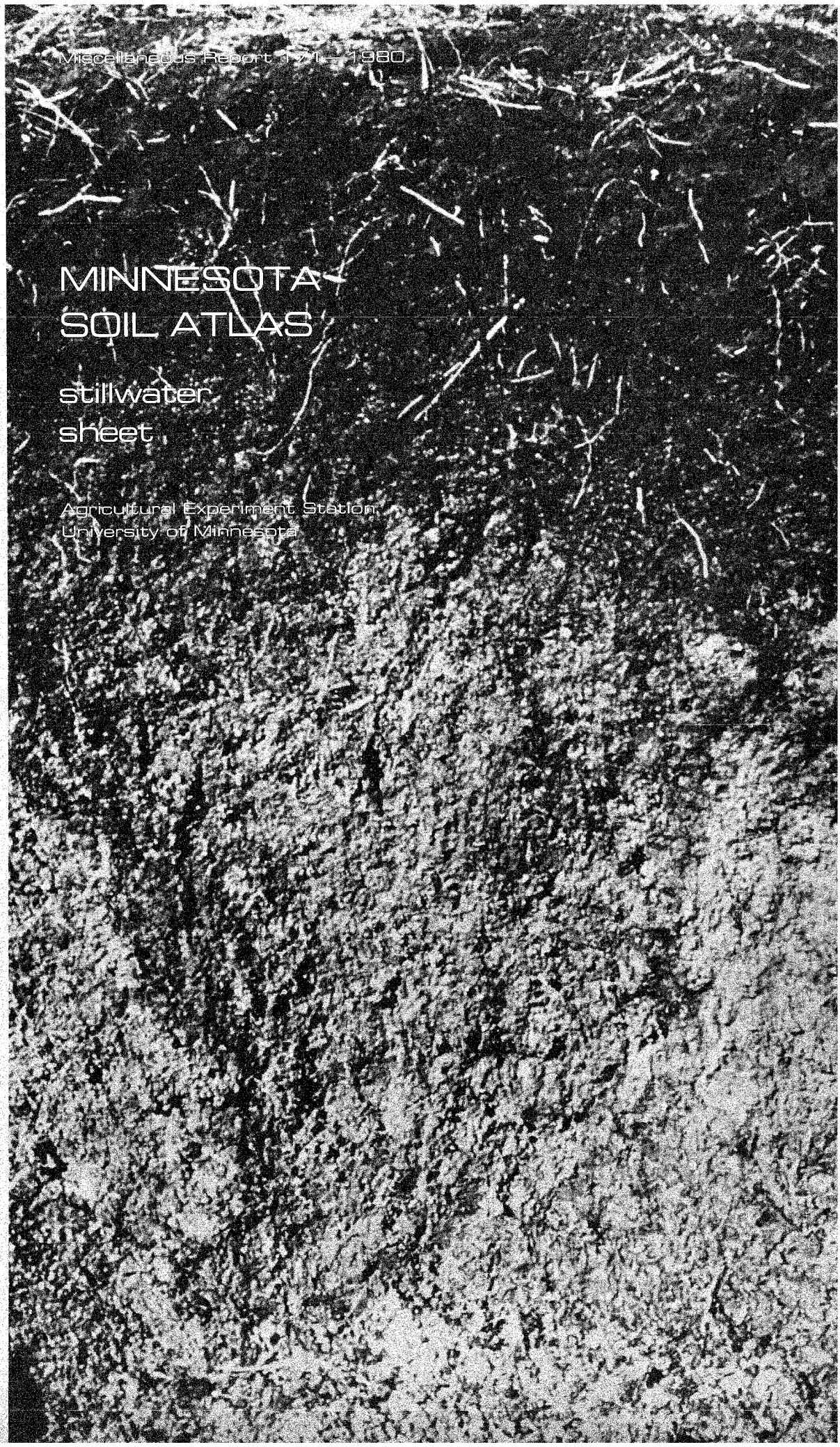
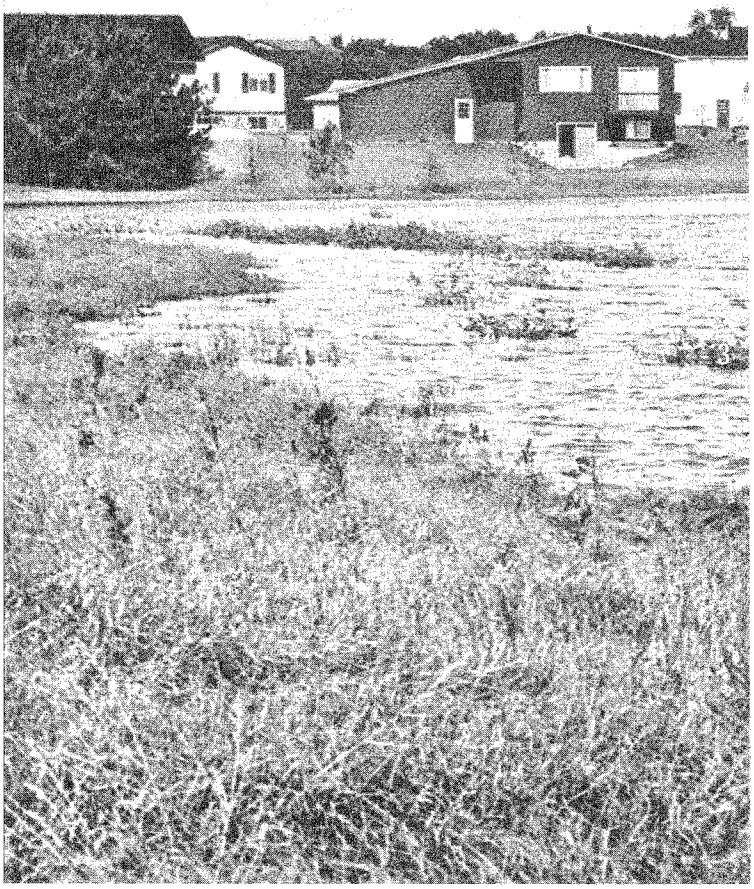
Miscellaneous Report 171 — 1980

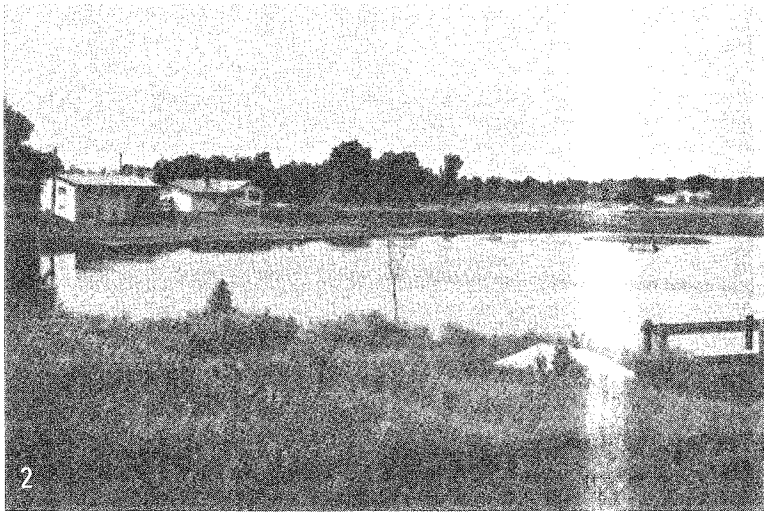


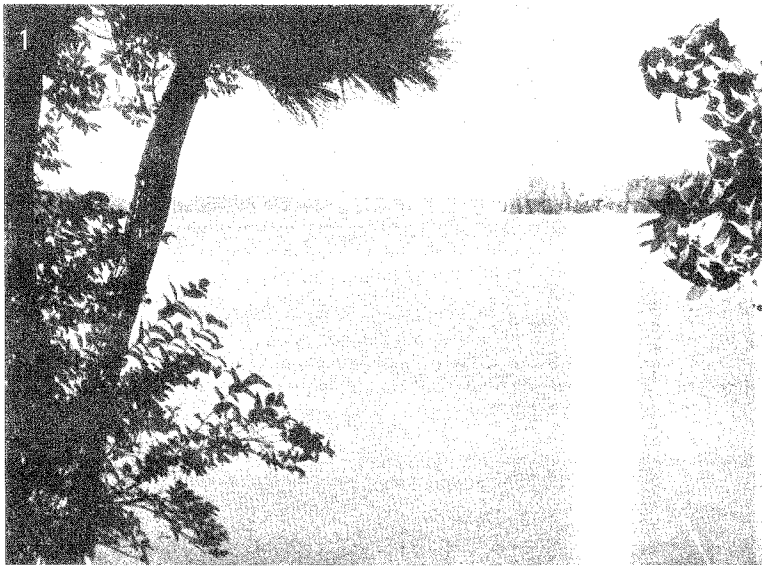
MINNESOTA SOIL ATLAS

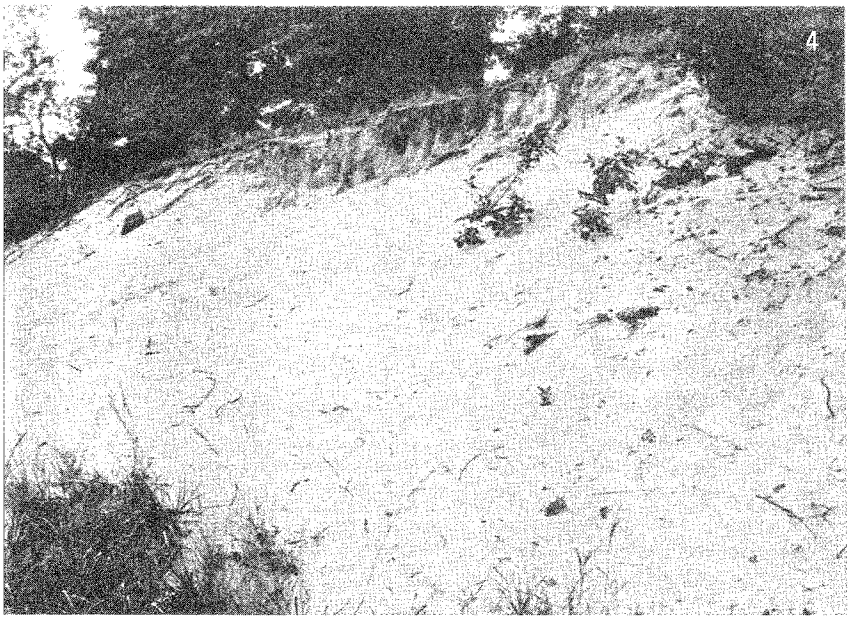
stillwater sheet

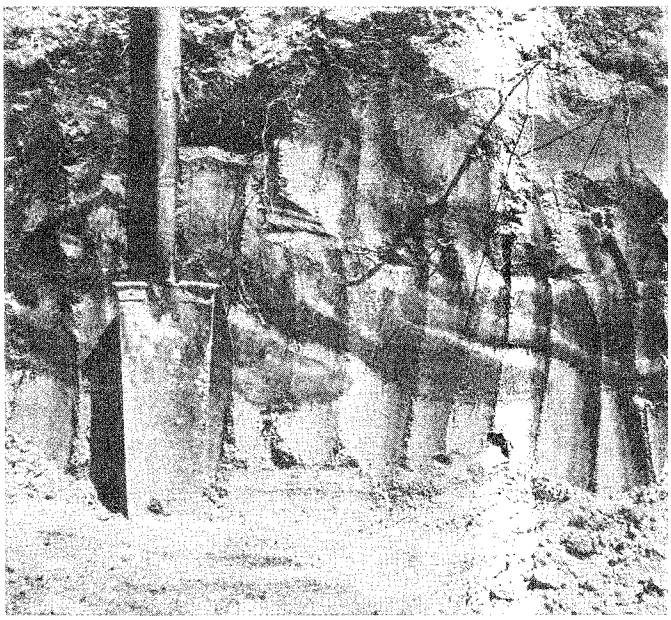
Agricultural Experiment Station
University of Minnesota



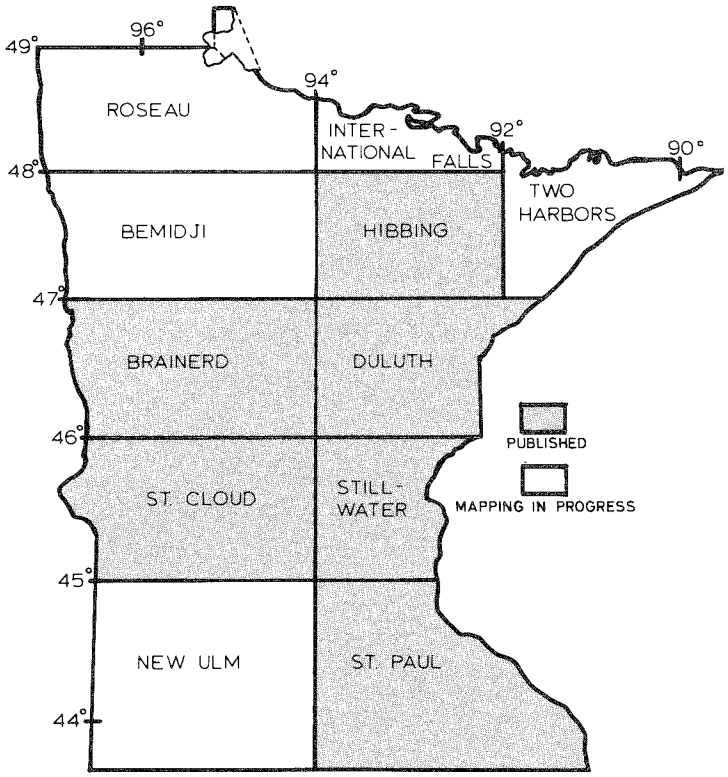








1. This residential development encountered problems with a high water table during years of above average precipitation.
2. & 3. Lakes located in glacial moraine areas often have steep banks and irregular shorelines with many bays (2) while lakes in outwash plains (3) have shorelines with low relief.
4. This Zimmerman loamy sand is common on the Anoka Sand Plain.
5. Restricted drainage is indicated on this sand plain soil by the dull colors in the subsoil and organic matter in the surface horizons.



CONTENTS PAGE

Acknowledgement

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-Stillwater Sheet, fifth in a series of eleven covering the entire state. Already published are the Brainerd Sheet, Miscellaneous Report 90 (1969); the Hibbing Sheet, Miscellaneous Report 110 (1971); the St. Paul Sheet, Miscellaneous Report 129 (1973); and, the Duluth Sheet, Miscellaneous Report 159 (1979). In addition, the Twin Cities Metropolitan Area Sheet, Miscellaneous Report 130 (1975) on a larger scale has also been published.

G. F. Harms, L. D. Hanson, and R. H. Rust did the Stillwater Sheet field work, map, and report.

J. F. Cummins, Soil Conservation Service, prepared the geomorphic area delineations. H. E. Wright, Jr., Department of Geology, University of Minnesota, gave technical assistance.

The assistance of the soil survey and district personnel of the Soil Conservation Service in field observations and with certain illustration is gratefully acknowledged.

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

Introduction

Information about the soils and landscape characteristics of Minnesota is being published in two different series of publications. This Stillwater Sheet is the sixth in a series of 11 maps that provides soil geography of Minnesota at a 1:250,000 scale.

The second series of publications is the basic county soil survey. At present 30 soil survey reports of Minnesota counties have been published by the United States Department of Agriculture, Soil Conservation Service in cooperation with the Minnesota Agricultural Experiment Station.

The scale of county soil surveys is either 1:15,850 or 1:20,000, so much more detailed information about the soils is provided in these reports than is possible in the more general soil atlas maps.

The atlas map series is being published with explanatory texts for each sheet 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.

The Stillwater Sheet encompasses approximately 2,692,610 acres in east central Minnesota: from 45° north latitude to 46° north latitude and from the Wisconsin-Minnesota state line on the St. Croix River to 94° west longitude and including parts or all of 13 counties. Soil Surveys have been published on 9 of these counties but 5 are more than 30 years old and out of print.

Table 1. Acreage estimates of geomorphic regions within the Stillwater Sheet

No.	Name	Acres	Percent
10C	Brainerd-Pierz Drumlin Area	426,500	15.8
29	Mississippi Valley Outwash	238,300	8.8
33	Lonsdale-Lerdal Till Region, Clayey, Rolling	39,540	1.4
34	Waconia-Waseca Moraine, Loamy, Rolling	212,500	7.9
35B	Emmons-Faribault Moraine, Irregular, Rolling	69,570	2.6
45	Twin Cities Formation, Loamy, Rolling	233,500	8.7
54	Anoka Sand Plain, Undulating	656,000	24.4
61	McGrath Till Plain, Loamy, Gently Rolling	684,900	25.5
62	Hinckley Outwash Plain, Sandy	131,800	4.9
		2,692,610	100.0

How the Map Was Prepared

The base map was prepared from the Stillwater quadrangle 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 surveys made by the Soil Conservation Service, U.S. Department of Agriculture (USDA) where available. Published surveys of Hennepin, Isanti, Kanabec, Mille Lacs, Pine, Ramsey, Sherburne, Washington and Wright counties were also used. Field work was necessary where no detailed soil survey existed.

To provide a generalized map for the user with minimum soils knowledge, 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 bedrock (R).

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, and excessively drained soils designated (W); and somewhat poorly, poorly, and very poorly drained soils designated (P). Units with (W) designation will normally have water tables below the rooting zone and units with (P), water table commonly within the rooting zone.

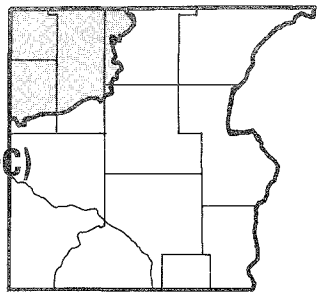
4. Color of surface soil with dark color designated (D); and light color designated (L).

Thus, the Hayden* series would appear on the map as LLWL and would be interpreted from the map as light-colored, well-drained loamy soil over loamy material (in this instance loamy glacial till). Brainerd, Milaca, and Bradford would also appear as this landscape unit. Some areas on the map do not have a four letter symbol of a soil landscape unit. These are land types such as P for peat or muck, M for marsh, and A for floodplains.

Nine geomorphic areas are delineated to illustrate broad physiographic features and to provide some identification as to nature of parent materials on which the soils have developed (table 1). Several geomorphic areas will extend into adjoining Atlas Sheets. 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. Tables 2 through 10 include representative soil series, when known.

*Brief descriptions of named soils in the region are in appendix A.

Brainerd-Pierz Drumlin Area (10C)



This region encompasses an area of approximately 426,500 acres or 15.8 percent of the Stillwater 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 portion, 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 (brome-grass, alfalfa, and red clover).

The nine landscape units occurring in this area, along with some selected features, are shown in table 2. 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.

P— This unit occurs in interdrumlin areas, broad drainage ways and in old lake bottoms. No present lakes occur. About 25 percent of the unit is comprised of very poorly drained mineral soils.

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.

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

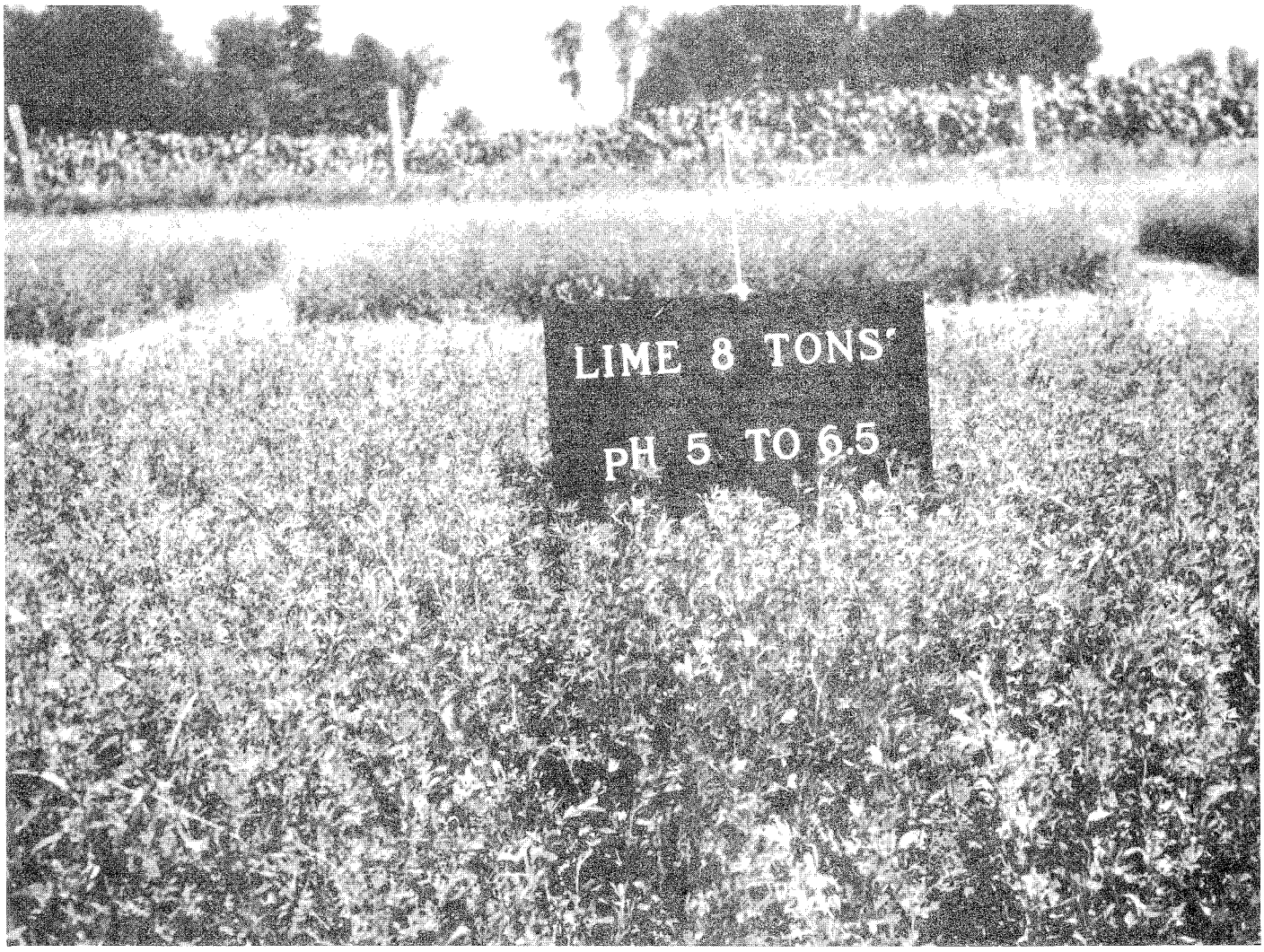
Table 2. Selected features of soil landscape units within the Brainerd-Pierz Drumlin Area (10C) geomorphic regions

			Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			
Soil landscape unit	Percent geomorphic region	Landscape position	Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	Representative soil series
LLWL	66	gently sloping and sloping drumlins	sandy loam (2-3)	sandy loam (3-20+)	9-12	moderately well drained	5.5-6.2	medium	low	Brainerd Flak Nokay
P	12	low lying depressions and drainage ways	peat (1-3)	peat (3+)	12+	very poorly drained	>6.0	low	low	Barrows Seelyeville
LLPL	10	low broad drainage ways and depressions	sandy loam (2-3)	sandy loam (3-20+)	9-12	poorly drained	5.5-6.2	medium	low	Nokay Barrows
LLPD	7	depressional to gently sloping upland	loam to clay loam (4)	loam to clay loam (4+)	9-12	poorly and very poorly drained	6.0-7.3	low	low to medium	Adolph Parent
SLWL	2	narrow stream bottoms	loam (2-4)	loam (4+)	4-12	poorly drained	<6.0	variable	variable	Unnamed

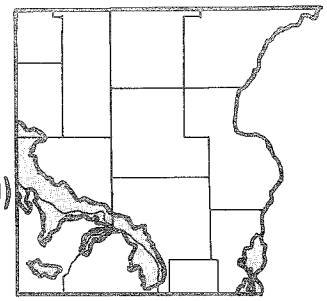
Table 2. (continued). Selected features of soil landscape units within the Brainerd-Pierz Drumlin Area (10C) geomorphic regions

			Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			
SLPD	1	level or depression areas on outwash	loam to sandy loam (2-3)	gravelly coarse sand (3+)	3-9	poorly drained	5.6-6.0	medium	low	Hillet
SLPL	<1	level or depression areas on outwash	loam to silt loam (2-3)	gravelly coarse sand (3+)	3-9	poorly drained	4.5-6.0	medium	low	Ogilvie
SSWL	<1	nearly level to gently rolling outwash	loamy sand (1-3)	sand and gravel (3-20+)	3-6	well to excessively drained	5.1-6.0	medium	low	Menagha

Soils in the Brainerd-Pierz Drumlin area are often acid and low in fertility but applications of lime and fertilizer can correct these deficiencies.



Mississippi Valley Outwash (29)



This region encompasses approximately 238,300 acres or 8.8 percent of the Stillwater Sheet.

The Mississippi Valley Outwash consists of nearly level terraces and bottoms along the Mississippi River and some of its tributaries. The water table is normally deeper than 10 feet on the terraces, but on the bottom lands is between the surface and 6 feet deep. The region contains some 8 lakes, each 160 acres or larger. The total water area is 12,650 acres.

The terraces are frequently a good source of gravel, consequently many large gravel pits are located there.

Most of the soils on the terraces range from loamy sand to a loam or silt loam less than 30 inches thick over sand and gravel. The water-holding capacity ranges from low to moderate. Bottomland soils, mostly loam or silt loam in texture, are subject to occasional to frequent flooding.

The original vegetation on the terraces was prairie grass. On the bottomlands, river bottom forest consisting of elm, ash, cottonwood, boxelder, basswood, soft maple, willow, and hackberry was the original vegetation. The terraces are mostly tilled for corn, soybeans, rye, sunflowers, and alfalfa-brome hay as the main crops. Bottomlands are about 75 percent in forest and the remainder in corn.

Eleven soil landscape units are mapped in the region: SSWD, SSWL, SLWL, SLWD, A, P, SSPD, RSWD, M, LLWL, and RLWD. Table 3 lists selected characteristics of the units. Additional information for some units follows:

SSWD— Sandy loam, loam or silt loam soils 24 to 36 inches thick comprise 10 to 20 percent of this unit.

SSWL— Peat bogs and low wet soils make up about 10 percent of this unit. Topography on this unit is rolling.

SLWL—This unit includes 5 to 10 percent loamy sand soils. About 5 percent of the unit is poorly drained. Topography on this unit is rolling.

SLWD—This unit includes 5 to 10 percent loamy sand soils. About 5 percent of the unit is poorly drained.

A— This unit includes about 5 percent small islands of sandy terrace soils. The bottoms range from well to moderately well-drained loam or silt loam to poorly drained silty clay soils. Near the rivers, where flooding is frequent, the soil materials are mixed, ranging from sand and gravel to clay.

P— Small sandy islands which make up about 5 to 10 percent of this unit are included.

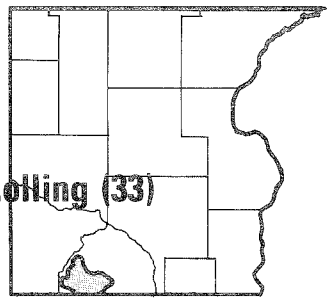
SSPD— Approximately 5 to 10 percent of this unit is well drained.

Table 3. Selected features of soil landscape units within the Mississippi Valley Outwash (29) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Representative soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
SSWD	73	nearly level to gently rolling outwash plain	loamy sand (1-3)	sand and gravel (3-20+)	3-6	excessively to well drained	5.1-6.5	low to medium	low	Hubbard, Sparta Estherville Dickman
SSWL	5	nearly level to gently rolling outwash plain	loamy sand (1-3)	sand (3-20+)	3-6	excessively drained	5.1-6.0	high	low	Plainfield, Nymore, Zimmerman
SLWL	4	gently sloping to rolling upland	sandy loam to loam (2-3)	loamy sand to sandy loam (3+)	3-9	well drained	5.1-6.5	medium	low to medium	Onamia, Kingsley

Table 3. (continued). Selected features of soil landscape units within the Mississippi Valley Outwash (29) geomorphic region

			Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			
SLWD	3	nearly level outwash plain	loam or silt loam (2-3)	sand and gravel (3-20+)	6-9	well drained	5.1-6.5	low to medium	low	Waukegan, Dakota, Wadena
A	3	nearly level stream bottom and low terraces	sandy loam loam or silt loam (2-4)	sandy loam loam or silt loam (4+)	6-12	well to poorly drained	5.6-7.8	variable	variable	Becker, Chaska
P	3	low lying depressions	peat (1-3)	sand	12+	very poorly drained to marshy	5.1-7.3	low	low	Adrian
SSPD	2	nearly level outwash plain	loamy sand (1-3)	sand (3-20+)	3-6	poorly drained	5.6-6.5	low	low	Isan
RSWD	1	steep bluffs along St. Croix River	loamy sand (1-3)	limestone or sandstone bedrock (3+)	3-6	well drained	4.5-6.5	low to medium	low	Bellechester
M	<1	low lying depressions	either organic muck or mineral soil	either organic muck or mineral soil	1-4 feet of water on surface	marshy				
LLWL	<1	gently sloping to steep upland	silt loam, loam or clay loam (4)	loam (4-20+)	9-12	well drained	5.1-7.3	high	medium	Hayden
RLWD	<1	Steep bluffs along St. Croix River	loam or silt loam (1-3)	limestone or sandstone bedrock (3+)	3-9	well drained	5.6-7.3	high	medium	Rockton Copaston
Gravel pits	<1									
Water	5									



Lonsdale-Lerdal Till Region, Clayey, Rolling (33)

This region has an area of approximately 39,540 acres or 1.4 percent of the Stillwater Sheet.

The region consists of clayey mantled moraines and ice disintegration features. The dominant land form is one of circular, level topped hills bounded by smooth side slopes and above a broad lower level.

The broad upper levels have nearly the same elevation. In places, the unobstructed view gives the impression of a level plain. Summit widths vary. Some have between 300 to 500 foot widths, some between 1,000 and 4,000 feet, and a few range to 4 miles. The summit is from 20 to 30 feet above the lower level where the clayey mantle ranges from a few to nearly 50 feet thick. Summit slopes are normally between 2 and 3 percent but range up to 6 percent.

Side slopes are smooth with convex shoulders and concave backslopes. Contour lines are reasonably parallel.

The lower level is interspersed with closed depressions containing lakes and peat bogs. Drainage is often controlled by the lake levels.

The water table is about 3 feet deep on the nearly level upper summits to more than 10 feet deep on the more sloping tops and side slopes. The water table on the lower level ranges from above the surface to about 6 feet deep. All water tables vary seasonally. The region contains 3 lakes of 160 acres or larger and a total water area of 1700 acres.

The level topped hills are capped by 2 to 4 feet of silty clay or silty clay loam underlain by clay loam till, which is calcareous. Approximately one-third of the surface texture is clayey with the balance of the region either loam, silt loam or clay loam. Because of the small but numerous clayey areas very few landscape units can be delineated on the map as clayey. The region has little or no gravel or sand.

Original vegetation known as the Big Woods, consisted of oak, elm, basswood, ash, maple, aspen, birch, wild cherry, butternut, and black walnut. Present crops are corn, soybeans, alfalfa-brome hay, oats, and wheat. Steep rolling areas and wet areas are usually pasture. Pasture makes up about 15 percent of the region; woodland, another 15 percent. Wildlife areas can frequently be developed in this region.

Five soil landscape units are mapped in the region: LLWL, M, LCPD, P, AND LLWD. Table 4 gives selected features of units. Additional information follows:

LLWL—Included within this unit are small areas with a clayey surface comprising 10 to 15 percent of the unit. Small peat bogs comprising 5 to 10 percent of the area are also included.

LCPD— Included with this unit are well-drained soils comprising about 10 percent.

P— About 10 percent of this unit includes mineral soils.

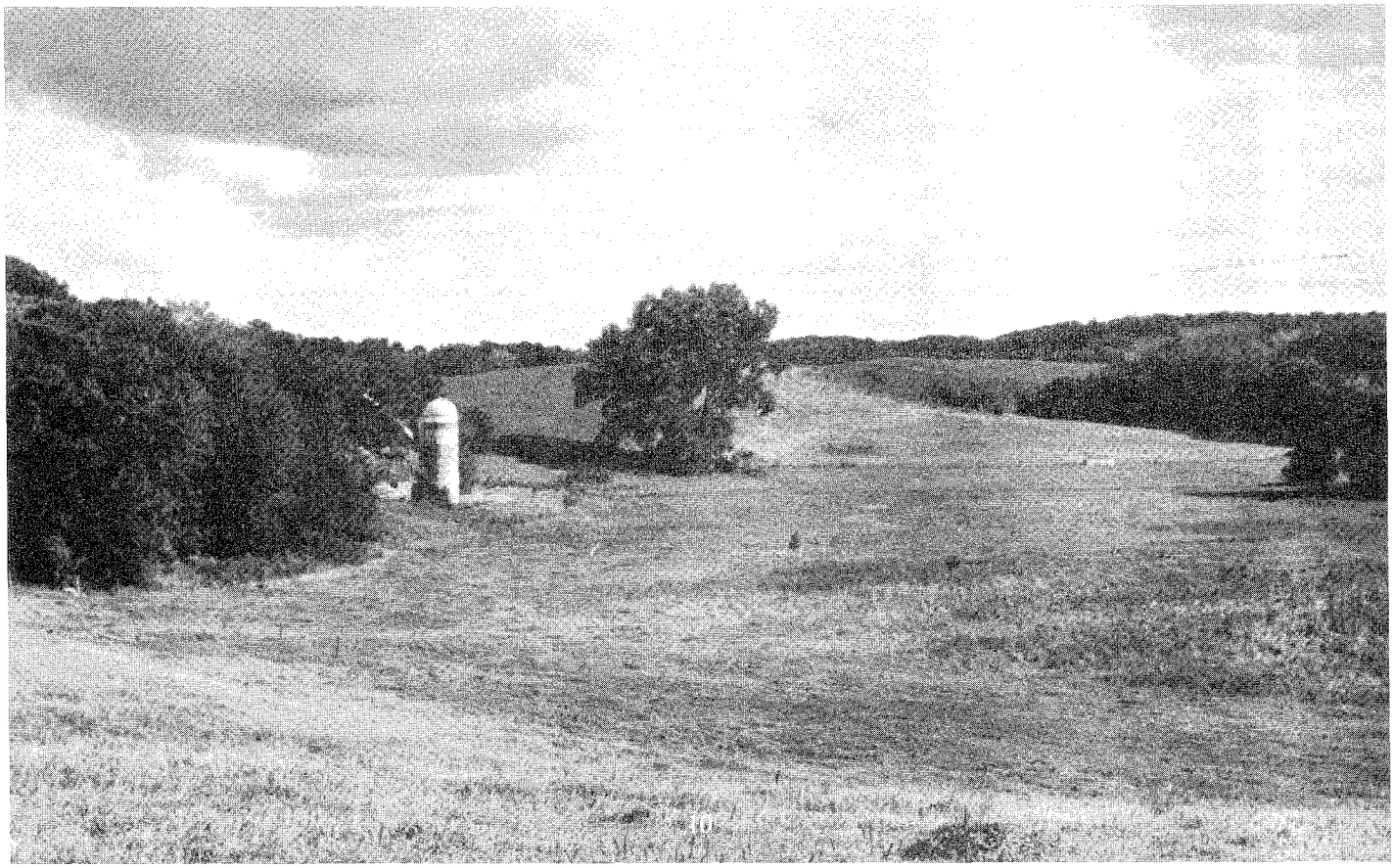
LLWD—Poorly drained and wet soils comprise about 15 percent of the unit. About 10 percent of the surface is clayey.

Long, smooth slopes are common in the Lonsdale-Lerdahl till region of Hennepin County. This scene is typical of the area around Lake Independence where cropland and horse pasture are the dominant land uses. Soils often have a three foot mantle of clay texture over loam substratum.

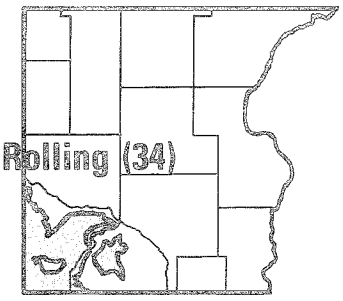
Table 4. Selected features of soil landscape units within the Lonsdale-Lerdal Till Region, Clayey, Rolling (33) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Representative soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWL	79	rolling upland	loam to silty clay loam (3-4)	loam to clay loam (4+)	9-12	well drained	5.1-6.5	medium	medium	Hayden Erin
M	6	low lying depressions	either organic or mineral soil	either organic or mineral soil	1-4 feet of water on surface	marshy				
LCPD	5	nearly level upland	silty clay loam to silty clay (3-4)	clay loam to loam (4+)	9-12	poorly drained	6.1-6.5	low to medium	low	Cordova
P	4	low lying depressions	muck and peaty muck (1-3)	limnic material or mineral soil (3-10+)	12+	very poorly drained to marshy	5.1-7.3	low	low	Palms Caron
LLWD	2	rolling upland	loam to silty clay loam (3-4)	loam to clay loam (4+)	9-12	well drained	5.1-6.5	low to high	medium	Kilkenny Clarion LeSueur, Lester
Water	4									

The urban land uses of housing, commercial development, and recreation have been replacing dairy farms in the southwest part of the Stillwater Sheet in the late 1970s.



Waconia-Waseca Moraine, Loamy, Rolling (34)



This region encompasses an area of approximately 212,500 acres or about 7.9 percent of the Stillwater Sheet.

The Waconia-Waseca Moraine consists of loamy mantled moraines and ice disintegration features. The dominant landform is one of circular, level topped hills bounded by smooth side slopes and above a broad lower level.

The broad upper levels have nearly concurrent elevations. In places the unobstructed view gives the impression of a level plain. Summit widths vary: some are between 200 and 500 feet, others from 1000 to 4000 feet, and a few up to 2 miles. The summits are from 10 to 30 feet above the lower level. Summit slopes are irregular and normally between 2 and 3 percent but range up to 6 percent.

Side slopes are smooth with convex shoulders and concave back slopes. Slopes range from 4 to 35 percent but are dominantly 8 to 14 percent. Contour lines are reasonably parallel.

The lower level is interspersed with closed depressions containing lakes and peat bogs. Drainage is often controlled by the lake levels.

The water table ranges from about 3 feet on the upper level to 10 feet on the more sloping sides and side slopes. Water tables on the lower level range from above the surface to about 6 feet deep. Water tables vary seasonally.

There are 17 lakes each 160 acres or more in size located in the region. Total water area is approximately 11,350 acres.

Little or no sand and gravel occur in the region.

Original vegetation, known as the Big Woods, consisting of oak, elm, basswood, ash, maple, aspen, birch, wild cherry, butternut, and black walnut covered most of this region. In the west in Wright County the region was covered with tall prairie grass with small areas of aspen-oak land and brush prairie. Present crops are corn, soybeans, alfalfa-brome hay, oats, and wheat. About 10 percent of the region is pastured. Woodland makes up another 10 percent.

Seven soil landscape units are mapped in the region: LLWL, LLWD, P, A, M, LCPD, and SSWD. Table 5 lists selected features of the units. Additional information follows:

LLWL—About 10 percent of this unit is dark-colored. Another 10 percent is poorly drained mineral soil or peat.

LLWD—Poorly drained soils comprise about 15 to 20 percent of the unit. About 5 percent of the unit is peat.

P— About 10 percent of this unit includes mineral soil.

LCPD— Within this unit are about 10 percent well-drained soils.

Table 5. Selected features of soil landscape units within the Waconia-Waseca Moraine, Loamy, Rolling (34) geomorphic region

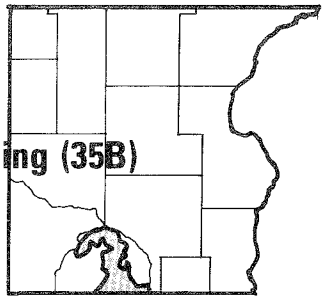
Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Representative soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWL	61	rolling upland	loam to clay loam (4)	loam to clay loam (4+)	9-12	well drained	5.1-6.5	medium	medium	Hayden Nessel
LLWD	26	undulating to rolling upland	loam to clay loam (4)	loam to clay loam (4+)	9-12	well drained	6.1-7.3	low	medium	Clarion Nicollet Lester, LeSueur
P	4	low lying depressions	muck and peaty muck (1-3)	limnic material or mineral Soil (3-10+)	12+	very poorly drained	5.1-7.3	low	low	Palms Caron

Table 5. (continued). Selected features of soil landscape units within the Waconia-Waseca Moraine, Loamy, Rolling (34) geomorphic region

			Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			
A	1	nearly level stream bottoms	loam or silt loam (4)	loam or silt loam (4+)	6-12	well to poorly drained	5.6-7.8	variable	variable	Becker Chaska
M	1	low lying depressions	organic or mineral soil	organic or mineral soil	1-4 feet of water on surface	marshy				
LCPD	<1	nearly level upland	silty clay loam to silty clay (4)	loam to clay loam (4+)	9-12	poorly drained	6.1-6.5	low to medium	medium	Cordova
SSWD	<1	nearly level to gently rolling outwash plain or terrace	loamy sand and sandy loam (1-3)	sand and gravel (3-20+)	3-6	excessively to well drained	5.1-6.5	low to medium	low	Hubbard Estherville
Water	5									

The high water holding capacity of the soils in the Waconia-Waseca Moraine allows a wide variety of crops, landscape materials, and trees to be grown.

Emmons-Faribault Moraine, Irregular, Rolling (35B)



This region has an area of approximately 69,570 acres or about 2.6 percent of the Stillwater Sheet.

The Emmons-Faribault Moraine consists of irregular ground, end and terminal moraines, and ice disintegration features of loamy texture. The dominant landform is a complex of knolls that rise irregularly above a lower level. The knolls seemingly are irregularly placed on an underlying slope. The underlying slope controls the drainage and the knolls ascend and descend with changes within this slope.

The dominant relief is 10 to 30 feet above the knoll base in the rolling areas. Contour lines have a very erratic pattern.

The lower level can normally be drained except for deeply inset depressions. The depressions and dead lakes are filled with peat. Water tables on the knolls are more than 10 feet deep. The water tables on the lower level range from above the surface to about 6 feet deep. There are 9 lakes of 160 acres or more in size in the region. The total water area is about 2,890 acres.

Original vegetation, known as the Big Woods, consisted of oak, elm, basswood, ash, maple, aspen, birch, wild cherry, butternut, and black walnut. Present crops are corn, soybeans, alfalfa-brome hay, oats, and wheat. About 10 to 15 percent of this region is pasture and 15 percent woodland.

Five soil landscape units are mapped in this region: LLWL, M, LLWD, P, AND SSWD. Table 6 lists selected features of the units. Additional information follows:

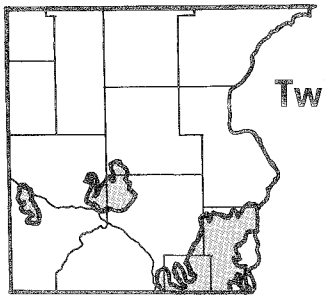
LLWL—About 10 percent of this unit is dark-colored. Another 10 percent is poorly drained.

LLWD—Poorly drained soils comprise about 10 percent of this unit. About 5 percent are light-colored.

P— About 10 percent of this unit is well-drained or poorly drained mineral soil.

Table 6. Selected features of soil landscape units within the Emmons-Faribault Moraine, Irregular, Rolling (35B) geomorphic region

			Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			
Soil landscape unit	Percent geomorphic region	Landscape position	Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	Representative soil series
LLWL	88	rolling upland	loam (4)	loam (4+)	9-12	well drained	5.1-6.5	medium	medium	Hayden
M	5	low lying depressions	either organic or mineral soil	either organic or mineral soil	1-4 feet of water on surface	marshy				
LLWD	2	gently rolling to rolling upland	loam to clay loam (4)	loam to clay loam (4+)	9-12	well drained	6.1-7.3	low	medium	Lester LeSueur
P	1	low lying depressions	muck and peaty muck (1-3)	limnic material or mineral soil (3-10+)	12+	very poorly drained	5.1-7.3	low	low	Palms Caron
SSWD	<1	rolling upland	loamy sand or thin sandy loam (1-3)	sand and gravel (3-20+)	3-6	excessively to well drained	5.6-7.3	low	low to medium	Estherville
Water	4									



Twin Cities Formation, Loamy, Rolling (45)

This geomorphic region has an area of approximately 233,500 acres, or 8.7 percent of the Stillwater Sheet.

The Twin Cities Formation consists of irregular end and terminal moraines and ice disintegration features of sandy and loamy textures. This formation is a complex mixture of gray till and reddish brown till. It is a heterogeneous mixture of sand, silt, clay, pebbles, cobbles, and boulders, but it contains lenses of predominantly silt or sand.

The landscape form consists of steep hills interspersed with deep depressions either filled with small lakes or peat. The relief ranges from 50 to 200 feet from hill base to hilltop. Contour lines have a very erratic pattern.

Water tables are near the surface in the depression but are deeper than 10 feet on the hills. Most depressions are closed and have limited drainage possibilities. There are 14 lakes larger than 160 acres in size. Total water area is approximately 14,260 acres

Kames and eskers are frequent among the hills. These are sources of sand and gravel.

Original vegetation has been described as consisting of "Oak openings and barrens." This cover type consisted mostly of oak, both red and scarlet. Frequently on the kames and eskers the oaks have poor growth. Present crops are corn, soybeans, alfalfa-brome hay, and oats. Woodland comprises about 25 percent of the region. Pasture makes up another 10 percent. Urbanization is advancing rapidly.

Fourteen soil landscape units are mapped in the region: LLWL, SSWL, P, SLWL, XLWL, SSWD, LLPD, LSWL, SSPL, LLPL, RSWD, SLWD, AND A. Table 7 gives selected features of the units. Additional information follows:

LLWL—Includes about 10 percent soil with a loamy sand surface. Some peat bogs are included.

SSWL— About 10 percent of the soils have a sandy loam or loam surface.

P— Includes about 10 percent well-drained or poorly drained mineral soils.

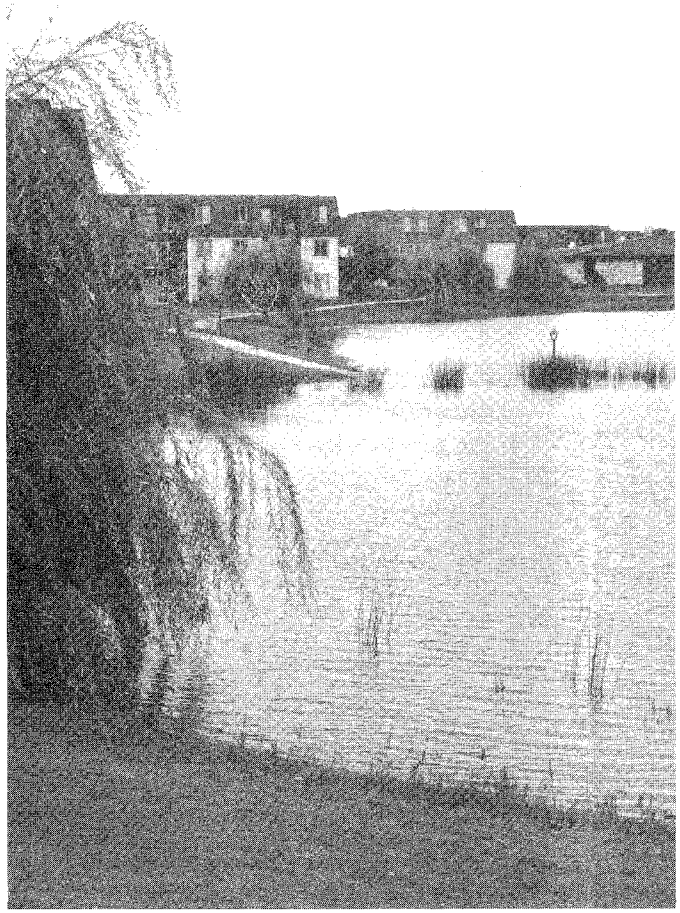
SLWL—Includes about 10 percent soil with a loamy sand surface.

XLWL—Includes about 10 percent soil with a loamy sand surface.

SSWD—Includes about 10 percent soils with light colored surface.

LLPD— Includes about 10 percent well drained soil.

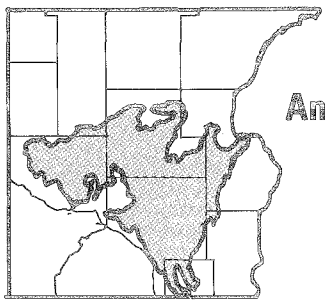
LSWL—Includes about 10 percent soil with loamy sand substrata.



In addition to 14 lakes over 160 acres in size in the Twin Cities geomorphic area, there are hundreds of ponds and small lakes.

Table 7. Selected features of soil landscape units within the Twin Cities Formation, Loamy, Rolling (45) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Representative soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWL	56	rolling to steep hilly upland	sandy loam to loam (3-4)	clay loam to loam (4+)	9-12	well and moderately well drained	5.1-6.5	medium	medium	Kingsley Hayden Nessel, Freeon
SSWL	20	rolling to steep hilly upland	loamy sand (1-3)	sand and gravel (3-20+)	3-6	well to excessively drained	5.6-7.8	medium	low to medium	Emmert Zimmerman
P	7	low lying depressions	organic (1-3)	organic (3+)	12+	very poorly drained	5.1-7.3	low	low	Seelyeville Cathro
SLWL	3	gently sloping to rolling upland	sandy loam to loam (2-3)	loamy sand to sandy loam (3+)	3-9	well drained	5.1-6.5	medium	low to medium	Onamia Kingsley
XLWL	2	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	Burkhardt Chetek, Emmert
SSWD	1	nearly level to rolling upland or outwash	loamy sand (1-3)	sand and gravel (3-20+)	3-6	excessively to well drained	5.6-7.3	low	low to medium	Hubbard Estherville
LLPD	1	depressional to gently sloping upland	loam to clay loam (4)	loam to clay loam (4+)	9-12	poorly and very poorly drained	6.6-7.3	low	low to medium	Webster Glencoe
LSWL	1	rolling to steep hilly upland	loamy sand (1-3)	sandy loam to loam (3+)	3-9	well drained	5.1-6.5	medium	low to medium	Braham Kingsley
SSPL	1	nearly level or depressional	loamy sand (1-3)	sand and gravel (3-20+)	3-6	poorly drained	5.5-6.2	medium	low	Lino Soderville
LLPL	1	nearly level to gently sloping upland	silt loam to clay loam (4)	loam to clay loam (4+)	9-12	poorly drained	5.5-6.5	low	low	Dundas
RSWD	<1	steep bluffs along St. Croix River	loamy sand (1-3)	limestone or sandstone bedrock (3+)	3-6	well drained	4.5-6.5	low to medium	low	Bellechester
SLWD	<1	nearly level to gently rolling outwash	loam or silt loam (2-3)	sand and gravel (3-20+)	6-9	well drained	5.1-7.3	low to medium	low	Dakota Waukegan
A	<1	stream bottoms subject to flooding	sand, loam, silt loam (2-5)	sand, sandy loam, loam, silt loam, silty clay loam (15-20+)	3-12	well to poorly drained	6.1-7.8	variable	variable	Otter



Anoka Sand Plain, Undulating (54)

This geomorphic region has an area of approximately 656,000 acres or 24.4 percent of the Stillwater Sheet.

The Anoka Sand Plain is an outwash plain formed during the retreat of the Grantsburg sublobe. The material making up the plain is principally fine sand. Depressions are common in the plain. These were formed when isolated blocks of ice later melted. These are now filled with peat deposits or are marshes and lakes.

The landscape form is that of a gently undulating plain.

Water tables are near the surface in the depressions. They are at depths of 3 to 10 feet on the rises. Many depressions are closed. There are 38 lakes larger than 160 acres in size. Total water area is approximately 18,970 acres.

On the well-drained sands, original vegetation was scrub oak, both red and scarlet. The poorly drained sands had mixed hardwood or sedges and marsh grass. Peat bogs had either sedges and marsh grass or tamarack. Present crops are corn, soybeans, hay, oats, and extensive acreages of sod and vegetable crops. Sod and vegetable truck crops are grown extensively on large drained peat and muck areas. A large bog area in northeast Anoka County has been developed as a wildlife and waterfowl refuge.

Twelve soil landscape units are mapped in the region: SSWL, P, A, SSPD, SSPL, SSWD, LSWL, SLWL, M, LLWL, SLWD, AND CLPD. Table 8 gives selected features of the units. Additional information follows:

SSWL— Includes about 10 to 15 percent poorly drained soils. It also includes approximately 10 percent small peat areas.

P— Includes many small sandy islands shown on the map by sand spot symbols.

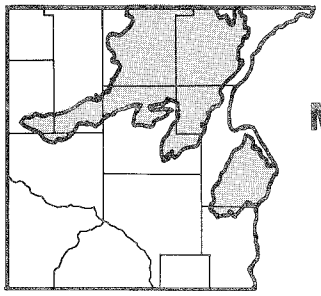
SSPD— Includes about 10 to 15 percent well-drained soils.

SSPL— Includes about 10 to 15 percent well-drained soils. Some dark colored soils are also included.

About 18 percent of the Anoka Sand Plain consists of peat bog depressions such as this one in Anoka County. Here carrots are being grown on a drained peat area.

Table 8. Selected features of soil landscape units within the Anoka Sand Plain, Undulating (54) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Representative soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
SSWL	66	nearly level to gently rolling outwash plain	loamy sand (1-3)	sand (3-20+)	3-6	well to excessively drained	5.1-6.0	high	low	Zimmerman Sartell Anoka
P	18	low lying depressions	organic (1-3)	organic or sandy mineral soil (3+)	12+	very poorly drained	5.1-7.3	low	low	Rifle Markey
A	4	nearly level stream bottom	sandy loam or loam (2-4)	sand, sandy loam or loam (4+)	6-12	well to poorly drained	5.6-7.3	variable	variable	Becker
SSPD	2	nearly level outwash plain	loamy sand (1-3)	sand (3-20+)	3-6	poorly drained	5.6-6.5	low	low	Isanti Duelm
SSPL	2	nearly level outwash plain	loamy sand (1-3)	sand (3-20+)	3-6	somewhat poorly drained	5.1-6.2	medium	low	Soderville Lino
SSWD	1	nearly level to gently rolling outwash plain	loamy sand (1-3)	sand and gravel (3-20+)	3-6	excessively to well drained	5.1-6.5	low to medium	low	Hubbard Estherville Dickman
LSWL	1	rolling upland	loamy sand (1-3)	sandy loam to loam (3+)	3-9	well drained	5.1-6.5	medium	low to medium	Braham
SLWL	1	nearly level to gently rolling outwash plain	sandy loam (2-3)	sand and gravel (3-20+)	3-9	well drained	5.5-6.2	medium	low	Burkhardt Chetek Onamia
M	1	low lying depressions	either organic or mineral soil	either organic or mineral soil	1-4 feet of water on surface	marshy				
LLWL	1	till island in outwash plain	silt loam to silty clay loam (4)	silt loam to silty clay loam (4+)	9-12	well drained	5.1-6.5	medium	medium	Hayden
SLWD	<1	nearly level outwash	loam, silt loam (2-3)	sand and gravel (3-20+)	6-9	well drained	5.1-7.3	low to medium	low	Dakota Waukegan
CLPD	<1	depressional	silt loam to clay loam (2-3)	silty clay loam to silty clay (3+)	9-12	poorly drained	5.5-6.5	medium	medium	Barronett
Water	3									



McGrath Till Plain, Loamy, Gently Rolling (61)

This geomorphic region has an area of approximately 684,900 acres or 25.5 percent of the Stillwater Sheet.

The McGrath Till Plain is dominantly undulating to gently rolling, but includes some nearly level and rolling areas. Most of this region on the Stillwater Sheet is gray till with fine sandy loam, loam, or silty clay loam surface textures. However, large areas of reddish brown till with fine sandy loam or loam surface textures are mixed through much of the region. Cobbles, stones, and boulders characterize the reddish brown till areas.

Around Cross and Pokegama Lakes a small lacustrine plain characterized by clayey calcareous sediments occurs. This till plain consists of many peat bogs (some fairly large) and some nearly level poorly drained areas.

Water tables are 6 to 10 feet or deeper on the knolls but range from above the surface to about 6 feet deep on the level or boggy areas. Some 17 lakes, 160 acres or more in size, occur in the region. Total water area is about 20,330 acres.

Hardwood forests originally covered most of this southeast section of the McGrath Till Plain. The soils, even on areas farmed for 100 years, still show a forest influence in the profile.

The native vegetation was mixed hardwoods and white pine on the heavier soils, white pine and red pine on the loose red drift, and jack pine on the very sandy areas. The swamps and wet land supported spruce and tamarack in the northern part but sedges, marsh grass or mixed hardwoods in the southern part. Present crops are corn, soybeans, alfalfa-brome hay, and oats. Marsh grass hay is harvested on many peat bogs. Woodland still covers 25 percent of the area, pasture 10 to 15 percent.

Twelve soil landscape units are mapped in this region: LLWL, P, SLWL, SSWL, CLPL, A, LLPL, LSWL, RLWL, SLPL, SSPL, AND M. Table 9 lists selected features of the units. Additional information follows:

LLWL—Includes about 10 percent soil with loamy sand surface. Some 10 percent of this unit is poorly drained. Also includes some small peat bogs.

P— Includes about 10 percent well-drained or poorly drained mineral soils.

SLWL—Includes about 10 percent soil with a loamy sand surface.

SSWL— About 10 percent of the soils have a sandy loam or loam surface. Five to 10 percent of the soils are poorly drained.

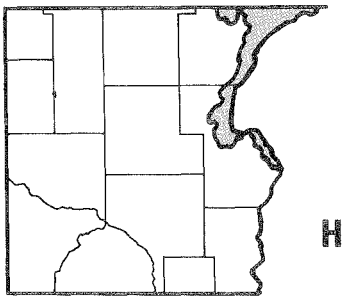
CLPL— About 10 to 15 percent of this unit has silt loam in the substratum. Some 10 percent is well drained.

LLPL— About 10 percent of this unit is well drained.

LSWL—Includes about 10 percent soil with loamy sand substrata.

Table 9. Selected features of soil landscape units within the McGrath Till Plain, Loamy, Gently Rolling (61) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Representative soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
LLWL	64	gently undulating to rolling upland	loam or sandy loam (4)	loam, clay loam (4+)	9-12	well drained	5.5-6.2	medium	low	Milaca, Mora Brainerd, Flak Nokay, Hayden,
P	14	low lying depressions	organic (1-3)	organic (3+)	12+	very poorly drained	5.1-7.3	low	low	Mooselake Rifle
SLWL	6	nearly level outwash plain	sandy loam or loam (2-3)	sand and gravel (3-20+)	3-9	well drained	5.5-6.2	medium	low	Chetek Onamia
SSWL	4	nearly level to rolling outwash	sand and loamy sand (1-3)	sand and gravel (3-20+)	3-6	well to excessively drained	5.5-6.2	medium	low	Menagha, Omega Zimmerman
CLPL	3	nearly level lake plain	silt loam to silty clay loam (2)	silty clay loam to silty clay (2+)	9-12	well drained	5.6-7.3			Brickton Dalbo
A	3	nearly level stream bottoms	sandy loam, loam or silt loam-silt (4)	sandy loam, loam or loam (4+)	6-12	well to poorly drained	5.6-7.8	variable	variable	Unnamed
LLPL	2	nearly level to depressional upland	loam or sandy loam (4)	loam, clay loam (4+)	9-12	poorly drained	5.5-6.2	medium	low	Adolph, Freer, Nokay Barrows, Mora
LSWL	1	gently undulating to sloping upland	loamy sand (4)	sandy loam, loam or clay loam (4+)	3-9	well drained	5.1-6.5	medium	low to medium	Pomroy Braham
RLWL	<1	steep bluffs along St. Croix River	loam (2-3)	sandstone bedrock (3+)	3-6	well drained	5.1-6.5	medium	medium	Dorerton
SLPL	<1	level or depression areas on outwash	sand loam or loam (2-3)	sand and gravel (3-20+)	3-9	poorly drained	4.5-6.0	medium	low	Ogilvie, Halder Warman
SSPL	<1	nearly level or depressional outwash	loamy sand (1-3)	sand and gravel (3-20+)	3-6	poorly drained	5.5-6.2	medium	low	Lino Soderville
M	<1	low lying depressions	either organic or mineral soil	either organic or mineral soil	1-4 feet of water on surface	marshy				
Water	3									



Hinckley, Outwash, Plain, Sandy (62)

This geomorphic region has an area of approximately 131,800 acres or 4.9 percent of the Stillwater Sheet.

The Hinckley Outwash Plain consists of nearly level terraces and bottoms along the St. Croix River. In a part of the region, gently rolling topography occurs. Large peat bogs occupy the low lying depressions.

The terraces are frequently a good source of gravel.

Water tables are 6 to 10 feet deep on the sloping areas but range from above the surface to about 6 feet deep on the level or depressional areas. There are no large lakes in this region.

Most of the soils on the terraces range from loamy sand to a fine sandy loam or very fine sandy loam less than 30 inches thick over reddish sand and gravel. The water holding capacity ranges from low to moderate. The terrace material is relatively thin over the red till and islands of loam or sandy loam till are common in this region. Bottomland soils, mostly sandy loam or loam in texture, are subject to occasional to frequent flooding.

The original vegetation on the very sandy soils was jack pine with a mixture of hardwoods and red pine on sandy loam areas. Mixed hardwoods and spruce occurred on the wetter mineral soils. Tamarack, sedges, and marsh grass were on the bog areas. Present crops are corn, soybeans, and vegetable truck crops on the southern peat and muck areas. Woodland covers 30 to 35 percent of the area, pasture 10 to 15 percent.

Eleven soil landscape units are mapped in the region: SSWL, P, LSWL, LLPL, A, SSPL, SLPD, LLWL, SLWL, RLWL, AND SSWD. Table 10 lists selected features of the units. Additional information follows:

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

P— Includes about 10 percent well-drained or poorly drained mineral soils.

LSWL—Includes about 10 percent soil with loamy sand substrata. Also about 10 percent has a sandy loam surface.

LLPL— Includes about 10 percent well-drained soil.

SSPL— Includes some small peat areas.

SLPD— Includes about 10 percent gravelly areas shown with gravel symbols on the map.

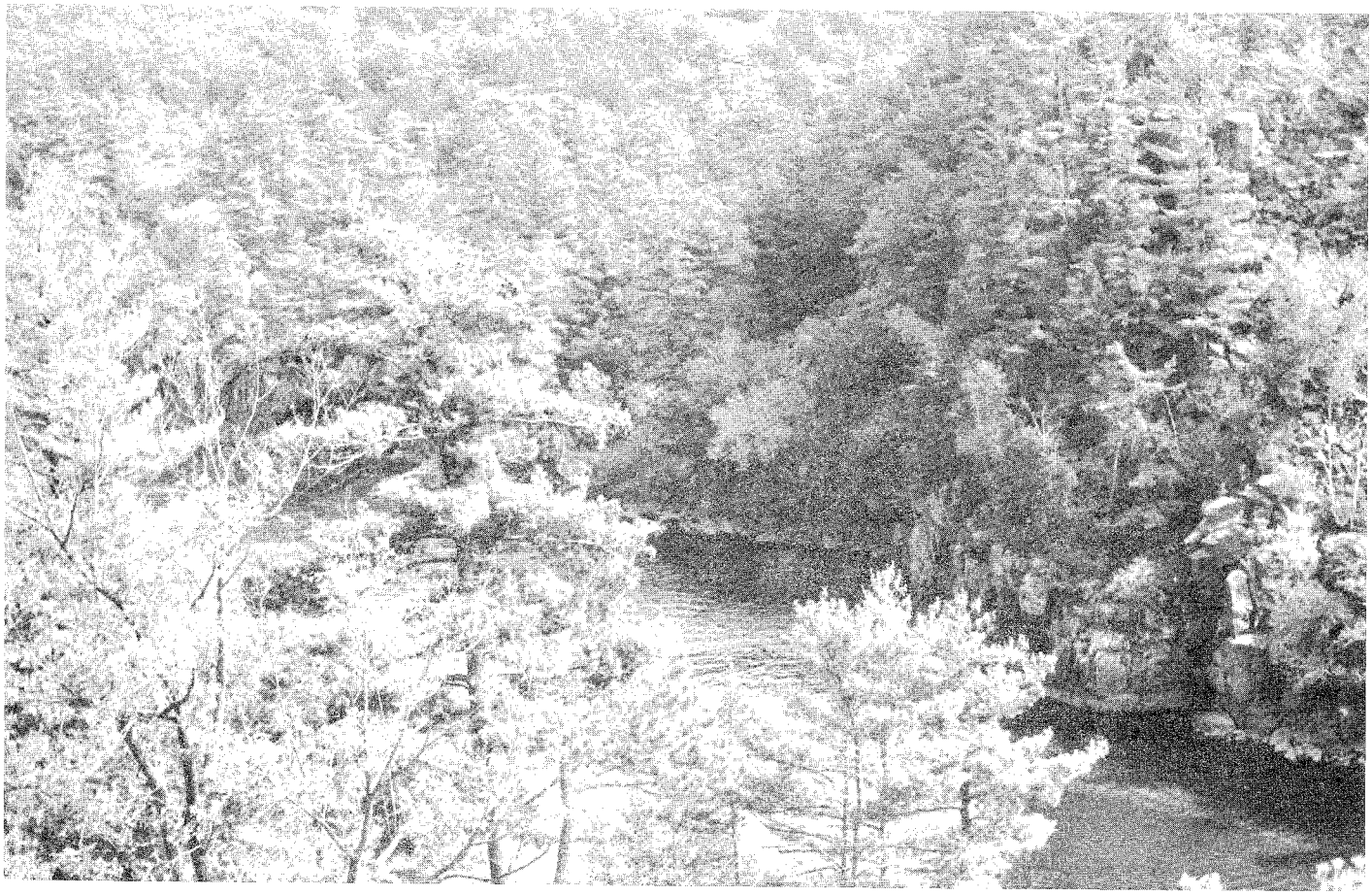
LLWL—These are sandy loam till "islands" in the outwash plain.

Table 10. Selected features of soil landscape units within the Hinckley Outwash Plain, Sandy (62) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Representative soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
SSWL	31	nearly level to gently rolling outwash plain	loamy sand (1-3)	sand and gravel (3-20+)	3-6	well to excessively drained	5.1-6.0	high	low	Omega
P	23	low lying depressions	organic (1-3)	organic (3+)	12+	very poorly drained	5.1-7.3	low	low	Mooselake Rifle
LSWL	15	nearly level lake or outwash plain	loamy sand (3-4)	sandy loam or loam (4+)	3-9	well drained	5.1-6.5	medium	low to medium	Pomroy Braham
LLPL	8	nearly level or depressional lake plain	sandy loam, loam or silt loam (3)	sandy loam, or loam (3+)	9-12	poorly drained	5.5-6.2	medium	low	Adolph

Table 10. (continued). Selected features of soil landscape units within the Hinckley Outwash Plain, Sandy (62) geomorphic region

Soil landscape unit	Percent geomorphic region	Landscape position	Most common texture and thickness (feet)		Moisture relationships		Approximate fertility in rooting zone			Representative soil series
			Rooting zone	Substratum	Inches of available water to 5 feet	Drainage class	pH	P	K	
A	5	mearly level stream bottom	sandy loam- or loam (2-4)	sandy, sandy loam or loam (4+)	6-12	well to poorly drained	5.6-7.3	variable	variable	Unnamed
SSPL	3	nearly level outwash plain	loamy sand (1-3)	sand (3-20+)	3-6	poorly drained	5.1-6.2	medium	low	Nemadji
SLPD	3	nearly level or depressional outwash plain	sandy loam or loam (2-3)	sand and gravel (3-20+)	3-9	poorly drained	5.6-6.0	medium	low	Hillet
LLWL	2	gently undulating to sloping upland	sandy loam (2-3)	sandy loam to loam (3+)	9-12	well drained	5.5-6.2	medium	low	Milaca Mora
RLWL	1	undulating to gently rolling upland	sandy loam (4-5)	sandstone bedrock (5+)	3-9	well drained	5.1-6.5	medium	low	Unnamed
SSWD	1	nearly level to gently rolling outwash plain	loamy sand (1-3)	sand and gravel (3-20+)	3-6	well to excessively drained	5.1-6.5	low to medium	low	Hubbard
Water	5									



The St. Croix River has cut a narrow gorge through bedrock south of Taylors Falls.

This is a popular recreation area for canoeing, hiking, and camping.

Geomorphic Regions of the Stillwater Sheet[1]

The glacial deposits of the Stillwater Sheet area can be classified by source area and relative age. Ice that accumulated in the Lake Superior Basin transported red sandstone and an admixture of igneous rocks from the northeastern portion of the state. Superior lobe drift is reddish in hue and is non-calcareous. Ice that advanced from the northwest Des Moines lobe carried materials entrained from the limestones and dolomites of Manitoba and northwest Minnesota, producing yellowish brown calcareous drift.

The landforms associated with the Superior lobe were constructed primarily during the St. Croix phase of Wisconsin glaciation about 20,000 years ago. The eastern St. Croix Moraine from St. Paul to Forest Lake is composed largely of the Twin Cities Formation (45). Two smaller areas of the St. Croix Moraine occur in northwestern Anoka County and northern Wright County. Also associated with the Superior lobe are the Drumlins in the northwest of the Stillwater Sheet designated as the Pierz Drumlin Area (10C). East of the drumlin area is a large till plain including some small drumlin areas which were deposited mostly by the Superior lobe but over-ridden on the southern edge by the Grantsburg sub-lobe. Within this till plain (McGrath Till Plain, 61) are included several areas of lacustrine material (P and CLPL landscape units, Brickton-Dalbo soils) attributed to glacial Lake Grantsburg.

Drift of the St. Croix phase in this region is extensively buried beneath the younger drift deposited about 16,000 years ago by the Des Moines lobe and its associated Grantsburg sublobe. The Des Moines lobe advanced along the bedrock lowland of the Red River and the Minnesota River. The Grantsburg sublobe branched eastward from the Des Moines lobe, entering the Minneapolis Lowland and advancing to the vicinity of present-day Grantsburg, Wisconsin. As it proceeded northeastward, this sublobe partially overrode the recently deposited St. Croix Moraine. The mixture of these two dissimilar drifts is the Twin Cities Formation (45). The drift of the Grantsburg sublobe locally modified the topography left by the Superior lobe.

Meltwaters coursing from the wasting Grantsburg sublobe constructed the extensive Anoka Sand Plain (54). This feature, as observed on aerial photographs, was apparently formed by braided streams flowing adjacent to the ice margin. River braids, sand dunes, and isolated till islands provide positive relief to the sand plain. Lakes and marshes, indicating the former presence of buried blocks of stagnant ice, produce negative relief characteristics.

The area of the McGrath Till Plain south of Pine City and east of the Anoka Sand Plain is of a character different from that of this geomorphic region north of Pine City. A case could be made for establishing an individual geomorphic region for this area in Chisago and Washington Counties since much of the surface glacial drift shows the influence of the Grantsburg sublobe.

After the Grantsburg sublobe had advanced to its maximum position, the Des Moines lobe proper flowed southward into the Des Moines River Valley in Iowa. The Lonsdale-Lerdal Till Region (33) and the Waconia-Waseca Moraine (34) represent the surface expression of Des Moines lobe activity. These areas are essentially ground moraine. Subsequent disintegration of this ice produced the flat-topped hills that dominate the landforms of these two regions. Between these ground moraine areas and the Mississippi Valley Outwash (29) is a terminal moraine of the Des Moines lobe (Emmons-Faribault Moraine 35B). This moraine does not have the flat-topped hills and includes pockets of sand and gravel not generally present in the ground moraine.

The Mississippi Valley Outwash (29) and the Hinckley Outwash Plain are expressed as river terraces and outwash plains graded to those terraces. Superior lobe materials contributed to the Hinckley Outwash Plain while the Mississippi Valley Outwash received material from the Des Moines lobe, the Superior lobe, and other sources.

Postglacial modifications of the landscape have been restricted primarily to river valleys and lakeshores. The Mississippi and St. Croix rivers have readjusted to the diminished discharge that resulted from the removal of glacial meltwaters from their drainage basins. The formation of Lake St. Croix resulted from damming at Point Douglas as the sedimentation rate of Mississippi River exceeded that of the St. Croix. Kettle holes formed in moraines and outwash plains as stagnant ice blocks melted. These depressions have become the lake basins that dominate the landscape throughout the Stillwater Sheet area.

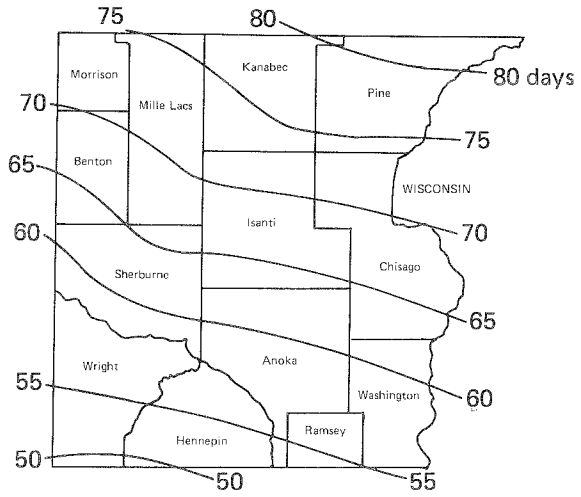
[1]For additional information on this topic the reader is referred to: *Quaternary History of Minnesota*, H. E. Wright, Jr., *Geology of Minnesota: A Centennial Volume*, pp. 515-517. Minnesota Geological Survey. 1972.

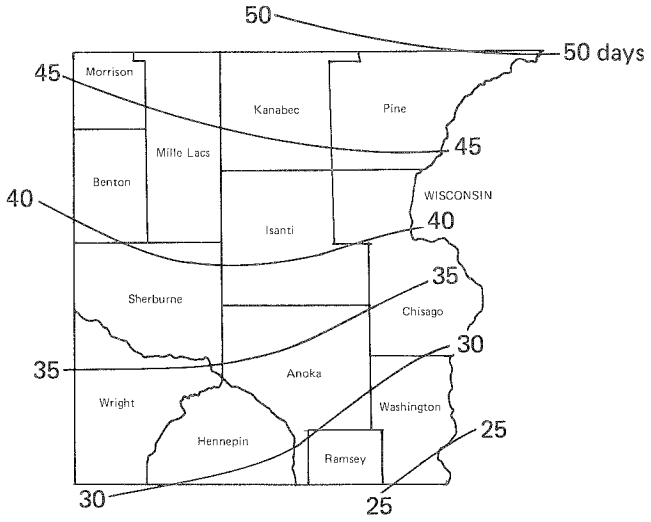
Climate of the Stillwater Sheet Area

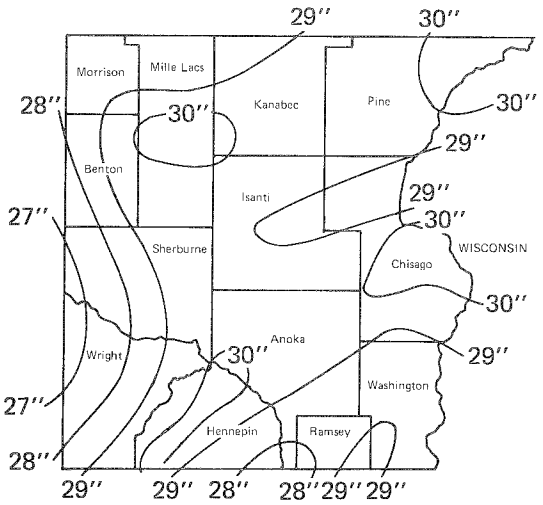
This area has a typical continental climate with wide extremes in temperature from summer to winter. Since there are no marked changes in topography, temperatures and precipitation have gradual changes across the area. Total annual precipitation varies from 27 inches in the western part to about 30 inches in the eastern and southern areas (figure 1). About 40 percent of the precipitation occurs during the summer.

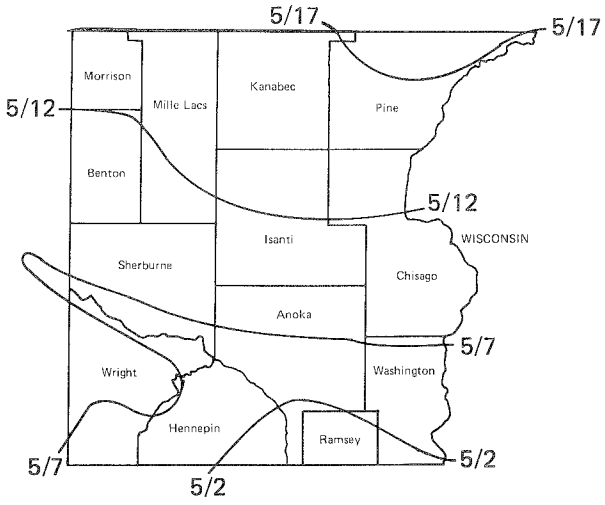
The annual snowfall averages about 45 inches. This is equivalent to about 4.5 inches water content. Figures 2 and 3 show that this area averages 50 to 80 days with 6 inches or more of snow and 25 to 50 days with 12 inches or more.

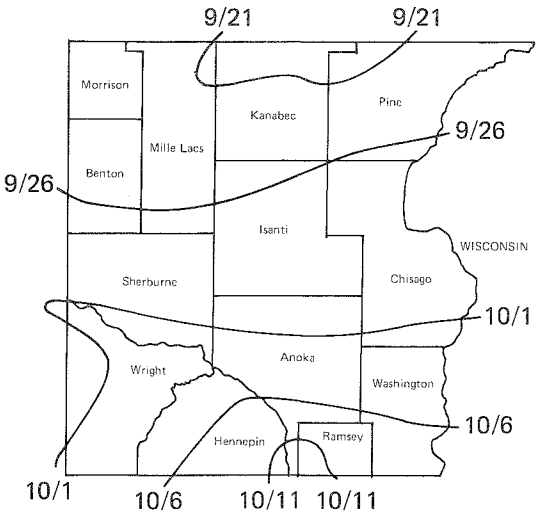
The average date of the last occurrence of frost in the spring ranges from May 2 to May 17 (figure 4), the first frost in the fall ranges from September 21 to October 11 (figure 5). The freeze-free period is long enough that the staple crops reach maturity without serious frost damage.

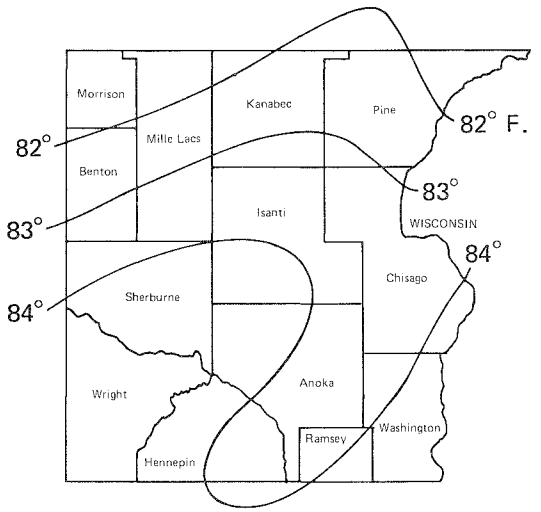


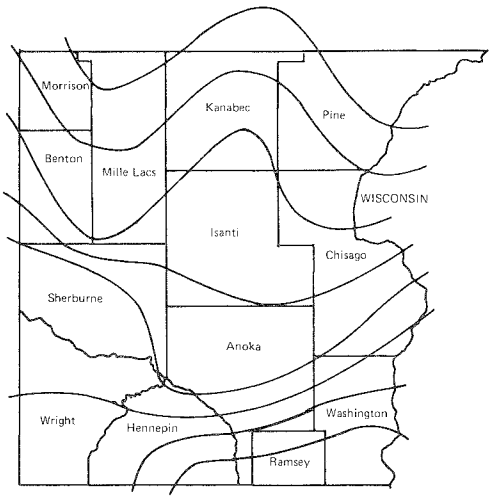












Summer weather is typically one of warm days and relatively cool nights. Figure 6 shows that maximum temperatures in July average 84°F in the sourthern counties to 82°F in the northern. The minimum temperature in July averages 56°F in the northern counties and 63°F in the southern (figure 7). Summertime humidity averages about 56 percent and wintertime, about 68 percent.

Agriculture

Farming is the dominant land use in the Stillwater Sheet, particularly in the southwest part of the area. Three main types of farming can be recognized in the sheet area. There are: 1) a diversified type with corn and soybeans as dominant crops, 2) a dairy-beef area where forage crops are important, and 3) a rather specialized irrigation farming area where potatoes, vegetables, and grass sod are important crops. The diversified corn-soybean farms are located in the southwest part of the sheet and around the eastern and northern margins of the Anoka Sand Plain. The livestock farms are primarily in the northern part of the sheet where the soils and climate are better suited for forage crops than corn and soybeans. Irrigated agriculture occurs throughout the Anoka Sand Plain but is particularly concentrated on the Mississippi Valley Outwash area.

In general, the intensity of cropland use of land is highest in the central part of Wright County in the southwest part of the sheet and is lowest in sandy land in the Hinckley Outwash Plain in the northeast corner of the sheet.

For example, in Wright County, 72 percent of the land is in farms and 58 percent is cropland. In Pine County only 31 percent is in farms and 14 percent of the land is used for annual crops.

For information regarding specific interpretations of soils for crop production the reader is referred to county soil survey reports.

Woodland

Most of the region is within the northern deciduous forest which was primarily covered with oak and other hardwood. The northern portion was merging into the coniferous forest region. Within the "oak" forest there were scattered areas of "oak openings."

On the sandy areas (54,62) the original cover was mainly bur oak, northern red oak, and pin oak. Wetter areas supported quaking aspen and paper birch. Organic soil areas were mostly treeless or occasional tamarack and northern white cedar.

Areas of soils developed from glacial till (10C, 33, 34, 35B, 45, 61) supported sugar maple, elm, basswood, white oak, green ash, butternut, ironwood, and aspen.

Presently woodland occurs in small tracts although present species are similar to the original. In such areas as the Rum River State Forest, the Sand Dunes State Forest and the Chengwatana State Forest efforts are being made to re-establish and expand the adopted species.

In table 11 some information is presented on management problems for different woodland species on the various soil landscape units.

Table 11. Woodland Site Information for Stillwater Sheet

Geomorphic Area	Landscape Unit	Important Trees	Site Index	Woodland Management Hazards: Erosion Hazard	Equipment Limitations	Seedling Mortality	Plant Competition	Suitable Species To Plant
10C	LLWL	Basswood Red Pine Aspen	55-75	slight	slight	slight	moderate	Red Pine White Spruce
	P	Black Spruce Tamarack	30-45	slight	severe	severe	severe	Black Spruce White Cedar
	LLPL	Aspen Basswood White Spruce	55-75	slight	moderate	slight	moderate	White Spruce Red Pine
	LLPD	Black Ash Black Spruce Cottonwood	60-70	slight	severe	severe	severe	Black Spruce Black Ash
	A	Soft Maple Cottonwood	70	slight	moderate	moderate	severe	Cottonwood
	SLWL	Red Oak White Ash Sugar Maple	50-60	slight to moderate	slight to moderate	slight	moderate	Red Pine White Pine
29	SSWD	Red Oak Jack Pine Red Pine	50-60	slight	slight to moderate	moderate	slight to moderate	White Pine Red Pine
	SSWL	Bur Oak Red Oak Red Pine	50-60	slight to moderate	slight to moderate	moderate to severe	slight	Red Pine White Pine Jack Pine
	SLWL	Red Oak Aspen Red Pine	50-60	slight to moderate	slight to moderate	slight to moderate	moderate	Red Pine White Pine Jack Pine
	SLWD	Oaks Red Pine Sugar Maple	55-60	slight to moderate	slight to moderate	slight to moderate	slight to severe	Red Pine White Pine White Spruce
	A	Soft Maple Cottonwood Ash	70	slight	moderate	moderate	severe	Cottonwood Ash
	P	Red Maple White Ash	40-45	slight	severe	severe	severe	Not suited
	SSPD	None		slight	moderate	moderate to severe	severe	Cottonwood Not suited
	RSWD	Bur Oak Red Cedar	35-55	severe	severe	moderate	moderate	Red Pine

Table 11. (continued). Woodland Site Information for Stillwater Sheet

Geomorphic Area	Landscape Unit	Important Trees	Site Index	Woodland Management Hazards: Erosion Hazard	Equipment Limitations	Seedling Mortality	Plant Competition	Suitable Species To Plant
33	LLWL	Sugar Maple Red Oak Basswood	60-70	slight to moderate	slight to moderate	slight	slight	Black Walnut Red Pine White Oak
	M							Not suited
	LCPD	Ash Cottonwood	55-60	slight	moderate	moderate to severe	severe	Cottonwood Silver Maple
	P	Silver Maple White Ash	46	slight	severe	severe	severe	Cottonwood Willow
	LLWD	Oak Maple Basswood Black Walnut	55-70	slight to moderate	slight to moderate	slight	severe	Red Pine Black Walnut White Pine
34	LLWL	Red Oak White Oak Basswood	60-70	slight to moderate	slight to moderate	slight	moderate	Black Walnut Red Pine White Oak
	LLWD	Maple Ash Red Oak Basswood	55-70	slight to moderate	slight to moderate	slight	severe	Red Pine Black Walnut White Pine
	P	Silver Maple White Ash	46	slight	severe	severe	severe	Soft Maple Cottonwood
	A	Aspen Oak Basswood	70	slight	slight	slight	moderate to severe	Red Pine White Pine White Spruce
	M							Not suited
35B	LLWL	Red Oak Basswood Sugar Maple	62-69	slight	slight	slight	slight	Black Walnut Red Oak Basswood
	M							Not suited
	LLWD	Red Oak Basswood Sugar Maple	55-70	slight to moderate	slight to moderate	slight	severe	Black Walnut Red Pine White Pine
	P	Red Maple Silver Maple White Ash	46	slight	severe	severe	severe	Soft Maple Cottonwood

Table 11. (continued). Woodland Site Information for Stillwater Sheet

Geomorphic Area	Landscape Unit	Important Trees	Site Index	Woodland Management Hazards: Erosion Hazard	Equipment Limitations	Seedling Mortality	Plant Competition	Suitable Species To Plant
45	LLWL	Red Oak Basswood White Oak Aspen	50-60	slight to moderate	slight to moderate	slight to moderate	moderate	Black Walnut Red Pine White Pine White Spruce
	SSWL	Red Pine Jack Pine Red Oak Bur Oak	50-60	slight to moderate	slight to moderate	slight to moderate	slight to moderate	Jack Pine Red Pine White Pine
	P	Balsam Fir		slight	severe	severe	severe	Not suited
	SLWL	Red Oak Sugar Maple Red Pine	50-60	slight to moderate	slight to moderate	slight to moderate	moderate	Red Pine White Pine
	XLWL	Jack Pine Red Oak Aspen Basswood	55-60	slight to moderate	slight to moderate	slight to moderate	slight to moderate	Red Pine White Pine Basswood
	SSWD	Bur Oak Red Pine Jack Pine	50-55	slight to moderate	slight to moderate	moderate to severe	slight	Red Pine White Pine Jack Pine
	LLPD	Cottonwood	60-70	slight	moderate	moderate	severe	Cottonwood Green Ash
	LSWL	Aspen Jack Pine Red Pine	50-60	slight to moderate	slight to moderate	slight to moderate	slight to moderate	Red Pine White Pine White Spruce
	SSPL	Aspen	78-84	slight	moderate	moderate	moderate	Red Pine White Pine White Spruce
	LLPL	Aspen Cottonwood	60-70	slight	moderate	moderate to severe	severe	Cottonwood
54	SSWL	Oak Jack Pine	50-60	slight	moderate	moderate	slight	Red Pine Jack Pine White Pine
	P	Black Spruce Black Ash		slight	severe	severe	severe	Not suited
	A	Aspen Basswood	70	slight	slight	slight	moderate to severe	Red Pine White Pine White Spruce

Table 11. (continued). Woodland Site Information for Stillwater Sheet

Geomorphic Area	Landscape Unit	Important Trees	Site Index	Woodland Management Hazards: Erosion Hazard	Equipment Limitations	Seedling Mortality	Plant Competition	Suitable Species To Plant
	SSPD	Aspen Bur Oak Jack Pine	50-55	slight	slight to moderate	moderate to severe	slight	Red Pine White Pine Jack Pine
	SSPL	Aspen	78-84	slight	moderate	moderate	moderate	Red Pine White Pine White Spruce
	SSWD	Bur Oak Red Pine Jack Pine	50-60	slight to moderate	slight to moderate	moderate	slight to moderate	Red Pine White Pine
	LSWL	Red Oak Aspen Basswood	57-64	slight to moderate	slight to moderate	moderate	slight to moderate	Red Pine White Pine White Oak
	SLWL	Red Pine Jack Pine Red Oak	60-65	slight	slight	slight	slight	Red Pine White Pine Jack Pine
54	M	None						
	LLWL	Red Oak Basswood	62-69	slight	slight	slight	slight	Black Walnut Red Oak Basswood
61	LLWL	Aspen Basswood Red Oak Red Pine	55-75	slight	slight	slight	moderate	Red Pine White Spruce White Pine
	P	None		slight	severe	severe	severe	Not suited
	SLWL	Jack Pine Red Oak Aspen	60-65	slight	slight	slight	slight	Red Pine White Pine Jack Pine
	SSWL	Bur Oak Red Pine Jack Pine	50-60	slight to moderate	slight to moderate	moderate to severe	slight	Red Pine Jack Pine
	CLPL	Aspen	75	slight	severe	severe	severe	Black Spruce Red Pine
	A	Aspen Basswood	70	slight	slight	slight	moderate	Red Pine White Spruce
	LLPL	Aspen Basswood Red Oak Sugar Maple	58-62	slight	moderate	slight	severe	White Spruce Red Oak Basswood

Table 11. (continued). Woodland Site Information for Stillwater Sheet

Geomorphic Area	Landscape Unit	Important Trees	Site Index	Woodland Management Hazards: Erosion Hazard	Equipment Limitations	Seedling Mortality	Plant Competition	Suitable Species To Plant
	LSWL	Aspen Jack Pine Red Oak	57-64	slight to moderate	slight to moderarate	moderate	slight to moderate	Red Pine White Pine White Spruce
62	SSWL	Jack Pine	56-64	slight	slight	moderate	slight	Red Pine Jack Pine
	P	None		slight	severe	severe	severe	Not suited
	LSWL	Red Oak Aspen Red Pine	57-64	slight to moderate	slight to moderate	moderate	slight to moderate	Red Pine White Pine White Spruce
	LLPL	Black Ash Black Spruce	40-50	slight	severe	severe	severe	Black Spruce
	A	Aspen Basswood	70	slight	slight	slight	moderate	Red Pine White Spruce
	SSPL	Black Spruce Black Ash	40-50	slight	severe	severe	severe	Black Spruce
	SLPD	Aspen Red Pine	55-60	slight	slight to moderate	moderate	moderate	Red Pine White Pine
	LLWL	Black Oak Basswood Aspen	55-75	slight to moderate	slight to moderate	slight to moderate	moderate	Black Walnut Basswood Red Pine
	SLWL	Red Oak Sugar Maple		slight	slight	slight	moderate	Red Pine White Pine
	RLWL	Red Pine Aspen Red Oak	55-60	slight	slight	slight	moderate	Red Pine
	SSWD	Bur Oak Red Pine	50-60	slight to moderate	slight to moderate	moderate	slight to moderate	Red Pine White Pine

This state park in Chisago County is one of the newest parks in the state.

Recreation

The recreational use of land and water is subject to increasing demand with the increasing population of the Stillwater Sheet area. Recreational use of land takes on many aspects—from intensive use as in playgrounds, to extensive use as in nature and hiking trails.

The following public recreation areas are located in the Stillwater Sheet:

William O'Brien State Park
Interstate State Park
Wild River State Park
St. Croix River (a national wild and scenic river)
Rum River
Carlos Avery Wildlife Area
Mille Lacs Wildlife Area
Sherburne National Wildlife Refuge

Table 12 is a general outline of kinds of limitations for various recreational activities as they might be adopted in the several soil landscape units of the Stillwater Sheet area. In the selection of recreational areas the total landscape generally needs to be considered. In the review of a given area, several soil landscape units may occur and should be evaluated collectively. Also, an association of land and water will be a significant consideration. A study of the map will reveal areas where these associations occur.

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

Table 12. Degree and kinds of limitations for specified recreational uses

Landscape unit	Description	Playground, athletic field and intensive play areas	Picnic areas, parks and extensive play areas	Bridle paths, nature and hiking trails	Golf course fairways	Cottages, service and utility buildings	Tents and trailer sites
SSPL	Sandy over sandy poorly drained, light colored soils.	Moderate-high water table.	Moderate-high water table.	Moderate-high water table.	Moderate-high water table and low natural fertility.	Severe-high water table.	Severe-high water table.
SCPL	Clayey over sandy poorly-drained, light colored soils.	Severe-high seasonal water table; poor trafficability; slow permeability.	Severe-high seasonal water table; poor trafficability.	Severe-high seasonal water table. Moderate-surface soil is sticky and soft when wet.	Severe-high seasonal water table. Moderate-surface soil is sticky and soft when wet.	Severe-high seasonal water table; slow permeability.	Severe-high seasonal water table; poor trafficability; slow permeability.
CLPD	Loamy over clayey, poorly-drained, dark colored soils.	Severe-high water table; frequently ponded. Moderate-surface soil is sticky and soft when wet.	Severe-high water table; frequently ponded. Moderate-surface soil is sticky and soft when wet.	Severe-high water table; frequently ponded. Moderate-surface soil is sticky and soft when wet.	Severe-high water table; frequently ponded; surface soil is sticky and soft when wet.	Severe-high water table; frequently ponded.	Severe-high water table; frequently ponded.
CLPL	Loamy over clayey, poorly-drained, light colored. soils.	Severe-high water table frequently ponded. Moderate-surface soil is sticky and soft when wet.	Severe-high water table; frequently ponded. Moderate-surface soil is sticky and soft when wet.	Severe-high water table; frequently ponded. Moderate-surface soil is sticky and soft when wet.	Severe-high water table; frequently ponded; surface soil is sticky and soft when wet.	Severe-high water table; frequently ponded.	Severe-high water table; frequently ponded.
XLWL	Loamy over mixed sandy and loamy well-drained, light colored soils.	Slight-0-2% slopes. Moderate-2-6% slopes. Severe-over 6% slopes.	Moderate-6-12% slopes. Severe-over 12% slopes.	Slight-2-12% slopes. Moderate-12-18% slopes. Severe-over 18% slopes.	Slight-2-6% slopes. Moderate-6-12% slopes. Severe-over 12% slopes.	Slight-2-6% slopes. Moderate-6-12% slopes. Severe-over 12% slopes.	Slight-2-6% slopes. Moderate-6-12% slopes. Severe-over 12% slopes.

index, percolation rates, shrink-swell potential, and corrosivity. These can be obtained from on site investigations. Table 12 gives an approximate range in the AASHO and Unified classification of materials in the respective landscape units.

Engineers may find this map useful for locating sources of sand and gravel. Large peat areas which may cause difficulties in road location can be observed. Landscape units with clay will likely have high shrink-swell potential.

Sources of gravel may be found in the Mississippi Valley Outwash and Hinckley Outwash Plain. Within the Twin Cities Formation, pockets of sand and gravel are common and many are indicated by sand and gravel symbols on the map.

Bedrock is generally shallow on the RLWD, RLWL, and RSWD soil landscape units. Some shallow to bedrock areas are shown by rock outcrop symbols. Limerock suitable for crushing usually occurs with the soil landscape units containing R.

Table 13. Approximate engineering classification of materials at the surface and at 5 feet in the soil landscape units delineated in the Stillwater Sheet

Soil landscape unit	AASHO[1]		UNIFIED[2]	
	Surface	5 feet +	Surface	5 feet +
SSWD, SSWL	A-2, A-2-4	A-1, A-2, A-3, A-2-4	SP, SP-SM, SM	SP, SP-SM, SM, GP
SSPD, SSPL	A-2, A-2-4	A-1, A-2, A-3, A-2-4	SP, SP-SM, SM	SP, SP-SM, SM, GP
SLWD, SLWL	A-2, A-4, A-6	A-1, A-2, A-3, A-2-4	SM, SM-SC, ML, ML-CL	SP, SP-SM, SM, GP
SLPD, SLPL	A-2, A-4, A-6	A-1, A-2, A-3, A-2-4	SM, SM-SC, ML, ML-CL	SP, SP-SM, SM, GP
LSWL	A-2, A-2-4	A-4, A-6	SP, SP-SM, SM	SM, SC, SM-SC, ML
LLWD	A-4, A-6, A-7	A-4, A-6, A-7	ML, ML-CL, CL[3]	CL, ML-CL
LLWL	A-2-4, A-6	A-2-4, A-6	SM, ML, CL	SM, ML, ML-CL, CL
LLPD	A-4, A-6, A-7	A-4, A-6, A-7	ML-CL, CL[3]	CL, ML-CL, MH-CH
LLPL	A-2-4	A-4, A-6	SM, ML, CL	SM, ML, ML-CL, CL
SCPL	A-6, A-7	A-1, A-2, A-3, A-2-4	CL, ML-CL, MH-CH[3]	SP, SP-SM, SM, GP
LCWL	A-6, A-7	A-4, A-6, A-7	ML, ML-CL, CL, MH-CH[3]	CL, ML-CL, MH-CH
LCPD	A-6, A-7	A-4, A-6, A-7	ML, ML-CL, CL, MH-CH[3]	CL, ML-CL, MH-CH
CLPD, CLPL	A-4, A-7, A-7	A-6, A-7	ML, CL	CL
XLWL	A-2-4, A-4, A-6	A-2, A-3, A-2-4, A-4, A-6	SM, SM-SC, ML	SP, SP-SM, SM, ML, CL
RLWL	A-2-4, A-6	Bedrock	SM, SM-SC, ML, ML-CL	Bedrock
RSWD	A-2, A-2-4	Bedrock	SP, SP-SM, SM	Bedrock
A	Variable	Variable	Variable	Variable
P	A-8	A-8	P+	P+

[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.

Houses replacing corn fields is a common change in the landscape of the Stillwater Sheet. This photo is from northern Dakota County when soils are well suited for both crop production and urban development.

Appendix A

Alphabetical list of major soils series.

Adolph—Moderately dark colored, very poorly drained, medium acid loams with clay loam or loam subsoils over reddish brown, stony, noncalcareous sandy loam glacial till or glacial outwash (Typic Haplaquolls).

Adrian—Wet, organic soil 16 to 50 inches thick over sandy sediments, very poorly drained to marshy (Terric Medisaprist).

Alluvial Land, undifferentiated—Consists of recent alluvium of variable textures and of variable drainage on flood plains.

Anoka—Light-colored, well-drained, loamy fine sand 12 to 36 inches thick over fine sand (Eutric Glossoboralf).

Barronett—Dark-colored, poorly drained silt loam or loam about 36 inches thick over stratified silts and very fine sands which are usually medium acid lacustrine sediments (Mollic Ochraqualfs).

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

Becker—Floor plain soils that are well- and moderately well-drained with sandy loam, loam, or silt loam 24 to 48 inches thick over sandy loam, loam, or silt loam (Typic Hapludoll).

Bellechester—Dark-colored, well-drained, loamy sand 40 to 70 inches thick over sandstone bedrock (Entic Hapludoll).

Braham—Light-colored, well-drained, loamy fine sand about 24 inches thick, over sandy clay loam or loam about 18 inches thick, over calcareous loam till (Arenic Eutrochrept).

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).

Brickton—Light-colored, well-drained, silt loam to silty clay loam 48 inches thick over silt loam to silty clay loam lacustrine sediments (Mollic Ochraqualf).

Burkhardt—Dark-colored, well-drained, loamy fine sand about 24 inches thick, over sandy clay loam or loam about 18 inches thick, over calcareous loam till (Typic Hapludoll).

Caron—Organic soil 16 to 50 inches thick over limnic material, very poorly drained to marshy (Limnic Medihemist).

Cathro—Organic soil developed from highly decomposed herbaceous material that is underlain by loamy mineral material at 16 to 50 inches. It is black in color and very poorly drained (Terric Borosaprist).

Chaska—Formed in loamy alluvium on flood plains and higher bottomlands, poorly drained loam or silt loam 24 to 48 inches thick over sandy loam, loam, or silt loam (Mollic Fluvaquent).

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

Clarion—Dark-colored, well-drained loams about 30 to 40 inches thick over calcareous loam till (Typic Hapludoll).

Copaston—Dark-colored, well-drained, loam or silt loam 20 to 40 inches thick over bedrock (Lithic Hapludoll).

Cordova—Dark-colored, poorly to somewhat poorly drained, silty clay loam over clay loam till (Typic Argiaquoll).

Dakota—Dark-colored, well-drained, loam or sandy loam over loam to about 24 to 40 inches over sand containing a few pebbles (Typic Argiudoll).

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

Dickman—Dark-colored, well-drained, loamy sand 12 to 36 inches thick over sand (Typic Hapludoll).

Doberton—Light-colored, well-drained soils formed in a loamy mantle or loess and erosional sediment 10 to 24 inches thick over fragmented limestone (Typic Hapludalfs).

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

Dundas—Light-colored, somewhat poorly to poorly drained, silt loam to clay loam about 48 inches thick over loam (Udollic Ochraqualf).

Emmert—Light-colored, well and moderately well-drained sand soil developed over loam and sandy loam material. The soil is usually leached of carbonates to a depth 24 to 50 inches (Typic Udorthent).

Erin—Light-colored, well and moderately well-drained soils developed from limy glacial till in which shale fragments are common. Depth to free carbonates is typically 40 to 60 inches (Glossoboric Hapludalf).

Estherville—Dark-colored, well-drained, slightly acid sandy loam with sandy loam subsoil over limy coarse sand and gravel below 15 to 24 inches (Typic Hapludoll).

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

Freeon—Light-colored, moderately well-drained soil developed in a thin silt mantle over sandy loam to loam till (Typic Glossoboralfs).

Freer—Light-colored, poorly drained, silt loam 18 inches thick over loam and fine sandy loam 24 inches thick over sandy loam red till (Aeric Ochraquallf).

Glencoe—Dark-colored, poorly drained, clay loam about 24 to 35 inches thick over loam grading to calcareous loam glacial till (Cumulic Haplaquoll).

Halder—Light-colored, somewhat poorly drained, loam to about 34 inches underlaid by stratified sands and loamy sands (Aquic Glossorboralf).

Hayden—Light-colored, well-drained, loam over slightly acid clay loam over calcareous loam glacial till (Typic Hapludalf).

Hillet—Dark-colored, poorly drained, silt 20 to 40 inches thick over leached reddish or brownish sand and gravel (Typic Haplaquoll).

Hubbard—Dark-colored, somewhat excessively drained, slightly to medium acid loamy coarse sand about 14 inches thick over slightly acid coarse sand (Udorthentic Haploboroll).

Isan—Dark-colored, poorly drained, loamy sand 12 to 36 inches thick over sand (Typic Haplaquoll).

Isanti—Dark-colored, poorly drained, loamy fine sand 12 to 36 inches thick over fine sand (Typic Haplaquoll).

Kanabec—Light-colored, moderately well drained, silt loam and silty clay loam, strongly acid, over calcareous stratified lacustrine sands and gravel (Aquic Glossoboralf).

Kilkenny—Dark-colored, well-drained loamy soils developed from limy shaly glacial till. Free carbonates occur from 36 to 64 inches in depth (Mollic Hapludalf).

Kingsley—Moderately dark-colored, well-drained, slightly acid sand loam to loamy sand about 14 inches thick over medium acid to strongly acid heavy sandy loam subsoil about 20 inches thick over medium acid sandy loam till (Mollic Hapludalf).

Lerdal—Dark-colored, somewhat poorly to moderately well-drained, slightly to medium acid silty clay loam about 14 inches thick over strongly to very strongly acid silty clay to heavy clay loam about 28 inches thick over calcareous clay loam shaly till (Udollic Ochraqualf).

Lester—Moderately dark-colored, well-drained, medium acid light clay loam about 13 inches thick over medium to slightly acid clay loam subsoil over calcareous loam till (Mollic Hapludalf).

Lesueur—Dark-colored, moderately well to somewhat poorly drained light clay loam about 19 inches thick over medium acid clay loam subsoil about 20 inches thick over calcareous loam till (Aquic Ariudoll).

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

Markey—Wet, organic soil about 36 inches thick over sandy sediments, very poorly drained (Terric Borosaprist).

Menahga—Light-colored, excessively drained, medium acid loamy sand and sands over slightly acid waterlaid sands (Typic Udipsamment).

Milaca—Light-colored, well-drained, with a fragipan beginning at depths of 14 to 24 inches, loam to sandy loam 36 to 48 inches thick over sandy loam (Typic Fragiochrept).

Mora—Light-colored, moderately to well-drained, with a fragipan beginning at depths of 18 to 32 inches, sandy loam to loam about 48 inches thick over sandy loam (Aquic Fragiboralf).

Nemadji—Light-colored, somewhat poorly drained, fine sand sediments sometimes grading to medium sand (Spodic Udipsamments).

Nessel—Light-colored, moderately well-drained, loam 18 inches thick over clay loam and loam to 39 inches underlain by calcareous, friable fine sandy loam or loam till (Glossic Hapludalfs).

Nicollet—Dark-colored, moderately well to somewhat poorly drained, slightly to medium acid, light clay loam over calcareous loam till (Aquic Hapludoll).

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

Ogilvie—Light-colored, somewhat poorly drained, silt loam and loam to 32 inches underlain by gravelly coarse sand (Mollic Haplaquepts).

Omega—Light-colored, excessively drained, medium acid fine sands over reddish-colored outwash acid sands (Spodic Udipsamments).

Onamia—Light-colored, sandy loam soil from 24 to 40 inches in depth. It is underlain by gravelly coarse sand (Typic Glossoboralf).

Otter—Dark-colored, poorly drained silt loam soils formed in deep silty and loamy flood plain materials. Neutral surfaces (Curmulic Haplaquoll).

Palms—Organic soil underlain by loamy mineral material at 16 to 50 inches. Soil is neutral throughout (Terric Medisaprist).

Parent—Dark-colored, poorly drained, loam and fine sandy loam 40 inches thick over firm reddish brown or brown sandy loam till (Typic Haplaquoll).

Plainfield—Light-colored, excessively drained, medium acid loamy sand to sand about 20 inches thick over strongly acid medium and coarse sand about 28 inches thick over strongly acid fine and medium sand (Typic Udipsamment).

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

Rifle—Organic soil over 36 inches thick, very poorly drained (Typic Borohemist).

Rockton—Dark-colored, well-drained, slightly to medium acid loam about 20 inches thick over medium acid loam to clay loam about 10 inches thick over limestone bedrock (Typic Argiudoll).

Sartell—Light-colored, well to excessively drained, fine sand throughout (Typic Udipsamment).

Seelyeville—Organic soil developed in highly decomposed, herbaceous materials that are more than 50 inches thick. It is very poorly drained and dark-colored (Typic Borasaprist).

Soderville—Light-colored, somewhat poorly to poorly drained, loamy fine sand 12 to 36 inches thick over sand (Aquic Glossoboralf).

Sparta—Dark-colored, excessively drained, neutral loamy sand, about 12 inches thick over medium to strongly acid loamy sand to sand about 24 inches thick over medium acid sand (Entic Hapludoll).

Wadena—Dark-colored, well-drained, neutral to slightly acid loam about 30 inches over slightly acid sandy loam about 5 inches thick, grading to calcareous coarse sand and fine gravel at about 35 inches (Typic Hapludoll).

Waukegan—Dark-colored, well-drained neutral to slightly acid silt loam about 15 inches over medium acid silt loam about 18 inches thick over coarse sand and fine gravel about 9 inches thick over calcareous coarse sand and gravel (Typic Hapludoll).

Webster—Dark-colored, poorly drained neutral clay loam about 27 inches thick, grading to calcareous loam glacial till (Typic Haplaquoll).

Zimmerman—Light-colored, excessively drained, acid loamy fine sand to fine sand about 60 inches thick over fine to medium sand (Alfic Udipsamment).

Appendix B

Status of current detailed soil surveys in counties totally or partially within the Stillwater Sheet as of June 1979.

County	Status	Total land acres
Anoka	Report available	272,000
Benton	Report available	258,560
Chisago	No work in progress	264,190
Hennepin	Report available	361,600
Isanti	Report available	282,880
Kanabec	No work in progress	336,000
Mille Lacs	No work in progress	363,245
Morrison	No work in progress	727,040
Pine	No work in progress	903,680
Ramsey	Field work complete	102,400
Sherburne	Report available	280,320
Washington	Field work complete	249,600
Wright	Report available	429,440

Glossary

Alluvium—(Alluvial deposits)—Soil material, such as sand, silt, or clay deposited on land by streams.

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—See Brainerd Text.

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 gently irregular surface. The debris is deposited underneath and at the margin of a glacier during the active recession of the ice sheet.

Lacustrine—Deposits formed on the bottom of lakes.

Limnic Materials—Materials deposited in fresh water lakes and consisting primarily of chemical and biological precipitates and partly decomposed aquatic organisms.

Limy—See calcareous.

Loess—A geological deposit of relatively uniform, silty material transported to its present position by wind.

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.

Organic Soil—All soils which have more than 16 inches of material with more than 25 percent organic matter.

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.

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, frequently of dissimilar materials, from which soils were formed.

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.

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

Terrace (Geological)—An old sandy and gravelly alluvial plain, ordinarily level or nearly level bordering a river. A terrace is seldom subject to overflow.

Texture, Soil—The relative proportions of sand, silt, and clay particles in a mass of soil. The 3 basic textural classes follow in order of increasing proportion of fine particles:

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.

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

Till Plain—See ground moraine.

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6. This Milaca sandy loam is a common type of soil on the McGrath Till Plain. It would be in the LLWL soil landscape unit.
7. Drainage ditches are needed to remove excess water on poorly drained mineral and organic soils for farming.
8. This gray loam to clay loam till is the parent material for the Hayden soils of Wright and Hennepin Counties.
9. In contrast to the gray, limy, clay rich till of No. 8, this reddish brown till is a common parent material in the area north and east of the Twin Cities. Kingsley soils are developed from this kind of parent material.
10. Phosphorus and other nutrients running off the land cause water plants to flourish in ponds and lakes.
11. Native red oak trees help beautify this Fridley neighborhood and are well adapted to glacial till developed soils with high water holding capacity.