali bulrush. The water in these areas is unsuitable for livestock or domestic use.

Salt water marsh has no agricultural value, but it provides food and cover for ducks, such as mudhens, and some shore birds.

Predicted yields

Predicted yields of the principal crops grown in Ward County under two levels of management are shown in table 2. These predictions are based on information obtained from farmers and other agricultural workers in the county. They are averages for a period long enough to include years of both favorable and unfavorable temperatures and moisture supply in the growing season. The predictions represent the acreage planted, rather than only the acreage harvested.

Woodland and Windbreaks[3]

Ward County has approximately 5,000 acres in native woodland. Most of the trees and shrubs grow on the Velva soils on bottom lands and the Souris River. The principal species are green ash, American elm, boxelder, chokecherry, and wild plum.

The county also has about 10,000 acres in tall shrubs and patches of woods. These are on bottoms of small coulees and on north-facing slopes of sides of valleys on Bowbells, Max, and Svea soils and on Alluvial land.

The early settlers used the native woodland as a source of fuel, fenceposts, shelter, and, to a lesser extent, lumber.

[3]By DAVID L. HINTZ, woodland conservationist, Soil Conservation Service, Huron, South Dakota.

TABLE 2.—*Predicted average yields per acre of principal crops under two levels of management*

[Yields in columns A are those expected under the common level of management, and yields in columns B are those expected under a high level of management. Dashed lines indicate the crop is seldom grown or the soil is poorly suited to the crop]

Soil	Wheat		Barley		Flax		Oats		Rye		Corn for fodder		Alfalfa		Tame grass	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Tons	Tons	Tons	Tons	Tons	Tons
Alluvial land	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.3	2.0
Arveson fine sandy loam	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Arvilla sandy loam, nearly level	11	15	16	25	5	8	22	30	12	21	3.5	4.5	1.1	1.6	.9	1.5
Arvilla sandy loam, gently sloping	10	14	15	23	4	7	20	28	10	20	3.0	4.0	1.0	1.5	.9	1.4
Barnes loam, level	20	30	25	51	8	12	35	60	18	28	3.5	4.5	1.2	1.8	1.0	1.6
Barnes loam, gently undulating	18	28	23	48	7	11	30	56	16	26	3.2	4.2	1.1	1.7	1.0	1.5
Barnes loam, gently sloping	17	27	22	46	7	10	28	54	15	25	3.0	4.0	1.1	1.6	1.0	1.4
Barnes loam, sloping	11	19	14	32	5	8	20	38	10	18	--	--	1.0	1.6	.9	1.3
Barnes loam, strongly sloping	--	--	--	--	--	--	--	--	--	--	--	--	.9	1.5	.8	1.2
Barnes-Buse loams, undulating	10	20	15	34	5	8	20	40	9	20	2.0	3.0	.8	1.4	.5	1.0
Barnes-Hamerly loams, undulating	15	23	19	39	6	9	27	46	14	26	--	--	1.0	1.8	1.0	1.6
Barnes-Svea loams, nearly level	20	30	25	51	8	11	35	60	18	28	3.2	4.2	1.2	1.8	1.2	1.8
Barnes-Tonka loams, gently undulating	18	28	22	48	7	10	28	56	15	25	3.0	4.0	1.2	1.6	1.2	1.8
Benoit loam	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bowbells loam, gently sloping	20	30	26	51	8	12	35	60	18	28	3.5	4.5	1.3	2.0	1.2	1.8
Bowbells-Parnell complex	16	25	24	43	7	11	28	50	15	24	--	--	1.1	1.8	1.5	2.0
Bowbells-Tonka loams	18	28	22	48	7	10	28	56	15	25	3.0	4.0	1.2	1.8	1.2	1.8
Bowbells-Williams complex, nearly level	20	30	26	51	8	12	35	60	20	30	3.5	4.5	1.1	1.8	1.1	1.7
Buse loam, hilly	--	--	--	--	--	--	--	--	--	--	--	--	.7	1.2	.5	1.0
Buse-Barnes loams, rolling	10	15	12	25	5	7	15	30	10	16	--	--	.7	1.2	.5	1.0
Buse-Barnes loams, hilly	--	--	--	--	--	--	--	--	--	--	--	--	.9	1.4	.8	1.2
Colvin silt loam 1/	10	22	18	37	5	8	25	44	10	20	--	--	--	--	1.2	2.0
Colvin silty clay loam, very poorly drained	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.5	2.5
Divide loam	14	24	20	41	6	9	27	48	14	24	--	--	1.2	1.8	1.2	1.8
Egeland fine sandy loam, undulating	13	20	18	34	5	8	23	40	11	24	3.5	4.5	1.2	1.8	1.1	1.5
Egeland fine sandy loam, till substratum, nearly level	14	23	19	39	6	9	25	46	12	25	4.0	5.0	1.3	2.0	1.2	1.6
Embden fine sandy loam	15	25	20	43	6	9	25	50	15	25	4.0	5.0	1.3	2.0	1.2	1.6

TABLE 2.—*Predicted average yields per acre of principal crops under two levels of management*—Continued

Soil	Wheat		Barley		Flax		Oats		Rye		Corn for fodder		Alfalfa		Tame grass	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Tons	Tons	Tons	Tons	Tons	Tons
Emrick-Heimdal loams, level	22	32	30	54	9	13	40	64	20	30	4.0	5.0	1.5	2.2	1.2	2.0
Fargo silty clay[1]/	19	30	25	51	9	15	34	60	19	30	--	--	.9	1.5	1.2	1.8
Freshwater marsh	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gravel pits	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hamerly loam	14	20	18	34	6	9	25	40	12	20	--	--	1.2	1.6	1.5	2.0
Harriet complex	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Harriet and Vallers soils, strongly saline	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hegne silty clay	14	24	18	41	6	9	25	48	12	20	--	--	--	--	1.2	1.8
Heil soils	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.6	1.0
Heimdal loam, undulating	16	26	21	44	7	11	26	52	16	26	3.5	4.5	1.2	1.8	1.1	1.5
Lamoure and Colvin soils	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.2	2.0
Lehr loam, nearly level	13	23	19	27	6	9	25	32	12	25	3.5	4.5	1.2	1.8	1.0	1.6
Lehr loam, undulating	11	19	14	25	5	7	20	30	11	23	3.0	4.0	1.1	1.6	1.0	1.5
Lihen-Telfer fine sandy loams, nearly level	12	20	16	32	6	8	22	38	11	22	3.5	4.5	1.2	1.8	1.0	1.5
Lihen-Telfer fine sandy loams, undulating	11	18	15	29	5	7	20	34	10	20	3.0	4.0	1.1	1.7	.9	1.4
Lihen-Telfer fine sandy loams, till substratum, nearly level	13	22	17	36	6	8	23	42	12	23	3.5	4.5	1.2	1.8	1.0	1.5
Lihen-Telfer fine sandy loams, till substratum, undulating	12	19	16	31	5	7	21	36	11	22	3.0	4.0	1.1	1.7	.9	1.4
Lihen-Telfer loamy fine sands, undulating	8	--	10	--	3	--	15	--	8	16	2.5	3.5	1.2	1.8	.9	1.4
Loamy lake beaches	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ludden silty clay loam	15	25	19	43	6	10	27	50	14	23	--	--	1.2	1.8	1.3	2.0
Ludden clay	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.2	2.0
Ludden clay, depressional	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Makoti silty clay loam, level	21	31	30	53	9	13	37	62	19	29	3.6	4.8	1.3	2.0	1.2	1.8
Manning sandy loam, nearly level	10	18	15	22	5	8	20	26	10	20	3.0	4.0	1.0	1.5	1.0	1.5
Manning sandy loam, undulating	9	16	12	20	4	7	18	24	9	18	2.5	3.5	.9	1.4	.9	1.4
Manning-Wabek sandy loams, rolling	8	10	10	17	3	6	15	20	8	16	--	--	.5	1.0	.5	1.0
Max-Bowbells-Zahl loams, hilly	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Max-Williams loams, undulating	15	25	20	43	6	10	25	50	15	25	3.0	4.0	1.1	1.6	1.0	1.4
Max-Williams loams, rolling	14	24	18	41	5	9	23	48	12	22	--	--	1.0	1.5	.9	1.3

TABLE 2.—*Predicted average yields per acre of principal crops under two levels of management*—Continued

Soil	Wheat		Barley		Flax		Oats		Rye		Corn for fodder		Alfalfa		Tame grass	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Tons	Tons	Tons	Tons	Tons	Tons
Max-Williams loams, strongly sloping	10	16	13	27	5	8	18	32	10	20	--	--	.9	1.4	.8	1.2
Max-Zahl stony loams, rolling	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Max-Zahl loams, rolling	10	20	15	34	5	7	18	40	9	18	--	--	.9	1.4	1.0	1.4
Mine pits and dumps	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Noonan-Miranda complex	--	--	--	--	--	--	--	--	--	--	--	--	.6	1.0	.6	1.0
Noonan-Niobell loams	10	15	12	25	5	7	15	30	10	16	--	--	.9	1.2	.8	1.2
Nutley silty clay, gently sloping	17	27	22	46	6	9	30	54	17	27	--	--	.9	1.5	.9	1.5
Nutley-Sinai silty clays, nearly level	20	30	26	51	7	10	36	60	20	30	--	--	.9	1.5	.9	1.5
Overly silty clay loam, mottled variant	22	32	30	54	10	14	40	64	20	30	4.0	5.0	1.2	2.0	1.2	1.8
Parnell silty clay loam	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Parnell soils, very poorly drained	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Renshaw loam, nearly level	12	18	16	31	6	9	21	36	12	18	4.0	5.0	1.3	1.9	1.0	1.6
Roseglen-Tansem silt loams, level	20	30	26	51	7	10	35	60	18	28	3.5	4.5	1.2	1.8	1.0	1.6
Salt water marsh	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Seroco fine sand, hummocky	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sinai silty clay loam, gently sloping	20	30	28	51	8	12	35	60	18	28	3.5	4.5	1.2	1.8	1.1	1.7
Sinai silty clay, level	21	31	30	53	9	13	37	62	19	29	3.6	4.8	1.3	2.0	1.2	1.8
Sioux soils, undulating	--	--	--	--	--	--	--	--	--	--	--	--	.5	1.0	.5	1.0
Svea loam, level	22	32	30	54	10	14	40	64	20	30	4.0	5.0	1.2	2.0	1.2	1.8
Svea loam, gently sloping	21	31	28	53	9	13	37	62	20	30	4.0	5.0	1.2	2.0	1.2	1.8
Svea loam, fans, nearly level	21	31	30	53	9	13	37	62	19	29	3.6	4.8	1.3	2.0	1.2	1.8
Svea loam, fans, gently sloping	20	30	28	51	8	12	35	60	18	28	3.5	4.5	1.2	1.8	1.1	1.7
Svea-Hamerly-Tonka loams	16	24	22	41	7	10	30	48	16	24	--	--	1.0	1.8	1.3	2.0
Svea-Lamoure complex	14	20	20	34	7	10	25	40	14	20	--	--	1.0	1.8	1.3	2.0
Svea-Tonka loams	16	24	22	41	7	10	30	48	16	24	--	--	1.0	1.8	1.3	2.0
Telfer-Lihen loamy fine sands, rolling	8	10	10	17	3	5	15	20	8	16	--	--	1.0	1.5	.9	1.5
Tonka silt loam[1/]	17	27	22	46	7	11	31	54	--	--	--	--	1.0	1.8	1.5	2.5
Vallers loam, saline	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.0	1.5
Velva fine sandy loam	--	--	--	--	--	--	--	--	--	--	--	--	1.5	2.2	1.2	1.8
Velva loam	17	27	22	46	9	13	31	54	16	26	4.0	5.0	1.2	2.0	1.0	1.6

TABLE 2.—*Predicted average yields per acre of principal crops under two levels of management*—Continued

Soil	Wheat		Barley		Flax		Oats		Rye		Corn for fodder		Alfalfa		Tame grass	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Tons	Tons	Tons	Tons	Tons	Tons
Velva loam, alkali variant	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Wabek soils, undulating	--	--	--	--	--	--	--	--	--	--	--	--	0.5	1.0	0.5	1.0
Wabek soils, hilly	--	--	--	--	--	--	--	--	--	--	--	--	.5	1.0	.5	--
Wabek, Max, and Zahl stony loams, rolling	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Williams loam, level	19	29	25	49	8	12	32	57	17	27	3.0	4.0	1.1	1.6	.9	1.5
Williams loam, gently undulating	18	28	24	48	7	11	30	56	16	26	3.0	4.0	1.0	1.5	.9	1.5
Williams loam, undulating	15	25	19	43	7	11	27	50	14	24	3.0	4.0	1.0	1.5	.9	1.5
Williams loam, sloping	10	18	13	31	5	7	18	36	10	18	--	--	--	--	.9	1.4
Williams clay loam, level	19	29	25	49	8	12	32	57	17	27	3.0	4.0	1.1	1.6	.9	1.5
Williams clay loam, undulating	17	27	23	46	7	11	28	54	15	25	3.0	4.0	1.0	1.5	.9	1.5
Williams clay loam, rolling	13	23	18	39	6	10	23	46	13	23	--	--	.9	1.4	.9	1.4
Williams clay loam, strongly sloping	12	22	19	37	5	9	20	44	12	22	--	--	.9	1.4	.9	1.4
Williams-Bowbells-Tonka loams, level	16	26	20	44	6	9	26	52	14	24	--	--	1.0	1.5	1.1	1.8
Williams-Hamerly loams, undulating	14	22	19	37	6	9	24	44	12	22	--	--	1.0	1.5	1.2	2.0
Williams-Niobell loams, level	16	26	21	44	7	10	27	52	14	24	3.0	4.0	1.0	1.5	.9	1.5
Zahl loam, hilly	--	--	--	--	--	--	--	--	--	--	--	--	.5	1.0	.5	1.0
Zahl-Max loams, rolling	9	14	11	23	4	6	14	28	9	15	--	--	.6	1.2	.5	1.0
Zahl-Max loams, hilly	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Zahl-Max loams, steep	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Zahl-Miranda loams, hilly	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

1/ Yields shown are for areas that are drained.

Now the woodland is used mainly for livestock protection, wildlife habitat, recreation, erosion control, and watershed protection.

Windbreaks have been planted since the days of the early settlers. Mainly the early plantings were for the protection of the farmstead and livestock. These types of plantings are still needed around many of the farmsteads. There is a growing interest in the planting of field windbreaks to help control soil erosion in cultivated areas that have a serious hazard of soil blowing. Thousands of acres of soils in Ward County are still in need of some form of wind protection (fig. 9).

Windbreaks provide many economic and environmental benefits to the landowner. They distribute and hold snow, which prevents the snow from becoming a problem around the farmstead; they protect the farm buildings and livestock from cold, wintery winds and reduce fuel and feed costs; they protect field crops, gardens, and orchards from strong, damaging winds; they reduce evaporation of moisture; they provide a suitable habitat for many kinds of birds and other wildlife; they help to control soil erosion; and they enhance the beauty of the farmstead and its surroundings.

Factors to consider before a windbreak is planted are (1) purpose of planting, (2) suitability of soils, (3) suitability of trees and shrubs, and (4) location. Improperly designed windbreaks can cause many problems.

Establishment of a windbreak and continued growth of the trees depend upon careful selection of the site, suitable preparation, and adequate maintenance. Grass and weeds must be eliminated before the trees are planted, and the re-

Figure 9.—End view of the thriving 33-year-old farmstead windbreak, on the windward side, in an area of Bowbells-Williams complex, nearly level. At left, but in the center of the windbreak, green ash trees average 35 feet in height, and at right, spruce trees average 28 feet. Note the snow trapped in the trees.

growth of the ground cover should be controlled for the entire life of the windbreak. Some replanting is likely to be needed in the first and second years.

Windbreak groups.—The soils of North Dakota have been grouped into ten windbreak groups. All of these groups occur in Ward County. The growth response for adapted trees and shrubs will be generally the same for all of the soils within one of the groups, if good management practices are applied.

Several factors are used in placing soils into windbreak groups, but the dominant and most critical factor is the amount and seasonal availability of soil moisture to trees. Most groups have soils that have a rather wide range of slope and of surface layer texture. These two characteristics largely determine the hazard of water erosion and soil blowing. The degree of slope also determines the need for water and soil conservation practices on soils having no other limiting characteristics.

The degree of susceptibility to soil blowing for various textures of soils used for windbreaks are (1) coarse textured, very serious; (2) moderately coarse textured, serious; (3) medium textured, moderate to slight; (4) moderately fine textured, slight; and (5) fine textured, serious. The degree of susceptibility to water erosion for various slope phases of soils used for windbreaks are (1) 0 to 3 percent, none to slight; (2) 3 to 6 percent, moderate; (3) 6 to 9 percent, serious; (4) 9 to 12 percent, serious to very serious; and (5) 12 percent and more, very serious.

All soils that are suited and planted to windbreaks and that have slopes of more than 6 percent need water conservation practices for satisfactory tree growth. All soils that have a hazard of water erosion or soil blowing need specialized site preparation and planting and cultivation practices to establish and maintain plantings successfully. The water table is beyond the reach of tree roots on all soils in groups 3 through 10, except for several soils in group 10. These soils are very wet in at least part of the year, and a few have additional limitations critical to growing trees and shrubs.

The land types Gravel pits, Freshwater marsh, Loamy lake beaches, Mine pits and dumps, and Salt water marsh are not rated. The soil characteristics are so variable that a rating is not feasible. These land types are suited to spot plantings for wildlife habitat and recreational and esthetic purposes in selected locations.

Windbreak ratings of soils and species suitability.—Table 3 lists most trees and shrubs used in windbreak plantings. The table gives the actual or estimated average height and the vigor of the various trees and shrubs at 20 years of age. The rating in the "Vigor" column refers to the density of foliage, the freedom from damage from insects or disease, and the general appearance of the tree. All height measurements and vigor ratings have been based on well-managed plantings.

Vigor ratings.—A plant that has a rating of "good" will generally exhibit one or more of the following conditions: Leaves or needles are normal in color and growth; small amounts of deadwood (tops, branches, twigs) occur within the live crowns; evidence of plant disease, insect pests, or climatic damage is limited; and slight evidence of stagnation or suppression appears in places.

A plant that has a rating of "fair" will exhibit one or more of the following conditions: Leaves or needles are obviously abnormal in color and growth; substantial amounts of deadwood (tops, branches, and twigs) occur within the live crowns; evidence of moderate disease, insect, or climatic damage is obvious; definite suppression or stagnation exists; and growth in the current year is obviously less than normal.

A plant that has a rating of "poor" will exhibit one or more of the following conditions: Leaves or needles are very abnormal in color and growth; very large amounts of deadwood (tops, branches, and twigs) occur within the live crowns; evidence of extensive plant disease, insect pests, or climatic damage is obvious; plants show the effects of severe stagnation, suppression, or decadence; and growth in the current year is essentially negligible. Plants that have this rating are not suitable for farmsteads, feedlots, or field windbreaks. They are satisfactory as plantings for some wildlife habitat and esthetic purposes.

WINDBREAK GROUP 1

This windbreak group consists of nearly level to sloping, well-drained to somewhat poorly drained, loamy soils of the Bowbells, Divide, Embden, Emrick, Roseglen, Svea, Velva series, the mottled variant of Overly series, and Alluvial land. Most of the soils are deep, but some are moderately deep to sand and gravel. The available water capacity is favorable for the survival and growth of trees and shrubs. Alluvial land and Divide, Overly, and Velva soils have a high water table, and therefore, tree roots grow within reach of ground water. The other soils in this group receive extra moisture in the form of runoff from the surrounding higher areas.

These soils are suited to all kinds of windbreaks and windbreak plantings.

There are no serious hazards or limitations to the use of these soils, except in areas where soil blowing is a serious hazard.

WINDBREAK GROUP 2

This windbreak group consists of nearly level, poorly drained, loamy or clayey soils of the Arveson, Benoit, Colvin, Fargo, Hegne, Lamoure, Ludden, Parnell, and Tonka series. Most of the soils are deep, but some are only moderately deep to sand and gravel. Salinity is low to moderate in

TABLE 3.—*Height and vigor of trees and shrubs by windbreak groups*

[Weight measurements and vigor ratings are for trees at 20 years of age. Windbreak groups 9 and 10 are omitted because the soils are not desirable for trees and shrubs]

Tree or shrub	Windbreak group															
	1		2		3		4		5		6		7		8	
	Vigor	Height	Vigor	Height	Vigor	Height	Vigor	Height	Vigor	Height	Vigor	Height	Vigor	Height	Vigor	Height
		Feet		Feet		Feet		Feet		Feet		Feet		Feet		Feet
Conifers:																
Black Hills spruce, Colorado blue spruce.	Good.	18-20	Good.	16-18	Good.	17-19	Poor.	----	Poor.	----	Poor.	----	Poor.	----	Poor.	----
Eastern redcedar or Rocky Mountain juniper.	Good.	10-12	Good.	12-14	Good.	10-12	Good.	9-11	Good.	8-10	Fair.	7-9	Fair.	7-9	Fair.	6-8
Ponderosa pine	Good.	18-20	Good.	18-20	Good.	18-20	Good.	16-18	Good.	18-20	Fair.	12-14	Fair.	12-14	Fair.	12-14
Deciduous shrubs:																
Caragana	Good.	8-10	Fair.	7-8	Good.	8-10	Good.	6-8	Good.	7-9	Fair.	6-8	Poor.	----	Fair.	4-5
Chokecherry	Good.	11-12	Fair.	8-10	Good.	8-10	Fair.	7-9	Fair.	6-8	Poor.	----	Poor.	----	Poor.	----
Honeysuckle	Good.	8-10	Good.	7-8	Good.	8-9	Good.	6-7	Good.	6-7	Poor.	----	Poor.	----	Poor.	----
Wild plum	Good.	6-8	Good.	5-6	Good.	6-8	Fair.	6-7	Fair.	4-6	Poor.	----	Poor.	----	Poor.	----
Deciduous trees:																
American elm	Good.	21-23	Good.	20-22	Good.	19-21	Fair.	14-16	Fair.	14-16	Poor.	----	Poor.	----	Poor.	----
Cottonwood	Fair to good.	42-46	Poor to good.	40-44	Poor.	----	Poor.	----	Poor.	----	Poor.	----	Poor.	----	Poor.	----
Green ash	Good.	20-22	Good.	20-22	Good.	19-21	Good.	16-18	Good.	14-16	Fair.	13-15	Poor.	----	Fair.	8-10
Russian-olive	Fair.	14-16	Fair.	12-14	Good.	13-15	Good.	16-18	Good.	16-18	Fair.	10-12	Poor.	----	Fair.	8-9
Siberian elm	Good.	28-30	Good.	28-30	Good.	24-27	Fair.	18-20	Good.	22-25	Fair.	18-20	Poor.	----	Fair.	10-12

the subsoil and underlying material. These soils are ponded or have a high water table. Unless they are drained, they are poorly suited or unsuited to trees and shrubs.

If adequately drained, these soils are well suited to all kinds of windbreaks and windbreak plantings. The number of trees and shrub species that are suited to Colvin and Lamoure soils is more limited than the number suited to other soils in this group.

The only critical limitation to the use of these soils is wetness, but, to a lesser extent, the high content of lime is also a limitation. Because of the high content of lime, soil blowing is a serious hazard on the clayey soils of this group, as well as on soils of the Arveson, Benoit, Colvin, Hegne, and Lamoure series.

WINDBREAK GROUP 3

This windbreak group consists of deep, nearly level to hilly, moderately well drained or well drained, loamy soils of the Barnes, Hamerly, Heimdal, Makoti, Max, Tansem, and Williams series (fig. 10). If proper care is given to conserving moisture, these soils are suited to nearly all trees and shrubs.

Figure 10.—Young farmstead windbreak planting on Barnes loam, level, which is in windbreak group 3. The soil has a cloddy surface.

These soils are well suited to all types of windbreaks and windbreak plantings.

There are no serious hazards or limitations to the use of these soils, except in areas where soil blowing or water erosion is a hazard. Soil blowing is only a slight hazard on most of these soils.

WINDBREAK GROUP 4

This windbreak group consists of deep, nearly level to sloping, well-drained or moderately well drained, loamy or clayey soils of the Niobell, Nutley, and Sinai series. These soils have a clayey subsoil. They are suited to only a limited number of trees and shrubs, and the choice of species to be planted needs to be selective.

These soils are suited to all types of windbreaks and windbreak plantings if selection of tree and shrub species is proper.

The only critical limitation to the use of these soils is the clayey texture of the subsoil, which limits the choice of species. Soil blowing and water erosion are slight to serious hazards on the various soils in this group.

WINDBREAK GROUP 5

This windbreak group consists of deep, nearly level to undulating, well-drained, moderately sandy soils of the Egeland series. Most of the precipitation is absorbed by these soils, but some is lost through runoff. The available water capacity is moderate. These soils are suited to only a limited number of trees and shrubs, and only suitable species should be planted.

These soils are suited to all types of windbreaks and windbreak plantings if selection of tree and shrub species is proper.

The main limitation is the moderate available water capacity of most of these soils. Soil blowing and water erosion are serious hazards.

WINDBREAK GROUP 6

This windbreak group consists of nearly level to sloping, somewhat excessively drained or well-drained, loamy soils of the Arvilla, Lehr, Manning, and Renshaw series. These soils are shallow or moderately deep to sand and gravel. Most of the precipitation is absorbed by these soils, but it moves very rapidly through the underlying material of sand and gravel. Available water capacity is low or moderate.

Arvilla and Manning soils are poorly suited to all types of windbreaks and windbreak plantings. Plantings can be established if selection of tree and brush species is proper, and if optimum survival, growth, and vigor are not required or expected. Using the same criteria, Lehr and Renshaw soils are poorly suited to wildlife, recreational, and beautification plantings and are unsuited to windbreak plantings.

The critical limitations to the use of these soils are low available water capacity and a restricted rooting zone. Soil blowing and water erosion are slight to serious hazards.

WINDBREAK GROUP 7

This windbreak group consists of deep, nearly level to rolling, well-drained or somewhat excessively drained, sandy soils of the Lihen and Telfer series. Most of the precipitation is absorbed by these soils, but little is retained. Available water capacity is low or moderate. The choice of tree and shrub species for planting is very limited.

These soils are suited to wildlife, recreational, and beautification plantings if optimum survival, growth, and vigor are not required or expected. They are poorly suited to field windbreaks.

The critical limitation to the use of these soils is low available water capacity. Soil blowing is a serious hazard, and water erosion is a slight to moderate hazard.

WINDBREAK GROUP 8

This windbreak group consists of deep, undulating, hilly, or steep, well-drained and excessively drained, loamy soils of the Buse and Zahl series. Slopes are convex. Most of the precipitation runs off these soils. Available water capacity is high, but excessive runoff restricts water intake and the amount of water available to trees and shrubs.

These soils are not suited to field windbreaks. They are suited to wildlife, recreational, and beautification plantings if optimum survival, growth, and vigor are not required or expected.

The main limitation to the use of these soils is steepness. This causes excessive runoff and low water intake. Water erosion is a serious hazard.

WINDBREAK GROUP 9

This windbreak group consists of deep, nearly level to sloping, moderately well drained or poorly drained, loamy soils of the Harriet, Heil, Miranda, Noonan, Vallers, and Zahl series, and the alkali variant of the Velva series. The subsoil in these soils is a dense claypan. The nonsodic and nonsaline root zone is generally less than 20 inches thick.

These soils are not suited to any type of windbreak or windbreak planting. They occur in complexes with soils that are suitable for trees and shrubs. The other soils in the complexes are suited to hand planting of trees and shrubs for wildlife, recreation, or beautification.

The main limitations to the use of these soils are the restricted rooting zone, moderate or low available water capacity, and salt toxicity. Soil blowing is a slight hazard, and water erosion is a slight to serious hazard.

WINDBREAK GROUP 10

This windbreak group consists of the saline soils of the Vallers series; the undrained soils of the Colvin, Lamoure, Ludden, and Parnell series; the stony soils of the Max and Zahl series; the sloping to very steep soils of the Seroco, Sioux, and Wabek series; and the steep soils of the Max and Zahl series. The soils in this group have a wide range of depth, texture, drainage, and slope. They have one or more characteristics that are highly critical for planting, survival, vigor, and growth of trees and shrubs. Some of the soils are not suited to trees and shrubs, because they are too waterlogged, low in available water capacity, stony, rocky, shallow, sodic, saline, steep, infertile, restrictive to rooting, or erodible.

These soils are not suited to windbreak plantings. Colvin, Lamoure, Parnell, and stony areas of Max and Williams soils are suited to hand planting for wildlife, recreation, and beautification. Careful selection of the planting site and of suitable tree and shrub species, however, is necessary.

Depending upon the particular soil within the group, limitations are wetness, stoniness, steepness, rockiness, shallowness, infertility, salinity, high sodium content, and restrictions related to available water capacity and depth of rooting zone. Soil blowing and water erosion are slight to serious hazards.

Range[4]

The native vegetation in Ward County consisted mainly of mid grasses and, to lesser extent, of short and tall grasses, broad-leaved forbs, and numerous kinds of legumes. The short grasses were dominant on the droughtier soils, and the tall grasses were common in places where the moisture supply was favorable, generally in areas subject to flooding, subirrigation, or drifting snow. Cool-season grasses predominated, but warm-season grasses also grew in most areas.

At present, about 26 percent of the county is in range. Most of this acreage consists of hilly glacial moraines, stream breaks, and ponded or saline soils. Most grassland has been depleted as a result of overuse. Some grassland has been damaged by silt that has washed from cultivated fields.

Range management

About 340,000 acres in Ward County is range. Range is an important resource and should be managed in a way that permits the best sustained yields of forage possible. Basic to all successful management is proper stocking of the range in relation to the capacity of the site for producing forage. Proper stocking in this county means that about only half of the annual growth on upland sites can be consumed.

Uniform distribution of grazing throughout all parts of the range is commonly obtained by the use of fences and by proper distribution of water and salt. In a well-balanced grazing program that provides ample high-quality forage for the longest period possible, supplemental pasture is provided by seeding annual crops, expanding areas of native range, or seeding tame grasses in permanent pasture. Areas of range should be rested occasionally so that the cover of desirable plants will remain vigorous. This can be accomplished by using a system of deferred grazing. Chemical and mechanical means of suppressing brush or weeds are effective in this county.

Range sites and condition classes

Soils are grouped into range sites on the basis of similarity in the characteristics that affect their capacity for producing native forage plants. Ten range sites are recognized in Ward County. Each site has a distinctive climax vegetation, the composition of which depends upon a combination of environmental conditions, mainly the combined effect of soil and climate. The climax vegetation reproduces itself so long as the environment remains the same.

Range condition is rated by comparing the composition of the existing vegetation with that of the climax vegetation. An estimate of the deterioration that has taken place indicates the degree of improvement possible.

Four range condition classes are recognized: excellent, good, fair, and poor. A range is in excellent condition if 75 to 100 percent of the existing vegetation is of the same composition as that of the potential stand. It is in good condition if the percentage is between 50 and 75, in fair condition if the percentage is between 25 and 50, and in poor condition if the percentage is 25 or less.

The plants on any given range site are grouped, according to their response to grazing, as decreasers, increasers, and invaders. Decreasers are plants in the climax vegetation that tend to die out if heavily grazed. Increasers are plants in the climax vegetation that become more abundant as the decreasers decline, and then tend to die out if heavy grazing continues. Invader plants are not a part of the climax vegetation, but they generally become established after the climax vegetation has been heavily grazed.

In the following pages each of the 10 range sites in Ward County is described, and estimates of average yields are given. The estimates are of the total annual growth of the plants above ground, not what would be removed by grazing or haying.

The names of the soil series represented are mentioned in the description of each site, but this does not mean that all the soils in a given series are in the range site. The range site classification of each soil is given in the "Guide to Mapping Units." The land types, Freshwater marsh, Gravel pits,

[4]By HUGH E. COSBY, range conservationist, Soil Conservation Service.

Loamy lake beaches, Mine pits and dumps, and Salt water marsh were not placed in a range site.

CLAYEY RANGE SITE

This range site consists mainly of fine-textured soils of the Fargo, Hegne, Ludden, Nutley, and Sinai series. If a good grass and mulch cover is maintained, the water intake of the soils in this site is nearly as high as in the soils of the Silty range site, but the water intake rate declines rapidly as grass cover deteriorates.

If this site is in good condition, most of the forage is produced by green needlegrass and western wheatgrass. If the range deteriorates from overuse, a decrease in green needlegrass and an increase in western wheatgrass is the first sign. If the range deteriorates further from continued overuse, western wheatgrass decreases, and blue grama and needleleaf sedge increase. The main increasing forb is fringed sagewort, and a common invader as the site deteriorates is curlycup gumweed.

If this site is in excellent condition, the estimated average yield of herbage, per acre, ranges from 1,200 pounds in unfavorable years to 2,500 pounds in favorable years.

CLAYPAN RANGE SITE

This range site consists of shallow, alkali, claypan soils of the Harriet, Heil, Miranda, and Noonan series. It has many panspot depressions where grasses do not grow so well as in the other areas. This site is not extensive in the county, and it is in association with other soils. It may occupy half or less than half of a mapped area. The associated soils vary with the location.

Most of the forage on this site is produced by western wheatgrass. If the range deteriorates because of overgrazing, western wheatgrass decreases. Continued overuse may cause this site to become nearly bare of vegetation in time.

If this site is in excellent condition, the estimated average yield of herbage, per acre, ranges from 500 pounds in unfavorable years to more than 1,200 pounds in favorable years when rainfall in summer is frequent and plentiful.

SALINE SUBIRRIGATED RANGE SITE

This range site consists of soils of the Harriet and Vallers series, and the alkali variant of the Velva series. The texture of these soils is variable. Seepage or a seasonal high water table has caused soluble salts to accumulate in the surface layer of these soils.

This site (fig. 11) supports mainly salt-tolerant plants. If overused it deteriorates more rapidly than the sites on uplands. One of the more important decreasers is Nuttall alkaligrass. Among the other decreasers are western wheatgrass, alkali cordgrass, slender wheatgrass, and plains bluegrass. If this range deteriorates because of overuse, an increase in inland saltgrass, mat muhly, and alkali muhly is the first sign. Foxtail barley and spike sedges are invaders in many places as the better species are lost.

If this site is in excellent condition, the estimated average yield of herbage, per acre, ranges from 1,000 pounds in unfavorable years to about 2,000 pounds in favorable years.

Figure 11.—Saline Subirrigated range site. At left of fence the range is in good condition and has climax vegetation that consists of Nuttall alkaligrass, western wheatgrass, inland saltgrass, and mat muhly. At right of fence the range is in poor condition and has been invaded by foxtail barley and Baltic rush. In background is Salt water marsh.

SANDS RANGE SITE

This range site consists of deep, nearly level to rolling, somewhat excessively drained soils of the Lihen, Seroco, and Telfer series. These soils are on glacial outwash plains. They are loose and coarse textured. The available water capacity is less on this site than on sites where the soils are medium textured or fine textured. The Lihen and Telfer soils have a surface layer of loamy fine sand.

These soils are well suited to deep-rooted plants. They are not well suited to shallow-rooted plants, because of the droughtiness caused by water soaking deep into the profile. The acreage is small, but seeding of grasses and special management are needed in many places.

If this site is in excellent condition, it has more tall grasses than other sites on uplands. Prairie sandreed is dominant and is more prevalent than other grasses; sand bluestem is an important grass in higher areas; big bluestem, little bluestem, and switchgrass grow in slight depressions. Purple prairie-clover, silky prairie-clover, leadplant amorpha, and American licorice are important legumes.

If the range deteriorates from overgrazing, an increase in needle-and-thread and sand dropseed is the first sign. If the range deteriorates further from continued overuse, blue grama, fringed sagewort, sun sedge, and stiff goldenrod are among the plants that increase. Blowout grass is more common on blowouts and dunes than in other areas, and, if given a chance, it is an important stabilizer in these areas.

If this site is in excellent condition, the estimated average yield of herbage, per acre, ranges from 1,200 pounds in unfavorable years to 2,500 pounds in favorable years.

SANDY RANGE SITE

This range site consists of moderately well drained, well-drained, and somewhat excessively drained, nearly level to rolling, moderately coarse textured soils of the Arvilla, Egeland, Embden, Lihen, Manning, and Telfer series. These soils are on glacial outwash plains. Most areas of these soils are used for crops, but they are only moderately suited to this use.

If this site is in excellent condition, a variety of grasses, forbs, and legumes are produced. These include prairie sandreed, Canada wildrye, needle-and-thread, western wheatgrass, big bluestem, little bluestem, and shorter species, such as blue grama and sun sedge. If the range deteriorates because of overuse, needle-and-thread and western wheatgrass increase temporarily. Continued overuse causes a decline in these species and an increase of shorter grasses and a large increase of fringed sagewort and other weedy plants.

If this site is in excellent condition, the estimated average yield of herbage, per acre, ranges from 1,200 pounds in unfavorable years to 2,500 pounds in favorable years.

SHALLOW TO GRAVEL RANGE SITE

This range site consists of excessively drained, nearly level to hilly, thin soils of the Sioux and Wabek series. These soils are on glacial outwash plains. They have a gravelly subsoil. This range site gives better economic returns if it remains in native grassland.

If this site is in excellent condition, needle-and-thread, a decreaser, is the dominant species. Other decreasers are western wheatgrass, plains muhly, and dotted gayfeather. If the range deteriorates because of overuse, the increasers are blue grama, fringed sagewort, and needleleaf sedge.

If this site is in excellent condition, the estimated average yield of herbage, per acre, ranges from about 700 pounds in unfavorable years to 1,600 pounds in favorable years.

SILTY RANGE SITE

This range site consists of well-drained and moderately well drained, nearly level to hilly, medium-textured soils of the Barnes, Bowbells, Divide, Emrick, Hamerly, Heimdal, Lehr, Makoti, Max, Niobell, Renshaw, Roseglen, Svea, Tansem, Velva, and Williams series, mottled variant of the Overly series, and Alluvial land. This site is dominant in the native grassland pastures on the morainic hills. This is the most extensive range site in Ward County.

This site supports mainly mid grasses, but a few tall grasses grow on the site, and an understory of short grasses, sedges, forbs, and legumes is scattered throughout. A gradual decline of green needlegrass, bearded wheatgrass, big bluestem, little bluestem, stiff sunflower, and silverleaf scurf-pea results from continued overuse. Western wheatgrass and needle-and-thread show a temporary increase, but they decline where overuse is continued. In many places needle-and-thread grows over long periods of time, but it is much dwarfed; blue grama increases to many times its original density; a fringed sagewort increases until it dominates the site. Curlycup gumweed is a common invader in the overgrazed areas.

Small amounts of western snowberry grew as part of the original vegetation, and in some areas silverberry was more common than snowberry. On parts of this range site, both of these species have gradually increased. Trees grew locally in coulees, especially on north and east exposures. Many of these areas have been invaded by other trees and shrubs that, in many places, form dense thickets.

If this site is in excellent condition, the estimated average yield of herbage, per acre, ranges from 1,200 pounds in unfavorable years to 2,500 pounds in favorable years.

SUBIRRIGATED RANGE SITE

This range site consists of poorly drained soils of the Arveson, Benoit, Colvin, Lamoure, and Vallers series. The texture of these soils is variable. These soils have a seasonally high water table, and the ground water subirrigates plants throughout most of the growing season but does not cover the plant crowns. This site is of limited extent in the county, but plants grow well in areas along the outwash drainageways in the northeastern part of the county and within the outwash plains in the southeastern part.

The moisture that is available because of the favorable position of this site allows it to support mainly tall grasses and a mixture of mid grasses. Big bluestem, switchgrass, prairie cordgrass, little bluestem, and prairie dropseed are the most important grasses. If the range deteriorates because of overuse, mat muhly, Baltic rush, spike sedges, foxtail barley, and other weedy plants invade. Overuse causes a decrease in the important nongrass plants, Maximilian sunflower and Rydberg's sunflower.

If this site is in excellent condition, the estimated average yield of herbage, per acre, ranges from 1,500 pounds in unfavorable years to 4,500 pounds in favorable years.

THIN SILTY RANGE SITE

This range site consists of thinly developed, undulating to steep, medium-textured soils of the Buse and Zahl series. These soils are on convex hilltops and on side slopes. Areas in native grassland are on the steep soils of river breaks and on the thin soils of the moraine.

Because these soils are steep, runoff is increased and less moisture is available for plants on this site. Little bluestem, plains muhly, and side-oats grama are important decreasers, and stiff sunflower and blacksamson echinacea are important decreasing forbs. Western wheatgrass occupies less space, but it is also an early decreaser. If this range deteriorates because of overgrazing, the plant cover decreases, and runoff and erosion increase. Overgrazing causes an increase of blue grama, needle-and-thread, needleleaf sedge, fringed sagewort, and other short and undesirable vegetation, but this increase does not off-set the overall decrease in plant cover.

If this site is in excellent condition, the estimated average yield of herbage, per acre, ranges from 700 pounds in unfavorable years to 2,000 pounds in favorable years.

WETLAND RANGE SITE

This range site consists of very poorly drained soils of the Colvin series and poorly drained soils of the Ludden, Parnell, and Tonka series. The texture of these soils is variable. The Colvin soil has a surface layer of silty clay loam, and the Ludden soil has a surface layer of clay. These soils are seasonally ponded or have a seasonally high water table, and the water covers the plant crowns seasonally. This site occurs throughout the county. Most areas remain in native grassland, because the soils generally are too wet to use for crops. Many areas are used as native meadow hayland.

On the Parnell soils the most important vegetation consists of rivergrass and slough sedge, and on the Colvin soils it consists of northern reedgrass and several of the larger sedges. If this range deteriorates because of overuse, the appearance of foxtail barley, American sloughgrass, Baltic rush, and spike sedges is the first sign. The quality of the hay in the native hayland areas is improved by early cutting. More of the forage can be used for hay than for pasture on this site.

Mulch and old grass should not be destroyed by burning or hard raking. Controlling the water level on these soils helps to maintain the climax vegetation and makes harvesting easier.

If this site is in excellent condition, the estimated average yield of herbage, per acre, ranges from 2,000 pounds in unfavorable years to 7,500 pounds in favorable years.

Wildlife[5]

The wildlife resources of Ward County provide outdoor recreation to many people. They also provide food, fur, and income to area residents. Proper use and management help to maintain and improve these resources. A few kinds of wildlife burrow or den in the soil, but most are dependent on plants for cover; therefore, the use and management of the soil directly affect wildlife, sometimes favorably and sometimes adversely.

The most important kinds of wildlife game in the county are sharp-tailed grouse, gray partridge, ducks, and white-tailed deer. The hunting of pheasant and geese has been rather limited. The hunting of mourning doves could be good, but it has not as yet become popular and is dependent on legislative action. The most important furbearers in the county are mink, muskrat, jackrabbits, badgers, fox, skunk, weasel, beaver, and raccoon.

The main purpose of this section is to point out the soil areas in the county that are well suited to various kinds of wildlife. Table 4 gives a relative suitability rating for each soil association in Ward County and an estimated, potential breeding population for pheasant, partridge, grouse, ducks, and deer. For example, if the potential for pheasant is indicated as good in a soil association, it is practical to develop and manage the association for increased production of pheasant. This means that the population level indicated would be practical for a landowner to attain. The soil associations are described in the section "General Soil Map."

Before improvement of the habitat is planned, an inventory and evaluation of the habitat should be made to determine the habitat needs of the wildlife concerned. When these needs are determined, the procedure is to select the vegetation or management practice suitable to the site that will fulfill the wildlife needs.

TABLE 4.—*Estimated potential breeding populations per square mile and relative suitability by soil association areas*

Soil association	Pheasant1/	Partridge1/	Sharp-tailed grouse1/	Ducks1/	Deer1/
Barnes-Svea	25-100G	6-15G	0-2P	16-50F	0-1P
Barnes	25-100G	6-15G	0-2P	16-50F	0-1P
Colvin-Vallers-Lamoure	6-24F	2-5F	7-30G	51-250G	2-4F
Barnes-Egeland-Emrick	25-100G	6-15G	0-2P	16-50F	0-1P
Manning-Lihen	6-24F	6-15G	0-2P	51-250G	2-4F
Max-Williams	6-24F	2-5F	3-6F	51-250G	5-15G
Max-Zahl	6-24F	2-5F	7-30G	51-250F	5-15G
Nutley-Sinai	25-100G	6-15G	0-2P	51-250G	2-4F
Wabek	6-24F	2-5F	7-30G	51-250G	2-4F
Williams-Bowbells	25-100G	6-15G	0-2P	16-50F	2-4F
Williams-Niobell	25-100G	6-15G	0-2P	0-15P	2-4F
Williams	25-100G	6-15G	0-2P	51-250G	2-4F
Zahl-Max-Williams-Velva	0-5P	0-1P	7-30G	0-15P	5-15G

1/ Numerical figures represent the range in population. Alphabetic symbol indicates suitability of the association; that is, G indicates good; F, fair; and P, poor.

Kinds and distribution of wildlife

The capability of the land to support wildlife depends on the kind of soil and the land use. Land use determines the amount and distribution of wildlife food and cover. Changes in land use are generally reflected in changes in kinds and numbers of wildlife in the area. Areas having the greatest potential for wildlife may not necessarily have the largest population at this time, but these are the areas where the largest population can be obtained with the least effort and the least amount of land.

Important kinds of wildlife in Ward County are sharp-tailed grouse, ducks, white-tailed deer, pheasant, gray partridge, geese, furbearers, and fish. These are discussed in the following paragraphs.

Sharp-tailed grouse.—This native game bird thrives in areas that have a high proportion of native grassland. It prefers range that has a good distribution of shrub thickets. Its highest potential is in the Wabek, Max-Williams, Max-Zahl, and Zahl-Max-Williams-Velva soil associations.

Ducks.—Well-known native ducks probably have the greatest potential among the wildlife in Ward County and are most important to the economy. The preservation of wetlands and the construction of water developments, such as a water source for livestock, tend to maintain and im-

[5]By ERLING B. PODOLL, biologist, Soil Conservation Service.

prove the potential of the habitat for producing and harvesting ducks. At present there are 12,000 acres of lakes and artificial ponds; 25,000 acres of natural or intermittent marshland; 2,000 acres of artificial refuge marshland; and 70,000 acres of classified wetlands. In addition, nearly 25,000 small, deep, intermittently ponded depressions and more than 25,000 small, shallow, temporarily ponded depressions are scattered throughout the county. The most suitable habitat for ducks is on Freshwater marsh and Parnell and Colvin soils. The Tonka soil and associated soils provide temporary water for breeding areas for waterfowl.

White-tailed deer.—The most suitable habitat for the white-tailed deer is in areas where woods and shrubs are most abundant and in areas where large sloughs have good stands of emergent vegetation and shrubs.

Pheasant.—The potential for pheasant is good on many soil associations in Ward County. This county is in the northern part of North Dakota where temperatures are colder and snowfall is greater so that much better quality and quantity of habitat is needed than farther south.

Gray partridge (Hungarian).—This small game bird was introduced from Europe. Its requirements and range are quite similar to pheasant, but its need for cover, such as escape, nesting, roosting, and loafing, are less demanding. It prefers cultivated areas.

Geese.—The production of geese is impractical on private lands, so management of these lands would concern the harvesting of geese. Ward County is not in the major goose flyway but has some goose stopovers, such as the Des Lacs National Wildlife Refuge and the Upper Souris National Wildlife Refuge. The potential for development to increase harvest is limited, but the better areas would be the nearly level areas in the Barnes-Svea and Williams-Bowbells soil associations, that are nearest the refuges.

Furbearers.—Several kinds of furbearing animals are in Ward county, and their economic importance fluctuates with the market demand. Furbearers that are in demand for short-haired fur are mink, muskrat, jack-rabbits, and weasel. Mink and muskrat are associated with wetlands and streams. Their best potential for production and development is on Parnell and Colvin soils and on Freshwater marsh. Important furbearers in the county that are harvested for long-haired fur are fox, skunk, and raccoon.

Fish.—The most important species of fish are northern pike, perch, and walleyed-pike. Lake Darling Reservoir and the Souris River just below it are good public fishing sites. Other sites on the Souris River are at Bakers Bridge and Burlington Dam. The Burlington Park Dams and other spots on the Des Lacs River provide some fishing. Rice Lake is the only lake for fishing in the county, but it is marginal. Winterkill is frequent. There are about ten private fishponds that provide local fishing. Suitable dam sites occur in the coulees of the steep Zahl-Max soil association, but water rights in the watershed of the Souris River cannot be secured at this time.

Development of wildlife habitat

Onsite investigation of areas used for wildlife habitat is needed before improvement can be planned. After the needs have been determined, suitable vegetation can be chosen and suitable management practices used to fit the needs of the soil and the kind of wildlife. Special practices are required to establish or improve the habitat where land use, such as cropland, woodland, range or pasture does not provide for the needs. Assistance in evaluating land for wildlife habitat and in applying suitable management practices can be obtained from the nearest office of the Soil Conservation Service or the Game and Fish Department.

Engineering Uses of the Soils[6]

Some soil properties are of interest to engineers because they affect construction and maintenance of roads, airports, pipelines, building foundations, facilities for water storage, erosion control structures, irrigation and drainage systems, and sewage disposal systems. Among the properties most important to engineers are permeability to water, shear strength, compaction characteristics, drainage, shrink-swell potential, texture, plasticity, and reaction. Other important properties are depth to water table, depth to bedrock, available water capacity, and topography.

Estimates of the soil properties significant in engineering are given in table 5, interpretations relating to engineering uses of the soils in table 6, and engineering test data in table 7. The estimates and interpretations of soil properties in these tables can be used to—

1. Make studies that will aid in selecting and developing industrial, business, residential, and recreational sites.
2. Make preliminary estimates of soil properties that are significant in the planning of agricultural drainage systems, farm ponds, irrigation systems, and diversion terraces.
3. Make preliminary evaluations of soil and ground conditions that will aid in selecting locations for highways, airports, pipelines, and cables and in planning detailed investigations at the selected locations.
4. Locate probable sources of gravel, sand, and other construction materials.
5. Correlate performance of engineering structures with soil mapping units to develop information for overall planning useful in designing and maintaining engineering structures.
6. Determine the suitability of soils for cross-country movement of vehicles and construction equipment.
7. Supplement the information obtained from other published maps and reports and aerial photographs for the purpose of making soil maps and reports that can be used readily by engineers.
8. Develop other preliminary estimates for construction purposes pertinent to the particular area.

With the use of the soil map for identification, the engineering interpretations in this section can be useful for many purposes. It should be emphasized that they do not eliminate the need for sampling and testing at the site of specific engineering works involving heavy loads and excavations deeper than the depths of layers here reported. Even in these situations, the soil map is useful for planning more detailed field investigations and for suggesting the kinds of problems that may be expected.

Some of the terms used in soil science, for example, clay, silt, and sand, have a special meaning to soil scientists and a different meaning to engineers. These terms and others are defined in the Glossary.

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[6]By CLINTON R. JOHNSON, State conservation engineer, Soil Conservation Service.

TABLE 5.—*Engineering*

[An asterisk in the first column indicates that at least one mapping unit in this series is made up of two or reason it is necessary to follow carefully the instructions for referring to other series that appear in the

Soil series and map symbols	Depth to seasonal high water table	Depth from surface (typical profile)	Classification			Percentage passing sieve—	
			Dominant USDA texture	Unified	AASHO	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)
	Feet	Inches					
Alluvial land: Ad. No estimates made because the soil material is too variable. Onsite investigation required.	0-5						
Arveson: Af	0-3	0-30	Fine sandy loam and loam.	SM or ML	A-2 or A-4	100	100
		30-60	Loamy sand, loamy fine sand, and coarse sand.	SP-SM or SM	A-2	100	100
Arvilla: ArA, ArB	5+	0-16	Sandy loam	SM	A-2	100	95-100
		16-60	Sand and gravel	SP	A-1 or A-2	85-90	75-80
*Barnes: BaA, BaB, BaC, BaD, BaE, BbB, BhB, BlA, BmB. For Buse part of BbB, see Buse series; for Hamerly part of BhB, see Hamerly series; for Svea part of BlA, see Svea series; for Tonka part of BmB, see Tonka series.	5+	0-42	Loam	ML or CL	A-4 or A-6	95-100	90-100
		42-60	Loam	CL	A-6	95-100	90-100
Benoit: Bn	0-3	0-25	Loam	ML	A-4	95-100	90-95
		25-60	Coarse sand and gravel.	SP-SM, GP-GM, SM, or GM	A-1 or A-2	55-75	25-45
*Bowbells: BoB, Bp, Br, BtA. For Parnell part of Bp, see Parnell series; for Tonka part of Br, see Tonka series; for Williams part of BtA, see Williams series.	5+	0-36	Loam and clay loam.	ML or CL	A-4 or A-6	95-100	90-100
		36-60	Loam	CL	A-6	95-100	90-95
*Buse: BuE, BvC, BvE. For Barnes part of BvC and BvE, see Barnes series.	5+	0-18	Loam	CL	A-6	90-95	85-95
		18-60	Loam	CL	A-6	90-95	85-95
Colvin: Co, Cv	0-3	0-60	Silt loam and silty clay loam.	CL	A-6 or A-7	100	100
Divide: Dd	2-5	0-16	Loam	ML or CL	A-4 or A-6	100	95-100
		16-24	Gravelly sandy loam.	SM	A-2 or A-4	70-85	65-75
		24-60	Coarse sand and gravel.	SP-SM, SM, GP-GM, or GM	A-1 or A-2	40-65	25-45
Egeland:							
EcB	5+	0-60	Fine sandy loam, sandy loam, and loamy sand.	SM or ML	A-2 or A-4	100	95-100
EdA	5+	0-36	Fine sandy loam, sandy loam, and loamy sand.	SM or ML	A-2 or A-4	100	95-100
		36-60	Loam	CL	A-6	95-100	90-95

properties of soils

more kinds of soil. The soil in such mapping units may have different properties and limitations, and for this first column of this table. The symbol < means less than; the symbol > means more than]

Percentage passing sieve—Continued		Permeability	Available water capacity	Reaction	Salinity	Dispersion	Shrink-swell potential
No. 40 (0.42 mm.)	No. 200 (0.074 mm.)						
		Inches per hour	Inches per inch of soil	pH			
70-85	25-55	2.0-6.3	0.12-0.14	7.4-8.4	None to low	Low	Low.
60-80	5-25	2.0-6.3	0.04-0.06	7.4-8.4	None	Low	Low.
70-85	25-35	6.3-20.0	0.11-0.13	6.1-7.3	None	Low	Low.
30-50	0-5	>20.0	0.03-0.05	7.4-8.4	None	Low	Low.
80-95	60-75	0.63-2.0	0.16-0.18	6.6-8.4	None	Low	Moderate.
80-95	60-75	0.20-0.63	0.15-0.17	7.4-8.4	None	Low	Moderate.
80-90	60-85	0.63-2.0	0.18-0.20	7.9-8.4	None	Low	Low.
10-30	5-20	>20.0	0.03-0.05	7.4-8.4	None	Low	Low.
85-95	60-80	0.63-2.0	0.16-0.18	6.6-7.3	None	Low	Moderate.
85-95	60-80	0.20-0.63	0.16-0.18	7.4-8.4	None	Low	Moderate.
80-90	60-85	0.63-2.0	0.16-0.18	7.4-8.4	None	Low	Moderate.
80-90	60-85	0.20-0.63	0.16-0.18	7.4-8.4	None	Low	Moderate.
95-100	85-100	0.63-2.0	0.19-0.21	7.4-9.0	None or low	Low	Moderate to high.
80-90	55-70	0.63-2.0	0.16-0.18	7.9-8.4	None or low	Low	Low.
50-60	20-40	2.0-6.3	0.06-0.08	7.9-8.4	None	Low	Low.
10-30	5-20	>20.0	0.02-0.04	7.4-8.4	None	Low	Low.
80-100	25-60	2.0-6.3	0.12-0.14	6.1-7.8	None	Low	Low.
80-100	25-60	2.0-6.3	0.12-0.14	6.1-7.8	None	Low	Low.
80-90	60-80	0.2-0.63	0.16-0.18	7.4-8.4	None	Low	Moderate.

TABLE 5.—*Engineering*

Soil series and map symbols	Depth to seasonal high water table	Depth from surface (typical profile)	Classification			Percentage passing sieve—	
			Dominant USDA texture	Unified	AASHO	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)
	Feet	Inches					
Embden: Em	5+	0-60	Fine sandy loam	SM or ML	A-2 or A-4	100	100
*Emrick: ErA. For Heimdal part of this unit, see Heimdal series.	5+	0-36	Loam	ML or CL	A-4 or A-6	95-100	90-100
		36-60	Loam	CL	A-6	95-100	90-100
Fargo: Fc	1-5	0-60	Silty clay	CH	A-7	100	100
Freshwater marsh: Fw. No estimates made because the soil material is too variable. Onsite investigation required.	0-3						
Gravel pits: Gp[1/]. No estimates made because the soil material is too variable. Onsite investigation required.	2-5+						
Hamerly: Hf	2-5	0-24	Loam	ML or CL	A-4 or A-6	95-100	85-95
		24-60	Loam	CL	A-6	95-100	85-95
*Harriet: Hh, Hk. For Vallers part of Hk, see Vallers series.	0-3	0-60	Loam, silt loam, and clay loam.	ML-CL or CL	A-4, A-6, or A-7	100	95-100
Hegne: Hr	1-5	0-60	Silty clay and clay.	CH	A-7	100	100
Heil: Hs	0-3	0-60	Silty clay	CH	A-7	100	100
Heimdal: HtB	5+	0-45	Loam and fine sandy loam.	ML	A-4	95-100	90-100
		45-60	Loam	CL	A-6	95-100	90-100
*Lamoure: Lc. For Colvin part of this unit, see Colvin series.	0-4	0-50	Silty clay loam	CL	A-6 or A-7	100	100
		50-60	Sand or sand and gravel.	SM or GM	A-1 or A-2	60-100	40-80
Lehr: LeA, LeB	5+	0-16	Loam	ML	A-4	90-100	85-95
		16-30	Gravelly coarse sandy loam.	SM	A-2 or A-4	70-85	65-75
		30-60	Sand and gravel	SM	A-1 or A-2	60-95	40-65
*Lihen: LfA, LfB, LlB. For Telfer part of these units, see Telfer series.	5+	0-20	Fine sandy loam or loamy fine sand.	SM	A-2 or A-4	100	95-100
		20-60	Loamy fine sand	SM	A-2	100	100
*Lihen, till substratum: LhA, LhB. For Telfer part of these units, see Telfer series.	5+	0-36	Fine sandy loam and loamy fine sand.	SM	A-2 or A-4	100	95-100
		36-60	Loam	CL	A-6	95-100	90-100
Loamy lake beaches: Lo. No estimates made because the soil material is too variable. Onsite investigation required.	0-5						
Ludden: Ls, Lt, Lu	0-5	0-60	Clay	CH	A-7	100	100
Makoti: MaA	4+	0-60	Silty clay loam	CL	A-7	100	100

properties of soils—Continued

Percentage passing sieve—Continued		Permeability	Available water capacity	Reaction	Salinity	Dispersion	Shrink-swell potential
No. 40 (0.42 mm.)	No. 200 (0.074 mm.)						
		Inches per hour	Inches per inch of soil	pH			
80-100	25-60	2.0-6.3	0.12-0.14	6.1-7.8	None	Low	Low.
80-95	55-90	0.63-2.0	0.17-0.19	6.6-7.8	None	Low	Low.
80-95	60-75	0.63-2.0	0.16-0.18	7.4-8.4	None	Low	Moderate.
95-100	90-100	0.06-0.2	0.17-0.19	6.6-8.4	None	Low	High.
80-95	55-75	0.2-0.63	0.16-0.18	7.4-8.4	None to moderate	Low	Low to moderate.
80-95	55-75	0.2-0.63	0.16-0.18	7.4-8.4	None to moderate	Low	Moderate.
85-95	60-90	0.06-0.2	0.05-0.07	8.5-9.0	Low to high	High	Moderate to high.
95-100	90-100	0.06-0.2	0.17-0.19	7.4-8.4	None to low	Low	High.
100	80-95	<0.06	0.05-0.07	7.4-9.0	None to moderate	High	High.
80-95	55-85	0.63-2.0	0.16-0.18	6.6-8.4	None	Low	Low.
80-95	60-80	0.2-0.63	0.16-0.18	7.4-8.4	None	Low	Moderate.
90-100	80-90	0.2-0.63	0.17-0.19	7.9-8.4	None to moderate	Low	Moderate to high.
20-40	10-30	6.3- >20.0	0.40-0.08	7.4-8.4	None	Low	Low.
80-90	50-65	2.0-6.3	0.12-0.14	6.6-7.3	None	Low	Low.
50-60	20-40	2.0-6.3	0.06-0.08	7.9-8.4	None	Low	Low.
20-40	10-30	>20.0	0.04-0.06	7.4-9.0	None	Low	Low.
90-100	25-45	2.0-6.3	0.13-0.15	6.6-7.3	None	Low	Low.
90-100	15-35	2.0-6.3	0.08-0.12	7.4-7.8	None	Low	Low.
90-100	25-45	2.0-6.3	0.13-0.15	6.6-7.3	None	Low	Low.
80-95	60-80	0.2-0.63	0.16-0.18	7.4-8.4	None	Low	Moderate.
95-100	90-100	0.06-0.2	0.16-0.18	7.4-8.4	None to low	Low	High.
90-100	90-95	0.2-0.63	0.19-0.21	6.6-8.4	None	None	High.

TABLE 5.—*Engineering*

Soil series and map symbols	Depth to seasonal high water table	Depth from surface (typical profile)	Classification			Percentage passing seive—	
			Dominant USDA texture	Unified	AASHO	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)
	Feet	Inches					
*Manning: MgA, MgB, MhC. For Wabek part of MhC, see Wabek series.	5+	0-24	Sandy loam	SM	A-2 or A-4	100	90-100
		24-60	Sand and gravel	SM	A-1 or A-2	60-80	40-65
*Max: MlE, MmB, MmC, MmD, MnC, MoC. For Bowbells part of MlE, see Bowbells series; for Zahl part of MlE, MnC, and MoC, see Zahl series; for Williams part of MmB, MmC, and MmD, see Williams series.	5+	0-30	Loam	ML or CL	A-4 or A-6	95-100	90-100
		30-60	Loam	CL	A-6	95-100	90-100
Mine pits and dumps: Mp. No estimates made because the soil material is too variable. Onsite investigation required.							
Miranda. Mapped only in complex with Noonan and Zahl soils.	4+	0-60	Loam and clay loam.	CL	A-6 or A-7	95-100	90-95
Niobell. Mapped only in complex with Noonan and Williams soils.	4+	0-9	Loam	ML or CL	A-4 or A-6	95-100	90-95
		9-60	Loam or clay loam	CL or CH	A-6 or A-7	95-100	90-95
*Noonan: Nm, Nn. For Miranda part of Nm, see Miranda series; for Niobell part of Nn, see Niobell series.	4+	0-10	Loam	ML or CL	A-4 or A-6	95-100	90-95
		10-60	Loam or clay loam	CL or CH	A-6 or A-7	95-100	90-95
*Nutley: NtB, NuA. For Sinai part of NuA, see Sinai series.	5+	0-60	Silty clay	CL or CH	A-7	100	100
Overly: Ov	4+	0-60	Silty clay loam	CL	A-6 or A-7	100	100
Parnell: Pa, Pe	0-5	0-20	Silty clay loam and silty clay.	MH or CH	A-7	100	100
		20-60	Silty clay and clay loam.	CH	A-7	100	100
Renshaw: ReA	5+	0-16	Loam	ML	A-4	100	95-100
		16-60	Coarse sand and gravel.	SP-SM or SM	A-1 or A-2	65-95	50-90
*Roseglen: RtA. For Tansem part of this unit, see Tansem series.	5+	0-21	Silt loam	ML	A-4	100	100
		21-60	Silt loam	ML or CL	A-4 or A-6	100	100
Salt water marsh: Sa. No estimates made because the soil material is too variable. Onsite investigation required.	0-5						
Seroco: SeC	5+	0-60	Fine sand	SM or SP-SM	A-2 or A-3	100	100
Sinai: SgB, SnA	5+	0-60	Silty clay	CL or CH	A-7	100	100

properties of soils—Continued

Percentage passing sieve—Continued		Permeability	Available water capacity	Reaction	Salinity	Dispersion	Shrink-swell potential
No. 40 (0.42 mm.)	No. 200 (0.074 mm.)						
		Inches per hour	Inches per inch of soil	pH			
70-85	30-50	2.0-6.3	0.14-0.16	6.6-7.3	None	Low	Low.
25-60	10-20	>20.0	0.05-0.07	7.4-9.0	None	Low	Low.
85-95	60-75	0.63-2.0	0.17-0.19	6.6-7.3	None	Low	Low to moderate.
85-95	60-75	0.2-0.63	0.16-0.18	7.4-8.4	None	Low	Moderate.
85-95	60-75	<0.06	0.05-0.07	6.6-9.0	Moderate to high	High	Moderate to high.
85-95	50-75	0.63-2.0	0.16-0.18	6.6-8.4	None	Low	Moderate.
85-95	60-80	0.2-0.63	0.10-0.12	8.5-9.0	None to low	High	Moderate to high.
85-95	60-75	0.63-2.0	0.10-0.12	6.6-7.3	None to low	Low to moderate.	Moderate.
85-95	60-80	0.06-0.2	0.10-0.12	7.9-9.0	Slight to high	High	Moderate to high.
95-100	85-95	0.06-0.2	0.14-0.17	7.4-8.4	None	Low	High.
95-100	85-95	0.2-0.63	0.19-0.21	6.6-8.4	None	Low	Moderate to high.
100	90-100	0.2-2.0	0.19-0.21	6.6-7.3	None	Low	High.
100	90-100	0.06-0.2	0.19-0.21	6.6-7.3	None	Low	High.
75-90	60-75	2.0-6.3	0.14-0.16	6.6-7.3	None	Low	Low.
5-50	5-20	>20.0	0.03-0.05	7.4-7.8	None	Low	Low.
80-100	70-95	0.63-2.0	0.17-0.19	6.6-7.8	None	Low	Low.
80-100	60-80	0.63-2.0	0.16-0.18	7.4-7.8	None	Low	Low to moderate.
70-90	5-25	6.3-20.0	0.03-0.05	6.6-7.8	None	Low	Low.
90-100	85-95	0.06-0.2	0.18-0.20	6.6-8.4	None	Low	High.

TABLE 5.—*Engineering*

Soil series and map symbols	Depth to seasonal high water table	Depth from surface (typical profile)	Classification			Percentage passing sieve--	
			Dominant USDA texture	Unified	AASHO	No. 4 (4.7 mm.)	No. 10 (2.0 mm.)
	Feet	*Inches*					
Sioux: SoB	5+	0-12	Gravelly loam and sandy loam.	SM	A-2	60-85	50-65
		12-60	Sand and gravel	SP, SM, GP, or GM	A-1 or A-2	40-65	20-55
*Svea: SvA, SvB, SwA, SwB, Sx, Sy, Sz. For Hamerly part of Sx, see Hamerly series; for Tonka part of Sx and Sz, see Tonka series; for Lamoure part of Sy, see Lamoure series.	5+	0-24	Loam	ML or CL	A-4 or A-6	95-100	90-100
		24-60	Loam	ML or CL	A-4 or A-6	95-100	90-100
Tansem. Mapped only in complex with Roseglen soils.	5+	0-14	Silt loam	ML	A-4	100	100
		14-60	Silt loam	ML or CL	A-4 or A-6	100	100
*Telfer: TlC. For Lihen part of this unit, see Lihen series.	5+	0-60	Loamy fine sand and fine sand.	SP-SM or SM	A-2 or A-3	100	95-100
Tonka: To	0-5	0-20	Silt loam and loam.	ML	A-4	100	95-100
		20-60	Clay loam and loam.	CL	A-6 or A-7	100	90-100
Vallers: Va	0-5	0-10	Loam	ML or CL	A-4 or A-6	100	95-100
		10-60	Loam	CL	A-6	100	95-100
Velva: Ve, Vh, Vk	4+	0-18	Loam and silt loam.	ML	A-4 or A-6	100	95-100
		18-60	Very fine sandy loam.	SM or ML	A-2 or A-4	100	95-100
*Wabek: WaB, WaE, WeC. For Max and Zahl parts of WeC, see Max and Zahl series.	5+	0-16	Gravelly sandy loam.	SM	A-2	95-100	90-100
		16-60	Sand and gravel	SP, SM, GM, or GP	A-1	55-65	35-45
*Williams: WlA, WlB, WlC, WlD, WmA, WmB, WmC, WmD, WoA, WrB, WsA. For Bowbells part of WoA, see Bowbells series; for Tonka part of WoA, see Tonka series; for Hamerly part of WrB, see Hamerly series; for Niobell part of WsA, see Niobell series.	5+	0-30	Loam and clay loam.	ML or CL	A-4 or A-6	95-100	90-100
		30-60	Loam	CL	A-6	95-100	90-100
*Zahl: ZaE, ZmC, ZmE, ZmF, ZnE. For Max part of ZmC, ZmE, and ZmF, see Max series; for Miranda part of ZnE, see Miranda series.	5+	0-15	Loam	CL or ML-CL	A-6	95-100	90-100
		15-60	Loam	CL or ML-CL	A-6	95-100	90-100

1/ Areas now mapped as Gravel pits were formerly Arvilla, Lehr, Renshaw, Sioux, or Wabek soils.

properties of soils—Continued

Percentage passing sieve—Continued		Permeability	Available water capacity	Reaction	Salinity	Dispersion	Shrink-swell potential
No. 40 (0.42 mm.)	No. 200 (0.074 mm.)						
		Inches per hour	Inches per inch of soil	pH			
30-50	15-20	2.0-6.3	0.10-0.12	7.4-8.4	None	Low	Low.
5-50	3-20	>20.0	0.02-0.04	7.9-8.4	None	Low	Low.
80-95	60-90	0.63-2.0	0.18-0.20	6.6-7.3	None	Low	Low to moderate.
80-95	60-90	0.2-0.63	0.16-0.18	7.4-8.4	None	Low	Low to moderate.
80-100	70-95	0.63-2.0	0.17-0.19	6.6-7.8	None	Low	Low.
80-100	60-80	0.63-2.0	0.16-0.18	7.4-8.4	None	Low	Low to moderate.
70-90	5-35	6.3-20.0	0.05-0.10	6.6-7.8	None	Low	Low.
90-100	70-85	0.63-2.0	0.17-0.19	6.1-6.5	None	Low	Low.
75-90	60-80	0.06-0.2	0.16-0.18	5.6-7.8	None	Low	Moderate to high.
80-95	60-80	0.2-0.63	0.16-0.18	7.9-8.4	Low to high	Low	Low to moderate.
80-95	60-80	0.2-0.63	0.16-0.18	7.9-8.4	Low to high	Low	Moderate.
85-100	50-60	0.63-2.0	0.16-0.18	7.4-7.8	None	Low	Low.
80-100	30-60	0.63-2.0	0.14-0.16	7.4-7.8	None or low	Low	Low.
50-75	15-35	2.0-6.3	0.10-0.12	6.6-7.8	None	Low	Low.
5-50	3-15	>20.0	0.02-0.04	6.6-7.8	None	Low	Low.
80-95	60-75	0.63-2.0	0.16-0.18	6.6-8.4	None	Low	Low to moderate.
80-95	60-75	0.2-0.63	0.16-0.18	7.4-8.4	None	Low	Moderate.
80-95	50-80	0.63-2.0	0.16-0.18	7.4-8.4	None	Low	Moderate.
80-95	50-80	0.2-0.63	0.16-0.18	7.9-8.4	None	Low	Moderate.

TABLE 6.—*Engineering*

[An asterisk in the first column indicates that at least one mapping unit in this series properties and limitations, and for this reason it is necessary to follow carefully the

Soil series and map symbols	Suitability as a source of—			Degree and kind of limitation for sewage disposal fields		Soil features affecting—
	Topsoil	Sand and gravel	Road fill	Septic tank filter fields	Lagoons	Highway location
Alluvial land: Ad. No estimates made because the soil material is too variable. Onsite investigation required.						
Arveson: Af	Poor	Poor: fines.	Good: high water table.	Severe: high water table.	Severe: high water table; moderately rapid permeability.	High water table.
Arvilla: ArA, ArB	Fair	Good	Good	Slight: possible pollution hazard.	Severe: very rapid permeability; pollution hazard.	Soil features favorable.
*Barnes: BaA, BaB, BaC, BaD, BaE, BbB, BhB, BlA, BmB. For Buse part of BbB, see Buse series; for Hamerly part of BbB, see Hamerly series; for Svea part of BlA, see Svea series; for Tonka part of BmB, see Tonka series.	Fair	Not suitable.	Fair: moderate shrink-swell potential.	Severe: moderately slow permeability.	Slight	Topography
Benoit: Bn	Poor	Fair	Good: high water table.	Severe: high water table.	Severe: high water table; very rapid permeability.	High water table.
*Bowbells: BoB, Bp, Br, BtA. For Parnell part of Bp, see Parnell series; for Tonka part of Br, see Tonka series; for Williams part of BtA, see Williams series.	Good in uppermost 12 inches.	Not suitable.	Fair: moderate shrink-swell potential.	Severe: moderately slow permeability.	Slight	Subject to frost heaving.
*Buse: BuE, BvC, BvE. For Barnes part of BvC and BuE, see Barnes series.	Poor	Not suitable.	Poor: moderate shrink-swell potential; slopes.	Severe: moderately slow permeability; slopes.	Severe: slopes.	Steep, uneven topography.
Colvin: Co, Cv	Poor	Not suitable.	Poor: moderate to high shrink-swell potential; high water table.	Severe: high water table.	Moderate: moderate permeability.	High water table.
Divide: Dd	Fair	Good	Good	Slight: possible pollution hazard.	Severe: very rapid permeability.	Seasonal high water table.
Egeland: EcB	Fair	Poor: fines.	Fair: subject to frost heaving.	Slight	Severe: moderately rapid permeability.	Subject to erosion.

interpretations of soils

is made up of two or more kinds of soil. The soil in such mapping units may have different instructions for referring to other series that appear in the first column of this table]

Soil features affecting—Continued					Degree and kind of limitation for foundations for low buildings
Farm ponds		Agricultural drainage	Irrigation	Grassed waterways	
Reservoir area	Embankments, dikes, and levees				
Suitable for dugouts.	High permeability in compacted material; hazard of piping.	High water table.	Moderate available water capacity; high water table.	Not applicable.	Severe: high water table.
Very rapid permeability.	High permeability in compacted material.	Not applicable.	Low available water capacity; shallow effective rooting depth.	Shallow to sand.	Slight: soil features favorable.
Soil features favorable.	Fair to good stability; low permeability in compacted material.	Not applicable.	Moderately slow permeability.	Soil features favorable.	Moderate: moderate shrink-swell potential.
Suitable for dugouts.	High permeability in compacted material.	High water table.	High water table; moderate available water capacity.	Not applicable.	Severe: high water table.
Soil features favorable.	Fair to good stability; low permeability in compacted material.	Not applicable.	Moderately slow permeability.	Soil features favorable.	Moderate: moderate shrink-swell potential.
Soil features favorable.	Fair to good stability; low permeability in compacted material.	Not applicable.	Moderately slow permeability; slopes.	Not applicable.	Moderate: moderate shrink-swell potential; shear strength in steep areas.
Suitable for dugouts.	Fair stability; hazard of piping.	High water table; outlets difficult to obtain.	Moderate permeability; high water table.	Not applicable.	Severe: moderate to high shrink-swell potential.
Very rapid permeability.	High permeability in compacted material.	Not applicable.	Moderate available water capacity; high water table in a few places.	Not applicable.	Severe: seasonal high water table.
Moderately rapid permeability.	High permeability in compacted material; hazard of piping.	Not applicable.	Moderate available water capacity.	Soil features favorable.	Slight: soil features favorable.

TABLE 6.—Engineering

Soil series and map symbols	Suitability as a source of—			Degree and kind of limitation for sewage disposal fields		Soil features affecting—
	Topsoil	Sand and gravel	Road fill	Septic tank filter fields	Lagoons	Highway location
EdA	Fair	Poor: fines.	Fair: moderate shrink-swell potential.	Severe: moderately slow permeability.	Slight	Subject to erosion.
Embden: Em	Good	Not suitable.	Fair: subject to frost heaving.	Slight	Severe: moderately rapid permeability.	Subject to erosion.
*Emrick: ErA. For Heimdal part of this unit, see Heimdal series.	Good	Not suitable.	Fair: moderate shrink-swell potential.	Moderate: moderate permeability.	Slight	Subject to frost heaving.
Fargo: Fc	Fair	Not suitable.	Poor: high shrink-swell potential; low shear strength.	Severe: slow permeability.	Slight	High plasticity.
Freshwater marsh: Fw. No estimates made because the soil material is too variable. Onsite investigation required.						
Gravel pits: Gp. No estimates made because the soil material is too variable. Onsite investigation required.						
Hamerly: Hf	Poor	Not suitable.	Fair: moderate shrink-swell potential.	Severe: moderately slow permeability; seasonal high water table.	Slight	Subject to frost heaving.
*Harriet: Hh, Hk. For Vallers part of Hk, see Vallers series.	Poor	Not suitable.	Poor: high shrink-swell potential; seasonal high water table.	Severe: slow permeability.	Slight	Subject to flooding; salts.
Hegne: Hr	Poor	Not suitable.	Poor: high shrink-swell potential; low shear strength.	Severe: slow permeability.	Slight	High plasticity; subject to frost heaving.
Heil: Hs	Poor	Not suitable.	Poor: high shrink-swell potential; low shear strength.	Severe: very slow permeability; subject to flooding.	Slight	Ponded water; high plasticity.
Heimdal: HtB	Fair	Not suitable.	Fair: moderate shrink-swell potential.	Severe: moderately slow permeability.	Slight	Subject to frost heaving.
*Lamoure: Lc. For Colvin part of this unit, see Colvin series.	Fair	Not suitable.	Poor: moderate to high shrink-swell potential; seasonal high water table.	Severe: seasonal high water table.	Severe: rapid permeability below depth of 50 inches.	Subject to flooding.

interpretations of soils—Continued

Soil features affecting—Continued: Farm ponds: Reservoir area	Farm ponds: Embankments, dikes, and levees	Agricultural drainage	Irrigation	Grassed waterways	Degree and kind of limitation for foundations for low buildings
Soil features favorable.	Fair to good stability; low permeability in compacted material.	Not applicable.	Moderate available water capacity.	Soil features favorable.	Moderate: moderate shrink-swell potential.
Moderately rapid permeability.	High permeability in compacted material; hazard of piping.	Not applicable.	Moderate available water capacity.	Soil features favorable.	Slight: soil features favorable.
Soil features favorable.	Fair to good stability; low permeability in compacted material.	Not applicable.	Moderate permeability.	Soil features favorable.	Moderate: moderate shrink-swell potential.
Soil features favorable.	Fair to poor stability; high compressibility; high shrink-swell potential.	Outlets difficult to obtain.	Slow permeability.	Not applicable.	Severe: high shrink-swell potential.
Soil features favorable.	Fair to good stability; low permeability in compacted material.	Soil features favorable.	Moderately slow permeability; seasonal high water table.	Soil features favorable.	Moderate to severe: moderate shrink-swell potential; seasonal high water table.
Soil features favorable.	Fair to poor stability; low permeability in compacted material.	Outlets not available.	Shallow effective soil depth; slow permeability; seasonal high water table.	Not applicable.	Severe: moderate to high shrink-swell potential; seasonal high water table.
Soil features favorable.	Fair to poor stability; high compressibility; high shrink-swell potential.	Outlets difficult to obtain.	Slow permeability.	Not applicable.	Severe: high shrink-swell potential.
Soil features favorable.	Fair to poor stability; high compressibility; high shrink-swell potential.	Outlets not available.	Very slow permeability; salinity; subject to flooding.	Not applicable.	Severe: high shrink-swell potential; subject to flooding.
Soil features favorable.	Fair to good stability; low permeability in compacted material if mixed with substratum.	Not applicable.	Moderately slow permeability.	Soil features favorable.	Moderate: moderate shrink-swell potential.
Suitable for dugouts.	Fair to poor stability; moderate to high shrink-swell potential.	Subject to flooding.	Moderately slow permeability; seasonal high water table.	Not applicable.	Severe: moderate to high shrink-swell potential; seasonal high water table.

TABLE 6.—Engineering

Soil series and map symbols	Suitability as a source of—			Degree and kind of limitation for sewage disposal fields		Soil features affecting—
	Topsoil	Sand and gravel	Road fill	Septic tank filter fields	Lagoons	Highway location
Lehr: LeA, LeB	Fair	Good	Good	Slight: possible pollution hazard.	Severe: very rapid permeability.	Soil features favorable.
*Lihen:						
LfA, LfB, LlB. For Telfer part of these units, see Telfer series.	Fair	Poor: fines.	Good	Slight: possible pollution hazard.	Severe: moderately rapid permeability.	Subject to erosion.
LhA, LhB. For Telfer part of these units, see Telfer series.	Fair	Poor: fines.	Good	Severe: slow permeability.	Slight	Subject to erosion.
Loamy lake beaches: Lo.	Poor	Not suitable.	Fair: subject to volume change.	Severe: seasonal high water table; subject to flooding.	Severe: subject to flooding.	Subject to flooding.
Ludden: Ls, Lt, Lu	Poor	Not suitable.	Poor: high shrink-swell potential; low shear strength.	Severe: slow permeability; subject to flooding.	Severe: subject to flooding.	Subject to flooding; high plasticity.
Makoti: MaA	Fair	Not suitable.	Poor: high shrink-swell potential; low shear strength.	Severe: moderately slow permeability.	Slight	Plasticity; subject to frost heaving.
*Manning: MgA, MgB, MhC. For Wabek part of MhC, see Wabek series.	Fair	Good	Good	Slight: possible pollution hazard.	Severe: very rapid permeability.	Soil features favorable.
*Max: MlE, MmB, MmC, MmD, MnC, MoC. For Bowbells part of MlE, see Bowbells series; for Williams part of MmB, MmC, and MmD, see Williams series; for Zahl part of MlE, MnC, and MoC, see Zahl series.	Fair	Not suitable.	Fair: moderate shrink-swell potential.	Severe: moderately slow permeability.	Slight to severe: slopes.	Topography
Mine pits and dumps: Mp. No estimates made because the soil material is too variable. Onsite investigation required.						
Miranda. Mapped only in complexes with Noonan and Zahl soils.	Poor	Not suitable.	Fair: moderate shrink-swell potential.	Severe: very slow permeability.	Slight	Plasticity; salts.
Niobell. Mapped only in complexes with Noonan and Williams soils.	Poor	Not suitable.	Poor: moderate to high shrink-swell potential; low shear strength.	Severe: moderately slow permeability.	Slight	Subject to frost heaving.

interpretations of soils—Continued

Soil features affecting—Continued					Degree and kind of limitation for foundations for low buildings
Farm ponds		Agricultural drainage	Irrigation	Grassed waterways	
Reservoir area	Embankments, dikes, and levees				
Very rapid permeability.	High permeability in compacted material.	Not applicable.	Moderate available water capacity; shallow effective rooting zone.	Shallow to gravel.	Slight: soil features favorable.
Moderately rapid permeability.	High permeability in compacted material; hazard of piping.	Not applicable.	Moderate available water capacity.	Not applicable.	Slight: soil features favorable.
Soil features favorable.	Fair to good stability; low permeability in compacted material.	Not applicable.	Slow permeability.	Not applicable.	Moderate: moderate shrink-swell potential.
Soil features favorable.	Fair to good stability.	Outlets difficult to obtain.	Subject to flooding.	Not applicable.	Severe: subject to flooding.
Soil features favorable.	Fair to poor stability; high shrink-swell potential.	Subject to flooding.	Very slow permeability; subject to flooding.	Not applicable.	High shrink-swell potential; subject to flooding.
Soil features favorable.	Fair to poor stability; high shrink-swell potential; high compressibility.	Soil features favorable.	Moderately slow permeability.	Soil features favorable.	Severe: high shrink-swell potential.
Very rapid permeability.	High permeability in compacted material.	Not applicable.	Shallow effective rooting zone; low available water capacity.	Shallow to gravel.	Slight: soil features favorable.
Soil features favorable.	Fair to good stability; low permeability in compacted material.	Not applicable.	Moderately slow permeability; slopes.	Soil features favorable.	Moderate: moderate shrink-swell potential.
Soil features favorable.	Fair to good stability; low permeability in compacted material.	Not applicable.	Very shallow effective rooting zone; very slow permeability.	Not applicable; salts.	Moderate shrink-swell potential.
Soil features favorable.	Fair to low stability; low permeability in compacted material; moderate to high shrink-swell potential.	Not applicable.	Medium effective rooting zone; moderately slow permeability.	Soil features favorable.	Severe: moderate to high shrink-swell potential.

TABLE 6.—Engineering

Soil series and map symbols	Suitability as a source of—			Degree and kind of limitation for sewage disposal fields		Soil features affecting—
	Topsoil	Sand and gravel	Road fill	Septic tank filter fields	Lagoons	Highway location
*Noonan: Nm, Nn. For Miranda part of Nm, see Miranda series; for Niobell part of Nn, see Niobell series.	Poor	Not suitable.	Poor: moderate to high shrink-swell potential; low shear strength.	Severe: slow permeability.	Slight	Salts; subject to frost heaving.
*Nutley: NtB, NuA. For Sinai part of NuA, see Sinai series.	Fair	Not suitable.	Poor: high shrink-swell potential; low shear strength.	Severe: slow permeability.	Slight	High plasticity
Overly: Ov	Fair	Not suitable.	Poor: moderate to high shrink-swell potential; low shear strength.	Severe: moderately slow permeability.	Slight	Plasticity; subject to frost heaving.
Parnell: Pa, Pe	Poor	Not suitable.	Poor: high shrink-swell potential; low shear strength.	Severe: slow permeability; subject to frequent flooding.	Slight	Ponded water
Renshaw: ReA	Fair	Good	Good	Slight: possible pollution hazard.	Severe: very rapid permeability.	Soil materials favorable.
*Roseglen: RtA. For Tansem part of this unit, see Tansem series.	Good	Not suitable.	Fair: low to moderate shrink-swell potential; subject to frost heaving.	Severe: moderate permeability.	Slight	Subject to frost heaving.
Salt water marsh: Sa. No estimates made because the soil material is too variable. Onsite investigation required.						
Seroco: SeC	Poor	Good as a source of sand. Not suitable for gravel.	Good	Slight	Severe: rapid permeability.	Highly susceptible to erosion; topography.
Sinai: SgB, SnA	Poor	Not suitable.	Poor: high shrink-swell potential; low shear strength.	Severe: slow permeability.	Slight	High plasticity
Sioux: SoB	Poor	Good	Good	Slight: possible pollution hazard.	Severe: very rapid permeability.	Topography

interpretations of soils—Continued

Soil features affecting—Continued: Farm ponds: Reservoir area	Farm ponds: Embankments, dikes, and levees	Agricultural drainage	Irrigation	Grassed waterways	Degree and kind of limitation for foundations for low buildings
Soil features favorable.	Fair to low stability; low permeability in compacted material; moderate to high shrink-swell potential.	Not applicable.	Shallow effective rooting zone; slow permeability.	Salts	Severe: moderate to high shrink-swell potential.
Soil features favorable.	Fair to low stability; low permeability in compacted material; high shrink-swell potential.	Not applicable.	Slow permeability.	Soil features favorable.	Severe: high shrink-swell potential.
Soil features favorable.	Fair to poor stability; moderate to high shrink-swell potential.	Soil features favorable.	Moderately slow permeability.	Soil features favorable.	Severe: moderate to high shrink-swell potential.
Suitable for dugouts.	Fair to poor stability; high shrink-swell potential.	Outlets difficult to obtain.	Not applicable	Not applicable	Severe: high water table; frequent flooding.
Very rapid permeability.	High permeability in compacted material.	Not applicable.	Shallow effective rooting zone; moderate available water capacity.	Shallow to gravel.	Slight: soil features favorable.
Moderately slow permeability.	Poor stability; hazard of piping.	Soil features favorable.	Moderate permeability.	Soil features favorable.	Moderate: low to moderate shrink-swell potential; subject to frost heaving.
Rapid permeability.	High permeability in compacted material.	Not applicable.	Low available water capacity.	Sand	Slight: soil features favorable.
Suitable for dugouts.	Fair to poor stability; high shrink-swell potential; high compressibility.	Soil features favorable.	Slow permeability.	Soil features favorable.	Severe: high shrink-swell potential; consolidation potential.
Very rapid permeability.	High permeability in compacted material.	Not applicable.	Very shallow effective rooting zone; very low available water capacity.	Sand and gravel.	Slight: soil features favorable.

TABLE 6.—Engineering

Soil series and map symbols	Suitability as a source of—			Degree and kind of limitation for sewage disposal fields		Soil features affecting—
	Topsoil	Sand and gravel	Road fill	Septic tank filter fields	Lagoons	Highway location
*Svea: SvA, SvB, SwA, SwB, Sx, Sy, Sz. For Hamerly part of Sx, see Hamerly series; for Tonka part of Sx and Sz, see Tonka series; for Lamoure part of Sy, see Lamoure series.	Good	Not suitable.	Fair: low to moderate shrink-swell potential.	Severe: moderately slow permeability.	Slight	Subject to frost heaving.
Tansem. Mapped only in complex with Roseglen soils.	Good	Not suitable.	Fair: low to moderate shrink-swell potential; subject to frost heaving.	Severe: moderate permeability.	Slight	Subject to frost heaving.
*Telfer: TlC. For Lihen part of this unit, see Lihen series.	Poor	Good as a source of sand. Not suitable for gravel.	Good	Slight	Severe: rapid permeability.	Subject to erosion.
Tonka: To	Fair	Not suitable.	Poor: moderate to high shrink-swell potential; high water table; low shear strength.	Severe: slow permeability; subject to flooding.	Slight	Ponded water
Vallers: Va	Poor	Not suitable.	Poor: moderate shrink-swell potential; seasonal high water table.	Severe: moderately slow permeability; seasonal high water table.	Slight	Seasonal high water table.
Velva: Ve, Vh, Vk	Fair	Not suitable.	Fair: subject to frost heaving.	Moderate: subject to flooding.	Severe: subject to flooding.	Subject to flooding.
*Wabek: WaB, WaE, WeC. For Max and Zahl parts of WeC, see Max and Zahl series.	Poor	Good	Good	Slight: possible pollution hazard.	Severe: very rapid permeability.	Topography; soil features favorable.
*Williams: WlA, WlB, WlC, WlD, WmA, WmB, WmC, WmD, WoA, WrB, WsA. For Bowbells and Tonka parts of WoA, see Bowbells and Tonka series; for Hamerly part of WrB, see Hamerly series; for Niobell part of WsA, see Niobell series.	Fair	Not suitable.	Fair: moderate shrink-swell potential.	Severe: moderately slow permeability.	Slight to severe: slopes.	Topography
*Zahl: ZaE, ZmC, ZmE, ZmF, ZnE. For Max part of ZmC, ZmE, and ZmF, see Max series; for Miranda part of ZnE, see Miranda series.	Poor	Not suitable.	Fair: moderate shrink-swell potential.	Severe: moderately slow permeability; slopes.	Severe: slopes.	Steep; uneven topography.

interpretations of soils—Continued

Soil features affecting—Continued: Farm ponds: Reservoir area	Farm ponds: Embankments, dikes, and levees	Agricultural drainage	Irrigation	Grassed waterways	Degree and kind of limitation for foundations for low buildings
Soil features favorable.	Fair to poor stability; hazard of piping.	Soil features favorable.	Moderately slow permeability.	Soil features favorable.	Moderate: low to moderate shrink-swell potential.
Moderate permeability.	Fair to poor stability; hazard of piping.	Not applicable.	Moderate permeability.	Soil features favorable.	Moderate: low to moderate shrink-swell potential.
Rapid permeability.	High permeability in compacted material.	Not applicable.	Low available water capacity.	Sand	Slight: soil features favorable.
Suitable for dugouts.	Fair to good stability; high shrink-swell potential.	Outlets difficult to obtain.	Slow permeability; subject to flooding.	Not applicable	Severe: moderate to high shrink-swell potential; subject to flooding.
Soil features favorable.	Fair to good stability; low permeability in compacted material.	Outlets difficult to obtain.	Seasonal high water table; moderately slow permeability.	Not applicable	Severe: seasonal high water table; moderate shrink-swell potential.
Moderate permeability.	Poor stability; hazard of piping; moderate permeability in compacted material.	Subject to flooding.	Subject to flooding.	Soil features favorable.	Severe: subject to flooding.
Very rapid permeability.	High permeability in compacted material.	Not applicable.	Very shallow effective rooting zone; very low available water capacity.	Sand and gravel.	Slight: soil features favorable.
Soil features favorable.	Fair to good stability; low permeability in compacted material.	Not applicable.	Moderately slow permeability; slopes.	Soil features favorable.	Moderate: moderate shrink-swell potential; slopes.
Soil features favorable.	Fair to good stability; low permeability in compacted material.	Not applicable.	Moderately slow permeability; slopes.	Not applicable	Moderate: moderate shrink-swell potential; slopes.

TABLE 7.—*Engineering*

[Tests performed by the North Dakota State University in cooperation with North Dakota State Highway Department
Association of State

Soil name and location	Parent material	North Dakota University report No. NDH-	Depth from surface	Moisture-density data1/		Mechanical analysis2/		
				Maximum dry density	Optimum moisture	Percentage passing sieve— 1 1/2-in.	3/4-in.	No. 4 (4.7 mm.)
			Inches	Lb. per cu. ft.	Percent			
Barnes loam: 1,050 feet east and 300 feet south of NW. corner of sec. 1, T. 156 N., R. 82 W. (modal).	Glacial till.	54	0-4	94	23	----	100	98
		55	4-14	107	17	----	100	98
		56	14-42	115	16	----	100	97
		57	42-66	116	15	----	100	98
Emrick loam: 1,080 feet west and 80 feet north of SE. corner of SW1/4 sec. 1, T. 155 N., R. 81 W. (modal).	Waterworked glacial till.	50	0-7	100	20	----	----	100
		51	7-16	104	19	----	----	---
		52	16-30	117	14	100	97	94
		53	42-72	118	14	----	100	98
Heimdal loam: 725 feet south and 65 feet east of NW. corner of SW1/4 sec. 24, T. 156 N., R. 81 W. (modal).	Waterworked glacial till.	45	0-8	113	14	----	----	---
		46	8-15	115	13	----	----	---
		47	15-23	115	12	----	----	---
		48	28-45	115	14	----	100	98
		49	45-65	115	14	----	100	98
Ludden clay: 1,200 feet west and 600 feet north of S1/4 corner of sec. 10, T. 156 N., R. 84 W. (modal).	Postglacial alluvium (flood plain).	67	1-8	91	23	----	----	---
		68	18-36	92	26	----	----	---
Manning sandy loam: 200 feet north and 100 feet west of SE. corner of NE1/4 sec. 11, T. 152 N., R. 85 W. (modal).	Glacial outwash.	27	7-15	116	13	----	----	100
		28	20-40	130	10	100	98	79
		29	40-60	114	14	----	100	96
Max loam: 250 feet north and 50 feet east of SW. corner of NW1/4 sec. 10, T. 152 N., R. 87 W. (modal).	Glacial till.	58	3-12	107	16	----	----	99
		59	12-24	112	16	----	----	---
		60	36-60	112	15	----	----	99
Noonan loam: 260 feet north and 105 feet east of SW. corner of sec. 28, T. 160 N., R. 89 W. (modal).	Glacial till.	36	2-7	104	17	----	100	99
		37	10-14	104	19	----	100	99
		38	17-25	112	14	----	100	99
Parnell silt loam: 1,850 feet east and 90 feet south of NW. corner of sec. 11, T. 154 N., R. 86 W. (very poorly drained).	Local glacial-alluvial materials.	61	3-16	61	53	----	----	---
		62	16-30	84	31	----	----	---
		63	45-60	90	28	----	----	---
Sioux gravelly loam: 1,620 feet north and 70 feet west of SE. corner of sec. 1, T. 157 N., R. 82 W. (modal).	Loam over gravel outwash.	39	0-7	112	14	----	100	95
		40	12-36	133	10	100	88	65
		41	36-60	131	11	100	96	56

test data

and U. S. Department of Commerce, Bureau of Public Roads, in accordance with standard procedures of the American Highway Officials (AASHO)]

Mechanical analysis2/—Continued							Liquid limit	Plasticity index	Classification	
Percentage passing sieve—Continued			Percentage smaller than—							
No. 10 (2.0 mm.)	No. 40 (0.42 mm.)	No. 200 (0.074 mm.)	0.05 mm.	0.02 mm.	0.005 mm.	0.002 mm.			AASHO3/	Unified4/
							Percent			
96	87	61	43	5/14	5/ 5	5/4	(5/ 6/)	(5/ 6/)	A-4(5)	ML
96	86	60	54	39	24	18	34	17	A-6(8)	CL
95	88	67	62	50	34	26	31	19	A-6(10)	CL
90	83	62	56	45	29	19	31	18	A-6(9)	CL
99	95	77	60	31	16	10	33	12	A-6(9)	CL
100	98	90	76	44	24	17	35	16	A-6(10)	CL
89	81	62	52	36	23	16	33	19	A-6(9)	CL
94	87	67	60	45	29	18	30	17	A-6(9)	CL
100	98	50	36	16	9	6	22	5	A-4(3)	SM-SC
100	99	46	34	19	14	11	(6/)	(6/)	A-4(2)	SM
100	99	42	29	16	10	8	(6/)	(6/)	A-4(1)	SM
96	89	66	60	45	33	25	37	23	A-6(11)	CL
96	88	65	60	48	34	25	34	18	A-6(9)	CL
100	98	93	68	5/37	5/26	5/20	63	41	A-7-6(20)	CH
---	100	98	87	70	53	46	72	50	A-7-6(20)	CH
95	76	39	32	22	14	11	26	10	A-4(1)	SC
61	35	12	9	5	3	2	(6/)	(6/)	A-1-b(0)	SW-SM
88	67	10	8	6	5	3	(6/)	(6/)	A-3(0)	SW-SM
99	91	5/46	5/29	5/11	5/6	5/4	31	13	A-6(3)	SC
100	95	54	41	26	18	14	24	11	A-6(4)	CL
97	92	72	65	49	34	26	34	18	A-6(11)	CL
98	89	54	38	5/14	5/5	5/3	32	6	A-4(4)	ML
97	91	66	55	38	26	20	41	27	A-7-6(13)	CL
98	94	76	68	55	42	36	39	23	A-6(13)	CL
100	94	71	46	16	8	6	91	43	A-7-5(19)	MH
100	99	97	80	46	25	19	74	27	A-7-5(20)	MH
100	99	95	86	66	42	24	70	49	A-7-6(20)	CH
87	43	28	21	9	4	3	48	35	A-2-7(1)	SM
47	8	3	3	2	1	1	(6/)	(6/)	A-1-a(0)	SW
35	10	3	2	2	1	1	(6/)	(6/)	A-1-a(0)	SW

TABLE 7.—*Engineering*

Soil name and location	Parent material	North Dakota University report No. NDH-	Depth from surface	Moisture-density data[1/]: Maximum dry density	Moisture-density data[1/]: Optimum moisture	Mechanical analysis[2/] Percentage passing sieve—: 1 1/2-in.	3/4-in.	No. 4 (4.7 mm.)
			Inches	Lb. per cu. ft.	Percent			
Telfer fine sandy loam: 1,320 feet south and 150 feet west of NE. corner of sec. 11, T. 151 N., R. 86 W. (modal).	Sandy lacustrine material or outwash.	19	0-7	115	12	----	----	---
		20	7-16	118	12	----	----	100
		21	16-30	117	12	----	----	100
		22	30-60	120	12	----	----	---
Vallers loam: 1,000 feet east and 30 feet south of NW. corner of NE1/4 sec. 22, T. 152 N., R. 85 W. (modal).	Glacial till.	42	3-10	112	16	100	93	88
		43	10-30	112	15	----	100	93
		44	30-75	110	17	----	----	99
Velva loam: 1,100 feet south of NE. corner of NW1/4NW1/4, sec. 26, T. 157 N., R. 85 W. (modal).	Postglacial alluvium (bottom land).	6	0-7	113	14	----	----	---
		7	7-15	113	15	----	----	---
		8	18-45	113	14	----	----	---
		9	45-65	115	14	----	----	---
Williams loam: 125 feet south and 300 feet east of NW. corner of sec. 33, T. 156 N., R. 85 W. (modal).	Glacial till.	1	6-19	107	17	----	100	99
		2	19-65	113	16	----	100	97
Zahl loam: 600 feet SE. of NW. corner o. 1/4 sec. 35, T. 156 N., R. 84 W. (modal).	Glacial till.	30	0-3	100	23	100	94	90
		31	7-24	113	15	----	100	98
		32	24-60	117	14	----	100	96
		33	60-96	117	12	----	----	99

1/ Based on the Moisture-Density Relations of Soils Using a 5.5-lb. Rammer and a 12-in. Drop, AASHO Designation T99-57, Methods A and C (1).

2/ Mechanical analyses according to the AASHO Designation T 88. Results by this procedure frequently may differ somewhat from results that would have been obtained by the soil survey procedure of the Soil Conservation Service (SCS). In the AASHO procedure, the fine material is analyzed by the hydrometer method and the various grain-size 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 analyses used in this table are not suitable for use in naming textural classes for soils.

Engineering classification systems

The system of classifying soils used by the American Association of State Highway Officials (AASHO) (*1*) is based on field performance of soils in highways. In this system soils that have about the same general load-carrying capacity are classified into seven principal groups. The groups range from A-1, which consists of gravelly soils of high bearing capacity, to A-7, which consists of clayey soils that have low strength when wet. The relative engineering values of the soils within each group are indicated by group index numbers, which range from 0 for the best material to 20 for the poorest. The group index of a soil can be established only by laboratory tests. The AASHO classifications in table 7, engineering test data, include group index numbers for the soils tested.

The Unified soil classification system developed by the Department of Defense (*15*) is based on texture, plasticity, and liquid limit and on performance as engineering construction material. In this system, soil materials are identified as coarse grained (eight classes), fine grained (six classes), or highly organic (one class). The coarse-grained soils (less than half the material, by weight, passes the No. 200 sieve) are identified by the following symbols: GC, GW, GP, GM, SW, SP, SM, and SC. The fine-grained soils (more than half the material, by weight, passes the No. 200 sieve) are identified by the following symbols: ML, CL, OL, MH, CH, and OH.

Estimated engineering properties

Table 5 gives estimates of soil properties that are significant in engineering. Depth to bedrock is not shown for soils in this county, because depth to bedrock is far enough below the surface to be no problem for engineering purposes. Some of the column headings in table 5 are discussed briefly in the following paragraphs.

Permeability indicates the rate at which water moves through undisturbed soil material. The estimates are based on structure and porosity and on the results of permeability and infiltration tests on undisturbed cores of similar soil material.

test data—Continued

Mechanical analysis 2/—Continued							Liquid limit	Plasticity index	Classification	
Percentage passing sieve—Continued			Percentage smaller than—							
No. 10 (2.0 mm.)	No. 40 (0.42 mm.)	No. 200 (0.074 mm.)	0.05 mm.	0.02 mm.	0.005 mm.	0.002 mm.			AASHO 3/	Unified 4/
							Percent			
100	94	34	25	13	10	7	(6/)	(6/)	A-2-4(0)	SM
99	94	27	21	12	9	7	(6/)	(6/)	A-2-4(0)	SM
99	94	23	20	14	12	10	(6/)	(6/)	A-2-4(0)	SM
100	95	37	33	26	20	16	20	3	A-4(0)	SM
83	71	5/43	5/33	5/21	5/14	5/11	35	19	A-6(4)	SC
84	77	59	53	42	28	22	38	23	A-6(10)	CL
94	85	66	59	45	31	24	37	21	A-6(11)	CL
100	99	51	39	26	20	17	25	6	A-4(3)	ML-CL
----	100	56	41	20	13	10	24	4	A-4(4)	ML-CL
----	100	60	48	31	19	16	27	8	A-4(5)	CL
----	100	56	46	28	18	16	23	2	A-4(4)	ML
97	92	67	58	44	31	19	40	20	A-6(10)	CL
93	88	67	57	38	27	20	35	17	A-6(9)	CL
88	78	5/50	5/28	5/8	5/4	5/3	39	14	A-6(4)	SM-SC
96	87	61	53	39	28	20	37	20	A-6(9)	CL
91	83	58	39	35	23	17	31	13	A-6(6)	CL
96	88	61	53	37	25	19	32	18	A-6(8)	CL

3/ Based on the Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes, AASHO Designation: M 145-49 (1).

4/ Based on the Unified Soil Classification System for roads, airfields, embankments and foundations (15). Soil Conservation Service and Bureau of Public Roads have agreed that any soil having plasticity index within 2 points of the A-line is to be given a borderline classification. SM-SC is an example of a classification so obtained.

5/ Percentages are low. The granulated surface soil is not dispersed.

6/ Nonplastic.

Available water capacity is 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.

Reaction (pH value) refers to the degree of acidity or alkalinity of a soil. The degrees of acidity or alkalinity are defined under "Reaction" in the Glossary. Soils that have a pH value of less than 8.5 are likely to have a higher potential of consolidation and better shear strength than other soils. A high degree of alkalinity, particularly a pH value of more than 8.5, promotes dispersion.

The soils that are shown in table 5 as having moderate to severe salinity contain gypsum. Gypsum is not harmful if the soil material is to be used as borrow material, but it is critical if it is to be used in foundations because abnormal porosity can result when the crystals dissolve.

Dispersion, as used in this publication, refers to the degree to which particles smaller than 0.005 millimeter are separate or dispersed. It should be distinguished from the single-grain or unaggregated condition of clean sand. In many places dispersed soils become slick when wet, and a crust of clay forms as the surface dries. Soil particles affected by calcium carbonate tend to aggregate rather than to disperse, but soils that contain a large amount of sodium are likely to disperse, as are acid, silty soils that formed under poor drainage conditions. Critically dispersed soils are dangerous in dams and other embankments, especially if they are used in the foundation or embankment without special preparation. They are made up of unstable aggregates that slake in water and go into suspension easily. They have low shear strength and high piping potential and are easily eroded.

Shrink-swell potential indicates the volume change to be expected when the moisture content changes. It is based on the liquid limit and plasticity index of the soil. Shrink-swell potential is low if the liquid limit is 30 or less and the plasticity index is 10 or less; it is moderate if the liquid limit is 31 to 40 and the plasticity index is 11 to 20; it is high if the liquid limit is 41 to 60 and the plasticity index is 21 to 40. Coarse sand and gravel have such a very low shrink-swell potential that they are designated as having none.

Engineering interpretations

Table 6 gives the suitability of each soil series and land type as a source of topsoil, sand and gravel, and road fill. It also indicates soil limitations for septic tank filter fields and sewage lagoons. It provides interpretations for highway location, farm ponds, agricultural drainage, irrigation, grassed waterways, and features affecting foundations for low buildings.

Normally, only the surface layer of a soil is rated for suitability as topsoil. Suitability for this use depends largely on texture and depth. Topsoil material must be capable of being worked into a good seedbed for seeding or sodding, and yet it must be clayey enough to resist erosion in steep areas.

The suitability of a soil as a source of sand or gravel depends on the qualifications of the material for use in road construction or use as concrete aggregate and on the thickness of the layer. To qualify as either a good or fair source, the layer should be at least 3 feet thick. Soils that are shown as suitable should be explored extensively to find material that meets gradation requirements for specific uses.

The suitability of a soil as a source of road fill depends mainly on texture and water content. Clay and organic material are poorest because they are highly plastic and contain a large amount of water. Silt and fine sand are fair to poor because they are erodible, are difficult to compact, and require moderately gentle slopes and rapid establishment of vegetation for control of erosion. In general, a sandy material that contains adequate binder is better than other material because it is least affected by adverse weather and can be worked in more months of the year.

Septic tank filter fields are influenced by the ease of the downward movement of effluent through the soil. Soils that have moderately slow to very slow permeability are rated severe. Other soil properties that affect septic tank filter fields are the hazard of flooding, seasonal high water table, salinity and alkalinity, and topography.

Sewage lagoons require that the suitability of the soil be considered for two functions: (1) as a container for impounded water and (2) as soil material for the dam. Adequate soil material that is suitable for the structure must be available, and when properly constructed, the lagoon must be capable of holding water with minimum seepage. Soils that flood have severe limitations as sites for lagoons. Floodwaters interfere with the functioning of the lagoon and carry away sewage before bacterial decomposition has taken place. Pollution of streams can be a serious problem resulting from such action.

In determining the soil features that affect highway location, the entire profile of an undisturbed soil is evaluated. Some of the features considered are depth to bedrock, depth to water table, stability, erodibility, and hazard of flooding.

Factors that influence pond reservoir areas are those features and qualities of undisturbed soils that affect their suitability for use as water impoundments. The most important properties of the soil to be considered for this use are permeability, depth to water table, and depth to bedrock.

The factors considered for agricultural drainage are those features and qualities of the soil that affect the installation and performance of surface and subsurface drainage systems. The soils listed in table 6 that are affected by these factors are the somewhat poorly drained and very poorly drained soils that have a seasonal or permanent high water table. They have severe limitations for the production of crops because saturation of the soil with water excludes air from plant roots and permits the growth of only water-tolerant plants.

The limitations of soils for irrigation are based mainly on the available water capacity, water intake rate, soil slope, and natural drainage. The type of irrigation, sprinkler or gravity, was not considered in use of the soils for irrigation. If the soils have low available water capacity, frequent applications of water are needed to maintain a rapid rate of plant growth. Slowly permeable soils are somewhat difficult to irrigate because water must be applied very slowly to allow the water to soak into the soil and avoid runoff.

Factors considered for grassed waterways are those features and qualities of soils that affect the establishment, growth, and maintenance of plants and features that hinder layout and construction.

The limitations of soils for use as foundations are for undisturbed soils that are evaluated for single family dwellings and other structures with similar foundation requirements. The rating does not apply to buildings of more than three stories and other buildings that have foundation loads in excess of those equal to three-story dwellings. Soils for dwellings are rated mainly for use as foundations, but soil slope, susceptibility to flooding, and other hydrologic conditions, such as seasonal wetness, that have effects beyond those related exclusively to foundations are considered. The properties that affect bearing strength and settlement of the natural soil are density, wetness, flooding, plasticity, texture, and shrink-swell potential. Onsite investigations are needed for specific placement of buildings and utility lines and for detailed design of foundations. All ratings are based on undisturbed soils to a depth of 5 feet.

Engineering test data

To help evaluate the soils in Ward County for engineering purposes, samples from 15 profiles were tested according to standard procedures. The results are given in table 7.

Moisture-density data are obtained by compacting soil material 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, the density obtained in the compaction test is termed "maximum dry density." Moisture-density data are important in earthwork because, generally, optimum stability is obtained if the soil is compacted to about the maximum dry density when it is at approximately the optimum moisture content.

Tests for liquid limit and plastic limit measure the effect of water on the consistence of soil material. As the moisture content of a soil is increased from a dry state, the material changes from a semisolid to a plastic state. As the moisture content is further increased, the material changes from a plastic state to a liquid state. The plastic limit is the moisture content at which the soil material changes from a semisolid to a plastic state. The liquid limit is the moisture content at which the material changes 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 in a plastic condition. If the liquid limit or plastic limit cannot be determined, or if the plastic limit is equal to or higher than the liquid limit, the plasticity index is given as nonplastic.

Formation and Classification of the Soils

This section describes the outstanding morphologic characteristics of the soils of Ward County and relates them to the factors of soil formation. Physical and chemical data are limited for these soils, and the discussion of soil genesis and morphology is correspondingly incomplete. The first part of the section discusses the environment of the soils; the second, the classification of soils; and the third, the chemical and physical analyses of selected soils.

Factors of Soil Formation

Soil is produced by the action of soil-forming processes on the surface materials covering Ward County. The characteristics of the soil at any given point are determined by (1) the physical and mineralogical composition of the parent material; (2) the climate that has prevailed since accumulation of the parent material; (3) the vegetation and living organisms on and in the soil; (4) the topography, or lay of the land and drainage; and (5) the length of time the forces of soil development have acted on the soil material.

Climate and vegetation are active factors of soil genesis. They act on the parent material that has accumulated through the weathering of rocks and slowly change it into a natural body with genetically related horizons. The effects of climate and vegetation are conditioned by relief. The parent material also affects the kind of profile that is formed and, in young soils, determines it entirely. Finally, time is needed for the changing of the parent material into a soil. It can be much or little, but some time is always needed for horizon differentiation. Generally a long time is needed for the development of distinct horizons.

The factors of soil genesis are so closely interrelated in their effects on the soil that generalizations regarding one factor cannot be made without involving the other four.

Parent material

The soils of Ward County have developed in four kinds of parent material: glacial till, glacial lacustrine deposits, glacial outwash, and postglacial alluvium (fig. 12).

Geologically, glacial till is the material in ground moraines, end moraines, and dead ice moraines. The materials are loam to light clay loam in texture and contain a variable assortment of sand grains, pebbles, cobblestones, and stones. The raw till also contains from 5 to 15 percent calcium carbonate and a significant amount of calcium sulfate. Unweathered till is firm and dense and is bluish gray in color. The weathered till underlying the soils is more friable

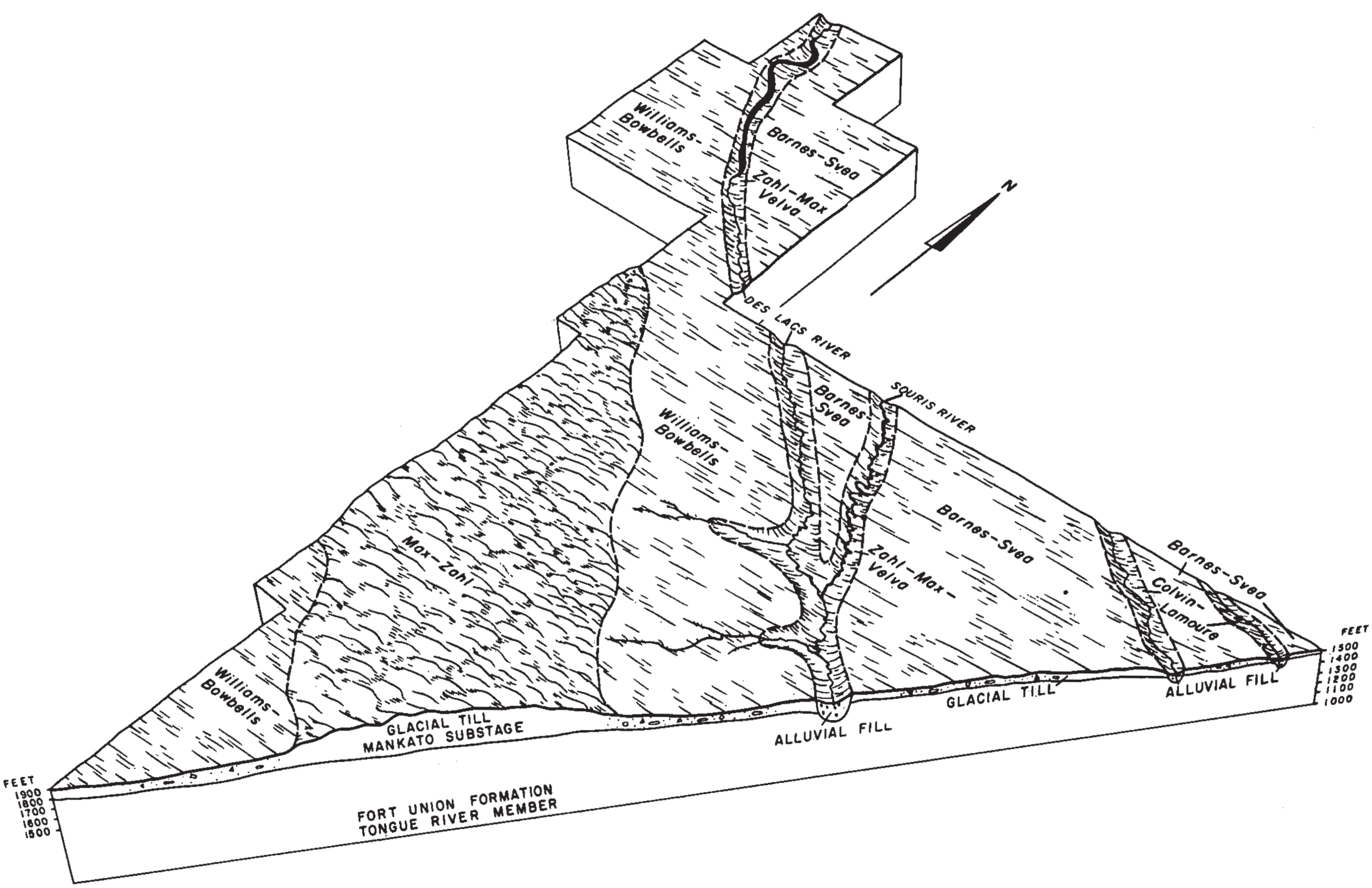

Figure 12.—Relationship of soils to topography and parent material.

and is mottled olive brown in color. Barnes, Buse, Svea, Williams, Max, Zahl, and Bowbells soils developed from glacial till in Ward County.

Glacial lacustrine material was deposited in local, ice-walled lake basins and closed drainage basins where the still melt water deposited silt and clay on glacial till. These materials range from silt loam to silty clay in texture and are free of stones. They range from less than 2 to more than 10 feet in thickness. Fargo, Makoti, Roseglen, and Nutley soils developed from glacial lacustrine material in Ward County.

Glacial outwash is the material in outwash channels, stream terraces, kames, and eskers laid down by rapidly moving glacial melt water. The outwash materials are basically sand and gravel, although mixed loamy material is on the coarser outwash in many places. These loose, permeable materials create a water table over the slowly permeable underlying till in many places. The deposits range from a thin mantle less than 2 feet thick to deep beds or hills more than 50 feet thick. The composition ranges from relatively uniform sand and fine gravel to mixtures of sand grains, pebbles, cobblestones, and boulders. The material is also calcareous, and the undersides of most pebbles are coated with lime. Sioux, Renshaw, Arvilla, Benoit, Wabek, Lehr, Manning, and Lihen soils developed from glacial outwash materials in Ward County.

Postglacial alluvium deposits are confined to the valleys of the Des Lacs and Souris Rivers. Fine-textured alluvium is in the upper Souris Valley north of Burlington; medium textured and moderately fine textured materials are dominant in other areas. Ludden and Velva soils developed from postglacial alluvium in Ward County.

Climate

Ward County has a typical continental climate that is characterized by wide seasonal variations.

Limited and seasonal rainfall along with cool temperatures has resulted in a climax vegetation of mixed grasses and has favored the accumulation of organic matter in the soil. Rainfall is too low to leach the soils or to maintain a ground water table in most soils. In the well-drained Williams soil, accumulations of lime are at a depth of less than 18 inches, and the reaction of the solum is neutral. Some colloidal clay has moved from the A horizon to form moderate clay films in the B_2 horizon. This action, along with frequent wetting and drying, has produced a horizon of increased clay content that is prismatic in structure.

Freezing and thawing of the soil profile is an important climatic factor in soil formation. The average penetration of frost in this area is to a depth of about 4 feet, and frost has been recorded to a depth of 6 1/2 feet. The expansion of the soil mass when freezing and the contraction when thawing increase the permeability and decrease the apparent specific gravity. Also a factor is the effect of an impermeable frozen substratum on a perched or permanent water table and on the movement and position of soluble salts and carbonates within the soil profile. Such a frozen substratum has been found in Colvin, Lamoure, and Arveson soils when field mapping in June.

Vegetation and living organisms

The native vegetation in Ward County consists of mixed native grasses, sedges, forbs, and shrubs. Trees and shrubs grow on the north and east faces of the steep valley breaks and along the river bottoms. Much of this growth consists of rather recent invaders, as indicated by little evidence of development of woodland soils. It is presumed that the development of grassland was rapid and complete after the glaciers receded because fine-textured soil materials were already present. This grassland helps to maintain and improve the ground cover until climax vegetation is established. It is easily retained or regained in spite of occasional fires or drought periods.

The grasses reproduce more commonly by rhizomes than by seeds. The growth of the root system of grasses exceeds the top growth. The annual decay of the growth provides mulch that increases water intake. Grass roots continually absorb nutrients from deep in the soil. The nutrients are returned to the surface soil as the plants die. Only short grasses grow well on the dry, sloping uplands, but in the swales and depressions, tall wetland grasses produce several times as much growth as the short grasses.

The number and kinds of living organisms are significant to the development of soils. The undecomposed organic matter in the soil is food for micro-organisms and, by the action of micro-organisms, is changed to humus. The humus contains nitrogen and other plant nutrients. The humus also helps to granulate the soil for better aeration and permeability. Although larger organisms, such as earthworms and cicadas, are considered important for soil formation elsewhere, they are not widespread enough in this area to be significant. The larger rodents, such as pocket gophers and ground squirrels, are tillers of the soil. The surface soil and subsoil are mixed by the burrowing of these rodents. Krotovinas are in many soil profiles.

Man has introduced new factors in soil formation. In places management practices are used to conserve and improve the fertility of the soil, and in other places the soil is allowed to erode faster than it is formed. Nearly two-thirds of the acreage in Ward County has been turned under by plowing. The Mandan experiment station has reported reductions in organic-matter content in cultivated soils of as much as 40 percent in less than 50 years (*5*).

Topography and drainage

Much of Ward County is nearly level, but some areas are rolling and hilly, and some are very steep along the river breaks. Only a small part of the county has an established drainage pattern. The landscape is characterized by thousands of small and large depressions that catch runoff from adjacent areas.

Topography affects runoff and drainage. Runoff is rapid in steep areas and slow or lacking in level areas. Runoff is greater on convex slopes than on concave slopes. Where there is too much runoff, less water enters the soil, plant growth is limited, and soil formation is slow. Soil horizons are thin and indistinct. Unless a good vegetative cover is maintained, soil erosion may progress faster than soil development. On Buse and Zahl soils, runoff is rapid.

In depressions and swales, runoff that is collected provides extra moisture for plant growth. In wet areas, slow or incomplete decay of organic matter results in a thicker and darker soil that is richer in organic matter content. Parnell soils receive much runoff. In many places poorly drained areas that have a high water table develop a zone near the surface that is high in content of lime. At times capillary action from the water table deposits salts near the surface, thus making the area saline or alkali. Vallers, Colvin, and Arveson soils are high in lime because of a water table.

Time

The soils of Ward County are relatively young. The last glaciation ended 12,000 years ago or less. Previous glaciations covered a period of fifty to seventy thousand years, but they left little evidence of their occurrence in this area. Soil materials more than 50 million years old belonging to the Tongue River member of the Fort Union formation underlie the till mantle in Ward County. The Tongue River member was deposited in an environment characterized by large continental swamps. The organic matter accumulated in these low areas at the same time as sand, silt, and clay were deposited by slow, eastward-flowing streams that meandered a broad flood plain. Sediments 500 to 1,000 feet thick accumulated in western North Dakota (*6*). This formation contained deposits of lignite and provided much of the fine material that was reworked by glaciation.

Soils developed more slowly in this area of limited rainfall than in areas of high rainfall. Because of the thick, fine mantle of glacial till inherent to these soils, native forbs, grasses, and sedges became established quickly. Because of the cool climate and limited moisture, organic matter and humus accumulated in the surface soil. Leaching of soluble salts occurred and translocation of the slightly soluble calcium carbonate progressed to such an extent that now the soils are leached of free lime to a depth of several feet in places and also have concentrations of lime where a water table prevented leaching. Except in a few soils that are high in sodium, the physical movement of organic and clay colloids has been negligible.

The primary process of soil formation has been the accumulation of organic matter, but a secondary effect of this soil enrichment has been the granulation of the soil material for greatly improved tilth and permeability. Under moderate to good drainage, the subsoil develops blocky to prismatic structure along root and other cleavage lines. These processes developed rapidly because root growth was not restricted by rock layers or hardpans.

Sufficient time has not elapsed for erosion to develop much of a drainage pattern; therefore, wet depressional soils are adjacent to deep coulees, and glacial kettle holes dot the landscape. Most soils of Ward County are about the same age because the Mankato substage of the late Wisconsin glaciation apparently covered the whole county. Younger soils developed in the post-glacial alluvium in the bottoms of the Souris and Des Lacs Rivers. The youth of this alluvium is reflected in the weak structure and buried horizons of the Velva soils.

Classification of the Soils

Classification consists of an orderly grouping of soils according to a system designed to make it easier to remember soil characteristics and interrelationships. Classification is useful in organizing and applying the results of experience and research. Soils are placed in narrow classes for discussion in detail soil surveys and for application of knowledge within farms and fields. The many thousands of narrow classes are then grouped into progressively fewer and broader classes in successively higher categories, so that information can be applied to large geographic areas.

Two systems of classifying soils above the series level have been used in the United States in recent years. The older system was adopted in 1938 (*3*) and later revised (*10*). The system currently used by the National Cooperative Soil Survey was developed early in the sixties (*8*) and was adopted in 1965 (*12*). It is under continual study.

The current system of classification has six categories. Beginning with the most inclusive, these categories are the order, the suborder, the great group, the subgroup, the family, and the series. The criteria for classification are soil properties that are observable or measurable, but the properties are selected so that soils of similar genesis are grouped together. The placement of some soil series in the current system of classification, particularly in families, may change as more precise information becomes available.

Table 8 shows the classification of each soil series of Ward County by family, subgroup, and order, according to the current system. The categories of the current system are defined in the following paragraphs.

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

Entisols are recent soils in which there has been little horizon development. This order is represented in Ward County by soils of the Seroco series.

Mollisols have a thick, dark-colored surface layer, moderate to strong structure, and base saturation of more than 50 percent. This order is represented by all the soil series in the county, except for the Seroco series.

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

Great group.—Each suborder is divided into great groups, on the basis of uniformity in the kinds of and sequence of major horizons and soil features. The horizons considered are those in which clay, iron, or humus has accumulated and those that have pans that interfere with the growth of roots or the movement of water. The features considered are the self-mulching properties of clays, soil temperature, chemical composition (mainly calcium, magnesium, sodium, and potassium), and the like.

Subgroup.—Each great group is divided into subgroups, one representing the central (typic) segment of the group, and other groups, called intergrades, that have properties of one great group and also one or more properties of another great group, suborder, or order.

Family.—Families are established within a subgroup primarily on the basis of properties that affect the growth of plants or the behavior of soils when used for engineering purposes. Among the properties considered are texture, mineralogy, reaction, soil temperature, permeability, thickness of horizons, and consistence.

Series.—The series is a group of soils that have major horizons that, except for texture of the surface layer, are similar in important characteristics and in arrangement in the profile.

TABLE 8.—*Classification of soil series by higher categories*

Series	Family	Subgroup	Order
Arveson	Coarse-loamy, mixed, frigid	Typic Calciaquolls	Mollisols.
Arvilla	Sandy, mixed	Udic Haploborolls	Mollisols.
Barnes	Fine-loamy, mixed	Udic Haploborolls	Mollisols.
Benoit	Fine-loamy over sandy or sandy-skeletal, frigid.	Typic Calciaquolls	Mollisols.
Bowbells	Fine-loamy, mixed	Pachic Argiborolls	Mollisols.
Buse	Fine-loamy, mixed	Udorthentic Haploborolls	Mollisols.
Colvin	Fine-silty, frigid	Typic Calciaquolls	Mollisols.
Divide	Fine-loamy over sandy or sandy-skeletal, frigid.	Aeric Calciaquolls	Mollisols.
Egeland	Coarse-loamy, mixed	Udic Haploborolls	Mollisols.
Embden	Coarse-loamy, mixed	Pachic Udic Haploborolls	Mollisols.
Emrick	Coarse-loamy, mixed	Pachic Udic Haploborolls	Mollisols.
Fargo	Fine, montmorillonitic, noncalcareous, frigid.	Vertic Haplaquolls	Mollisols.
Hamerly	Fine-loamy, frigid	Aeric Calciaquolls	Mollisols.
Harriet	Fine, mixed, calcareous, frigid	Typic Natraquolls	Mollisols.
Hegne	Fine, montmorillonitic, frigid	Typic Calciaquolls	Mollisols.
Heil	Fine, noncalcareous, frigid	Typic Natraquolls	Mollisols.
Heimdal	Coarse-loamy, mixed	Udic Haploborolls	Mollisols.
Lamoure	Fine-silty, mixed, calcareous, frigid	Cumulic Haplaquolls	Mollisols.
Lehr	Fine-loamy over sandy or sandy-skeletal, mixed.	Typic Haploborolls	Mollisols.
Lihen	Sandy, mixed	Pachic Haploborolls	Mollisols.
Ludden	Fine, montmorillonitic, calcareous, frigid.	Vertic Haplaquolls	Mollisols.
Makoti	Fine-silty, mixed	Typic Haploborolls	Mollisols.
Manning	Coarse-loamy, mixed	Typic Haploborolls	Mollisols.
Max	Fine-loamy, mixed	Typic Haploborolls	Mollisols.
Miranda	Fine, mixed	Leptic Natriborolls	Mollisols.
Niobell	Fine-loamy, mixed	Glossic Natriborolls	Mollisols.
Noonan	Fine-loamy, mixed	Typic Natriborolls	Mollisols.
Nutley	Fine, montmorillonitic	Udertic Haploborolls	Mollisols.
Overly, mottled variant.	Fine-silty, mixed	Pachic Udic Haploborolls	Mollisols.
Parnell	Fine, montmorillonitic, noncalcareous, frigid.	Cumulic Haplaquolls	Mollisols.
Renshaw	Fine-loamy over sandy or sandy-skeletal, mixed.	Udic Haploborolls	Mollisols.
Roseglen	Fine-loamy, mixed	Pachic Haploborolls	Mollisols.
Seroco	Mixed, frigid	Typic Ustipsamments	Entisols.
Sinai	Fine, montmorillonitic	Pachic Udic Haploborolls	Mollisols.
Sioux	Sandy-skeletal, mixed	Udorthentic Haploborolls	Mollisols.

TABLE 8.—*Classification of soil series by higher categories*—Continued

Series	Family	Subgroup	Order
Svea	Fine-loamy, mixed	Pachic Udic Haploborolls	Mollisols.
Tansem	Fine-loamy, mixed	Typic Haploborolls	Mollisols.
Telfer	Sandy, mixed	Entic Haploborolls	Mollisols.
Tonka	Fine, montmorillonitic, frigid	Argiaquic Argialbolls	Mollisols.
Vallers	Fine-loamy, frigid	Typic Calciaquolls	Mollisols.
Velva	Coarse-loamy, mixed	Fluventic Haploborolls	Mollisols.
Wabek	Sandy-skeletal, mixed	Entic Haploborolls	Mollisols.
Williams	Fine-loamy, mixed	Typic Argiborolls	Mollisols.
Zahl	Fine-loamy, mixed	Entic Haploborolls	Mollisols.

Mechanical and Chemical Analysis

Detailed mechanical and chemical analysis of the following soils in and adjacent to Ward County are given in Soil Survey Investigation Report No. 2 (*14*) entitled "Soil Survey Laboratory Data and Descriptions for Some Soils of North Dakota:" Barnes loam S50ND-38-2, Hamerly loam S50ND-38-7, Williams loam S54ND-51-1, Makoti silty clay loam S58ND-31-3, Miranda loam S58ND-51-1.

These data are useful to soil scientists in classifying soils and in developing concepts of soil genesis. They are helpful in estimating available water capacity, wind erodibility, fertility, tilth, and other properties that affect practical aspects of soil management.

General Nature of the County

Very little land was cultivated before 1900 in Ward County. Early ranchers squatted or settled in the river valleys, and open-range cattle ranching reached its peak in the 1880's. One railroad reached Minot in 1886, and another reached it in 1893. An extended drought early in the nineties discouraged new settlement. Between 1898 and 1906 most of Ward County was homesteaded, and by 1911, the county was reduced to its present size of 57 townships. The census tabulations from 1910 through 1960 show trends that are still going on, such as the increase in size of farms and decrease in number of operators. The development of mechanized farming is readily indicated by the decrease in horses and increase in tractors, combines, and electric service.

The number of livestock and the acreage used for crops varied with the economy and conditions of weather, but the figures for acreage and production clearly show that wheat is the main crop in this area. In addition to the acreage of wheat that is harvested, much of the acreage in summer fallow is directed toward the production of wheat.

The 1964 Agricultural Census reports the following production statistics and number of acres used for crops in Ward County:

Crop:	Amount	Acres
Wheat	bushels—6,094,530	225,268
Barley	bushels—3,078,358	101,637
Oats	bushels—2,059,099	46,445
Flax	bushels— 400,385	39,327
Rye	bushels— 682,585	31,585
Corn	tons of silage— 29,989	10,562
Alfalfa	tons of hay— 32,838	22,347
Cultivated field in summer fallow	0	298,180

In addition to these uses and according to this census, 272,069 acres are used for pasture and 47,910 acres for wild hay. The livestock enterprises consist of 6,607 milk cows and 25,845 beef cows. Farms make up 1,262,607 acres, and there are 1,503 farm units that average 839.4 acres in size, and 1,312 commercial farms that average about 960 acres.

Among the important natural resources in Ward County are lignite and sand and gravel. Estimates of lignite reserves in the Minot area indicate more than 18 billion tons (*2*). About 600,000 tons are mined each year and used locally for fuel and the generation of electric power.

Natural deposits of sand and gravel (fig. 13) are well distributed throughout the county. There are about 60,000 acres where the soils have a gravelly substratum that ranges from 2 to more than 50 feet in thickness. Sand and gravel reserves are closely associated with the Arvilla, Lehr, Manning, Renshaw, Sioux, and Wabek soils. Millions of cubic yards of gravel have been used in the county in the construction of roads, railroads, and concrete structures and as base materials.

Because Ward County has only one small lake and a few private ponds, only a few lake cottages have been built. Lake Metigoshe, or Garrison Dam, is used for recreational activities.

The partly wooded valley of the Souris River, coulees, and breaks provide many natural picnic spots and room to hike, ride, or observe nature. Modern camping facilities are provided at the Minot parks. Many additional sites could be developed along the scenic parts of U.S. Highways No. 2 and No. 52 in the valley of the Souris River. The Svea and Velva soils are well suited to landscaping, woody plantings, and irrigation. Natural wooded areas provide a good basis for such developments.

The long steep areas of the Zahl-Max soil association provide many natural ski slopes and could readily be developed into excellent skiing and tobogganing facilities near

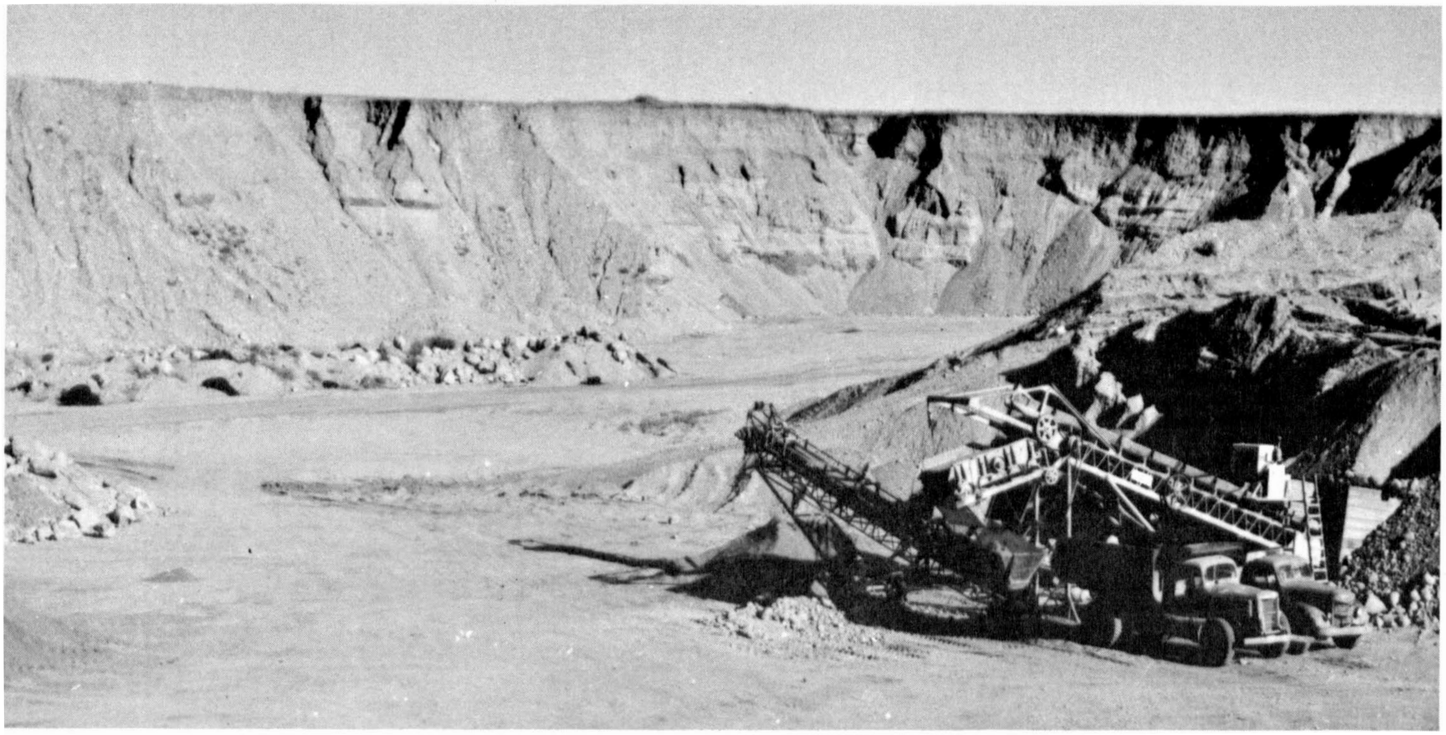

Figure 13.—Part of a sand and gravel pit, near Minot, from which all sizes of gravel and crushed stone have been taken. This area was formerly Wabek soils but is now mapped as Gravel pits.

the city of Minot. Skating and curling facilities are provided in the city of Minot.

There are many opportunities for public and private beautification projects along highways and near cities and villages. Soils now used mainly as cropland, such as those of Barnes, Svea, Williams, and Bowbells series that adjoin the highways, are suitable for decorative as well as practical windbreak tree plantings.

Climate[7]

Ward County, which is near the geographical center of North America, has a continental climate typical of the northern Great Plains. The Rocky Mountains far to the west effectively limit the modifying influence of maritime air masses from the Pacific Ocean, but there are no obstacles to air movement from the north or from the south. Consequently, summers are quite warm and have occasional hot periods, but only a few days can be considered humid. Winters are cold, but the temperatures vary widely from day to day, month to month, and even year to year. Cold arctic outbreaks can be expected every winter, but there are also compensating periods of mild weather.

Topographic features of the county exert only a minor influence on the climate; therefore, unless otherwise noted, most of what follows is based upon weather records maintained at Minot.

Table 9 shows the more salient features of the temperature regime throughout the year. The temperature reaches 90° F. or higher on an average of 18 days each year. Seven of these are generally in July. The highest temperature recorded at Minot was 109° on June 20, 1910, and on July 11, 1936. In contrast, the temperature drops to zero or below on about 55 days each year. The lowest temperature recorded at Minot was 49° below zero on February 15, 1936; however, at Parshall, only 45 miles southwest of Minot in Mountrail County, has been recorded the lowest temperature in the State, or 60° below zero on February 15, 1936. The temperature rises to above 32° on about 24 days in the winter.

Table 10 shows the chance of freezing temperatures after a given date in spring and before a given date in fall (7). There may be variations up to several days from the average dates given because of the effects of the local terrain. Thus, in small depressions that are well protected from any air movements, on an average, the last freezing temperature is somewhat later in spring and the first freezing temperature is somewhat earlier in fall than shown in the table. On open hillsides and hilltops that have completely free air movement, the freeze-free periods are somewhat longer than indicated in the table.

The distribution of precipitation is a most significant factor in the agricultural economy of the county. Table 9 indicates the average total of distribution for early in summer, which is so important to growing crops. On the average nearly 50 percent falls in May, June, and July, and more than 75 percent falls in the growing season, April through September. The annual average total decreases slightly as distance toward the western part of the county increases; however, the average June total remains uniformly high throughout the county.

[7]By CARL J. SANDERSON, climatologist for North Dakota, National Weather Service.

TABLE 9.—*Temperature and precipitation data*

[Data from Minot, North Dakota]

Month	Temperature				Precipitation				
	Average daily maximum	Average daily minimum	Two years in 10 will have at least 4 days with—		Average total	One year in 10 will have—		Days with snow cover 1 inch or more	Average depth of snow on days with snow cover
			Maximum temperature equal to or higher than—	Minimum temperature equal to or lower than—		Less than—	More than—		
	°F.	°F.	°F.	°F.	Inches	Inches	Inches	Number	Inches
January	18	-4	41	-28	0.48	0.1	1.1	24	4
February	22	1	45	-25	.44	.1	.9	22	5
March	34	13	57	-11	.63	.1	1.6	15	4
April	53	28	75	12	1.24	.2	2.4	3	2
May	66	40	85	26	2.15	.6	4.3	(1/)	(2/)
June	75	50	91	38	3.25	1.2	5.6	--	--
July	83	55	96	44	2.13	.6	3.8	--	--
August	81	52	95	39	1.87	.5	3.6	--	--
September	70	42	89	28	1.40	.3	3.0	(1/)	(2/)
October	57	32	79	16	.86	.1	1.8	1	1
November	37	17	60	-5	.70	.1	1.7	9	2
December	24	4	45	-21	.47	.1	1.0	18	3
Year	52	28	3/101	4/-32	15.62	10.9	20.7	92	4

1/ Less than one-half day.

2/ Trace.

3/ Average annual highest temperature.

4/ Average annual lowest temperature.

TABLE 10.—*Probability of freezing temperatures later than specified dates in spring and earlier than specified dates in fall*

[All data from Minot, North Dakota]

Probability	Dates for given probability and temperature				
	32° F. or lower	28° F. or lower	24° F. or lower	20° F. or lower	16° F. or lower
Spring:					
10 percent later than	June 4	May 24	May 15	May 6	April 26
25 percent later than	May 28	May 17	May 7	April 29	April 18
50 percent later than	May 21	May 10	April 29	April 20	April 9
75 percent later than	May 14	May 3	April 21	April 12	March 31
90 percent later than	May 7	April 26	April 13	April 4	March 23
Fall:					
10 percent earlier than	September 3	September 15	September 20	October 1	October 10
25 percent earlier than	September 9	September 21	September 28	October 9	October 18
50 percent earlier than	September 15	September 28	October 6	October 18	October 27
75 percent earlier than	September 21	October 5	October 14	October 27	November 5
90 percent earlier than	September 27	October 11	October 22	November 4	November 13

Precipitation of 0.10 inch or more can be expected on an average of 39 days each year, and 1 inch or more can be expected on 2 or 3 days each year. These averages do not present a complete picture. The county is subject to large variations in precipitation from year to year, and thunderstorms in summer occasionally dump huge amounts of water in a very short time. Much of the water may run off before it can soak into the soils. Thus, at Minot, the total annual precipitation has ranged from 7.13 inches in 1934 to as much as 24.90 inches in 1941. The greatest amount recorded in a single month was 10.63 inches in June 1944. Thunderstorms occur on an average of about 30 days each year.

Table 11 shows approximately the percent probability of receiving stated amounts of precipitation in 1-, 2-, and 3-week periods throughout the growing season (*4*). These probabilities have been computed for only 10 stations in North Dakota, none of which are in Ward County. Bottineau is the nearest station to Ward County that has a nearly equivalent precipitation, and data in table 11 are based on records at Bottineau. This table shows that the probability of receiving 1 inch or more of precipitation in a 7-day period is greatest in the latter part of June when it is about once in 3 years. Apparently, the probability of a dry 7-day period, trace or less, is greatest late in October and early in November, when the chance is nearly once in 2 years. Another study on rainfall intensities over the United States indicates that for any point in Ward County the following amounts are expected to occur about once in 2 years (*13*): 0.80 inch in 30 minutes; 1.00 inch in 1 hour; 1.15 inches in 2 hours; 1.25 inches in 3 hours; 1.50 inches in 6 hours; 1.75 inches in 12 hours; and 1.90 inches in 24 hours. More than 4.5 inches of rain in a 24-hour period can be expected about once in 100 years.

On an average, about 32 inches of snow falls each year. The seasonal snowfall at Minot ranged from 100 inches in the winter of 1949-50 to less than 7 inches in the winter of 1930-31. Nearly 28 inches of snow fell in April 1950, and 17 inches of snow fell in a single day on April 24, 1950. These two are some of the largest amounts ever reported in Ward County. Measurable snowfall can be expected about once in 2 years in October, 2 years in 3 in April, and 1 year in 8 in May. In the months, November through March, snowfall can be expected every year. Table 9 shows the average number of days the ground is covered with 1 inch or more of snow each month and year. Snowmelt increases the effective moisture on Bowbells, Svea, Tonka, and Parnell soils.

The water balance, which is the relationship between precipitation and evapotranspiration, is difficult to evaluate. The potential evapotranspiration is computed by the Thornthwaites method (*9*). This method tends to underestimate the true potential in dry climates; thus the true potential likely lies somewhere between the value that is computed and that shown by the Class A evaporation pan. At any rate it is quite evident that generally water is used at a faster rate than it can be replenished through the normal precipitation in the growing season.

Table 12 summarizes wind velocities as recorded at the airport at Minot. These data indicate that winds blow more frequently from the northwest than from any other direction in all months of the year. On an average, about one-third of all winds of 25 miles per hour or higher blow from the northwest, and about 70 percent of all winds 25 miles per hour or higher blow from some direction between west and north, or from the northwest quadrant. The remaining 30 percent or so are fairly evenly distributed among the remaining directions. If observed wind directions are combined into the 4 quadrants for the year, the data indicates that approximately 35 percent of all winds blow from the northwest quadrant, 28 percent from the southwest quadrant, 21 percent from the southeast quadrant, and only 14 percent from the northeast quadrant. The wind is calm less than 2 percent of the time.

TABLE 11.—*Probability of receiving the stated amounts of precipitation during 1-week, 2-week, and 3-week periods*

1-week period	Probability of receiving at least—				
	Trace or none	0.2 inch	0.6 inch	1 inch	2 inches
	Pct.	Pct.	Pct.	Pct.	Pct.
March 29-April 4	34.0	25.5	4.9	0.5	0
April 5-April 11	24.0	26.3	4.4	1.5	0
April 12-April 18	36.0	30.3	6.8	1.5	0
April 19-April 25	28.0	46.8	21.1	9.6	1.4
April 26-May 2	20.0	50.4	20.3	8.2	.6
May 3-May 9	30.0	42.9	21.1	11.0	2.3
May 10-May 16	22.0	49.8	24.1	12.1	2.3
May 17-May 23	20.0	59.1	30.3	15.2	2.7
May 24-May 30	20.0	54.4	29.4	16.6	4.2
May 31-June 6	2.0	64.8	32.6	17.0	3.5
June 7-June 13	4.0	69.9	40.0	23.3	6.2
June 14-June 20	6.0	74.8	48.9	32.2	11.5
June 21-June 27	6.0	78.1	53.6	36.7	14.3
June 28-July 4	6.0	74.3	44.8	26.6	7.2
July 5-July 11	6.0	72.1	38.5	19.9	3.7
July 12-July 18	10.0	64.4	35.3	19.7	4.7
July 19-July 25	14.0	58.5	32.0	18.2	4.7
July 26-August 1	14.0	53.6	22.4	9.5	.9
August 2-August 8	14.0	66.9	42.9	28.0	9.9
August 9-August 15	12.0	62.5	34.5	19.5	4.8
August 16-August 22	18.0	46.7	23.3	12.6	3.1
August 23-August 29	10.0	55.2	25.5	12.3	2.2
August 30-September 5	24.0	52.9	28.1	15.3	3.5
September 6-September 12	22.0	48.0	21.1	9.6	1.4
September 13-September 19	24.0	45.9	17.4	6.6	.4
September 20-September 26	22.0	46.8	15.6	5.1	.2

2-week period	Probability of receiving at least—				
	Trace or none	0.2 inch	0.6 inch	1 inch	2 inches
	Pct.	Pct.	Pct.	Pct.	Pct.
March 29-April 11	6.0	48.8	13.9	4.0	0
April 12-April 25	8.0	66.4	32.5	15.6	2.4
April 26-May 9	4.0	73.9	43.0	25.0	6.3
May 10-May 23	10.0	76.5	51.5	33.7	11.2
May 24-June 6	0	84.0	57.5	39.1	14.6
June 7-June 20	0	93.3	75.0	57.8	28.0
June 21-July 4	2.0	93.5	78.5	63.0	33.1
July 5-July 18	0	93.0	70.1	48.6	16.7
July 19-August 1	4.0	82.8	55.4	35.6	11.0
August 2-August 15	4.0	83.8	63.3	47.6	23.3
August 16-August 29	0	81.2	50.6	30.9	8.8
August 30-September 12	4.0	80.0	50.5	30.8	8.4
September 13-September 26	8.0	77.8	40.6	18.2	1.1
3-week period					
March 22-April 11	6.0	70.7	29.8	11.3	0.5
April 12-May 2	4.0	83.0	54.0	33.2	8.9
May 3-May 23	2.0	85.7	63.2	46.0	20.3
May 24-June 13	0	96.3	81.8	65.4	32.6
June 14-July 4	0	99.3	93.6	84.3	56.5
July 5-July 25	0	98.2	86.6	70.1	33.5
July 26-August 15	0	94.0	77.5	61.7	32.6
August 16-September 5	0	92.9	71.5	51.8	20.7
September 6-September 26	2.0	90.8	63.1	38.5	8.8

TABLE 12.—*Summary of wind at Minot, North Dakota*

[Hourly observations from December 1948 to June 1960]

Month	Wind velocity of—						Calm	Average wind velocity	Maximum wind 1/		Prevailing wind	
	1 to 3 miles per hour	4 to 11 miles per hour	12 to 24 miles per hour	25 to 31 miles per hour	32 to 45 miles per hour	More than 45 miles per hour			Velocity	Direction	Velocity	Direction
	Number of hours	Number of hours	Number of hours	Number of hours	Number of hours	Number of hours	Number of hours	Miles per hour	Miles per hour		Miles per hour	
January	50	322	306	33	10	(2/)	23	12.4	46	NNE	15.9	NW
February	38	308	285	22	7	(2/)	12	12.5	51	WNW	16.6	NW
March	37	338	314	33	10	(2/)	12	12.8	55	W	16.7	NW
April	28	307	329	33	15	(2/)	8	13.6	47	WNW	16.8	NW
May	30	349	319	27	9	1	9	12.7	54	NW	16.2	NW
June	32	361	285	24	9	0	9	12.3	45	WNW	14.3	NW
July	42	426	258	7	1	0	10	10.9	44	WNW	13.7	NW
August	49	418	256	7	1	0	13	10.8	40	N	13.3	NW
September	39	363	272	26	7	(2/)	13	11.9	46	WNW	14.9	NW
October	33	383	278	24	7	0	19	11.8	45	NW	15.8	NW
November	33	326	298	35	14	1	13	13.1	52	NW	17.9	NW
December	45	357	294	26	9	(2/)	13	12.2	46	WNW	16.3	NW
Year	456	4,258	3,494	297	99	2	154	12.4	55	W	15.9	NW

1/ Maximum observed 1-minute wind speed and direction from hourly observations, at 30 feet above ground.

2/ Less than 1/2 hour.

Hail is an unfortunate concomitant of some thunderstorms. Of the nearly 30 days that have thunderstorms on the average each year, 2 or 3 days are expected to have some hail. The records of the weather stations at Devils Lake, Bismarck, and Williston show approximately the following distribution by months:

Month:	Percent
April	7
May	17
June	25
July	23
August	17
September	7
October	3

Hailstorms not only occur most often in June and July, but they almost always attain their greatest severity late in June and in July and August. They are capable of inflicting great damage, especially on maturing crops.

The records of the North Dakota State Hail Insurance Department provide data on the severity of hail. They show that from 1941 to 1961 Ward County had an average loss of 9.09 percent of insured acres that had been damaged 5 percent or more. This is less than half of the State average of 18.23 percent.

Physiography, Relief, and Drainage

Ward County lies in the glaciated plains in the north-central part of North Dakota. Elevations range from 1,520 feet in the valley of the Souris River below Sawyer to more than 2,300 feet in the morainic hills southwest of Hartland. The continental divide between the watershed of the Hudson Bay to the north and the watershed of the Missouri and Mississippi Rivers to the south follows the morainic hills across central Ward County from northwest to southeast. The valleys of the Des Lacs and Souris Rivers are entrenched more than 200 feet into the nearly level morainic plain of northeastern Ward County. They flow southeastward and leaves the county near Sawyer. Several dry coulees are entrenched in the plains for several miles to the west of the Des Lacs and Souris Rivers, and other intermittent creeks cut the plains northeast of the rivers. In spite of this apparent drainage pattern, at least one-half of this area has no surface drainage outlets, and shallow depressions dot the landscape. The morainic hills and the southwestern till plains have almost no external drainage system. All local runoff collects in sloughs, marshes, and lakes. Most are intermittent bodies of water that are dependent on annual recharge from spring runoff.

Water

Although an abundant supply of good water lies only 45 miles southwest of Minot in the Garrison Reservoir on the Missouri River, this distance and the height of the intervening moraine, which is about 400 feet, have so far prohibited its use in Minot. An alternative route, the Velva Canal, is dependent on the timely development of the Garrison Diversion Irrigation Project. The proper development of a system will relieve the local water limitations that inhibit expansion in the Minot area. Present water supplies at Minot are from an aquifer in the Souris River valley. Although about 200 feet of outwash and alluvial material occupy the valley floor and the city wells have pumped profusely for years, recent expansion plans have met with diminishing reserves.

Water supplies for farms are obtained from several sources. Shallow wells in glacial outwash or in pockets of coarse-textured material provide good hard water for home use. Deep wells tap lignite or sandstone strata in the Fort Union formation at depths of 2 to 500 feet. Such water is soft, but in many places it is highly alkaline. Many of these wells flow or stand near the surface in the till plain area between the morainic hills and the Des Lacs and Souris Rivers. A third source of water used mainly for livestock are dugouts or surface reservoirs. In soils that have a high water table, such as Colvin and Lamoure soils, the water level is maintained by seepage into these surface excavations. On impermeable soils, such as Parnell soils, runoff fills the dugout. A fourth source or supply of water occurs naturally as sloughs, marshes, and lakes in the closed or weakly developed drainage pattern of the till plains. Thousands of shallow, temporary potholes along with the more permanent wetlands make this one of the top wild duck propagation areas of North America.

Literature Cited

(1) American Association of State Highway Officials.
1970. *Standard Specifications for Highway Materials and Methods of Sampling and Testing*. Ed. 10, 2 v., illus.

(2) Andrews, David P.
1939. *Geology and Coal Resources of the Minot Region, North Dakota*. Geol. Survey Bul. 506-B, 84 pp., illus.

(3) Baldwin, Mark, Kellogg, Charles E., and Thorp, James.
1938. *Soil Classification*. U.S. Dept. Agr. Ybk.: 979-1001, illus.

(4) Barger, Gerald L., Shaw, R. W., and Dale, R. J.
1959. *Chances of Receiving Selected Amounts of Precipitation in the North Central Region of the United States*. Agr. Home Econ. Expt. Sta., Iowa State Univ.

(5) Haas, H. J., and Evans, C. E.
1957. *Nitrogen and Carbon Changes in Great Plains Soils as Influenced by Cropping and Soil Treatments*. U.S. Dept. Agr. Tech. Bul. 1164, 111 pp., illus.

(6) Lemke, Richard W.
1960. *Geology of the Souris River Area, North Dakota*. Geol. Survey. Prof. Paper 325, 138 pp., illus.

(7) Sanderson, Carl J.
1963. *The Probability of Freezing Temperatures in Spring and Fall in North Dakota*. N. Dak. Expt. Sta. Bul. 443, 24 pp., illus.

(8) Simonson, Roy W.
1962. *Soil Classification in the United States*. Science 137: 1027-1034.

(9) Thornwaite, C. W., and Mather, J. R.
1955. *The Water Balance*. In Climatology. Drexel Inst. Tech., v. 8, No. 1.

(10) Thorp, James, and Smith, Guy D.
1949. *Higher Categories of Soil Classification: Order, Suborder, and Great Soil Groups*. Soil Sci. 67: 117-126.

(11) United States Department of Agriculture.
1951. *Soil Survey Manual*. U.S. Dept. Agr. Handbook 18, 503 pp., illus., with 1962 supplement.

(12) ————
1960. *Soil Classification, a Comprehensive System, 7th Approximation*. 265 pp., illus. [Supplements issued March 1967 and September 1968]

(13) United States Department of Commerce.
1961. *Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Period from 1 to 100 Years*. Weather Bureau Tech. Paper 40, 115 pp, illus., chiefly maps.

(14) ————
1966. *Soil Survey Laboratory Data and Descriptions for Some Soils of North Dakota*. Soil Survey Investigations Rept. No. 2, 271 pp.

(15) United States Department of Defense.
1968. *Unified Soil Classification System for Roads, Airfields, Embankments and Foundations*. MIL-STD-619B, 30 pp., illus.

Glossary

Aeration, soil. The exchange of air in soil with air from the atmosphere. The air in a well-aerated soil is similar to that in the atmosphere; but that in a poorly aerated soil is considerably higher in carbon dioxide and lower in oxygen.

Aggregate, soil. Many fine particles held in a single mass or cluster. Natural soil aggregates, such as crumbs, blocks, or prisms, are called peds. Clods are aggregates produced by tillage or logging.

Alluvium. Soil material, such as sand, silt, or clay, that has been deposited on land by streams.

Available water capacity (also termed available moisture capacity). The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field capacity and the amount at wilting point. It is commonly expressed as inches of water per inch of soil.

Calcareous soil. A soil containing enough calcium carbonate (often with magnesium carbonate) to effervesce (fizz) visibly when treated with cold, dilute hydrochloric acid.

Clay. As a soil separate, the mineral soil particles less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

Claypan. A compact, slowly permeable soil horizon that contains more clay than the horizon above and below it. A claypan is commonly hard when dry and plastic or stiff when wet.

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). Drainage that existed during the development of the soil, as opposed to altered drainage, which is commonly the result of artificial drainage or irrigation but may be caused by the sudden deepening of channels or the blocking of drainage outlets. Seven different classes of natural soil drainage are recognized.

Excessively drained soils are commonly very porous and rapidly permeable and have a low water-holding capacity.

Somewhat excessively drained soils are also very permeable and are free from mottling throughout their profile.

Well-drained soils are nearly free from mottling and are commonly of intermediate texture.

Moderately well drained soils commonly have a slowly permeable layer in or immediately beneath the solum. They have uniform color in the A horizon and upper part of the B horizon and have mottling in the lower part of the B horizon and in the C horizon.

Somewhat poorly drained soils are wet for significant periods but not all the time. Some soils commonly have mottling at a depth below 6 to 16 inches.

Poorly drained soils are wet for long periods; they are light gray and generally mottled from the surface downward, but some have few or no mottles.

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.

Erosion. The wearing away of the land surface by wind (sandblast), running water, and other geological agents.

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:

0 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 0 horizon. This horizon is the one in which living organisms are most active and therefore is marked by the accumulation of humus. The horizon may have lost one or more of soluble salts, clay, and sesquioxides (iron and aluminum oxides).

B horizon.—The mineral horizon below an A horizon. The B horizon is in part a layer of change from the overlying A to the underlying C horizon. The B horizon also has distinctive characteristics caused by (1) accumulation of clay, sesquioxides, humus, or some combination of these; (2) prismatic or blocky structure; (3) redder or stronger colors than the A horizon; or (4) some combination of these. Combined A and B horizons are usually called the solum, or true soil. If a soil lacks a B horizon, the A horizon alone is the solum.

C horizon.—The weathered rock material immediately beneath the solum. In most soils this material is presumed to be like that from which the overlying horizons were formed. If the material is known to be different from that in the solum, a Roman numeral precedes the letter C.

R layer.—Consolidated rock beneath the soil. The rock usually underlies a C horizon but may be immediately beneath an A or B horizon.

Humus. The well-decomposed, more or less stable part of the organic matter in mineral soils.

Leaching. The removal of soluble materials from soils or other material by percolating water.

Munsell notation. A system for designating color by degrees on 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.

Nutrient, plant. Any element taken in by a plant, essential to its growth, and used by it in the production of food and tissue. Nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, copper, boron, zinc, and perhaps other elements obtained from the soil and carbon, hydrogen, and oxygen obtained largely from the air and water, are plant nutrients.

Organic matter. A general term for plant and animal material, in or on the soil, in all stages of decomposition. Readily decomposed organic matter is often distinguished from the more stable forms that are past the stage of rapid decomposition.

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. In words, the degrees of acidity or alkalinity are expressed thus:

	pH		pH
Extremely acid	Below 4.5	Neutral	6.6 to 7.3
Very strongly acid	4.5 to 5.0	Mildly alkaline	7.4 to 7.8
Strongly acid	5.1 to 5.5	Moderately alkaline	7.9 to 8.4
Medium acid	5.6 to 6.0	Strongly alkaline	8.5 to 9.0
Slightly acid	6.1 to 6.5	Very strongly alkaline	9.1 and higher

Relief. The elevations or inequalities of a land surface, considered collectively.

Saline soil. A soil that contains soluble salts in amounts that impair growth of plants but that does not contain excess exchangeable sodium.

Saline-alkali soil. A soil that contains a harmful concentration of salts and exchangeable sodium; or contains harmful salts and has a highly alkaline reaction; or contains harmful salts and exchangeable sodium and is strongly alkaline in reaction. The salts, exchangeable sodium, and alkaline reaction occur in the soil in such location that growth of most crop plants is less than normal.

Sand. As a soil separate, individual rock or mineral fragments that range from 0.05 millimeter to 2.0 millimeters in diameter. Most sand grains consists of quartz, but the sand may be of any mineral composition. As a textural class soil that is 85 percent or more sand and not more than 10 percent clay.

Silt. As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). As a textural class, soil that 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.

Stripcropping. Growing crops in a systematic arrangement of strips, or bands, to serve as vegetative barriers to wind and water erosion.

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 grain* (each grain by itself, as in dune sand) or *massive* (the particles adhering together without any regular cleavage, as in many claypans and hardpans).

Stubble mulch. Stubble or other crop residues left on the soil, or partly worked into the soil, to provide protection from wind and water erosion after harvest, during preparation of a seedbed for the next crop, and during the early growing period of the new crop.

Subsoil. Technically, the B horizon; roughly, the part of the solum below plow depth.

Summer fallow. The tillage of uncropped land during the summer to control weeds and allow storage of moisture in the soil for the growth of a later crop. A practice common in semiarid regions, where annual precipitation is not enough to produce a crop every year. Summer fallow is frequently practiced before planting of winter grains.

Surface soil. The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, about 5 to 8 inches in thickness. The plowed layer.

Tilth, soil. The condition of the soil in relation to the growth of plants, especially soil structure. Good tilth refers to the friable state and is associated with high noncapillary porosity and stable, granular structure. A soil in poor tilth is nonfriable, hard, nonaggregated, and difficult to till.

Topsoil. A presumed fertile soil or soil material, or one that responds to fertilization, ordinarily rich in organic matter, used to topdress roadbanks, lawns, and gardens.

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 soil 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.

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