United States
Environmental Protection
Agency

Region 5
230 South Dearborn Street
Chicago, Illinois 60604

Water

EPA

Environmental Impact Statement

Draft Appendices

Moose Lake-Windemere Sanitary District Wastewater Treatment System Pine and Carlton Counties, Minnesota

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APPENDICES

DRAFT ENVIRONMENTAL IMPACT STATEMENT

on the

PROPOSED WASTEWATER TREATMENT SYSTEM

for the

MOOSE LAKE-WINDEMERE SANITARY DISTRICT

PINE and CARLTON COUNTIES, MINNESOTA

Prepared by the

United States Environmental Protection Agency

Region V

Chicago, Illinois

and

WAPORA, Inc.

Chicago, Illinois

March 1983

LIST OF APPENDICES

Appendix A

A-1. The Notice of Intent (NOI)

APPENDIX A NOTICE OF INTENT

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
REGION V
230 SOUTH DEARBORN ST.
CHICAGO, ILLINOIS 60604

REPLY TO ATTENTION OF:
5WEE/EIS

JUL 11 1980

NOTICE OF INTENT

TO ALL INTERESTED GOVERNMENT AGENCIES, PUBLIC GROUPS AND CITIZENS:

In accordance with the procedures for the preparation of Environmental Impact Statements, an Environmental Review has been performed on the proposed action described below.

Name of Applicant: Moose Lake-Windemere Sanitary Sewer District Moose Lake, Minnesota

Planning Area: The Facilities Planning area, as recommended by the Minnesota Pollution Control Agency (MPCA), includes the Moose Lake-Windemere Sanitary Sewer District and the City of Burnum including the Northern Pacific Railroad and the corridor between the Cities of Moose Lake and Burnum, (see attached map). The planning area encompasses approximately 60 square miles. The majority of the District lies in central northern Pine County, but the majority of the District's year round population resides in central southern Carlton County, Minnesota. The City of Moose Lake is the largest incorporated area of the District having a 1970 population of 1452. In addition to the City of Moose Lake, the Moose Lake-Windemere Sanitary Sewer District also serves Windemere Township in Pine County and Moose Lake Township in Carlton County.

Proposed Action: The District has prepared, with grant assistance from this Agency, a facilities plan which was completed in March 1980. The selected alternative of the facilities plan proposes to construct collection sewers around Island and Sturgeon Lakes, construct interceptor sewers and pump stations to bring Island and Sturgeon Lakes in the system, modify existing interceptors, infiltration/inflow correction in the Moose Lake sewer system, rebuild or construct a new pump station, construct a storm water overflow pond and modify the existing wastewater treatment facility located in the City of Moose Lake.

State and Federal agency review of the above proposed project identified the possibility of significant environmental impacts involving the following issues.

A. Impact on Water Quality

There was no documentation supporting the need to sewer around Island and Sturgeon Lakes except that there appears to be public opinion that the increased degradation of these lakes is caused by failing or poorly designed on-site treatment systems.

B. Socioeconomic Impact

The substantial local costs will probably have a significant impact on the service area families, particularly those on fixed or lower incomes in the Island and Sturgeon Lakes area, encouraging or forcing them to sell their property and thus accelerating changes in occupancy patterns. As presented in the March 28, 1980 public hearing, the cost of repairs to the existing sewer system and construction of new interceptors would cost all homes in Sewer District $8.40 a month. Additionally the cost of the collection system around Island and Strugeon Lakes would cost those residents another $22.40 per month assuming a $3,000.00 assessment and a 50% grant from Farmers Home Administration, along with low interest long-term loans.

C. Secondary Impact and Induced Growth

The probable development and land use change induced by the project, and its effect on the demand for future services, must be assessed.

Consequently, this Agency has determined that the preparation of an Environmental Impact Statement (EIS) on the above project is warranted.

If you or your organization need additional information, want to be placed on the mailing list, and/or wish to participate in the preparation of the Draft EIS for the Moose Lake-Windemere Sanitary Sewer District, please contact the EIS Section, (5WEE) at the letterhead address.

Sincerely yours,

John McGuire
Regional Administrator

Attachment

Appendix B

B-1. Soils Survey of a Portion of Windemere Township, Pine County, Minnesota.

B-2. Soil Map Plates.

B-3. Soils Testing Data.

B-4. Summary and interpretation of soils information.

APPENDIX B Soils information.

Appendix B-1.

SOIL SURVEY OF PART OF WINDEMERE TOWNSHIP, PINE COUNTY, MINNESOTA

BY

Harlan R. Finney
Professional Soil Scientist

1828 Draper Drive
St. Paul, Minnesota 55113

November, 1981

Contents

ABSTRACT

A soil survey of about 7,000 acres of land in Windemere Township, Pine County, Minnesota was conducted 14 September to 6 November 1981. The survey area comprises lands surrounding Island, Passenger, Rush, and Sturgeon Lakes. A soil survey consists of the following parts: (1) identification and classification of soils of the area, (2) a map showing the location of the different kinds of soil, and (3) interpretations about the response of the different kinds of soil to use and management.

Ten major kinds of soil were identified and classified on the basis of properties in the upper 60 inches of soil. These comprise 3 that formed in loamy glacial till, 3 that formed in sandy glacial outwash, 1 that formed in a mantle of glacial outwash and underlying glacial till, organic soils, alluvial soils and soils on lake beaches.

The 3 kinds of soil that formed in till and the 3 kinds that formed in outwash are distinguished one from another in the basis of properties associated with degree of wetness. Soils that formed in till are the well and moderately well drained Duluth series, the somewhat poorly and poorly drained Dusler series, and the very poorly drained Blackhoof series. Soils that formed in glacial outwash are the somewhat excessively drained Omega series, the somewhat poorly drained Nemadji series, and the poorly and very poorly drained Newson series. Three phases of both the Duluth and Omega series are recognized on the basis of slope.

The three dominant soils in the survey area are the Duluth and Omega series and organic soils. The Duluth series and its wetter associates are on most all land adjacent to Island Lake and on land adjacent the northern and eastern parts of Sturgeon Lake. The Omega series and its wetter associates are dominant on land adjacent to Passenger and Rush Lakes and on land adjacent to the southern and southwestern parts of Sturgeon Lake. Organic soils are in small to large areas throughout the survey area, but the largest single area of such soils begins not too far from the central part of the west shore of Sturgeon Lake.

The National Cooperative Soil Survey has rated the soils in regards to limitations for conventional septic tank absorption fields among other uses. The ratings are slight, moderate, and severe. The Duluth, Dusler, and Blackhoof series are rated as severe because of low rates of percolation or the presence of a seasonal high water table or both. The Omega, Nemadji, and Newson series likewise are rated as severe because of being a poor filter of sewage effluent or for having a seasonal high water table or both. Organic soils are rated as severe because of a seasonal high water table.

DESCRIPTION OF SOILS

Important features of taxonomic and map units are described here. Taxonomic units are the basic kinds of soil that were identified in the survey area, whereas map units are bodies of soil that are delineated on the maps.

The following items are described.

Taxonomic Units

- Landscape setting and some interpretations
- Associated soils
- Seasonal high water
- Description of a representative pedon
- Range in characteristics

Map Units

- Setting
- Inclusions

The permeability class for each taxonomic unit is given in the first paragraph. This class is based on the most restrictive horizon within a depth of 60 inches. Estimates of the permeability of each horizon are in the detailed pedon description. Rates and class names follow:

Inches/hour	Class name
<0.06	very slow
0.06- 0.20	slow
0.20- 0.60	moderately slow
0.60- 2.00	moderate
2.00- 6.00	moderately rapid
6.00-20.00	rapid

The pattern of soils in most of the survey area is very complex. Thus, even at the rather large map scale of this survey, small area of different kinds of soil are included in many of the delineations of each map unit.

Soils in this survey area were identified and mapped on the basis of properties of the upper 60 inches of the soil. Statements here, thus, only refer to the nature of the soil from the surface to a depth of 60 inches.

If the meaning of some terms used in this report is not known, refer to the glossary of a modern soil survey report, for example, Carlton County, Minnesota.

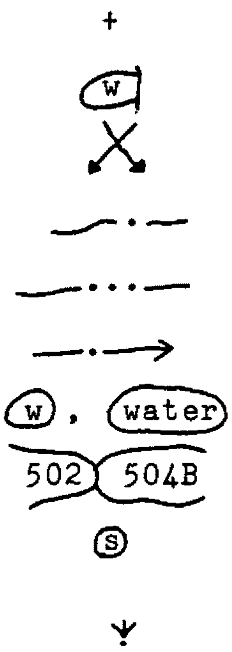
An identification legend with the map units arranged numerically by map symbol is attached to the soil map. An identification legend with the map units arranged alphabetically follows.

Identification Legend

Map Units

Map Symbol	Name
1002	Alluvial soils
1016	Altered soils
614	Blackhoof muck
504B	Duluth loan, 1 to 4 percent slopes
504C	Duluth loam, 4 to 15 percent slopes
504E	Duluth loam, 15 to 60 percent slopes
1350B	Duluth variant loamy fine sand, 1 to 4 percent slopes
1350C	Duluth variant loamy fine sand, 4 to 15 percent slopes
502	Dusler loam
1032	Lake beaches
995	Organic soils
186	Nemadji loamy sand
274	Newson mucky sandy loam
188B	Omega loamy sand, 0to 5 percent slopes
188C	Omega loamy sand, 5 to 20 percent slopes
188E	Omega loamy sand, 20 to 60 percent slopes

Conventional and Special Features



- Section corners
- Dams and associated reservior
- Gravel and sand pits
- Perennial drainage way
- Intermittent drainage way
- End of drainage way
- Unnamed lakes and ponds
- Soil delineations and map unit symbols
- Soil sample site
- Small area, 1/8 to 1/2 acre, of poorly drained or wetter soils in delineations of better drained soils

Taxonomic and Mapping Units

Alluvial Soils

Alluvial soils consist of poorly to moderately well drained sandy and loamy soils that formed in alluvium on flood plains. They have moderately slow to rapid permeability. These soils typically are flooded one or more times each year.

Alluvial soils are primarily associated with soils of the Duluth and Omega series, which are on bluffs adjacent to the flood plains. The Duluth series formed in glacial till and Omega soils formed in glacial outwash. Organic soils are associated with Alluvial soils in a few places. No description of a pedon of Alluvial soils is given because of their limited extent, great variability, and insignificance to the purpose of this soil survey.

1002 Alluvial soils, mixed. This map unit has linear slopes with gradient of less than 1 percent on flood plains, delineations of this unit primarily are elongate in shape and are about 2 to 20 acres in size. Areas of these soils are in pasture or forest.

Small areas of organic soils are included in some delineations of this map unit.

Altered Soils

Areas where the soils have been altered by cutting and filling are the basic components of this unit. Most areas are on glacial moraines. Thus, most areas resulting from cutting consist of loamy material as in the B and C horizons of soils such as Duluth. Further, most areas resulting from filling consist of similar material. The internal drainage of these soils mostly ranges from somewhat poor to moderately well drained. Permeability is mostly slow.

1016 Altered soils. Only one map unit of altered soils is used in this survey. Areas of altered soils along roads, highways, and around houses and cabins are not included in this map unit. Instead they are considered as normal inclusions in other appropriate units where delineations of them include such cultural features. This map unit of altered soils consists mostly of discrete, cut and filled areas away from those cultural features except in on place where extensive cutting and filling has occurred along a county highway.

Blackhoof Series

The Blackhoof series consists of nearly level, very poorly drained, slowly and very slowly permeable soils that formed in a thin mantle of organic soil material and in underlying loamy glacial till or old local aluvium or both. These soils have concave and linear slopes and are in depressions and drainage ways on glacial moraines.

The Blackhoof series primarily is associated with the Dusler and Duluth series and organic soils. This series is wetter and has colors of low chroma to greater depth than the Dusler and Duluth series. This series has a thinner mantle of organic soil material than Organic soils.

The seasonal high water table in the Blackhoof series commonly begins within one foot of the surface throughout most of the year. Water is on the surface in most of the spring and autumn months.

A description of a representative pedon (S-81-MN-58-9-samples 1 to 5) of the Blackhoof series in the mapping unit of Blackhoof muck (map symbol 614) which is located in the upper part of a drainage way about 530 feet east and 370 feet south of the northwest corner of the southwest ¼ of section 10, R. 19 W.,T. 45 N. is in the following paragraphs. This pedon was described and sampled 5 November 1981. It is located in a thicket of alder with a ground cover of grasses and sedges. A delineation of Duluth loam, 4 to 15 percent slopes is adjacent to this delineation of Blackhoof muck. The water table was at the surface.

Oa--8 to 0 inches; black (10YR 2/1) broken face and rubbed, sapric material (muck); moderate very fine and fine granular structure; very friable, slightly sticky; many very fine and fine and few medium and coarse roots; pH 5.0; moderate permeability; clear smooth boundary.

A11(A1)* --0 to 5 inches; black (N 2/0) mucky silt loam; moderate very fine and fine granular structure; very friable, slightly sticky; common very fine and fine roots; pH 5.0; moderate permeability; abrupt smooth boundary.

A12(A2)-- 5 to 8 inches; black (10YR 2/1) silt loam; massive; firm, slightly sticky; few very fine roots; pH 5.0; slow permeability; abrupt smooth boundary.

*Recently revised designations for horizons are given in this part of descriptions if they differ from former designations.

B21g(Bgw1)--8 to 25 inches; dark gray (5Y 4/1) silty clay loam; many medium and large olive brown (2.5Y 4/4) mottles throughout and common fine prominent dark brown (7.5YR 4/4) mottles mostly in the lower part; massive; very firm, slightly sticky; pH 7.0; very slow permeability; diffuse smooth boundary.

B22g(Bgw2)-- 25 to 48 inches; gray (5Y 5/1) silt loam near loam; many fine distinct light olive brown (2.5Y 5/4), common medium distinct greenish gray (5G 5/1) and few fine prominent yellowish red (5YR 4/6) mottles; massive; firm, slightly sticky; pH 7.5; slow permeability.

The O horizon ranges from 4 to 16 inches in thickness. The A horizon is 3 to 9 inches thick, and is loam, silt loam, clay loam, or silty clay loam. The B horizon is silt loam, loam, silty clay loam, or clay loam.

614 Blackhoof muck. This map unit is in depressions and drainageways on glacial moraines. It has concave and linear slopes with gradient 0 to 1 percent. Delineations of this soil which encompass drainageways commonly are narrow and enlongated in shape and mostly range from 2 to 10 acres in size. Delineations in depression commonly are circular in shape and mostly range from 2 to 8 acres in size. Most areas of these soils are in pasture or forest.

Soils included in delineations of this map unit have similar interpretations. Common included soils are Organic soils, and soils that are similar to the Blackhoof series except that they lack the layer of organic soil material. Also, a few included soils are sandy in some to all parts of the A horizon and B horizon. Further, small areas of Newson soils are included in a few delineations.

Duluth Series

The Duluth series consists of gently undulating to very steep, moderately well and well drained, moderately slow and slowly permeable soils that formed mostly in loamy calcareous glacial till on glacial moraines. They mostly have convex slopes, but they have linear or concave slopes on the lower parts of some steep and very steep slopes.

The Duluth series is primarily associated with the Blackhoof and Dusler series, and Organic soils. The Duluth series lacks a seasonal high water table within depths of 5 feet, whereas these associated soils have a seasonal high water table beginning at depths of 4 feet or less. Also, the Duluth series lacks mottles in the B horizon, whereas the Blackhoof and Dusler series have mottles in the B horizon. The Duluth series is similar to Duluth variant. The Duluth series formed either entirely in till or in a thin mantle of outwash and in underlying till, whereas the Duluth variant formed in a mantle of sandy outwash that is 20 to 40 inches in thickness and in underlying till.

The Duluth series typically lacks a seasonal high water table within depths of 5 feet. However, some soils of the Duluth series are saturated in some horizons for short periods of time during periods of above normal rainfall.

Since the Duluth series is the dominant soil in the area, descriptions of two pedons are presented. The first (S-81-MN-58-8-samples 1 to 7) is in a delineation of Duluth loam, 1 to 4 percent slopes (map symbol 504B), located about 800 feet east and 1,050 feet south of the northwest corner of the southwest ¼, section 10, R. 19 W., T. 45 N. It has a convex slope of about 2 percent and is about 100 feet from the boundary of a delineation of Duluth loam, 15 to 60 percent slopes (map symbol 504E) on the bluffs adjacent to Sturgeon Lake. It is in an old meadow field. It was described and sampled 5 November 1981. It was very moist in the upper 30 inches and moist below.

Ap--0 to 6 inches; dark brown (7.5YR 3/2) loam; moderate fine and medium granular structure; friable; many very fine and fine roots; about 2 percent coarse fragments; pH 6.5; moderate permeability; abrupt smooth boundary.

A2(E)--6 to 10 inches; brown (7.5YR 5/2) loam; massive in some parts and weak thick platy structure in other parts; firm, fractures abruptly under pressure; common very fine and fine roots; about 2 percent coarse fragments; pH 6.5; slow permeability; abrupt wavy boundary.

B&A(B/E)--10 to 13 inches; B part comprising about 85 percent is reddish brown (2.5YR 4/4) clay loam; A part comprising about 15 percent as tongues and interfingers is brown (7.5YR 5/2) loam; weak fine and medium prismatic structure parting to moderate fine and medium subangular blocky; very firm, slightly sticky; few thin clay films on faces of secondary peds; few very fine and fine roots mostly on faces of peds; about 2 percent coarse fragments; pH 5.0; moderately slow permeability; clear smooth boundary.

B21t(Bt1)--13 to 22 inches; reddish brown (2.5YR 4/4) clay loam; weak fine and medium prismatic structure parting to moderate fine and medium angular blocky; firm, sticky; common thin and medium clay films on faces of peds; common thin coatings of A2 material on faces of prisms; few fine roots; about 2 percent coarse fragments; pH 4.5; moderately slow permeability; diffuse smooth boundary.

B22t(Bt2)--22 to 36 inches; reddish brown (2.5YR 4/4) loam near clay loam; moderate fine angular blocky structure; firm, sticky; common thin clay films on faces of peds; few fine and medium roots; about 2 percent coarse fragment; pH4.5; moderately slow permeability; diffuse smooth boundary.

B3t(BCt)--36 to 64 inches; reddish brown (2.5YR 4/4) loam; moderate fine angular blocky structure; firm, slightly sticky; few thin clay films on faces of peds; few thin black coatings on faces of peds; few very fine roots; about 2 percent coarse fragments; pH 7.5; moderately slow permeability; clear smooth boundary.

C--64 to 76 inches; reddish brown (5YR 4/3) loam; weak thin to thick platy structure; firm, slightly sticky; common very fine and fine masses of $CaCO_3$; about 2 percent coarse fragments; pH 7.8; slow permeability.

The second pedon (S-81-MN-58-10-samples 1 to 6) is in a delineation of Duluth loam, 4 to 15 percent slopes (map symbol 504C) located about 330 feet east and 460 feet south of the northwest corner of section 3, R. 19., T. 45 N. It has a convex slope of about 8 percent. It is about 200 feet from the boundary of a delineation of Duluth loam, 15 to 60 percent slopes (map symbol 504E) on the bluffs adjacent to Island Lake. It is under a plantation of white spruce. It was described and sampled 5 November 1981. It was very moist in the upper 36 inches, and slightly moist below.

Ap--0 to 6 inches; dark brown (7.5YR 3/2) to brown (7.5 YR 4/2) loam; moderate medium granular structure; friable; common very fine and fine and few medium and coarse roots; about 2 percent coarse fragments; pH 6.5; moderate permeability; abrupt smooth boundary.

B&A(B/E)--6 to 9 inches; B part comprising about 85 percent is reddish brown (2.5YR 4/4) clay loam; A part comprising about 15 percent as tongues and interfingers is reddish brown (5YR 5/3) sandy loam; moderate fine and medium prismatic structure parting to moderate fine and medium subangular blocky; firm, slightly sticky; few thin clay films on faces of secondary peds; common fine and medium roots mostly on faces of peds; about 2 percent coarse fragments; pH 6.0; moderately slow permeability; clear wavy boundary.

B21t(Bt1)--9 to 18 inches; reddish brown (2.5YR 4/4) clay loam; moderate medium prismatic structure parting to moderate fine and medium angular blocky; firm, slightly sticky; many thin and medium clay films on faces of peds; few thin coatings of A2 material on faces of peds; few fine and medium roots; about 2 percent coarse fragments; pH 5.5; moderately slow permeability; gradual smooth boundary.

B22t(Bt2)--18 to 38 inches; reddish brown (5YR 4/4) light clay loam; moderate medium and coarse angular blocky structure parting to moderate very fine angular blocky; firm slightly sticky; common thin clay films on faces of peds; about 2 percent coarse fragments; pH 5.5; moderately slow permeability; diffuse smooth boundary.

B3(BC)--38 to 60 inches; reddish brown (2.5YR 4/4) loam; weak very fine angular blocky structure; firm, slightly sticky; few thin clay films on faces of peds; few thin black coatings on faces of peds; few fine roots; about 2 percent coarse fragments; pH 7.5; moderately slow permeability; sampled at depths of 38 to 49 and 49 to 60 inches.

The thickness of solum and depth to free carbonates ranges from 40 to 80 inches. The content of coarse fragments ranges from 1 to 8 percent. The A horizon is fine sandy loam, sandy loam, loam, or silt loam. The B horizon has hue of 2.5YR or 5YR and has 18 to 35 percent clay. It is loam or clay loam. The C horizon is loam or clay loam and has weak platy or angular blocky structure.

<u>504B Duluth loam, 1 to 4 percent slopes.</u> This map unit mostly has convex slopes and is on glacial moraines. Delineations of this map unit are variable in size and shape. They range from as small as one acre to as large as 100 acres in size. In some places they are circular and other places elongated. This map unit commonly is on the higher parts of the landscape. Most areas of these soils are in pasture and forest, but significant areas of them are used as sites for homes or cabins. Duluth soils in this map unit commonly have thicker sola than they do in the other two map units.

Small areas of Blackhoof and Dusler series are included in some delineations of this map unit. Most areas of these kinds of included soils are indicated by the symbol for wet spots and drainage ways. Small areas of the Duluth variant and soils similar to Duluth soils except for having sandy A horizons, also, are included in some delineations of this map unit. Further, soils that are similar to the Duluth series except for having more clay in the B horizon or C horizon or both are included in a few delineations of this map unit. Small areas with slopes steeper than 4 percent are included in a few places.

<u>504C Duluth loam, 4 to 15 percent slopes.</u> This map unit mostly has convex and linear slopes on glacial moraines. Linear slopes primarily are on the lower lying parts of delineations of this map unit. Delineations primarily are rather narrow and elongated, and commonly range from 2 to 20 acres in size. They primarily are on slopes adjacent to lower lying wetter soils. Most areas of these soils are in forest or pasture, but significant areas of them are used as sites for cabins and homes. Duluth soils in this map unit commonly have sola that are intermediate in the range of thickness.

Small areas of Blackhoof and Dusler series are included in a few delineations of this map unit. Most of these inclusions are indicated by the symbol for wet spots and drainage ways. Small areas of Duluth variant and soils similar to Duluth except for having sandy A horizons and upper B horizons or only sandy A horizons are included in a few delineations. Further, soils that are similar to the Duluth series except for having more clay in the B horizon or C horizon or both are included in a few delineations of this map unit. Small areas with slopes of less than 4 percent and more than 15 percent are included in a few places.

504E Duluth loam, 15 to 60 percent slopes. This map unit has convex, linear, and concave slopes. Linear and concave slopes are on the lower lying parts of delineations of this map unit. Delineations primarily are rather narrow and elongated and commonly range from 5 to 50 acres in size. This map unit primarily is on bluffs adjacent to Island and Sturgeon Lakes. Most areas of these soils are in forest, but a few are in pasture. Duluth soils in this map unit commonly have the shallower range in thickness of sola.

A few small areas of wetter soils are included in a few delineations of this unit. Such soils are mostly in drainage ways. Small areas of the Duluth variant and soils similar to the Duluth series except for having sandy A horizons and upper B horizons or sandy A horizons only are included in a few delineations. Further, soils that are similar to the Duluth series except for having more clay in the B horizon or C horizon or both are included in a few delineations. Small areas with slopes of less than 15 percent and more than 60 percent are included in a few places.

Duluth Variant

The Duluth variant soils consist of gently sloping and sloping, moderately well and well drained, moderately slow and slowly permeable soils that formed in a 20 to 40-inch thick mantle of sandy outwash and in underlying loamy calcareous glacial till on glacial moraines. These soils mostly have convex and linear slopes.

Soils here identified as Duluth variant have not yet been recognized as a named soil series by the Cooperative Soil Survey of Minnesota. They have unique properties and are significant enough in extent to recognize as a discrete kind of soil in this survey. They primarily occur in a transition zone between soils such as the Duluth series which formed in till in the eastern part of the survey area and soils such as the Omega series which formed in outwash in the western part of the survey area. Duluth variant soils have sandy horizons extending from the surface to depths of 20 to 40 inches, whereas the Duluth series formed in glacial till and has loamy upper horizons. Duluth variant soils have loamy B horizons beginning within depths of 20 to 40 inches, whereas the Omega series formed in glacial outwash and is sandy throughout.

The Duluth variant soils typically lack a seasonal high water table within depths of 5 feet. However, some of the Duluth variant soils are saturated in the lower part of the sandy mantle or in the upper part of the soil in glacial till for short periods of time during periods of above normal rainfall.

A description of a representative pedon (S-81-MN-58-2-samples 1 to 7) in a large delineation of the mapping unit Duluth variant loamy fine sand, 1 to 4 percent slopes (map symbol 1350B) which is located near the summit of a knoll with a convex slope of 2 percent on a glacial moraine about 2,440 feet west and 2,380 feet south of the northeast corner of section 17, R. 19 W., T. 45 N. is in the following paragraph. The delineation with this pedon primarily is bounded by Omega soils to the west and Duluth and Dusler soils to the east. It is in an old field on the Y.M.C.A. property. This pedon was described and sampled 3 November 1981. It was moist throughout.

Ap--0 to 9 inches; dark brown (7.5YR 3/2) loamy fine sand; weak fine and medium granular structure; very friable, non-sticky; many very fine and fine roots; pH 6.5; rapid permeability; abrupt smooth boundary.

B21(Bw1)--9 to 20 inches; dark reddish brown (5YR 3/4) loamy fine sand; weak fine subangular blocky structure; very friable; common very fine and fine roots; pH 6.0; rapid permeability; clear smooth boundary.

B22(Bw2)--20 to 25 inches; dark reddish brown (5YR 3/4) loamy sand; massive; very friable; common very fine and fine roots; about 5 percent gravel; pH 6.0; rapid permeability; abrupt smooth boundary.

11B&A(2B/E)--25 to 31 inches; B part comprising about 85 percent is yellowish red (5YR 4/6) clay loam; A part comprising about 15 percent as tongues and interfingers is reddish brown (5YR 5/3) sandy loam and loamy sand; weak fine and medium prismatic structure parting to moderate medium subangular blocky; firm; few fine roots on faces of peds; about 2 percent coarse fragments; pH 5.5; moderately slow permeability; gradual smooth boundary.

11B21t(2Bt1)--31 to 41 inches; reddish brown (2.5YR 4/4) clay loam; few fine distinct yellowish red (5YR 5/6) mottles; weak medium prismatic structure parting to moderate fine and medium subangular blocky; firm; common thin clay films and few thin to thick reddish gray (5YR 5/2) coatings of A2 material on faces of peds; few fine dark colored concretions; few fine roots mostly on faces of peds; about 5 percent coarse fragments; pH 5.5; moderately slow permeability; diffuse boundary.

IIB22t(2Bt2)--41 to 52 inches; reddish brown (2.5YR 4/4) clay loam; weak fine and medium angular blocky structure; firm; few thin clay films on faces of peds; irregular mass of sandy loam in lower part; about 5 percent coarse fragments; pH 6.5; moderately slow permeability; diffuse boundary.

IIB3(2BC)--52 to 60 inches; dark reddish brown (2.5YR 3/4) clay loam near loam; weak very fine and fine angular blocky structure; firm; few thin clay films on faces of peds; about 5 percent coarse fragments; pH 7.0; slow permeability.

The thickness of solum ranges from 50 to 80 inches. The mantle of outwash is 20 to 40 inches thick. That mantle lacks or has as much as 20 percent of coarse fragments. These fragments are more common in the lower part of the mantle. Horizons in glacial till have 1 to 10 percent of coarse fragments. Horizons in the mantle of outwash typically have texture of fine sand, sand, loamy fine sand, or loamy sand. However, the A horizon in some pedons is fine sandy loam or sandy loam. The part of the B horizon in the sandy mantle has hue of 7.5YR or 5YR. The B and C horizons in glacial till have hue of 2.5YR or 5YR and are loam or clay loam. Those horizons have 18 to 35 percent clay.

<u>1350B Duluth variant loamy fine sand, 1 to 4 percent slopes.</u> This map unit mostly has convex slopes, but some parts of it has linear or concave slopes. This unit is on glacial moraines. Most delineations of this unit are elongate in shape and typically ar 4 to 100 acres in size. Most areas of these soils are in forest, but few are in pasture and sites for homes and cabins. The Duluth variant soils in this map unit have the full range of properties described for that soil.

Small areas of the Duluth and Omega series are included in some delineations. Also, small areas of soils that are wetter than Duluth variant soils are in some delineations. Most areas of such soils are shown by the symbols for wet spots and drainage ways. Further, a few small areas of soils with sandy loam or fine sandy loam texture in the upper part of the B horizon are included. Small areas with slopes of more than 4 percent are included in a few places.

<u>1350C Duluth variant loamy fine sand, 4 to 15 percent slopes.</u> This map unit mostly has convex slopes. However, some parts of it has linear and concave slopes, and these kinds of slopes are mostly on the lower lying parts of it. This map unit is on glacial moraines. Some delineations are circular in shape and are on knolls typically ranging from 2 to 10 acres in size. Other delineations of it are elongate and typically range from 5 to 20 acres in size. Most areas of these soils are in forest or pasture, but a

few areas are used as sites for cabins and homes. The Duluth variant soils in this map unit have the full range of properties described for that soil.

Small areas of the Duluth and Omega series are included in a few delineations. Also, a few small areas of soils with sandy loam or fine sandy loam texture in the upper part of the B horizon are included. Small areas with slopes of less than 4 percent or more than 15 percent are included in a few places.

Dusler Series

The Dusler series consists of nearly level, somewhat poorly and poorly drained, slowly permeable soils that formed mostly in loamy calcareous glacial till. These soils have slightly convex to slightly concave slopes on glacial moraines.

The Dusler series primarily is associated with the Blackhoof and Duluth series and Organic soils. The Dusler series is wetter than the Duluth series, and it has mottles in the B horizon which are lacking in the Duluth series. The Dusler series is not as wet as the Blackhoof series and Organic soils.

The seasonal high water table in the Dusler series commonly begins within depths of 1 to 4 feet during the period of October to June. It commonly is at greater depths in other times of the year.

A description of a representative pedon (S-81-MN-58-1-samples 1 to 6) of the Dusler series in the map unit of Dusler loam (map symbol 502) located on a linear slope of about 0.5 percent 1,520 feet west and 2,380 feet south of the northeast corner of section 17, R. 19 W., T. 45 N. is in the following paragraphs. This pedon is about 500 feet from the shore of Sturgeon Lake. The delineation in which this pedon occurs primarily is bounded by Duluth, Duluth variant, and Organic soils. This pedon is in a deciduous-coniferous forest on the Y.M.C.A. property. It was described and sampled on 3 November 1981. Free water began at depths of about 5 inches.

A1(A)--0 to 6 inches; very dark gray (10YR 3/1) loam; moderate fine and medium granular structure; slightly sticky; many fine and medium and few large roots; about 2 percent coarse fragments; pH 6.0; moderate permeability; clear smooth boundary.

A2(E)--6 to 12 inches; dark grayish brown (10YR 4/2) loam; few fine prominent yellowish red (5YR 4/6) mottles; moderate medium granular structure; slightly sticky; common fine and few large roots; about 2 percent coarse fragments;

pH 6.0; moderate permeability; clear smooth boundary.

B&A(B/E)--12 to 17 inches; B part comprising about 80 percent is brown (7.5YR 4/4) heavy loam with common fine distinct yellowish red 5YR 4/6) mottles; A part comprising about 20 percent as tongues and interfingers is brown (7.5YR 5/2) loam with few fine distinct gray (5YR 6/1) mottles; weak fine and medium prismatic structure parting to weak medium and coarse subangular blocky; very firm, sticky; few thin clay films on faces of secondary peds; common fine roots mostly on faces of peds; about 2 percent coarse fragments; horizon not yet saturated; pH 5.5; slow permeability; clear wavy boundary.

B21t(Bt1)--17 to 28 inches; reddish brown (5YR 4/4) clay loam; weak fine and medium prismatic structure parting to moderate fine and medium subangular blocky; sticky; many thin and medium reddish gray (5YR 5/2) and dark reddish gray (5YR 4/2) clay films and coatings on faces of peds; few fine roots mostly on faces of peds; about 2 percent coarse fragments; pH 5.0; moderately slow permeability; gradual boundary.

B22t(Bt2)--28 to 42 inches; dark reddish brown (5YR 3/4) clay loam near loam; weak fine and medium angular blocky structure; sticky; few thin clay films on faces of peds; few fine roots mostly on faces of peds; about 2 percent coarse fragments; p H 6.5; moderately slow permeability; diffuse boundary.

B3(BC)--42 to 60 inches; reddish brown (5YR 4/3 heavy loam; weak very fine and fine angular blocky structure; slightly sticky; very few fine roots; about 2 percent coarse fragments; pH 7.5; slow permeability.

The thickness of solum ranges from 50 to 70 inches. The content of coarse fragments typically ranges from 1 to 8 percent, but fragments are lacking in the upper part of some pedons. The A horizon is sandy loam, fine sandy loam, loam, or silt loam. The B horizon primarily has a matrix with hue of 2.5YR or 5YR. Mottles in the upper part of the B horizon range from few to many. The B horizon has 18 to 35 percent clay.

502 Dusler loam. This map unit typically has linear or concave slopes, but it has slightly convex slopes in a few places. Slope gradient ranges from 0 to 2 percent. These soils are on glacial moraines. Delineations of the map unit are variable in size and shape. They range from as small as about one acre to as large as about 40 acres. The range in shape from elongate to circular. Most areas of these soils are pasture or forest. Dusler soils in this map unit have the full range in properties described here for the series.

Small areas of Blackhoof series and Organic soils are included in some delineations. Most of thsee inclusions are indicated by the symbol for wet spots and drainage ways. Small areas of Duluth soils are included in some delineations. These are on small low knolls. Small areas of soils that are similar to Dusler except for having sandy textures in the A horizon or upper part of the B horizon or both, also are included in a few delineations. Small areas of Nemadji soils are included in a few delineations.

Lake Beaches

Lake beaches consist of nearly level, very poorly to moderately well drained, moderately to rapidly permeable soils that formed mostly in recent to rather old sandy beach deposits adjacent to lakes. The deposits in which these soils formed result from the action of wind and ice. The higher lying parts of these soils may be a result of once higher lake levels.

Lake beaches are bounded by soils of Duluth and Omega series on their upslope side. These soils are on bluffs around the lakes among other places. They are bounded by water on their down-slope side. The part of these soils that are adjacent to lakes have free water beginning at or near the surface throughout the year. Where Lake beaches border Duluth and Omega soils, they have a water table beginning within 1 to 3 feet of the surface during the wetter parts of the year.

No soil series have yet been defined by the Minnesota Cooperative Soil Survey to comprise soils here called Lake beaches. Actually two or three soil series would be needed to adequately define the soils in Lake beaches in this survey area. Since no series exist for these soils, the name Lake beaches is used for them in this report.

An example of a pedon (S-81-MN-58-5-samples 1 to 6) in a delineation Lake beaches (map symbol 1032) located near the west shore of Passenger Lake about 990 feet east and 2,510 feet north of the center of section 32, R. 19 W., T. 45 N. is in the following paragraphs. This pedon has a concave slope with gradient of about ½ percent. It is about 50 feet east of the beginning of a delineation of Omega loamy sand, 20 to 60 percent slopes, which is on the bluffs around the lake. It is about 100 feet west of the border of that lake and is about 3 feet above the level of the lake. A deciduous-coniferous forest is at the site. The pedon was described and sampled 4 November 1981. The water table began at about 30 inches. The soil was moist above that depth.

Oa--2 to 0 inches; black (5YR 2/1) sapric material (muck); moderate very fine and fine granular structure; very friable; many very fine and fine and many medium and coarse roots; many particles of sand; pH 4.5; moderate permeability; abrupt smooth boundary.

A1(A)--0 to 3 inches; very dark grayish brown (10YR 3/2) sandy loamy; weak fine and medium granular structure; very friable; many very fine and fine and common medium and coarse roots; pH 4.5; moderate permeability; clear smooth boundary.

B2(Bw)--3 to 21 inches; brown (7.5YR 5/2 to 5/4) sand; few fine and medium distinct yellowish red (5YR 4/8) mottles; single grained; loose; few medium and coarse roots; pH 6.0; rapid permeability; clear smooth boundary.

C1--21 to 29 inches; stratified brown (7YR 5/2) and very dark grayish brown (10YR 3/2) sand and loamy sand; massive; friable in some parts and very friable in other parts; few small masses and strata of black (10YR 2/1) sapric and hemic materials; pH 6.0; moderately rapid permeability; gradual smooth boundary.

C2--29 to 36 inches; dark brown (7.5YR 4/2) sand; few fine and medium distinct gray (N 5/0) mottles; single grained; loose; few pebbles in some parts; pH 4.5; rapid permeability; clear smooth boundary.

C3--36 to 60 inches; dark gray (5YR 4/1) stratified sand, coarse sand, and gravelly and very gravelly sand and coarse sand; few fine and medium distinct gray (N 5/0) mottles; single grained; loose; gravel mostly 0.2 to 1.0 cm; pH 6.0; rapid permeability.

The content of gravel ranges from 0 to 35 percent. The color in these soils below the A horizon has hue from 5Y to 5YR, value of 4 to 6 and chroma of 1 to 4. The depth to horizons with mottles ranges from 0 to 30 inches. The A horizon ranges from sands to sandy loams with or without gravel. Textures below the A horizon are mostly sands or loamy sands with or without gravel. Textures commonly are stratified within the limits of a pedon, but some pedons lack such stratification.

<u>1032 Lake beaches.</u> Delineations of this map unit are narrow and elongated and typically range from 1 to 20 acres in size. These soils primarily are adjacent to Passenger and Sturgeon Lakes, but small areas of them are adjacent to Island and Rush Lakes. Most areas of these soils are forested or have shruby and herbaceous, wetland vegetation. However, significant areas of these soils are used as sites for cabins and homes.

Lake beaches that have glacial till beginning at shallow depths are included in a few places. Such inclusions primarily are along Island Lake and along the eastern and northern shore of Sturgeon Lake.

Organic Soils

Organic soils consist of very poorly drained, nearly level soils with slow to moderately rapid permeability. They formed in organic soil material, namely slightly to highly decomposed remains of a variety of plants. They primarily are in small to large depressions on glacial moraines and outwash plains. Some of these depressions were formerly lakes. These soils are on floodplains in a few places.

Organic soils primarily are associated both with soils formed in glacial till, namely the Duluth, Dusler, and Blackhoof series and soils formed in glacial outwash, namely the Omega, Nemadji, and Newson series. Of the above named associated soils, Organic soils are most similar to the Blackhoof anf Newson series. However, they differ from those series by having a thicker layer of organic soil material.

The water table typically begins within depths of less than one foot throughout the year. Further, water commonly is on the surface during several months of the growing season.

Different kinds of Organic soils were not mapped in this survey because of lack of time to properly identify them and because interpretive differences among the different kinds were not important to the purpose of this soil survey.

A description of a representative pedon (S-81-MN-58-3 samples 1 to 4) of Organic soils in the largest bog in the survey area is in the following paragraphs. This pedon is in the map unit of Organic soils (map symbol 995) and is located about 800 feet north and 150 feet east of the southwest corner of section 9, R. 19 W., T. 45 N. This pedon has a linear slope with gradient of less that ½ percent. It is in a coniferous forest dominated by black spruce and tamarack. Moss-covered hummocks rise as much as 10 inches above the common surface. Mosses are the dominant ground cover. This pedon was described and sampled on 3 November 1981. The water table began about 10 inches below the surface. This bog has been partially drained.

Oa--0 to 4 inches; very dark brown (10YR 2/2) broken face and rubbed sapric material (muck); moderate very fine granular structure; sticky; pH 4.0; moderately permeable; clear smooth boundary.

Oe1--4 to 22 inches; dark brown (7.5YR 3/2) matrix, dark yellowish brown (10YR 4/4) fiber, dark brown (7.5YR 3/2) rubbed, hemic material (mucky peat); about 60 percent fiber, about 40 percent after rubbing; massive; non sticky; mostly herbaceous fiber with a trace of woody fragments; pH 4.0; moderate permeability; gradual boundary.

Oe2--22 to 65 inches; very dark gray (10YR 3/1) matrix, dark yellowish brown (10YR 4/4) fiber, dark brown (7.5YR 3/2) rubbed, hemic material (mucky peat); about 40 percent fiber, about 20 percent after rubbing; massive; slightly sticky; mostly herbaceous fiber, trace of woody fragments; pH 5.5; moderate permeability; clear boundary.

Oe3--65 to 80 inches; very dark grayish brown (10YR 3/2) matrix, brown (10YR 4/3) fiber, dark yellowish brown (10YR 3/4) rubbed, hemic material (mucky peat); about 60 percent fiber, about 40 percent after rubbing; massive; non sticky; herbaceous fiber; pH 6.0; moderate permeability.

Organic soils in this survey area have a wide range in properties and several series could have been identified. The thickness of organic soil material ranges from 16 inches to more than 6 feet in thickness. This material is mostly sapric (muck) and hemic material (mucky peat), but a few have some fibric material (peat). This material is mostly derived from herbaceous plants, but in some it is derived from woody anc mossy plants. The mineral soil material underlying the organic soil material primarily is sandy or loamy.

<u>995 Organic soils.</u> This map unit has nearly level slopes, gradient of less than 1 percent. Individual delineations of this map unit are variable in shape and size. Some are nearly circular in shape and others are narrow and elongated. They range from about one acre to more than 100 acres in size. Most areas of these soils are forested or are dominated by herbaceous plants such as sedges.

This map unit has few inclusions of other kinds of soil. Included soils primarily are the Blackhoof and Newson soils, and these primarily are near the boundary between Organic soils and other kinds of soil.

Nemadji Series

The Nemadji series consists of nearly level, somewhat poorly drained, rapidly permeable soils that formed in sandy glacial outwash. These soils have slightly convex to slightly concave slopes on glacial outwash plains.

The Nemadji series primarily is associated with Newson and Omega series and Organic soils. The Nemadji series has mottles in the B horizon, but the better drained Omega series lacks mottles in that horizon. The Nemadji series has higher chroma in the B horizon than does the wetter Newson series. The Nemadji series lacks or has a thin layer of organic soil material, whereas Organic soils have thicker layers of organic soil material and are wetter.

The seasonal high water table typically begins within depths of 1.5 to 4 feet during the months of March to June. It commonly is at greater depths during other parts of the year except during periods of above normal rainfall.

A description of a representative pedon (S-81-MN-58-6-samples 1 to 7) of the Nemadji series in the map unit Nemadji loamy sand (map symbol 186) located on a linear slope of about 0.5 percent about 2,050 feet west and 1,190 feet north of the southeast corner of section 21, R. 19 W., T. 45 N. is in the following paragraphs. The delineation with this pedon is bounded by delineations of the Omega and Newson series and Organic soils. This pedon is in a coniferous-deciduous forest. It was described and sampled 4 November 1981. Free water began at depths of about 50 inches. The soil was moist above that depth.

O-- 2 to 0 inches; very dark gray (10YR 3/1) highly decomposed leaf litter, weak fine and medium granular structure; very friable; many clean sand grains; many very fine to medium roots; pH 4.5; moderate permeability; abrupt smooth boundary.

A1(A)--0 to 4 inches; dark brown (7.5YR 3/2) loamy sand; weak very fine and fine granular structure; very friable; common clean sand particles; many very fine and fine and common medium and large roots; pH 4.5; moderately rapid permeability; abrupt smooth boundary.

B21(Bw1)--4 to 11 inches; reddish brown (5YR 4/4) sand; few medium faint yellowish red (5YR 4/6) mottles; weak very fine and fine granular structure; very friable; common medium and large roots; pH 5.5; rapid permeability; clear smooth boundary.

B22(Bw2)--11 to 25 inches; yellowish red (5YR 4/8) sand; many fine and medium in upper part and large in lower part distinct (5YR 5/3) mottles; massive; very friable; few fine slightly consolidated masses of dark reddish brown (2.2YR 3/4); few medium and large roots; about 1 percent pebbles; pH 5.5; rapid permeability; gradual smooth boundary.

B23(Bw3)--25 to 42 inches; reddish brown (5YR 5/3) sand; many fine to coarse distinct yellowish red (5YR 4/8) mottles; single grained; loose; about 1 percent pebbles; few medium and large roots; pH 6.0; rapid permeability; gradual smooth boundary.

B3(BC)--42 to 55 inches; dark reddish brown (5YR 3/4) sand; many medium and coarse faint reddish brown (5YR 5/3) mottles; single grained ; loose; about 1 percent pebbles; few very fine roots; pH 6.5; rapid permeability; gradual smooth boundary.

C--55 to 60 inches; dark grayish brown (5YR 4/2) sand; single grained; loose; pH 6.5; rapid permeability.

The sola range from 40 to 60 inches in thickness. The B and C horizons have a matrix with hue of 2.5YR or 5YR. The depth to horizons with mottles ranges from 3 to 30 inches. However, mottles with chroma of 2 or less are lacking within depths of 40 inches. The A and B2 horizons are sand, fine sand, loamy sand or loamy fine sand. The B3 and C horizons are sand or fine sand.

186 Nemadji loamy sand. Delineations of this map unit typically are elongated in shape and range from 2 to about 30 acres in size. Some areas of these soils are in cropland and pasture and others are in forest. The Nemadji series in this map unit have the full range of properties described for the series here in a previous paragraph.

Delineations of Nemadji loamy sand located in sections 4 and 20 have some soils that contain either more coarse sand, gravel or silt and clay than the Nemadji series. However, most interpretations for such soils are similar to those for the Nemadji series.

Newson Series

The Newson series consists of nearly level, poorly and very poorly drained, rapidly permeable soils that formed mostly in sandy glacial outwash. These soils have linear to concave slopes on glacial outwash plains.

The Newson series primarily is associated with the Nemadji and Omega series and with Organic soils. The Newson series is wetter than the Nemadji and Omega series and has colors with lower chroma in the B horizon than those soils. The Newson series lacks or has a thinner layer of organic soil material than Organic soils.

The seasonal high water table typically is within depths of 1 foot during the months of November through June. The water table typically begins at greater depths during other parts of the year except during periods of above normal rainfall.

A description of a representative pedon (S-81-MN-58-7-samples 1 to 6) of the Newson series in the map unit of Newson mucky sand loamy (map symbol 274) located on a slightly concave slope of about 0.5 percent about 1,390 feet west and 1,720 feet north of the southeast corner of section 21, R. 19 W., T. 45 N. is in the following paragraphs. The delineation with this pedon is bounded by delineations of the Nemadji series, Duluth variant, and Organic soils. The pedon is in a thicket of alder with grasses and sedges dominant in the herbaceous layer. It was described and sampled 4 November 1981. Free water began at depths of 8 inches. The soil was very moist above that depth.

Oa--4 to 0 inches; black (10YR 2/1) sapric material (muck); strong fine and medium granular structure; very friable; many very fine, fine and medium roots; pH 4.5; moderate permeability; abrupt smooth boundary.

A1(A)--0 to 4 inches; very dark gray (10YR 3/1) sandy loam; massive; firm; breaks into angular fragments under moderate pressure; few medium and coarse roots; pH 4.5; moderately permeability; abrupt smooth boundary.

B21g(Bgw1)--4 to 12 inches; dark gray (10YR 4/1) loamy sand near sandy loam; few fine distinct dark brown (7.5YR 4/4) mottles; massive; firm; breaks into angular fragments under moderate pressure; few medium and coarse roots; pH 4.5; moderate permeability; clear smooth boundary.

B22g(Bgw2)--12 to 22 inches; grayish brown (10YR 5/2) loamy sand; common medium distinct dark brown (7YR 4/4) and few fine prominent yellowish red (5YR 5/6) mottles; massive; friable; few very fine to medium roots; pH 5.5; moderately rapid permeability; gradual smooth boundary.

C1--22 to 49 inches; reddish brown (5YR 5/4) sand; single grained; loose; pH 6.0; rapid permeability; diffuse smooth boundary.

C2--49 to 60 inches; reddish brown (5YR 5/3) sand; few coarse faint reddish brown (5YR 4/4) mottles; single grained; loose; pH 6.0; rapid permeability.

The sola range from 20 to 40 inches in thickness. The layer of organic soil material is lacking in some pedons and is thick as 6 inches in others. The A horizon is loamy sand or sandy loam. It is 3 to 8 inches thick. The B2 horizon has a matrix with hue of 10YR to 5Y and chroma of 1 or 2. It is sand or loamy sand. The C horizon has a matrix with hue of 5YR to 10YR. It is sand or loamy sand.

274 Newson mucky sandy loam. Delineations of this map unit typically are elongated in shape and range from 3 to 15 acres in size. Most areas of these soils are in shruby forest, but some have been cleared and are in pasture. The Newson soils in this map unit have the full range in properties described for the series here in a previous paragraph.

Delineations of Newson mucky sandy loam in section 4 and 20, have some soils that contain either more coarse sand, gravel, or silt and clay than the Newson series. However, most interpretations for such soils are similar to those for the Newson series.

Omega Series

The Omega series consists of nearly level to very steep, somewhat excessively drained, rapidly permeable soils that formed in sandy glacial outwash. These soils have convex to concave slopes on glacial outwash plains and moraines.

The Omega series primarily is associated with the Nemadji and Newson series and the Duluth variant and Organic soils. The Omega series lacks mottles in the B horizon, whereas the wetter Nemadji and Newson soils have mottles in their B horizon. The Omega soils are sandy throughout, but the Duluth variant soils have horizons in loamy glacial till beginning within depths of 20 to 40 inches. The Omega series is much better drained than Organic soils.

Soils of the Omega series lack a seasonal high water table beginning within depths of 5 feet.

A description of a representative pedon (S-81-MN-58-4-samples 1 to 5) of the Omega series in the map unit Omega loamy sand, 0 to 5 percent slopes (map symbol 188B) located on a 2 percent convex slope about 600 feet east and 330 feet south of the center of section 32, R. 19., T 45 N. is in the following paragraphs. The delineation in which this pedon is located extends for many hundreds of feet to the west and is bounded on the east at a distance of 100 feet by a delineation of Omega loamy sand, 20 to 60 percent slopes, which is on the bluffs around the west edge of Passenger Lake. This pedon is in a deciduous-coniferous forest. It was described and sampled 4 November 1981. It was moist throughout.

A1(A)--0 to 3 inches; very dark gray (10YR 3/1) loamy sand; weak fine and medium granular structure; very friable; common clean sand particles; many very fine and fine and common medium and large roots; pH 4.5; moderately rapid permeability; abrupt smooth boundary.

B21(Bw1)--3 to 9 inches; dark reddish brown (10YR 3/4) sand near loamy sand; weak fine and medium granular structure; very friable; many fine and medium and few large roots; pH 5.5; rapid permeability; gradual smooth boundary.

B22(Bw2)--9 to 22 inches; reddish brown (5YR 4/4) sand; weak medium and coarse subangular blocky structure; very friable; many medium and coarse roots; pH 5.5; rapid permeability; gradual smooth boundary.

B31(BC1)--22 to 38 inches; yellowish red (5YR 4/6) stratified sand and coarse sand; single grained; loose; few medium and coarse roots; about 2 percent gravel; pH 6.0; rapis permeability; gradual smooth boundary.

B32(BC2)--38 to 60 inches; reddish brown (5YR 4/4) coarsesand; single grained; loose; few coarse roots; about 5 gravel; pH 6.5; rapid permeability.

The thickness of solum ranges from 20 to more than 60 inches in thickness. The 10 to 40 inch depth zone lacks or has as much as 10 percent of gravel. The A1 horizon is 1 to 4 inches in thickness. It is sand, fine sand, loamy sand, or loamy fine sand, sandy loam or fine sandy loam. The B horizon has a hue of 2.5YR or 5YR. It is sand, fine sand, loamy sand, loamy fine sand, sandy loam, or fine sandy loam in the upper part and coarse sand, sand or fine sand in the lower part.

<u>188B Omega loamy sand, 0 to 5 percent slopes.</u> This map unit has convex through concave slopes mostly on glacial outwash plains. It is on glacial moraines in a few places. Delineations of this map unit are variable in size and shape. They range from about 5 acres to more than 100 acres in size. They typically are elongate in shape. They mostly are on the higher lying parts of the landscapes. Most areas of these soils are forested, but some areas are use for pasture, cropland, and sites for homes and cabins. Soils of the Omega series in this unit have sola that comprise the thicker range in thickness described in a previous paragraph, but they have the full range described for other properties.

Most delineations of this map unit have few included soils. However, some soils with more gravel, or coarse sand, or silt and clay are included in this map unit primarily in section 4 and 22. Also, a few soils with layers of loamy sand, loamy fine sand or finer textures in the B horizon are included in a few places. Further soils that have mottles in the lower part of the B horizon or in the upper part of the C horizon are included in a few places. Small areas of poorly drained or wetter soils are included in a few places, and most of them are indicated by the symbol for wet spots.

A few small areas with steeper slopes are included in a few places.

188C Omega loamy sand, 5 to 20 percent slopes. This map unit mostly has convex slopes. However, linear and concave slopes commonly are on lower lying parts of this map unit. Most of this unit is on glacial outwash plains, but it is on glacial moraines in a few places. Most delineations of this unit are elongated and rather narrow in shape. They primarily are on slopes adjacent to lakes, peat bogs, and drainage ways. Thy mostly range from 5 to 30 acres in size. Most areas of these soils are forested, but a few areas are in pasture or sites for homes and cabins. Soils of the Omega series in this unit have sola that comprise the intermediate range in thickness described in a previous paragraph, but they have the full range described for other properties.

Most delineations of this map unit have few included soils. However, some soils with more coarse sand and gravel in the solum and C horizon or more silt and clay in the A horizon are included in a few places. Such included soils are mostly in delineations of this map unit in sections 3, 4, and 22. A few small areas with slopes of less than 5 percent or more than 20 percent are included in some delineations.

188E Omega loamy sand, 20 to 60 percent slopes. This map unit mostly has convex slopes, but it has linear and concave slopes on the lower lying parts. Most of this unit is on glacial outwash plains. Delineations of it there are narrow and elongate and typically 10 to 30 acres in size. They mostly are on bluffs along lakes and peat bogs. It is on hills in glacial moraines in a few places. Delineations of it there are elongate to circular in shape and typically are 3 to 20 acres in size. Most areas of this unit are in forest. Soils of the Omega series in this unit have sola in the thin range in thickness, but they have the full range described for other properties.

Most delineations of this map unit have few included soils. However, some soils with more coarse sand and gravel in the solum and C horizon, or more silt and clay in the A horizon and upper part of the B horizon are included in a few places. Also, small areas of the Duluth series and Duluth variant soils are included in a few places. A few small areas with slopes of less than 20 percent or more than 60 percent are included in some delineations.

INVESTIGATION PROCEDURES

I began a review of the literature about the soils and soil forming factors of the area immediately after WAPORA made initial contact with me on 2 September 1981. The more important literature that I reviewed follows.

Clayton, L. and T.F. Freers (Chief Ed.'s). 1967 Glacial geology of the Missouri Coteau and adjacent area. N.D. Geol. Sur. Mis. Series 30. 170 pp.

Cummins, J.F. and D.F. Grigal. 1981. Soils and land surfaces of Minnesota - 1981. Minn. Agr. Exp. Sta. Soils Series No. 110, Misc. Pub. 11. 59 pp. Map.

Lewis, R.R., P.R.C. Nyberg, R.O. Paulson, and J.A. Sharp. 1978. Soil Survey of Carlton County, Minnesota. U.S.D.A. Soil Cons. Serv. Gov. Printing Off. 77 pp. Maps.

Simmons, C.S. and A.E. Shearin. 1941. Soil Survey of Pine County, Minnesota. U.S.D.A. Bur. Plant Ind. 44 pp. Maps.

Soil Survey Staff. 1978. Soil survey laboratory data and descriptions for some soils of Minnesota. U.S.D.A. Soil Cons. Serv. and Minn. Agr. Exp. Sta. Soil Sur. Invest. Rpt. No. 33. 123 pp.

Wright, H.E., Jr. 1972. Quaternary history of Minnesota. Pp. 515-548 in Sims, P.K. and G.B. Morey (Ed.'s) Geology of Minnesota - A centennial volume. Minn. Geol. Sur.

Wright, H.E., Jr. 1973. Tunnel valleys, glacial surges, and subglacial hydrology of the Superior lobe, Minnesota. Geol. Soc. Am. Mem. 136:251-276.

Wright, H.E., Jr. and W.A. Watts. 1969 Glacial and vegetational history of northeastern Minnesota. Minn. Geol. Surv. SP-11. 59 pp.

I did have some knowledge of the soils of the area because I worked in soil survey in Minnesota from 1965-1979. During that period, I was State Soil Correlator, Assistant State Soil Scientist and State Soil Scientist for the Soil Conservation Service. I was involved in field reviews, sampling and correlation for the soil survey of Carlton County.

I received verbal approval of my proposal for this soil survey on 11 September 1981. I began field work on 14 September 1981, and completed it 5 November 1981.

My first task enroute to the field was to stop at the district office of the Soil Conservation Service at Hinckley, Minnesota. I wanted to inform them about my project, and, more importantly, to determine if any mapping had been done in the survey area. I learned that about 500 acres had been mapped. I borrowed aerial photography of 22 April 1957 from them because it was of excellent quality especially for stereoptic viewing and it had all previous soil mapping on it.

Procedures used in this soil survey were within the specifications of both the National and Minnesota Cooperative Soil Surveys as recorded in the following documents.

Soil Survey Staff. 1951. Soil Survey Manual. U.S.D.A. Handb. 18, 503 pp.

Soil Survey Staff. 1974 to present. National Soils Handbook. (An evolving, working document.)

Soil Survey Staff. 1975. Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys. U.S.D.A. Handb. 436, 754 pp.

Soil Survey Staff. Various dates. Soil series descriptions and interpretations.

Soil Survey Staff, Minn. 1979. Soil survey mapping legend, Minnesota. Minn. Coop. Soil Surv. 46 pp.

Soil as used in the report refers to the upper 60 inches of the regolith.

I made a reconniassance of the survey area during my first few days in the field to develop a trial legend for mapping. During this period I studied the landscape, geologic materials, and soils of the area.

I began mapping on 21 September 1981. I mainly used two sets of aerial photography while mapping, namely the 9 April 1977 photography of Mark Hurd Aerial Surveys, Inc. which had been enlarged to a scale of 1:9,750 and the 22 April 1957 photography that I had borrowed form S.C.S. The later was at a scale of 1:15,840 and it was used primarily for stereoptic study of the landscape. The former was used for recording boundaries. Also, the true color photography of 11 October 1980 at a scale of 1:30,000 and the color infrared photography of 20 October 1980 at a scale of 1:7,000 were used to further study the landscape and soil boundaries. These latter two sets of photography are in the report "EPA-Resource inventory and septic system survey, Moose Lake-Windmere Sewer District, Minnesota, October-November 1980".

Tools used in this soil survey include various kinds of sampling tubes, bucket augers, and shovels for examining the soil. A clinometer was used for measuring the inclination of slopes. A "Hellige-Truog soil reaction tester kit" was used for determing soil pH. Munsell color charts were used for measuring soil color. A "pocket" stereoscope was used for studying aerial photographs.

Ten pedons were described and sampled 2-5 November 1981. Most pedons were exposed by digging a small pit to depths of 30 to 40 inches. A large bucket auger was subsequently used to obtain samples from that depth to a depth of 60 inches. One pedon was described and sampled from road-cut. The pedon of an organic soil was exposed with a "Macaulay peat sampler." Samples of about ½ pint in size were collected from all soil horizons in each pedon. Large samples of about 1 quart in size were collected from 2 to 4 major horizons of each pedon. A standard indentifacation symbol was given to each pedon. For example, in the symbol S-81-58-1-2, S signifies sample, 81 is the year 1981, 58 is the number for Pine County, 1 is the pedon number, and 2 is the second horizon sampled from that pedon. In the introduction to pedon descriptions in the section of this report entitled "Description of Soils" the last entry in the identification number, 1 to 6 for example, indicates that 6 horizons were sampled from that pedon.

A.E. Jacobson, an SCS soil scientist stationed at Duluth, Minnesota, and I conducted a review and correlation of this soil survey on 23 October 1981.

Boundaries between soils along the boundary between Carlton and Pine Counties do not join some places. The main reason for these no-joins is that this survey was mapped at a larger scale and at higher intensity than was the survey of Carlton County.

Appendix B-2.

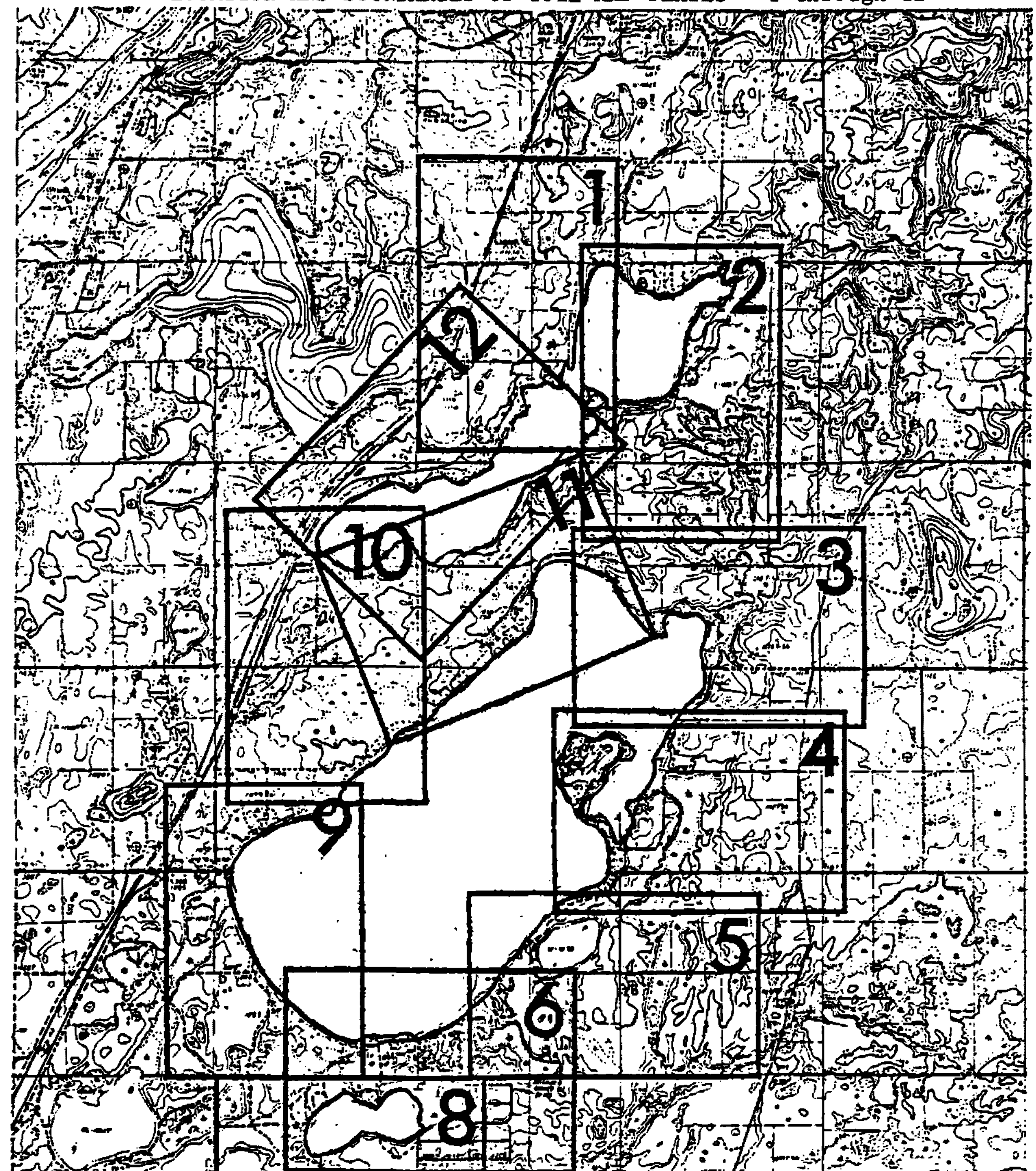
SOIL MAP PLATES

SOIL MAP PLATES OF THE LAND AREA IMMEDIATELY SURROUNDING ISLAND, STURGEON, RUSH, AND PASSENGER LAKES

Pine County MN

Scale: 6 inches/mile

LOCATION AND BOUNDARIES OF SOIL MAP PLATES - 1 through 12



Soil Map Identification Legend

for

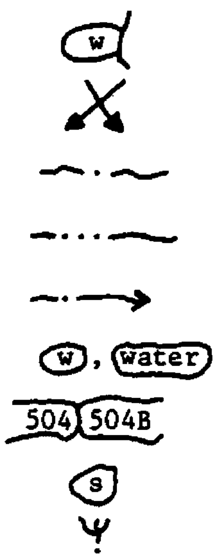
[1]THE SOIL SURVEY OF A PORTION OF WINDEMERE TOWNSHIP, PINE COUNTY, MN

- Map Units -

Map symbol	Name of soil
186	Nemadji loamy sand
188B	Omega loamy sand, 0 to 5% slopes
188C	Omega loamy sand, 5 to 20% slopes
188E	Omega loamy sand, 20 to 60% slopes
274	Newson mucky sandy loam
502	Dusler loam
504B	Duluth loam, 1 to 4% slopes
504C	Duluth loam, 4 to 15% slopes
504E	Duluth loam, 15 to 60% slopes
614	Blackhoof muck
995	Organic soils
1002	Alluvial soils
1016	Altered soils
1032	Lake beaches
1350B	Duluth variant loamy fine sand, 1 to 4% slopes
1350C	Duluth variant loamy fine sand, 4 to 15% slopes

- Conventional and Special Features -

+ Section corners



Dams and associated reservoirs

Gravel or sand pits

Perennial drainage way

Intermittent drainage way

End of drainage way

Unnamed lakes and ponds

Soil delineations and map unit symbols

Soil sample site

Small area (1/8 to 1/2 acre) of poorly drained or wetter soils in delineations of better drained soils.

[1]The soil map for which this legend was developed is not rectified and thus may not be used to overlay other rectified maps of the area.


N
HIGHWAY
502
504 C
504B
995
614
1350B
188B
274
504C
186
4
W
188C
1032
1350 B
504 E

Plate #1

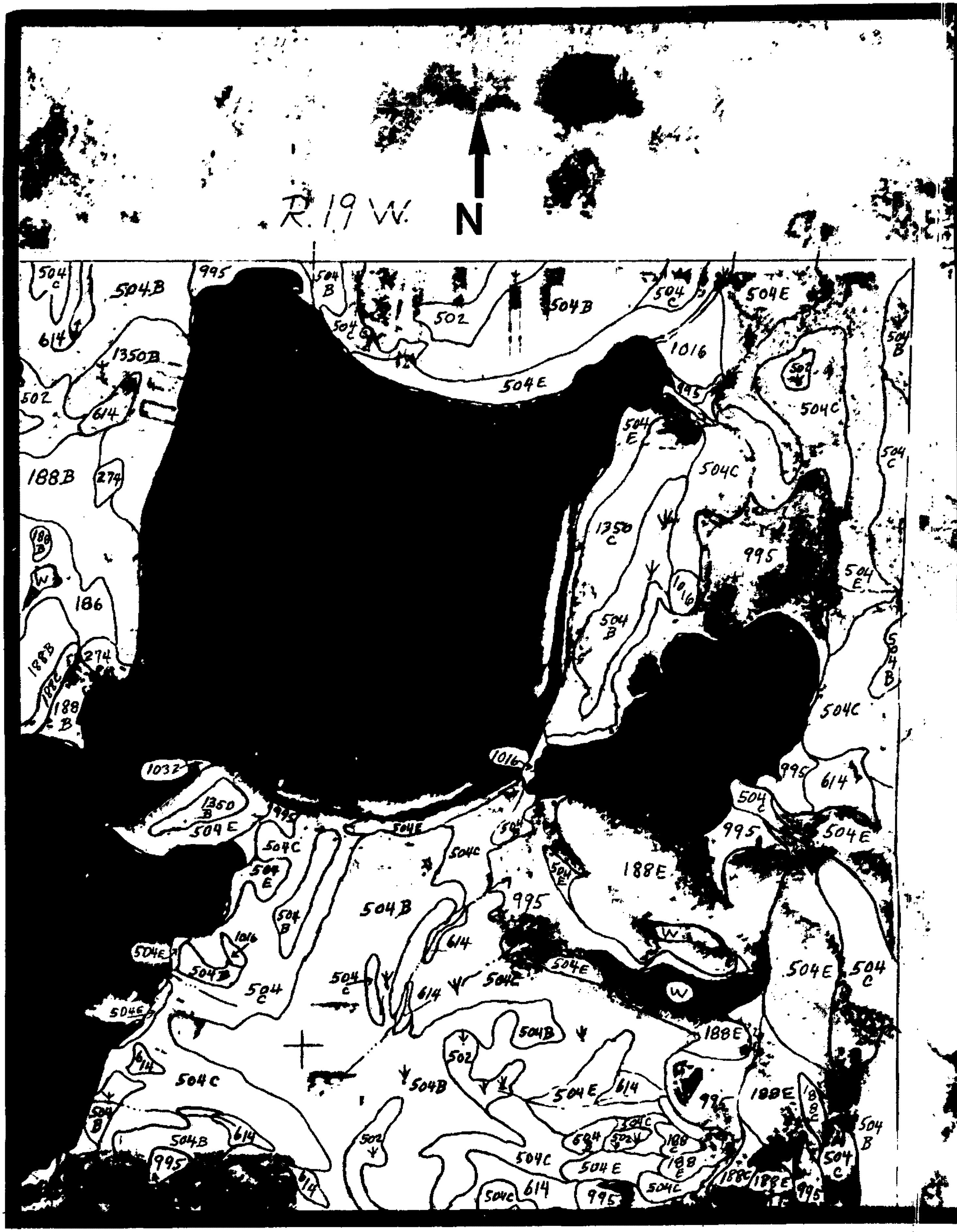

R.19W.
N
504B
995
502
504E
1016
504C
188B
274
186
1350B
614
1350C
188E
1032
W

Plate #2

Plate #3


NO ACCESS
— unmapped —
N
15
16
504B
504C
504E
502
614
995
1016
1032

Plate #4

Plate #5

Plate #6

Plate #7

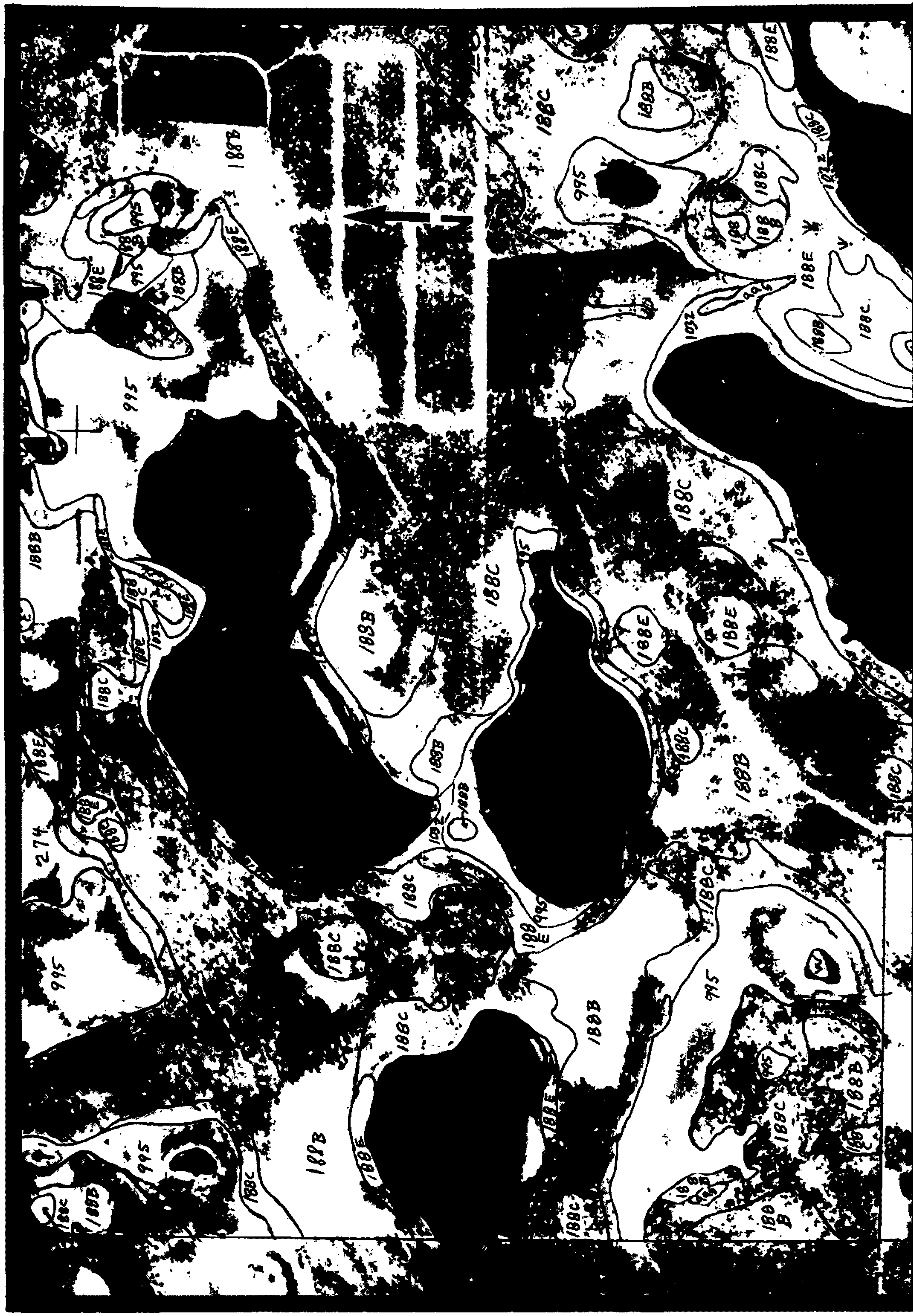


Plate #8


HIGHWAY
188B
188C
1350B
1350 C
995
1032
995
1032
188B
188C
1032
188B
186
274
1032
188B
995
188C
274
995
188E

Plate #9


N
HIGHWAY
504C
995
1350B
1016
504B
614
504
502
1031
504E
188B
1350C
188C
1350
1032
17

Plate #10

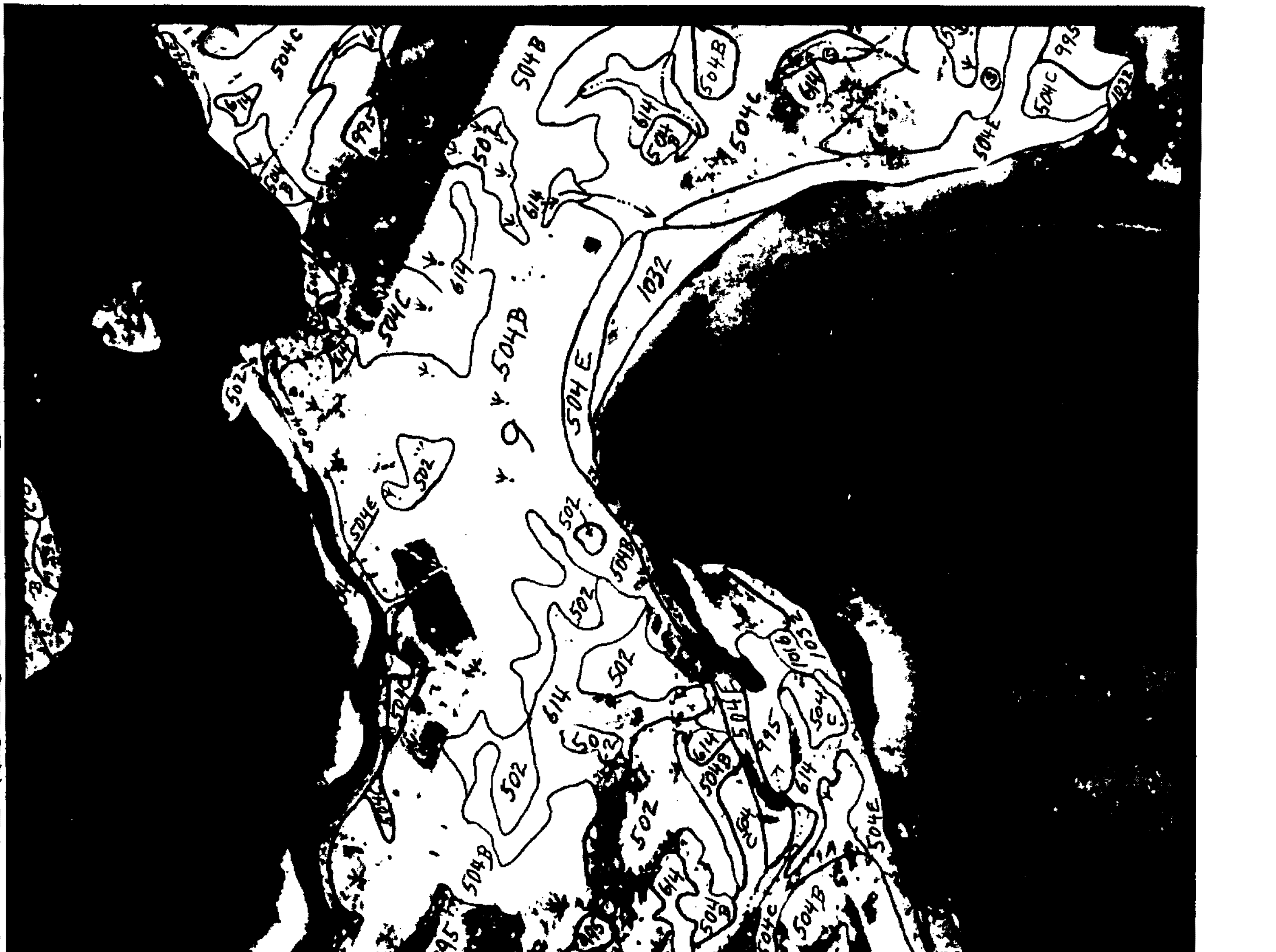


Plate #11

Plate #12

APPENDIX B-3

SOILS TESTING DATA

Paricle Size Distributions

For Soil Samples Taken in Windemere TN

Pine County MN

SOIL TESTING SERVICES, INC.

GRAIN SIZE DISTRIBUTION — DATE: 1-19-82

BORING NO. : B-21T — STS JOB NO.: 22561
SAMPLE NO. : 4 — PROJECT : MOOSE LAKE WINDEMERE
DEPTH : 17.00-28.00 in. — W/C: — — SP.GR.: —
CLASSIFICATION: Dusler Loam — LL : — PL : — PI : —

SIEVE ANALYSIS-

SAMPLE WEIGHT: 94.61 GRAMS

SIEVE SIZE	WEIGHT RETAINED	PER CENT RETAINED	PER CENT PASSING
.375"	0.00	0.00	100.00
#4	1.07	1.13	98.87
#10	0.48	0.51	98.36
#16	0.30	0.32	98.04
#40	1.55	1.64	96.41
#60	4.29	4.53	91.87
#140	7.71	8.15	83.72
#200	2.39	2.53	81.20
#325	2.17	2.29	78.91

HYDROMETER ANALYSIS-

SAMPLE WEIGHT: 52.03 GRAMS
SOIL SPECIFIC GRAVITY:
ZERO HYDROMETER HEIGHT: 10.45
CORRECTION FACTOR: 5.5

ELAPSED TIME	TEMPERATURE	ACTUAL READING	ADJUST READING	GRAIN SIZE	PER CENT FINER
0.25	22.5	50.00	44.50	0.0740	83.24
0.50	22.5	48.50	43.00	0.0531	80.43
1.00	22.5	46.50	41.00	0.0383	76.69
5.00	22.5	45.00	39.50	0.0174	73.89
8.00	22.5	44.00	38.50	0.0139	72.02
15.00	22.5	42.50	37.00	0.0103	69.21
30.00	22.5	40.50	35.00	0.0074	65.47
60.00	22.5	38.00	32.50	0.0053	60.79
134.00	22.5	35.00	29.50	0.0037	55.18
1390.00	22.5	27.00	21.50	0.0012	40.22

SOIL TESTING SERVICES, INC.

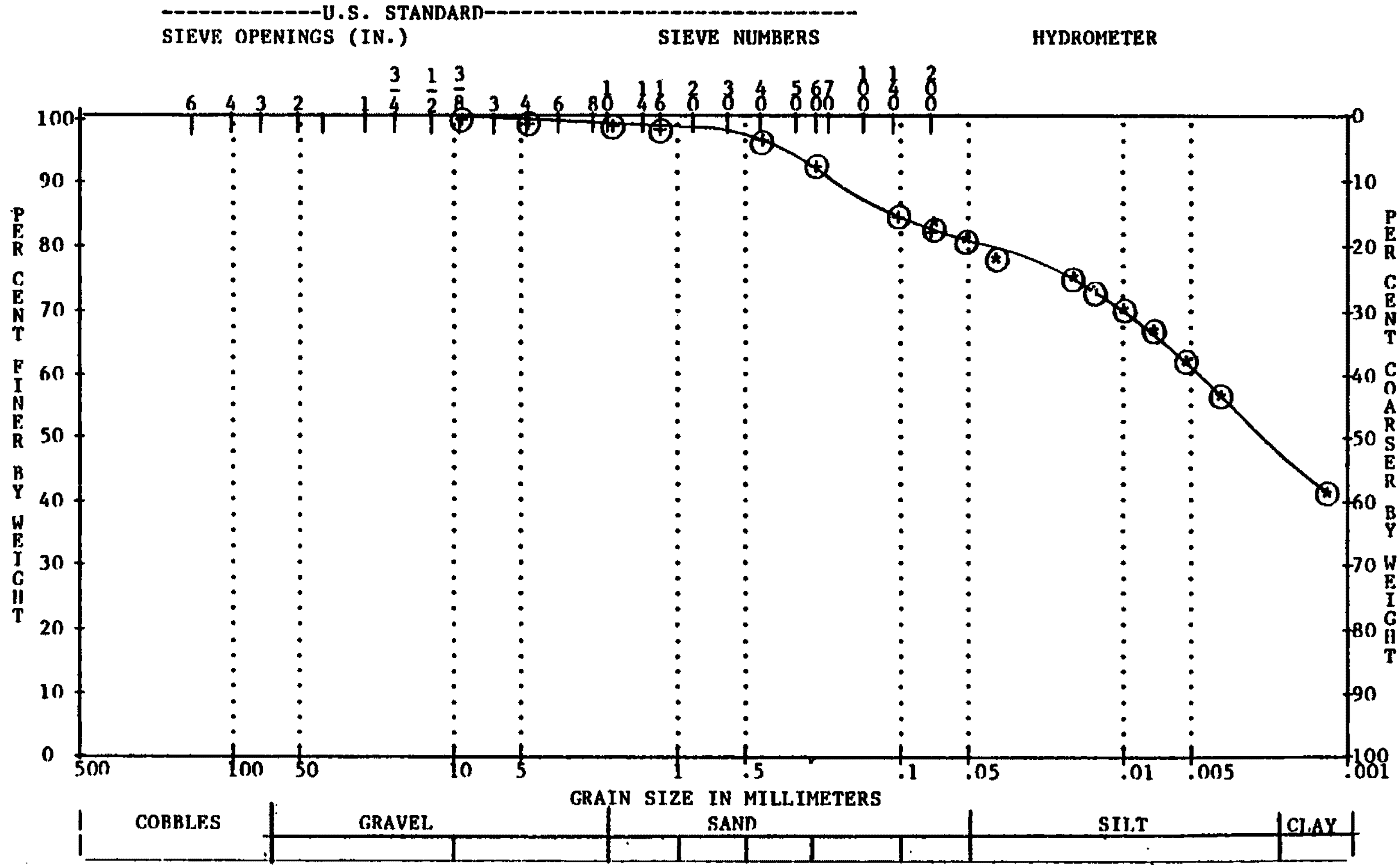
GRAIN SIZE DISTRIBUTION — DATE: 1-19-82

BORING NO. : B-21T — STS JOB NO.: 22561

SAMPLE NO. : 4 — PROJECT : MOOSE LAKE WINDEMERE

DEPTH : 17.00-28.00 in. — W/C: — SP.GR.: —

CLASSIFICATION: Dusler loam — LL : — PL : — PI : —



SOIL TESTING SERVICES, INC.

GRAIN SIZE DISTRIBUTION DATE: 1-19-82

BORING NO. : II-B3 STS JOB NO.: 22561

SAMPLE NO. : 7 PROJECT : MOOSE LAKE WINDEMERE

DEPTH : 52.00 -60.00 in. W/C: — SP.GR.: —

CLASSIFICATION: Duluth varient loam fine sand LL : — PL : — PI : —

SIEVE ANALYSIS-

SAMPLE WEIGHT: 72.83 GRAMS

SIEVE SIZE	WEIGHT RETAINED	PER CENT RETAINED	PER CENT PASSING
.375"	0.00	0.00	100.00
#4	0.48	0.66	99.34
#10	0.36	0.49	98.85
#16	0.20	0.27	98.57
#40	1.10	1.51	97.06
#60	3.36	4.61	92.45
#140	6.13	8.42	84.03
#200	1.84	2.53	81.50
#325	2.17	2.98	78.52

HYDROMETER ANALYSIS-

SAMPLE WEIGHT: 51.61 GRAMS
SOIL SPECIFIC GRAVITY:
ZERO HYDROMETER HEIGHT: 10.45
CORRECTION FACTOR: 5.5

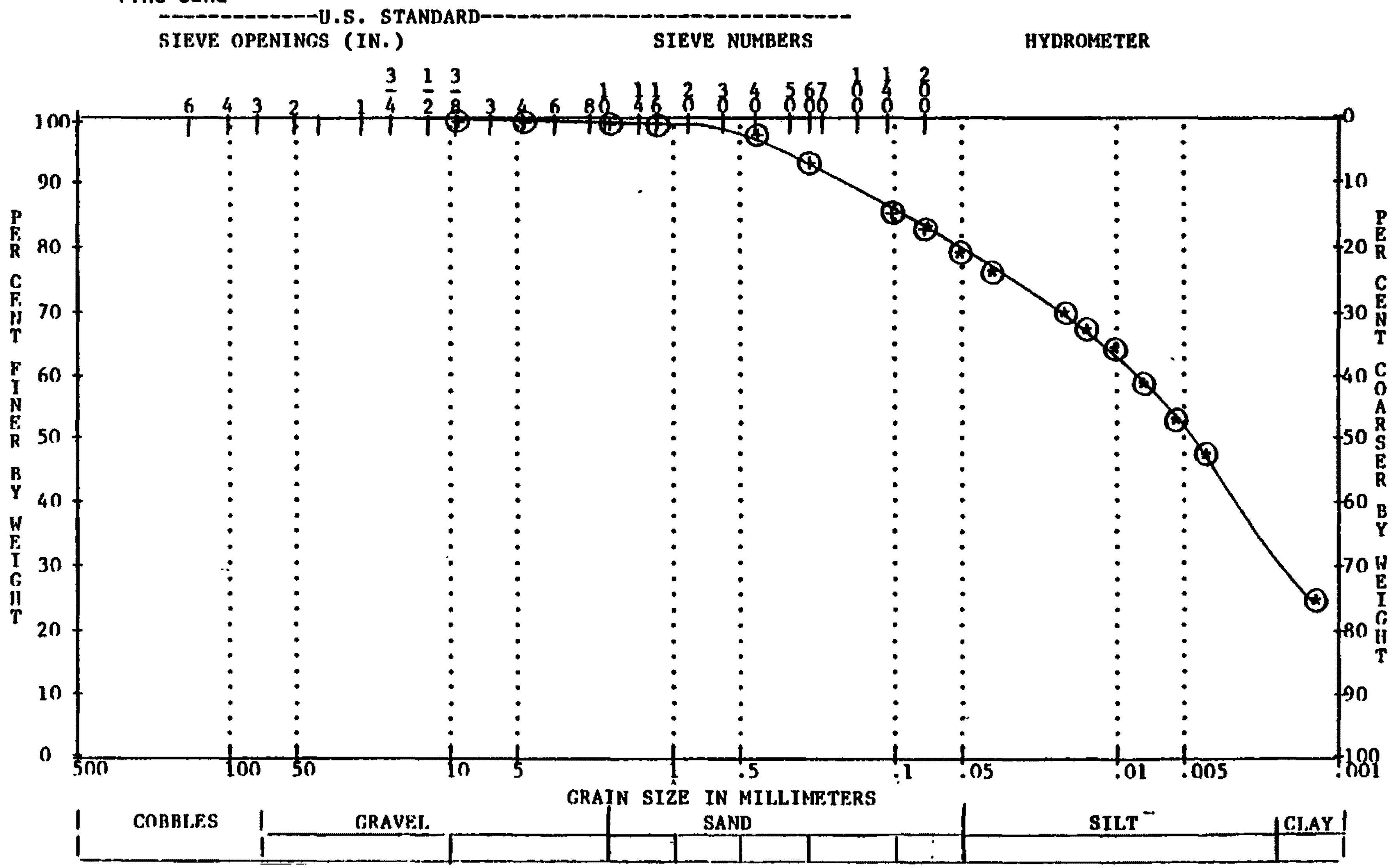
ELAPSED TIME	TEMPERATURE	ACTUAL READING	ADJUST READING	GRAIN SIZE	PER CENT FINER
0.25	22.5	49.00	43.50	0.0737	81.56
0.50	22.5	47.00	41.50	0.0531	77.81
1.00	22.5	45.50	40.00	0.0381	75.00
5.00	22.5	42.00	36.50	0.0176	68.44
8.00	22.5	40.50	35.00	0.0141	65.63
15.00	22.5	39.00	33.50	0.0104	62.81
30.00	22.5	36.00	30.50	0.0076	57.19
60.00	22.5	33.00	27.50	0.0055	51.56
120.00	22.5	30.00	24.50	0.0040	45.94
1425.00	22.5	18.00	12.50	0.0012	23.44

SOIL TESTING SERVICES, INC.

GRAIN SIZE DISTRIBUTION

DATE: 1-19-82

BORING NO. : II-B3	STS JOB NO.: 22561		
SAMPLE NO. : 7	PROJECT : MOOSE LAKE WINDEMERE		
DEPTH : 52.00 -60.00 in.	W/C: —		SP.GR.: —
CLASSIFICATION: Duluth varient loam fine sand	LL : —	PL : —	PI : —



SOIL TESTING SERVICES, INC.

GRAIN SIZE DISTRIBUTION DATE: 1-19-82

BORING NO. : B-31 STS JOB NO.: 22561
SAMPLE NO. : 4 PROJECT : MOOSE LAKE WINDEMERE
DEPTH : 22.00-38.00 in. W/C: — SP.GR.: —
CLASSIFICATION: Omega loamy sand LL : — PL : — PI : —

SIEVE ANALYSIS-

SAMPLE WEIGHT: 147.99 GRAMS

SIEVE SIZE	WEIGHT RETAINED	PER CENT RETAINED	PER CENT PASSING
.75"	0.00	0.00	100.00
.5"	3.24	2.19	97.81
#4	2.87	1.94	95.87
#10	2.89	1.95	93.92
#16	4.39	2.97	90.95
#40	56.83	38.40	52.55
#60	57.70	38.99	13.56
#140	12.81	8.66	4.91
#200	1.26	0.85	4.05
#325	0.20	0.14	3.91

HYDROMETER ANALYSIS-

SAMPLE WEIGHT: 54.08 GRAMS
SOIL SPECIFIC GRAVITY:
ZERO HYDROMETER HEIGHT: 10.45
CORRECTION FACTOR: 5.5

ELAPSED TIME	TEMPERATURE	ACTUAL READING	ADJUST READING	GRAIN SIZE	PER CENT FINER
0.25	22.5	8.00	2.50	0.1043	4.40
0.50	22.5	8.00	2.50	0.0737	4.40
1.00	22.5	8.00	2.50	0.0521	4.40
5.00	22.5	8.00	2.50	0.0233	4.40
8.00	22.5	8.00	2.50	0.0184	4.40
15.00	22.5	8.00	2.50	0.0135	4.40
30.00	22.5	8.00	2.50	0.0095	4.40
60.00	22.5	7.50	2.00	0.0068	3.52
127.00	22.5	7.00	1.50	0.0047	2.64
1390.00	22.5	6.50	1.00	0.0014	1.76

SOIL TESTING SERVICES, INC.

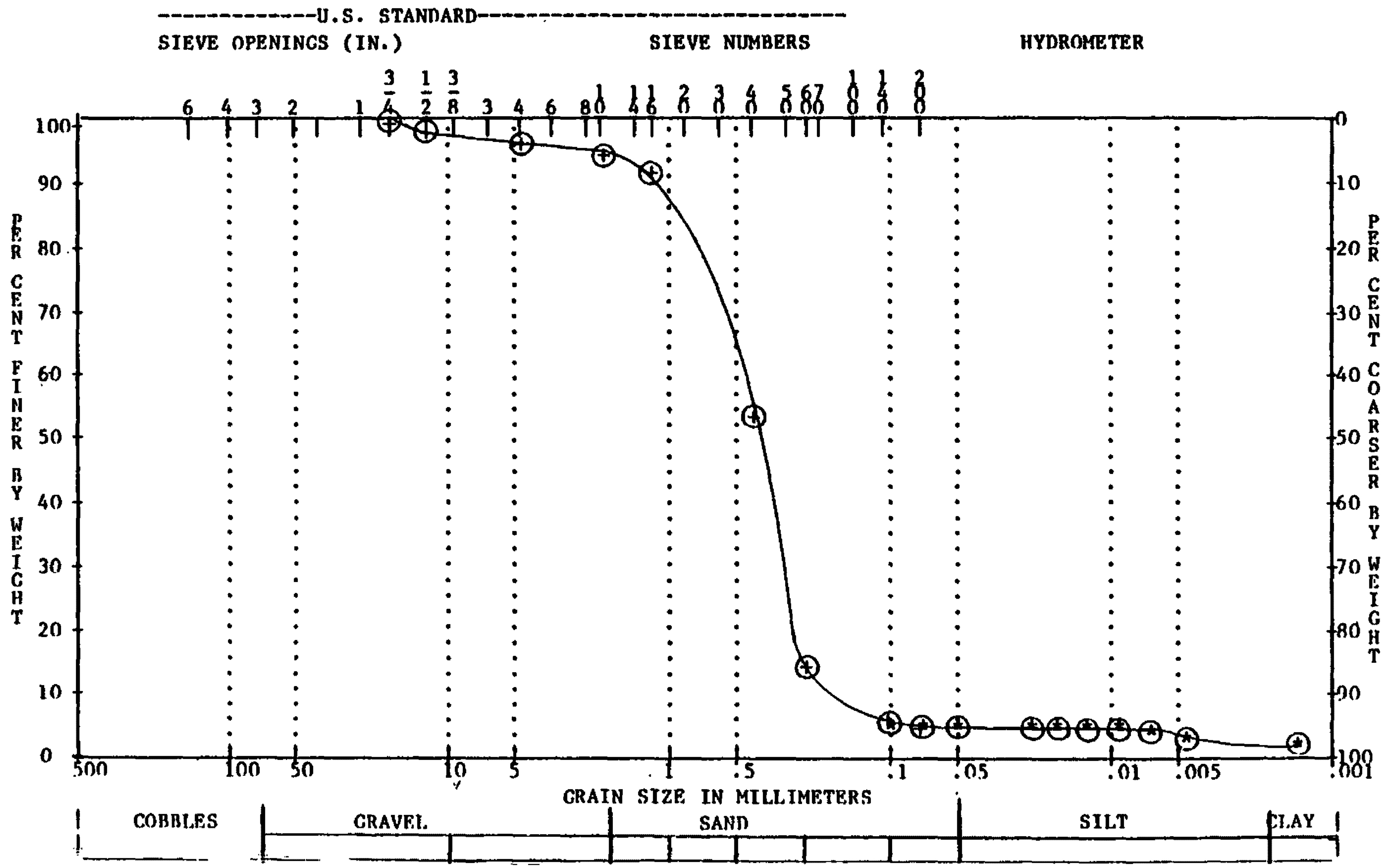
GRAIN SIZE DISTRIBUTION DATE: 1-19-82

BORING NO. : B-31 STS JOB NO.: 22561

SAMPLE NO. : 4 PROJECT : MOOSE LAKE WINDEMERE

DEPTH : 22.00-38.00 in. W/C: — SP.GR.: —

CLASSIFICATION: Omega loamy sand LL : — PL : — PI : —



SOIL TESTING SERVICES, INC.

GRAIN SIZE DISTRIBUTION . DATE: 1-19-82

BORING NO. : B-22T STS JOB NO.: 22561

SAMPLE NO. : 5 PROJECT : MOOSE LAKE WINDEMERE

DEPTH : 22.00-36.00 in. W/C: — SP.GR.: —

CLASSIFICATION: Duluth Loam #1 LL : — PL : — PI : —

SIEVE ANALYSIS-

SAMPLE WEIGHT: 86.79 GRAMS

SIEVE SIZE	WEIGHT RETAINED	PER CENT RETAINED	PER CENT PASSING
#4	0.00	0.00	100.00
#10	0.22	0.25	99.75
#16	0.23	0.27	99.48
#40	1.31	1.51	97.97
#60	4.21	4.85	93.12
#140	7.64	8.80	84.32
#200	2.49	2.87	81.45
#325	2.26	2.60	78.85

HYDROMETER ANALYSIS-

SAMPLE WEIGHT: 51.66 GRAMS
SOIL SPECIFIC GRAVITY:
ZERO HYDROMETER HEIGHT: 10.45
CORRECTION FACTOR: 5.5

ELAPSED TIME	TEMPERATURE	ACTUAL READING	ADJUST READING	GRAIN SIZE	PER CENT FINER
0.25	22.5	49.00	43.50	0.0737	82.23
0.50	22.5	47.50	42.00	0.0529	79.39
1.00	22.5	45.50	40.00	0.0381	75.61
5.00	22.5	42.50	37.00	0.0175	69.94
8.00	22.5	41.50	36.00	0.0140	68.05
15.00	22.5	40.00	34.50	0.0103	65.21
30.00	22.5	38.00	32.50	0.0074	61.43
60.00	22.5	35.50	30.00	0.0054	56.71
120.00	22.5	33.00	27.50	0.0039	51.98
1405.00	22.5	25.00	19.50	0.0012	36.86

SOIL TESTING SERVICES, INC.

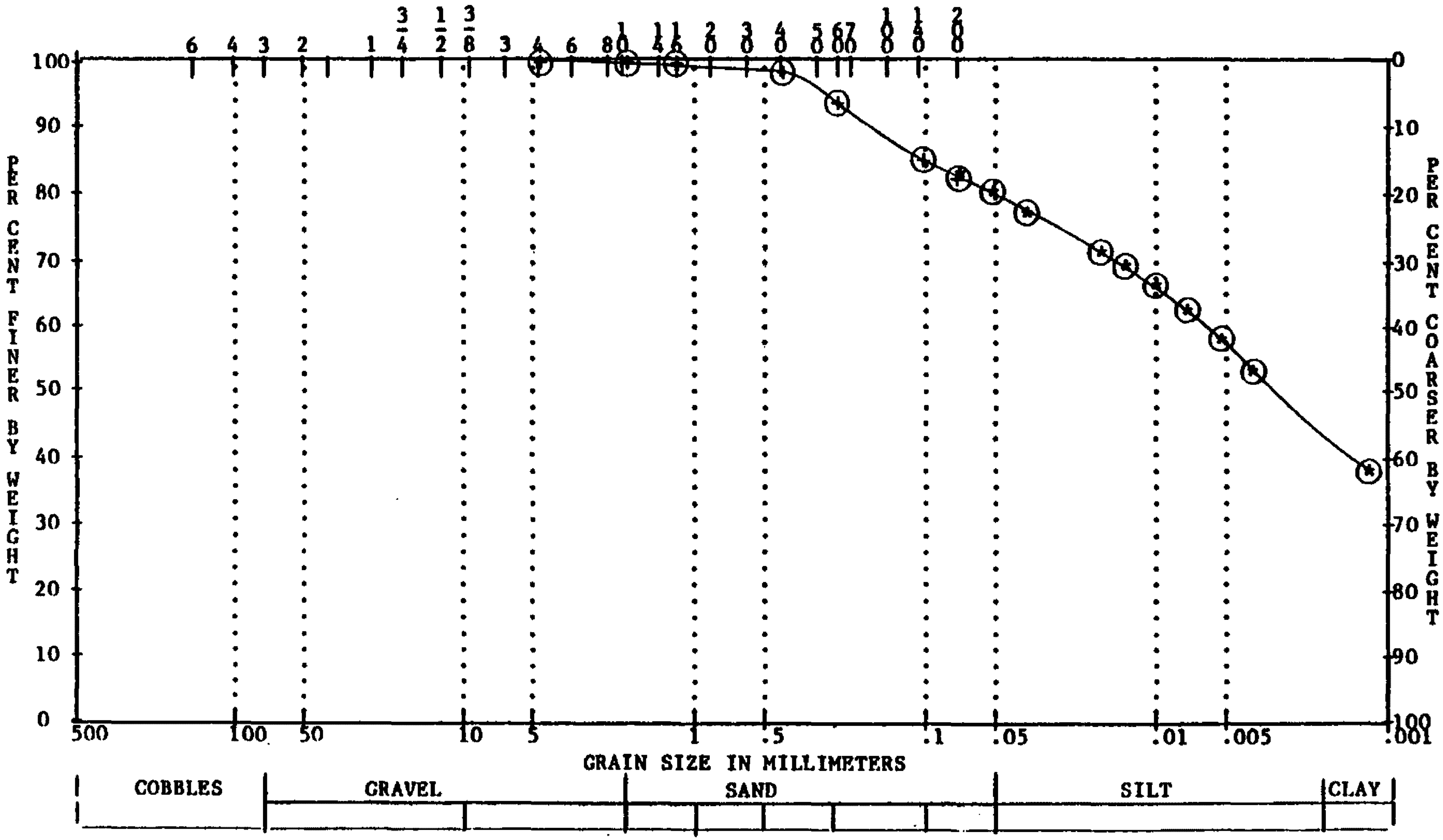
GRAIN SIZE DISTRIBUTION — DATE: 1-19-82

BORING NO. : B-22T — STS JOB NO.: 22561

SAMPLE NO. : 5 — PROJECT : MOOSE LAKE WINDEMERE

DEPTH : 22.00-36.00 in. — W/C: — — SP.GR.: —

CLASSIFICATION: Duluth loam #1 — LL : — PL : — PI : —



SOIL TESTING SERVICES, INC.

GRAIN SIZE DISTRIBUTION DATE: 1-19-82

BORING NO. : B-22T STS JOB NO.: 22561
SAMPLE NO. : 4 PROJECT : MOOSE LAKE WINDEMERE
DEPTH : 18.00 -38.00 in. W/C: — SP.GR.: —
CLASSIFICATION: Duluth Loam #2 LL : — PL : — PI : —

SIEVE ANALYSIS-

SAMPLE WEIGHT: 111.5 GRAMS

SIEVE SIZE	WEIGHT RETAINED	PER CENT RETAINED	PER CENT PASSING
#4	0.00	0.00	100.00
#10	0.69	0.62	99.38
#16	0.29	0.26	99.12
#40	1.27	1.14	97.98
#60	3.64	3.26	94.72
#140	6.43	5.77	88.95
#200	2.05	1.84	87.11
#325	2.21	1.98	85.13

HYDROMETER ANALYSIS-

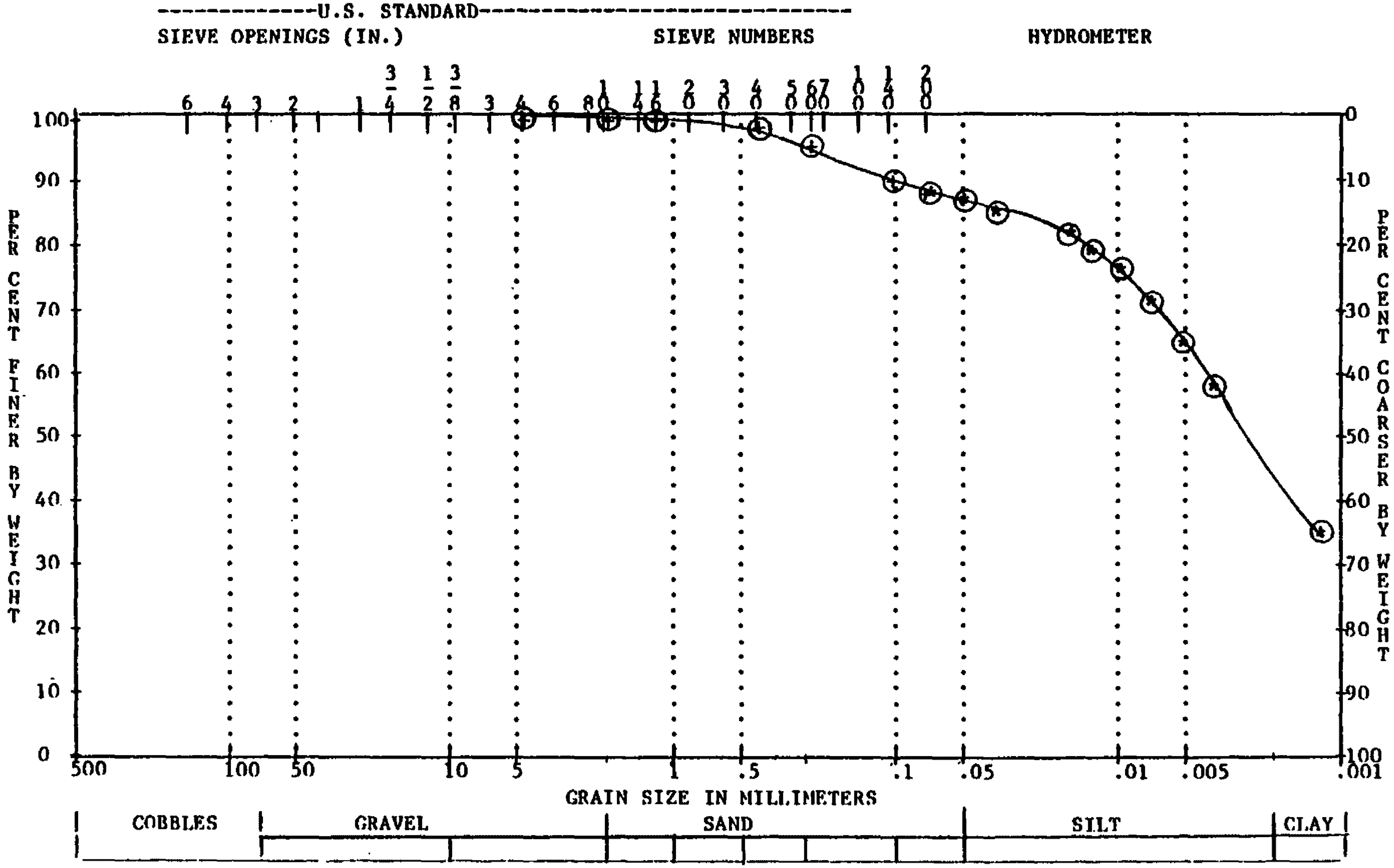
SAMPLE WEIGHT: 51.67 GRAMS
SOIL SPECIFIC GRAVITY:
ZERO HYDROMETER HEIGHT: 10.45
CORRECTION FACTOR: 5.5

ELAPSED TIME	TEMPERATURE	ACTUAL READING	ADJUST READING	GRAIN SIZE	PER CENT FINER
0.25	22.5	51.50	46.00	0.0724	87.17
0.50	22.5	51.00	45.50	0.0515	86.22
1.00	22.5	50.00	44.50	0.0368	84.32
5.00	22.5	48.00	42.50	0.0168	80.53
8.00	22.5	46.50	41.00	0.0135	77.69
15.00	22.5	45.00	39.50	0.0100	74.85
30.00	22.5	42.50	37.00	0.0072	70.11
63.00	22.5	39.00	33.50	0.0051	63.48
125.00	22.5	35.50	30.00	0.0037	56.85
1386.00	22.5	23.50	18.00	0.0012	34.11

SOIL TESTING SERVICES, INC.

GRAIN SIZE DISTRIBUTION DATE: 1-19-82

BORING NO. : B-22T		STS JOB NO.: 22561	
SAMPLE NO. : 4		PROJECT : MOOSE LAKE WINDEMERE	
DEPTH : 18.00 -38.00 in.	W/C: —		SP.GR.: —
CLASSIFICATION: Duluth Loam #2	LL : —	PL : —	PI : —



SOIL TESTING SERVICES, INC.

GRAIN SIZE DISTRIBUTION DATE: 1-19-82

BORING NO. : B-3 STS JOB NO.: 22561
SAMPLE NO. : 6 PROJECT : MOOSE LAKE WINDEMERE
DEPTH : 49.00-60.00 in. W/C: — SP.GR.: —
CLASSIFICATION: Duluth loam #2 LL : — PL : — PI : —

SIEVE ANALYSIS-

SAMPLE WEIGHT: 71.43 GRAMS

SIEVE SIZE	WEIGHT RETAINED	PER CENT RETAINED	PER CENT PASSING
#4	0.00	0.00	100.00
#10	0.17	0.24	99.76
#16	0.15	0.21	99.55
#40	0.52	0.73	98.82
#60	1.60	2.24	96.58
#140	3.15	4.41	92.17
#200	1.09	1.53	90.65
#325	1.40	1.96	88.69

HYDROMETER ANALYSIS-

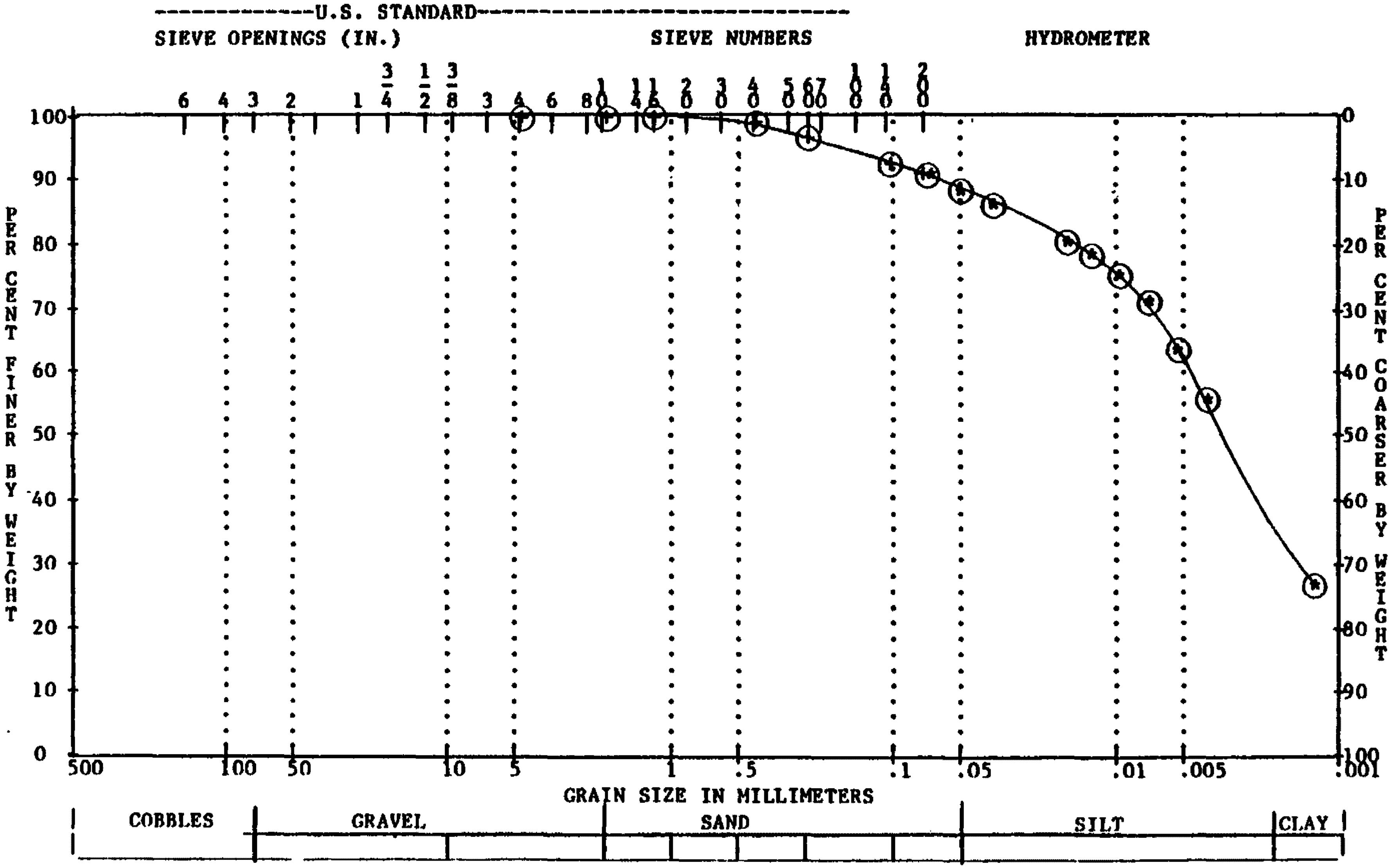
SAMPLE WEIGHT: 51 GRAMS
SOIL SPECIFIC GRAVITY:
ZERO HYDROMETER HEIGHT: 10.45
CORRECTION FACTOR: 5.5

ELAPSED TIME	TEMPERATURE	ACTUAL READING	ADJUST READING	GRAIN SIZE	PER CENT FINER
0.25	22.5	52.50	47.00	0.0710	90.01
0.50	22.5	51.00	45.50	0.0510	87.13
1.00	22.5	50.00	44.50	0.0365	85.22
5.00	22.5	47.00	41.50	0.0168	79.47
8.00	22.5	46.00	40.50	0.0134	77.56
15.00	22.5	44.00	38.50	0.0100	73.73
30.00	22.5	42.00	36.50	0.0072	69.90
60.00	22.5	38.00	32.50	0.0053	62.24
120.00	22.5	34.00	28.50	0.0038	54.58
1410.00	22.5	19.00	13.50	0.0012	25.85

SOIL TESTING SERVICES, INC.

GRAIN SIZE DISTRIBUTION DATE: 1-19-82

BORING NO. : B-3		STS JOB NO.: 22561	
SAMPLE NO. : 6		PROJECT : MOOSE LAKE WINDEMERE	
DEPTH : 49.00 -60.00 in.		W/C: —	SP.GR.: —
CLASSIFICATION: Duluth loam #2		LL : — PL : —	PI : —



Appendix B-4.

SUMMARY AND INTERPRETATION OF SOILS INFORMATION

B-4.1. Soil Types

Each soil association (Section 2.2.1.) contains a number of soil types. A brief description of the eleven identified soil types follows, including a discussion of the topography, drainage properties (Figure B-1), and other characteristics of the area's soils in relation to the suitability for conventional soil absorption systems (Table B-1). No assessment is made of the suitability of the area's soils for "innovative" or unconventional on-site waste treatment systems.

DRAINAGE CLASS

- *Excessively drained.*—Water is removed from the soil very rapidly. Excessively drained soils are commonly very coarse textured, rocky, or shallow. Some are steep. All are free of the mottling related to wetness.
- *Somewhat excessively drained.*—Water is removed from the soil rapidly. Many somewhat excessively drained soils are sandy and rapidly pervious. Some are shallow. Some are so steep that much of the water they receive is lost as runoff. All are free of the mottling related to wetness.
- *Well drained.*—Water is removed from the soil readily, but not rapidly. It is available to plants throughout most of the growing season, and wetness does not inhibit growth of roots for significant periods during most growing seasons. Well drained soils are commonly medium textured. They are mainly free of mottling.
- *Moderately well drained.*—Water is removed from the soil somewhat slowly during some periods. Moderately well drained soils are wet for only a short time during the growing season, but periodically for long enough that most mesophytic crops are affected. They commonly have a slowly pervious layer within or directly below the solum, or periodically receive high rainfall, or both.
- *Somewhat poorly drained.*—Water is removed slowly enough that the soil is wet for significant periods during the growing season. Wetness markedly restricts the growth of mesophytic crops unless artificial drainage is provided. Somewhat poorly drained soils commonly have a slowly pervious layer, a high water table, additional water from seepage, nearly continuous rainfall, or a combination of these.
- *Poorly drained.*—Water is removed so slowly that the soil is saturated periodically during the growing season or remains wet for long periods. Free water is commonly at or near the surface for long enough during the growing season that most mesophytic crops cannot be grown unless the soil is artificially drained. The soil is not continuously saturated in layers directly below plow depth. Poor drainage results from a high water table, a slowly pervious layer within the profile, seepage, nearly continuous rainfall, or a combination of these.
- *Very poorly drained.*—Water is removed from the soil so slowly that free water remains at or on the surface during most of the growing season. Unless the soil is artificially drained, most mesophytic crops cannot be grown. Very poorly drained soils are commonly level or depressed and are frequently ponded. Yet, where rainfall is high and nearly continuous, they can have moderate or high slope gradients, as for example in "hillpeats" and "climatic moors."

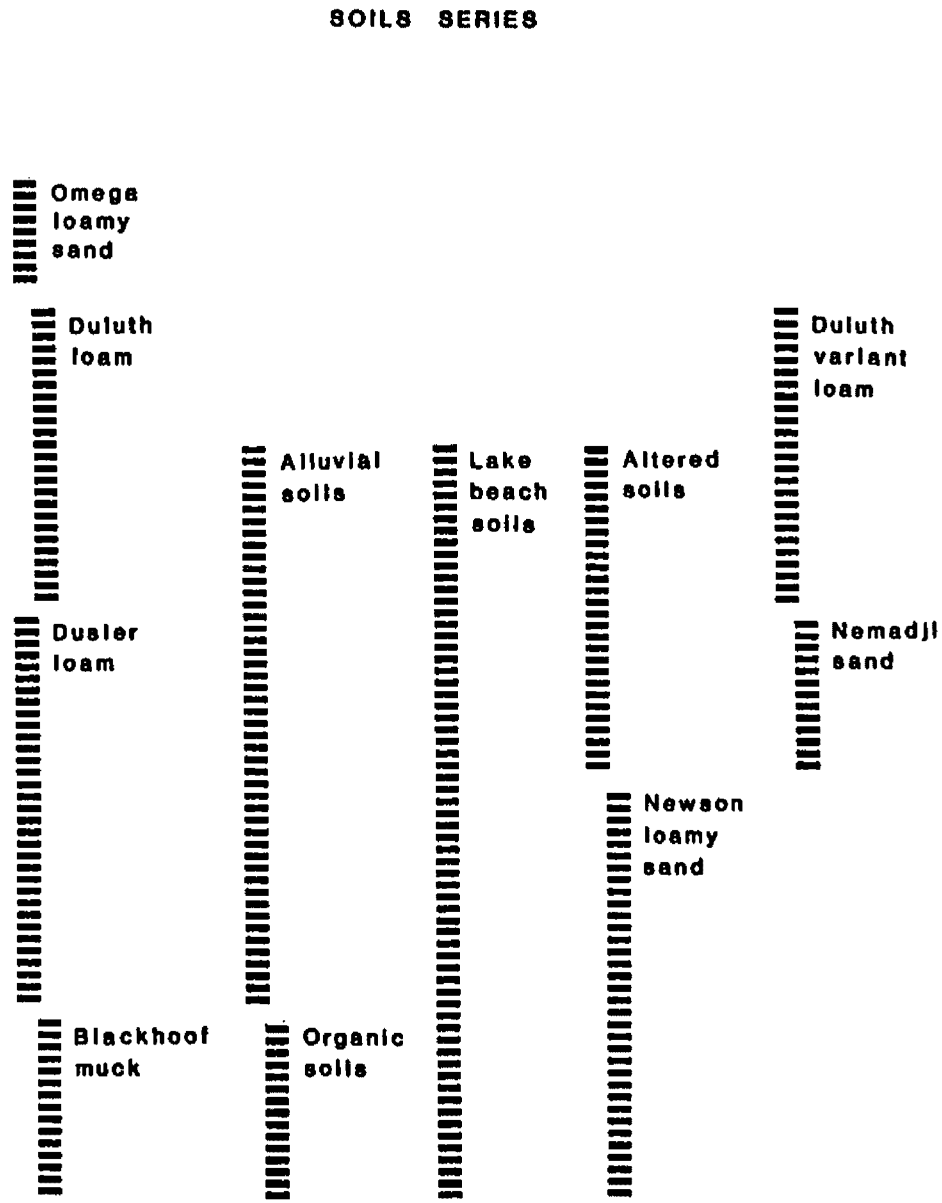


Figure B-1. Drainage class ranges of soils in a portion of Windemere Township. Derived from Finney (1981) and SCS (1978).

Table B-1. Soil series characteristics and soil absorption system ratings for soils in the surveyed portion of Windemere Township (Finney 1981; SCS 1978).

Predominant Substratum	SCS Soil Name and Mapping Symbol		Slope Range (percent)	Surface Texture	Substratum Texture	Depth to Water Table	Permeability Range (inches/hour)	SCS Rating Soil Absorption Systems[a]
Loam								
	Duluth	504B	1-4	loam	loam	72"	0.06-0.20 (13"), 0.20-0.60 (64")	Severe; sp
		504C	4-15	"	"	72"	" "	Severe; sp
		504E	15-60	"	"	72"	" "	Severe; sl, sp
	Duluth Variant[b]	1350B	1-4	loamy sand	clay loam	72"	6.00-20.00 (20"), 0.20-0.60 (52")	-
		1350C		"	"	72"	" "	-
	Dusler	502	0-2	loam	clay loam	12"-48"	0.60-2.00 (12"), 0.20-0.60 (42")	Severe, sp
	Blackhoof	614	0-1	mucky silt loam	silt loam	0-12"	0.06 (5"), 0.06-0.20 (48")	Severe; shwt
Sand or Gravelly Sand								
	Omega	188B	0-5	sand	coarse sand	72"	6.00-20.00 (22"), 6.00-20.00 (60")	Slight[c]
		188C	5-50	"	"	72"	" "	Severe; sl[c]
		188E	20-60	"	"	72"	" "	Severe; sl[c]
	Nemadji	186	0-2	sand	sand	18"-48"	6.00-20.00 (11"), 6.00-20.00 (55")	Severe; shwt
	Newson	274	0-1	loamy sand	"	12"	0.60-0.20 (22"), 6.00-20.00 (65")	Severe; shwt
	Lake Beaches[b]	1032	0-2	sand	coarse sand	12"-36"	6.00-20.00 (21"), 6.00-20.00 (60")	-
Other								
	Organic	995	0-2	mucky peat	mucky peat	12"	0.60-2.00 (22"), 0.60 - 2.00 (65")	-
	Alluvial	1002	0-1	-	-	Occasional flooding	variable	-
	Altered	1016	-	mostly loam	mostly loam	variable	mostly 0.06-0.20	-

[a] Ratings abbreviations for soil absorption systems are: sp - slow permeability, sl - slope, shwt - shallow high water table.

[b] These soils series were identified during the soils survey of the project area, but have not yet been recognized by the Minnesota Co-operative Soils Survey.

[c] Rapid permeability represents potential hazard to groundwater supplies if pollution is present.

Loamy Soils

Soils with loamy substrata predominate in the northern half of the surveyed area. The loamy soils identified in the survey include the Duluth, Duluth Variant, Dusler, and Blackhoff series.

Duluth Loam

The Duluth series consists of gently undulating to very steep, moderately well and well drained, moderately slow and slowly permeable soils that formed mostly in loamy calcareous glacial till on glacial moraines. They mostly have convex slopes, but they may also have linear or concave slopes on the lower parts of some steep and very steep slopes.

The SCS rates Duluth soil as having "severe" limitations to soil absorption systems use because of its relatively slow permeability. Duluth soil can accommodate a soil absorption system under certain conditions if the design is appropriate. However, on sites with steep slopes, or with lot size constraints or with low soil permeabilities, unconventional designs for soil absorption systems may have to be used to obtain satisfactory performances.

It is estimated that approximately 60% of the platted lakeshore lot area around Island Lake is mapped as Duluth soil. Most of the platted areas with Duluth soil are found along the south shore of the Lake. Duluth soil is also common along the north half of Sturgeon Lake, covering approximately 40% of its platted lakeshore lot area. Duluth soil was not mapped in significant amounts around the platted shoreline areas of Rush and Passenger lakes.

Duluth Variant

Duluth Variant soil consists of gently sloping and sloping, moderately well and well drained, moderately slow and slowly permeable soils that were formed in a 20- to 40-inch thick mantle of sandy glacial outwash material and in underlying loamy calcareous glacial till on glacial moraines. These soils may have both convex and linear slopes.

As was discussed in Section 2.2.1., Duluth Variant soils are found in the transition area between the two major soil associations. The upper horizons of the Duluth Variant soil have a rapid permeability. Thus, septic tank effluent absorption systems constructed in adequate depths of this upper horizon should function satisfactorily. Duluth Variant has not been formally recognized as a named soil series by the Cooperative Soil Survey of Minnesota. Therefore, no SCS rating for soil absorption system operation is available.

Duluth Variant soil is primarily found at some distance from the lakeshore away from existing development within the surveyed area. Although common in the surveyed area, Duluth Variant soil was mapped on only approximately 10% of the platted lakeshore lot area around Island Lake, and on approximately 5% of the platted area around Sturgeon Lake. Duluth Variant soil is uncommon in the vicinity of Rush and Passenger lakes.

Dusler Loam and Blackhoof Muck

Dusler soil consists of nearly level, somewhat poorly and poorly drained, slowly permeable soils that were formed mostly in loamy calcareous glacial till. This soil has slightly convex to slightly concave slopes on glacial moraines.

Blackhoof soil consists of a nearly level, very poorly drained, slowly to very slowly permeable soil that was formed in a thin mantle of organic soil and in underlying loamy glacial till or in old aluvium or both. This soil has concave or linear slopes and is found in depressions and drainage ways on glacial moraines.

Dusler and Blackhoof soils both have "severe" soil absorption system ratings according to the SCS. Although Dusler soil has a permeability similar to Duluth soil, septic systems are still more difficult to operate in Dusler soil because Dusler soil is often poorly drained. In addition to having low permeability, Blackhoof soil also has the water table within one foot of the land surface. Therefore, conventional soil absorption systems will not function properly in Blackhoof soil.

Dusler and Blackhoof soils each are mapped on approximately 3% percent of the platted lakeshore lot area around Island Lake, mostly in areas along the northwest shoreline. Dusler and Blackhoof soils are uncommon on platted lakeshore lots around Sturgeon, Rush, or Passenger lakes. However, relatively large areas of these soils are found adjacent to platted lots along the northwest shore of Sturgeon Lake.

Sandy Soils

Soils with sandy substrata predominate in the southern half of the surveyed area. The sandy soils identified in the survey are the Omega, Nemadji, and Newson series. A special classification termed Lake Beach soil was also made in the southern portion of the surveyed area.

Omega Loamy Sand

The Omega series consists of nearly level to very steep, somewhat excessively drained, rapidly permeable soils that were formed from sandy glacial outwash materials. These soils have convex to concave slopes on glacial outwash plains and moraines.

Septic tank absorption systems operate very well in Omega soil. However, the SCS rates Omega soil as having severe limitations for soil absorbtion systems because this soil may occasionally have excessive drainage (high permeability). This rating is due to the potential for wastewater to pass through Omega soils too quickly for proper treatment to occur, thereby causing adjacent wells to become contaminated. The chances of such contamination occuring can be minimized by not locating absorption fields on Omega soils dominated by very coarse sand or by replacing the coarse sand by fine sand or loam.

Omega loamy sand is the predominant soil in the southern half of the survey area. Around Island Lake approximately 8% of the platted lakeshore lot area is mapped as Omega soil, while Omega covers approximately 20% of the platted shore area of Sturgeon Lake. The estimated proportion of Omega soil mapped on the platted lakeshore lot area around Rush and Passenger lakes is much higher; 85% and 50% respectively.

Nemadji Loamy Sand and Newson Mucky Sandy Loam

The Nemadji series consists of nearly level, somewhat poorly drained, rapidly permeable soils that were formed in sandy glacial outwash materials. These soils have slightly convex to slightly concave slopes on glacial outwash plains.

The Newson series consists of nearly level, poorly and very poorly drained, rapidly permeable soils that were formed mostly from sandy glacial outwash materials. These soils have linear to concave slopes located on glacial outwash plains.

Nemadji and Newson soils are rated by SCS as having "severe" limitations for the operation of septic tank absorption systems because of poor drainage and the presence of a high water table. There is little that can be done to engineer conventional absorption systems to work properly in these two soils unless the drainage characteristics of a site can be physically altered.

Nemadji and Newson soils are mapped on a small proportion of the total surveyed area and a small proportion (approximately 1%) of the platted lakeshore lot area around Island Lake. A small proportion of the land area with platted lots around Sturgeon Lake also is mapped as Nemadji soil; Newson soil was not found near Sturgeon Lake. Nemadji and Newson soils were not mapped in significant areas around Rush and Passenger lakes.

Lake Beach

Lake Beach soil consists of a nearly level, very poorly to moderately well drained, moderately to rapidly permeable soil that was formed in recent to rather old sandy deposits adjacent to lakes. The formation of this soil resulted from the action of water and ice and the higher lying parts of this soil are a result of historically higher lake levels.

Lake Beach soil has not been formally recognized by the Minnesota Cooperative Soil Survey, and therefore it has no SCS soil absorption system limitation rating. The characteristics of Lake Beach soil relative to the operation of septic tank absorption systems may vary considerably from site to site. It can be stated however, that on Lake Beach soil with good drainage, an absorption system will probably operate well from the standpoint of percolation. It is estimated that Lake Beach soil is mapped on roughly 20% of the platted lakeshore lot area around Sturgeon Lake, 10% of the platted area around Rush Lake, and 50% around Passenger Lake. Lakes Beach soil is uncommon along the shores of Island Lake.

Other Soils

Three miscellaneous soil types also were identified during the soil survey. Organic soil is the major type in this category. Small areas of Altered and Alluvial soils also were identified.

Organic Soil

Organic soil consists of very poorly drained, nearly level soil with slow to moderately rapid permeability. It is formed from the slightly to highly decomposed remains of a variety of plants. Organic soil was found primarily in depressions on glacial moraines and outwash plains. Some of these depressions were formerly small lakes.

Soil absorption systems will not operate properly in Organic soil due to poor drainage and the presence of a high water table. Because Organic soils also possess significant limitations to construction, very few dwellings are located on this soil inside the surveyed area.

Organic soil is mapped on approximately 20% of the total surveyed area, but is mapped on less that 5% of the platted lakeshore lot area around each of the four lakes. Large areas of Organic soil are found in the wetlands to the northwest of Sturgeon Lake (surrounding a 100 to 120 acre bog), and in a 60 acre wetland immediately adjacent to the northeast shore of Rush Lake.

Altered and Alluvial Soils

Altered soil was identified in the soil survey where natural soils had been altered by cutting and filling. Most altered soils were found adjacent to the lakeshore in or near areas of Duluth soils, in the northern portion of the surveyed area. Altered soils may exhibit a range of absorption system performances depending on the degree of compaction and the nature of the fill materials. Altered soils are mapped on less than 5% of the platted lakeshore lot area around both Island and Sturgeon Lakes. No Altered soils were identified around Rush and Passenger lakes.

Alluvial soil consists of sandy and loamy soils that were formed in alluvium (material deposited by rivers). Such soil is usually flooded one or more times each year, and if this is the case would not provide an acceptable site medium for soil absorption systems. Although limited areas having Alluvial soil were identified in the soil survey, this soil was not found in significant amounts on the platted lakeshore lot areas.

B-4.2. Soil Texture

The SCS Soil Survey of Carlton County, Minnesota (1978) contains particle size distribution (texture) data for many soils of the same series found in the surveyed area. Particle size distributions were measured for six representative soils sampled in the surveyed area in order to ensure that the textural classifications were consistent with the classifications made for Carlton County. Any significant differences in soil texture will be considered in the development of wastewater management alternatives.

Testing Methodology

Soil particles are the discrete units which make up the solid portion of soils. The relative proportions of the different sized particles of a soil are relatively stable and can be used as a basis to determine the agricultural and engineering properties of particular soils. When quantified, the proportions of these particles are termed 'particle size distributions'.

Particle size distributions are commonly represented by the relative mass proportions (percentage by weight) of soil particles less than or equal to a given particle diameter. The proportions are measured by physical fractionation procedures, usually in a two step process. To fractionate the larger diameter soil particles, a soil sample is passed through a series of sieves with decreasing mesh sizes, each sieve successively letting soil particles pass through the mesh openings of known diameter. The fractions of clay and silt are then measured by mixing what has passed through the smallest sieve size with water and measuring the change in the density of the water over time as the suspended particles settle. The rate of change in density is related to the size of the particles by an empirical mathematical relationship.

Comparison of Sample Testing Results with Regional Soil Survey Data

Particle size distributions reported in the SCS Carlton County Soil Survey were compared to the analytical results for six Pine County soil samples (Table B-2). The Pine County soil samples were found to have particle size distributions which indicate a somewhat finer texture of soils than those reported for the same soil types in the Carleton County Soil Survey. In the loamy soils examined, the percent of material passing through a number 200 seive (all the clay, silt and part of the very fine sand) exceeded the upper limit of the estimated range presented in the Carlton County survey. Based on these results, it was concluded that the Duluth and Dusler soils in the project area are more silty and clayey in texture than those in Carlton County, and thus could pose greater constraints to the design of soil absorption systems.

The particle size distribution data can be further analyzed to determine whether the observed fraction of fine particles would actually limit the use of septic tank absorption fields in the surveyed area. The hydrometer tests that were performed on the portion of the soil sample which passed through the smallest mesh size can be used to distinguish the percent clay and the percent silt of the sample (by weight). The remainder is made up of sand of varying size distributions. The individual clay, silt, and sand fractions of each sample can then be interrelated to classify the

Table B-2. Comparison of particle size distribution data from the Carlton County Soil Survey (SCS 1978) with particle size distribution data obtained from testing soil samples taken during the soil survey of a portion of Windemere Township (Finney 1981).

Soil Type	Horizon	Depth of sample	Percent of sample passing #4 sieve (4.7mm)		Percent of sample passing #10 sieve (2.0mm)		Percent of sample passing #40 sieve (0.42mm)		Percent of sample passing #200 sieve (0.074mm)	
			Carlton Cty.	Windemere Tn.	Carlton Cty.	Windemere Tn.	Carlton Cty.	Windemere Tn.	Carlton Cty.	Windemere Tn.
[1]Duluth Loam	B22t	22"-36"	95 - 100	100	85 - 98	100	85 - 95	98	55 - 75	81
[2]Duluth Loam	B22t	18"-38"	95 - 100	100	85 - 98	99	85 - 95	98	55 - 75	87
[3]Duluth Loam	B3	49"-60"	95 - 100	100	85 - 98	100	85 - 95	99	55 - 75	91
[4]Duluth Variant	IIB3	52"-60"	--------	99	-------	99	-------	97	-------	82
[5]Dusler Loam	B21t	17"-28"	95 - 100	99	85 - 98	98	85 - 95	96	55 - 75	81
[6]Omega Loamy Sand	B31	22"-38"	95 - 100	96	90 - 100	94	70 - 90	53	2 - 10	4

[1]Sample taken near north shore of Island Lake.

[2,3]Sample taken near north shore of Sturgeon Lake.

[4]Sample taken near northwest shore of Sturgeon Lake. Not recognized as a soil series in the Carlton County Soil Survey published by the US Soil Conservation Service. Substratum of the Duluth Variant was observed to be similar in texture to Duluth Loam.

[5]Sample taken near northwest shore of Sturgeon Lake.

[6]Sample taken near west shore of Passenger Lake.

soil. These data are of interest because silt is much more hydraulically conductive than clay and the relative fractions of both must be known before it can be concluded that soils are tight enough to pose limitations for the use of septic absorption fields. In general, a high clay fraction indicates poor septic absorption field performance regardless of silt or sand content. Conversely, a high silt content indicates good septic leachate field performance if clay content is moderate to low. Additionally, the silt/clay fractions can be used to determine whether the clay and silt content is too low to provide adequate treatment of septic leachate.

The USDA (1980) definition of silt includes those soil particles within the diameter range of 0.002 millimeters to 0.05 millimeters. Using the particle size distribution graphs (Appendix B-3 to interpolate within these diameters the silt weight fraction can be determined. USDA defines clay as particles of less than 0.002 millimeters in diameter. The weight fraction of the material finer than this diameter also can be determined by interpolating from the graphs in Appendix A. The percent by weight of silt, clay, and sand in six soil samples were estimated and classified based on the above definitions (Table B-3). The soil textural classes presented in the soil survey (Appendix A) characterize only the surface horizon. Samples from deeper horizons must be analyzed and classified for the substratum. The six soil samples tested for this report were from horizons which ranged from 17 to 60 inches in depth. These horizons are being classified because soil characteristics at that depth range are important to the performance of septic absorption fields. The silt, clay, and sand fractions for the six samples were plotted on the Textural Triangle presented in Figure B-2 and the resultant substratum classifications were compared with the descriptions of those horizons which were made in the field (Table B-3).

Comparison of the six substratum classifications with descriptions made in the field indicates that the soils of the Duluth and Dusler series which were mapped in Windemere Township had higher than expected clay content at depth. Additionally, the relatively fine texture of these sampled horizons as compared to similar horizons reported in the Carlton County Soil Survey appears to be a result of the high clay content and not a

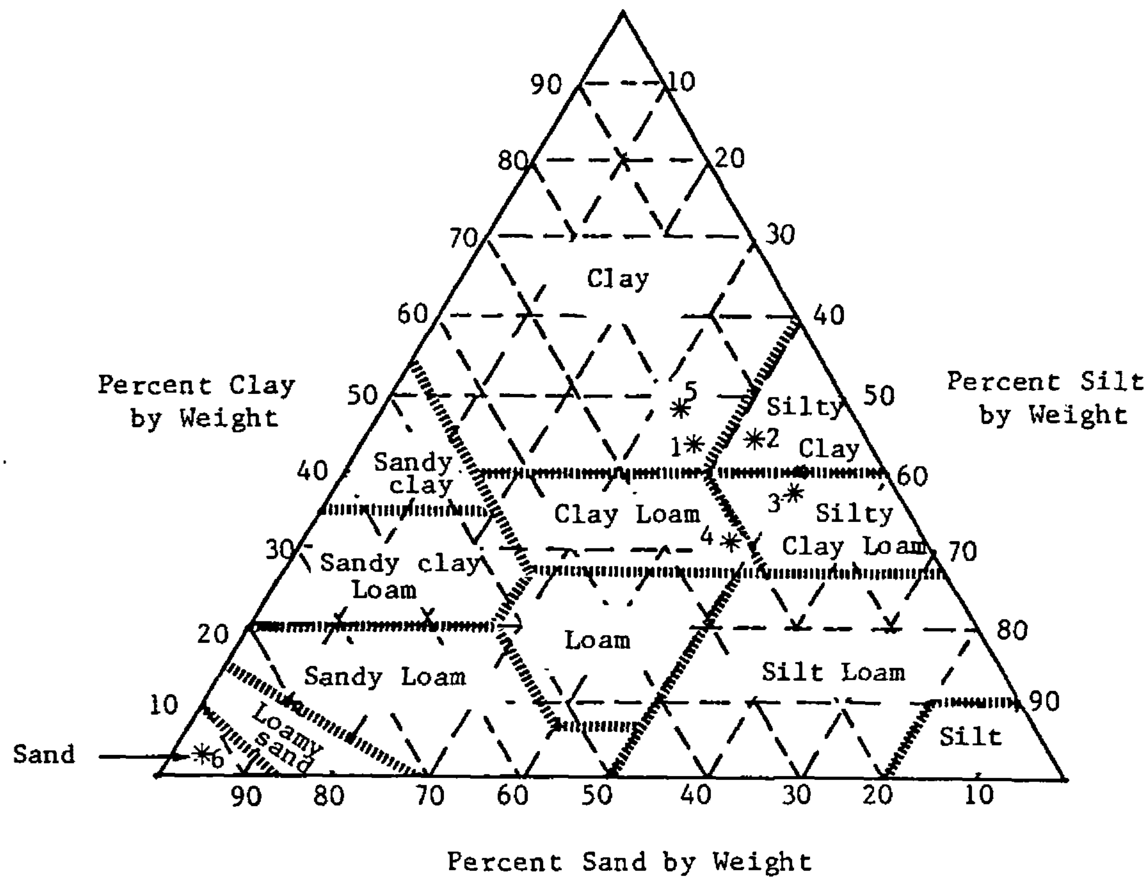
Table B-3 Comparison of textural classifications for soil samples taken during the soil survey of a portion of Windemere Township.

#	Soil Sample	Horizon	Weight Fractions by Percent Silt	Clay	Sand	[1] Description of the Sample Based on Field Observation	[2] Textural Classification of the Sample Based on Weight Fraction by %
1	Duluth loam	B22t 22"-36"	37%	43%	20%	loam, near clay loam	clay
2	Duluth loam	B22t 18"-38"	43%	44%	13%	loam, near clay loam	silty clay
3	Duluth loam	B3 49"-60"	51%	37%	12%	loam	silty clay loam
4	Duluth variant loamy find sand	IIB3 52"-60"	48%	31%	21%	clay loam, near loam	clay loam
5	Dusler loam	B21t 17"-28"	33%	48%	19%	clay loam	clay
6	Omega sandy loam	B31 22"-38"	3%	2%	95%	sand and coarse sand	sand

[1] Samples of the various horizons were examined in the field and the classifications reported on in the soil survey by Finney (1981).

[2] Textural classifications were made based on the weight fractions of silt, clay, and sand as determined from particle size distribution data and based on application of the weight fraction data to the Textural Triangle as developed by USDA (1962).

Figure B-2. Textural triangle of soil particle fractions for the classification of soil samples. Sample locations are indicated by an asterix. Textural triangle is from USDA references (1962).



Sample 1; Duluth loam, 22"-36", B22t
Sample 2; Duluth loam, 18"-38", B22t
Sample 3; Duluth loam, 49"-60", B3
Sample 4; Duluth variant, 52"-60", IIB3
Sample 5; Dusler loam; 17"-28", B21t
Sample 6; Omega loamy sand, 22"-38", B31

→ See Table B-3 for classifications

result of high silt content (except in the Duluth Variant loamy fine sand sample where no comparison is possible).

The degree to which the six substratum samples represent all comparable horizons on the mapped areas of Duluth and Dusler soils has not been established. It appears, however, that substratum textural limitations to the use of septic absorption fields in the surveyed portion of Windermere Township may be more restrictive than would be expected based on typical soils classification definitions.

Appendix C

C-1. Methods and Results of the Septic Leachate Survey.

C-2. Well Testing Data

Appendix C-1.

METHODS AND RESULTS OF THE SEPTIC LEACHATE SURVEY

Methods

The Septic Leachate Detector System's operational functions are outlined in the following description, excerpted from the manufacturer's operations manual:

- The ENDECO Type 2100 Septic Leachate Detector System is a portable field instrument that monitors two parameters; fluorescence (organic channel) and conductivity (inorganic channel). The system is based on a stable relationship between fluorescence and conductivity in typical leachate outfalls. Readings for each channel appear visually on panel meters while the information is recorded on a self-contained strip chart recorder. Recording modes are selectable between individual channel outputs or a combined output. The combined output is the arithmetic result of an analog computer circuit that sums the two channels and compares the resultant signal against the background to which the instrument was calibrated. The resultant output is expressed as a percentage of the background. Also, the combined recorded output is automatically adjusted for slow background changes. The system can be operated from a small boat enabling an operator to continuously scan an expansive shoreline at walking pace and, through real time feedback, effectively limit the need for discrete grab samples to areas showing high probability of effluent leaching. Expensive laboratory time for detailed nutrient analysis is greatly reduced while survey accuracy is increased substantially...

- The Septic Leachate Detector System consists of the subsurface probe, the water intake system, the logic analyzer control unit, panel meters and the strip chart recorder...

- The probe/wand is submerged along the shoreline. Background water plus groundwater seeping through the shore bottom is drawn into the subsurface intake of the probe and is lifted upwards to the analyzer unit by a battery operated, submersible pump...

- Upon entering the analyzer unit the solution first passes through the fluorometer's optical chamber where a continuous measurement is made of the solution's narrow band response to UV excitation. The solution then flows through a conductivity measurement cell. An electrode-type conductivity/thermistor probe continuously determines the solution's conductivity. The solution exits the conductivity cell directly to the discharge where discrete samples may be collected if indicated by the response of the leachate detector. Both parameters are continuously displayed on separate panel meters. Zero controls are provided for both parameters (organic and inorganic) to enable "dialing out" the background characteristics to provide maximum sensitivity, as well as enhancing the response caused by a suspected abnormality. Span controls are also provided to control the sensitivity for each parameter separately during instrument calibration...

- The signals generated and displayed on the panel meters are also sent to an arithmetic/comparator analog computer circuit designed to detect changes in the ratio of organics and inorganics typical of septic leachate. The output of this circuitry is recorded continuously on a strip chart and is the key indicator of a suspected leachate outfall. However, isolated increases in either parameter may be cause for concern and should be sampled for analysis for other potential forms of nutrient pollution.

The magnitude of the signal outputs and of the synthesized "combined output" when detecting an effluent plume is subject to many non-instrumental factors related to variable dilution of effluents in lake water. Interference with the survey could potentially be caused by overland or sub-surface flow of water bearing large amounts of organic substances such as would be the case with barnyard runoff or with water moving out of a bog or marsh. Additionally, rapidly changing wind conditions may change the ambient water quality of the lake by introducing waters from the deeper zones of the lake which also contain large amounts of organic substances. Therefore, detailed field notes and subsequent map analysis of recorded data are necessary parts of the survey design. Expert interpretive analysis is required to deduce the significance of an increase in instrument signal output under such changing conditions.

The Septic Leachate Survey of Island, Sturgeon, Rush, and Passenger lakes was completed during the period of 2-9 October 1981. The survey covered the developed shorelines of Sturgeon, Island, Rush, and Passenger lakes and was conducted from a 12 foot boat with a 20 horsepower outboard motor. The boat was operated at its lowest speed (approximately 0.5 to 1 mph) as near as possible to the shore. An electrically powered trolling motor was used in waters too shallow for the outboard motor. Dense colonies of emergent aquatic plants occasionally prevented scanning along a course closely parallel with the shoreline. Paths leading through these dense stands to mooring areas near houses were utilized to approach the shore for surveying such areas. Sampling was always performed as close as possible to the shoreline to minimize the effects of dilution and wave/current disruption of emergent effluent plumes.

During scans the detector's meters were adjusted to maximum sensitivity. Adjusting the meters to maximum sensitivity requires a greater emphasis on operator real-time interpretation of recorded signals, but also increases the likelihood of detection of effluent plumes.

During most scans the instrument was set to record data on the combined signal output mode. This setting provides automatic adjustment for changing background levels of fluorescence or conductivity, but still records the short-term increases indicative of localized sources such as effluent plumes. It also permits the operator to pay greater attention to observing possible sources and to recording observations. Prior to scanning the shoreline, the instrument was calibrated by recording fluorescence along a transect to mid-lake (no signal expected above background) and along a developed shoreline (varying signals expected). These calibration checks enable the instrument to be used throughout the entire lake without futher adjustment, and thus allows relative comparisons to be made between plume readings.

One particularly useful feature of the Septic Leachate Detector for sample collection is the nearly instantaneous flow-through and signal recording of water samples. This feature provides for precise location of a plume's center and recording of the sample's fluorescence or combined signal as it is being collected. After effluent plumes were located, water quality samples were collected from the meter's discharge. In the laboratory these samples were analyzed for:

- Nitrate, nitrite, and ammonia nitrogen
- Total phosphorus, pH, alkalinity, and Methylene Blue Active Substances
- Fecal coliform bacteria concentration.

For most samples, analysis of all parameters except fecal coliform bacteria was begun within 24 hours at the WAPORA, Inc. Cincinnati laboratory. One group of samples arrived 3 days late at the lab, exceeding the recommended holding time. Although the recommended time was exceeded, this delay is not expected to have altered the levels of total nitrogen and total phosphorus measured in the samples. Analyses of fecal coliform samples were begun within 6 hours of collection at ERA Laboratories, Inc., in Duluth, Minnesota.

Selection of suspected wastewater plumes for sampling was a field decision weighed in favor of the most concentrated plumes and intended to identify those shoreline areas most seriously affected by the influx of septic leachate.

Results of the Septic Leachate Survey

Two sources of positive instrument readings were detected during the leachate survey: streams and suspected wastewater plumes. The locations of these sources are shown in Figures 2-6, 2-7, 2-8, and 2-9. A positive instrument reading was recorded when, in the judgement of the operator, there was a significant and simultaneous increase in the flouescence and conductivity readings.

Streams

A single runoff water source was found to be discharging into Rush Lake. No runoff water sources were found discharging into Passenger Lake. The two tributaries of Island Lake produced positive combined signals on the leachate detector. Intermittent localized stormwater runoff sources to Island Lake and Sturgeon Lake also produced positive responses. These positive signals were always generated by rapid increases in fluorescence accompanied by relatively lessor increases in conductivity. The highest such readings recorded were generated by runoff waters entering Sturgeon Lake from a long narrow wetland, the mouth of which is located between groundwater flow stations 24 and 43. These high readings appeared to be caused by the flourescent products of vegetative decay which were being released from the wetland. Runoff or stream sources of dissolved organic matter, because of their considerable volume, are not as readily diluted by lake water as are septic leachate plumes and therefore may cause interference problems in locating nearby septic leachate plumes. High flourescence and conductivity readings resulting from stream sources caused interference difficulties with effluent plume data along the north shore of Island Lake and near the public launch on the north shore of Sturgeon Lake.

Wave action and currents also may cause localized variations in flourescence sometimes resulting in a natural pattern resembling closely spaced septic plumes. Misinterpretation from this interference source was avoided by observing the uniformity of conductivity measurements and spacing of lakeshore development, then disregarding detector readings obviously caused by wave action patterns.

Suspected Wastewater Sources

All non-stream related localized variations in fluorescence and/or conductivity recorded by the leachate detector were initially assumed to be due to wastewater percolating into the lake from nearby on-site wastewater systems. Typically, such signals were highly localized (brief in duration and low in magnitude) compared to stream plumes. Along shorelines exposed to moderate wave action, the magnitude of these signals was generally less because of rapid dispersion by currents. Under calm conditions, the magnitude and duration of the signals tended to be greater because the plumes were less rapidly dispersed.

The number of potential effluent plumes identified by this survey were not evenly distributed around the lakes. Plume emergence appeared to be strongly controlled by factors such as land use, topography, and lakeshore groundwater flow patterns (Figures 2-6 through 2-9).

A total of 39 potential septic plumes were detected, which represents less than 10% of the residences along surveyed shorelines. During identification of the 17 suspected septic leachate plumes around Sturgeon Lake, the strengths of the instrument signals were lessened by the water currents created by the high winds prevailing at the time of the survey. Therefore, some additional weak or more transient plumes may not have been located on Sturgeon Lake due to these high winds.

Not all plumes located at seasonal residences were fully emergent because the survey was conducted during the first week of October when seasonal occupancy was low. On the other hand, a considerable amount of precipitation had preceded the survey and would have generally increased the lakeward flow of groundwater. Thus, while this survey may not have located the septic leachate plumes from all seasonal homes it probably did detect all lakeward moving plumes generated by permanent residences. Permanent residences with on-site systems have the greatest potential pollutional significance due to the fact that they contribute waste flows year round, whereas seasonal residences only do so for parts of the summer season.

Results of the Chemical and Bacterial Analyses

During the onshore portion of the septic leachate survey, background groundwater quality samples were gathered for comparison with groundwater samples taken directly from the centers of onshore effluent plumes. These data are presented in Tables C-1, C-2, and C-3.

One small discharge of runoff water was found entering into the north side of Rush Lake, but was not sampled. Analytical water quality results of influent stream samples collected near the perimeters of Island and Sturgeon Lakes are shown in Table C-1. These data indicate that incoming streams were not contaminated by septic leachate. The relatively high fecal coliform counts made in samples of the runoff and streamwater are probably associated with extensive habitat utilization by resident waterfowl in backwater areas or with runoff from pastures or barnyards. The stream influence points and pastures or barnyards are shown in Figures 2-6 through 2-9.

Nitrate levels in runoff or streams were always found to be below detection limits. Total phosphorus also was low and ammonia concentrations were consistent with those to be expected from wetland areas where decaying vegetation is present.

Table C-1. Analytical results of water quality samples and leachate detector readings for surface water runoff entering Island and Sturgeon Lakes.

Chemical Sampling Station #	Approximate Location	Nitrate (mg-N/l)	Nitrite (mg-N/l)	Ammonia (mg-N/l)	Total Phosphorus (mg-P/l)	pH	Total Alkalinity (mg/l $CaCO_3$)	Fecal Coliforms (#/100ml)	Leachate Detector (Relative Scale) Combined	Floures-cense	Conduc-tivity
	Island lake										
C62	Near Flow Station 16	0.05	0.05	0.24	0.01	6.5	38.2	560	30	35	100
C73	200 yds. South of Flow Station 22	0.05	0.05	0.15	0.02	6.6	34.2	70	100	100	100
C60	At Flow Station 1	0.05	0.05	0.26	0.01	6.2	50	10	100	100	100
C61	Near NE Corner of Lake	0.05	0.05	0.22	0.01	6.6	42	60	100	100	0
C72	Near Flow Station 21	0.05	0.05	0.16	0.40	6.5	51.4	50	100	80	100
	Sturgeon lake										
C77	At Wetland, W. of Public Access	0.05	0.05	0.15	0.01	7.1	52.2	10	100	100	100
C85	At Stream Mouth, 300 yds. South of Flow Station 32	0.05	0.05	0.16	0.02	7.0	44.0	70	85	100	100
Background Values	Island Lake (center)								0	30	30
	Sturgeon Lake (center)								0	30	30

Island Lake data gathered 7 October 1981, Sturgeon Lake data gathered 8 October 1981.

Table C-2. Analytical results of water quality samples and leachate detector readings for the Island Lake survey of septic leachate plumes.

Chemical Sampling Station #	Approximate Location/Type	Nitrate (mg-N/l)	Nitrite (mg-N/l)	Ammonia (mg-N/l)	Total Phosphorus (mg-P/l)	pH	Total Alkalinity (mg/l $CaCO_3$)	MBAS (mg-LAS/l)	Fecal Coliforms (#/100ml)	Leachate Detector (Relative Scale) Floures-cense	Leachate Detector (Relative Scale) Conduc-tivity
	Near Flow Sta. 23:										
C74	Background	0.06	0.05	0.17	0.89	6.3	97.0	-	10	248	198
C75	Plume	0.05	0.05	0.22	0.87	6.6	130	0.010	40	313	2000
C76	Detector	0.05	0.05	0.17	0.01	6.4	32.4	-	10	207	206
(collected 7 October 1981)											
	Near Flow Sta. 20:										
C69	Background	0.05	0.05	0.23	1.01	6.4	74.4	-	10	532	463
C70	Plume	2.10	0.05	0.12	0.29	6.2	42.4	0.010	50	802	732
C71	Detector	0.05	0.05	0.25	0.01	6.6	30.2	-	10	-	-
(collected 7 October 1981)											
	Near Flow Sta. 16:										
C63	Background	0.05	0.05	0.26	0.04	6.5	47.4	-	10	230	341
C64	Plume	0.05	0.05	0.24	0.93	6.1	106	0.035	10	1000	868
C65	Detector	0.05	0.05	0.22	0.06	6.5	36.2	-	20	-	-
(collected 7 October 1981)											
	Near Flow Sta. 19:										
C66	Background	0.12	0.05	0.09	0.53	6.3	83.0	-	350	416	558
C67	Plume	0.61	0.05	0.12	0.49	5.9	41.4	0.016	2300	2000	862
C68	Lake Sample	0.05	0.05	0.10	0.03	5.9	22.8	-	10	213	270
(collected 9 October 1981)											

Background -- uncontaminated groundwater collected onshore in vicinity of suspected leachate effluent plume.

Plume -- contaminated groundwater collected onshore from leachate effluent plume.

Detector -- lakewater sample collected directly from detector discharge during period of positive reading.

Lake Sample — lakewater grab sample collected during period of positive leachate detector reading.

Table C-3. Analytical results of water quality samples and leachate detector readings for the Sturgeon, Rush, and Passenger Lake surveys of septic leachate plumes.

Chemical Sampling Station #	Approximate Location/Type	Nitrate (mg-N/l)	Nitrite (mg-N/l)	Ammonia (mg-N/l)	Total Phosphorus (mg-P/l)	pH	Total Alkalinity (mg/l $CaCO_3$)	MBAS (mg-LAS/l)	Fecal Coliforms (#/100ml)	Leachate Detector (Relative Scale) Floures-cense	Leachate Detector (Relative Scale) Conduc-tivity
	Near Flow Sta. 29										
C78	Background	0.05	0.05	0.16	0.13	7.1	63.0	-	10	292	301
C79	Plume	0.05	0.05	0.11	0.31	6.7	51.6	0.010	10	815	273
C80	Detector	0.05	0.05	0.27	0.01	7.1	46.0	-	10	-	-
(collected 8 October 1981)											
	Near Flow Sta. 33										
C81	Background (high)	2.41	0.05	0.26	0.04	6.8	53.4	-	10	349	418
C82	Background (low)	0.05	0.05	0.19	0.01	6.9	45.6	-	10	152	241
C83	Plume	0.05	0.05	0.10	0.06	6.9	67.6	0.010	10	573	320
C84	Lake sample	0.48	0.05	0.16	0.01	7.0	44.2	-	10	26	279
(collected 8 October 1981)											
	Near Flow Sta. 45										
C86	Background	0.20	0.05	0.26	0.13	6.8	62.0	0.031	10	183	292
C87	Plume	0.05	0.05	0.12	0.26	6.0	76.0	0.030	10	478	336
C88	Detector	0.05	0.05	0.16	0.01	6.8	68.5	-	10	-	-
(collected 8 October 1981)											
	Near Flow Sta. 50										
C89	Background	0.05	0.05	0.19	1.54	6.3	43.6	-	10	135	211
C90	Plume	0.05	0.05	0.12	0.26	6.0	62.4	0.010	10	2000	281
C91	Detector	0.05	0.05	0.16	0.01	6.3	49.7	-	10	74	236
(collected 9 October 1981)											
	Near Flow Sta. 59										
C92	Background	0.37	0.05	0.10	0.14	5.5	28.0	0.010	10	28	262
C93	Plume	0.52	0.05	0.10	1.00	6.1	49.6	-	10	773	420
C94	Lake Sample	0.05	0.05	0.10	0.01	6.7	68.0	-	10	135	230
(collected 9 October 1981)											

Background -- uncontaminated groundwater collected onshore in vicinity of suspected leachate effluent plume.

Plume -- contaminated groundwater collected onshore from suspected leachate effluent plume.

Detector -- lakewater sample collected directly from detector discharge during period of positive reading.

Lake Sample -- lakewater grab sample collected during period of positive detector reading.

Analyses of samples collected at locations of nine septic plumes which were strongly detected are presented in Tables C-2 and C-3. These water quality or "chemical" sampling locations are depicted in Figures 2-6 through 2-9. Three subsamples were obtained from each sampled plume:

- Lake water collected either by grab sample or directly from the detector overflow while the probe was held within an emergent plume. (Indicated as either "lake sample" or "detector" respectively in Tables C-2 and C-3.
- Groundwater sampled on shore directly from the effluent plume center using a portable well point
- Groundwater background sample collected onshore at a distance from the apparent plume; data used for comparison with groundwater plume parameters.

When a strong plume of probably septic origin was encountered, a sample was collected directly from the flow-through outlet of the leachate detector. Groundwater samples were collected at 20-foot intervals in a transect made along the shoreline perpendicular to the plume flow direction and a portion of each sample was then injected into the detector to determine relative levels of fluorescence and conductivity. The device used to collect the samples was a small-diameter well point, slotted along its pointed end, with a hand-operated pump attached. After identifying the approximate groundwater plume location, two samples were collected: one from the approximate plume center and one from the interval characterized by the lowest instrument readings. The latter sample functioned as a measure of groundwater background levels.

All samples of groundwater and surface water showed measurable levels of ammonia nitrogen (mg-N/l) which in no case exceeded a value of 0.30 mg ammonia -N/l. No significant differences were noted in comparisons of ammonia concentrations from stream influx, lake water, or groundwater in plumes. Thus, either the on-site systems which were studied are effectively transforming ammonia to the oxidized nitrogen form, nitrate, or ambient ammonia nitrogen levels in surface waters were seasonally high due to the decomposition of plant material of the fall season. If higher ammonia levels had been detected in groundwater or in plumes emerging into the lake than in runoff or streams, this would have indicated rapid off-shore transport of incompletely treated leachate. This was not the case. Largely due to the probable presence of naturally elevated ammonia levels during the fall survey, data are inconclusive with regard to the pollutional significance of ammonia from on-site systems.

Fecal coliforms were detected at all four of the suspected septic plume water quality sampling stations on Island Lake. Measurable coliform counts also were found in the onshore groundwater leachate plumes at sampling stations C67, C70, and C75. The fecal coliform count of 2,300 organisms per milliliter (C67) reported for the groundwater plume at flow station 19 could have indicated the presence of septic leachate. However, the data are insufficient to preclude the possibility of non-human fecal material being the source of the organisms that were found. Dogs or waterfowl can also introduce fecal coliform organisms into the soil surface and water table aquifer through their fecal material. A background groundwater sample collected at a distance from the plume center (C66) also contained measurable fecal coliforms, as did the sample (C65) which was collected from the detector overflow. Fecal coliforms in the latter sample were very low in concentration and therefore not clearly associated with the suspected plume.

Except for the stream sample (C85) described earlier, none of the Sturgeon Lake samples contained measurable fecal coliform counts. No fecal coliforms were found in the groundwater samples collected at Rush and Passenger Lakes. One of the samples collected from Rush Lake via the detector overflow had a measurable, but very small coliform count; thus, the sample was not clearly associated with the suspected plume.

Nitrite concentrations in all samples were below the limit of detection (0.05 mg -N/1). Nitrites in measurable quantities could have been present in the samples collected on 9 October 1981, but the acceptable holding time for this group of samples was exceeded by 3 days. Three days is sufficient time for nitrites to transform to nitrates via oxidation.

Nitrate levels in the samples were consistently low and of an order of magnitude which naturally occurs in groundwater not contaminated by human activities. The highest detected concentration, 2.4 mg -N/l, was found in a groundwater background sample collected near a suspected septic plume in Sturgeon Lake. It was evident that during the time of the survey, elevated concentrations of nitrate were not being introduced to any of the lakes.

In general, phosphorus concentrations measured in samples taken in suspected on-shore effluent plumes were high (Tables C-2 and C-3). Several values measured over 1.0 mg total dissolved P per liter with the highest value measured at 1.5 mg total dissolved -P per liter in the groundwater plume. The observed low levels of this nutrient in samples collected from these plumes at their points of emergence into the lake (called "detector" sample in Tables C-2 and C-3) indicates that a large percentage of the phosphorus of human origin was being removed by the soil, precluding entry to the lake. The total -P data indicate little significant influx of phosphorus from the suspected plumes during the time of the survey.

The pH range of all samples measured in the laboratory was 5.5 to 7.1, with only three values lower than 6.0. The highest and lowest total alkalinity values, 130 and 23 mg/l $CaCO_3$, respectively, were found in Island Lake.

Methylene Blue Active Substances (MBAS) are those organic substances which form a quantitative reaction product with methylene blue which can be measured by a standard analytical method. The MBAS of most significance to water quality is linear alkylate sulfonate (LAS), which is an anionic surfactant used to make detergents and other cleaning products. High MBAS concentrations are indicative of detergent contamination. Ten samples, mostly from suspected wastewater plumes, were analyzed for MBAS. Only four of the samples showed detectable levels, and these levels do not indicate significant detergent contamination.

Appendix C-2.

WELL-WATER QUALITY DATA FOR PINE AND CARLTON COUNTIES, MINNESOTA

Well-water quality data for Pine and Carlton Counties. Information was obtained in 1979, 1980 and 1981 (Minnesota Department of Public Health, unpublished).

1979

Well Number	County	Well Depth(ft)	Static Water Level(ft)	Nitrates (mg/l)	Californ Bacteria(MPN)	Specific Conductivity (Umhos/cm)	Fluoride mg/l
1	P[a]	94	42	<0.4	<2.2	-	-
2	C[b]	52	26	<0.4	16.0	-	-
3	C	90	42	<0.4	9.2	-	-
4	C	117	6	<0.4	<2.2	-	-
5	C	210	15	<0.4	<2.2	-	-
6	P*	145	32	<0.4	<2.2	-	-
7	P	112	28	5.3	<2.2	-	-
8	P	105	24	<0.4	<2.2	-	-
9	C	62	14	<0.4	<2.2	-	-
10	P	155	21	<0.4	<1.0	-	-
11	C	300	92	<0.4	<2.2	-	-
12	C	175	10	<0.4	>2.0	-	-
					<2.2 resampled	-	-
13	P	80	45	<0.4	<2.2	-	-
14	P	95	33	3.0	<2.2	-	-
15	P	66	8	<0.4	<2.2	-	-
16	P	60	8	<0.4	<2.2	-	-
17	C	64	14	<0.4	<2.2	-	-

Well-water quality data for Pine and Carlton Counties (continued).

1980

Well Number	County	Well Depth(ft)	Static Water Level(ft)	Nitrates	Caliform Bacteria(MPN)	Specific Conductivity (vmhos/cm)	Fluoride mg/l
18	P	155	36	<0.4	<2.2	190	0.10
19	P	50	14	<0.4	<2.2	350	0.15
20	P	95	32	<0.4	<2.2	480	0.14
21	P	90	16	<0.4	<2.2	330	0.12
22	P	91	13	<0.4	<2.2	320	0.10
23	P	80	15	<0.4	<2.2	170	0.12
24	C	185	25	<0.4	<2.2	300	0.24
25	C	170	52	<0.4	<2.2	300	0.20
26	P	95	50	<0.4	<2.2	370	0.14
27	P*	230	33	<0.4	<2.2	230	0.22
28	P	43	10	<0.4	<2.2	270	0.14
29	P	50	11	<0.4	<2.2	320	0.18
30	P	163	56	0.72	<2.2	370	0.20
31	P	275	18	<0.4	<2.2	340	0.13
32	P	50	4	<0.4	2.2	190	0.10
				---	<2.2 resampled	240	0.10
33	P*	300	66	<0.4	<2.2	300	0.62
34	P	125	100	<0.4	<2.2	370	0.26
35	P	110	45	<0.4	<2.2	190	0.13
36	P	155	24	<0.4	<2.2	---	0.50
37	P	144	5	<0.4	<2.2	310	0.13
38	P	126	27	<0.4	<2.2	300	0.24
39	P	102	17	<0.4	2.2	240	0.14
				---	<2.2 resampled	---	---
40	P	96	41	<0.4	<2.2	390	0.18
41	P	90	16	<0.4	<2.2	279	0.12
42	P	45	---	1.4	>2.0	254	0.12

Well-water quality data for Pine and Carlton Counties (concluded).

1981

Well Number	County	Well Depth(ft)	Static Water Level(ft)	Nitrates	Caliform Bacteria(MPN)	Specific Conductivity (vmhos/cm)	Fluoride mg/l
43	P	138	24	<0.4	<2.2	280	0.18
44	P*	64	26	<0.4	<2.2	280	0.26
45	P*	176	50	<0.4	5.1	146	0.12
					<2.2 resampled	---	----
46	P	105	21	<0.4	<2.2	300	0.18
47	P*	66	23	<0.4	>2.0	250	0.1
48	P	50	13	<0.4	>2.0	110	0.1
49	P	113	41	0.92	<2.2	---	----
50	P	105	12	0.4	<2.2	---	----
51	P	181	49	0.4	<2.2	---	----
52	C	538	77	0.4	<2.2	---	----
53	P*	115	21	0.88	<2.2	---	----
54	C	78	32	<0.4	<2.2	---	----
55	P*	125	28	<0.4	>2.0	---	----
56	P*	160	40	<0.4	<2.2	---	----
57	P*	165	42	<0.4	<2.2	---	----
58	P*	171	35	<0.4	<2.2	---	----
59	C	217	70	<0.4	<2.2	---	----
60	C	43	30	1.1	<2.2	---	----

P^a = Pine County

P^b = Carlton County

* = indicates well was located in Windemere Township

Appendix D

Design Criteria and Component Options for Centralized Wastewater Management Systems

Wastewater Load Factors

Wastewater flow projections for each project alternative for the Island Lake and Sturgeon Lake areas were developed based on a projected year 2000 design population (Section 3.2.1.3), an average daily base flow (ADBF) of 45 gallons per capita per day (gpcd) for individual systems served by holding tanks and 60 gpcd for all other services, and a design infiltration of 10 gpcd for gravity sewers (based on maximum permissible infiltration rate of 200 (gallons per inch-diameter per mile per day).

The organic loads were projected on the basis of the accepted design values of 0.17 pounds of BOD_5 per capita per day and 0.20 pounds of suspended solids (SS) per capita per day (ten state standards). These values were applied to the projected year 2000 population.

Effluent Requirements

The Minnesota Pollution Control Agency (MPCA) issued effluent limits for the City of Moose Lake wastewater treatment facility, as presented in Section 2.1.

Economic Factors

The economic cost criteria consist of an amortization or planning period from the present to the year 2000, or approximately 20 years; an interest rate of 7.625%, and service lives of 20 years for treatment and pumping equipment, 40 years for structures, and 50 years for conveyance facilities. Salvage values were estimated using straight-line depreciation for items that could be used at the end of the 20-year planning period. An annual appreciation rate of 3% over the planning period was used to calculate the salvage value of the land. Operation and maintenance (O&M) costs include labor, materials, and utilities (power). Costs associated with the treatment works, pumping stations, solids handling and disposal processes, conveyance facilities, and on-site systems are based on prevailing rates.

Costs are based on the USEPA STP Construction Cost Index of 410.9, the USEPA Complete Urban Sewer System (CUSS) Construction Cost Index of 193, and the Engineering News Record (ENR) Construction Cost Index of 3,370 for the first quarter of 1982 (March 1982 for Minneapolis MN). The total capital cost includes the initial construction cost plus a service factor. The service factor includes costs for engineering, contingencies, legal and administrative, and financing. The service factors used for different alternative components are summarized in Table D-1. The economic cost criteria are summarized in Table D-2.

System Components

—Flow and Waste Reduction—

Economy in the construction and operation of sewage collection, treatment, and disposal facilities, is, in many localities, achieveable by controlling waste flows or the amounts of impurities carried in the sewage. This economy is generally recognized in the short-term monetary savings that result from the reduced design capacities of facilities or from the long-term savings realized when facility expansion or replacement is unnecessary. Other savings can be achieved throughout the life of the facilities from reduced operational costs.

Methods of flow and waste reduction considered for use in the study area include water conservation measures and waste segregation.

Table D-1. Service factor[a].

Item	Conventional Collection and Treatment System (%)	Pressure Sewer, Cluster, and On-site Systems (%)
Contingencies	10	15
Engineering	10	13
Legal & Administrative	3	3
Financing	4	4
Total	27	35

[a] A service factor is applied to the construction cost to compute the capital cost. Interest during construction is not included.

Table D-2. Economic cost criteria.

Item	Units	Value
Amortization period	years	20
Interest (discount) rate	%	7-5/8
STP construction cost index - 1st Quarter 1982	-	410.9
Sewer (CUSS) construction cost index - 1st Quarter 1982	-	193
ENR construction cost index - 1st Quarter 1982		3730
Service life		
Equipment	years	20
Structures	years	40
Conveyance facilities	years	50
Land	years	permanent
Salvage value		
Equipment	%	0
Structures	%	50
Conveyance facilities	%	60
Land	%	103

—Water Conservation Measures—

Clean water has for many years often been regarded as one of the nation's bountiful free goods. Concerns over water supply and wastewater disposal and an increasing recognition of the benefits that may accrue through water conservation are serving to greatly stimulate the development and application of water conservation practices. The diverse array of water conservation practices may, in general, be divided into these major categories:

- Elimination of non-functional water use
- Water-saving devices, fixtures, and appliances
- Wastewater recycle/reuse system.

Non-functional water use is typically the result of the following:

- Wasteful, water-use habits such as using a toilet flush to dispose of a cigarette butt, allowing the water to run while brushing teeth or shaving, or operating a clotheswasher or dishwasher with only a partial load

- Excessive water supply pressure - for most dwellings a water supply pressure of 40 pounds per square inch (psi) is adequate and a pressure in excess of this can result in unnecessary water use and wastewater generation, especially with wasteful water-use habits

- Inadequate plumbing and appliance maintenance - unseen or apparently insignificant leaks from household fixtures and appliances can waste large volumes of water. Most notable in this regard are leaking toilets and dripping faucets. For example, even a pinhole leak which may appear as a dripping faucet can waste up to 170 gallons per day at a pressure of 40 psi. More severe leaks can generate larger wastewater quantities.

The quantity of water traditionally used by household fixtures or appliances often is considerably greater than actually needed. Typically, toilet flushing, bathing, and clotheswashing collectively account for over 70% of the household's interior water use and waste flow volume (Siegrist, Woltanski, and Waldorf 1978). Thus, efforts to accomplish major reductions in the wastewater flow volume, as well as its pollutant mass, have been directed toward the toilet flushing, bathing, and clotheswashing areas. Some selected water conservation/waste load reduction devices and systems developed for these household activities include:

- Toilet devices and systems
  - Toilet tank inserts - such as water filled and weighted plastic bottles, flexible panels, and/or dams
  - Dual-flush toilet devices
  - Shallow-trap toilets
  - Very low volume flush toilets
  - Non-water carriage toilets

- Bathing devices and systems
  - Shower flow control devices
  - Reduced-flow shower fixtures

- Clotheswashing devices and systems of a clotheswasher with a suds-saver attachment

  The suds-saver feature is included as an optional cycle setting on several commercially made washers. The selection of suds-saver cycle when washing provides for storage of the washwater from the wash cycle for subsequent use as the wash water for the next wash load. The rinse cycle remains unchanged.

Wastewater Recycle/Reuse Systems

These systems provide for the collection and processing of all household wastewater or the fractions produced by certain activities for subsequent reuse. A system which has received a majority of development efforts includes the recycling of bathing and laundry wastewater for flushing water-carriage toilets and/or outside irrigation.

Other Water Conservation Measures

One possible method for reduction of sewage flow is the adjustment of the price of water to control consumption. This method normally is used to reduce water demand in areas with water shortages. It probably would not be effective in reducing sanitary sewer flows because much of its impact is usually on luxury water usage, such as lawn sprinkling or car washing. None of the luxury uses impose a load on a separated sewerage system and on on-site systems. Therefore, the use of price control probably would not be effective in significantly reducing wastewater flows. More importantly most of homes in the service area have their own wells and therefore are not charged for water use.

Other measures include educational campaigns on water conservation in everyday living and the installation of pressure-reduction valves in areas where the water pressure is excessive (greater than 60 pounds per square inch). Educational campaigns usually take the form of spot television and radio commercials, and the distribution of leaflets with water and sewer bills. Water saving devices must continue to be used and maintained for flow reduction to be effective.

Wastewater flows on the order of 15 to 30 gpcd can be achieved by installation of combinations of the following devices and systems:

- Replace standard toilets with dual cycle or other low volume toilets
- Reduce shower water use by installing thermostatic mixing valves and flow control shower heads. Use of showers should be encouraged rather than baths whenever possible
- Replace older clotheswashing machines with those equipped with water-level controls or with front-loading machines
- Eliminate water-carried toilet wastes by use of in-house composting toilets
- Use recycled bath and laundry wastewaters to sprinkle lawns in summer
- Recycle bath and laundry wastewaters for toilet flushing. Filtration and disinfection of bath and laundry wastes for this purpose has been shown to be feasible and aesthetically acceptable in pilot studies (Cohen and Wallman 1974; McLaughlin 1968). This is an alternative to in-house composting toilets that could achieve the same level of wastewater flow reduction
- Commercially available pressurized toilets and air-assisted shower heads using a common air compressor of small horsepower would reduce sewage volume from these two largest household sources up to 90%.

Methods that reduce the flow or pollutant loads can provide the following benefits to a wastewater management program:

- Reduce the sizes and capital costs of new sewage collection and treatment facilities
- Delay the time when future expansion or replacement facilities will be needed
- Reduce the operational costs of pumping and treatment

- Mitigate the sludge and effluent disposal impacts
- Extend the life of the existing soil absorption system for an existing system functioning satisfactorily
- Reduce the wastewater load sufficiently to remedy a failing soil absorption system in which the effluent is surfacing or causing backups
- Reduce the size of the soil disposal field in the case of new on-site systems. However, the pretreatment process of the on-site systems should be maintained at full-size to provide the necessary capacity to treat and attenuate peak flows.

--Waste Segregation--

Various methods for the treatment and the disposal of domestic wastes involve separation of toilet wastes from other liquid waste. Several toilet systems can be used to provide for segregation and separate handling of human excreta (often referred to as blackwater), and, in some cases, garbage wastes. Removal of human excreta from the wastewater serves to eliminate significant quantities of pollutants, particularly suspended solids, nitrogen, and pathogenic organisms (USEPA 1980a).

Wastewaters generated by fixtures other than toilets are often referred to collectively as graywater. Characterization studies have demonstrated that typical graywater contains appreciable quantities of organic matter, suspended solids, phosphorus, and grease. The organic materials in graywater appear to degrade at a rate not significantly different from those in combined residential water. Microbiological studies have demonstrated that significant concentrations of indicator organisms, such as total and fecal coliforms, are typically found in graywater (USEPA 1980).

Although residential graywater does contain pollutants and must be properly managed, graywater may be simpler to manage than total residential wastewater due to a reduced flow volume. A number of potential strategies for management of segregated human excreta (blackwater) and graywater are presented in Figure D-1 and Figure D-2 , respectively.

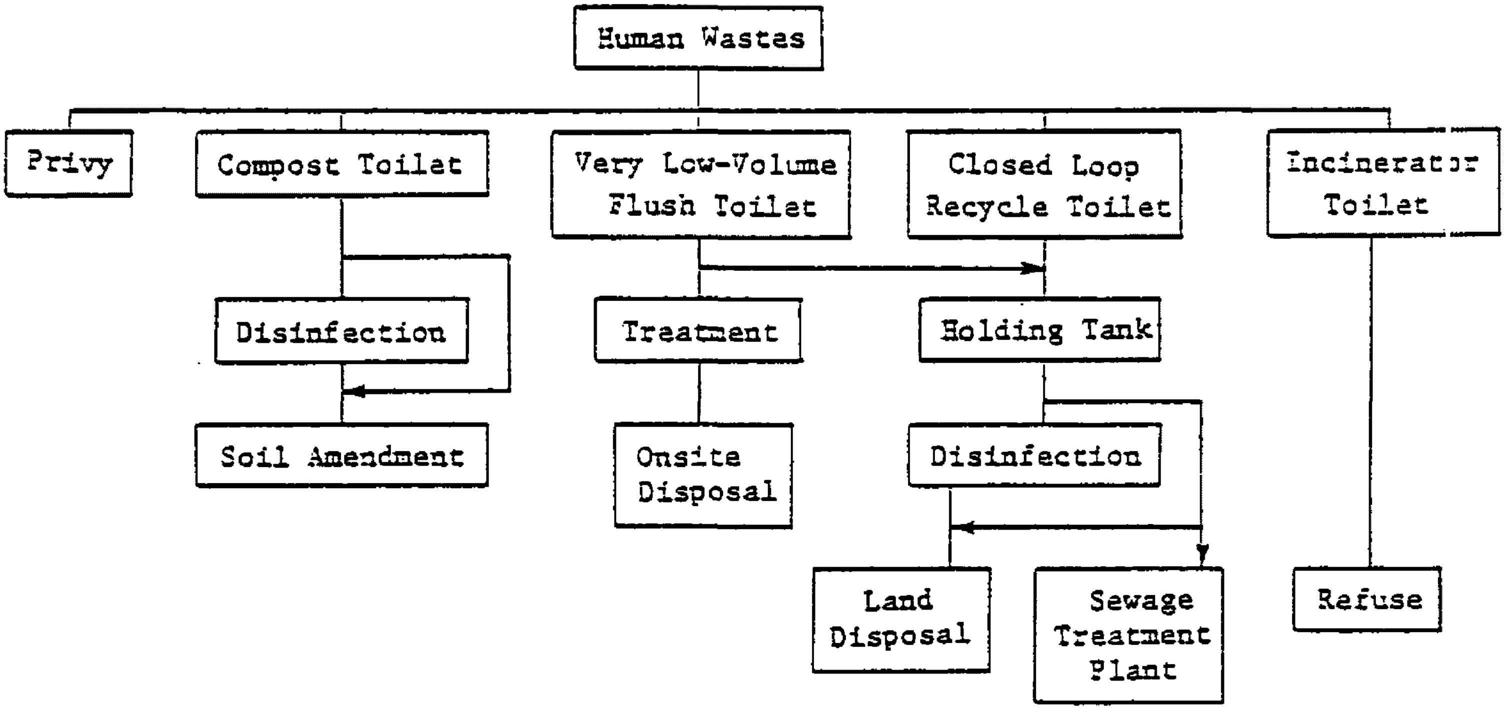


Figure D-1. Example strategies for the management of segregated human wastes.

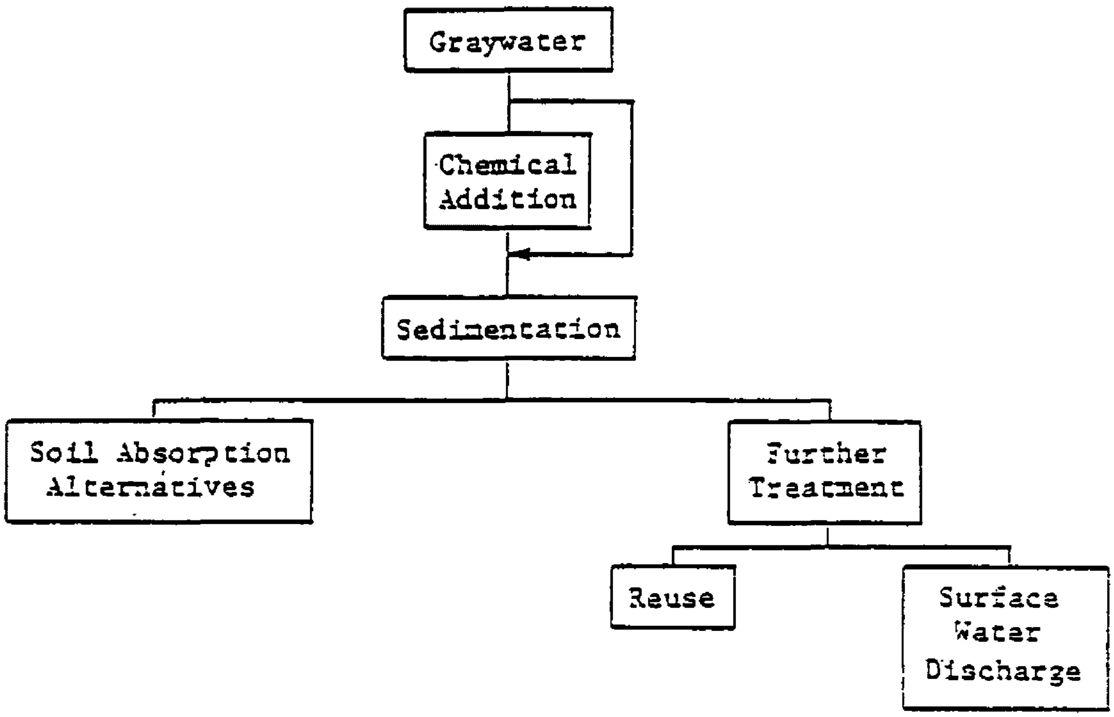


Figure D-2. Example strategies for the management of residential greywater.

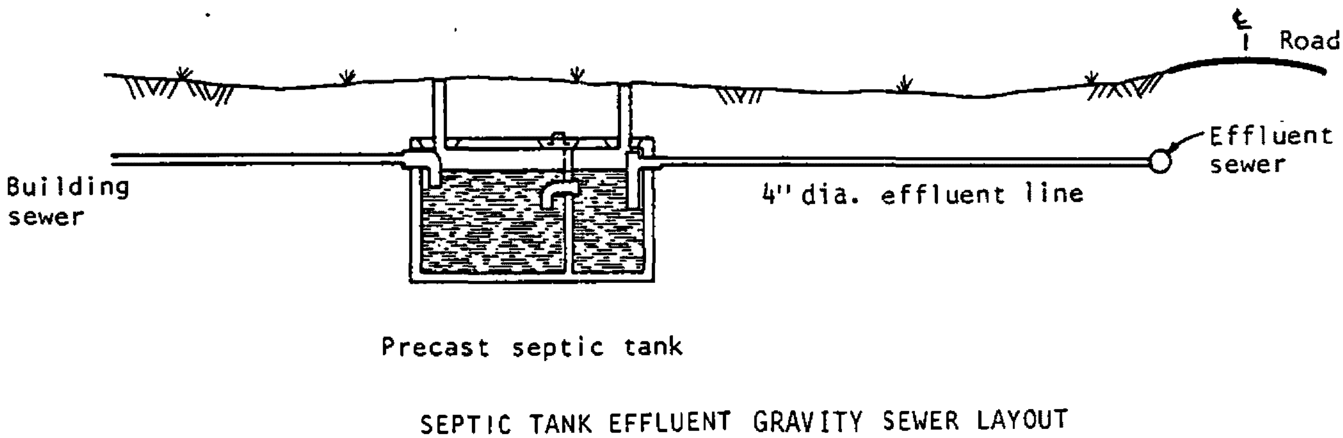


Figure D-3. Septic tank effluent gravity sewer layout.

pressurizing inlet points and a single outlet, as shown in Figure D-4. The pressure main follows a generally direct route to a treatment facility or to a gravity sewer, depending on the application. The primary purpose of this type of design is to minimize sewage retention time in the sewer.

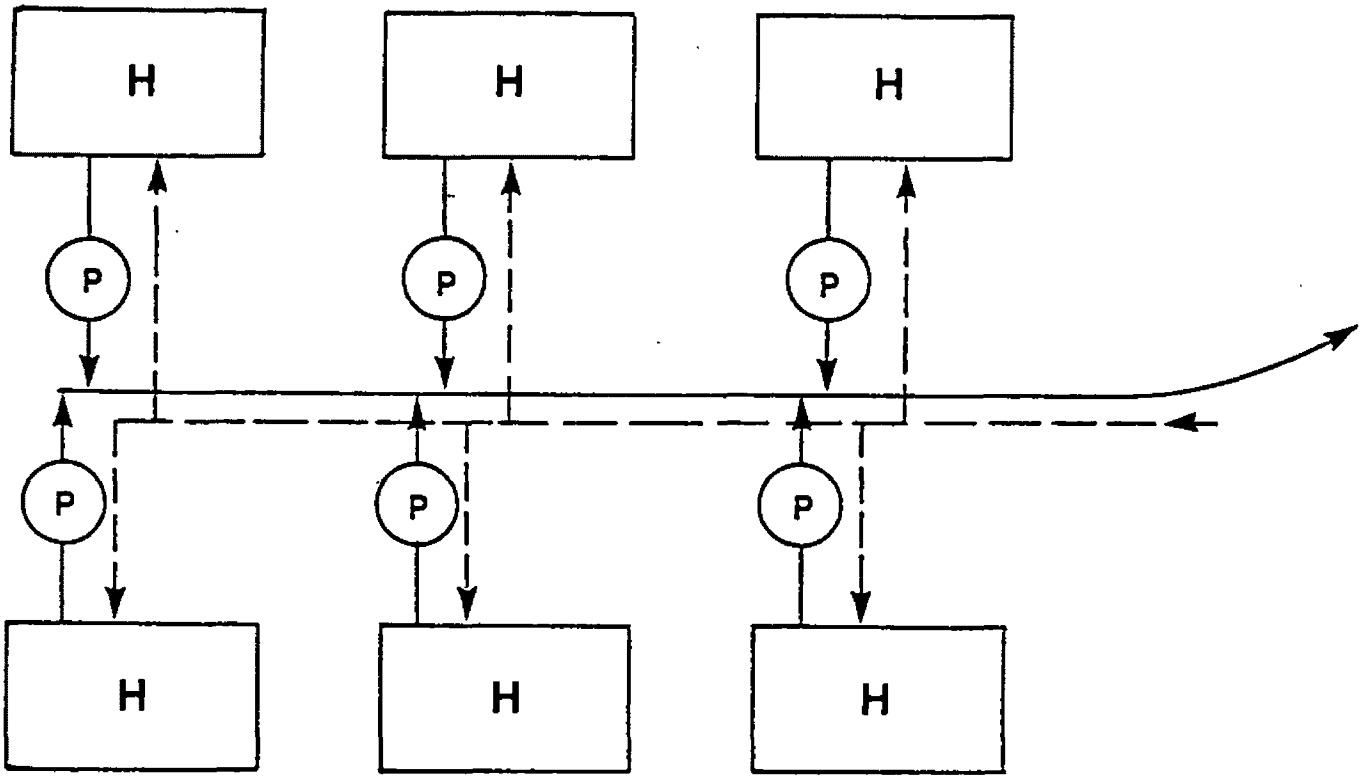
There are two major types of pressure sewer systems: the grinder pump (GP) system and the septic tank effluent pump (STEP) system. As shown in Figure D-5 , the major differences between the alternative systems are in the on-site equipment and layout. There are also some subtle differences in the pressure main design methods and in the treatment systems required to reduce the pollutants in the collected wastewater to an environmentally acceptable level. Neither pressure sewer system alternative requires the modification of household plumbing, although neither precludes it if such modifications are deemed desirable.

The advantages of pressure sewers are primarily related to installation costs and inherent system characteristics. Because these systems use small-diameter plastic pipes buried just below the frost penetration depth, their installation costs can be quite low compared to conventional gravity systems in low-density areas. Other site conditions that enhance this cost differential include hilly terrain, rock outcropping, and high water tables. Because pressure sewers are sealed conduits, there should be no opportunity for infiltration. The sewers can be designed to handle only the domestic sewage generated in the houses serviced, which excludes the infiltration that occurs in most gravity systems. The high operation and maintenance costs for the use of mechanical equipment at each point of entry to the system is the major disadvantage of a pressure sewer system.

Most of the dwellings in the proposed service area have existing septic tanks. Therefore, the septic tank effluent pump (STEP) system was considered for the centralized collection system alternatives.

Wastewater Treatment Processes

A variety of treatment options were considered in the Facilities Plan in development of alternative wastewater management plans including:



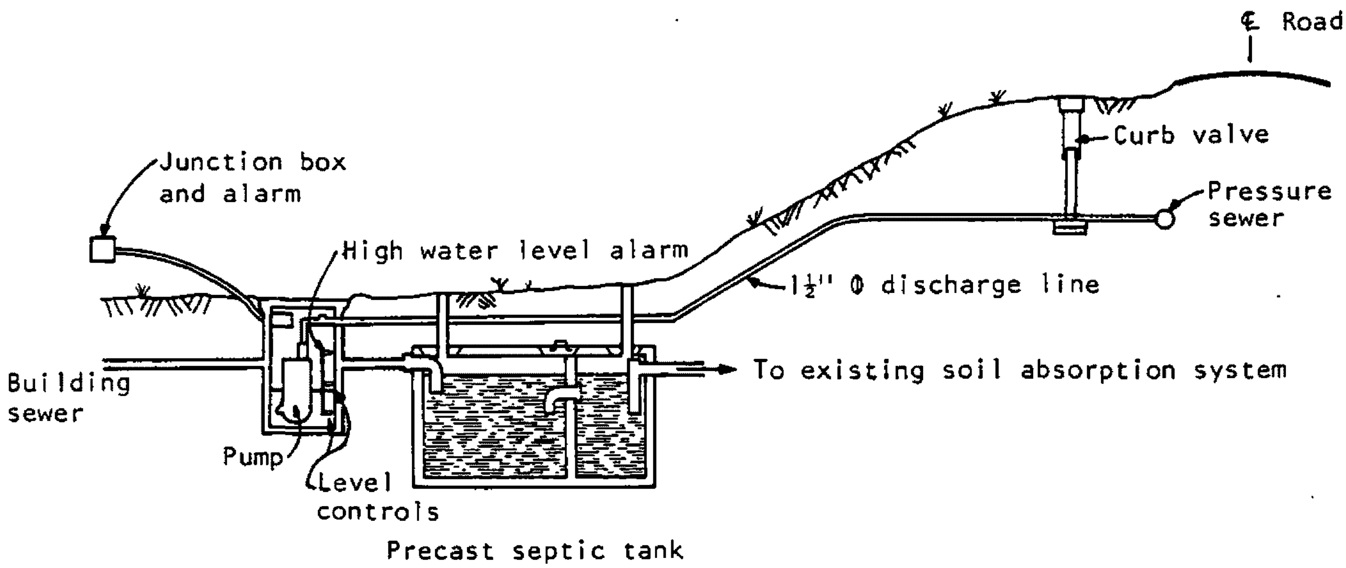
Pressure sewer

Water main (under pressure)

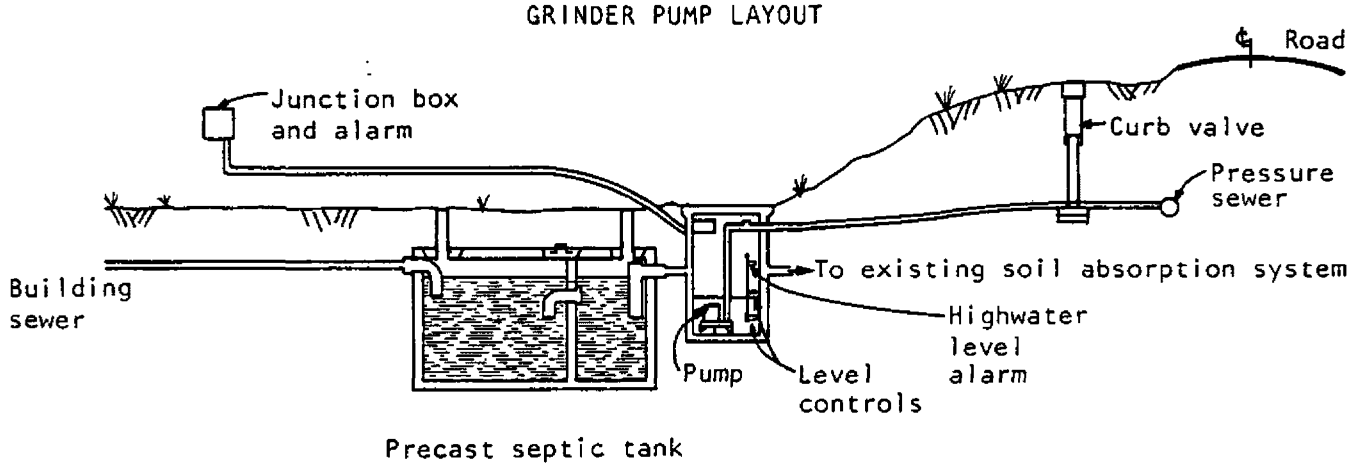
P Pressure sewer pump

H Housing unit

Figure D-4. Pressure sewer layout versus potable water supply layout.



GRINDER PUMP LAYOUT



SEPTIC TANK EFFLUENT PUMP LAYOUT

Figure D-5. Types of pressure sewer systems.

- use of existing lagoons
- activated sludge
- oxidation ditch.

The facilities planner recommended modification and expansion of the City of Moose Lake's existing lagoon system.

Effluent Disposal Methods

Three effluent disposal options are available: stream discharge, land application, and reuse.

The Moose Horn River is the receiving stream for discharge of treated wastewater effluent. The discharge is regulated by the NPDES permit issued by MPCA.

Land application or land treatment of wastewater utilizes natural physical, chemical, and biological processes in vegetation, soils, and underlying formations to renovate and dispose of domestic wastewater. Land application methods have been practiced in the United States for more than 100 years and presently are being used by hundreds of communities throughout the nation (Pound and Crites 1973).

In addition to wastewater treatment, the benefits of land application may include nutrient recycling, timely water applications, groundwater recharge, and soil improvement. These benefits accrue to a greater extent in arid and semi-arid areas, but are also applicable to humid areas. Secondary benefits include preservation of open space and summer augmentation of streamflow.

The components of a land application system include a centralized collection and conveyance system, some level of primary treatment, possible secondary treatment, possible storage and disinfection, and the land application site and equipment. In addition, collection of the treated water may be included in the system design along with discharge or reuse of the collected water. These optional components may be necessary to meet state requirements or to make the system operate properly.

Land application of municipal wastewater for treatment encompasses a wide variety of possible processes or methods of application. The three principal processes utilized in land treatment of wastewater are:

- Overland flow
- Slow-rate or crop irrigation
- Rapid infiltration.

Because there is an existing wastewater lagoon system (City of Moose Lake system) the construction of a new land treatment system would forego any economic advantages of utilizing existing facilities (which would require some improvements). Consequently, land treatment processes of overland flow, slow rate-irrigation, and rapid infiltration were screened from consideration as a centralized wastewater treatment process.

Wastewater management techniques included under the category of treated effluent reuse may be identified as:

- Public water supply
- Groundwater recharge
- Industrial process uses or cooling tower makeup
- Energy production
- Recreation and turf irrigation
- Fish and wildlife enhancement.

Reuse of treatment plant effluent as a public water supply or for groundwater recharge could present potential public health concerns. There are no major industries in the area that require cooling water. The availability of good quality surface water and groundwater and the abundant rainfall limit the demand for the use of treated wastewater for recreational and turf irrigation. Organic contamination and heavy metal concentrations also are potential problems. Direct reuse would require very costly advanced wastewater treatment (AWT), and a sufficient economic incentive is not available to justify the expense. Thus, the reuse of treated effluent currently is not a feasible management technique for the study area.

Sludge Treatment and Disposal

Some of the wastewater treatment processes considered will generate sludge. The amount of sludge generated will vary considerably, depending on the process. A typical sludge management program would involve interrelated processes for reducing the volume of the sludge (which is mostly water) and final disposal.

Volume reduction depends on the reduction of both the water and the organic content of the sludge. Organic material can be reduced through the use of digestion, incineration, or wet-oxidation processes. Moisture reduction is attainable through concentration, conditioning, dewatering, and/or drying processes. The mode of final disposal selected determines the processes that are required. In the case of waste stabilization ponds, the sludge would collect in the bottom of the pond and would undergo anaerobic digestion. Inert solids that are not biologically decomposed would remain in the pond and may require cleanout and removal once every 10 to 20 years.

Appendix E

Cost Effectiveness Analysis

Cost Methodology

1. Costs for the conventional gravity sewer collection alternatives were developed from the bids received in August 1981 for the proposed sewers to serve Island Lake, and from published cost data.

2. Costs for the septic tank effluent pressure and gravity sewer collection alternatives were developed from the August 1981 Island Lake bids, costs from other project bids localized and updated, and published cost data.

3. Costs for the on-site system, cluster, and bog treatment alternatives were developed from bid costs from other projects localized and updated locally quoted prices, and published cost data.

4. Costs for upgrading the City of Moose Lake treatment plant were developed from published cost data.

5. Costs for materials, construction, and O&M were updated to June 1981 price levels. Construction costs for treatment units and sewers were based on USEPA indexes for Minneapolis of 410.9 (STP) and 193 (CUSS), respectively. The Engineering News Record Construction Cost Index of 3,730 for March 25, 1982 also was used.

4. Salvage values were determined using straight-line depreciation for a planning period of 20 years. The land value was considered to appreciate by 3 percent per year. The service life of structures, including buildings, concrete process units, etc., was assumed to be 50 years. The service life of process and auxiliary equipment such as clarifier mechanisms, standby generators, pumps, electric motors, etc. was assumed to be 20 years.

7. Capital costs were based on construction costs plus a service factor for engineering, administration, legal and contingencies (See Table 2-16 and Section 2.3.1.3.)

8. Present worth of slavage value, O&M costs, and average annual equivalent costs were determined for 20 years using a discount rate of 7.625%.

9. Present worth of salvage values was determined using a single payment present worth factor of 0.2300 (Salvage value x 0.2300 = present worth of salvage).

10. Present worth of O&M costs were determined using a uniform or equal payment series factor of 10.0983 (average annual O&M cost x 10.0983 = present worth of O&M).

11. Average annual equivalent costs were determined using a capital recovery factor of 0.0990 (total present worth x 0.0990 = average annual equivalent cost).

INDEX TO COST TABLES

Summary Tables

Collection system costs - Table E-1
Cluster systems, WWTPs, and administrative costs - Table E-16
On-site upgrade costs - Table E-24

Detail Tables

Component	Alternative												
	2	3	4A	4B	4C	5A	5B	6A	6B	6C	7A	7B	7C
Collection system													
Island Lake	-	-	E-2	E-3	E-4	E-5	E-6	E-7	E-8	E-9	E-11	E-13	E-15
Sturgeon Lake	-	-	-	-	-	-	-	-	-	-	E-10	E-12	E-14
Cluster system													
Island Lake	-	E-18	-	-	-	-	-	-	-	-	-	-	-
Sturgeon Lake	-	E-17	E-17	E-17	E-17	E-17	E-17	E-17	E-17	E-17	-	-	-
WWTP	-	-	E-19	E-19	E-19	E-20	E-20	E-21	E-21	E-21	E-22	E-22	E-22
On-site upgrade													
Island Lake	E-25	E-28	E-30	E-30	E-30	E-30	E-30	-	-	-	-	-	-
Sturgeon Lake	E-26	E-29	E-31	E-31	E-31	E-31	E-31	E-32	E-32	E-32	-	-	-
Other[a]	E-27	E-27	E-27	E-27	E-27	E-27	E-27	E-27	E-27	E-27	E-27	E-27	E-27
Administrative	E-23	E-23	E-23	E-23	E-23	E-23	E-23	E-23	E-23	E-23	E-23	E-23	E-23

[a] Includes the remainder of the EIS service area (Rush Lake, Passenger Lake, Wild Acres and Hogans Acres)

Table E-1. Summary of collection system costs.

Item	Initial Cost						Future Construction Cost								Total
				Present Worth			Annual	Total	Incremental	Present Worth					
	Capital	Salvage	O&M	Salvage	O&M	Total	Construction	Salvage	Ann. O&M	Construction	Salvage	O&M	Total		Present Worth
Alternative 4 (Island Lake)															
4A Conventional Gravity	892,570	383,500	7,567	88,210	76,410	880,770	1,757	20,230	3	17,740	4,650	220	13,310		894,080
4B STE Gravity	778,700	314,790	7,930	72,400	80,080	786,380	3,747	44,120	17	37,840	10,150	1,230	28,920		815,300
4C STE Pressure	754,180	261,570	6,764	60,160	68,300	762,320	6,220	51,200	101	62,810	11,780	7,280	58,310		820,630
Alternative 5 (Island Lake)															
5A STE Gravity	833,980	334,430	7,976	76,920	80,540	837,600	3,770	44,120	77	38,070	10,150	5,550	33,470		871,070
5B STE Pressure	748,760	259,170	6,781	59,610	68,480	757,630	6,220	51,200	101	62,810	11,780	7,280	58,310		815,940
Alternative 6 (Island Lake)															
6A Conventional Gravity	1,702,890	737,410	14,202	169,600	143,420	1,676,710	3,931	47,260	6	39,700	10,870	430	29,240		1,705,950
6B STE Gravity	1,523,310	614,840	14,692	141,410	148,360	1,530,260	7,627	89,840	38	77,020	20,660	2,740	59,100		1,589,360
6C STE Pressure	1,340,670	469,560	11,630	108,000	117,440	1,350,110	13,215	105,840	227	133,450	24,340	16,370	125,480		1,475,590
Alternative 7															
7A Conventional Gravity - IL	1,670,350	733,020	14,253	168,590	143,930	1,645,590	3,931	47,160	6	39,700	10,850	430	29,280		1,674,970
- SL	2,182,010	942,570	16,629	216,790	167,920	2,133,140	5,239	62,860	6	52,900	14,460	430	38,870		2,172,010
- Total	3,852,360	1,675,590	30,882	385,380	311,850	3,778,830	9,170	110,020	12	92,600	25,310	860	68,150		3,846,980
7B STE Gravity - IL	1,485,420	608,990	14,989	140,070	151,360	1,496,710	7,624	89,840	38	76,990	20,660	2,740	59,070		1,555,780
- SL	1,996,020	805,270	17,388	185,210	175,590	1,986,400	9,532	112,700	49	96,260	25,920	3,530	73,870		2,060,270
- Total	3,481,440	1,414,260	32,377	325,280	326,950	3,483,110	17,156	202,540	87	173,250	46,580	6,270	132,940		3,616,050
7C STE Pressure - IL	1,463,950	517,650	14,037	119,060	141,750	1,486,640	13,215	105,840	227	133,450	24,340	16,370	125,480		1,612,120
- SL	1,818,610	625,050	18,856	143,760	190,410	1,865,260	17,135	134,270	306	173,030	30,880	22,060	164,210		2,029,470
- Total	3,282,560	1,142,700	32,893	262,820	332,160	3,351,900	30,350	240,110	533	306,480	55,220	38,430	289,690		3,641,590

IL = Island Lake
SL = Sturgeon Lake

Table E-2. Quantities and costs for conventional gravity sewers for the north and west shorelines of Island Lake, and transmission to existing Sand Lake sewers. (Alternative 4A).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer Pipe						
8"	LF	13,900	$ 26.50	$368,350	$221,010	$1,043
Force main						
common trench						
2½"	LF	1,060	6.50	6,890	4,130	-
3"	LF	1,540	7.50	11,550	6,930	-
individual trench						
2"	LF	1,200	11.50	13,800	8,280	-
2½"	LF	450	11.80	5,310	3,190	-
3"	LF	2,750	12.70	34,930	20,960	-
3" Highway Crossing	EA	1		36,800	22,080	-
Lift Station						
A 75 gpm, TDH 28 Ft	EA	1		25,400	7,620	1,710
B 60 gpm, TDH 32 ft	EA	1		22,600	6,780	1,700
C 40 gpm, TDH 26 ft	EA	1		22,600	6,780	1,510
D 25 gpm, TDH 19 ft	EA	1		22,600	6,780	1,480
Auxiliary Power Units						
2 Hp	EA	3	6,300	18,900	5,670	-
Wye	EA	88	49	4,310	2,590	-
Service connection	EA	88	140	12,320	7,390	-
House lead						
gravity	EA	86	1,000	86,000	51,600	-
grinder pump	EA	2	2,850	5,700	1,710	124
Abandon septic tank, privy or holding tank	EA	88	54	4,750	-	-
Subtotal initial cost				702,810	383,500	7,567
Service factor (27%)				189,760		
Subtotal initial capital cost				892,570		
Future connection cost						
Wye	EA	28	49	1,370	820	-
Service connection	EA	28	140	3,920	2,350	-
Houselead						
gravity	EA	27	1,000	27,000	16,200	-
grinder pump	EA	1	2,850	2,850	860	62
Subtotal future connection cost				35,140	20,230	62
Annual future connection cost				1,757		3

Table E-3. Quantities and costs for STE gravity sewers for the north and west shorelines of Island Lake, and transmission to existing Sand Lake sewers. (Alternative 4B).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
STE gravity sewer pipe						
4"	LF	9,530	$ 16.90	$161,060	$96,630	$ 362
6"	LF	4,320	18.40	79,490	47,700	164
Manholes	EA	3	1,160	3,480	2,090	-
Force main						
common trench						
2½"	LF	1,060	6.50	6,890	4,130	-
3"	LF	1,540	7.50	11,550	6,930	-
individual trench						
2"	LF	1,200	11.50	13,800	8,280	-
2½"	LF	450	11.80	5,310	3,190	-
3"	LF	2,750	12.70	34,930	20,960	-
3" Highway Crossing	EA	1		36,800	22,000	-
Lift Station						
A 75 gpm, TDH 28 ft	EA	1		25,400	7,620	1,710
B 60 gpm, TDH 32 ft	EA	1		22,600	6,780	1,700
C 40 gpm, TDH 26 ft	EA	1		22,600	6,780	1,510
D 25 gpm, TDH 19 ft	EA	1		22,600	6,780	1,480
Auxiliary Power Units						
2 Hp	EA	3	6,300	18,900	5,670	-
Service connection						
STE gravity	EA	86	958	82,390	49,430	-
STE pump	EA	2	2,790	5,580	1,680	124
Septic tank						
new + abandon privy	EA	14	854	11,960	7,170	140
upgrade	EA	68	175	11,900	7,140	680
replace	EA	6	854	5,120	3,070	60
Building sewer	EA	14	90	1,260	760	-
Subtotal initial cost				584,220	314,790	7,930
Service factor (35%)				207,480		
Subtotal initial capital cost				778,700		
Future connection cost						
Service connection						
STE gravity	EA	27	958	25,870	15,520	-
STE pump	EA	1	2,790	2,790	840	62
Septic tank						
new	EA	28	800	22,400	13,440	280
replace	EA	25	854	21,350	12,810	-
Building sewer	EA	28	90	2,520	1,510	-
Subtotal future connection cost				74,930	44,120	342
Annual future connection cost				3,747		17

Table E-4. Quantities and costs for STE pressure sewers for the north and west shorelines of Island Lake and transmission to existing Sand Lake sewers. (Alternative 4C).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe						
2"	LF	1,220	$10.10	$ 12,320	$ 7,390	$ 23
2½"	LF	1,830	10.50	19,220	11,530	35
3"	LF	13,550	11.40	154,470	92,680	257
4"	LF	600	15.40	9,240	5,540	11
STE gravity sewer pipe						
6"	LF	2,700	18,40	49,680	29,810	102
6" Highway crossing	EA	1		36,800	22,080	-
Manhole	EA	1	1,160	1,160	700	-
Service connection-STE pump	EA	88	2,790	245,520	73,670	5,456
Septic tank						
new + abandon privy	EA	14	854	11,960	7,170	140
upgrade	EA	68	175	11,900	7,170	680
replace	EA	6	854	5,120	3,070	60
Building sewer	EA	14	90	1,260	760	-
Subtotal initial cost				558,650	261,570	6,764
Service factor (35%)				195,530		
Subtotal initial capital cost				754,180		
Future connection cost						
Service connection						
STE pump	EA	28	2,790	78,120	23,440	1,736
Septic tank						
new	EA	28	800	22,400	13,440	280
replace	EA	25	854	21,350	12,810	-
Building sewer	EA	28	90	2,520	1,510	-
Subtotal future connection cost				124,390	51,200	2,016
Annual future connection cost				6,220		101

Table E-5. Quantities and costs for STE gravity sewers for the north and west shorelines of Island Lake, and transmission to Bog Treatment. (Alternative 5A)

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
STE gravity sewer pipe						
4"	LF	9,530	$ 16.90	$161,060	$96,630	$ 362
6"	LF	5,520	18.40	101,570	60,940	210
Manholes	EA	4	1,160	4,640	2,780	-
Force main, common trench						
2½"	LF	1,060	6.50	6,890	4,130	-
3"	LF	1,540	7.50	11,550	6,930	-
4"	LF	1,000	8.40	8,400	5,040	-
Force main, individual trench						
2"	LF	1,200	11.50	13,800	8,280	-
2½"	LF	450	11.80	5,310	3,190	-
3"	LF	700	12.70	8,890	5,330	-
4"	LF	4,550	13.70	62,340	37,400	-
Lift Station						
A 82 gpm, TDH 88 ft	EA	1		25,400	7,620	1,710
B 60 gpm, TDH 32 ft	EA	1		22,600	6,780	1,700
C 40 gpm, TDH 26 ft	EA	1		22,600	6,780	1,510
D 25 gpm, TDH 19 ft	EA	1		22,600	6,780	1,480
Auxiliary power units						
3 Hp	EA	2	7,800	15,600	4,680	-
2 Hp	EA	1	6,300	6,300	1,890	-
Service connection						
STE gravity	EA	86	958	82,390	49,430	-
STE pump	EA	2	2,790	5,580	1,680	124
Septic tank						
new + abandon privy	EA	14	854	11,960	7,170	140
upgrade	EA	68	175	11,900	7,140	680
replace	EA	6	854	5,120	3,070	60
Building sewer	EA	14	90	1,260	760	-
Subtotal initial cost				617,760	334,430	7,976
Service factor (35%)				216,220		
Subtotal initial capital cost				833,980		
Future connection cost						
Service connection						
STE gravity	EA	27	958	25,870	15,520	-
STE pump	EA	1	2,790	2,790	840	62
Septic tank						
new	EA	28	800	22,400	13,440	280
replace	EA	25	854	21,810	12,810	-
Building sewer	EA	28	90	2,520	1,510	-
Subtotal future connection cost				75,390	44,120	342
Annual future connection cost				3,770		17

Table E-6. Quantities and costs for STE pressure sewers for the north and west shorelines of Island Lake, and transmission to Bog Treatment. (Alternative 5B).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewer pipe						
2"	LF	660	$ 10.10	$ 6,670	$ 4,000	$ 13
2½"	LF	890	10.50	9,350	5,610	17
3"	LF	2,740	11.40	31,240	18,740	52
4"	LF	16,670	12.50	208,380	125,030	317
STE gravity sewer pipe						
6"	LF	1,200	18.40	22,080	13,250	46
Manhole	EA	1	1,160	1,160	700	-
Service connection						
STE pump	EA	88	2,790	245,520	73,670	5,456
Septic tank						
new + abandon privy	EA	14	854	11,960	7,170	140
upgrade	EA	68	175	11,900	7,170	680
replace	EA	6	854	5,120	3,070	60
Building sewer	EA	14	90	1,260	760	-
Subtotal initial cost				554,640	259,170	6,781
Service factor (35%)				194,120		
Subtotal initial capital cost				748,760		
Future connection cost						
Service connection						
STE pump	EA	28	2,790	78,120	23,440	1,736
Septic tank						
new	EA	28	800	22,400	13,400	280
replace	EA	25	854	21,350	12,810	-
Building sewer	EA	28	90	2,520	1,510	-
Subtotal future connection cost				124,390	51,200	2,016
Annual future connection cost				6,220		101

Table E-7. Quantities and costs for conventional gravity sewers for the entire shoreline of Island Lake, and transmission to existing Sand Lake sewers. (Alternative 6A).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer Pipe						
8"	LF	28,290	$ 26.50	$ 749,690	$449,810	$2,122
Force main, common trench						
2"	LF	1,710	6.20	10,600	6,360	-
2½"	LF	700	6.50	4,550	2,730	-
3"	LF	2,790	7.50	20,930	12,560	-
4"	LF	1,020	8.40	8,570	5,140	-
Force main individual trench						
2"	LF	2,660	11.50	30,590	18,350	-
3"	LF	1,480	12.70	18,800	11,280	-
4"	LF	2,050	13.80	28,290	16,970	-
3" Lake Crossing				40,000	24,000	-
4" Highway Crossing				36,800	22,080	-
Lift Station						
A 150 gpm, TDH 43 Ft				25,400	7,620	2,189
B 110 gpm, TDH 31 ft				25,400	7,620	2,081
C 40 gpm, TDH 21 ft				22,600	6,780	1,498
D 25 gpm, TDH 19 ft				22,600	6,780	1,481
E 50 gpm, TDH 33 ft				22,600	6,780	1,677
F 25 gpm, TDH 10 ft				22,600	6,780	1,472
G 25 gpm, TDH 34 ft				22,600	6,780	1,496
Auxiliary Power Units						
5 Hp	EA	2	8,050	16,100	4,830	-
2 Hp	EA	3	6,300	18,900	5,670	-
Wye	EA	151	49	7,400	4,440	-
Service connection	EA	151	140	21,140	12,680	-
House lead						
gravity	EA	148	1,000	148,000	88,800	-
grinder pump	EA	3	2,850	8,550	2,570	186
Abandon septic tank, privy or holding tank	EA	151	54	8,150	-	-
Subtotal initial cost				1,340,860	737,410	14,20[illegible]
Service factor (27%)				362,030		
Subtotal initial capital cost				1,702,890		
Future connection cost						
Wye	EA	63	49	3,090	1,850	-
Service connection	EA	63	140	8,820	5,390	-
Houselead						
gravity	EA	61	1,000	61,000	36,600	-
grinder pump	EA	2	2,850	5,700	3,420	12[illegible]
Subtotal future connection cost				78,610	47,260	12[illegible]
Annual future connection cost				3,931		[illegible]

Table E-8. Quantities and costs for STE gravity sewers for the entire shoreline of Island Lake and transmission to existing Sand Lake sewers. (Alternative 6B).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
STE gravity sewers						
4"	LF	23,430	$ 16.90	$395,970	$237,580	$ 890
6"	LF	3,320	18.40	61,090	36,650	126
8"	LF	2,260	24.10	54,470	32,680	86
Manholes	EA	8	1,160	9,280	5,570	-
Force main, common trench						
2"	LF	1,710	6.20	10,600	6,360	1
2½"	LF	700	6.50	4,550	2,730	-
3"	LF	2,790	7.50	20,930	12,560	-
4"	LF	1,020	8.40	8,570	5,140	-
Force main, individual trench						
2"	LF	2,660	11.50	30,590	18,350	-
3"	LF	1,480	12.70	18,800	11,280	-
4"	LF	2,050	13.80	28,290	16,970	-
3" Lake crossing				40,000	24,000	-
4" Highway Crossing				36,800	22,080	-
Lift Stations						
A 150 gpm, TDH 43 ft				25,400	7,620	2,189
B 110 gpm, TDH 31 ft				25,400	7,620	2,081
C 40 gpm, TDH 21 ft				22,600	6,780	1,498
D 25 gpm, TDH 19 ft				22,600	6,780	1,481
E 50 gpm, TDH 33 ft				22,600	6,780	1,677
F 25 gpm, TDH 10 ft				22,660	6,780	1,472
G 25 gpm, TDH 34 ft				22,600	6,780	1,496
Auxiluary power units						
5 Hp	EA	2	8,050	16,100	4,830	-
2 Hp	EA	3	6,300	18,900	5,670	-
Service connection						
STE gravity	EA	148	958	141,780	85,070	-
STE pump	EA	3	2,790	8,370	2,510	186
Septic tank						
new + abandon privy	EA	35	854	29,890	17,930	350
upgrade	EA	107	175	18,730	11,240	1,070
replace	EA	9	854	7,690	4,610	90
Building sewer	EA	35	90	3,150	1,890	-
Subtotal initial cost				1,128,380	614,840	14,692
Service factor (35%)				394,930		
Subtotal initial capital cost				1,523,310		
Future connection cost						
Service connection						
STE gravity	EA	61	958	58,440	35,060	-
STE pump	EA	2	2,790	5,580	1,670	124
Septic tank						
new	EA	63	800	50,400	30,240	630
replace	EA	38	854	32,450	19,470	-
Building sewer	EA	63	90	5,670	3,400	-
Subtotal future connection cost				152,540	89,840	754
Annual future connection cost				7,627		38

Table E-9. Quantities and costs for STE pressure sewers for the entire shoreline of Island Lake, and transmission to existing Sand Lake sewers. (Alternative 6C).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure sewers						
2"	LF	2,020	$10.10	$ 20,400	$ 12,240	$ 38
2½"	LF	2,280	10.50	23,940	14,360	43
3"	LF	12,900	11.40	147,060	88,240	245
4"	LF	17,340	12.50	216,750	130,050	329
STE gravity sewers						
8"	LF	2,700	24.10	65,070	39,040	103
Manholes	EA	2	1,160	2,320	1,390	-
8" Highway crossing	EA	1		36,800	22,080	-
Service connection STE pump	EA	151	2,790	421,290	126,390	9,362
Septic tank						
new + abandon privy	EA	35	854	29,890	17,930	350
upgrade	EA	107	175	18,730	11,340	11,630
replace	EA	9	854	7,690	4,610	90
Building sewer	EA	35	90	3,150	1,890	-
Subtotal initial cost				993,090	469,560	11,630
Service factor (35%)				347,380		
Subtotal initial cost				1,340,670		
Future connection cost						
Service connection						
STE pump	EA	63	2,790	175,770	52,730	3,906
Septic tank						
new	EA	63	800	50,400	30,240	630
replace	EA	38	854	32,450	19,470	-
Building sewer	EA	63	90	5,670	3,400	-
Subtotal future connection cost				264,290	105,840	4,536
Annual future connection cost				13,215		227

Table E-10. Quantities and costs for conventional gravity sewers for the entire shoreline of Sturgeon Lake and transmission to new Island Lake sewers. (Alternative 7A).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer Pipe 8"	LF	34,200	$26.50	$906,300	$543,780	$2,567
Force main, common trench						
2"	LF	1,740	6.20	10,790	6,470	-
4"	LF	960	8.40	8,060	4,840	-
6"	LF	500	11.10	5,550	3,330	-
Force main, individual trench						
2"	LF	1,900	11.50	21,850	13,110	-
2½"	LF	2,610	11.80	30,800	18,480	-
3"	LF	3,640	12.70	46,230	27,740	-
4"	LF	1,880	13.80	25,940	15,570	-
6"	LF	8,900	16.70	148,630	89,180	-
Lift Stations						
A 25 gpm, TDH 8 ft				22,600	6,780	1,478
B 60 gpm, TDH 51 ft				22,600	6,780	1,745
C 90 gpm, TDH 24 ft				25,400	7,620	1,713
D 110 gpm, TDH 21 ft				25,400	7,620	2,058
E 190 gpm, TDH 54 ft				25,400	7,620	2,234
F 35 gpm, TDH 49 ft				22,600	6,780	1,553
G 25 gpm, TDH 69 ft				22,600	6,780	1,508
H 25 gpm, TDH 95 ft[a]				22,600	6,780	1,525
Auxiliary Power Units						
5 HP	EA	2	8,050	16,100	4,830	-
3 HP	EA	4	7,800	31,200	9,360	-
2 HP	EA	4	6,300	25,200	7,560	-
Wye	EA	197	49	9,650	5,790	-
Service connection	EA	197	140	27,580	16,550	-
House lead						
gravity	EA	193	1,000	193,000	115,800	-
grinder-pump	EA	4	2,850	11,400	3,420	248
Abandon septic tank, privy or holding tank	EA	197	54	10,640	-	-
Subtotal initial cost				1,718,120	942,570	16,629
Service factor (27%)				463,890		
Subtotal initial capital cost				2,182,010		
Future connection cost						
Wye	EA	85	49	4,170	2,500	-
Service connection	EA	85	140	11,900	7,140	-
Houselead						
gravity	EA	83	1,000	83,000	49,800	-
grinder pump	EA	2	2,850	5,700	3,420	124
Subtotal future connection cost				104,770	62,860	124
Annual future connection cost				5,239		6

[a] Serving Island Lake and Sturgeon Lake.

Table E-11. Quantities and costs for conventional gravity sewers for the entire shoreline of Island Lake, and transmission of both Island Lake and Sturgeon Lake wastewater to existing Sand Lake sewers. (Alternative 7A).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
Sewer Pipe						
8"	LF	27,600	$26.50	$731,400	$438,840	$2,070
10"	LF	700	22.20	19,040	11,420	53
Force main, common trench						
2½"	LF	2,410	6.50	15,670	9,400	-
3"	LF	2,790	7.50	20,930	12,560	-
6"	LF	1,020	11.10	11,320	6,790	-
Force main, individual trench						
2"	LF	1,970	11.50	22,660	13,590	-
2½"	LF	690	11.80	8,140	4,890	-
3"	LF	1,480	12.70	18,800	11,280	-
6"	LF	2,050	16.70	34,240	20,540	-
3" Lake crossing	LS			40,000	24,000	-
6" Highway crossing	LS			36,000	22,080	-
Lift Stations						
A 280 gpm, TDH 23 ft				25,400	7,620	2,467
B 110 gpm, TDH 31 ft				25,400	7,620	2,081
C 40 gpm, TDH 21 ft				22,600	6,780	1,498
D 25 gpm, TDH 19 ft				22,600	6,780	1,481
E 50 gpm, TDH 33 ft				22,600	6,780	1,677
F 25 gpm, TDH 10 ft				22,600	6,780	1,472
G 40 gpm, TDH 36 ft				22,600	6,780	1,538
Wye	EA	151	49	7,400	4,440	-
Service connection	EA	151	140	21,140	12,680	-
House lead						
gravity	EA	148	1,000	148,000	88,800	-
grinder-pump	EA	3	2,850	8,550	2,570	186
Abandon septic tank, privy or holding tank	EA	151	54	8,150	-	-
Subtotal initial cost				1,315,240	733,020	14,523
Service factor (27%)				355,110		
Subtotal initial capital cost				1,670,350		
Future connection cost						
Wye	EA	63	49	3,090	1,850	-
Service connection	EA	63	140	8,820	5,290	-
House lead						
gravity	EA	61	1,000	61,000	36,600	-
grinder pump	EA	2	2,850	5,700	3,420	124
Subtotal future connection cost				78,610	47,160	124
Annual future connection cost				3,931		6

Table E-12. Quantities and costs for STE gravity sewers for the entire shoreline of Sturgeon Lake and transmission to new Island Lake sewers. (Alternative 7B).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
STE gravity sewer						
4"	LF	25,120	$16.90	$424,530	$254,720	$ 955
6"	LF	4,640	18.40	85,380	51,230	176
8"	LF	5,920	24.10	142,670	85,600	225
Manholes	EA	4	1,160	4,640	2,780	-
Force main, common trench						
2"	LF	1,740	6.20	10,790	6,470	-
4"	LF	960	8.40	8,060	4,840	-
6"	LF	500	11.10	5,550	3,330	-
Force main, individual trench						
2"	LF	1,900	11.50	21,850	13,110	-
2½"	LF	2,610	11.80	30,800	18,480	-
3"	LF	3,640	12.70	46,230	27,740	-
4"	LF	1,880	13.80	25,940	15,570	-
6"	LF	8,900	16.70	148,630	89,180	-
Lift Stations						
A 25 gpm, TDH 8 ft				22,600	6,780	1,478
B 60 gpm, TDH 51 ft				22,600	6,780	1,745
C 90 gpm, TDH 21 ft				25,400	7,620	1,713
D 110 gpm, TDH 21 ft				25,400	7,620	2,058
E 190 gpm, TDH 54 ft				25,400	7,620	2,234
F 35 gpm, TDH 49 ft				22,600	6,780	1,553
G 25 gpm, TDH 69 ft				22,600	6,780	1,508
H 25 gpm, TDH 95 ft[a]				22,600	6,780	1,525
Auxiliary Power Units[a]						
5 HP	EA	2	8,050	16,100	4,830	-
3 HP	EA	4	7,800	31,200	9,360	-
2 HP	EA	4	6,300	25,200	7,560	-
Service connection						
STE gravity	EA	193	958	184,890	110,940	-
STE pump	EA	4	2,790	11,160	3,350	248
Septic tank						
new + abandon privy	EA	30	854	25,630	15,370	300
upgrade	EA	155	175	27,130	16,280	1,550
replace	EA	12	854	10,250	6,150	120
Building sewer	EA	30	90	2,700	1,620	-
Subtotal initial cost				1,478,530	805,270	17,388
Service factor (35%)				517,490		
Subtotal initial capital cost				1,996,020		
Future connection cost						
Service connection	EA					
STE gravity	EA	83	958	79,510	47,710	-
STE pump	EA	2	2,790	5,580	1,670	124
Septic tank						
new	EA	85	800	68,000	40,800	850
replace	EA	35	854	29,890	17,930	-
Building Sewer	EA	85	90	7,650	4,590	-
Subtotal future connection cost				190,630	112,700	974
Annual future connection cost				9,532		49

[a] Serving Island Lake and Sturgeon Lake

Table E-13. Quantities and costs for STE gravity sewers for the entire shoreline of Island Lake and transmission of Island Lake and Sturgeon Lake wastewater to existing Sand Lake sewers. (Alternative 7B).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
STE gravity sewer						
4"	LF	22,020	$16.90	$372,140	$223,280	$ 837
6"	LF	3,320	18.40	61,090	36,650	126
8"	LF	2,260	24.10	54,470	32,680	86
10"	LF	800	24.80	19,840	11,900	30
Manhole	EA	10	1,160	11,600	6,960	-
Force main, common trench						
2½"	LF	2,410	6.50	15,670	9,400	-
3"	LF	2,790	7.50	20,930	12,560	-
6"	LF	1,020	11.10	11,320	6,790	-
Force main, individual trench						
2"	LF	1,970	11.50	22,660	13,590	-
2½"	LF	690	11.80	8,140	4,890	-
3"	LF	1,480	12.70	18,800	11,280	-
6"	LF	2,050	16.70	34,240	20,540	-
3" Lake Crossing				40,000	24,000	-
6" Highway Crossing				36,000	22,080	-
Lift Stations						
A 280 gpm, TDH 23 ft				25,400	7,620	2,467
B 110 gpm, TDH 31 ft				25,400	7,620	2,081
C 40 gpm, TDH 21 ft				22,600	6,780	1,498
D 25 gpm, TDH 19 ft				22,600	6,780	1,481
E 50 gpm, TDH 33 ft				22,600	6,780	1,677
F 25 gpm, TDH 10 ft				22,600	6,780	1,472
G 40 gpm, TDH 36 ft				22,600	6,780	1,538
Service connection						
STE gravity	EA	148	958	141,780	85,070	-
STE pump	EA	3	2,790	8,370	2,510	186
Septic tank						
new + abandon privy	EA	35	854	29,890	17,930	350
upgrade	EA	107	175	18,730	11,240	1,070
replace	EA	9	854	7,690	4,610	90
Building sewer	EA	35	90	3,150	1,890	-
Subtotal initial cost				1,100,310	608,990	14,989
Service factor (35%)				385,110		
Subtotal initial capital cost				1,485,420		
Future connection cost						
Service connection						
STE gravity	EA	61	958	58,440	35,060	-
STE pump	EA	2	2,790	5,580	1,670	124
Septic tank						
new	EA	63	800	50,400	30,240	630
replace	EA	38	854	32,450	19,470	-
Building sewer	EA	63	90	5,670	3,400	-
Subtotal future connection cost				152,470	89,840	754
Annual future connection cost				7,624		38

Table E-14. Quantities and costs for STE pressure sewers serving the entire shoreline of Sturgeon Lake and transmission to new Island Lake sewers. (Alternative 7C).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure pipe						
2"	LF	1,300	$10.10	$ 13,130	$ 7,880	$ 25
2½"	LF	6,900	10.50	72,450	43,470	131
3"	LF	15,070	11.40	171,800	103,080	286
4"	LF	13,880	12.50	173,500	104,100	264
6"	LF	2,950	15.40	45,430	27,260	56
STE gravity sewer						
4"	LF	1,740	16.90	29,410	17,640	66
Manholes	EA	2	1,160	2,320	1,390	-
Force main, individual trench						
6"	LF	9,650	16.70	161,160	96,690	-
Lift stations[a]						
B 50 gpm, TDH 99 ft				22,600	6,780	1,784
C 130 gpm, TDH 18 ft				25,400	7,620	2,060
Auxiliary Power Units[b]						
5 HP	EA	2	8,050	16,100	4,830	-
Service connection STE pump	EA	197	2,790	549,630	164,890	12,214
Septic tank						
new + abandon privy	EA	30	854	25,620	15,370	300
upgrade	EA	155	175	27,130	16,280	1,290
replace	EA	12	854	10,250	6,150	120
Building sewer	EA	30	90	2,700	1,620	-
Subtotal initial cost				1,347,120	625,050	18,856
Service factor (35%)				471,490		
Subtotal initial capital cost				1,818,610		
Future connection cost						
Service connection						
STE pump	EA	85	2,790	237,150	71,150	5,270
Septic tank						
new	EA	85	800	68,000	40,800	850
replace	EA	35	854	29,890	17,730	-
Building sewer	EA	85	90	7,650	4,590	-
Subtotal future connection cost				342,690	134,270	6,120
Annual future connection cost				17,135		306

[a] Lift station A is included on Table E-15.

[b] Serving Island Lake and Sturegon Lake.

Table E-15. Quantities and costs for STE pressure sewers for the entire shoreline of Island Lake and transmission of Island Lake and Sturgeon Lake wastewater to existing Sand Lake sewers. (Alternative 7C).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure pipe						
2"	LF	1,920	$10.10	$ 19,390	$ 11,640	$ 36
2½"	LF	2,020	10.50	21,210	12,730	38
3"	LF	11,260	11.40	128,360	77,020	214
4"	LF	13,540	12.50	169,250	101,550	257
STE gravity sewer						
6"	LF	2,000	18.40	36,800	22,080	76
8"	LF	3,270	24.10	78,810	47,280	124
Manhole	EA	3	1,200	3,600	2,160	-
8" Highway crossing	EA	1		36,800	22,080	-
Force main, individual trench						
6"	LF	2,350	16.70	39,250	23,550	-
6" Highway crossing	EA	1		36,800	22,080	-
Force main, common trench						
6"	LF	720	11.10	7,990	4,800	-
Lift Stations						
A 200 gpm, TDH 34 ft				25,400	7,620	2,420
Service connection-STE pump	EA	151	2,790	421,290	126,390	9,362
Septic tank						
new + abandon privy	EA	35	854	29,890	17,930	350
upgrade	EA	107	175	18,730	11,240	1,070
replace	EA	9	854	7,690	4,610	90
Building sewer	EA	35	90	3,150	1,890	-
Subtotal initial cost				1,084,410	517,650	14,037
Service factor (35%)				379,440		
Subtotal initial capital cost				1,463,950		
Future connection cost						
Service connection STE pump	EA	63	2,790	175,770	52,730	3,906
Septic tank						
new	EA	63	800	50,400	30,240	630
replace	EA	38	854	32,450	19,470	-
Building sewer	EA	63	90	5,670	3,400	-
Subtotal future connection cost				264,290	105,840	4,536
Annual future connection cost				13,215		227

Table E-16. Summary of cluster systems, WWTP, and administrative costs.

Item	Initial Cost						Future Construction Cost							Total
				Present Worth			Annual	Total	Incremental	Present Worth				
	Capital	Salvage	O&M	Salvage	O&M	Total	Construction	Salvage	Ann. O&M	Construction	Salvage	O&M	Total	Present Worth
Cluster Systems														
Island Lake (Alt. 3)	483,250	187,980	3,373	43,240	34,060	474,070	1,433	13,010	18	14,470	2,990	1,300	12,780	486,850
Sturgeon Lake (Alt. 3,4,5,6)	453,630	153,200	6,491	35,240	65,550	483,940	1,472	10,970	29	14,860	2,520	2,090	14,430	498,370
Total (Alt. 3)	936,880	341,180	9,864	78,480	99,610	958,010	3,205	23,980	47	29,330	5,510	3,390	27,210	985,220
WWTP[a]														
Alt. 4	287,150	180,980	2,260	41,630	22,820	286,340	-	-	-	-	-	-	-	268,340
Alt. 5 (Bog treatment)	244,850	67,490	9,689	15,520	97,840	327,170	-	-	-	-	-	-	-	327,170
Alt. 6	377,190	254,320	3,010	58,490	30,400	349,100	-	-	-	-	-	-	-	349,100
Alt. 7	688,340	491,950	4,940	113,150	49,890	625,080	-	-	-	-	-	-	-	625,080
Administrative (All Alts.)	-	-	28,400	-	286,790	286,790	-	-	-	-	-	-	-	286,790

[a]Upgrade existing Moose Lake WWTP (except for Alt. 5)

Table E-17. Quantities and costs for STE pressure collection for a limited area on the east shore of Sturgeon Lake, transmission, and treatment and disposal in a Cluster Drainfield. (Alternatives 3, 4, 5 and 6)

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
Collection & transmission						
STE gravity pipe						
4"	LF	2,100	$16.90	$35,490	$21,290	$ 80
STE pressure pipe						
3"	LF	7,850	11.40	89,490	53,690	149
Lift Station						
25 gpm, TDH 66 ft				22,600	6,780	1,502
Auxiliary Power						
3 Hp	EA	1	7,800	7,800	2,340	-
Service connection						
STE pump	EA	20	2,790	55,800	16,740	1,240
Septic tank						
new + abandon privy	EA	1	854	850	510	10
upgrade	EA	18	175	3,150	1,890	180
replace	EA	1	854	850	510	10
Building sewer	EA	1	90	90	50	-
Cluster Drainfield						
Gravel road	LF	800	7.00	5,600	-	320
Land	AC	5	3,000	15,000	27,090	-
Fence	LF	1,900	8.14	15,570	-	95
Fence gate	EA	1	560	560	-	-
Dosing chamber (7000 gal)	EA	1	7,500	7,500	4,500	-
Dosing pumps (Duplex 250 gpm, TDH 20 ft)	EA	1	16,000	16,000	4,800	2,180
6" STE gravity pipe	LF	1,630	13.30	21,680	13,010	62
Monitoring well & testing	EA	2	1,250	2,500	-	240
Trench drainfield	SF	16,900	2.10	35,490	-	423
Subtotal initial cost				336,020	153,200	6,491
Service factor (35%)				117,610		
Subtotal initial capital cost				453,630		
Future connection cost						
Service connection						
STE pump	EA	8	2,790	22,320	6,700	500
Septic tank						
new	EA	8	800	6,400	3,840	80
Building sewer	EA	8	90	720	430	-
Subtotal future connection cost				29,440	10,970	580
Annual future connection cost				1,472		29

Table E-18. Quantities and costs for STE pressure sewers for two areas on the western shoreline of Island Lake, transmission, and treatment and disposaling cluster drainfield. (Alternative 3)

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
STE pressure pipe						
2"	LF	700	$10.10	$ 7,070	$ 4,240	$ 13
2½"	LF	5,100	10.50	53,550	32,130	97
3"	LF	3,250	11.40	37,050	22,230	62
Service connection						
STE pump	EA	30	2,790	83,700	25,110	1,860
Septic tank						
new & abandon privy	EA	9	854	7,690	4,610	90
upgrade	EA	13	175	2,280	1,370	130
replace	EA	8	854	6,830	4,100	80
Building sewer	EA	9	90	810	490	-
Cluster Drainfield						
Land	AC	11	3,000	33,000	59,600	-
Fence	LF	2,700	8.14	21,980	-	135
Fence Gate	EA	1	560	560	-	-
Dosing Chamber	EA	1	7,500	7,500	4,500	-
6" STE gravity pipe	LF	3,710	13.30	49,340	29,600	141
Monitoring well & testing	EA	2	1,250	2,500	-	240
Trench drainfield	SF	21,000	2.10	44,100	-	525
Subtotal initial cost				357,960	187,980	3,373
Service factor (35%)				125,890		
Subtotal initial capital cost				483,250		
Future connection cost						
Service connection						
STE pump	EA	5	2,790	13,950	4,190	310
Septic tank						
new	EA	5	800	4,000	2,400	50
replace	EA	12	854	10,250	6,150	-
Building Sewer	EA	5	90	450	270	-
Subtotal future connection cost				28,650	13,010	360
Annual future connection cost				1,433		18

Table E-19. Quantities and costs for upgrading existing Moose Lake WWTP to serve North and West shorelines of Island Lake. (Alternative 4)

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
Land	AC	14	$3,000	$ 42,000	$ 75,860	-
Lagoon Construction & Site Work	LS			166,300	99,780	$1,000
Bentonite liner	LS			13,200	3,960	-
Main Lift Station Incremental capacity	LS			4,600	1,380	1,260
Subtotal				226,100	180,980	2,260
Service factor (27%)				61,050		
Total initial capital cost				287,150		

Table E-20. Quantities and costs for Bog Treatment WWTP to serve north and west shorelines of Island Lake. (Alternative 5)

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
Land	AC	20	$2,000	$ 40,000	$53,600	-
Site evaluation	LS			15,200	-	-
Site preparation	LS			1,600	-	-
Trench construction	CY	11,330	4.20	47,590	-	-
Curtain drain trench	LF	1,580	6.50	10,270	2,370	$ 93
Pumps & chambers	EA	2	3,400	6,800	670	1,487
Dewatering piping	LF	800	4.00	3,200	1,920	305
Flow meter assembly	LS			10,000	3,000	-
Distribution Box	LS			2,000	1,200	-
Pipe to trenches (Matl. only)	LF	2,625	3.00	7,880	4,730	-
Monitoring wells	EA	6	100	600	-	-
Laboratory analysis	LS			-	-	7,480
Service Roads	LF	300	7.00	2,100	-	120
Fencing	LF	4,070	8.14	33,130	-	204
Electrical service	LS			1,000	-	-
Subtotal				181,370	67,490	9,689
Service factor (35%)				63,480		
Total initial capital cost				244,850		

Table E-21. Quantities and costs for upgrading existing Moose Lake WWTP to serve the entire shoreline of Island Lake. (Alternative 6).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
Land	AC	22	$3,000	$ 66,000	$119,200	-
Lagoon construction & sitework	LS			199,600	119,760	$1,300
Bentonite liner	LS			19,800	11,880	-
Main lift station incremental capacity	LS			11,600	3,480	1,710
Subtotal				297,000	254,320	3,010
Service factor (27%)				80,190		
Total initial capital cost				377,190		

Table E-22. Quantities and costs for upgrading existing Moose Lake WWTP to serve the entire shoreline of Island Lake and Sturgeon Lake. (Alternative 7).

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
Land	AC	48	$3,000	$144,000	$260,080	-
Lagoon construction & sitework	LS			332,600	199,560	$2,100
Bentonite Liner	LS			42,300	25,380	-
Main lift station Incremental capacity	LS			23,100	6,930	2,840
Subtotal				542,000	491,950	4,940
Service factor (27%)				146,340		
Total initial capital cost				688,340		

Table E-23. Administrative costs. (All Alternatives)

Item	Unit	Quantity	Unit Cost	Construction	Salvage	O&M
Office/Garage	LS			-	-	$ 1,400
Administrative Personnel Services	LS			-	-	27,000
Subtotal initial cost				-	-	28,400

Table E-24. Summary of on-site upgrade costs.

Item	Initial Cost						Future Construction Cost							Total Present Worth
				Present Worth			Annual	Total	Incremental	Present Worth				
	Capital	Salvage	O&M	Salvage	O&M	Total	Construction	Salvage	Ann. O&M	Construction	Salvage	O&M	Total	
Alternative 2														
Island Lake	171,360	17,140	5,334	3,940	53,860	221,280	13,000	53,110	202	131,280	12,220	14,570	133,630	354,910
Sturgeon Lake	105,660	23,940	4,522	5,510	45,670	145,820	13,430	65,980	211	135,620	15,180	15,220	135,660	281,480
Other[1]	14,510	6,450	420	1,480	4,240	17,270	7,590	40,920	72	76,660	9,410	5,190	72,440	89,710
Total	291,530	47,530	10,276	10,930	103,770	384,370	34,020	160,010	485	343,560	36,810	34,980	341,730	726,100
Alternative 3														
Island Lake	156,520	14,410	4,349	3,320	43,920	197,120	10,480	44,290	156	105,830	10,190	11,250	106,890	304,010
Sturgeon Lake	51,650	17,090	1,456	3,930	14,700	62,420	12,240	60,640	128	123,600	13,950	9,230	118,880	181,300
Other[1]	14,510	6,450	420	1,980	4,240	17,270	7,590	40,920	72	76,660	9,410	5,190	72,440	89,710
Total	222,680	37,950	6,225	8,730	62,860	276,810	30,310	145,860	406	306,090	33,550	25,670	298,210	575,020
Alternatives 4 & 5														
Island Lake	56,250	6,600	1,850	1,520	18,680	73,410	5,640	25,350	74	56,950	5,830	5,340	56,460	129,870
Sturgeon Lake	51,650	17,090	1,456	3,930	14,700	62,420	12,240	60,640	128	123,600	13,950	9,230	118,880	181,300
Other[1]	14,510	6,450	420	1,480	4,240	17,270	7,591	40,920	72	76,660	9,410	5,190	72,440	89,710
Total	122,410	30,140	3,726	6,930	37,620	153,100	25,471	126,910	274	257,210	29,190	19,760	247,780	400,880
Alternative 6														
Sturgeon Lake	51,650	17,090	1,456	3,930	14,700	62,420	12,240	60,640	128	123,600	13,950	9,230	118,800	181,300
Other[1]	14,510	6,450	420	1,480	4,240	17,270	7,591	40,920	72	76,660	9,410	5,190	72,440	89,710
Total	66,160	23,540	1,876	5,410	18,940	79,690	19,831	101,560	200	200,260	23,360	14,420	191,320	271,010
Alternative 7														
Other[1]	14,510	6,450	420	1,480	4,240	17,270	7,591	40,920	72	76,660	9,410	5,190	72,440	89,710

[1] Includes the remainder of the EIS service area (Rush Lake, Passenger Lake, Hogans Acres and Wild Acres)

Table E-25. Quantities and costs for upgrading and operation of on-site systems for Island Lake. (Alternative 2).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
Upgrade (minor)	89	175	15,575	9,345	890
Upgrade (major)	9	854	7,686	4,612	90
Soil absorption system					
Trench	7	1,129	7,903	-	-
Seepage bed (400 sq ft)	2	904	1,808	-	-
Mound (400 sq ft incld. pump)	32	2,504	80,128	-	2,304
Waste separation					
Blackwater HT - Permanent	5	885	4,425	2,655	1,915
Blackwater HT - Seasonal	1	885	885	531	135
Low flow toilet	6	1,420	8,520	-	-
Initial cost			126,930	17,140	5,334
Service factor (35%)			44,426	-	-
Initial capital costs			171,360	-	-
Future costs					
Building sewer	63	90	5,670	3,402	-
Septic tank, new	63	800	50,400	30,240	630
Septic tank, upgrade	38	854	32,452	19,471	-
Trench SAS	35	1,129	39,515	-	-
Seepage bed SAS	23	904	20,792	-	-
Mound (400 sq ft incld. pump)	43	2,504	107,672	-	3,096
Total future costs			260,001	53,110	4,036
Annual future costs			13,000	-	202

HT - holding tank, SAS - soil absorption system

Table E-26. Quantities and costs for upgrading and operation of on-site systems for Sturgeon Lake. (Alternative 2).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
Upgrade (minor)	129	175	22,575	13,545	1,290
Upgrade (major)	12	854	10,248	6,149	120
Soil absorption system					
Trench	2	1,129	2,258	-	-
Mound (400 sq ft incld. pump)	3	2,504	7,512	-	216
Mound (250 sq ft incld. pump)	8	2,154	17,232	-	576
Waste separation					
Blackwater HT - Permanent	5	885	4,425	2,655	1,915
Blackwater HT - Seasonal	3	885	2,655	1,593	405
Low flow toilet	8	1,420	11,360	-	-
Initial cost			78,265	23,940	4,522
Service factor (35%)			27,393	-	-
Initial capital costs			105,660	-	-
Future costs					
Building sewer	85	90	7,650	4,590	-
Septic tank, new	85	800	68,000	40,800	850
Septic tank, upgrade	35	854	29,890	17,934	-
Trench SAS	33	1,129	37,257	-	-
Seepage bed SAS	68	904	61,472	-	-
Mound (400 sq ft incld. pump)	19	2,504	47,576	-	1,368
Mound (250 sq ft incld. pump)	3	2,154	6,462	-	216
Pump chamber	6	700	4,200	-	372
Blackwater HT - Permanent	3	885	2,655	1,593	1,149
Blackwater HT - Seasonal	2	885	1,770	1,062	270
Low flow toliet	5	350	1,750	-	-
Total future costs			268,682	65,980	4,225
Annual future costs			13,430		211

HT - Holding tank, SAS - soil absorption system

Table E-27. Quantities and costs for upgrading and operation of on-site systems for Rush Lake, Passenger Lake, Hogans Acres and Wild Acres. (Alternatives 2, 3, 4, 5, 6, and 7).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
Upgrade (minor)	37	175	6,475	3,885	370
Upgrade (major)	5	854	4,270	2,562	50
Initial cost			10,745	6,450	420
Service factor (35%)			3,761	-	-
Initial capital costs			14,506	-	-
Future costs					
Building sewer	68	90	6,120	3,672	-
Septic tank, new	68	800	54,400	32,640	680
Septic tank, upgrade	9	854	7,686	4,612	-
Seepage bed SAS	70	904	63,280	-	-
Mound (400 sq ft incld. pump)	7	2,504	7,528	-	504
Pump chamber	4	700	2,800	-	248
Total future costs			151,814	40,924	1,432
Annual future costs			7,591	-	72

SAS- soil absorption system

Table E-28. Quantities and costs for upgrading and operation of on-site systems for Island Lake. (Alternative 3).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
Upgrade (minor)	68	175	11,900	7,140	680
Upgrade (major)	9	854	7,686	4,612	90
Soil absorption system					
Trench	7	1,129	7,903	-	-
Seepage bed (400 sq ft)	2	904	1,808	-	-
Mound (400 sq ft incld. pump)	30	2,504	75,120	-	2,160
Waste separation					
Blackwater HT - Permanent	3	885	2,655	1,593	1,149
Blackwater HT - Seasonal	2	885	1,770	1,062	270
Low flow toilet	5	1,420	7,100	-	-
Initial cost			115,942	14,410	4,349
Service factor (35%)			40,580	-	-
Initial capital costs			156,520	-	-
Future cost					
Building sewer	58	90	5,220	3,132	-
Septic tank, new	58	800	46,400	27,840	580
Septic tank, upgrade	26	854	22,204	13,322	-
Trench SAS	30	1,129	33,870	-	-
Seepage bed SAS	23	904	20,792	-	-
Mound (400 sq ft. incld. pump)	31	2,504	77,624	-	2,232
Pump chamber	5	700	3,500	-	310
Total future costs			209,610	44,290	3,122
Annual future costs			10,480	-	156

HT - holding tank, SAS - soil absorption system.

Table E-29. Quantities and costs for upgrading and operation of on-site systems for Sturgeon Lake. (Alternative 3).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
Upgrade (minor)	114	175	19,950	11,970	1,140
Upgrade (major)	10	854	8,540	5,124	100
Soil absorption system					
Trench	2	1,129	2,258	-	-
Mound (400 sq ft incld. pump)	3	2,504	7,512	-	216
Initial cost			38,260	17,094	1,456
Service factor (35%)			13,391	-	-
Initial capital costs			51,651	-	-
Future costs					
Building sewer	76	90	6,840	4,104	-
Septic tank, new	76	800	60,800	36,480	760
Septic tank, upgrade	35	854	29,890	17,934	-
Trench SAS	33	1,129	37,257	-	-
Seepage bed SAS	68	904	61,472	-	-
Mound (400 sq ft)	14	2,504	35,056	-	-
Mound (200 sq ft incld. pump)	2	2,154	4,308	-	144
Pump chamber	6	700	4,200	-	372
Blackwater HT Permanent	3	885	2,655	1,593	1,149
Blackwater HT Seasonal	1	885	885	531	135
Low flow toliet	4	350	1,400	-	-
Total future costs			244,763	60,642	2,560
Annual future costs			12,238	-	129

SAS - soil absorption system, HT - holding tank

Table E-30. Quantities and costs for upgrading and operation of on-site systems for Island Lake. (Alternatives 4 and 5).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
Upgrade (minor)	28	175	4,900	2,940	280
Upgrade (major)	3	854	2,562	1,537	30
Soil absorption system					
Trench	5	1,129	5,645	-	-
Seepage bed (400 Sq Ft)	2	904	1,808	-	-
Mound (400 sq ft incld. pump)	7	2,504	17,528	-	504
Waste Separation					
Blackwater HT - Permanent	2	885	1,770	1,062	766
Blackwater HT - Seasonal	2	885	1,770	1,062	270
Low flow toilet	4	1,420	5,680	-	-
Initial cost			41,663	6,600	1,850
Service factor (35%)			14,582	-	-
Initial capitol costs			56,250	-	-
Future costs					
Building sewer	35	90	3,150	1,890	-
Septic tank, new	35	800	28,000	16,800	350
Septic tank, upgrade	13	854	11,102	6,661	-
Trench SAS	15	1,129	16,935	-	-
Seepage bed SAS	19	904	17,176	-	-
Mound (400 sq ft incld. pump)	14	2,504	35,056	-	1,008
Pump chamber	2	700	1,400	-	124
Total future costs			112,820	25,350	1,482
Annual future costs			5,640	-	74

HT- holding tank, SAS- soil absorption system

Table E-31. Quantities and costs for upgrading and operation of on-site systems for Sturgeon Lake. (Alternatives 4 and 5).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
Upgrade (minor)	114	175	19,950	11,970	1,140
Upgrade (major)	10	854	8,540	5,124	100
Soil absorption system					
Trench	2	1,129	2,258	-	-
Mound (400 sq ft incld. pump)	3	2,504	7,512	-	216
Initial cost			38,260	17,090	1,456
Service factor (35%)			13,391	-	-
Initial capitol costs			51,650	-	-
Future costs					
Building sewer	76	90	6,840	4,104	-
Septic tank, new	76	800	60,800	36,480	760
Septic tank, upgrade	35	854	29,890	17,934	-
Trench SAS	33	1,129	37,257	-	-
Seepage bed SAS	68	904	61,472	-	-
Mound (400 sq ft)	14	2,504	35,056	-	-
Mound (200 sq ft incld. pump)	2	2,154	4,308	-	144
Pump chamber	6	700	4,200	-	372
Blackwater HT Permanent	3	885	2,655	1,593	1,149
Blackwater HT Seasonal	1	885	885	531	135
Low flow toliet	4	350	1,400	-	-
Total future costs			244,760	60,640	2,560
Annual future costs			12,240	-	128

SAS - soil absorption system, HT - holding tank

Table E-32. Quantities and costs for upgrading and operation of on-site systems for Sturgeon Lake. (Alternative 6).

Item	Quantity	Unit Cost	Construction	Salvage	O&M
Septic tank					
Upgrade (minor)	114	175	19,950	11,970	1,140
Upgrade (major)	10	854	8,540	5,124	100
Soil absorption system					
Trench	2	1,129	2,258	-	-
Mound (400 sq ft incld. pump)	3	2,504	7,512	-	216
Initial cost			38,260	17,090	1,456
Service factor (35%)			13,391	-	-
Initial capitol costs			51,650	-	-
Future costs					
Building sewer	76	90	6,840	4,104	-
Septic tank, new	76	860	60,800	36,480	760
Septic tank, upgrade	35	854	29,890	17,934	-
Trench SAS	29	1,129	37,257	-	-
Seepage bed SAS	68	904	61,472	-	-
Mound (400 sq ft)	14	2,504	35,056	-	-
Mound (200 sq ft incld. pump)	2	2,154	4,308	-	144
Pump chamber	6	700	4,200	-	372
Blackwater HT Permanent	3	885	2,655	1,593	1,149
Blackwater HT Seasonal	1	885	885	531	135
Low flow toliet	4	350	1,400	-	-
Total future costs			244,760	60,640	2,560
Annual future costs			12,240	-	128

SAS - soil absorption system, HT - holding tank

Appendix F

Analysis of Grant Eligibility

APPENDIX F - Analysis of Grant Eligibility

GRANT ELIGIBILITY

The eligibility of initial capital costs for State and USEPA grants are based on MPCA policy and USEPA Region V policy which are in turn based on the Code of Federal Regulations, Title 40, Part 35. These regulations are currently being revised. Interim Final regulations were issued in the Federal Register on May 12, 1982, and the Final regulations are expected in the immediate future. Current MPCA policy was used to determine costs eligible for grants (Mr. L. Zdon, MPCA, to WAPORA, Inc., 18 August 1982 and 29 November 1982).

A project that is determined to be innovative and alternative qualifies for a greater percentage of grant funding of eligible initial capital costs than conventional projects. The percentage is shown below:

	Grant Percentage of Eligible Costs[1]		
	USEPA Grant	State Grant	Total Grant
Innovative and Alternative	85%	9%	94%
Conventional	75%	15%	90%

The initial capital costs include the following:

- o Eligible costs - Initial capital costs eligible for USEPA and state grants.
- o Ineligible costs - Initial capital costs not eligible for USEPA and State grants (not including homeowner ineligible costs).
- o Homeowner inelgible costs - Initial capital costs that must be financed by the individual homeowner.

Operation and maintenance costs are not grant eligible.

Grant eligibility in this report was based on the following:

Collection and Conveyance

1. STE gravity and STE pressure sewers - All costs were considered eligible for innovative and alternative funding, except for building sewers which were considered homeowner ineligible.

2. Conventional gravity sewers - Pump stations, force mains, and any gravity sewers used only as inteceptors were considered eligible for conventional funding. Gravity collection sewers were considered ineligible. House leads (piping from the residence to the edge of the sewer easement) were considered ineligible.

Centralized Treatment

1. Upgrading the Moose Lake WWTP - All costs were considered eligible for conventional funding except for land purchase which was considered ineligible

2. Bog Treatment - All costs (including land) were considered eligible for innovative and alternative funding.

Cluster Drainfields

All costs were considered eligible for innovative and alternative funding (including STE gravity and STE pressure collection systems) except building sewers which were considered homeowner ineligible.

Upgrading On-Site Systems

Upgrading on-site systems for lots inhabited prior to December 1977 were considered eligible for innovative and alternative funding. The number of eligible residences was determined from permits and questionnaires. All ineligible residences were assumed to require minor upgrades only. Low-flow toilets were considered homeowner ineligible.

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[1] For construction started after 30 September 1984 the Federal share will be 55% for conventional systems and 75% for innovative and alternative systems (Federal Register, Vol 47, NO 92, May 12, 1982; Changes in regulations governing construction grants for treatment works). The state share after 30 September 1984 is not known at this time.

Table F-1. Governmental grants and local share costs for Alternative 2 (costs stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Component	Total Estimated Capital Cost	Annual O&M (Local Cost)	USEPA Grant		USEPA Grant & State Grant		
			Federal	Local	Federal	State	Local
On-site Systems							
eligible	262.7	-	223.3 (85%)	39.4 (15%)	223.3 (85%)	23.6 (9%)	15.8 (6%)
ineligible	28.8	10.3	-	28.8 (100%)	-	-	28.8 (100%)
Administrative							
ineligible	-	28.4	-	-	-	-	-
Total	291.5	38.7	223.3	68.2	223.3	23.6	44.6

Table F-2. Governmental grants and local share costs for Alternative 3 (costs stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Component	Total Estimated Capital Cost	Annual O&M (Local Cost)	USEPA Grant		USEPA Grant & State Grant		
			Federal	Local	Federal	State	Local
On-Site Systems							
eligible	207.0	-	176.0 (85%)	31.0 (15%)	176.0 (85%)	18.6 (9%)	12.4 (6%)
ineligible	15.7	6.2	-	15.7 (100%)	-	-	15.7 (100%)
Cluster Systems							
eligible	936.0	-	795.6 (85%)	140.4 (15%)	795.6 (85%)	84.2 (9%)	56.2 (6%)
homeowner ineligible	0.9	9.9	-	0.9 (100%)	-	-	0.9 (100%)
Administrative							
ineligible	-	28.4	-	-	-	-	-
Total	1,159.6	44.5	971.6	188.0	971.6	102.8	85.2

Table F-3. Governmental grants and local share costs for Alternative 4A (costs stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Component	Total Estimated Capital Cost	Annual O&M (Local Cost)	USEPA Grant		USEPA Grant & State Grant		
			Federal	Local	Federal	State	Local
On-Site Systems							
eligible	109.2	-	92.8 (85%)	16.4 (15%)	92.8 (85%)	9.8 (9%)	6.6 (6%)
ineligible	13.2	3.7	-	13.2 (100%)	-	-	13.2 (100%)
Cluster Systems							
eligible	453.5	-	385.5 (85%)	68.0 (15%)	385.5 (85%)	40.8 (9%)	27.2 (6%)
homeowner ineligible	0.1	6.5	-	0.1 (100%)	-	-	0.1 (100%)
Centralized Collection							
eligible	412.3	-	309.2 (75%)	103.1 (25%)	309.2 (75%)	61.9 (15%)	41.2 (10%)
ineligible	388.0	7.6	-	308.0 (100%)	-	-	388.0 (100%)
homeowner ineligible	91.7	-	-	91.7 (100%)	-	-	91.7 (100%)
Centralized Treatment							
eligible	245.2	-	183.9 (75%)	61.3 (25%)	183.9 (75%)	36.8 (75%)	24.5 (10%)
ineligible	42.0	2.3	-	42.0 (100%)	-	-	42.0 (100%)
Administrative							
ineligible	-	28.4	-	-	-	-	-
Total	1,755.2	48.5	971.4	783.8	971.4	149.3	634.5

Table F-4. Governmental grants and local share costs for Alternative 4B (costs stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Component	Total Estimated Capital Cost	Annual O&M (Local Cost)	USEPA Grant		USEPA Grant & State Grant		
			Federal	Local	Federal	State	Local
On-site Systems							
eligible	109.2	-	92.8 (85%)	16.4 (15%)	92.8 (85%)	9.8 (9%)	6.6 (6%)
ineligible	13.2	3.7	-	13.2 (100%)	-	-	13.2 (100%)
Cluster Systems							
eligible	453.5	-	385.5 (85%)	68.0 (15%)	385.5 (85%)	40.8 (9%)	27.2 (6%)
homeowner ineligible	0.1	6.5	-	0.1 (100%)	-	-	0.1 (100%)
Centralized Collection							
eligible	777.4	-	660.8 (85%)	116.6 (15%)	660.8 (85%)	70.0 (9%)	46.6 (6%)
ineligible	-	7.9	-	-	-	-	-
homeowner ineligible	1.3	-	-	1.3 (100%)	-	-	1.3 (100%)
Centralized Treatment							
eligible	245.2	-	183.9 (75%)	61.3 (25%)	183.9 (75%)	36.8 (15%)	24.5 (10%)
ineligible	42.0	2.3	-	42.0 (100%)	-	-	42.0 (100%)
Administrative							
ineligible	-	28.4	-	-	-	-	-
Total	1,641.9	48.8	1,323.0	318.9	1,323.0	157.4	161.5

Table F-5. Governmental grants and local share costs for Alternative 4C (costs stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Component	Total Estimated Capital Cost	Annual O&M (Local Cost)	USEPA Grant		USEPA Grant & State Grant		
			Federal	Local	Federal	State	Local
On-site Systems							
eligible	109.2	-	92.8 (85%)	16.4 (15%)	92.8 (85%)	9.8 (9%)	6.6 (6%)
ineligible	13.2	3.7	-	13.2 (100%)	-	-	13.2 (100%)
Cluster Systems							
eligible	453.5	-	385.5 (85%)	68.0 (15%)	385.5 (85%)	40.8 (9%)	27.2 (6%)
homeowner ineligible	0.1	6.5	-	0.1 (100%)	-	-	0.1 (100%)
Centralized Collection							
eligible	752.9	-	640.0 (85%)	112.9 (15%)	640.0 (85%)	67.8 (9%)	45.1 (6%)
ineligible	-	6.8	-	-	-	-	-
homeowner ineligible	1.3	-	-	1.3 (100%)	-	-	1.3 (100%)
Centralized Treatment							
eligible	245.5	-	183.9 (75%)	61.3 (25%)	183.9 (75%)	36.8 (15%)	24.5 (10%)
ineligible	42.0	2.3	-	42.0 (100%)	-	-	42.0 (100%)
Administrative							
ineligible	-	28.4	-	-	-	-	-
Total	1,617.4	47.7	1,302.2	315.2	1,302.2	155.2	160.0

Table F-6. Governmental grants and local share costs for Alternative 5A (costs stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Component	Total Estimated Capital Cost	Annual O&M (Local Cost)	USEPA Grant		USEPA Grant & State Grant		
			Federal	Local	Federal	State	Local
On-site Systems							
eligible	109.2	-	92.8 (85%)	16.4 (15%)	92.8 (85%)	9.8 (9%)	6.6 (6%)
ineligible	13.2	3.7	-	13.2 (100%)	-	-	13.2 (100%)
Cluster Systems							
eligible	453.5	6.5	385.5 (85%)	68.0 (15%)	385.5 (85%)	40.8 (9%)	27.2 (6%)
homeowner ineligible	0.1	-	-	0.1 (100%)	-	-	0.1 (100%)
Centralized Collection							
eligible	832.7	-	707.8 (85%)	124.9 (15%)	707.8 (85%)	74.9 (9%)	50.0 (6%)
ineligible	-	8.0	-	-	-	-	-
homeowner ineligible	1.3	-	-	1.3 (100%)	-	-	1.3 (100%)
Centralized Treatment							
eligible	244.9	-	208.2 (85%)	36.7 (15%)	208.2 (85%)	22.0 (9%)	14.7 (6%)
ineligible	-	9.7	-	-	-	-	-
Administrative							
ineligible	-	28.4	-	-	-	-	-
Total	1,654.9	56.3	1,394.3	260.6	1,394.3	147.5	113.1

Table F-7. Governmental grants and local share costs for Alternative 5B (costs stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Component	Total Estimated Capital Cost	Annual O&M (Local Cost)	USEPA Grant		USEPA Grant & State Grant		
			Federal	Local	Federal	State	Local
On-Site Systems							
eligible	109.2	-	92.8 (85%)	16.4 (15%)	92.8 (85%)	9.8 (9%)	6.6 (6%)
ineligible	13.2	3.7	-	13.2 (100%)	-	-	13.2 (100%)
Cluster Systems							
eligible	453.5	6.5	385.5 (85%)	68.0 (15%)	385.5 (85%)	40.8 (9%)	27.2 (6%)
homeowner ineligible	0.1	-	-	0.1 (100%)	-	-	0.1 (100%)
Centralized Collection							
eligible	747.5	-	635.4 (85%)	112.1 (15%)	635.4 (85%)	67.3 (9%)	44.8 (6%)
ineligible	-	6.8	-	-	-	-	-
homeowner ineligible	1.3	-	-	1.3 (100%)	-	-	1.3 (100%)
Centralized Treatment							
eligible	244.9	-	208.2 (85%)	36.7 (15%)	208.2 (85%)	22.0 (9%)	14.7 (6%)
ineligible	-	9.7	-	-	-	-	-
Administrative							
ineligible	-	28.4	-	-	-	-	-
Total	1,569.7	55.1	1,321.9	247.8	1,321.9	139.9	107.9

Table F-8. Governmental grants and local share costs for Alternative 6A (costs stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Component	Total Estimated Capital Cost	Annual O&M (Local Cost)	USEPA Grant		USEPA Grant & State Grant		
			Federal	Local	Federal	State	Local
On-Site Systems							
eligible	66.2	-	56.3 (85%)	9.9 (15%)	56.3 (85%)	6.0 (9%)	3.9 (6%)
ineligible	7.0	1.9	-	7.0 (100%)	-	-	7.0 (100%)
Cluster Systems							
eligible	453.5	6.5	385.5 (85%)	68.0 (15%)	385.5 (85%)	40.8 (9%)	27.2 (6%)
homeowner ineligible	0.1	-	-	0.1 (100%)	-	-	0.1 (100%)
Centralized Collection							
eligible	759.9	-	569.9 (75%)	190.0 (25%)	569.9 (75%)	114.0 (15%)	76.0 (10%)
ineligible	786.4	14.2	-	786.4 (100%)	-	-	786.4 (100%)
homeowner ineligible	156.6	-	-	156.6 (100%)	-	-	156.6 (100%)
Centralized Treatment							
eligible	311.2	-	233.4 (75%)	77.8 (25%)	233.4 (75%)	46.7 (15%)	31.1 (10%)
ineligible	66.0	3.0	-	66.0 (100%)	-	-	66.0 (100%)
Administrative							
ineligible	-	28.4	-	-	-	-	-
Total	2,606.9	54.0	1,245.1	1,361.8	1,245.1	207.5	1,154.3

Table F-9. Governmental grants and local share costs for Alternative 6B (costs stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Component	Total Estimated Capital Cost	Annual O&M (Local Cost)	USEPA Grant		USEPA Grant & State Grant		
			Federal	Local	Federal	State	Local
On-Site Systems							
eligible	66.2	-	56.3 (85%)	9.9 (15%)	56.3 (85%)	6.0 (9%)	3.9 (6%)
ineligible	7.0	1.9	-	7.0 (100%)	-	-	7.0 (100%)
Cluster Systems							
eligible	453.5	6.5	385.5 (85%)	68.0 (15%)	385.5 (85%)	40.8 (9%)	27.2 (6%)
homeowner ineligible	0.1	-	-	0.1 (100%)	-	-	0.1 (100%)
Centralized Collection							
eligible	1,520.1	-	1,292.1 (85%)	228.0 (15%)	1,292.1 (85%)	136.8 (9%)	91.2 (6%)
ineligible	-	14.7	-	-	-	-	-
homeowner ineligible	3.2	-	-	3.2 (100%)	-	-	3.2 (100%)
Centralized Treatment							
eligible	311.2	-	233.4 (75%)	77.8 (25%)	233.4 (75%)	46.7 (15%)	31.1 (10%)
ineligible	66.0	3.0	-	66.0 (100%)	-	-	66.0 (100%)
Administrative							
ineligible	-	28.4	-	-	-	-	-
Total	2,427.3	54.5	1,967.3	460.0	1,967.3	230.3	229.7

Table F-10. Governmental grants and local share costs for Alternative 6C (costs stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Component	Total Estimated Capital Cost	Annual O&M (Local Cost)	USEPA Grant		USEPA Grant & State Grant		
			Federal	Local	Federal	State	Local
On-Site Systems							
eligible	66.2	-	56.3 (85%)	9.9 (15%)	56.3 (85%)	6.0 (9%)	3.9 (6%)
ineligible	7.0	1.9	-	7.0 (100%)	-	-	7.0 (100%)
Cluster Systems							
eligible	453.5	6.5	385.5 (85%)	68.0 (15%)	385.5 (85%)	40.8 (9%)	27.2 (6%)
homeowner ineligible	0.1	-	-	0.1 (100%)	-	-	0.1 (100%)
Centralized Collection							
eligible	1,337.5	-	1,136.9 (85%)	200.6 (15%)	1,136.9 (85%)	120.4 (9%)	80.2 (6%)
ineligible	-	11.6	-	-	-	-	-
homeowner ineligible	3.2	-	-	3.2 (100%)	-	-	3.2 (100%)
Centralized Treatment							
eligible	311.2	-	233.4 (75%)	77.8 (25%)	233.4 (75%)	46.7 (15%)	31.1 (10%)
ineligible	66.0	3.0	-	66.0 (100%)	-	-	66.0 (100%)
Administrative							
ineligible	-	28.4	-	-	-	-	-
Total	2,244.7	51.4	1,812.1	432.6	1,812.1	213.9	218.7

Table F-11. Governmental grants and local share costs for Alternative 7A (costs stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Component	Total Estimated Capital Cost	Annual O&M (Local Cost)	USEPA Grant		USEPA Grant & State Grant		
			Federal	Local	Federal	State	Local
On-site Systems							
eligible	9.6	-	8.2 (85%)	1.4 (15%)	8.2 (85%)	0.9 (9%)	0.5 (6%)
ineligible	4.9	0.4	-	4.9 (100%)	-	-	4.9 (100%)
Centralized Collection							
eligible	2,503.9	-	1,877.9 (75%)	626.0 (25%)	1,879.9 (75%)	375.6 (15%)	250.4 (10%)
ineligible	1,344.9	30.9	-	1,344.9 (100%)	-	-	1,344.9 (100%)
homeowner ineligible	3.6	-	-	3.6 (100%)	-	-	3.6 (100%)
Centralized Treatment							
eligible	544.4	-	408.2 (75%)	136.1 (25%)	408.2 (75%)	81.6 (15%)	54.5 (10%)
ineligible	144.0	11.5	-	144.0 (100%)	-	-	144.0 (100%)
Administrative							
ineligible	-	28.4	-	-	-	-	-
Total	4,555.2	71.2	2,294.3	2,260.9	2,294.3	458.1	1,802.8

Table F-12. Governmental grants and local share costs for Alternative 7B (costs stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Component	Total Estimated Capital Cost	Annual O&M (Local Cost)	USEPA Grant Federal	USEPA Grant Local	USEPA Grant & State Grant Federal	USEPA Grant & State Grant State	USEPA Grant & State Grant Local
On-site Systems							
eligible	9.6	-	8.2 (85%)	1.4 (15%)	8.2 (85%)	0.9 (9%)	0.5 (6%)
ineligible	4.9	0.4	-	4.9 (100%)	-	-	4.9 (100%)
Centralized Collection							
eligible	3,475.5	-	2,954.2 (85%)	521.3 (15%)	2,954.2 (85%)	312.8 (9%)	208.5 (6%)
ineligible	-	32.4	-	-	-	-	-
homeowner ineligible	5.9	-	-	5.9 (100%)	-	-	5.9 (100%)
Centralized Treatment							
eligible	544.3	-	408.2 (75%)	136.1 (25%)	408.2 (75%)	81.6 (15%)	54.5 (10%)
ineligible	144.0	11.5	-	144.0 (100%)	-	-	144.0 (100%)
Administrative							
ineligible	-	28.4	-	-	-	-	-
Total	4,184.2	72.4	3,370.6	813.6	3,370.6	395.3	418.3

Table F-13. Governmental grants and local share costs for Alternative 7C (costs stated in 1000's of dollars followed in parenthesis by the percentage share of capital costs).

System Component	Total Estimated Capital Cost	Annual O&M (Local Cost)	USEPA Grant		USEPA Grant & State Grant		
			Federal	Local	Federal	State	Local
On-site Systems							
eligible	9.6	-	8.2 (85%)	1.4 (15%)	8.2 (85%)	0.9 (9%)	0.5 (6%)
ineligible	4.9	0.4	-	4.9 (100%)	-	-	4.9 (100%)
Centralized Collection							
eligible	3,276.7	-	2,785.2 (85%)	491.5 (15%)	2,785.2 (85%)	294.9 (9%)	196.6 (6%)
ineligible	-	32.9	-	-	-	-	-
homeowner ineligible	5.9	-	-	5.9 (100%)	-	-	5.9 (100%)
Centralized Treatment							
eligible	544.3	-	408.2 (75%)	136.1 (25%)	408.2 (75%)	81.6 (15%)	54.5 (10%)
ineligible	144.0	11.5	-	144.0 (100%)	-	-	144.0 (100%)
Administrative							
ineligible	-	28.4	-	-	-	-	-
Total	3,985.4	73.2	3,201.5	783.9	3,201.6	377.4	406.4

Table F-14. Average annual residential user costs with Federal and State grants.

Alternative	Cost ($1,000x) Capital costs	Federal Share	State Share	Local Share	Annual Equivalent of Local Share[1]	Annual O & M[2]	Annual Cost to Local Residents	1980 Residences Served[3]	Average Annual Cost per Residence	Average Annual Cost per Residence
2	291.5	223.3	23.6	44.6	4.7	38.7	43.4	286	12.64	151.68
3	1,159.6	971.6	102.8	85.2	8.9	44.5	53.4	301	14.79	177.48
4A	1,755.2	971.4	149.3	634.5	66.4	48.5	114.9	309	31.00	372.00
4B	1,641.9	1,323.0	157.4	161.5	16.9	48.8	65.7	309	17.72	212.64
4C	1,617.4	1,302.2	155.2	160.0	16.8	47.7	64.5	309	17.38	208.56
5A	1,654.9	1,394.3	147.5	113.1	11.8	56.3	68.1	309	18.38	220.56
5B	1,569.7	1,321.9	139.9	107.9	11.3	55.1	66.4	309	17.91	214.92
6A	2,606.9	1,245.1	207.5	1,154.3	120.9	54.0	174.9	335	43.50	522.00
6B	2,427.3	1,967.3	230.3	229.7	24.1	54.5	78.6	335	19.54	234.48
6C	2,244.7	1,812.1	213.9	218.7	22.9	51.4	74.3	335	18.48	221.76
7A	4,555.2	2,294.3	458.1	1,802.8	189.8	71.2	260.0	390	55.55	666.60
7B	4,184.2	3,370.6	395.3	418.3	43.8	72.4	116.2	390	24.83	297.96
7C	3,985.4	3,201.5	377.4	406.4	42.6	73.2	115.8	390	24.73	296.76

[1] Local share is amortized at 8 3/8% interest at 20 years (0.10471)

[2] Includes administrative costs

[3] See Table 2-22

Table F-15. Average annual residential user costs with Federal grant only.

Alternative	Cost ($1,000x) Capital costs	Federal Share	Local Share	Annual Equivalent of Local Share[1]	Annual O & M[2]	Annual Cost to Local Residents	1980 Residences Served[3]	Average Annual Cost per Residence	Average Annual Cost per Residence
2	291.5	223.3	68.2	7.1	38.7	45.8	286	13.36	160.32
3	1,159.6	971.6	188.0	19.7	44.5	64.2	301	17.77	213.24
4A	1,755.2	971.4	783.8	82.1	48.5	130.6	309	35.21	422.52
4B	1,641.9	1,323.0	318.9	33.4	48.8	82.2	309	22.17	266.04
4C	1,617.4	1,302.2	315.2	33.0	47.7	80.7	309	21.75	261.00
5A	1,654.9	1,394.3	260.6	27.3	56.3	83.6	309	22.54	270.48
5B	1,569.7	1,321.9	247.8	26.0	55.1	81.1	309	21.86	262.32
6A	2,609.9	1,245.1	1,361.8	142.6	54.0	196.6	335	48.90	586.80
6B	2,427.3	1,967.3	460.0	48.2	54.5	102.7	335	25.54	306.48
6C	2,244.7	1,812.1	432.6	45.3	51.4	96.7	335	24.05	288.60
7A	4,555.2	2,294.3	2,260.9	236.7	71.2	307.9	390	65.80	789.60
7B	4,184.2	3,370.6	813.6	85.2	72.4	157.6	390	33.67	404.04
7C	3,985.4	3,201.5	783.9	82.1	73.2	155.3	390	33.18	398.16

[1] Local share is amortized at 8 3/8% interest for 20 years (0.10471)

[2] Includes administrative costs

[3] See Table 2-22

Table F-16. Average annual residential user costs without any governmental grants.

Alternative	Cost ($1,000x) Capital Costs	Annual Equivalent of Local Share[1]	Annual O & M[2]	Annual Cost to Local Residents	1980 Residences Served[3]	Average Monthly Cost per Residence	Average Annual Cost per Residence[2]
2	291.5	30.5	38.7	69.2	286	20.17	242.04
3	1,159.6	121.4	44.5	165.9	301	45.94	551.28
4A	1,755.2	183.8	48.5	232.3	309	62.64	751.68
4B	1,641.9	171.9	48.8	220.7	309	59.53	714.36
4C	1,617.4	169.4	47.7	217.1	309	58.54	702.49
5A	1,654.9	173.3	56.3	229.6	309	61.92	743.03
5B	1,569.7	164.4	55.1	219.5	309	59.19	710.28
6A	2,609.9	273.3	54.0	327.3	335	81.41	976.92
6B	2,427.3	254.2	54.5	308.7	335	76.78	921.36
6C	2,244.7	235.0	51.4	286.4	335	71.25	855.00
7A	4,555.2	477.0	71.2	548.2	390	117.13	1,405.56
7B	4,184.2	438.1	72.4	510.5	390	109.09	1,309.08
7C	3,985.4	417.3	73.2	490.5	390	104.81	1,257.72

[1] Local share is amortized at 8 3/8% interest for 20 years (0.10471).

[2] Includes administrative costs

[3] See Table 2-22.

Appendix G

Impacts of On-site Wastewater

Treatment Systems on Soils

IMPACTS ON SOILS

The application of septic tank effluent to soil in the operation of the cluster drainfields (Alternatives 3 through 6) and on-site systems (alternatives 2 through 7) will have an impact on the amount of prosphorus and nitrogen in the soil.

Phosphorus would be present in septic tank effluent in an inorganic form as orthophosphate (primarily HPO_4-2), as polyphosphates (or condensed phosphates), and as organic phosphate compounds. Because the pH is alkaline, the predominant form usually is orthophosphate (USEPA 1976). Polyphosphate is converted quickly to orthophosphate in conventional wastewater treatment, in soil, or in water. Dissolved organic phosphorus is converted more slowly (day to weeks) to orthophosphate.

When septic tank effluent is applied to soils, dissolved inorganic phosphorus (orthophosphate) may be adsorbed by the iron, aluminum, and/or calcium compounds, or may be precipitated through with soluble iron, aluminum, and calcium. Because it is difficult to distinguish between adsorption and precipitation reactions, the term "sorption" is utilized to refer to the removal of phosphorus by both processes (USEPA and others 1977). The degree to which phosphorus is sorbed in soil depends on its concentration, soil pH, temperature, time, total loading, and the concentration of other wastewater constituents that directly react with phosphorus, or that affect soil pH and oxidation-reductions (USEPA and others 1977).

The phosphorus in the absorbed phase in soil exists in equilibrium with the concentration of dissolved soil phosphorus (USEPA and others 1977). As an increasing amount of existing adsorptive capacity is used, such as when wastewater enriched with phosphorus is applied, the dissolved phosphorus concentration of phosphorus in the percolate, and thus in the groundwater or in the recovered underdrainage water.

Eventually, adsorbed phosphorus is transformed into a crystalline-mineral state, re-establishing the adsorptive capacity of the soil. This transformation may occur slowly, requiring from months to years. However, work by various researchers indicate that as much as 100% of the original adsorptive capacity may be recovered in as little as 3 months. In some instances it may take years for the adsorptive capacity to fully recover because the active cations may become increasingly bound in the crystalline form. The possible amount of phosphorus that could precipitate to the crystalline form, based on a 2% to 4$ iron and 5% to 7.5% aluminum soil content, is estimated to be 250,000 pounds of phosphorus per acre-foot of soil (Ellis and Erickson 1969).

Dissolved organic phosphorus can move quickly through permeable soils. Adequate retention of the wastewater in the unsaturated soil zone is necessary to allow enough time for the organic phosphorus to be hydrolized by microorganisms to the orthophosphate form. In the orthophosphate form, it then can be adsorbed.

Nitrogen loadings in the septic tank effluent are of greatest concern because of the potential for well contamination by nitrates. Nitrogen would be present in applied wastewater principally in the form of ammonium (NH_4) and organic nitrogen. When septic tank effluent is applied to soils, the natural supply of soil nitrogen is increased. As in the natural processes, most added organic nitrogen slowly is converted to ionized ammonia by microbial action in the soil. This form of nitrogen, and any ionized ammonia in the effluent, is adsorbed by soil particles.

Plants and soil microbes both utilize ammonium directly. Microbes oxidize ammonium to nitrite (NO_2) that is quickly converted to the nitrate (NO_3) from through nitrification.[2] Nitrate is highly soluble and is utilized by plants, or leached from the soil into the groundwater. Under anaerobic conditions (in the absence of oxygen), soil nitrate can be reduced by soil microbes to gaseous nitrogen forms (denitrification). These gaseous forms move upward through the soil atmosphere and are dissipated into the air. Denitrification depends on organic carbon for an energy source; thus, the interface between natural soil and the gravel fill in a drain bed has both requisite characteristics for denitrification.

Unlike phosphorus, nitrogen is not stored in soil except in organic matter. Organic matter increases within the soil would result from increased microbial action and from decreased oxidation. The increased organic matter improves the soil tilth (workability), water holding capacity, and capability of retaining plant nutrients.

Appendix H

Excerpts from the Report on Algae

APPENDIX H - Excerpts from the Report on Algae

Excerpts from the Report on Algae (USEPA 1982).

Excerpts were taken from the Report on Algae to provide summaries and conclusions regarding the major topical areas covered. The full Report on Algae was originally published and distributed by USEPA Region V in January of 1982. This report was prepared as a supporting technical reference document for the Environmental Impact Statement on the Moose Lake-Windemere Sanitary District's proposed wastewater treatment system. Complete copies of the Report on Algae are available from the Project Monitor.

2.3.5. Summary of Blue-Green Algal Toxicity

Three genera of freshwater blue-green algae, *Anacystis*, *Anabaena* and *Aphanizomenon*, are most commonly associated with toxin production and have been reported to produce several different types of toxins. The toxicological and pharmacological properties of the toxins as well as their chemical identities are not well understood. In addition, very little is currently known about the physiological and/or ecological factors and interactions that lead to toxic episodes.

There is well documented evidence, however, that blue-green algae can produce toxic effects in animals and livestock. Livestock and wildlife poisonings occur most frequently in lakes, reservoirs, and ponds in temperate climates. Toxic blooms usually occur between late spring and early autumn. Toxic effects in animals can occur only through ingestion of contaminated water. A variety of toxic effects have been documented in the laboratory and from observations of livestock and wildlife populations and include convulsions, gastrointestinal disorders, respiratory disorders, liver failure, and death. There are, however, no documented or reported cases of human mortality associated with toxic strains of freshwater blue-green algae.

Although more than 12 species belonging to 9 genera of freshwater cyanophytes have been implicated in cases of animal poisoning, toxic strains of the three most common bloom forming species, *Microcystis aeruginosa*, *Anabaena* flos-aque, and Aphanizomenon flos-aque have been responsible for the majority of the documented episodes. (In the literature, Anacystis is used synonymosly with the genus Microcystis.) The poisonings attributable to Anabaena flos-aque have been more dramatic in terms of the number of animals affected, but toxic strains of Microcystis aeruginosa appear to be more widely distributed geographically.

To date, twelve different toxins have been identified from strains and/or blooms of the three most common toxigenic species. The toxins differ in their reaction time and their chemical structure. Several of the toxins are very fast-acting and are suspected of being alkaloids. Some have a pronounced latent period following ingestion and are suspected of being peptides. The available evidence also indicates that a single bloom may contain several different toxins simultaneously.

Investigations into the nature and occurrence of toxic blooms of blue-green algae indicate that such blooms have a highly variable and mosaic nature. The development of toxic blooms is unpredictable and usually occurs in short-lived pulses. They infrequently recur in the same body of water in subsequent years. The fact that bloom toxicity is so varied and unpredictable makes any bloom potentially dangerous and suspect at all times, even though the majority are actually nontoxic.

There have been several documented episodes of toxic blue-green algae blooms in southern Minnesota. Toxic blooms are rare, however, in the northern part of the state.

3.3. Summary of the Causes of Swimmers' Itch

Swimmers' itch can be cercarial related or blue-green algae related. Man is not a host or "carrier" of the schistosome which causes the cercarial dermatitus form of swimmers itch. Therefore human waste (excrement) can not be responsible for the presence of this more severe type of swimmers' itch. However, the blue-green algae blooms which are responsible for the less serious form of dermatitus can in part be caused by an influx of nutrients from human waste.

4.0. PHYTOPLANKTON COMMUNITY STRUCTURE AND EVIDENCE OF PUBLIC HEALTH PROBLEMS: MOOSE LAKE, MINNESOTA

Four lakes in the Moose Lake-Windermere Sanitary District were investigated to gather baseline information on phytoplankton community structure and on existing water quality. The objective of this investigation was to evaluate the relative abundance of blue-green algae in the four lakes and to assess potential problems associated with blooms of blue-green algae. A secondary purpose was to determine if cercarial dermititus (swimmers' itch) is a problem in the Moose Lake area. The Moose Lake-Windermere Sanitary District is located in eastern Minnesota between Minneapolis and Duluth. The four lakes that were studied are Island, Sturgeon, Rush, and Passenger Lakes (Figure 4-1).

The description and evaluation of the phytoplankton community structure was based on lake sampling and water quality data analysis. Information on blue-green toxicity events and swimmers' itch outbreaks was gathered in interviews with local physicians and veterinarians as well as with state health officials.

4.1. Phytoplankton Community Structure

4.1.1. Description of Phytoplankton Community Structure

Phytoplankton community structure is determined primarily through interactions involving physical-chemical factors, zooplankton, and fish. Typically, the dominance of a phytoplankton community by a particular species will shift during the course of a year. That is, a particular phytoplankton species may form the greatest proportion of the algal community biomass (weight of living matter) only at certain times of the year when the interactions taking place within the water body favor that particular phytoplankton. As the aquatic ecosystem changes during the year, numerous interactions occur that may, in sequence, favor other phytoplankton. For example, in eutrophic lakes diatoms may be the dominant phytoplankton in the spring because they are favored by high silicate concentrations, high light peneration, and cool water temperatures present at that time of the year. In early summer as silicate

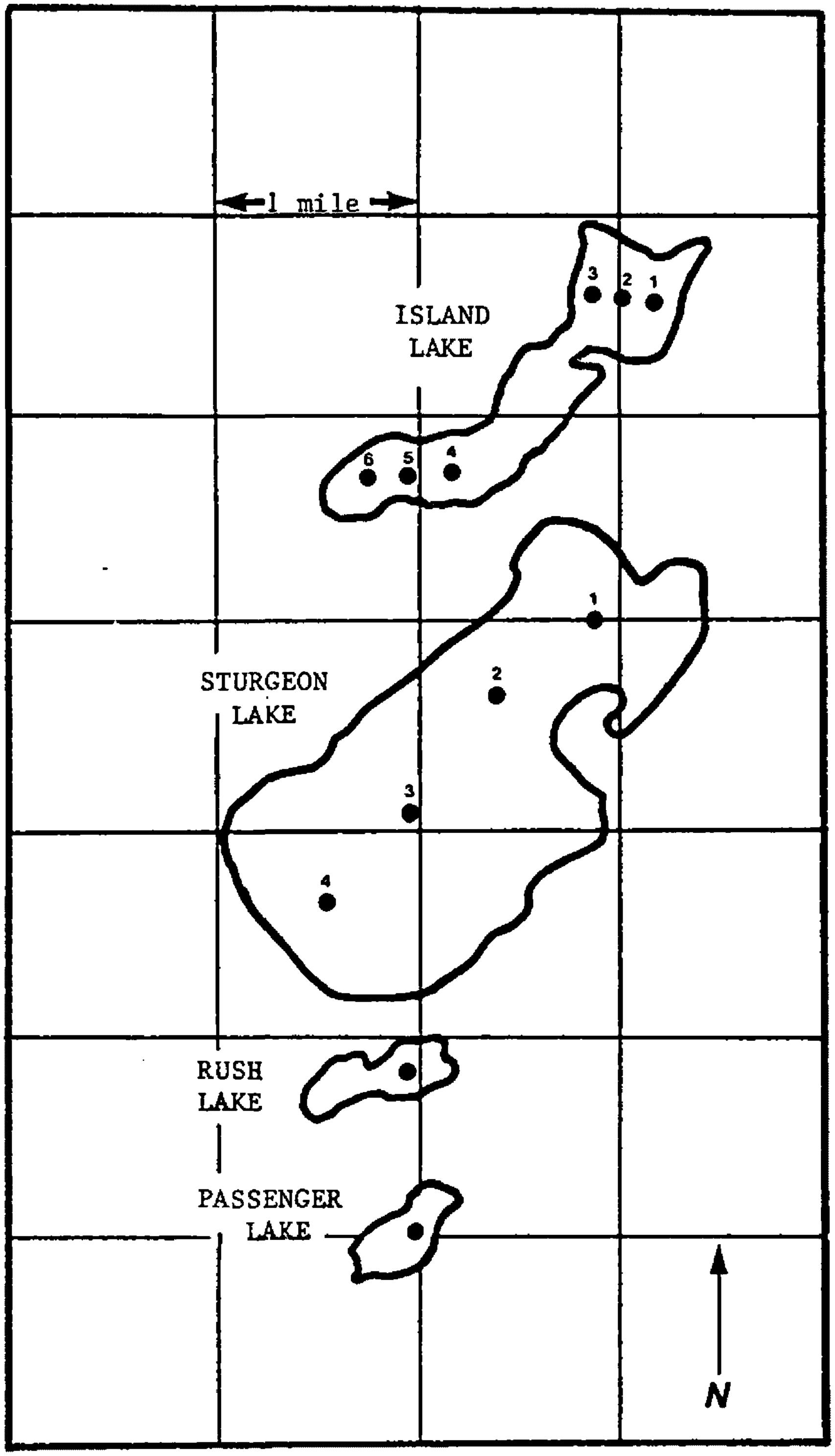


Figure 4-1. Locations of mid-lake sampling stations for phytoplankton, nutrient, temperature, dissolved oxygen and chlorophyll data.

concentrations decrease, green algae may become dominant because of increased water temperatures and increased nutrient availability. As water temperature reaches the late summer peak, and as dissolved nitrate levels decrease following uptake by green algae and by rooted aquatic plants, blue-green algae may become dominant. In late summer blue-green algae hold an advantage over other algal species when levels of phosphorous are high compared to nitrogen because blue-greens alone can fix atmospheric nitrogen into a useful nutrient form. In addition, blue-green algae use their unique gas vacuoles to remain in position at the water surface and take advantage of the diminished sunlight as well as shade out other algae found deeper in the water column.

Algal groups such as blue-greens, diatoms, or greens are characterized as dominant based on biovolume measurements micrometers cubed per milliliter ($\mu m^3/ml$). Biovolume is a parameter which generally reflects biomass. It is expressed in this Report as a volume of plankton per unit volume of water and is therefore indicative of visible accumulations of living matter.

Phytoplankton samples were collected from Island Lake (6 stations) and Sturgeon Lake (4 stations) on four sampling dates during late summer and early autumn. Passenger and Rush Lakes were sampled on three dates during the same period at one station in the middle of each the lakes. Phytoplankton samples were taken in each instance at one meter below the surface, at mid-depth, and at one meter from the bottom. The sampling station locations are shown in Figure 4-1. Algal identification was taken at least to the genus level and to the species level where possible. Phytoplankton dimensional measurements were made of the most numerous phytoplankton species found. Measurements for other less numerous phytoplanktons were taken from unpublished species lists for Minnesota lakes (by letter, Nancy Holm, Limnological Research Center, University of Minnesota) and from Wetzel (1975). The list of phytoplankton volumes used to calculate biovolumes in this investigation is included in Appendix A-3. Chlorophyll a samples were collected concurrent with phytoplankton sampling on two dates at the same sample locations and depths. Secchi disk depth was measured at all sample sites and on all sample dates.

Island Lake

Phytoplankton biovolume (abundance) and the percent composition (dominance) of major phytoplankton groups for Island Lake at the surface, mid-depth, and bottom depths are depicted in Figure 4-2. From 26 August to September 9 there was an overall decrease in algal density and a dramatic shift in algal dominance. The decrease in algal density was due primarily to the decline of the large dinoflagellate, Ceratium hirundinella, which had an estimated volume of 75,000 um^3 per organism. Over this same time period a large blue-green species, Anabaena macrospora (45,000 μm^3 per organism) and another blue-green, Aphanizomenon flos-aquae (2800 μm^3 per organism) grew in number while a smaller blue-green, Phormidium mucicola (10 μm^3 per organism) decreased in number. Thus, although the total blue-green algae cell number per ml remained relatively constant from 26 August to 9 September, because of the shift from small blue-green algae species to large-sized blue-green algae species and declines in other phytoplankton (the dinoflagellates declined from 77% to less than 1% of the phytoplankton biovolume), blue-green algae increased from 16% to 94% of the total phytoplankton biovolume. For the remainder of September, blue-greens were dominant in Island Lake, with the blue-green abundance reaching a peak around the September 14 sampling date (Table 4-1).

Throughout the sampling period (26 August to October 5) Island Lake consistently had the highest phytoplankton density of the four lakes investigated. High blue-green algal and other phytoplankton densities in Island Lake also contributed to poor water clarity. Island Lake had the lowest Secchi disk readings of the four lakes. The changes in the average Island Lake Secchi disk readings were followed closely by the changes in phytoplankton abundance (Figure 4-3a and b).

Sturgeon Lake

Changes in phytoplankton abundance and dominance in the water column for the four Sturgeon Lake sampling dates are shown in Figure 4-4. The total phytoplankton biovolume in Sturgeon Lake was lower than in Island Lake but blue-green algae were still the dominant phytoplankton group throughout the month of September. The dominant blue-green species was Anacystis spp. Diatoms were an important component of the phytoplankton community in Sturgeon Lake on all four sampling dates and were found at all depths but never accounted for more than 24% of the phytoplankton biovolume. Based on Secchi disk readings, water clarity was observed to be much greater in Sturgeon Lake than in Island Lake (Figure 4-3a).

ISLAND LAKE

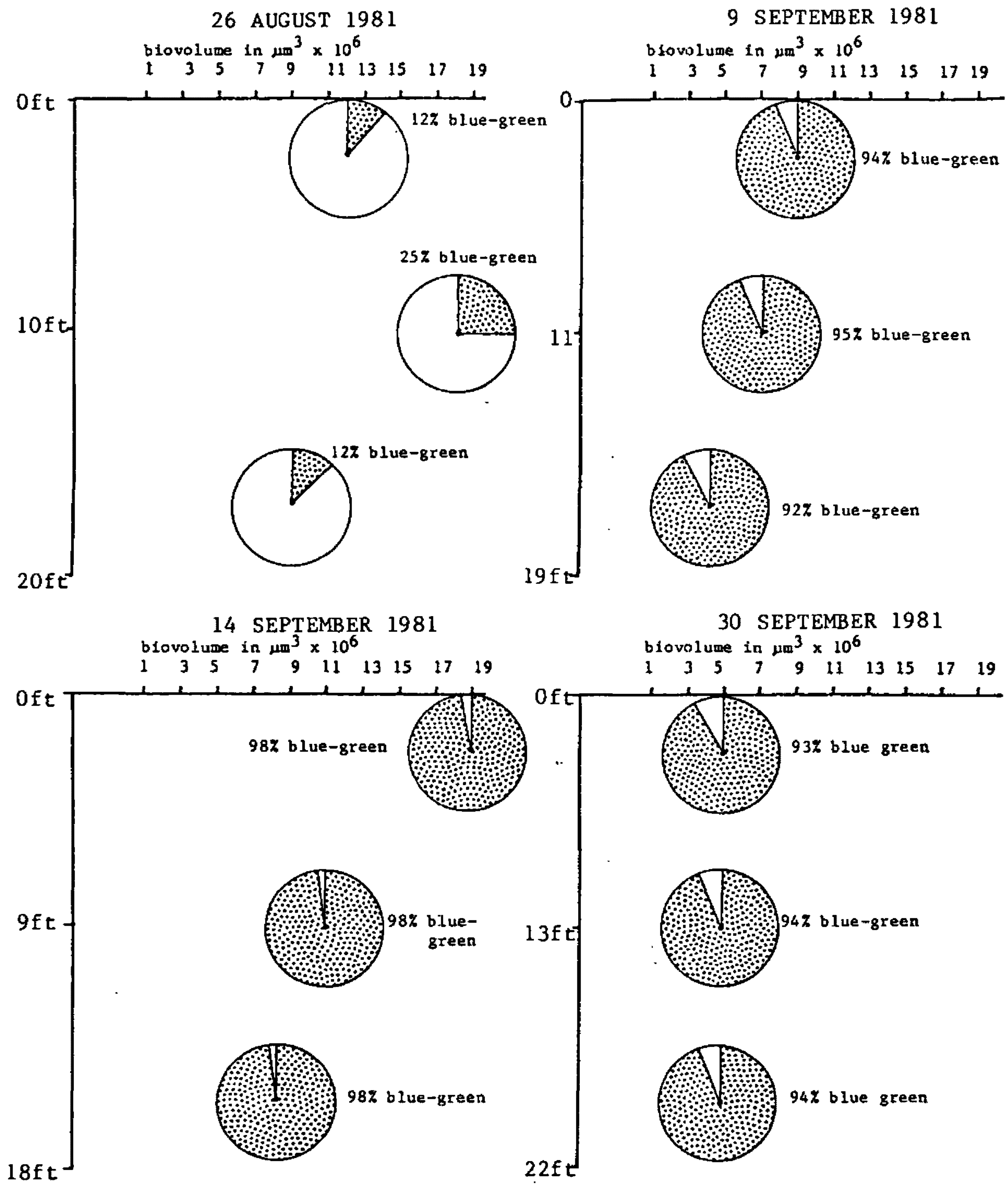


Figure 4-2. Abundance and dominance of major phytoplankton forms based on biovolume data. Derived from plankton counts made on samples taken from Island Lake on four sampling dates. Depths of samples are approximately as shown.

Table 4-1. Blue-green algal biovolumes ($\mu m^3 \times 10^4/ml$) of four lakes in the Moose Lake area and four lakes from southern Minnesota (the Minneapolis-St. Paul area). Blue-green algae genera listed are those most commonly associated with incidences of blue-green algae toxicity in North America.

Location/ Date	Anabaena spp.	Anacystis spp.	Aphanizomenon flos-aquae	Sampling Depth
Island Lake				
26 August 1981	61	17	67	Surface
9 September 1981	671	7	169	
14 September 1981	1336	11	466	
30 September 1981	92	8	358	
Sturgeon Lake				
27 August 1981	30	58	0	Surface
9 September 1981	41	102	1	
15 September 1981	74	66	0	
5 October 1981	30	48	1	
Passenger Lake				
10 September 1981	0	18	0	Surface
15 September 1981	14	14	0	
1 October 1981	5	2	0	
Rush Lake				
10 September 1981	30	0	0	Surface
15 September 1981	27	24	0	
1 October 1981	0	4	0	
Cedar Lake, MN				
9 September 1974	14	2	169	2 meters
Lake Harriet, MN				
22 July 1974	41	2	297	2 meters
Lake of the Isles, MN				
22 July 1974	476	2	460	Surface
Lake Calhoun, MN				
26 August 1974	232	0	544	Surface

WATER CLARITY
(SECCHI DISK MEASUREMENTS)

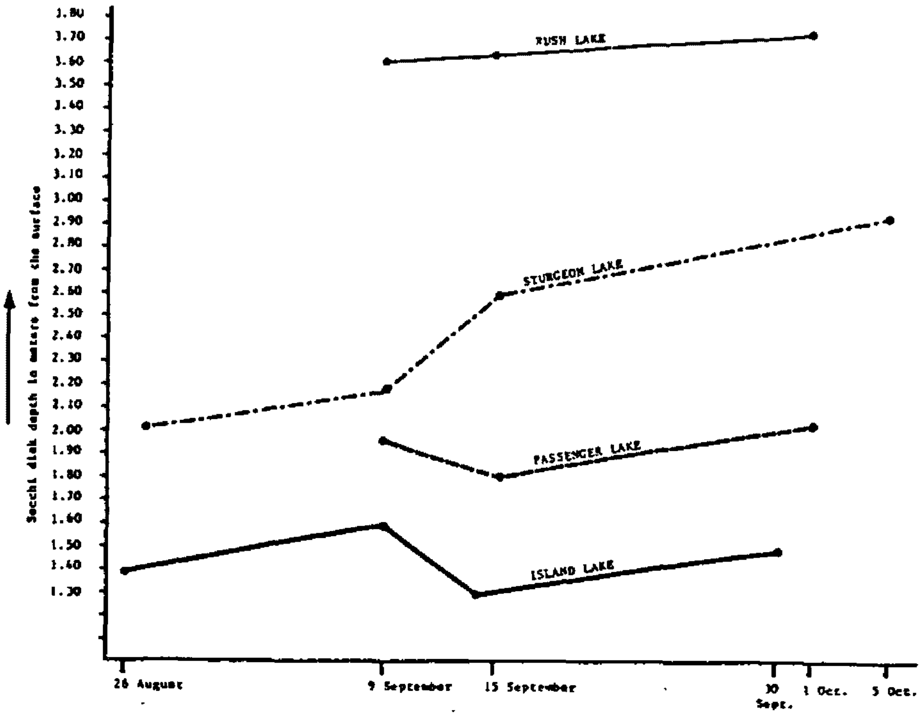


Figure 4-3a. Average Secchi disk values for the project area lakes versus time. Data are from 1981 field surveys.

PHYTOPLANKTON ABUNDANCE
(BIO-VOLUME ESTIMATES FROM CELL COUNTS)

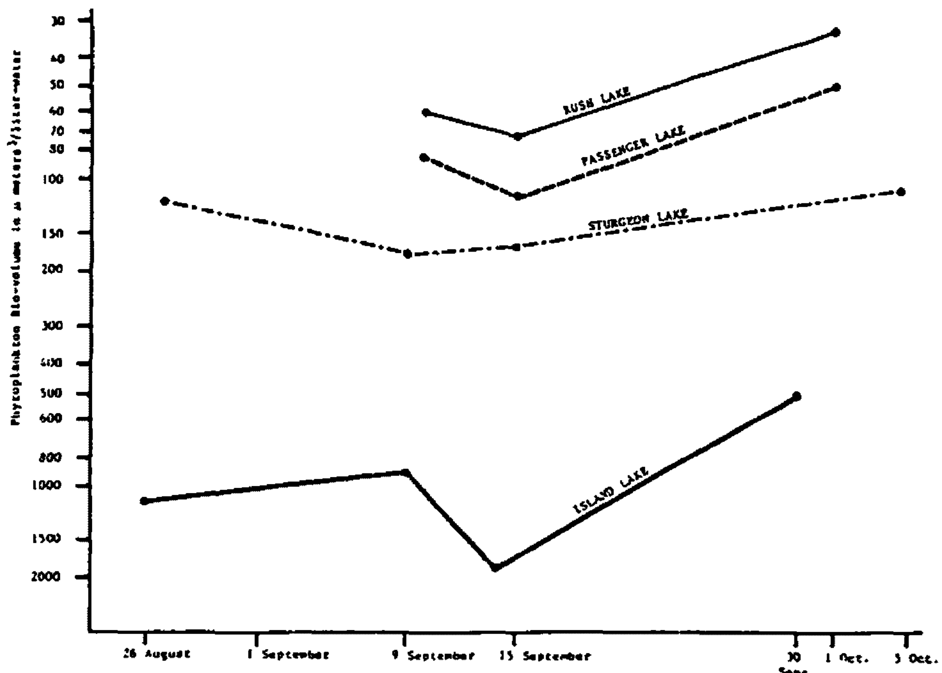


Figure 4-3b. Average phytoplankton biovolumes for the project area lakes versus time. Plotted data are representative of the photic zones of the lakes,as only samples from just below the surface of the water were taken into the averages.

STURGEON LAKE

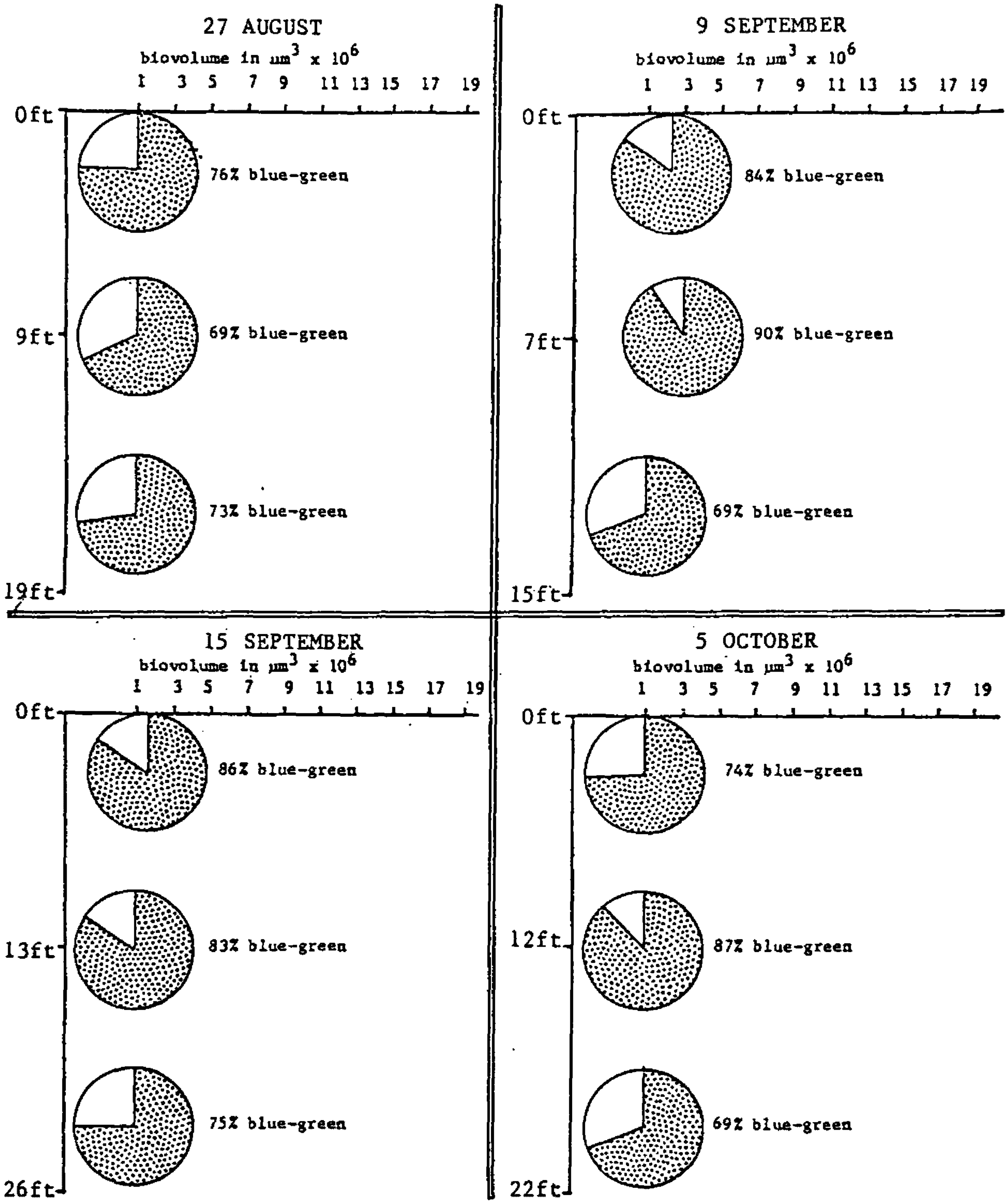


Figure 4-4. Abundance and dominance of major phytoplankton forms based on biovolume data. Derived from plankton counts made on samples taken from Sturgeon Lake on four sampling dates. Depths of samples are approximately as shown.

Passenger Lake

Passenger Lake had low phytoplankton biovolumes (Figures 4-3b and 4-5) and low blue-green algae biovolumes (Table 4-1) compared to Island and Sturgeon Lakes. Although Passenger Lake had the highest cell count per milliliter of all four lakes (Appendix A) the phytoplankton that accounted for these high numbers (Ochromonas spp; 4500 cells/ml) was a small golden-brown algae (40 μm^3 per organism). For the three sampling dates, two phytoplankton groups were dominant, the golden-brown algae and the cryptomonads. Based on the the findings of lower biovolumes in Passenger Lake than in Sturgeon Lake, deeper Secchi disk readings in Passenger Lake would be expected. This was not observed (Figure 4-3a). The lower (shallow) Secchi disk readings in Passenger Lake may have been due to increased light scattering caused by the high number of phytoplankton cells, by color due to dissolved organics, by suspended solids brought into the photic zone (surface layer) from bottom sediment resuspension, or by sediments carried into the Lake from the surrounding watershed.

Rush Lake

Rush Lake had the lowest phytoplankton abundance (Appendix A-2), and had blue-green biovolumes similar to Passenger Lake. Consequently, a relatively small blue-green biovolume could dominate the overall phytoplankton community (Figure 4-6). Other groups that were important in terms of the the biovolume percentages of Rush Lake included cryptonomads and dinoflagellates. Cell sizes in the phytoplankton samples were small (less than 1000 μm^3 per organism) except for the dinoflagellate, Ceratium hirundinella. Large phytoplankton can have a significant impact on biomass concentrations even at low densities. For example, in the 10 September mid-depth sample the total cell density was 748 cells/ml, and although Ceratium was found at only 5 cells/ml, it represented 38% of the total phytoplankton biomass (Appendix A-1 and Figure 4-5). The low phytoplankton biovolumes in Rush Lake are associated with the highest (deepest) Secchi disk readings of the four lakes investigated. Based on the survey data of September 1981 it appears Rush Lake had the greatest water clarity of the four studied lakes (Figure 4-3a).

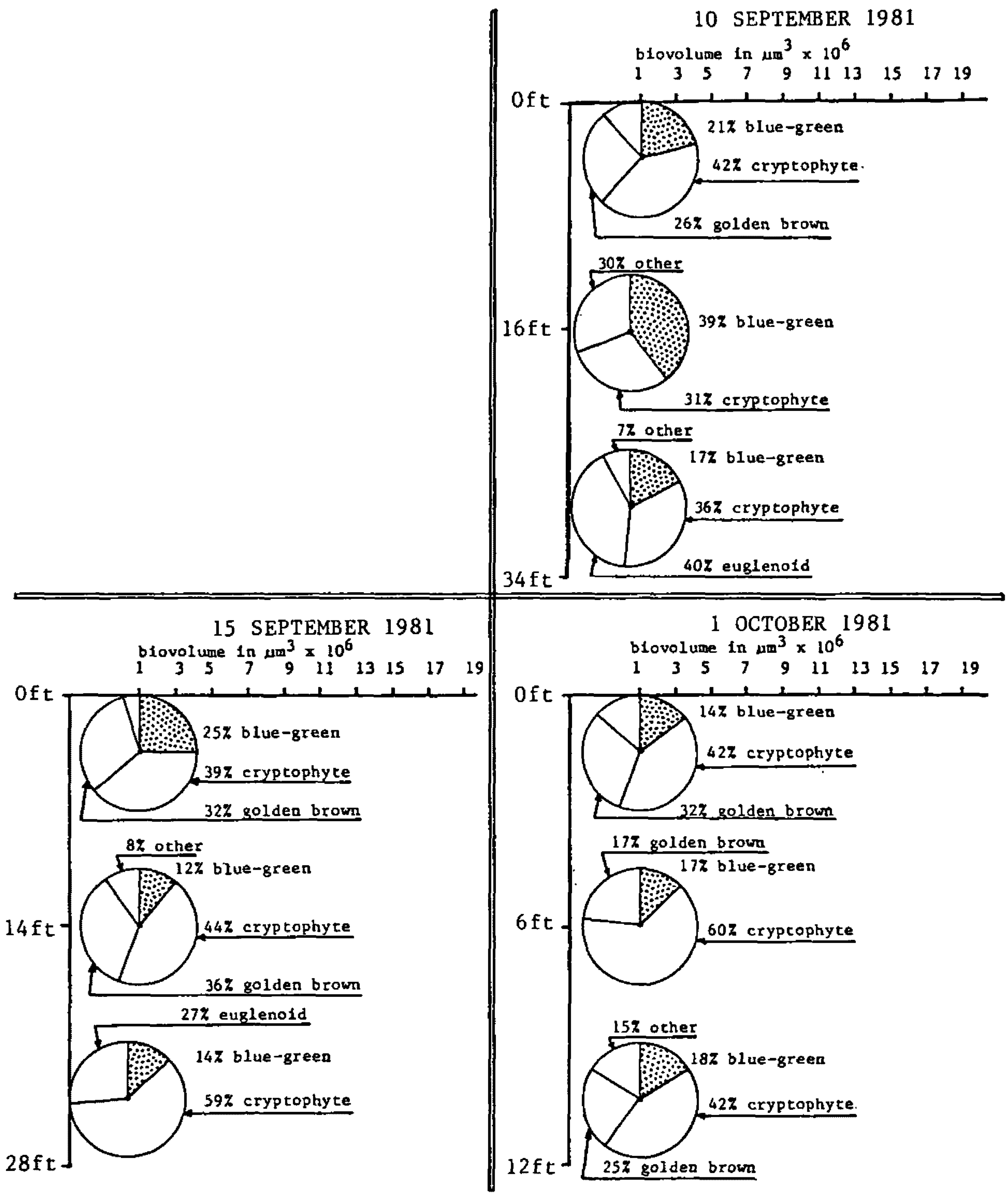


Figure 4-5. Abundance and dominance of major phytoplankton forms based on biovolume data. Derived from plankton counts made on samples taken from Passenger Lake on three sampling dates. Depths of samples are approximately as shown.

RUSH LAKE .

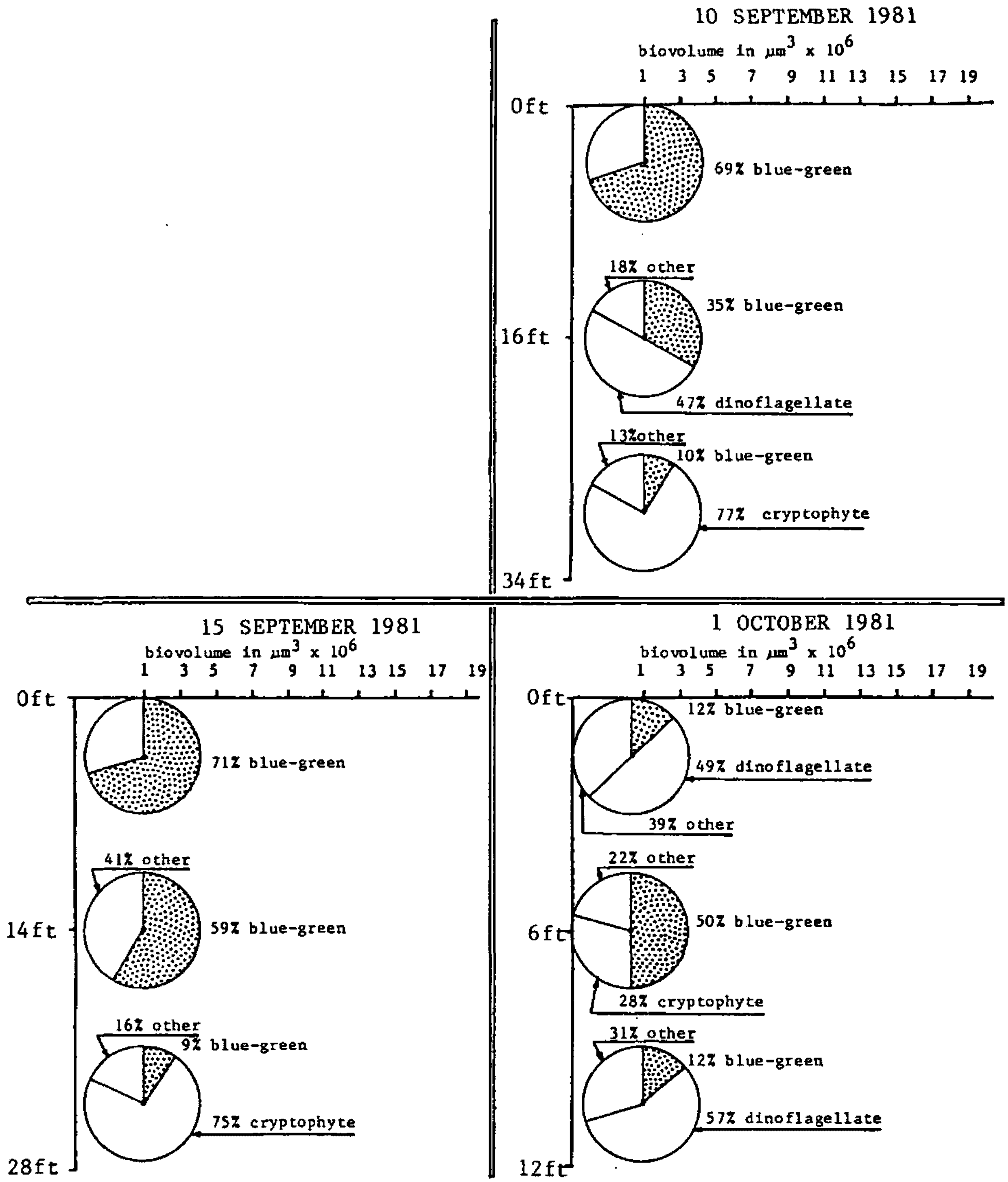


Figure 4-6. Abundance and dominance of major phytoplankton forms based on biovolume data. Derived from phytoplankton counts made on samples taken from Rush Lake on three sampling dates. Depths of samples are approximately as shown.

Chlorophyll a was another parameter measured in the four lakes. Chlorophyll a is a general indicator of the total phytoplankton biomass but does not differentiate between specific groups and does not always correlate well to water clarity. Table 4-2 lists chlorophyll a concentrations for the 8 September and 15 September sampling dates. In general, chlorophyll a concentrations in Island Lake samples were higher than in Sturgeon, Rush, or Passenger Lake samples. Higher chlorophyll a concentrations may also have resulted in the observed green appearance of Island Lake's water compared to the other three lakes. This characteristic has been reported by a number of lakeside residents and may be enhanced by the presence in Island Lake of suspended clay matter which scatters (back-reflects) light. The presence of clayey soils in the watershed of Island Lake is discussed in Section 4.1.2. below.

Table 4-2. Chlorophyll a concentrations (μg/l) for Island, Sturgeon, Passenger, and Rush Lakes.

	SEPTEMBER 8			SEPTEMBER 15		
	Surface	Mid-depth	Bottom	Surface	Mid-depth	Bottom
Island						
Is-1	37	34	28	19	45	26
Is-2	28	26	19	30	--	12
Is-3	28	33	24	39	33	28
Is-4	32	24	8	9	32	22
Is-5	32	28	14	26	40	6
Is-6	36	29	21	29	20	16
Sturgeon						
St-1	10	11	10	8	8	9
St-2	3	9	11	10	7	13
St-3	9	8	9	8	8	8
St-4	8	8	7	9	14	8
Passenger	11	6	28	10	7	53
Rush	20	10	4	5	16	13

4.2. Physician and Veterinarian Interview Report

A survey of medical practitioners was conducted to determine whether any human, pet or livestock health problems had been diagnosed in the drainage areas of Island, Sturgeon, Passenger or Rush Lakes since 1979. Personal and telephone interviews were conducted with local medical and veterinary clinics; state, county, and local health and water agencies; and experts. All respondents were asked to consult their records and to poll their staffs on medical problems that might be attributed to water pollution in the study area. They were requested to document cases involving toxic effects attributable to blue-green algae, bacterial and viral infections, and outbreaks of cercarial dermatitus (swimmers' itch). An explanation of symptoms exhibited by humans, pets and livestock after exposure to toxic strains of blue-green algae, and of swimmers' itch was provided to all survey participants. A phone number was left with each respondant and they were encouraged to contact USEPA if they wished to provide additional information.

None of the agencies, clinics, or experts polled had records of or were aware of any medical problems associated with water contaminated by blue-green algae, or due to the presence of bacteria or virus originating from human waste in the study area (Table 4-4).

The Minnesota Department of Natural Resources' (MDNR) Water Monitoring and Control Unit (WMCU) is responsible for issuing permits for applying copper sulfate to provide emergency control of cercarial dermatitus (swimmers' itch), rooted aquatic plants and phytoplankton growth. No permits have been issued for copper sulfate applications on Island, Sturgeon, Passenger or Rush Lakes during the past twenty years (By telephone, Howard Krosch, Supervisor WMCU, MDNR 10 November 1981).

Instances of animal illness or death attributed to blue-green algae are rare in the northern portion of the state of Minnesota. Occasional toxic blue green algae blooms have been recorded in southern and western Minnesota, typically reappearing in two to three year intervals (By telephone, Howard Krosch, WMCU, MDNR 18 November 1981). There have been no documented domestic animal deaths attributable to blue-green algae in northern Minnesota near the Moose Lake area (Personal communication, Dr. Clarence Stowe, Large Animal Clinic - University of Minnesota, 9 November 1981).

Conversely, cercarial dermatitus (swimmers' itch) is reported to be common in lakes throughout Minnesota (By telephone, Gene Jordan, Minnesota State Department of Health, 5 November 1981). However, none of the state or

Table 4-4. Responses to public health survey questions. (Based on telephone interviews November, 1981)

Respondents	Since 1979, have you recorded or are you aware of any health problems (human, pet or livestock) associated with ground or surface water contamination in the drainage areas of Island, Passenger, Rush or Sturgeon lakes?	If health problems were documented, check the appropriate cause: Blue-Green Algae	Bacteria	Virus	Cercarial Dermatitus	Are you aware of any health problems associated with water quality in the study area which are not covered in this survey?
Minnesota Department of Natural Resources - Water Monitoring and Control Unit St. Paul						
Howard Knosch - Supervisor	No	—	—	—	—	No
David Zapitillo - Aquatic Biologist	No	—	—	—	—	No
Minnesota Department of Health: Epidemiology Department Minneapolis						
Dr. Michael Olsterholm	No	—	—	—	—	No
Public Water Supply Department Minneapolis						
Richard Clark, Supervisor	No	—	—	—	—	No
Charles Schneider, Engineer	No	—	—	—	—	No
Minnesota Department of Health, Duluth						
Gene Jordan, Supervisor	No	—	—	—	—	No
Minnesota Pollution Control Agency Water Quality Division St. Paul						
Larry Livesay, Biologist-Limonologist	No	—	—	—	—	No

Minnesota Board of Animal Health St. Paul						
Dr. Keller Dr. Flint	No	___	___	___	___	No
University of Minnesota Large Animal Clinical Services St. Paul						
Dr. Clarence M. Stowe	No	___	___	___	___	No
Moose Lake Veterinary Clinic Moose Lake						
Dr. Frank J. Skalko	No	___	___	___	___	No
Moose Lake Windemere Sanitary District Moose Lake						
Harold Westholm, Director	Yes	___	___	___	[illegible]	No
Pine County Department of Human Services Pine City Janet Schumaker	No	___	___	___	___	No
Carlton County Board of Health Cloquet						
Rachel Pulte, Nurse	No	___	___	___	___	No
Carlton County Zoning Office Cloquet						
Bruce Benson	No	___	___	___	___	No
Pine City Area Clinic Pine City						
Dr. Mock	No	___	___	___	___	No
Hinckley Area Clinic Hinckley						
Mary Marks Clinic Coordinator	No	___	___	___	___	No
Dr. Charles Bloom	No	___	___	___	___	No
Mora Medical Clinic Mora						
Lorraine Carlson, Insurance Director	No	___	___	___	___	No
Gateway Family Health Clinic Moose Lake						
Dr. Raymond Christensen	No	___	___	___	___	No
Dr. Kenneth Etterman	No	___	___	___	___	No

county agencies surveyed had records of any outbreaks of swimmers' itch in Island, Sturgeon, Rush or Passenger Lakes (Table 4-4). Most patients treated for swimmers' itch in the Moose Lake area probably contracted it while swimming in Moose Head lake (By telephone, Doctors Raymond Christensen and Kenneth Etterman, 12 November 1981). Local citizens have not reported occurences of swimmers' itch on Sturgeon, Rush or Passenger Lakes. One instance of swimmers' itch occurring on 4 July 1981 was reported by a home owner on the south shore of Island Lake (Personal communication, Harold Westholm, November 1981). No reoccurences have been reported.

Table A-2. Phytoplankton bio-volume data and Secchi disk data for four lakes in Pine County MN.[1]

	[a]26, [b]27 AUGUST 1981			[c]9, [d]10 SEPTEMBER 1981			[e]14, [f]15 SEPTEMBER 1981			[g]30 SEPTEMBER and [h]1, [i]5 OCTOBER		
	Surface	Mid-depth	Bottom	Surface	Mid-depth	Bottom	Surface	Mid-depth	Bottom	Surface	Mid-depth	Bottom
[a,c,e,g.]ISLAND LAKE												
% blue-green algae, bio-volume	12	25	12	94	95	92	98	98	98	93	94	94
% dinoflagellate, bio-volume	82	71	81	0	0	0	0	0	0	0	0	0
% other phytoplankton, bio-volume	6	4	7	6	5	8	2	2	2	7	6	6
μm^3 (total biovolume) x 10^4/ml.	1211	1808	921	899	746	379	1851	1113	835	491	532	484
Secchi disk depth (meters)	1.39	—	—	1.59	—	—	1.29	—	—	1.48	—	—
[b,c,f,i.]STURGEON LAKE												
% blue-green algae, bio-volume	76	69	73	84	90	69	86	83	75	74	87	69
% cryptomond, bio-volume	14	13	13	0	0	0	0	0	0	0	0	0
% diatom, bio-volume	0	13	0	11	0	24	0	0	16	11	0	10
% other phytoplankton, bio-volume	10	5	14	5	10	7	14	17	9	15	13	21
μm^3 (total biovolume) x 10^4/ml.	116	107	94	173	338	102	163	128	86	106	138	107
Secchi disk depth (meters)	2.02	—	—	2.16	—	—	2.58	—	—	2.93	—	—
[c,f,h.]RUSH LAKE												
% blue-green algae, bio-volume	—	—	—	69	35	10	71	59	9	12	50	12
% cryptomonad, bio-volume	—	—	—	15	0	77	18	10	75	11	28	22
% dinoflagellate, bio-volume	—	—	—	0	47	0	0	24	0	49	0	57
% euglenoid, bio-volume	—	—	—	0	0	0	0	0	15	0	0	0
% other phytoplankton, bio-volume	—	—	—	16	18	13	11	7	1	28	22	9
μm^3 (total biovolume) x 10^4/ml.	—	—	—	60	80	103	71	102	20	32	22	40
Secchi disk depth (meters)	—	—	—	3.60	—	—	3.63	—	—	3.72	—	—
[d,f,h.]PASSENGER LAKE												
% blue-green algae, bio-volume	—	—	—	21	39	17	25	12	14	14	17	18
% cryptomonad, bio-volume	—	—	—	42	31	36	39	44	59	42	60	42
% golden brown algae, bio-volume	—	—	—	26	20	0	32	36	0	32	23	25
% euglenoid, bio-volume	—	—	—	0	0	40	0	0	27	0	0	0
% other phytoplankton, bio-volume	—	—	—	11	10	7	4	8	0	12	0	15
μm^3 (total biovolume) x 10^4/ml.	—	—	—	84	28	25	112	79	12	49	52	57
Secchi disk depth (meters)	—	—	—	1.95	—	—	1.80	—	—	2.02	—	—
[h] SAND LAKE												
% blue-green algae, bio-volume	—	—	—	—	—	—	—	—	—	55	53	56
% diatom, bio-volume	—	—	—	—	—	—	—	—	—	15	19	11
% golden brown algae, bio-volume	—	—	—	—	—	—	—	—	—	12	10	16
% cryptomonad, bio-volume	—	—	—	—	—	—	—	—	—	0	17	15
% other phytoplankton, bio-volume	—	—	—	—	—	—	—	—	—	18	1	2
μm^3 (total biovolume) x 10^4/ml.	—	—	—	—	—	—	—	—	—	75	72	79
Secchi disk depth (meters)	—	—	—	—	—	—	—	—	—	2.05	—	—

[1]Recorded bio-volume values are based on mathematical averages of cell counts reported from a number of sampling stations on Island and Sturgeon Lakes (6 and 4 stations, respectively). Rush and Passenger Lake values are singular as those lakes had one sampling station each. Total depths at sampling stations ranged from 18 to 20 feet at Island Lake, from 15 to 26 feet at Sturgeon Lake, 26 feet at Rush Lake, and to 26 feet at Passenger Lake.

Table A-3. Phytoplankton Measurements

	μm^3
CYANOPHYTA	
Anabaena macrospora	45,000
Anabaena spiroides	9,000[a]
Anacystus spp	1,000
Aphanizomenon flos-aquae	2,800
Oscillatoria sp	300[a]
Phormiduim mucicola	10[a]
CRYPTOPHYTA	
Chroomonas acuta	70
Cryptomonas erosa	1000[b]
CRYSOPHYTA	
Chrysococcus sp	1100[a]
Dinobryon sp	500
Mallomonas pseudocoronata	500[a]
Mallomonas tonsurata	550[a]
Ochromonas spp	40
Uroglena sp	450
PYRRHOPHTA	
Ceratium hirundinella	75,000[a]
EUGLENOPHYTA	
Trachelmonas sp	1400[a]
BACILLARIOPHYTA	
Asterionella formosa	3200[a]
Fragilaria crotonensis	1800
Melosira granulata	3000[a]
Melosira islandica	2000[a]
Navicula spp	690[a]
Stephanodiscus astraea	2000[b]
Tabellaria fenestrata	840[a]
CHLOROPHYTA	
Ankistrodesmus falcatus	250[b]
Chlamydomonas sp	300[a]
Oocystis	620[a]
Scenedesmus bijuga	150[a]
Scenedesmus quadricauda	650[a]
Sphaerocystis schroeteri	500[a]

[a]University of Minnesota measurements/unpublished

[b]Wetzel, p 319, 1975

Appendix I

Methodology for Population Projections

Methodology for Population Projections

The available census data on population within the Townships is for year-round residents only. Thus, estimates of the peak population (seasonal plus year-round) are derived by assigning an average household size for seasonal dwellings to the number of seasonal dwellings and combining the result with the projected number of year-round residents. Because of the large proportion of seasonal dwellings in Windemere Township and the documented historic variability in the growth of the year-round population versus the growth in the total number of housing units, a population based projection would have to incorporate subjective assumptions concerning the change in the ratio of seasonal to permanent residents over time.

Accurate population projections are essential for designing cost effective wastewater treatment facilities. Thus, the peak population is of greatest importance because the wastewater treatment facilities must be designed to accommodate the maximum anticipated wastewater flow for the life of the facilities. A housing unit based projection that is developed from historic data yields a total housing unit projection that can be used to estimate the total population, i.e., year-round as well as seasonal residents.

To determine the population of an area when the number of housing units is known requires two assumptions: the average household size and the ratio of seasonal to permanent residents at the end of the projection period. In this report, a slight decrease in the household size of year-round residents was forecasted because of the documented trend toward smaller households and the high median age in the project area which underscores the attraction of the local region as a retirement area. Site specific information on the average household size of seasonal dwelling is not readily available. In one study conducted by the University of Wisconsin Recreation Resources Center, an average household size of 3.0 was found for seasonal dwellings in a similar rural lake area (University of Wisconsin Recreation Resources Center 1979). Accordingly, the seasonal population projections assume a household size of 3.0 during the planning period. A slight decrease in the proportion of seasonal dwellings to year-round dwellings also is assumed based on the trend apparent during the 1970s when the growth rate for permanent dwellings exceeded the growth rate for seasonal dwellings. In spite of these household size assumptions, and their potential for error, the total projected population, as derived from the housing unit projections, should not result in significant error if the total housing unit growth rates occur as projected. For example, if in the year 2000 the actual number of housing units equals the total number projected, but there are fewer permanent residents than expected, the population on an annual basis should not vary significantly because the summer season population will be larger than estimated while the average winter season population is less.

Projections for Windemere Township

The housing unit projections were made by the "growth rate" method, based on an extrapolation of past growth rates. This method was used because it more closely models actual changes than any of the other methods. The "share" method was not used because it is not suitable for jurisdictions in counties where there is a fluctuation in subcounty population growth rates, i.e., if some places are growing while others are losing. The "ratio-trend" method was not used because of the historical variability in the ratio between Windemere Township's population and Pine County's population. Additionally, the use of the "growth rate" method provides for several different projections based on different assumptions concerning future growth. The different projections can then be comapred with other factors such as the amount of buildable land, land values, public services availability, etc. in determing the most reasonable projection for the facility planning or "service area".

The growth rate method is the only method by which the increase in the number of housing units can be projected directly. One problem with the growth rate method, though, is that the projection results from exponentially applying the average annual growth rate to the previous year's population. If the study area experienced unusually rapid growth in the last decade, the exponential application of the average annual growth rate can lead to an unrealistically high projection. Housing unit projections were initially developed for Windemere Township based on four different assumptions concerning future growth (Table I-1 ; Figure I-1).

Table I-1. Housing Unit Projections, Windemere Township, 1980 to 2000.

Assumptions	1980	1990	2000
1. Straight average: growth rate for the projection period remains constant at the 1960 to 1980 average	919	1,565	2,673
2. Trend rate: growth rate for the projection period changes at the same rate as the 1960 to 1980 change	919	1,349	1,883
3. Rate slowdown: growth rate from 1980 to 1990 equals the 1970 to 1980 growth rate and rate from 1990 to 2000 is onehalf 1970 to 1980 growth rate	919	1,286	1,614
4. Rate change slowdown: growth rate from 1980 to 1990 equals one-half the 1960 to 1980 growth rate and rate from 1990 to 2000 equals one-half the 1960 to 1980 growth rate.	919	1,201	1,375

The exponential aspect of the growth rate method is apparent when the projections are depicted on a graph (Figure I-1). Assumptions 1 and 2 for Windemere Township result in growth taking place at a rate exceeding that experienced in the Township in the last decase. Assumption 3, although termed a "rate slowdown," essentially is a straight-line projection. Assumption 4 for Windemere Township was the projection that was determined to be most realistic. This projection assumes that growth will continue in the Township from 1980 to 1990 at a rate similar to the growth experienced from 1960 to 1980. After 1990, the projection assumes that the growth rate will decrease as the area approaches "saturation."

Rural recreational areas such as the Island Lake and Sturgeon Lake portions of Windemere Township are attractive to development because of the amenities associated with lakefront property. As the first tier of lake contiguous lots becomes fully developed, it is not unusual for growth rates to decrease because property in the second tier (backlots) or on outlying lots is in less demand. There are a total of 151 homes on the platted land areas adjacent to Island Lake at present, and the first tier of these lakeshore lots can accommodate an estimated 185 to 200 homes. Given this situation, is expected that most of the available lakefront lots around Island Lake will be developed in the next 10 years while in the second half of the planning period (1990 to 2000) total growth around the Lake will level off because developable lots will only be available in the second tier (backlots). Assumption 4 appears to represent the possibility that growth will continue, but not at the extremely high rates that were experienced in the 1960s and 1970s.

The housing unit projection for Windemere Township was dissaggregated so that the number of housing units within the subareas could be projected (Table I-2). The housing unit projection for the subareas within Windemere Township assumes that after 1990, more of the Township growth will take place in ED 503 as the supply of lakefront lots around Island and Sturgeon Lakes becomes depleted. The housing unit projections indicate a year 2000 total of 214 and 282 housing units around Island and Sturgeon Lakes, respectively, and 1,375 housing units within Windemere Township. The housing unit projections were further disaggregated according to seasonal and permanent units based on survey information obtained from the

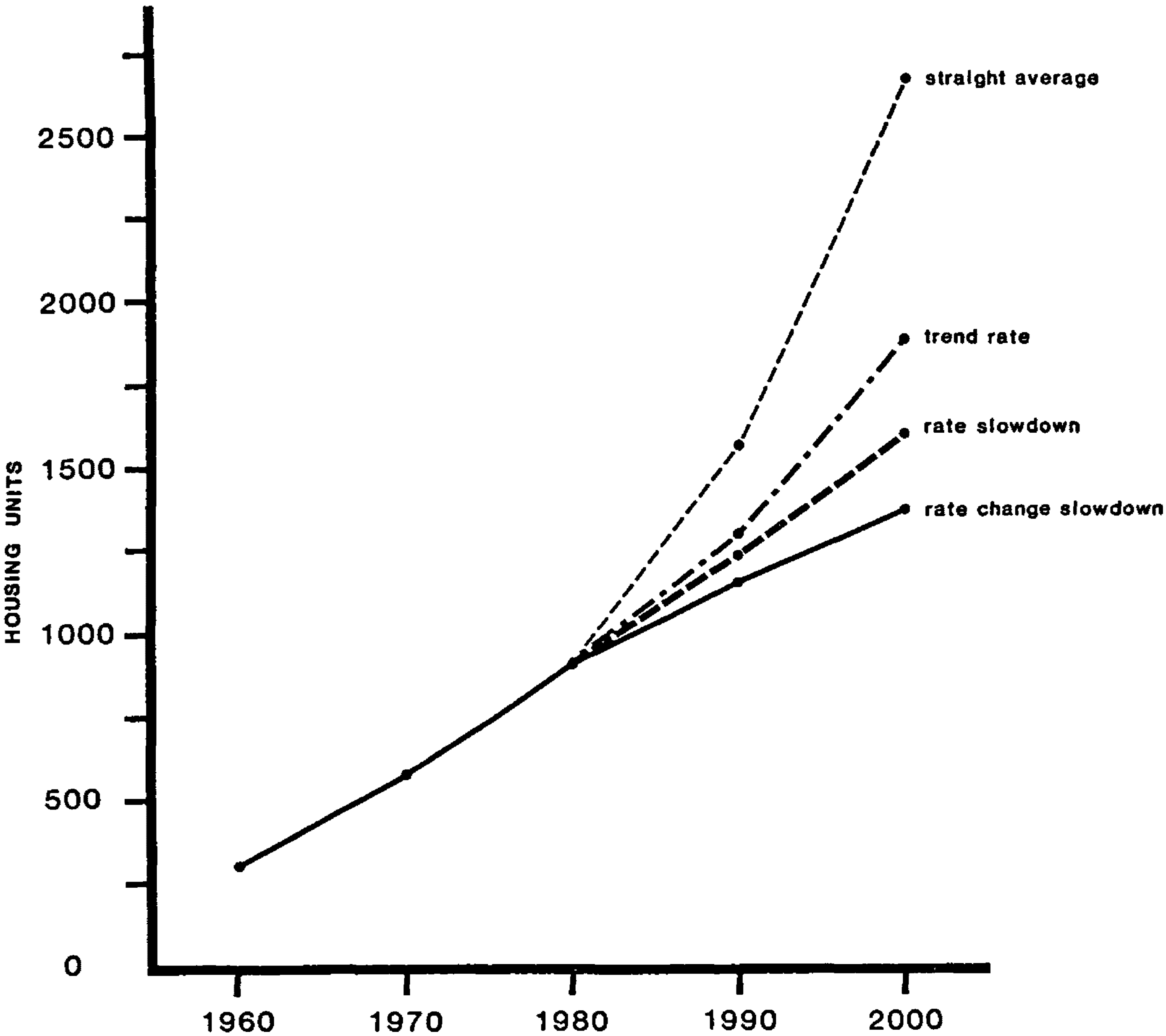


Figure I-1. Windemere Township housing units actual growth 1960 to 1980 and projected growth 1980 to 2000

MLWSD and the 1980 census (Table I-3). The seasonal to permanent projections also assume that permanent residences will form a greater proportion of the total after 1990 as a result of increased numbers of retired residents living in the area on a year-round basis. Information from the 1970 and 1980 census' support this assumption. Between 1970 and 1980, the number of year-round residents in Windemere Township increased by 79.1% while the number of housing units increased by 56.6% (US Bureau of the Census 1981). This is an indication that some housing units that were previously used on a seasonal basis are now being occupied on a year-round basis.

Table I-2. Housing unit projections within Windemere Township, 1980 to 2000 (US Bureau of the Census 1982).

Location	1980	1990	2000
ED 504	397	519	564
Island Lake	151	197	214
Sturgeon Lake	197	260	282
Outlying Areas	49	62	68
ED 503	522	682	811
Windemere Township	919	1,201	1,375

Note: The disaggregated projections assume that growth from 1980 to 1990 is spread evenly between the subareas. Because the amount of developable land in ED 504 is limited, the year 2000 projection assumes that the percentage of the population is ED 504 decreases from 43% to 41% by the year 2000.

Table I-3. Seasonal and permanent housing unit projection within Windemere Township, 1980 to 2000.

	1980		1990		2000	
Location	Permanent	Seasonal	Permanent	Seasonal	Permanent	Seasonal
ED 504	138	259	180	339	223	341
Island Lake	64	87	84	113	103	111
Sturgeon Lake	42	155	55	205	72	210
Outlying Areas	32	17	41	21	48	20
ED 503	269	253	351	331	446	365
Windemere Township	407	512	531	670	670	705

Note: The split between seasonal and permanent housing units was determined from MLWSD records and 1980 census data. The 1990 projections assume the same proportion of seasonal to permanent residents as in 1980. The year 2000 projection assume an increasing proportion of permanent residents as a result of increased demand by retired people for year-round residences and a lower demand for seasonal residences.

Appendix J

Water Quality Tables and Figures

APPENDIX J - Water Quality Tables and Figures.

Table J-1. Sampling program and schedule for surface water sampling in Island, Little Island, Sturgeon, Rush, and Passenger Lakes, Pine County MN.

Lake	Sampling Dates	Parameters[a]	Number of Stations Sampled
Island	26 August 1981	d/t; Sd; b	6
	09 September 1981	d/t; Sd; b; chl	6
	14 September 1981	d/t; Sd; b; chl	6
	30 September 1981	d/t; Sd; b	6
	03 February 1982	d/t; P_t	2
Little Island	03 February 1982	d/t; P_t	2
Sturgeon	27 August 1981	d/t; Sd; b	4
	09 September 1981	d/t; Sd; b; chl	4
	15 September 1981	d/t; Sd; b; chl	4
	05 September 1981	d/t; Sd; b	4
	04 February 1982	d/t; P_t	2
Rush	10 September 1981	d/t; Sd; b, chl	1
	15 September 1981	d/t; Sd; b; chl	1
	01 October 1981	d/t; Sd; b	1
Passenger	10 September 1981	d/t; Sd; b; chl	1
	15 September 1981	d/t; Sd; b; chl	1
	01 October 1981	d/t; Sd; b	1

[a]Parameter Key:

d/t = Dissolved oxygen and temperature at 2-foot depth intervals from the surface

Sd = Secchi disk depth at each station

b = biovolume of phytoplankton at surface, mid-depth, and above the lake bottom

chl = chlorophyll a (corrected for breakdown products) at surface, mid-depth, and above the lake bottom

P_t = Total phosphorus at surface (under the ice) and above the lake bottom

Field investigations were conducted in the project area in 1981 during the periods of 24-27 August; 7-15 September; 28-30 September; and 1-5 October. During these sampling periods, prevailing wind directions were easterly; westerly changing to southerly and then back to northwesterly; easterly; and widely variable, respectively.

Table J-2. Peak daily air temperature and prevailing sky cover as recorded at the Duluth International Airport during the four sampling visits made to the Moose Lake Area (NOAA 1981).

Date	Peak Daytime Temperature, °F	Prevailing Daytime Sky Cover
24 August	65	Overcast
25 August	63	Overcast
26 August	68	Overcast
27 August	59	Overcast
07 September	65	Overcast
08 September	67	Clear
09 September	81	Clear
10 September	77	Overcast
11 September	77	Clear
12 September	77	Clear
13 September	78	Clear
14 September	65	Scattered Clouds
15 September	55	Overcast
28 September	46	Overcast
29 September	44	Overcast
30 September	42	Overcast
01 October	40	Overcast
02 October	48	Clear
03 October	50	Overcast
04 October	47	Overcast
05 October	48	Overcast

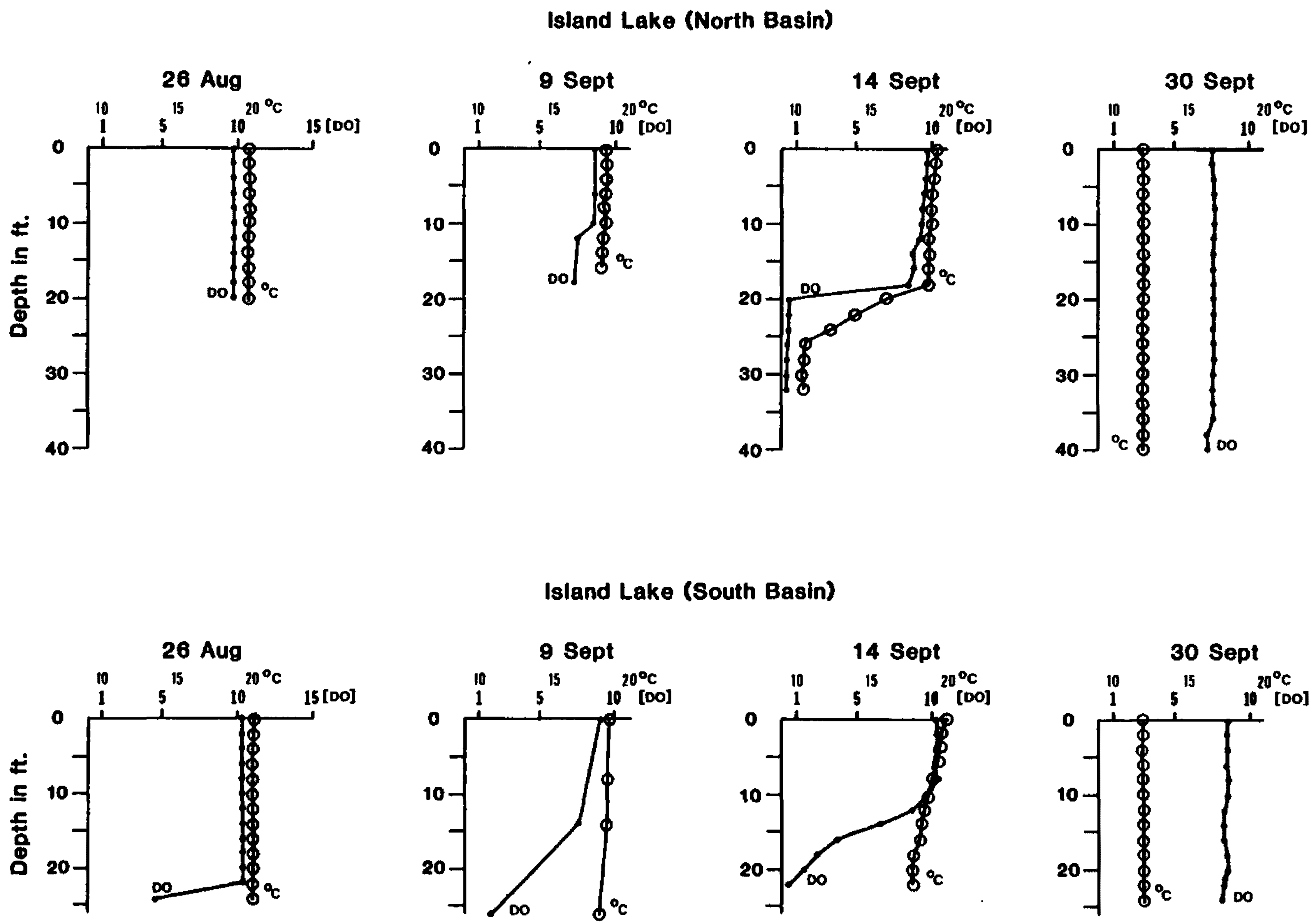


Figure J-1. Dissolved oxygen and temperature profiles for the north and south basins of Island Lake, Pine County, MN. Data are from 1981 field surveys.

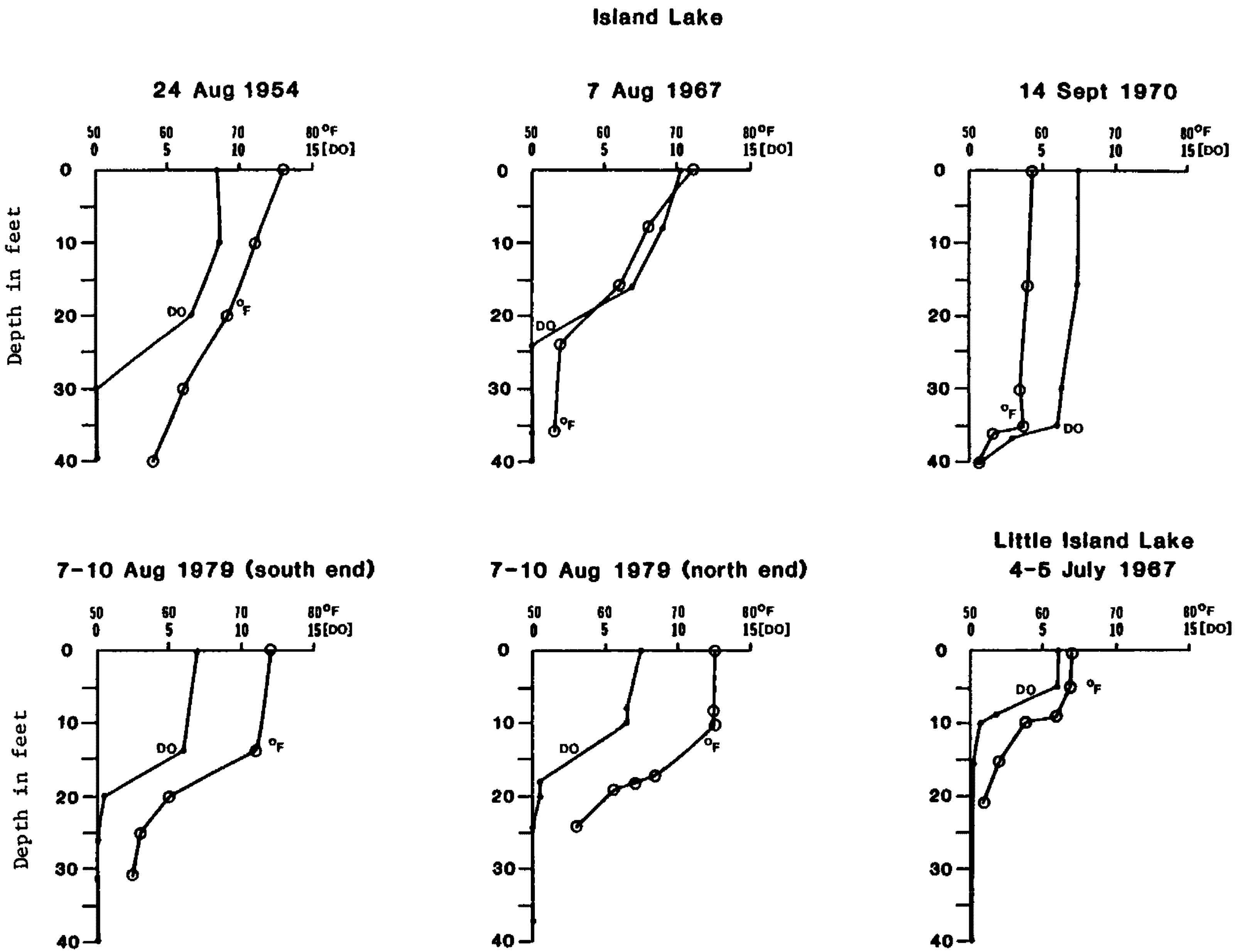


Figure J-2. Dissolved oxygen and temperature profiles for Island Lake and for Little Island Lake, Pine County, MN. Data are from unpublished files of the Minnesota Department of Natural Resources.

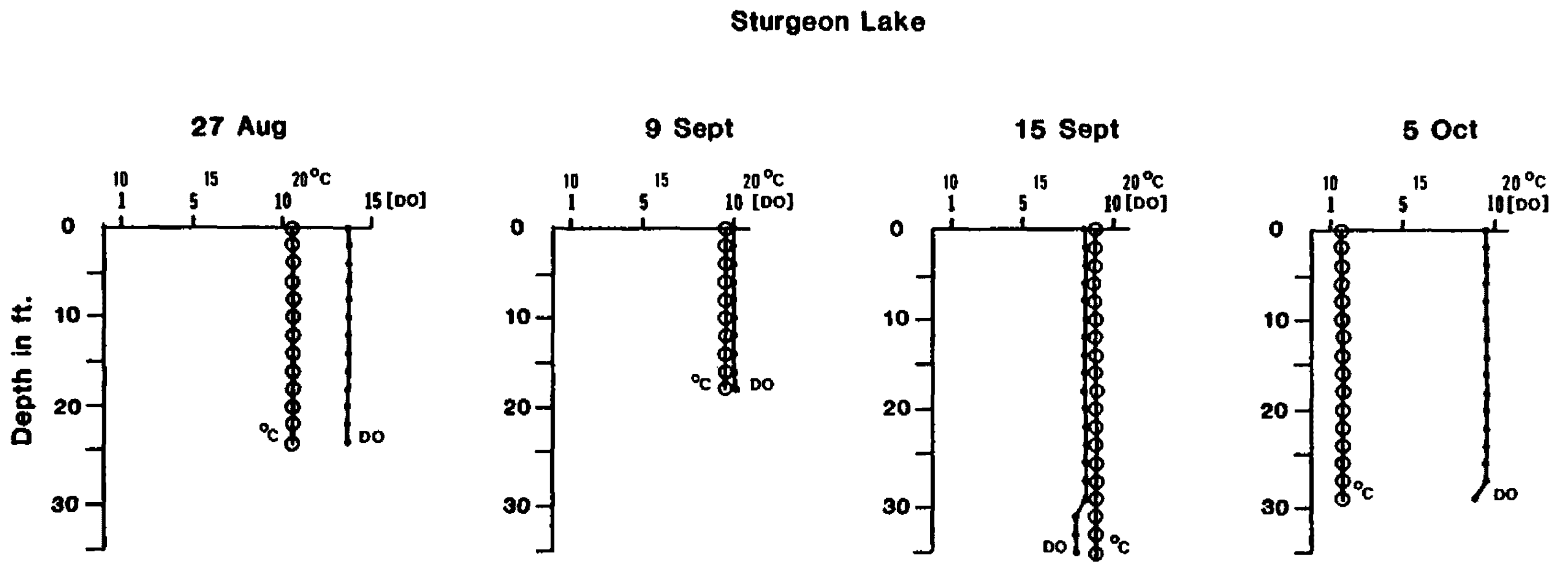


Figure J-3. Dissolved oxygen and temperature profiles for Sturgeon Lake, Pine County, MN. Data are from 1981 field surveys.

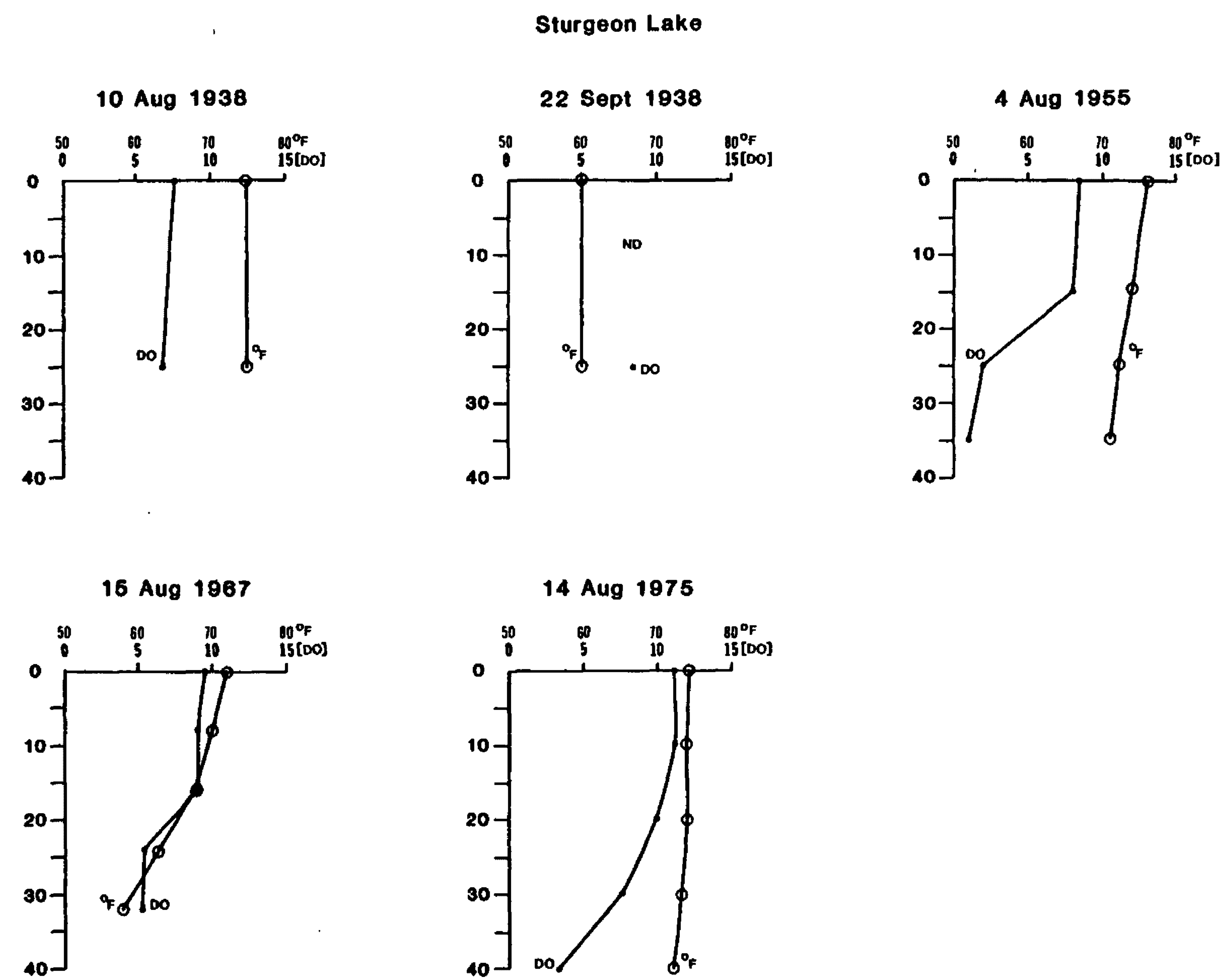


Figure J-4. Dissolved oxygen and temperature profiles for Sturgeon Lake, Pine County, MN. Data are from unpublished files of the Minnesota Department of Natural Resources.

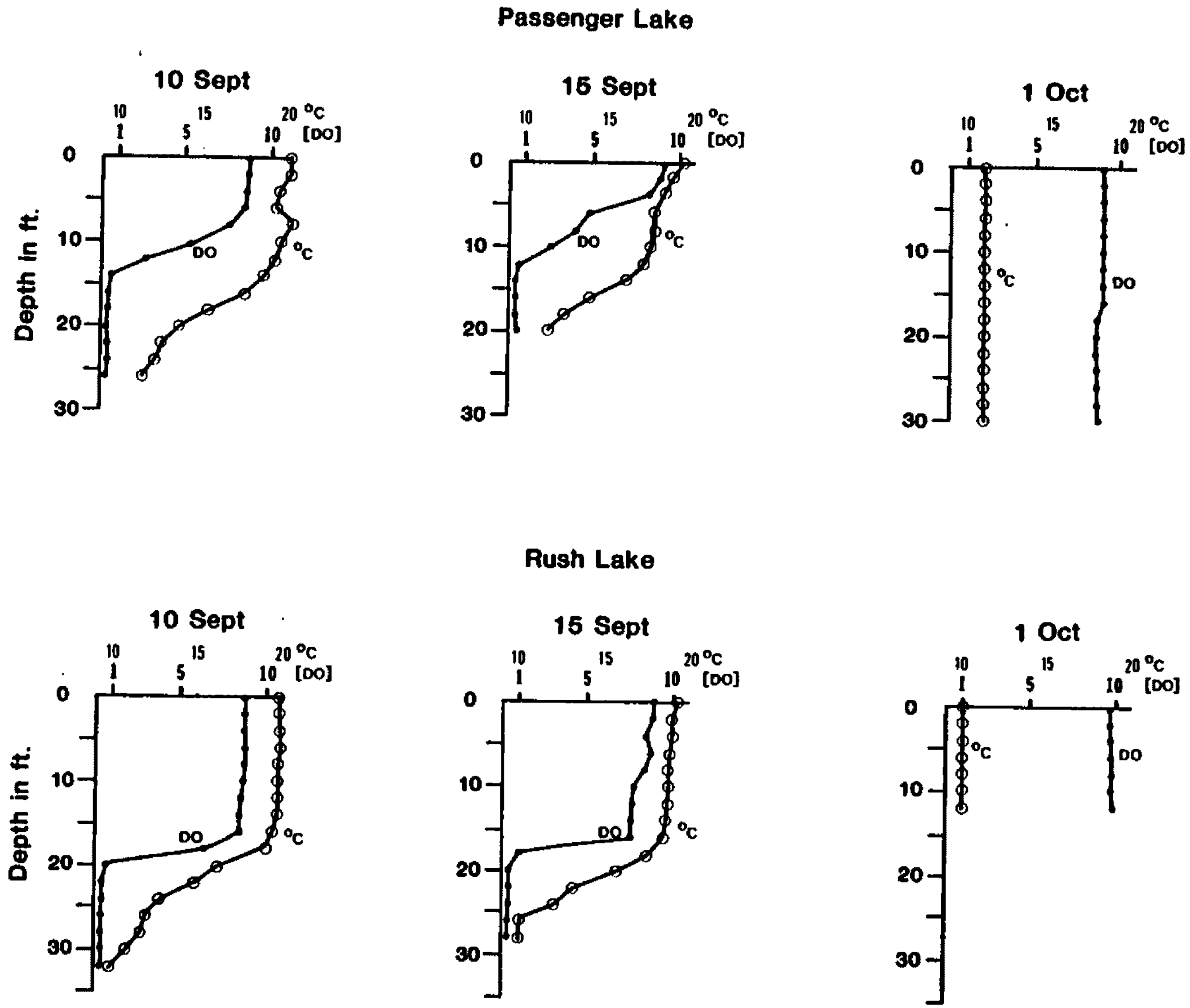


Figure J-5. Dissolved oxygen and temperature profiles for Passenger Lake and for Rush Lake, Pine County, MN. Data are from 1981 field surveys.

Appendix K

Letter to Citizen's Advisory Committee

APPENDIX K - Letter to Citizen's Advisory Committee

Rte. 2, Box 140-B
Island Lake
Sturgeon Lake, Mn. 55783
372-3169

Jan. 25, 1982

Mr. Gregory Dean Evenson
Chairman
Citizens Advisory Committee
Moose Lake, Minn. 55767

Dear Mr. Evenson:

You requested ideas from the Citizens Advisory Committee on Jan. 7, 1982 at the meeting which concerned the Draft Report on Algae. Here are my ideas.

First of all and most importantly I am open minded to what this study is investigating concerning the 4 lakes of Windemere Township. It appears that this study must be enacted to satisfy federal and state regulations. From what I have gathered by talking to PCA and WAPORA people, from public meetings, and personally observing Finney doing field work I feel that WAPORA is doing a professional job. However, this work needs to be monitored by Windemere Citizens.

The jewels of Windemere Township our lakes must have truly been that as observed by the native American Indians, early explorers and the early hardy Scandanavian pioneers.

The logging, fires, and land clearing was especially hard on Island Lake due to the heavy clay soil comprising the bulk of the watershed. The pioneers knew that the land around Island Lake would be many times more productive than the relatively sterile jack pine outwash plain around Rush Lake.

The heavy farmland clearing around Island Lake must have contributed greatly to it's eutrophication. As a casual observer around Island Lake since the late 1940's I have noticed contributing factors to eutrophication.

In the NE¼ Section 8, T. 45 R. 18 was located a barnyard directly on the lakeshore with pig pens going right out into the lake. At least two other farms in that Quarter Section had barnyards that drained into the lake. In Section 4 at the end of the present Twilight Lane Holsteins contently grazed along the lake following a fence that went out into the lake to take a drink. There were other barnyards in Sec. 3 and 4 that contributed runoff, as in Sections 9 and 10.

Island Lake has walleyes that grow at 2 times the State average. As being a young fishing partner of Ted Anderson who learned techniques and spots from him, and in turn showed him spots, I can attest to having caught almost numerous quantities of these tasty fish from 6 to 11 pounds. It is my unscientific opinion that the land clearing and barnyard nutrient enrichment has been a factor in good fish growth.

However, land use around Island Lake is changing or has changed to chiefly residential-recreational use.

I had occassion to observe when the bulk of the initial cabin and homesite development took place along the lakeshore. In Sections 3,4 & 9 some filling took place on swampy shoreline. In Sections 3 and 9 some steep clay banks were graded with heavy equipment in the Fall. The following Spring heavy rainfall washed large amounts of clay into the lake. For a time the water along that shore was of a reddish-brown opague color due to clay particles suspended in the water. Each additional developed lot contributes some erosion therefore affecting nutrient balance in the lake.

Of course, inadequate septic tank drainfield systems have added their share of pollutants.

I recall Island Lake as always having "dog days" or algae bloom in August or Sept. in the late 1940's and the 1950's when kids such as myself were told not to go swimming. However, it seems that the blooms are more severe now and I don't let my kids go swimming in "dog days".

A weed came into the lake in the 1950's which we called hair weed, which I believe is milfoil. A truly noxious type of weed as it choked out less noxious valuable shoreline and submerged weed beds. In late Summer large matts of floating "hair weed" would make rowing a boat difficult in shallow areas. The weed is still here but seems to get chopped up by the large number of power boats on the lake today.

In summary I think that this <u>Draft Report On Algae</u> is helping to bring scientific biological investigation to the factors and core problems affecting the eutrophication of these 4 lakes in Pine County, Let us hope that the remainder of the studies will allow us to become better informed citizens to study the alternatives available for the protection of our "jewels" for our children.

Sincerely,

cc Ken Dobbs

Walter C. Johnson

Appendix L

Paleolimnological Investigation

APPENDIX L - Paleolimnological Investigation

ONSITE WASTE TREATMENT AND LAKE EUTROPHICATION: ANALYSIS WITH DATED LAKE SEDIMENTS

S. R. McComas[1], J. C. Laumer[1], P. Garrison[2], and D. Knauer[2],

[1]WAPORA, Inc., Suite 490, 35 E. Wacker Drive, Chicago, IL 60601
[2]Lake Management Consultants, Inc., 166 Dixon Street, Madison, WI 53704

ABSTRACT:

Three seepage lakes in north central Minnesota were studied to evaluate the relative impacts of onsite waste treatment systems and other nutrient sources on lake trophic status. Island and Sturgeon Lakes, having extensive shoreline development served exclusively with onsite systems, were compared to a third lake (Little Island Lake) having no shoreline residential development. Interpretation of sediment core results indicated all three lakes had phosphorus concentrations, chlorophyll degradation products, and diatom communities indicative of predominant land uses in their watersheds. The present trophic condition for Island Lake was established after the turn of the century (with conversion of forest lands to agricultural use) and prior to development of a large lakeshore community. Sturgeon Lake has a relatively small watershed and phosphorus concentrations in the sediment core appear to have been influenced in the last 40 years by one farmstead located on the lakeshore. Little Island Lake had the highest chlorophyll and phosphorus sediment concentrations of the three lakes. Little Island Lake is shallow, and macrophytes represent a chlorophyll and phosphorus sink. Relatively minor changes in all three lakes' trophic status have occurred since the 1950s, the period when lakeshore development began to increase exponentially around Island and Sturgeon Lakes.

INTRODUCTION

An increase in lake eutrophication by wastewater discharge from municipal sewage treatment plants has been well documented (Edmundson 1970, Megard 1972, Larson 1975). Few studies have shown the effects of nutrient inputs associated with onsite waste treatment systems on lake eutrophication. Typically, the first type of wastewater treatment serving lakeshore residences is onsite. Lakeshore homeowners may correlate increasing lake eutrophication symptoms with additional development of lakeshore lots and the increase in onsite systems. They assume the input of partially treated wasteflows from onsite systems is the primary factor for water quality degradation. But, from the literature, the actual role of onsite systems in lake eutrophication is unclear.

The literature describes a range of possibilities in regard to the importance of nutrient inputs from onsite systems. Water chemistry data and nutrient budget calculations for a number of lake watersheds in the northern United States indicate septic tank/drainfield systems contribute generally less than 30% of the total phosphorus or nitrogen load to the aquatic system (Kerfoot and Skinner 1980, Jones and Lee 1977, USEPA 1979a, 1979b, 1979c, 1979d, 1979e, 1981, 1982). Typically, agricultural land use in the watershed dominates the phosphorus load (Dillon and Kirchner 1974). However, estimates using total phosphorus may overestimate the importance of nutrients in runoff since not all of the total phosphorus component is biologically available (Logan et al. 1982). Phosphorus associated with septic tank effluent entering the groundwater flow field is typically in the dissolved form and therefore, biologically available. Some studies indicate that the potential for relatively high dissolved phosphorus inputs from onsite systems (Brandes 1974, Viraraghaven and Warnock 1976) and Lee (1976) suggests groundwater inputs could be especially significant to lake water quality when water influx is dominated by seepage.

In this study, we examined stratigraphic characteristics of lake sediment to determine changes in lake trophic indicators (including organic matter, chlorophyll, diatoms, and phosphorus) covering a time period from the settlement of the watersheds by non-Indians to the present. Sediment cores were taken from three seepage lakes in north central Minnesota. Two of the lakes, Island and Sturgeon, have residences with onsite systems around them, and currently are documented to have blue-green algae as the dominant late summer phytoplankter (USEPA 1982). The third lake (Little Island), is contiguous to Island Lake and has had only one house in its watershed in the last 100 years and no visual signs of blue-green algae blooms. Other than onsite systems, no wastewater treatment flows or other point sources enter these lakes. It is assumed the major pathways for nutrient introduction into these lakes have always been groundwater, atmospheric deposition, runoff in the direct drainage area, and internal nutrient recycling. Hydrologic and watershed parameters for all three lakes are presented in Table 1.

It was hypothesized that if septic tanks played a major role in the eutrophication of Island and Sturgeon Lakes, an increase in the eutrophic indicators in the sediment core should be correlated with the onset of intense development around both lakes (circa 1950). Little Island Lake would be expected to have relatively unchanged indicators through this time period because no onsite systems are situated on its shore. Alternatively, if nutrient inputs from septic tanks played a minor role in the eutrophication of the two developed lakes, the trends of the trophic indicators for all three lakes should have some degree of consistency.

METHODS

In March 1982, two cores of 60 cm length were taken from each of Island, Sturgeon and Little Island Lakes using a plexiglass piston corer with a 11.25 cm inside diameter. One core was extruded in the field in 2 cm sections for determination of sedimentation rates using Cesium-137 dating (Eberline Laboratories, Inc., West Chicago, IL). The other core was sectioned into 3 cm sections for determination of diatom composition, chlorophyll degradation products, phosphorus fractions, and organic matter. The samples were stored in sealed plastic bags and frozen until analyzed.

Table 1. Lake and watershed parameters for Island, Sturgeon, and Little Island Lakes. Information was obtained from recent lake surveys conducted by WAPORA, Inc. and Minnesota Department of Natural Resources, Fisheries Section.

	Island	Sturgeon	Little Island
Number of onsite systems	151	197	0
Length of shoreline (km)	10.1	12.9	1.7
Ratio onsite systems/km of lake shore			
Watershed area (ha)	1151	560	294
Lake surface area (ha)	211	686	17
Ratio watershed/lake surface	5.5	0.8	17.3
Mean Depth (m)	3.4	6.9	1.6
Mean Secchi disk (m)	1.4 (n=24)	2.4 (n=16)	0.9
Chlorophyll a (ug/l)	29 (n=35)	8 (n=24)	NA
Total phosphorus, winter values (mg/l)	0.04 (n=4)	0.02 (n=4)	0.03 (n=2)
Average Carlson Trophic Status Index	---	---	---
Current lake trophic status	eutrophic	meso-eutrop.	eutrophic

Percent moisture was determined by measuring weight loss of sediment after a least 24 hours of dessication at 105° C. Organic matter was determined after weight loss on ignition at 550° C for one hour. Pigment analysis was performed on wet sediment using the procedure of Vallentyne (1955). Pigments were extracted with 90% acetone containing 0.5% dimethylanaline as suggested by Wetzel and Manny (1978) and reported as sedimentary pigment degradation unit (SPDU)/gram dry weight. The sediment phosphorus fractions of apatite phosphorus, nonapatite phosphorus, and organic phosphorus were determined following the methods outlined by Williams et al. (1976a). All concentrations have been reported on a dry sediment basis. The diatom preparation, identification, and enumeration was conducted following the methods of Bradbury (1975).

RESULTS AND DISCUSSION

Sedimentation Rates

Counting the activity of radioactive Cesium (Cesium-137) in lake sediments can be used to determine recent lake sedimentation rates. Cesium-137 is found in lake sediments as a result of nuclear weapons testing and subsequent atmospheric contamination by the isotope. Testing first began on a small scale in 1946 but increased in 1957 with the peak activity occurring in 1963-1964. Because a 6 to 12 month delay typically occurs between deposition of Cesium-137 in the watershed and delivery to the lake, the maximum peak recorded in lake sediments is assumed to be 1965 (Ritchie et al. 1973).

The recent sedimentation rate in both Sturgeon Lake and Island Lake is estimated to range between 0.41 - 0.44 cm $year^{-1}$ (Figure 1). At this sedimentation rate, a 1 cm segment would represent about 2.5 years. The sedimentation rate is not as easily defined in Little Island Lake, but because of the nature of the increase of Cesium-137 activity at 5 cm, the sedimentation rate is estimated to be 0.29 cm per year (J. B. McHenry, personal comm.). A 1 cm segment would represent about 3.45 years. Extrapolating sedimentation rates to the bottom of the core represents a time period of around 1835 for Island and Sturgeon Lakes, and around 1775 for Little Island Lake.

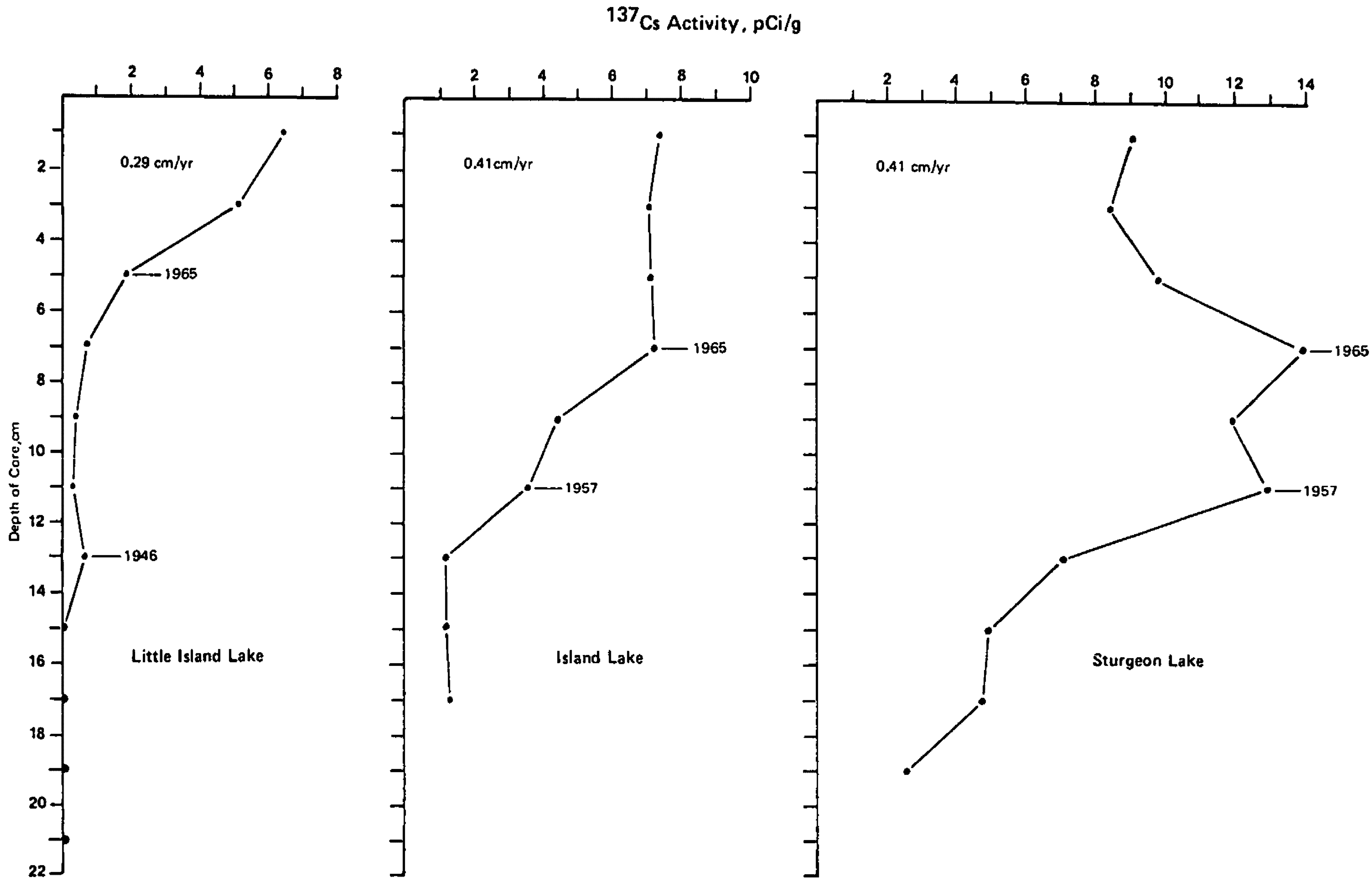


Figure 1: Sedimentation rates for Little Island, Island, and Sturgeon Lakes.

Although the sedimentation rate varies within a lake basin, Davis and Ford (1982) found sediment arriving in the deep basin of a lake is well mixed due to resuspension and reposition and qualitatively representative of much of the basin. The sediment cores collected in this study were from the deepest part of the lake basins. The Island and Little Island Lake watersheds are located in clayly glacial till. One-half of Sturgeon Lake's watershed is in glacial outwash sand and the other half is in the clayey glacial till. Cores from all three lakes were taken in the clayey glacial till.

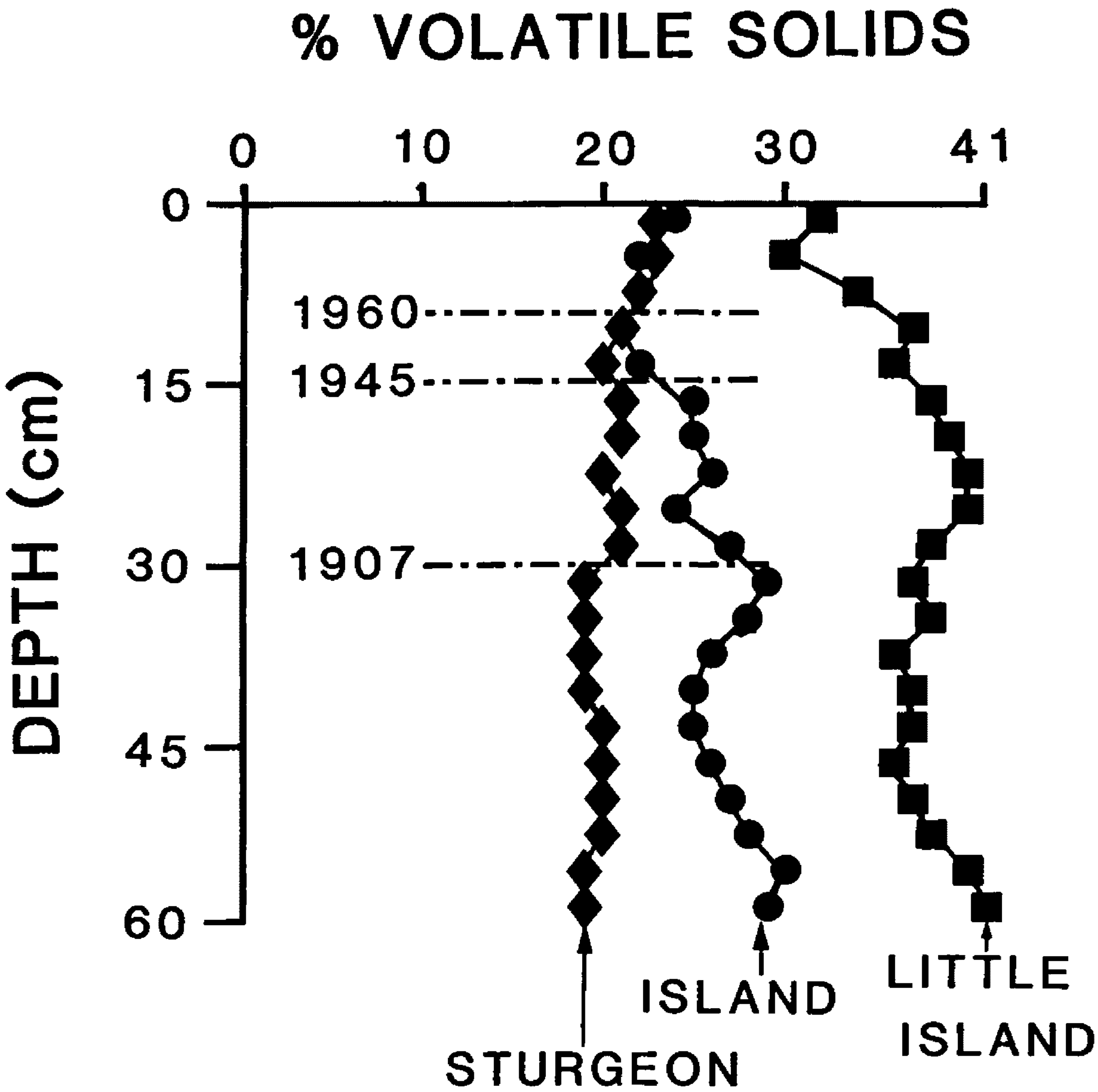
Organic Matter and Chlorophyll Degradation Products

In the Sturgeon Lake core, organic matter (Figure 2) and sedimentary chlorophyll degradation product (Figure 3) profiles showed little change over time. Organic matter ranged from 19 to 23 percent while chlorophyll ranged from 6 to 12 SPDU/gram dry weight. Organic matter was relatively unchanged in the lower part of the core although there was a slight increase above 12 cm (1955). Chlorophyll degradation products increased slightly above 6 cm (1965).

In the Island Lake core, organic matter (Figure 2) and sedimentary chlorophyll degradation product values (Figure 3) are typically higher than Sturgeon Lakes values. Organic matter ranged from 20 to 30 percent and tends to decline slightly from the bottom to the top of the core. Since the 1950s (above 12 cm) the % organic matter in the cores from Island and Sturgeon Lakes is similar. Sedimentary chlorophyll degradation products in the Island Lake core ranged from 14 to 30 SPDU/gram dry wt. The highest value was at the bottom of the core. From 30 cm to 17 cm (1910-1940) chlorophyll decreased somewhat. Since about 1940 (17 cm) chlorophyll increased (especially in the top surficial segment) but has not exceeded levels observed in the middle of the core.

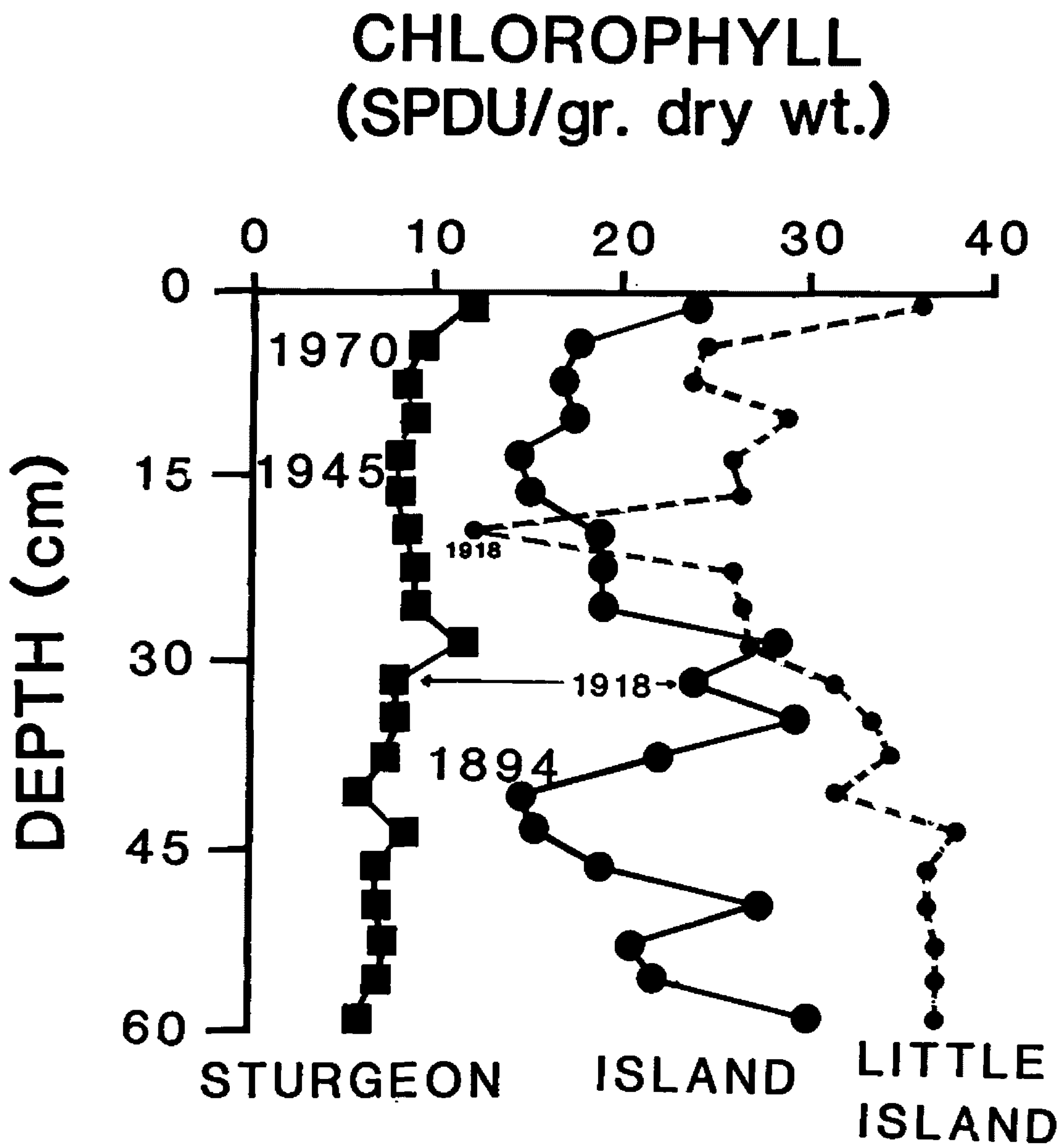
In the Little Island Lake core, organic matter (Figure 2) and sedimentary chlorophyll degradation product (Figure 3) values are generally greater than either Sturgeon or Island Lakes values. The organic matter profile shows a declining trend from the bottom to the top of the core and values range from 30 to 41 percent. The chlorophyll degradation products

Figure 2



% VOLATILE SOLIDS
0
10
20
30
41
DEPTH (cm)
0
15
30
45
60
1960
1945
1907
STURGEON
ISLAND
LITTLE ISLAND

Figure 3


CHLOROPHYLL
(SPDU/gr. dry wt.)
0
10
20
30
40
0
15
30
45
60
DEPTH (cm)
1970
1945
1918
1918
1894
STURGEON
ISLAND
LITTLE
ISLAND

were unusually low at 19 cm (1915-1920). In 1918, the Moose Lake Forest Fire burned much of the lake's watershed and may have had an impact on the chlorophyll values. Prior to 1918, chlorophyll values were declining. The next core segment after 1918 (at 16 cm) shows chlorophyll values returning to pre-1918 levels. Chlorophyll in the surficial core segment increased dramatically compared to the underlying 3-6 cm segment, but is comparable to values at the bottom of the core.

Although chlorophyll degradation product concentrations in the surficial sediments increase sharply for both Sturgeon and Island Lakes, there are parallel increases in Little Island Lake. No reasons for the increases are speculated on but, because they occurred in all three lakes, they can not be attributed strictly to onsite systems. Little Island Lake has no onsite systems on its shoreline.

Diatoms

In the Sturgeon Lake core a total of 97 diatom taxa were identified. Melosira ambigua and Fragilaria construens v. venter were dominant species (Figure 4). From 60 cm up to 37 cm (1835 - 1890), F. construens v. venter represented 20 to 40 percent of the diatom community. At 37 cm (1890), coinciding with a decline in the logging industry and an increase in farming in the region (Pine County 1947), F. construens v. venter strongly declined and M. ambigua, a planktonic diatom, increased. Between 17 cm and 7 cm (1940 - 1965) the percentage of littoral species increased (especially Achnanthes spp., Eunotia pectinalis, and E. incisa) while M. ambigua declined. Grouping eutrophic diatom indicators together indicates a trend toward eutrophic conditions starting in the 1960s. However, the continued presence of Cyclotella bodanica and the high level of Melosira ambigua indicate the lake's trophic status has not changed drastically during the time period covered by the sediment core. Similarly, the percent of eutrophic indicators above the fcm level is comparable to the percent representing the 1890s.

In the Island Lake core a total of 118 diatom taxa were identified. The dominant species are Melosira ambigua, M. italica, and Tabelaria fenestrata (Figure 5). These species are representative of mesotrophic-type

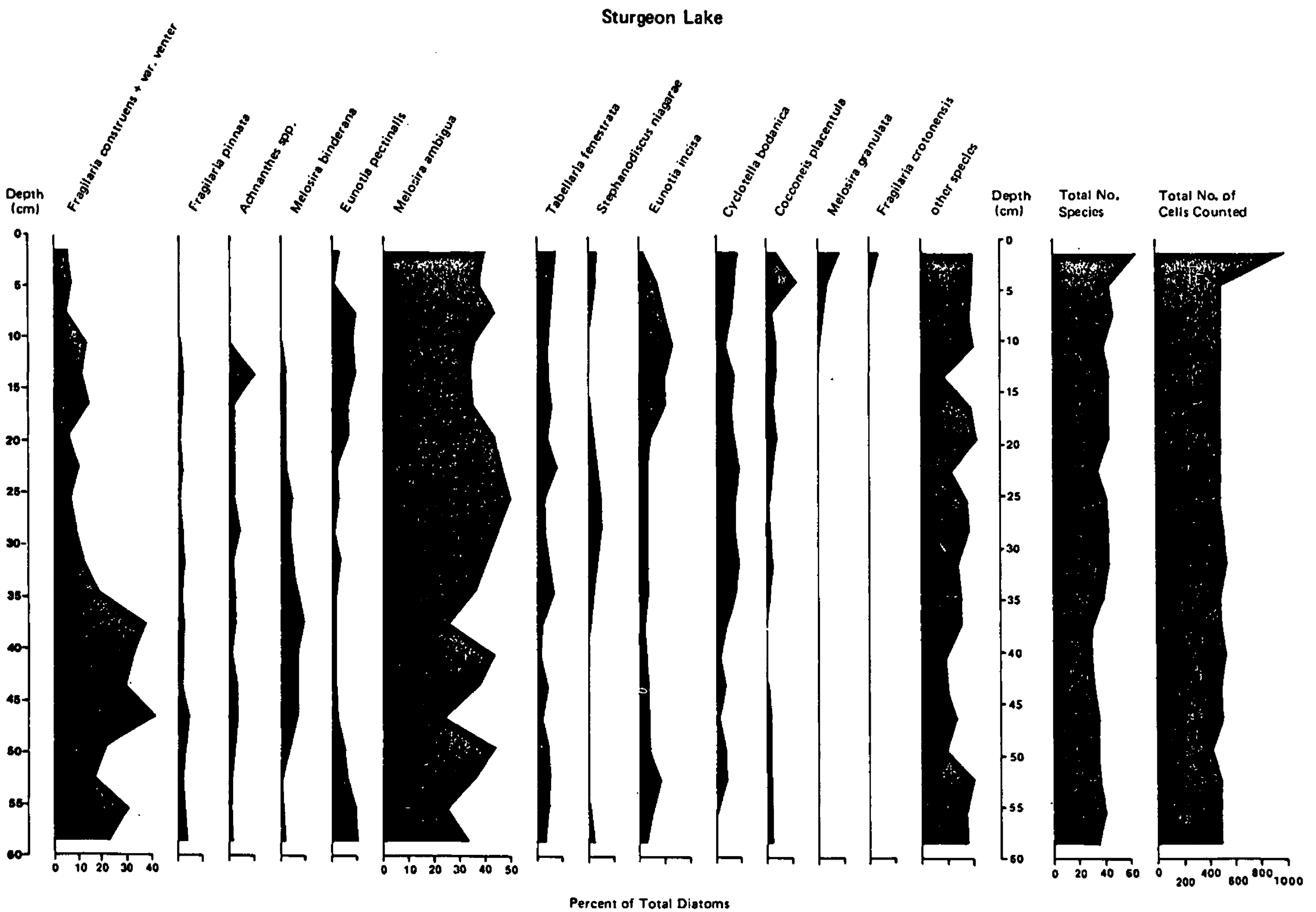


Figure 4. Stratigraphic diatom spectrum from Sturgeon Lake.

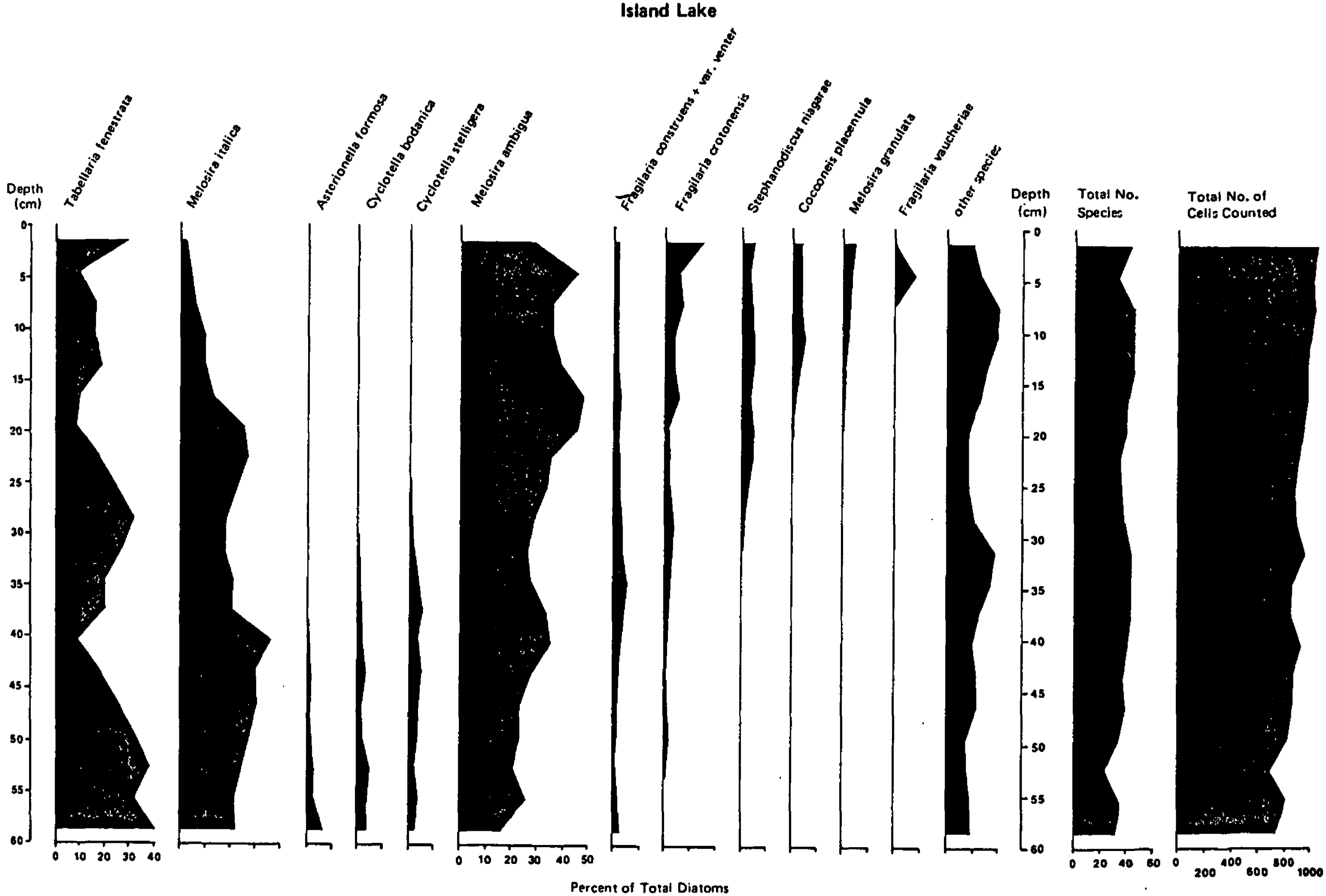


Figure 5. Stratigraphic diatom spectrum from Island Lake.

conditions (Davis and Larson 1976) and give the mesotrophic indicator species a majority of the diatom community percentage. However, above 20 cm (1935), M. italica dramatically decreases in abundance while M. ambigua remain high. Also at about 1935, Cocconeis placentula, Melosira granulata, and Fragilaria crotonensis either first appeared or increased in abundance, resulting in an increase in the percentage of eutrophic indicators.

In the Little Island Lake core a total of 107 diatom taxa were identified. The diatom stratigraphy is much different compared to the other two lakes. Most of the species identified are not associated with the pelagial community. Although no single species dominates the community like Melosira ambigua does in Island and Sturgeon Lakes, Fragilaria construens v. venter and Melosira binderana were common (Figure 6). The diatom stratigraphy showed few changes throughout the core. Starting at about 20 cm (1916) there was a gradual but definite increase in the abundance of Achnanthes lancelata, Cocconeis placentula, Fragilaria capucina, and Navicula cryptocephala. All four species have been found in eutrophic lakes or ponds (Jorgensen 1948, Stormer and Young 1970).

Changes in the diatom community have been interpreted in a qualitative context with indicator species assigned to one of three categories; eutrophic, mesotrophic, and other. The "other" category includes species associated with benthic conditions or species that have no specific trophic affiliation. Assignments to a category were made with the usual assumptions and limitations that have been expressed by other authors (Bradbury 1975, Kalff and Knoechel 1978, Harris and Vollenweider 1982).

In Sturgeon Lake, the percent of eutrophic indicator diatoms has increased twice since the 1920s. The second increase, starting in the 1960s, coincides with the onset of rapid residential development around the lake. However, the percent of eutrophic indicators found after 1960 is still less than what was found in segments representing the early 1900s. Island Lake showed an increase in eutrophic indicators that dates to the 1930s. However, onsite systems probably were insignificant nutrient sources in the 1930s. It was not until the end of that decade that electricity became available in the area for well pumps and it was not

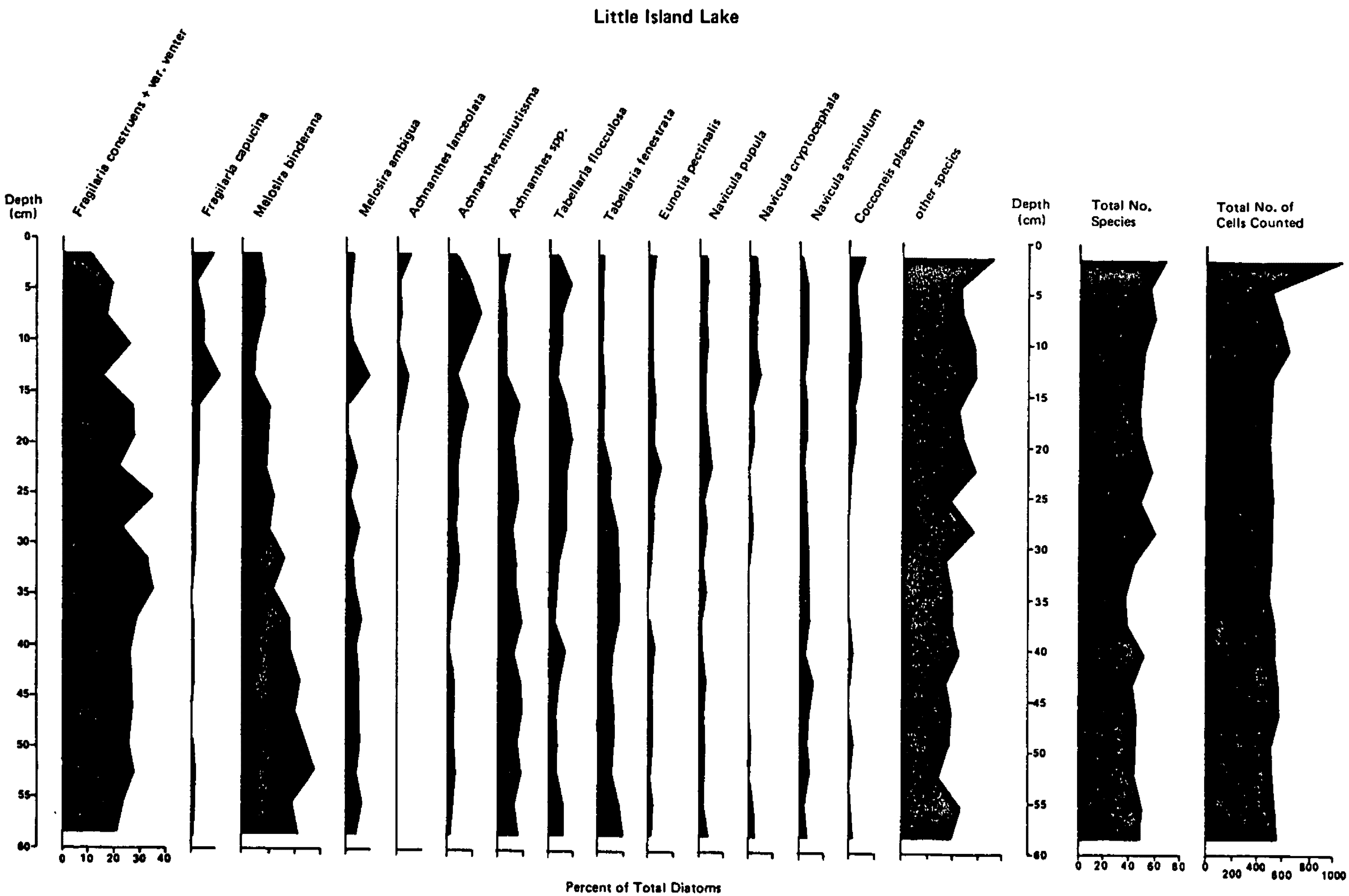


Figure 6. Stratigraphic diatom spectrum from Little Island Lake.

until the 1940s that most cabins installed indoor plumbing (Don Classen, City clerk, pers. comm.). Until the decade of the 40s, nearly all lakeshore residences were seasonal and used privies for waste treatment. Because of the minimal water use in residences that have privies and because the privy pit is usually in unsaturated soils, there was probably little nutrient input from the seasonally used privies. Coinciding with the increase in eutrophic indicators for Island Lake in the 1930s was a peak in agricultural land use intensity (USDA Census records) and a severe drought lasting several years which lowered both groundwater levels and lake levels (David Ford, MDNR, pers. comm.) A drought would have affected the lake similarly whether onsite systems or agricultural land use were the impetus for an increase in eutrophic diatom indicators. But, based on literature values for loading rates (USEPA 1980) and on land use characteristics in the watersheds, the agricultural component would contribute a much higher phosphorus load than onsite systems. Little Island Lake has the most diverse diatom community (based on average Shannon-Weiner values). Although Little Island Lake had the highest percentage of eutrophic indicators, it also had the highest percentage of littoral or benthic species. Because Little Island Lake now has a large macrophyte community covering 30% of the surface area (MDNR 1975, unpublished) the consistancy of benthic and littoral species in the core indicates Little Island Lake has been shallow and productive, probably predating the earliest sediment core date of 1775.

Phosphorus

Phosphorus in the sediment cores was fractioned into three categories; apatite phosphorus (A-P), nonapatite inorganic phosphorus (NAI-P), and organic phosphorus (org-P). Apatite phosphorus represents phosphorus present in the crystal lattices of apatite grains and generally is of detrital origin (Williams et al. 1976a). Nonapatitic inorganic phosphorus consists of phosphorus not associated with A-P or org-P, and orginates naturally, (i.e. by chemical weathering in the watershed) or from anthropogenic sources (i.e. fertilizers, septic tank drainfields, etc). Organic phosphorus includes all phosphorus associated with organic molecules or more specifically with carbon atoms by C-O-P or C-P bonds and may be an indicator of lake productivty.

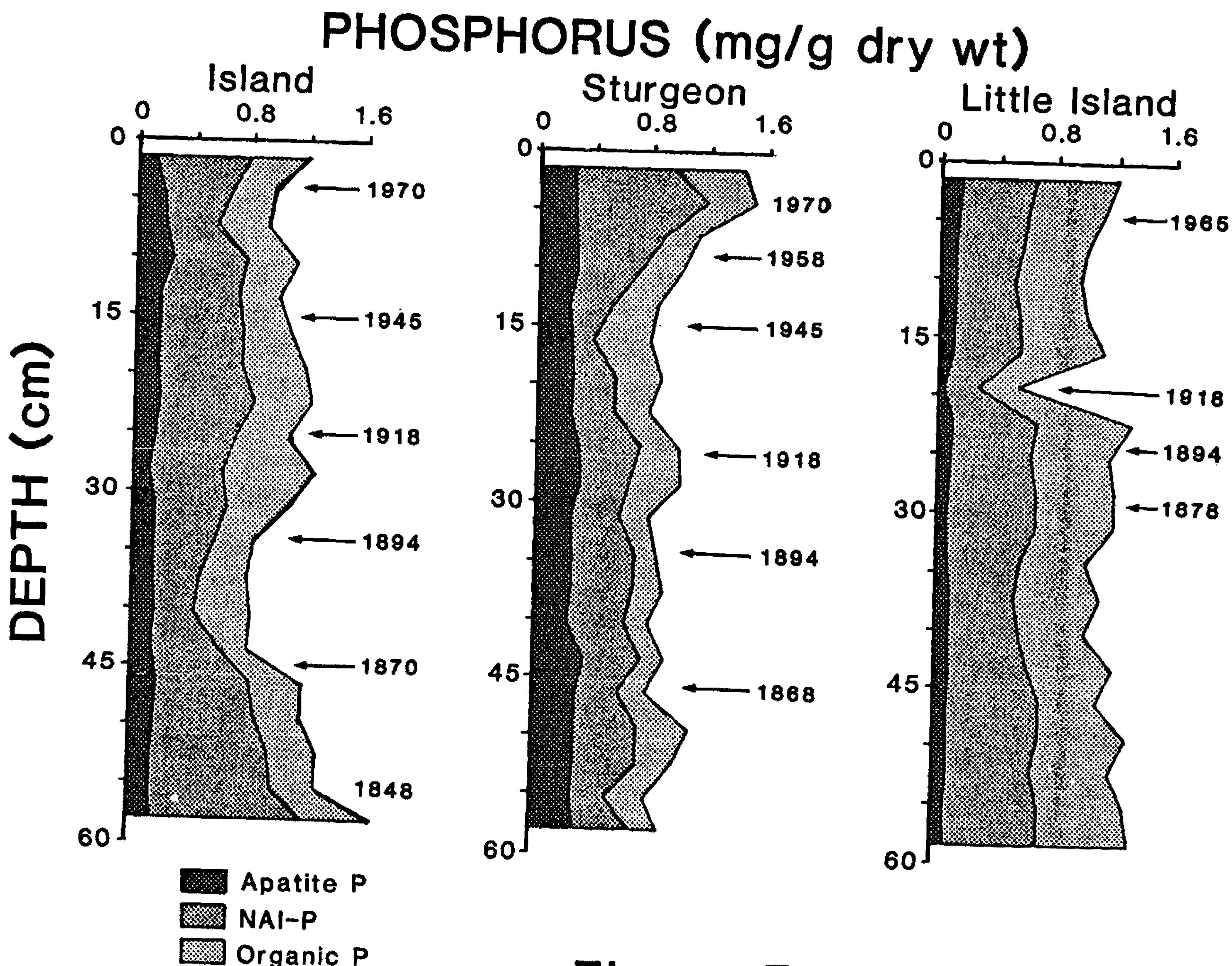

PHOSPHORUS (mg/g dry wt)
Island
Sturgeon
Little Island
0
0.8
1.6
DEPTH (cm)
0
15
30
45
60
1970
1945
1918
1894
1870
1848
1970
1958
1945
1918
1894
1868
1965
1918
1894
1878
Apatite P
NAI-P
Organic P

Figure 7

In Sturgeon Lake, the apatite-P is relatively constant throughout the length of the core (Figure 7). NAI-P increases above 15 cm (1945) but decreases at 5 cm (1970). Org-P is also fairly constant throughout the length of the core with a slight increase above 5 cm (1970). Of the 3 lakes, Sturgeon Lake has the highest total phosphorus concentration in surficial sediments.

In Island Lake, total phosphorus was highest at the bottom of the core and declined until about the 43 cm segment (1875) (Figure 7). It was somewhat steady from 43 cm to 35 cm and then increased to a peak of about 1.25 mg/g near the middle of the core, the 25 to 30 cm segment, (circa 1910). NAI-P makes up the largest percentage of the three phosphorus fractions and increases above the 7 cm mark (1965). The Org-P and A-P fractions were relatively constant throughout the sediment core.

Historically, Little Island Lake had high total phosphorus values in the sediments except for the period of 1915-1920. Otherwise the three phosphorus fractions were relatively constant, only slightly increasing since the 1940s. The organic phosphorus levels are higher than the other two lakes indicating Little Island may be more productive.

An increase in sedimentary phosphorus concentrations in Sturgeon Lake beginning in the 1950s coincides with increased housing development. However, if these phosphorus trends were related to onsite system use, a phosphorus decline in the sediment core from 1970 to 1980 would not be expected. The explanation may be tied to a farmstead adjoining the shoreline. On the northeast shoreline lies one farm house, a barn, and a pasture sloping toward the lake. The current owner of the property purchased the farm acreage in 1947 and immediately thereafter expanded dairy and crop operations. The owner has stated that prior to 1947 there was not much farming activity on this acreage. The owner retired in 1970 and since that time there has been no active farming. The phosphorus increase and decrease in the core correlates over time with the reported changes in this farming operation. In a small watershed, without other major nutrient sources, this potential source of phosphorus could be significant. Most of the phosphorus in the 15 cm to 5 cm segment is in the NAI-P fraction. Since org-P and chlorophyll degradation products in this segment did not show parallel increases, this increased phosphorus did not increase phytoplankton productivity, although the percent of eutrophic indicators did increase.

The rapid conversion of forested land to agricultural use in the Island Lake watershed may have been responsible for the phosphorus increases following the 1890s. The Hinckly Forest Fire of 1894 which burned much of the region apparently did not burn Island Lake's watershed, but did hasten the conversion of the lumbering economy to an agricultural economy in the area. Farmlands extended to the lake until at least the early 1920s, when the land was subdivided for development. After the 1950s, the phosphorus profile in Island Lake decreased until 1970, when it increased slightly. Housing units around the lake have increased in number exponentially since the 1950s, and numbers of planktivorous fish have increased dramatically since 1970 as well. It is speculated that there may be a link with fishing pressure, an increase in planktivorous fish, and a decrease in zooplankton: resulting in increased phytoplankton and sediment phosphorus in the lake after 1970 (Table 2).

The phosphorus profile for Little Island Lake has been relatively constant except for the short segment where there was a sharp phosphorus decline and recovery. A similar change in chlorophyll was observed over this short segment. Extrapolating from the Cesium-137 derived sedimentation rate, this segment of lowest phosphorus and chlorophyll concentration was dated 1915-1920, and corresponds to the time of the Moose Lake Fire (1918). A 1918 U.S. Forest Service map indicated that most of Little Island Lake's watershed burned, a small portion of Island Lake's watershed burned, and none of Sturgeon Lake's watershed burned in this fire.

The high total phosphorus and high org-P fractions indicate Little Island Lake has always been productive. The primary vestibule of productivity is macrophytes. The bottom sediments are of a peaty composition with a high organic matter content.

Addressing the Hypothesis

Because the increase in eutrophication indicators in Sturgeon and Island Lakes is not readily correlated with an increasing number of onsite systems (circa 1950), onsite systems do not appear to be the predominate cause of eutrophication in Island or Sturgeon Lakes. The results from the sediment core analysis somewhat support the alternative hypothesis that sediment core profiles from all three lakes follow similar trends. All three lakes are limnologically distinct; however, similar trends are found in all three lakes in the respect that sediment core profiles have reflected the impact of significant events in the watershed. If onsite tank systems had an impact on the lakes through nutrient enrichment, the effects were masked by contributions from other sources.

Analysis of the sediment core from Shagawa Lake, Minnesota shows that distinct changes in trophic status could be attributable to point source wastewater discharges from a small municipal wastewater treatment plant (Bradbury 1975, 1978). This study did not show evidence of those types of changes correlated with the increasing introduction of the diffuse wastewater flows from onsite systems. The basic trophic trends in all three lakes appear to have been established prior to the time period covered by our sediment cores. In addition, unpublished MDNR fishery records (1938, 1955, 1967, 1970, 1975, 1979) cover the period when development was rapidly increasing around Sturgeon and Island Lakes and indicate Secchi disk depth readings have changed less than 1 meter for Sturgeon and Island Lakes since 1938 (Table 2).

Based on our results of the sediment core data for the three seepage lakes in north central Minnesota, the predominant characteristics of the lake's watersheds have an overriding influence on their trophic status. The contribution of onsite systems to eutrophication in Island or Sturgeon Lakes appears to be low and this should be a consideration in determining the effectiveness of sewering these lakes to remove the nutrient input associated with onsite systems.

Acknowledgements

This project was funded by USEPA as part of an Environmental Impact Statement for determining wastewater treatment alternatives in the Moose Lake, Minnesota area. Mr. J. Novak was project monitor. We thank M. Brookfield for performing the diatom analysis and E. Dahlen, R. Kulb, and R. Wedepohl for field assistance. We appreciate the review and comments made by J. Lenssen. We thank Mrs. D. Jackson-Hope for typing the manuscript.

Table 2. Summary of data from Minnesota Department of Natural Resources fisheries lake surveys.

Date	House Count		Secchi Disc Measurement		Planktivorous Fish[a]	
	Sturgeon	Island	Sturgeon	Island	Sturgeon	Island
1982	--	--	2.4	1.4	--	--
1979-80	208	169	2.3	1.3	57	189
1975	170	--	2.4	2.0	18	--
1970	--	128	--	1.4	--	20
1967	120	110	2.9	1.7	47	57
1954-55	81	35	--	1.1	30	37
1938	--	--	2.4	--	--	--

[a] Planktivorous fish include yellow perch, bluegill, pumkinseed, and black crappie. Values represent number of fish caught per set and includes trapnets and gillnets.

[a]Range and means of sediment parameters from sediment cores.

	Island Lake	Sturgeon Lake	Little Island Lake
CaCO	0.7-3.3	0.7-1.9	0.8-1.8
(%)	1.7	1.3	1.2
Organic Matter	20.8-29.4	19.0-22.9	29.8-41.1
%	25.6	20.4	36.8
Chlorophyll	57.4-102.0	32.6-54.8	31.0-112.3
(SPDU/g. org. matt.)	79.4	40.7	83.3
Total Phosphorus	0.80-1.72	0.80-1.50	0.54-1.32
(mg/g dry wt.)	1.07	0.95	1.12
Organic Phosphorus	0.21-0.52	0.15-0.40	0.26-0.64
(mg/g dry wt.)	0.34	0.27	0.51
Inorganic Phosphorus	0.44-1.20	0.39-1.18	0.28-0.72
(mg/g dry wt.)	0.73	0.68	0.61
Apatite Phosphorus	0.08-0.24	0.22-0.37	0.04-0.14
(mg/g dry wt.)	0.15	0.27	0.09
Nonapatite Inorganic P.	0.29-1.05	0.15-0.92	0.24-0.63
(mg/g dry wt.)	0.58	0.41	0.52

[a]Note that chlorophyll breakdown products are presented herein on a gram of dry organic matter basis.

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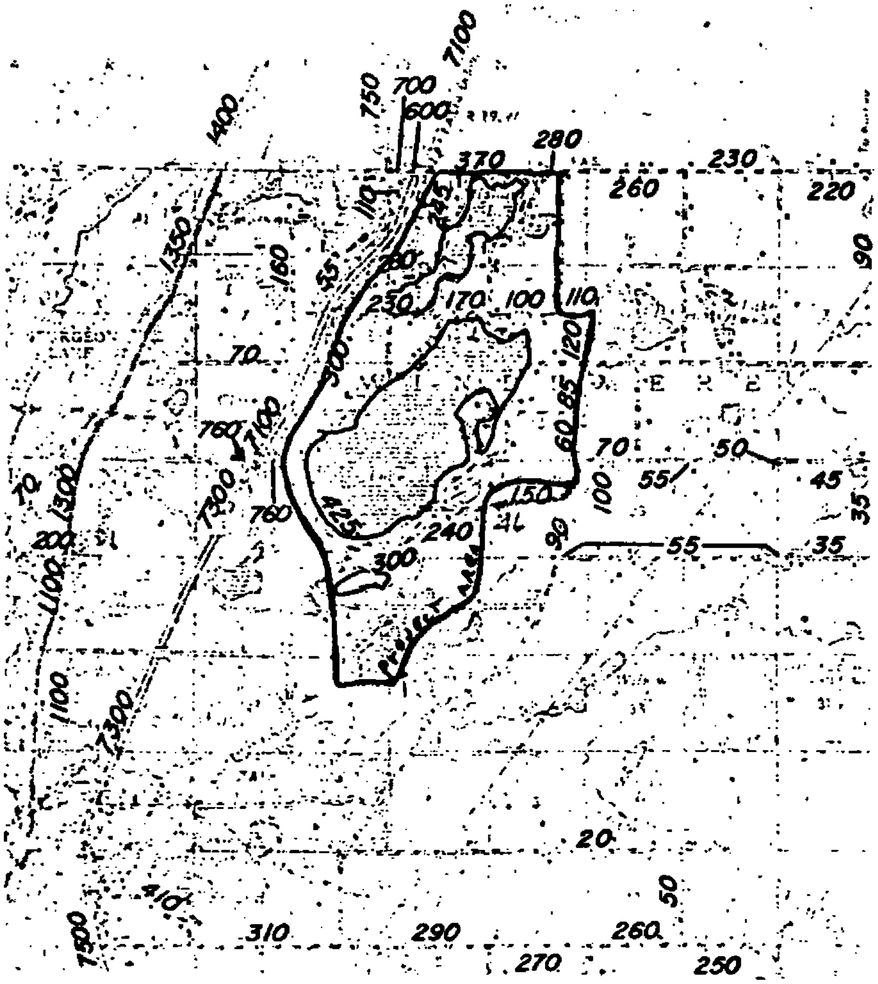

Figure M-1. 1979 average annual daily traffic in northwestern Pine County (MDOT). Traffic volume on the state highway is for 1978.

Figure M-1.

Figure N-1. Unit price for residental energy during the period from April 1980 to March 1981 (Minnesota Energy Agency 1981).

Location	Use	Natural Gas (per 1,000 cubic feet)	Electricity (per Kelo watt hour)	Fuel Oil (per gallon)	LP Gas (per gallon)
		Fuel Type			
Region 3	Space heating	$3.70	4.72¢	$1.22	71.1¢
	Non-space heating	4.42	5.46		
Region 7E	Space heating	3.33	4.70	1.17	74.7
	Non-space heating	3.85	5.53		
Minnesota	Space heating	3.51	3.64	1.16	69.8
	Non-space heating	4.10	5.21		

[a]The basis for heating values of the fuels are:

Natural gas: 1,000 BTU per cubic feet
Electricity: 3,412 BTU per KW hour
Distillate
Composite (fuel oil): 138,690 BTU per gallon
Propane: 91,500 BTU per gallon

United States
Environmental Protection
Agency

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Chicago, Illinois 60604

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Agency
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