

Miscellaneous Report 168—1980

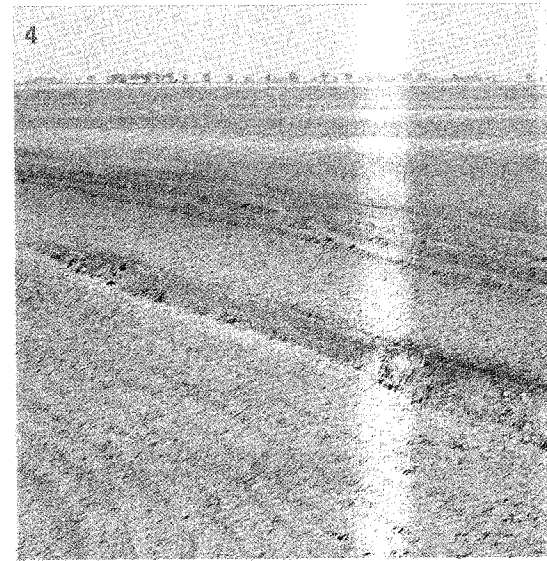
MINNESOTA SOIL ATLAS

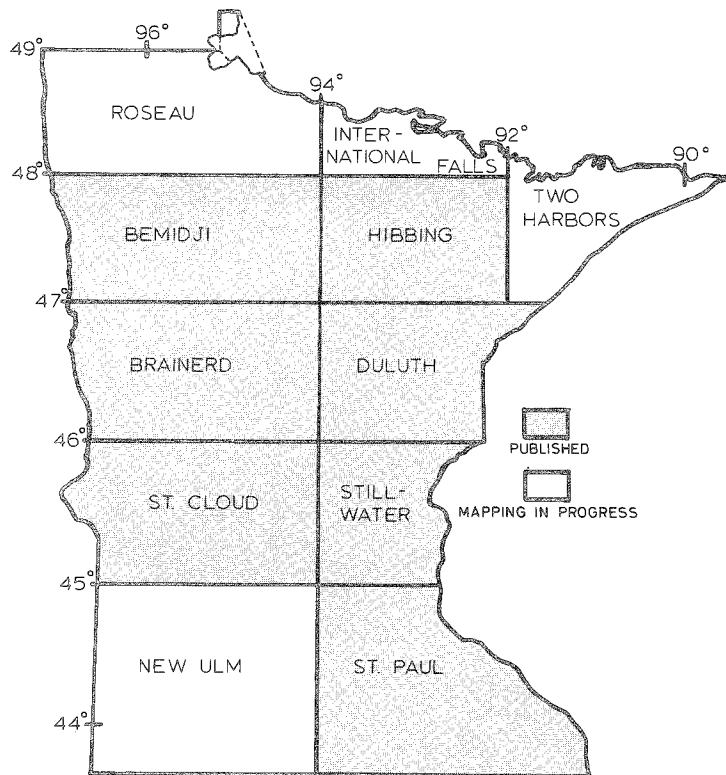
bemidji
sheet

Agricultural Experiment Station
University of Minnesota



1. Large farms and nearly level land characterize the Agassiz Lacustrine Plain, Red River Valley Area (1).
2. Sunflowers are a crop of increasing importance in unit LLWD of the Agassiz Lacustrine Plain, Red River Valley Area (1).
3. Swathing barley in unit CCPD of the Agassiz Lacustrine Plain, Red River Valley Area (1).
4. Color of topsoil reflects slight differences in elevation of portions of the Agassiz Lacustrine Plain, Red River Valley Area (1). Lighter areas are slightly higher and are calcareous at the surface.
5. Soil properties can change significantly in a very short distance as seen in the cross section of a soil complex (unit CCPD of geomorphic area 1).





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Brainerd (MR 90) (\$3); Hibbing (MR 110) (\$3); St. Paul (MR 120) (\$4); Metro (MR 130) (\$3); Duluth (MR 148) (\$4); St. Cloud (MR 159) (\$5); Stillwater (MR 171) (\$5). Price of this publication: \$5.

Acknowledgment

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

R. A. Erickson, R. H. Rust, and G. F. Harms did the field work, map, and report. H. E. Wright, Jr., Department of Geology, University of Minnesota, assisted in developing the geomorphic areas.

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Introduction

Information is lacking on the soils and landscape characteristics of large areas of Minnesota. Many planning agencies simply have to go without information needed for their work. Detailed soil surveys published on a scale of 1:20,000 or 1:15,480 are being made by the National Cooperative Soil Survey to fill this need. Because they cannot be supplied rapidly enough for broad planning, the Soil Atlas is being developed. It is not intended to replace detailed soil survey reports, which are essential for planning the use of smaller pieces of land. Detailed soil survey work, carried on in most counties but unavailable in published form, has been assembled and supplemented to compile the Bemidji Sheet of the Minnesota Soil Atlas.

Until detailed soil surveys are available for all Minnesota counties, broad planning can be facilitated by the eleven sheets to be published in the Minnesota Soil Atlas series (see page 3). As detailed soil surveys become available, the broad view of large planning will still be necessary. It is proposed that this series of maps be published with explanatory texts for each quadrangle in the state. For uniformity the Atlas Sheets are being published on the same scale as the U.S. Geological Survey topographic maps and other maps prepared by the Minnesota Geological Survey.

The Bemidji Sheet encompasses approximately 5,875,000 acres in northwestern Minnesota: from 47° to 48° N. latitude and from 94° W. longitude to the western border of the state, extending from Lake Winnibigoshish to Grand Forks and including parts or all of 13 counties. Only one published county soil survey is available in this area. Appendix B indicates the extent of modern soil surveys in this area.

Use of the Soil Atlas

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

1. To determine areas suitable for various crops such as potatoes, sugar beets, and canning crops to enable processors to locate plants within areas of greatest potential.
2. To determine areas' potential for various types of farming, forestry, or recreation.
3. To determine areas that would benefit from drainage or irrigation.
4. To prepare wildlife density maps.
5. To locate pulp and lumber mills within areas of greatest potential supply.
6. To locate feasible routes for utility lines and highways.
7. To serve as reference for science teachers in junior high, high school, and college courses.

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

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

How the Map Was Prepared

The base map was prepared from the Bemidji quadrangle and the eastern portion of the Grand Forks 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 detailed soil surveys where available. The published survey of Hubbard County was also used. Field work was necessary where no soil survey information existed.

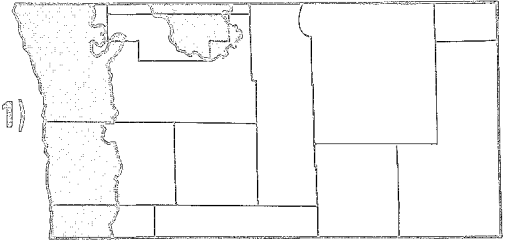
In the attempt to provide a generalized map for the user with a minimum knowledge of soils, soils are grouped into soil landscape units based on the following factors:

1. Texture of the soil material below 5 feet into sandy (S); loamy or silty (L); clayey (C); mixed sandy and loamy (X); mixed silty or loamy and clayey (Y); 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 well-drained soils designated (W); and poorly drained designated (P). Units with (W) designation will normally have water tables below the rooting zone and units with (P), water tables commonly within the rooting zone.
4. Color of the surface soil with dark color designated (D); and light color designated (L). Thus, the Nebish* series would appear on the map as LLWL and would be interpreted from the map as a light-colored, well-drained loamy soil over loamy material (in this instance loamy glacial till). Beltrami and Warba soils would also appear in this landscape unit. Some areas on the map do not have a four-letter symbol. These are soil landscapes such as SP for shallow peat over sandy, LP for shallow peat over loamy, NP for non-acid deep peat, AP for acid deep peat, A for flood plain, and M for marsh.

Twenty three geomorphic areas are delineated to illustrate broad physiographic features and to provide some identification of parent materials on which the soils have developed (table 1). Several geomorphic areas will extend into adjoining counties. Soil landscape units are mostly delineated within the geomorphic areas. The soil series which occur within a soil landscape unit commonly differ among geomorphic areas. Principal soil series, when known, are included in tables 2 to 25.

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

Agassiz Lacustrine Plain, Red River Valley Area (1)



This region covers approximately 1,111,000 acres or 19 percent of the Bemidji Sheet.

The Red River Valley consists of a low nearly level plain formerly occupied by Glacial Lake Agassiz. The Red River forms the western boundary in Minnesota and most of the region occurs west of the beaches which form the eastern boundary. This area formed in an estimated 250 to 300 feet of water. Lake-laid sediments are commonly from 5 to 10 feet thick. Clay, silty clay, and silt loam textures are most common.

An area east of the Inter-Beach (IC) region is included in the region mainly because of the loamy textures. Water depth in this part of the lake was much less than nearer the Red River, consequently lake-laid sediments are much shallower. In places the sediments consist of water-worked till.

The Red River is a slow-moving, winding stream with about 5 feet fall per mile. The basin slopes gradually westward and northward. Red Lake, Marsh, and Rice rivers are the main tributaries flowing through the region into the Red. Depth of the water table is normally 5 to 10 feet. Near the beach line it is less than 5 feet. No lakes 160 acres or more in size occur in the region.

About 66 percent of the region consists of poorly drained soils. The remaining 34 percent has moderately well to somewhat poorly drained soils. Runoff is slow to very slow, permeability is slow and the water-holding capacity is high.

Original vegetation was mainly tall prairie grass. Northern hardwoods occurred along the main streams, and brush prairie occupied most of the northern Red Lake County. About 5 percent remains forested, mainly to northern hardwoods along the main streams. Ten to 20 percent is grass and brush occurring in small tracts. Some of these are pastured. Seventy-five to 85 percent is cropland. Barley, wheat, soybeans, sunflowers, sugar beets, and potatoes are the main crops.

Thirteen soil landscape units are mapped in the region: CCPD, LLWD, LLPD, CLPD, A, SLWD, SLPD, CLWD, LP, SSWD, SSPD, LSPD, and LSWD. Table 2 gives selected features of the units. Additional information follows:

CCPD Approximately 25 percent of the soils are limy throughout. About 5 percent are loamy in the upper 2 to 3 feet. Another 5 percent are silty. These loamy and silty soils are better drained. (Vertic Haplaquolls)

LLWD In 5 to 10 percent of the unit lacustrine clays occur at 3 to 4 feet below the surface. During wet peri-

ods, a perched water table builds up above the clay zone. Another 5 to 10 percent have very fine sands below 2 to 3 feet. Most of the soils in the unit are alkaline. Gypsum crystals occur in many of the soils below 2 to 3 feet. (Aeric Calciaquolls)

LLPD Loam and clay loam soils developed on water-modified till are dominant in this unit. The soils are generally calcareous below 20 inches and 25 to 35 percent are alkaline to the surface. Five to 10 percent are moderately well drained. (Typic Haplaquolls)

CLPD Silt loam soils are intermixed with clayey soils. Most of the silt loam soils are slightly better drained. About 80 percent of the soils are alkaline. Gypsum crystals occur below 2 to 4 feet in some places. (Typic Calciaquolls)

A Most of this unit occurs along Red Lake River. (Unclassified)

SLWD The unit includes 10 to 20 percent sandy soils. Another 5 to 15 percent are poorly drained. Five to 10 percent are deep silt loams. Most of the soils are alkaline. (Aeric Calciaquolls)

SLPD Most of the soils in the unit are alkaline. An estimated 10 percent are moderately well drained; 10 percent are deep silt loams and another 10 percent are sandy. The water table is normally less than 6 feet deep. (Typic Calciaquolls)

CLWD Soils in most of the unit are alkaline. The unit includes 10 to 15 percent deep silty soils, 5 to 10 percent clayey soils, and another 10 to 15 percent poorly drained soils. (Aeric Calciaquolls)

LP The peat is less than 4 feet deep in most of the unit. Included are 10 to 20 percent poorly drained mineral soils. (Terric Borosaprists)

SSWD The unit includes sandy and gravelly soils on beach lines and deep sandy soils. About 10 percent are very fine sandy loams in the upper 24 inches. Another 10 percent are poorly drained. (Aeric Calciaquolls)

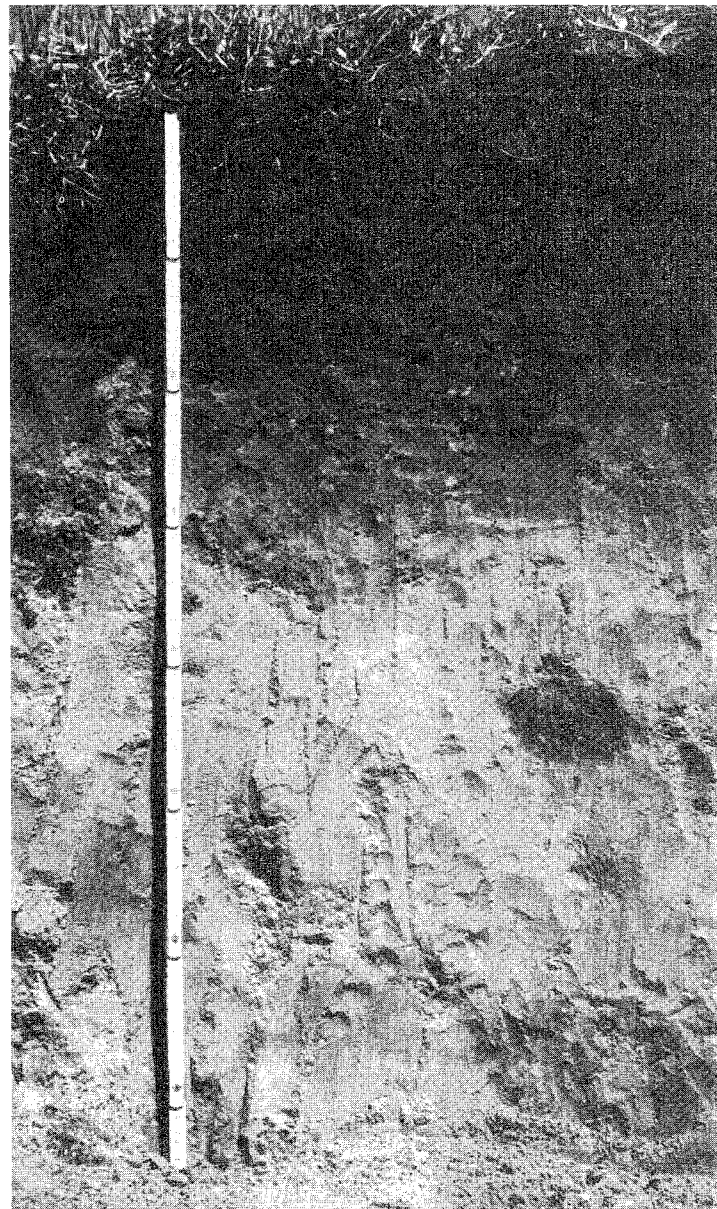
SSPD The unit includes 10 to 15 percent better drained soils. (Typic Calciaquolls)

LSPD About 15 percent are deep sands. (Typic Haplaquolls)

LSWD About 15 percent are deep sands. (Udorthentic Haploborolls)

Table 1. Acreage estimates of geomorphic areas within the Bemidji Sheet

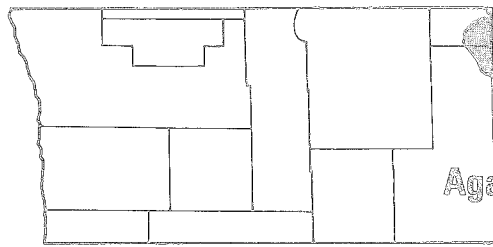
| No. | Name | Acres | Percent of sheet |
|-----|---|------------------|------------------|
| 1 | Agassiz Lacustrine Plain, Red River Valley Area | 1,111,000 | 19 |
| 1B | Agassiz Lacustrine Plain, Big Fork Valley Area | 59,000 | 1 |
| 1C | Agassiz Lacustrine Plain, Inter-Beach Area | 555,000 | 9 |
| 1D | Agassiz Lacustrine Plain, Red Lake Area | 315,000 | 5 |
| 2 | Fergus Falls (Young Gray Drift) Till Plain | 130,000 | 2 |
| 2A | Fosston Till Plain, loamy | 289,000 | 5 |
| 2B | Blackduck Till Plain, loamy | 467,000 | 8 |
| 2C | Falk Till Plain, loamy | 104,000 | 2 |
| 3 | Alexandria Moraine Complex | 311,000 | 5 |
| 3A | Erskine Moraine, loamy | 153,000 | 3 |
| 3B | Northome Moraine, loamy | 42,000 | 1 |
| 3C | Clearbrook Moraine, loamy | 145,500 | 3 |
| 4 | Detroit Lakes Pitted Outwash Plain | 1,000 | T |
| 5 | Mahnomen Lacustrine Plain | 229,000 | 4 |
| 8 | Park Rapids - Staples Outwash Plain | 95,000 | 2 |
| 11 | Itasca Moraine Complex, rolling | 764,000 | 13 |
| 22A | Marcell Moraine Complex | 4,800 | T |
| 22B | Sugar Hills Complex, rolling to hilly | 29,000 | 1 |
| 24 | Swatara Plain, silty | 65,500 | 1 |
| 25 | Aitkin Lacustrine Plain, sandy | 191,500 | 3 |
| 47 | Bagley Outwash Plain, sandy and gravelly | 225,000 | 4 |
| 48 | Guthrie Till Plain, loamy | 238,000 | 4 |
| 49 | Bemidji Sand Plain | 272,000 | 5 |
| | Total | 5,796,300 | 100 |



Profile of soil landscape unit LLWD formed in silt loam sediments of glacial Lake Agassiz. This unit makes up a major portion of geomorphic area 1.

Table 2. Selected features of soil landscape units within the Agassiz Lacustrine Plain, Red River Valley Area (1) 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 | |
| CCPD | 27 | level lake plain | silty clay and clay (3) | clay (3-20+) | 8-12 | poorly drained | 6.5-7.8 | low | high | Fargo Hegne Viking |
| LLWD | 25 | level lake plain | silt loam and silty clay loam (4) | silt loam and silty clay loam (4+) | 8-12 | moderately well and somewhat poorly drained | 7.2+ | low | high | Bearden |
| LLPD | 17 | level lake plain | loam, sandy loam, clay loam (4) | clay loam and silt loam (4+) | 8-12 | poorly drained | 7.2+ | low | medium | Roliss Rockwell Colvin |
| CLPD | 11 | nearly level lake plain; some micro relief | silt loam, silty clay loam and silty clay (3) | clay and silty clay loam (3-20+) | 8-12 | poorly and somewhat poorly drained | 6.5-7.8 | low | high | Fargo Colvin Bearden |
| A | 11 | nearly level | silty clay and clay loam (2-4) | silty clay and clay loam (4+) | 8-12 | somewhat poorly and poorly drained | 6.1-7.2 | variable | variable | Cashel, Unnamed |
| SLWD | 3 | level lake plain | loam, very fine sandy loam and silt loam (2-3) | loamy very fine sand (3-4+) | 4-8 | moderately well and somewhat poorly drained | 7.2+ | low | medium | Glyndon |
| SLPD | 1 | level lake plain | very fine sandy loam, loam and silt loam (2-3) | loamy very fine sand (3-4+) | 4-8 | poorly drained | 7.2+ | low | low to medium | Borup |
| CLWD | 1 | nearly level lake plain | loam and very fine sandy loam (2-3) | clay and silty clay (3-20+) | 8-12 | somewhat poorly and moderately well drained | 7.2+ | low | medium | Wheatville |
| LP | 1 | level to depressional | muck and peat (1-3) | loam and clay loam (3-4+) | 8-12 | very poorly drained | 5.5-7.8 | low | low | Cathro Haug |
| SSWD | 1 | nearly level to gently sloping lake plain and beaches | sandy loam, loamy fine sand and gravelly loam (1-2) | fine sand, and sand and gravel (2-4+) | <4 | moderately well, somewhat poorly and excessively drained | 6.8+ | medium | low | Ulen Sioux Flaming |
| SSPD | <1 | level to slightly depressional lake plain | sandy loam and loamy sand (1-2) | fine sand (2-4+) | <4 | poorly drained | 7.2+ | medium | low | Fossum |
| LSPD | <1 | level lake plain | loamy sand and sand (1-3) | loam and clay loam (3-4+) | 4-8 | poorly drained | 6.2-7.2 | medium | low | Kratka Grygla |
| LSWD | <1 | nearly level lake plain | sandy loam and loamy sand (1-3) | clay loam and loam (3-4+) | 4-8 | moderately well drained | 7.2-7.8 | high | medium | Towner |
| Lakes | <1 | | | | | | | | | |



Agassiz Lacustrine Plain, Big Fork Valley Area (1B)

The region covers an area of approximately 59,000 acres or 1 percent of the Bemidji Sheet.

The Big Fork Valley is a relatively level depressed plain formerly occupied by the eastern portion of Glacial Lake Agassiz. Only a small portion of this region is located in the Bemidji Sheet. The water table is normally surface to 6 feet deep on the peat bogs, and over 6 feet deep in the remainder of the region. There is one lake covering about 700 acres.

The plain is generally covered by 5 feet or more of silty and clayey lacustrine sediments over calcareous loamy till. The water-holding capacity is high.

The original vegetation was mainly upland spruce and balsam fir. Tamarack, black spruce, and alder occurred on peat bogs. An estimated 80 to 90 percent is forested, largely by aspen, spruce, and balsam fir. Vegetation on the bogs has not changed much. Ten to 20 percent is cropland. Oats, timothy, and brome are the principal crops.

Nine soil landscape units are mapped in the region: LLPL, CCPL, LLWL, LP, CCWL, SSWL, LSWL, P, and NP. Table 3 gives selected features of the units. Additional characteristics follow:

LLPL The soils in this unit are quite similar to those in LLWL except that they occupy slightly lower landscape position and are more poorly drained. (Typic Ochraqualfs)

CCPL The soils are calcareous below 12 to 20 inches. (Typic Ochraqualfs)

LLWL Most of the cultivated land in Big Fork Valley Area is in this unit. Minor areas of the poorly drained soils are included. The soils are limy below 15 to 24 inches. (Aquic Eutroboralfs)

LP The peat is over 3 feet thick over most of this unit. The unit includes a small percentage of mineral soils. (Terric Borosaprists)

CCWL The soils in this unit are closely associated with those in CCPL but differ in occupying a slightly higher position and being better drained. (Aquic Eutroboralfs)

SSWL This unit consists largely of a narrow beach line which has 6 feet or less of higher elevation than the surrounding lake plain. (Aquic Udipsamments)

LSWL The sands range from 18 to 40 inches thick over calcareous water worked loam till. (Spodic Udipsamments)

P About 10 percent of the unit consists of shallow peat and 5 to 10 percent poorly drained mineral soils. (Typic Borohemists)

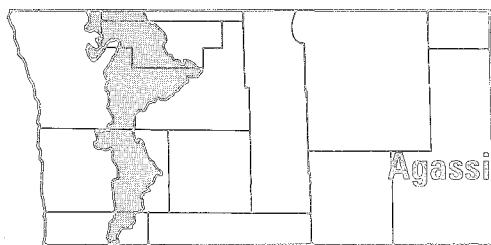
NP Somewhat poorly and very poorly drained mineral soils occupy about 10 percent of the unit. (Typic Borosaprists)

Table 3. Selected features of soil landscape units within the Agassiz Lacustrine Plain, Big Fork Valley Area (1B) 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 | |
| LLPL | 40 | level to slightly depressed lake plain | very fine sandy loam, silt loam, and silty clay loam (2-3) | silt loam (3-5+) | 8-12 | somewhat poorly to very poorly drained | 5.8-6.6 | low | low | Spooner Kelsey |
| CCPL | 16 | level to slightly depressed lake plain | silty clay and clay (2-3) | clay (3-5+) | 8-12 | poorly and very poorly drained | 5.2-6.2 | high | medium | Indus Wabanica |
| LLWL | 13 | level to gently sloping lake plain | very fine sandy loam, silt loam, and silty clay loam (2-4) | silt loam (4+) | 8-12 | moderately well and somewhat poorly drained | 5.5-6.4 | medium | medium | Eaudette Spooner |

Table 3 (continued). Selected features of soil landscape units within the Agassiz Lacustrine Plain, Big Fork Valley Area (1B) 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 | |
| LP | 10 | level to depressed lake plain | peat (2-3) | peat - 3 to 4 feet over clay loam (4-5+) | 8+ | very poorly drained | 5.5-7.8 | low | low | Seelyeville Cathro |
| CCWL | 10 | nearly level to undulating lake plain | silty clay and clay (2-3) | clay (3-5+) | 8-12 | moderately well drained | 5.2-6.2 | high | medium | Taylor |
| SSWL | 3 | nearly level to undulating lake plain | loamy fine sand and fine sand (1-3) | fine sand (3-5+) | <4 | moderately well to somewhat poorly drained | 5.2-6.8 | very high | low | Hiwood Redby |
| LSWL | 6 | nearly level to undulating lake plain | loamy fine sand and fine sand (2-4) | clay loam (4-5+) | 4-8 | moderately well drained | 5.2-6.2 | medium to high | low | Gudrid |
| P | 5 | level to depressed lake plain | peat (2-3) | peat (3-6) | >12 | very poorly drained | 5.5-7.8 | low | low | Mooselake |
| NP | 1 | level to depressed lake plain | peat (1-3) | peat (3+) | >12 | very poorly drained | 5.5-7.8 | low | low | Seelyeville Cathro |
| Water | 1 | | | | | | | | | |



Agassiz Lacustrine Plain, Inter-Beach Area (1C)

The region contains an area of approximately 555,000 acres or 9 percent of the Bemidji Sheet.

The Inter-Beach Area consists of beaches formed during the different stages of Glacial Lake Agassiz and the lower poorly drained areas between the beaches. The ridges usually are 2 to 15 feet high, but locally may be several feet higher. Width ranges from about 150 to 500 feet. Commonly several are grouped together in complexes of a half mile or more wide. The beaches act as natural levees holding back water long enough to form long narrow, poorly and very poorly drained areas. Depth of the water table on the well-formed beaches and better-drained areas is normally over 10 feet, but between beaches is usually less than 6 feet deep. Three lakes, each at least 160 acres in size and totaling about 1,300 acres, are located in the region.

Soils on the beaches are sandy, gravelly, and droughty. Non-beach areas generally range from sandy to loamy but include smaller areas of clayey and peat soils. The water-holding capacity on sandy soils is low and on other areas high.

The original vegetation was prairie with numerous clumps of aspen except in Red Lake County. There the vegetation was open prairie-woodland. An estimated 30 to 40 percent of the region is cropland, 35 to 45 percent is pasture and meadow land, and 20 to 30 percent is wooded, mainly to aspen. The main crops are oats, barley, wheat, and sunflowers.

Sixteen soil landscape units are mapped in the region: SSWD, LLPD, SSPD, LLWD, LSWD, CCPD, A, SLPD, SLWD, LSPD, LP, SP, SSWL, CLPD, CLWD, and M. Table 4 gives selected features of each unit. Additional characteristics follow:

- SSWD Most of the unit occurs on beaches. Included are 15 to 25 percent of loamy poorly and very poorly drained soils between beaches too narrow to delineate. (Udorthentic Haploborolls)
- LLPD Beach ridges too narrow to delineate are included. They make up 10 to 20 percent of the unit. Another 10 to 20 percent have a sandy layer 10 to 20 inches thick within the 36 inch depth. Approximately 40 percent of the unit has alkaline soils. (Typic Haplaquolls, calcareous)
- SSPD An estimated 10 to 20 percent of the soils occur on narrow beach ridges. An additional 10 to 20 percent are poorly drained loamy soils. Most of the soils are alkaline. (Typic Haplaquolls)

- LLWD The unit includes 10 to 20 percent poorly drained loamy soils, 5 to 10 percent shallow sandy over loamy soils, and 5 to 10 percent sandy soils. (Aquic Haploborolls)
- LSWD An estimated 10 to 20 percent are deep sandy soils, 10 to 20 percent are poorly drained, and another 5 to 10 percent are deep loamy soils. (Udorthentic Haploborolls)
- CCPD In 5 to 10 percent of the unit the upper 20 to 30 inches consists of loamy sediments and in another 5 percent fine sands occur below 36 to 48 inches. Approximately 25 percent of the unit is alkaline. (Typic Haplaquolls)
- A This unit comprises the flood plains along the Red Lake and Clearwater rivers. It is subject to frequent flooding. (unclassified)
- SLPD Included are narrow beach ridges. These make up 10 to 20 percent of the unit. Deep loamy soils comprise 10 to 20 percent, and sandy soils make up another 5 to 10 percent. (Typic Calcicquolls)
- SLWD Inclusions in this unit are small areas of deep sandy soils, of poorly drained soils, and of deep loamy soils. (Aeric Calcicquolls)
- LSPD The unit includes minor areas of deep sandy soils and deep loamy soils. A few areas are well drained. (Typic Haplaquolls)
- LP Approximately 30 percent of the peat is less than 3 feet thick. Mineral soils make up about 15 percent of the unit. These are mainly poorly and very poorly drained loams, but include some gravelly soils. (Terric Borosaprists)
- SP Mineral soils occur in about 10 percent of the unit.
- SSWL About 20 percent are moderately dark-colored soils; 15 percent are underlain by loamy sediments at 2 to 4 feet; and 15 percent are poorly drained. (Aquic Udipsamments)
- CLPD The clayey and silty soils are intermixed in this unit and in places the silty soils are less than 3 or 4 feet thick over clay. (Vertic Haplaquolls)
- CLWD The unit includes small areas of clayey and deep loamy soils. (Aeric Calcicquolls)
- M These areas are covered with water much of the year. (unclassified)

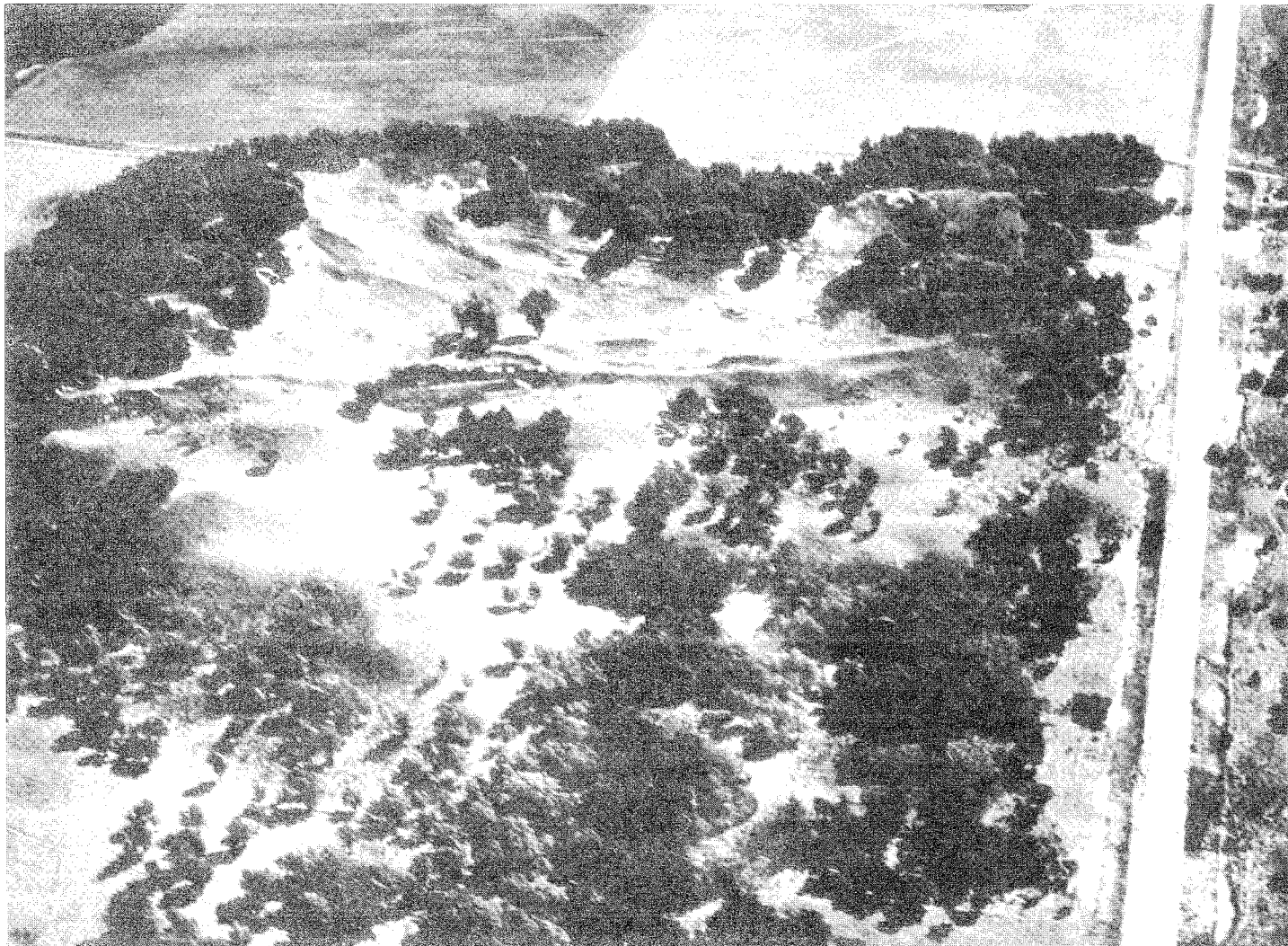
Table 4. Selected features of soil landscape units within the Agassiz Lacustrine Plain, Inter-Beach Area (1C) geomorphic region

| 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 | 35 | nearly level to undulating lake plain and beaches | loamy sand gravelly sandy loam and fine sand (1-3) | sand and gravel fine sand (3+) | <4 | excessively and moderately well drained | 6.8+ | medium | low | Sioux Flaming Ulan |
| LLPD | 28 | level to depressional lake plain | loam, sandy loam, and clay loam (2-4) | loam and clay loam (4+) | 8-12 | poorly and very poorly drained | 7.2+ | low | medium | Roliss Rockwell |
| SSPD | 12 | level to depressional lake plain | loamy fine sand and fine sandy loam (1-2) | fine sand (2-4+) | <4 | poorly and very poorly drained | 7.2+ | medium | low | Fossum Hamar Unnamed |
| LLWD | 8 | level to gently sloping plain | loam and clay loam (4) | clay loam (4+) | 8-12 | moderately well to somewhat poorly drained | 6.8-7.6 | low | medium | Kittison |
| LSWD | 4 | level to gently sloping lake plain | loamy sand and sandy loam (2-3) | clay loam (3-5+) | 4-8 | moderately well and somewhat poorly drained | 6.8+ | high | low | Towner Grimstad |
| CCPD | 3 | level lake plain | clay and silty clay (3) | clay (3-5+) | 8-12 | poorly drained | 6.8+ | low | high | Viking Hegne Fargo |
| A | 3 | narrow stream bottoms | loam and clay loam (2-4) | loam and clay loam (4+) | 8-12 | poorly drained | 6.1-7.2 | variable | variable | Unnamed |
| SLPD | 2 | level to depressional lake plain | very fine sandy loam and silt loam (2-3) | loamy very fine sand and very fine sand (3-5+) | 4-8 | poorly drained and very poorly drained | 7.6+ | low | low | Borup Arveson |
| SLWD | 2 | nearly level lake plain | very fine sandy loam and loam (2-3) | loamy very fine sand and very fine sand (3-5+) | 4-8 | moderately well to somewhat poorly drained | 7.2+ | low | medium | Glyndon |
| LSPD | 1 | level to depressional lake plain | fine sandy loam, loamy fine sand, and fine sand (2-3) | clay loam (3-5+) | 4-8 | poorly and very poorly drained | 5.2-6.2 | medium | low | Kratka Grygla |
| LP | <1 | slightly depressed lake plain | peat (1-3) | clay loam (3-5+) | 8+ | very poorly drained | 5.5-7.8 | low | low | Cathro Haug |
| SP | <1 | level to depressional lake plain | peat (1-3) | peat, sand and loam (3+) | 8+ | very poorly drained | 5.5-7.8 | low | low | Deerwood Markey |
| SSWL | <1 | nearly level to undulating lake plain and beaches | loamy fine sand and fine sand (2-3) | clay loam (3-5+) | 4-8 | moderately well to somewhat poorly drained | 5.2-6.8 | very high | low | Hiwood Marquette |

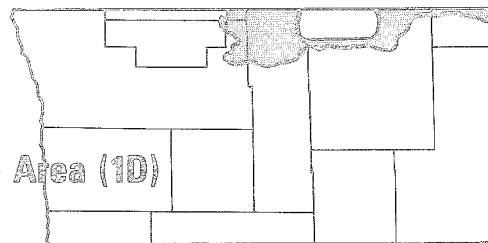
Table 4 (continued). Selected features of soil landscape units within the Agassiz Lacustrine Plain, Inter-Beach Area (1C) geomorphic region

| 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 | |
| CLPD | <1 | level to depressional lake plain | silty clay loam silt loam and silty clay (3) | clay and silty clay loam (3-5+) | 8-12 | poorly and somewhat poorly drained | 6.5+ | low | high | Fargo Colvin Bearden |
| CLWD | <1 | level to nearly level lake plain | loam and very fine sandy loam (2-3) | silty clay and clay (3-5+) | 8-12 | moderately well to somewhat poorly drained | 7.2+ | low | medium | Wheatville Donaldson |
| M | <1 | depressed lake plain | peat or mineral soil (2-3) | peat or mineral soil (3-5+) | 1-4 feet of marshy water on surface | | | | | |

Dunes formed by blowing sand from the beaches of glacial Lake Agassiz.



Agassiz Lacustrine Plain, Red Lake Area (1D)



This region contains an area of approximately 315,000 acres or about 5 percent of the Bemidji Sheet.

The region is a large nearly level, depressed plain formerly occupied by Glacial Lake Agassiz. It includes the organic and sandy soils in the vicinity of Lower Red Lake, and a beach along the southern margin. Most of Lower Red Lake, a total of 129,000 acres, is located in the region. Depth of the water table is normally over 10 feet on better drained soils and between the surface and 6 feet on more poorly drained soils.

The region contains shallow lacustrine sediments over calcareous loam and clay loam till. The upper portion of the till has been modified by wave action. Much of the area south and east of the lake has a sand cap, generally over 4 feet thick, but 2 to 4 feet thick in many places. The beaches are discontinuous and in most places 5 to 10 feet high. They are sandy and gravelly. The water-holding capacity of the sandy soils in the region is low and on loamy soils, high.

The original vegetation along the western side was prairie with numerous clumps of aspen. South and east of Lower Red Lake was largely upland spruce and fir. Swamp conifers occupied the peat areas. Approximately 35 percent of the land is under cultivation. Oats, barley, clover, alfalfa, and brome are the main crops. About 10 percent is pasture land, 45 percent forested, and 10 percent is marsh. Aspen occurs on the mineral soils and black spruce and tamarack on the peat land.

Fifteen soil landscape units are mapped in the region: NP, M, LLPD, SSWL, SSPL, LSPL, LLPL, LSWL, SSWD, SSPD, A, SP, LP, LLWL, and LSPD. Table 5 shows selected characteristics of each soil landscape unit. Additional characteristics follow:

- | | | | |
|------|--|------|---|
| NP | The organic soils are predominantly over 3 feet thick over calcareous clay loam till. A sandy substratum occurs in a few places. In about 25 percent of the unit the peat is less than 3 feet thick. Poorly drained mineral soils occupy less than 5 percent of the unit. (Typic Borosaprists) | SSWL | Approximately 30 percent of the unit occurs on beaches. These are generally coarse sandy and gravelly soils. About 10 percent of the unit is underlain at 30 to 48 inches by clay loam till. About 10 percent is poorly drained. (Aquic Udipsamments) |
| M | The unit consists of a relatively large marshy area with some open water. Soils are mostly formed in deep peat, but include some mineral soils. (Unclassified) | SSPL | Included in 10 to 15 percent of this unit are soils which are underlain at 30 to 48 inches by clay loam till. Another 10 to 15 percent are moderately well drained. Shallow peat occupies another 5 to 10 percent. (Typic Psammaquents) |
| LLPD | The upper 1 to 2 feet is mainly water reworked till over calcareous loam to clay loam till. The surface foot, in places, is lacustrine. Approximately 5 percent of the area includes peat soils. (Typic Haplaquolls) | LSPL | Approximately 10 percent of soils in this unit are moderately well drained, 10 to 15 percent are deep sands and another 5 percent are loamy. (Typic Haplaquents) |
| | | LLPL | Ten to 15 percent of the soils are moderately well drained. Another 10 percent has a sandy surface 10 to 20 inches thick. Shallow peat occupies about 5 percent of the unit. (Typic Ochraqualls) |
| | | LSWL | In 10 to 15 percent of the unit the sands are over 4 feet thick, 5 to 10 percent are loamy and another 10 to 15 percent are poorly drained. (Spodic Udipsamments) |
| | | SSWD | The eastern part of this unit grades into light-colored soils. (Udorthentic Haploborolls) |
| | | SSPD | An estimated 10 percent of the unit is underlain by clay loam till at 30 to 40 inches. Ten to 15 percent has moderately well drained soils. (Mollic Psammaquents) |
| | | A | This unit represents the flood plain along two rivers flowing into Lower Red Lake from the east. (unclassified) |
| | | SP | Poorly drained mineral soils comprise 5 to 10 percent of this unit. (Histic Humaquepts) |
| | | LP | Mineral soils comprise about 10 to 15 percent of the unit. (Terric Borosaprists) |
| | | LLWL | Somewhat poorly to poorly drained soils make up about 30 percent of the unit. Shallow peat occurs in 5 percent and silty soils in another 5 percent of the unit. (Aquic Eutroboralfs) |
| | | LSPD | Approximately 15 percent of this soil landscape unit consists of deep sands, 5 percent is shallow peat and 25 percent is moderately well-drained, light-colored soils. (Typic Haplaquolls) |

Table 5. Selected features of soil landscape units within the Agassiz Lacustrine Plain, Red Lake Area (1D) geomorphic region

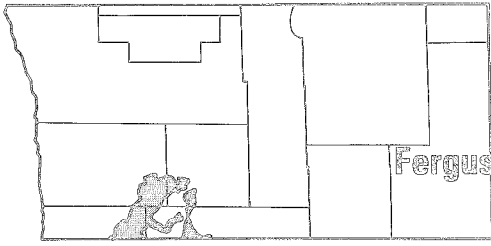
| Soil landscape unit | Percent geomorphic region | Landscape position | Most common texture and thickness (feet) | | Moisture relationships | | Approximate fertility in rooting zone | | | Representative soil series |
|---------------------|---------------------------|---|--|--------------------------------------|-------------------------------------|---|---------------------------------------|----------------|----------|------------------------------|
| | | | Rooting zone | Substratum | Inches of available water to 5 feet | Drainage class | pH | P | K | |
| NP | 24 | level to depressional lake plain | peat (1-3) | peat (3+) | >12 | very poorly drained | 5.5-7.8 | low | low | Soelyville Carnro |
| M | 10 | level to depressional | peat (1-3) | peat or mineral (3+) | 1-4 feet of water on surface | marshy | | | | |
| LLPD | 9 | level to depressed lake plain | clay loam, sandy loam, and loam (2-4) | loam and clay loam (4+) | 8-12 | poorly and very poorly drained | 7.2+ | low | medium | Rolfas Rockwell |
| SSWL | 7 | nearly level lake plain and sloping beaches | loamy sand, sandy loam and fine sand (1-2) | fine sand, sand and gravel (2-5+) | <4 | well to somewhat poorly drained | 5.2-6.8 | very high | low | Hiwood Redby Marquette |
| SSPL | 7 | level lake plain | loamy fine sand and fine sand (1-3) | fine sand (3+) | <4 | poorly and somewhat poorly drained | 5.2-6.2 | high | low | Redby Cormant |
| LSPL | 7 | level lake plain | loamy fine sand and fine sand (2-3) | loam and clay loam (3+) | 4-8 | poorly and very poorly drained | 5.2-6.2 | medium | low | Grygla Unnamed |
| LLPL | 2 | level lake plain | loam and silt loam (4) | clay loam and silt loam (4+) | 8-12 | poorly and somewhat poorly drained | 5.5-6.4 | low | low | Chilgren Spooner |
| LSWL | 2 | nearly level lake plain | loamy fine sand and fine sand (2-3) | clay loam and loam (3+) | 4-8 | moderately well and somewhat poorly drained | 5.2-6.2 | medium to high | low | Gudrid |
| SSWD | 1 | gently sloping beaches | loamy sand and sandy loam (1-2) | sand and gravel (2-5+) | <4 | excessively drained | 6.6-7.8 | low to medium | low | Sioux Lohnes |
| SSPD | 1 | level to depressed lake plain | loamy fine sand and fine sand (1-3) | fine sand (3-5+) | <4 | poorly and very poorly drained | 5.2-6.2 | medium to high | low | Unnamed Cormant |
| A | 1 | narrow stream bottoms | loam, clay loam, and sandy loam (2-4) | loam, clay loam, and sandy loam (4+) | 8-12 | poorly drained | | variable | variable | Unnamed |
| SP | 1 | level to depressional | peat (1-3) | peat, sand and loam (3+) | 8+ | very poorly drained | 5.5-7.8 | low | low | Deerwood Markey |
| LP | <1 | slightly depressed lake plain | peat and loam (1-3) | clay loam (3-5+) | 8+ | very poorly drained | 5.5-7.8 | low | low | Cathro Haug |

Table 5 (continued). Selected features of soil landscape units within the Agassiz Lacustrine Plain, Red Lake Area (1D) 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 | <1 | nearly level to gently sloping lake plain | loam, sandy, clay loam, and fine sandy loam (3-4) | fine sandy loam and loam (4-5+) | 8-12 | moderately well drained | 6.2-7.2 | low | high | Garnes |
| LSPD | <1 | level to depressed lake plain | loamy sand and sand (2-3) | loam and clay loam (3-5+) | 4-8 | poorly drained | 5.2-6.2 | medium | low | Kratka Grygla |
| Water | 27 | | | | | | | | | |

Black spruce and tamarack are the dominant tree species in the forested peat lands south of Lower Red Lake.





Fergus Falls (Young Gray Drift) Till Plain, (2)

This region encompasses an area of about 130,000 acres or about 2 percent of the Bemidji Sheet.

The Fergus Falls Till Plain is gently rolling but includes some nearly level to rolling areas. Small marshes and depressions are common. Three small lakes, each at least 160 acres in size and totaling approximately 890 acres, are located in the region. The water table is normally more than 10 feet deep on the well-drained soils and at the surface to about 6 feet deep in lower poorly drained positions.

The soils developed on loamy calcareous glacial till, but include areas intermixed with sand and gravel and small areas intermixed with clayey till. Some stones occur on the land, but most have been removed on cultivated fields. The water-holding capacity is high.

The original vegetation was tall grass prairie. Bottomland hardwoods occurred along the Wild Rice River. Seventy to 75 percent is under cultivation. Principal crops are wheat, barley, oats, and corn; other crops are flax, alfalfa, brome, soybeans, and sunflowers. Twenty to 25 percent is pasture and native meadow. Small marshes and bogs make up the rest.

Seven soil landscape units are mapped in the region: LLWD, LLPD, A, XLWD, SLWD, YLWD, and LP. Table 6 gives selected features of the units. Additional information follows:

LLWD About 15 percent is mainly made up of poorly drained soils. Depressions and small potholes represent about 5 percent of the unit. (Udic Haploborolls)

LLPD Soils of the unit commonly occur in depressions. About 20 percent of the unit has moderately well-drained soils. (Typic Haplaquolls)

A The unit includes small areas of organic soils, and small areas of upland soils. (Unclassified)

XLWD Sandy and gravelly soils occur in about 30 to 35 percent of the unit. Poorly drained depressions occupy about 5 percent of the unit. (Udic Haploborolls)

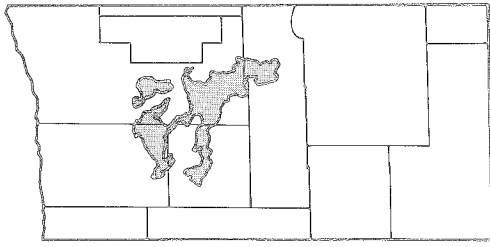
SLWD Approximately 15 percent of the unit consists of deep loamy soils. (Udic Haploborolls)

YLWD Clayey soils occur in 25 to 30 percent of the unit. (Mollic Eutroboralfs)

LP About 20 percent are very poorly to moderately well-drained mineral soils. Less than 10 percent are deep peat soils. (Terric Borosaprists)

Table 6. Selected features of soil landscape units within the Fergus Falls Till Plain (2) geomorphic region

| Soil landscape unit | Percent geomorphic region | Landscape position | Most common texture and thickness (feet) | | Moisture relationships | | Approximate fertility in rooting zone | | | Representative soil series |
|---------------------|---------------------------|------------------------------|---|--|-------------------------------------|-----------------------------------|---------------------------------------|----------|---------------|-----------------------------------|
| | | | Rooting zone | Substratum | Inches of available water to 5 feet | Drainage class | pH | P | K | |
| LLWD | 87 | gently rolling upland | loam (4) | loam (4-20+) | 8-12 | well drained | 6.1-7.2 | low | high | Barnes Langhei Svea |
| LLPD | 5 | nearly level to depressional | loam, silt loam and clay loam (2-4) | loam (4-20+) | 8-12 | poorly to very poorly drained | 6.1-7.2+ | low | medium | Flom Quam Urness Vallers |
| A | 3 | narrow stream bottoms | variable—mainly sandy loam and loam (2-4) | variable—mainly sandy loam and loam (4+) | 4-12 | poorly to moderately well drained | 6.1-7.2+ | variable | variable | Unnamed |
| XLWD | 1 | rolling upland | loam, sand and gravel (2-4) | loam, sand and gravel (4-20+) | 4-12 | well and excessively drained | 6.1-7.2 | low | low to medium | Barnes Langhei Sioux |
| SLWD | 1 | gently rolling upland | loam and sandy loam (2-3) | sand and gravel (3-20+) | 4-8 | somewhat excessively drained | 6.2-7.2 | low | medium | Sverdrup Arvilla Unnamed |
| YLWD | 1 | rolling upland | loam to silty clay loam (2-4) | loam to silty clay (4-20+) | 8-12 | well drained | 6.1-7.2 | medium | medium | Waukon Unnamed |
| LP | <1 | level to depressional upland | peat and loam muck (1-3) | peat and loam (3-20+) | 8+ | very poorly drained to marshy | 5.5-7.8 | low | low | Cathro Haug |



Fosston Till Plain, Loamy (2A)

This region has approximately 289,000 acres or 5 percent of the Bemidji Sheet.

The Fosston Till Plain is characterized by gently rolling topography with a few areas of more rolling landscape. Depressions, potholes, and small bogs are common. The water table is normally deeper than 10 feet. On peat bogs and poorly drained soils it is at the surface to 6 feet deep. Five lakes, each at least 160 acres and totaling 7,000 acres, are located in the region.

Soils developed on calcareous loam till. Soils in some places bordering on the Mahnomen Lacustrine Plain (5) are silty in the upper 12 to 24 inches.

In Norman County the original vegetation was tall grass prairie. The rest of the region contained an open hardwood forest, commonly termed prairie border. It was probably originally prairie, which was later invaded by hardwoods. The more common species were maple, elm, oak, basswood, and ash. An estimated 65 percent is cropland. Principal crops are oats, wheat, barley, and corn. Approximately 20 percent is pasture and 10 percent woodland. The remaining 5 percent is marsh or peat bogs.

Eleven soil landscape units are mapped in the region: LLWD, LLPD, LLWL, A, LP, SSWD, SSPD, LSWD, SLWD, NP, and SLPD. Table 7 gives selected features of the units. Additional characteristics follow:

LLWD Poorly drained soils comprise about 5 percent of the unit. Approximately 5 percent of the unit has sandy surface soils and about 5 percent has clayey soils. (Mollic Eutroboralfs)

LLPD Moderately well-drained soils make up about 10 percent of the unit. About 5 percent is sandy. (Typic Haplaquolls)

LLWL About 10 percent of the unit is moderately dark-colored soils. An estimated 5 percent is sandy and 5 percent is poorly drained. (Typic Eutroboralfs)

A These are relatively narrow stream bottoms subject to frequent overflows. (Unclassified)

LP Poorly and moderately well-drained loamy mineral soils comprise about 10 percent of the unit. (Terric Borosaprists)

SSWD The sand and gravel are underlain by loam till at 4 to approximately 20 feet. About 10 percent of the unit has loamy soils. (Udorthentic Haploborolls)

SSPD Approximately 15 percent is moderately well drained and 5 percent is loamy soils. Shallow peat occurs in about 5 percent of the unit. (Typic Haplaquolls)

LSWD About 10 percent is deep loamy soils. (Psammenitic Haploborolls)

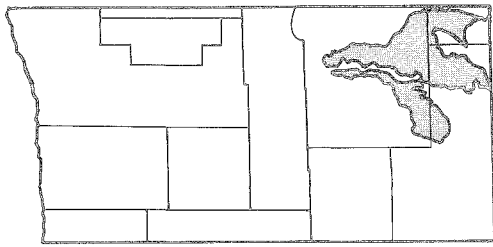
SLWD Approximately 15 percent is loamy and 5 percent has a gravelly substratum. (Udic Haploborolls)

SLPD About 15 percent is sandy and 10 percent is loamy. (Typic Calciaquolls)

NP About 10 percent of the unit is very poorly drained mineral soil. (Typic Borosaprists)

Table 7. Selected features of soil landscape units within the Fosston Till Plain (2A) 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 | |
| LLWD | 69 | undulating upland | loam to clay loam (4) | loam (4-20+) | 8-12 | well and moderately well drained | 6.1-7.2 | medium | medium | Waukon Gonvick |
| LLPD | 17 | level to depressional upland | clay loam and silty clay loam (2-4) | loam and clay loam (4-20+) | 8-12 | poorly and very poorly drained | 6.1-7.2+ | low | medium | Flom Roliss Rockwell |
| LLWL | 6 | gently rolling to rolling upland | upland to clay loam (2-4) | loam (4-20+) | 8-12 | well drained | <6.0 | medium | medium | Nebish |
| A | 3 | narrow stream bottoms | variable—mainly sand loam and loam (2-4) | variable—mainly sand loam and loam (4+) | 4-12 | poorly to moderately well drained | 6.1-7.2 | variable | variable | Unnamed |
| LP | 1 | level to depressional | peat and muck (1-3) | peat and loam (3+) | 8+ | very poorly drained | 5.5-7.8 | low | low | Cathro Haug Seelyeville |
| SSWD | 1 | gently rolling to rolling upland | loamy sand (1-2) | sand and gravel (2-4+) | <4 | excessively drained | 6.8-7.8 | medium | low | Sioux Maddock |
| SSPD | <1 | nearly level to depressional | loamy sand and sand (2-4) | sand and fine sand (4-20+) | 4-8 | poorly drained | 7.2+ | medium | low | Hamar Unnamed |
| LSWD | <1 | gently rolling upland | loamy sand to sandy loam (2-4) | loam (4-20+) | 4-8 | well drained | 6.8-7.6 | high | low | Unnamed Foldahl |
| SLWD | <1 | gently rolling | sandy loam (2-3) | loam fine sand (3+) | 4-8 | well drained | 6.1-7.2 | low | medium | Sverdrup Unnamed |
| SLPD | <1 | gently sloping to depressional | sandy loam to loam (2-3) | sand and gravel (3+) | 4-8 | poorly to very poorly drained | 6.8+ | low | medium | Syrene Unnamed |
| NP | <1 | level to depressional upland | peat (1-3) | peat (3+) marshy | >12 | very poorly drained to marshy | 5.5-7.8 | low | low | Seelyeville Cathro Mooselake |
| Water | 2 | | | | | | | | | |



Blackduck Till Plain, loamy (2B)

The region encompasses an area of approximately 467,000 acres or 8.1 percent of the Bemidji Sheet.

The Blackduck Till Plain consists largely of undulating upland topography. In Beltrami County, the area between Pemushe and Pool Lakes ranges from gently rolling to rolling. Two relatively large areas of nearly level to slightly depressional landforms occur in the plain. One is located generally north of Funkley along the Beltrami County line and westward towards Lower Red Lake. The other area occurs in the northeast part of the region. Numerous peat bogs up to 300 acres in size occur throughout the plain. There are 15 lakes, each at least 160 acres in size. Total water area is approximately 13,400 acres. The water table is normally more than 10 feet deep on higher elevations and at the surface to about 6 feet deep in lower positions.

The soils developed on loamy calcareous glacial till and have a high water-holding capacity. A 2 to 4 feet thick sandy cap covers the till in an area bordering the Mississippi River and Winnibigoshish Lake.

The original vegetation was largely white and red pine on the upland. Tamarack and black spruce occupied most peat bogs. At present 10 to 20 percent is forested mainly to aspen and upland hardwoods. The species have not changed much on the peat bogs. An estimated 60 to 70 percent is cropland, and 15 to 25 percent pasture. The principal crops are alfalfa, brome, timothy, red clover, and oats. The pastures include some peat bogs, small marshes, and wooded areas.

Nine soil landscape units are mapped in the region: LLWL, LLPL, NP, LSWL, LSPL, SSWL, YLWL, A, and P. Table 8 gives selected features of the units. Additional information follows:

LLWL Somewhat poorly drained soils occupy about 15 percent of the unit. Another 5 percent consists of very poorly drained mineral and organic soils. The unit also includes approximately 5 percent clayey soils. (Typic Eutroboralfs)

LLPL Organic soils occur in about 15 percent of this unit. Inclusions of loamy moderately well-drained soils account for an additional 15 percent. (Aeric Ochraqualfs)

NP Approximately 55 percent of the unit is deep peat and 35 percent is shallow. The shallow peat occurs mainly in the smaller bogs and along the edges of the larger ones. The unit includes about 10 percent somewhat poorly to very poorly drained soils. There are minor inclusions of well-drained loamy soils. (Typic Borosaprists)

LSWL The sand cap generally is less than 48 inches thick over calcareous loamy till. The unit includes about 20 percent deep loamy well and moderately well-drained soils. Approximately 5 percent of the unit is somewhat poorly to very poorly drained soils. (Psammentic Eutroboralfs)

LSPL The sand is underlain at 48 inches or less by calcareous loamy till. Approximately 20 percent of the unit has loamy or shallow organic soils. Approximately 15 percent of the unit has well and moderately well-drained soils. (Aeric Ochraqualfs)

SSWL Loamy till is within 48 inches of the surface in about 15 percent of the unit. Another 5 percent is deep loamy soils. Approximately 5 percent is poorly drained. (Typic Udipsamments)

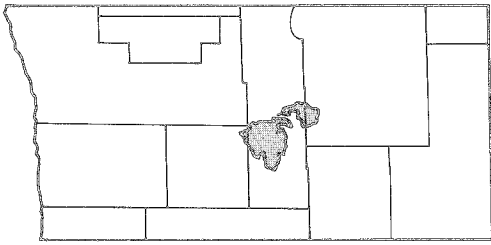
YLWL Approximately 65 percent of the unit has loamy substrata and 35 percent has clayey. An estimated 10 percent of the unit consists of poorly drained soils. (Typic Eutroboralfs)

A This unit occurs along South Branch of the Cormorant River. (Unclassified)

P About 5 percent of the unit consists of very poorly drained mineral soils. (Typic Borohemists)

Table 8. Selected features of soil landscape units within the Blackduck Till Plain, (2B) 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 | 53 | gently rolling to rolling upland | loam to clay (3) | loam (4-20+) | 9-12 | well to moderately well drained | <6.0 | medium | medium | Nebish Beltrami Shooker |
| LLPL | 28 | nearly level to depressional upland | loam to silty clay loam (2-4) | clay loam (4-20+) | 8-12 | somewhat poorly to very poorly drained | 6.0-6.8 | low | low | Shooker Bluffton Unnamed |
| NP | 9 | level to depressional upland | peat (1-3) | peat (3+) | >12 | very poorly drained to marshy | 5.5-7.8 | low | low | Seelyeville Cathro Mooselake |
| LSWL | 2 | gently rolling to rolling upland | loamy sand and sand (2-4) | loam 4-20+ | 4-12 | well drained | <6.0 | high to very high | low | Kinghurst |
| LSPL | 2 | nearly level to depressional upland | loamy sand and sand (2-4) | loam (4-20+) | 4-12 | somewhat poorly to very poorly drained | 6.0-6.8 | medium | low | Unnamed |
| SSWL | 2 | gently rolling to rolling upland | loamy sand and sand (1-3) | sand and gravel (3+) | <4 | excessively drained | <6.0 | high | low | Menahga Marquette |
| YLWL | <1 | gently rolling to rolling upland | loam, clay loam and silty clay (4) | loam and silty clay (4-20+) | 8-12 | well drained | <6.0 | medium | medium | Nebish Beltrami Unnamed |
| A | <1 | narrow stream bottoms | variable—mainly sandy loam and loam (2-4) | variable—mainly sandy loam and loam (4+) | 4-12 | poorly to moderately well drained | 6.1-7.2+ | variable | variable | Unnamed |
| P | <1 | level to depressional upland | peat (1-3) | peat (3+) | >12 | very poorly drained | 5.5-7.8 | low | low | Mooselake |
| Water | 3 | | | | | | | | | |



Falk Till Plain, loamy (2C)

The region encompasses approximately 104,000 acres or 2 percent of the Bemidji Sheet.

The Falk Till Plain is characterized by a gently rolling landform containing numerous long relatively narrow depressional areas. The largest peat bog has an area of about 10,000 acres. Numerous small bogs and depressions also occur in the region. On higher positions the water table normally is more than 10 feet deep. However, on lower levels it occurs at the surface to 6 feet deep. The water area in the region totals about 400 acres.

The soils developed on calcareous loamy glacial till. Small pockets of sandy and gravelly soils occur in the region. In places the till contains a sand cap less than 48 inches thick. Generally, the soils have a high water-holding capacity.

The original forest was primarily white and red pine. Tamarack and black spruce occupied most of the peat bogs. An estimated 20 to 30 percent of the region is presently forested, mainly by aspen. Fifty to 60 percent is under cultivation and 15 to 25 percent is pasture land. The primary crops are oats, alfalfa, brome, and timothy.

Six soil landscape units are mapped in the region: LLWL, LLPL, NP, XLWL, LSWL, and SSWL. Table 9 gives selected features of the units. Additional information follows:

LLWL Somewhat poorly drained soils occur in about 10 percent of the unit. Very poorly drained soils

make up another 5 percent. About 5 percent of the unit has sandy soils. (Typic Eutroboralfs)

LLPL An estimated 15 percent of the unit consists of moderately well-drained loamy soils. (Aeric Ochraqualfs)

NP Deep peat occurs in about 55 percent of the unit. Another 35 percent is shallow peat. Somewhat poorly and very poorly drained mineral soils occupy about 10 percent of the unit. Inclusions of minor areas of moderately well-drained soils also occur. (Typic Borosaprists)

XLWL The proportion of loamy to gravelly and sandy soils is about 65 to 35. Somewhat poorly to very poorly drained soils occur in about 5 percent of the unit. (Typic Eutroboralfs)

LSWL The sand cap is generally less than 48 inches thick over calcareous loamy till. In about 10 percent of the unit, however, the sands are over 48 inches thick. The unit includes approximately 20 percent deep loamy, well-drained soils. (Psammentic Eutroboralfs)

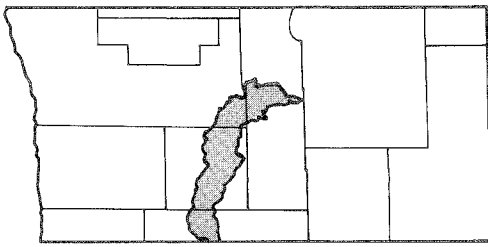
SSWL In about 10 percent of the unit, the sands are less than 48 inches thick over till. (Typic Udipsamments)

Pasturing is an important land use on unit LLPL, which is often too wet for cropland

Table 9. Selected features of soil landscape units within the Falk Till Plain, loamy (2C) 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 | 65 | gently rolling to rolling upland | loam to clay loam (4) | loam (4-20+) | 8-12 | well to moderately well drained | <6.0 | medium | medium | Nebish Beltrami |
| LLPL | 18 | nearly level to depressional upland | loam to silty clay loam (2-4) | clay loam (4-20+) | 8-12 | somewhat poorly to very poorly drained | 6.0-8.0 | low | low | Shooker Bluffton |
| NP | 12 | level to depressional | peat (1-3) | peat and loam (3-20+) | >12 | very poorly drained | 5.5-7.8 | low | low | Cathro Seelyeville Mooselake |
| XLWL | 3 | rolling, upland | loam, clay loam, sandy loam, sand and gravel (2-4) | loam, sand and gravel (4-20+) | 4-12 | well to excessively drained | <6.0 | medium to high | low to medium | Nebish Marquette |
| LSWL | 1 | gently rolling to rolling upland | loamy sand and sand (2-4) | loam (4-20+) | 4-8 | well drained | <6.0 | high to very high | low | Kinghurst |
| SSWL | 1 | gently rolling to rolling upland | loamy sand, sand and gravel (1-3) | sand and gravel (3+) | <4 | excessively drained | <6.0 | high | low | Menahga Marquette |





Alexandria Moraine Complex (3)

The region represents approximately 311,000 acres or about 5 percent of the Bemidji Sheet.

The Alexandria Moraine is a prominent knob and kettle type landform which ranges from 30 to 60 feet higher in elevation than the till plain along the west border. The topography is rolling to hilly including a few steep areas. Potholes and small marshes are numerous. The region has 12 lakes, each at least 160 acres, and totaling 11,580 acres. The water table normally is deeper than 10 feet on the upland and surface to 6 feet deep in the depressions. The sandy and gravelly area located south of Strawberry Lake in Becker County probably is a tunnel valley which was one of the subglacial streams which drained the Bagley Outwash Plain.

The glacial drift consists mainly of calcareous loam till. A narrow strip roughly along the middle of the region contains numerous pockets of clayey till. Glacial stones are fairly common over most of the region. The soils have a high water-holding capacity.

The original vegetation along the east side was northern hardwoods. The main species were oak, elm, and maple. The western side was a transition zone between forest to the east and prairie to the west. Present land use is estimated to be 45 to 55 percent cropland, 25 to 35 percent woodland, and 15 to 25 percent pasture. Oats, wheat, corn, alfalfa, and brome are the principal crops. Aspen, maple, and oak are the main woodland species at present.

Nine soil landscape units are mapped in the region: LLWL, LLWD, YLWL, SSWL, LP, A, LLPD, XLWL, and LLPL. Table 10 gives selected features of the units. Additional information follows:

LLWL The unit includes about 15 percent sandy and gravelly soils and 10 percent poorly and very poorly drained soils. A sand cap 2 to 4 feet thick over till occurs in about 5 percent of the area. (Typic Eutroboralfs)

LLWD Approximately 15 percent of the soils are limy within 12 inches of the surface. Another 10 percent is poorly to very poorly drained. About 10 percent is sandy and gravelly. Minor areas of clayey soils are included. The unit also includes about 10 percent light-colored soils. (Mollic Eutroboralfs)

YLWL Clayey till occurs in about 30 percent of the unit. About 5 percent of the unit has sandy and gravelly soils and another 5 percent has very poorly drained mineral and peat soils. (Typic Eutroboralfs)

SSWL Approximately 15 percent is loamy in the upper 20 to 30 inches with sand and gravel below. Loamy till occurs in about 10 percent of the unit and another 5 percent has peat and poorly drained sandy soils. (Psammentic Eutroboralfs)

LP Approximately 15 percent of the peat is marshy. Shallow peat makes up about 55 percent of the unit. Somewhat poorly to very poorly drained mineral soils occur in about 10 percent of the unit. (Terric Borosaprists)

A This unit is cut up by the winding Wild Rice River. It includes about 10 percent loamy well-drained upland soils. (Unclassified)

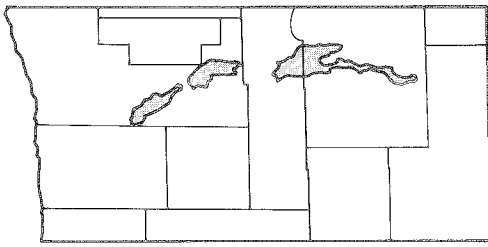
LLPD The unit includes some moderately well-drained soils. (Typic Haplaquolls)

XLWL About 30 percent of the unit is underlain by loamy till and about 70 percent by sandy till.

LLPL About 10 percent of the unit consists of well-drained soils.

Table 10. Selected features of soil landscape units within the Alexandria Moraine Complex (3) geomorphic region

| Soil landscape unit | Percent geomorphic region | Landscape position | Most common texture and thickness (feet) | | Moisture relationships | | Approximate fertility in rooting zone | | | Representative soil series |
|---------------------|---------------------------|-------------------------|--|--------------|-------------------------------------|----------------|---------------------------------------|--------|--------|----------------------------|
| | | | Rooting zone | Substratum | Inches of available water to 5 feet | Drainage class | pH | P | K | |
| LLWL | 52 | rolling to hilly upland | loam to clay loam (4) | loam (4-20+) | 8-12 | well drained | <6.0 | medium | medium | Nebish |
| LLWD | 26 | rolling to hilly upland | loam and clay loam (4) | loam (4-20+) | 8-12 | well drained | 6.1-7.2 | medium | medium | Waukon Gonvick |



Erskine Moraine, loamy (3A)

This region contains approximately 153,000 acres or 3 percent of the Bemidji Sheet.

The Erskine is dominantly a rolling moraine, but includes local areas of hilly topography. Potholes and small marshy bogs are quite common. The elevation generally is less than 100 feet higher than the till plain located along the south side. Ten lakes, each at least 160 acres in size and totaling about 8,700 acres, are located in the moraine. The water table normally is over 10 feet deep on higher positions and at the surface to 6 feet on lower levels.

In some areas the till is intermixed with water-sorted sand and gravel. Two relatively large areas of sandy to gravelly soils are delineated. One occurs along the border between Beltrami and Clearwater counties. The other is in the vicinity of the village of Trail near the Polk and Red Lake county line. The loamy soils have a high water-holding capacity. In the sandy soils, it is low to very low.

Most of the region was originally forested mainly by white and red pine. Part of the region was a transition area between the prairie and forest. This area consisted mainly of oak openings. At present 25 to 35 percent is forested. Aspen is the main species. Cropland accounts for 40 to 50 percent of the land and pastureland the remaining 20 to 30 percent. Main crops are oats, barley, alfalfa, and brome.

Fourteen soil landscape units are mapped in the region: LLWL, LLWD, SSWD, XLWL, CCWL, SSWL, NP, LLPD, A, SLWL, SLPD, LSWL, LSWD, and XLWD. Table 11 gives selected features of the units. Additional information follows:

- LLWL Approximately 5 percent of each of the following inclusions occur in this unit: moderately dark-colored soils; coarse textured soils; and somewhat poorly to very poorly drained soils. (Typic Eutroboralfs)
- LLWD This unit includes minor percentages of poorly to very poorly drained mineral and shallow peat soils. Inclusions of coarse-textured soils also occur. (Mollic Eutroboralfs)
- SSWD About 5 to 10 percent of the unit has loamy soils. (Udorthentic Haploborolls)

- XLWL Loamy substrata materials make up about 65 percent of the unit and sandy, 30 percent. About 5 percent is somewhat poorly to very poorly drained mineral and shallow peat soils. (Typic Eutroboralfs)
- CCWL About 5 percent of this unit consists of poorly drained soils. (Aquic Eutroboralfs)
- SSWL About 25 percent of the unit consists of loamy materials 18 to 24 inches thick over sand and gravel. Deep loamy soils occur in 10 percent and shallow organic soils in 5 percent of the unit. (Psammentic Eutroboralfs)
- NP Approximately 55 percent of the unit is deep peat and 35 percent shallow. The remaining 10 percent includes loamy mineral soils. (Typic Borosaprists)
- LLPD Moderately well-drained soils occur in about 15 percent of the unit. Ten percent is shallow peat. (Typic Haplaquolls)
- A This unit includes some shallow peat and bordering upland loamy soils. (Unclassified)
- SLWL About 15 percent of the unit has deep sandy soils and 10 percent is deep loamy. (Typic Eutroboralfs)
- SLPD This unit includes 20 percent deep sandy soils and about 10 percent which is deep loamy. Another 5 percent is shallow peat. (Typic Haplaquolls)
- LSWL Deep loamy soils comprise approximately 15 percent of the unit and deep sandy, another 10 percent. (Psammentic Eutroboralfs)
- LSWD About 10 percent of this unit consists of deep loamy soils. (Psammentic Haploborolls)
- XLWD Approximately 65 percent of the unit has loamy substrata materials and 35 percent has sandy. (Mollic Eutroboralfs)

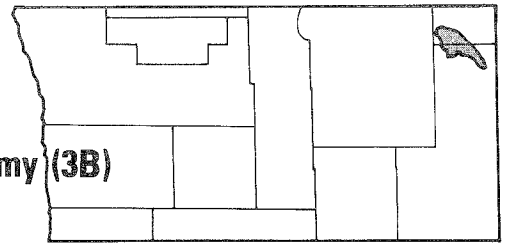
Table 11. Selected features of soil landscape units within the Erskine Moraine, loamy (3A) geomorphic region

| 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 | 52 | rolling upland | loam and clay loam (4) | loam (4-20+) | 8-12 | well drained | <6.0 | medium | medium | Nebish |
| LLWD | 18 | rolling upland | loam and clay loam (4) | loam (4-20+) | 8-12 | well drained | 6.1-7.2 | medium | medium | Waukon |
| SSWD | 7 | rolling to hilly outwash | loamy sand, sandy loam and gravelly sandy loam (1-2) | sand and gravel (2-20+) | <4 | excessively drained | 6.8-7.8 | medium | low | Sioux Arvilla |
| XLWL | 5 | rolling to hilly upland | loam, clay loam, sandy loam, sand and gravel (2-4) | loam, sand and gravel (4-20+) | 4-12 | well to excessively drained | <6.0 | medium to high | low to medium | Nebish Marquette |

Table 11 (continued). Selected features of soil landscape units within the Erskine Moraine, loamy (3A) 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 | |
| CCWL | 5 | rolling upland | silty clay (3) | silty clay to silty clay loam (3-20+) | 8-12 | well drained | <6.0 | medium | low | Taylor |
| SSWL | 4 | rolling outwash | loamy sand, sandy loamy and gravelly loam sand (1-2) | sand and gravel (2-20+) | <4 | excessively drained | <6.0 | high | low | Marquette Lengby |
| NP | 2 | level to depressional | peat (1-3) | peat and loam (3+) | >12 | very poorly drained | 5.5-7.8 | low | low | Seelyeville Cathro |
| LLPD | 2 | gently sloping to depressional upland | loam to silty clay loam (2-4) | loam to clay loam (4-20+) | 8-12 | poorly to very poorly drained | 6.1-7.2 | medium | medium | Flom Quam |
| A | 1 | narrow stream bottoms | variable—mainly loam to sandy loam (2-4) | variable—mainly loam to sandy loam (4+) | 4-12 | poorly to moderately well drained | 6.1-7.8 | variable | variable | Unnamed |
| SLWL | 1 | rolling upland | sandy loam to loam (1-3) | sand and gravel (3-20+) | 4-8 | somewhat excessively drained | <6.0 | high | low | Marquette |
| LSWD | 1 | gently rolling upland | loamy sand to sandy loam | clay loam and loam (3-4+) | 4-8 | moderately well to well drained | 6.8-7.8 | high | medium to low | Towner Foldahl |
| SLPD | <1 | gently sloping to depressional | sandy loam to loam (2-3) | sand and gravel (3+) | 4-8 | poorly to very poorly drained | 6.8+ | low | medium | Unnamed |
| LSWL | <1 | rolling upland | loamy sand and sand (2-4) | loam (4-20+) | 4-8 | well drained | <6.0 | high to very high | low | (Kinghurst)* |
| XLWD | 1 | rolling upland | loam, clay loam, sandy loam, sand and gravel (2-4) | loam, sand and gravel (4-20+) | 4-12 | well to excessively drained | 6.0-7.2 | medium | medium to low | Waukon Sioux |

*Series in parentheses have been used in older soil reports.



Northome Moraine, loamy (3B)

The region encompasses an area of about 42,000 acres or 1 percent of the Bemidji Sheet.

The landform in the Northome Moraine is primarily rolling and in places hilly. It generally is not a prominent moraine considering that the elevation is only 40 to 80 feet higher than the till plain along the north border. Four lakes are located in the region, each 160 acres or more in size, and totaling about 4,100 acres. The water table normally is over 10 feet deep on the well-drained areas and at the surface to 6 feet deep on lower positions.

Most of the region consists of loamy glacial till. An exception is an area of clayey till west of Island Lake in Itasca County. Small pockets of clayey till, too small to delineate, occur in most of the region (northwestern Itasca County). The water-holding capacity of most soils in the region is high.

The original forest vegetation was mainly white spruce and balsam fir. Most of the region remains in forest. Aspen, spruce, and fir are the principal species. Less than 15 percent is cropland and pasture.

Six soil landscape units are mapped in this region: LLWL, LLPL, CCWL, NP, LP, and SSWL. Table 12 gives selected features of the units. Additional information follows:

- LLWL Clayey soils occur in approximately 15 percent of this unit. Another 5 percent is shallow peat bogs. Sandy soils occur in about 5 percent of the unit. (Typic Eutroboralfs)
- LLPL Approximately 10 percent of the unit has well-drained soils. Small amounts of deep peat occur. (Aeric Ochraqualfs)
- CCWL This unit includes about 10 percent of well-drained loamy and 5 percent poorly drained clayey soils. (Aquic Eutroboralfs)
- NP Approximately 60 percent of the unit is deep peat and 30 percent shallow. Acid peat occurs in about 10 percent of the unit. Loamy soils occur in 10 percent of the area. (Typic Borohemists)
- LP This unit includes about 5 percent mineral soils. (Terric Borosaprists)
- SSWL This unit includes about 10 percent poorly drained soils. (Aquic Udipsamments)

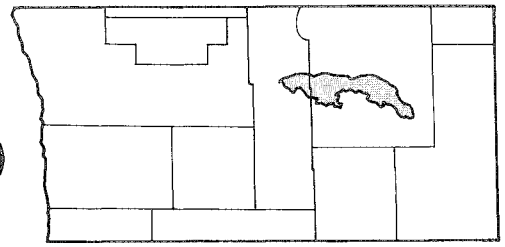


Aspen stand with understory of balsam fir is a common scene in the Northome Moraine Area.

Table 12. Selected features of soil landscape units within the Northome Moraine, loamy (3B) 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 | rolling upland | loam to silty clay loam (4) | loam (4-20+) | 8-12 | well drained | <6.0 | medium | medium | Nebish |
| LLPL | 10 | gently sloping to depressional | loam to silty clay loam (2-4) | loam (4-20+) | 8-12 | somewhat poorly to very poorly drained | 6.0-6.8 | low | low | Shooker Bluffton |
| CCWL | 8 | rolling upland | silty clay (3) | silty clay to silty clay loam (3-20+) | 8-12 | well drained | <6.0 | medium | low | Taylor |
| NP | 4 | level to depressional | peat (1-3) | peat (3+) | >12 | very poorly drained | 5.5-7.8 | low | low | Mooselake Cathro |
| LP | 3 | level to depressional | peat (1-3) | peat and loam (3+) | 8+ | very poorly drained | 5.5-7.8 | low | low | Cathro Haug |
| SSWL | 1 | rolling outwash | loamy sand, sandy loam, and gravelly loamy sand (1-2) | sand and gravel (2-5+) | <4 | excessively drained | <6.0 | high | low | Marquette Lengby |
| Water | 10 | | | | | | | | | |

Clearbrook Moraine, loamy (3C)



This moraine encompasses an area of approximately 145,500 acres or about 3 percent of the Bemidji Sheet.

The Clearbrook Moraine consists of a rolling hilly knob and kettle land form. It is a prominent moraine which in places is 200 feet higher in elevation than the till plain on the north side. Twenty six lakes, each at least 160 acres in size, are located in the region. The total water area is approximately 16,000 acres. The water table normally is more than 10 feet deep on well-drained areas and at the surface to 6 feet deep in lower positions.

In places the loamy till is intermixed with coarser sediments. One area in the southern part of the region is intermixed with clayey material. This area is an extension of the loam-clay intermixed area mapped in the Alexandria Moraine Complex (3). The soils have a high water-holding capacity.

Northern hardwoods originally covered most of this region. The southern part of the region was a transition zone between prairie and forest. It consisted mainly of oak openings. Present land use is approximately 45 percent cropland, 35 percent forest, and 20 percent pasture. Principal crops are oats, alfalfa, and brome. Aspen, which locally is mixed with northern hardwoods, is the principal species.

Five soil landscape units are mapped: LLWL, LSWL, NP, XLWL, and SSWL. Table 13 gives selected features. Additional information follows:

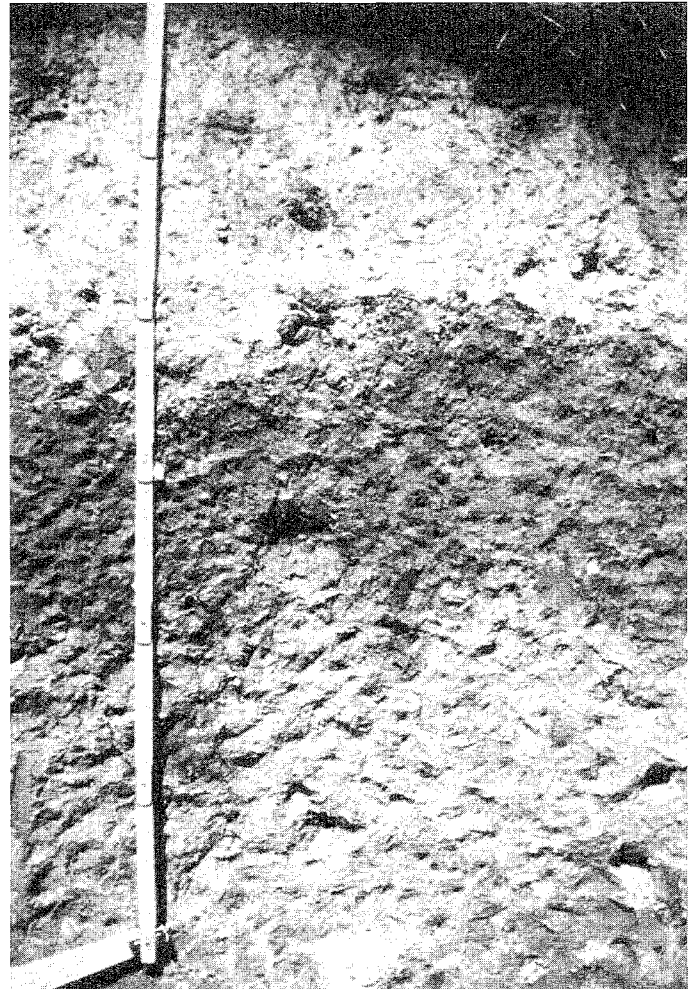
LLWL Approximately 15 percent of the unit includes sandy soils. Another 5 percent is clayey and 5 percent is poorly drained mineral and shallow peat soils. Approximately 10 percent is moderately dark-colored soils. (Typic Eutroboralfs)

LSWL Deep loamy well-drained soils occupy about 10 percent of this unit. Deep sandy soils comprise another 10 percent. Shallow peat occurs in 5 percent of the area. (Psammentic Eutroboralfs)

NP Approximately 55 percent are deep and 35 percent shallow peat soils. The unit also includes 10 percent somewhat poorly and very poorly drained mineral soils. (Typic Borosaprists)

XLWL Approximately 60 percent of the unit has loamy substrata and 35 percent, sandy. Shallow peat occurs in about 5 percent of the unit. (Typic Eutroboralfs)

SSWL In this unit about 15 percent of the soil is loamy to depths of 18 to 24 inches. Shallow sand over loamy till occupies about 10 percent of the area. (Psammentic Eutroboralfs)

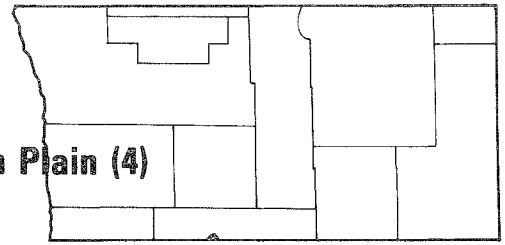


Profile of unit LLWL, the dominant soil of the Clearbrook Moraine. The influence of forest vegetation on soil formation is seen in the very light-colored materials immediately below the dark surface layer.

Table 13. Selected features of soil landscape units within the Clearbrook Moraine, loamy (3C) 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 | 73 | rolling to hilly upland | loam to clay loam (4) | loam (4-20+) | 3-12 | well drained | <6.0 | medium | medium | Nebish |
| LSWL | 10 | rolling to hilly upland | loamy sand to sand (2-4) | loam (4-20+) | 4-8 | well drained | <6.0 | high to very high | low | Unnamed |
| NP | 5 | level to depressional | peat (1-3) | peat and loam (3+) | >12 | very poorly drained | 5.5-7.8 | low | low | Saelyville Cathro |
| XLWL | 4 | rolling to hilly upland | loam, clay loam sandy loam, sand and gravel (2-4) | loam to sand and gravel (4-20+) | 4-12 | well to excessively drained | <6.0 | medium to high | low to medium | Nebish Marquette |
| SSWL | 2 | rolling outwash | loamy sand, sandy loam, and gravelly loamy sand (1-2) | sand and gravel (2-5+) | <4 | excessively drained | <6.0 | high | low | Marquette Lengby |
| Water | 6 | | | | | | | | | |

Detroit Lakes Pitted Outwash Plain (4)



The region has an area of approximately 1,000 acres or less than 1 percent of the Bemidji Sheet.

The plain is mainly gently rolling. Only the northern tip of this region occurs in the Bemidji Sheet. The bulk of it is in the Brainerd Sheet. The water table normally is over 10 feet deep. Total lake area is about 260 acres.

The outwash sediments consist of water sorted sand and gravel. The water-holding capacity is low to very low.

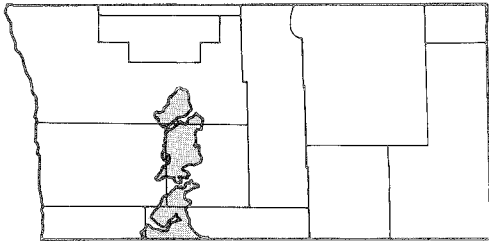
The region was originally covered by pine forest. Approximately 85 percent remains in forest, mainly aspen. About 15 percent is cropland and pasture. Oats, corn, and alfalfa are the main crops.

Only one soil landscape unit is mapped. Table 14 gives selected features. Additional information follows:

SSWL About 15 percent of the unit has dark-colored soils. (Psammentic Eutroboralfs)

Table 14. Selected features of soil landscape units within the Detroit Lakes Pitted Outwash Plain (4) geomorphic region

| Soil landscape unit | Percent geomorphic region | Landscape position | Most common texture and thickness (feet) | | Moisture relationships | | Approximate fertility in rooting zone | | | Representative soil series |
|---------------------|---------------------------|------------------------|---|-------------------------|-------------------------------------|---------------------|---------------------------------------|------|-----|----------------------------|
| | | | Rooting zone | Substratum | Inches of available water to 5 feet | Drainage class | pH | P | K | |
| SSWL | 69 | gently rolling outwash | loamy sand, sandy loam and loamy sand (1-2) | sand and gravel (2-20+) | <4 | excessively drained | <6.0 | high | low | Marquette Lengby |
| Water | 31 | | | | | | | | | |



Mahnomen Lacustrine Plain (5)

This region covers an area of about 229,000 acres or 4 percent of the Bemidji Sheet.

The land form in the Mahnomen Lacustrine Plain is undulating to shallow depressional. Water-laid silts generally 2 to 4 feet thick cover the loamy till in most of the region. Two lakes totaling about 2,500 acres are located in the region. On higher positions the water table normally is 6 to 10 feet deep. On lower levels it is at the surface to 6 feet deep.

Most of the soils are limy at the surface. Soils on higher positions generally are moderately well drained. Those on lower nearly level land are somewhat poorly to poorly drained, and in depressions they are very poorly drained. The soils have a high water-holding capacity.

Prairie grasses originally covered the region. An exception was the bottomlands along the rivers. These were covered by northern hardwoods. Most of the bottomlands remain forested by hardwoods. About 75 percent of the region is under cultivation. Principal crops are wheat, oats, barley, alfalfa, and brome. Twenty percent is

pastureland and the rest is low wet areas used mainly for wildlife.

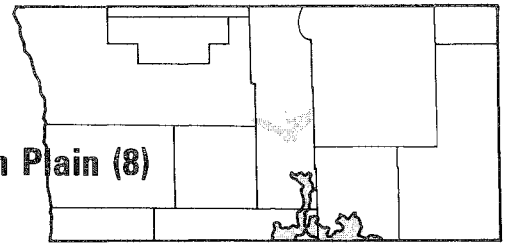
Four landscape units are mapped: LLWD, LLPD, A, and LP. Table 15 gives selected features. Additional information follows:

- LLWD** Soils in approximately 20 percent of the unit are poorly drained. Very poorly drained mineral and shallow peat soils occur in 5 percent of the area. (Aeric Calciaquolls)
- LLPD** This unit includes about 15 percent moderately well-drained and about 5 percent shallow peat soils. (Typic Calciaquolls)
- A** Approximately 10 percent of the unit includes adjoining well-drained soils. (Unclassified)
- LP** Included are minor areas of poorly and very poorly drained mineral soils. (Terric Borosaprists)

Table 15. Selected features of soil landscape units within the Mahnomen Lacustrine Plain (5) geomorphic region

| Soil landscape unit | Percent geomorphic region | Landscape position | Most common texture and thickness (feet) | | Moisture relationships | | Approximate fertility in rooting zone | | | Representative soil series |
|---------------------|---------------------------|--|--|---|-------------------------------------|--|---------------------------------------|----------|----------|----------------------------|
| | | | Rooting zone | Substratum | Inches of available water to 5 feet | Drainage class | pH | P | K | |
| LLWD | 64 | undulating lake plain | silt loam and loam (2-4) | loam (4-20+) | 8-12 | moderately well to somewhat poorly drained | 7.2+ | low | medium | McIntosh |
| LLPD | 32 | gently sloping depressional lake plain | silt loam and loam (2-4) | loam (4-20+) | 8-12 | poorly to very poorly drained | 7.2+ | low | medium | Winger |
| A | 2 | narrow stream bottoms | variable—mainly sandy loam to loam (2-4) | variable—mainly sandy loam to loam (4+) | 4-12 | poorly to moderately well drained | 6.1-7.8 | variable | variable | Unnamed |
| LP | <1 | level to depressional lake plain | peat (1-3) | peat and loam (3+) | 8+ | very poorly drained | 5.5-7.8 | low | low | Cathro Haug |
| Water | 1 | | | | | | | | | |

Park Rapids - Staples Outwash Plain (8)



The region encompasses an area of about 95,000 acres or about 2 percent of the Bemidji Sheet.

This outwash plain is nearly level to rolling with inclusions of a few strongly rolling to hilly areas. Depressions and small peat bogs are fairly common. Sixteen lakes, at least 160 acres in size, are located in the region. Total water area is approximately 10,500 acres. The water table normally is 10 feet or more deep. In lower positions it is surface to 6 feet deep.

The surface 12 to 18 inches ranges from gravelly loamy sand to sandy loam. This is underlain by stratified sand and gravel. Some areas are predominantly sand. The water-holding capacity is low to very low.

The original vegetation in most of the region was jack pine forest. The area in Becker County in the vicinity of Big Rush Lake was a transition area between prairie and forest and consisted of oak openings. The soils are moderately dark colored in this area. Approximately 50 percent of the region is forested, mainly by aspen, jack pine, and oak. About 30 percent is cropland and 20 percent pastureland. The principal crops are oats, corn, alfalfa, and brome.

Eight soil landscape units are mapped: SSWL, SLWL, SLWD, SP, P, LSWL, LLWL, and NP. Table 16 gives selected features. Additional information follows:

SSWL Soils in about 20 percent of the unit are loamy to depths of 18 to 24 inches. Twenty percent is deep sand and about 5 percent is deep loamy. Five percent or less is shallow peat. (Psammentic Eutroboralfs)

SLWL Approximately 15 percent of the unit has deep sandy soils. Ten percent of the soils are underlain by sand instead of the more common sand and gravel. Loamy till and shallow sand over till comprises another 5 percent. Shallow peat occurs in 5 percent of the area. (Typic Eutroboralfs)

SLWD This unit includes approximately 10 percent sandy surfaces. About 5 percent has poorly drained soils and shallow peat. (Mollic Eutroboralfs)

SP Approximately 10 percent of the unit consists of deep peat. Poorly and very poorly drained mineral soils occupy another 10 percent. (Terric Borosaprists)

P About 30 percent of this unit is underlain by sand at about 3 feet. (Typic Borohemists)

LSWL The sand is deeper than 4 feet in about 10 percent of this unit and 10 percent are loamy soils. Poorly drained mineral soils and shallow peat occur in about 5 percent of the area. (Psammentic Eutroboralfs)

LLWL A thin sandy surface occurs in some of this unit. (Typic Eutroboralfs)

NP About 30 percent of this unit is underlain by loamy till at about 3 feet. (Typic Borohemists)

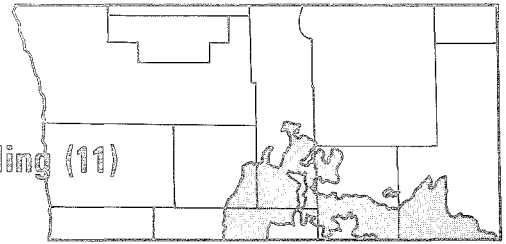
Table 16. Selected features of soil landscape units within the Park Rapids - Staples Outwash Plain (8) geomorphic region

| Soil landscape unit | Percent geomorphic region | Landscape position | Most common texture and thickness (feet) | | Moisture relationships | | Approximate fertility in rooting zone | | | Representative soil series |
|---------------------|---------------------------|---------------------------------|--|-------------------------|-------------------------------------|------------------------------|---------------------------------------|--------|-----|--------------------------------|
| | | | Rooting zone | Substratum | Inches of available water to 5 feet | Drainage class | pH | P | K | |
| SSWL | 44 | undulating to rolling outwash | sandy loam, loamy sand, and gravelly loam sand (1-2) | sand and gravel (2-20+) | <4 | excessively drained | <6.0 | high | low | Marquette Lengby Menahga |
| SLWL | 19 | undulating to rolling outwash | sandy loam to loam (1-3) | sand and gravel (3-20+) | 4-8 | somewhat excessively drained | <6.0 | high | low | Unnamed |
| SLWD | 15 | level to gently sloping outwash | sandy loam to loam (2-3) | sand and gravel (3+) | 4-8 | somewhat excessively drained | 6.2-7.4 | medium | low | Dorset Unnamed |

Table 16 (continued). Selected features of soil landscape units within the Park Rapids - Staples Outwash Plain (8) geomorphic region

| Soil landscape unit | Percent geomorphic region | Landscape position | Most common texture and thickness (feet) | | Moisture relationships | | Approximate fertility in rooting zone | | | Representative soil series |
|---------------------|---------------------------|----------------------------------|--|--------------------------|-------------------------------------|---------------------|---------------------------------------|-------------------|--------|------------------------------|
| | | | Rooting zone | Substratum | Inches of available water to 5 feet | Drainage class | pH | P | K | |
| SP | 7 | level to depressional | peat (1-3) | peat, sand and loam (3+) | 8+ | very poorly drained | 5.5-7.8 | low | low | Deerwood Markey |
| P | 2 | level to depressional | peat (1-3) | peat and sand (3+) | >12 | very poorly drained | 5.5-7.8 | low | low | Mooselake |
| LSWL | 1 | gently rolling to rolling upland | loamy sand to sand (2-4) | loam (4-20+) | 4-8 | well drained | <6.0 | high to very high | low | Kinghurst |
| LLWL | 1 | gently rolling to rolling upland | loam to clay loam (4) | loam (4-20+) | 8-12 | well drained | <6.0 | medium | medium | Nebish |
| NP | <1 | level to depressional | peat (1-3) | peat and loam (3+) | >12 | very poorly drained | 5.5-7.8 | low | low | Seelyeville Mooselake Cathro |
| Water | 11 | | | | | | | | | |

Itasca Moraine Complex, rolling (11)



This region encompasses an area of about 764,000 acres or about 13 percent of the Bemidji Sheet.

The Itasca moraine is a prominent moraine deposited by the Wadena lobe. It consists of a rolling to steeply irregular land form, characterized by numerous depressions and small peat bogs. The moraine is roughly 300 to 600 feet higher in elevation than the outwash plain bordering on the north and northwest. The elevation is 2,040 feet above sea level at the fire tower east of Bass Lake in southwestern Clearwater County and 1,935 feet at the fire tower southwest of Itasca State Park. Numerous troughs dissect the moraine which may have been eroded as tunnel valleys by swift southward flowing subglacial streams. Some of these are filled with sand and gravel, others occur as rows of small lakes. The water table is more than 20 feet deep. Twenty eight lakes and part of another, each at least 160 acres in size, are located in the region. The total water area is about 114,000 acres.

Original vegetation was principally red and white pine, but included areas of jack pine and northern hardwoods. Present land use is estimated to consist of 65 to 75 percent forest, mostly aspen, 15 to 25 percent pastureland, and 5 to 15 percent cropland. The main crops are oats, brome, and alfalfa.

Nine soil landscape units are mapped in the region: LLWL, XLWL, SSWL, NP, LSWL, SLWL, LLPL, SP, and P. Table 17 gives selected properties of each. Additional information follows:

LLWL Sandy and gravelly soils make up 10 to 20 percent of the unit. Another 5 to 10 percent occur as small peat bogs and poorly drained depressions. (Typic Eutroboralfs)

XLWL Deep loamy soils occur in 45 to 55 percent of the unit. Intermixed with these soils are soils with sandy substrata which represent 35 to 45 percent of the unit. Wet and marshy areas total another 5 to 15 percent. (Typic Eutroboralfs)

SSWL Deep loamy soils represent 5 to 10 percent of the unit. Another 10 to 20 percent is loamy over sand and gravel. (Psammentic Eutroboralfs)

NP The depth of peat ranges from 4 to 5 feet in 60 to 70 percent of the unit. Poorly drained mineral soils and shallow peat occur in 30 to 40 percent of the unit. (Typic Borosaprists)

LSWL Inclusions of 10 to 20 percent deep loamy soils, and 5 to 15 percent poorly drained and shallow peat soils occur in the unit. (Psammentic Eutroboralfs)

SLWL An estimated 5 to 10 percent of the unit has deep loamy soils and 10 to 20 percent has sandy and gravelly surfaces. (Typic Eutroboralfs)

LLPL About 15 percent of the unit has well-drained soils; 10 percent is in shallow peat and another 10 percent is deep sandy and gravelly. (Aeric Ochraqualfs)

SP About 30 percent of the unit is underlain by loamy till. (Terric Borohemists)

P Poorly drained mineral soils occur in about 30 percent of the unit. (Typic Borohemists)

Table 17. Selected features of soil landscape units within the Itasca Moraine Complex, rolling (11) 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 | 36 | rolling to steep upland | sandy loam to clay loam (4) | sandy loam to loam (4-20+) | 8-12 | well drained | <6.0 | medium | medium | Nebish Rockwood |
| XLWL | 31 | rolling to steep upland | sandy loam, clay loam, sand and gravel (2-4) | sandy loam, loam, sand and gravel (4-20+) | 4-12 | well to excessively drained | <6.0 | medium to high | low to medium | Nebish Rockwood Marquette |

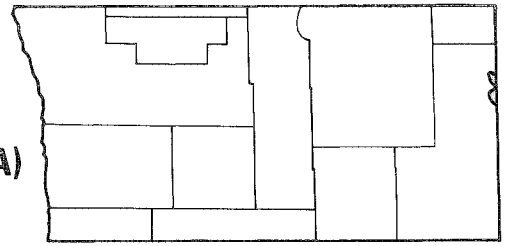
Table 17 (continued). Selected features of soil landscape units within the Itasca Moraine Complex, rolling (11) geomorphic region

| 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 | 10 | rolling to hilly outwash | loamy sand, sandy loam, and gravelly loamy sand (1-2) | sand and gravel (2-20+) | <4 | excessively drained | <6.0 | high | low | Marquette Lengby (Todd)* |
| NP | 3 | level to depressional | peat (1-3) | peat and loam (3+) | >12 | very poorly drained | 5.5-7.8 | low | low | Seelyeville Mooselake Cathro |
| LSWL | 2 | rolling to hilly upland | loam sand to sand (2-4) | loam (4-20+) | 4-8 | well drained | <6.0 | high to very high | low | (Kinghurst)* |
| SLWL | 1 | rolling to hilly outwash | sandy loam to loam (1-3) | sand and gravel (3+) | 4-8 | somewhat excessively drained | <6.0 | high | low | (Todd)* Lengby |
| LLPL | 1 | gently sloping to depressional upland | loam to silty clay loam (2-4) | loam to clay loam (4-20+) | 8-12 | somewhat poorly to very poorly drained | 6.0-6.8 | low | low | Shooker Bluffton |
| SP | <1 | level to depressional | peat (1-3) | peat, sand and loam (3+) | 8+ | very poorly drained | 5.5-7.8 | low | low | Deerwood Markey |
| P | <1 | level to depressional | peat (1-3) | peat (3+) | >12 | very poorly drained | 5.5-7.8 | low | low | Mooselake |

Water 16

*Series in parentheses have been used in older soil reports.

Marcell Moraine Complex (22A)



The region encompasses an area of approximately 4,800 acres or less than one percent of the Bemidji Sheet.

The Marcell moraine in the Bemidji Sheet is a rolling, complex type of landform. Small peat bogs and marshy areas are fairly common. One lake and part of another is located in the region. The water area is about 2,150 acres. Normally the water table is over 10 feet deep on higher levels and surface to 6 feet deep in lower positions.

The soils are loams and clay loams, although a sand cap up to 4 feet thick covers some areas. Generally the water-holding capacity is high.

This region was originally covered by upland spruce and fir. Approximately 85 percent remains forested. As-

pen with some spruce and fir are the main species. The remaining 15 percent is cropland and pasture. Alfalfa, brome, timothy, and oats are the principal crops.

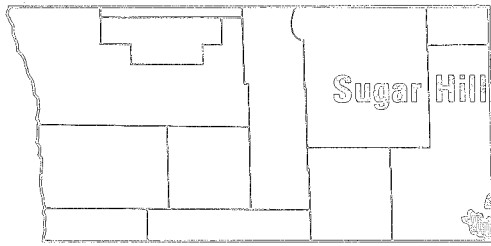
Two soil landscape units are mapped in the region: LLWL and LSWL. Table 18 gives selected features. Additional information follows:

LLWL Approximately 10 percent of the unit has soils with sandy surfaces. Another 10 percent is somewhat poorly to very poorly drained mineral and shallow peat soil. (Glossic Eutroboralfs)

LSWL Five to 15 percent is deep loamy soil. (Psammentic Eutroboralfs)

Table 18. Selected features of soil landscape units within the Marcell Moraine Complex (22A) 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 | 49 | rolling upland | loam to clay loam (4) | loam and clay loam (4-20+) | 8-12 | well drained | <6.0 | medium | medium | Warba Nebish |
| LSWL | 3 | rolling upland | loamy sand to sand (2-4) | loam to clay loam (4-20+) | 4-8 | well drained | <6.0 | high to very high | low | Unnamed |
| Water | 48 | | | | | | | | | |



Sugar Hills Moraine Complex, rolling to hilly (22B)

This region has an area of approximately 29,000 acres or about 1 percent of the Bemidji Sheet.

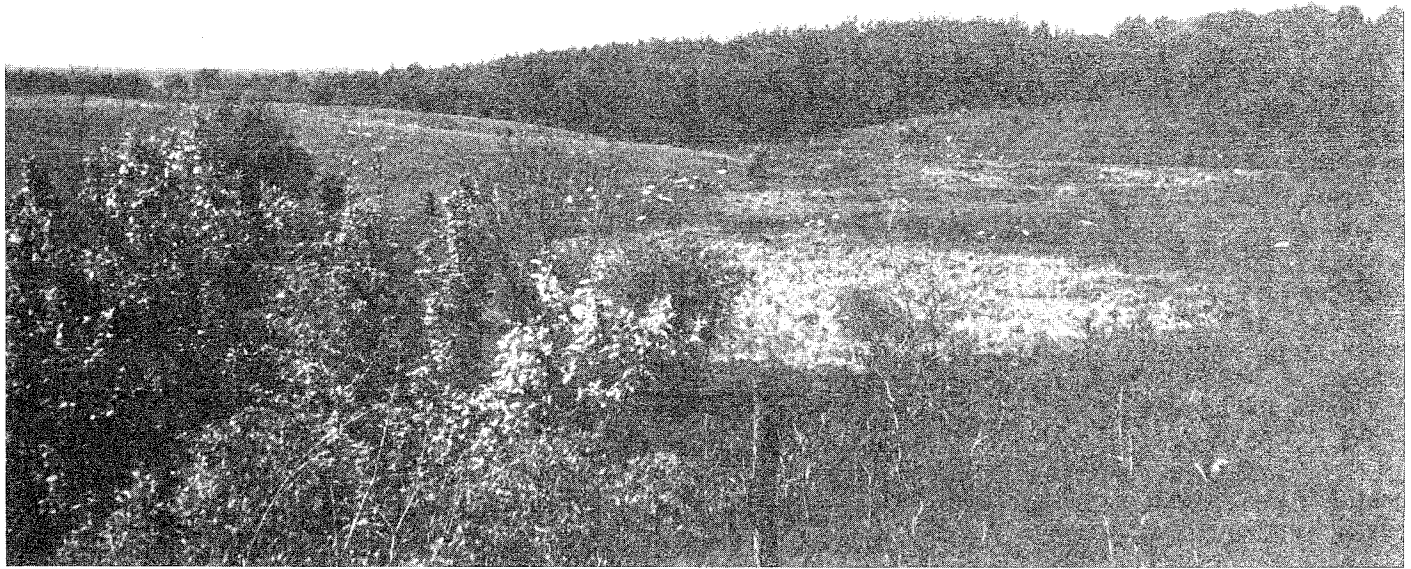
The Sugar Hills moraine has a rolling to hilly topography. The landform is complex with many depressions and small peat bogs. Seven small lakes, each 160 acres or more in size, totaling about 3,300 acres are located in the region. The water table normally is over 10 feet deep on higher elevations and surface to 6 feet deep on lower positions.

The till is loamy to silty, but includes areas intermixed with coarser material. A sandy and gravelly area of soils is located in the southwestern part of the region. Most of the soils have a moderate to high water-holding capacity.

The original forest was primarily white and red pine with some areas of northern hardwoods. Eighty to 90 percent remains forested. Aspen with some hardwoods are the principal species. Ten to 20 percent is cropland and pasture. Alfalfa, brome, timothy, and oats are the main crops.

Six soil landscape units are mapped in this region: LLWL, NP, P, SSWL, LLPL, and XLWL. Table 19 gives selected features of the units. Additional information follows:

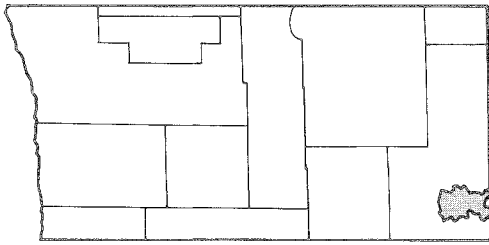
- LLWL Soils in about 10 percent of this unit are silty rather than loamy. Fifteen percent is deep sandy soils. (Typic Eutroboralfs)
- NP Approximately 60 percent of the unit is deep peat and 30 percent shallow peat. Somewhat poorly and very poorly drained loamy soils occupy the remaining 10 percent. (Typic Borohemists)
- P Included are small islands of poorly drained mineral soils. (Typic Borohemists)
- SSWL In this unit about 30 percent is gravelly soil. About 10 percent has a loamy substratum with a sand cap up to 4 feet thick and 5 percent is deep loamy. Shallow peat occupies about 5 percent of the area. (Typic Udipsamments)
- LLPL Approximately 20 percent of this unit has moderately well-drained soils and 15 percent has shallow peat soils. (Aeric Ochraqualfs)
- XLWL Fifty-five percent of the unit has loamy substrata and 35 percent, sandy. Shallow peat occupies 10 percent of the area. (Typic Eutroboralfs)



Hardwood forest has been cleared for pasture in this rolling landscape, typical of the Sugar Hills Moraine Complex.

Table 19. Selected features of soil landscape units within the Sugar Hills Moraine Complex, rolling to hilly (22B) 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 | rolling to hilly upland | loam, silt loam and clay loam (4) | loam (4-20+) | 8-12 | well drained | <6.0 | medium | medium | Nebish |
| NP | 6 | level to depressional | peat (1-3) | peat and loam (3+) | <12 | very poorly drained | 5.5-7.8 | low | low | Mooselake Cathro |
| P | 6 | level to depressional | peat (1-3) | peat and loam (3+) | <12 | very poorly drained | 5.5-7.8 | low | low | Mooselake |
| SSWL | 7 | rolling outwash | sand, loamy sand and gravelly sandy loam (1-2) | sand and gravel (2-20+) | <4 | excessively drained | <6.0 | high | low | Menahga Marquette |
| LLPL | 4 | gently sloping to depressional | loam to silty clay loam (2-4) | loam to clay loam (4-20+) | 8-12 | somewhat poorly to very poorly drained | 6.0-6.8 | low | low | Shooker Bluffton |
| XLWL | 3 | rolling to hilly upland | loam, clay loam, sandy loam, sand and gravel (2-4) | loam to sand and gravel (4-20+) | 4-12 | well to excessively drained | <6.0 | medium | medium | Nebish Marquette |
| Water | 10 | | | | | | | | | |



Swatara Plain, silty (24)

The region encompasses an area of approximately 65,500 acres or about 1 percent of the Bemidji Sheet.

The Swatara Plain consists of gently rolling land with a few small more rolling areas. One relatively large peat bog and several small ones occupy the plain. Part of Leech Lake is included with this region. Total water area is approximately 12,500 acres. Normally the water table is over 10 feet deep in the well-drained soils and surface to 6 feet deep in lower positions.

The till is loamy to silty. Variations include clayey soils along the north boundary and loamy soils intermixed with coarse-textured soils along the east boundary. The soils have a high water-holding capacity.

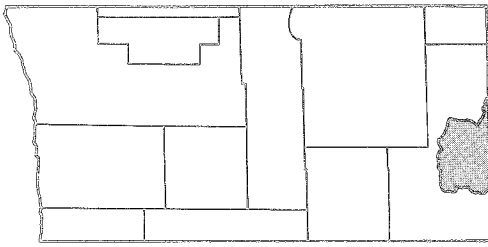
White and red pine originally covered the better-drained areas. Swamp conifers, mainly tamarack and black spruce, occupied the peat bogs. Native vegetation on the peat bogs has not changed much. About 80 percent of the region is covered by forest. Aspen is the principal species. Twenty percent is under cultivation and in pasture. Oats, alfalfa, brome, and timothy are the main crops.

Five soil landscape units are mapped in this region: LLWL, NP, LLPL, CCWL, and SSPL. Table 20 gives selected features of the units. Additional information follows:

- LLWL Depth to free carbonates in places is 4 to 5 feet. The till is mostly a brownish color. Soil textures in the unit generally are loams to clay loams. Clayey soils occur in about 5 percent of the unit. In another 10 percent the soils are somewhat poorly to very poorly drained with some areas of shallow peat. (Typic Eutroboralfs)
- NP Approximately 70 percent of the unit is deep and 20 percent shallow peat. Very poorly to moderately well-drained loamy soils occur in 10 percent of the area. (Typic Borohemists)
- LLPL Inclusions in this unit are approximately 15 percent well-drained loamy soils and 10 percent shallow peat. (Aeric Ochraqualfs)
- CCWL About 10 percent has somewhat poorly drained soils and about 5 percent has shallow peat. Another 10 percent has deep loamy soils. (Aquic Eutroboralfs)
- SSPL Some well-drained soils and some soils in shallow peat are included. (Aquic Udipsamments)

Table 20. Selected features of soil landscape units within the Swatara Plain, silty (24) 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 | 44 | gently rolling upland | loam, silt loam and clay loam (4) | loam and silt loam (4-20+) | 8-12 | well drained | <6.0 | medium | medium | Nebish |
| NP | 29 | level to depressional | peat (1-3) | peat and loam (3+) | >12 | very poorly drained | 5.5-7.8 | low | low | Mooselake Cathro |
| LLPL | 4 | gently sloping depressional upland | loam to silty clay loam (2-4) | loam to clay loam (4-20+) | 8-12 | somewhat poorly to very poorly drained | 6.0-6.8 | low | low | Shooker Bluffton |
| CCWL | 3 | gently rolling upland | silty clay and clay (3) | silty clay and clay (3+) | 8-12 | well to moderately well drained | <6.0 | medium | low | Taylor |
| SSPL | 1 | gently sloping depressional | loamy fine sand and fine sand (1-3) | fine sand (3+) | <4 | somewhat poorly to poorly drained | 5.2-6.2 | high | low | Redby Cormant |
| Water | 19 | | | | | | | | | |



Aitkin Lacustrine Plain, sandy (25)

This region has an area of approximately 191,500 acres or about 3 percent of the Bemidji Sheet.

The region is a level to gently undulating lake plain. A large peat bog is located along Leech Lake River. Normally the water table is 6 to 10 feet below the surface on higher elevations and surface to 6 feet deep on lower positions and peat bogs. Part of Leech Lake and four smaller lakes, at least 160 acres in size, are located in the region. The total water area is about 12,500 acres.

The lake sediments are mainly fine sands to depths of over 4 feet. Sand less than 4 feet thick over silts occurs in some areas. There are also minor areas of clayey soils and sands over clay. The division between the Aitkin Lacustrine Plain and the Bemidji Sand Plain is indistinct. For this report the division between fine and medium sand is considered the boundary line. Most of the soils have a low to very low water-holding capacity.

Originally the sandy soils were covered by jack pine and the peat bogs by black spruce and tamarack. White and red pine occupied the finer-textured soils. Approximately 90 percent is forested. Aspen and jack pine now cover the sandy soils and tamarack and black spruce cover the peat bogs. Most of the remaining 10 percent is pastureland.

Seven soil landscape units are mapped: SSWL, NP, P, LLPL, SSPL, LSPL, and LSWL. Table 21 gives selected features. Additional information follows:

- SSWL This unit includes about 10 percent poorly drained soils and about 5 percent shallow peat. Another 5 percent consists of shallow fine sand over silt. (Entic Haplorthod)
- NP Approximately 55 percent of the unit has deep peat and 35 percent, shallow. Silty soils occupy 10 percent and sandy soils 5 percent of the unit. (Typic Borohemists)
- LLPL Soils in about 15 percent of the unit are moderately well drained. Shallow peat occupies about 10 percent and sandy soils 5 percent of the area. (Typic Ochraqualfs)
- SSPL Approximately 30 percent of the soils in this unit are moderately dark colored; 10 percent are moderately well drained; and 10 percent are shallow peat. (Typic Psammaquents)
- LSPL About 65 percent of the unit consists of somewhat poorly and poorly drained soils. Another 20 percent is very poorly drained. Inclusions are 10 percent deep sand and 5 percent shallow peat. (Typic Psammaquents)
- LSWL This unit includes about 10 percent poorly drained silt loams and about 10 percent with sands over 4 feet deep. Shallow peat occupies another 5 percent of the area. (Typic Haplorthods)

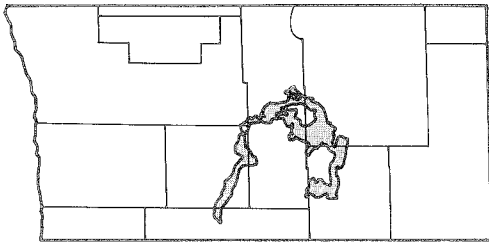
Drought resistant jack pines are common on the sandy soils of unit SSWL in the Aitkin Lacustrine Plain (25), Bagley Outwash Plain (47), and the Bemidji Sand Plain (49).



Table 21. Selected features of soil landscape units within the Aitkin Lacustrine Plain, silty (25) 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 | 37 | level to gently sloping lake plain | loamy fine ssnd to fine and very fine sand (2-4) | fine and very fine sand (4+) | <4 | moderately well to somewhat poorly drained | <6.0 | very high | low | (Swatara)* (Raboy)* |
| NP | 35 | level to depressional lake plain | peat (1-3) | peat, fine sand to silt loam (3+) | >12 | very poorly drained | 4.5-7.0 | low | low | Mooselake Dawson Cathro |
| LLPL | 8 | gently sloping depressional lake plain | silt loam (2-4) | silt loam and silt (4+) | 8-12 | somewhat poorly to very poorly drained | 5.8-6.6 | low | low | Spoooner (Kelsey)* |
| SSPL | 8 | gently sloping to depressional lake plain | loamy fine to fine sand (1-3) | fine sand (3+) | <4 | somewhat poorly to very poorly drained | 5.2-6.2 | high | low | Unnamed |
| P | 6 | level to depressional | peat (1-3) | peat, fine sand to silt loam (3+) | >12 | very poorly drained | 4.5-7.0 | low | low | Mooselake |
| LSPL | 1 | gently sloping to depressional lake plain | loamy sand to fine sand (2-4) | silt loam to silty clay loam (4+) | 4-8 | somewhat poorly to very poorly drained | 6.0-6.8 | medium | low | Unnamed |
| LSWL | 1 | level to gently sloping lake plain | loamy sand to fine sand (2-4) | silt loam to silty clay loam (4+) | 4-8 | moderately well to somewhat poorly drained | <6.0 | medium | low | Unnamed |
| Water | 4 | | | | | | | | | |

*Series in parentheses have been used in older soil reports.



Bagley Outwash Plain, sandy to gravelly (47)

The region has an area of approximately 225,000 acres or 4 percent of the Bemidji Sheet.

This is a pitted outwash plain consisting of nearly level to gently rolling topography, but includes some areas of rolling terrain. Two such areas occur in Beltrami County, one south of Wilton and one south of Whitefish Lake. Another area is located in western Mahanomen County, extending into Becker County between Sinder and Strawberry Lakes. This is the southern end of a north-south oriented trough which was probably a sand and gravel filled glacial tunnel valley. The water table is normally more than 10 feet deep on the well-drained soils. In lower positions it occurs between the surface and 6 feet deep. Twelve lakes, each at least 160 acres in size, are located in the region totaling about 10,000 acres.

Soils in the region range from loamy to sandy and in most places have sand and gravel substrata. The water-holding capacity is low to very low.

Originally the region was forested. Jack pine was the principal species on well-drained positions and swamp conifers on peat bogs. An estimated 60 to 70 percent of the land area is presently forested, chiefly to aspen and jack pine. Swamp conifers cover most peat bogs. Ten to 20 percent of the region is in pasture and another 5 to 10 percent is in cropland. Main crops are oats and timothy.

Eleven soil landscape units are mapped in the region: SSWL, SP, SSPL, SLWL, LSWL, A, LLWL, LSPL, LLPL, LP, and NP. Table 22 gives selected features of units. Additional information follows:

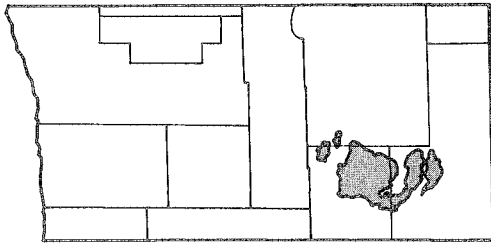
SSWL Approximately 10 percent of the unit includes soils which are loamy to depths of 18 to 24 inches over sand and gravel. In some of these soils the gravel is present in very small amounts. Loamy

till occurs in about 10 percent of the area. Poorly drained and shallow organic soils occur in about 5 percent of the area. (Psammentic Eutroboralfs)

- SP** About 30 percent of this unit consists of shallow peat. Ten percent of the unit has well-drained coarse textured soils and 5 percent poorly drained sandy soils. (Terric Borosaprists)
- SSPL** Approximately 15 percent of the soils are well drained. Five to 10 percent are shallow peat over coarse material. (Typic Psammaquents)
- SLWL** Poorly and very poorly drained soils occur in 5 percent of the area. (Typic Eutroboralfs)
- LSWL** About 75 percent of the unit has 2 to 4 feet of sand over calcareous loamy till. The sand is over 4 feet deep in about 15 percent of the unit. In 5 percent of the area loamy soils are included. Poorly drained sandy soils and shallow peat occupy 5 percent of the area. (Psammentic Eutroboralfs)
- A** The unit includes about 10 percent shallow peat soils and 10 percent well-drained sandy soils. (Unclassified)
- LLWL** This unit includes small areas of shallow sand over loam. (Aquic Eutroboralfs)
- LSPL** Small areas of loamy soils, sands, and shallow peat are included in this unit. (Typic Psammaquents)
- LLPL** Minor areas of sandy soils occur in this unit. (Aeric Ochraqualfs)

Table 22. Selected features of soil landscape units within the Bagley Outwash Plain, sandy to gravelly (47) 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 | 63 | level to gently sloping outwash | sandy loam to sand and gravel (1-2) | sand and gravel (2-5+) | <4 | excessively drained | <6.0 | high | low | Marquette Menahga |
| SP | 18 | level to depressional outwash | peat (1-3) | peat, sand and loam (3+) | 8+ | very poorly drained | 5.5-7.8 | low | low | Markey Dawson |
| SSPL | 5 | level to depressional outwash | sandy loam to sand and gravel (1-3) | sand and gravel (3+) | <4 | somewhat poorly to very poorly drained | 5.2-6.2 | high | low | Unnamed |
| SLWL | 2 | level to gently sloping outwash | loam to sandy loam (2-3) | sand and gravel (3+) | 4-8 | somewhat excessively drained | <6.0 | high | low | Unnamed |
| LSWL | 2 | gently rolling to rolling upland | loamy sand to sand (2-4) | loam (4-20+) | 4-8 | well drained | <6.0 | high to very high | low | Unnamed |
| A | 2 | narrow stream bottoms | variable—mainly sandy loam to loam (2-4) | variable—mainly sandy loam to loam (4+) | 4-12 | poorly to moderately well drained | 6.1-7.8 | variable | variable | Unnamed |
| LLWL | 1 | gently rolling upland | loam to clay loam (4) | loam (4-20+) | 8-12 | moderately well to well drained | <6.0 | low | medium | Beltrami Nebish |
| LSPL | 1 | gently sloping to depressional | loamy sand to sand (2-4) | loam (4-20+) | 4-8 | somewhat poorly to very poorly drained | 6.0-6.8 | medium | low | Unnamed |
| LLPL | 1 | gently sloping to depressional | loam to silty clay loam (2-4) | loam to clay loam (4-20+) | 8-12 | somewhat poorly to very poorly drained | 6.0-6.8 | low | low | Shooker Bluffton |
| LP | <1 | level to depressional lake plain | peat (1-3) | peat and loam (3+) | 8+ | very poorly drained | 5.5-7.8 | low | low | Cathro Haug |
| NP | <1 | level to depressional | peat (1-3) | peat and loam (3+) | >12 | very poorly drained | 5.5-7.8 | low | low | Mooselake Cathro |
| Water | 4 | | | | | | | | | |



Guthrie Till Plain, loamy (48)

The region encompasses an area of approximately 238,000 acres or 4 percent of the Bemidji Sheet.

The Guthrie Till Plain consists mainly of gently rolling topography but includes areas of more rolling land bordering lakes and peat bogs. The landform is one of irregular short slopes with numerous small depressions. The water table is normally more than 10 feet deep on well-drained locations, and between the surface and 6 feet deep on peat bogs and poorly drained positions. Part of Leech Lake and four small lakes, each at least 160 acres in size, are located in the region. The total water area is about 10,000 acres.

Soils in the region developed on sandy loam and loam glacial till. Cobble and stones are common in localized areas. A sand cap up to 42 inches thick covers the till in places.

The largest area occurs between Leech Lake and Steamboat Bay. It extends northward to Cass Lake. Another area of 10 to 15 square miles is located southwest of Lake Winnibigoshish.

The original land cover was northern hardwoods, and white and red pine. Present land use is estimated to consist of 60 to 70 percent forest, mainly aspen, 10 to 20 percent pasture, and 10 to 20 percent cropland. Oats, timothy, and alfalfa are the main crops.

Eight soil landscape units are mapped in the region: LLWL, LSWL, NP, LLPL, SSWL, LSPL, SLWL, and A. Table 23 gives selected characteristics of the unit. Additional features follow:

LLWL Soils in about 10 percent of the unit have a sand cap 2 to 4 feet deep over loam. Five percent are

coarse textured and 5 percent are very poorly drained mineral soils or shallow peat soils. (Typic Eutroboralfs)

LSWL An estimated 10 percent of the unit is loamy surface soils. About 10 percent has sandy surface over 4 feet deep. The area includes minor amounts of poorly drained soils. (Psammentic Eutroboralfs)

NP Approximately 70 percent of the unit is deep peat and 25 percent shallow. Acid peat (pH less than 5.5) occurs in about 10 percent of the area. Five percent of the unit has poorly drained mineral soils. (Typic Borohemists)

LLPL The soils in about 10 percent of the unit are moderately well drained. (Aeric Ochraqualfs)

SSWL In about 15 percent of the unit the sand is less than 4 feet deep over a loamy substratum. Another 5 percent has poorly drained sands or shallow peat. (Typic Udipsamments)

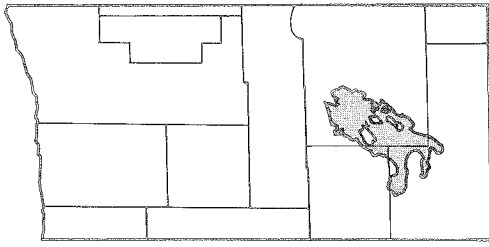
LSPL The sand is over 4 feet deep in about 10 percent of this unit. Another 15 percent has loamy surface. Ten percent has shallow peat. (Typic Psammaquents)

SLWL About 20 percent is coarse-textured soils. (Typic Eutroboralfs)

A About 10 percent is loamy upland soils. (Unclassified)

Table 23. Selected features of soil landscape units within the Guthrie Till Plain, loam (48) geomorphic area

| 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 | 68 | gently rolling upland | sandy loam to clay loam (4) | sandy loam to loam (4-20+) | 8-12 | well to moderately well drained | <6.0 | medium | medium | Nebish Beltrami Rockwood |
| LSWL | 12 | gently rolling upland | loamy sand to sand (2-4) | loam (4-20+) | 4-8 | well drained | <6.0 | high to very high | low | Unnamed |
| NP | 10 | level to depressional | peat (1-3) | peat and loam (3+) | >12 | poorly to very poorly drained | 5.5-7.8 | low | low | Mooselake Cathro |
| LLPL | 3 | gently sloping depressional upland | loam to silty clay loam (2-4) | loam to clay loam (4-20+) | 8-12 | excessively drained | 6.0-6.8 | low | low | Shooker Bluffton |
| SSWL | 2 | gently rolling outwash | loamy sand to sand (4) | sand (4+) | <4 | excessively drained | <6.0 | high | low | Menahga |
| LSPL | 1 | gently sloping to depressional | loamy sand to sand (2-4) | loam to sandy loam (4-20+) | 4-8 | somewhat poorly to very poorly drained | 6.0-6.8 | medium | low | Unnamed |
| SLWL | <1 | gently sloping outwash | loam to sandy loam (2-4) | sand and gravel (4+) | 4-8 | somewhat excessively drained | <6.0 | high | low | Unnamed |
| A | <1 | narrow stream bottoms | variable—mainly sandy loam to loam (2-4) | variable—mainly sandy loam to loam (4+) | 4-12 | poorly to moderately well drained | 6.1-7.8 | variable | variable | Unnamed |
| Water | 4 | | | | | | | | | |



Bemidji Sand Plain (49)

The Bemidji Sand Plain encompasses an area of approximately 272,000 acres or 4 percent of the Bemidji Sheet.

The region consists of nearly level to gently sloping topography with steeper slopes bordering most lakes. The water table is normally over 10 feet deep on most of the higher well-drained areas and 6 feet or less in lower poorly drained positions. Thirty-three lakes, each at least 160 acres in size and totaling about 50,000 acres, occur in the Bemidji Sand Plain. Cass Lake and Lake Bemidji are the largest.

Most of the soils are sandy throughout and have a very low water-holding capacity.

The original vegetation was mainly jack pine. An estimated 60 to 70 percent is presently jack pine and aspen forest. Ten to 20 percent is pasture and another 10 to 20 percent is cropland. Oats and timothy are the main crops.

Nine soil landscape units are mapped in the region: SSWL, NP, P, SSPL, LSWL, A, SLWL, CCPL, and CLPL. Table 24 gives selected features of the units. Additional information on some units follows:

SSWL Approximately 10 percent of this unit has poorly to very poorly drained mineral soils or shallow

peat. Small areas of loamy soils are included. (Typic Udipsamments)

- NP** This unit consists of about 60 percent deep peat, 30 percent shallow peat, and 10 percent sandy soils. (Typic Borohemists)
- SSPL** About 10 percent of the unit has well-drained soils and 10 percent has soils in shallow peat. Loamy soils underlain by sand occupy 15 percent of the unit. (Typic Psammaquents)
- LSWL** The unit includes about 10 percent loamy soils, 10 percent deep sands, and 5 percent poorly drained mineral soils or shallow peat. (Psammentic Eutroboralfs)
- A** This unit includes some sandy soils bordering the stream bottom and areas of peat along the bottom land. (Unclassified)
- SLWL** Approximately 10 percent of this unit has sandy surfaces and 10 percent has poorly drained mineral soils or shallow peat. (Typic Eutroboralfs)

Table 24. Selected features of soil landscape units within the Bemidji Sand Plain (49) 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 | 63 | nearly level gently sloping outwash | loamy sand to sand (4) | sand (4+) | <4 | excessively drained | <6.0 | high | low | Menahga |
| NP | 10 | level to depressional | peat (1-3) | peat to sand (3+) | >12 | very poorly drained | 4.5-7.0 | low | low | Mooselake Dawson |
| SSPL | 2 | gently sloping to depressional | loamy sand to sand (2-4) | sand (4+) | <4 | somewhat poorly to very poorly drained | 5.2-6.2 | high | low | Unnamed |
| LSWL | 2 | gently sloping upland | loamy sand to sand (2-4) | loam (4-20+) | 4-8 | well drained | <6.0 | high to very high | low | Unnamed |
| A | >1 | narrow stream bottoms | variable—mainly sandy loam to loam (2-4) | variable—mainly sandy loam to loam (4+) | 4-12 | poorly to moderately well drained | 6.1-7.8 | variable | variable | Unnamed |
| SLWL | <1 | nearly level to gently sloping outwash | sandy loam to loam (2-3) | sand (3+) | (4-8) | somewhat excessively drained | >6.0 | high | low | Lengby |
| CLPL | <1 | gently sloping to depressional lake plain | silt loam to very fine sandy loam (2-4) | silty clay (4+) | 8-12 | somewhat poorly to very poorly drained | 5.8-6.6 | medium | medium | Unnamed |
| CCPL | <1 | nearly level lake plain | silty clay and clay (2-3) | silt clay (3+) | 8-12 | poorly to very poorly drained | 5.5-6.5 | high | medium | Indus |
| Water | 22 | | | | | | | | | |

Development of Landforms in the Bemidji Sheet Area

Landforms in the Bemidji Sheet area largely resulted from glacial processes more than 7,000 years ago through two ice advances. The Wadena lobe advanced over the area east of the Alexandria Moraine Complex (3). The Des Moines lobe covered the western part of the sheet area and the St. Louis sublobe of the Des Moines lobe passed over much of the eastern part.

The Wadena lobe advanced from the northwest into the Red Lakes lowlands. At the same time the Rainy ice lobe was coming from the northeast diverting the eastward movement of the Wadena lobe towards the southwest and probably terminating on the south and west in the Alexandria moraine complex (3). At this time the Red River lowland must have been occupied by the Des Moines lobe, otherwise the Wadena lobe would have advanced that way because it is lower topographically than the Red Lake lowlands.

As the Wadena lobe retreated northward it formed the prominent Itasca moraine (11). Several tunnel valleys were formed in the Itasca moraine. Meltwater, under high hydrostatic pressure, formed closed water-filled drainage tunnels at the base of the ice, which formed gorges in the substratum. As the ice thinned during wastage, the hydrostatic pressure was reduced and began depositing sand and gravel in the channels. In this sheet area, meltwater from the Wadena lobe formed the Park Rapids-Staples outwash plain (8). The till of the Wadena lobe is buff colored, sandy, loam to loam, calcareous, and without cretaceous shale.

The Des Moines lobe crossed the Alexandria moraine complex (3), capping the drift deposited earlier by the Wadena lobe. Till from this lobe also formed the Fergus Falls Till Plain (2) and the Fosston Till Plain (2A). The St. Louis sublobe probably contributed to the eastern part of the Fosston Till Plain. Meltwater from the Des Moines lobe formed the Detroit Lakes Pitted Outwash Plain (4). Most of this plain occurs in the Brainerd Sheet area.

The Rainy lobe had retreated out of the survey area to or beyond the Vermillion moraine. The Superior lobe moved out of the deep Superior basin and probably blocked the drainage of the St. Louis River thus forming the first stage of Glacial Lake Aitkin (25), with drainage into the Mississippi system. Lake Aitkin possibly received reddish lake clay and silt from the Superior lobe and brown lake sediments from ice to the northwest or north.

By this time the Wadena lobe must have retreated well towards the north, because the St. Louis sublobe of the Des Moines lobe advanced eastward along the Red Lake lowland over-riding Glacial Lake Aitkin. Till deposited by the St. Louis sublobe is relatively thin, probably less than 25 feet thick, occurring as a mantle over the landscape formed by the advance and retreat of the Wadena lobe, and probably changed it very little. The St. Louis sublobe

apparently picked up some clayey lacustrine material from pre-existing lake beds in the lowland, because the till contains patches of clayey sediments intermixed with the loamy till.

The advance and retreat of the St. Louis sublobe formed the Erskine (3A), Northome (3B), Clearbrook (3C), Marcell (22A), and Sugar Hills (22B) moraines. The sublobe also formed the Blackduck (2B), Falk (2C), Swatara (24), and Guthrie (48) till plains.

During the wastage stage of the Superior lobe the St. Louis sublobe retreated and formed Glacial Lake Aitkin at its front. The Aitkin Lacustrine Plain (25) is a product of this lake. Most of the lake occurs in the Duluth and Hibbing Sheet areas. Meltwater from the waning St. Louis sublobe carrying sand and gravel formed the Bagley Outwash Plain (47) and further from the ice front the water deposited sand to form the Bemidji Sand Plain (49). Some of the fine sand in the Aitkin Lacustrine Plain (25) probably is a delta formation, especially the area south of Lake Winnibigoshish. The Mahnomen Lacustrine Plain (5), located west of the Alexandria Moraine Complex (3), was formed when a lake existed for a short period in front of the waning ice of the St. Louis sublobe. The silt generally is less than 4 feet thick over till.

Till from the Des Moines lobe and St. Louis sublobe is calcareous, shaly, grayish brown colored, and loamy.

About 14,000 years before present (B.P.) the Red River Valley was completely covered by glacial ice for the last time. Sometime after 14,000 B.P. the glacier had re-

Rolling landscape of the Alexandria Moraine Complex formed by the Wadena lobe and later capped with calcareous loamy till by the Des Moines lobe.



treated far enough north to expose the drainage divide in south central Minnesota and northern South Dakota to deposit sediments in the meltwater that was ponded between the divide and the glacier. Later the ice readvanced southward. By about 13,500 B.P. the glacier had retreated again beyond the drainage divide.

The duration of Glacial Lake Agassiz has been divided into five phases or periods: Cass (high-water); Caledonia glacial advance; Lockhart (high-water); Moorhead (low-water); and Emerson (high-water).

—Cass Phase—(before 13,500 B.P. to before 12,800 B.P.): The first high-water stage of Lake Agassiz was formed by meltwater ponded north of the divide. The outlet during this stage was southward through the present Minnesota River Valley. Stagnant ice surrounded the lake and the level was well above the Herman Beach. During this period the lower part of the Argusville Formation was deposited in the southern part of the lake plain. The Wylie Formation was also deposited during this time. The sediment was largely clay supplied by the Cheyenne River cutting through the Pierre Formation to the west in North Dakota. The Wylie Formation is recognized in southeastern Manitoba; therefore, the ice had retreated into Canada during this time. The Wylie Formation consists of laminated to unbedded clay and silt. Slickensides are common. The Argusville Formation consists of 54 to 84 percent clay and is unbedded.

—Caledonia Advance—(before 12,800 B.P. to before 12,000 B.P.): Sometime before 12,800 B.P. the ice advanced up the Red River Valley again, terminating at the Edenburg moraine in Trail County, North Dakota. In places it completely eroded the lacustrine sediment of the Wylie Formation.

—Lockhart Phase—(before 12,000 B.P. to 11,000 B.P.): During this phase the lake spread northward as the ice margin retreated and deposited sediment of the Brenna Formation. The major sediment source was shale from the Pierre Formation. During this phase the Herman Beach was formed at about 1,060 feet above sea level (A.S.L.). The Brenna Formation consists of clay and silty clay and contains from 58 to 95 percent clay. It is vaguely laminated to unbedded; calcareous nodules are abundant in places; and slickensides are common. As the outlet eroded deeper the level of the lake began to drop. It stabilized for a period at about 1,040 feet A.S.L. and formed the Norcross beach. Further lowering and stabilizing of the outlet lowered the lake to about 1,020 feet A.S.L. and formed the Tintah beach. It is not as well developed as the Herman or Norcross beaches. Downcutting of the south outlet continued until the Campbell level was attained. The outlet finally stabilized at that level, 980 feet A.S.L., when a granite base was reached. The lake stood at this level until about 11,000 B.P. when a lower outlet was opened eastward into the Lake Superior basin and ending the Lockhart Phase.

—Moorhead Phase—(11,000 B.P. to 9,900 B.P.): With a lower eastern outlet the lake level began to lower. During this phase there were several lake fluctuations as follows: (a) By about 10,900 B.P. the lake was at the Ojata level. (b) Advancing ice again plugged the eastern outlet and by 10,700 B.P. Lake Agassiz had risen back to the Campbell beach level. The lower part of the Sherack Formation may

have been deposited during the rise to this level. (d) The ice receded, reopening the eastern outlet and Lake Agassiz again dropped until about 10,500 B.P.; it was back to the Ojata level. (d) A lower outlet opened and by about 10,300 B.P. Lake Agassiz dropped below the Ojata level. (e) When advancing ice blocked the lower eastern outlet, about 10,100 B.P., the lake rose back to the Ojata level, where it was maintained for about 200 years, when the higher eastern outlet again was blocked by advancing ice.

—Emerson Phase—(9,900 B.P. to 9,000 B.P.): This phase begins with the rise of Lake Agassiz back to the Campbell level at about 9,900 B.P. By this time sediment entering the lake basin was glacial rather than Pierre shale. The lake stood at the Campbell level until about 9,000 B.P., when the eastern outlets were opened. The Sherack Formation was mostly deposited during this phase. This formation consists of clay, silty clay, and silt; laminations are vague to distinct; and gypsum crystals are common. The formation of the Agassiz Lacustrine Plain, Big Fork Valley (1B) was completed when the lake level dropped to the Campbell level. It is poorly drained and consists mainly of clay and silt sediments, so developed in relatively still water. The Agassiz Lacustrine Plain, Red Lake area (1D) was also completed by the time the lake level reached the Campbell beach. It is mixed in composition containing areas of sand, peat, and loam, along with some marshy areas. Lower Red Lake is within this region. The McCauleyville beach was formed when the lake was draining eastward at its highest level. The Agassiz Lacustrine Plain, Inter-Beach Area (1C) developed during the period from about 12,000 B.P. to 9,000 B.P. It represents the area of most beach concentration and the poorly drained to wet areas between beaches. Most wet areas are loamy, including some shallow peat. The beach ridges are sandy and gravelly. With the final opening of lower outlets to the east and north, after 9,000 B.P., the Emerson Phase of Lake Agassiz came to an end as the lake drained from Minnesota and North Dakota. By this time the Agassiz Lacustrine Plain, Red River Valley (1) had formed covering a span from about 13,500 B.P. to 9,000 B.P.

As the glacial ice to the north continued to disintegrate, lower outlets opened, and lowering the lake level until about 7,500 B.P. it became little more than present Lake Winnipeg.

Glacial Lake Agassiz was in existence for about 6,000 years. In the survey area it spanned a period of about 4,500 years. The lake apparently stood at the Campbell level longer than at any other level because of the massive beach formed during this stage. The sand and gravel of the Campbell beach are well-rounded and well-sorted as compared with other beaches in the vicinity, an indication of duration.

Four large lakes, Lower Red, Leech, Winnibigoshish, and Cass, are located almost totally within the Bemidji Sheet area. In general, most lakes are confined to the moraines and outwash plains. With the exception of Lower Red Lake, very few occur in the lacustrine plains. Lake Winnibigoshish is located in the Aitkin Lacustrine plain; however, it borders the Bemidji sand plain.

The western and northern areas drain into the Red River of the North and the southeastern area drains into the Mississippi River.

Climate of the Bemidji Sheet Area

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

Some of the general climate characteristics of this area are given in the series of nine diagrams. The area has a typical continental climate with wide extremes in temperature from summer to winter. Total annual precipitation ranges from 20 inches per year in the western part to 27 inches in the southeastern portion (figure a). Nearly half of the precipitation falls during the summer (figure b).

Snowfall is an important component of annual precipitation and averages 30 to 60 inches (figure c). Figures d and e show that this area normally has 40 to 100 days with 6 inches of snow on the ground and 10 to 70 days with over 12 inches.

The average date of the last occurrence of frost ranges from May 17 in the southwestern corner to May 27 in the central and northeastern part of the area (figure f). Where soils suited to agriculture occur, wheat, barley, oats, flax, soy beans, sugar beets, potatoes, sunflowers, early maturing corn, alfalfa and other hay crops are grown successfully. Adapted vegetables and small fruits are also cultivated throughout the area. Fall frost normally occurs September 21 to 26 (figure g).

Summer weather is typically one of warm days and cool nights. Figures h and i show that the warmest temperatures in July average from 80° to 84°F., and the minimum from 54° to 59°. Summer and fall weather is usually very comfortable for outdoor recreational activities.

One of the important aspects of the climate is the temperature and moisture range which occurs within the soil and within the air zone several feet above ground. The nature of the soil, local topography, direction of slope and vegetation, all interact with the general patterns of air and moisture flow to modify long term temperature averages. For example, the southeastern portion is somewhat affected by the proximity of the Red, Leach, and Winnibi-

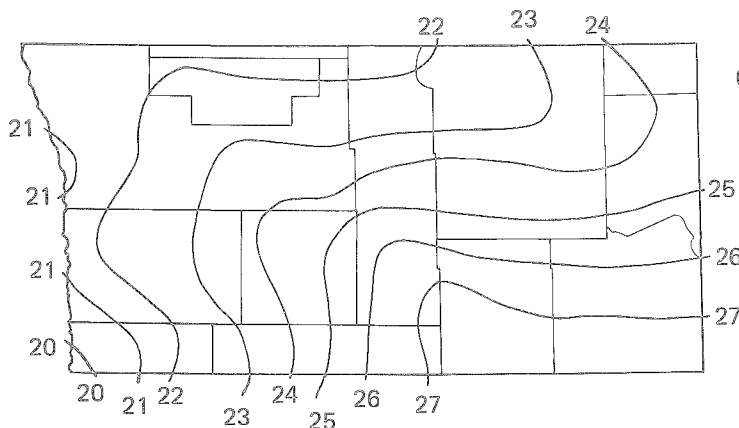


Figure a. Annual normal precipitation in inches, 1941-1970, Bemidji Sheet. (Adapted from Minnesota Technical Bulletin 314, 1978)

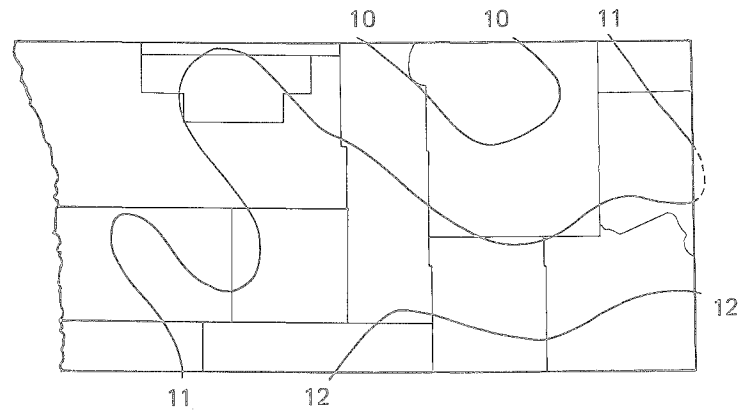


Figure b. Summer (June, July, August) normal precipitation in inches, 1941-1970, Bemidji Sheet. (Adapted from Minnesota Technical Bulletin 314, 1978)

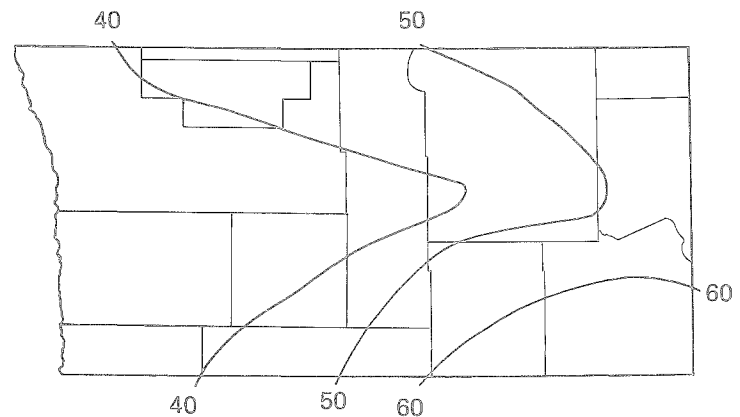


Figure c. Annual snowfall in inches, 1950-1975, Bemidji Sheet. (After Kuehnast and Baker)

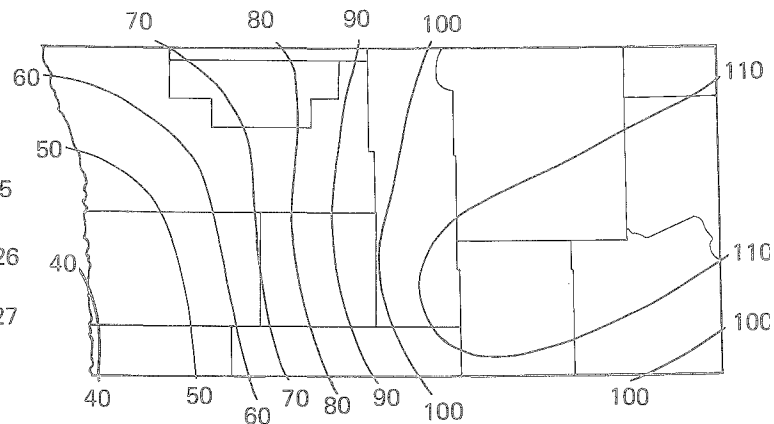


Figure d. Average number of days per year when snow cover is more than 6 inches, 1960-1979, Bemidji Sheet. (After Kuehnast, State Climatology Office, Department of Natural Resources)

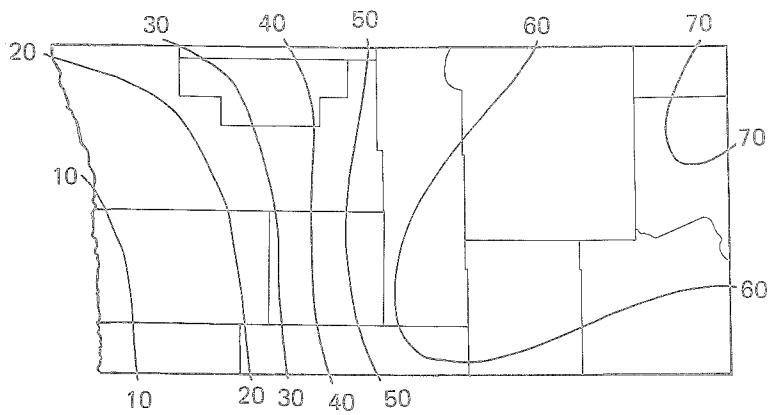


Figure e. Average number of days per year when snow cover is more than 12 inches, 1960-1979, Bemidji Sheet. (After Kuehnast, State Climatology Office, Department of Natural Resources)

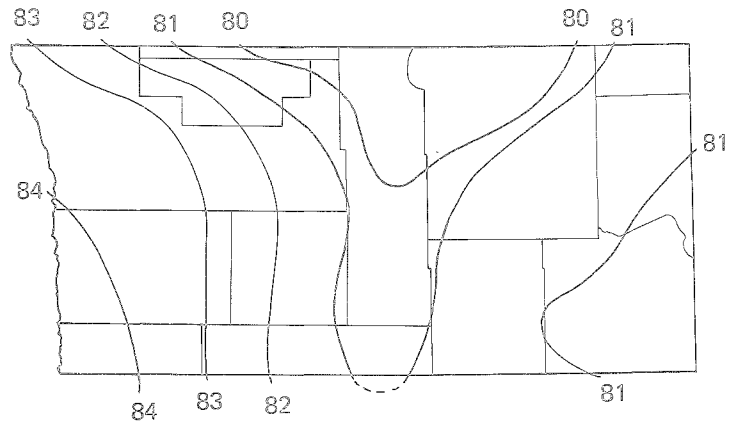


Figure h. Average daily maximum temperature during July 1931-1960, Bemidji Sheet. (Adapted from Minnesota Technical Bulletin 248, 1965)

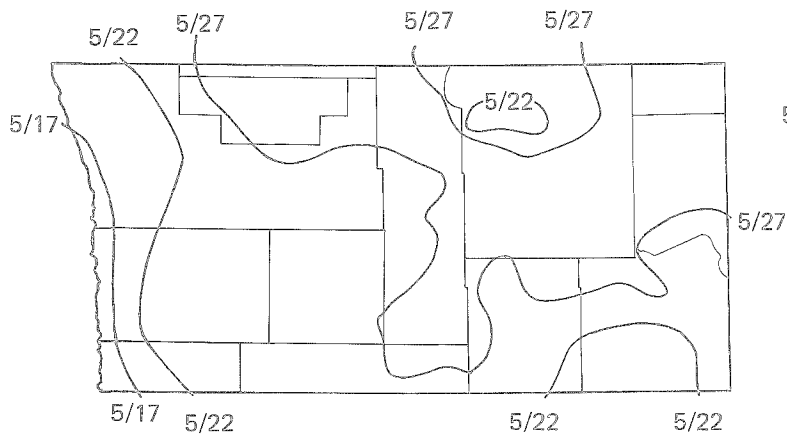


Figure f. Average date of last occurrence of 32° F or lower in the spring, Bemidji Sheet. (Adapted from Minnesota Technical Bulletin 243, 1963)

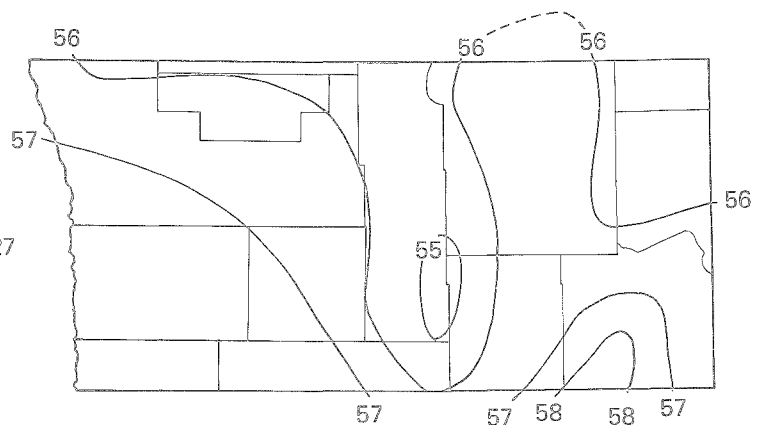


Figure i. Average daily minimum temperature during July, 1931-1960, Bemidji Sheet. (Adapted from Minnesota Technical Bulletin 248, 1965)

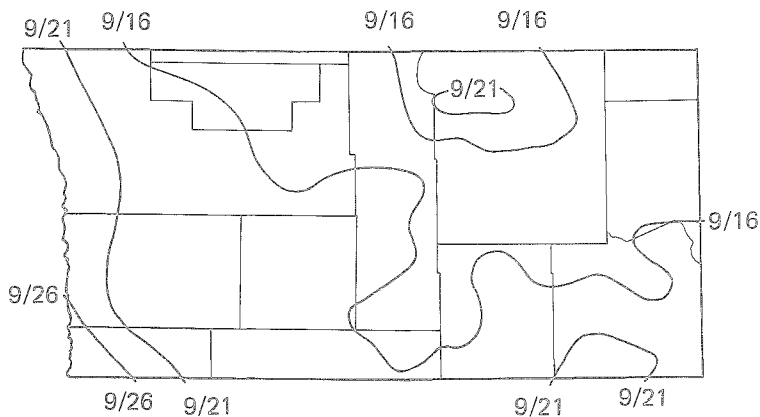


Figure g. Average date of occurrence of 32° F or lower in the fall, Bemidji Sheet. (Adapted from Minnesota Technical Bulletin 243, 1963)

goshish lakes resulting in slightly lower summer temperatures. The Agassiz Plains (1, 1B, and 1D) are nearly level, therefore slope and elevation have no effect on temperatures in those regions. The numerous areas of peat also produce a microclimate effect resulting in a somewhat shorter growing season but, because of the large water-holding capacity, often a temperature moderation. Soils on beaches and outwash plains are sandy and generally gravelly with a relatively low water-holding capacity, while lacustrine soils are clayey or silty with a high water-holding capacity.

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

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

Agriculture

Agriculture is an important industry in the Bemidji Sheet land area. Data from the 1974 Census of Agriculture show that about 40 percent of the 5.79 million acres is used for cropland. The types of farming range from an intensive crop oriented, large operations of the Red River Valley to diversified and part time farms in the eastern counties of the sheet.

The deep prairie soils and level topography of the Agassiz Lacustrine Plain (Red River Valley) make this section of Minnesota and North Dakota one of the prime crop production areas of the United States. East of the beach area, soils are more variable and the climate favors forest vegetation. Agricultural land here is discontinuous and most farms are using livestock to make maximum use of land suitable for pasture and hay crops.

The following tabulation lists the acreages and yields of the major crops from three counties of the Bemidji Sheet. Norman County is representative of the Agassiz Lacustrine Plain and Hubbard and Beltrami Counties represent the eastern part of the sheet.

Average acreage and yield of major crops in representative counties, 1977 and 1978¹

Beltrami county

| <u>Crop</u> | <u>Acreage</u> | <u>Yield</u> | <u>Crop acreage percent</u> |
|--------------|----------------|--------------|-----------------------------|
| Corn | 6,000 | 74.0 bu. | 6.8 |
| Wheat | 7,250 | 24.7 bu. | 8.1 |
| Oats | 20,650 | 46.6 bu. | 23.1 |
| Barley | 3,500 | 36.8 bu. | 3.9 |
| Sunflowers | 800 | 1314 lbs. | 0.9 |
| Hay | 51,250 | 1.7 tons | 57.3 |
| <i>Total</i> | <i>89,450</i> | | |

Hubbard county

| <u>Crop</u> | <u>Acreage</u> | <u>Yield</u> | <u>Crop acreage percent</u> |
|--------------|----------------|--------------|-----------------------------|
| Corn | 9,600 | 56.3 bu. | 17.4 |
| Wheat | 900 | 31.5 bu. | 1.6 |
| Oats | 12,350 | 43.6 bu. | 22.3 |
| Barley | 2,150 | 46.3 bu. | 3.9 |
| Sunflowers | 350 | 1490 lbs. | 0.6 |
| Hay | 27,000 | 1.3 tons | 49.0 |
| Potatoes | 2,900 | 348 cwt. | 5.2 |
| <i>Total</i> | <i>55,250</i> | | |

Norman county

| <u>Crop</u> | <u>Acreage</u> | <u>Yield</u> | <u>Crop acreage percent</u> |
|--------------|----------------|--------------|-----------------------------|
| Corn | 19,300 | 65.6 bu. | 4.2 |
| Soybeans | 5,300 | 21.0 bu. | 1.2 |
| Wheat | 167,750 | 35.7 bu. | 36.9 |
| Oats | 47,450 | 61.7 bu. | 10.4 |
| Barley | 97,500 | 53.0 bu. | 21.4 |
| Sunflowers | 63,500 | 1618 lbs. | 14.0 |
| Hay | 28,500 | 2.1 tons | 6.3 |
| Potatoes | 2,200 | 143 cwt. | 0.5 |
| Sugarbeets | 21,550 | 19.6 tons | 4.7 |
| Flax | 2,050 | 14.5 bu. | 0.5 |
| <i>Total</i> | <i>455,100</i> | | |

¹Data from Minnesota Agricultural Statistics, 1979 Minnesota Crop and Livestock Reporting Service.

Selected agricultural data, 1978¹

| <u>County</u> | <u>Total land area</u> | <u>Cropland acres</u> | <u>Percent of land in cropland</u> |
|---------------|------------------------|-----------------------|------------------------------------|
| Beltrami | 1,604,160 | 89,450 | 5.6 |
| Hubbard | 596,224 | 55,250 | 9.2 |
| Norman | 566,402 | 455,100 | 80.0 |

¹Data from Minnesota Agricultural Statistics, 1979 Minnesota Crop and Livestock Reporting Service.

Forestry

Forestry is an important land use in the eastern portion of the Bemidji Sheet area in 1979. In the early logging days it was within the pine and spruce country. Today aspen, spruce, jack pine, and tamarack occur extensively and are important in the logging industry and for the aesthetic beauty of the area. Northern hardwoods are common on the moraines in Becker, Mahanomen, and Clearwater counties.

For some timber interpretations on principal soil landscape units within geomorphic regions see table 25. The timber interpretations in respect to seedling mortality, productivity for pulpwood and sawtimber, and species recommendations are based on physical and chemical characteristics of the soils, prevailing water table positions, and general climatic considerations. Prevalence of disease and insect control problems are also reflected in the interpretations.

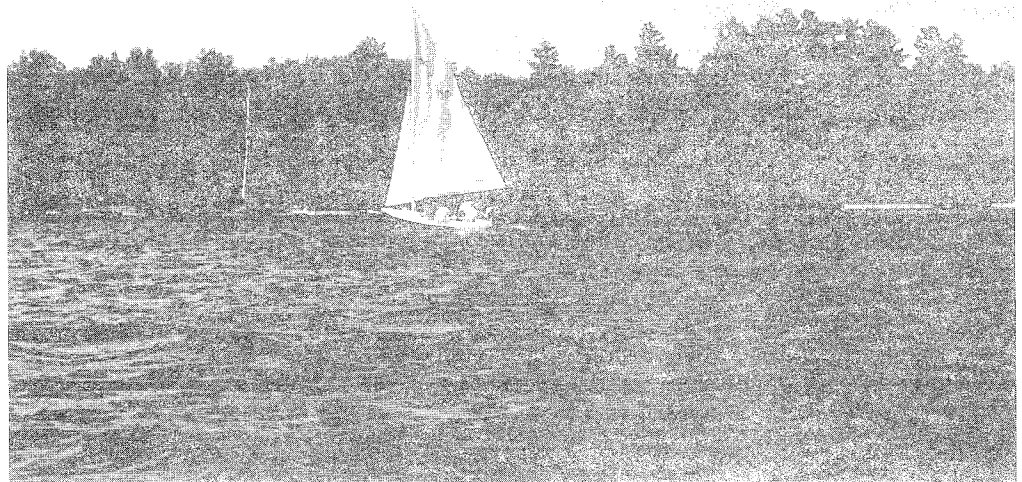
Table 25. Some timber interpretations within geomorphic regions of the Bemidji Sheet area based on soil characteristics

| <u>Geomorphic regions</u> | <u>Soil landscape unit</u> | <u>Texture</u> | <u>Water table position</u> | <u>Seedling mortality</u> | <u>Root restriction</u> | <u>Forest productivity</u> | | <u>Recommended species</u> | <u>Representative soil series</u> |
|----------------------------|----------------------------|----------------|-----------------------------|---------------------------|-------------------------|----------------------------|------------------|----------------------------|-----------------------------------|
| | | | | | | <u>Pulpwood</u> | <u>Sawtimber</u> | | |
| Big Fork (Agassiz) (1B) | SSWL | loamy | medium to | slight | slight | fair | poor | white spruce | Marquette |
| Inter-Beach (Agassiz) (1C) | | sand over | low | | | | | red pine | Menahga |
| Red Lake (Agassiz) (1D) | | sand and | | | | | | white pine | Hiwood |
| Aitkin Lacustrine (25) | | gravel | | | | | | jack pine | |
| | | | | | | | | aspen | |

Table 25 (continued). Some timber interpretations within geomorphic regions of the Bemidji Sheet area based on soil characteristics

| Geomorphic regions | Soil landscape unit | Texture | Water table position | Seedling mortality | Root restriction | Forest productivity | | Recommended species | Representative soil series |
|--|------------------------------|--|----------------------|-----------------------|-----------------------|---------------------|-----------------|--|---|
| | | | | | | Pulpwood | Sawtimber | | |
| | | | | | | | | | |
| Till plains (2A, 2B, 2C, 4B) Moraines (3, 3A, 3B, 3C, 11, 22B) Outwash plains (4, 8, 4, 7, 49) | SSWL SSWD | loamy sand over sand or gravelly sand | low | slight | slight | fair to good | fair | red pine jack pine aspen white spruce | Marquette Menahga Lengby Doraet Sioux Lonnea |
| Till plain (48) Moraines (3A, 11) Outwash plains (8, 47, 49) | SLWL | sand loam gravelly sand | low | slight | moderate | good | fair to good | | Todd Lengby Unnamed |
| Big Fork (Agassiz) (1B) Red Lake (Agassiz) (1D) Aitkin Lacustrine Plain (25) | LLWL LSWL SLWL | silt loam over silt loam or sand and loamy sand over loam | medium to low | slight to moderate | slight | good | fair to good | white spruce red pine aspen white birch | Saudette Games Unnamed |
| Till plains (2A, 2B, 2C, 4B) Moraines (3, 3A, 3B, 3C, 11, 22A, 22B) Outwash plain (8, 47) | LLWL LSWL XLWL YLWL | loam to sandy over loam | low | slight to moderate | slight | good | fair to good | white spruce red pine aspen white birch | Nebish Beltrami Kinghurst Rockwood |
| Till plain (2A) Moraines (3, 3A, 3B, 3C) | LLWD LSWD XLWD | loam and loamy sand over loam | low | moderate | slight | good | fair | aspen red pine white spruce | Waukon Unnamed Genwick |
| Big Fork (Agassiz) (1B) Northome Moraine (3B) | CCWL LCWL | silty clay to shallow clay over loam | medium to low | moderate to severe | moderate | good | good to fair | white spruce red pine white pine | Taylor Unnamed |
| Red Lake (Agassiz) (1D) Aitkin Lacustrine Plain (25) Till plains (2C, 24) Outwash plains (47, 49) | SSPL | loamy sand over sand | medium to high | moderate to severe | moderate to severe | fair | poor | black spruce white spruce white cedar | Redby Cormant Unnamed Meehan Newson Sebaka |
| Aitkin Lacustrine Plain (25) | SLPL | loamy over sand | medium to high | moderate to severe | moderate to severe | fair | poor | black spruce white spruce white cedar | Unnamed |
| Agassiz Lacustrine (1D) Aitkin Lacustrine (25) Till plains (2C, 24) Bagley Outwash Plain (47) | LLPL LSPL | silt loam to loamy sand over silt loam | medium to high | moderate to severe | moderate to severe | good | fair | white spruce aspen | Spooner Grygle Unnamed Kalsey Shooker |
| Big Fork (Agassiz) (1B) Red Lake (Agassiz) (1D) Aitkin Lacustrine (25) | CCPL CCPD CLPL | silty clay | high to medium | moderate to severe | moderate to severe | good | fair | white spruce aspen | Indus Wabanica Wildwood Unnamed |

Sailing and other water sports are popular on the numerous lakes of the Bemidji Sheet area.



Recreation

During the summer vacation season, parts of the Bemidji Sheet area become very popular. About 203 lakes, each at least 160 acres in size, are located in the area. Leech, Winnibigoshish, Lower Red, Cass, and Bemidji are the largest of these lakes.

Fishing, canoeing, boating, swimming, and water-skiing are popular summer activities.

Autumn brings deer, grouse, duck, and geese hunters into the area.

Snowmobiling is a popular winter sport. For principal recreational activities within geomorphic regions, refer to table 26. Table 27 is a general outline of limitations for various recreational activities in the soil landscape units of the Bemidji Sheet area.

Table 26. Recreational activities in the Bemidji Sheet Area by geomorphic regions

| Geomorphic region | Principal game | Water oriented | Resorts, picnic and camp grounds | Snowmobiling | Additional information |
|--|-------------------------|---|--|--------------|---|
| Agassiz Lacustrine Plain, Red River Valley (1) | deer grouse | canoeing on Red Lake and Sand rivers | | extensive | |
| Agassiz Lacustrine Plain, Big Fork Valley (1B) | deer grouse moose | boating and fishing | | limited | |
| Agassiz Lacustrine Plain, Inter-Beach (1C) | deer | canoeing on Clearwater, Red Lake, and Sand Rivers | | extensive | |
| Agassiz Lacustrine Plain, Red Lake (1D) | deer moose grouse | boating and fishing | | limited | Lower Red Lake fished commercially by Indians |
| Fergus Falls Till Plain (2) | deer ducks geese | | | extensive | |
| Fosston Till Plain (2A) | deer ducks geese | boating and fishing | Resort on Maple Lake camp and picnic grounds | extensive | numerous cottages on Maple Lake |
| Blackduck Till Plain (2B) | deer | boating and fishing | some camp and picnic grounds | extensive | |

Table 26 (continued). Recreational activities in the Bemidji Sheet Area by geomorphic regions

| Geomorphic region | Principal game | Water oriented | Resorts, picnic and camp grounds | Snowmobiling | Additional information |
|----------------------------------|-------------------------|--|---|--------------|--|
| Falk Till Plain (2C) | deer | | | extensive | |
| Alexandria Moraine (3) | deer ducks | boating and fishing | camp and picnic grounds some resorts | extensive | many small lakes some skiing many cottages |
| Erskine Moraine (3A) | deer ducks | boating and fishing | camp and picnic grounds numerous resorts | extensive | many small lakes numerous cottages |
| Northome Moraine (3B) | deer grouse | boating and fishing | camp and picnic grounds | extensive | cottages on island lake |
| Clearbrook Moraine (3C) | deer grouse | boating and fishing | camp and picnic grounds | extensive | many cottages numerous lakes |
| Detroit Lakes Pitted Outwash (4) | deer | | | extensive | minor region |
| Mahnomen Lacustrine Plain (5) | deer ducks | | | extensive | |
| Park Rapids-Staples Outwash (8) | deer | boating and fishing | camp and picnic grounds | extensive | |
| Itasca Moraine (11) | deer grouse ducks | boating and fishing | camp and picnic grounds; many resorts | limited | Itasca State Park, Lake Itasca—headwaters of Mississippi River; many cottages |
| Marcell Moraine (22A) | deer | | | limited | minor region |
| Sugar Hills Moraine (22B) | deer grouse | boating and fishing | camp and picnic grounds | limited | numerous cottages on Boy Lake |
| Swatara Plain (24) | deer grouse | | | limited | |
| Aitkin Lacustrine Plain (25) | deer grouse | boating and fishing | camp and picnic grounds | limited | a few cottages on Winnibigoshish, Leech and Six Mile lakes |
| Bagley Outwash Plain (47) | deer grouse ducks | boating and fishing | camp and picnic grounds; few resorts | extensive | cottages on several lakes |
| Guthrie Till Plain (48) | deer grouse ducks | boating and fishing | | limited | few cottages on Leech Lake |
| Bemidji Sand Plain (48) | deer grouse | boating and fishing very popular | camp and picnic grounds resorts on several lakes | extensive | cottages on several lakes, several large lakes |

Table 27. Degree and limitations for specific recreational uses

| Soil landscape unit | Description | Playgrounds, 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 |
|---------------------|--|--|--|---|--|--|--|
| PSWL | sandy over sandy or gravelly, light-colored soils well drained | moderate to severe difficult to maintain vegetation moderate-sandy surface soil, moderate-2-6% slopes severe-over 12% slopes | moderate-difficult to maintain vegetation sandy surface soil, moderate-6-12% slopes severe-over 12% slopes | moderate-sandy surface soil, moderate-12-18% slopes, severe-over 18% slopes | moderate to severe-low natural fertility, difficult to maintain vegetation, moderate-sandy surface soil, moderate-6-12% slopes, severe-over 12% slopes | slight-sandy surface soil makes vegetation difficult to maintain slight 2-6% slopes moderate-6-12% slopes severe-over 12% slopes | moderate-sandy surface soil, moderate-6-12% slopes, severe-over 10% slopes |
| SSPL | sandy over sandy or gravelly, poorly drained, light colored | 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 |
| SLWD | sandy over sandy or gravelly, well drained dark colored | moderate to severe difficult to maintain vegetation moderate-sandy surface soil, moderate-2-6% slopes severe-over 6% slopes | moderate-difficult to maintain vegetation sandy surface soil, moderate-6-12% slopes severe-over 12% slopes | moderate-sandy surface soil moderate-12-18% slopes severe-over 18% slopes | severe-difficult to maintain vegetation slight-0-6% slopes moderate-6-12% slopes severe-over 12% slopes. | slight-sand surface soil makes vegetation difficult to maintain slight-0-6% slopes moderate-6-12% slopes severe-over 12% slopes | moderate-sandy surface soil, moderate-6-12% slopes severe-over 12% slopes |
| SSPD | sandy over sandy or gravelly, poorly drained dark colored. | moderate-high water table | moderate-high water table | moderate-high water table | moderate-high water table | severe-high water table | severe-high water table |
| SLWL | loamy over sandy or gravelly, well drained light colored | slight-0-2% slopes moderate-2-6% slopes | slight | slight | slight | slight | slight |
| SLPL | loamy over sandy or gravelly, poorly drained, light colored. | severe-high water table, moderate-surface soil is sticky and soft when wet. | severe-high water table, moderate-surface soil is sticky and soft when wet. | severe-high water table, moderate-surface soil is sticky and soft when wet. | moderate-high water table | severe-high water table | severe-high water table |
| SLWD | loamy over sandy or gravelly, well drained dark colored. | slight-0-2% slopes moderate-2-6% slopes | slight | slight | slight | slight | slight |
| SLPD | loamy over sandy or gravelly, poorly drained, dark colored. | severe-high water table, moderate-surface soil is sticky and soft when wet. | severe-high water table, moderate-surface soil is sticky and soft when wet | severe-high water table, moderate-surface soil is sticky and soft when wet. | moderate-high water table | severe-high water table | severe-high water table |
| LSWL | sandy over loamy, well drained, light colored | moderate-vegetation difficult to maintain in some places, moderate-2-6% slopes, severe-over 6% slopes | moderate-vegetation difficult to maintain in some places, moderate-6-12% slopes severe-over 12% slopes | slight-2-12% slopes moderate-12-18% slope severe-over 18% slope | moderate-vegetation may be difficult to maintain in some places, 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 |

Table 27 (continued). Degree and limitations for specific recreational uses

| Soil landscape unit | Description | Playgrounds, 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 |
|---------------------|---|--|--|--|---|---|--|
| LSPL | sandy over loamy, poorly drained, light colored | severe—high water table | severe—high water table | severe—high water table | severe—high water table | severe—high water table | severe—high water table |
| LSWD | sandy over loamy, well drained, dark colored. | slight | slight | slight | slight | slight | slight |
| LSPD | sandy over loamy poorly drained, dark colored | severe—high water table | severe—high water table | severe—high water table | severe—high water table | severe—high water table | severe—high water table |
| LLWL | deep silty or loamy, moderately well to well drained, light colored | slight to moderate—surface soil may be sticky when wet. moderate—2-6% slopes severe—over 6% slopes | slight to moderate—surface soil may be sticky when wet. moderate—2-6% slopes severe—over 6% slopes | slight to moderate—surface soil may be sticky when wet. moderate—2-6% slopes severe—over 6% slopes | slight to moderate—surface soil may be sticky when wet. moderate—2-6% slopes severe—over 6% 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 |
| LLPL | deep silty or loamy, poorly drained, light colored. | severe—seasonal high water table, occasional ponding. moderate—slow permeability, surface soil is sticky when wet | severe—seasonal high water table, occasional ponding. moderate—surface soil is sticky when wet. | severe—seasonal high water table, occasional ponding. moderate—surface soil is sticky when wet. | moderate—seasonal high water table, occasional ponding. | severe—seasonal high water table, slow permeability | severe—seasonal high water table occasional ponding moderate—surface soil is sticky when wet. |
| LLWD | deep silty or loamy, somewhat poorly to well drained, dark colored. | slight to moderate—surface soil may be sticky when wet. moderate—2-6% slopes severe—over 6% slopes | slight to moderate—surface soil may be sticky when wet. moderate—2-6% slopes severe—over 6% | slight to moderate surface soil may be sticky when wet. moderate—2-6% slopes severe—over 6% slopes | slight to moderate—surface soil may be sticky when wet. Moderate—2-6% slopes severe—over 6% 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. |
| LLPD | deep silty or loamy, poorly drained dark colored. | severe—seasonal high water table; occasional ponding. moderate—slow permeability, surface soil is sticky when wet. | severe—seasonal high water table; occasional ponding. moderate—surface soil is sticky when wet. | severe—seasonal high water table; occasional ponding. moderate—surface soil is sticky when wet. | moderate—seasonal high water table; occasional ponding. | severe—seasonal high water table; slow permeability. | severe—seasonal high water table; occasional ponding moderate—surface soil is sticky when wet. |
| LCWL | clayey over loamy; moderately well drained; light colored. | moderate—surface soil is sticky when wet. slow permeability moderate—2-6% slopes | moderate—surface soil is sticky when wet. slow permeability moderate—2-6% slopes. | moderate—surface soil is sticky when wet. moderate—2-6% slopes. | moderate—surface soil is sticky when wet. moderate—2-6% slopes. | slight | moderate—surface soil is sticky when wet. slow permeability |
| CLWD | loamy or silty over clayey; moderately well drained. dark colored | slight | slight | slight | slight | slight | slight |

Table 27 (continued). Degree and limitations for specific recreational uses

| Soil landscape unit | Description | Playgrounds, 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 |
|---------------------|---|--|---|--|---|--|--|
| CLPL | loamy over clayey; poorly drained, light | severe—seasonal high water table; occasional ponding. | severe—seasonal high water table; occasional ponding. | severe—seasonal high water table; occasional | severe—seasonal high water table; occasional ponding | severe—seasonal high water table; slow permeability | severe—seasonal high water table; slow |
| CLPD* | colored. | moderate—slow permeability; soil is sticky when wet. | moderate—slow permeability. soil is sticky when wet. | ponding; moderate surface soil is sticky when wet; slow permeability | moderate—surface soil is sticky when wet. | | permeability. |
| CCWL | deep clayey; well drained; light colored | moderate—soil is sticky when wet. moderate—2-6% slopes severe—over 6% slopes | moderate—soil is sticky when wet; slow permeability moderate—6-12% slopes severe—over 12% slopes. | moderate—soil is sticky when wet. slow permeability. | moderate—surface soil is sticky when wet. moderate—6-12% slopes | slight | moderate—surface soil is sticky when wet. slow permeability moderate—6-12% slopes |
| CCPL | deep clayey; poorly drained; light colored. | severe—seasonal high water table; occasional ponding; poor trafficability; moderate—slow permeability. | severe—seasonal high water table; occasional ponding; poor trafficability; | severe—seasonal high water table. moderate—surface soil is sticky when wet. | severe—seasonal high water table. moderate—surface soil is sticky when wet. | severe—seasonal high water table. | severe—seasonal high water table; poor trafficability moderate—slow permeability. |
| CCPD | deep clayey; poorly to very poorly drained; dark colored. | severe—seasonal high water table; occasional ponding; poor trafficability. moderate—slow permeability. | severe—seasonal high water table; occasional ponding; poor trafficability. | severe—seasonal high water table; surface soil sticky when wet; moderate—occasional ponding. | severe—seasonal high water table; occasional ponding; surface soil sticky when wet. | severe—seasonal high water table; occasional ponding. | severe—seasonal high water table; surface soil is sticky when wet. moderate—slow permeability. |
| XLWL | loamy over | slight—0-2% slopes. | slight—2-6% slopes | slight- | slight—2-6% slopes | slight—2-6% slopes | slight—2-6% |
| XLWD | sandy, gravelly and loamy, well drained. | moderate—2-6% slopes. severe—over 6% slopes. | moderate—6-12% slopes. severe—over 12% slopes. | moderate—12-18% slopes. severe—over 18% slopes | moderate—6-12% slopes. severe—over 12% slopes. | moderate—6-12% slopes. severe—over 12% slopes. | moderate—6-12% slopes. severe—over 12% slopes. |
| YLWL | loamy over | slight to moderate— | slight to moderate— | slight to moderate— | slight to moderate— | slight—2-6% slopes | slight—2-6% |
| YLWD | clayey and loamy; well drained. | surface soil may be sticky when wet. moderate—2-6% slopes. severe—over 6% slopes. | surface soil may be sticky when wet. moderate—2-6% slopes. severe—over 6% slopes. | surface soil may be sticky when wet. moderate—2-6% slopes. severe—over 6% slopes | surface soil may be sticky when wet. moderate—2-6% slopes. severe—over 6% slopes. | moderate—6-12% slopes. severe—over 12% slopes. | moderate—6-12% slopes. severe—over 12% slopes |
| LP | organic soil | severe—high water table; seasonally ponded; soft organic surface soil. | severe—high water table; seasonally ponded. soft organic surface soil. | severe—high water table; seasonally ponded; soft organic surface soil. | severe—high water table; seasonally ponded. soft organic surface soil. | severe—high water table; seasonally ponded; soft organic surface soil. | severe high water table; seasonally ponded; soft organic surface soil. |
| SP | peat over | | | | | | |
| NP | loamy, | | | | | | |
| AP | sandy, or peat | | | | | | |
| P | very poorly drained. | | | | | | |
| A | alluvial land. | moderate to severe—occasionally to frequently flooded. | moderate to severe—occasionally to frequently flooded. | moderate to severe—occasionally to frequently flooded. | moderate to severe—occasionally to frequently flooded. | moderate to severe—occasionally to frequently flooded. | moderate to severe—occasionally to frequently flooded. |
| M | marsh-organic and mineral soils. ponded most of the year. | severe—high water table; ponded most of the year. | severe—high water table; ponded most of the year. | severe—high water table; ponded most of the year. | severe—high water table; ponded most of the year. | severe—high water table; ponded most of the year. | severe—high water table; ponded most of the year. |

*minor soil landscape unit.

Information for the Engineer

Because of the general nature of soil landscape units, which include several major and minor soil series, it is impossible to give specific engineering data such as engineering classification, particle size, liquid limit, plasticity index, percolation rates, shrink-swell potential, and corrosivity. These can be obtained from onsite investigations. Table 28 gives an approximate range in the American Association of State Highway Officials

(AASHO) and unified classification of materials in the respective soil 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.

Prime sources of gravel will be found in the Inter-Beach Area (1C).

Table 28. Approximate engineering classification of materials at the surface and at 5 feet in the soil landscape units delineated in the Bemidji Sheet

| Soil landscape unit | AASHO ¹ | | UNIFIED ² | |
|---------------------|----------------------|---------------|--------------------------------|----------------------|
| | Surface | 5 feet+ | Surface | 5 feet+ |
| SSWL | A-1, A-2, A-3 | A-1, A-3 | SM, SP-SM, SC | SP, SP-SM |
| SSPL | A-2, A-3 | A-2, A-3 | SM, SP-SM | SP, SP-SM |
| SSWD | A-1, A-2, A-4 | A-1, A-2 | SM, SC, ML, CL, CL, GM, GC | GM, GC, SM, SC |
| SSPD | A-2, A-3, A-4 | A-2, A-4 | SP, SP-SM, SM | SP, SP-SM, SM |
| SLWL | A-2-4, A-4 | A-1, A-2, A-3 | SM, SM-SC, ML-CL | SP, SP-SM, SM, GP |
| SLPL | A-4 | A-1, A-2, A-3 | SM, SM-SC, ML, ML-CL | SP, SP-SM, SM |
| SLWD | A-2-4, A-4 | A-1, A-2, A-3 | OL, ML, CL-ML | ML, CL-ML |
| SLPD | A-2-4, A-4 | A-1, A-2, A-3 | SM, SM-SC, ML, ML-CL | SP, SP-SM, SM, GP |
| LSWL | A-2, A-3 | A-4, A-6 | SP-SM, SM | ML, CL, ML-CL |
| LSPL | A-2, A-3 | A-4, A-6 | SP-SM, SM | ML, CL, ML-CL |
| LSWD | A-2, A-3, A-4 | A-4, A-6 | SM, SM-SC, ML, CL, SP-SM | SC, CL, SM-SC, CL-ML |
| LSPD | A-2, A-3, A-4 | A-4, A-6 | SM, SM-SC, ML, CL, SP-SM | CL, ML |
| LLWL | A-2-4, A-4, A-6, A-7 | A-4, A-6, A-7 | ML, CL, SM | ML, CL, SM |
| LLPL | A-2-4, A-4, A-6, A-7 | A-4, A-6, A-7 | ML, CL, SM | ML, CL, SM |
| LLWD | A-4, A-6, A-7 | A-4, A-6, A-7 | ML, ML-CL, CL ³ | CL, ML-CL, MH, CH |
| LLPD | A-4, A-6, A-7 | A-4, A-6, A-7 | ML, ML-CL, CL ³ | CL, ML-CL, MH, CH |
| LCWL | A-7 | A-4, A-6, A-7 | CH, ML | CL, ML-CL, MH, CH |
| CLWD | A-4, A-6, A-7 | A-7 | ML, ML-CL, CL, CH ³ | CH |
| CLPL | A-4, A-6, A-7 | A-7 | ML, ML-CL, CL, CH | CH |

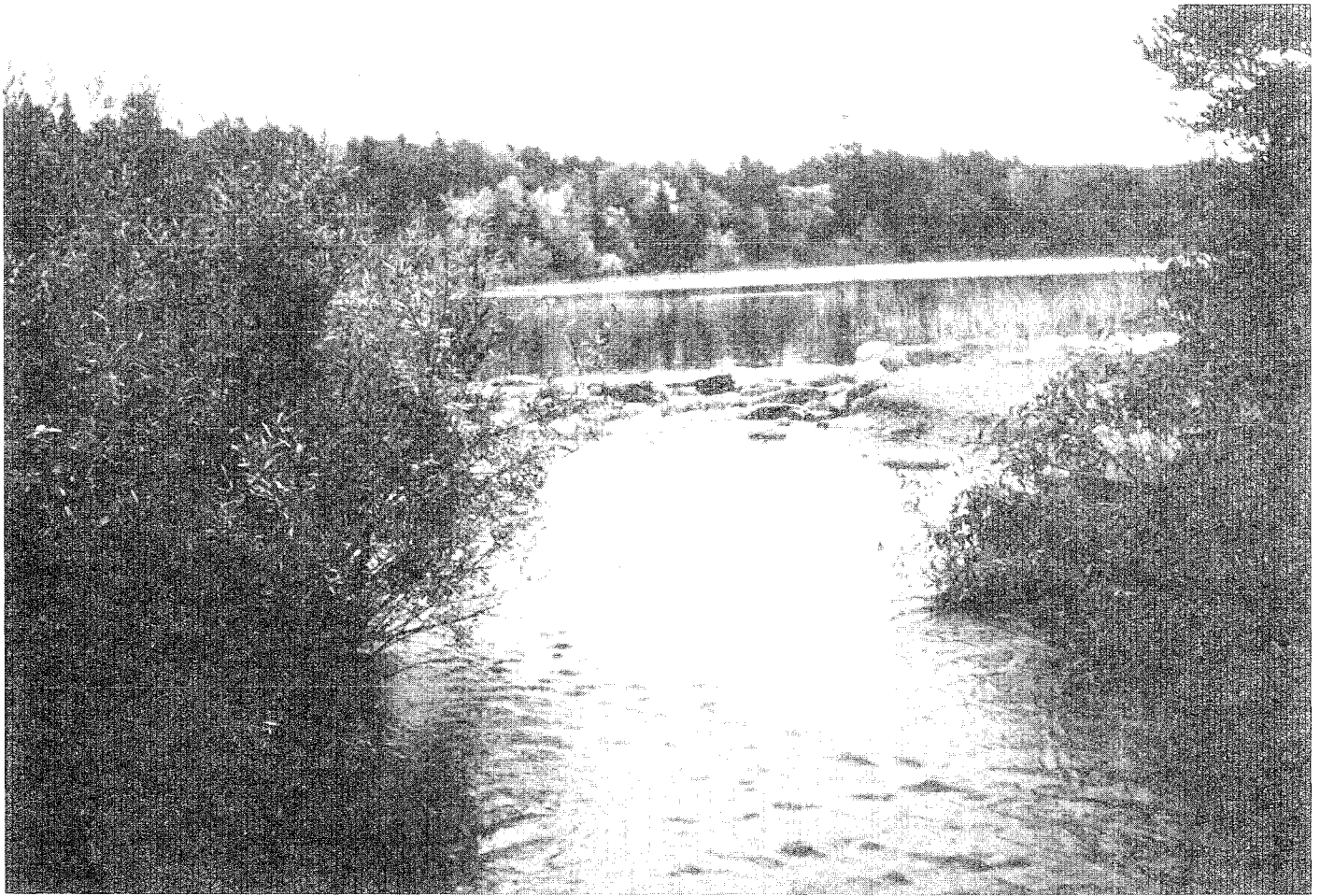
Table 28 (continued). Approximate engineering classification of materials at the surface and at 5 feet in the soil landscape units delineated in the Bemidji Sheet

| Soil landscape unit | AASHO ¹ | | UNIFIED ² | |
|---------------------|--------------------|--------------------|--------------------------------|------------------------------|
| | Surface | 5 feet+ | Surface | 5 feet+ |
| CLPD | A-4, A-6, A-7 | A-7 | ML, ML-CL, CL, CH ³ | CH |
| CCWL | A-7 | A-7 | CH | CH |
| CCPL | A-7 | A-7 | CH | CH |
| CCPD | A-7 | A-7 | CH ³ | CH |
| XLWL | A-2, A-4 | A-1, A-2, A-3, A-4 | SP, SP-SM, SM, ML | SP, SP-SM, SM, ML, ML-CL, CL |
| XLWD | A-2, A-4 | A-1, A-2, A-3, A-4 | SP, SP-SM, SM, ML ³ | SP, SP-SM, SM, ML, ML-CL, CL |
| YLWL | A-4, A-6, A-7 | A-4, A-6, A-7 | ML, ML-CL, CL | ML, ML-CL, CL |
| YLWD | A-4, A-6, A-7 | A-4, A-6, A-7 | ML, ML-CL, CL | ML, ML-CL, CL |
| LP | A-8, A-4, A-6 | A-4, A-6 | PT, OH, ML, CL, SM, SC | ML, CL, SM, SC |
| SP | A-8, A-2, A-3, A-4 | A-1, A-2, A-3 | PT, OL, ML, SM, SP | SM, SP |
| NP | A-8 | A-8, A-4, A-6 | PT | PT, OH, ML, CL, SM |
| AP | A-8 | A-8, A-4, A-6 | PT | PT, OH, ML, CL, SM |
| A | Variable | Variable | Variable | Variable |
| M | | | | |

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

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

³The 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.



Headwaters of the Mississippi River is at Lake Itasca, near the southern edge of the Bemidji Sheet. It is a favorite spot for tourists and natives of Minnesota, too. Maneuvering across the rocks, on foot, takes some agility, but lots of photo albums point to it as an accomplishment.

Hydrology

This section is divided into two parts: (1) Watersheds of Red Lake and Wild Rice Rivers; and (2) Mississippi Headwaters.

1. Watersheds of Redlake and Wild Rice Rivers. Streamflow of the Red River of the North is adequate because it is supplemented by release of stored water from Red Lakes within the watershed, and Orwell Reservoir and Lake Ashtabula which are outside the watershed.

In the glacial till areas wells which tap thin and discontinuous sand and gravel strata generally yield less than 25 gallons per minute. Most communities have local undeveloped aquifers which may yield several hundred gallons per minute. The most productive aquifers can be expected to occur in the outwash and ice-contact deposits within the moraines.

Chemical quality of surface and most ground water is suitable for domestic and agricultural uses. This water at depths generally less than 50 feet is the calcium magnesium type. Most surface and ground water has a low sodium hazard but a moderate to high salinity hazard for irrigation use. Water hardness generally ranges from 200 to 2,000 milligrams per liter. Hardness of 500 milligrams per liter occurs in Red Lake County. In West Polk County the hardness ranges from 500 to 2,000 towards East Grand Forks. In the lake plain (region 1) at depths over 50 feet the

water is of the highly mineralized sodium chloride type. It generally is not suitable for domestic or agricultural purposes. This water type is commonly associated with the Cretaceous sediments which occur below the glacial drift. The iron content in the watersheds of Red Lake and Wild Rice Rivers may be high.

2. Mississippi Headwaters

Streamflows of the Mississippi River and tributaries are adequate. Flows of the Mississippi are supplemented by dams which maintain levels of Winnibigoshish and Leech lakes.

The outwash, moraine, and till areas have adequate ground water supplies in most places. See table 30 for additional information.

The water is very hard containing 180 milligrams per liter or more as calcium carbonate and frequently an excess of iron and magnesium. The sodium adsorption ratio is low and the boron content is within the permissible

limits of boron-sensitive plants. The water consequently is suitable for irrigation of crops.

For streamflow data on several streams in the Bemidji Sheet Area see table 29.

Table 30. Yields of ground water from wells, potential yields, and thicknesses of aquifers by glacial sediments in the Mississippi Headwaters

| Geomorphic area | Range of yield per well (gpm)* | Potential obtained per well (gpm)* | Thickness of aquifers (feet) |
|-----------------|--------------------------------|------------------------------------|------------------------------|
| Outwash () | 3-81 | 2000 | 1-200 |
| End Moraine () | 1-50 | 1000 | 2-50 |
| Till Plain () | 1-13 | 500 | 1-16 |
| Glacial Lakes | 0.5-7.5 | 500 | 1-68 |

*gallons per minute

Table 29. Stream flow data on several streams in the Bemidji Sheet Area

| River | Location | Drainage area (sq. miles) | Years on record | Discharge in CFS | | Average (cfs) | Average annual runoff (inches) |
|------------------------|----------------|---------------------------|--------------------|------------------|---------------|---------------|--------------------------------|
| | | | | Maximum (cfs) | Minimum (cfs) | | |
| Red River of the North | Grand Forks | 30,100 | 1854-85 | 30,000 | 2.4 | 2,858 | 1.65 |
| Red Lake | Cookston | 5,220 | 1962-85 | 21,400 | 0.0 | 1,921 | 2.58 |
| Clearwater | Red Lake Falls | 1,370 | 1910-17 1935-65 | 9,318 | 0.0 | 280 | 2.98 |
| Clearwater | Plummer | 512 | 1940-65 | 3,640 | 7.9 | 169 | 4.48 |
| Lost | Oklee | 266 | 1961-65 | 1,780 | 0.0 | 76 | 3.89 |
| Clearwater | Leonard | 153 | 1935-45 | 655 | 2.0 | 61 | 5.48 |
| Puffy Brook | Gonvick | 45.2 | 1961-85 | 412 | 0.6 | 14 | 4.33 |
| Wild Rice | Wendrum | 1,600 | 1946-85 | 8,900 | 0.0 | 218 | - |
| Wild Rice | Ada | 1,100 | 1949-53 | 1,700 | 0.0 | 125 | - |
| Wild Rice | Twin Valley | 888 | 1910-17 1931-65 | 9,200 | 0.5 | 161 | 2.46 |
| Sand Hill | Climax | 405 | 1944-65 | 4,580 | 8.0 | 59 | 2.01 |
| South Branch Wild Rice | Borup | 254 | 1944-49 | 1,150 | 0.0 | 36 | 1.96 |
| Marsh | Shelly | 151 | 1945-65 | 4,660 | 0.0 | 57 | - |
| Mississippi (at dam) | Winnibigoshish | 1,443 | 1884-88 | 4,370 | 0.0 | 430 | 4.70 |
| Leach Lake | Federal Dam | 1,163 | 1884-64 | 2,520 | 0.0 | 357 | 3.94 |



Trees planted along field boundaries in the Red River Valley help reduce wind erosion from soils such as Arveson, Beardon, and Borup series.

Appendix A

Short Descriptions of Soil Series Classified at the Subgroup Category

Alluvial Land, undifferentiated

This land type consists of recent alluvium of variable textures and variable drainage, occurring on stream flood plains. (Unclassified)

Arveson—Dark-colored, poorly and very poorly drained, mildly alkaline loam 10 to 20 inches thick, over gray moderately alkaline loam to sandy loam, grading to 24 to 36 inches of gray calcareous lacustrine loamy sand or fine sand. (Typic Calciaquolls)

Arvilla—Dark-colored, somewhat excessively drained, neutral sandy loam 6 to 12 inches thick over brown, neutral sandy loam subsoil underlain at 14 to 24 inches with brown, calcareous gravelly coarse outwash sand. (Udic Haploborolls)

Barnes—Dark-colored, well-drained, neutral loam over brown, neutral loam subsoil over brownish gray calcareous loamy glacial till at 14 to 20 inches. (Udic Haploborolls)

Baudette—Light-colored, moderately well-drained, slightly acid very fine sandy loam to silt loam, over mildly acid to neutral brownish silty clay

loam subsoil, over brownish gray lacustrine silt loam at 18 to 24 inches. (Aquic Eutroboralfs)

Beardon—Dark-colored, somewhat poorly drained slightly alkaline silt loam to silty clay loam, over light olive brown strongly calcareous silt loam to silty clay loam. The substratum at about 30 inches is light brownish gray calcareous, lacustrine silt loam to silty clay loam. (Aeric Calciaquolls)

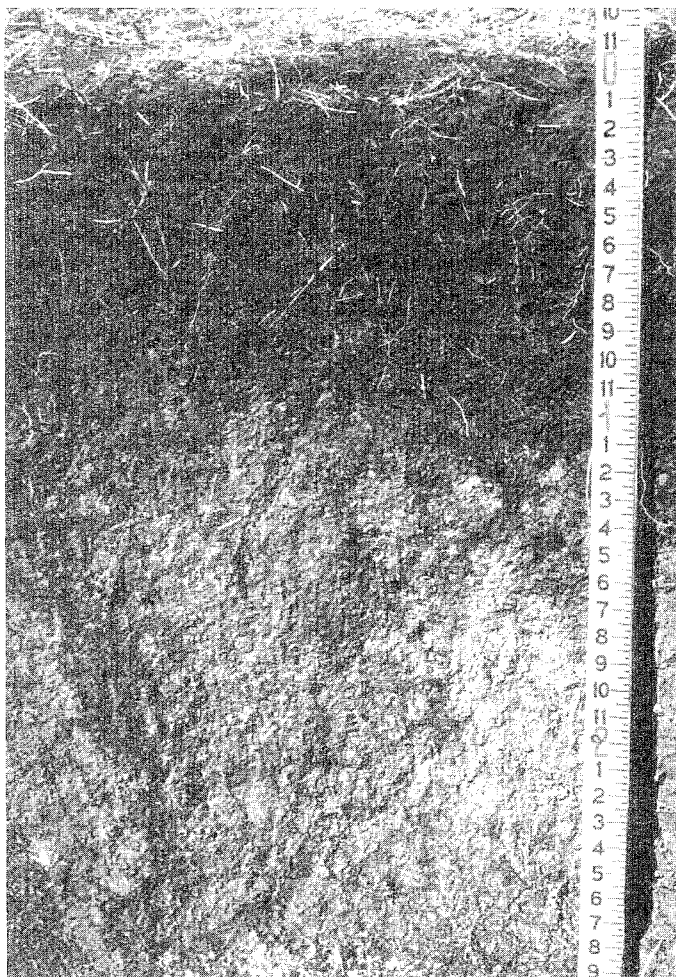
Beltrami—Light-colored, moderately well-drained, slightly acid sandy loam to loam 10 to 15 inches thick, over brownish slightly acid clay loam subsoil. This is underlain at 26 to 36 inches by olive brown, calcareous loamy glacial till. (Aquic Eutroboralfs)

Bluffton—Dark-colored, mildly alkaline, very poorly drained silty clay loam about 6 inches thick over light-colored, clay loam subsurface, over pale olive mildly alkaline clay loam subsoil. At 20 to 30 inches this grades to grayish olive, calcareous loamy glacial till. (Mollic Haplaquents)

Borup—Dark-colored, poorly drained very fine sandy loam to sandy clay loam 10 to 15 inches thick, over dark gray to olive gray sandy clay loam, grading at 20 to 30 inches to calcareous lacustrine loamy very fine sand. These soils are mildly alkaline. (Typic Calciaquolls)

Cashel—Dark-colored, somewhat poorly drained, mildly alkaline silty clay 10 to 20 inches thick, over gray-

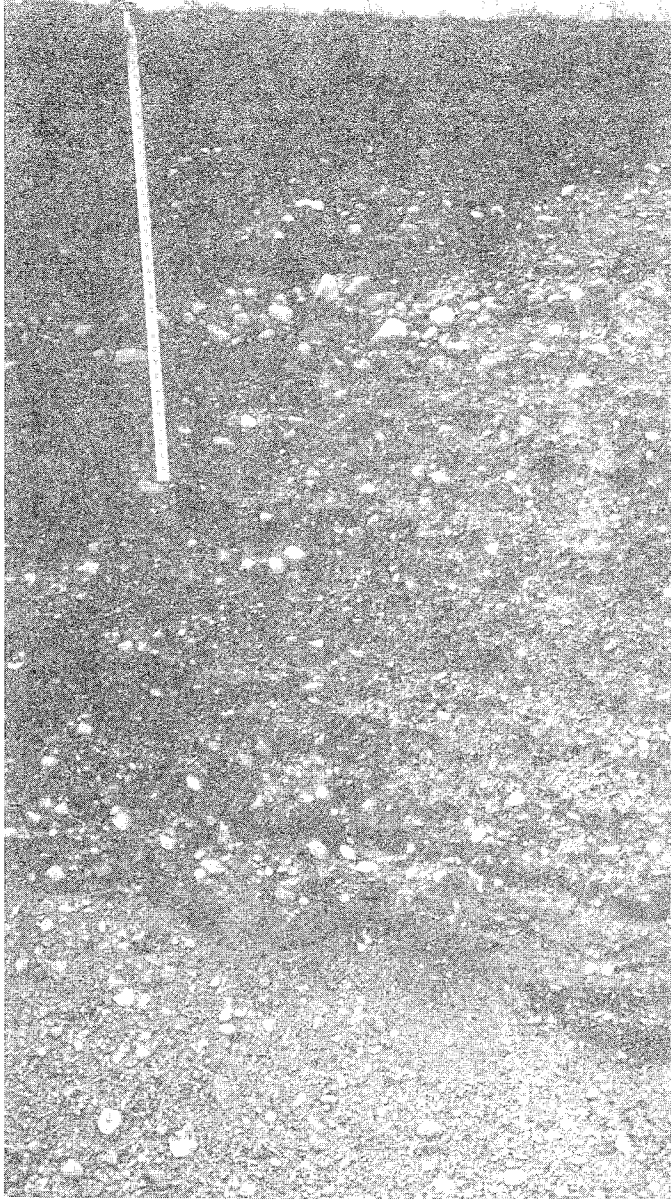
Dark surface materials extend down into the subsoil where dry summers have caused cracks to appear in the Fargo clay.



- ish brown calcareous silty clay alluvium along bottomlands. (Mollic Udifluvents)
- Cathro—Dark-colored, neutral very poorly drained muck or peat 16 to 50 inches thick, over grayish brown sandy loam. (Terric Borosaprists)
- Chilgren—Light-colored, poorly to somewhat poorly drained, neutral to slightly acid silt loam or loam, over dark grayish brown, slightly alkaline to neutral silty clay loam. At 12 to 18 inches the substratum is pale olive calcareous loamy glacial till. (Typic Ochraqualfs)
- Colvin—Dark-colored, poorly drained, mildly alkaline silty clay loam 10 to 16 inches thick, over olive gray, moderately alkaline, lacustrine silty clay loam. (Typic Calciaquolls)
- Cormant—Moderately dark-colored poorly and very poorly drained, neutral loamy fine sand about 6 inches thick, over brownish gray neutral fine sand. The soil occurs on lake plains, deltas, and outwash plains. (Mollic Psammaquents)
- Dawson—Dark reddish brown, very poorly drained, extremely acid peat, mainly sphagnum moss, over herbaceous peat. Below 16 to 50 inches the sediments are grayish brown extremely acid outwash sand. A layer of silt loam occurs between the peat and sand in many places. (Terric Borosaprists)
- Deerwood—Dark-colored, mildly alkaline muck or peat 4 to 16 inches thick, over grayish brown, moderately alkaline fine sand or gravelly sand. (Histic Humaquepts)
- Donaldson—Dark-colored, moderately to somewhat poorly drained, neutral very fine sandy loam 6 to 14 inches thick over dark brown neutral loamy very fine sand. This becomes mildly alkaline at about 16 inches. At 20 to 40 inches this changes abruptly to olive gray, calcareous lacustrine clay. (Aquic Haploborolls)
- Dorset—Moderately dark-colored, well to somewhat excessively drained, slightly acid sandy loam, over dark brown neutral sandy loam, grading at 18 to 34 inches to brownish, calcareous gravelly coarse outwash sand. (Mollic Eutroboralfs)
- Fargo—Dark-colored, poorly drained, neutral silty clay, over dark gray, neutral to mildly alkaline silty clay subsoil. Cracks ½ to 5 inches wide and filled with surface soil extend into the subsoil. Below 20 to 30 inches the substratum is olive, calcareous lacustrine silty clay. These soils are very sticky and plastic. (Vertic Haplaquolls)
- Flaming—Dark-colored, well-drained, medium acid loamy fine sand 10 to 16 inches thick, over brownish medium acid fine sand subsoil. Below 20 to 40 inches the material is grayish medium acid lacus-

- trine fine sand which becomes calcareous below 40 to 60 inches. (Aquic Haploborolls)
- Flom—Dark-colored, poorly to somewhat poorly drained, neutral silty clay loam, over olive gray, mildly alkaline clay loam subsoil. The glacial till at about 20 inches is olive gray, calcareous loam. (Typic Haplaquolls)
- Foldahl—Dark-colored, moderately well-drained, neutral sandy loam over dark yellowish brown, neutral loamy sand or sand. Below 20 to 40 inches the material is grayish brown, moderately alkaline loamy glacial till or lacustrine sediment. (Aquic Haploborolls)
- Fossum—Dark-colored, poorly drained sandy loam, over dark gray loamy sand grading to olive gray fine sand at about 15 inches. The soils are calcareous throughout. (Typic Haplaquolls)
- Garnes—Light-colored, moderately well-drained neutral loam, over dark brown, neutral sandy clay loam subsoil. The material below 8 to 20 inches is grayish brown, calcareous loamy glacial till. (Aquic Eutroboralfs)
- Glyndon—Dark-colored, moderately well to somewhat poorly drained loam to very fine sandy loam over light yellowish brown loam to very fine sandy loam. This grades at about 28 inches to brownish gray lacustrine loamy very fine sand. These soils are calcareous throughout. (Aeric Calciaquolls)
- Gonvick—Moderately dark-colored, moderately well-drained, neutral loam over dark grayish brown, neutral clay loam, 24 to 36 inches thick over the olive brown, calcareous loamy glacial till. (Aquic Argiborolls)
- Greenwood—Dark brown to dark reddish brown, extremely to very strongly acid, moderately decomposed herbaceous peat more than 51 inches thick. (Typic Borochemists)
- Grimstad—Dark-colored, somewhat poorly drained sandy loam 6 to 10 inches thick, over grayish brown loamy fine sand, over brownish gray loamy glacial till or lacustrine sediments. The soils are calcareous throughout. (Aeric Calciaquolls)
- Grygla—Moderately dark-colored, poorly to somewhat poorly drained, medium acid fine sand 24 to 40 inches thick, over calcareous loamy glacial till or lacustrine sediments. (Mollic Haplaquents)
- Gudrid—Light-colored, moderately well-drained, medium acid lacustrine fine sand 24 to 48 inches thick, over calcareous loamy glacial till or lacustrine sediments. (Aquic Udorthents)
- Hamar—Dark-colored, poorly to somewhat poorly drained, mildly alkaline loamy fine sand 10 to 20 inches thick, over dark gray to olive gray mildly to medium alkaline lacustrine fine sand. (Typic Haplaquolls)
- Hangaard—Dark-colored, poorly to somewhat poorly drained, mildly alkaline, sandy loam to loamy coarse sand 7 to 20 inches thick, over brownish gray calcareous gravelly coarse outwash sand. (Typic Haplaquolls)
- Haug—Dark-colored, very poorly drained, neutral peat 4 to 16 inches thick, over black mildly alkaline mucky sandy loam 12 to 20 inches over grayish calcareous loam. (Histic Humaquepts)
- Hegne—Dark-colored, poorly drained silty clay, over grayish silty clay to clay, over olive gray lacustrine clay. The soils are calcareous throughout. (Typic Calciaquolls)
- Hill City—Light-colored, well to moderately well-drained, medium acid silt loam, over brownish, medium acid silt loam subsoil. At about 20 inches is a brownish yellow slightly acid to neutral silt loam to very fine sandy loam. (Typic Dystrochrepts)
- Hiwood—Light-colored, moderately well to well-drained, medium acid loamy fine sand to fine sand 6 to 12 inches thick, over brownish yellow, medium acid lacustrine fine sand which becomes neutral at about 30 inches. (Spodic Udipsamments)
- Indus—Light-colored, poorly drained, slightly acid clay, over mildly to moderately alkaline clay subsoil, grading at 20 to 35 inches to olive, calcareous lacustrine clay to silty clay. (Typic Ochraqualfs)
- Kelsey—Moderately dark-colored, very poorly drained, slightly acid silt loam, over olive gray neutral, lacustrine silt loam, which becomes calcareous at about 40 inches. (Typic Haplaquolls)
- Kinghurst—Light-colored, well-drained, slightly acid loamy sand, over yellowish, slightly acid sand. This grades at 20 to 40 inches to olive brown, calcareous loamy glacial till. (Psammentic Eutroboralfs)
- Kittson—Dark-colored, moderately well or somewhat poorly drained, neutral loam, over dark grayish brown, neutral loam. Underlying this at 15 to 30 inches is olive brown, calcareous, loamy glacial till. (Aquic Haploborolls)
- Kratka—Dark-colored, poorly and very poorly drained, mildly alkaline loam over grayish brown, mildly alkaline sand, over olive gray, calcareous, loamy glacial till or lacustrine sediments at 12 to 24 inches. (Typic Haplaquolls)
- Langhei—Dark-colored, somewhat excessively drained, calcareous loam 5 to 8 inches thick over grayish brown, calcareous loamy glacial till. (Typic Udorthents)
- Lengby—Light-colored, well-drained, slightly acid loam to sandy loam, over yellowish brown, medium acid sandy clay loam subsoil. At 24 to 36 inches the material is yellowish brown, slightly acid, outwash sand. (Typic Eutroboralfs)
- Lohnes—Dark-colored, somewhat excessively drained, neutral sandy loam, over brown, mildly alkaline loamy sand subsoil. The substratum at 12 to 20 inches is brownish gray, calcareous coarse sand. (Udorthentic Haploborolls)

- Maddock—Dark-colored, well-drained, neutral loamy fine sand, over brown, neutral fine sand subsoil. Below 24 to 40 inches the material is brownish gray calcareous fine sand. (Udorthentic Haploborolls)
- Markey—Very dark brown, very poorly drained, mildly alkaline, herbaceous peat 16 to 50 inches thick, over gray, mildly alkaline sand or loamy sand. (Terric Medisaprists)
- Marquette—Light-colored, somewhat excessively drained, neutral loamy sand to gravelly loamy sand, over brownish, mildly to moderately alkaline gravelly sandy loam, grading at 8 to 24 inches to gravelly coarse sand on beach ridges and outwash plains. (Psammentic Eutroboralfs)
- Mavie—Dark-colored, poorly drained, mildly alkaline loam 7 to 16 inches thick, over brownish calcareous gravelly loamy sand to gravelly coarse sand. At 20 to 40 inches these layers are underlain by olive gray calcareous loamy glacial till or silt loam to silty clay loam lacustrine sediments. (Typic Calciaquolls)
- McIntosh—Dark-colored, moderately well to somewhat poorly drained, moderately alkaline silt loam, over olive brown, calcareous silt loam. At 20 to 40 inches the material is light olive brown, calcareous loamy glacial till. (Aeric Calciaquolls)
- Meehan—Light-colored, somewhat poorly drained loamy sand, over brownish loamy sand to sand subsoil, over brown sand. The soil ranges from slightly to strongly acid. (Aquic Udipsamments)
- Menahga—Light-colored, excessively drained, medium acid loamy sand to fine sand about 33 inches thick, over brownish yellow, slightly acid to neutral loose sand. (Typic Udipsamments)
- Mooselake—Dark reddish brown, very poorly drained, medium acid, moderately decomposed peat, mostly of wood origin, and more than 51 inches thick. (Euic Typic Borohemists)
- Nebish—Light-colored, well-drained, slightly acid loam to fine sandy loam, over dark yellowish brown, medium acid clay loam subsoil. Below 20 to 28 inches the material is olive brown calcareous loamy glacial till. (Typic Eutroboralfs)
- Newson—Dark-colored poorly and very poorly drained loamy sand about 6 inches thick, over dark grayish brown loamy sand subsoil 20 to 30 inches thick over brownish, outwash sand. The soil is strongly to very strongly acid. (Humaqueptic Psamments)
- Quam—Dark-colored, very poorly drained, neutral water sorted silty clay loam 30 to 50 inches thick, over olive gray calcareous loamy glacial till. The surface 10 inches may be mucky. (Cumulic Haplaquolls)
- Redby—Light-colored, somewhat poorly drained, slightly acid loamy fine sand and fine sand, over brown slightly acid fine sand. At about 36 inches the sediments are brownish gray, neutral to mildly alkaline, lacustrine or deltaic fine sand. (Aquic Udipsamments)
- Rockwell—Dark-colored poorly to very poorly drained sandy clay loam to loam, over dark gray fine sandy loam grading to fine sand. Below 20 to 40 inches the material is olive gray, loamy glacial till or silt loam lacustrine sediments. The soil is calcareous throughout. (Typic Calciaquolls)
- Rockwood—Light-colored, well-drained, medium acid sandy loam 12 to 18 inches thick, over dark brown, medium acid sandy clay loam having a weak fragipan. Below 24 to 36 inches the soil materials are olive brown, calcareous sandy loam glacial till. (Typic Fragiboralfs)
- Roliss—Dark-colored, poorly and very poorly drained, mildly alkaline loam, over olive gray, mildly alkaline loam subsoil, grading at 12 to 20 inches to grayish brown, calcareous loamy glacial till. (Typic Haplaquolls)
- Seelyville—Dark-colored, very poorly drained, medium acid to neutral muck about 16 inches thick, over very dark brown, medium acid to neutral peat to depths of 51 inches or more. The fibers are mostly derived from herbaceous plants. (Euic Typic Borosaprists)
- Shooker—Light-colored, poorly drained, medium acid loam or silt loam, over grayish brown, medium acid sandy clay loam overlying, at 28 to 40 inches, the calcareous loamy glacial till. (Aeric Ochraqualfs)
- Sioux—Dark-colored, excessively drained, mildly alkaline loam to sandy loam, over brownish calcareous gravelly sandy loam, over brownish gray, calcareous gravelly sand at 6 to 14 inches. These soils occur on beach ridges and outwash plains. (Udorthentic Haploborolls)
- Sletten—Dark-colored, very poorly drained, calcareous silt loam to silty clay loam over dark gray, calcareous silt loam to silty clay loam subsoil. This grades at 25 to 40 inches to grayish brown, calcareous silt loam to silty clay loam lacustrine sediments. The upper 10 inches may be mucky. (Typic Calciaquolls)
- Spooner—Light-colored, poorly to somewhat poorly drained, neutral silt loam about 22 inches thick over calcareous lacustrine silt loam. (Typic Ochraqualfs)
- Svea—Dark-colored, moderately well drained, neutral loam, over grayish brown, neutral loam. The material at about 21 inches is yellowish brown, calcareous loamy glacial till. (Pachic Udic Haploborolls)
- Sverdrup—Dark-colored, somewhat excessively drained, neutral sandy loam, over brown, neutral sandy loam subsoil grading into loamy sand. Below 24 to 30 inches is pale brown calcareous loose sand. (Udic Haploborolls)
- Taylor—Light-colored, moderately well and well-drained, slightly acid loam over slightly acid silty



Horizontal beds in this Sioux profile indicate the gravels were deposited by running water.

clay to clay subsoil, over calcareous lacustrine clay at about 22 inches. (Aquic Eutroboralfs)

Todd—Light-colored, somewhat excessively drained, medium acid sandy loam, over dark brown, slightly acid sandy loam to sandy clay loam subsoil, over brown, calcareous very gravelly coarse outwash sand below 18 to 30 inches. (Typic Eutroboralfs)

Towner—Dark-colored, moderately well-drained, neutral sandy loam 16 to 24 inches thick over neutral yellowish brown loamy sand. This is over yellowish brown, calcareous clay loam to loam glacial till at 25 to 36 inches. (Pachic Udic Haploborolls)

Ulen—Dark-colored, somewhat poorly and moderately well-drained loamy fine sand 10 to 20 inches thick, over grayish brown loamy fine sand. At about 32 inches is yellowish fine sand of glacio-lacustrine origin. These soils are calcareous throughout. (Aeric Calciaquolls)

Urness—Dark-colored, calcareous, mucky silt loam 30 to 80 inches, over black calcareous silt loam to silty clay loam. (Mollic Fluvaquents)

Vallers—Dark-colored, poorly drained, calcareous silty clay loam, over grayish strongly calcareous clay loam grading at about 24 inches to olive gray, loamy, calcareous glacial till. (Typic Calciaquolls)

Viking—Dark-colored, poorly drained, mildly alkaline clay, over olive gray, mildly alkaline clay subsoil. Below 20 to 30 inches the substratum is calcareous, olive gray, lacustrine clay. (Typic Haplaquolls)

Wabanica—Light-colored, poorly and very poorly drained, mildly alkaline silty clay, over olive gray, calcareous lacustrine clay. (Typic Haplaquepts)

Wahpeton—Dark-colored, moderately well-drained, mildly alkaline silty clay 24 to 60 inches thick. The soil commonly has one or more buried surface horizon sandwiched between dark gray silty clay layers. (Udertic Haploborolls)

Warba—Light-colored, moderately well-drained, medium to slightly acid loam, over yellowish brown, medium acid, heavy clay loam. Below about 40 inches the material is grayish brown neutral clay loam glacial till which becomes calcareous at about 54 inches. (Glossic Eutroboralfs)

Waukon—Moderately dark-colored, well-drained, neutral loam, over brownish, neutral clay loam. Underlying at 20 to 32 inches is olive brown, calcareous loam glacial till. (Mollic Eutroboralfs)

Wheatville—Dark-colored, somewhat poorly and moderately well-drained, mildly alkaline loam to silt loam over brownish, calcareous very fine sandy loam. At 20 to 40 inches is grayish brown, calcareous, lacustrine silty clay or clay. (Aeric Calciaquolls)

Wildwood—Dark-colored, very poorly drained, slightly acid peat or muck up to 12 inches thick, over dark gray, neutral to slightly acid silty clay or clay. (Histic Humaquepts)

Winger—Dark-colored, somewhat poorly to poorly drained light silty clay loam to silt loam, over olive gray silt loam, over olive gray loamy glacial till at 24 to 40 inches. (Typic Calciaquolls)

Appendix B

Percent of area within counties, or parts of counties, in the Bemidji Sheet having detailed soil surveys as of July 1, 1979.

| | |
|-------------|-----|
| Becker | 19 |
| Beltrami | 5 |
| Cass | 3 |
| Clay | 100 |
| Clearwater | 4 |
| Hubbard | 2 |
| Itasca | 90 |
| Koochiching | 7 |
| Mahnomen | 8 |
| Norman | 100 |
| Pennington | 90 |
| Polk | 13 |
| Red Lake | 9 |

Glossary

Aquifers—Underground water bearing sand and gravel strata.

Calcareous—Material having a high percentage of lime carbonate.

Cretaceous—Shale deposits underlying the glacial drift.

Delta—Material deposited by streams entering a lake from the land.

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

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

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

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

Ice contact—Outwash material laid down where one side was fixed by presence of glacial ice.

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

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

Lacustrine—Deposits formed on the bottom of lakes.

Limy—See calcareous.

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

Moraine—Unconsolidated rock and mineral debris deposited by glacial ice. It commonly consists of a

heterogeneous mass of unsorted material, but that deposited by glacial melt water is sorted. See also ground moraine and terminal moraine.

Natural Drainage—The conditions that existed during the development of the soil, as opposed to altered drainage which is commonly the result of artificial drainage or irrigation, but may be caused by the sudden deepening of channels or the blocking of drainage outlets. Six classes of natural drainage are recognized in this report. Excessively drained soils are commonly very porous and rapidly permeable (sandy and gravelly) and have a low moisture-storage capacity. Well-drained soils are nearly free from mottling and are commonly of intermediate texture.

Moderately well-drained soils commonly have a moderately to 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, but the subsoil is uniformly grayish. Very poorly drained soils are wet nearly all the time. They have a dark gray or black surface layer and are gray or light gray, with or without mottling in the rooting zone below the surface soil.

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

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

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

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

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

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

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

Slickensides—Polished and grooved surfaces produced by one mass sliding past another. Common in swell-

ing clays that have marked changes in moisture content.

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

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

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

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

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

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

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

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

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

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

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

Till plain—See ground moraine.

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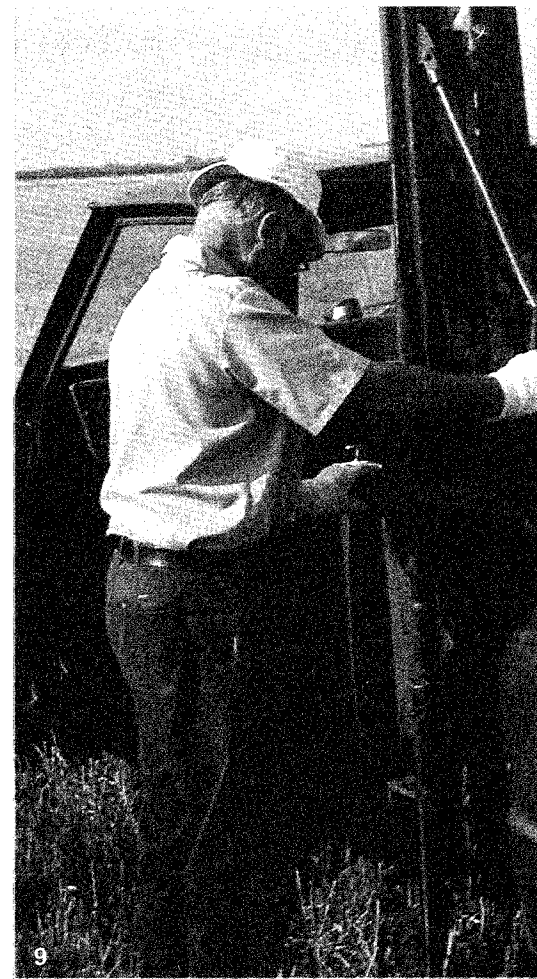
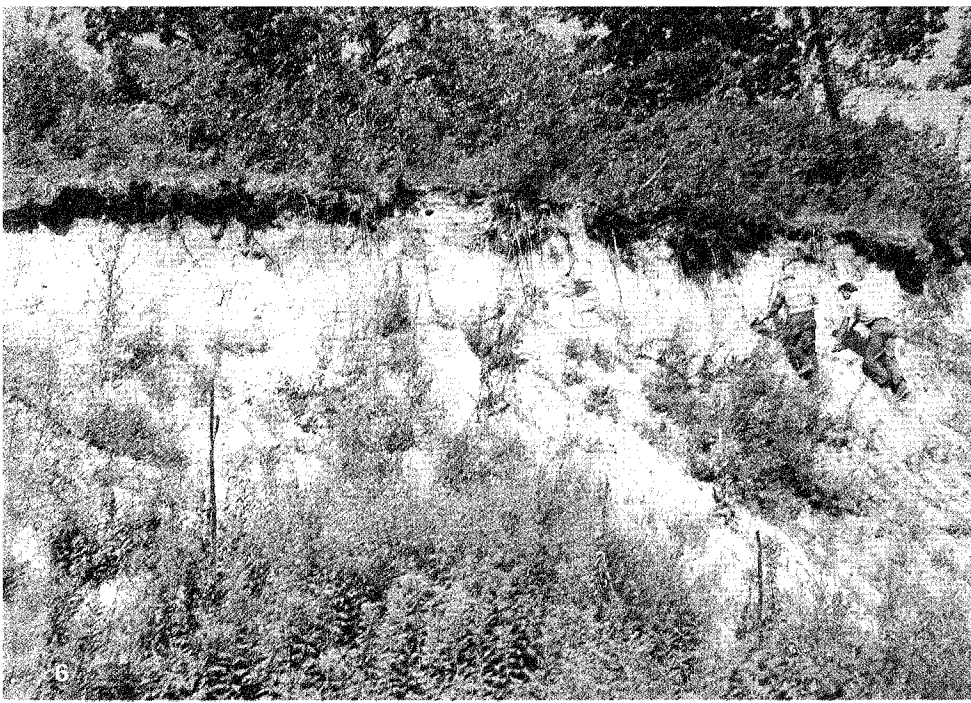
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6. Calcareous loamy till deposited by the Des Moines lobe is the dominant surface material of the Fergus Falls Till Plain (2), the Fosston Till Plain (2A), and the Alexandria Moraine Complex (3). 7. Light-colored materials are often exposed when soil landscape unit LLWL is cleared of forest vegetation and plowed for agriculture. 8. Black spruce and tamarack are the most common tree species on forested peat bogs in the Agassiz Lacustrine Plain, Red Lake Area (1D). 9. Operating a hydraulic probe to obtain an undisturbed core which is used by the soil scientist to classify and map the soil. 10. A core sample showing varves of clay, silt, and very fine sand at depths of 5 to 7 feet in the Agassiz Lacustrine Plain, Red River Valley Area (1).

