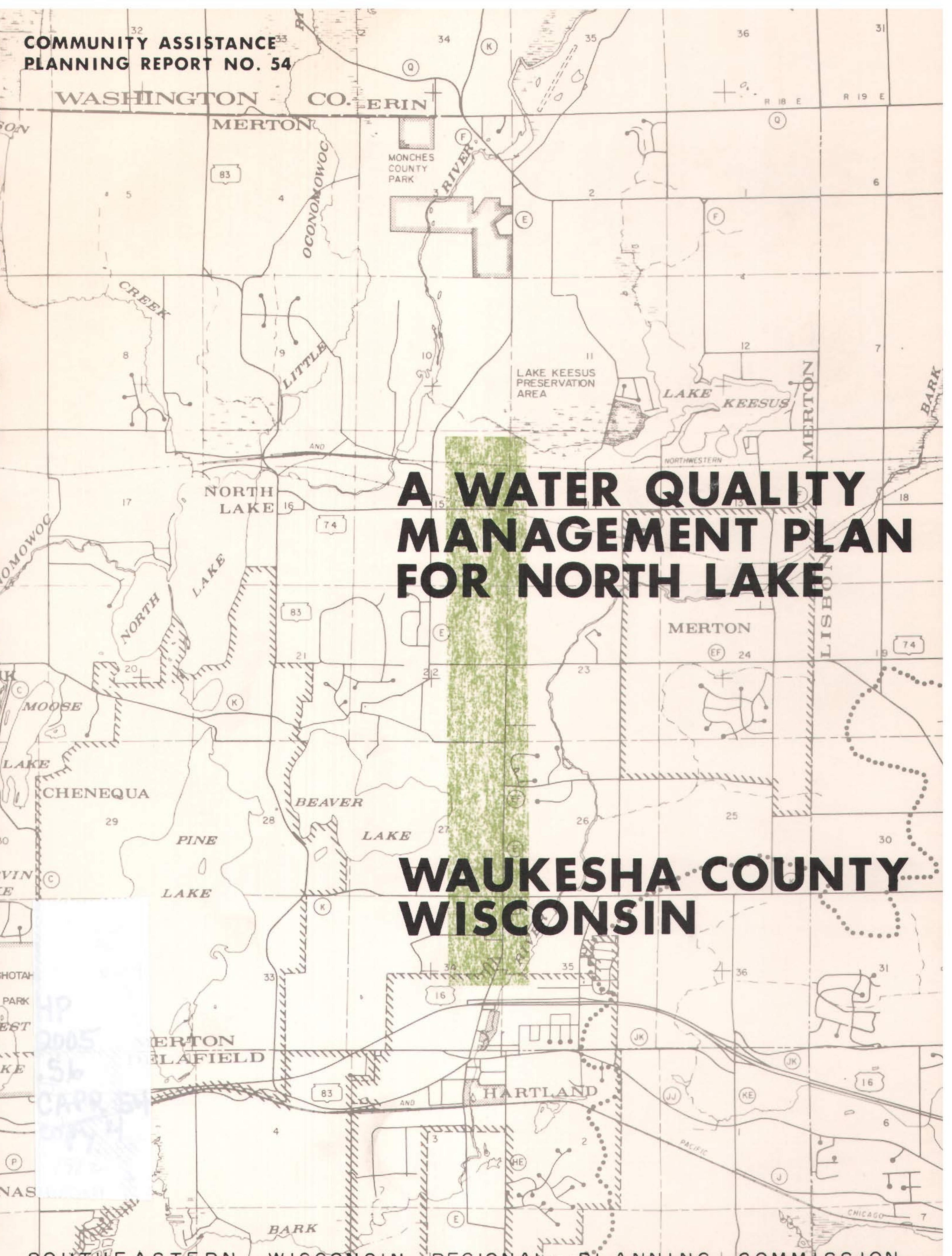
COMMUNITY ASSISTANCE PLANNING REPORT NO. 54

A WATER QUALITY MANAGEMENT PLAN FOR NORTH LAKE

WAUKESHA COUNTY WISCONSIN



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WAUKESHA COUNTY, WISCONSIN

Prepared by the
Southeastern Wisconsin Regional Planning Commission
P. O. Box 769
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In Cooperation with the
Wisconsin Department of Natural Resources
Madison, Wisconsin 53707

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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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June 14, 1982

TO: All Units and Agencies of Government and Citizen Groups
Involved in Water Quality Management for North Lake

In 1976 the Southeastern Wisconsin Regional Planning Commission entered into a cooperative agreement with the Wisconsin Department of Natural Resources to study the water quality conditions of North Lake, identify existing and potential problems related thereto, and propose measures which could be applied to resolve those problems and to protect and enhance the water quality of the lake. The findings and recommendations of that study are presented in this report.

The report describes the physical properties of North Lake, the quality of its waters, and the conditions affecting that quality, including existing land use and the present utilization of the lake. All sources of pollution of the lake are identified and, to the extent possible, quantified; and alternative, as well as recommended, means for the abatement of these sources of pollution and for the protection and enhancement of the water quality of the lake are described.

Members of the Commission staff met on August 20, 1979, with concerned citizens of the Village of Chenequa to discuss the preliminary findings and recommendations of this report. Several informal meetings were also held with interested citizens of the Town of Merton to discuss the study. The findings and recommendations of this report reflect the pertinent comments and suggestions made at such meetings, and addresses written remarks submitted during review of preliminary drafts.

The water quality management plan presented herein constitutes a refinement of the areawide water quality management plan adopted by the Regional Planning Commission in July 1979. Accordingly, upon adoption by the local units and agencies of government concerned with water quality management for North Lake and subsequent adoption by the Regional Planning Commission, the plan presented in this report will become an element of the adopted areawide water quality management plan.

The plan presented in this report is believed to provide a sound guide to the making of development decisions concerning the wise management of North Lake as an aesthetic and recreational asset of immeasurable value. Accordingly, careful consideration and adoption of the plan presented herein by all of the concerned water quality management agencies is respectfully urged. In its continuing role in the coordination of water quality management planning and plan implementation within southeastern Wisconsin, the Regional Planning Commission stands ready to assist the various units and agencies of government concerned in carrying out the recommendations contained in this report.

Respectfully submitted,

Kurt W. Bauer
Executive Director

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Chapter I

INTRODUCTION

Thirteen major inland lakes in southeastern Wisconsin were studied under a special program conducted by the Southeastern Wisconsin Regional Planning Commission in cooperation with the Wisconsin Department of Natural Resources, local lake protection and rehabilitation districts, and other lake organizations. Eight of the 13 lakes--Eagle Lake, Friess Lake, Lac La Belle, North Lake, Oconomowoc Lake, Pewaukee Lake, Pike Lake, and Wandawega Lake--were studied by the Regional Planning Commission in cooperation with the Wisconsin Department of Natural Resources, Bureau of Research; and four of the lakes--Ashippun Lake, George Lake, Okauchee Lake, and Paddock Lake--were studied by the Regional Planning Commission in cooperation with the Wisconsin Department of Natural Resources, Office of Inland Lake Renewal and the local lake protection and rehabilitation districts concerned. One of the 13 lakes--Geneva Lake--was studied by the Regional Planning Commission in cooperation with the Geneva Lake Watershed Environmental Agency. The objectives of these studies were to acquire definitive information concerning lake water quality and related land use and land management practices in the lake drainage area; to identify the factors affecting lake water quality, particularly the amount, kind, and temporal distribution of pollutants contributed by the various sources; and to develop recommendations for the abatement of pollution in order to maintain or improve water quality conditions.

On April 23, 1976, the Southeastern Wisconsin Regional Planning Commission entered into a cooperative agreement with the Wisconsin Department of Natural Resources to study North Lake. The cooperative study included the design and conduct of a water quality sampling program to determine existing lake water quality conditions, and inventories and analyses of pertinent tributary watershed characteristics affecting water quality conditions, including land use and management practices, existing water uses, and sources of pollution. The detailed lake water quality sampling program was conducted from May 1976 through April 1977. However, some inventory data collected as recently as 1980 are incorporated into this report. This report summarizes the results of the sampling program; the physical, chemical, and biological characteristics of the lake and the direct tributary drainage area; and provides an evaluation and interpretation of the data collected and collated. From these analyses, feasible alternative actions for the maintenance and enhancement of lake water quality are proposed and evaluated, and water quality management measures are recommended.

North Lake is a 439 acre[1] lake located within U. S. Public Land Survey Township 8 North, Range 18 East, Town of Merton, in Waukesha County. The lake is fed and drained by the Oconomowoc River. Properly managed, the 1,686-acre drainage area directly tributary to this lake can contribute to the maintenance of the lake as an important asset to the residents of the County and the Region of which the County is an integral part. More importantly, however, the quality of the Oconomowoc River, which provides the singular largest inflow to the lake, must be protected if North Lake is

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[1]*In SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide, (1968), the area of North Lake was reported to be 437 acres, as measured from 1956 aerial photographs. Based on 1975 aerial photographs, the area of North Lake was estimated to be 439 acres. The difference of less than one-half of one percent in the two estimates is well within the limitations of the accuracy of the measurement techniques involved.*

to retain its recreational value. Such protection will require, as a first step, the development of a comprehensive watershed plan for the tributary portions of the Oconomowoc River basin. The primary management objectives for North Lake include: 1) providing water quality suitable for recreational use and the maintenance of fish and aquatic life, and 2) reducing the severity of the occasional nuisance problem of excessive algal growth which constrain or preclude intended water uses.

In addition, occasional flooding of homes adjacent to North Lake is perceived by local residents to be a major local lake management problem. The resolution of flooding and flood damage problems in a hydrologic system like that of the Oconomowoc River requires a comprehensive study of the entire watershed and the development of basinwide alternative plans designed to abate the flooding and flood damage. Such a study must include careful assessment of the upstream and downstream costs and benefits attendant to the various alternatives for the abatement of the quantified flood damages in the North Lake area, and of the social and environmental consequences of alternative flood control measures; as well as agreement on a recommended plan composed of the optimal and cost-effective combination of control measures; and the identification of appropriate agencies and units of government for implementation of the recommended measures. Such a study effort transcends the technical and financial limitations of the water quality study reported in this volume. Although a flood control study, if properly conducted, would consider water quality impacts, this report cannot prejudge the results of a sound flood control planning effort. Therefore, this report sets forth alternative and recommended water quality control measures in the context of the existing watershed hydrology and hydraulics. The measures recommended herein should, however, be essentially compatible with most flood control measures that may be required and warranted.

The local units of government concerned were asked to review a preliminary draft of this report, and comments based upon that review are incorporated into this final draft of the report. Accordingly, the lake water quality management plan herein presented should constitute a practical guide for the management of the water quality of North Lake and for the management of the land surfaces which drain directly to this lake body.

Chapter II

PHYSICAL DESCRIPTION

LAKE BASIN AND SHORE CHARACTERISTICS

North Lake is one of six major lakes in a chain which is fed and drained by the Oconomowoc River. North Lake is the uppermost lake in the chain, save one--Friess Lake. The lake lies within glacial outwash terraces associated with terminal moraines. Basic hydrographic and morphometric data for North Lake are presented in Table 1. About 14 percent of North Lake has a water depth less than 10 feet, 35 percent has a water depth between 10 and 40 feet, and 51 percent of the lake has a water depth of more than 40 feet. The mean depth of North Lake is 37 feet and the maximum depth is 73 feet. North Lake is 1.2 miles long and about 0.7 mile wide at its widest point. The lake is comprised of two basins separated by a 1,000 foot long sand bar which has a 30 foot wide channel at its north end. The major axis of each lake basin lies in a north-south direction. North Lake has a volume of approximately 16,300 acre-feet and a surface area of about 439 acres. The lake has a shoreline length of 5.1 miles, with a shoreline development factor of 1.7, indicating that the Lake's shoreline is about 1.7 times as long as that of a circular lake of the same area. The morphometry of the North Lake basin is illustrated on Map 1. Figure 1 presents an aerial photograph of the lake and surrounding shoreline.

WATERSHED CHARACTERISTICS

The drainage area directly tributary to North Lake--that is, that area which drains directly to the lake rather than draining to the lake through the Oconomowoc River--is 1,686 acres, or 2.63 square miles, in extent and is shown on Map 2. The total drainage area to the lake, including the area drained by the Oconomowoc River is 41,117 acres, or 64.25 square miles. North Lake has a low watershed-to-lake area ratio of 3.8 if only the direct drainage area is considered. A much higher watershed-to-lake area ratio--93.7--is computed when the total drainage area is considered.

The lake has three inlets, two located on the north shore of the lake and the third on the south shore. The Oconomowoc River is the major lake inlet, with Mason Creek and the channel from Cornell Lake being the other two inlets. The lake outlet, located on the western shore, is the Oconomowoc River, which subsequently flows through several additional lakes and eventually joins the Rock River about 23 miles downstream at a point in Jefferson County. The Little Oconomowoc River flows into the Oconomowoc River about 100 feet upstream of North Lake. The Oconomowoc River, the Little Oconomowoc River, and Mason Creek are perennial streams which support resident populations of fish.

Lakeshore bottom sediment types and location are shown on Map 3. Sand and gravel are the dominant shore materials covering about 80 percent of the bottom along the shoreline. The remainder of the bottom along the shoreline consists of silt, primarily in the vicinity of the inlets to the lake. The remaining lake bottom is covered by soft, flocculent sediments, including muck, marl, detritus, clay, and silt. The shore areas are characterized by a steep bank on the southeast shore and low wetland areas along the north and northwest shores.

One of the important locally-perceived, water resource-related problems of North Lake is the flooding which occurs in residential areas along the north and west shores.

Table 1

HYDROGRAPHY AND MORPHOMETRY OF NORTH LAKE: 1975

Parameter	Measurement
Size	
Area of Lake	439 acres
Area of Total Drainage Area	41,117 acres
Area of Direct Tributary Drainage Area	1,686 acres
Lake Volume	16,300 acre-feet
Residence Time[a]	9.5 months
Shape	
Length of Lake	1.2 miles
Length of Shoreline	5.1 miles
Width of Lake	0.7 mile
Shoreline Development Factor[b]	1.7
Depth	
Area of Lake Less Than 10 Feet	14 percent
Area of Lake 10 to 40 Feet	35 percent
Area of Lake More Than 40 Feet	51 percent
Mean Depth	37 feet
Maximum Depth	73 feet

[a] *The "residence time" is estimated as the time period required for the full volume of the lake to be replaced by inflowing waters, during a year of normal precipitation.*

[b] *The shoreline development factor is the ratio of the shoreline length to that of a circular lake of the same area.*

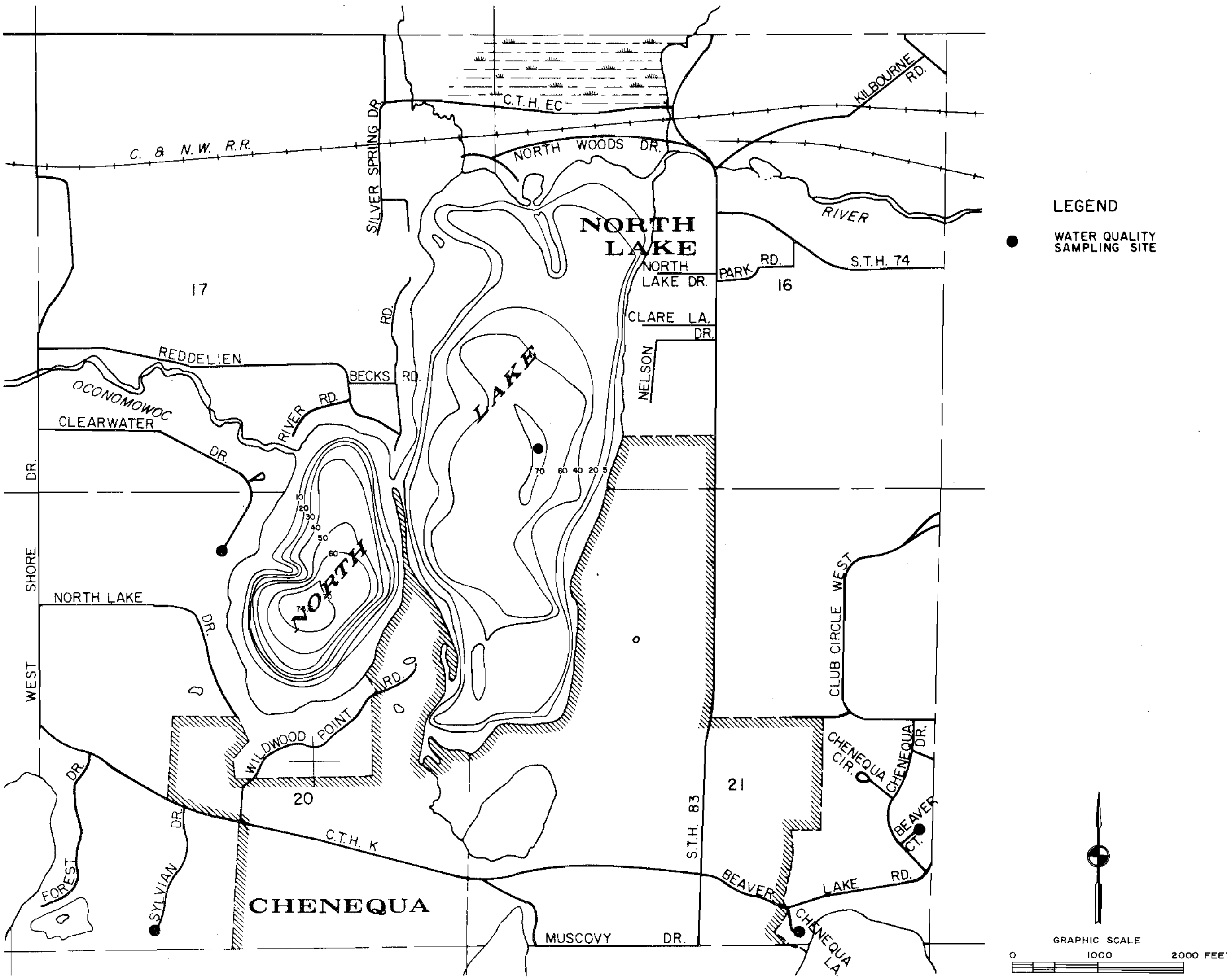
Source: Wisconsin Department of Natural Resources and SEWRPC.

Locally discussed alternatives to resolve this problem have included: 1) the reconstruction or enlargement of the outlet control structure--which is in a state of disrepair--at "Funk's Millpond" to provide flood storage capacity in the pond which is located on the Oconomowoc River about 1.1 miles upstream from North Lake; 2) the construction of an outlet control structure for North Lake and attendant channelization to increase the capacity of the Oconomowoc River channel and provide for higher rates of discharge from the lake; 3) channel clearing in the Oconomowoc River downstream of the lake; 4) construction of a low concrete floodwall to protect those properties subject to flooding; and 5) floodproofing existing structures subject to flooding.[1] Proper consideration of such control measures must address the

[1] *The U. S. Army Corps of Engineers, Rock Island District, recently completed a report entitled "Reconnaissance Report for Section 205 Flood Control Project North Lake, Waukesha County, Wisconsin, July 1982," which evaluated alternative flood control measurs for North Lake. A summary of the findings of that report are presented in Appendix A.*

Map 1

HYDROGRAPHIC AND MORPHOMETRIC MAP OF, AND WATER QUALITY SAMPLING SITE FOR, NORTH LAKE

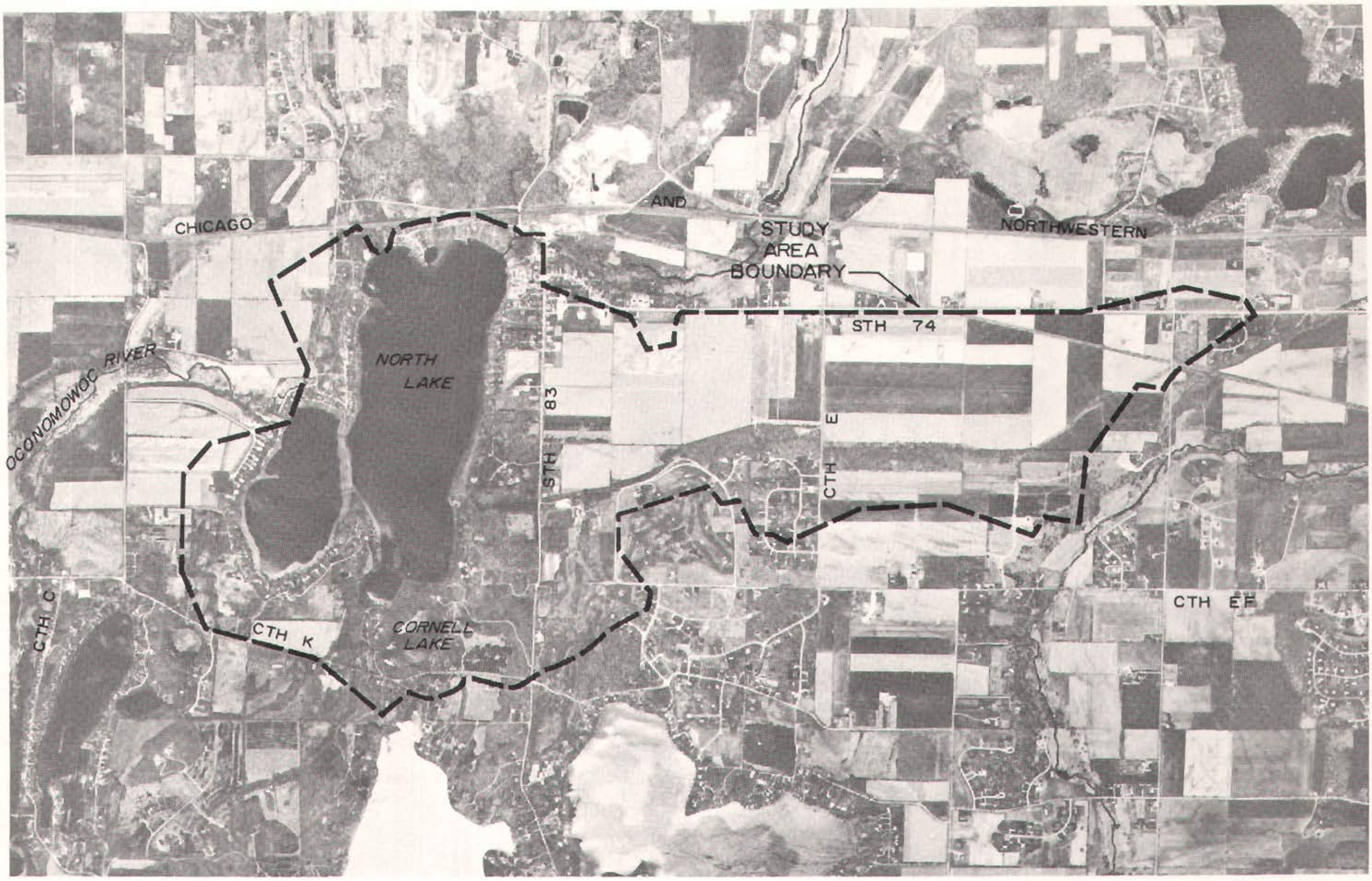


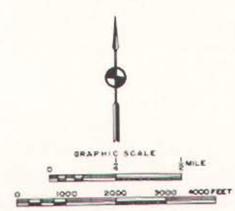
Source: SEWRPC.

upstream and downstream effects on flood flows and stages, the possible effects on agricultural drainage, the water quality impacts, the effects on fish and wildlife habitat, wetland impacts, and the impacts upon land use, as well as the costs and benefits entailed in the flood control measures. These two alternatives, as well as combinations of them, are worthy of consideration along with other alternatives; but cannot be fairly and fully evaluated in the framework of this water quality management plan. Without a thorough analysis on a watershed basis involving all affected agencies and units of government, using state-of-the-art analytic tools for hydrology and hydraulics and using engineering estimates of the costs and benefits, there can be no assurance that the most cost-effective and environmentally sound alternative would be chosen. Without such assurances, any project would likely be hampered during implementation, during the regulatory permit process, and in obtaining state or federal financial assistance. With respect to the alternative for construction of an

Figure 1

AERIAL PHOTOGRAPH OF THE NORTH LAKE STUDY AREA: 1980





Source: SEWRPC.

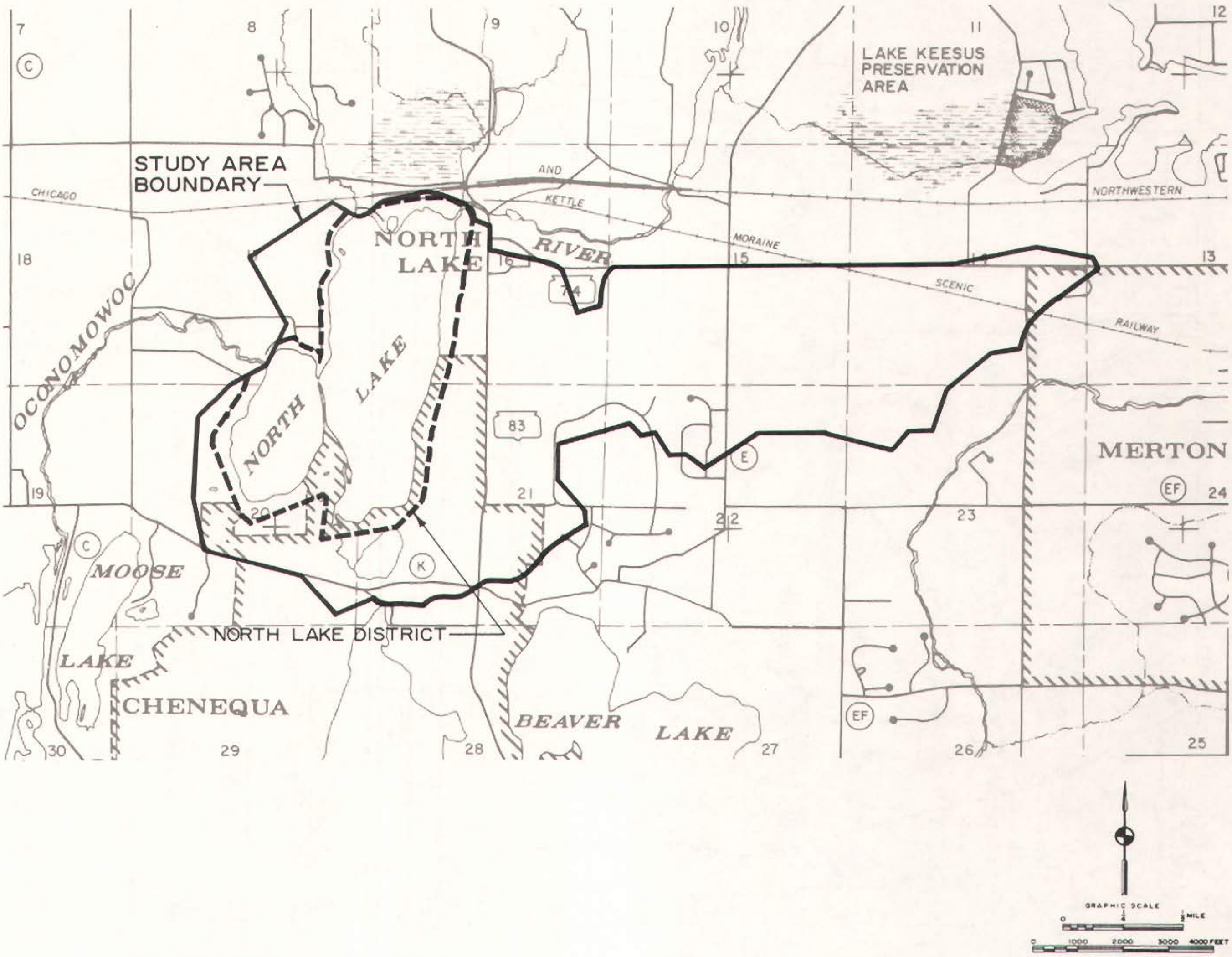
outlet control structure for North Lake, and associated channel dredging, it should be noted that an April 1975 preliminary analysis of this concept by the Wisconsin DNR staff indicated that severe adverse environmental effects may be expected to attend such a project. Accordingly, the DNR, at that time, indicated that this alternative would not be viewed favorably in the permit issuance process. The Commission staff believes the alternative should be considered, but within the framework of a comprehensive watershed study.

Climate and Hydrology

Long-term average monthly air temperature and precipitation values for the Oconomowoc, Wisconsin area are set forth in Table 2. These averages were taken from official National Oceanic and Atmospheric Administration (NOAA) records for the weather recording station at Oconomowoc. The records of this station may be considered typical of the lake area in northwestern Waukesha County. Table 2 also sets forth

Map 2

DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE AND THE NORTH LAKE DISTRICT BOUNDARY



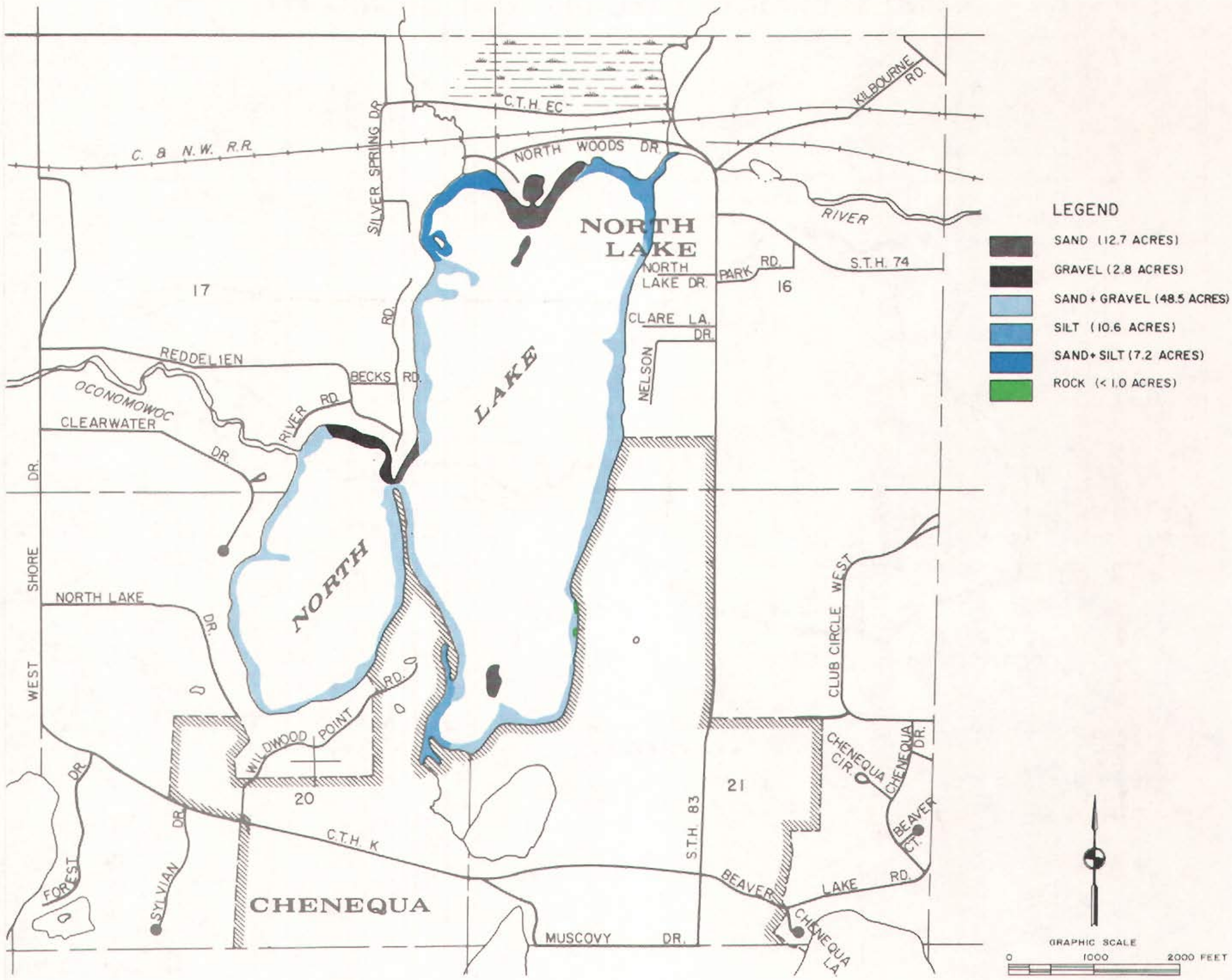
Source: SEWRPC.

storm water runoff values derived from U. S. Geological Survey (USGS) flow records for the Rock River at Afton, in Jefferson County, Wisconsin--downstream from the confluence of the Oconomowoc and Rock Rivers. The mean annual temperature of 46.6°F at Oconomowoc is quite similar to other recording locations in southeastern Wisconsin. The mean annual precipitation at Oconomowoc is 29.60 inches. More than half the normal yearly precipitation falls during the growing season, from May to September. Runoff rates are generally low during this period, since evapotranspiration rates are high, vegetative cover is good, and soils are not frozen. Normally, less than 15 percent of the summer precipitation is expressed as surface runoff, but intense summer storms occasionally produce higher runoff fractions. Approximately 25 percent of the annual precipitation occurs during the winter or early spring when the ground is frozen, resulting in high surface runoff during those seasons.

The 12-month period over which the North Lake water quality sampling study was carried out--May 1976 through April 1977--was a period of average temperatures and extreme drought in southeastern Wisconsin, as indicated in Table 2. Temperatures were

Map 3

LAKESHORE BOTTOM SEDIMENTS OF NORTH LAKE



Source: SEWRPC.

generally below normal during the early winter of 1976, above normal in the spring of 1977, and about normal for the remainder of the study period. Precipitation at Oconomowoc during the sampling period was about 10.1 inches, or 34 percent below normal, with the greatest decrease from the average occurring in June through September 1976. Ten of the twelve months of the study period--all months except May 1976 and March 1977--experienced below normal amounts of precipitation. Groundwater levels were substantially reduced by this drought, and these reduced groundwater levels were, in turn, reflected in the below normal flow levels in the Rock River. At Afton, Wisconsin the flow of the Rock River during the study period was 56 percent below normal. Therefore, during the study period, the hydrologic regime of the lake was significantly affected by the drought period.

Table 2

LONG-TERM AND 1976-1977 STUDY YEAR CLIMATOLOGICAL AND RUNOFF DATA FOR THE NORTH LAKE AREA

Climatological Data	Long Term Average Monthly Values												Annual
	May	June	July	August	September	October	November	December	January	February	March	April	
Mean Monthly Air Temperature-°F (Oconomowoc) (1954-1977)...............	58.1	67.3	72.1	70.3	61.8	51.2	36.8	23.5	16.9	22.0	32.2	46.9	46.6
Mean Monthly Precipitation-Inches (Oconomowoc) (1954-1977)..............	3.03	3.77	3.89	3.67	3.54	2.33	1.78	1.34	0.95	0.81	1.7	2.79	29.6
Mean Runoff-Inches (Rock River at Afton) (1914-1978)......	0.85	0.56	0.45	0.34	0.37	0.41	0.45	0.46	0.42	0.46	1.14	1.36	7.27

Climatological Data	Study Period Average Monthly Values												Annual
	1976								1977				
	May	June	July	August	September	October	November	December	January	February	March	April	
Mean Monthly Air Temperature-°F (Oconomowoc)...........................	53.9	68.0	72.8	68.6	58.6	44.0	28.1	12.7	2.4	19.3	39.5	51.7	43.3
Departure from Normal Mean Monthly Air Temperature-°F (Oconomowoc)...........................	-4.2	0.7	0.7	-1.7	-3.2	-7.0	-8.7	-10.8	-14.5	-2.7	7.3	4.6	-3.3
Precipitation-Inches (Oconomowoc).......	3.32	2.23	1.80	1.86	0.44	1.91	0.39	0.29	0.63	0.49	3.48	2.61	19.45
Departure from Normal Precipitation-Inches (Oconomowoc)....................	0.29	-1.54	-2.09	-1.81	-3.1	-0.42	-1.39	-1.05	-0.32	-0.32	1.78	-0.18	-10.15
Runoff-Inches (Rock River at Afton).....	1.31	0.37	0.18	0.18	0.15	0.16	0.19	0.17	0.17	0.15	0.42	0.65	4.1
Departure from Normal Runoff-Inches (Rock River at Afton)..................	0.46	-0.19	-0.27	-0.16	-0.22	-0.25	-0.26	-0.29	-0.25	0.31	-0.72	-0.71	-3.17

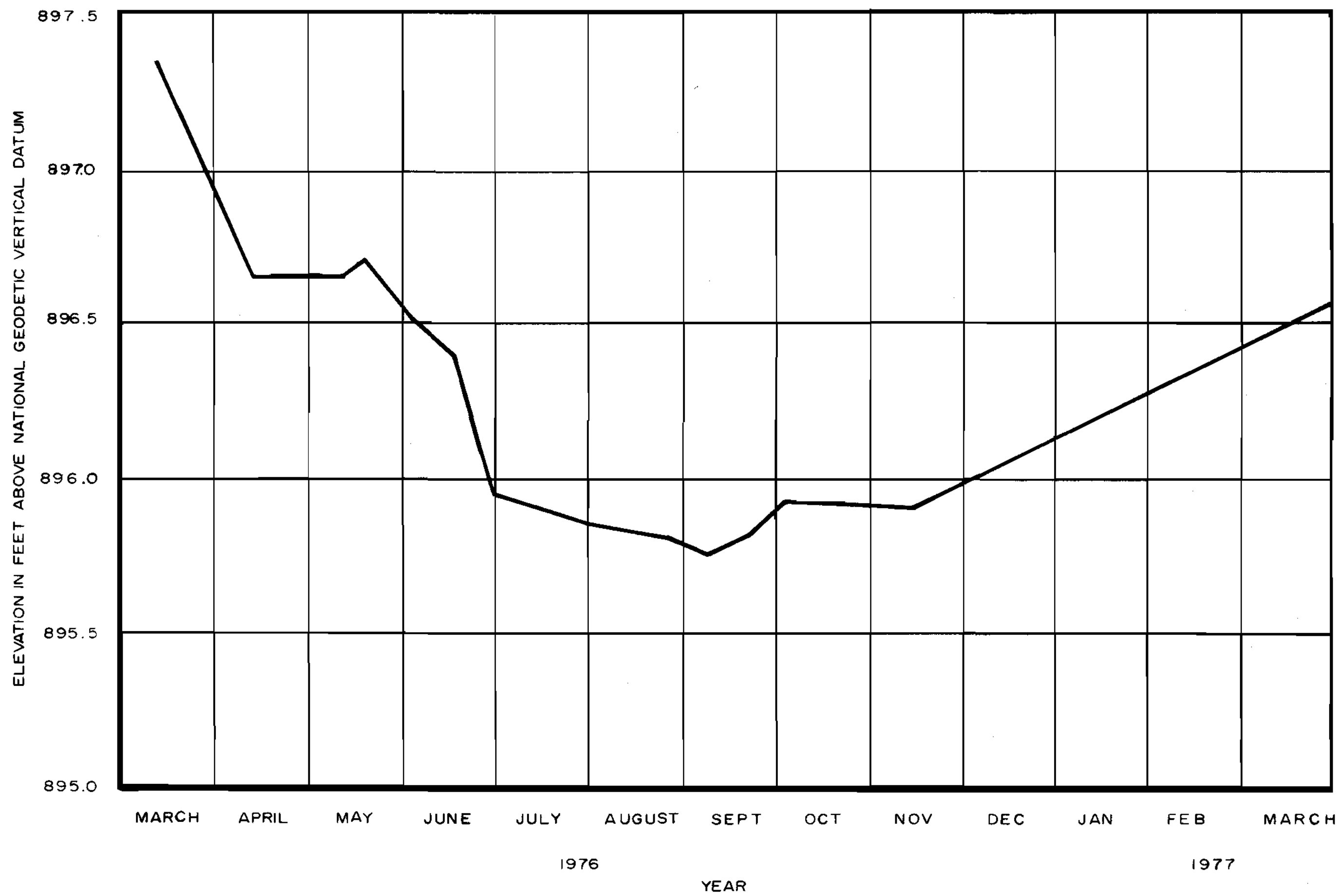
Source: National Oceanic and Atmospheric Administration, U. S. Geological Survey, and SEWRPC.

The water level of North Lake is primarily determined by the rate of inflow and outflow of the Oconomowoc River. There is no water level control structure at the outlet. As shown in Figure 2, the water level of North Lake fell in 1976 from a high elevation of 897.45 feet NGVD, on March 11, 1976, to a low elevation of 895.86 feet NGVD, on September 9, 1976, at the height of the severe drought. Increased rates of precipitation resulted in a raising of the lake level to an elevation of 896.71 feet NGVD in the spring of 1977.

A water budget for North Lake was computed from estimated precipitation, inflow from the Oconomowoc River, Mason Creek, and the Cornell Lake channel inlets, direct tributary surface runoff, groundwater inflow and outflow, and outflow through the Oconomowoc River, evaporation, transpiration, and lake level data, and is set forth in Figure 3. For North Lake during the year of the study, it is estimated that approximately 23,911 acre-feet of water entered the lake. Of this total, about 16,760 acre-feet, or 70 percent, was contributed by inflow from the Oconomowoc River; about 1,770 acre feet, or 7 percent, was contributed by inflow from Mason Creek; about 1,270 acre-feet, or 5 percent, was contributed by inflow from the Cornell Lake channel; direct precipitation contributed about 1,170 acre-feet, or 5 percent; and about 770 acre-feet, or 3 percent was contributed by surface runoff from the direct tributary drainage area. Groundwater was estimated to have a net input to the lake of 2,171 acre-feet, or 10 percent. There was also a reduction in the volume of water stored in the lake of about 329 acre-feet, as a consequence of below normal precipitation during the study. Of the total water output from North Lake of 24,240 acre-feet, about 23,040 acre-feet, or 95 percent was discharged via the Oconomowoc River and 1,200 acre-feet, or five percent, evaporated from the surface of the lake.

Figure 2

LAKE LEVEL FLUCTUATIONS ON NORTH LAKE: MARCH 1976-MARCH 1977



Source: Wisconsin Department of Natural Resources and SEWRPC.

Six pairs of groundwater sampling wells, located as shown on Map 4, were used to measure the direction and flow of groundwater around North Lake. Inflow of groundwater occurred along the northern portion of the west shore. Most of the eastern shoreline of North Lake served as a transition zone, with groundwater sometimes flowing into, and sometimes out of, the lake. The remaining southern and southwestern portions of the lake serve as groundwater recharge areas. The quality of the groundwater was also measured at some of these wells. It should be noted that low groundwater levels during the study period may have had an undetermined effect on measured flows at the test wells.

Map 4 also shows the location of known storm sewer outlets and drainage ditches which discharge into the Lake. There were five known discrete locations of surface drainage discharge to North Lake. The water discharged from these sites is included in the direct tributary surface water volumes presented above.

The hydraulic residence time is important in determining the expected response time of the lake to increased or reduced nutrient and other pollutant loadings. The hydraulic residence time for North Lake during the study period of May 1976 through

April 1977, which was, as already noted, a year of significantly below average precipitation, was approximately eight months. During a year of average climatologic conditions, the hydraulic residence time would be about 9.5 months, according to Commission estimates.

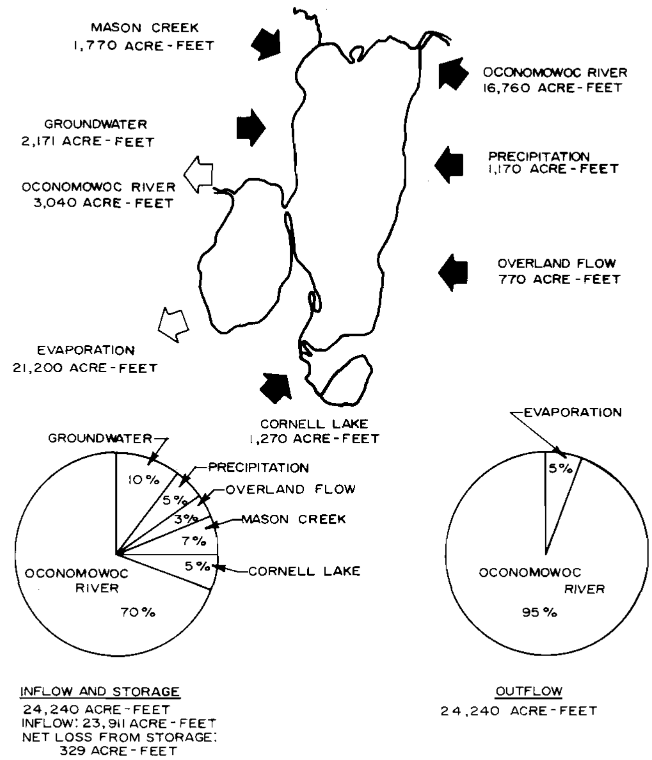
Soil Type and Conditions

Composition, slope, use, and management are among the more important factors determining the effect of soils on lake water quality. Major specific soil types were inventoried in the drainage area directly tributary to North Lake and analyzed in terms of the associated hydrologic characteristics. An assessment was made of soil erodibility and soil suitability for use of onsite septic tank sewage disposal systems. These assessments were then used to identify areas of incompatible land use and management.

Soil composition, slope, and vegetative cover are important factors affecting the rate, amount, and quality of storm water runoff. The shape and stability of aggregates of soil particles--expressed as soil structure--influence the permeability, infiltration rate, and erodibility of soils. Slope is important in determining storm water runoff rates, and hence, susceptibility to erosion.

Figure 3

HYDROLOGIC BUDGET FOR NORTH LAKE: MAY 1976-APRIL 1977



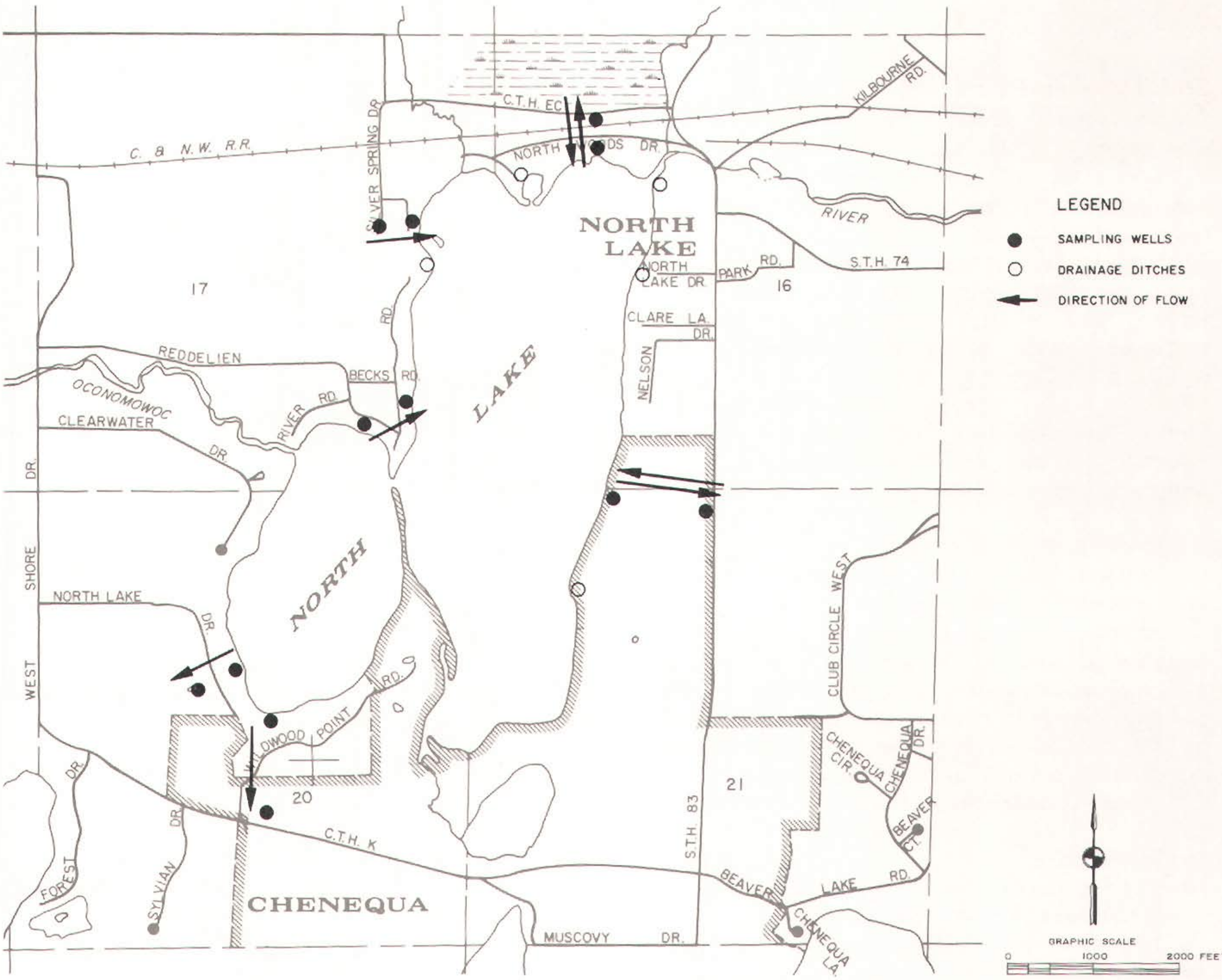
Source: Wisconsin Department of Natural Resources and SEWRPC.

Soils within the drainage area directly tributary to North Lake may be categorized into four main hydrologic groups and "made land" as indicated in Table 3. The relative proportion of the total direct drainage area covered by each of the hydrologic soil groups is: Group A, well drained soils, 9 percent; Group B, moderately drained soils, 87 percent; Group C, poorly drained soils, 1 percent; Group D, very poorly drained soils, 2 percent; and "made land," 1 percent. The areal extent of these soils and their locations within the watershed are shown on Map 5. The major specific soil types present within the direct tributary drainage area are: Fox silt loam, Fox loam, Casco loam, Casco-Rodman complex, Hochheim loam, and St. Charles silt loam.

Soils within the direct drainage area were examined for their suitability for septic tank system use. The suitability of soils in the direct drainage area for septic tank systems on residential lots one acre or less in area is indicated on Map 6 according to three major groupings: slightly limited--70 percent, severely limited--26 percent, and very severely limited--4 percent. In the direct drainage area of North Lake as of 1975, 92 of the estimated 257 septic systems, or 36 percent, were located on soils having severe or very severe limitations for the use of such systems.

Map 4

LOCATION OF GROUNDWATER SAMPLING WELLS AND SURFACE DRAINAGE DISCHARGES, AND THE DIRECTION OF GROUNDWATER FLOW AROUND NORTH LAKE: 1976-1977



Source: Wisconsin Department of Natural Resources and SEWRPC.

Another consideration of interest for watershed management is the suitability of the soils for land application of residual wastewater treatment sludges. The Commission inventory of sewage sludge management practices within the Region indicated that, in 1976, sludge was not applied in the drainage area directly tributary to the lake. About 58.0 percent of the total area of the drainage area directly tributary to North Lake is covered by soils rated as having only slight limitations for wastewater sludge application, as shown on Map 7. About 23.0 percent of the directly tributary drainage area could not be rated in terms of suitability for sewage sludge application due to the disturbed nature of the soils, or were not rated for sludge application because of generally urbanized land uses which would be incompatible with wastewater sludge application. The remaining 19 percent of the area is covered by soils which have moderate or severe limitations for sludge application; and any such application in these areas could potentially be detrimental to lake water quality.

Table 3

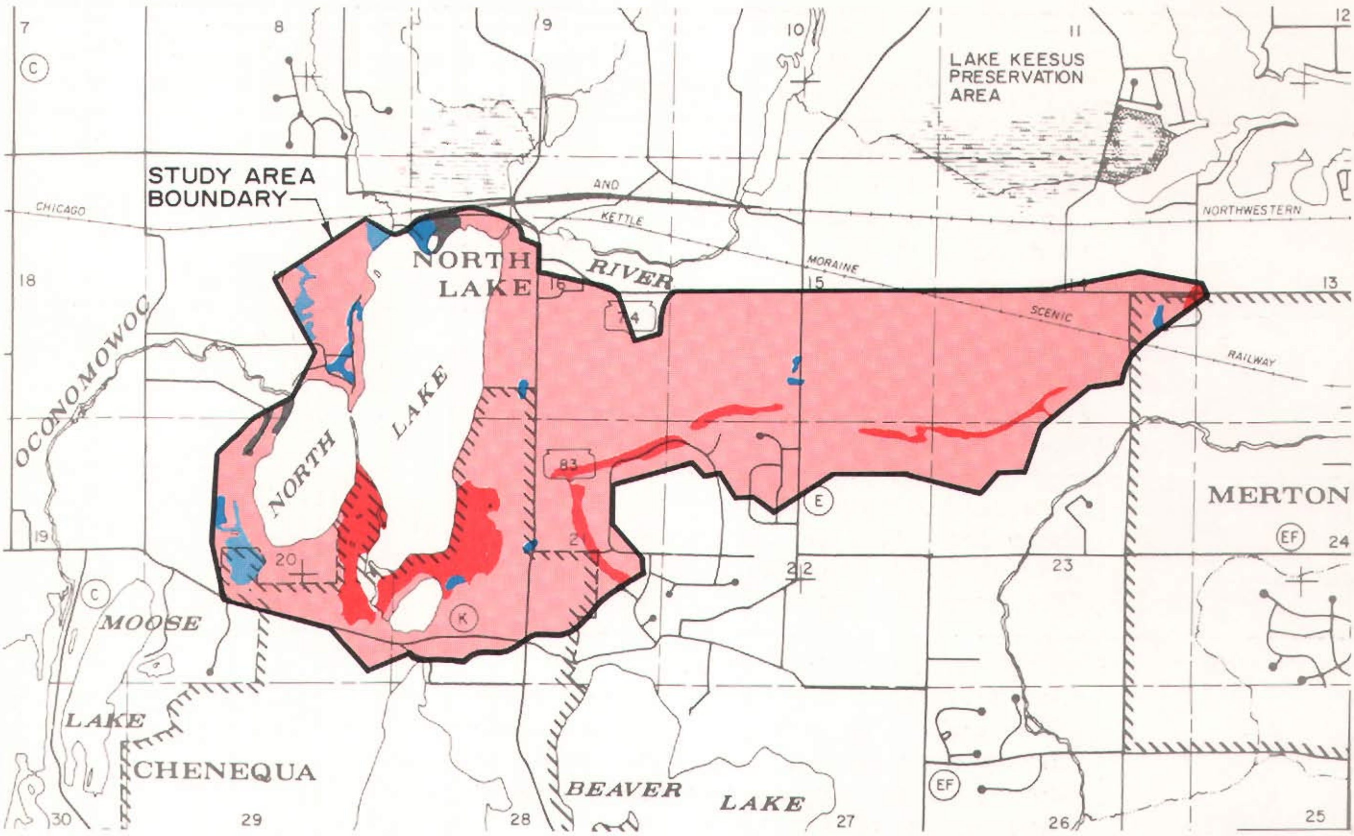
GENERAL HYDROLOGIC SOIL TYPES IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE

Group	Soil Characteristics	Extent (acres)	Percent of Total
A	High infiltration rates Well drained and excessively drained sandy or gravelly soils High rate of water transmission and low runoff potential	157	9
B	Moderate infiltration rates Moderately well drained Moderately coarse textures Moderate rate of water transmission	1,465	87
C	Slow infiltration rates Moderately fine or fine-textured or layers that impede downward movement of water Slow rate of water transmission	20	1
D	Very low infiltration rates Clay soils with high shrink-swell potential; soils with a high permanent water table; soils with a clay layer at or near the surface; shallow soils over nearly impervious substrate Very slow rate of water transmission	30	2
Made Land	Open pit mining areas, man-made fill areas, dumps and landfills, containing widely varying soils and other materials	14	1
Total		1,686	100.00

Source: SEWRPC.

Map 5

HYDROLOGIC SOIL GROUPS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE



LEGEND

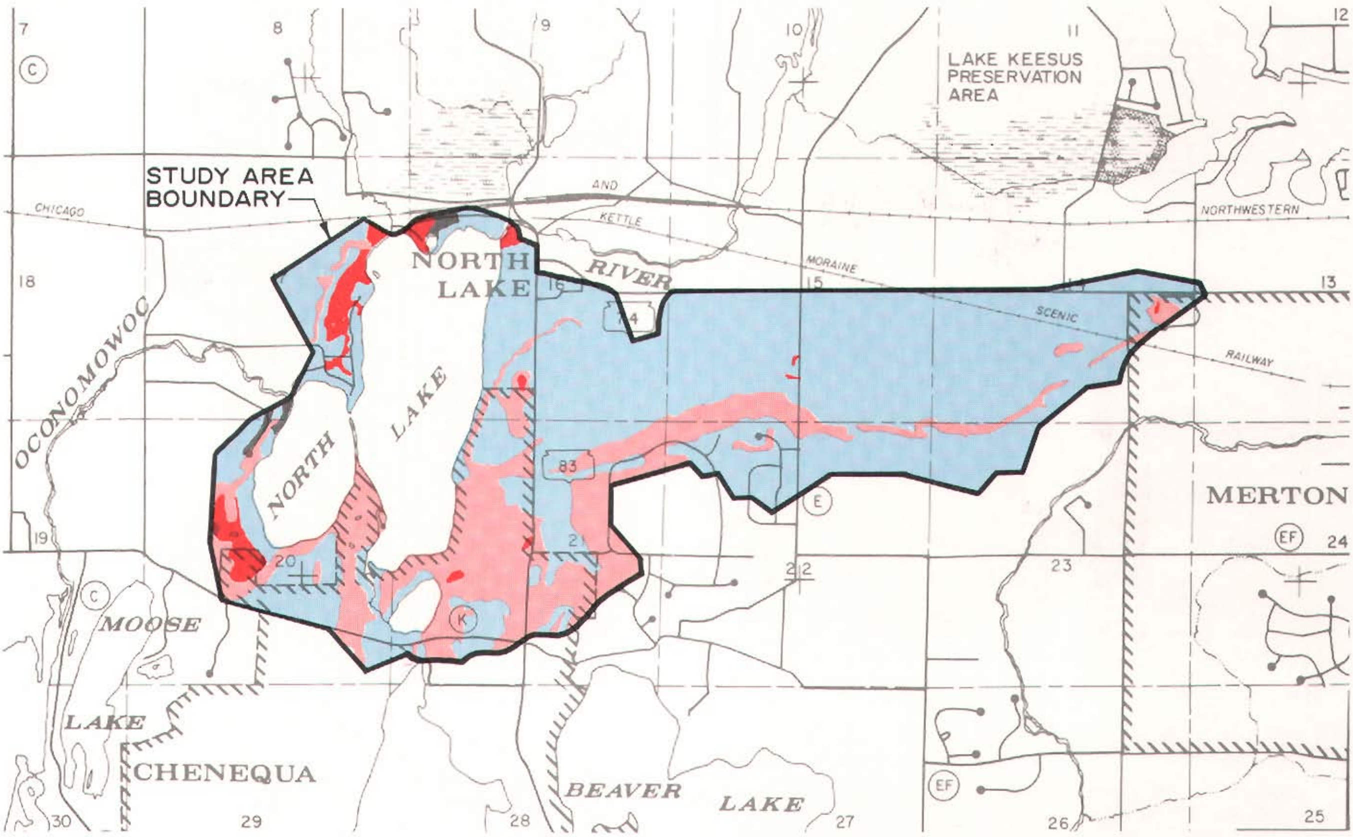
- GROUP A HIGH INFILTRATION RATES
- GROUP B MODERATE INFILTRATION RATES
- GROUP C LOW INFILTRATION RATES
- GROUP D VERY LOW INFILTRATION RATES
- MADE LAND: OPEN PIT MINING AREAS, DUMPS AND LANDFILLS, CONTAINING WIDELY VARYING SOILS AND OTHER MATERIALS

GRAPHIC SCALE
0 ½ 1 MILE
0 1000 2000 3000 4000 FEET

Source: SEWRPC.

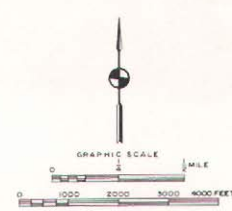
Map 6

SUITABILITY OF SOILS FOR CONVENTIONAL PRIVATELY OWNED ONSITE SEWAGE DISPOSAL SYSTEMS ON LOTS ONE ACRE OR LESS IN SIZE IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE



LEGEND

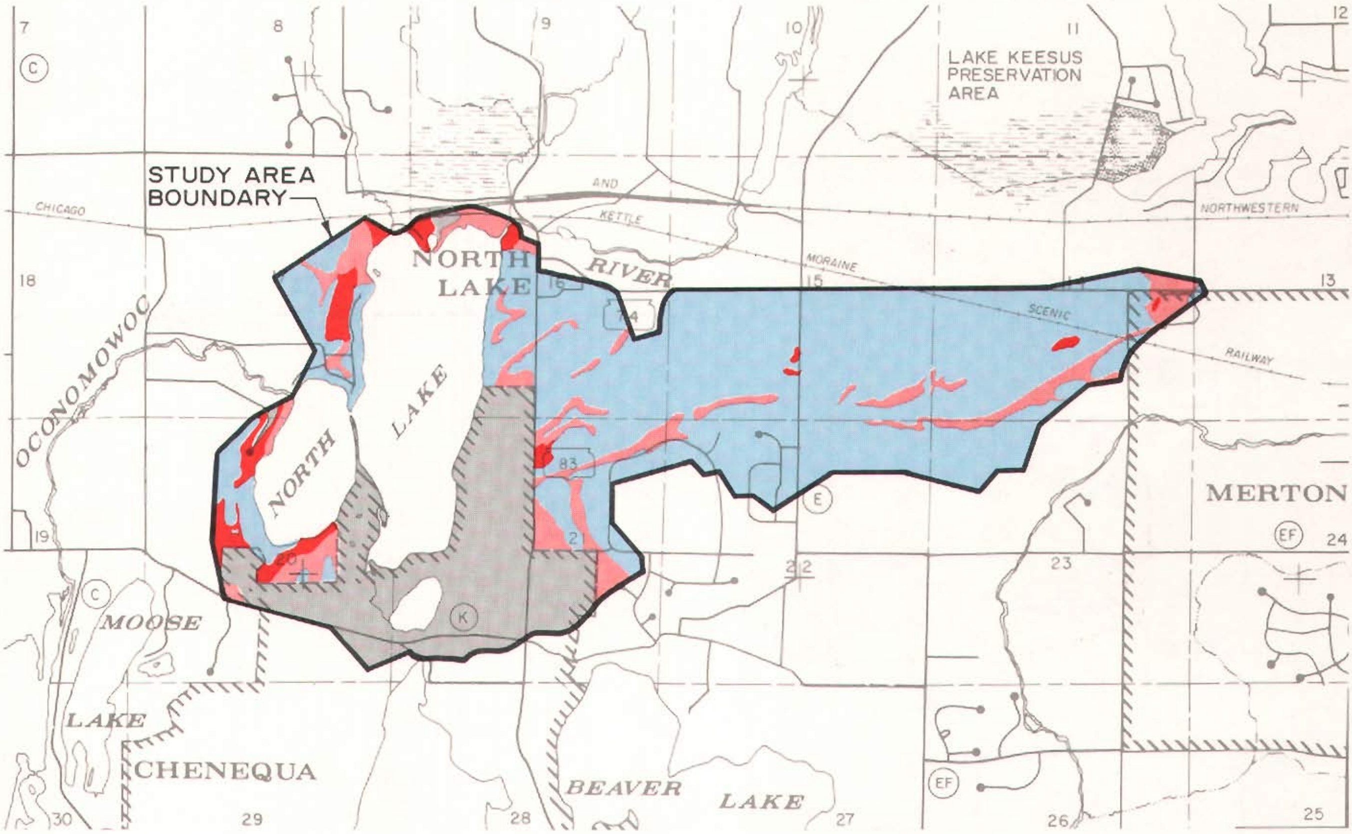
- SOILS WITH VERY SEVERE LIMITATIONS
- SOILS WITH SEVERE LIMITATIONS
- SOILS WITH SLIGHT OR MODERATE LIMITATIONS
- MADE LAND: OPEN PIT MINING AREAS, DUMPS, AND LANDFILLS, CONTAINING WIDELY VARYING SOILS AND OTHER MATERIALS



Source: SEWRPC.

Map 7

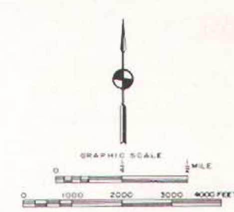
SUITABILITY OF SOILS FOR WASTEWATER SLUDGE APPLICATION IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE



LEGEND

- SOILS WITH SEVERE LIMITATIONS
- SOILS WITH MODERATE LIMITATIONS
- SOILS WITH SLIGHT LIMITATIONS
- URBAN AND MADE LANDS

NOTE: THE SUITABILITY OF AN AREA FOR SLUDGE APPLICATION AS INDICATED ON THIS MAP IS BASED UPON SOIL RATINGS WHICH CONSIDER SOIL CHEMISTRY, SOIL PERMEABILITY, DEPTH TO BEDROCK, AND DEPTH TO GROUNDWATER. SITE SPECIFIC INVESTIGATIONS SHOULD ALSO BE BASED UPON A SEPARATE CONSIDERATION OF SLOPE LIMITATION. AREAS WITHIN 0 TO 6 PERCENT SLOPES ARE CONSIDERED TO HAVE SLIGHT LIMITATIONS, WITHIN 7 TO 12 PERCENT SLOPES TO HAVE MODERATE LIMITATIONS, AND WITHIN SLOPES GREATER THAN 12 PERCENT TO HAVE SEVERE LIMITATIONS FOR APPLICATION OF WASTEWATER SLUDGE.



Source: SEWRPC.

Chapter III

HISTORICAL, EXISTING, AND FORECAST LAND USE AND POPULATION

INTRODUCTION

Water pollution problems, and ultimate solutions to those problems, are a function of the human activities within the drainage area of a water body and of the ability of the underlying natural resource base to sustain those activities. This is especially true in an area directly tributary to a lake, because lakes are more susceptible to water quality degradation than are streams and are more permanently damaged by such degradation. This lake degradation is more likely to interfere with desired water uses, and is often difficult and costly to correct.

Superimposed on the irregular drainage area directly tributary to North Lake is a generally rectilinear pattern of local civil division boundaries, as shown on Map 8. The drainage area directly tributary to North Lake includes portions of the Villages of Chenequa and Merton, and of the Town of Merton, all of which are located in Waukesha County. However, none of these civil divisions lies entirely within the direct drainage area. The area and proportion of the direct drainage area lying within the jurisdiction of each civil division, as of 1975, are set forth in Table 4. Geographic boundaries of the civil divisions are an important factor which must be considered in any water quality management planning effort for a lake, since these local units of government provide the basic structure of the decision-making framework within which intergovernmental environmental problems must be addressed.

POPULATION

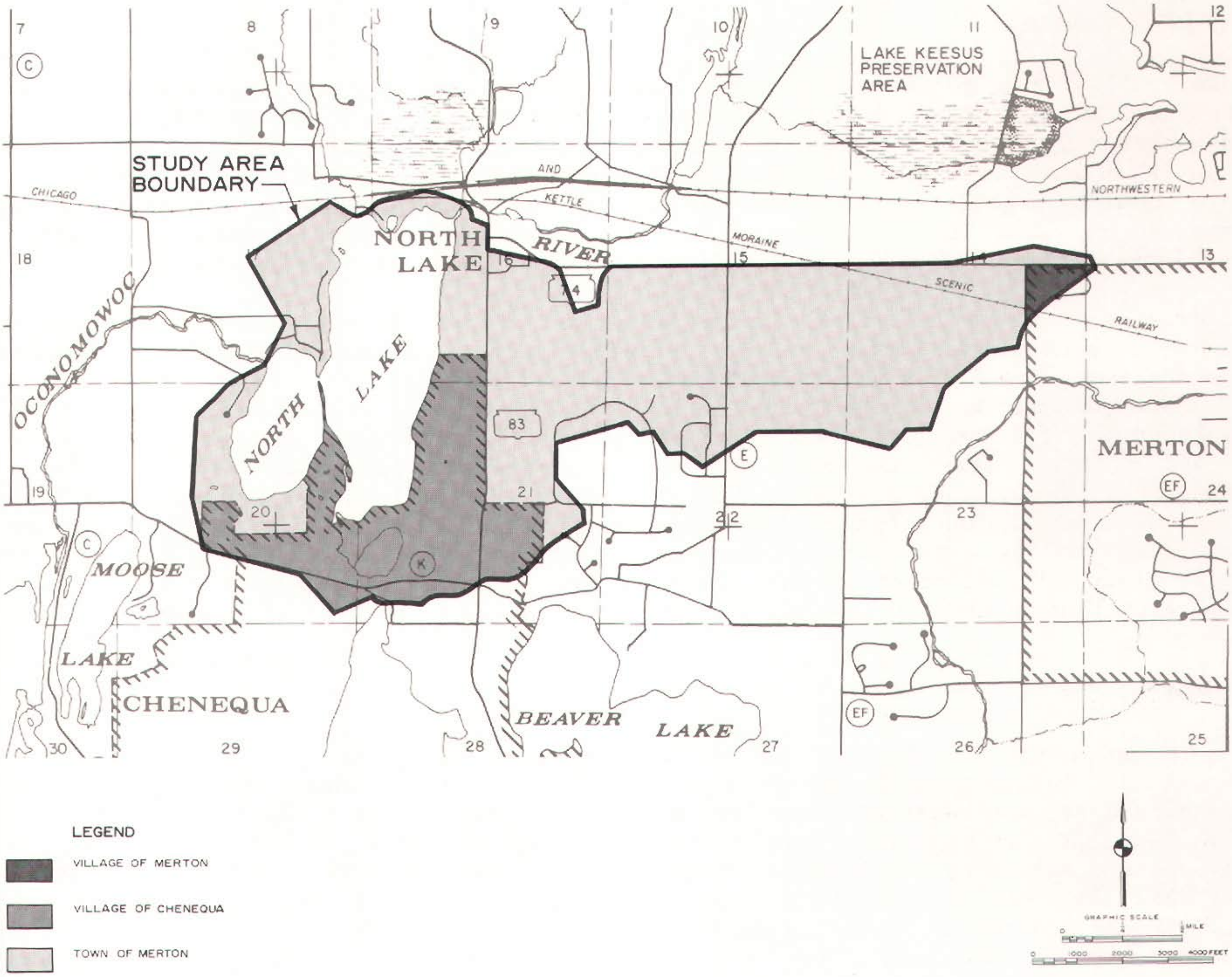
As indicated in Table 5, the resident population of the drainage area tributary to North Lake has increased rapidly since 1950. The 1975 resident population of the drainage area, estimated at about 620 persons, was double the estimated 1950 population. In 1980 the population had increased to approximately 730 persons. Population forecasts prepared by the Regional Planning Commission, on the basis of a normative regional land use plan, indicate, as shown in Table 5, that the population of the drainage area directly tributary to North Lake may be expected to increase to about 980 persons by the year 2000. A comparison of historic, existing, and forecast population levels for the drainage area directly tributary to North Lake, Waukesha County, and the Southeastern Wisconsin Region is set forth in Figure 4. Compared to Waukesha County and the Southeastern Wisconsin Region, population growth in the North Lake drainage area since 1950 has increased at somewhat lower and higher rates, respectively. Forecast population growth to the year 2000 in the lake drainage area is expected to remain at a higher rate than that for the Region, and at about the same rate as that for Waukesha County. This population growth may be expected to place continued and increasing stress on the natural resource base of the North Lake drainage area, and as the populations of the lake direct drainage area, the County, and the Region continue to grow and change, water resource demands and use conflicts may be expected to increase.

LAND USE

The type, intensity, and spatial distribution of land uses are important determinants of the resource demands in the lake drainage area. The existing land use pattern can best be understood within the context of its historical development.

Map 8

CIVIL DIVISION BOUNDARIES IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE: 1975



Source: SEWRPC.

The movement of European settlers into the Southeastern Wisconsin Region began about 1830. Completion of the U. S. Public Land Survey in southeastern Wisconsin in 1836 and subsequent sale of public lands brought a rapid influx of settlers into the area. Map 9 shows the original plat of the U. S. Public Land Survey for the North Lake area. Significant urban land use development in the North Lake area apparently began in the 1920's. Map 10 and Table 6 indicate the historic urban growth pattern in the drainage area directly tributary to North Lake.[1] The largest increases in urban development occurred between 1970 and 1975.

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[1]*Urban development, as defined for the purposes of this discussion, includes those areas within which houses or other buildings have been constructed in relatively compact groups, thereby indicating a concentration of urban land uses. Scattered residential developments were not considered urban in this analysis.*

Table 4

AREAL EXTENT OF CIVIL DIVISIONS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE: JANUARY 1, 1976

Civil Division	Civil Division Area Within Direct Drainage Area (square miles)	Percent of Direct Drainage Area Within Civil Division	Percent of Civil Division Within Direct Drainage Area
Waukesha County			
Villages			
Chenequa ..	0.64	19.28	13.82
Merton	0.05	1.51	2.20
Town			
Merton	2.63	79.21	9.14
County Subtotal	3.32	100.00	0.57
Total	3.32[a]	100.00	--

[a] *Includes the surface water area of 439 acres, or 0.69 square mile of the lake itself.*

Source: SEWRPC.

Table 5

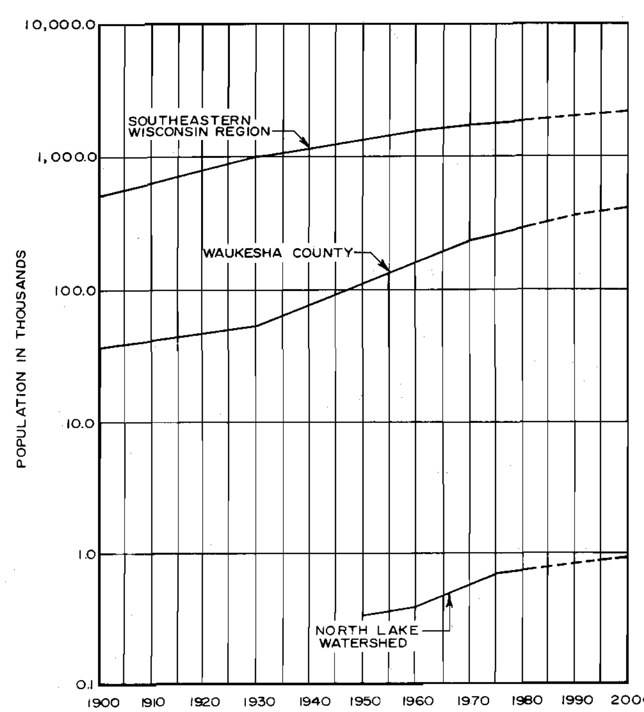
HISTORIC AND FORECAST RESIDENT POPULATION LEVELS OF THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE: 1950-2000

Year	Population
1950	300
1960	350
1970	550
1975	620
1980	730
2000	980

Source: SEWRPC.

Figure 4

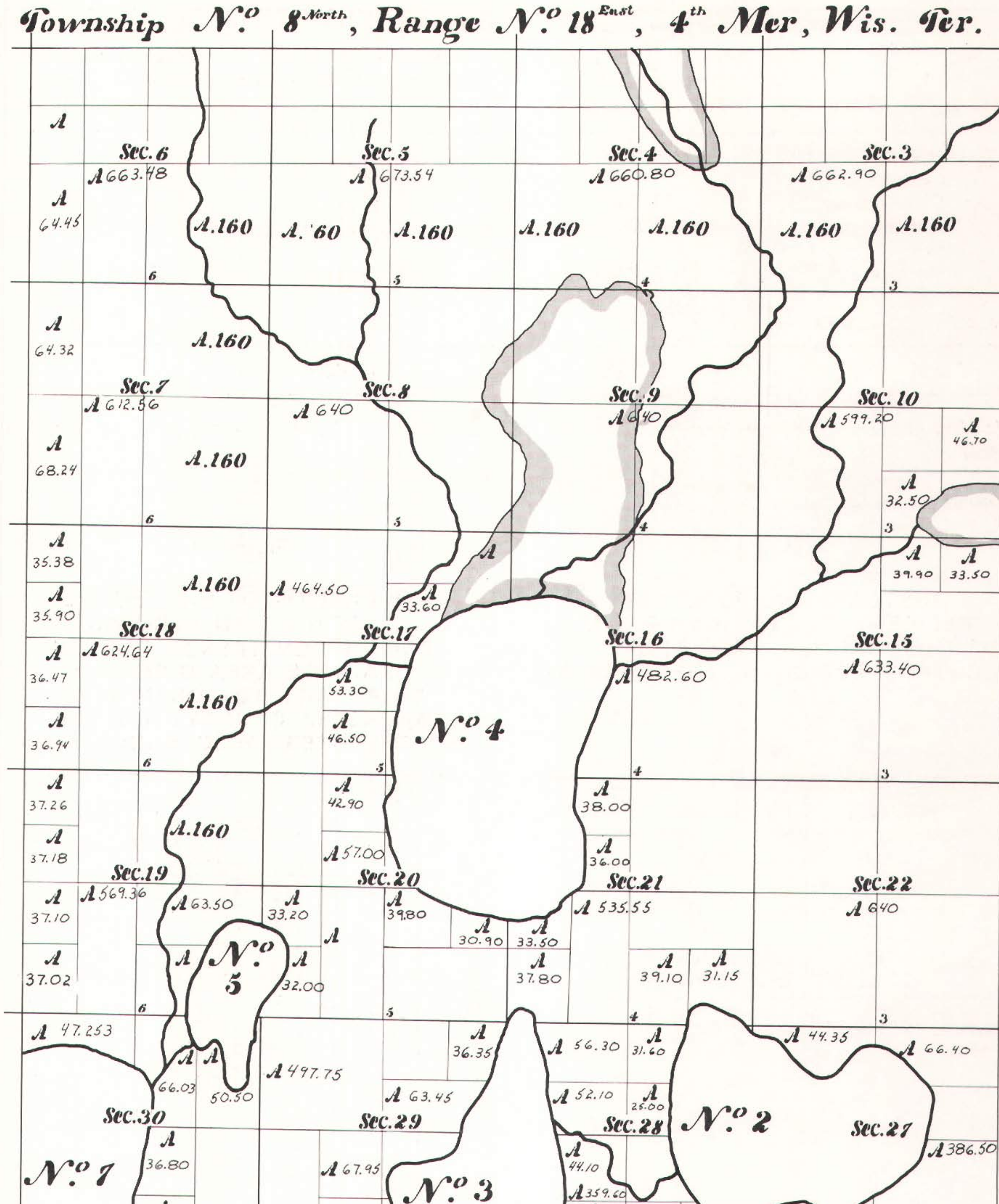
COMPARISON OF HISTORICAL, EXISTING, AND FORECAST POPULATION TRENDS FOR THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE, WAUKESHA COUNTY, AND THE SOUTHEASTERN WISCONSIN REGION



Source: SEWRPC.

Map 9

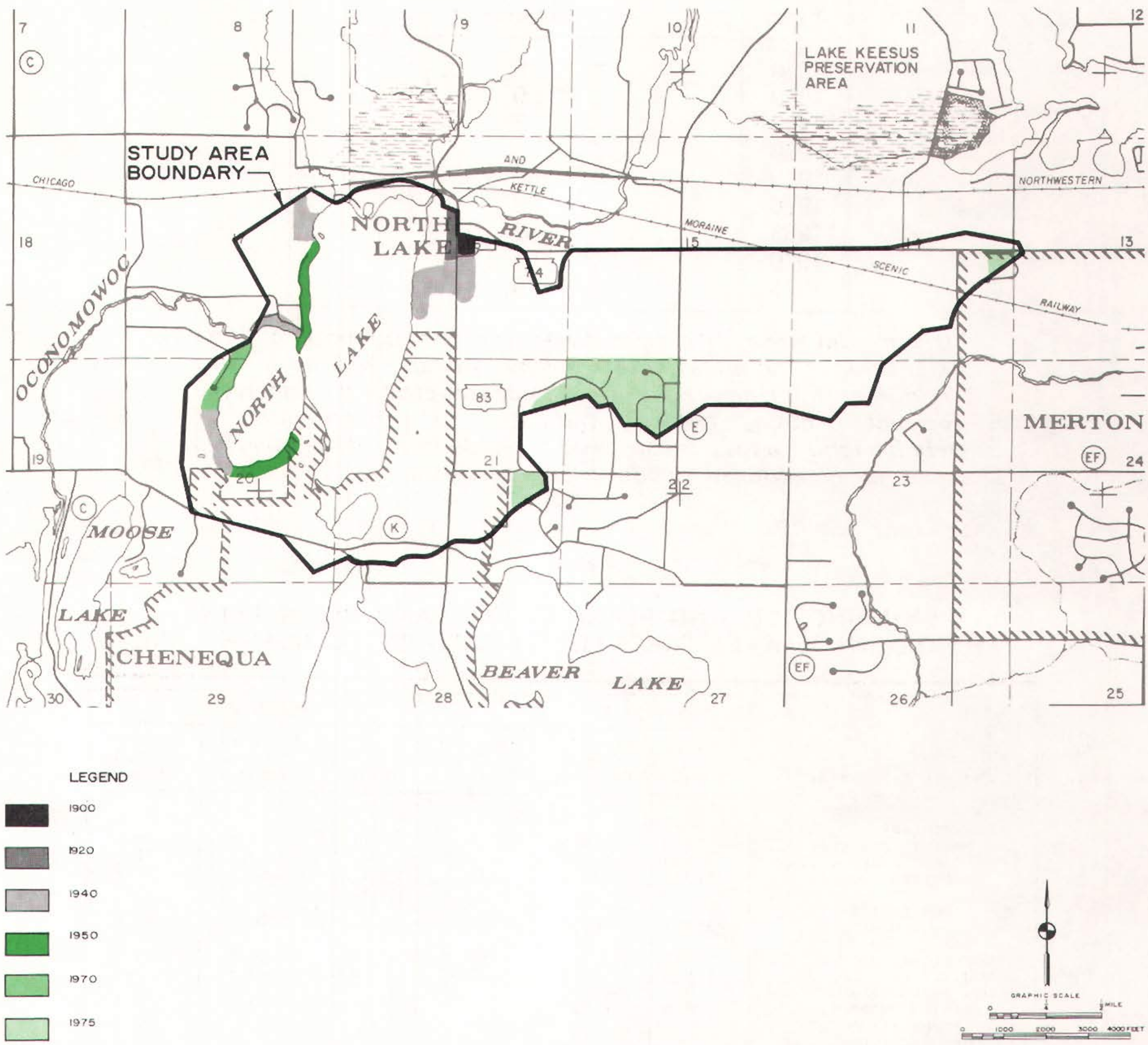
ORIGINAL UNITED STATES PUBLIC LAND SURVEY MAP
FOR THE NORTH LAKE AREA: 1836



Source: U. S. Public Land Survey and SEWRPC.

Map 10

HISTORIC URBAN GROWTH IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE: 1850-1975



Source: SEWRPC.

The existing land use pattern in the drainage area directly tributary to North Lake, as of 1975, is shown on Map 11 and the existing land uses are quantified in Table 7. As indicated in Table 7, about 31 percent of the total direct drainage area was in urban land use, with the dominant urban land use being residential, encompassing 70 percent of the urban land area. Most of the medium-density residential development is located along the west shore of the lake and in an area northeast of the Oconomowoc River inlet, adjacent to STH 83. Much of the residential development along the immediate shoreline of the lake is of a low density. As of 1975, about 50 percent of

Table 6

EXTENT OF HISTORIC URBAN GROWTH IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE: 1850-1975

Year	Extent of Urban Development[a] (acres)
1850	0
1880	0
1900	2
1920	5
1940	65
1950	89
1963	89
1970	91
1975	179

[a]Urban development, as defined for the purpose of this discussion, includes those areas within which houses or other buildings have been constructed in relatively compact groups, thereby indicating a concentration of urban land uses. Scattered residential developments were not considered urban in this analysis.

Source: SEWRPC.

Table 7

EXISTING 1975 AND PLANNED 2000 LAND USE WITHIN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE

Land Use Categories	Existing 1975			Planned 2000		
	Acres	Percent of Major Category	Percent of Study Area	Acres	Percent of Major Category	Percent of Study Area
Urban						
Residential						
Medium-Density......	50.0	9.5	3.0	50.0	8.3	3.0
Low-Density.........	136.0	25.9	8.1	193.7	32.3	11.5
Suburban	181.1	34.5	10.7	181.2	30.2	10.7
Residential Subtotal	367.1	69.9	21.8	424.9	70.8	25.2
Commercial............	0.6	0.1	0.0[b]	0.7	0.1	0.0[b]
Industrial............	0.6	0.1	0.0[b]	0.6	0.1	0.0[b]
Governmental and Institutional........	4.8	0.9	0.3	5.6	0.9	0.3
Transportation, Communication, and Utilities........	99.4	19.0	5.9	113.8	19.1	6.7
Recreation............	53.0	10.0	3.1	54.0	9.0	3.2
Urban Land Use Total	525.5	100.0	31.1	599.6	100.0	35.4
Rural						
Agricultural..........	847.6	73.0	50.3	783.1	72.0	46.5
Water[a]...............	18.0	1.6	1.0	18.0	1.7	1.1
Wetlands..............	43.7	3.7	2.5	42.0	3.9	2.5
Woodlands.............	232.9	20.1	14.0	227.2	20.9	13.5
Other Open Lands......	18.5	1.6	1.1	16.3	1.5	1.0
Rural Land Use Total	1,160.7	100.0	68.9	1,086.6	100.0	64.6
Direct Drainage Area Total	1,686.2	--	100.0	1,686.2	--	100.0

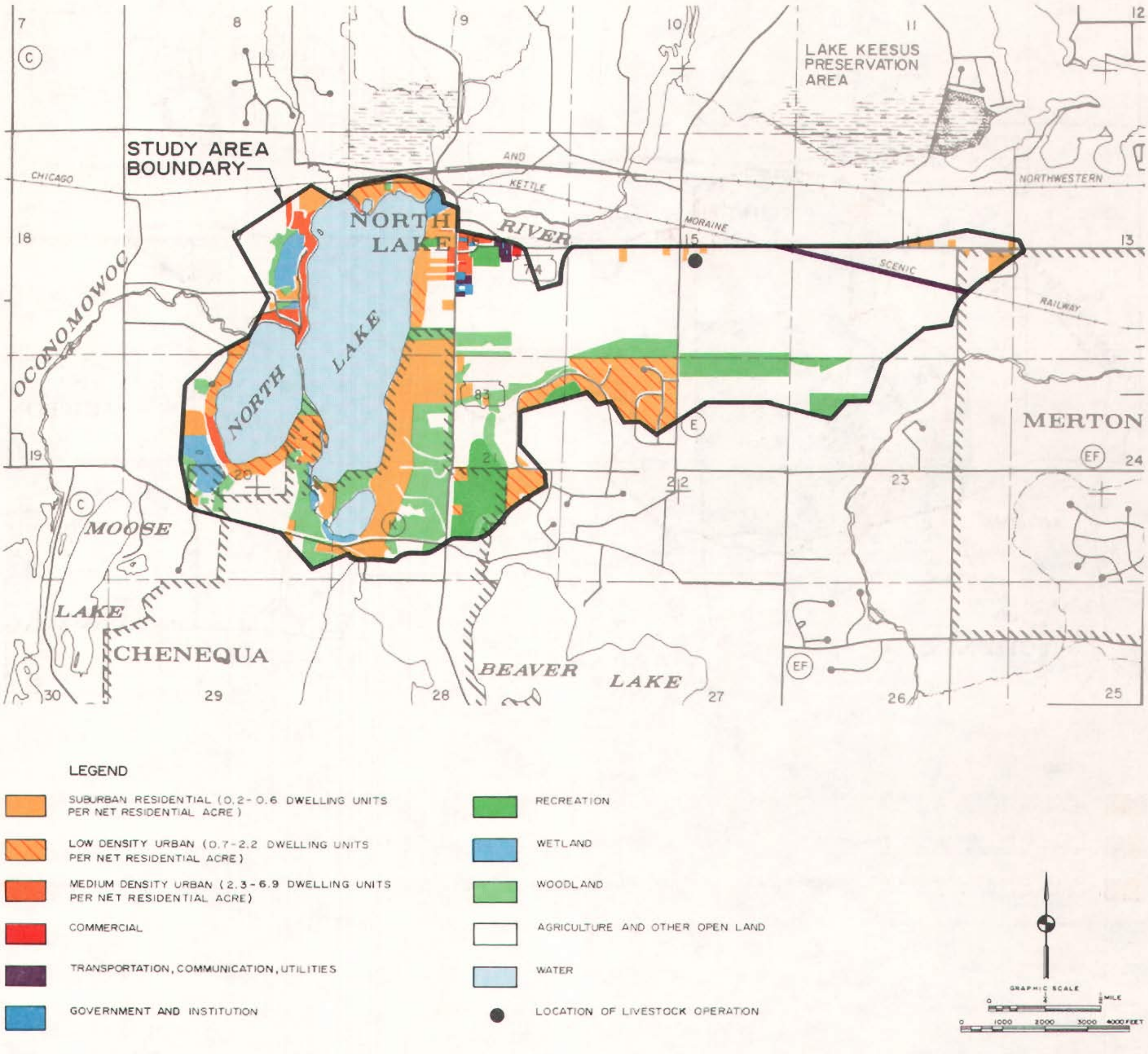
[a]Excludes the surface area of North and Cornell Lakes.

[b]Less than 0.05 percent.

Source: SEWRPC.

Map 11

EXISTING LAND USE IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE: 1975



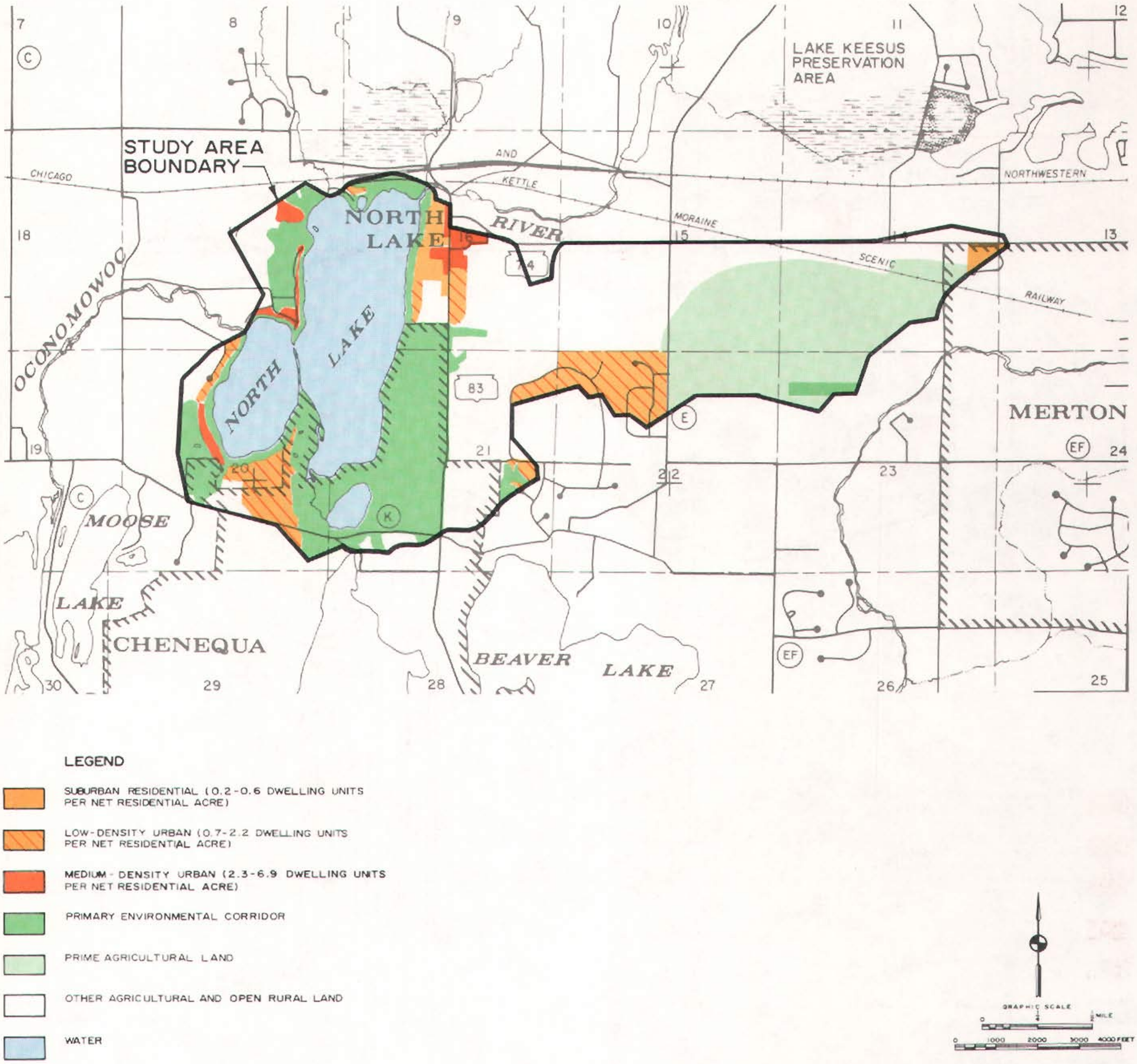
Source: SEWRPC.

the lake drainage area was still in agricultural use, most of the agricultural lands being located east of the Lake. Open lands and woodlands comprised about 15 percent of the drainage area. Wetlands and surface water, excluding the surface areas of North and Cornell Lakes, accounted for 5 percent of the total direct tributary drainage area.

If present trends continue, the approximately 360 new residents expected in the direct drainage area between 1975 and 2000 will require some increase in urban development. The year 2000 land use plan adopted by the Regional Planning Commission, as set forth on Map 12 and quantified in Table 7, recommends that most new residen-

Map 12

GENERALIZED PLANNED LAND USE IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE: 2000



Source: SEWRPC.

tial development in the drainage area directly tributary to North Lake occur at low densities. Compared to existing 1975 land uses, a 14 percent increase in urban land use, and a 16 percent increase in residential land use are envisioned by the year 2000. A 478-acre area of land located to the east of North Lake is designated as prime agricultural land. The land immediately surrounding North and Cornell Lakes, and the surface area of those lakes, a large portion of the existing suburban development, woodlands in the northern portion of the Village of Chenequa, and a few scattered areas, which together encompass 887 acres, are recommended to be preserved in essentially natural, open uses as environmental corridor.

Chapter IV

WATER QUALITY

HISTORICAL DATA

Some data predating the present study on the water quality and biota of North Lake has been collected. However, most of the information is relatively recent. Limnological studies of North Lake date back to the early 1900's when E. A. Birge and C. Juday, widely recognized lake researchers, collected basic information on the lake.[1] As shown in Table 8, water chemistry data for North Lake was collected in 1906, 1907 and 1909. Additional sources of historic data include a 1963 Wisconsin Department of Natural Resources Report, Surface Water Resources of Waukesha County,[2] and miscellaneous Wisconsin Department of Natural Resources file data and reports. A comparison of the historic data set forth in Table 8 and the more recent data set forth in Table 9, indicates that except for dissolved oxygen, the data available are insufficient to permit identification of any long-term trends or changes in water quality which may be occurring. The variations in the chemical data set forth in Table 8 can be attributed to a number of factors including the different types of analytical methods which were employed.

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[1] *E. A. Birge and C. Juday, "The Dissolved Gases of the Water and Their Biological Significance," The Inland Lakes of Wisconsin, Wisconsin Geological Natural History Survey, Bulletin No. 22, 1911.*

[2] *R. J. Poff and C. W. Threinen, Surface Water Resources of Waukesha County, Wisconsin Conservation Department, 1963.*

Table 8

COMPARISON OF HISTORICAL AND CURRENT WATER QUALITY CHARACTERISTICS OF NORTH LAKE: 1906-1979

Water Quality Parameter[a]	Sampling Date						
	August 1906	June 1907	September 1907	September 1909	Average 1906-1909	October 1960	Average 1973-1979
Calcium	45.0	47.3	38.3	42.3	43.2	--	69.4
Magnesium	28.7	28.0	25.5	30.5	28.0	--	40.6
Sodium	--	--	2.2	4.8	3.5	--	7.4
Potassium	--	--	1.2	2.4	1.8	--	2.6
Chloride	3.0	4.0	6.8	4.2	4.5	--	14.6
Specific Conductance (micromhos/cm)	--	--	--	--	--	645	555
pH Acidity (standard units)	--	--	--	--	--	8.3	7.9-8.3[b]
Alkalinity	--	--	--	--	--	228.0	251.5

[a] All values reported in mg/l unless otherwise specified.

[b] Range of pH levels during period 1973-1979.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 9

WATER QUALITY CONDITIONS OF NORTH LAKE: 1973-1979

Water Quality Parameter[a]	Sampling Dates								
	September 20, 1973	November 20, 1973	February 7, 1974	April 5, 1974	July 11, 1974	November 20, 1974	February 20, 1975	April 24, 1975	July 2, 1975
Nitrite Nitrogen........	0.03	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01
Nitrate Nitrogen........	0.60	0.52	1.22	1.06	1.63	0.47	1.02	1.34	1.03
Ammonia Nitrogen........	<0.03	0.25	<0.03	<0.03	0.12	0.23	0.18	0.08	<0.03
Organic Nitrogen........	0.68	0.53	0.79	0.48	0.90	1.06	0.43	0.55	0.46
Total Nitrogen..........	1.31	1.31	2.01	1.55	2.66	1.78	1.64	1.97	1.48
Phosphate Phosphorus....	0.05	0.07	0.06	0.04	0.05	0.10	0.06	0.08	0.05
Total Phosphorus........	0.06	0.11	0.06	0.06	0.02	0.11	0.05	0.07	0.07
Calcium[b]..............	75.2	54.6	59.0	--	108.7	116.0	52.3	76.5	64.0
Magnesium[b]............	40.7	30.3	30.3	--	52.0	44.0	38.0	38.0	50.0
Sodium[b]...............	5.4	6.8	7.3	10.0	25.3	3.5	3.7	6.5	8.3
Potassium[b]............	2.9	2.3	5.8	3.9	1.1	<0.5	5.9	1.6	1.1
Iron[b].................	--	--	--	--	--	--	--	--	0.40
Manganese[b]............	--	--	--	--	--	--	--	--	0.13
Specific Conductance (micromhos/cm).........	487	509	576	562	511	629	597	511	495
Sulfate[b]..............	35.7	54.0	50.3	46.0	42.3	39.0	43.0	41.5	33.0
Chloride................	13.3	14.0	16.0	14.0	14.3	12.5	19.0	12.5	13.0
pH (standard units).....	7.9	8.1	8.1	8.1	8.2	8.2	8.3	8.0	8.1
Alkalinity..............	231.0	251.0	261.0	241.0	233.0	259.0	269.0	241.0	243.0
Turbidity (Formazin Units)[b]......	1.8	1.6	1.5	1.7	3.5	13.3	1.4	1.9	2.4

Table 9 (continued)

	Sampling Dates								
	November 24, 1975	Mid-March to Mid-June 1976	Mid-June to Mid-September 1976	Mid-September to Mid-December 1976	Mid-December to Mid-March 1977	March 16, 1979	April 26, 1979	Range	Mean
Nitrite Nitrogen........	<0.01	0.02	0.04	0.06	0.03	<0.01	0.01	<0.01-0.06	0.02
Nitrate Nitrogen........	0.40	0.71	0.54	0.30	0.52	1.08	0.91	0.30-1.63	0.81
Ammonia Nitrogen........	0.22	0.05	0.16	0.17	0.04	0.10	0.03	<0.03-0.25	0.11
Organic Nitrogen........	0.64	0.64	0.68	0.64	0.38	0.47	0.43	0.38-1.06	0.61
Total Nitrogen..........	1.25	1.42	1.44	1.16	0.96	1.66	1.37	0.96-2.66	1.56
Phosphate Phosphorus....	0.03	0.02	0.07	0.06	0.02	0.04	0.03	0.02-0.10	0.05
Total Phosphorus........	0.06	0.05	0.09	0.13	0.03	0.04	0.06	0.02-0.13	0.07
Calcium[b]..............	52.0	76.0	62.0	53.0	53.0	70.7	68.0	52.0-116.0	69.4
Magnesium[b]............	41.0	36.0	50.0	42.0	39.0	41.7	36.3	30.3-52.0	40.6
Sodium[b]...............	5.5	6.0	8.5	6.0	4.0	6.0	6.0	3.5-25.3	7.4
Potassium[b]............	2.2	2.4	1.1	1.9	6.0	1.6	1.9	<0.5-6.0	2.6
Iron[b].................	0.12	--	0.48	1.20	--	<0.08	<0.08	<0.08-1.20	0.39
Manganese[b]............	0.05	--	0.11	0.03	--	0.04	<0.03	<0.03-0.13	0.07
Specific Conductance (micromhos/cm).........	541	547	526	532	550	693	622	487-693	555
Sulfate[b]..............	34.0	42.0	34.0	--	43.0	--	--	33.0-54.0	41.4
Chloride................	13.5	14.0	14.0	15.0	16.0	16.0	15.7	12.5-19.0	14.6
pH (standard units).....	8.2	--	--	--	--	8.1	8.1	7.9-8.3	--
Alkalinity..............	257.0	233.0	246.0	266.0	271.0	277.0	245.0	231.0-277.0	251.5
Turbidity (Formazin Units)[b]......	2.6	5.2	5.3	2.4	1.8	0.9	1.8	0.9-13.3	3.1

[a]All values reported in mg/l unless otherwise specified.

[b]Data collected in 1975 during same time periods.

Source: Wisconsin Department of Natural Resources.

RECENT PHYSICAL AND CHEMICAL CHARACTERISTICS

The water quality of North Lake has been monitored periodically from 1973 through 1979. The resulting data were used in the management plan preparation to determine the condition of the lake and to characterize its suitability for recreational use and the support of fish and aquatic life. The primary station for most sampling activities was located at the deepest portion of North Lake as shown on Map 3. Typical monthly temperature and dissolved oxygen profiles taken at this station are shown in Figure 5. Water temperatures in North Lake ranged from a minimum of 32°F (0°C) during the winter to a maximum of 77° (25°C) during the summer. Dissolved oxygen concentrations in the hypolimnion ranged from 16.0 mg/l in December to 0.0 mg/l during late summer.

Complete mixing of deep lakes, such as North Lake, is restricted by thermal stratification during the summer and winter. Thermal stratification is a result of differential heating of the lake water and water temperature density relationships. Water is unique among liquids in that it reaches its maximum density--weight per unit volume--at about 39°F. As summer begins, the lake absorbs the sun's energy at the surface. Wind action and to some extent, internal heat transfer transmit some of this energy to the underlying waters. As the upper layer of water is heated by the sun's energy, however, a physical barrier begins to form between the warmer surface water and the lower, heavier, colder water as shown in Figure 5-B, 5-K, and 5-L for the months of August 1976, and July and September 1977. This "barrier" is marked by a sharp temperature gradient known as the metalimnion or thermocline, which separates the warmer, lighter, upper layer of water--called the epilimnion--from the cooler, heavier, lower layer--called the hypolimnion. Although this barrier is easily crossed by fish, it essentially prohibits the exchange of water between the two layers, a condition which has a great impact on both chemical and biological conditions and activities in North Lake. The development of the thermocline begins in early summer and reaches its maximum in late summer. This stratification period lasts until the fall, when air temperatures cool the surface water and wind action results in a disappearance of the thermocline.

As the surface water cools, it becomes heavier, sinking and displacing the warmer water below. The colder water sinks and mixes under wind action to erode the thermocline until the entire column of water is of uniform temperature as shown in Figures 5-C and 5-D. This action, which follows summer stratification, is known as the fall turnover. When the water temperature drops below 39°F, it again becomes lighter and "floats" near the surface. Eventually the water near the surface is cooled to 32°F at which temperature ice begins to form and covers the surface of the lake, isolating it from the atmosphere for up to four months. In North Lake, ice cover typically exists from late November through March. As shown in Figure 5-G from the month of February, winter stratification occurs as the colder, lighter water and ice remains close to the surface, and is again separated from the relatively warmer and heavier water near the bottom of the lake. Spring brings a reversal of the process. As the ice thaws and the upper layer of water warms, it becomes more dense and begins to approach the temperature of the warmer, lower water until the entire water column reaches the same temperature. Mixing, induced by the wind, continues until the water reaches 39°F, as shown for March in Figure 5-H. This lake season, which follows winter stratification, is referred to as the spring turnover. Beyond this point, the water warms at the surface and again becomes lighter and floats above the colder water. Wind and resulting waves carry, to a limited extent, some of the energy of the warmer, lighter water to lower depths. Thus begins the formation of the thermocline and another summer thermal stratification.

Dissolved oxygen concentration is one of the most critical factors affecting a lake ecosystem. In shallow, fertile lakes, and small bays of large lakes, winter brings the threat of dissolved oxygen depletion and fish mortality under ice cover. If ice cover is thick and snow cover deep, light penetration is sometimes insufficient to maintain oxygen-production from the plants in the lakes. When plant life dies, it, along with organic bottom muck, consumes dissolved oxygen in the process of decaying. This process may result in oxygen depletion which will kill fish if the supply of dissolved oxygen is not sufficient to meet the total demand. This condition, commonly referred to as winterkill, has generally not been a problem in the open waters of North Lake. Dissolved oxygen levels at most depths were found to be more than adequate for the support of fish throughout the winter, as shown in Figure 5-E and 5-F for the months of December and January. However, a minor period of depletion was noted during February, as shown in Figure 5-G.

Dissolved oxygen profiles during summer stratification on North Lake show total oxygen depletion in the hypolimnion. Beginning in early summer, as the thermocline develops, the lower, colder hypolimnion becomes isolated from the upper, warmer epilimnion, cutting off the surface supply of dissolved oxygen to the hypolimnion; while in the epilimnion, wind turbulence or atmospheric equilibrium, wave action, and plant photosynthesis maintain an adequate supply of dissolved oxygen. Gradually, if there is not enough dissolved oxygen to meet the total oxygen demand from decaying material, the dissolved oxygen concentration may be reduced to zero. This oxygen depletion was observed in North Lake as shown in Figure 5-B, 5-K, and 5-L for the months of August 1976, and July and September 1977 and is common of many lakes in southeastern Wisconsin. In August 1976, the dissolved oxygen level at a depth of 30 feet and 40 feet dropped to 1.3 milligrams per liter (mg/l) and 0.0 mg/l, respectively. This depleted oxygen level causes many species of fish to move upward in the water column, where higher dissolved oxygen concentrations exist.

Dissolved oxygen profiles of North Lake were also measured during the summers of 1906 through 1909. These profiles, as shown in Figure 6, indicate that depletion of oxygen in the hypolimnion during summer was also common in the early 1900's. There appears to have been little change in the dissolved oxygen concentrations and characteristics of North Lake over the 70-year period of record.

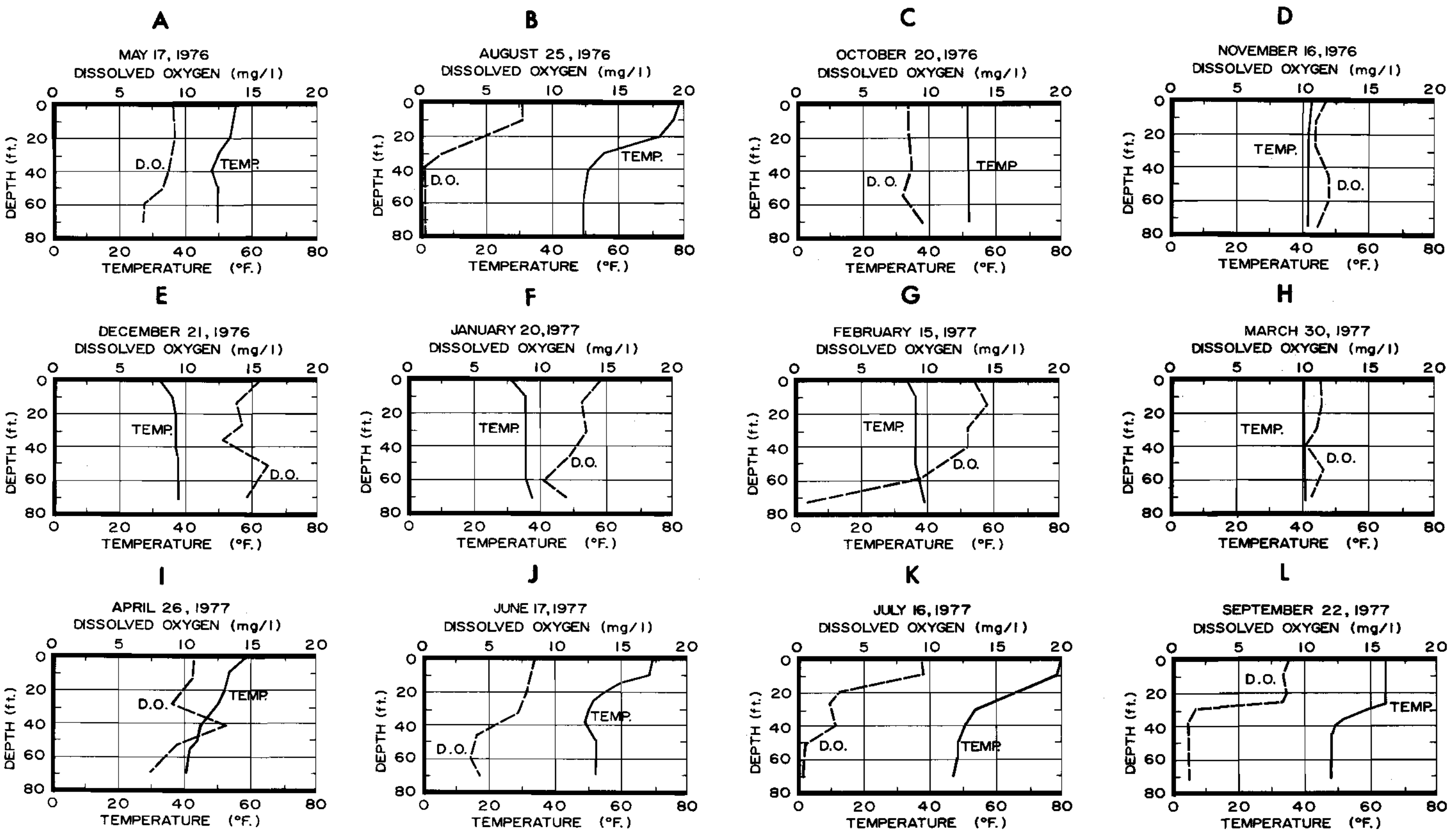
The range of depths within which photosynthetic activity occurs depends, to a large extent, on the transparency of the water. A Secchi Disc was used to measure water clarity. This is a black and white, 8-inch disc which is lowered to a depth where it is just no longer visible from the surface. At that point a reading is recorded. Water clarity in lakes is typically highly variable. Secchi Disc depth measurements for the period of 1973 through 1979 for North Lake are shown in Figure 7. In North Lake the Secchi Disk readings ranged from a low of 3.3 feet in July, 1974 to a high of 15.6 feet in February, 1977, with an average of 8.4 feet.

Chlorophyll-a is the major photosynthetic pigment in algae. The amount of chlorophyll-a present is an indicator of the biomass of live algae in the water and its level of concentration is useful in determining the trophic status of lakes and hence their suitability for certain water uses. As shown in Figure 8, chlorophyll-a concentrations were determined 17 times in North Lake: 12 in 1976 and 5 in 1977. The chlorophyll-a values in North Lake ranged from a low of 0.7 milligram per cubic meter (mg/m^3) in February 1977, to a high of 36.5 mg/m^3 in November, 1976, with an average value of 6.5 mg/m^3.

Water samples collected from North Lake between 1973 and 1979 were tested for pH (acidity), specific conductance (a measure of the amount of dissolved solids), magnesium, sodium, potassium, iron, calcium, manganese, sulfate, alkalinity,

Figure 5

TEMPERATURE AND DISSOLVED OXYGEN PROFILES FOR NORTH LAKE: 1976-1977



Source: Wisconsin Department of Natural Resources and SEWRPC.

turbidity, chloride, and different forms of the plant nutrients nitrogen and phosphorus. Ranges and mean values found for these water quality indicators are set forth in Table 9.

Chloride concentrations ranged from 12.5 to 19.0 milligrams per liter (mg/l) with a mean of 14.6 mg/l. These values are considered typical of lakes in southeastern Wisconsin. As set forth in Table 10, chloride concentrations in southeastern Wisconsin lakes generally lie in the range of from 10 to 40 mg/l. This contrasts to the normally expected background chloride concentrations of about 5-10 mg/l, and is attributed to the long-term increases in chloride which accompany human activities. Sources of chlorides include road deicing salt, treated and untreated sewage, animal wastes, water softeners, and natural leaching of rock minerals.

Specific conductivity ranged from 487 to 693 micromhos/cm, and pH fluctuated between 7.9 and 8.3 standard units. The metals data collected are typical of the hard water lakes in the area.[3] Turbidity, another measure of poor water clarity, is low to moderate, indicating clear water throughout the year. Total alkalinity was average for lakes in Waukesha County.

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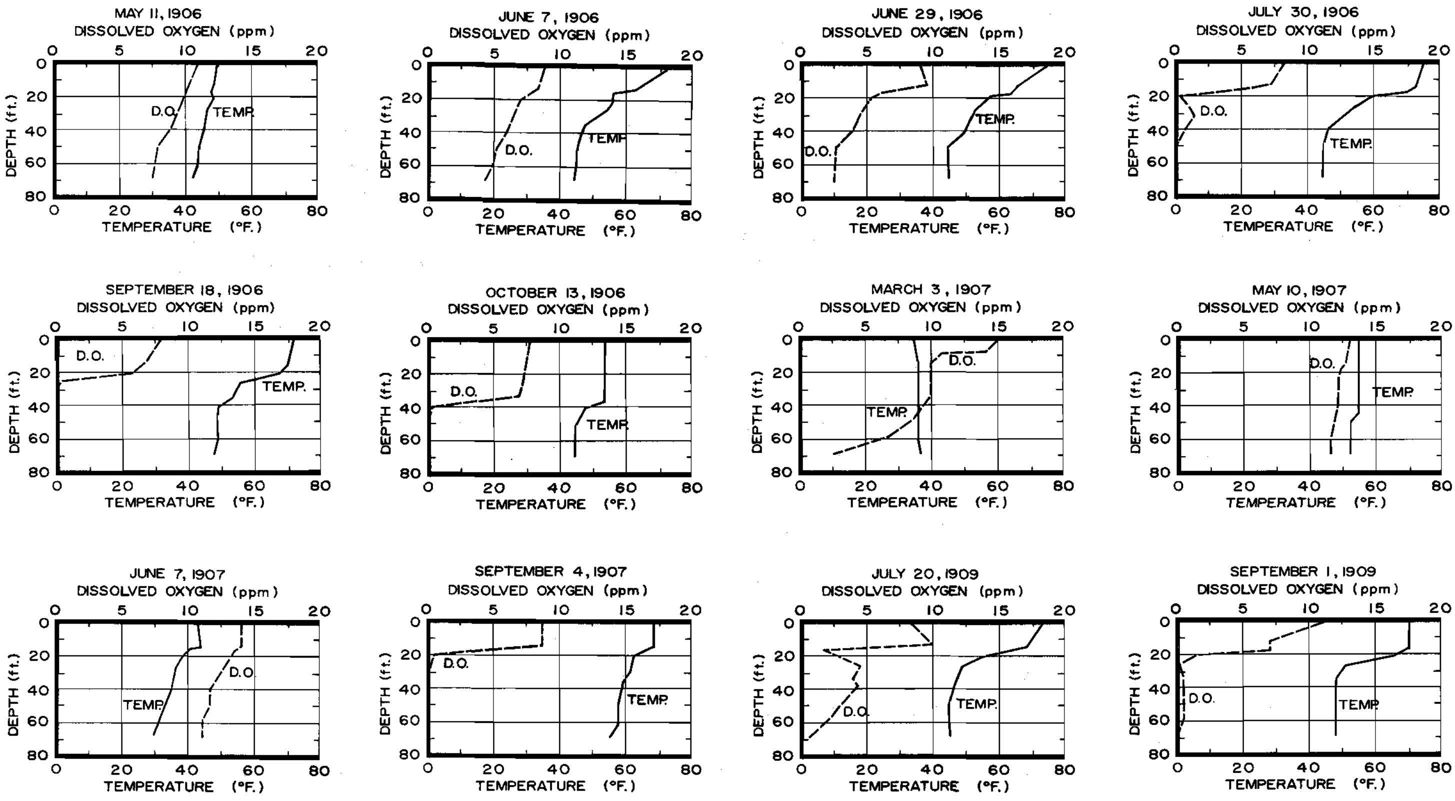
[3] *Ibid.*

Figure 6

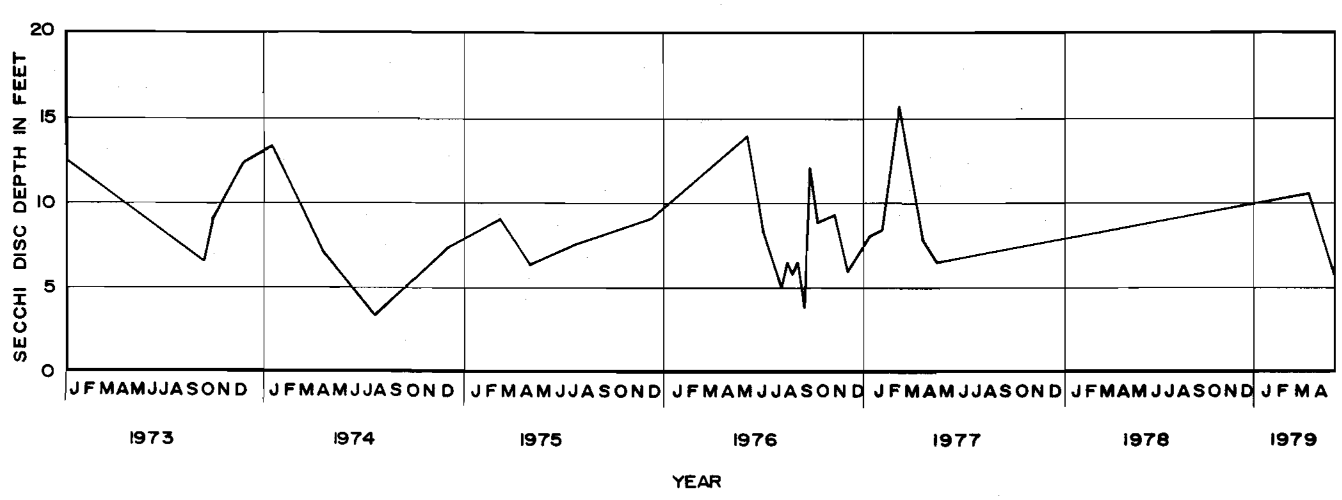
HISTORICAL TEMPERATURE AND DISSOLVED OXYGEN PROFILES FOR NORTH LAKE: 1906-1909



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 7

MEASURED SECCHI DISC DEPTHS IN NORTH LAKE: 1973-1979



Source: Wisconsin Department of Natural Resources and SEWRPC.

The nutrients nitrogen and phosphorus, which are necessary for the growth of aquatic plants, including algae, have a significant effect on the suitability of lakes for recreational activities. In lakes where supplies of nutrients are limited, plant growth is limited and the lakes are typically clear and classified as oligotrophic. Where abundant supplies of nutrients are available, aquatic plant growth is usually prolific, resulting in nuisance algae blooms and/or excessive macrophytes. Lakes experiencing these conditions are unattractive for certain recreational uses.

Phosphorus concentrations in North Lake were found to exceed the levels believed necessary to support periodic nuisance algae blooms. The recommended water quality standard for recreational use and warmwater fish and aquatic life set forth in the Regional Planning Commission's adopted regional water quality management plan indicates that algae blooms are likely to occur in lakes where the total phosphorus concentration exceeds 0.02 milligram per liter (mg/l) during spring turnover. This is the level considered in the regional plan as required to limit algae and aquatic plant growth to levels consistent with the recreational and the warmwater fishery and aquatic life water use objectives. In North Lake, during the period of 1973 through 1979, the mean concentration of total phosphorus was 0.06 mg/l during the spring turnover, and 0.07 mg/l on an average annual basis.

Despite high nutrient loading levels and high inlake concentrations, North Lake did not exhibit severe algae or macrophyte problems during the study year. Other lakes in Wisconsin that appear to exhibit these same characteristics are Big Cedar (Washington County) and Mirror (Waupaca County) Lakes.[4]

Large volume to surface ratios, zooplankton grazing, deep-water algae species (Oscillatoria), or agricultural herbicides inadvertently introduced into the lake system are possible explanations why vegetative growth more typical of lakes with excessive phosphorus has not developed in North Lake. However, the density of zooplankton does not seem sufficient to crop enough algae to lower the chlorophyll values to the levels observed. Species of Oscillatoria are characteristically deep-water species and were not found during the summer or spring, since only the upper six feet were sampled. In November, Oscillatoria were found near the surface and were the second most abundant algae, indicating that while this algae may be present year-round, it inhabits the strata near the thermocline most of the time.

Closer examination of the vertical distribution of reactive phosphorus (PO_4) and total phosphorus during the summer stratification period may provide the reason for low algal densities despite high mean in-lake phosphorus concentrations. As phosphorus is removed from the epilimnion by algae and macrophytes, it is transferred to the hypolimnion via the continual "rain" of dead plant and animal matter. Phosphorus transfer from lake sediments to the overlying water is facilitated by anaerobic conditions in the hypolimnion, especially during the summer, when warm water temperatures accelerate chemical reactions. Unless the epilimnion is continually replenished, it can soon become stripped of nutrients, although some nutrient recycling (eroding) from the hypolimnion can occur, depending on the depth of the thermocline, rate of nutrient loading to the lake, and meteorological conditions (especially temperature and wind).

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[4] *Information provided by D. Knauer and P. Garrison, Wisconsin Department of Natural Resources, Office of Inland Lake Renewal, Madison, Wisconsin.*

Figure 9 and Table 11 illustrate total nitrogen, reactive and total phosphorus dynamics in the hypolimnion of North Lake. Throughout summer stratification, the epilimnion made up an average of 70 percent, and the hypolimnion an average of 30 percent, of the total lake volume. Under normal conditions, nutrients trapped in the hypolimnion are not available for algae production. The portion of the total lake mass of reactive phosphorus in the hypolimnion was at a maximum of 96 percent in late August and a minimum of 64 percent in late June, with a mean of 83 percent during summer stratification. Thus, most of the bulk phosphorus was concentrated in roughly 30 percent of the total lake volume during most of the growing season, and was unavailable for plant growth. As the lake turns over in the fall, phosphorus is returned to the upper waters where it may be utilized by algae.

Stream flow entering a lake tends to seek its own density, which is a function primarily of temperature, although sediment or dissolved solids or salts can increase the density of the incoming water. During the summer, the position and temperature of the thermocline probably prohibit contact between entering stream flow and the hypolimnion. Thus, stream temperatures were in the same range as the epilimnion and thermocline, and only the water above the thermocline would be exchanged. Also, because of the lake configuration, it is unlikely that the entire epilimnion is involved in the exchange.

The ratio of total nitrogen (N) to total phosphorus (P) in lake water indicates which nutrient is the factor most likely limiting aquatic plant growth in a lake.[5] Where the N:P ratio is greater than 14:1, phosphorus is most likely to be the limiting nutrient. If the ratio is less than 10:1, nitrogen is most likely to be the limiting nutrient. As shown in Table 12, in North Lake the N:P ratio was always equal to or greater than 14:1, except in November, 1973 when the ratio was 11.9:1, and in the Fall of 1976 when the ratio of average concentrations of nitrogen to phosphorus was 8.9:1. This indicated that summer aquatic plant growth in North Lake is generally limited by phosphorus.

Sediment contributions also have an important effect on the condition of a lake. As a lake bottom is covered by material washed into the lake or by the remains of aquatic plants, valuable benthic habitats may be destroyed, substrate suitablity to accommodate rooted plants may be increased, fish spawning areas may be destroyed, and aesthetic nuisances may develop. In addition, sediment particles may act as a transport mechanism for other substances, such as phosphorus, nitrogen, organic substances, pesticides, and heavy metals from the watershed and atmosphere.

EXISTING AND PROBABLE FUTURE POLLUTION SOURCES AND LOADINGS

Estimates were made of the nitrogen, phosphorus, and suspended solid loadings to North Lake from direct drainage area runoff and atmospheric contributions, and of losses through the outlet during the study year. Input and output from surface water were based on flow and water quality data collected at the Oconomowoc River, Little Oconomowoc River, Mason Creek, the outlet of Cornell Lake, and the outlet of North Lake. Ranges and mean values for water quality parameters measured at these sites and in the groundwater wells are set forth in Table 13.

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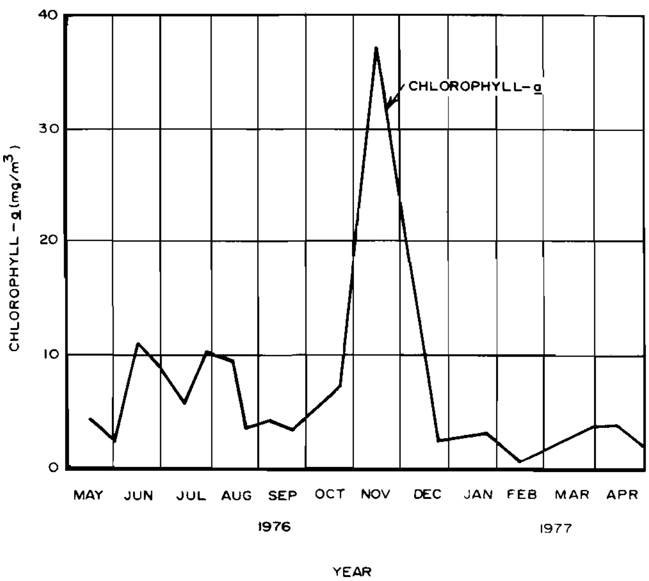
[5] *M. O. Allum, R. E. Gessner, and T. H. Gokstatter, An Evaluation of the National Eutrophication Data. U. S. Environmental Protection Agency Working Paper No. 900, 1977.*

Figure 8

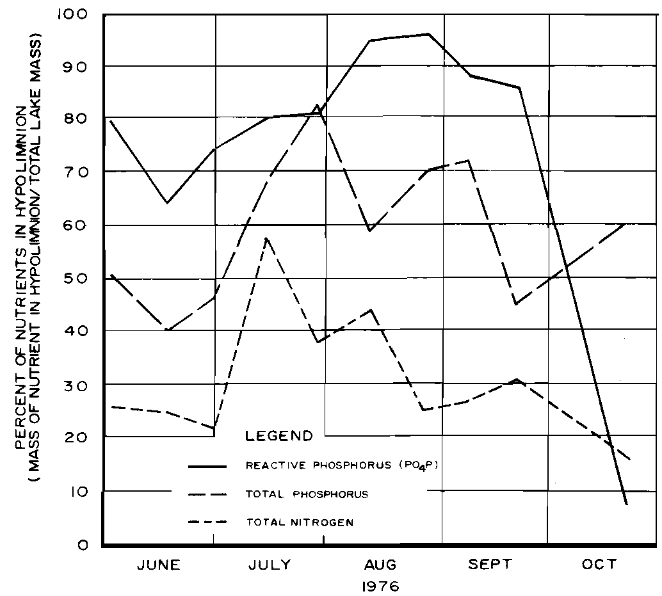
MEASURED CHLOROPHYLL-a CONCENTRATIONS IN NORTH LAKE: 1976-1977



Source: Wisconsin Department of Natural Resources.

Figure 9

PERCENTAGE OF HYPOLIMNETIC NITROGEN, TOTAL PHOSPHORUS, AND REACTIVE PHOSPHORUS (PO_4) IN NORTH LAKE: 1976



Source: Wisconsin Department of Natural Resources.

Table 10

CHARACTERISTIC CHLORIDE CONCENTRATIONS IN REPRESENTATIVE LAKES IN SOUTHEASTERN WISCONSIN

Lake	County	Period of Record	Mean Chloride (mg/l)	Number of Samples
Ashippun........	Waukesha	April 1975-April 1978........	18.1	11
Eagle...........	Racine	July 1975-April 1979.........	28.5	4
Geneva..........	Walworth	November 1973-April 1979.....	14.5	15
George..........	Kenosha	February 1976-July 1977......	34.3	6
Lac La Belle....	Waukesha	March 1976-March 1977........	18.0	17
North...........	Waukesha	September 1973-April 1979....	14.5	12
Oconomowoc......	Waukesha	September 1973-April 1979....	15.2	11
Okauchee........	Waukesha	September 1973-April 1978....	14.6	21
Paddock.........	Kenosha	September 1973-July 1977.....	24.5	9
Pewaukee........	Waukesha	June 1972-March 1979.........	36.6	11
Pike............	Washington	August 1973-November 1975....	28.8	11
Wandawega.......	Walworth	March 1979-April 1979........	4.7	2

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 11

TOTAL NITROGEN AND REACTIVE AND TOTAL PHOSPHORUS DYNAMICS IN THE HYPOLIMNION OF NORTH LAKE: 1976

Date (1976)	Hypolimnion		Hypolimnetic Percentages Based on Total Hypolimnetic Mass per Total Lake Mass		
	Volume (acre-feet)	Percent of Total Lake Volume	Percent of Total Nitrogen	Percent of Phosphate Phosphorus	Percent of Total Phosphorus
June 2..........	4,557	25	26	80	51
June 17.........	4,557	25	25	64	40
June 30.........	4,557	25	22	74	46
July 15.........	10,289	57	58	80	68
July 29.........	7,128	39	38	81	82
August 11.......	7,128	39	44	95	59
August 25.......	4,557	25	25	96	70
September 9.....	4,557	25	27	88	72
September 22....	4,557	25	31	86	45
October 22......	2,473	14	16	8	60
Mean	5,436	30	31	75	59

Source: Wisconsin Department of Natural Resources.

Table 12

RATIO OF OBSERVED IN-LAKE CONCENTRATIONS OF NITROGEN TO PHOSPHORUS FOR NORTH LAKE: 1973-1979

Sample Date	Nitrogen (milligrams per liter)	Phosphorus (milligrams per liter)	Nitrogen to Phosphorus Ratio
September 20, 1973.................	1.31	0.06	20.8
November 20, 1973..................	1.31	0.11	11.9
February 2, 1974...................	2.01	0.06	35.3
April 5, 1974......................	1.55	0.06	23.8
July 11, 1974......................	2.66	0.02	115.7
November 20, 1974..................	1.78	0.11	16.2
February 20, 1975..................	1.64	0.05	30.9
April 24, 1975.....................	1.97	0.07	28.1
July 2, 1975.......................	1.48	0.07	22.1
November 24, 1975..................	1.25	0.06	20.8
Spring 1976			
Mid-March to Mid-June............	1.42	0.05	28.4
Summer 1976			
Mid-June to Mid-September........	1.44	0.09	16.0
Fall 1976			
Mid-September to Mid-December....	1.16	0.13	8.9
Winter 1976-1977			
Mid-December to Mid-March........	0.96	0.03	32.0
March 16, 1979.....................	1.66	0.04	41.5
April 22, 1979.....................	1.37	0.06	21.7

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table 13

WATER QUALITY PARAMETERS FOR THE INLETS, OUTLET, AND GROUNDWATER WELLS OF NORTH LAKE: 1976-1977

Water Quality Parameter[a]	Inlets								Outlet		Groundwater Wells 11, 13, 15, 17, 18	
	Oconomowoc River		Little Oconomowoc River		Mason Creek		Cornell Lake		Oconomowoc River			
	Range	Mean[b]	Range	Mean[b]	Range	Mean[b]	Range	Mean[b]	Range	Mean[b]	Range	Mean[b]
Nitrite (NO_2)	<0.001-0.121	0.018(24)	<0.001-0.059	0.019(23)	0.001-0.039	0.014(24)	0.002-0.143	0.028(13)	<0.001-0.079	0.012(26)	0.003-0.135	0.044(7)
Nitrate (NO_3)	0.14-1.71	0.78(24)	0.11-4.48	0.92(23)	0.20-5.22	2.65(25)	<0.02-0.55	0.21(13)	0.06-0.95	0.43(26)	--	--
Ammonia (NH_3)	<0.03-0.15	0.04(24)	<0.04-0.15	0.06(23)	<0.03-0.31	0.06(25)	<0.04-0.13	0.04(13)	<0.03-0.12	0.04(26)	0.04-3.86	1.69(7)
Organic Nitrogen (OrgN)	0.17-1.17	0.71(24)	0.24-2.40	1.00(23)	0.14-2.59	0.74(25)	0.54-114	0.83(13)	0.31-0.97	0.58(26)	0.04-6.12	2.17(7)
Total Nitrogen (TotN)	0.31-1.95	1.55(24)	0.59-6.64	1.98(23)	1.07-6.60	3.67(25)	0.85-1.64	1.09(13)	0.55-1.77	1.06(26)	--	--
Reactive Phosphorus (PO_4P)	0.008-0.064	0.026(24)	0.022-0.292	0.097(23)	0.011-0.782	0.095(25)	0.023-0.169	0.099(13)	0.009-0.091	0.025(26)	--	--
Total Phosphorus	0.01-0.25	0.08(24)	0.06-0.45	0.14(23)	0.03-0.99	0.12(25)	0.06-0.52	0.20(13)	<0.01-0.22	0.05(26)	0.01-0.04	0.02(7)
Chloride (Cl)	13-19	15(18)	11-26	17(17)	12-26	16(19)	8-23	14(10)	11-20	16(20)	--	--
Specific Conductance (micromhos/cm)	485-639	552(18)	397-731	569(17)	491-863	623(19)	324-555	439(10)	449-578	503(20)	--	--
pH (standard units)	7.6-8.3	8.0(17)	7.4-8.1	7.8(16)	7.6-8.3	8.0(18)	7.2-7.9	7.9(10)	7.6-8.5	8.1(19)	--	--
Total Suspended Solids	1.67-43.20	16.61(9)	0.80-44.80	14.93(6)	1.20-14.60	5.42(8)	4.0-15.20	7.10(4)	0.40-8.33	4.03(8)	--	--
Biological Oxygen Demand	1.4-13.0	52(9)	1.2-6.4	3.8(6)	0.8-11.0	3.8(8)	1.6-13.2	7.6(4)	0.8-11.8	4.3(8)	2.2-6.8	4.8(6)
Chemical Oxygen Demand	6.02-52.43	26.62(9)	6.60-77.31	50.55(6)	6.73-86.64	38.94(8)	21.93-45.32	32.16(4)	12.04-27.54	19.16(8)	32.5-149.9	63.9(5)
Membrane Filter Fecal Count per 100 Milliliters	--	--	--	--	--	--	--	--	--	--	<10-8,100	<10(12)

[a] All values reported in mg/l unless otherwise specified.

[b] Number of samples in parentheses.

Source: Wisconsin Department of Natural Resources and SEWRPC.

Atmospheric contributions of nitrogen, phosphorus, and suspended solids were calculated based on precipitation records and literature values for the different constituents, which are considered to be the most representative for the North Lake region.[6] [7]

The measured concentrations during the study period were used to develop annual loading budgets for nitrogen, phosphorus, and sediment as shown in Table 14 and Figures 10, 11, and 12. During the year of the study, it is estimated that 2 percent of the phosphorus and 16 percent of the nitrogen entering the lake came from groundwater, 2 percent of the phosphorus and 5 percent of the nitrogen came from direct drainage, 89 percent of the phosphorus and 75 percent of the nitrogen came from the major inlets and 7 percent of the phosphorus and 6 percent of the nitrogen came from precipitation and dry fallout on the lake surface. The largest source of sediment loading input--78 percent--is the Oconomowoc River. Of the total mass of nutrients and sediment entering North Lake, 47 percent of the nitrogen, 68 percent of the phosphorus, and 67 percent of the sediment remained in the lake. The nitrogen and phosphorus mass in North Lake for the June 1976 to April 1977 period is shown in Figure 13.

Groundwater quality was monitored in paired observation wells around North Lake. Groundwater contributions for inorganic nitrogen--nitrites (NO_2) and nitrates (NH_3)--ranged from 0.003 to 3.86 milligrams per liter (mg/l) while phosphorus values ranged from 0.01 to 0.04 mg/l, with a mean value of 0.02 mg/l. Other parameters are given in Table 13. Because the study was conducted in a drought period, the percent of nutrient contribution attributed to groundwater--16 percent of total nitrogen and 2.4 percent of total phosphorus--during the study could be higher than during a year of normal precipitation.

Phosphorus has been identified as the factor generally limiting aquatic plant growth in North Lake. Excessive levels of phosphorus in the lake are likely to result in conditions which interfere with the desired use of the lake. Existing and forecast year 2000 phosphorus sources to the lake were identified and quantified using Commission 1975 land use inventory data; Commission planned year 2000 land use data, derived from the adopted regional land use plan; and the Commission water quality simulation model.

Table 15 sets forth the estimated phosphorus loads to North Lake under 1975 and anticipated year 2000 conditions, if no nonpoint source controls are implemented in the lake watershed. Direct tributary phosphorus loads in the lake watershed may be expected to remain approximately the same in the drainage area. The estimated annual direct tributary total phosphorus load to North Lake is about 913 pounds and 942 pounds under existing 1975 and anticipated year 2000 conditions, respectively. The major direct tributary sources of phosphorus in the lake drainage area under existing conditions are livestock operations, septic tank systems, and direct atmospheric contributions to the water surface. Septic tank systems are not expected to be as major a source of phosphorus under anticipated year 2000 conditions following the provision of sanitary sewer service to a large segment of direct drainage area. In addition to the direct tributary phosphorus load, about 4,300 pounds of phosphorus, representing about 82 percent of the total phosphorus load to the lake, is contributed under existing 1975 conditions by the upstream drainage from the Oconomowoc

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[6] *J. W. Kluesner, Nutrient Transport and Transformation in Lake Wingra, Wisconsin, Ph.D. Thesis, University of Wisconsin at Madison, 1972.*

[7] *T. J. Murphy and P. V. Joskey, Inputs of Phosphorus from Precipitation to Lake Michigan, Journal of Great Lakes Research, Volume 2, No. 1, 1976, pp. 66-70.*

Table 14

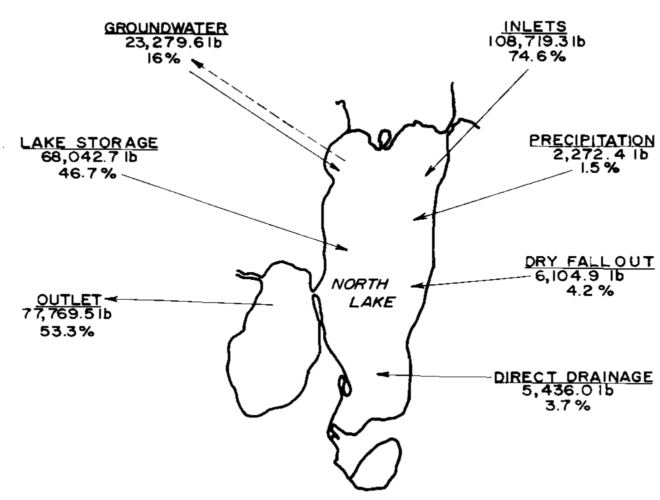
ANNUAL LOADING BUDGETS TO NORTH LAKE FOR NITROGEN, PHOSPHORUS, AND SEDIMENT BASED ON MEASURED DATA: 1976-1977

Source	Nitrogen		Phosphorus		Sediment	
	Amount (pounds)	Total Input (percent)	Amount (pounds)	Total Input (percent)	Amount (pounds)	Total Input (percent)
Inputs						
Oconomowoc River..............	64,614	44	3,101	55	651,650	78
Little Oconomowoc River.......	16,128	11	886	16	62,933	8
Mason Creek...................	17,238	12	415	7	43,861	5
Cornell Lake Outlet...........	10,739	7	636	11	15,964	2
Inlets Subtotal	108,719	74	5,038	89	774,408	93
Direct Shoreland Drainage.....	5,436	4	101	2	38,720	5
Precipitation.................	2,272	2	44	1	--	--
Dry Fallout...................	6,105	4	314	6	19,163	2
Groundwater (net).............	23,280	16	136	2	--	--
Total Inputs	145,812	100	5,633	100	832,291	100
	Amount (pounds)	Total Output (percent)	Amount (pounds)	Total Output (percent)	Amount (pounds)	Total Output (percent)
Outputs						
Oconomowoc River Outlet.......	77,769	53	1,783	32	271,455	33
Net Deposition into Bottom Sediments.............	68,043	47	3,850	68	560,836	67
Total Outputs	145,812	100	5,633	100	832,291	100

Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 10

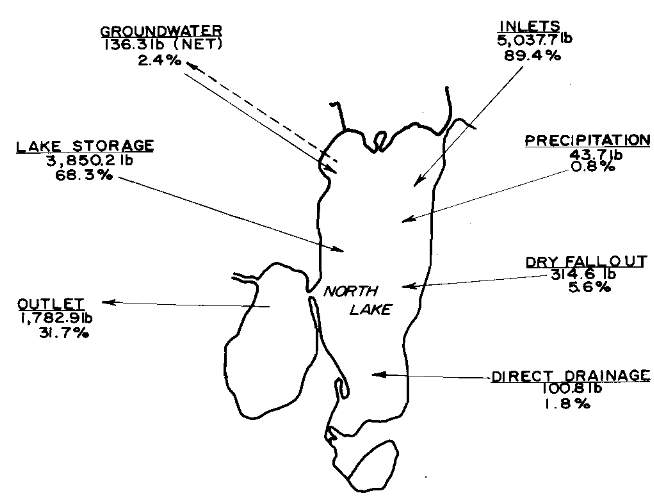
NITROGEN BUDGET FOR NORTH LAKE: 1976-1977



Source: Wisconsin Department of Natural Resources.

Figure 11

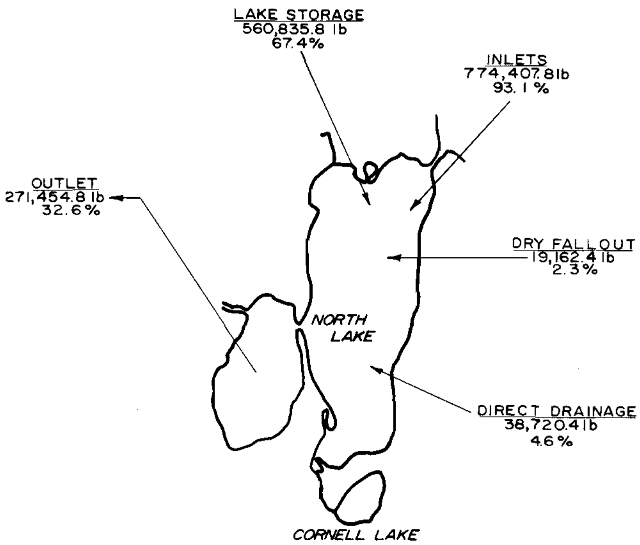
PHOSPHORUS BUDGET FOR NORTH LAKE: 1976-1977



Source: Wisconsin Department of Natural Resources.

Figure 12

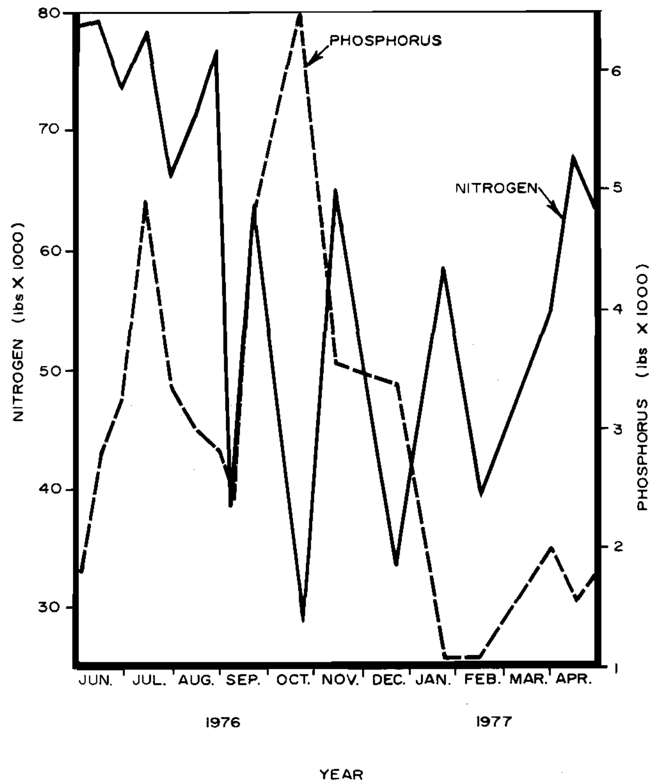
SEDIMENT BUDGET FOR NORTH LAKE: 1976-1977



Source: Wisconsin Department of Natural Resources.

Figure 13

NITROGEN AND PHOSPHORUS MASS IN NORTH LAKE: JUNE 1976-APRIL 1977



Source: Wisconsin Department of Natural Resources.

River and Mason Creek. Under anticipated year 2000 conditions, and following the implementation of recommended water pollution control measures in the upstream drainage areas, the phosphorus load from the Oconomowoc River is expected to decrease to about 2,600 pounds per year, representing about 73 percent of the total phosphorus load to the lake.

TROPHIC CONDITION RATING

Lakes are commonly classified according to their degree of nutrient enrichment--or trophic status. The ability of lakes to support a variety of recreational activities and healthy fish and aquatic life communities is often correlated to the degree of nutrient enrichment which has occurred. There are three terms generally used to describe the trophic status of a lake: oligotrophic, mesotrophic, and eutrophic.

Oligotrophic lakes are nutrient-poor lakes. These lakes characteristically support relatively few aquatic plants and often do not contain productive fisheries. Oligotrophic lakes may provide excellent opportunities for swimming, boating, and waterskiing. Because of the naturally fertile soils and the intensive land use activities, there are relatively few oligotrophic lakes in southeastern Wisconsin.

Table 15

ESTIMATED TOTAL PHOSPHORUS LOADS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE: 1975 AND 2000

Source of Phosphorus	Existing 1975			Anticipated 2000[a]		
	Extent	Total Loading (pounds per year)	Percent Distribution	Extent	Total Loading (pounds per year)	Percent Distribution
Residential Land	367.1 acres	41.8	4.6	420.0 acres	47.9	5.1
Commercial Land	0.6 acre	0.4	<0.1	0.7 acre	0.4	<0.1
Industrial Land	0.6 acre	0.4	<0.1	0.6 acre	0.4	<0.1
Governmental and Institutional Land	4.7 acres	3.0	0.3	5.6 acres	3.5	0.4
Transportation Land	99.4 acres	62.6	6.9	113.8 acres	71.7	7.6
Construction Activities	--	--	--	4.9 acres	222.3	23.6
Recreational Land	53.0 acres	8.2	0.9	54.0 acres	8.4	0.9
Septic Tank System	92 systems[c]	266.8	29.2	22 systems[c]	63.8	6.8
Urban Subtotal	--	383.2	41.9	--	418.4	44.4
Agricultural Land	847.6 acres	71.2	7.8	783.0 acres	65.8	7.0
Direct Atmospheric Contributions to Water Surfaces[b]	457.0 acres	228.5	25.0	457.0 acres	228.5	24.3
Woodlands	232.9 acres	28.1	3.2	227.2 acres	27.3	2.9
Wetlands	43.7 acres	--	--	42.0 acres	--	--
Open Land	18.4 acres	1.8	0.2	16.3 acres	1.6	0.2
Livestock	100 animal units[d,e]	200.0	21.9	100 animal units[d,e]	200.0	21.2
Rural Subtotal	--	529.6	58.1	--	523.2	55.6
Total	--	912.8[f]	100.0	--	941.6[f]	100.0

[a] Assumes provision of sanitary sewer service as recommended in the regional water quality management plan, assumes no nonpoint source control.

[b] Includes the area of North Lake.

[c] Includes only those systems on soils having severe or very severe limitations for disposal of septic tank effluent.

[d] An animal unit is the equivalent in waste production of a 1,000-pound dairy cow.

[e] Updated loading rate based on 1981 field inventory information.

[f] Does not include the 1975 estimated phosphorus load of 4,300 pounds per year or the year 2000 anticipated phosphorus load of 2,600 pounds per year contributed by the upstream drainage from the Oconomowoc and Little Oconomowoc Rivers and Mason Creek.

Source: SEWRPC.

Mesotrophic lakes are moderately fertile lakes which may support abundant aquatic plant growths and may support productive fisheries. Nuisance growths of algae and macrophytes are usually not exhibited by mesotrophic lakes. These lakes may provide opportunities for all types of recreational activities, including boating, swimming, fishing, and waterskiing. Many lakes in southeastern Wisconsin are mesotrophic.

Eutrophic lakes are nutrient-rich lakes. These lakes often exhibit excessive aquatic macrophyte growths and/or experience frequent algae blooms. If the lakes are shallow, fish winterkills may be common. While portions of these lakes are not ideal for swimming and boating, many eutrophic lakes support very productive fisheries.

The trophic status of North Lake was evaluated by the application of three commonly used methods: the Lake Condition Index, the Dillon and Rigler Model, and the Trophic State Index.

Uttormark and Wall developed a method for lake classification based on four indicators of eutrophication: dissolved oxygen levels; water clarity (transparency); occurrence of fish winterkills; and recreational use impairment due to algae blooms and/or excessive macrophyte growth.[8] A measure--referred to as a Lake Condition Index--was devised in which points are assigned for undesirable symptoms of water pollution. Thus if a lake exhibits no undesirable symptoms of eutrophication, it receives no points and has a Lake Condition Index of zero. Conversely, a lake with all the undesirable characteristics in the most severe degree has a Lake Condition Index of 23. Using the Uttormark-Wall classification system, North Lake received a Lake Condition Index of 8--as set forth in Table 16--which is indicative of mesotrophic lakes. This value is higher--that is, more eutrophic--than 12 of the 22 rated lakes in Waukesha County, and higher than 32 of the 65 rated lakes in the seven-county Southeastern Wisconsin Region, as shown in Table 17. Therefore, based on the Lake Condition Index, North Lake is less eutrophic than approximately 50 percent of the lakes in Waukesha County and in southeastern Wisconsin.

Dillon and Rigler developed a model for predicting the total phosphorus concentration of a lake during spring turnover based on the physical characteristics of the lake, hydrologic data, and phosphorus loading data.[9] The predicted phosphorus concentrations can also be correlated to average summer chlorophyll-a and Secchi Disc (water transparency) levels. Using phosphorus loads estimated by the Commission's water quality simulation model, the Dillon and Rigler model was applied to North Lake under existing conditions. The model analysis resulted in a predicted total phosphorus concentration of 0.04 mg/l for North Lake. This predicted value is above the recommended SEWRPC phosphorus standard of 0.02 mg/l established for lakes to support recreational use and warmwater fish and aquatic life, as discussed in Chapter 7. For North Lake, an average summer chlorophyll-a concentration of 17.5 micrograms per liter (ug/l) and an average summer Secchi Disc depth of 4.4 feet are also predicted. These data indicate that North Lake would be classified as a mesotrophic lake. Table 18 compares the predicted phosphorus concentration, chlorophyll-a concentration, and Secchi Disc depth to measured data for North Lake. The table indicates that the predicted values compare reasonably well with measured values.

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[8] *P. D. Uttormark and J. P. Wall, Lake Classification--A Trophic Characterization of Wisconsin Lakes, Environmental Protection Agency Report No. EPA-660/3-75-033, 1975.*

[9] *D. J. Dillon and F. H. Rigler, "A Simple Method for Predicting the Capacity of a Lake for Development Based on Lake Trophic Status," Journal of the Fisheries Research Board of Canada, Volume 32, 1975, pp. 1519-1531.*

Table 16

LAKE CONDITION INDEX CALCULATION FOR NORTH LAKE

Lake Conditions	Lake Condition Index Penalty Points
Dissolved Oxygen Concentrations:	
Zero During Some Periods in Portions of the Hypolimnion	4
Water Clarity:	
Secchi Disc Values Average About 5 Feet	2
Occurrence of Fish Winterkills:	
None	0
Recreational Use Impairments Due to Algae Blooms and/or Aquatic Macrophyte Growth:	
Occasional Blue-Green Algae Blooms and Moderate Aquatic Macrophyte Growth	2
Total	8

Source: SEWRPC.

A third measure of trophic condition can be achieved by the application of the Trophic State Index (TSI).[10] The Trophic State Index may be computed using total phosphorus, Secchi Disc, and chlorophyll-a measurements to assign a trophic status rating to a lake.

The equation for calulating these three TSI values are:

$$TSI_{\text{Total Phosphorus}} = 10\left(6 - \frac{\text{Natural log of } 40.5/\text{Total Phosphorus in } \mu g/l}{\text{Natural log of } 2}\right)$$

$$TSI_{\text{Secchi Disc}} = 10\left(6 - \frac{\text{Natural log of Secchi Disc in Meters}}{\text{Natural log of } 2}\right)$$

$$TSI_{\text{Chlorophyll-}a} = 10\left(6 - \frac{2.04 - 0.68 \text{ Natural log of Chlorophyll-}a \text{ in } \mu g/l}{\text{Natural log of } 2}\right)$$

TSI ratings of less than 35 are indicative of oligotrophic lakes; ratings of 35 to 50 signify mesotrophic lakes; and ratings higher than 50 are indicative of eutrophic lakes.

[10] *R. E. Carlson, "A Trophic State Index for Lakes," Limnology and Oceanography, Volume 22, No. 2, 1977, pp. 361-369.*

Table 17

LAKE CONDITION INDEX OF SELECTED MAJOR LAKES IN SOUTHEASTERN WISCONSIN: 1975

Watershed	Major Lake Name	County	Lake Condition Index[a]	Category
Des Plaines.	Benet and Shangrila	Kenosha	13	very eutrophic
Des Plaines.	Paddock	Kenosha	9	mesotrophic
Fox	Beulah	Walworth	7	mesotrophic
Fox	Big Muskego	Waukesha	12	eutrophic
Fox	Bohners	Racine	6	mesotrophic
Fox	Booth	Walworth	6	mesotrophic
Fox	Browns	Racine	8	mesotrophic
Fox	Buena	Racine	6	mesotrophic
Fox	Camp	Kenosha	14	very eutrophic
Fox	Center	Kenosha	6	mesotrophic
Fox	Como	Walworth	13	very eutrophic
Fox	Denoon	Waukesha	8	mesotrophic
Fox	Eagle	Racine	20	very eutrophic
Fox	Eagle Spring	Waukesha	5	mesotrophic
Fox	Echo	Racine	6	mesotrophic
Fox	Elizabeth	Kenosha	6	mesotrophic
Fox	Geneva	Walworth	5	mesotrophic
Fox	Green	Walworth	9	mesotrophic
Fox	Little Muskego	Waukesha	12	eutrophic
Fox	Long	Racine	17	very eutrophic
Fox	Lower Phantom	Waukesha	9	mesotrophic
Fox	Marie	Kenosha	8	mesotrophic
Fox	Middle	Walworth	7	mesotrophic
Fox	Mill	Walworth	8	mesotrophic
Fox	North	Walworth	13	very eutrophic
Fox	Pell	Walworth	12	eutrophic
Fox	Pewaukee	Waukesha	13	very eutrophic
Fox	Pleasant	Walworth	4	oligotrophic
Fox	Potters	Walworth	12	eutrophic
Fox	Powers	Kenosha	8	mesotrophic
Fox	Silver	Kenosha	8	mesotrophic
Fox	Spring	Waukesha	4	oligotrophic
Fox	Tichigan	Racine	21	very eutrophic
Fox	Upper Phantom	Waukesha	6	mesotrophic
Fox	Wandawega	Walworth	13	very eutrophic
Fox	Waubeesee	Racine	7	mesotrophic
Fox	Wind	Racine	7	mesotrophic
Milwaukee	Big Cedar	Washington	5	mesotrophic
Milwaukee	Little Cedar	Washington	5	mesotrophic
Milwaukee	Mud	Ozaukee	10	eutrophic
Milwaukee	Silver	Washington	3	oligotrophic

Figure 14 sets forth the TSI calculations for the period of 1973 through 1977 for North Lake. The Secchi Disc values shown in Figure 14 indicate that North Lake is a mesotrophic lake, whereas the total phosphorus values indicate that the lake is eutrophic. The values do not indicate any long-term trends in water quality conditions.

Based on the above classifications and analyses, it may be concluded that the characteristics of North Lake are indicative of a mesotrophic lake.

Table 17 (continued)

Watershed	Major Lake Name	County	Lake Condition Index[a]	Category
Rock	Beaver	Waukesha	7	mesotrophic
Rock	Comus	Walworth	15	very eutrophic
Rock	Delavan	Walworth	14	very eutrophic
Rock	Druid	Washington	6	mesotrophic
Rock	Five	Washington	12	eutrophic
Rock	Friess	Washington	3	oligotrophic
Rock	Golden	Waukesha	8	mesotrophic
Rock	Keesus	Waukesha	8	mesotrophic
Rock	Lac La Belle	Waukesha	10	eutrophic
Rock	Loraine	Walworth	12	eutrophic
Rock	Lower Nemahbin	Waukesha	5	mesotrophic
Rock	Middle Genesee	Waukesha	3	oligotrophic
Rock	Nagawicka	Waukesha	13	very eutrophic
Rock	North	Waukesha	5	mesotrophic
Rock	Oconomowoc	Waukesha	8	mesotrophic
Rock	Okauchee	Waukesha	5	mesotrophic
Rock	Pike	Washington	3	oligotrophic
Rock	Pine	Waukesha	7	mesotrophic
Rock	Silver	Waukesha	5	mesotrophic
Rock	Tripp	Walworth	6	mesotrophic
Rock	Turtle	Walworth	5	mesotrophic
Rock	Upper Nashotah	Waukesha	4	oligotrophic
Rock	Upper Nemahbin	Waukesha	7	mesotrophic
Rock	Whitewater	Walworth	7	mesotrophic

[a] *Lake Condition Index Trophic Classification*

0 - 1 = very oligotrophic
2 - 4 = oligotrophic
5 - 9 = mesotrophic
10-12 = eutrophic
13-23 = very eutrophic

Source: SEWRPC.

Table 18

COMPARISON OF MEASURED AND PREDICTED TOTAL PHOSPHORUS, CHLOROPHYLL-a, AND SECCHI DISC LEVELS IN NORTH LAKE

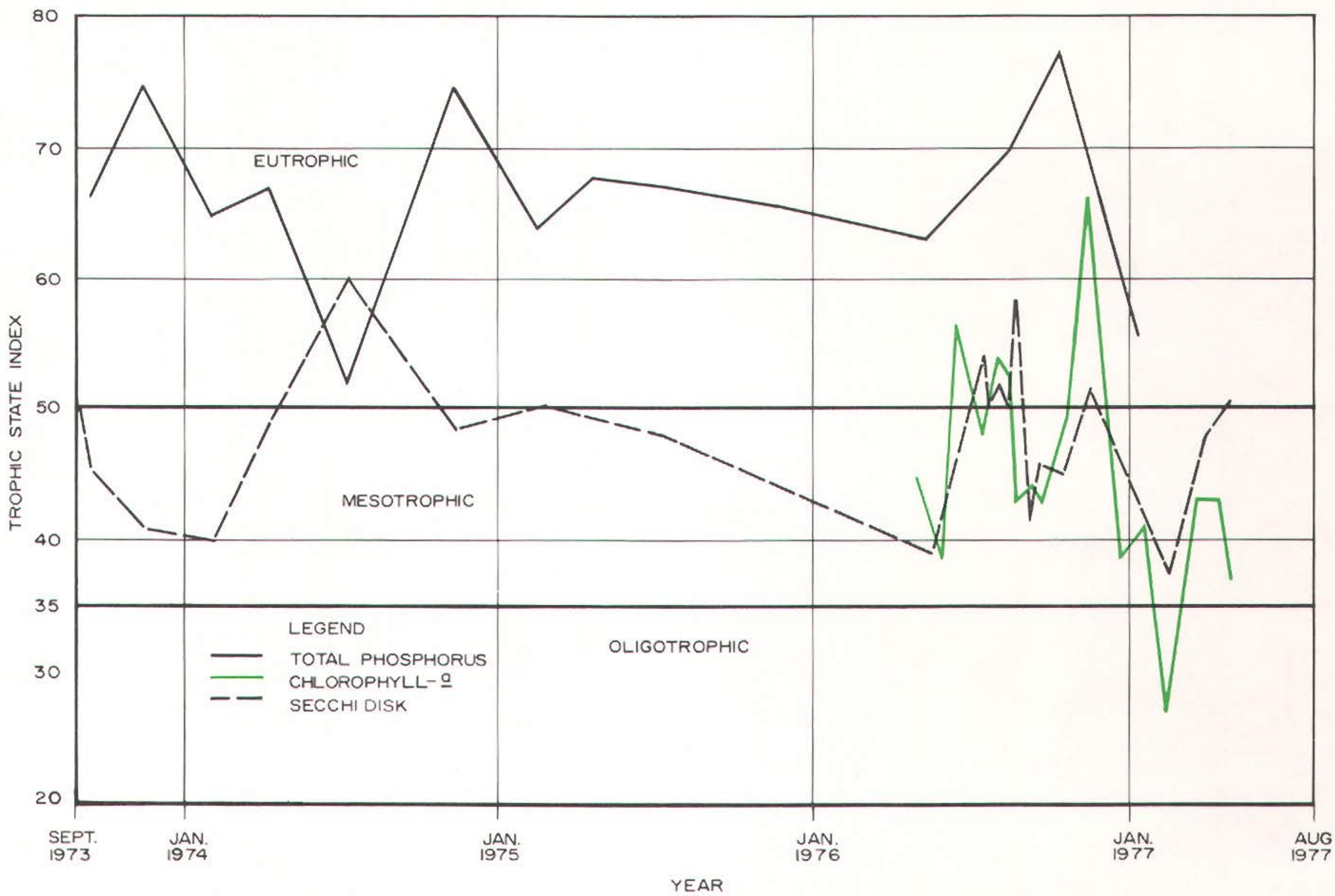
Water Quality Parameter	Predicted[a]	Measured[b]	
		Range	Mean
Total Phophorus[c] Concentration (mg/l) . . .	0.04	0.04-0.07	0.06
Chlorophyll-a[d] Concentration (µg/l) . . .	17.5	2.3-11.0	7.1
Secchi Disc[d] Depth (feet)	4.4	3.3-8.3	5.8

[a] *Based on the Dillon and Rigler (1974) model.*
[b] *Based on measured data from 1973 through 1979.*
[c] *Concentration during spring turnover.*
[d] *Average summer values.*

Source: SEWRPC.

Figure 14

TROPHIC STATE INDEX CALCULATIONS FOR NORTH LAKE: 1973-1977



Source: Wisconsin Department of Natural Resources and SEWRPC.

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Chapter V

NATURAL RESOURCE BASE AND RECREATIONAL ACTIVITIES

AQUATIC PLANTS

Macrophytes

Aquatic macrophytes, such as pondweeds, coontails, water milfoils, rushes, and cat-tails, play an important role in the ecology of southeastern Wisconsin lakes. Depending on distribution and abundance, they can be either beneficial or a nuisance. Macrophytes growing in the proper locations and in reasonable densities in lakes are beneficial because they provide habitat for other forms of aquatic life and may remove nutrients from the water that otherwise could contribute to excessive algae growth. However, aquatic plants may become a nuisance when heavy densities interfere with swimming and boating activities. Many factors, including lake configuration, depth, water clarity, nutrient availability, bottom substrate, wave action, and type and size of fish populations present determine the distribution and abundance of aquatic macrophytes in a lake.

To document the types, distribution, and relative abundance of aquatic macrophytes in North Lake, a survey was conducted on August 12, 1976. The vegetation was identified and the frequency of occurrence and the relative abundance of each species noted. Ten distinct areas with different plant groups were identified. Map 13 shows the location of these ten distinct areas. The macrophyte species, frequency of occurrence, and relative abundance are listed in Table 19. Illustrations of representative macrophyte species identified in North Lake are set forth in Appendix B.

The survey of aquatic macrophytes indicated that generally sparse to moderate vegetative growth existed in eight of the 10 study areas. As shown in Table 19, some of the areas surveyed either had very low densities of macrophyte growth--areas 2, 5, 6, and 8--or none at all--areas 4 and 7. This lack of growth was attributed primarily to the presence of inadequate substrata.

The dominant macrophytes found in the survey areas were curly-leaf pondweed (Potamogeton crispus), leafy pondweed (Potamogeton foliosus), water milfoil (Myriophyllum excalbescens), and yellow waterlily (Nupha sp.). The area surveyed in the southern tip of the main lake basin was found to have the greatest diversity of plant species. Curly-leaf pondweed and yellow waterlily were the most dominant species, with isolated patches of leafy pondweed, sago pondweed (Potamogeton pectinatus), and coontail (Ceratophyllum sp.) also present. The littoral area from "Jobe's Hole"--as shown on Map 1--to the inlet of the Oconomowoc River in the northwest corner of the main lake basin had abundant stands of water milfoil. Curly-leaf pondweed and leafy pondweed were also found to be common in this area. Accumulations of water milfoil may occasionally reach nuisance conditions in this area of the lake.

Many species of macrophytes are beneficial for lakes. Stonewort (Chara sp.), bushy pondweed (Najas flexilis), and other pondweeds (Potamogeton spp.), provide food, shelter, and habitat for wildlife, such as amphibians, reptiles, and waterfowl.[1] Coontail (Ceratophyllum demersum), stonewort, bushy pondweed, other pondweeds, and water milfoil, provide valuable food and shelter for fish and other aquatic life.

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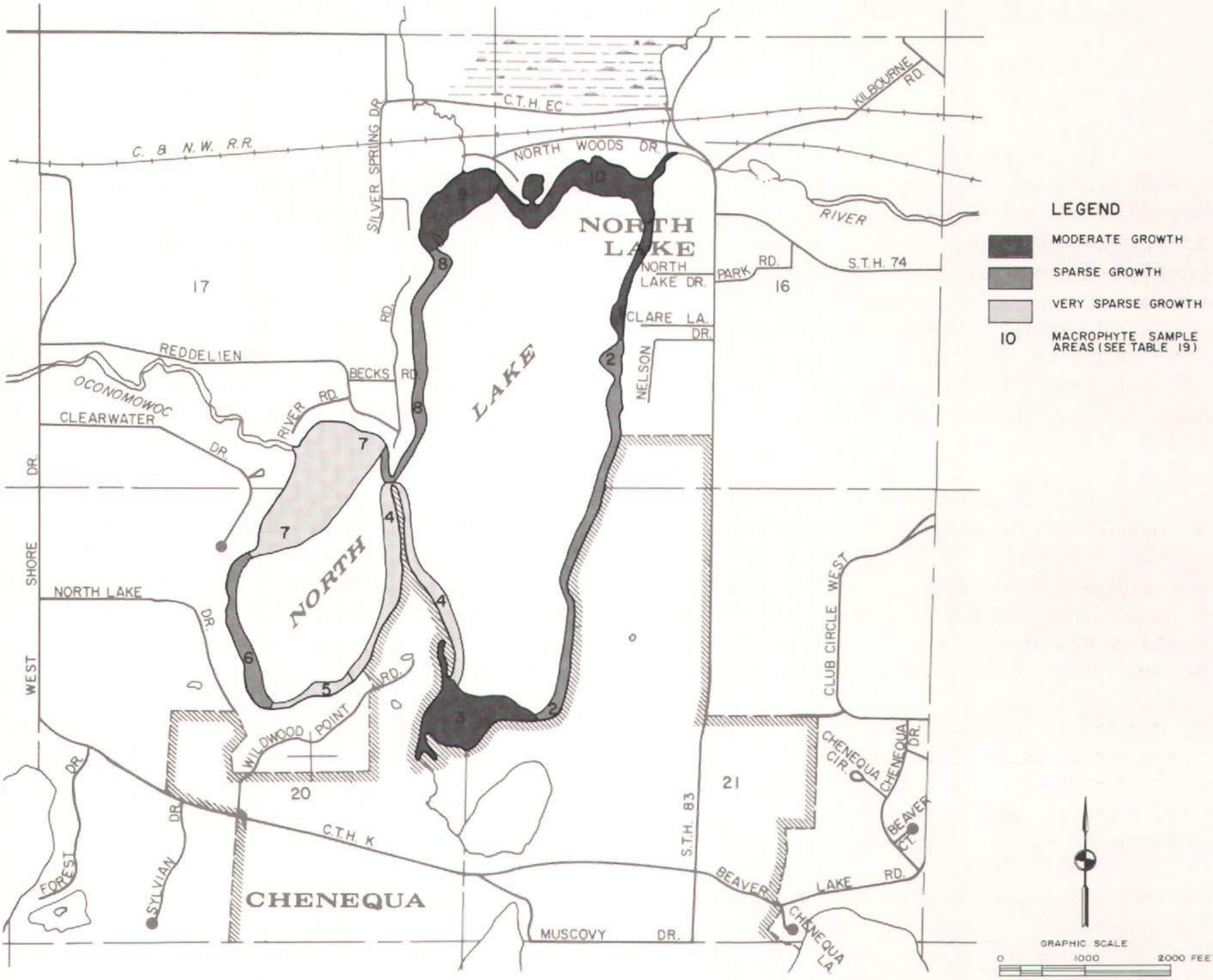
[1] *Stonewort (Chara sp.) is actually a macroscopic algae, but for the purposes of this analysis, is discussed under macrophytes.*

Map 13

LOCATION OF AQUATIC MACROPHYTES IN NORTH LAKE: 1976



Source: Wisconsin Department of Natural Resources and SEWRPC.

Algae

Algae are small, generally microscopic plants that are found in all lakes and streams. They occur in a wide variety of forms, as single cells or colonies, and can be either attached or free floating. Algae are primary producers that form the base of the aquatic food chain. Through photosynthesis, they convert energy and nutrients to the compounds necessary to support life in the aquatic system. Oxygen, which is vital to higher forms of life in a lake or stream, is also produced in the photosynthetic process.

Green algae (Chlorophyta) are the most important source of food for zooplankton--or microscopic animals--in the lakes of southeastern Wisconsin. Blue-green algae (Cynaophyta) are not ordinarily utilized by zooplankton or fish populations, and may become over-abundant and out of balance with the organisms that do feed on them.

Table 19

NORTH LAKE MACROPHYTE SPECIES AND RELATIVE ABUNDANCE BY LAKE AREA: AUGUST 12, 1976

Area	Macrophyte Species	Common Name	Relative Abundance
1	Potamogeton foliosus	Leafy pondweed	Moderate
	Potamogeton crispus[a]	Curly leaf pondweed	Sparse
	Typha latifolia	Cat-tail	Very sparse
	Myriophyllum excalbescens	Water milfoil	Sparse
2	Juncus spp.	Rush	Very sparse
	Potamogeton crispus[a]	Curly leaf pondweed	Very sparse
3	Nuphar spp.	Water lily	Sparse
	Potamogeton foliosus	Leafy pondweed	Very sparse
	Juncus spp.	Rush	Very sparse
	Myriophyllum excalbescens	Water milfoil	Very sparse
	Potamogeton pectinatus[a]	Sago pondweed	Very sparse
	Potamogeton crispus[a]	Curly leaf pondweed	Moderate
	Ceratophyllum spp.	Coontail	Very sparse
4	No vegetation	--	--
5	Potamogeton pectinatus[a]	Sago pondweed	Very sparse
6	Potamogeton pectinatus[a]	Sago pondweed	Very sparse
	Potamogeton crispus[a]	Curly leaf pondweed	Very sparse
	Chara spp.	Stonewort	Very sparse
	Najas flexilis	Bushy pondweed	Very sparse
7	No vegetation	--	--
8	Nuphar spp.	Water lily	Sparse
	Juncus spp.	Rush	Very sparse
	Myriophyllum excalbescens	Water milfoil	Very sparse
	Potamogeton crispus[a]	Curly leaf pondweed	Very sparse
	Potamogeton pectinatus[a]	Sago pondweed	Very sparse
9	Nuphar spp.	Water lily	Moderate
	Potamogeton crispus[a]	Curly leaf pondweed	Moderate
	Myriophyllum excalbescens	Water milfoil	Sparse
	Potamogeton pectinatus	Sago pondweed	Sparse
10	Nuphar spp.	Water lily	Sparse
	Najas flexilis	Bushy pondweed	Very sparse
	Myriophyllum excalbescens	Water milfoil	Moderate
	Potamogeton crispus[a]	Curly leaf pondweed	Moderate
	Potamogeton foliosus	Leafy pondweed	Moderate
	Potamogeton pectinatus	Sago pondweed	Very sparse

[a] *Alien or nonnative species.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Dramatic population increases--blooms--of blue-green algae may occur when excessive nutrient supplies are available, optimum sunlight and temperature conditions exist, and there is a lack of competition from other aquatic plant species and insufficient grazing by zooplankton.

Algae blooms may reach nuisance proportions in fertile--or eutrophic--lakes, resulting in the accumulation of surface scum or slime. In some cases, heavy concentrations of wind-blown algae accumulate on shorelines, where they die and decompose, causing noxious odors and unsightly conditions. The decaying process of algae consumes oxygen, sometimes depleting available supplies and resulting in fish kills. Also, certain species of decomposing blue-green algae may release toxic materials into the water.

The types and concentrations of algae found in North Lake are presented in Figures 15 and 16. In North Lake, algae populations were highest in late August 1976. Generally the phytoplankton were most numerous--greater than 10 million cells/liter of lake water--from mid-June through mid-November, with slight decrease in mid-July--6 million cells/liter--and October--8 million cells/liter.

During the winter and early spring the algal populations fluctuated between a low of two million to a high of nine million cells/liter. With the exception of May 1976, the blue-green algae were dominant during the entire year. Aphanizomenon was the most abundant blue-green algae genus present. This algae often occurs as bundles of floating, rod-shaped filaments that resemble pieces of grass clippings in the water. During the month of May, green algae were the dominant group present, comprising 61 percent of the phytoplankton; and Schorederia setigera was the dominant species of green algae present. Other groups of algae occurring in North Lake included the golden brown algae (Cryptophyta), diatoms, (Bacillariophyta), yellow-green algae (Bacillariophyta) and (Chrysophyta), and brown algae (Pyrrophyta). None of these algae were found to be dominant at any time during the study.

Although algae are not considered a major problem in North Lake, occasional algae blooms could adversely affect recreational activities such as swimming in certain areas of the lake.

AQUATIC ANIMALS

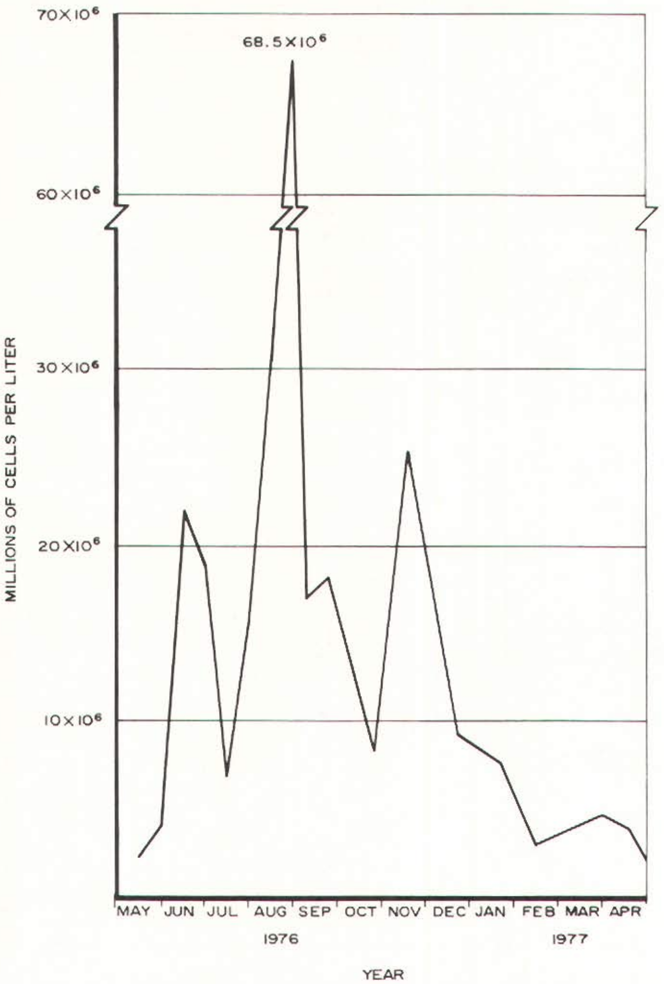
Zooplankton

Zooplankton are microscopic animals which inhabit the same environment as phytoplankton--microscopic plants. An important link in the food chain, crustacean zooplankton feed mostly on algae and, in turn, are a good food source for fish. Zooplankton were collected in the deepest area of the lake, using a No. 20 mesh conical net hauled vertically from the bottom to the surface. The plankton collected in the net were immediately preserved in a 5 percent buffered formalin solution and later identified and counted using a compound microscope.

As shown in Figure 17 and Table 20, 14 species of zooplankton were found in North Lake during the study. The seasonal succession of zooplankton species--pulses--within North Lake during the study year was dominated by a spring pulse of species of Cyclops and Daphnia. Increases were also noted for the cyclops species Skistodiaptomus oregonensis, Daphnia schodleri, and Daphnia galeata mendotae in the fall. Populations cycles of other species of zooplankton during the summer were found

Figure 15

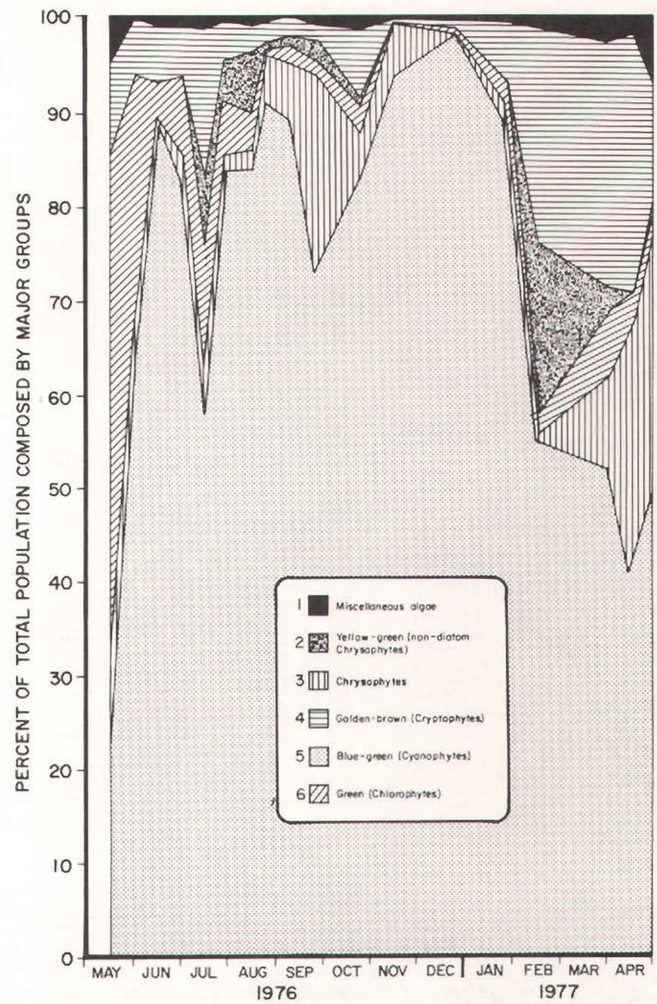
MONTHLY ALGAE POPULATIONS FOR NORTH LAKE: 1976-1977



Source: Wisconsin Department of Natural Resources.

Figure 16

TYPES OF ALGAE FOUND IN NORTH LAKE: 1976-1977



Source: Wisconsin Department of Natural Resources.

to be variable. Cyclops bicuspidatus thomasi, Skistodiaptomus oregonensis, Daphnia galeata mendotae, D. pulicaria and D. schodleri were the dominant animals in the zooplankton community.

In addition to being most abundant, D. galeata mendotae, D. pulicaria and D. schodleri were also the largest zooplankton species in North Lake. These large cladocerans frequently are a major food item in the diets of planktivorous fish and young game fish. In general, fish are selective feeders and consume the largest zooplankton available. As a result of their smaller size, ability to hang motionless, or to make sudden movements, most copepods are not as common a food item for fish as the larger zooplankton. Bosmina longirostris, Diaphanosoma leuchtenbergianum, Chydorus sphaericus, Leptodora kindtii, and Alona guttata were also found in North Lake during the study period. D. leuchtenbergianum and L. kindtii are large cladocera, and the latter species is predaceous on other zooplankton.

Table 20

CRUSTACEAN ZOOPLANKTON FOUND IN NORTH LAKE: 1973-1975 AND 1976-1977

		1973-1975[a]	1976-1977[b]
Class Crustacea			
Subclass:	Copepoda		
Order:	Cyclopoida		
	Cyclops bicuspidatus thomasi	X	X
	Mesocyclops edax	X	X
	Acanthocyclops vernalis	X	X
	Tropocyclops prasinus	X	X
	Eucyclops speratus	X	--
	Eucyclops serrulatus	X	--
Order:	Calanoida		
	Skistodiaptomus oregonensis	X	X
Subclass:	Branchiopoda		
Order:	Cladocera		
	Daphnia pulicaria	X	X
	Daphnia schodleri	--	X
	Daphnia galeata mendotae	X	X
	Daphnia sp.	--	X
	Bosmina longirostris	X	X
	Diaphanosoma leuchtenbergianum	X	X
	Chydorus sphaericus	X	X
	Leptodora kindtii	X	X
	Alona guttata	--	X
	Alona affinis	X	--
	Alona quadrangularis	X	--

[a] *B. G. Torke, Crustacean Zooplankton Data for 199 Selected Wisconsin Inland Lakes, Wisconsin Department of Natural Resources Report No. 101, 1979.*

[b] *Wisconsin Department of Natural Resources.*

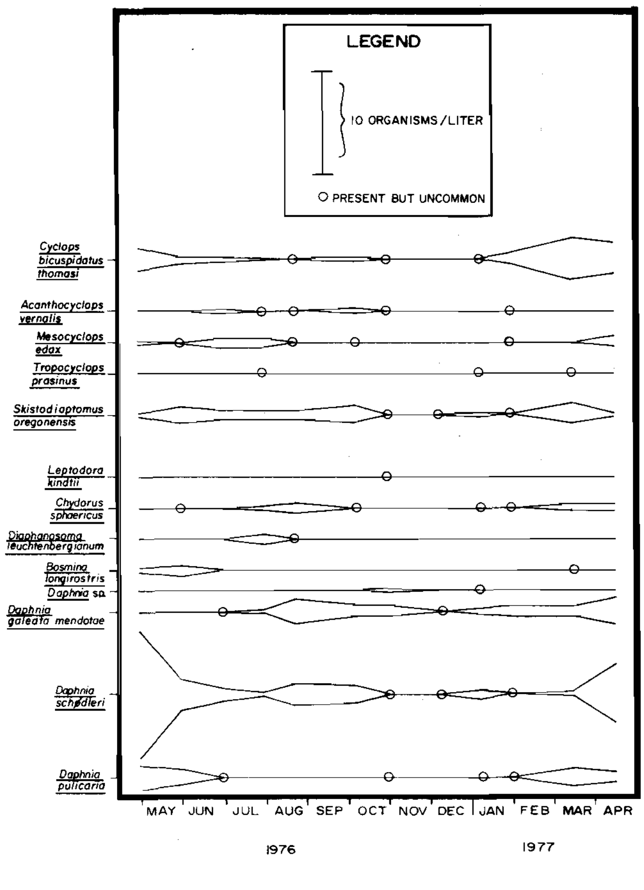
Source: SEWRPC.

An analysis of other zooplankton samples from North Lake collected from 1973 to 1975 by Torke, showed that in addition to the aforementioned species, Alona affinis and Alona quadrangula were present in North Lake. However, Torke did not report sampling Alona guttata or D. schodleri. The presence or absence of any of these species does not indicate a shift in species composition. The species of Alona were rare or uncommon in all samples which may indicate that it was missed or overlooked in his sample analysis. In addition, Torke does not consider D. schodleri to be a valid species and this species would have been included with D. pulicaria. Skistodiaptomus oregonensis was the only calanoid sampled in the lake during both of the studies.

Cyclops bicuspidatus thomasi was the most common cyclopoid copepod found during the Wisconsin Department of Natural Resources study. Other copepods found in North Lake were: Mesocyclops edax, a large and predaceous zooplankton; Acanthocyclops vernalis

Figure 17

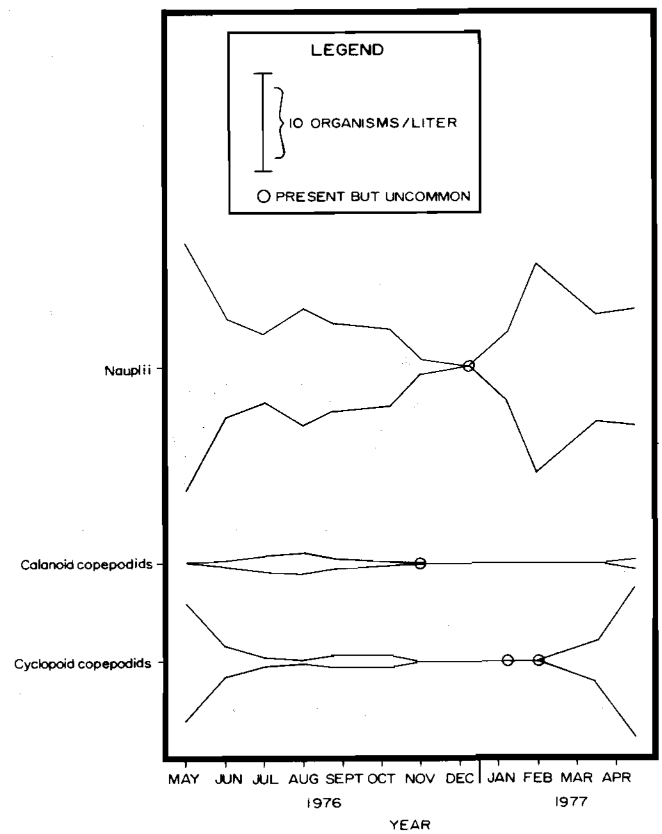
ZOOPLANKTON SPECIES AND ABUNDANCE IN NORTH LAKE: 1976-1977



Source: Wisconsin Department of Natural Resources.

Figure 18

ABUNDANCE OF NAUPLII AND COPEPODIDS FOUND IN NORTH LAKE: MAY 1976-APRIL 1977



Source: Wisconsin Department of Natural Resources.

and Tropocyclops prasinus. In addition to the above species, Torke noted Eucyclops speratus and E. serrulatus which tend to be found in weedy, littoral areas and were rare in his collection.

There are three stages in the life cycle of copepods: egg stage; naupliar larva; and copepodids. Nauplii and copepodids are each, in turn, divided into six stages, the sixth copepodid being the adult. In analyzing the collections, nauplii and copepodids were not separated into their different developmental stages but were grouped into nauplii and copepodids. The abundance of nauplii and copepodids found in North Lake during the study year are presented in Figure 18.

Benthos

The benthic, or bottom dwelling, macroinvertebrate communities of lakes which include such organisms as sludge worms, midges, and caddisfly larvae may be used to assess the existing and recent past water quality of a lake. These organisms are an

Table 21

BENTHIC FAUNA OF NORTH LAKE: 1976 AND 1977

Species	1976[a]		1977[b]	
	Larval Number Per Square Meter	Percent	Larval Number Per Square Meter	Percent
Class: Insecta				
Order: Diptera				
Family: Chaoboridae				
Chaoborus flavicans.....	--	--	84	32
Chaoborus punctipennis..	140	46	37	14
Family: Chironomidae				
Procladius sp...........	--	--	6	2
Eukiefferiella sp.......	--	--	37	14
Orthocladius sp.........	--	--	6	2
Chironomus attenuatus...	158	52	6	2
Chironomus plumosus.....	5	2	--	--
Chironomus staegeri.....	--	--	6	2
Pseudochironomus sp.....	--	--	84	32
Total Larval Number Per Square Meter	303	100	266	100
Number of Species	3		8	

[a]Depth 15m (45 feet).

[b]Depth 12m (65 feet).

Source: Wisconsin Department of Natural Resources.

important part of the food chain, acting as processors of the organic material that accumulates on the lake bottom. Some benthic macroinvertebrate organisms are opportunistic in their feeding habits, while others are openly predaceous. The diversity of communities present is one of the factors that often reflects the trophic status of a lake. In general, greater diversity is indicative of a less eutrophic lake. There is no single "indicator organism" to indicate trophic status; rather the entire community must be assessed. The time of year for this assessment is also an important consideration; and since these populations fluctuate widely during the summer months, early spring or winter sampling is best. The stable population thus found better reflects the lake's character.

North Lake was sampled in the early springs of 1976 and 1977 prior to metamorphosis and adult emergence. Samples were collected at the 15 and 21 meter depths. The larvae were picked from the debris, counted, and classified. Larvae of the Chironomidae--midges--were not reared to adult stages and therefore species names must be considered tentative.

The benthic fauna of North Lake, composed of nine species typical of mesotrophic lakes, are set forth in Table 21. The predominant species were the phantom midges Chaoborus flavicans, and Chaoborus punctipennis, and the midge Chironomus attenuatus. The latter, plus the midge Pseudochironomus sp. comprise the omnivorous portion of the fauna and feed upon organic matter that comes into contact with their mud burrows. The carnivores are both planktonic--or free-floating--(Chaoborus punctipennis) and benthic--or bottom dwelling--(Procladius sp.). Chaoborus spends the daylight hours in or adjacent to the mud substrate and migrates vertically into the water column at night to feed upon zooplankton. The midge Procladius is restricted to the bottom muds and actively seeks its prey which consists of micro-crustacea and small insect larvae, predominantly the young of other benthic species. The population of Chaoborus varies with variations in food supply and predation by fish and other organisms. The results of the two years of sampling do not indicate any trend between the years; the changes in observed numbers being most likely the result of normal population shifts.

The presence of Chiromomus attenuatus, Charoborus flavicans, and Psuedochironomus sp. all support the mesotrophic status of North Lake. The remaining benthic organisms occur in small numbers and all indicate a mesotrophic lake condition where benthic oxygen does not remain absent for long periods of time during summer or winter months. A worsening trophic status would eliminate the present faunal diversity and possibly reduce total numbers, thereby reducing available food organisms. Representative benthic invertebrates identified in North Lake are represented in Appendix B.

Fish

North Lake supports a relatively large and diverse fish community. Studies conducted by the Wisconsin Department of Natural Resources indicate that 27 different fish species have been captured in the lake, as shown in Table 22.[1] [2] However, this list is considered incomplete since other fish species are known to occur in the Oconomowoc River chain.

Good populations of game and panfish and a naturally reproducing walleye population occur in the lake. The fishery has not been stocked in recent years and no stocking programs are planned in the immediate future. None of the fish positively identified in North Lake is classified as a rare or endangered species. However, the slender madtom (Noturus exilis), a small catfish which inhabits rocky riffle zones has been collected from the Oconomowoc River immediately downstream from the North Lake outlet. Slender madtoms have been identified as endangered in Wisconsin. Illustrations of representative fish species identified in North Lake are set forth in Appendix B.

WILDLIFE RESOURCES

Wildlife habitat areas were initially inventoried by the Regional Planning Commission in 1963 and this initial inventory was updated in 1970 for the Commission by the Wisconsin Department of Natural Resources, Bureau of Research. The wildlife habitat areas were classified by the Commission as deer, pheasant, waterfowl, muskrat-mink, songbird, or mixed habitat. These designations were applied to help characterize a particular habitat area as meeting the particular requirements of the indicated species. This classification does not imply that the named species is the most important or dominant species in that particular habitat. For example, an area designated as a deer habitat may also provide squirrel and songbird habitat as well.

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[1] *W. R. Byan, Fish Population Survey of North Lake, Waukesha County, Wisconsin Department of Natural Resources Files, Madison, Wisconsin, 1965.*

[2] *D. M. Fago, Fish Population Survey of the Rock River Drainage Basin, Wisconsin Department of Natural Resources Files, Madison, Wisconsin, 1975.*

Table 22

SPECIES OF FISH CAPTURED IN NORTH LAKE

Common Name	Scientific Name
Black Bullhead	Ictalurus melas
Black Crappie	Poxomis nigromaculatus
Bluegill	Lepomis macrochirus
Bluntnose Minnow	Pimephales notatus
Bowfin	Amia calva
Brook Silverside......	Labidesthes sicculus
Brown Bullhead	Ictalurus nebulosus
Carp	Cyprinus carpio
Common Shiner	Notropis cornutus
Creek Chub	Semotilus atromaculatus
Emerald Shiner	Notropis atherinoides
Grass Pickerel........	Esox americanus vermiculatus
Green Sunfish	Lepomis cyanellus
Johnny Darter........	Etheostoma nigrum
Lake Chubsucker.....	Erimyzon sucetta
Largemouth Bass	Micropterus salmoides
Mimic Shiner	Notropis volucellus
Northern Pike	Esox lucius
Pumpkinseed	Lepomis gibbosus
Rainbow Darter.......	Ethestoma caeruleum
Rock Bass............	Ambloplites rupestris
Smallmouth Bass......	Micropterus dolomieui
Walleye...............	Stizostedion vitreum vitreum
White Bass	Morone chrysops
White Sucker	Catostomus commersoni
Yellow Bullhead	Ictalurus natalis
Yellow Perch	Perca flavescens

Source: Wisconsin Department of Natural Resources.

The five major criteria used to determine the value of these wildlife habitat areas are listed as follows:

1. Diversity--An area must maintain a high but balanced diversity of species for a temperate climate; balanced in that the proper predator-prey (consumer-food) relationships can occur. In addition, a reproductive interdependence must exist.

2. Territorial Requirements--The maintenance of proper spatial relationships among species which allows for a certain minimum population level can only occur if the territorial requirements of each major species within a particular habitat are met.

3. Vegetative Composition and Structure--The composition and structure of vegetation must be such that the required levels for nesting, travel routes, concealment, and protection from weather are met for each of the major species.

4. Location With Respect to Other Wildlife Habitat Areas--It is very desirable that a wildlife habitat maintain proximity to other wildlife habitat areas.

5. Disturbance--Minimum levels of disturbance from human activities are necessary (other than those activities of a wildlife management nature).

On the basis of these five criteria, the wildlife habitat areas in the North Lake watershed were rated as high, medium, or low quality. The quality ratings used are defined below:

1. High-value wildlife habitat areas contain a good diversity of wildlife, are adequate in size to meet all of the habitat requirements for the species concerned, are generally located in proximity to other wildlife habitat areas, and meet all five criteria listed above.

2. Medium-value wildlife habitat areas generally lack one of the five criteria in the preceding list for a high-value wildlife habitat.

3. Low-value wildlife habitat areas are remnant in nature in that they generally lack two or more of the five criteria for a high-value wildlife habitat but may nevertheless be important if located in close proximity to other medium- and/or high-value habitat areas, if they provide corridors linking higher value wildlife habitat areas, or if they provide the only available range in an area.

As shown on Map 14, the North Lake direct drainage area contains about 383 acres of wildlife habitat, most of which is situated in the southeastern and eastern portions of the lake drainage basin. Within the drainage area directly tributary to North Lake, woodlands cover approximately 233 acres; and wetlands and open water areas exclusive of the lake surfaces--North Lake and Cornell Lake--comprise about 62 acres. The upland woods located south and east of the main lake basin provide medium-value deer and squirrel habitat. A 20-acre stand of mixed pines situated east of the main basin also provides some low-value pheasant habitat. The wetland complexes located in the northwestern and southwestern portions of the direct drainage area provide high- and medium-value pheasant habitats, respectively. Several small shallow and deep marsh areas and sedge meadows south of North Lake and adjacent to Cornell Lake also provide some medium-value waterfowl habitat.

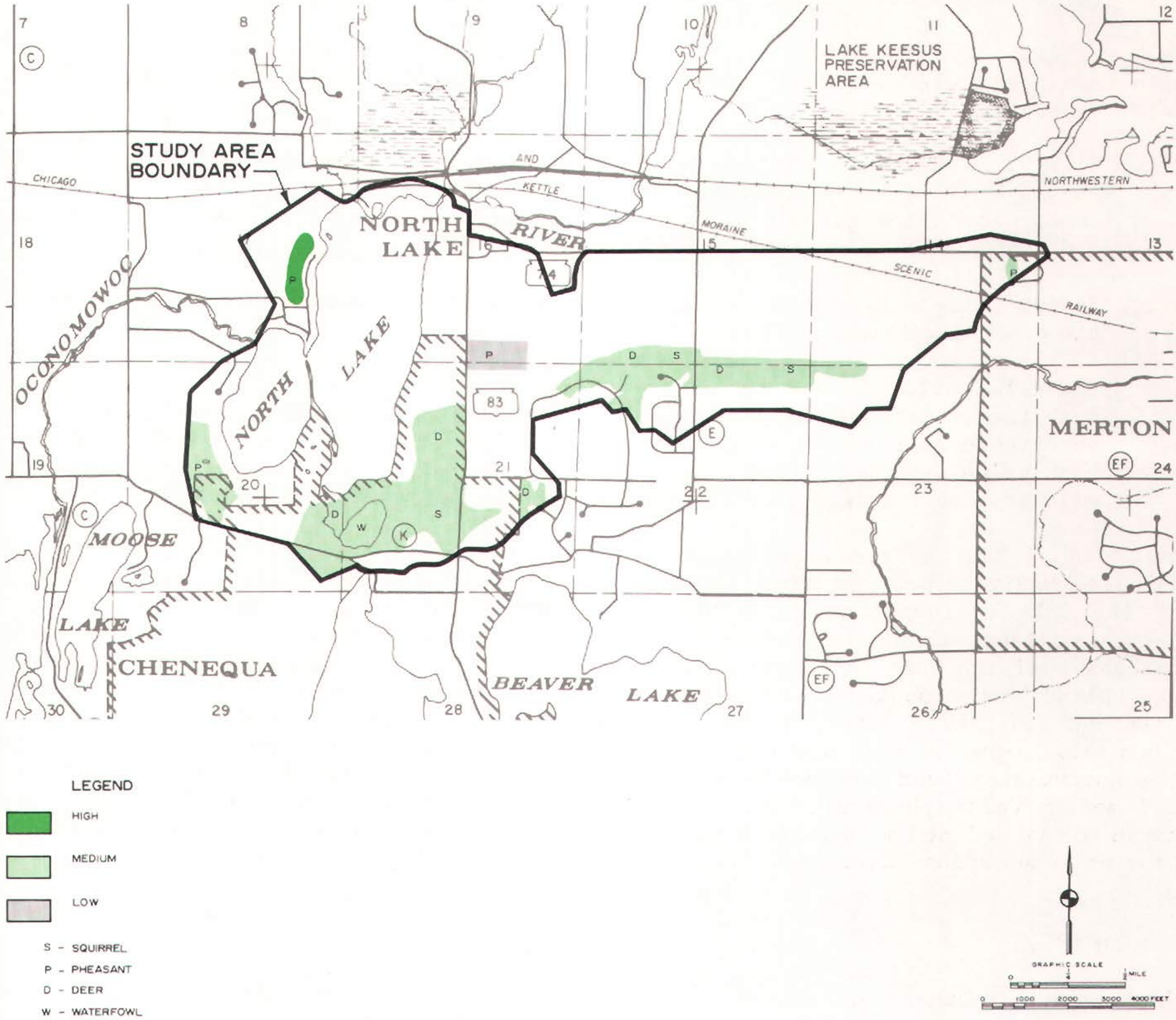
WOODLANDS

Woodlands in southeastern Wisconsin are defined as those areas containing 17 or more trees per acre which have at least a four-inch diameter at breast height.[3] In addition, the native woodlands are classified as dry, dry-mesic, mesic, wet-mesic and wet hardwoods and conifer swamp forests. The latter three woodland classifications are also considered wetlands and for the purposes of this report are discussed in the section on wetlands. The drainage area directly tributary to North Lake contains five of the six native woodland classifications.

[3]*The diameter at breast height (dbh) is measured at 4.5 feet above the ground.*

Map 14

WILDLIFE HABITAT IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE



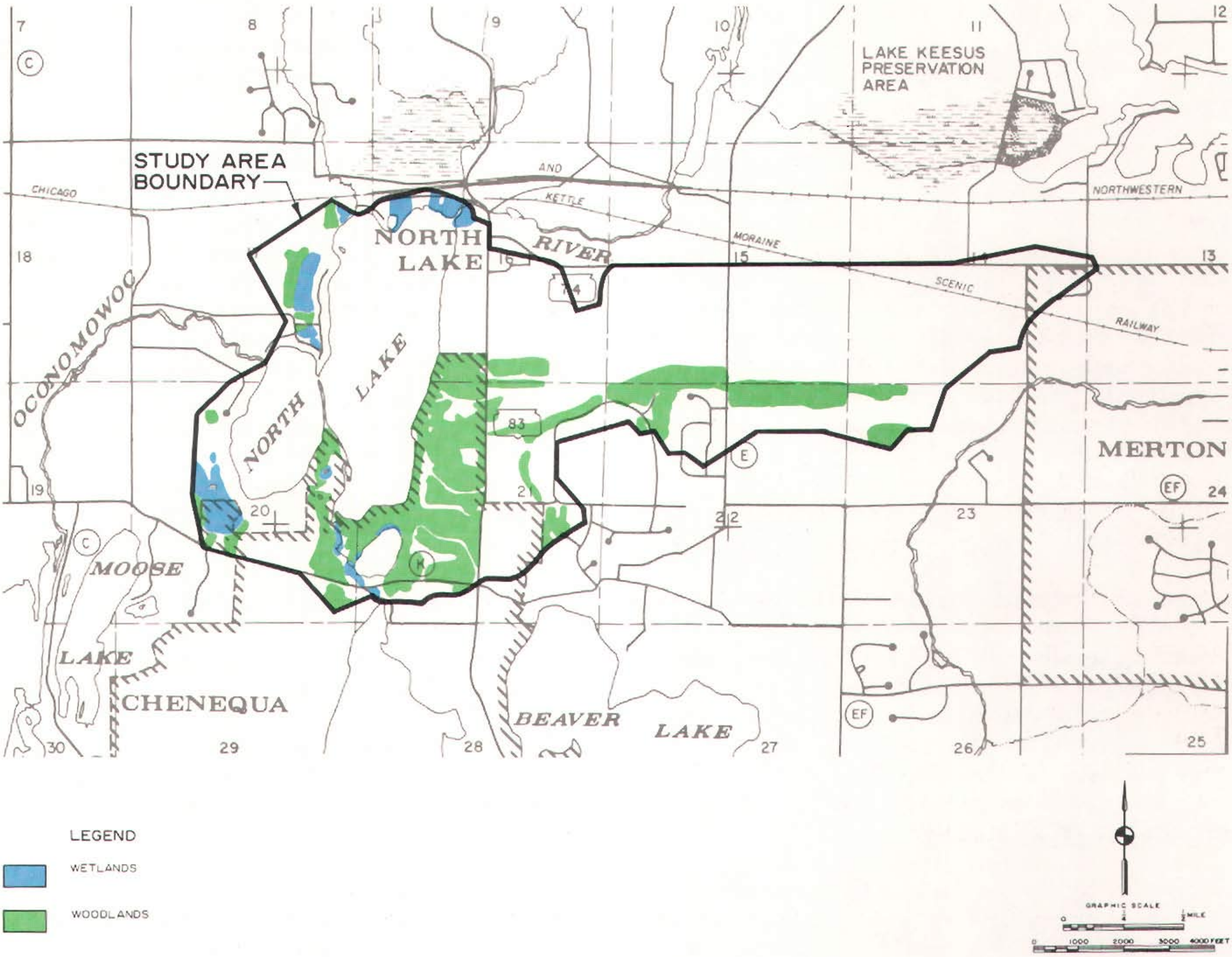
Source: Wisconsin Department of Natural Resources and SEWRPC.

Specifically, as shown on Map 15, upland woods in the North Lake drainage basin include southern dry hardwoods, which are characterized by white oak (Quercus alba), shagbark hickory (Carya ovata), black cherry (Prunus serotina), and red cedar (Juniperus virginiana); southern dry-mesic hardwoods characterized by northern red oak (Quercus borealis), and white ash (Fraxinus americana); and southern mesic hardwoods dominated by sugar maple (Acer saccharum) and basswood (Tilia americana).

Within the North lake drainage basin woodlands are conspicuous along the western and southern shore of the main lake basin. Additional large wooded tracts are situated along a broad ridge stretching through the eastern portion of the direct drainage

Map 15

WETLANDS AND WOODLANDS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE



Source: Wisconsin Department of Natural Resources and SEWRPC.

area. Most of these wooded tracts contain dry to dry-mesic hardwoods. However, several stands of conifers, composed largely of planted red pine (Pinus resinosa) and eastern white pine (Pinus strobus), are also present. Scattered woodlands in the southern portion of the basin contain mesic hardwoods where sugar maples predominate.

WETLANDS

Wetlands in southeastern Wisconsin are classified as deep marsh, shallow marsh, bog, fen, low prairie, southern sedge meadow, fresh (wet) meadow, shrub carr, southern wet and wet-mesic hardwood forest, and conifer swamp. The major wetland communities located in the direct drainage area tributary to North Lake, as shown on Map 15, include deep and shallow marsh, sedge meadow, fresh (wet) meadow, shrub carr, and southern wet to wet-mesic hardwoods. Table 23 characterizes the wetland plant species typically found in the drainage basin.

Lowland forests in the North Lake drainage basin include southern wet to southern wet-mesic hardwood forests, and were found predominately in the northern and southwestern portions of the watershed. These areas are characterized by black willow (Salix nigra), cottonwood (Populus deltoides), green ash (Fraxinus americana), and American elm (Ulmus americana).

Sedge meadows are considered to be stable wetland plant communities that tend to perpetuate themselves if dredging activities and water level changes are prevented from occurring. Sedge meadows in southeastern Wisconsin are characterized by the tussock sedge (Carex stricta) and to a lesser extent, by Canada bluejoint grass (Calamagrostis canadensis). Sedge meadows that are drained or disturbed to some extent typically succeed to shrub carrs. Shrub carrs, in addition to the sedges and grasses found in the sedge meadows, contain an abundance of shrubs such as willows (Salix spp.) and red osier dogwood (Cornus stolonifera). In extremely disturbed shrub carrs, the willows, red osier dogwood, and sedges are replaced by such exotic plants as honeysuckle (Lonicera sp.), buckthorn (Rhamnus sp.) and the very aggressive reed canary grass (Phalaris arundinacea). Fresh (wet) meadows are essentially lowland grass meadows which are dominated by Canada bluejoint grass and forbes such as marsh (Aster simplex), red-stem (Aster puniceus), and New England (Aster novae-angliae) asters, and giant goldenrod (Solidago gigantea).

Sedge meadows and fresh (wet) meadows in the North Lake direct drainage area were situated primarily in the northwest and southwest portions of the watershed. These areas have been subjected to varying degrees of disturbance including filling for residential development and water level fluctuations. Plant communities have remained relatively diverse in the wetland complex in the southeast one-quarter of Section 20, Town 8 North, Range 18 East. However, the wetland plant communities in the northwest one-quarter of Section 20, Town 8 North, Range 18 East, reflect past disturbance through the low species diversity and dominance of the aggressive reed canary grass (Phalaris arundinacea).

Several small, shallow and deep marsh areas are scattered in the southern portion of the direct drainage area. These areas are dominated by broadleaf cat-tail (Typha sp.), purple loosestrife (Lythrum salicaria), bulrush (Scirpus sp.), and sedges (Carex sp.).

RECREATIONAL USE

North Lake, which has a relatively large surface area, is generally free of shallow areas, excessive algae growths, and underwater hazards. As such, it provides opportunities for a variety of water-based outdoor recreation activities, including fishing, boating, swimming, and nature studies. Fishing and sailing are the most popular summer outdoor recreation activities on North Lake. North Lake provides a high quality habitat for northern pike, largemouth bass and panfish. The size and the numbers of fish in the lake provide a good resource to both the lake residents and the lake users.

Sailing is the most popular boating activity on North Lake. An adequate power boating resource exists, but a lack of public access limits this activity almost exclusively to lake residents. An aerial survey of boating activity conducted in July 1976 indicated that high speed boating--waterskiing and pleasure boating--was limited. Higher concentrations of these uses could cause serious conflicts with other lake uses.

Table 23

EMERGENT WETLAND PLANT SPECIES IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE

Polypodiaceae	
Thelypteris palustris	Marsh fern
Cypressaceae	
Thuja occidentalis	White cedar
Typhaceae	
Typha latifolia	Broadleaf cat-tail
Typha angustifolia	Narrowleaf cat-tail
Sparganiaceae	
Sparganium eurycarpum	Bur-reed
Alismataceae	
Sagittaria latifolia	Arrow-head
Gramineae	
Glyceria striata	Fowl manna grass
Phragmites communis	Reed grass
Calamogrostis canadensis	Canada bluejoint grass
Spartina pectinata	Prairie cord grass
Phalaris arundinacea[a]	Reed canary grass
Cyperaceae	
Scirpus validus	Softstem bulrush
Scirpus acutus	Hardstem bulrush
Scirpus atrovirens	Green bulrush
Carex stricta	Tussock sedge
Carex lacustris	Lake sedge
Carex spp.	Sedges
Araceae	
Symplocarpus foetidus	Skunk cabbage
Iridaceae	
Iris versicolor	Blue flag
Salicaceae	
Salix nigra	Black willow
Salix interior	Sandbar willow
Salix discolor	Pussy willow
Betulaceae	
Betula pumila	Bog birch
Ulmaceae	
Ulmus americana	American elm
Urticaceae	
Urtica dioica	Stinging nettle
Polygonaceae	
Rumex orbiculatus	Water dock
Polygonum natans	Smartweed
Rosaceae	
Physocarpus opulifolius	Ninebark
Aceraceae	
Acer saccharinum	Silver maple
Acer negundo	Boxelder
Ranunculaceae	
Caltha palustris	Marsh marigold
Thalictrum dasycarpum	Meadow rue

Cruciferae	
Cardamine bulbosa	Bitter cress
Balsaminaceae	
Impatiens biflora	Jewel-weed
Rhamnaceae	
Rhamnus cathartica[a]	Common buckthorn
Lythraceae	
Decodon verticillatus	Water-willow
Lythrum salicaria[a]	Purple loosestrife
Umbelliferae	
Angelica atropurpurea	Angelica
Oxypolis rigidior	Cowbane
Cornaceae	
Cornus amomum	Silky dogwood
Cornus stolonifera	Red osier dogwood
Primulaceae	
Lysimachia thyrsiflora	Tufted loosestrife
Oleaceae	
Fraxinus pennsylvanica	Green ash
Fraxinus nigra	Black ash
Asclepiadaceae	
Asclepias incarnata	Marsh milkweed
Verbenaceae	
Verbena hastata	Blue vervain
Labiatae	
Pycnanthemum virginianum	Mountain-mint
Lycopus uniflorus	Northern bugle weed
Lycopus americanus	Common water horehound
Mentha arvensis	Wild mint
Caprifoliaceae	
Viburnum trilobum	Highbush cranberry
Sambucus canadensis	Elderberry
Cucurbitaceae	
Echinocystis lobata	Wild cucumber
Compositae	
Bidens coronata	Bur marigold
Ambrosia trifida	Giant ragweed
Solidago gigantea	Giant goldenrod
Aster novae-angliae	New England aster
Aster puniceus	Redstem aster
Aster luciduous	Swamp aster
Aster simplex	Marsh aster
Eupatorium maculatum	Joe-pye weed
Eupatorium perfoliatum	Boneset

[a] *Alien or nonnative plant species.*

Source: SEWRPC.

Table 24

PUBLIC ACCESS SITES ON NORTH LAKE: JUNE 1981

Location Town 8 North, Range 18 East	Owner	Type	Size		Available Spaces	
			Area (acres)	Lake Frontage (feet)	Car and Trailer	Car
Section 16	Town	Walk-in-trail	0.1	50	0	0
Section 16	Private	Ramp[a]	0.5	70	50	10
Section 16	Private	Ramp[a]	0.1	100	6	0
Section 17	Town	Walk-in-trail	0.1	50	0	0
Section 17	Town	Walk-in-trail	0.1	50	0	0

[a] Wisconsin Department of Natural Resources site surveys of 1976 indicated a need for improved maintenance of these sites.

Source: Wisconsin Department of Natural Resource.

Swimming is another popular recreational activity. North Lake has many fine natural sand and gravel beaches and good water quality. However, public access to the beach areas is limited. Nature study opportunities are provided by the marsh areas north of the lake and the large wooded tracts of land on the southeastern shore. Deer, muskrat, pheasants and ducks use these areas on a year round basis. Winter sports enjoyed on North Lake include skating, snowmobiling, cross-country skiing and ice fishing.

Participation in various recreational activities on North Lake by non-lake residents requires adequate public access points to the lake. In the adopted regional park and open space plan--SEWRPC Planning Report No. 27, A Regional Park and Open Space Plan for Southeastern Wisconsin: 2000--the Commission established objectives, principles, and standards for the provision of facilities to support participation by the residents of southeastern Wisconsin in extensive water-based outdoor recreational activities on the major inland lakes. The adopted standards provided a means of quantifying the number of public access points consistent with safe and enjoyable participation in water-based recreational activities to be provided on the major inland lakes throughout the Region. Based on those adopted standards, which require that at least one boat access open to the general public be provided at each major inland lake, as of June 1982 there is a need for such access at North Lake.

In 1976, the Wisconsin Department of Natural Resources (DNR) surveyed access sites around North Lake. Results of the survey are presented in Table 24. Two sites were judged to be in need of maintenance, while three were found to be in good condition.

The DNR also evaluated the adequacy of the existing public access sites for non-resident use. A site was judged by the DNR to be adequate if the site was publicly owned, had sufficient facilities for boat launching and parking, and had reasonable fees (based on standard fees charged in State parks). Private sites were not considered adequate because there can be no assurance that the sites will be open from one day to the next, or one year to the next; nor is there any assurance concerning the reasonableness of fees charged for access. Sites evaluated as marginal had inadequate parking, fees that were too high, or difficult launching sites. Inadequate sites were basically unusable (i.e., posted as closed, blocked from

Table 25

RECREATIONAL RATING OF NORTH LAKE: 1980

Fishing:		
__ 9 High production	X 6 Medium production	__ 3 Low production
X 9 No problems	__ 6 Modest problems such as infrequent winter-kill, small rough fish problems	__ 3 Frequent and over-bearing problems such as winterkill, carp, excessive fertility
Subtotal: 15		
Swimming:		
__ 6 Sand or gravel (75 percent or more)	X 4 Sand or gravel (25-75 percent)	__ 2 Sand or gravel (<25 percent)
X 6 Clean water	__ 4 Moderately clean	__ 2 Turbid or darkly stained
X 6 No algae or weed	__ 4 Moderate algae or weed problems	__ 2 Frequent algae or weed problems
Subtotal: 16		
Boating:		
X 6 Adequate depths (>75 percent of basin >five feet deep)	__ 4 Adequate depths (50-75 percent of basin >five feet)	__ 2 Adequate depths (<50 percent of basin)
__ 6 Adequate size for extended boating (>1,000 acres)	X 4 Adequate size for some boating (200-1,000 acres)	__ 2 Limit of boating challenge and space (<200 acres)
__ 6 Good water quality	X 4 Some inhibiting factors such as weedy bays, algae blooms, etc.	__ 2 Overwhelming inhibiting factors such as weed beds throughout
Subtotal: 14		
Aesthetics:		
X 6 Existence of 25 percent or more wild shore	__ 4 Less than 25 percent wild shore	__ 2 No wild shore
X 6 Varied landscape	__ 4 Moderately varied landscape	__ 2 Unvaried landscape
X 6 Few nuisances such as excessive algae, carp, dumps, etc.	__ 4 Moderate nuisance conditions	__ 2 High nuisance conditions
Subtotal: 18		
Total Quality Rating: 63 out of a possible 72		

Source: Wisconsin Department of Natural Resources and SEWRPC.

access, having no parking available, or with an unusable boat launching site). No sites on North Lake were judged to be adequate; two were judged to be marginal, and three were judged to be inadequate.

The Wisconsin Department of Natural Resources, under guidelines established in the Wisconsin Administrative Code, Chapters NR 1.90 and NR 1.92, recommended that at least one access and public boat launching site open to the general public be provided on all major inland lakes. The DNR recommendation for a publicly owned boat launch facility is reportedly not met on North Lake.[4] Consequently, DNR policies would normally require the development of a publicly owned boat launching facility if the Lake District is to receive financial and/or technical assistance from the DNR for inlake management programs. Such programs could include lake rehabilitation, fish management, and/or water safety aides.

In general, North Lake provides opportunities for a variety of outdoor recreational activities in a high quality setting. An outdoor recreational rating technique was developed by the Wisconsin DNR to summarize the outdoor recreational value of inland lakes. As shown in Table 25, North Lake scored 63 out of a possible 72 rating points, placing it among those lakes in southeastern Wisconsin providing diverse, high quality outdoor recreational opportunities. To ensure that North Lake will continue to provide such recreation opportunities, the resource values of the lake must be protected and preserved.

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[4]*Information provided by Mr. Ronald Piening, DNR Waters Classification Specialist, November 3, 1980.*

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Chapter VI

EXISTING WATER QUALITY MANAGEMENT ACTIONS AND INSTITUTIONAL STRUCTURES AFFECTING WATER QUALITY

SEWAGE DISPOSAL

The sanitary and household wastewaters from all 620 persons estimated to reside in the drainage area directly tributary to North Lake, as of 1975, were treated and disposed of through the use of onsite soil absorption systems. An onsite sewage disposal system may be a conventional septic tank system, or a mound system. Holding tanks may also be considered onsite sewage disposal systems, although they do not meet a strict definition of such systems. As of 1975, 257 septic tank systems were estimated to be in operation in the direct drainage area of the lake. No holding tanks or mound systems were reported to be in use during or prior to 1975.

A septic tank system consists of two components: a septic tank proper used to provide partial treatment of the raw sewage--by skimming, settling, and anaerobic decomposition--and a soil absorption field for final treatment and disposal of liquid discharged from the septic tank. Both components are installed below the ground surface. The septic tank is a water-tight tank intended to separate floating and settleable solids from the liquid fraction of domestic sewage and to discharge the liquid, together with its burden of dissolved substances, into the biologically active zone of the soil mantle through a subsurface percolation system. The discharge system may be a tile field, a seepage bed or an earth-covered sand filter. Liquid passing through the active soil zone percolates downward until it strikes an impervious layer of soil or the groundwater. Thus, the purpose of the percolation system is to dispose of sewage effluents by utilizing the same natural phenomena which lead to the accumulation of groundwater.

Providing that a septic tank system is located, installed, used, and maintained properly, and that there is an adequate depth--four to five feet--of moderately permeable, unsaturated soil below the drainage field and above the groundwater level, layer of impervious soil, or bedrock, the system should operate with few problems for periods of up to 20 years. However, in the direct drainage area of North Lake as of 1975, 92 of the estimated 257 septic systems, or 36 percent, were located on soils having severe or very severe limitations for the use of septic tank systems.

Failure of a septic tank system occurs when the soil surrounding the seepage area will no longer accept or properly stabilize the septic tank effluent, when the groundwater rises to levels which will no longer allow for uptake of liquid effluent by the soils, or when age or lack of proper maintenance cause the system to malfunction. Hence, septic system failure may result from improper location, poor installation, or inadequate maintenance. In many older, improper installations, the septic tank effluent may not receive the benefit of soil infiltration, but rather be discharged directly from the septic tank through a drain tile to surface water.

A precise identification of septic tank problems requires a complete sanitary survey. A sanitary survey was conducted of all residences located immediately around the lake by the Waukesha County Board of Health in 1971/1972. In that survey, 199 septic tank systems, or 77 percent of the 257 systems in the watershed, were inspected. At that time, eight of these systems, or 4 percent of those surveyed, were identified as discharging improperly treated sewage to either the ground surface or to the groundwater and were therefore not in compliance with the provisions of the then existing State plumbing codes. The State plumbing codes were violated because of improper lavatory waste discharges to the ground surface, or to the lake, or because of other improper plumbing arrangements. The survey could not assure identification of wet weather effluent ponding problems or of straight-pipe connections to the lake. Because of the difficulty in identifying malfunctioning septic tank systems associated with direct sewage discharges--which are not easily observed--and because of the intermittent use of systems by seasonal residents, surveys of this type usually underestimate the total extent of failing septic tank systems. Moreover, water quality samples taken during the study indicated bacteriologic contamination in some groundwater samples, indicating the extent of very real health hazards in the North Lake area as a result of the septic tank problems.

As of 1980, no portions of the drainage area directly tributary to North Lake were served by sanitary sewers.

EXISTING ZONING REGULATIONS

A comprehensive zoning ordinance represents one of the most important and significant tools available to local units of government in directing the proper use of lands within their area of jurisdiction. The drainage area directly tributary to North Lake includes portions of the Village of Chenequa and the Town and Village of Merton, located in Waukesha County. Consequently, three zoning ordinances are administered within the North Lake drainage area. The zoning ordinance currently in effect within the Village of Chenequa was initially approved and adopted in February 1929, and was most recently amended in August 1971. The Town of Merton zoning ordinance was initially approved and adopted in November 1949, and was most recently amended in May 1974. The Village of Merton zoning ordinance was initially approved and adopted October 1967, and was most recently amended in July 1980. A summary of the zoning districts currently available for use in the three civil divisions is presented in Table 26. The areas of land placed in each of the districts are shown on Map 16 and are quantified in Table 26.

In addition to the three comprehensive zoning ordinances administered within the North Lake direct drainage area, the Waukesha County Board of Supervisors adopted a Shoreland and Floodland Protection Zoning Ordinance in 1970. This ordinance, prepared pursuant to the requirements of the Wisconsin Water Resources Act of 1965, imposes special land use regulations on all lands located within 1,000 feet of the shoreline of any navigable lake, pond, or flowage, and within 300 feet of the shoreline of any navigable river or stream, or to the landward side of the floodplain, whichever is greater. The floodland and shoreland zoning map applicable to the portion of the Town of Merton located within the North Lake direct drainage area was prepared and adopted in 1970, and last amended in 1979 and is shown on Map 17. A summary of the existing zoning districts currently available for use which are affected by the floodland and shoreland zoning districts in the drainage area directly tributary to North Lake is presented in Table 27.

The availability of 77 percent of the total North Lake direct drainage area for essentially urban and suburban land use development under the existing zoning ordinances encourages the diffusion of urban-type development throughout the drainage area in a manner that conflicts with the recommendations contained in the adopted regional land use and water quality management plans. In order to prevent undesirable urban development in the drainage area directly tributary to North Lake, it will be necessary for the appropriate public officials in the County and the three civil divisions concerned to critically review the individual zoning ordinances and accompanying zoning district maps for the North Lake direct drainage area and amend the ordinances and district maps so as to preserve and enhance the existing natural resource base of the North Lake direct drainage area.

AQUATIC PLANT MANAGEMENT

Records of aquatic plant management efforts were not maintained by the Wisconsin Department of Natural Resources prior to 1950. Efforts to manage the aquatic plants in North Lake were first recorded in 1952 when 300 pounds of copper sulfate were applied to the lake to control algae growth. In addition, 5,600 pounds of sodium arsenite were applied to the lake in 1954 to control macrophyte growth. There is no record of any other aquatic plant management practices, such as macrophyte harvesting, chemical control of macrophytes, and/or chemical algae control, since 1954 on North Lake.

Chemical Macrophyte Control

Since 1941, the use of chemicals to control aquatic plants has been regulated in Wisconsin, although chemicals were used to control aquatic plant growth in lakes and streams prior to this date. In 1926, sodium arsenite, an agricultural herbicide, was first applied to lakes in the Madison, Wisconsin area. By the 1930's, sodium arsenite was widely used for aquatic plant control, and no other chemicals were applied in significant amounts to control macrophytes. As noted above, the only recorded application of sodium arsenite to North Lake was in 1954 when 5,600 pounds were applied. Compared to nearby lakes in Waukesha County in Table 28, this application represents a relatively small amount.

The sodium arsenite was usually sprayed within 200 feet of the shoreline. Treatment typically occurred between mid-June and mid-July. The amount of sodium arsenite used was usually calculated to result in a sodium arsenite concentration of about 10 parts per million in the treated lake water. Most of the sodium arsenite would be expected to have remained in the water column for less than 120 days. The arsenic residue was naturally converted from a highly toxic trivalent form to a relatively less toxic--and less biologically active--pentavalent form in the lake sediments. Much of the arsenic residue was deposited in the lake sediments. Algae, diatoms, and macrophytes have been known to accumulate and concentrate arsenic in their tissue up to levels exceeding 2,000 micrograms per gram (ug/g) dry weight. However, biomagnification of arsenic through the food chain has not been known to occur. Analyses of fish tissue from some treated lakes, taken by the Wisconsin Department of Natural Resources in 1960 and 1971, indicated no excessive levels of arsenic.

When it became apparent that arsenic was accumulating in the sediments of treated lakes, the use of sodium arsenite was discontinued in the State in 1969. The application and accumulation of arsenic were concluded to present potential health hazards to human and aquatic life. In drinking water supplies, arsenic is suspected of being carcinogenic and has been known to cause skin cancer and brain, liver, kidney, and bone marrow damage. Under certain conditions, arsenic may leach to and contaminate the groundwater, especially in sandy soils. The U. S. Environmental Protection Agency drinking water standard for arsenic is 0.05 milligrams per liter (mg/l).

At the relatively low levels of application to North Lake, it is unlikely that existing arsenic levels in North Lake are excessive. During anaerobic conditions, arsenic may be released from the sediments to the water column. In this manner, some arsenic may be expected to continue to be "flushed out" of North Lake through the outlet. In addition, the arsenic laden sediments are continually being covered by new sediments. Therefore, the concentrations of arsenic in the water and surface sediments can be expected to decrease with the passage of time.

Table 26

SUMMARY OF EXISTING COMPREHENSIVE ZONING DISTRICTS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE

Zoning District	Permitted Uses		Conditional/Special Uses	Area Regulations Minimum Lot Size		Civil Division Area Zoned Within Direct Drainage Area (acres)	Percent of Direct Drainage Area
	Principal	Accessory		Area	Width		
TOWN OF MERTON ZONING ORDINANCE							
C-1 Conservancy District	Grazing, harvesting of wild crops, hunting and fishing, sustained yield forestry, dams and hydroelectric power stations, telephone and telegraph and power transmission lines	--	None	No minimum required	No minimum required	52	3.1
A-1 Agricultural District	Any use permitted in the C-1 Conservancy District, one-family dwellings, public parks and recreation areas, farming, roadside stands, horticulture, home occupations, professional offices	Private garages, private boathouses, guesthouses, kennels, occupations, and professional offices	Airports, landing fields, antique shops, studios, automobile service stations, animal hospitals, cemeteries, churches, commercial fish and bait ponds, drive-in establishments, laboratories for testing and experimental purposes	3 acres	200 feet	653	38.7
A-2 Rural Home District	All uses permitted in the A-1 Agricultural District, one-family dwellings, keeping of poultry	--	Animal hospitals, kennels, cemeteries, churches, commercial fish and bait ponds, residential planning unit development, public and semi-public uses, private clubs	3 acres	200 feet	--	--
A-3 Suburban Estate District	Any use permitted in the A-2 Rural Home District	--	Same as A-2 Rural Home District	2 acres	175 feet	--	--
R-1 Residential District	Any use permitted in the A-2 Rural Home District	--	Same as A-2 Rural Home District	1 acre	150 feet	396	23.5
R-2 Residential District	Any use permitted in the R-1 Residential District	--	Same as A-2 Rural Home District	30,000 square feet	120 feet	43	2.6
R-3 Residential District	Any use permitted in the R-2 Residential District, two-family dwellings	--	Same as A-2 Rural Home District	20,000 square feet	120 feet	83	4.9
P-1 Public District	None	--	Private clubs, public and semi-public uses	No minimum required	No minimum required	8	0.5
B-1 Restricted Business District	Small retail shops, boarding houses, offices	--	Same as A-2 Rural Home District	20,000 square feet	120 feet	--	--
B-2 Local Business District	Any use permitted in the B-1 Restricted Business District	--	Same as A-2 Rural Home District	20,000 square feet	120 feet	9	0.5
B-3 General Business District	Wholesalers, distributors, theaters, dance halls, dry cleaning, auto sales, etc.	--	Antique shops, studios, auto service stations, animal hospitals, cemeteries, churches, commercial fish or bait ponds, drive-in establishments, feed lots, laboratories, private clubs, public and semi-public uses, disposal sites	20,000 square feet	120 feet	--	--
Q-1 Quarrying District	Any use permitted in an A-1 Agricultural District and residential uses accessory to permitted uses, quarrying	Manufacture of concrete, building blocks, production of ready-mixed concrete	Animal hospitals, cemeteries, commercial fish or bait shops, public and semi-public uses, disposal sites	1 acre	150 feet	--	--
M-1 Limited Business District	Any use permitted in B-3 General Business or A-1 Agricultural District, light industry	--	Same as B-3 General Business District	1 acre	150 feet	--	--

Table 26 (continued)

Zoning District	Permitted Uses: Principal	Permitted Uses: Accessory	Conditional/Special Uses	Area Regulations, Minimum Lot Size: Area	Area Regulations, Minimum Lot Size: Width	Civil Division Area Zoned Within Direct Drainage Area (acres)	Percent of Direct Drainage Area
TOWN OF MERTON ZONING ORDINANCE (continued)							
M-2 General Industrial District	Any use permitted in M-1 Limited Industrial Dis- District, quarrying	--	Same as B-3 General Business District	1 acre	150 feet	--	--
Subtotal	--	--	--	--	--	1,244	73.8
VILLAGE OF CHENEQUA ZONING ORDINANCE							
Residence District	Single-family dwellings, municipal utilities and buildings, churches and temples, schools, parks and country clubs, farming	Accessory private garages and barns	None	2-4.5 acres for lakeshore property 5 acres for all other property	150 feet	410	24.3
Subtotal	--	--	--	--	--	410	24.3
VILLAGE OF MERTON ZONING ORDINANCE							
C-1 Conservancy District	River bank and lake shore protection, soil reforestation, hunting, fishing, public hatcheries and water control	--	Grazing, wild crop harvesting, forestry, dams, power and communication transmission lines, accessory structures, truck farming, orchards, drainage and cultivation	No minimum required	No minimum required	--	--
A-1 Agricultural District	Any principal or conditional use permitted in the C-1 Conservancy District, ordinary farm uses, nurseries, greenhouses, and hatcheries	Agricultural-related buildings	Airports, colleges, universities, hospitals, sanitariums, religious, charitable, penal, and correctional institutions, and cemeteries, etc. (see Village Zoning Ordinance)	5 acres	200 feet	18	1.1
R-1 Residential District	One-family dwellings	--	Governmental and cultural uses, including fire and police stations, community centers, libraries, public emergency shelters, parks, playgrounds, and museums	40,000 square feet	150 feet	14	0.8
R-2 Residential District	One-family dwellings	--	Governmental, cultural, and educational uses including: fire and police stations, community centers, libraries, public emergency shelters, parks, playgrounds, and museums, public, parochial, and private elementary and secondary schools	20,000 square feet	120 feet	--	--
B-1 General Business District	Retail stores, financial institutions, hotels, schools, clinics, business and professional offices, grocery stores, etc.	--	Governmental and cultural uses, including fire and police stations, community centers, libraries, public emergency shelters, playgrounds, and museums, public passenger transportation terminals, funeral homes, tourist homes, vehicle sales, service stations, and public parking lots	20,000 square feet	100 feet	--	--
B-2 Planned Business District	None	--	Same as B-1 General Business District	2 acres	200 feet	--	--
M-1 Limited Industrial District	Commercial bakeries, distributors, wholesalers, machine shops, manufacturing of plastic, leather, wood, and paper products	--	Airports, government and cultural uses including fire and police stations, community centers, libraries, public emergency shelters, parks, playgrounds, and museums, etc. (see Village Zoning Ordinance)	1 acre	150 feet	--	--

Table 26 (continued)

Zoning District	Permitted Uses: Principal	Permitted Uses: Accessory	Conditional/Special Uses	Area Regulations: Minimum Lot Size: Area	Area Regulations: Minimum Lot Size: Width	Civil Division Area Zoned Within Direct Drainage Area (acres)	Percent of Direct Drainage Area
VILLAGE OF MERTON ZONING ORDINANCE (continued)							
M-2 Heavy Industrial District	Any principal or conditional use permitted in the M-1 Limited Industrial District, freight yards, fuel storage except flammable liquids, breweries, crematories, and warehouses	--	Same as M-1 Limited Industrial District	1 acre	150 feet	--	--
P-1 Public and Semi-Public District	Parks, arboretums, playgrounds, fishing, wading, swimming, beaches, skating, sledding, sustained yield forestry, wildlife preserves, soil and water conservation, water measurements and water control facilities	--	Airports, airstrips, and landing fields, governmental and cultural uses such as fire and police stations, community centers, libraries, public emergency shelters, parks, playgrounds, and museums, public, parochial, and private elementary and secondary schools, and churches, colleges, universities, hospitals, sanitariums, religious, charitable, penal, and correctional institutions, cemeteries and crematories	No minimum required	No minimum required	--	--
Subtotal	--	--	--	--	--	32	1.9
Direct Drainage Area Total	--	--	--	--	--	1,686.0	100.0

Source: SEWRPC.

All aquatic plant control chemicals used today must be approved by the U. S. Environmental Protection Agency and the Wisconsin Department of Natural Resources. The federal Insecticide, Fungicide and Rodenticide Act as amended in 1972 requires that all pesticides be registered.

The advantages of chemical use are the relatively low cost and the ease, speed, and convenience of their application. Disadvantages associated with chemical control include the following:

1. Although the short-term, lethal effects of chemicals are relatively well-known, potential long-term, sublethal effects--especially on fish and fish-food organisms--are relatively unknown.

2. The elimination of macrophytes reduces their competition with algae for light and nutrients. Thus increased algae blooms may develop.

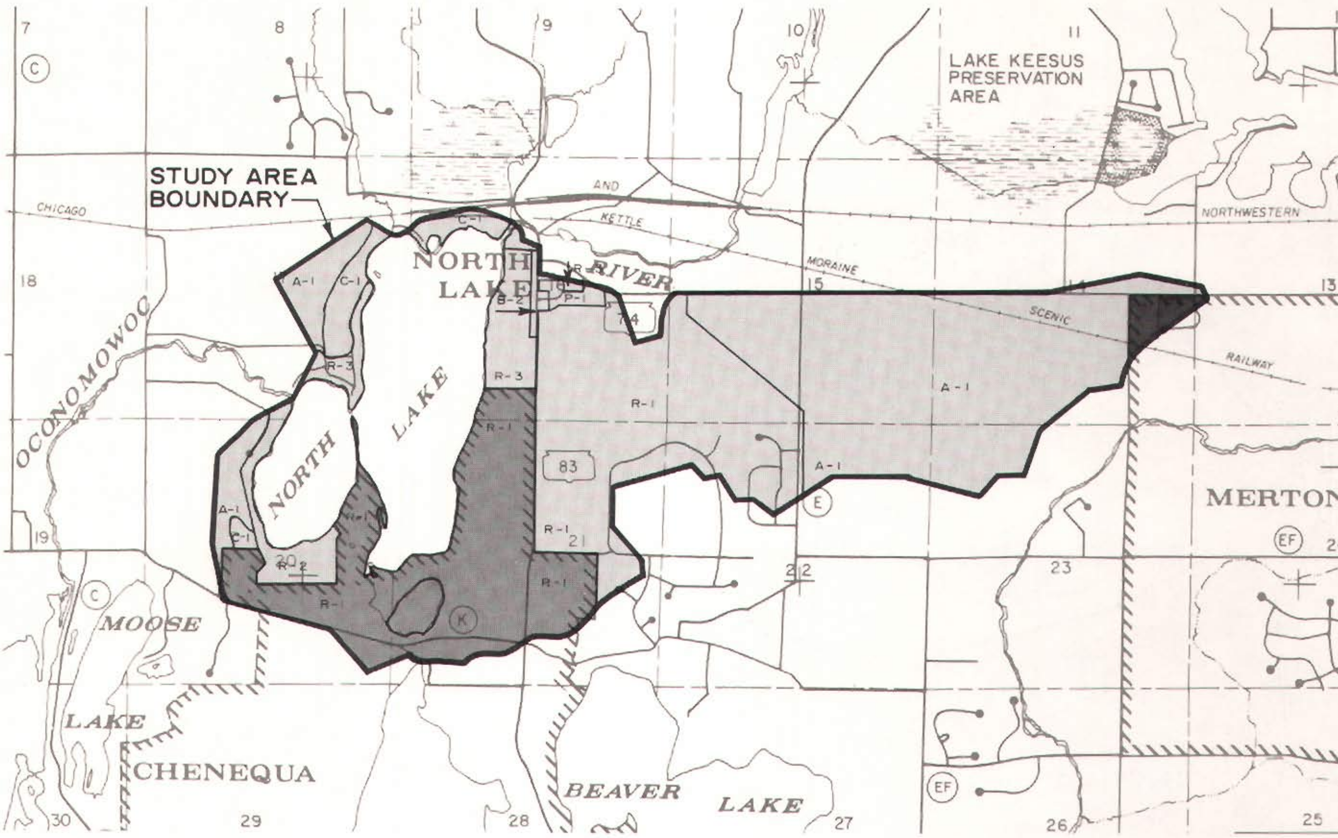
3. Much of the dead plant material is not removed from the lake and upon decomposition the nutrients contained in this plant material will be released to the water. Decomposition of the plant material also consumes dissolved oxygen and increases the potential of fish kills.

4. The elimination of macrophyte beds destroys important cover, food sources, and spawning areas for desired fish species.

5. Adverse impacts on other aquatic organisms may be expected. Diquat has been shown to kill the zooplankton Daphnia (water fleas) and Hyalella (scuds) at the

Map 16

EXISTING ZONING DISTRICTS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE: 1979



LEGEND

TOWN OF MERTON

C-1 CONSERVANCY DISTRICT
A-1 AGRICULTURAL DISTRICT
R-1 RESIDENTIAL DISTRICT
R-2 RESIDENTIAL DISTRICT
R-3 RESIDENTIAL DISTRICT
P-1 PUBLIC DISTRICT
B-2 LOCAL BUSINESS DISTRICT

VILLAGE OF CHENEQUA

R-1 RESIDENTIAL DISTRICT

VILLAGE OF MERTON

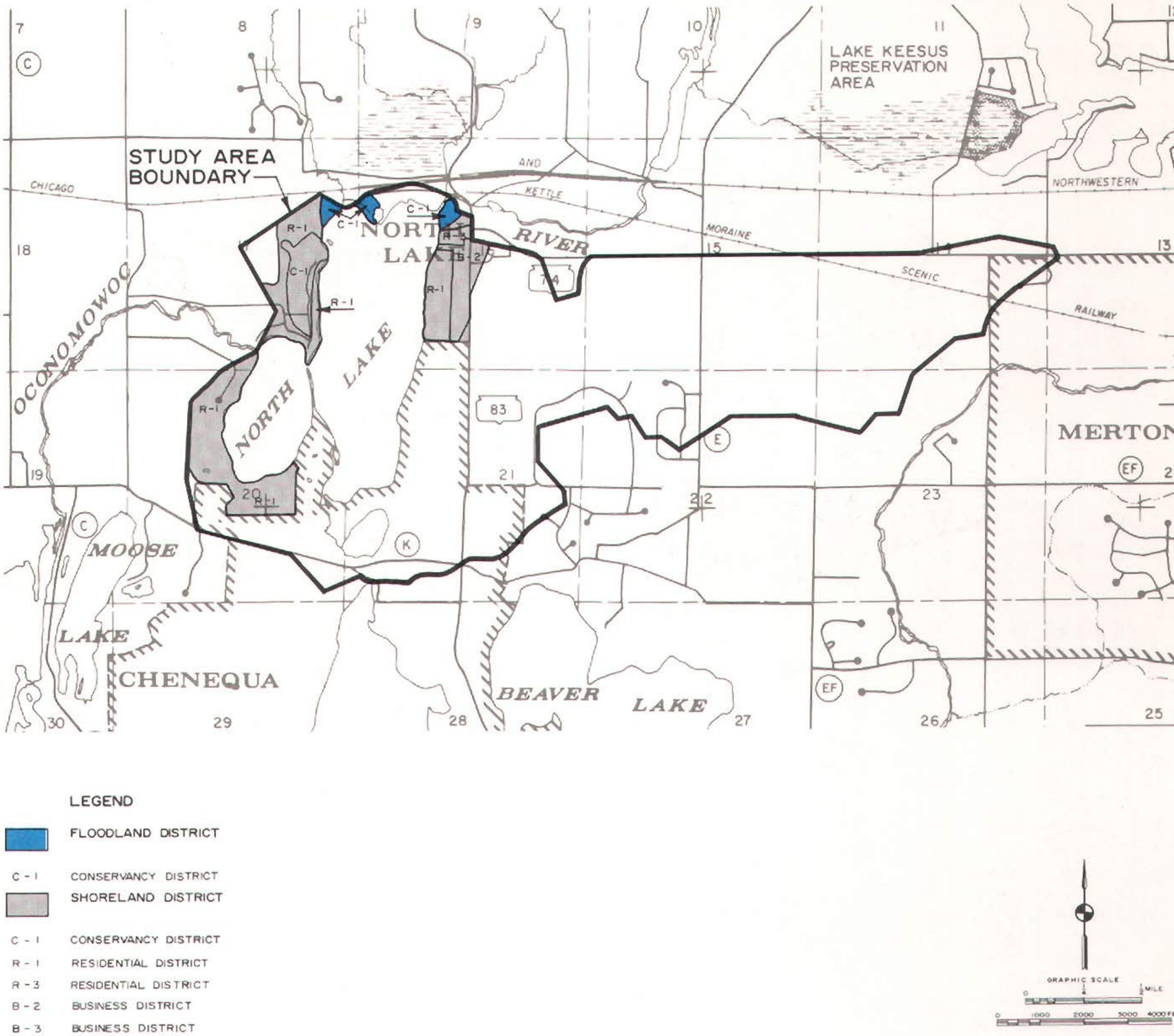
A-1 AGRICULTURAL DISTRICT
R-1 RESIDENTIAL DISTRICT

GRAPHIC SCALE
0 1000 2000 3000 4000 FEET

Source: Waukesha County Park and Planning Commission and SEWRPC.

Map 17

EXISTING FLOODLAND AND SHORELAND ZONING DISTRICTS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE: 1979



Source: Waukesha County Park and Planning Commission and SEWRPC.

level applied for macrophyte control. Both Daphnia and Hyalella are important fish foods, with Daphnia being the primary food for the young of nearly all fish species.

Chemical Algae Control

As noted previously, 300 pounds of copper sulfate were applied to North Lake in 1952. Many of the disadvantages of chemical macrophyte control discussed above apply to chemical algae control as well. In addition, copper, the active ingredient in algicides, may accumulate in the bottom sediments. Excessive levels of copper are toxic to fish and benthic animals.

Table 27

SUMMARY OF THE EXISTING ZONING DISTRICTS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE IN WHICH PART OF THE DISTRICT IS SUBJECT TO SHORELAND AND FLOODLAND ZONING DISTRICT REGULATIONS

Zoning District	Permitted Uses		Conditional/Special Uses	Area Regulations: Minimum Lot Size	
	Principal	Accessory		Area	Average Width
C-1 Conservancy District	Grazing, harvesting of any wild crops, hunting and fishing, sustained yield forestry, dams and hydroelectric power stations, telephone, telegraph, and power transmission lines, parks and recreation areas, nonresidential buildings used solely in conjunction with the raising of waterfowl, minnows, and other similar lowland animals, fowl, or fish	--	Commercial fish or bait ponds or hatcheries	No minimum	No minimum
R-1 Residential District	Any use as permitted in the C-1 Conservancy District, the AE Exclusive Agriculture District or the A-1 Agricultural District, one-family dwellings, public parks and recreation areas, home occupations, and professional offices	--	Antique shops, gift shops, art studios, cemeteries, mausoleums, planned unit developments, private clubs and outdoor recreational facilities, public and semi-public buildings and uses	1 acre	150 feet
R-3 Residential District	Any use as permitted in the R-1 and the R-2 Residential Districts	--	Any use as permitted in the R-1 Residential District, multiple-family units	20,000 square feet	120 feet
B-2 Local Business District	Any use as permitted in the R-1, R-2, and R-3 Residential Districts and the B-1 Restricted Business District. In addition, see list of local retail establishments printed in the Shoreland and Floodland Protection Ordinance	--	Automobile service stations, marinas and boat liveries, motels, hotels, outdoor theaters, planned unit developments, private clubs and outdoor recreational facilities, public and semi-public buildings and uses and clean fill disposal sites	30,000 square feet	120 feet

NOTE: These districts are not quantified because they are not comparable to the quantifications in Table 26.

Source: SEWRPC.

Table 28

LAKES RECEIVING THE 10 LARGEST AMOUNTS OF SODIUM ARSENITE IN WISCONSIN FOR AQUATIC MACROPHYTE CONTROL: 1950-1969

Lake	County	Amount of Sodium Arsenite (pounds)
Pewaukee	Waukesha	334,232
Okauchee	Waukesha	181,580
Big Cedar	Washington	179,164
Pine	Waukesha	129,337
Fowler Lake[a]	Waukesha	87,456
Nagawicka	Waukesha	87,214
Lac La Belle	Waukesha	77,858
Onalaska	La Crosse	64,676
Shangrila (Benet)	Kenosha	59,020
Browns	Racine	56,600
Total	--	1,257,137[b]

[a] *Includes application of sodium arsenite to the Oconomowoc River near Fowler Lake.*

[b] *The 1,257,137 pounds of sodium arsenite applied to these lakes constitutes 57 percent of the total amount of sodium arsenite applied to a total of 167 lakes and streams in Wisconsin during the period 1950 to 1969.*

Source: Wisconsin Department of Natural Resources.

GOVERNMENTAL AGENCIES WITH WATER QUALITY MANAGEMENT RESPONSIBILITIES

A number of local, state, and federal agencies have potential water quality management responsibilities for North Lake. These agencies could include an inland lake protection and rehabilitation district, sanitary districts, the civil towns, cities, and villages, counties, soil and water conservation districts, the Regional Planning Commission, the Wisconsin Department of Natural Resources, the Wisconsin Department of Health and Social Services, the University of Wisconsin-Extension, the U. S. Environmental Protection Agency, the U. S. Department of Agriculture, Soil Conservation Service, and the U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service. A detailed discussion of the roles of these agencies in water quality management is presented in Chapter VI, Volume One, SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000. However, the role of each of these agencies is briefly described below.

Inland Lake Protection and Rehabilitation Districts

Inland lake protection and rehabilitation districts are special purpose units of government created pursuant to Chapter 33 of the Wisconsin Statutes. In its initial declaration of intent, the Wisconsin Legislature summarized the underlying philosophy behind the creation of these special purpose districts:

The legislature finds environmental values, wildlife, public rights in navigable waters, and the public welfare are threatened by the deterioration of public lakes; that the protection and rehabilitation of the public inland lakes of this state are in the best interest of the citizens of this state, that the public health and welfare will be benefited thereby; that the current state effort to abate water pollution will not undo the eutrophic and other deteriorated conditions of many lakes; and that the positive public duty of this state as trustee of waters requires affirmative steps to protect and enhance this resource and protect environmental values.

Inland lake protection and rehabilitation districts are formed at the local level. The district organizers, who may be any local property owners, propose appropriate boundaries encompassing the riparian property and as much of the lake watershed as deemed necessary. Once the district boundary has been so proposed, the organizers must obtain a petition signed by at least 51 percent of the property owners or by the owners of at least 51 percent of the land within the proposed district boundaries. The petition is presented to the County Board which holds a hearing after notifying all property owners in the proposed district. Following the hearing, the county board may form an inland lake protection and rehabilitation district.

The lake district has powers to enter into contracts; own property; disburse money; and to bond, borrow, and levy special assessments to raise money. Its specific lake management powers include:

1. Study existing water quality conditions and determine the causes of existing or expected future water quality problems.

2. Control aquatic macrophytes, algae, and swimmer's itch.

3. Implement lake rehabilitation techniques, including aeration, diversion, nutrient removal or inactivation, selective discharge, dredging, sediment covering, and drawdown.

4. Construct and operate water level control structures.

5. Control nonpoint source pollution.

The districts do not have police powers but may ask counties, towns, villages, or cities to enact ordinances necessary to improve or protect the lake. The governing body of a lake district is a board of commissioners, which consists of:

- Three property owners from within the district, elected by all property owners within the district.

- A county board member who is also a Soil and Water Conservation District Supervisor who has been nominated by the Supervisors of the Soil and Water Conservation District and appointed by the County Board, and

- A representative of the town, village or city having the highest assessed valuation within the district who is appointed by the governing body of that unit of government.

Sanitary Districts

Sanitary districts may be created under Section 66.30 of the Wisconsin Statutes to plan, construct, and maintain centralized sanitary sewerage systems. Town sanitary districts have limited authority to construct and maintain storm sewer systems and provide garbage and refuse collection and disposal. Such districts have also been used as an organizational vehicle for lake macrophyte harvesting.

Towns

Towns have authority to undertake a wide variety of activities with respect to the abatement of pollution from both point and nonpoint sources. Towns that contain both urban and rural areas generally have elected to establish separate sanitary and utility districts for the provision of services to urban development, particularly including sanitary sewer and storm water management services. Towns may also undertake stream and lake improvements and watershed protection projects.

Cities and Villages

Cities and villages possess authority to implement both the point and urban nonpoint source pollution abatement plans. Cities and villages possess general home rule authority and have specific authority to construct, operate, and maintain a sanitary sewerage system. In addition, cities and villages have authority to convey and treat storm waters, including construction, operation, and maintenance of urban storm water conveyance, storage, and treatment facilities. Cities and villages can undertake nonpoint source pollution abatement activities in conjunction with traditional public works activities, including litter and leaf control, animal waste control, and street sweeping and cleaning. Thus, cities and villages are granted all of the powers required to implement the point and nonpoint source pollution abatement elements of the plan in urban areas. Those powers may be exercised in the promulgation of construction erosion control ordinances, the construction and operation of storm water management systems, the development and enforcement of urban sanitation and refuse control ordinances, and the construction, operation, and maintenance of sanitary sewerage systems and attendant sewage treatment works.

Counties

Counties are authorized to engage in soil and water conservation projects, lake and river improvements, property acquisitions, water protection, and solid waste management. In addition, counties may regulate nonpoint source pollution through their planning, zoning, subdivision, building, and health code authorities. Counties are also important to the functioning of the soil and water conservation districts. Not only are such districts fiscally dependent upon county boards, but in effect the districts are governed by a county board committee. In implementation of the North Lake water quality management plan, therefore, it would be necessary for the Waukesha County Board and the County Soil and Water Conservation District to work together in a fully integrated effort.

Soil and Water Conservation Districts

Soil and water conservation districts, as authorized under Section 92.05 of the Wisconsin Statutes, have the authority to develop plans for the conservation of soil and water resources and for the prevention of soil erosion. In addition, the districts have authority to request the County Board of Supervisors to adopt special land use regulations that would implement such plans in unincorporated areas. Such adoption, however, requires a referendum in which a simple majority of the eligible electors who voted and were residents of the area affected approve the proposed regulations. Soil and water conservation districts have the authority to acquire--through eminent domain proceedings--any property or rights therein for watershed protection, soil and water conservation, flood prevention works, and fish and wildlife conservation and recreational works.

Regional Planning Commissions

In its role as a coordinating agency for water pollution control activities within southeastern Wisconsin, the Regional Planning Commission utilizes the legally adopted and certified regional plan elements as a basis for review of federal and state grants in aid, discharge permits, and sanitary sewer extensions. The Commission provides technical assistance pertaining to water quality management topics, and further promotes plan implementation through community assistance planning services, as appropriate. In addition, the Commission stands ready to provide a forum for the discussion of intergovernmental issues which may become critical to the orderly and timely implementation of water quality management projects. These indirect plan implementation functions must be distinguished from the plan implementation responsibilities of the other management agencies, through whose direct actions the plans are converted to reality.

Wisconsin Department of Natural Resources

The responsibility for water pollution control in Wisconsin is centered in the Wisconsin Department of Natural Resources. The basic authority and accompanying responsibilities relating to the water pollution control functions of the Department are set forth in Chapter 144 of the Wisconsin Statutes. Under this chapter, the Department is given broad authority to prepare as well as to approve or endorse water quality management plans; to establish water use objectives and supporting water quality standards; to review and approve all plans and specifications for components of sanitary sewerage systems; to conduct research and demonstration projects on sewerage and waste treatment matters; to operate an examining program for the certification of sewage treatment plant operators; to order the installation of centralized sanitary sewerage systems; to review and approve the creation of joint sewerage systems and metropolitan sewerage districts; to regulate water level elevations; and to administer a financial assistance program for the construction of pollution prevention and abatement facilities, or for the application of land management measures. The Wisconsin Statutes also authorize the Department to consider conformance with an approved areawide water quality management plan when reviewing locally proposed sanitary sewer extensions. This permissive authority is in addition to the Department's mandatory review for engineering soundness and for relation to public health and safety.

Under Chapter 147 of the Wisconsin Statutes, the Department is given broad authority to establish and carry out a pollutant discharge elimination program in accordance with the policy guidelines set forth by the U. S. Congress under the Federal Water Pollution Control Act. Pursuant to this authority, the Department has established a waste discharge permit system. No permit may be issued by the Department for any discharge from a point source of pollution that is in conflict with any areawide water quality management plan approved by the Department. Also under this authority, the Department has rule-making powers to establish effluent limitations, water quality-related limitations, performance standards related to classes or categories of pollution, and toxic and pretreatment effluent standards. All permits issued by the Department must include conditions that waste discharges are to meet, in addition to effluent limitations, performance standards, effluent prohibitions, pretreatment standards, and any other limitations needed to achieve the adopted water use objectives and supporting water quality standards. As appropriate, the permits may include a timetable for appropriate action on the part of the owner or operator of any point source waste discharge.

Wisconsin Department of Health and Social Services, Division of Health

In performing its functions relating to the maintenance and promotion of public health, the Wisconsin Division of Health is charged with the responsibility of regulating the installation and operation of private septic tank sewage disposal systems. The Division reviews plats of all land subdivisions not served by public sanitary sewerage systems and may object to such plats if onsite sanitary waste disposal facilities are not properly provided for in the plat layout.

University of Wisconsin-Extension

The Extension Service operates on a contractual basis with counties to provide technical and educational assistance within the counties. Of particular importance to implementation of the areawide water quality management plan is the provision of technical assistance by the Extension Service to county soil and water conservation districts, county boards, and county zoning and planning committees. In addition, the Extension Service is well equipped to provide educational services, especially in the areas of nonpoint source pollution and sludge management.

U. S. Environmental Protection Agency

The U. S. Environmental Protection Agency has broad powers under the federal Water Pollution Control Act to administer federal grants-in-aid for the construction of publicly owned waste treatment works and related sewerage facilities; to promote and fund areawide waste treatment planning and management; to set and enforce water quality standards, including effluent limitations, through the establishment of water quality inventories and inspection and monitoring programs; and to establish a national pollutant discharge elimination system. The Environmental Protection Agency, thus, acts as the key federal water pollution control agency and must approve all basin and areawide water quality management plans as certified to it by appropriate state agencies.

U. S. Department of Agriculture, Soil Conservation Service

The U. S. Department of Agriculture, Soil Conservation Service, administers resource conservation and development projects under Public Law 566 and provides technical and financial assistance through soil and water conservation districts to landowners in the planning and construction of measures for land treatment, agricultural water management, and flood prevention, and for public fish, wildlife, and recreational development. The Soil Conservation Service also conducts detailed soils surveys and provides interpretations as a guide to the use of soil survey data in local planning and development. The technical assistance programs of the Soil Conservation Service are of great importance to implementation of the areawide water quality management plan.

U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service

The U. S. Department of Agriculture, Agricultural Stabilization and Conservation Service, administers the federal Agricultural Conservation Program (ACP), which provides grants to rural landowners in partial support of carrying out approved soil, water, woodland, wildlife, and other conservation practices. These grants are awarded under yearly and long-term assistance programs, providing guaranteed funds for carrying out approved conservation work plans. Grants from the federal Agricultural Conservation Program are important to implementation of the areawide water quality management plan. In addition, the Agricultural Stabilization and Conservation Service has relatively new authority under Section 208(J) of the federal Water Pollution Control Act to administer a cost-sharing grant program for the purpose of installing and maintaining agricultural measures found needed to control nonpoint source pollution.

PRIVATE ACTION FOR WATER POLLUTION CONTROL

The foregoing discussion deals exclusively with water quality management by units and agencies of government. Direct action may also be taken, however, by private individuals or organizations to effectively abate water pollution. As shown later in the "Alternative Water Quality Management Measures" chapter, some of the most important, yet least costly, management practices can be readily carried out by individual citizens. In addition, most of the activities of the agencies previously discussed require the cooperation and support of individual citizens and of citizen groups, in order to be effectively implemented.

Chapter VII

WATER USE OBJECTIVES AND WATER QUALITY STANDARDS

The Regional Planning Commission adopted areawide water quality management plan, as set forth in SEWRPC Planning Report No. 30, A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, recommends water use objectives and supporting water quality standards for all major lakes and streams in the Region. The water use objectives recommended for North Lake, as well as for the Oconomowoc River, are full recreational use and support of a healthy warmwater fishery. The water quality standards which support these objectives are set forth in Table 29. Standards are recommended for temperature, pH, dissolved oxygen, fecal coliform, residual chlorine, un-ionized ammonia nitrogen, and total phosphorus.

The total phosphorus standard of 0.02 milligram per liter (mg/l) applies to lakes during spring turnover, when the lakes are not stratified and maximum vertical mixing is occurring. The achievement of this standard is expected to prevent excessive macrophyte and algae growths in most lakes, although lake rehabilitation techniques may also be required to avoid seasonal problems associated with the recycling of phosphorus from the bottom sediments. Excessive total phosphorus levels may stimulate large growths of algae and aquatic macrophytes, which interfere with recreational use. As these plant masses die and decompose, dissolved oxygen depletions may result which threaten the survival of fish and aquatic life. Although many factors are involved, one pound of phosphorus may produce from 1,000 to 10,000 pounds wet weight of aquatic plant material. Upon the decomposition of this amount of plant material generated from one pound

Table 29

RECOMMENDED WATER QUALITY STANDARDS TO SUPPORT RECREATIONAL AND WARMWATER FISH AND AQUATIC LIFE USE

Parameter	Standard
Maximum Temperature	89°F[a,b]
pH Range	6.0-9.0 standard units
Minimum Dissolved Oxygen	5.0 mg/l[b]
Maximum Fecal Coliform	200/400 MFFCC/100 ml[c]
Maximum Total Residual Chlorine	0.01 mg/l
Maximum Un-ionized Ammonia Nitrogen	0.02 mg/l
Maximum Total Phosphorus	0.02 mg/l[d]
Other	--[e,f]

[a] *There shall be no temperature changes that may adversely affect aquatic life. Natural daily and seasonal temperature fluctuations shall be maintained. The maximum temperature rise at the edge of the mixing zone above the existing natural temperature shall not exceed 5°F for streams and 3°F for lakes.*

[b] *Dissolved oxygen and temperature standards apply to streams and the epilimnion of stratified lakes and to the unstratified lakes; the dissolved oxygen standard does not apply to the hypolimnion of stratified inland lakes. Trends in the period of anaerobic conditions in the hypolimnion of stratified inland lakes should be considered important to the maintenance of water quality, however.*

[c] *The membrane filter fecal coliform count per 100 milliliters (MFFCC/100 ml) shall not exceed a monthly geometric mean of 200 per 100 ml based on not less than five samples per month, nor a monthly geometric mean of 400 per 100 ml in more than 10 percent of all samples during any month.*

[d] *The values presented for lakes are the critical total phosphorus concentrations which apply only during spring when maximum mixing is underway.*

[e] *All waters shall meet the following minimum standards at all times and under all flow conditions: substances that will cause objectionable deposits on the shore or in the bed of a body of water shall not be present in such amounts as to interfere with public rights in waters of the State. Floating or submerged debris, oil, scum, or other material shall not be present in such amounts as to interfere with public rights in the waters of the State. Materials producing color, odor, taste, or unsightliness shall not be present in amounts which are acutely harmful to animal, plant, or aquatic life.*

[f] *Unauthorized concentrations of substances are not permitted that alone or in combination with other materials present are toxic to fish or other aquatic life. The determination of the toxicity of a substance shall be based upon the available scientific data base. References to be used in determining the toxicity of a substance shall include, but not be limited to, Quality Criteria for Water, EPA-440/9-76-003, U. S. Environmental Protection Agency, Washington, D. C., 1976, and Water Quality Criteria 1972. EPA R3-73-003, National Academy of Engineering, U. S. Government Printing Office, Washington, D. C., 1974. Questions concerning the permissible levels, or changes in the same, of a substance, or combination of substances, or undefined toxicity to fish and other biota shall be resolved in accordance with the methods specified in Water Quality Criteria 1972 and Standard Methods for the Examination of Water and Wastewater, 14th Edition. American Public Health Association, New York, 1975, or other methods approved by the Department of Natural Resources.*

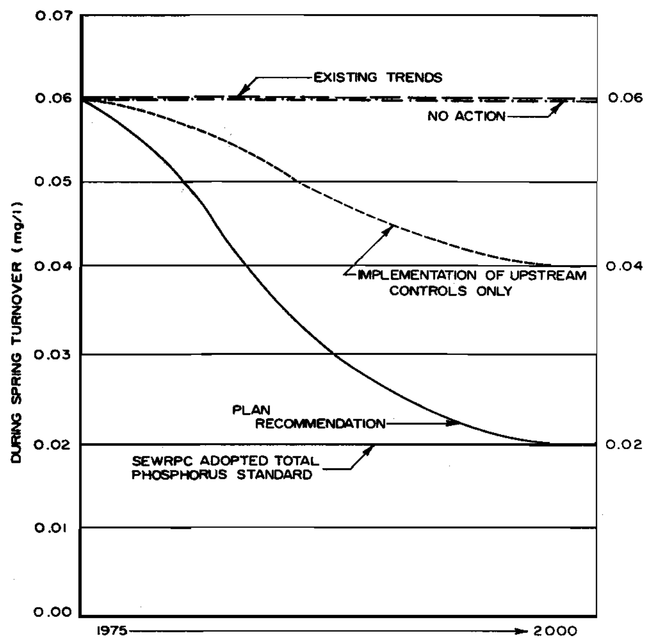
Source. SEWRPC.

of phosphorus, 100 pounds or more of dissolved oxygen would be consumed.

The phosphorus concentration in the lake is directly related to the phosphorus load contributed to the lake via tributary runoff, and atmospheric sources, although some recycling of phosphorus from the lake bottom sediments may also occur. Figure 19 indicates the total phosphorus concentrations expected to occur in North Lake during spring turnover under alternative water quality management actions in the lake watershed. Failure to implement any management measures in the lake watershed may be expected to result in continued excessive phosphorus levels, and a resulting decrease in water quality and water use potential. Complete implementation of the plan recommendations set forth in this report are estimated to result in the achievement of the phosphorus standard of 0.02 mg/l and subsequently to provide water quality suitable for a full range of recreational use opportunities and for support of a balanced warmwater fishery.

Figure 19

TOTAL PHOSPHORUS LEVELS IN NORTH LAKE UNDER ALTERNATIVE POLLUTION CONTROL ACTIONS



NOTE: TOTAL PHOSPHORUS CONCENTRATIONS ARE SIMULATED USING THE 1976 DILLON AND RIGLER VOLLENWEIDER MODEL.

Source: SEWRPC.

Chapter VIII

ALTERNATIVE WATER QUALITY MANAGEMENT MEASURES

INTRODUCTION

Potential measures for water quality management of North Lake include point source pollution control measures, nonpoint source pollution control measures and lake rehabilitation techniques. Point source pollution control measures consist of the design, construction, and operation of sanitary sewerage systems. Nonpoint source pollution control measures consist of the improved management of both urban and rural land uses to reduce pollutants discharged to the lake by direct overland drainage, by drainage through natural or man-made channels, and by groundwater inflow. Lake rehabilitation techniques either directly treat the symptoms of lake eutrophication, such as macrophyte harvesting, or alter the characteristics of the lake basin which may be interfering with the achievement of water use objectives, such as limited dredging of bottom sediments.

In developing alternative water quality management measures, it was assumed that the recommendations set forth in the adopted areawide water quality management plan for the Oconomowoc River drainage area upstream of North Lake would be implemented. Accordingly, the recommendations in this report deal primarily with water quality management measures in the drainage area directly tributary to North Lake or within the lake basin itself.

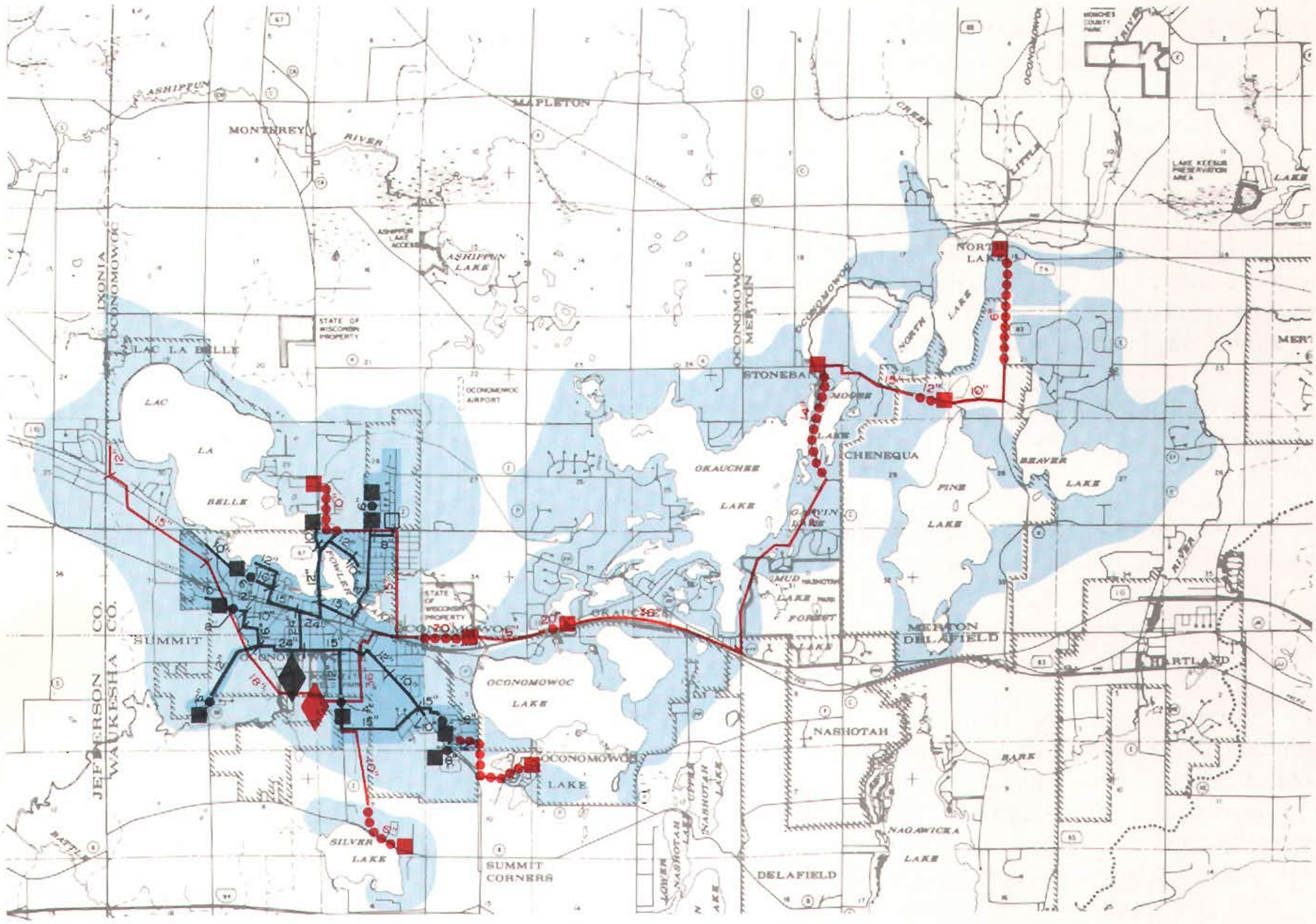
POINT SOURCE POLLUTION CONTROL

As recommended in the regional sanitary sewerage system plan, adopted by the Commission in 1974, the Oconomowoc sewage treatment plant would serve as a regional facility to provide wastewater treatment service to the Oconomowoc--Lac La Belle, Oconomowoc Lake, Okauchee Lake, North Lake, Pine Lake, Beaver Lake, and Silver Lake sewer service areas. That recommendation was reaffirmed in the regional water quality management plan adopted by the Commission in 1979.

In 1978, the wastewater treatment facility serving the City of Oconomowoc was upgraded and expanded to provide secondary waste treatment, tertiary waste treatment, and auxiliary waste treatment for effluent disinfection and expanded to provide an average hydraulic design capacity of 4 million gallons per day (mgd). It is anticipated that the extension of service to existing and proposed urban development around Lac La Belle, Okauchee Lake, North Lake, Pine Lake, Beaver Lake, Silver Lake and Oconomowoc Lake and the flow from the existing and proposed sewer service area of the City of Oconomowoc will require an average hydraulic capacity of 3.1 mgd by 1985. Final extension of sanitary sewer service to urban development around Okauchee Lake, Pine Lake, Beaver Lake, North Lake, and Silver Lake may be expected to require an average hydraulic design capacity at the City of Oconomowoc sewage treatment plant of 6.5 mgd by the year 2000. Therefore, additional capacity may be expected to be required at the Oconomowoc facility before the year 2000. The proposed sewer service area and trunk sewer system are shown on Map 18. As of 1975, there were no known industrial point sources of wastewater tributary to North Lake or to streams tributary to the lake which required treatment or elimination.

Map 18

RECOMMENDED SANITARY SEWERAGE SYSTEM PLAN FOR THE OCONOMOWOC-LAC LA BELLE, OCONOMOWOC LAKE, OKAUCHEE LAKE, NORTH LAKE, PINE LAKE, BEAVER LAKE, AND SILVER LAKE SEWER SERVICE AREAS--MIDDLE ROCK RIVER SUBREGIONAL AREA: 2000



LEGEND

SEWER SERVICE AREAS

EXISTING 1975

PROPOSED 2000

SEWAGE TREATMENT FACILITIES

EXISTING PUBLIC TO BE RETAINED

PROPOSED PUBLIC

SEWERS AND APPURTENANT FACILITIES

EXISTING TRUNK SEWER

PROPOSED TRUNK SEWER

EXISTING FORCE MAIN

PROPOSED FORCE MAIN

EXISTING LIFT STATION

EXISTING PUMPING STATION

PROPOSED PUMPING STATION

Source: SEWRPC.

NONPOINT SOURCE POLLUTION CONTROL

Nonpoint sources of water pollution include urban sources--such as runoff from residential, commercial, industrial, transportation, and recreational land uses; construction activities; and septic tank systems--and rural sources--such as runoff from cropland, pasture, and woodland; livestock wastes; and atmospheric contributions.

The water quality analyses presented previously in this report indicate that a reduction in nutrient loads from nonpoint sources in the tributary area would be needed to meet the recommended water use objectives and supporting water quality standards. Alternative nonpoint source control measures are set forth in Table 30. About a 35 percent reduction in the existing nonpoint source loads from the tributary drainage area is needed to meet the recommended water use objectives and supporting standards.

LAKE REHABILITATION TECHNIQUES

Although preventing further deterioration in lake water quality conditions, the reduction of nutrient inputs to North Lake alone should not be expected to result in the elimination of existing water quality problems. In mesotrophic or eutrophic lakes, especially in the presence of anaerobic conditions in the hypolimnion, such as occur in North Lake, significant amounts of phosphorus may be released from the existing sediments to the overlying water column. Consequently, the water quality improvements expected from a reduced nutrient input may be inhibited or prevented by this condition. If this occurs, or if other characteristics of the lake result in restricted water use potential, the application of lake rehabilitation techniques should be considered.

The applicability of specific lake rehabilitation techniques is highly dependent on lake characteristics. The success of any lake rehabilitation technique can seldom be guaranteed since the state-of-the-art is still in the early stages of development. Because of the relatively high cost of applying most techniques, a cautious approach to implementing lake rehabilitation techniques is recommended. Certain lake rehabilitation techniques should be applied only to lakes in which: 1) nutrient inputs to the lake have been reduced to below the critical level; 2) there is a high probability of success; and 3) the possibility of adverse environmental impacts is minimal. Finally, it should be noted that some lake rehabilitation techniques require issuance of permits from appropriate state and/or federal agencies prior to implementation.

Alternative lake rehabilitation and in-lake management measures discussed below include hypolimnetic aeration, dredging, sediment covering, nutrient inactivation, dilution flushing, selective discharge, macrophyte harvesting, algae harvesting, chemical controls, and fish management. All cost figures related to the measures discussed are presented in January 1980 dollars.

Hypolimnetic Aeration

The purpose of hypolimnetic aeration is to provide oxygen to the hypolimnion of a stratified lake without disrupting the stratification. The hypolimnion of North Lake underlies about 236 acres, or about 54 percent of the lake surface area. During some portions of the summer, the entire volume of the hypolimnion was found to have dissolved oxygen levels of less than 2.0 mg/l. To provide hypolimnetic aeration, typically the bottom water is airlifted up a vertical tube, with oxygenated water returned to the hypolimnion, as shown in Figure 20. Aeration of the hypolimnion increases the decomposition of organic matter, and promotes sorption of phosphorus by

Table 30

GENERALIZED SUMMARY OF METHODS AND EFFECTIVENESS OF NONPOINT SOURCE POLLUTION ABATEMENT MEASURES

Applicable Land Use	Control Measures[a]	Summary Description[b]	Approximate Percent Reduction of Released Pollutants[c]	Assumptions for Costing Purposes
Urban	Litter and pet waste control ordinance	Prevent the accumulation of litter and pet wastes on streets and residential, commercial, industrial, and recreational areas	2-5	Ordinance administration and enforcement costs are expected to be funded by violation penalties and related revenues
	Improved timing and efficiency of street sweeping, leaf collection and disposal, and catch basin cleaning	Improve the scheduling of these public works activities, modify work habits of personnel, and select equipment to maximize the effectiveness of these existing pollution control measures	2-5	No significant increase in current expenditures is expected
	Management of onsite sewage treatment systems	Regulate septic system installation, monitoring, location, and performance; replace failing systems with new septic systems or alternative treatment facilities; develop alternatives to septic systems; eliminate direct connections to drain tiles or ditches; dispose of septage at sewage treatment facility	10-30	Replace one-half of estimated existing failing septic systems with properly located and installed systems and replace one-half with alternative systems, such as mound systems or holding tanks; all existing and proposed onsite sewage treatment systems are assumed to be properly maintained; assume system life of 25 years. The estimated cost of a septic tank system is $2,300 and the cost of an alternative system is $4,500. The annual maintenance cost of a disposal system is $45. A holding tank would cost $1,300 with an annual operation and maintenance cost of $1,200. However, because septic system management is an existing function necessary for the preservation of public health and the maintenance of drinking water supplies, these costs are not included as part of the areawide water quality maintenance plan
	Increased street sweeping	On the average, sweep all streets in urban areas an equivalent of once or twice a week with vacuum street sweepers; require parking restrictions to permit access to curb areas; sweep all streets at least eight months per year; sweep commercial and industrial areas with greater frequency than residential areas	30-50	Estimate curb miles based on land use, estimated street acreage, and Commission transportation planning standards; assume one street sweeper can sweep 2,000 curb miles per year; assume sweeper life of 10 years; assume residential areas swept once weekly, commercial and industrial areas swept twice weekly. The cost of a vacuum street sweeper is approximately $38,000. The cost of the operation and maintenance of a sweeper is about $10 per curb/mile swept
	Increased leaf and clippings collection and disposal	Increase the frequency and efficiency of leaf collection procedures in fall; use vacuum cleaners to collect leaves; implement ordinances for leaves, clippings, and other organic debris to be mulched, composted, or bagged for pickup	2-5	Assume one equivalent mature tree per residence plus five trees per acre in recreational areas; 75 pounds of leaves per tree; 20 percent of leaves in urban areas not currently disposed of properly. The cost of the collection of leaves in a vacuum sweeper and disposal is estimated at $25 per ton of leaves

Table 30 (continued)

Applicable Land Use	Control Measures[a]	Summary Description[b]	Approximate Percent Reduction of Released Pollutants[c]	Assumptions for Costing Purposes
Urban (continued)	Increased catch basin cleaning	Increase frequency and efficiency of catch basin cleaning; clean at least twice per year using vacuum cleaners; catch basin installation in new urban development not recommended as a cost-effective practice for water quality improvement	2-5	Determine curb miles for street sweeping; vary percent of urban area served by catch basins by watershed from Commission inventory data; assume density of 10 catch basins per curb mile; clean each basin twice annually by vacuum cleaner. The cost of cleaning a catch basin is approximately $8
	Reduced use of deicing salt	Reduce use of deicing salt on streets; salt only intersections and problem areas; prevent excessive use of sand and other abrasives	Negligible for pollutants addressed in this chapter but helpful for reducing chlorides and associated damage to vegetation	Increased costs, such as for slower transportation movement, are expected to be offset by benefits such as reduced automobile corrosion and damage to vegetation
	Improved street maintenance and refuse collection and disposal	Increase street maintenance and repairs; increase provision of trash receptacles in public areas; improve trash collection schedules; increase cleanup of parks and commercial centers	2-5	Increase current expenditures by approximately 15 percent. The annual cost per person is about $4
	Parking lot storm water temporary storage and treatment measures	Construct gravel-filled trenches, sediment basins, or similar measures to store temporarily the runoff from parking lots, rooftops, and other large impervious areas; if treatment is necessary, use a physical-chemical treatment measure such as screens, dissolved air flotation, or a swirl concentrator	5-10	Design gravel-filled trenches for 24-hour, five year recurrence interval storm; apply to off-street parking acreages. For treatment—assume four-hour detention time. The capital cost of storm water detention and treatment facilities is estimated at $9,000 per acre of parking lot area, with an annual operation and maintenance cost of about $100 per acre
	Onsite storage—residential	Remove connections to sewer systems; construct onsite storm water storage measures for subdivisions	5-10	Remove roof drains and other connections to sewer system wherever needed; use lawn aeration if applicable; apply dutch drain storage facilities to 15 percent of residences. The capital cost would approximate $200 per house, with an annual maintenance cost of about $10

Table 30 (continued)

Applicable Land Use	Control Measures[a]	Summary Description[b]	Approximate Percent Reduction of Released Pollutants[c]	Assumptions for Costing Purposes
Urban (continued)	Storm water storage—urban	Store storm water runoff from urban land in surface storage basins or, where necessary, subsurface storage basins	10-35	Design all storage facilities for a 1.5 inch of runoff event, which corresponds approximately to a five-year recurrence interval event with a storm event being defined as a period of precipitation with a minimum antecedent and subsequent dry period of from 12 to 24 hours; apply subsurface storage tanks to intensively developed existing urban areas where suitable open land for surface storage is unavailable; design surface storage basins for proposed new urban land, existing urban land not storm sewered, and existing urban land where adequate open space is available at the storm sewer discharge site. The capital cost for storm water storage would range from $1,000-$10,000 per acre of tributary drainage area, with an annual operation and maintenance cost of about $20-$40 per acre
	Storm water treatment	Provide physical-chemical treatment which includes screens, microstrainers, dissolved air flotation, swirl concentrator, or high-rate filtration, and/or disinfection, which may include chlorination, high-rate disinfection, or ozonation to storm water following storage	10-50	To be applied only in combination with storm water storage facilities above; general cost estimates for microstrainer treatment and ozonation were used; same costs were applied to existing urban land and proposed new urban development. Storm water treatment has an estimated capital cost of from $900-$7,000 per acre of tributary drainage area, with an average annual operation and maintenance cost of about $35 per acre
Rural	Conservation practices	Includes such practices as strip cropping, contour plowing, crop rotation, pasture management, critical area protection, grading and terracing, grassed waterways, diversions, wood lot management, fertilization and pesticide management, and chisel tillage	Up to 50	Costs for Soil Conservation Service (SCS)-recommended practices are applied to agricultural and related rural land; the distribution and extent of the various practices were determined from an examination of 56 existing farm plan designs within the Region. The capital cost of conservation practices ranges from $0.30-$14 per acres of rural land, with an average annual operation and maintenance cost of from $2-$4 per rural acre

Table 30 (continued)

Applicable Land Use	Control Measures[a]	Summary Description[b]	Approximate Percent Reduction of Released Pollutants[c]	Assumptions for Costing Purposes
Rural (continued)	Animal waste control system	Construct stream bank fencing and crossovers to prevent access of all livestock to waterways; construct a runoff control system or a manure storage facility, as needed, for major livestock operations; prevent improper applications of manure on frozen ground, near surface drainageways, and on steep slopes; incorporate manure into soil	50-75	Cost estimated per animal unit; animal waste storage (liquid and slurry tank for costing purposes) facilities are recommended for all major animal operations within 500 feet of surface water and located in areas identified as having relatively high potential for severe pollution problems. Runoff control systems recommended for all other major animal operations. It is recognized that dry manure stacking facilities are significantly less expensive than liquid and slurry storage tanks and may be adequate waste storage systems in many instances. The estimated capital cost and average operation and maintenance cost of a runoff control system is $90 per animal unit and $10 per animal unit, respectively. The capital cost of a liquid and slurry storage facility is about $425 per animal unit, with an annual operation and maintenance cost of about $30 per unit. An animal unit is the weight equivalent of a 1,000-pound cow
	Base-of-slope detention storage	Store runoff from agricultural land to allow solids to settle out and reduce peak runoff rates. Berms could be constructed parallel to streams	50-75	Construct a low earthen berm at the base of agricultural fields, along the edge of a floodplain, wetland, or other sensitive area, design for 24-hour, 10-year recurrence interval storm; berm height about four feet. Apply where needed in addition to basic conservation practices; repair berm every 10 years and remove sediment and spread on land. The estimated capital cost of base-of-slope detention storage would be about $250 per tributary acre, with an annual operation and maintenance cost of $10 per acre
	Bench terraces	Construct bench terraces, thereby reducing the need for many other conservation practices on sloping agricultural land	75-90	Apply to all appropriate agricultural lands for a maximum level of pollution control. Utilization of this practice would exclude installation of many basic conservation practices and base-of-slope detention storage. The capital cost of bench terraces is estimated at $625 per acre, with an annual operation and maintenance cost of $45 per acre

Table 30 (continued)

Applicable Land Use	Control Measures[a]	Summary Description[b]	Approximate Percent Reduction of Released Pollutants[c]	Assumptions for Costing Purposes
Urban and Rural	Public education programs	Conduct regional- and county-level public education programs to inform the public and provide technical information on the need for proper land management practices on private land, the recommendations for management programs, and the effects of implemented measures; develop local awareness programs for citizens and public works officials; develop local contact and education efforts	Indeterminate	For first 10 years includes cost of one person, materials, and support for each 25,000 population. Thereafter, the same cost can be applied to for every 50,000 population. The cost of one person, materials, and support is estimated at $33,000 per year
	Construction erosion control practices	Construct temporary sediment basins; install straw bale dikes; use fiber mats, mulching and seeding; install slope drains to stabilize steep slopes; construct temporary diversion swales or berms upslope from the project	20-40	Assume acreage under construction is the average annual incremental increase in urban acreage; apply costs for a typical erosion control program for a construction site. The estimated capital cost and operation and maintenance cost for construction erosion control is $2,200 and $400 per acre under construction, respectively
	Materials storage and runoff control facilities	Enclose industrial storage sites with diversions; divert runoff to acceptable outlet or storage facility; enclose salt piles and other large storage sites in crib and dome structures	5-10	Assume 40 percent of industrial areas are used for storage and to be enclosed by diversions; assume existing salt storage piles enclosed by cribs and dome structures. The estimated capital cost of industrial runoff control is $1,100 per acre of industrial land. Material storage control costs are estimated at $30 per ton of material
	Stream protection measures	Provide vegetative buffer zones along streams to filter direct pollutant runoff to the stream; construct stream bank protection measures, such as rock riprap, brush mats, tree revetment, jacks, and jetted willow poles where needed	5-10	Apply a 50-foot-wide vegetative buffer zone on each side of 15 percent of the stream length; apply stream bank protection measures to 5 percent of the stream length. Vegetative buffer zones are estimated to cost $21,200 per mile of stream, and streambank protection measures cost about $37,000 per stream mile
	Pesticide and fertilizer application restrictions	Match application rate to need; eliminate excessive applications and applications near or into surface water drainageways	0-3	Cost included in public education program
	Critical area protection	Emphasize control of areas bordering lakes and streams; correct obvious erosion and other pollution source problems	Indeterminate	Indeterminate

[a] *Not all control measures are evaluated for each watershed. The characteristics of the watershed, the estimated required level of pollution reduction needed to meet the applicable water quality standards, and other factors will influence the estimation of costs of specific practices for any one watershed. Although the control measures costed represent the recommended practices developed at the regional level on the basis of the best available information, the local implementation process should provide more detailed data and identify more efficient and effective sets of practices to apply to local conditions.*

[b] *For a more detailed description of pollution control measures for diffuse sources, see SEWRPC Technical Report No. 18, State of the Art of Water Pollution Control for Southeastern Wisconsin, Volume Three, Urban Storm Water Runoff, and Volume Four, Rural Storm Water Runoff.*

[c] *The approximate effectiveness refers to the estimated amount of pollution produced by the contributing category (urban or rural) that could be expected to be reduced by the implementation of the practice. The effectiveness rates would vary greatly depending on the characteristics of the watershed and individual diffuse sources. It should be further noted that practices can have only a "sequential" effect, since the percent pollution reduction of a second practice can only be applied against the residual pollutant load which is not controlled by the first practice. For example, two practices of 50 percent effectiveness would achieve a theoretical total effectiveness of only 75 percent control of the initial load. Further, the general levels of effectiveness reported in the table are not necessarily the same for all pollutants associated with each source. Some pollutants are transported by dissolving in water and others by attaching to solids in the water; the methods summarized here reflect typical pollutant removal levels.*

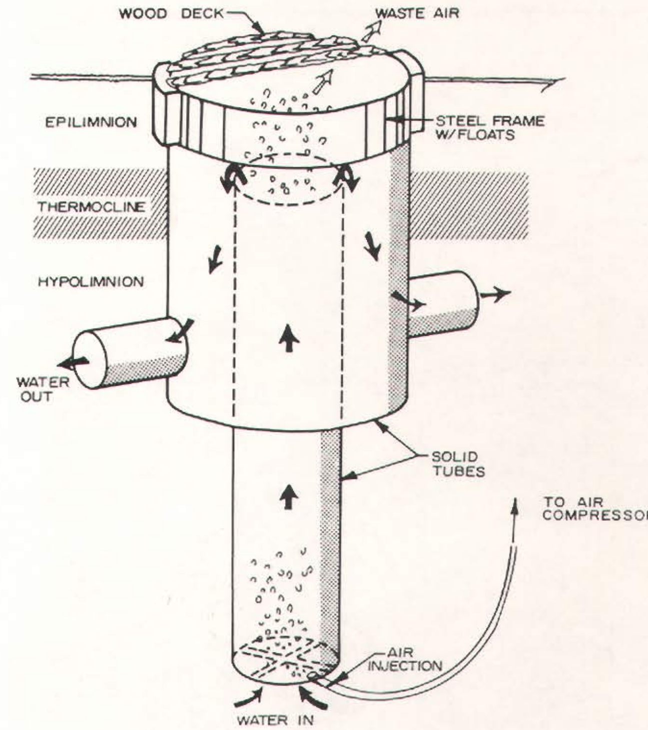
Source: SEWRPC.

the hydrous-oxides of iron and manganese presented in the lake bottom sediments. The result is that the concentration of phosphorus in the bottom waters may be substantially reduced, and oxygen levels improved, resulting in an improved habitat for fish and aquatic life. Hypolimnetic aeration also provides additional habitat for zooplankton, which can seek refuge from feeding fish during the day in the dark bottom lake waters, and migrate towards the surface at night to graze on algae. Increased zooplankton populations can effectively reduce certain species of algae.

Hypolimnetic aeration in North Lake to aerate the zone depicted on Map 19, at depths greather than 35 feet below the surface, would involve a capital cost of about $95,660, with an annual operation and maintenance cost of about $4,800. It is unlikely that the effects of nonpoint source pollution control measures in the lake watershed alone would--for some years, if ever--improve dissolved oxygen conditions in the hypolimnion substantially. However, hypolimnetic aeration could be implemented--even prior to the control of nonpoint pollution sources--in order to provide additional and more improvement in dissolved oxygen conditions in the lake bottom.

Figure 20

TYPICAL HYPOLIMNETIC AERATION SYSTEM FOR AN INLAND LAKE



Source: Adapted by SEWRPC from A.W. Fast, "The Effects of Artificial Aeration on Lake Ecology," U.S. EPA Water Pollution Control Research Series, 16010EXE, 1971.

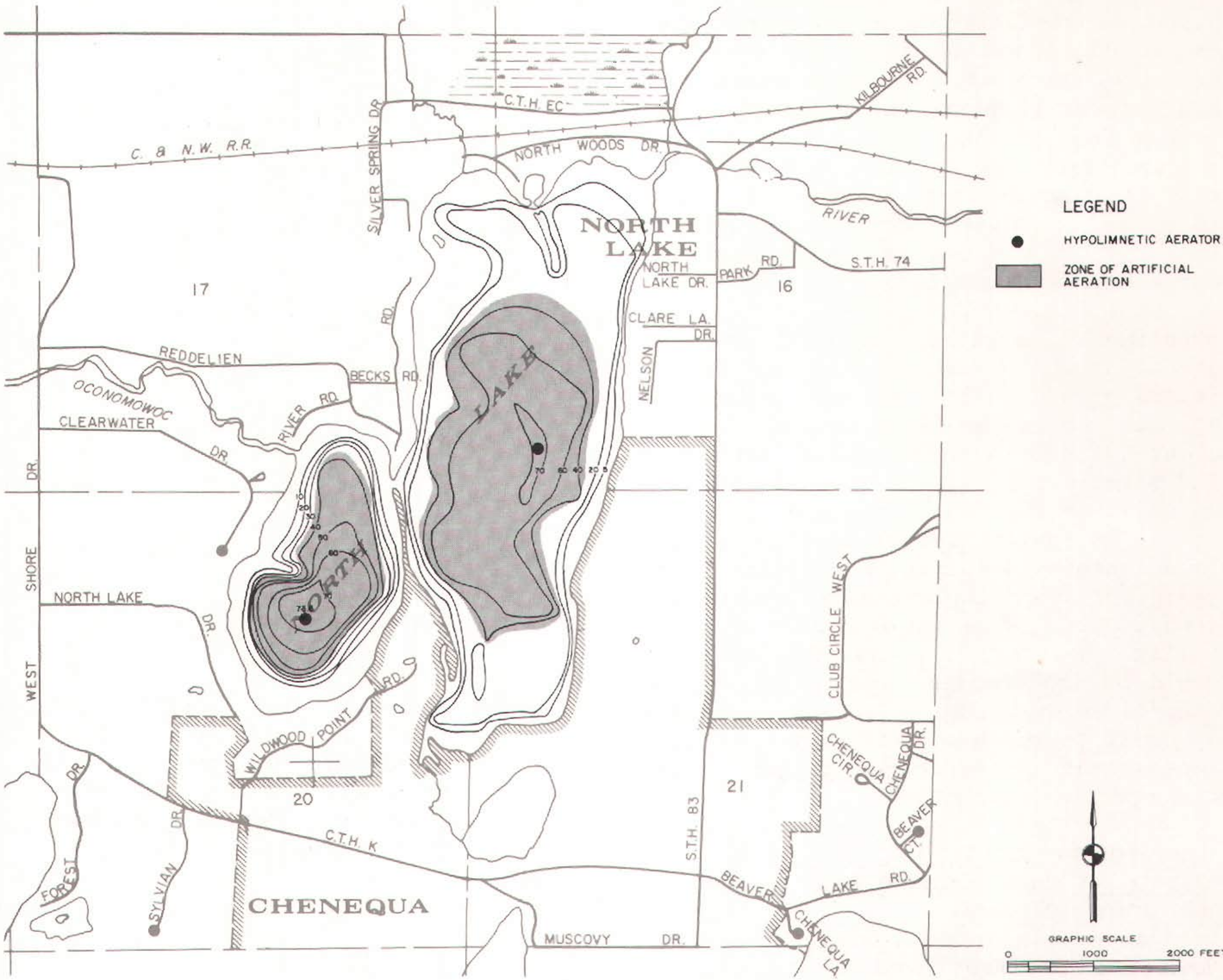
Measures for Controlling Sediment Effects on Water Column and Macrophyte Growth

Dredging, sediment covering, and drawdown for sediment consolidation serve to either deepen the lake or to provide bottom sediments which are less likely to release nutrients to the water column or support excessive macrophyte growth. Because of the relatively high cost of these practices, and the disruption to the lake community which occurs when these techniques are utilized on a large scale, implementation of these practices should be reserved only for lakes with the most severe water quality problems.

Rooted aquatic vegetation generally does not grow in nuisance concentrations in deep water and/or where bottom sediments are predominately composed of sand and gravel. As shown on Maps 1 and 3, North Lake is relatively deep and the bottom strata in the littoral zone is primarily sand and gravel. As was discussed in Chapter 5, a macrophyte survey conducted by the Wisconsin Department of Natural Resources in August 1976 revealed that the lake supports modest aquatic vegetative growth. Some dense patches of aquatic vegetation were recorded in the northern portion of the main basin where deposition of silt and sediment at the mouth of the Oconomowoc River has

Map 19

PLAN ALTERNATIVE FOR PLACEMENT OF HYPOLIMNETIC AERATION SYSTEMS IN NORTH LAKE AND ZONES OF ARTIFICIAL AERATION



Source: SEWRPC.

resulted in substrates more conducive to macrophyte growth. However, the areas of relatively dense growth on the lake are generally limited but provide necessary food, cover, and nesting habitat for many species of fish and other wildlife.

Dredging and sediment covering to control macrophyte growth or the release of nutrients from bottom sediments on North Lake are not necessary. The modest aquatic macrophyte growth, adequate lake depth, and predominate sand and gravel substrate are conditions which do not warrant the aforementioned in-lake management practices.

Nutrient Inactivation

The purpose of nutrient inactivation is to 1) change the form of a nutrient to make it unavailable to plants; 2) remove the nutrient from the photic (light-penetrated) zone, and 3) prevent release or recycling of potentially available nutrients from the lake sediments. Nutrient inactivation of phosphorus, which is usually accomplished by application of aluminum or another metallic salt, can be conducted for the entire lake--if nutrients from the epilimnion as well as the hypolimnion are to be removed--or for just the hypolimnion--if nutrients from only the hypolimnion are to be removed. Nutrient inactivation is most applicable to lakes which have long hydraulic residence times or in which recycling of phosphorus from the bottom sediments is significant. The hydraulic residence time of North Lake is moderate--about 9 months--and there is no indication that the amounts of phosphorus being released from the bottom sediments are having significant water quality effects. However, nutrient inactivation may be an effective technique for removing nutrients from the water column of North Lake, if combined with watershed management practices to reduce external phosphorus loads to the lake. The application of nutrient inactivation to the entire North Lake would cost about $43,900; application to the hypolimnion would only cost about $23,600. The treatment may need to be repeated periodically.

Dilution/Flushing

Dilution/flushing is intended to alleviate excessive algal growths and associated problems by reducing nutrient levels within a lake by the replacement of nutrient-rich waters with nutrient-poor waters, thereby flushing phytoplankton and the nutrients contained therein from the lake. Lake restoration projects have attempted nutrient dilution by two procedures: 1) pumping water out of the lake, thus permitting the increased inflow of nutrient-poor groundwater; and 2) routing additional quantities of nutrient-poor surface waters into the lake. Dilution/flushing is most applicable for lakes which have very long hydraulic residence times, so that significant natural flushing does not occur, or where the lake has received excessive pollutant loadings which have resulted in a highly eutrophic condition. In the latter case, once the pollution source has been removed, dilution flushing may be effective in reducing the time of water quality improvement in the lake. North Lake is not highly eutrophic and does not have an excessive hydraulic residence time. Therefore, dilution/flushing would not be expected to result in a significant increase in water quality conditions in the lake.

Selective Discharge

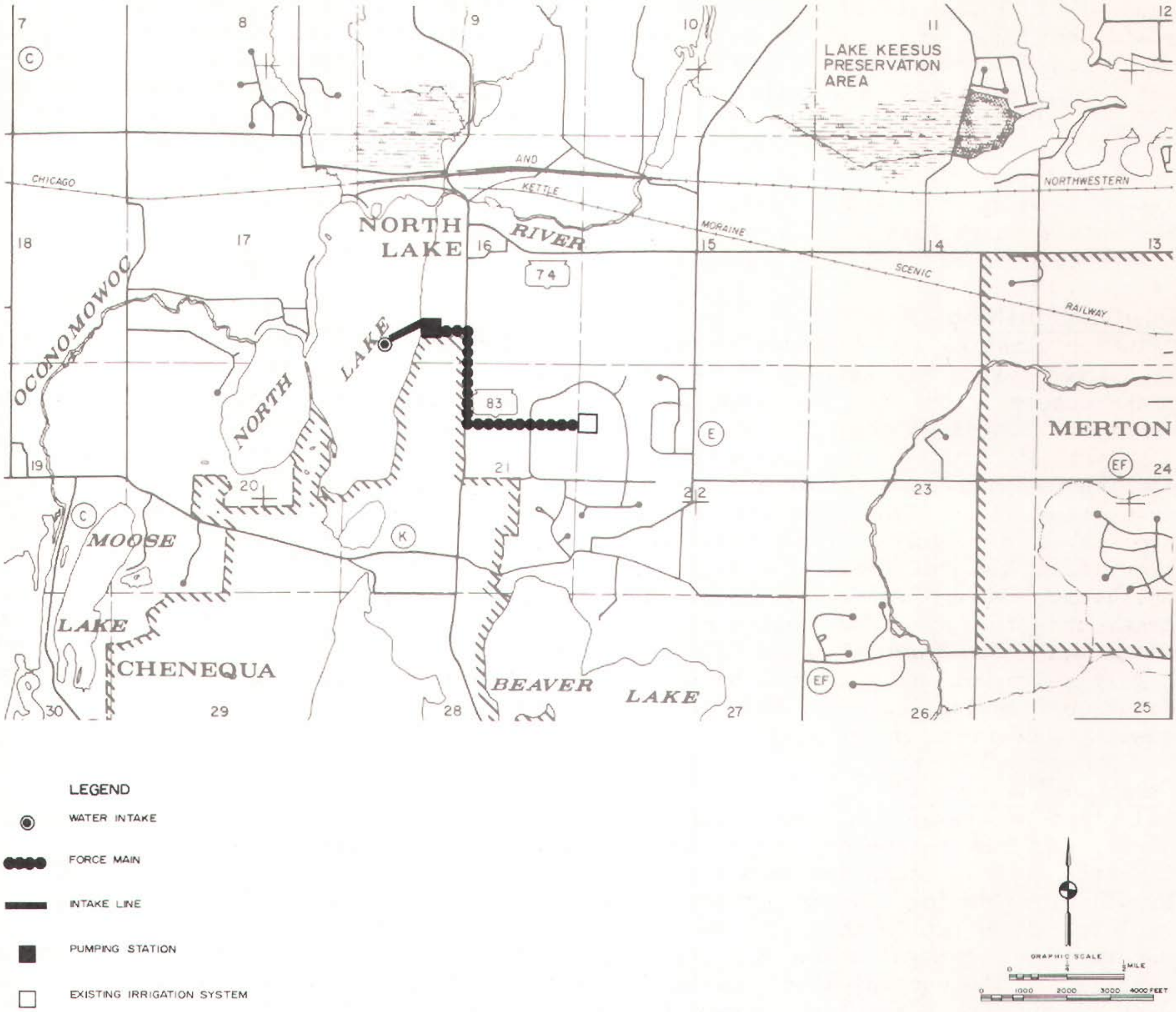
Selective discharge has been employed to substantially improve the dissolved oxygen levels near the bottom of, and to increase the nutrient output from, a lake by up to 25 percent. This technique involves releasing anaerobic, nutrient-rich water from the hypolimnion during summer stratification. Typically, the technique is readily employed in a lake with a suitable outlet control structure, but water may also be pumped from the hypolimnion and discharged downstream. Pumping from one site in the hypolimnion the equivalent of one-half of the volume of the hypolimnion of North Lake each summer, would require a capital cost of about $311,500 and an annual operation and maintenance cost of about $16,600. The water quality impacts may be expected to be favorable. In order to avoid the adverse effects associated with discharging nutrient-rich, oxygen-poor water into the Oconomowoc River, the cost assumes discharge to a suitable nearby irrigation system for surface discharge of the water, as depicted in Map 20. If an irrigation system could be developed even closer to the lake than assumed, the cost of the project could be reduced. Prior to discharge via the irrigation system, it would be necessary to determine the degree to which arsenic residues--from historical applications of sodium arsenite for macrophyte control--are released to the lake water during anaerobic conditions, and what effect this arsenic would have on the irrigated vegetation and underlying groundwater quality.

Aquatic Plant Harvesting

Macrophyte harvesting to control excessive growth of aquatic vegetation has never been required on North Lake. Limited dense concentrations of macrophytes sometimes

Map 20

PLAN ALTERNATIVE FOR THE SELECTIVE DISCHARGE OF WATER FROM NORTH LAKE



Source: SEWRPC.

occur in the northern sections of the lake. However, the overall modest aquatic macrophyte growth characteristic of North Lake does not warrant initiation of a harvesting program.

Algae harvesting has seldom been used for large-scale in-lake applications. The only practical system currently developed involves filtration of the lake water through a screen system such as a microstrainer. A pump and microstrainer system designed to treat about one-half the water in North Lake each summer would entail a capital cost of about $842,250 and an annual operation and maintenance cost of about $16,330. Approximately 180 pounds of phosphorus would be removed from the lake if this method was implemented. Algae levels generally do not occur at nuisance levels in the lake. Consequently, algae harvesting was not considered to be justified for North Lake.

Chemical Control of Algae and Macrophytes

Chemical control of algae and macrophytes is not currently practiced on North Lake. The adverse effects of chemical control on aquatic plant growth were noted in Chapter VI. Limited amounts of sodium arsenite and copper sulfate were applied to North Lake in the 1950's. However, chemical control is not recommended unless practices intended to reduce nutrient levels and the associated occasional increases in macrophyte growth through lake management techniques and improved land management practices prove to be ineffective or impractical. All chemical treatment programs require a permit from the Wisconsin Department of Natural Resources; and treatment of areas over one acre requires supervision by the Department of Natural Resources staff.

Fish Management

North Lake supports a well balanced fishery characterized by a high diversity of gamefish and panfish and a naturally reproducing walleye population. The alternative future management efforts identified by the Commission staff take into consideration the limited public access on North Lake. The following recommendations for management of the fishery should be considered by the Lake Protection and Rehabilitation District:

1. The lake district or the Wisconsin Department of Natural Resources should consider purchasing the best remaining spawning areas in the lake and areas along the Oconomowoc River downstream from North Lake.

2. Stocking of Northern pike, Walleye, and other species, as appropriate, following detailed evaluations of the existing fishery by the Wisconsin Department of Natural Resources, to provide continued gamefish resources.

3. Development of a periodic fish surveillance program for North Lake by the Wisconsin Department of Natural Resources, including a specific schedule for periodic fishing surveys.

4. Conduct a creel census (a survey of sport fishing) by the Wisconsin Department of Natural Resources to determine the composition of the angler catch and the numbers of each species harvested. This information could be correlated to the relative abundance of each species to determine the effects on the fishery resource.

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Chapter IX

RECOMMENDED PLAN

INTRODUCTION

This chapter--which is built upon the land use, land and water management, biological and water quality inventory findings; pollution source analyses; land use and population forecasts; and alternative water quality management plan evaluations previously presented--develops a recommended management plan for North Lake. The plan consists of the recommended means for: 1) providing water quality conditions suitable for the maintenance of fish and aquatic life; 2) reducing the severity of occasional nuisance problems, such as caused by algae growths which may constrain or preclude certain intended water uses; and 3) maintaining and enhancing opportunities for water-based recreational activities. The analyses of water quality conditions and water-based recreational activities at North Lake indicated that the general condition of the lake water quality was good and that water-based recreation was not inhibited by nuisance growths of algae and macrophytes. The analyses, however, indicated that the nutrient loading to the lake is relatively high. This may result in an increased rate of eutrophication in the future. Therefore, the recommended plan is directed at attaining improved land use practices to reduce nonpoint pollution and to reduce the nutrient loads entering the lake from onsite sewage disposal systems. The plan recommendations were developed through an evaluation of the many tangible and intangible factors bearing upon water pollution control for the lake. The primary emphasis of the plan, however, is placed upon the degree to which the water use objectives are met, and also upon the cost-effectiveness of the recommended measures and alternatives thereto. A roster of local citizens who provided assistance in the conduct of field studies and comments on the preliminary draft plan are identified in Appendix C.

LAND USE

A fundamental and basic element of sound water quality management for North Lake is the prudent use of the lands lying in the drainage area directly tributary to the lake. The type and location of urban and rural land uses in the drainage area will determine to a considerable degree the character, magnitude, and distribution of nonpoint sources of pollution; the practicality of, as well as the need for, various forms of land management; and ultimately, the water quality condition of the lake.

The basis for the land use recommendations set forth in this report is the adopted regional land use plan set forth in SEWRPC Planning Report No. 25, A Regional Land Use Plan and a Regional Transportation Plan for Southeastern Wisconsin: 2000. The regional land use plan--as shown in graphic summary form on Map 12--recommends that some additional urban land use development occur at medium and low densities in the lake watershed through the year 2000.

The prime agricultural lands located east of North Lake are recommended to be preserved in agricultural use. Certain lands lying north and south of the main lake basin are recommended to be permanently preserved in essentially natural, open uses, as environmental corridors. The regional land use plan can be an effective tool for water quality protection only if local action is taken to adopt and implement the plan. The Town of Merton, the Villages of Chenequa and Merton, and Waukesha County have primary authority for local land use planning and plan implementation in the watershed of the lake.

ZONING ORDINANCE MODIFICATION

As noted in Chapter V, an abundance of valuable natural resource base features are located within the drainage area directly tributary to North Lake. In order for the existing zoning ordinances to be effective tools for the preservation of these natural resource features, as recommended, certain modifications to the ordinances are required. As previously noted, the public officials involved in land use planning for the Town and Village of Merton and the Village of Chenequa, should critically review the existing zoning ordinances and accompanying zoning district maps, and amend and modify the ordinances and district maps as necessary to preserve and enhance the existing natural resource base in the direct drainage area.

The following zoning districts should be considered for inclusion in any modification of the existing zoning ordinances and district maps. The areas of land which should be placed in each of the zoning districts are shown on Map 21, quantified by civil divisions in Table 31, and compared with the existing zoning practices in Table 32.

Lowland Conservancy District

A Lowland Conservancy District should be used to preserve, protect, and enhance the wetland areas of the direct drainage area. No new urban development would be permitted in this district. It is proposed that about 73 acres, or about 4 percent of the direct drainage area, be placed in the Lowland Conservancy District. The 73 acres are located in portions of the Village of Chenequa and the Town of Merton, Waukesha County.

Under the existing zoning ordinances administered within the direct drainage area, approximately 34 of the 73 acres, or 46 percent, are currently included in conservancy districts, approximately 26 acres, or 36 percent, are included in residential districts, and the remaining 13 acres, or 18 percent, are included in agricultural districts. The existing C-1 Conservancy District applied in the Town of Merton is deemed adequate to protect the wetlands and can be continued to be used for this purpose. However, a Lowland Conservancy District should be included in the Village of Chenequa zoning ordinance and applied to the 26 acres of wetland within the direct drainage area of the lake which lie in the Village.

Upland Conservancy District

The Upland Conservancy District should be used to preserve, protect and enhance the significant woodlands, related scenic areas, and marginal farmlands of the direct drainage area while allowing for rural estate type residential development that would help to maintain the rural character of the North Lake drainage area. It is proposed that 42 acres, or about 2.5 percent of the direct drainage area, be included in an Upland Conservancy District. The 92 acres are located in the Town of Merton.

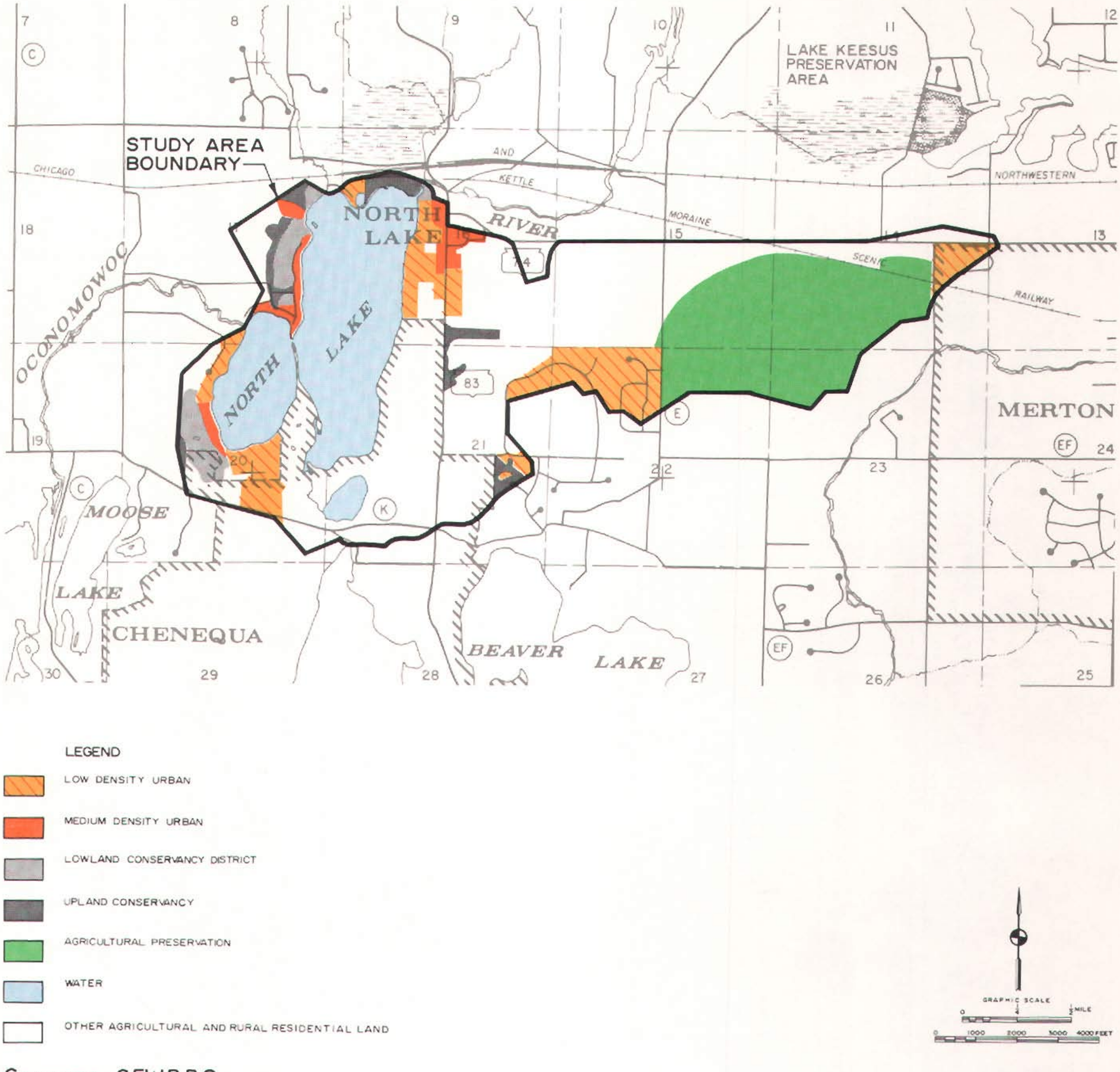
Under the existing zoning ordinances administered within the direct drainage area, approximately 8 of the 42 acres, or 19 percent, are currently included in residential districts, 24 acres, or 57 percent, are in agricultural districts, and 10 acres, or 24 percent, are in existing conservancy districts. An Upland Conservancy District should be included as a new zoning district in the Town of Merton zoning ordinance.

Agricultural Preservation District

An Agricultural Preservation District should be used to preserve and enhance lands within the direct drainage area historically used for agricultural purposes. The district should provide for a minimum parcel size of 35 acres in order to preserve workable farm units, and should prohibit the intrusion of urban land uses. Agricultural-related industrial use such as a cheese factory, food processing plant, or agricultural supply center could be permitted as conditional uses in this district.

Map 21

PROPOSED ZONING DISTRICTS FOR THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE



Source: SEWRPC.

Table 31

PROPOSED ZONING MODIFICATIONS BY CIVIL DIVISION IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE

Proposed Zoning Districts	Town of Merton		Village of Merton		Village of Chenequa		Direct Tributary Drainage Area	
	Acres	Percent	Acres	Percent	Acres	Percent	Acres	Percent
Lowland Conservancy.........	53	4.3	--	--	20	4.9	73	4.3
Upland Conservancy..........	42	3.4	--	--	--	--	42	2.5
Agricultural Preservation...	366	29.4	8	25.0	--	--	374	22.2
General Agriculture.........	611	49.1	10	31.3	23	5.6	644	38.2
Rural Residential...........	--	--	--	--	330	80.5	330	19.6
Low-Density Urban...........	121	9.7	14	43.7	37	9.0	172	10.2
Medium-Density Urban........	51	4.1	--	--	--	--	51	3.0
Total	1,244	100.0	32	100.0	410	100.0	1,686	100.0

Source: SEWRPC.

Table 32

SUMMARY OF PROPOSED ZONING MODIFICATIONS IN THE DRAINAGE AREA DIRECTLY TRIBUTARY TO NORTH LAKE

Proposed Zoning District	Existing Zoning Classifications (acres)				Total Acres	Percent of Direct Tributary Drainage Area
	General Conservancy	Agricultural	Residential	Other[a]		
Lowland Conservancy..........	34	13	26	--	73	4.3
Upland Conservancy...........	10	24	8	--	42	2.5
Agricultural Preservation....	--	373	1	--	374	22.2
General Agriculture..........	--	257	383	4	644	38.2
Rural Residential............	--	--	330	--	330	19.6
Low-Density Urban............	6	--	165	1	172	10.2
Medium-Density Urban.........	2	4	33	12	51	3.0
Total	52	671	946	17	1,686	100.0

[a]Includes Public and Local Business Districts.

Source: SEWRPC.

About 374 acres, or about 22 percent of the direct drainage area, should be included in the Agricultural Preservation District. The 374 acres are located in the Town and Village of Merton.

Under the existing ordinances administered within the direct drainage area, 373 acres are included in agricultural districts (A-1), which permit residential development on lots of five acres or more in size in the Village of Merton and three acres in size in the Town of Merton. The remaining one acre, in the Town of Merton, is currently zoned Residential. An Agricultural Preservation District would be included as a new zoning district in both the Town and Village of Merton zoning ordinances.

General Agricultural District

A General Agricultural District could be used to preserve and protect open space lands in areas having marginal farmland value, while at the same time allowing for estate-type residential development that maintains the rural character of the countryside. Such a district should provide for a minimum lot size of 10 acres and permit a mixture of farm site and estate-type residential uses. About 644 acres, or about 39 percent of the direct drainage area, should be included in a General Agricultural District. The 644 acres are located in portions of the Town and Village of Merton, Waukesha County.

Under the existing zoning ordinances administered within the direct drainage area, approximately 257 of these 644 acres, or 40 percent, are included in agricultural districts, 383 acres, or 59 percent, are included in residential areas, and 4 acres, or 1 percent, are included in public areas. The General Agricultural District should be included as a new zoning district in both the Town and Village of Merton zoning ordinances.

Low-Density and Medium-Density Residential Districts

Low- and Medium-Density Residential Districts should be used to preserve and protect existing and proposed residential areas within a physical environment that is healthy, safe, convenient, and attractive. The Commission defines low-density residential and medium-density residential land use as containing approximately 0.7 to 2.2 and 2.3 to 6.9 dwelling units per net residential acre, respectively. About 172 acres, or about 10 percent of the direct drainage area, should be included within low-density residential districts. About 51 acres, or 3 percent of the direct drainage area, should be included within medium-density residential districts.

Under the existing zoning ordinances administered within the direct drainage area, approximately 198 of the 223 acres, or 89 percent, are included in residential districts, 9 acres, or 4 percent, are included in business districts, 8 acres, or 3 percent, are included in conservancy districts, 4 acres, or 2 percent, are included in public districts, and 4 acres, or 2 percent, are included in agricultural use districts.

Rural Residential District

A rural residential district is utilized to accommodate the demand for rural residential development by that segment of the population that desires to live away from an urban environment. Such a district would not only accommodate this desire, but would assure that development is indeed rural and does not create environmental problems such as drainage and flooding, nor demands for urban services. Frequently, a rural residential district can be used to protect and preserve environmental corridor lands. Such a district should require a minimum lot size of five acres for new development. About 330 acres, or about 20 percent of the direct drainage area, should be included within a rural residential district.

Under the existing zoning ordinances administered with the direct drainage area, approximately 330 acres in the Village of Chenequa are included in a residential district which conforms to the rural residential district recommended herein.

POINT SOURCE POLLUTION CONTROL

The provision of sanitary sewer service to the direct drainage area tributary to North Lake, as described in the preceding chapter, is recommended to eliminate malfunctioning septic tank systems and to provide an appropriate means of sanitary sewage collection and treatment for existing and planned urban development. Sewage treatment would be provided by the City of Oconomowoc sewage treatment facility. These recommendations were incorporated from the adopted regional water quality management plan as set forth in SEWRPC Planning Report No. 30.

NONPOINT SOURCE POLLUTION CONTROL AND LAKE MANAGEMENT

A water quality management plan for the lake should address methods for reducing the nutrient loading to the lake from nonpoint sources, and techniques for related lake water quality management. As described below, the implementation of nonpoint source controls and lake management techniques requires urban nonpoint source control practices, agricultural land management practices, and increased regulation of certain land management activities. Technical and financial assistance from state and federal units of government will also be required to implement such practices and regulations.

Inland Lake Protection and Rehabilitation District

It was initially envisioned during the early stages of preparing this report, that an inland lake protection and rehabilitation district would be formed for North Lake in order to utilize technical and financial assistance available under state and federal lake protection and renewal programs. On November 1, 1980, the Waukesha County Board of Supervisors, responding to a petition submitted by local residents, acted unanimously to create such a district, as shown on Map 2. The Wisconsin Department of Natural Resources, Office of Inland Lake Renewal, coordinates the lake protection and renewal technical and financial aid programs for such lake districts in Wisconsin. Creation of the district should assure a viable organization to conduct needed lake protection and management programs. To obtain state financial assistance for lake management techniques, it is necessary under the Wisconsin Administrative Rules for lake districts to conduct a feasibility study to evaluate the lake's water quality problems and consider alternative pollution abatement measures or rehabilitation techniques. The Wisconsin Department of Natural Resources has indicated that this water quality management report can serve as the basis for such a feasibility study for North Lake.

It is also recommended that the lake district conduct a continuing in-lake water quality sampling program to assess the effects of the implemented lake management measures over time. This sampling program would, at a minimum, consist of measurements of soluble and total phosphorus; nitrate-, nitrite-, organic- and ammonia-nitrogen; chlorophyll-a; and water clarity. The sampling program would also include the development of temperature and dissolved oxygen profiles at least twice each summer and once each spring turnover. All measurements and profiles should be obtained at the deepest point in the lake. Lake freeze-up and thaw dates, as well as snow cover conditions should be recorded annually. Such a data collection program would have an estimated cost of $500 per year. Further, surveys of fish, macrophytes, and algae should periodically be conducted by, or with the technical assistance of, the Wisconsin Department of Natural Resources.

Urban Nonpoint Source Pollution Controls

The implementation of nonpoint source controls in urban areas requires the cooperative efforts of the Waukesha County Board of Supervisors, the Waukesha County Board of Health, the Waukesha County Soil and Water Conservation District, the North Lake District, the Town of Merton, and the Villages of Chenequa and Merton. The recommended responsibilities of each of these governmental agencies--consistent with their legal authorities under existing state and federal laws--are summarized in Table 33. The specific management issues and objectives for the methods of nonpoint source pollution control, including development of septic tank management programs, construction erosion control programs, and development and implementation of urban land management practices are discussed below.

Septic Tank System Management Program: The basic objective of a septic tank system management program is to ensure the proper installation, operation, and maintenance of existing septic tank systems, and of any new systems that may be required to serve existing urban development in the drainage area directly tributary to North Lake. It is important that a septic tank system management program be conducted in the lake drainage area until recommended sanitary sewer service is provided.

A septic tank system management program is recommended to consist of at least the following actions to assure proper management of those septic systems which would not be eliminated by the recommended centralized sanitary sewer system:

1. The revision of the Waukesha County sanitary ordinance to include regulation of the operation and maintenance of onsite sewage disposal systems, including septic tanks, holding tanks, and "mound" systems or other systems approved by the applicable State regulations.

2. The establishment through such sanitary ordinances of a regular program of inspection of onsite sewage disposal systems by the Waukesha County Board of Health. Such a program would include the visual inspection of each onsite sewage disposal system by trained individuals. The purpose of the inspection would be to identify any malfunctioning sewage disposal systems. Each system within the lake drainage basin should be inspected once every five years, and, accordingly, one-fifth of all such systems should be inspected annually. It is envisioned that the onsite system inspection program in the North Lake direct tributary drainage area be developed within the context of the countywide program. As such, the program may be refined to be more effective in scheduling inspections, either more or less frequently, depending on the soil suitability, number of systems, and age and past maintenance requirements of such systems. The inspection program should result in the issuance of orders, as necessary, to abate improper practices and take appropriate corrective measures. These recommendations have been partially implemented by the Waukesha County Department of Health. The Department has established a program under which joint certification by property owners and licensed sanitary waste haulers is required at two-year intervals for onsite septic systems installed after June 30, 1979. This certification program ensures that septic systems installed after this date will be pumped out and properly maintained at the required two-year interval. The ordinance also requires that property owners who receive a permit from the County Health Department for repairing and/or replacing a septic system installed on or before June 30, 1979, also properly pump out and/or maintain their septic system every two years.

3. The continuation of an educational program whereby homeowners and developers would be advised of the rules and regulations governing the installation and operation of onsite sewage disposal systems and would be encouraged to undertake preventive maintenance measures.

Construction Erosion Control Program: It is recommended that Waukesha County, the Town of Merton, and the Villages of Chenequa and Merton undertake steps to ensure the reduction of water pollution--particularly nutrient pollution associated with the introduction of phosphorus--as a result of soil erosion from land undergoing a change in use and related construction activity. It is recommended that the County and these designated urban management agencies establish construction erosion control programs and review their subdivision regulations, zoning ordinances, and building codes for the inclusion of appropriate erosion control measures, to assure that such regulations, ordinances, and codes taken together address administrative procedures, erosion control performance standards, and enforcement provisions.

It is recommended that the ordinances be properly expanded to require the submittal of an erosion control plan by land developers, and that the erosion control plan be reviewed and approved by the County Soil and Water Conservation District. It is recommended that each designated agency adopt the appropriate ordinance modifications; require the submittal of erosion control plans for all construction projects; and review such plans with technical assistance from the Soil and Water Conservation Districts, in conjunction with local municipal engineers. Further, each designated management agency should provide for the proper enforcement, through inspection, of the erosion control measures to be implemented. The review and evaluation of the plans and control measures implemented should be based on criteria set forth in the Soil and Water Technical Guide of the Soil Conservation Service of the U. S. Department of Agriculture. Enforcement would be through the land subdivision, zoning, and building code approval authorities of each designated management agency. The Southeastern Wisconsin Regional Planning Commission has published model ordinances in Appendices H through M of SEWRPC Planning Guide No. 5, Floodland and Shoreland Development Guide, and it can, upon request, assist in the development of the required regulations.

Development and Implementation of Urban Land Management Practices: The development of urban nonpoint source pollution abatement practices should be a highly localized, detailed, and individualized effort. It requires highly specific knowledge of the physical, managerial, social, and fiscal considerations that affect the local landowners concerned. Accordingly, it is recommended that the North Lake District work with property owners to attain application of the land management practices recommended herein, as necessary, to achieve about a 25 percent reduction in urban nonpoint source pollution runoff.

It is recommended that the North Lake District, in cooperation with the Town of Merton and the Villages of Chenequa and Merton, identify the specific sources of nonpoint source pollution within the urban areas of the watershed, and develop programs to implement measures to control these specific sources. These designated agencies should inventory and assess the existing land management practices, and determine the extent and location of problem areas. Further, the appropriate pollution control measures for these problem areas and the estimated effectiveness and costs of these control measures should be assessed. Finally, a program for implementing and financing the recommended control measures should be developed.

It is recommended that urban nonpoint source control measures to be implemented as applicable through the drainage area tributary to North Lake include the following: a public education program to provide information on the relationship of land management practices to water quality; improved street cleaning and maintenance; the proper collection and disposal of leaves, grass clippings, and other vegetative debris; the proper use of fertilizers, pesticides, and other lawn care measures; improved refuse collection and disposal; the proper vegetative management of shoreland areas; the adequate maintenance of stormwater drainage ditches and storm sewer systems,

Table 33

LOCAL GOVERNMENTAL MANAGEMENT AGENCIES AND RESPONSIBILITIES FOR URBAN NONPOINT SOURCE WATER POLLUTION CONTROL

Urban Nonpoint Source Management Agency	Local Land Use Planning and Zoning	Undertake Septic System Management Program	Undertake Construction Erosion Control Program	Review Public Works Maintenance Practices	Conduct Educational and Informational Program	Provide Technical Assistance	Provide Fiscal Support to Soil and Water Conservation District
Waukesha County............	X	--	X	--	X	--	X
Waukesha County Board of Health...........	--	X	--	--	X	--	--
Waukesha County Soil and Water Conservation District......	--	--	--	--	--	X	--
North Lake District.........	--	--	--	X	X	--	--
Town of Merton.............	X	--	X	X	--	--	--
Village of Chenequa.........	X	--	X	X	X	--	--
Village of Merton...........	X	--	X	X	X	--	--

Source: SEWRPC.

Table 34

LOCAL GOVERNMENTAL MANAGEMENT AGENCIES AND RESPONSIBILITIES FOR RURAL NONPOINT SOURCE WATER POLLUTION CONTROL

Urban Nonpoint Source Management Agency	Local Land Use Planning and Zoning	Develop Livestock Waste Control Program	Develop and Implement Detailed Plan for Rural Practices	Conduct Educational and Informational Program	Provide Technical Assistance	Provide Fiscal Support to Soil and Water Conservation District
Waukesha County..........	X	X	--	X	--	X
Waukesha County Soil and Water Conservation District...	--	X	X	--	X	--
North Lake District......	--	--	X	X	--	X

Source: SEWRPC.

including discharge sites; the proper disposal of litter and pet wastes; and other measures as locally identified. It is recommended that a publication identifying specific residential land management practices beneficial to water quality be prepared and distributed to property owners with the assistance of the University of Wisconsin-Extension Service. It is further recommended that the designated agencies seek technical assistance in the preparation and implementation of the aforementioned detailed practices from the Waukesha County Soil and Water Conservation District, and also seek assistance in the form of public education and information programs from the Waukesha County office of the University of Wisconsin-Extension Service.

Rural Nonpoint Source Pollution Controls

The implementation of nonpoint source pollution controls in rural areas requires the cooperative efforts of the newly formed North Lake District, Waukesha County, and the Waukesha County Soil and Water Conservation District. The recommended responsibilities of each governmental agency are set forth in summary form in Table 34.

As with urban nonpoint source pollution abatement practices, the development of rural nonpoint source pollution abatement practices should be a highly localized, detailed, and individualized effort. Accordingly, it is recommended that the Waukesha County Soil and Water Conservation District, in cooperation with the North Lake District, undertake the development of plans for needed design of detailed rural soil and water conservation practices on each farm in the watershed. It is recommended that the Lake District be the lead agency in the preparation of such plans. As the lead agency, the Lake District should formally request that the County Soil and Water Conservation District work with the landowners to design detailed practices applicable to each land parcel for agricultural nonpoint source pollution control in the lake drainage area. This should include estimates of soil loss and recommendations for specific abatement measures for each identified source. The estimated cost and effectiveness of each practice recommended should also be included. Agricultural nonpoint source abatement measures which may be appropriate for use in the North Lake drainage area include crop rotation, conservation tillage, grassed waterways, vegetative buffer strips, contour strip-cropping, and livestock waste control. Implementation of those practices necessary to obtain about a 25 percent reduction in rural nonpoint source pollution runoff should be sought. Some agricultural areas in the lake drainage area with relatively steep slopes are located in proximity to the lake, are particularly susceptible to erosion, and are therefore potentially most harmful to the lake environment. Such areas should receive priority for the planning and implementation of control measures. It is envisioned that the North Lake District would--through an intergovernmental memorandum of understanding--cooperate with the Waukesha County Soil and Water Conservation District in the necessary detailed planning.

Following the selection of detailed practices for the abatement of nonpoint source pollution in rural areas, it is recommended that the management agencies take appropriate steps to install the practices. This would include the establishment of public educational programs by the Lake District in cooperation with the University of Wisconsin-Extension Service, continued work with the farm operators, and the undertaking of actions to protect critical areas from erosion. It is further recommended that the Waukesha County Soil and Water Conservation District provide all necessary technical assistance in installing the practices.

IN-LAKE MANAGEMENT TECHNIQUES

The only recommended in-lake management technique is the management of the fishery resources. It is recommended that a periodic fish surveillance sampling program be established for the lake. Under such a program, a specific schedule for fishery surveys would be established. The Wisconsin Department of Natural Resources would conduct the necessary sampling effort and would assess, evaluate, and monitor the long-term trends in the fishery resource of the lake.

Hypolimnetic aeration is not recommended for North Lake at this time. The water quality problems which hypolimnetic aeration alleviates--anaerobic conditions in the hypolimnion, nutrient release from bottom sediments, and excessive algae growths--have not been identified as severe water quality problems affecting the beneficial use of North Lake. Therefore, the existing water quality problems in North Lake do not appear to warrant the application of hypolimnetic aeration.

Nutrient inactivation and selective discharge are also not recommended for North Lake at this time. These lake management techniques are generally used to reduce aquatic macrophyte and algae concentrations. As was previously discussed, North Lake supports a modest macrophyte population and algae generally are not present at nuisance levels. However, if algae blooms become severe in the future, nutrient inactiviation should be reconsidered as a means for reducing this growth.

COST ANALYSES

Cost estimates--expressed in 1980 dollars--for recommended nonpoint source controls in the North Lake watershed and in-lake management techniques are set forth in Table 35. The total capital cost of the recommended plan is $190,950 over a 20-year plan implementation period with an average annual operation and maintenance cost of $5,900, resulting in a total annual average cost of $14,980. Of these totals, $46,850, or 24 percent, of the capital cost; $2,150, or 36 percent, of the annual operation and maintenance cost; and $4,350, or 29 percent, of the total annual cost would be borne by the local units of government. The remaining costs would be borne by individual property owners or by state or federal cost-sharing programs.

About $187,000, or 98 percent, of the total capital cost of the recommended watershed management measures, is associated with control of erosion from construction activities, with 75 percent of the erosion control cost being borne by the private sector. The in-lake management costs include a total average annual cost of $500 for an in-lake water quality sampling program. Table 36 sets forth the estimated costs of implementing the recommended plan that could be expected to be provided by state or federal cost-sharing funds. Based on the estimated 1985 population of the lake drainage area, the total average annual cost for each lake drainage area resident would be about $20, or $70 per household. The average annual local public sector cost for each lake drainage area resident would be about $6, or $20 per household.

Table 35

ESTIMATED COST OF RECOMMENDED WATER QUALITY AND LAKE MANAGEMENT MEASURES FOR NORTH LAKE

Water Quality or Lake Management Measure[b]	Estimated Cost 1980-2000[a]					
	Capital		Average Annual Operation and Maintenance		Total Average Annual	
	Total	Local Public Sector	Total	Local Public Sector	Total	Local Public Sector
Sanitary Sewer Service[c]...	$ --	$ --	$ --	$ --	$ --	$ --
Septic Tank System Management[d]........	--	--	--	--	--	--
Rural Land Management.....	250	--	2,250	--	2,260	--
Livestock Waste Control...	3,600	--	300	--	470	--
Urban Land Management.....	100	100	1,250	1,250	1,250	1,250
Construction Erosion Control..........	187,000	46,750	1,600	400	10,500	2,600
Watershed Management Subtotal	$190,950	$46,850	$5,400	$1,650	$14,480	$3,850
Fish Management[e]..........	$ --	$ --	$ --	$ --	$ --	$ --
Water Quality Sampling Program.........	--	--	500	500	500	500
In-Lake Management Subtotal	$ --	$ --	$ 500	$ 500	$ 500	$ 500
Total	$190,950	$46,850	$5,900	$2,150	$14,980	$4,350

[a] All costs expressed in January 1980 dollars.

[b] Land use plan element costs are not presented.

[c] Nearly all urban development in the drainage area directly tributary to North Lake is recommended to be served by sanitary sewers by the year 2000. The sewage generated in this area would be conveyed to and treated at the City of Oconomowoc sewage treatment plant. The estimated cost for a portion of the treatment facility and major trunk sewers serving the drainage area, together with local hookup and operation and maintenance of the system includes a total capital cost of about $1.4 million, with an annual operation and maintenance cost of about $50,000.

[d] The proper maintenance and replacement of the remaining septic tank systems is recommended to help improve the water quality of North Lake. However, because septic tank systems management is an existing function necessary for the preservation of public health and the maintenance of drinking water supplies, this cost is not included in the water quality management plan. The estimated expenditures for septic system management in the North Lake drainage basin include a capital cost over the period of 1980-2000 of $84,000, with an average annual operation and maintenance cost of $10,200.

[e] Costs for fish management will be borne by the Wisconsin Department of Natural Resources.

Source: SEWRPC.

Table 36

POTENTIAL STATE AND FEDERAL COST-SHARING FOR IMPLEMENTATION OF THE RECOMMENDED NORTH LAKE WATER QUALITY MANAGEMENT PLAN

Water Quality or Lake Management Measure	Estimated Total Cost 1980-2000		Anticipated State or Federal Cost-Share	State or Federal Cost-Share Program
	Capital	Annual Operation and Maintenance		
Rural Land Management Practices[a]......	$ 250	$2,250	50-75 percent of capital cost, none for operation and maintenance	Federal Agricultural Conservation Program (ACP) administered by the USDA Agricultural Stabilization and Conservation Service (ASCS) and the Soil Conservation Service (SCS)
Livestock Waste Control....	3,600	300	$1,200 of capital cost, none for operation and maintenance	Federal Agricultural Conservation Program (ACP) administered by the USDA Agricultural Stabilization and Conservation Service (ASCS) and the Soil Conservation Service (SCS)
Urban Land Management Practices......	100	1,250	None	--
Fish Management............	--	--	--	Costs will be borne by the Wisconsin Department of Natural Resources
Water Quality Sampling Program..........	--	500	None	--

[a] Cost-sharing and technical assistance for nonpoint source controls could also be applied for as a local priority project under the Wisconsin Fund Nonpoint Source Pollution Abatement Program administered by the Wisconsin Department of Natural Resources.

Source: SEWRPC.

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Chapter X

SUMMARY

The preparation of the water quality management plan for North Lake as presented herein was a cooperative effort of the Southeastern Wisconsin Regional Planning Commission and the Wisconsin Department of Natural Resources. The lake study included the design and conduct of a water quality sampling program--with field sampling conducted from March, 1976 through April, 1977--and the inventory and analysis of land use, watershed characteristics, natural resource base, recreational use, and existing management practices. The objectives of the plan were to provide a level of water quality in North Lake suitable for the maintenance of a healthy warmwater fishery, to reduce the severity of occasional nuisance conditions caused by excessive algae growth, and to improve opportunities for water-based recreational activities.

North Lake is located within U. S. Public Land Survey Township 8 North, Range 18 East, Town of Merton in Waukesha County. The lake has a surface area of 439 acres, a maximum depth of 73 feet, and a mean depth of 37 feet. The lake has a direct tributary drainage area of 1,686 acres, or 2.63 square miles, and a total watershed area of 41,117 acres, or 64.25 square miles.

The drainage area of North Lake includes portions of the Villages of Merton (0.05 square mile, or 1.5 percent) and Chenequa (0.64 square mile, or 19.3 percent), and the Town of Merton (2.63 square miles, or 79.2 percent), all of which are located in Waukesha County. As of 1975, the resident population of the drainage area directly tributary to the lake was estimated by the Commission to be 620 persons.

The type, intensity, and spatial distribution of land uses are important factors determining resource demand in the direct tributary drainage area. As of 1975, approximately 525 acres, or 31 percent of the 1,686-acre direct tributary drainage area, was in urban land use, with the dominant urban land use--367 acres, or 70 percent--in residential use. The remaining urban land uses--commercial, industrial, governmental and institutional, transportation, communication, utilities, and recreational--constituted about 158 acres, or 30 percent of the North Lake direct drainage area. Approximately 1,161 acres, or 69 percent of the direct tributary drainage area, was in rural land use, with the dominant rural land use--848 acres, or 73 percent--in agricultural use. Woodlands and open lands comprised about 251 acres, or 22 percent of the rural land area. Wetlands and surface water, excluding the surface area of North and Cornell Lakes, accounted for 62 acres, or 5 percent of the rural land area.

As of 1975, the sanitary and household wastewaters from the estimated 620 persons residing in the drainage area directly tributary to the lake were treated and disposed of through the use of onsite disposal systems. There are approximately 257 septic tank systems in the directly tributary drainage area--92 of which were located in areas covered by soils having severe or very severe limitations for the use of such systems. No holding tanks or mound systems were known to exist, as of 1975, in the direct tributary drainage area.

For the year of study, it is estimated that approximately 23,911 acre-feet of water entered the lake. Of this total, about 16,760 acre-feet, or 70 percent, was contributed by inflow from the Oconomowoc River; about 1,770 acre-feet, or 7 percent, was contributed by inflow from Mason Creek; about 1,270 acre-feet, or 5 percent, was contributed by inflow from the Cornell Lake channel; direct precipitation contributed about 1,170 acre-feet, or 5 percent; and about 770 acre-feet, or 3 percent, was contributed by surface runoff from the directly tributary drainage area. In addition, groundwater was estimated to have a net input to the lake of 2,171 acre-feet, or 10 percent. Of the total water output from North Lake, about 95 percent was discharged via the Oconomowoc River and 5 percent was evaporated from the surface of the lake.

Monthly temperature and dissolved oxygen profiles indicate that complete mixing of North Lake is restricted during the summer by thermal stratification. The data indicate that North Lake, like other mesotrophic or eutrophic lakes in southeastern Wisconsin, experiences oxygen depletion in the hypolimnion or bottom water layer. Oxygen depletion in the hypolimnion may increase the release of phosphorus from the bottom sediments and cause fish to migrate upward in the water column where higher dissolved oxygen concentrations exist. Water clarity, as measured by a Secchi Disc, ranged from about 3.3 feet to 15.6 feet, with an average Secchi Disc depth of 8.4 feet in North Lake.

North Lake supports a relatively large and diverse fish community. Wisconsin Department of Natural Resources survey reports indicated that from 1946 through 1975, 27 different fish species were surveyed in the lake. No threatened or endangered fish species were found in the lake.

The Regional Planning Commission recommended water quality standard for recreational use and warmwater fish and aquatic life indicates that nuisance aquatic growth is likely to occur in lakes where the total phosphorus concentration exceeds 0.02 milligrams per liter (mg/l) during the spring turnover. In North Lake, the mean concentration of total phosphorus in the spring was about 0.06 mg/l, which indicates that the potential for nuisance aquatic plant growths exists in the lake. However, an examination of the vertical distribution of total phosphorus in North Lake showed that the bottom water layers contained an average of 83 percent of the phosphorus present in the lake during the summer stratification period. As a result, nuisance concentrations of algae and macrophytes were not present during the study year.

In general, the aquatic weed growth in North Lake was moderate and diverse. Populations of blue-green algae in the lake indicated a potential for bloom conditions. However, as previously noted, accumulations of algae in nuisance "bloom" conditions were not observed.

It is estimated that under the existing conditions, as of 1975, the total phosphorus load to North Lake during an average year would be approximately 5,200 pounds per year. Of this total, about 4,300 pounds, or 82 percent, was estimated to be contributed by the Oconomowoc River and Mason Creek. In addition, livestock operations were estimated to contribute about 200 pounds, or 4 percent of the total. Malfunctioning septic tank systems contributed approximately 270 pounds, or 5 percent of the total phosphorus load to the lake. The remaining land uses in the North Lake direct drainage area--residential, commercial, industrial, governmental and institutional, transportation, and recreational lands, and direct atmospheric fallout, woodlands, and other open land--contributed an estimated 430 pounds, or 9 percent of the phosphorus load to the lake.

Based on the study data, North Lake was classified as mesotrophic, a term describing moderately fertile lakes which may support abundant aquatic plant growths and may support productive fisheries. Nuisance growths of algae and weeds are usually not exhibited by mesotrophic lakes.

According to the adopted Commission land use plan, the population of the North Lake direct tributary drainage area is expected to increase by 58 percent, or approximately 360 residents, by the year 2000. The year 2000 land use plan recommends that most new residential development in the direct tributary drainage area occur at low densities. Under the year 2000 land use plan, approximately 600 acres, or 36 percent of the 1,686-acre direct tributary drainage area, would be in urban land use, with the dominant urban land use being residential, encompassing 425 acres, or about 71 percent of the urban land area. The remaining 175 acres, or 29 percent of the urban land, would be in a mixture of commercial, industrial, governmental, institutional, transportation, communication, utility, and recreational land uses. Compared to 1975 land use, this represents a 14 percent increase in urban land uses and, specifically, a 16 percent increase in residential land in the direct tributary drainage area. Most of the planned development would occur on land presently in agricultural, woodland or other open space land uses. According to the adopted Commission land use plan, the remaining 1,086 acres, or 64 percent of the direct drainage area, would be in a mixture of water, wetland, woodland, other open lands, and agricultural land uses.

The Commission also estimated that under year 2000 conditions, the total phosphorus load to the lake would be approximately 3,500 pounds per year, or about 30 percent less than the estimated 1975 loadings. Of this total, approximately 2,600 pounds, or 74 percent, would be contributed by the Oconomowoc River and Mason Creek. The anticipated decrease of about 1,600 pounds in phosphorus loading from the Oconomowoc River and Mason Creek would occur following implementation of the upstream water pollution control measures recommended in the regional water quality management plan. Further, there would also be a decrease of approximately 200 pounds of phosphorus--from about 270 pounds per year in 1975 to approximately 64 pounds per year, or 2 percent of the load in the year 2000--entering the lake from malfunctioning septic tank systems following provision of sanitary sewer service to residents of North Lake, also as recommended in the regional water quality management plan. The other major sources of phosphorus, under anticipated year 2000 conditions, would be livestock operations, representing about 200 pounds, or 6 percent; direct atmospheric contributions, representing 230 pounds, or 7 percent; construction activities, representing about 220 pounds, or 6 percent. The remaining land uses in the North Lake direct drainage area--residential, commercial, industrial, governmental and institutional, transportation, recreational lands, agricultural, woodlands, and other open lands, would contribute the remaining 186 pounds, or 5 percent of the phosphorus load to the lake.

Management measures required to meet the water use objectives for North Lake must address the nonpoint source pollution controls needed. Commission estimates indicated that there would need to be a reduction of 35 percent in nonpoint source phosphorus loads from the direct tributary drainage area in order to meet the recommended water use objectives and supporting standards. As noted, the provision of sanitary sewer service to the drainage area directly tributary to North Lake is recommended as a point source control measure in the adopted regional water quality management plan. This would abate a nonpoint source by eliminating all but approximately 22 of the septic tank systems located on soils with severe or very severe limitations for the use of such systems. Sewage treatment would be provided by the City of Oconomowoc sewage treatment facility. Other nonpoint source control measures, as discussed in Chapter IX, consist of improved management of both urban and rural land uses to reduce pollutant discharges to the lake by direct overland drainage, by drainage from natural or man-made channels, and by groundwater inflow. These actions would be designed to reduce the in-lake concentration of total phosphorus in North Lake during the spring turnover to the Commission recommended standard of 0.02 mg/l.

Alternative lake rehabilitation and in-lake management techniques were evaluated to examine the feasibility of conducting an in-lake management program. Techniques assessed included hypolimnetic aeration, dredging, sediment covering, nutrient inactivation, dilution and flushing, selective discharge, macrophyte harvesting, algae harvesting, chemical controls, and fish management. As a result of these analyses, the Commission recommended that the fishery resources of North Lake be evaluated and managed, and that a continuing in-lake water quality monitoring program be established. No other in-lake management was deemed necessary.

In summary, the water quality management recommendations for North Lake were developed within the framework of the adopted regional water quality management plan for the upstream tributary areas draining to the Oconomowoc River, and include:

1. The modification of local land use zoning ordinances to bring local planning and zoning into conformance with the Commission's adopted regional land use plan.

2. The provision of sanitary sewer service to portions of the direct drainage area tributary to the lake to provide for collection and conveyance of sanitary wastewaters with treatment and discharge at the City of Oconomowoc sewage treatment plant.

3. The implementation of nonpoint source controls in both urban and rural areas, including a public education program, improved public works activities, improved urban "housekeeping" practices, improved agricultural management, and technical and financial assistance from state and federal units of government.

4. The revision of the Waukesha County sanitary ordinance to address the operation, maintenance, and inspection of the privately owned onsite sewage disposal systems which would not be eliminated by the proposed centralized sanitary sewerage system.

5. The implementation of construction erosion control ordinances by Waukesha County, the Town of Merton, and the Villages of Chenequa and Merton.

6. The implementation of a continuing in-lake water quality and fishery resource monitoring program by the North Lake District and the Wisconsin Department of Natural Resources.

Implementation of the recommended nonpoint source controls in the drainage area directly tributary to North Lake and in-lake management would entail a total capital cost of about $190,950, with an average annual operation and maintenance cost of about $5,900, and a total average annual cost of $14,980 over a 20-year plan period. About 98 percent of the capital cost of watershed management is associated with control of erosion from construction activities, with 75 percent of this construction erosion control cost being borne by the private sector. The in-lake management costs include a total average annual cost of $500 for an in-lake water quality monitoring program. Based on the estimated 1985 population of the direct tributary drainage area to the lake, the total average annual cost--$14,980--would be about $70 for each household in the lake drainage area, or about $20 per resident. The average annual local public sector cost of the recommended plan is about $4,350, or about $20 for each household in the lake drainage area, or about $6 per resident.

North Lake is a valuable natural resource in the Southeastern Wisconsin Region. There is a delicate, complex relationship between the water quality conditions of a lake and the land uses within the direct tributary drainage area of the lake. In addition, since North Lake is one of the six major lakes in a chain along the Oconomowoc River, integrated watershedwide planning and management programs are essential to maintain the water quality of the lakes and the river. Projected increases in population, urbanization, income, leisure time, and individual mobility forecast for the Region will result in additional pressure for development in the direct drainage area of lakes in southeastern Wisconsin and for water-based recreation on the lakes themselves. Without the adoption and administration of an effective water quality management program for North Lake, based upon comprehensive water quality management and related land use plans, the water quality protection needed to maintain conditions in North Lake suitable for recreational use and for maintenance of fish and other aquatic life will not be provided.

APPENDICES

Appendix A

SUMMARY OF U. S. ARMY CORPS OF ENGINEERS RECONNAISSANCE REPORT FOR NORTH LAKE, WAUKESHA COUNTY, WISCONSIN, JULY 1982

At the request of the North Lake District, the U. S. Army Corps of Engineers initiated a study in August 1980 to evaluate flooding problems on North Lake which result from increased lake elevations during periods of heavy rains and snowmelt. The objectives of the study were to evaluate alternative measures to reduce problems associated with the flooding of urban areas on North Lake while preserving the existing natural resources and cultural resources in the study area.

Six alternative measures for alleviating the flooding problems on North Lake were developed and evaluated. The alternatives which were evaluated include: 1) upstream storage; 2) construction of a spillway and flood flow bypass conduit; 3) channel improvements downstream of North Lake in the Oconomowoc River; 4) construction of a floodwall; 5) floodproofing of existing residences and associated structures; and 6) evacuation and relocation of residents and dwellings within the areas susceptible to flooding.

An analysis of the economic and environmental impacts and benefits of the six alternatives indicated that further Corps of Engineers' participation in flood control measures to alleviate the flooding problems on North Lake was not justified based upon an analysis of benefits and costs. However, the report suggested the following actions to the North Lake District to reduce flood damage on the Lake:

- Protection of existing buildings by utilizing temporary structures which can be placed over doors and windows in areas susceptible to flooding. Such structures can reduce or eliminate damage during moderate or low-stage flooding.

- Utilization of the guidelines developed by the National Flood Insurance Program to assist communities in effectively controlling future development and changes in land use through floodplain management.

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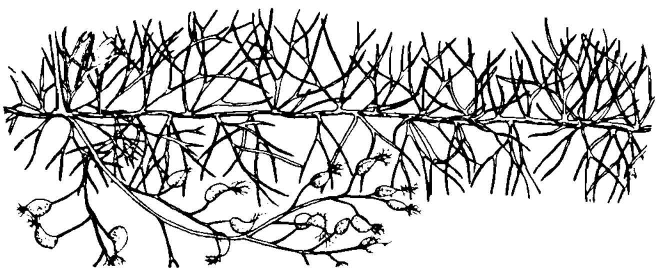
Appendix B

ILLUSTRATIONS OF REPRESENTATIVE BIOTA IN NORTH LAKE

Appendix B-1

REPRESENTATIVE MACROPHYTES FOUND IN SOUTHEASTERN WISCONSIN LAKES

BLADDERWORT (Utricularia sp.)

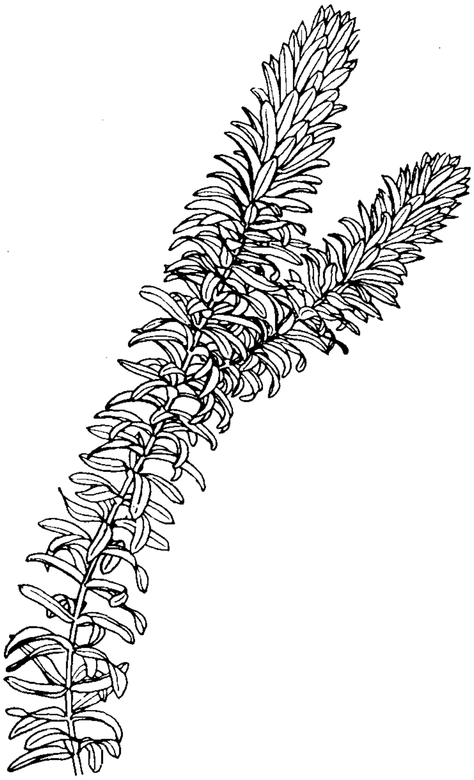


Bladderwort is a carnivorous plant which occurs in shallow ponds and lakes or on wet soils. The small bladders are traps which catch tiny animal life, particularly crustaceans. Bladderwort provides some food and cover for fish. It is never abundant enough to become a nuisance.

BUSHY PONDWEED (Najas flexilis)

Bushy pondweed is a common species in ponds, small lakes, and slow-moving streams in southeastern Wisconsin. It provides food and cover for fish. Bushy pondweed may become a nuisance during late summer in some lakes.

COMMON WATERWEED (Anacharis canadensis)



Common waterweed is a submerged plant which usually occurs in hard water. It provides cover for many small aquatic organisms which serve as food for the fish population. Waterweed is an aggressive plant and may suppress the growth of other aquatic plants.

COONTAIL (Ceratophyllum demersum)

Coontail is a submerged plant which prefers hard water. It supplies cover for shrimp and young fish and supports insects which are valuable as fish food. A heavy growth of coontail is an indication of very fertile lake conditions.

CURLY LEAF PONDWEED (Potamogeton crispus)

Curly leaf pondweed is an introduced plant species which does well in hard or brackish water which is usually polluted. However, curly leaf pondweed does provide good food, shelter, and shade for fish and is valuable for early spawning fish.

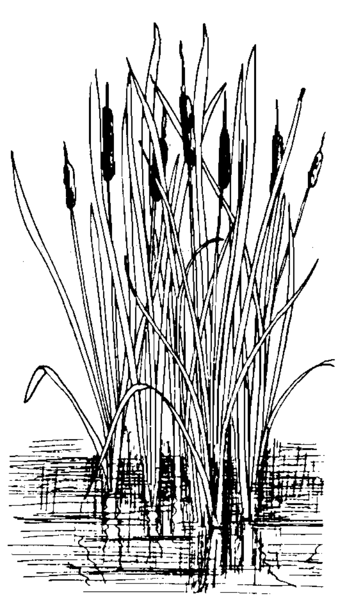
FLOATING LEAF PONDWEED (Potamogeton natans)

Floating leaf pondweed has leaves which float on the surface with the rest of the plant submerged. It provides food and shelter for fish and other aquatic species.

LARGE LEAF PONDWEED (*Potamogeton amplifolius*)

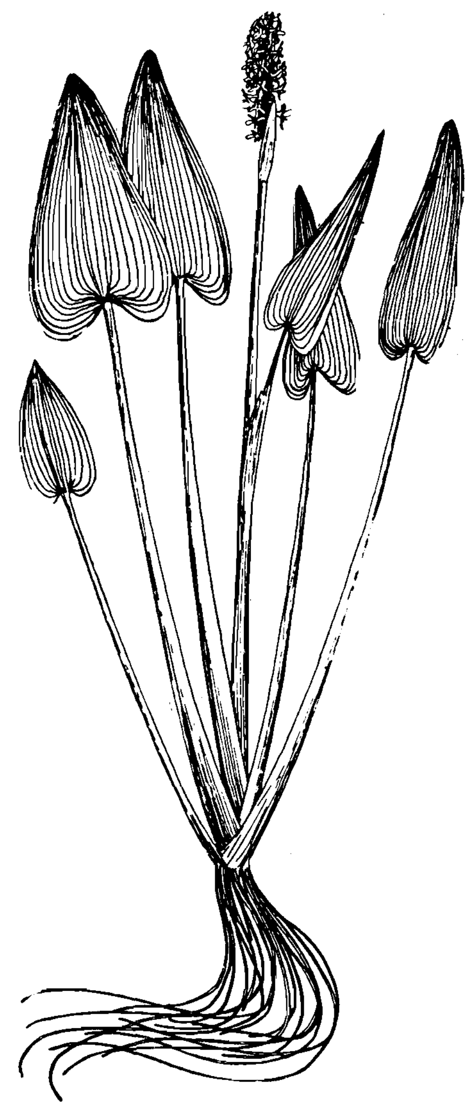
Large leaf pondweed is usually found in relatively hard water. Submersed, it supports insects and provides a good food supply for fish.

NARROW-LEAVED CATTAIL (*Typha angustifolia*)



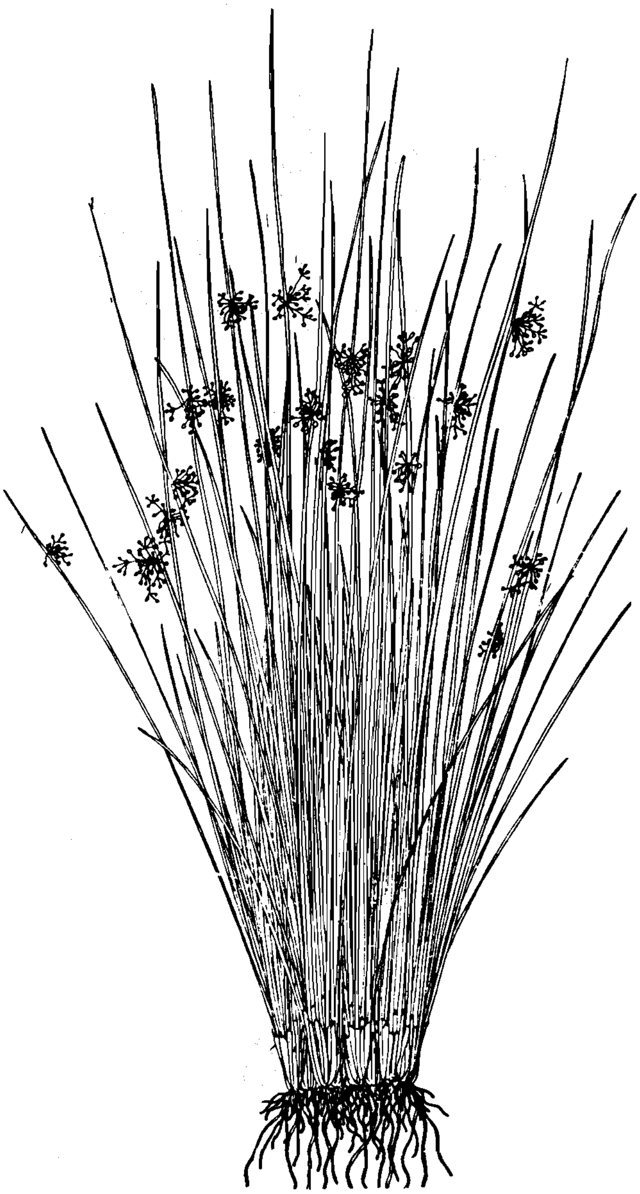
Narrow-leaved cattail may appear in almost any wet place. It is used as a spawning area for sunfish and shelter for various species of young fish, as well as a variety of other forms of wildlife. Cattails often occur in dense stands and therefore may become a nuisance.

PICKEREL WEED (*Pontederia cordata*)



Pickerel weed is common in shallow water with muddy shores. It provides shade and shelter for fish but has only slight value as food and cover. Pickerel weed usually is not abundant enough to be a nuisance.

RUSH (Juncus sp.)

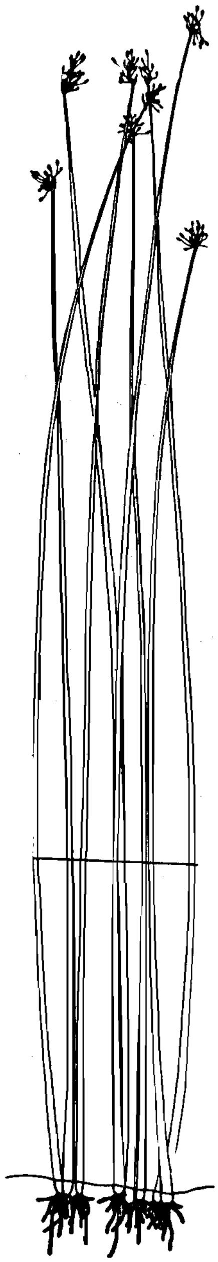


Rushes are an emergent aquatic plant with a widespread habitat which ranges from wet meadows and lakeshores to shallow pools. Thick growths of rushes often form spawning grounds for rock bass, bluegills, and other sunfish.

SAGO PONDWEED (Potamogeton pectinatus)

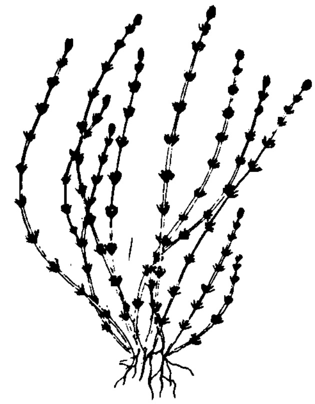
Sago pondweed is found in hard or brackish water of lakes and slow-flowing streams. Sago pondweed provides food and shelter for young trout and other fish.

SOFTSTEM BULRUSH (Scirpus validus)



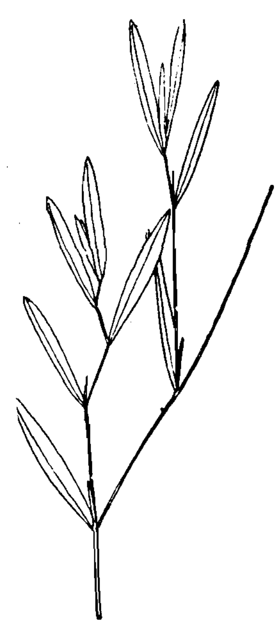
Softstem bulrush is an emergent aquatic species. It supports insects and provides food for young fish and many species of waterfowl.

STONEWORT (Chara aspera)



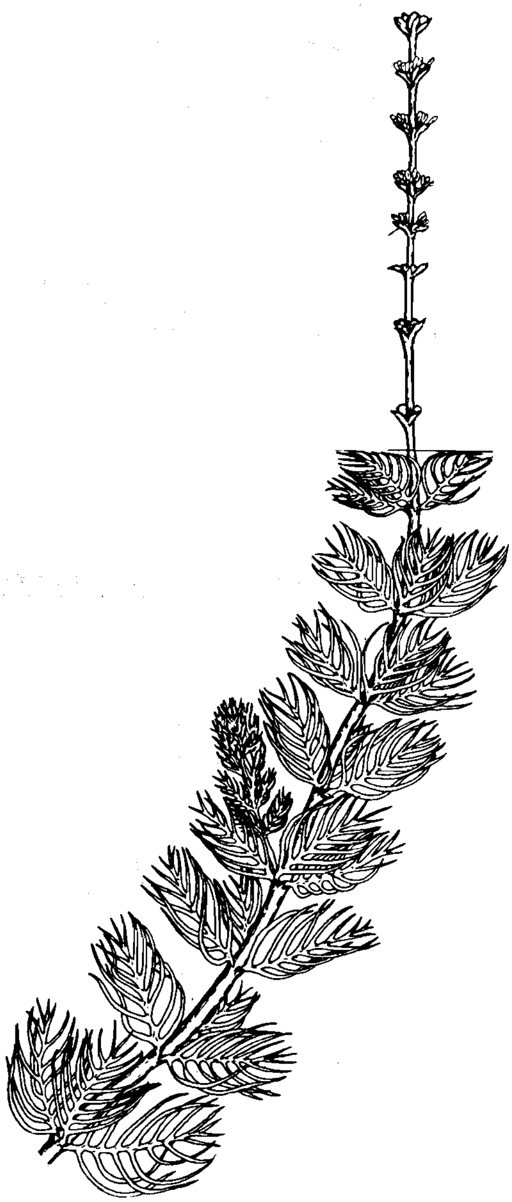
Stonewort is a type of algae which usually occurs in hard water. It provides fair cover for fish and produces excellent food for young trout, large and small mouth bass, and black bass.

VARIABLE PONDWEED (Potamogeton gramineus)



Variable pondweed is a submergent species. However, it will occasionally grow on muddy shores. Variable pondweed provides food and cover for fish.

WATER MILFOIL (Myriophyllum exalbescens)

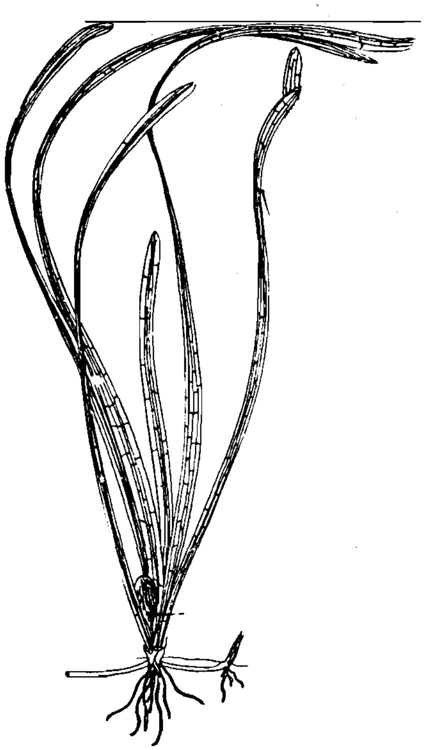


Water milfoil is a submergent plant which may cause extensive weed problems in lakes and streams. However, when not overabundant, water milfoil provides cover for fish and is a valuable food source for many forms of aquatic life.

WATER SMARTWEED (Polygonum natans)

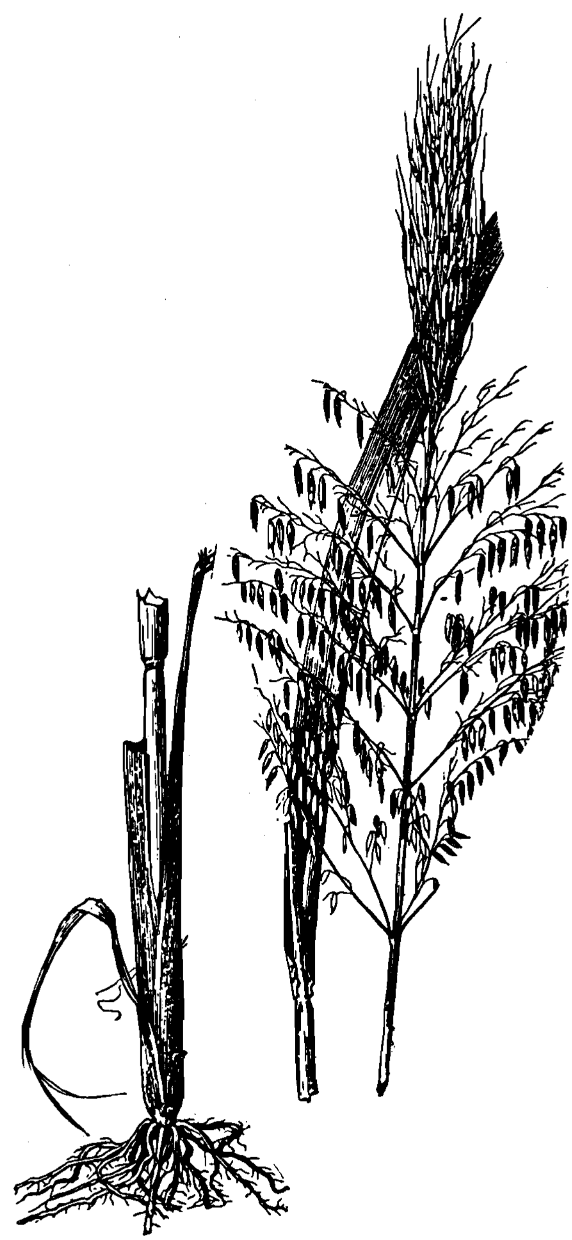
Water smartweed is found along the shoreline of shallow water. It provides food and cover for fish and wildlife. Water smartweed is never abundant enough to cause aquatic nuisance problems.

WILD CELERY OR EEL GRASS (Vallisneria americana)



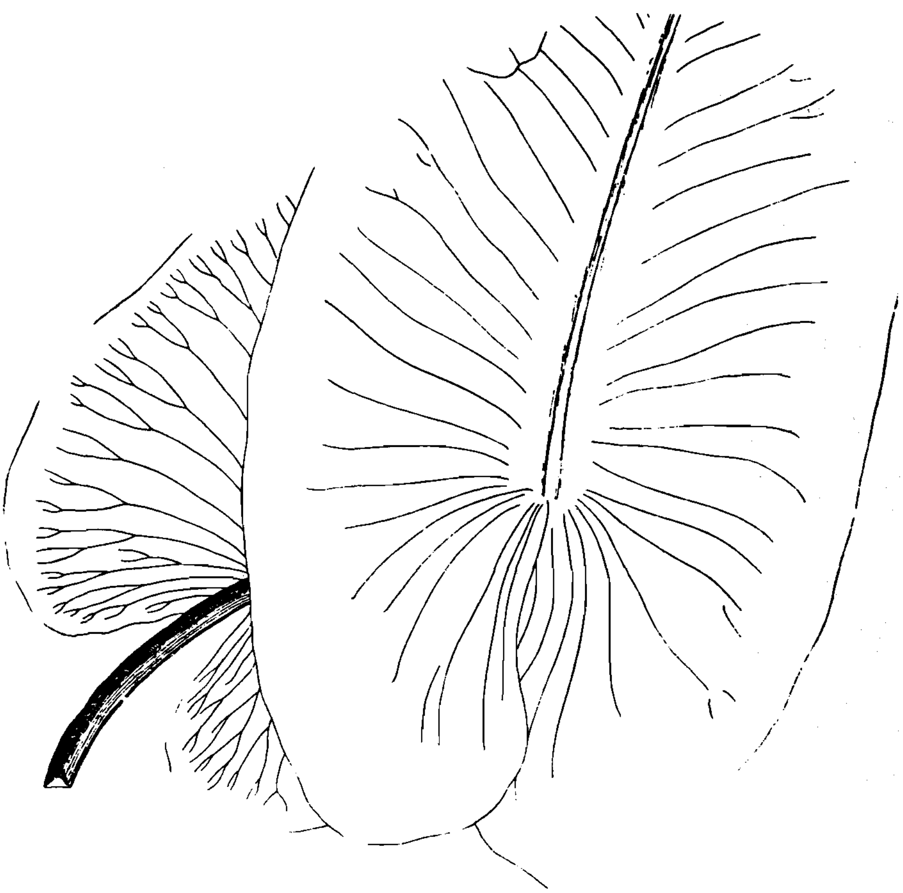
Eel grass is a submersed plant which provides shade, shelter, and food for fish. It supports insects and is a valuable food source for waterfowl. Sometimes forming dense growths, eel grass may be undesirable in swimming areas.

WILD RICE (Zizania aquatica)



Wild rice is a valuable emergent aquatic grass. Wild rice prefers clean water with low turbidity during the growing season. Wild rice is an annual grass with seeds that depend on sufficient light penetration in spring and early summer for germination. Wild rice is an important food source for many species of fish and waterfowl. It is also a food source for humans.

YELLOW WATER LILY (Nuphar variegatum)



Yellow water lily and white water lily are found in shallow portions of lakes and ponds. The leaves float on the surface of the water and algae and insects often grow under the leaves. Yellow and white water lilies provide shade and shelter for fish but may cause problems because of the extensiveness of their beds in shallow portions of lakes.

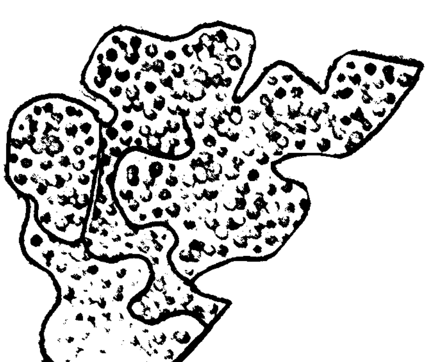
Appendix B-2

REPRESENTATIVE PHYTOPLANKTON FOUND IN SOUTHEASTERN WISCONSIN LAKES

Anabaena

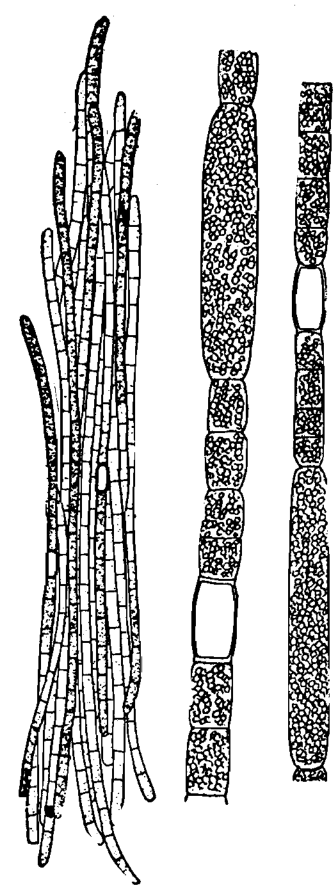
There are many individual species of the bluegreen algae, Anabaena. Some species are solitary while others form aggregated masses of indefinite shape. Anabaena seldom cause disagreeable conditions in lakes and reservoirs when they bloom, as they remain suspended throughout the water column and do not form surface scums. However, some species of Anabaena have been known to cause toxic water supplies which have caused animal fatalities.

Anacystis



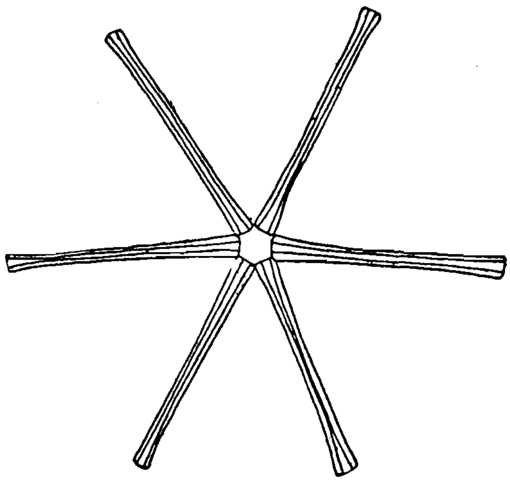
Anacystis is a loose colony of small spherical bluegreen algae cells contained in a gelatinous mass. The colony floats in the water column and is visible to the naked eye. Like Anabaena, Anacystis have been known to cause toxic water supplies.

Aphanizomenon



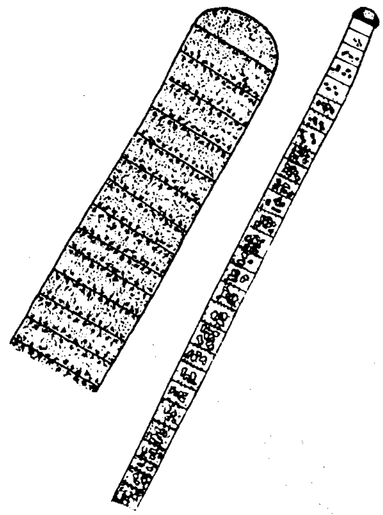
Individual cells of Aphanizomenon form strands which lie parallel in bundles and often occur so abundantly that the water appears to be filled with bits of chopped grass. The individual cells contain air spaces which give the plants great bouyancy. This accounts for the abundant growths of this bluegreen algae becoming concentrated on or near the surface where floating scum results. Dense growths may lead directly or indirectly to the death of fish through oxygen depletion or the secretion of toxins.

Asterionella



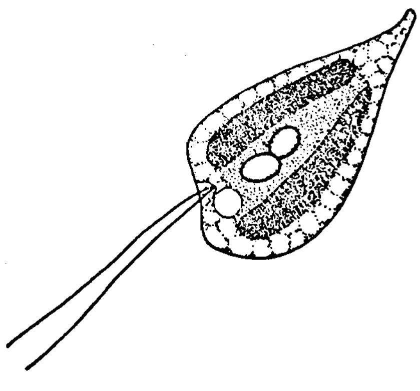
The diatom, Asterionella, usually occurs as a member of lake plankton. It prefers hard-water lakes and is readily identified by the spoke-like arrangement of the rectangular arms about a common center. Asterionella may be so abundant that lake water used for domestic water supplies may have a fishy taste.

Oscillatoria



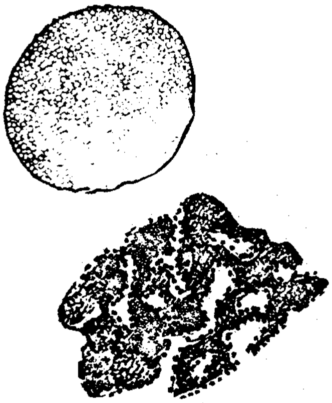
Oscillatoria is a filamentous bluegreen algae that grows in dense darkly colored clumps or mats. A characteristic of this bluegreen algae is the active oscillating movement for which it is named.

Dinobryon



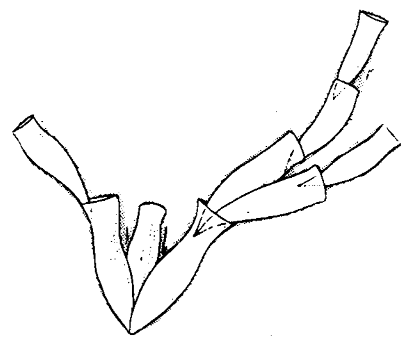
Dinobryon typically inhabit hard water lakes and, under certain conditions, may bloom. Dinobryon may produce disagreeable odors and tastes in domestic water supplies.

Microcystis



The cells of Microcystis, a bluegreen algae, are closely compacted and irregularly arranged in colonies enclosed in mucilage. Where some species of Microcystis occur, the habitat is completely dominated by this algae to the exclusion of all other forms of algae. Dense growths of Microcystis may cause oxygen depletion or secrete toxins which cause fish kills.

YELLOW GREEN ALGAE (Chrysophyta)



Many freshwater Chrysophyta are restricted to cold brooks, especially mountain streams, springs, and lakes during cool seasons. Most thrive in water relatively free of pollution.

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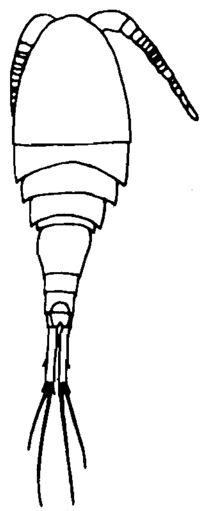
Appendix B-3

A FORM OF ZOOPLANKTON FOUND IN SOUTHEASTERN WISCONSIN LAKES

COPEPODS (Diacyclops thomasi)



A common example of copepods found in permanent bodies of water of all types from shallow ponds and marshes to lakes is Diacyclops thomasi. The adults are predaceous on other zooplankton and can injure fish fry.

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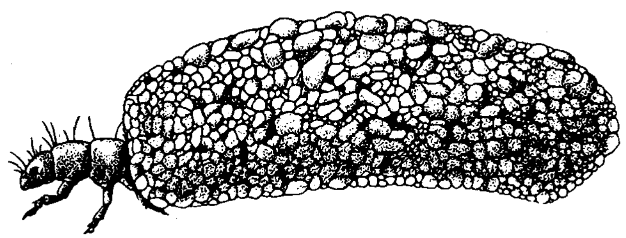
Appendix B-4

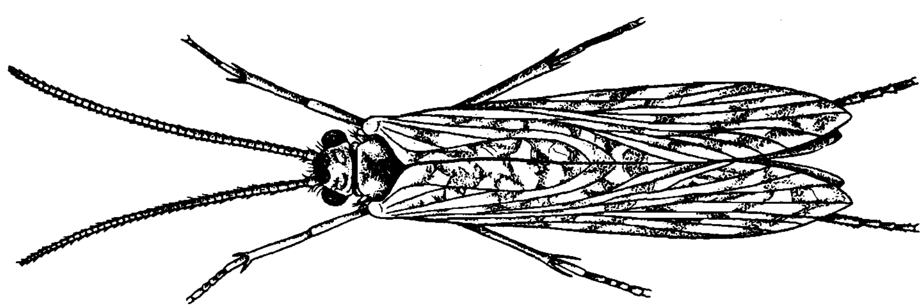
A FORM OF BENTHIC OR BOTTOM DWELLING ORGANISM FOUND IN SOUTHEASTERN WISCONSIN LAKES

CADDISFLIES (Trichoptera)

Caddisfly Larvae and Case



Adult Caddisfly



Caddisflies are found in most types of freshwater habitat, including streams, spring seepages, rivers, lakes, marshes, and temporary pools. Their tolerance to organic pollution varies widely, with some species being quite tolerant. Caddisflies are a food source for many species of fish.

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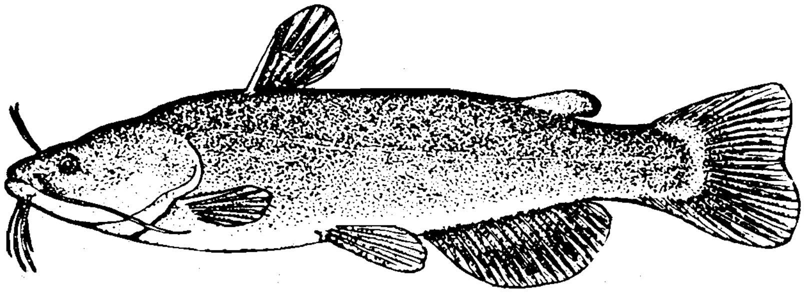
Appendix B-5

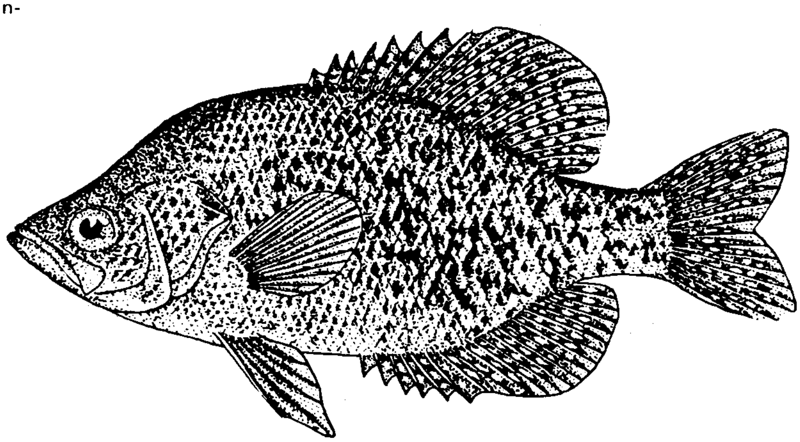
REPRESENTATIVE FISH SPECIES FOUND IN SOUTHEASTERN WISCONSIN LAKES

BLACK BULLHEAD (Ictalurus melas)



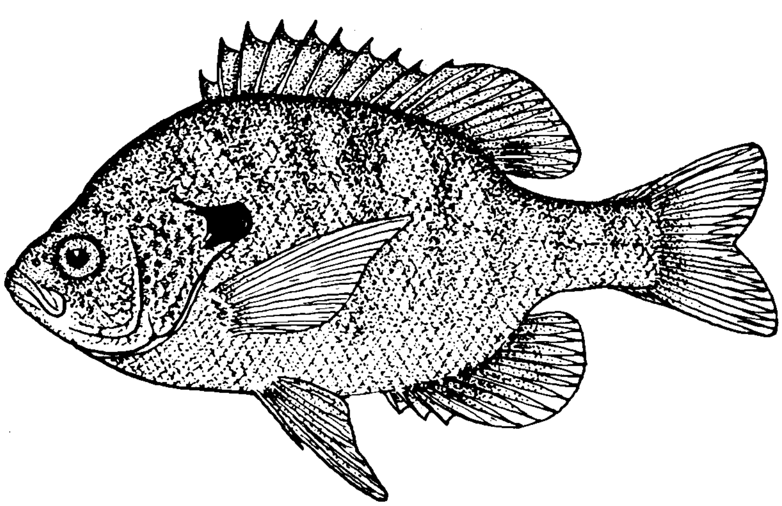
The black bullhead is common in shallow lakes and muddy streams. It nests in shallow water on either a sand or mud bottom. Bullheads are scavengers and will eat whatever food is available, such as minnows, leeches, crayfish, and amphipods.

BLACK CRAPPIE (Pomoxis nigromaculatus)



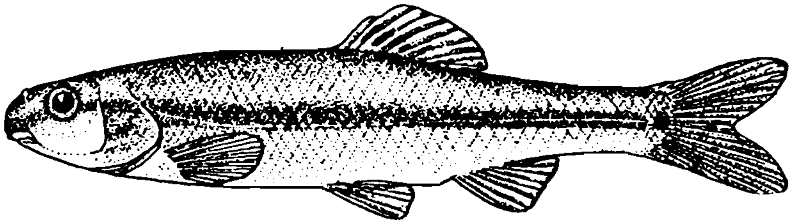
The black crappie prefers large streams and medium-sized lakes. It nests in water between three and six feet deep with a somewhat muddy bottom. Crappies feed on aquatic insects, small crustaceans, minnows, and other small fish.

BLUEGILL (Lepomis macrochirus)



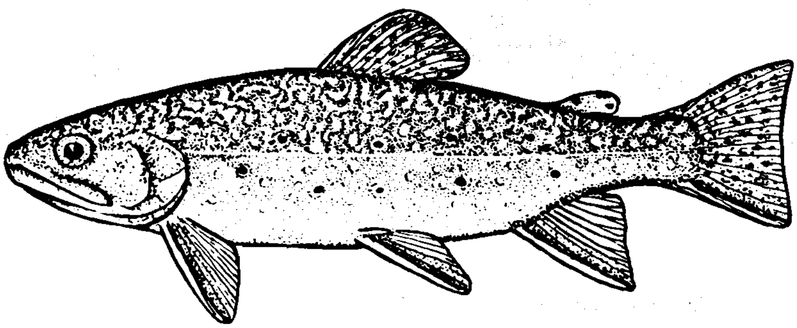
The bluegill is found in nearly all clear water lakes and streams. It nests in shallow areas with sandy bottoms; nests are often crowded together. Bluegills feed on small aquatic insects, worms, snails, and amphipods.

BLUNTNOSE MINNOW (Pimephales notatus)



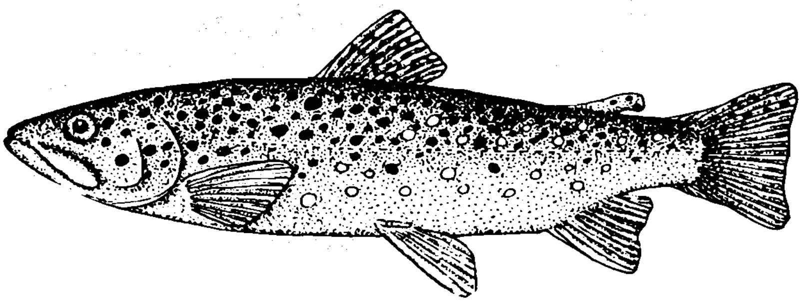
The bluntnose minnow is common in lakes and streams, but not in large rivers. The nest is built under an object, such as a rock or log. Bluntnose minnows feed mainly on algae.

BROOK TROUT (Salvelinus fontinalis)



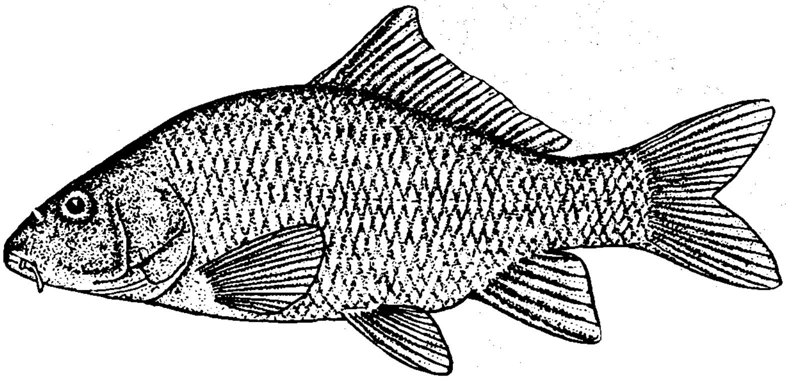
The brook trout, a native species in southeastern Wisconsin, prefers clear brooks and rivers in which the mean annual temperature rarely exceeds 50°F. The nest or redd is built on gravel bottoms in shallow riffle areas. Brook trout feed on adult aquatic insects and their larvae.

BROWN TROUT (Salmo trutta)



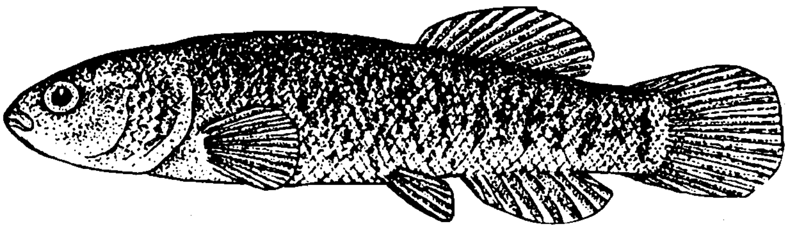
The brown trout is an introduced trout species which has become common in cold water streams. Nests or redds are built on sand and gravel bars at the mouths of tributaries. Young brown trout feed on small crustaceans and aquatic insects. Adults eat small fish, snails, crayfish, and terrestrial insects.

CARP (Cyprinus carpio)



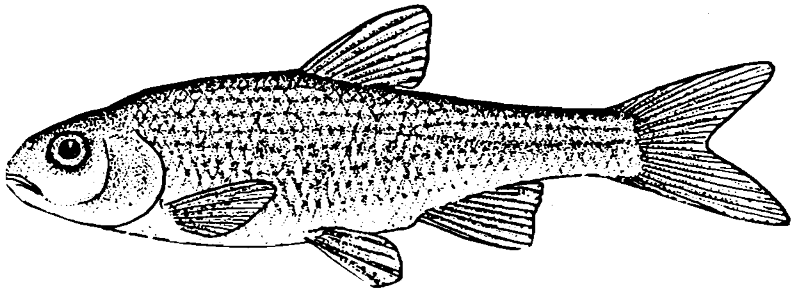
The carp is an introduced species which is tolerant of low dissolved oxygen conditions and prefers warm waters, with shallow mud-bottom lakes. Carp eat a wide variety of food. The uprooting of vegetation during feeding results in suspension of bottom sediments into the water column and a loss of aquatic plant beds which other fish species depend on.

CENTRAL MUDMINNOW (Umbra limi)



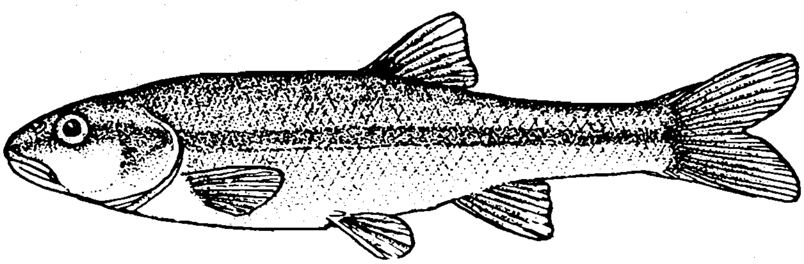
The central mudminnow prefers bog habitats, ditches, and streams with mud bottoms supporting dense aquatic vegetation. Spawning occurs in late spring and early summer. Mudminnows feed on insects, small crustaceans, and worms.

COMMON SHINER (Notropis cornutus)



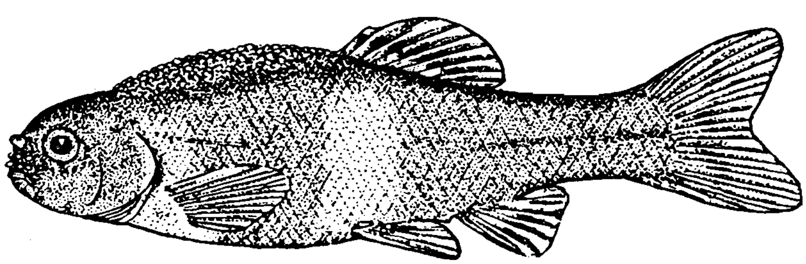
The common shiner occurs in habitats ranging from intermittent streams to large rivers and lakes. Common shiners are a forage fish that have value as a food source for game species. Shiners feed on small insects, crustaceans, and some algae.

CREEK CHUB (Semotilus atromaculatus)



The creek chub prefers small streams and rivers but occasionally is found in lakes and large rivers. Creek chubs are quite common in beaver dam pools and may compete with trout for food. Chubs feed on all types of insects, amphipods, vegetation, and other, smaller fish.

FATHEAD MINNOW (Pimphales promelas)

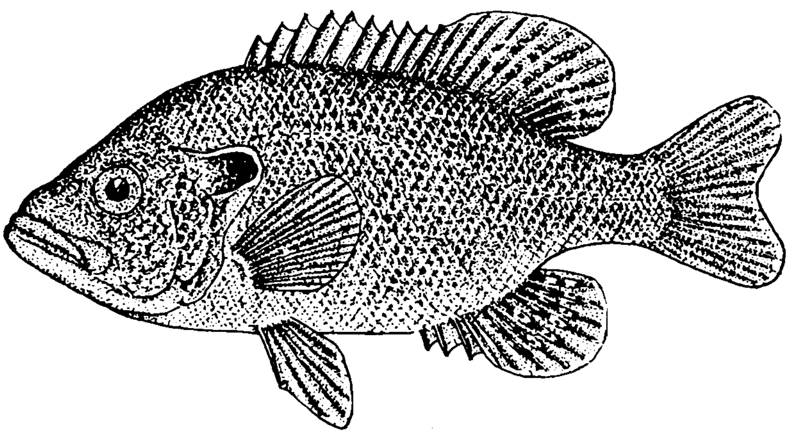


The fathead minnow prefers shallow lakes, ponds, and ditches. Nests are built on the underside of sticks, boards, and rocks in water between 3 and 12 inches deep. The fathead minnow can withstand very low oxygen conditions and, therefore, are very tolerant to pollution. Young fathead minnows feed on algae, while adults feed on a variety of aquatic insects, worms, and plants. The fathead minnow is a forage species and serves as a food source for many types of game fish.

GRASS PICKERAL (Esox americanus vermiculatus)

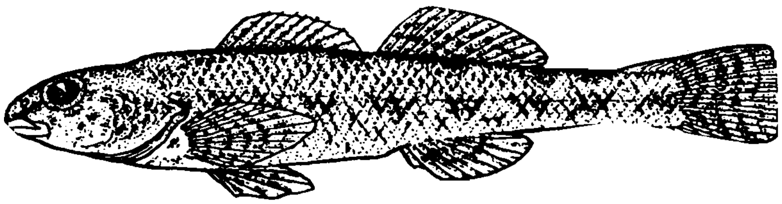
The grass pickerel is common in weedy portions of lakes and rivers. Pickerels are predators and as such feed almost exclusively on other fish. Grass pickerel are too small to have much value as a game fish.

GREEN SUNFISH (Lepomis cyanellus)



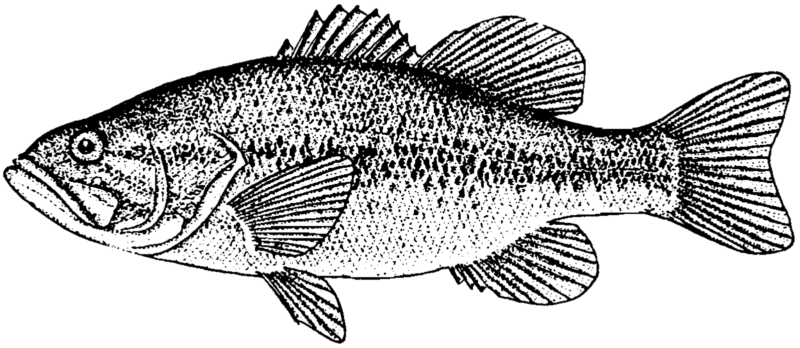
The green sunfish prefers small, shallow lakes and is common in creeks. Green sunfish feed on aquatic insects and any flying insects that happen to fall into the water. Large numbers of stunted adults may occur in some lakes and as such may decrease the viability of the existing fishery.

JOHNNY DARTER (Etheostoma nigrum)



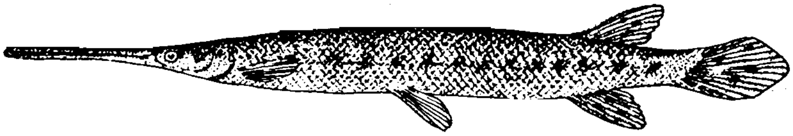
The johnny darter occurs in relatively clean lakes and streams. Nests are built under sticks and stones. The johnny darter feeds on algae and small, immature insects.

LARGEMOUTH BASS (Micropterus salmoides)



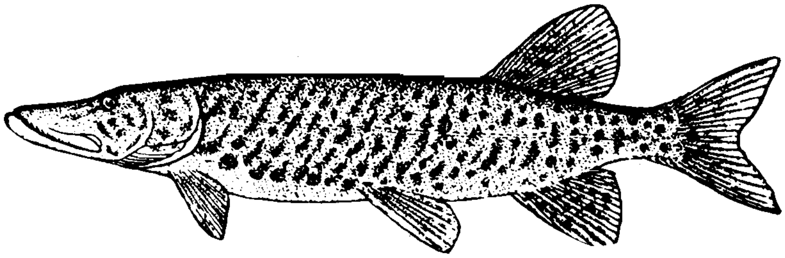
The largemouth bass prefers small- to medium-sized hardwater lakes with clear water, sandy shores, and marginal weed beds. The largemouth bass is carnivorous and as an adult feeds on perch, minnows, and small sunfish.

LONGNOSE GAR (Lepisosteus osseus)



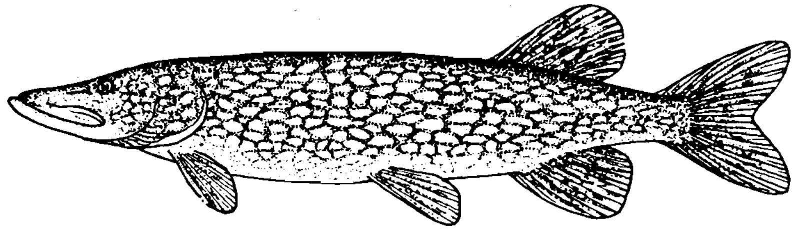
The longnose gar is a warmwater fish that often can tolerate surface waters which are too polluted for other species. Gars feed on game and forage fish and in some instances may alter fish populations enough to damage a fishery resource.

MUSKELLUNGE (Esox masquinongy)



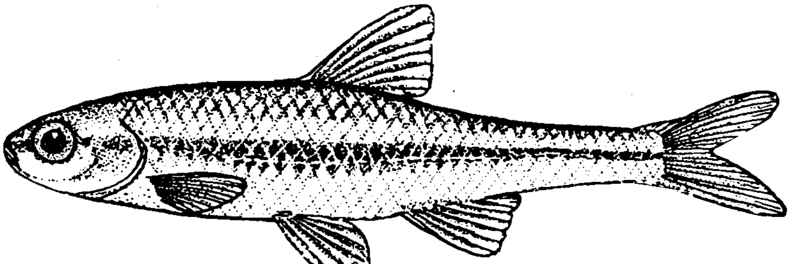
The muskellunge is common in lakes but is seldom abundant because it requires a large area of water to supply enough food for its voracious appetite. Spawning occurs in early May in tributary streams and shallow lake channels. Muskellunge are strictly carnivorous, feeding primarily on perch and suckers. A hydrid strain (tiger muskie) is stocked in many lakes in southeastern Wisconsin.

NORTHERN PIKE (Esox lucius)



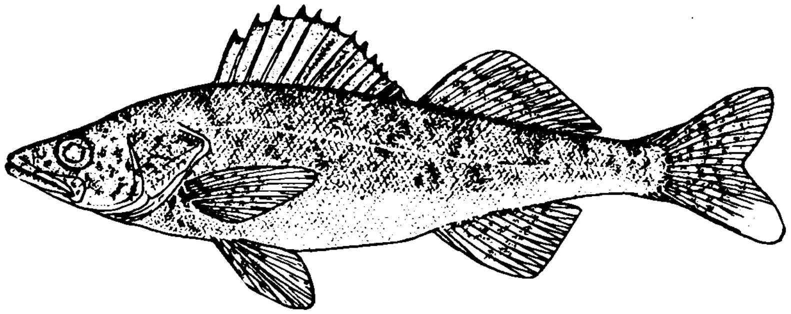
The northern pike is common in southeastern Wisconsin lakes. It feeds on a variety of fish, including perch, small suckers, sunfish, and even smaller northern pike. Spawning occurs immediately after the ice melts in April or early May in wetlands adjacent to lakes and streams.

PUGNOSE SHINER (Notropis anogenus)



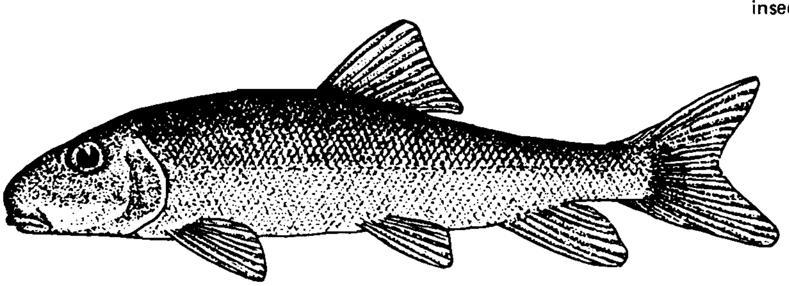
The pugnose shiner is threatened in Wisconsin. This small fish—up to two inches in length—prefers weedy waters in streams and lakes. Little is known about its life history as it is one of the rarest shiners. Changes by man in streams, rivers, and lakes have been responsible for its disappearance and resulting inclusion on the threatened species list in Wisconsin.

WALLEYE (Stizostedion vitreum vitreum)



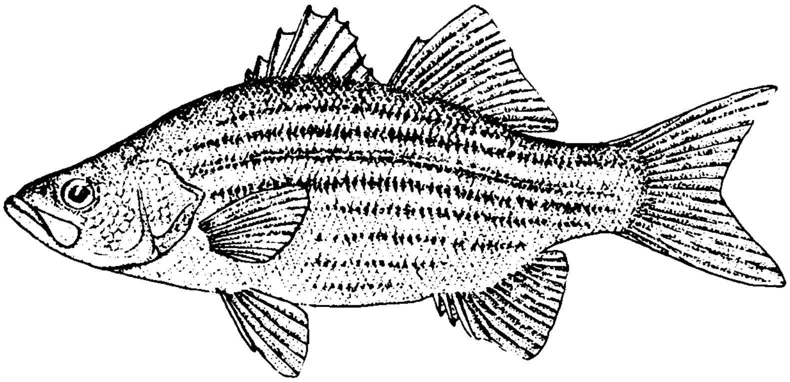
The walleye prefers clean and moderately warm to cold lakes and rivers. Spawning occurs in early spring on sand bars and shoals. Walleye feed on small minnows, small bullheads, and leeches. Walleye are a very desirable game fish.

WHITE SUCKER (Catostomus commersoni)



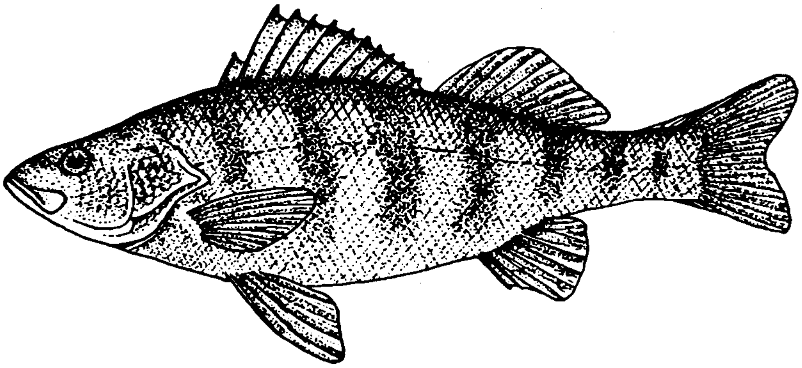
The white sucker occurs in almost every permanent body of fresh water, from small streams to large lakes. White suckers have an important role in cleaning lakes and streams. White suckers are a forage species and serve as a food source for many other species of fish.

WHITE BASS (Morone chrysops)



The white bass occurs in large rivers and connected lakes. White bass usually travel in large schools near the surface. Eggs are scattered randomly on shallow bars and gravelly reefs. White bass feed on insects and small fish.

YELLOW PERCH (Perca flavescens)



Yellow perch are schooling fish common to lakes and streams which do not experience winter kills. Eggs are deposited in a gelatinous, ribbonlike bank over submerged aquatic plants or branches. Perch are predaceous and feed on minnows, aquatic insects, crayfish, leeches, and snails. In addition, perch may compete with other game fish for food and space if populations get too large.

Appendix C

ACKNOWLEDGEMENT OF ASSISTANCE IN PREPARATION OF NORTH LAKE STUDY

Local citizens, units of government, and private groups who provided assistance to the Wisconsin Department of Natural Resources in the conduct of field studies:

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