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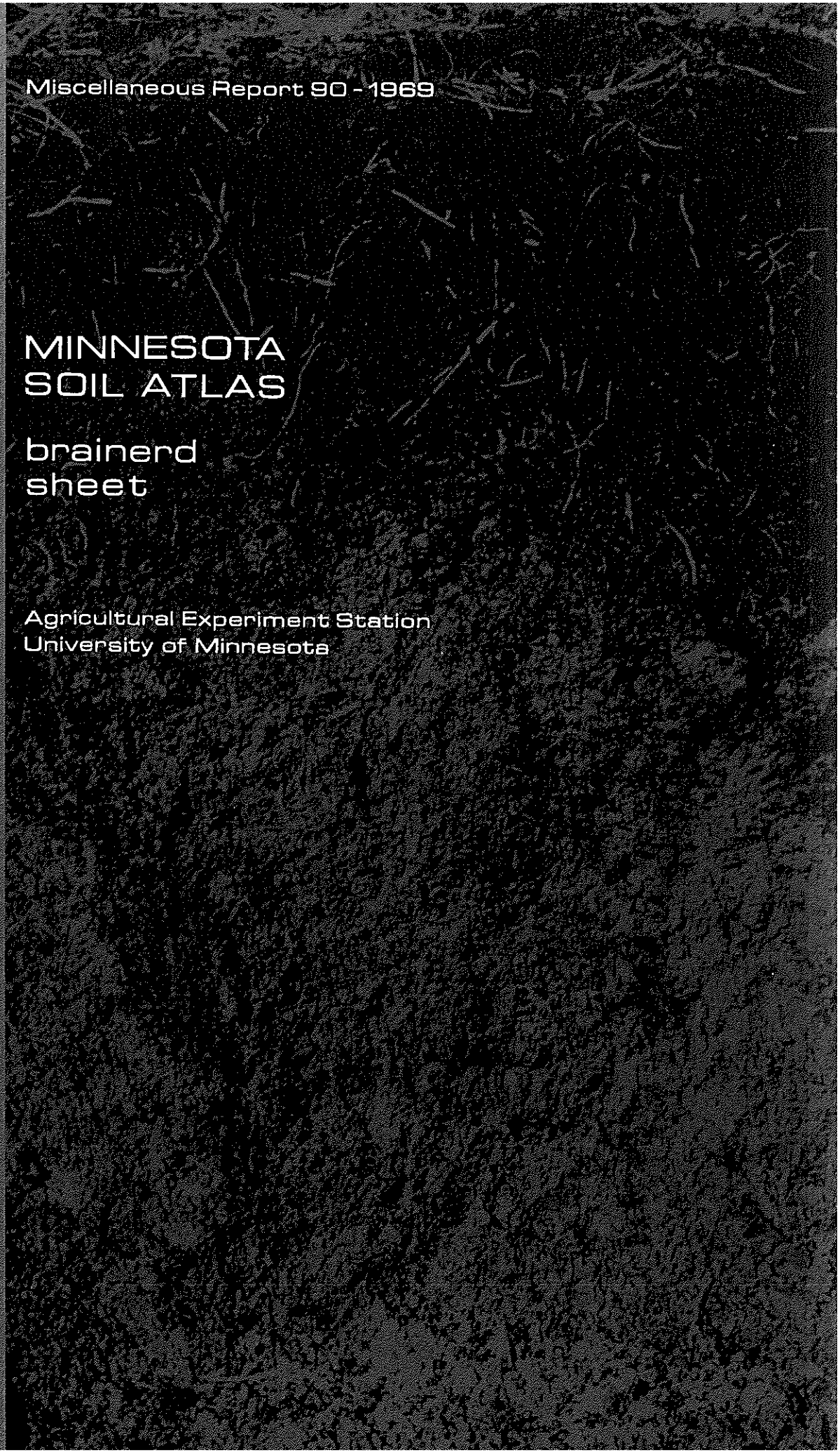
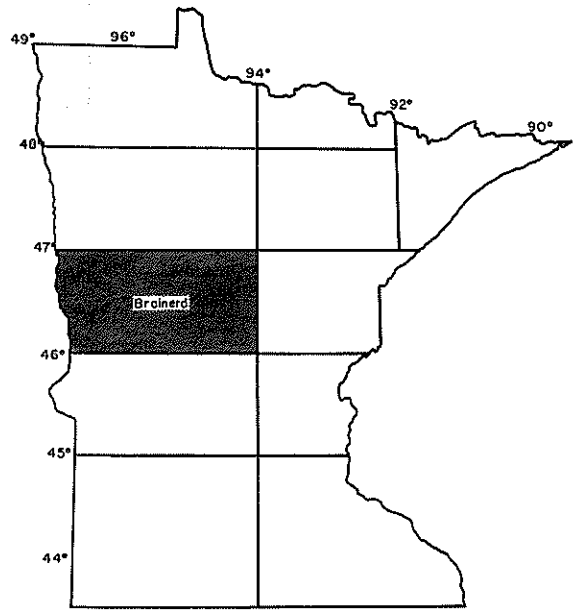


MINNESOTA SOIL ATLAS

brainerd sheet

Agricultural Experiment Station
University of Minnesota



Status of Minnesota Soil Atlas Project

ACKNOWLEDGMENT

The Department of Soil Science, University of Minnesota in cooperation with the Soil Conservation Service, U.S. Department of Agriculture, and the Minnesota Geological Survey prepared this Minnesota Soil Atlas-Brainerd Sheet, first in a series of eleven covering the entire state.

H. F. Arneman, R. A. Erickson, G. F. Harms, L. D. Hanson, and R. H. Rust did the field work, map, and reports.

H. E. Wright, Jr., Department of Geology, University of Minnesota, assisted in developing the geomorphic areas.

The assistance of the soil survey personnel of the Soil Conservation Service is gratefully acknowledged.

Project funds were supplied in part by an allocation from the Minnesota Resources Commission.

CONTENTS

INTRODUCTION

Information is lacking on the soils and landscape characteristics of large areas of Minnesota. Many planning agencies simply have to go without information needed for their work. Detailed soil surveys published on a scale of 1:20:000 are being made by the United States Department of Agriculture, Soil Conservation Service in cooperation with the Minnesota Agricultural Experiment Station to fill this need, but because they cannot be supplied rapidly enough for broad planning, the Soil Atlas is being developed. It is not intended to replace detailed soil survey reports which are essential for planning the use of smaller pieces of land. Detailed soil survey work, done in most counties but not available in published form, has been gathered and supplemented to compile the Brainerd Sheet of the Minnesota Soil Atlas.

Until detailed soil surveys are available for all Minnesota counties, broad planning can be facilitated by the eleven sheets to be published in the Minnesota Soil Atlas series (see figure 1). Even as detailed soil surveys become available, the broad view of large planning areas will still be necessary. It is proposed that this series of maps be published with explanatory texts for each quadrangle in the state. For uniformity the Atlas Sheets are being published on the same scale as the U.S. Geological Survey topographic maps and other maps prepared by the Minnesota Geological Survey. Sometimes one quadrangle is combined with part of another: the Brainerd Sheet contains the Brainerd quadrangle and the eastern (Minnesota) portion of the Fargo quadrangle.

The Brainerd Sheet encompasses approximately 5,111,-000 acres in west central Minnesota: from 46° to 47° north latitude and from 94° west longitude to the western border of the state, extending from Brainerd to Fargo and including parts or all of 13 counties. Only four published surveys of this area are available and three are more than 35 years old and out of print. Appendix B indicates the extent of modern detailed soil surveys in this area.

USE OF THE SOIL ATLAS

The Minnesota Soil Atlas provides essential information for broad planning. Some of the uses that can be developed from this map follow:

1. To determine areas suitable for various crops such as potatoes, sugar beets, and canning crops to enable processors to locate plants within areas of greatest potential.

2. To determine areas' potential for various types of farming, forestry, or recreation.

3. To determine areas that would benefit from drainage or irrigation.

4. To locate sources of sand and gravel.

5. To prepare wildlife density maps.

6. To locate pulp and lumber mills within areas of greatest potential supply.

7. To locate feasible routes for utility lines and highways.

8. To serve as reference for science teachers in junior high, high school, and college courses.

For specific planning of individual farms, cities, towns, recreation areas; tax equalization; and road building purposes, more detailed surveys are necessary than this map. However, this map may point out priority areas where detailed surveys will be most useful.

This map and text are not designed to present the interpretations and uses, only to provide the essential information for such uses. Subsequent interpretive material will be prepared as needed.

HOW THE MAP WAS PREPARED

The base map was prepared from the Brainerd quadrangle and eastern portion of the Fargo, by the U.S. Geological Survey, Department of Interior. The scale of 1:250,000, or about ¼ inch to 1 mile, makes it possible to show areas as small as 1 square mile. Contour intervals of 50 feet indicate some of the topography.

Soil landscape delineations were developed from 4 inch to 1 mile detailed soil surveys made by the Soil Conservation Service, U.S. Department of Agriculture (USDA), where available. Published surveys of Wadena, Hubbard, and Crow Wing counties were also used. Field work was necessary where no detailed soil survey existed.

In the effort to provide a generalized map for the user with a minimum knowledge of soils, soils were grouped into soil landscape units based on the following factors:

1. Texture of the soil material below 5 feet into sandy (S); loamy or silty (L); clayey (C); mixed sandy and loamy (X); and mixed silty and clayey (Y).

2. Texture of the material above 5 feet, or a significant part of it, into sandy (S); loamy or silty (L); and clayey (C).

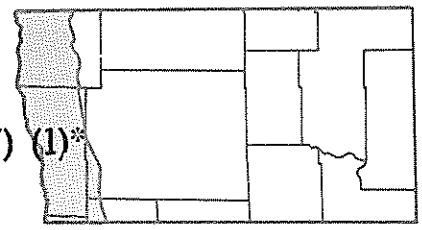
3. Drainage with moderately well, well, excessively drained designated (W); and somewhat poorly, poorly, and very poorly drained designated (P). Units with (W) designation will generally have water tables below the rooting zone and units with (P), water tables commonly within the rooting zone.

4. Color of surface soil with dark color designated (D); and light color designated by (L).

Thus, the Barnes series would appear on the map as LLWD and would be interpreted from the map as a dark-colored, well-drained loamy soil over loamy material (in this case loamy glacial till). Svea and Bearden soils would also appear in this landscape unit.

Seventeen geomorphic areas are delineated to illustrate broad physiographic features and to provide some identification as to the nature of parent materials on which the soils have developed. Several geomorphic areas will extend into adjoining counties. Soil landscape units are mostly delineated within the geomorphic areas. The soil series which occur within a soil landscape unit commonly differ among geomorphic areas. Principal soil series, when known, are included in tables 2-19.

AGASSIZ LACUSTRINE PLAIN (RED RIVER VALLEY) (1)*



This region encompasses an area of approximately 746,000 acres or about 14.6 percent of the Brainerd Sheet.

The Red River Valley is a large depressed plain, formerly occupied by Glacial Lake Agassiz. The southern terminus is in Traverse County and extends north into Canada, a distance of 232 miles. The valley averages about 20 miles wide on the Brainerd Sheet.

The lake plain slopes very gradually to the north and west from the shoreline. Descent from the southern border to Breckenridge averages about 2 feet per mile. From Breckenridge to Moorhead, the fall is about 1.5 feet per mile. From Moorhead to Grand Forks, the descent averages about 1 foot per mile.

Westward slope to Red River in Wilkin County averages approximately 1 foot per mile. The slope in Clay County is slightly greater. Generally, the slope westward is less uniform than the slope northward.

A slow moving winding stream, the Red River, has only about 5 inches fall per mile. The flood plain is narrow with steep banks rising to the lake plain. Main tributaries are the Otter Tail and Buffalo rivers. In the lake plain, these two rivers are winding, relatively sluggish streams.

The level lakebed pattern showed that during nearly all stages of its life, wide stretches of shallow water occurred along the lake margins. Wave action carried finer particles in suspension, and redeposited them in deeper water, and pushed coarse sand and gravel out to form beaches. Five beach lines were formed during different height stages of the lake. The beaches vary from a few rods to a half mile in width and from 5 to 20 feet or more in height. The Herman Beach was formed during the highest stage; Norcross was formed at the next stage; then Tintah, Campbell, and McCauleyville at succeeding lower stages. Lake sediments range up to 50 feet or more in thickness in the valley.

The original vegetation was tall grass prairie. An estimated 70 to 80 percent of the valley is now under cultivation with barley, wheat, soybeans, corn, flax, potatoes, and sugar beets the main crops. The valley's remaining 20 to 30 percent is in native grass: some pasture, the rest meadow. Some woods, mostly elm and basswood, occur along the Red and Buffalo rivers.

Nine soil landscape units occur in the Red River Valley: CCPD, CLPD, LLPD, LLWD, SLPD, SLWD, SSPD, SSWD, and A. Selected features of each soil landscape unit for the geomorphic region are given in table 2. Other features peculiar to each unit follow.

CCPD — Lacustrine clays are generally thickest in an area 2 to over 10 miles wide bordering the Red and Bois des Sioux rivers. An area of about three townships extending from the town of Kent, in Wilkin County, south into Traverse and bordering the Red and Bois des Sioux rivers contains numerous areas, 20 to 50 feet in diameter, which are grayer and more silty in the surface than typical for the unit. The substratum below 18 to 24 inches is very high in clay and restrictive to moisture movement. These grayer spots make up about 10 percent of these three townships. Some small alkali patches are found in this unit. Their surface is very hard when dry and exceedingly sticky when wet. These spots are almost impervious to water. The main areas occur north of Breckenridge in the vicinity of Brushvale and Kent. Lacustrine clays are shallow over water-worked till in much of the landscape unit southeast of Breckenridge. A few boulders occur on the surface. Over 90 percent of the soils in this unit are alkaline throughout the profiles. Gypsum crystals are present at depths of 2 to 4 feet below the surface in many places. The unit contains several unnamed soils.

CLPD — Over 90 percent of the soils in this unit are alkaline throughout the profiles. Gypsum crystals are present at depths of 2 to 4 feet in many places.

LLPD — Soils of about 80 percent of this unit are alkaline. The water table in many areas towards the east side of the lake plain is within 2 to 4 feet of the surface. Gypsum crystals occur in many places within the soil. The unit has several unnamed soils.

LLWD — Soils in most of this unit developed in lacu-

Table 1. Acreage estimates of geomorphic areas in the Brainerd and Fargo quadrangles

		Acres	Percent
1.	Agassiz Lacustrine Plain (Red River Valley)	746,200	14.6
2.	Fergus Falls Till Plain	434,000	8.5
3.	Alexandria Moraine Complex	680,000	13.3
4.	Detroit Lakes Pitted Outwash Plain	490,000	8.0
5.	Mahnomen Lacustrine Plain	15,000	0.3
6.	Henning Till Plain	199,000	3.9
7a.	Wadena Drumlin Area	200,000	3.9
7b.	Todd Drumlin Area	179,000	3.5
7c.	Cass Drumlin Area	107,000	2.1
8.	Park Rapids-Staples Outwash Plain	777,000	15.2
9.	St. Croix Moraine Complex	296,000	5.8
10a.	Pine River Drumlin Area	66,000	1.3
10b.	Darling Drumlin Area	36,000	0.7
10c.	Brainerd-Pierz Drumlin Area	174,000	3.4
11.	Itasca Moraine Complex	194,000	3.8
12.	Stewart Lake Till Plain	72,000	1.4
13.	Crow Wing Outwash Plain	480,000	9.4
14.	Mille Lacs Moraine	10,000	0.2
	Total	5,111,000	

* Numbers in parentheses refer to geomorphic area number symbols as they appear on the Brainerd Sheet.

strine silts varying in thickness from 3 to over 7 feet over lacustrine clay. Permeability of the silts is moderately rapid. During wet periods a perched water table occurs above the clay zone. Over 90 percent of the unit consists of alkaline soils. Gypsum crystals are quite common in the profile in many locations.

SLPD — Soils in the unit are alkaline throughout the profiles in over 90 percent of the area. Gypsum crystals occur in many places. The water table is frequently within 2 to 4 feet of the surface, especially towards the eastern edge of the valley.

SLWD — Conditions in this unit are similar to those in SLPD, except that the water table is lower.

SSPD — Soils in an estimated 70 to 80 percent of the area are alkaline. The water table is frequently within 2 to 4 feet of the surface.

SSWD — This landscape unit consists mainly of beach ridges. Many beaches are a good source of gravel and are continually being utilized for highway construction and road surfacing.

A — The flood plains in most of the area are cut up by winding rivers. Flooding occurs rather frequently. Most of the unit is pastured woodland. Several unnamed soils occur in the unit.

Zinc deficiencies and iron chlorosis may occur on susceptible crops grown on the alkaline soils.

Table 2. Selected features of soil landscape units within the Agassiz Lacustrine Plain (1) (Red River Valley) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
CCPD	35	level lake plain	silty clay and clay (3)	silty clay and clay (3-20+)	8-12	poorly drained poor surface drainage	6.1-7.2	low	high	Fargo Rocksbury Hegne
CLPD	20	level lake plain	fine sandy loam (3)	silty clay and clayey (3-20+)	8-12	poorly drained	7.2+	low	medium	Rockwell
LLPD	15	level lake plain	silt loam and loam (4)	silt loam and loam (4+)	8-12	poorly drained	7.2+	low	medium	Colvin Blue Earth
LLWD	10	nearly level plain	silt loam (4)	silt loam (4+)	8-12	somewhat poorly drained	7.2+	low	medium	Bearden
SLPD	5	level lake plain	silt loam (3)	fine sand (3-4+)	4-8	poorly drained	7.2+	low	medium	Borup
SLWD	5	level lake plain	silt loam (3)	fine sand (3-4+)	4-8	somewhat poorly drained	7.2+	low	medium	Glyndon
SSPD	5	level lake plain	fine sandy loam (2)	fine sand (2-4+)	4	poorly drained	7.2+	medium	medium	Fossum
SSWD	2	gently sloping beach lines	loamy sand (2)	sand, gravel (2-10+)	4	well drained	6.1-7.2	medium	low	Sioux
A	3	narrow bottom land	silty clay and clay (4)	silty clay and clay (4+)	8-12	poorly drained	6.1-7.2	low	medium	LaMoure

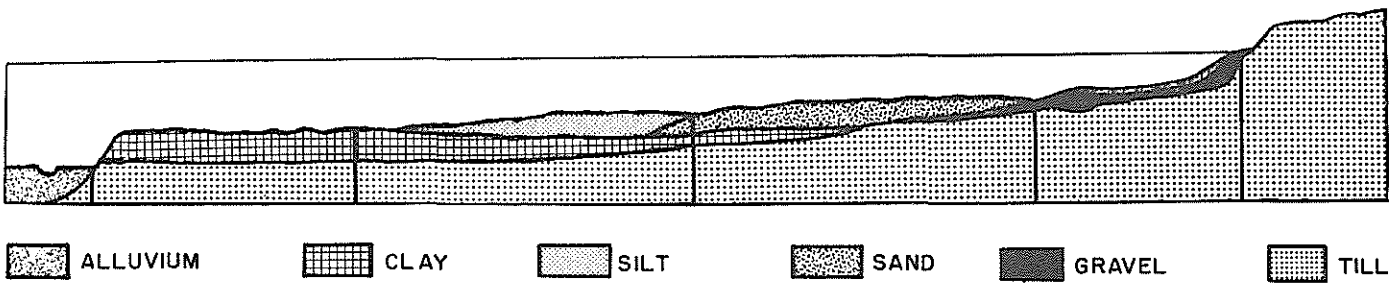
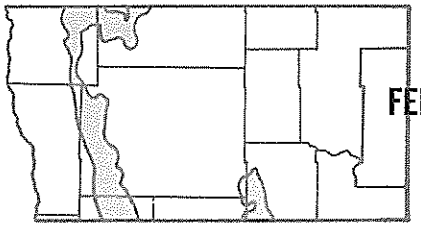


Figure 1. Cross section of the Glacial Lake Agassiz area showing the distribution of different types of soil parent materials. (Adapted from figure 28, Soil Survey of Red River Valley Area, 1939.)



FERGUS FALLS TILL PLAIN (2)

This region encompasses an area of approximately 434,000 acres or about 8.5 percent of the Brainerd Sheet.

The Fergus Falls Till Plain is dominantly undulating to gently rolling, but includes some nearly level and rolling areas. Potholes and small marshes are common. There are 17 lakes, most of them less than 300 acres each, and totaling about 4,100 acres.

The region consists of calcareous loam glacial till deposited during the late Wisconsin glaciation. Till along the western side of the plain is, in places, covered by a mantle of silt 2 to 6 feet thick. The most extensive area is near Rothsay; although patches of silts have been observed north to the Clay County line and south to the Otter Tail River. Glacial stones are fairly common in the soils, but cause very little trouble with modern farm machinery.

Based on deep well records, the till, in places, is over 400 feet thick over bedrock, which near Rothsay is 465 feet below the surface.

Original vegetation in the region consisted of tall grass prairie. An estimated 20 percent is native pasture and meadow. Marshes make up less than 5 percent of the landscape and tilled land over 75 percent. Barley, oats, wheat, corn, soybeans, flax, brome, and alfalfa are the main crops.

Seven soil landscape units occur in the region: LLWD, LLPD, XLWD, YLWD, SLPD, A, and P. About 80 percent of the region is LLWD. The remaining 6 units total only 20 percent. Selected features of the units are given in table 3. Additional information follows:

LLWD — Poorly drained and wet soils comprise about 10 percent of the unit. Approximately 15 percent of the area soils have limy profiles throughout.

LLPD — This unit occupies lower-lying positions than the adjacent well-drained units. Poorly drained peat soils make up 25 to 35 percent of the area.

XLWD — This unit occurs in some of the more rolling portions of the region. The ratio of loamy soils to those with coarse substrata is about 60:40. Approximately 25 percent of the unit consists of limy soils.

YLWD — This is a minor soil landscape unit in the vicinity of Audubon and is an extension of the YLWD unit in the Alexandria Moraine Complex. An estimated 60 to 70 percent of the soils have silty clay substrata.

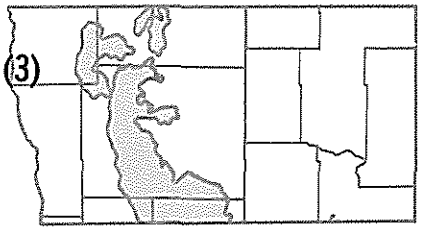
SLPD — Soils in the unit are quite varied in textures and depths to underlying materials. The water table is usually less than 5 feet below the surface.

Table 3. Selected features of soil landscape units within the Fergus Falls Till Plain (2) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWD	80	undulating to gently rolling upland	loam (4)	loam (4-20+)	8-12	well drained	6.1-7.2	low	high	Svea, Hantho Barnes, Buse Rothsay, Zell
LLPD	10	nearly level depressional upland	silty clay loam (4)	loam (4-20+)	8-12	wet to poorly drained	6.1-7.2+	low	medium	Flom Parnell Blue Earth
XLWD	4	rolling upland	loam (2-4)	sandy loam to loam (4-20+)	4-12	well drained	6.1-7.2	low	low to medium	Barnes, Buse Sioux, Arvilla
YLWD	2	undulating to gently rolling upland	loam (2-4)	clay loam to loam (4-20+)	8-12	well drained	6.1-7.2	low	high	Barnes, Unnamed soil on clayey till
SLPD	2	nearly level depressional upland	loam (2-3)	sand and gravel (3-20+)	4-8	poorly drained to wet	6.1-7.2+	low	medium	Talcot, Biscay Benoit
A	2	narrow stream bottoms subject to flooding	sandy loam to loam (2-4)	sandy loam to loam (4+)	4-12	poorly drained	6.1-7.2+	low	medium	Alluvial soils undifferentiated
P	t*	level depressional organic	peat (1-4)	loam (4-20+)	12+	wet	6.1-7.2+	low	low	Peat

* = trace.

ALEXANDRIA MORAINE COMPLEX (3)



This region encompasses an area of approximately 680,000 acres or 13.3 percent of the Brainerd Sheet.

The Alexandria Moraine Complex is a prominent moraine formed by ice lobes from both the eastern and western sides. Considerable overlapping resulted. Its topography is dominantly rolling to hilly knob and kettle-like. It abounds in numerous small potholes and marshes and many good recreation lakes. There are over 90 lakes, 160 acres or larger, totaling 62,000 acres in the moraine. Geologically, the region consists mainly of limy loam and light clay loam glacial till. Extensive areas are intermixed with morainic outwash, sandy and gravelly material. North of Detroit Lakes, in Becker County, the medium-textured till is intermixed with fine-textured till. Seeps and small springs characterize some areas such as north of Fergus Falls in the vicinity of Long Lake and in southeastern Clay County.

Glacial stones are more common in this region than in the Fergus Falls Till Plain. Some localized spots up to 10 acres in size are very stony.

The transition between the prairies on the west and the forests on the east occurs in a strip of land varying in width from 1 to over 15 miles. This transitional zone is located along the western and southern portions of the

Table 4. Selected features of soil landscape units within the Alexandria Moraine Complex (3) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWD	45	rolling upland	clay loam (4)	loam (4-20+)	8-12	well drained	6.1-7.2	medium	high	Nokuaw Buse
LLWL	20	rolling to hilly uplands	clay loam (4)	loam (4-20+)	8-12	well drained	< 6.0	high	medium	Nebish
XLWL	15	rolling to hilly upland	loam (2-4)	gravelly loam to loam (4-20+)	4-12	well drained	< 6.0	high	low to medium	Nebish Marquette Todd
XLWD	12	rolling to hilly upland	loam (2-4)	gravelly loam to loam (4-20+)	4-12	well drained	6.1-7.2	low to medium	medium	Estherville Salida Nokuaw
SLWD	2	undulating to nearly level outwash	sandy loam (2-3)	sand and gravel (3-20+)	4-8	well drained	6.1-7.2	low	medium	Arvilla Estherville
SSWD	1	rolling to steep outwash	loamy sand (1-2)	sand and gravel (2-20+)	0-4	well drained	6.1-7.2	low	low	Salida Sioux
YLWD	3	rolling to hilly upland	clay loam (4)	clay loam to silty clay (4-20+)	8-12	well drained	6.1-7.2	medium	high	Nutley Nokuaw
CLWL	t*	nearly level to sloping lacustrine	silt loam (4)	silty clay loam (4+)	8-12	well drained	< 6.0	high	medium	Dalbo
P	1	level peat bog	peat (1-3)	peat (3+)	12+	marshy	< 6.0	low	low	Peat
LLPD	t*	depressional to gently sloping upland	silty clay loam (4)	loam (4-20+)	8-12	poorly drained to wet	6.1-7.2	low	medium	Flom Parnell Peat
A	t*	narrow stream bottoms	sandy loam to loam (4)	sandy loam to loam (4-20+)	4-12	poorly drained	6.1-7.2	low	medium	Alluvial soils undifferentiated
CLPL	t*	nearly level to gently sloping lacustrine	silt loam (4)	silty clay loam (4+)	8-12	poorly drained	< 6.0	high	medium	Brickton

* = trace.

region. It is commonly called a prairie border area. Prairie grasses which first covered the area were invaded by hardwood forest. As a result, the soils show influences of both prairie and forest vegetation. The eastern portion consisted of northern hardwood forest. Some good stands still remain. An estimated 45 to 55 percent of the landscape is tilled. Pastures and woodland make up 15 to 25 percent each. The remaining 5 to 15 percent is marshy. Main crops are oats, barley, wheat, corn, alfalfa, and brome.

Eleven soil landscape units occur in the Alexandria Moraine Complex: 4 major and 7 minor. Major units representing about 95 percent of the region are LLWD, LLWL, XLWL, and XLWD. Minor units are SLWD, SSWD, YLWD, CLWL, P, LLPD, A, and CLPL. Selected features of the units are given in table 4. Additional information by units follows:

LLWD — The topography is mainly rolling to hilly knob and kettle type with numerous good recreational lakes. Small peat bogs make up 5 to 10 percent and calcareous Buse soils comprise another 10 percent of the unit. A few silty unnamed soils occur in northwestern Otter Tail County.

LLWL — Approximately 10 percent of the unit consists of small peat bogs and is generally of steeper topography than LLWD.

XLWL — The acreage of loamy and sandy soils is fairly evenly divided. Peat makes up about 10 percent of the unit. The topography is similar to LLWL.

XLWD — Approximately 60 percent of the unit consists of loamy soils. Small peat bogs occur in about 5 percent of the area. Topographically, XLWD is similar to LLWD.

SLWD — The unit represents small islands of outwash within the moraine.

SSWD — Approximately 20 percent of the unit consists of sandy loam soils.

YLWD — Soils with a clayey substrata comprise about 70 percent of the unit.

CLWL — This landscape unit is in a lower position than the surrounding upland, is gently rolling to nearly level, and stone free.

CLPL — The unit is similar to CLWL except that most of the soils are poorly drained and the terrain is nearly level.

LLPD — An estimated 5 to 15 percent of the unit is peat.

P — Much of the peat borders lakes and is generally over 40 inches deep.

A — The bottoms are subject to frequent overflow of the streams.

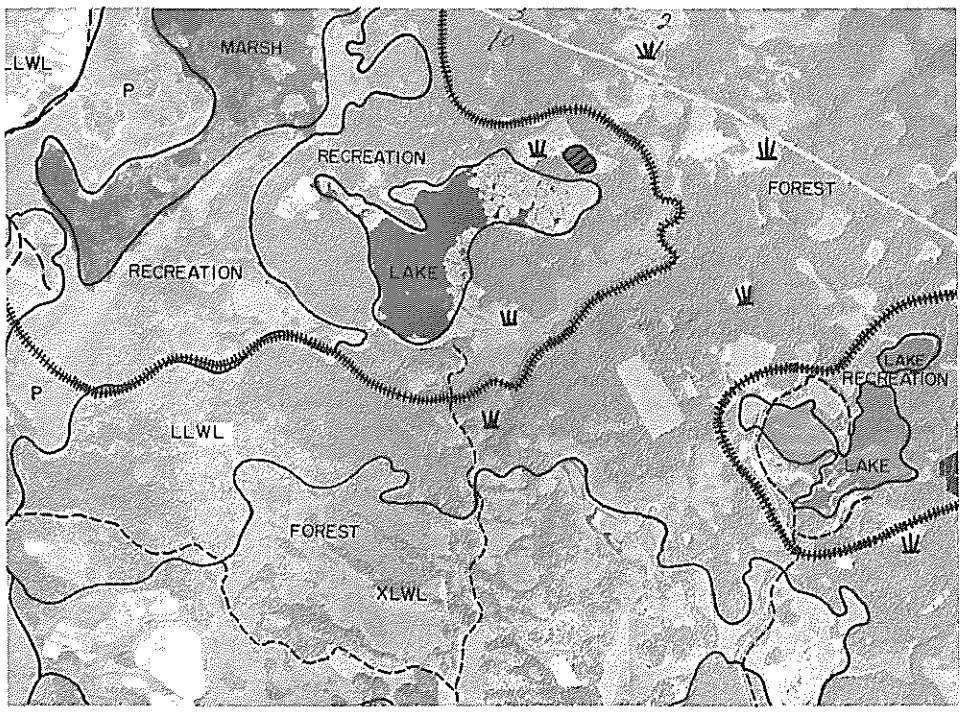
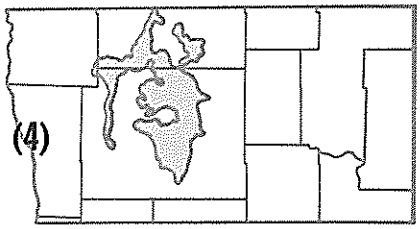


Figure 2. Soil landscape units, LLWL, XLWL, and P, delineated from an aerial view as they occur in a portion of the Alexandria Moraine Complex (3). Marsh areas commonly occur with P (Peat). Two principal land uses are also shown: land around lakes and marshes is commonly used for recreation (hunting, fishing, lakeshore cabins) and the rest of this area is mostly forested. Limited agriculture occurs in small, isolated fields.

DETROIT LAKES PITTED OUTWASH PLAIN (4)



This region encompasses an area of approximately 409,000 acres or 8 percent of the Brainerd Sheet.

Topography over most of the plain varies from undulating to gently rolling. Rolling to steep terrain occurs in Otter Tail County north of Star and Dead lakes, in the northwestern portion of the county, and in much of the Becker County plain. A nearly level area is located in the vicinity of Perham.

Depth of glacial drift over bedrock near Perham is approximately 215 feet. Outwash sand and gravel in places range up to and over 100 feet thick. In the Perham area, and in some other localized spots, the substratum below 18 to 24 inches is primarily underlain by medium and coarse sand several feet thick with little or no gravel.

The outwash plain is a good source of gravel and many large gravel pits are located in it.

Most of the soils range from loamy sand to light loam less than 24 inches thick over sand and gravel. Consequently, with low water holding capacity, the soils are quite droughty. Water table ranges from a few feet in some low areas to over 50 feet below the surface in higher elevations.

Approximately 90 lakes, each 160 acres or more in size, and totaling 79,019 acres, are located in the outwash plain. They include some of the more popular recreational lakes in the Brainerd Sheet.

The original vegetation was dominantly prairie with scattered oak openings. North of Star and Dead lakes in north central Otter Tail County, the vegetation was largely oak forest. An estimated 5 to 15 percent of the region still is forested, 15 to 25 percent pasture and native meadow, and 60 to 70 percent tilled, with oats, soybeans, corn, rye, alfalfa, and brome the main crops.

Six soil landscape units are mapped in the outwash plain: SSWD, SLWD, SSWL, SLWL, SLPD, and P. Selected characteristics of the units are listed in table 5. Some additional information for each unit follows:

SSWD — In the Perham area the unit includes sandy loam soils 14 to 24 inches thick over medium and coarse sand. Peat bogs comprise less than 5 percent of the unit.

SLWD — Less than 5 percent of the unit consists of peat bogs. Loamy sand soils occur in 15 to 25 percent of the unit.

SSWL — Peat bogs and low, wet soils make up about 10 percent of the landscape unit.

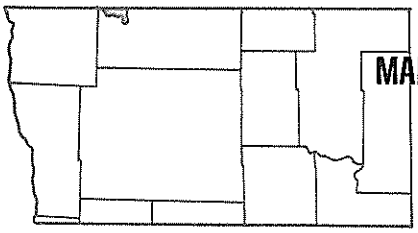
SLWL — Shallow loamy sands comprise 10 to 20 percent of the unit. Marshy peat bogs occur in about 10 percent.

SLPD — The principal soils are unnamed. Approximately 30 percent of the unit is marshy peat bogs. In the remaining area the water table is generally 2 to 6 feet below the surface.

Soils in the eastern portion of the Detroit Lakes Pitted Outwash Plain normally are deficient in sulphur.

Table 5. Selected features of soil landscape units within the Detroit Lakes Pitted Outwash Plain (4) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
SSWD	43	nearly level to rolling outwash	loamy sand (1-3)	sand and gravel (3-20+)	<4	well drained	6.1-7.2	low	low	Salida Sioux Hubbard
SLWD	30	nearly level to gently rolling outwash	sandy loam (2-3)	sand and gravel (3-20+)	4-8	well drained	6.0-7.2	low	medium	Estherville Arvilla
SSWL	15	gently rolling to hilly outwash	loamy sand (1-3)	sand and gravel (3-20+)	<4	well drained	<6.0	high	low	Marquette Lengby
SLWL	5	nearly level to rolling outwash	sandy loam (2-3)	sand and gravel (3-20+)	4-8	well drained	<6.0	high	low	Todd Lengby
SLPD	2	level to depressional outwash and peat bogs	loam (2-3)	sand and gravel (3-20+)	4-8	poorly drained	<6.0	high	low	Unnamed Peat
P	5	marshy peat bog	peat (1-3)	peat (3+)	12+	very poorly drained marshy	<6.0	low	low	Peat



MAHNOMEN LACUSTRINE PLAIN (5)

This region encompasses an area of approximately 15,000 acres or about .3 percent of the Brainerd Sheet.

Most of the plain is located in the southern part of the adjacent Bemidji Sheet. It has a somewhat lower elevation than the adjoining Fergus Falls Till Plain, undulating to nearly level topography, and is moderately well drained with some marshy depressions. The water laid silts are generally 2 to 4 feet thick over limy loam till. Depth of till over bedrock, in most of the area, is over 300 feet.

Originally tall grass prairie covered the geomorphic region. An estimated 10 to 15 percent remains in native grasses as pasture and meadows. Marshes and wet spots comprise 5 to 10 percent of the landscape with an estimated 80 to 85 percent tilled. Principal crops are barley, wheat, oats, soybeans, corn, alfalfa, and bromegrass.

Four soil landscape units occur in the geomorphic region: LLWD, LLPD, P, and A. Selected features of the landscape units are shown in table 6. Additional information follows:

LLWD — This is by far the most important landscape unit in the geomorphic region. Poorly drained soils in slightly lower positions make up 10 to 20 percent of the unit. Wet depressions comprise 5 to 10 percent of the landscape. Most of the soils are limy throughout the profile.

LLPD — This unit occurs in slightly lower positions than LLWD. During wet periods, the water table may be within 3 or 4 feet of the surface. Twenty to 30 percent of the unit consists of depressions. Some higher moderately well-drained areas are included, making up 5 to 15 percent of the unit. Nearly all soils are limy.

P — Most of the area, except where drainage has been installed, is wet or marshy. The unit includes 10 to 15 percent of wet and poorly drained mineral soils.

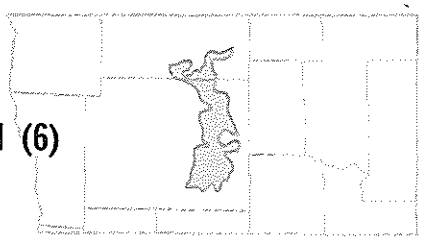
A — The bottoms are narrow, wet to poorly drained, and subject to frequent overflows.

Because of the high lime soils, zinc deficiencies and iron chlorosis may occur in susceptible crops.

Table 6. Selected features of soil landscape units within the Mahnomen Lacustrine Plain (5) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWD	70	nearly level to undulating lake plain	silt loam (4)	loam (4-20+)	8-12	well drained	7.2+	low	low	McIntosh
LLPD	15	nearly level to depressional lake plain	silt loam (4)	loam (4-20+)	8-12	poorly drained	7.2+	low	low	Winger Blue Earth
P	10	depressional bog	peat (3)	peat (3+)	12+	very poorly drained marshy	6.1-7.2	low	low	Peat
A	5	narrow stream bottom	sandy loam to loam (4)	sandy loam to loam (4-20+)	8-12	very poorly drained	6.1-7.2	low	medium	Rauville

HENNING TILL PLAIN (6)



This region encompasses an area of approximately 199,000 acres or 3.9 percent of the Brainerd Sheet.

The region is typified by undulating to rolling knob and kettle-type topography, intermixed with numerous wet depressions and small peat bogs. Several larger peat bogs, 1 to over 5 sections in size, are located in the region.

The Henning Till Plain consists of limy sandy loam glacial till deposited during the Cary substage of the Wisconsin Age. Till is generally over 200 feet thick over bedrock. Glacial stones and cobble are numerous on the surface and throughout the soil profiles. The region has a few small isolated areas of outwash.

Most of the region was originally forested. Forests consisted of white and red pine in the northern part, and northern hardwoods in the southern part.

An area north and west of Henning, Otter Tail County, has darker and thicker surface soils, evidence of prairie influence at some early period. Later, forest invaded the prairie.

Approximately 25 percent of the landscape remains in forest. About 15 percent is pasture and an estimated 10 percent is marshy. The remaining 50 percent is under cultivation. Main crops are oats, corn, bromegrass, alfalfa, and clover.

There are seven soil landscape units in the Henning Till Plain: LLWL, LLWD, P, LLPL, XLWL, XLWD, and SLWD. Selected features of the soil landscape units are given in table 7. Additional information concerning the units follows:

LLWL — An estimated 15 to 25 percent of the landscape is in lower positions and varies from poorly drained to marshy. In these areas, the water table is often within 3 to 5 feet of the surface.

LLWD — About 25 percent of the landscape occurs in lower positions and varies from poorly drained to marshy. The water table is frequently within 3 to 5 feet of the surface. The unit contains several poorly and very poorly drained unnamed soils.

P — An estimated 5 to 10 percent of the unit consists of poorly drained mineral soils.

LLPL — About 15 percent of the unit occurs on slightly higher positions. The topography is nearly level to gently sloping and the soils are well drained. About 50 percent of the unit is wet to marshy. Several unnamed soils occur in the unit.

XLWL — Soils with sandy and gravelly substrata make up about 40 percent of the area. Wet and marshy soils occur in 10 to 20 percent of the unit.

XLWD — Soils in about 35 percent of the soil landscape unit are underlain by sand and gravel. About 20 percent are poorly drained to marshy.

SLWD — Approximately 5 percent of the unit is poorly drained to wet. Approximately 10 percent consists of shallow loamy sand soils and another 10 percent of loams 2 to 3 feet thick over sand and gravel. Some unnamed soils occur in the unit.

Some soils in the region may be deficient in sulphur.

Table 7. Selected features of soil landscape units within the Henning Till Plain (6) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWL	50	gently rolling to rolling upland	sandy loam (4)	sandy loam (4-20+)	4-8	well drained	< 6.0	high	low	Nebish Beltrami
LLWD	20	undulating to gently rolling upland	sandy loam (4)	sandy loam (4-20+)	8-12	well drained	6.1-7.2	medium	medium	Waukon Gonvick
P	15	bogs	peat (1-3)	peat (3+)	12+	very poorly drained marshy	< 6.0	low	low	Peat
LLPL	5	nearly level to depressional upland	sandy loam (4)	sandy loam (4-20+)	8-12	poorly drained	< 6.0	high	low	Shooks Beltrami Bluffton, Peat
XLWL	5	gently rolling to rolling upland	sandy loam (2-4)	sandy loam and sand and gravel (4-20+)	0-8	well drained	< 6.0	high	low	Nebish Beltrami, Todd Marquette
XLWD	3	gently rolling to rolling upland	sandy loam (2-4)	sandy loam and sand and gravel (4-20+)	0-8	well drained	6.1-7.2	low to medium	low to medium	Waukon Gonvick, Salida Estherville Peat
SLWD	2	nearly level to undulating	sandy loam (2-3)	sand and gravel (3-20+)	4-8	well drained	6.1-7.2	low	medium	Estherville Wadena Salida

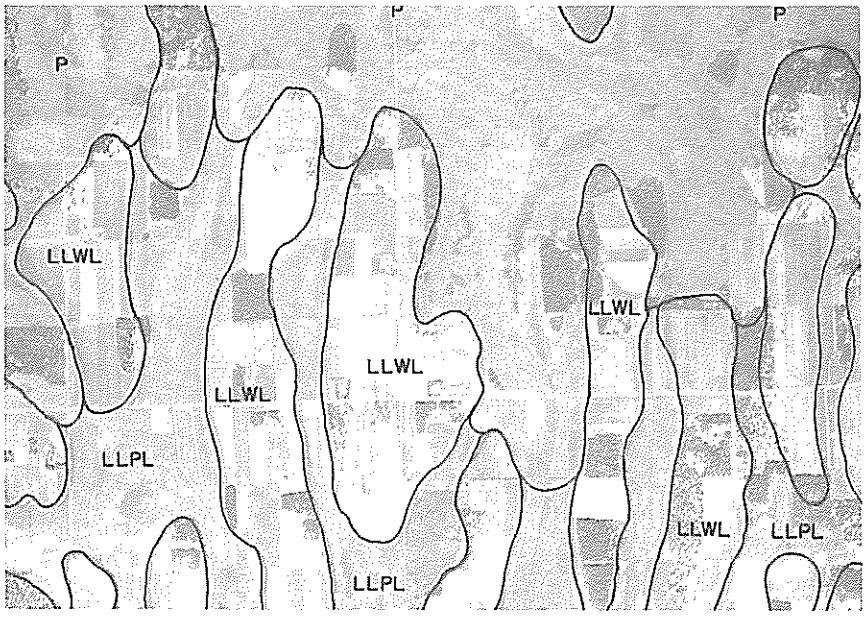
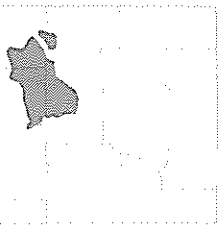


Figure 3. An aerial photo (scale 1 inch equals 3.17 miles) showing typical soil landscape unit pattern in the Wadena Drumlin area, and, generally, in other drumlin areas. The LLWL areas are the elongated, low hills, mostly under cultivation; the LLPL areas, the lower and mostly wet soils commonly supporting reed canary or other wet-adapted grasses.

WADENA DRUMLIN AREA (7A)



This region encompasses an area of approximately 200,000 acres or 3.9 percent of the Brainerd Sheet.

The geomorphic region is characterized by relatively low drumlins with long gentle slopes separated by wet to marshy areas, which, in places, are over a quarter mile wide. The drumlins are generally oriented in a northeast-southwest direction in Wadena County, with a gradual shift to east-west in Becker and Otter Tail counties. They range from 0.1 to 0.5 miles wide and 1 to 4 miles long.

The material consists of limy sandy loam till. Surface and subsoils are quite high in cobblestones. The region has one lake, 217 acres in size.

The original vegetation was largely white and red pine. Northern hardwoods predominated in an area in southwestern Becker and northeastern Otter Tail counties. An estimated 30 percent is marshy; an estimated 30 percent is pasture and woodland. Approximately 40 percent is tilled. Oats, corn, bromegrass, alfalfa, and clover are the principal crops.

Seven soil landscape units occur in the Wadena Drumlin Area: LLWL, LLPL, P, SLWL, SLPL, SSWL, and LSWL. Selected features of the units are given in table 8. Additional information about each unit follows:

LLWL — Wet to marshy areas separating drumlins make up about 20 percent of the unit. Sandy and gravelly pockets occur in less than 5 percent of the landscape.

LLPL — This unit represents low, somewhat poorly drained drumlins, and the wider areas between well-drained drumlins. Approximately 15 percent of the unit is fairly well drained, and about 40 percent is somewhat poorly drained.

P — Approximately 15 percent of the unit consists of poorly and very poorly drained mineral soils.

SLWL — The underlying substrata consists of medium and coarse sand in many locations. Small poorly drained areas are included.

SLPL — The principal soils comprising 60 to 70 percent of the unit are unnamed. They are poorly to very poorly drained. About 10 percent of the unit consists of peat bogs.

SSWL — Approximately 35 percent of the unit consists of sandy loam soils. About 15 percent is poorly to very poorly drained. Several unnamed soils occur in the unit.

LSWL — This unit consists of drumlins with a thin sand cap.

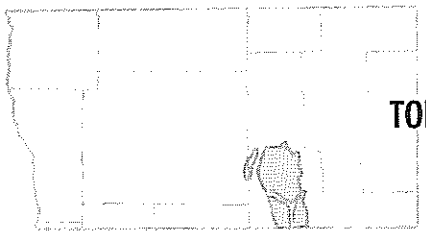
Some sulphur deficiencies may occur in the area.

Subsoils in the drumlins become somewhat restrictive (fragipan) to downward movement of moisture when dry. Heavy rains after a dry spell may result in a perched water table for several days.

Table 8. Selected features of soil landscape units within the Wadena Drumlin Area (7a) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWL	65	gently sloping drumlins	sandy loam (2-4)	sandy loam (4-20+)	4-8	well drained	< 6.0	high	low	Rockwood Blowers Peat, Paddock
LLPL	20	low nearly level to broad depressions	sandy loam (2-4)	sandy loam (4-20+)	8-12	poorly drained to very poorly drained	< 6.0	high	low	Paddock Runeberg Peat
P	10	low broad depressions	peat (1-3)	peat (3+)	12+	very poorly drained	< 6.0	low	low	Peat
SLWL	2	nearly level outwash	sandy loam (2-3)	sand and gravel (3-20+)	4-8	well drained	< 6.0	high	low	Todd
SLPL	2	level to depressional	sandy loam (2-3)	sand and gravel (3-20+)	4-8	poorly drained to very poorly drained	< 6.0	low	low	Unnamed Isanti
SSWL	1	nearly level	loamy sand (1-3)	sand and gravel (3-20+)	< 4	well drained	< 6.0	high	low	Lengby Marquette Nymore
LSWD	t*	sloping	loamy sand (3)	sandy loam (3-20+)	4-8	well drained	< 6.0	high	low	Unnamed

* = trace.



TODD DRUMLIN AREA (7B)

This region encompasses an area of approximately 179,000 acres or 3.5 percent of the Brainerd Sheet.

It is characterized by relatively prominent drumlins. With slopes about 1/3 mile long and ranging from 4 to 10 percent in steepness, the drumlins are separated by poorly drained mineral and organic soils and are oriented in an approximate north-south direction. The crest of the drumlins range from 50 to 150 feet above the low lying interdrumlin areas. They average about ½ mile wide and range from ½ to 1½ miles long.

The till in the drumlins is a limy sandy loam — often stony.

Originally the area had a mixture of pines and hardwoods. Now, about 80 percent of the area is used for farming, 20 percent is in hardwoods. The farmland is about equally divided in pasture, hay (alfalfa, bromegrass, clover), and cultivated crops (oats and corn).

Five soil landscape units occur in the Todd Drumlin Area. These are shown in table 9, along with some selected properties of each. Other features follow:

LLWL — These are the higher drumlin areas. They are most pronounced in the area near Bertha and Hewitt. Some wet areas are included because they are too narrow to delineate on the scale used.

LLPL — These are the wider interdrumlin areas and drainage ways. Many of the areas contain from 30 to 40 percent peat in patterns too small to show individually on the map.

P — A few of the large peat areas were separated. The peat areas are primarily open grass or sedge-covered bogs.

LSWL — In the drumlin area northeast of Browerville, the glacial till of the drumlins is "capped" with windblown fine to medium sand. These soils make up only a small proportion of the Todd Drumlin Area.

SSPD — In a few areas, narrow bands of outwash are shown adjacent to streams. These make up only a trace of the entire area.

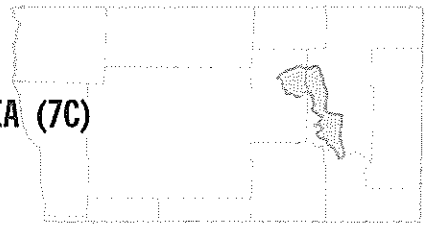
The soils of the Todd Drumlin Area have less pronounced fragipans and are not as deeply leached of carbonates as the Wadena Drumlin Area.

Table 9. Selected features of soil landscape units within the Todd Drumlin Area (7b) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWL	57	gently sloping to sloping drumlins	sandy loam (2-3)	sandy loam to loam (3-20+)	4-8	well and moderately well drained	5.8-6.3	medium	low	Rockwood Blowers Peat, Paddock
LLPL	35	interdrumlin low areas and nearly level drumlins	sandy loam (2-4)	sandy loam to loam (3-20+)	8-12	poorly to very poorly drained	5.8-6.3	medium	low	Paddock Peat Blowers
P	5	low lying depressions & drainage ways	peat (1-3)	peat (3+)	12+	very poorly drained	5.0-7.0	low	low	Peat
LSWL	3	gently sloping drumlins	sand to loamy sand (2-3)	sandy loam (3-20+)	4-8	well drained	5.8-6.3	medium	low	Langola Pomroy
SSPD	t*	low lying drainage ways	loamy sand (2-3)	sand or gravel (3+)	< 4	poorly drained	6.0-6.5	medium	low	Runeberg

* = trace.

CASS DRUMLIN AREA (7C)



This region has an area of approximately 107,000 acres or 2.1 percent of the Brainerd Sheet.

It is characterized by relatively high, well-developed drumlins in the southern portion to low drumlins in the north. The drumlins have a core of calcareous sandy loam till capped by noncalcareous brown sandy loam till. The drumlins are oriented in a north-south direction. Their width and length are variable: in some places, width is only ¼ mile, in others, ¾ mile; length ranges from ½ to 1½ miles.

The original vegetation in this area was primarily pine (white and red) mixed with hardwoods. Now about 50 percent of it is in woods, consisting primarily of second growth aspen and red oak and 50 percent in farms with about half of the farms in hay and pasture and half in cultivated crops, such as oats and some corn.

The five soil landscape units, along with some of the properties of the soils of the Cass Drumlin Area are shown in table 10. Additional special features follow:

LLWL — This unit occurs on the higher drumlins. The cap of brown sandy loam till overlying the calcareous gray till varies from 3 to 6 feet in thickness. This unit is moderately stony.

LLPL — This unit occurs on low drumlins and on poorly drained interdrumlin areas. The soils are very stony in some areas. The most common land use is for permanent pasture.

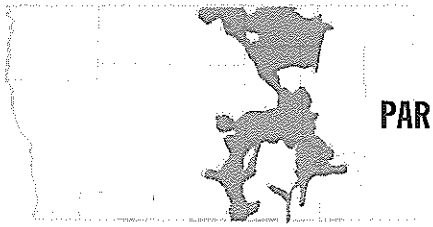
LSWL — This unit occurs on drumlins where the limy glacial till is capped by sand. These soils appear sandy, but have fair water holding capacities because of the firm underlying till. This area is not as stony as the LLWL and LLPL units.

SLWL — There are a few areas of soils formed from outwash included in the area. The substratum is comprised of stratified noncalcareous sand and gravel.

Many of the soils in the drumlins have compact fragipan horizons. When summer precipitation exceeds the soil's water holding capacity, the fragipan has the effect of impeding downward water movement. Excess lateral water movement results in seepy areas on lower slopes.

Table 10. Selected features of soil landscape units within the Cass Drumlin Area (7c) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWL	35	gently sloping and sloping drumlins	sandy loam to loam (4)	sandy loam (4-20+)	4-8	well drained	5.8-6.3	medium	low	Rockwood Brainerd
LLPL	30	low lying drainage ways and drumlins	sandy loam to loam (4)	sandy loam (4-20+)	8-12	poorly drained to wet	5.8-6.3	medium	low	Paddock Nokay Barrows
LSWL	20	gently sloping drumlins	sand or loamy sand (2-4)	sandy loam (4-20+)	4-8	well drained	5.8-6.3	medium	low	Langola Pomroy
SLWL	5	narrow elongated outwash areas	sandy loam (2-3)	sand or gravel	< 4	well drained	5.5-6.0	medium	low	Chetek
P	10	depressions and low drainage ways	peat	peat	12+	very poorly drained	< 6.0	low	low	Peat



PARK RAPIDS-STAPLES OUTWASH PLAIN (8)

This region encompasses an area of approximately 777,000 acres or 15.2 percent of the Brainerd Sheet.

The topography ranges from nearly level to gently rolling with a few strongly rolling areas. There are 69 lakes, each of more than 160 acres and totaling about 12,000 acres. Peat bogs are most prevalent towards the southeastern portion of Otter Tail County: the largest covers over 15 square miles. Sediments were deposited by melt waters from the ice sheet which formed the Henning Till Plain and the Itasca Moraine Complex. Soils range from loams to loamy sands, and are underlain by sand and gravel up to 100 feet thick or more over till. Depth to bed rock in most places is probably over 150 feet. A well west of Bluffton is 135 feet deep and one at Parkers Prairie is 230 feet deep: neither reached bedrock.

Original vegetation over much of the region was prairie grass and occasional oak openings. Some areas were forested. The four main types of forest were jack pine, white, red pine, and northern hardwoods. An estimated 25 to 35 percent is presently forested: most of it located in Becker County. Pasture accounts for 10 to 20 percent, marshes 10 to 15 percent, and 40 to 50 percent is tilled. Oats, corn, soybeans, bromegrass, and alfalfa are the main crops.

The region consists of eight soil landscape units: SLWD, SSWD, SSWL, SLWL, P, SLPD, SLPL, and LLWL. Selected features of the units are given in table 11. Additional information follows with several unnamed soils of all drainage classes occurring in all units:

SLWD — Minor areas of wet and marsh soils occur in the unit.

SSWD — Less than 10 percent of the unit consists of wet and marshy areas. An estimated 10 to 15 percent of the unit has sandy loam surface soils.

SSWL — Peat bogs and poorly drained mineral soils each make up about 5 percent of the unit; approximately 10 percent has sandy loam surface soils.

SLWL — About 5 percent each of peat and poorly drained mineral soils occur in the unit; 15 to 20 percent of the landscape unit has loamy sand surface soils.

P — Approximately 10 percent of the unit consists of poorly drained mineral soils.

SLPD — An estimated 30 percent of the unit is peat, and 10 percent is well-drained sandy loam soils.

SLPL — These areas are quite variable in composition. An estimated 10 percent consists of peat bogs, and 10 to 20 percent is fairly well drained. The principal soils are unnamed.

LLWL — This unit consists of small outliers of till.

Sulphur deficiencies may occur in all units.

Figure 4. Riding trail along the Crow Wing River, Park Rapids-Staples Outwash Plain (8). (Soil Conservation Service Photo, E. W. Cole)

Table 11. Selected features of soil landscape units within the Park Rapids-Staples Outwash Plain (8) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
SLWD	30	nearly level to gently rolling	sandy loam (2-3)	sand and gravel (3-20+)	4-8	well drained	6.1-7.2	low	medium	Dorset Estherville
SSWD	20	gently rolling to rolling	loamy sand (1-3)	sand and gravel (3-20+)	0-4	well drained	6.1-7.2	low	medium	Salida Hubbard
SSWL	15	gently rolling to rolling	loamy sand (1-3)	sand and gravel (3-20+)	0-4	well drained	< 6.0	high	low	Marquette Lengby Menahga
SLWL	15	undulating to rolling	sandy loam (2-3)	sand and gravel (3-20+)	4-8	well drained	< 6.0	high	low	Todd Lengby
P	15	level to depressional	peat (1-3)	peat (3+)	12+	very poorly drained marshy	< 6.0	low	low	Peat
SLPD	4	nearly level to depressional	sandy loam (1-3)	sand (3-20+)	4-8	very poorly drained	< 6.0	medium	low	Duelm Peat
SLPL	1	nearly level to depressional	sandy loam (2-3)	sand and gravel (3-20+)	4-8	very poorly drained	< 6.0	medium	low	Unnamed Peat, Isanti
LLWL	t*	gently rolling to rolling	sandy loam (4)	sandy loam (4-20+)	4-8	well drained	< 6.0	high	low	Nebish Beltrami

* = trace.

Figure 5. The dominant agriculture on the soils of the Lake Agassiz Lacustrine Plain is one of extensive small grains, soybeans, and sugar beets. There are large acreages of potatoes and sugar beets. Tree tracts were established by the pioneer settlers on many homesteads.

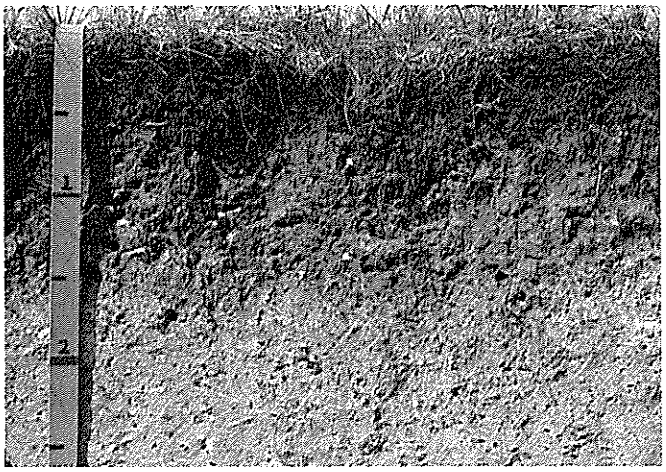


Figure 7. Barnes loam occurs extensively in landscape unit LLWD principally in the Fergus Falls (Young Gray Drift) Till Plain (2). This relatively fertile soil is used intensively for small grain and legume-grass production. (Scale is in feet.)

Figure 6. Fargo silty clay is probably the most extensive soil in landscape unit CCPD in the Agassiz Lacustrine Plain (1) and is under intensive agricultural use for small grains, sugar beets, and soybeans. (Scale is in tenths of feet.)

Figure 8. Nebish loam is the principal soil in landscape unit LLWL in the Alexandria Moraine Complex (3). While developed under forest cover, probably a third of these soils has been cleared for small grain and legume-grass hay and pasture, the remainder used for permanent pasture and forest production.

Figure 9. Autumn landscape in the Alexandria Moraine Complex (3).

Figure 11. Typical drumlin landscape in Todd Drumlin Area (7b). Stones have been largely cleared from cultivated fields and piled along fence rows or, in recent years, buried with a bulldozer.

Figure 10. Estherville sandy loam commonly occurs in landscape unit SLWD in the Detroit Lakes Pitted Outwash Plain (4). Estherville is one of the more suitable soils for sprinkler irrigation because of its moderate water holding capacity and relatively level topography.

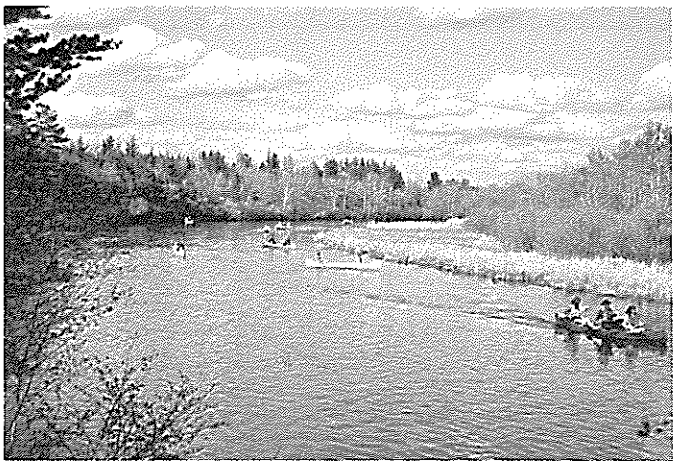


Figure 12. Canoeing on the Crow Wing River, Park Rapids-Staples Outwash Plain (8). The Crow Wing is a relatively small, year-round stream flowing through scenic areas where campsites and landings can be established.

Figure 13. Typical lakeshore development as in the Crow Wing Outwash Plain (13) or the Detroit Lakes Pitted Outwash Plain (6).

Figure 14. Typical jack pine stand on landscape unit SSWL extensive in the Crow Wing Outwash Plain (13). Jack pine is the principal forest tree on these soils: its principal use is in the pulpwood industry.

Figure 9. Autumn landscape in the Alexandria Moraine Complex (3).

Figure 11. Typical drumlin landscape in Todd Drumlin Area (7b). Stones have been largely cleared from cultivated fields and piled along fence rows or, in recent years, buried with a bulldozer.

Figure 10. Estherville sandy loam commonly occurs in landscape unit SLWD in the Detroit Lakes Pitted Outwash Plain (4). Estherville is one of the more suitable soils for sprinkler irrigation because of its moderate water holding capacity and relatively level topography.

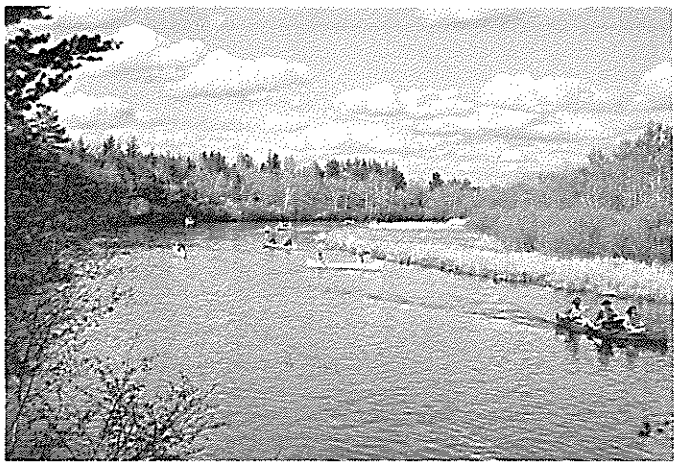


Figure 12. Canoeing on the Crow Wing River, Park Rapids-Staples Outwash Plain (8). The Crow Wing is a relatively small, year-round stream flowing through scenic areas where campsites and landings can be established.

Figure 13. Typical lakeshore development as in the Crow Wing Outwash Plain (13) or the Detroit Lakes Pitted Outwash Plain (6).

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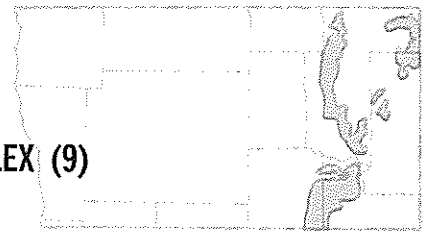


ST. CROIX MORAINE COMPLEX (9)

This region encompasses an area of approximately 296,000 acres or 5.8 percent of the Brainerd Sheet.

The St. Croix Moraine in central Minnesota was formed primarily by ice advancing from the east-northeast. The materials carried by the glacier from this source are usually noncalcareous and have a sandy loam texture. In places, this material is mixed with calcareous till which it overrode. This mixing is much more noticeable along the western borders of the moraine. In some places where the moraine overrode gravelly outwash, the soils in the moraine are developed from this outwash material. There are many small wet depressions in the moraine.

The native vegetation throughout the moraine was forest. In some places, hardwoods were most common and in others, conifers predominated. There is very little agriculture in the moraine because of the coarse soil materials and the topography.

The various units mapped in this area, along with selected properties of the soils, are shown in table 12. Additional features follow:

XLWL — This is the most common unit in the area. The underlying materials are a mixture of sand, gravel, and sandy loam glacial till. The topography is very irregular and there are numerous small poorly drained spots present.

SSWL — This unit occurs along the edges of the moraine where the ice picked up previously deposited outwash. Little of the area is used for agriculture.

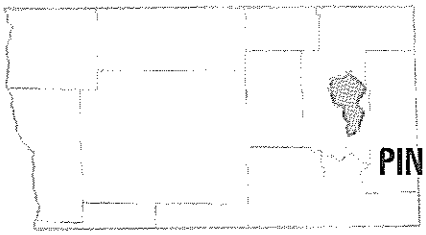
LLWL — Soils in this unit developed from brown noncalcareous sandy loam till. They occur on more level topography than the soils of the XLWL unit.

LLPL — A few areas of level soils developed from till occur within the moraine.

Table 12. Selected features of soil landscape units within the St. Croix Moraine Complex (9) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
XLWL	70	rolling to hilly moraine	sandy loam (1-3)	sandy loam sand and gravel (3-20+)	0-8	well to excessively drained	5.5-6.2	medium	low	Flak Brainerd Chetek Emmert
SSWL	10	rolling outwash	sandy loam and loamy sand (1-2)	sand and gravel (2-20+)	0-4	excessively drained	5.5-6.2	low	low	Chetek Emmert
LLWL	10	rolling moraine	sandy loam (1-3)	sandy loam (3-20+)	4-8	well drained	5.5-6.2	medium	low	Flak Brainerd
LLPL	5	low lying depressions	sandy loam (1-3)	sandy loam (3-20+)	8-12	poorly to very poorly drained	5.5-6.2	medium	low	Nokay Barrows
SLWL	t*	rolling outwash	sandy loam (2-3)	sand and gravel (3-20+)	0-4	well drained	5.5-6.2	medium	low	Chetek
P	5	low lying depressional	peat (2-3)	peat (3+)	12+	wet	> 6.0	low	low	Peat
SSPL	t*	nearly level to depressional	loamy sand to sandy loam (1-3)	sand and gravel (3+)	0-4	poorly drained	5.5-6.2	medium	low	Isanti Lino Warman
LSWL	t*	rolling till	loamy sand (1-3)	sandy loam (3+)	4-8	well drained	5.6-6.5	medium	low	Pomroy Langola

* = trace.



PINE RIVER DRUMLIN AREA (10A)

This region encompasses an area of approximately 66,000 acres or 1.3 percent of the Brainerd Sheet.

It is characterized by relatively low relief drumlins. The drumlins have only narrow areas of poorly drained interdrumlin soils, many too small to map at the scale of the accompanying map. The drumlins range from ¼ to ½ miles wide and ¾ to 1½ miles long.

The till in the drumlin area is a brown noncalcareous sandy loam which is usually compact. Water movement through the till is slow.

The native vegetation in this area was a mixture of red pine, white pine, and various hardwoods. In this area, 60 percent of the land is estimated as being in farms, the other 40 percent is in second growth hardwood forest. Of the farmland, about ½ is in pasture and ½ in crops such as oats, corn, hay (alfalfa, bromegrass, and clover).

The four soil landscape units mapped in this area are listed in table 13, along with selected features of each unit. Additional features follow:

LLWL — The moderately well-drained Brainerd soils have fragipans which deter the downward movement of water. Stones are a problem in many of the areas and must be removed before the soils can be cultivated.

LLPL — The major soil in this area is the Nokay soil. It occupies the areas between the drumlins and, at times when the drumlins are nearly level, can be found over the entire drumlin. Many areas are extremely stony.

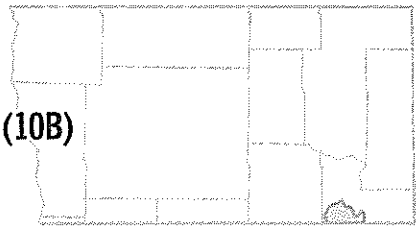
P — The areas shown as peat have about 25 percent of their area occupied by very poorly drained mineral soils.

SSWL — This unit is minor in extent and is made up of a few small areas where the soils have developed from noncalcareous outwash.

Table 13. Selected features of soil landscape units within the Pine River Drumlin Area (10a) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWL	70	gently sloping drumlins	sandy loam to loam (2-3)	sandy loam (3-20+)	4-8	well and moderately well drained	5.5-6.2	medium	low	Brainerd Flak Nokay
LLPL	23	nearly level drumlins	loam and sandy loam (2-3)	sandy loam and loam (3-20+)	8-12	poorly drained	5.5-6.2	medium	low	Nokay Barrows
P	6	broad drainage ways	peat (1-3)	peat (3+)	12+	very poorly drained	>6.0	low	low	Peat
SSWL	1	small outwash area	loamy sand (1-3)	sand and gravel (3-20+)	>4	well drained	5.5-6.2	medium	low	Menahga

DARLING DRUMLIN AREA (10B)



This region encompasses an area of approximately 36,000 acres or .7 percent of the Brainerd Sheet.

It has, in places, fairly prominent drumlins, but in other places it has the appearance of a till plain. It is primarily gently sloping with a few rolling areas along the Little Elk River. The drumlins in the area are oriented in a north-south direction. The poorly drained areas occur as broad flats as well as the interdrumlin areas.

The till is a noncalcareous brown sandy loam which is somewhat compact and has a slow permeability rate.

The native vegetation was primarily hardwoods, with some pine. Now, about 30 percent of the area is in second growth hardwoods, about 70 percent in farms, about 30 percent of the farms are in pasture. The major crops are oats, corn, and hay (bromegrass, clover, alfalfa).

The seven soil landscape units mapped in this area, along with selected properties, are shown in table 14. Other features follow:

LLWL — Near the Little Elk River, the unit resembles a moraine more than a drumlin.

LLPL — This unit is nearly level, with a predominance of somewhat poorly drained soils. Some potholes are present. The drumlins are not well defined.

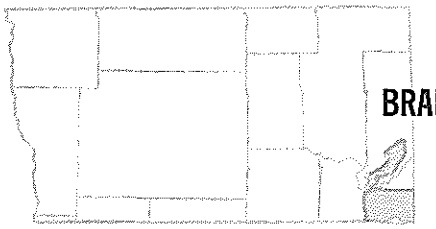
LSPL — There are some small nearly level sand-capped till areas in the eastern part of the region. The sands are primarily fine and medium and glacial till occurs 2 to 3 feet below the surface.

SSWL — This unit occurs in a narrow band between the villages of Darling and Randolph. It appears to be a poorly developed esker-like deposit.

Table 14. Selected features of soil landscape units within the Darling Drumlin Area (10b) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWL	26	gently sloping drumlins and moraines	sandy loam to loam (2-3)	sandy loam (3-20+)	4-8	well drained	5.5-6.2	medium	low	Flak Brainerd Nokay
LLPL	50	nearly level to gently sloping drumlins and till plain	loam (2-3)	sandy loam (3-20+)	8-12	somewhat poorly to very poorly drained	5.5-6.2	medium	low	Nokay Barrows Brainerd
P	12	poorly drained wet drainage ways	peat (1-3)	peat (3+)	12+	very poorly drained	> 6.0	low	low	Peat
LSPL	6	sand-capped till areas	loamy sand (2-3)	sandy loam (3-20+)	4-8	poorly and very poorly drained	5.5-6.2	medium	low	Unnamed
SSWL	4	esker-like formation	gravelly loamy sand (2-3)	stratified sand and gravel (3-20+)	> 4	well to excessively drained	5.5-6.2	low	low	Emmert Chetek
XLWL	2	drumlin with mixed parent materials	sandy loam (1-2)	sandy loam and sand and gravel mixed (2-20+)	> 8	well drained	5.5-6.2	medium	low	Brainerd Chetek
LSWL	t*	small sand capped drumlins	loamy sand (2-3)	sandy loam (3-20+)	4-8	well drained	5.5-6.2	medium	low	Pomroy

* = trace.



BRAINERD-PIERZ DRUMLIN AREA (10C)

This region encompasses an area of approximately 174,000 acres or 3.4 percent of the Brainerd Sheet.

It is characterized by relatively low drumlins with gentle slopes. The drumlins are separated by low, wet areas containing wet mineral soils and peat. Many of the interdrumlin areas were too small to show on the map. The drumlins are northeast-southwest oriented with a short axis at the center of about ¼ to ½ mile and a long axis of about 1 to 2 miles.

The till in these drumlins is brown, a sandy loam, often dense and usually stony.

The original vegetation was a mixture of red pine, white pine, and white spruce with balsam fir in the poorly drained areas. Some hardwoods were found in the area. In the southern part, about three-fourths of the land is farmed, while in the northern portions, only one-third to one-half is farmed. Where the land is not farmed, the major tree species now are aspen, birch, and some elm and oak.

The land used for farming is about one-third in pasture. The principal crops grown are oats, corn, hay (bromegrass, alfalfa, and red clover).

The five soil landscape units occurring in this area, along with some selected features, are shown in table 15. Additional features follow:

LLWL — This unit occurs on drumlins that are more sloping. The poorly drained soils between the drumlins make up about 30 percent of this unit. Scattered sand or gravel pockets make up less than 5 percent.

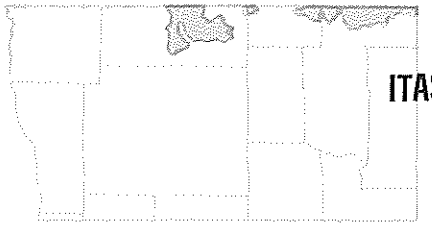
LLPL — This unit occurs in the low nearly level drumlins and includes the poorly and very poorly drained interdrumlin areas. About 20 percent of the unit is made up of areas of LLWL too small to separate.

P — This unit occurs in broad drainage ways and in old lake bottoms. About 25 percent of the unit is comprised of very poorly drained mineral soils.

LSWL — This unit is found in areas where the drumlins occur adjacent to outwash areas and where there are shallow deposits of windblown sands capping the brown till drumlins.

Table 15. Selected features of soil landscape units within the Brainerd-Pierz Drumlin Area (10c) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWL	45	gently sloping and sloping drumlins	sandy loam (2-3)	sandy loam (3-20+)	4-8	moderately well drained	5.5-6.2	medium	low	Brainerd Flak Nokay
LLPL	45	low broad drainage ways and depressions	sandy loam (2-3)	sandy loam (3-20+)	8-12	poorly drained	5.5-6.2	medium	low	Nokay Barrows Brainerd Peat
P	6	low lying depressions and drainage ways	peat (1-3)	peat (3+)	12+	very poorly drained	> 6.0	low	low	Peat Barrows
LSWL	3	sloping to gently sloping sand capped drumlins	loamy sand (2-3)	sandy loam (3-20+)	4-8	well drained	5.5-6.2	medium	low	Pomroy Langola
A	1	narrow stream bottoms	loam (2-4)	loam (4+)	4-12	poorly drained	< 6.0	variable	variable	Unnamed



ITASCA MORAINE COMPLEX (11)

This region encompasses an area of approximately 194,000 acres or 3.8 percent of the Brainerd Sheet.

The prominent Itasca Moraine Complex has rolling to steep knob and kettle topography. Small, wet potholes and peat bogs are common. There are 38 lakes, each over 160 acres in size located in this geomorphic region. The moraine consists of limy sandy loam glacial till laid down during the Cary substage of the Wisconsin Age. Pockets of sand and gravel are intermixed with the till in about 60 percent of the region. Such areas are classified as XLWL. The region includes a few small gravelly outwash areas.

Original vegetation was principally white and red pine forest. An estimated 55 to 65 percent of the region consists of cutover timberland. Pasture comprises 5 to 15 percent and marshes 5 to 10 percent of the region. Approximately 15 to 25 percent is tilled. Oats, corn, bromegrass, and alfalfa are the principal crops.

Five soil landscape units make up the Itasca Moraine Complex: XLWL, LLWL, P, SSWL, and LLPL. For selected features of the units, refer to table 16. Additional characteristics of the units follow:

XLWL — Glacial till makes up 45 to 55 percent of the unit. Intermixing of sandy and gravelly areas total 35 to 45 percent of the landscape. Wet and marshy areas occur in 5 to 15 percent.

LLWL — Poorly drained and marshy depressions make up 10 to 15 percent of the unit.

P — An estimated 5 to 15 percent of the unit consists of poorly drained mineral soils.

SSWL — Sandy loam soils make up 20 to 30 percent of the unit.

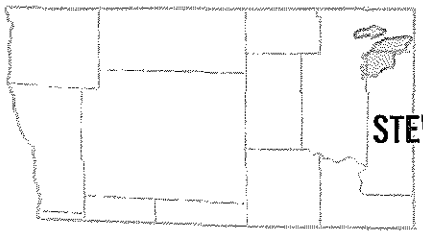
LLPL — The unit ranges from somewhat poorly drained to marshy. It occurs in a lower position than the surrounding area.

Some soils are deficient in sulphur.

Figure 15. Snowmobiling is an increasingly popular winter sport in areas such as the Itasca Moraine Complex (11).

Table 16. Selected features of soil landscape units within the Itasca Moraine Complex (11) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
XLWL	60	rolling to steep	sandy loam (2-4)	sandy loam, sand, and gravel (4-20+)	0-8	well drained	< 6.0	high	low	Nebish Marquette Todd Lengby
LLWL	30	rolling to steep	sandy loam (4)	sandy loam (4-20+)	4-8	well drained	< 6.0	high	low	Nebish
P	6	level depressional	peat (1-3)	peat (3+)	12+	marshy	< 6.0	low	low	Peat
SSWL	4	undulating to rolling	loamy sand (1-3)	sand and gravel (3-20+)	< 4	well drained	< 6.0	high	low	Marquette Lengby
LLPL	t	nearly level to depressional	sandy loam (4)	sandy loam (4-20+)	4-8	poorly drained	< 6.0	high	low	Shooks



STEWART LAKE TILL PLAIN (12)

This region encompasses an area of approximately 72,000 acres or 1.4 percent of the Brainerd Sheet.

It is characterized by a relatively low relief. There are a few areas with features resembling low drumlins, but they are not well defined. Poorly drained soils prevail in the area. The glacial material is primarily noncalcareous, brown, sandy loam till similar to that found in the Pine River drumlin area and the Brainerd-Pierz drumlin area.

There are 12 lakes, each more than 160 acres in size, located in this region.

Little of this till plain is used for agriculture. It is primarily in second growth hardwoods with aspen predominating. Some red oak and ash also occur. The region is stony and does not lend itself well to agriculture.

The four soil landscape units, with selected properties of each, are given in table 17. Additional information on the units follows:

LLWL — Many of the soils in these units are found on land forms resembling drumlins, but are not well defined physiographically. The area is quite stony. A few areas are used for pasture and hay land.

LLPL — About 20 to 30 percent of the area is covered with peat. The areas of mineral soils are usually quite stony. Only small acreages are under cultivation.

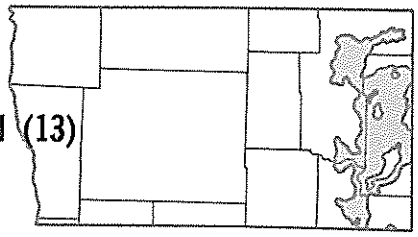
P — The peat occurs in depressions and bogs throughout the area.

XLWL — This unit comprises a few rolling areas where the underlying material is mixed outwash and sandy loam till.

Table 17. Selected features of soil landscape units within the Stewart Lake Till Plain (12) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWL	20	undulating till plain	sandy loam (2-3)	sandy loam (3-20+)	4-8	well- and moderately well-drained	5.5-6.2	medium	low	Flak Brainerd
LLPL	60	nearly level to depressional till plain	sandy loam (2-3)	sandy loam (3-20+)	8-12	poorly and very poorly drained	5.5-6.2	medium	low	Nokay Barrows Brainerd
P	10	depressions	peat (2)	peat (2+)	12+	very poorly drained	<6.0	low	low	Peat
XLWL	10	rolling kames and kame moraines	sandy loam (2-3)	sandy loam to gravel (3+)	0-8	well to excessively drained	5.5-6.2	low	low	Flak Chetek Emmert

CROW WING OUTWASH PLAIN (13)



This region encompasses an area of approximately 480,000 acres or 9.4 percent of the Brainerd Sheet.

It covers a major portion of Crow Wing County and extends west and north into the adjoining counties. Most of the topography is nearly level land, but it ranges to strongly rolling in a few areas. About 10 percent is Mississippi River outwash. A major portion is the large outwash flat reaching from Brainerd northward to Pine River and the Whitefish chain of lakes. The terrace along the Mississippi River is primarily sandy. North from Brainerd toward Pequot Lakes, the outwash appears increasingly gravelly and, in places, cobbly. A few till "islands" are found in the outwash flat. These are areas where high water table sandy soils are prominent. Peat makes up about 5 percent of the area. One of the most distinguishing features is the great number of lakes: 115, each more than 160 acres in size. One of Minnesota's best known vacation areas has developed around these lakes.

The native vegetation and much of the present day vegetation is jack pine. Some of it is harvested for pulp manufacture, and paper companies are replanting areas to jack pine and red pine.

Only scattered areas, primarily in the Pine River area, are used for agriculture.

The soil landscape units for the area, along with selected properties, are given in table 18. Additional features follow:

SSWL — This area is used almost entirely for forest production; 5 to 10 percent contains poorly drained soils.

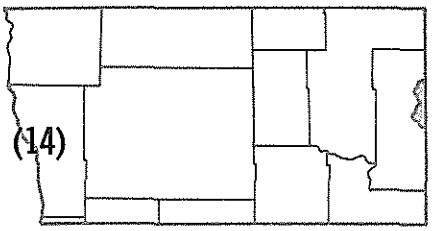
SSPL — The largest area of these high water table sandy soils is northwest and northeast of the town of Brainerd on the Mississippi River terrace. Part of this landscape unit is used for agriculture — windbreaks control erosion.

SLWL — These soils are most prominent in the area around Pine River where there is some agriculture. These are some of the highest producing soils for jack pine in central Minnesota.

Table 18. Selected features of soil landscape units within the Crow Wing Outwash Plain (13) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
SSWL	45	nearly level to rolling	sand and loamy sand (1-3)	sand and gravel (3+)	0-4	well to excessively drained	5.5-6.2	medium	low	Menahga Zimmerman
SSPL	20	nearly level or depressional	loamy sand (1-3)	sand and gravel (3+)	0-4	poorly drained	5.5-6.2	medium	low	Lino
P	5	depressional	peat (1-3)	peat (3+)	12+	very poorly drained	< 6.0	low	low	Peat
SSWD	15	nearly level to undulating	loamy sand (2-3)	sand (3-20+)	0-4	well drained	5.8-6.5	medium	low	Hubbard
SSPD	5	nearly level to depressional	loamy sand (2-3)	sand (3+)	0-4	poorly drained	5.8-6.5	medium	low	Unnamed
SLWL	10	nearly level	sandy loam (2-3)	sand and gravel (3-20+)	4-8	well drained	5.5-6.2	medium	low	Chetek Onamia

MILLE LACS MORAINE COMPLEX (14)



This region encompasses an area of approximately 10,000 acres or .2 percent of the Brainerd Sheet.

The Mille Lacs Moraine covers only a small portion of this map sheet — most of it is on the map sheet to the east. The materials are primarily red-colored clayey till. The topography is rolling to hilly, with a few nearly level areas. Along the west edge of the moraine, the materials are mixed with brown, sandy loam till. There are some lakes. In one area, open pit iron mines have completely obliterated the original material: this area is mapped as Mines and Dumps.

Most of the area supports a growth of climax hardwoods, including maple, basswood, and oak. A few scattered areas are used for agriculture, but not enough to give a cropping pattern.

The soil landscape units, along with selected properties, are listed in table 19. Other features follow:

CLWL — These soils, because of their fine texture, have relatively slow infiltration rates. They cause problems when used for roads and must be compacted well to eliminate the possibility of frost damage in the spring.

XLWL and LLWL — These units contain glacial material deposited in the till of the Brainerd-Pierz drumlin area and its outwash. The material was moved and redeposited by the glacier carrying the till of the Mille Lacs Moraine.

Table 19. Selected features of soil landscape units within the Mille Lacs Moraine (14) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Major soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
CLWL	70	rolling to steep terminal moraine	loam and silt loam (1-2)	silty clay (2-20+)	8-12	well drained	5.5-6.2	medium	medium	Hibbing Zim
XLWL	10	rolling moraine	sandy loam (2-3)	sandy loam, sand, and gravel (3+)	0-8	well drained	5.5-6.2	high	low	Flak Chetek
LLWL	15	rolling moraine	sandy loam (2-3)	sandy loam (3-20+)	4-8	well drained	5.5-6.2	medium	low	Flak Brainerd
P	5	depressional	peat (2-3)	peat (3+)	12+	very poorly drained	> 6.0	low	low	Peat

CLIMATE OF THE BRAINERD SHEET AREA

The climate of any land area is an extremely important component of the resources. Climate affects, to some degree, most of man's activities.

Some of the general climate characteristics of this area are given in the series of eight diagrams. The area has a typical continental climate with wide extremes in temperature from summer to winter. Total annual precipitation ranges from 19 inches per year in the northwestern part to 26 inches in the eastern portions (see figure 16). Nearly half of the preciptation falls during the summer (see figure 17).

Snowfall is an important component of annual precipitation, particularly in the northeastern part of this Sheet. Figures 18 and 19 show that this area normally has more than 80 days with 3 inches of snow on the ground and 60 to 80 days with over 6 inches.

The average date of the last occurrence of frost ranges from May 22 in the north to May 12 on the southern border of this area (see figure 20). Corn and soybeans are grown throughout the area where agricultural soils occur, but early maturing varieties must be used. Fall frost normally occurs September 16 in the east and 10 days later, September 26, in the west and southwest (see figure 21).

Summer weather is typically one of warm days and cool nights. Figures 22 and 23 show that the warmest temperatures in July average from 81° F. to 85° F., while night air cools to the upper 50's. Summer and fall weather is usually very comfortable for outdoor recreational activities.

One of the important aspects of the climate is the temperature and moisture range which occurs within the soil and within the air zone several feet above ground. The nature of the soil, local topography, direction of slope, and vegetation, all interact with the general patterns of air and moisture flow to modify long term temperature averages. For example, drouth conditions are much more common on the Park Rapids-Staples Outwash Plain than around Moorhead in the Agassiz Lake Plain, although the Moorhead area normally has 6 inches less rainfall per year. This is because the outwash plain soils are sandy and have a relatively low water holding capacity, while lacustrine soils are silty or clayey with a high water holding capacity.

Surprising differences in temperatures and wind speed can result from differences in location of lake residences. Usually, lake homes or cabins on the south and east shore of a lake will have a cooler, more windy site than one located on the west or north because prevailing winds are from the northwest. Shelter from trees or hills also is an important factor.

Additional information about the climate of the area is available from references listed at the end of this report.

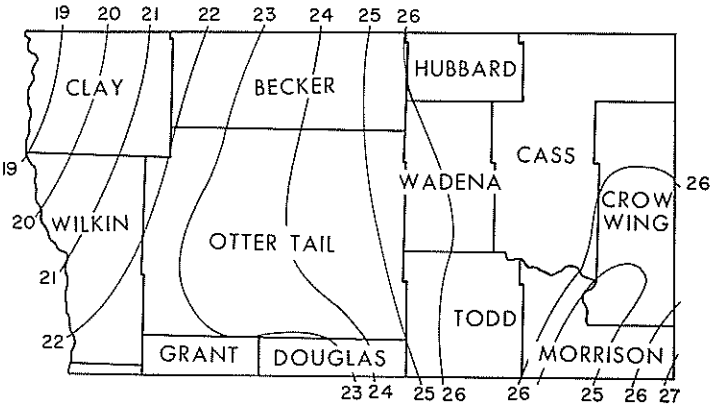


Figure 16. Annual normal precipitation in inches, 1931-60, Brainerd Sheet. (Adapted from Minn. Tech. Bull. 254, 1967)

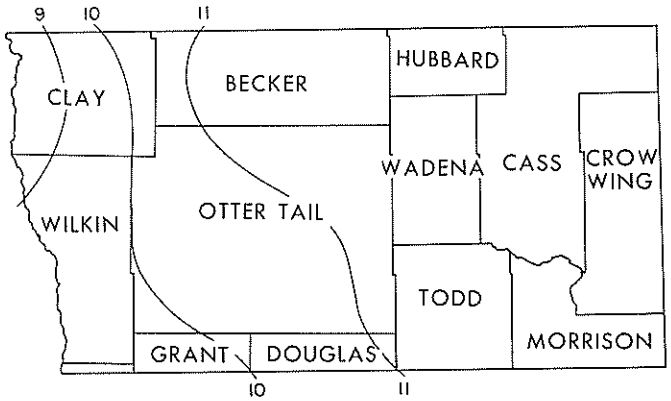


Figure 17. Summer (June, July, and August) normal precipitation in inches, 1931-60, Brainerd Sheet. (Adapted from Minn. Tech. Bull. 254, 1967)

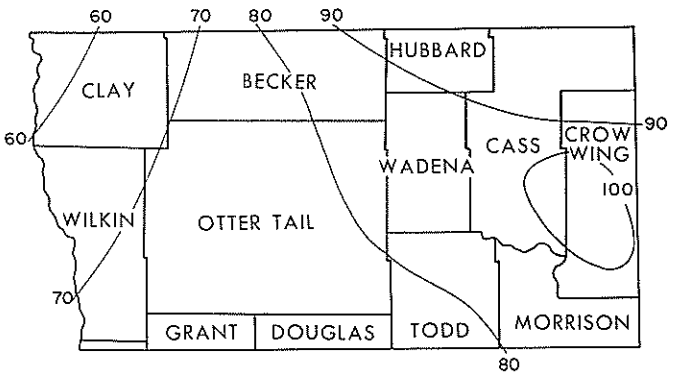


Figure 18. Average number of days per year with more than 3 inches of snow on ground, 1931-60, Brainerd Sheet. (Adapted from Minn. Climatological Data, U.S. Dept. of Commerce)

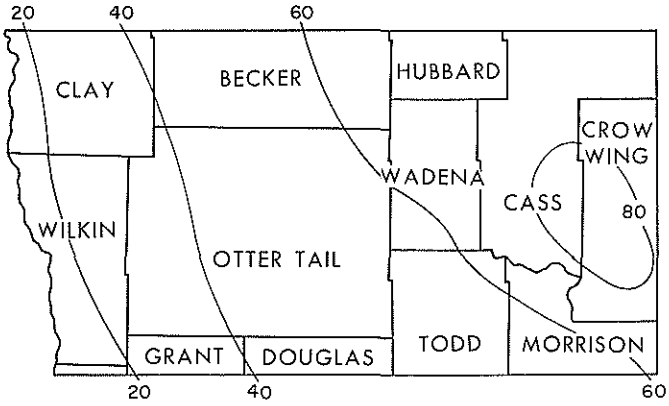


Figure 19. Average number of days per year with more than 6 inches of snow on ground, 1931-60, Brainerd Sheet. (Adapted from Minn. Climatological Data, U.S. Dept. of Commerce)

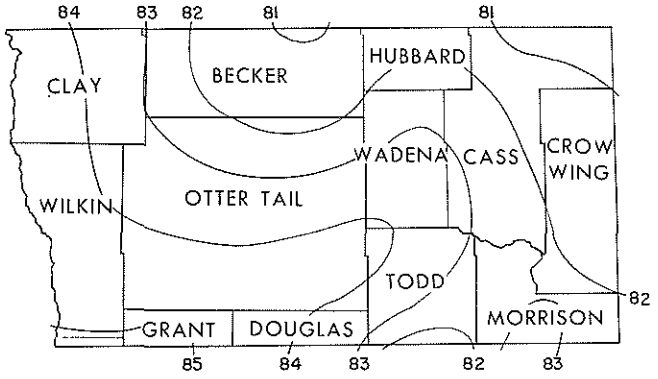


Figure 22. Average daily maximum temperatures during July, 1931-60, Brainerd Sheet. (Adapted from Minn. Tech. Bull. 248, 1965)

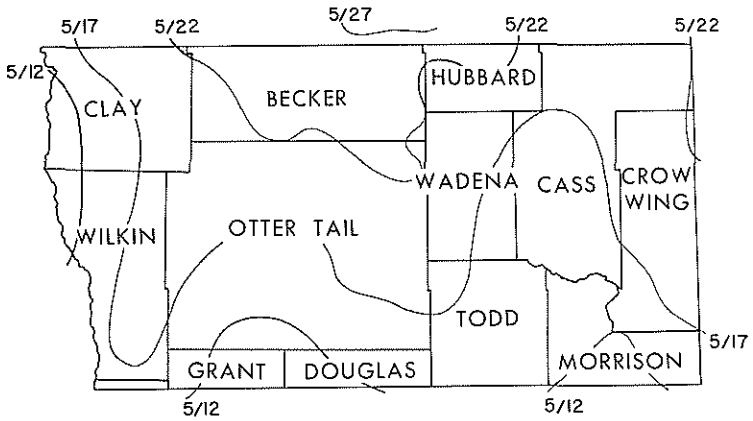


Figure 20. Average date of last occurrence of 32° F. or lower in the spring, Brainerd Sheet. (Adapted from Minn. Tech. Bull. 243, 1963)

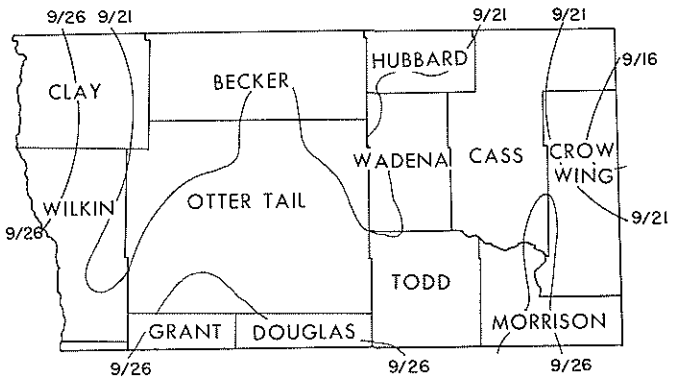


Figure 21. Average date of first occurrence of 32° F. or lower in the fall, Brainerd Sheet. (Adapted from Minn. Tech. Bull. 243, 1963)

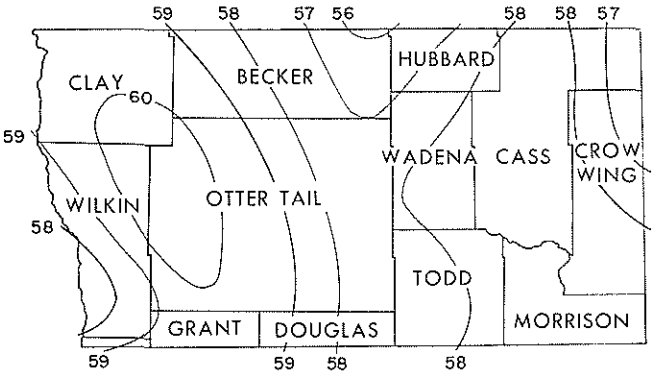


Figure 23. Average daily minimum temperatures during July, 1931-60, Brainerd Sheet. (Adapted from Minn. Tech. Bull. 248, 1965)

INFORMATION FOR THE ENGINEER

Because of the general nature of soil landscape units, which include several major and minor soil series, it is impossible to give specific engineering data such as engineering classification, particle size, liquid limit, plasticity index, available water holding capacity, percolation rates, shrink-swell potential, and corrosivity. These can be obtained from onsite investigation. Table 20 gives an approximate range in the AASHO and Unified classification of materials in the respective soil landscape units.

Engineers may find this map useful to locate sources of sand and gravel or large peat areas which could be avoided in road location. Any landscape unit with clay in it will probably have a high shrink-swell potential.

Prime sources of sand and gravel will be found in the Detroit Lakes Pitted Outwash Plain, Park Rapids-Staples Outwash Plain, and Crow Wing Outwash Plain. Within the Alexandria Moraine Complex, St. Croix Moraine Complex, Itasca Moraine Complex, and Mille Lacs Moraine, sand and gravel is found in kames and eskers or smaller pockets especially in landscape units XLWL and XLWD. The eastern side of the Agassiz Lacustrine Plain has numerous old lake beaches which are important sources of sand and gravel. The drumlin areas and till plains do not have large supplies of sand and gravel. Small outwash areas, kames, and eskers included within these drumlin areas and till plains may yield small supplies.

Bedrock often is used to supplement sand and gravel in areas of short supply. However, bedrock in the Brainerd Sheet normally lies from 80 to more than 400 feet below the surface. Granite crops out in only two spots: a few miles northeast of Staples in Cass County and near Freedhem in east central Morrison County.

Table 20. Approximate engineering classification of materials at the surface and at 5 feet in the soil landscape units delineated in the Brainerd Sheet

Soil landscape unit	AASHO[1]		Unified[2]	
	Surface	5 feet+	Surface	5 feet+
SSWD	A-2	A1,A2,A3	SP,SP-SM,SM	SP,SP-SM,SM,GP
SSPD	A-2	A1,A2,A3	SP,SP-SM,SM	SP,SP-SM,SM,GP
SSWL	A-2	A1,A2,A3	SP,SP-SM,SM	SP,SP-SM,SM,GP
SSPL	A-2	A1,A2,A3	SP,SP-SM,SM	SP,SP-SM,SM,GP
SLWD	A2,A4,A6	A1,A2,A3	SM,SM-SC,ML,ML-CL	SP,SP-SM,SM,GP
SLPD	A2,A4,A6	A1,A2,A3	SM,SM-SC,ML,ML-CL	SP,SP-SM,SM,GP
SLWL	A2,A4,A6	A1,A2,A3	SM,SM-SC,ML,ML-CL	SP,SP-SM,SM,GP
SLPL	A2,A4,A6	A1,A2,A3	SM,SM-SC,ML,ML-CL	SP,SP-SM,SM,GP
LSWD	A2	A2,A4	SP,SP-SM,SM	SM,SC,SM-SC,ML
LSWL	A2	A2,A4	SP,SP-SM,SM	SM,SC,SM-SC,ML
LSPL	A2	A2,A4	SP,SP-SM,SM	SM,SC,SM-SC,ML
LLWD	A4,A6,A7	A4,A6,A7	ML,ML-CL,CL[3]	CL,ML-CL
LLPD	A4,A6,A7	A4,A6,A7	ML-CL,CL[3]	CL,ML-CL,MH-CH
LLWL	A2,A4	A2,A4,A6	SM,ML	CL,SM,SM-SC
CLPD	A2,A4,A6	A6,A7	SM,ML-CL[3]	CL,CH
CLWL	A4,A6,A7	A6,A7	SC,ML,CL,ML-CL,CH	CL,ML-CL,MH-CH
CLPL	A4,A6,A7	A6,A7	ML-CL,CL	CL
CCWD	A7	A7	MH,CH,MH-CH[3]	CH
CCPD	A7	A6,A7	MH,CH[3]	CH,CL
XLWD	A2,A4	A1,A2,A3,A4	SP,SP-SM,SM,ML	SP,SP-SM,SM,ML,ML-CL,CL
XLWL	A2,A4	A1,A2,A3,A4	SP,SP-SM,SM,ML	SP,SP-SM,SM,ML,ML-CL,CL
YLWD	A4,A6,A7	A4,A6,A7	ML,ML-CL-CL	ML,ML-CL, CL
P	A8	A8	Pt	Pt
A	Variable	Variable	Variable	Variable

[1] American Association of State Highway Officials. Standard Specification for Highway Materials and Methods of Sampling and Testing. 1961.

[2] Waterways Experiment Station, Corps of Engineers. The Unified Soil Classification System Tech. Memo. 3-357, Vol. 2. 1953.

[3] The surface 1 to 2 feet of these soil landscape units has considerable organic matter. The Unified Classification is OL or OH. This material should be removed and stockpiled for use as topsoil on cuts and embankments.

APPENDIX A

Short Descriptions of Soil Series Classified at the Subgroup Category*

Alluvial soils, undifferentiated — Consists of recent alluvium, of variable textures, occurring in poorly drained narrow flood plains.

Arvilla — Dark-colored medium and coarse sandy loams 14 to 24 inches thick over coarse sand and gravel. (Udic Haploboroll)

Barnes — Dark colored loams 16 to 20 inches thick over calcareous loam till. (Udic Haploboroll)

Barrows — Dark-colored, poorly to very poorly drained sandy loams over noncalcareous sandy loam till. Frequently stony. (Mollic Haplaquept)

Bearden — Dark-colored, alkaline silt loams 3 to 6 feet or more deep over lacustrine clay. (Aeric Calciaquoll)

Beltrami — Light-colored, moderately well-drained, medium acid sandy loams with sandy clay loam subsoils. Limy sandy loam till occurs below 28 to 50 inches. (Aquic Eutroboralf)

Benoit — Dark-colored, poorly drained akaline loams and sandy loams 14 to 24 inches thick over coarse sand and gravel. (Typic Calciaquoll)

Biscay — Dark-colored, poorly drained, alkaline loams and silty clay loams 24 to 36 inches thick over medium sand and gravel. (Typic Haplaquoll)

* Soil series classified at the subgroup category in the Soil Classification System (revised).

Blowers — Light-colored, medium acid sandy loam surfaces and sandy clay loam subsoils 12 to 18 inches thick. Subsoils, when dry, restrict downward movement of water (fragipan). Calcareous sandy loam till underlies below 30 to 40 inches. These soils are moderately well-drained. (Aquic Fragiboralf)

Blue Earth — High in organic content to depths of 24 inches over lake-laid silts and silty clay loams; calcareous throughout. (Cumulic Haplaquoll)

Bluffton — Very poorly drained, light-colored medium acid loams. Subsoils are clay loams underlain by limy, sandy loam till below 18 to 24 inches. (Mollic Haplaquept)

Borup — Dark-colored, poorly drained, alkaline silty clay loams 24 to 36 inches thick over fine and very fine sand. (Typic Calciaquoll)

Brainerd — Light-colored, moderately well-drained sandy loams over a somewhat cemented sandy loam subsoil (fragipan) over noncalcareous sandy loam till. Frequently stony. (Aquic Fragiochrept)

Buse — Dark-colored, slightly calcareous, well-drained soils 4 to 10 inches deep over limy loam till. In eroded portions of cultivated fields, limy till is usually mixed with the surface. (Udorthentic Haploboroll)

Chetek — Moderately dark-colored, well to excessively drained sandy loams over sandy clay loam over noncalcareous sand and gravel. (Typic Eutroboralf)

Colvin — Poorly drained, dark-colored alkaline silty clay loams on lacustrine silts. Silts are underlain by clays at 3 to 6 feet or more. (Typic Calciaquoll)

Dalbo — Moderately well-drained, dark-colored, medium acid silt loam soils; subsoils are silty clay loams, underlain by calcareous lacustrine silts and clays at 20 to 30 inches. (Aquic Eutroboralf)

Dorset — Moderately dark-colored, medium acid, well-drained sandy loams with sandy clay loam subsoils underlain by sand and gravel at 24 to 36 inches. Lime is reached at 5 to 6 feet. Surface and subsoils contain some cobble. (Boralfic Argiboroll)

Duelm — Dark-colored, somewhat poorly drained, medium acid sandy loam soils over medium sand at 18 to 24 inches. Sands are limy below 4 to 5 feet. (Aquic Haploboroll)

Emmert — Light-colored, excessively drained loamy sands or gravelly loamy sands over noncalcareous materials of boulders, cobblestones, gravel, and sand. (Typic Udorthent)

Estherville — Well-drained, dark-colored, slightly acid sandy loams with sandy clay loam subsoils with limy coarse sand and gravel below 14 to 24 inches. (Typic Hapludoll)

Fargo — Dark-colored, poorly drained silty clays underlain by limy lacustrine clays below 14 to 24 inches. (Vertic Haplaquoll)

Flak — Light-colored, well-drained sandy loams with sandy clay loam subsoils over sandy loam to sandy clay loam till. Frequently stony. (Typic Fragiochrept)

Flom — Poorly drained, dark-colored silty clay loams 18 to 28 inches thick over limy clay loam till. (Typic Haplaquoll)

Fossum — Dark-colored, poorly drained, calcareous fine sandy loams 18 to 24 inches thick over fine sands. The material is clayey below 4 to 7 feet. (Typic Haplaquoll)

Glyndon — Dark-colored, somewhat poorly drained, calcareous silt loams, underlain at 24 to 36 inches by fine and very fine sand. Sands rest on lacustrine clays below 4 to 7 feet. (Aeric Calciaquoll)

Gonvick — Moderately dark-colored, moderately well-drained, slightly acid sandy loams. Subsoils are sandy clay loams 8 to 16 inches thick underlain by calcareous sandy loam till at 20 to 30 inches. (Aquic Argiboroll)

Hantho — Dark - colored, moderately well-drained silt loams 18 to 24 inches thick over limy silts. Loam till occurs below 3 to 6 feet. (Pachic Udic Haploboroll)

Hegne — Dark-colored, poorly drained calcareous silty clays, 6 to 12 inches thick over lacustrine clay. (Typic Calciaquoll)

Hibbing — Light-colored, moderately well to well-drained silt loams to silty clay loams with silty clay subsoils over calcareous silty clay till. (Typic Eutroboralf)

Hubbard — Dark colored, well-drained, slightly acid loamy sands 14 to 20 inches thick over fine and medium sand. Limy sands occur below 4 to 6 feet. (Udic Haploboroll)

Isanti — Very poorly drained, moderately dark-colored, medium acid sandy loams or loamy sands with loamy sand subsoils. Fine and medium sands occur below 14 to 20 inches. Sand is limy below 4 to 6 feet. (Typic Haplaquoll)

Kinghurst — Light-colored, well-drained, medium acid loamy fine sands 10 to 15 inches thick. Loose, fine sand subsoils overlie sandy loam till at 30 to 40 inches. Till is limy below 40 to 60 inches. (Arenic Eutroboralf)

LaMoure — Dark-colored, poorly drained, silty clay loams on alluvial bottoms subject to occasional overflows. (Cumulic Haplaquoll)

Langola — Moderately dark-colored, well to moderately well-drained loamy sands over firm, sandy loam till. (Udic Haploboroll)

Lengby — Light-colored, well-drained, medium acid sandy loams with sandy clay loam subsoils over fine and medium sand at 18 to 24 inches. Sands are limy below 25 to 40 inches. (Typic Eutroboralf)

Lino — Moderately dark-colored, somewhat poorly drained loamy sands over medium or fine sand. (Aquic Udipsamment)

Marquette — Light-colored, medium acid, well-drained loamy sand or gravelly loamy sand surfaces and gravelly sandy loam subsoils. Limy sand and gravel underlie at 14 to 20 inches. (Typic Eutroboralf)

McIntosh — Dark-colored, moderately well-drained, calcareous silt loams 6 to 12 inches thick over calcareous lacustrine silts. Limy loam till occurs below 20 to 40 inches. (Aeric Calciaquoll)

Menahga — Light-colored, well-drained, medium acid loamy fine sands or fine sands 4 to 8 inches thick over fine sand. Sands are limy below 4 to 6 feet. (Typic Udipsamment)

Nebish — Light-colored, well-drained, medium acid loams and sandy loams with silty clay loam to sandy clay loam subsoils. Limy loam to sandy loam till underlies at 24 to 40 inches. (Typic Eutroboralf)

Nokay — Moderately dark-colored, somewhat poorly drained or poorly drained sandy loam over brown, acid, sandy loam glacial till. (Aeric Fragiaqualf)

Nokuaw — Moderately dark-colored, well-drained slightly acid loams with clay loam subsoils. Limy loam till underlies at 20 to 36 inches. (Typic Argiboroll)

Nutley — Dark-colored, moderately well-drained clayey soils underlain by limy, clayey till at 16 to 24 inches. (Udertic Haploboroll)

Nymore — Moderately dark-colored, well-drained medium acid loamy sands 6 to18 inches thick over fine and medium sand. Limy sand occurs below 4 to 6 feet. (Typic Udipsamment)

Onamia — Moderately dark-colored well-drained loams or sandy loams over sandy loam to clay loam subsoils. At 24 to 40 inches, the substratum is acid stratified sand and gravel. (Typic Eutroboralf)

Paddock — Light-colored, somewhat poorly drained, medium acid sandy loam soils. Subsoils are sandy clay loams with slight restriction (fragipan) to downward movement of water. Soils are underlain by limy, sandy loam till below 30 to 40 inches. (Aeric Fragiaqualf)

Parnell — Dark-colored, very poorly drained silty clay loams underlain by limy clay loam till at 24 to 34 inches. (Typic Argiaquoll)

Peat — Wet, organic soils 12 to over 40 inches thick. In western part of the sheet, they are neutral to calcareous. In eastern portion, they are acid.

Pomeroy — Light-colored, moderately well-drained and well-drained loamy sands to 18 to 42 inches overlying an acid, sandy loam, firm glacial till. (Typic Fragiochrept)

Rauville — Dark-colored, very poorly drained, limy silty clay loams developed on alluvium. (Cumulic Haplaquoll)

Rocksbury — Dark-colored, silty clay loams underlain by calcareous waterworked clayey till. (Typic Haplaquoll)

Rockwell — Dark-colored, poorly drained calcareous loam or sandy loam 10 to 20 inches thick over loamy sand. Calcareous clayey substrata underlie at 30 to 40 inches. (Typic Calciaquoll)

Rockwood — Light-colored, well-drained, medium acic sandy loams over sandy clay loam subsoils with slightly restricted (fragipan) downward movement of moisture. Below the subsoil at 30 to 40 inches is limy, sandy loam till. (Typic Fragiboralf)

Rothsay — Dark-colored, well drained silt loams 16 to 20 inches thick over limy silts. Till underlies at 3 to 6 feet. (Udic Haploboroll)

Runeberg — Very poorly drained, light-colored, medium acid sandy loams. Subsoils are sandy clay loams over limy sandy loam at 25 to 35 inches. (Typic Haplaquept)

Salida — Dark-colored, well-drained loamy sands or gravelly loamy sands. Subsoils are gravelly sandy loams underlain by calcareous coarse sand and gravel at 12 to 18 inches. (Entic Haplaquept)

Shooks — Somewhat poorly drained, light-colored, medium acid sandy loams. Subsoils are sandy clay loams over limy sandy loam till at 26 to 46 inches. (Typic Ochraqualf)

Sioux — Dark-colored, well-drained loamy sands or gravelly loamy sands. Limy coarse sand and gravel underlies at 10 to 20 inches. (Udorthentic Haploboroll)

Svea — Dark-colored, moderately well-drained loams 18 to 24 inches thick over limy loam till. (Pacific Udic Haploboroll)

Talcot — Wet, dark-colored, calcareous silty clay loams 30 to 48 inches over limy sand and gravel. (Typic Haplaquoll)

Todd — Light-colored, well-drained, medium acid sandy loams with sandy clay loam subsoils over limy sand and gravel below 16 to 24 inches. (Typic Eutroboralf)

Wadena — Dark-colored, well-drained slightly acid loams, 2 to 3 feet thick over limy sand and gravel. (Typic Hapludoll)

Warman — Light-colored, poorly and very poorly drained loams to sandy loams underlain at 24 to 42 inches by acid sand and gravel. (Mollic Haplaquept)

Waukon — Moderately dark-colored, well-drained, slightly acid sandy loams with sandy clay loam subsoils 8 to 16 inches thick. Limy sandy loam till underlies at 24 to 36 inches. (Mollic Eutroboralf)

Winger — Poorly drained, dark-colored calcareous silty clay loams 6 to 12 inches thick over limy silt. Till underlies below 20 to 40 inches. (Typic Calciaquoll)

Zell — Dark-colored, well-drained silt loams 4 to 10 inches thick over calcareous silts. Cultivation has, in places, mixed the limy silts with the surface. Loam till occurs below 3 to 6 feet. (Udorthentic Haploboroll)

Zim — Light-colored, somewhat poorly drained silt loams over silty clay loam subsoils over clay loam, silty clay or clay glacial till which is calcareous at about 4 feet. (Typic Ochraqualf)

Zimmerman — Light-colored, excessively drained loamy fine sands or fine sands over acid fine sand and medium sand. (Alfic Udipsamment)

APPENDIX B

Percent of area within counties, or parts of counties, in the Brainerd Sheet having detailed soil surveys as of December 1968.

Becker	35
Cass	2
Clay	50
Crow Wing	22*
Douglas	100
Grant	35
Hubbard	3
Morrison	13
Otter Tail	22
Todd	4
Traverse	50
Wadena	45
Wilkin	53

* Balance of Crow Wing has been mapped on a reconnaissance scale (2 inches to mile).

GLOSSARY

Calcareous — Material having a high percentage of lime carbonate.

Drift — (glacial drift) — Any deposit in a glaciated area originating as a result of glaciation.

Drumlin — A streamlined (cigar-shaped) hill of glacial drift with the long axis parallel to the direction of the flow of the glacier.

Esker — A ridge of sand and gravel deposited by a subglacial stream flowing in an ice tunnel.

Fragipan — A subsoil layer, somewhat compacted or cemented, which restricts downward movement of water.

Ground moraine — Glacial debris consisting chiefly of unsorted material that occurs in wide areas and has a gently irregular surface. The debris is deposited underneath and at the margin of a glacier during the active recession of the ice sheet.

Kame — A rounded hill or oblong ridge of glacial origin composed of gravel and sand.

Knob and kettle — Topography designation signified by extreme pitting. This results in a series of knolls and associated basin.

Lacustrine — Deposits formed on the bottom of lakes.

Limy — See calcareous.

Melt water — The water which flows on, in, or out of a glacier.

Moraine — Unconsolidated rock and mineral debris deposited by glacial ice. It commonly consists of a heterogeneous mass of unsorted material, but that deposited by glacial melt water is sorted. See also ground moraine and terminal moraine.

Natural drainage — The conditions 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. Six classes of natural drainage are recognized in this report.

Excessively drained soils are commonly very porous and rapidly permeable (sandy and gravelly) and have a low moisture-storage capacity.

Well-drained soils are nearly free from mottling and are commonly of intermediate texture.

Moderately well-drained soils commonly have a moderately and slowly permeable layer in or immediately beneath the rooting zone. They have uniform color in the upper rooting zone and are mottled below 16 to 20 inches. Somewhat poorly drained soils are wet for significant periods, and are commonly mottled below a depth of 6 to 16 inches.

Poorly drained soils are wet for longer periods. They are dark gray or black and are generally mottled within a depth of 18 inches. In some soils, mottling may be absent or nearly absent.

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 rooting zone below the surface soil.

Outwash plain — A plain formed by deposition of sorted and stratified material by glacial melt waters.

Peat — A dark brown or black residuum produced by the partial decay of plants growing in wet places.

Permeability — The ability of the soil to transmit air or water.

Pitted outwash plain — A plain composed of glacial sand and gravel and containing small pits left by the melting of enclosed ice blocks.

Reaction — The degree of acidity or alkalinity of soil expressed in pH values or in words as follows:

	pH
Extremely acid	below 4.5
Very strongly acid	4.5-5.0
Strongly acid	5.1-5.5
Medium acid	5.6-6.0
Slightly acid	6.1-6.5
Neutral	6.6-7.3
Mildly alkaline	7.4-7.8
Moderately alkaline	7.9-8.4
Strongly alkaline	8.5-9.0
Very strongly alkaline	9.1 and higher

Relief — In geology, the difference in height from the lowest parts to the highest parts of an area.

Subsoil — Roughly, the part of the soil profile between the subsurface and the substratum.

Substratum — A layer beneath the subsoil consisting of material from which soils were formed, or frequently of dissimilar materials.

Subsurface — Soil layer immediately below the surface soil or plow layer ranging from 6 to 12 inches thick.

Surface soil — Ordinarily the plow layer or the surface 5 to 12 inches.

Terrace (geological) — An old sandy and gravelly alluvial plain, ordinarily level or nearly level bordering a river. They are seldom subject to overflow.

Texture, soil — The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportion of fine particles as related to the three classes used in this report, follow:

S — sand and loamy sand (also includes gravel).

L — sandy loam, loam, silt loam, silt, sandy clay loam, and clay loam.

C — silty clay loam, sandy clay, silty clay, and clay.

Terminal moraine — Glacial debris heaped in the form of a belt or zone of hills and basins at the terminus or margin of a glacier. It marks the maximum extent of the ice during a major advance.

Till — Unstratified and unsorted glacial drift deposited directly by a glacier.

Till plain — See ground moraine.

SELECTED REFERENCES AND SOURCES OF ADDITIONAL INFORMATION OF PHYSICAL RESOURCES OF THE BRAINERD SHEET — MINNESOTA SOIL ATLAS

Climate

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