COMMUNITY ASSISTANCE
PLANNING REPORT NO. 253

# A LAKE MANAGEMENT PLAN FOR DELAVAN LAKE

## WALWORTH COUNTY WISCONSIN

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Special acknowledgment is due to Dr. Joseph E. Boxhorn, environmental consultant, for his contribution to the preparation of this report. Acknowledgement also is due to Dr. Jeffrey A. Thornton, CLM, PH, SEWRPC Principal Planner, Dr. Thomas M. Slawski, SEWRPC Senior Planner, Ms. Rachel E. Lang, SEWRPC Senior Biologist, Ms. Christine M. Hinz, former SEWRPC Planner, and Mr. Edward J. Schmidt, SEWRPC Research Analyst, for their contributions to the conduct of this study and the preparation of this report.

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# A LAKE MANAGEMENT PLAN FOR DELAVAN LAKE

# WALWORTH COUNTY, WISCONSIN

Prepared by the

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The preparation of this publication was financed in part through a grant from the Wisconsin Department of Natural Resources Lake Management Planning Grant Program.

May 2002

| | |
|---|---|
| Inside Region | $ 10.00 |
| Outside Region | $ 20.00 |

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# Chapter I

# INTRODUCTION

Delavan Lake is a 2,072-acre drainage lake, situated within U.S. Public Land Survey Sections 13, 14, 20, 21, 22, 23, 27, 28, 29, 31, 32, and 33, Township 2 North, Range 16 East, City and Town of Delavan, Walworth County. The Lake is located on Jackson Creek, a tributary of Turtle Creek draining to the Lower Rock River. The Lake offers a variety of water-based recreational opportunities and is the focus of the lake-oriented community surrounding the Lake. The Lake has historically experienced various management problems, including excessive aquatic plant and algal growths, recreational user conflicts and water quality-related use limitations, and public concerns over the aesthetic degradation of the resource. In addition, concerns had been raised regarding deteriorating water quality conditions, the need to protect environmentally sensitive areas, and the prevention of the spread of exotic plant species within the lake basin.

The Lake has been subject to a number of lake management actions, initiated in response to community concerns. These concerns over the state of the Lake resulted in the formation, during 1969, of a town sanitary district, under Section 60.70 of the *Wisconsin Statutes*, serving the urban development surrounding Delavan Lake. The regional water quality management plan included a recommendation to provide a public sanitary sewer system to serve the urban development surrounding Delavan Lake.[1] Provision of public sanitary sewer service was initiated during 1979 and completed in 1981.[2] Wastewater from the Delavan Lake Sanitary District service area is treated at the Walworth County Metropolitan (WalCoMet) Sewerage District sewage treatment plant and discharged to Turtle Creek downstream of the Lake.

Subsequent to the completion of the public sewer project, Delavan Lake experienced a series of summer algal blooms culminating in a highly notorious blue-green algal bloom during the summer of 1983. It was determined that the sources of the contaminants contributing to the excessive algal growth in the Lake were diffused throughout the drainage basin tributary to the Lake. This finding, set forth in the Turtle Creek Priority Watershed Plan and its subsequent amendment,[3] initiated the development and implementation of a further series of lake management measures designed to reduce the delivery of nonpoint-sourced pollutants to the Lake. This plan refined the nonpoint source pollution reduction measures recommended in the regional water quality management plan, and resulted in further in-lake and watershed-level interventions designed to restore and rehabilitate Delavan Lake.

Seeking to improve the usability of Delavan Lake, and to prevent future deterioration of the natural assets and recreational potential of the Lake, Federal, State, and local agencies began a major, multi-year program of lake

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[1]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, *Volume Three,* Recommended Plan, *June 1979.*

[2]*SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995.*

[3]*Wisconsin Department of Natural Resources,* Turtle Creek Priority Watershed Plan, *March 1984; Wisconsin Department of Natural Resources,* Turtle Creek Priority Watershed Plan Amendment—The Delavan Lake Restoration Project, *August 1989.*

rehabilitation program that was conducted on Delavan Lake between 1989 and 1993. That program was designed and implemented with funds provided by the U.S. Environmental Protection Agency, acting in concert with other agencies, including the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers, the Wisconsin Department of Natural Resources (WDNR), the City and Town of Delavan, the Delavan Lake Sanitary District, and the University of Wisconsin. Details of the project design and construction are set forth in the 1986[4] and 1989[5] reports prepared by the University of Wisconsin and WDNR, respectively, as means of guiding and evaluating lake management measures to be applied to Delavan Lake.

The major structural works undertaken as part of the lake restoration and rehabilitation program set forth in the aforereferenced reports provided for the construction of a flow diversion berm within the Lake designed to divert nutrient-rich inflows around the main lake basin, and a constructed wetland system situated upstream of the Lake on Jackson Creek designed to intercept and retain nonpoint source nutrient loads from the urbanizing tributary drainage area to the Lake. These construction works were completed in 1992. Additional actions, including hydraulic improvements to the outflow channel, alum-dosing of the lake basin, and biocide-based aquatic plant and fisheries management programs, were also completed between 1989 and 1992. Review of the water quality data and analysis prepared by the U.S. Geological Survey, and set forth in Chapter IV, indicates that these management actions have had the effect of markedly improving water quality within the main lake basin during and since 1993.[6]

Since 1995, the Town of Delavan has undertaken additional programs to evaluate water quality conditions and identify specific refinements to the management measures designed to improve the water quality and recreational use potential of Delavan Lake. The Lake has been enrolled in the WDNR Self-Help Monitoring Program, and the USGS is currently monitoring lake water quality. Based upon these latter studies, the USGS has identified a substantial increase in internal loading of phosphorus to the Lake from the northeastern portion of the Lake, known locally as the Delavan Lake inlet, downstream of the Mound Road wetland.[7] The likely cause of this loading was determined to be related to the presence of high concentrations of phosphorus in the sediments within the inlet. Field investigations, completed during this planning program, suggest that aquatic macrophytes within the inlet enhance phosphorus cycling during the spring and summer to the extent that the internal phosphorus loading from the inlet sediments can contribute up to approximately one-half of the total seasonal load of phosphorus to the Lake. This source of phosphorus loading is in addition to the significant external phosphorus load, primarily from the Jackson Creek tributary drainage area. Operation of the inflow bypass has not been as effective in enhancing the short-circuiting of this phosphorus load, in part, due to technical difficulties with the remote operation of the dam gate control and incomplete implementation of the "chain of islands" initially proposed as an element of this management measure. Thus, community concerns regarding the state of Delavan Lake remain.

In an effort to collect, synthesize, and evaluate the combined effects of the various lake management measures implemented in and around Delavan Lake since the early 1980s, and to provide direction for future lake management actions to be carried out by the Town of Delavan and its partner agencies, the Town requested the Southeastern Wisconsin Regional Planning Commission to prepare a comprehensive lake management plan for

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[4]*University of Wisconsin-Madison, Institute for Environmental Studies,* Delavan Lake: A Recovery and Management Study, *September 1986.*

[5]*Wisconsin Department of Natural Resources,* Environmental Impact Statement on the Delavan Lake Rehabilitation Project, Walworth County, Wisconsin, *March 1989.*

[6]*Dale M. Robertson, Gerald L. Goddard, Daniel R. Helsel, and Kevin L. MacKinnon, "Rehabilitation of Delavan Lake, Wisconsin,"* Lake and Reservoir Management, *Vol. 16, No. 3, pp. 155-176, 2000.*

[7]*U.S. Geological Survey Water-Resources Investigations Report No. 96-4160,* Phosphorus Dynamics in Delavan Lake Inlet, Southeastern Wisconsin, 1994, *1996.*

Delavan Lake. This lake management plan represents an ongoing commitment by the Town of Delavan, the Delavan Lake Sanitary District, the Wisconsin Department of Natural Resources, the U.S. Geological Survey, the U.S. Fish and Wildlife Service, the U.S. Army Corps of Engineers, the University of Wisconsin, and the private sector to sound environmental planning. This plan, prepared by the Regional Planning Commission in response to the request of the Town of Delavan, incorporates and analyzes the data and information developed in the aforementioned lake management-related studies, and other data and information acquired during the planning period, including data from aquatic plant surveys made in the Lake during 1992 through 1994 and 1996 through 1998,[8] and recreational boating-use surveys conducted during 1997. In addition, this report presents feasible, alternative in-lake measures for enhancing the water quality conditions, and for providing opportunities for safe and enjoyable use of the Lake, identified by a technical advisory group comprised of individuals from the abovereferenced agencies and organizations, convened during 2000 under the auspices of the Town, Sanitary District, and Regional Planning Commission. More specifically, this report describes the physical, chemical, and biological characteristics of the Lake and pertinent related characteristics of the tributary watershed, as well as the feasibility of various watershed and in-lake management measures which may be applied to enhance the water quality conditions, biological communities, and recreational opportunities of the Lake.

The primary objectives which this plan is intended to achieve are: 1) to contribute to the overall conservation and wise use of Delavan Lake through the environmentally sound management of vegetation, fishes, and wildlife populations in and around the Lake; 2) to provide the potential for high-quality, water-based recreational experiences by residents and visitors to the Lake; 3) to effectively control the severity of nuisances resulting from the recurring excessive aquatic macrophyte and algal growths in portions of the Delavan Lake basin; and 4) to facilitate the conduct of water-based recreational activities, to improve the aesthetic value of the Lake, and to enhance its resource value. This plan should serve as a practical guide over time for achieving these objectives in a technically sound manner.

[8]*Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1992*; *Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1993*; *Aron & Associates,* Delavan Lake Aquatic Plant Management Plan, *September 1993*; *Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1994; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1996; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1997; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1998.*

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# Chapter II

# PHYSICAL DESCRIPTION

## INTRODUCTION

The physical characteristics of a lake and its watershed are important factors in any evaluation of existing and likely future water quality conditions and lake uses, including recreational uses. Characteristics, such as watershed topography, lake morphometry, and local hydrology, ultimately influence water quality conditions and the composition of plant and fish communities within the lake. Therefore, these characteristics must be considered during the lake management planning process. Accordingly, this chapter provides pertinent information on the physical characteristics of Delavan Lake, its watershed, and on the climate and hydrology of the Delavan Lake drainage area. Subsequent chapters address land use conditions, and the chemical and biological environments of the Lake.

## WATERBODY CHARACTERISTICS

Delavan Lake is located in the City and Town of Delavan, as shown on Map 1. Delavan Lake is a drainage or flow-through Lake with a defined inlet and outlet. The shallow inlet and outlet areas are situated to the north of the Lake's single, deep basin, which is oriented in an approximately northeast-southwest direction. The drainage area tributary to the Lake is located within Walworth County. Jackson Creek, entering the Lake through the inlet to the north of the Lake, is the principle inflow, and Swan Creek, a tributary to Turtle Creek which drains to the Lower Rock River basin, is the principle outflow, draining the Lake toward the west, as shown on Map 2.

Basic hydrographic and morphometric data on the Lake are presented in Table 1. The Lake has a surface area of approximately 2,072 acres, a maximum depth of about 56 feet, and a volume of approximately 44,800 acre-feet. The Lake has a mean depth of about 21 feet. The lake level of Delavan Lake is augmented by about eight feet by a dam constructed during the mid-1930s and located at the outlet of the Lake. The bathymetry of the Lake is shown on Map 3.[1]

Delavan Lake has a shoreline length of about 13 miles, and a shoreline development factor of 2.2, indicating that the lake shoreline is irregular and is about two times as long as that of a circular lake with the same radius. The shoreline of Delavan Lake is almost entirely developed for residential uses, with the exception of the wetland areas located along portions of the Delavan Lake inlet, which are in open space use.

Erosion of shorelines results in the loss of land, damage to shoreland infrastructure, and interference with access and lake use. Such erosion is usually caused by wind-wave action, ice movement, and wakes from motorized boat traffic. A survey of the Delavan Lake shoreline, conducted during the summer of 1997 by Commission staff, identified existing shoreline protection conditions around the Lake, as shown on Map 4. About 4.6 miles, or 35 percent of the shoreline of Delavan Lake, were found to be in a natural condition, while the remaining 8.4 miles

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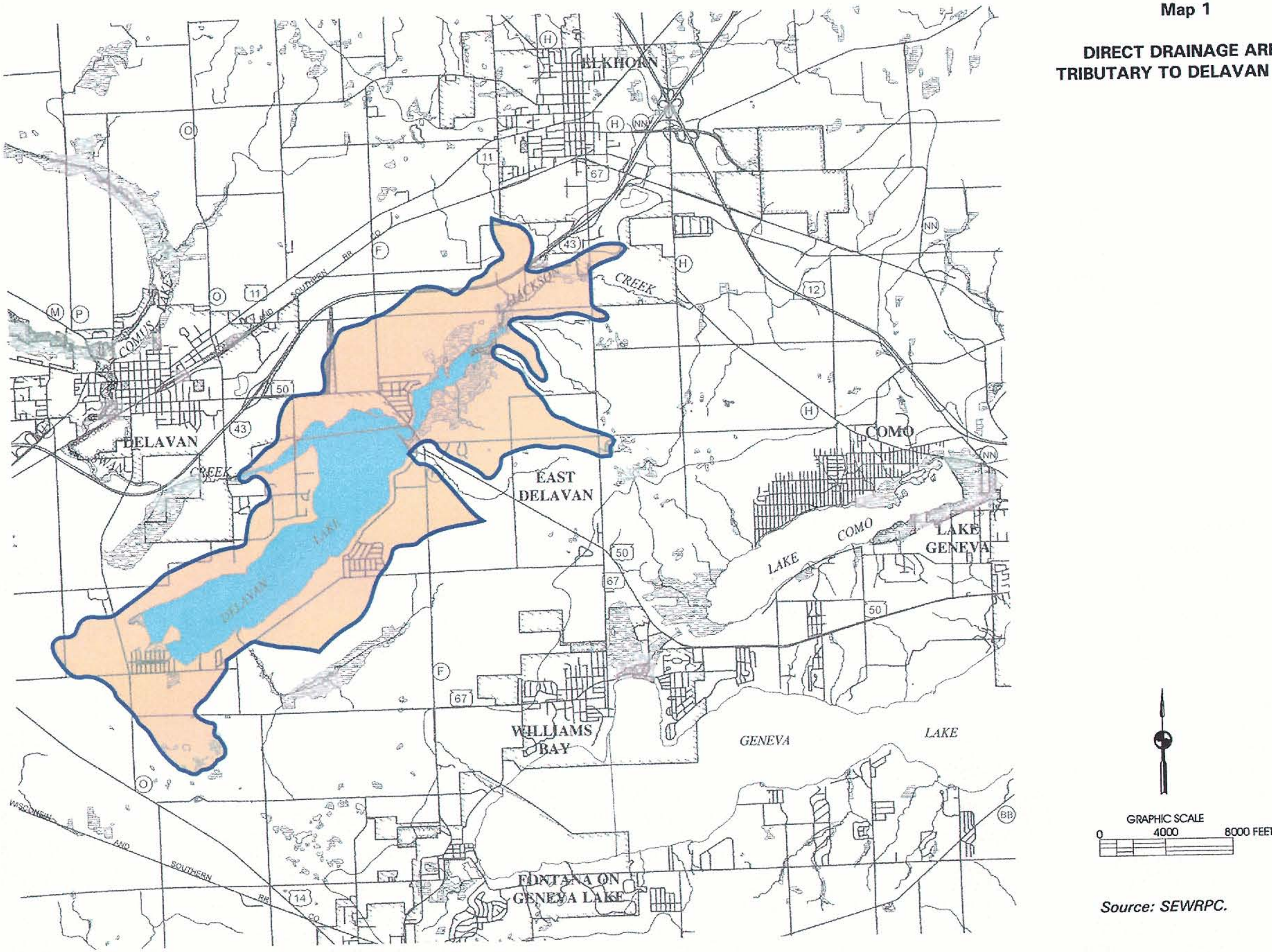
[1] *U.S. Geological Survey Water-Resources Investigations Report No. 87-4168,* Hydrology and Water Quality of Delavan Lake in Southeastern Wisconsin, *August 1988.*

**Map 1**

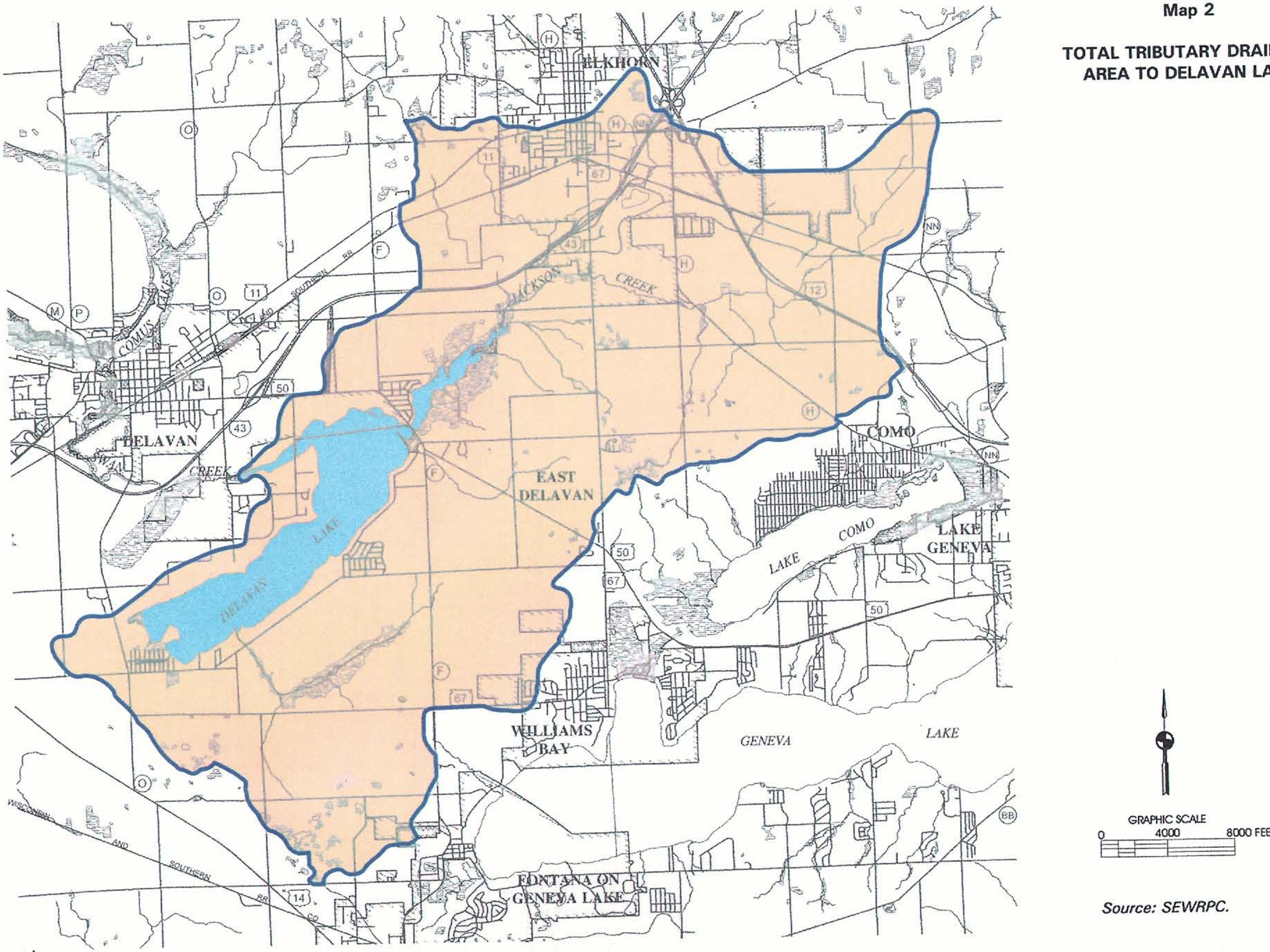
**DIRECT DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE**




*Source: SEWRPC.*

## Map 2

### TOTAL TRIBUTARY DRAINAGE AREA TO DELAVAN LAKE




*Source: SEWRPC.*

Table 1

HYDROGRAPHY AND MORPHOMETRY OF DELAVAN LAKE

| Parameter | Measurement |
|---|---|
| Size | |
| Area of Lake | 2,072 acres |
| Total Drainage Area | 26,115 acres |
| Direct Drainage Area | 8,143 acres |
| Lake Volume | 44,800 acre-feet |
| Hydraulic Residence Time[a] | 2.0 years |
| Shape | |
| Length of Lake | 3.9 miles |
| Length of Shoreline | 13.0 miles |
| Width of Lake | 1.0 mile |
| Shoreline Development Factor[b] | 2.2 |
| Depth | |
| Portion of Lake Less than 10 Feet | 29 percent |
| Portion of Lake between 10 and 20 Feet | 14 percent |
| Portion of Lake between 20 and 30 Feet | 15 percent |
| Portion of Lake between 30 and 40 Feet | 17 percent |
| Portion of Lake between 40 and 50 Feet | 22 percent |
| Portion of Lake More than 50 Feet | 3 percent |
| Mean Depth | 21 feet |
| Maximum Depth | 56 feet |

[a]*The "hydraulic residence time" is estimated as the time period for a 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: *U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.*

were found to be protected by some type of shore protection structure, including bulkheads, vertical walls, revetments, sloping stonewalls, and areas where riprap had been used to stabilize the shoreline. Most of the observed shoreline protection measures were in a good state of repair.

A survey of the lake bottom substrate composition within the littoral zone of Delavan Lake was conducted during 1992 by Aron & Associates.[2] The littoral zone is defined as the lakeward extent of the shoreland zone in which aquatic plant growth occurs, extended from the ordinary high water mark to about 10 feet in depth. A previous survey of the entire lake bottom was conducted by the U.S. Geological Survey.[3] These surveys, summarized on Map 5, indicated that a majority of the lake bottom was covered by soft sediments. Of the surveyed bottom sediments, about 73 percent was covered by muck and silt and about 15 percent was covered by sand and gravel. The remaining portion of the lake bottom, comprising about 12 percent of the lake bottom, was covered by rock, as shown on Map 5. The depths of the soft sediments were measured in the inlet and ranged from 1.4 feet to 4.4 feet.[4]

## WATERSHED CHARACTERISTICS

The drainage area tributary to Delavan Lake totals about 26,000 acres, or about 41 square miles in areal extent, as shown on Map 2. The watershed-to-lake area ratio of Delavan Lake is approximately 13:1. Jackson Creek, the principal inflow, drains an area of approximately 13,700 acres, or about 21 square miles, northeast of the Lake. Inflow from this source is supplemented by surface runoff from the drainage area directly tributary to the Lake. In addition, two unnamed tributaries, located to the east and south of the main lake basin, and direct precipitation onto the lake surface contribute to the hydrologic budget of the Lake. The lake discharges via Swan Creek to the Turtle Creek tributary of the Lower Rock River, as shown on Map 2.

As noted above, the lands riparian to Delavan Lake are largely developed for urban residential use, although portions of the total tributary drainage area to the Lake remain in agricultural uses. Those agricultural lands situated to the north of the Lake have been largely converted to urban residential uses in recent years, although some agricultural land uses remain along Jackson Creek. Map 6 reproduces the 1873 Public Land Survey map for the Delavan Lake area.

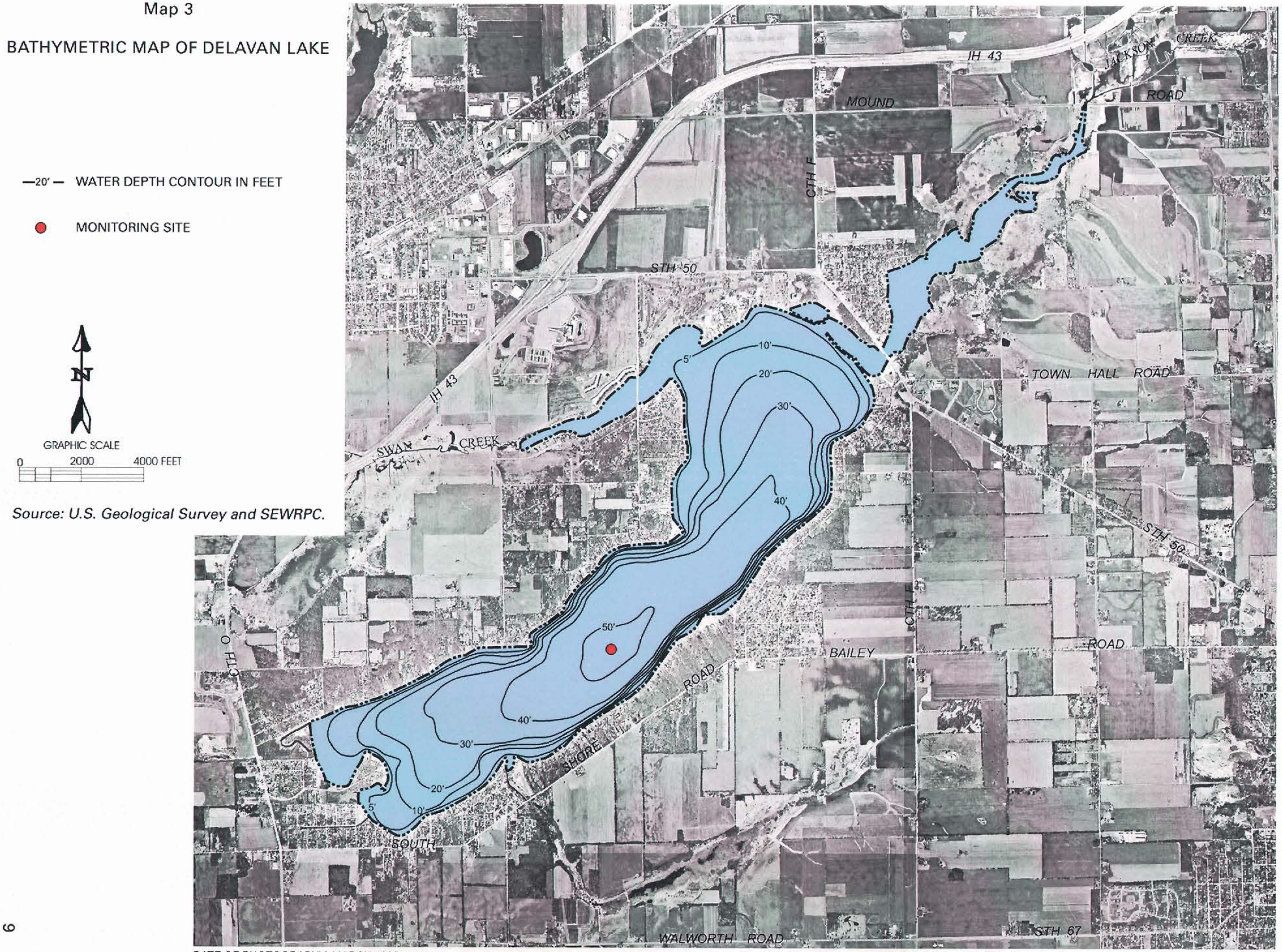
[2]*Aron & Associates,* Delavan Lake Plant Management Plan, *September 1993.*

[3]*U.S. Geological Survey Water-Resources Investigations Report 87-4168,* op. cit.

[4]Ibid.

Map 3

BATHYMETRIC MAP OF DELAVAN LAKE




Source: U.S. Geological Survey and SEWRPC.

DATE OF PHOTOGRAPHY: MARCH 1995

Map 4

SHORELINE PROTECTION STRUCTURES
ON DELAVAN LAKE: 1997

RIPRAP

BEACH

NATURAL

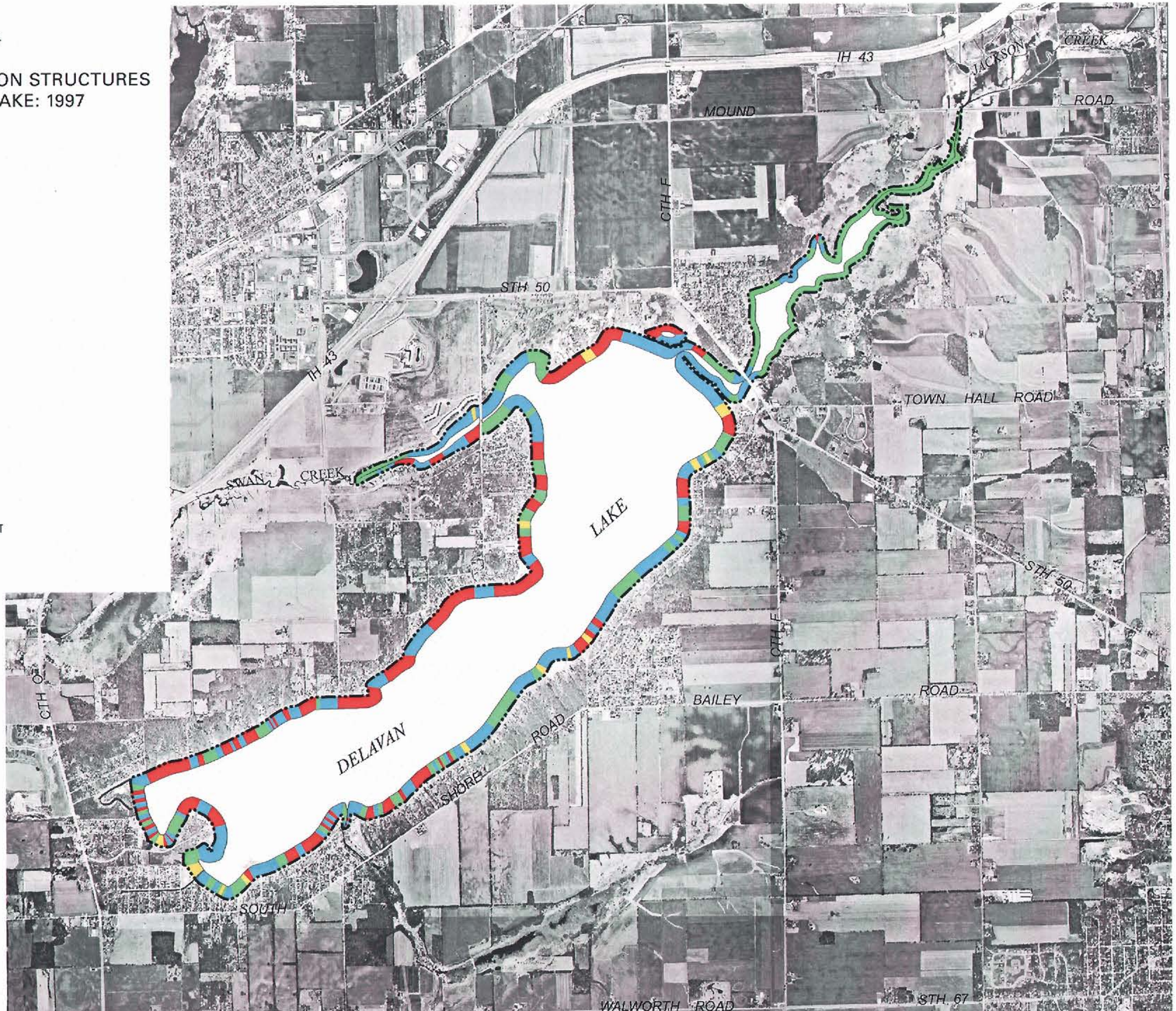
BULKHEAD

N

GRAPHIC SCALE

0 2000 4000 FEET

*Source: SEWRPC.*




DATE OF PHOTOGRAPHY: MARCH 1995

Map 5

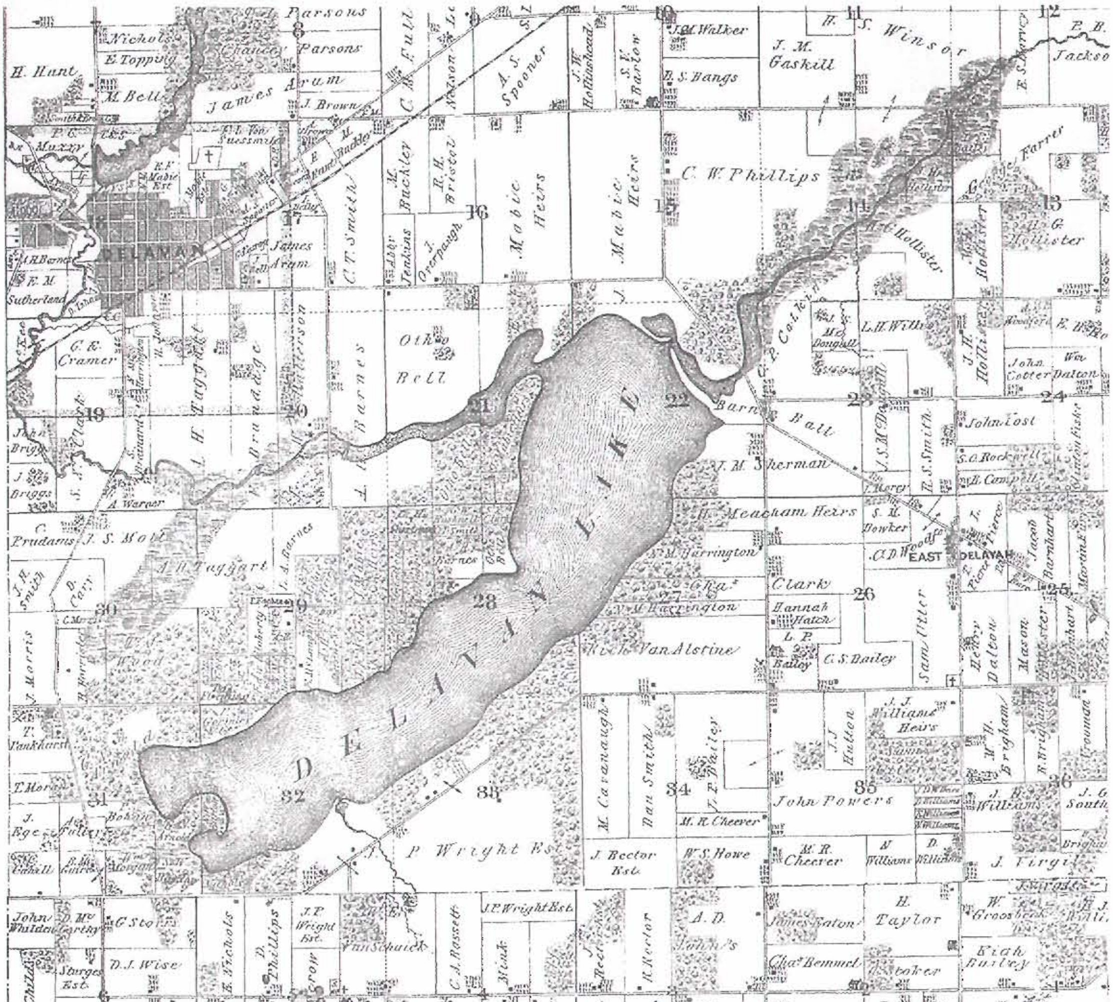
SEDIMENT SUBSTRATE DISTRIBUTION IN DELAVAN LAKE




*Source: U.S. Geological Survey, Aron & Associates, and SEWRPC.*

## Map 6

**HISTORIC PLAT MAP FOR THE DELAVAN LAKE AREA: 1873**




*Source: Everts, Baskin, and Stewart,* Combination Atlas Map of Walworth County, Wisconsin, *1873.*

## SOIL TYPES AND CONDITIONS

Soil type, land slope, and land use and management practices are among the more important factors determining lake water quality conditions. Soil type, land slope, and vegetative cover are also important factors affecting the rate, amount, and quality of stormwater runoff. The soil texture and the shape and stability of aggregates of soil particles, expressed as soil structure, influence the permeability, infiltration rate, and erodibility of soils. Land slopes are also important determinants of stormwater runoff rates and of susceptibility to erosion.

The U.S. Natural Resources Conservation Service under contract to the Southeastern Wisconsin Regional Planning Commission completed a detailed soil survey of the entire seven-county planning region, including the Delavan Lake area in 1966.[5] The soil survey contained interpretations for planning and engineering applications and for suitability for various types of urban land uses, as well as for agricultural applications. Using the regional soil survey, an assessment was made of hydrologic characteristics of the soils in the drainage area of Delavan Lake. Soils within the total drainage area tributary to Delavan Lake were categorized into four main hydrologic soil groups, as well as an "other" category, as indicated in Table 2. The areal extent of these soils and their locations within the watershed are shown on Map 7. Less than 1 percent of the total drainage area tributary to Delavan Lake is covered by well-drained soils, but about 71 percent is covered by moderately well-drained soils.

The regional soil survey also contained interpretations of the suitability of the soils for urban residential development using three common development scenarios: development with conventional onsite sewage disposal systems, development with alternative onsite sewage disposal systems, and development with public sanitary sewers. The soil ratings reflected the requirements of Chapter Comm 83 of the *Wisconsin Administrative Code* governing onsite sewage disposal systems as they existed early in the year 2000. During 2000, the Wisconsin Legislature amended Chapter Comm 83 and adopted new rules governing onsite sewage disposal systems. These rules, which had an effective date of July 1, 2000, increased the number of types of onsite sewage disposal systems that legally could be used from four to nine. The Wisconsin Department of Commerce envisions that other systems also will be approved in the future. Although the new rules included a provision that allows counties the option of waiting three years before implementing the new onsite sewage disposal system rules and permitting the use of the new types of systems, the use of the new technologies in Walworth County was not delayed and the new technologies are currently allowed where appropriate in accordance with the new code.

These new rules significantly alter the existing regulatory framework and increase the area in which onsite sewage disposal systems may be utilized. The ratings, shown on Maps 8 and 9 for the onsite and alternative onsite sewage disposal systems, respectively, are based upon the rules in force through early 2000. These ratings are included herein solely to provide a basis for assessing the likelihood of contamination of the lake water from nutrients and other contaminants entering the Lake from onsite sewage disposal systems, stormwater basins, and other discharges to or below the land surface. The ratings are not intended to indicate suitability of the soils for urban residential development under the current provisions of Chapter Comm 83.

With respect to residential development utilizing conventional onsite sewage disposal systems under the rules in force through early 2000, therefore, shown on Map 8, about 10 percent of the total drainage area tributary to Delavan Lake is covered by soils suitable for such development, and about 31 percent by soils unsuitable for such development. Soil suitability for urban development based upon conventional onsite sewage disposal systems could not be determined without further field study for 59 percent of the land in the drainage area. Nearly all of the shoreline residential development surrounding Delavan Lake, that is currently served by public sanitary sewerage service, falls into this latter category.

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[5]*SEWRPC Planning Report No. 8,* Soils of Southeastern Wisconsin, *June 1966.*

Table 2

GENERAL HYDROLOGIC SOIL TYPES WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE

| Group | Soil Characteristics | Direct Tributary Drainage Area (acres) | Percent of Total | Total Tributary Drainage Area (acres) | Percent of Total |
|---|---|---|---|---|---|
| A | Well drained; very rapidly to rapid permeability; low shrink-swell potential | 4 | <1 | 4 | <1 |
| B | Moderately well drained; texture intermediate between coarse and fine; moderately rapid to moderate permeability; low to moderate shrink-swell potential | 5,194 | 64 | 18,472 | 71 |
| C | Poorly drained; high water table for part or most of the year; mottling, suggesting poor aeration and lack of drainage, generally present in A to C horizons | 109 | 1 | 1,069 | 4 |
| D | Very poorly drained; high water table for most of the year; organic or clay soils; clay soils having high shrink-swell potential | 849 | 10 | 4,559 | 17 |
| Other | Group not determined | 23 | 1 | 26 | <1 |
| - - | Water | 1,964 | 24 | 1,985 | 8 |
| - - | Total | 8,143 | 100 | 26,115 | 100 |

*Source: SEWRPC.*

Using alternative onsite sewage disposal systems under the rules in force through early 2000, such as mound systems, yields additional land that may be suitable for urban residential development, as shown on Map 9. About 67 percent of the total drainage area tributary to Delavan Lake is covered by soils suitable for urban residential development using alternative onsite sewage disposal systems. About 26 percent is covered by soils unsuitable for such development. The soil suitability could not be determined for about 7 percent of the tributary drainage area.

At present, all residential lands riparian to Delavan Lake, and portions of those lands within the drainage area tributary to Delavan Lake, are served by a public sanitary sewer system.

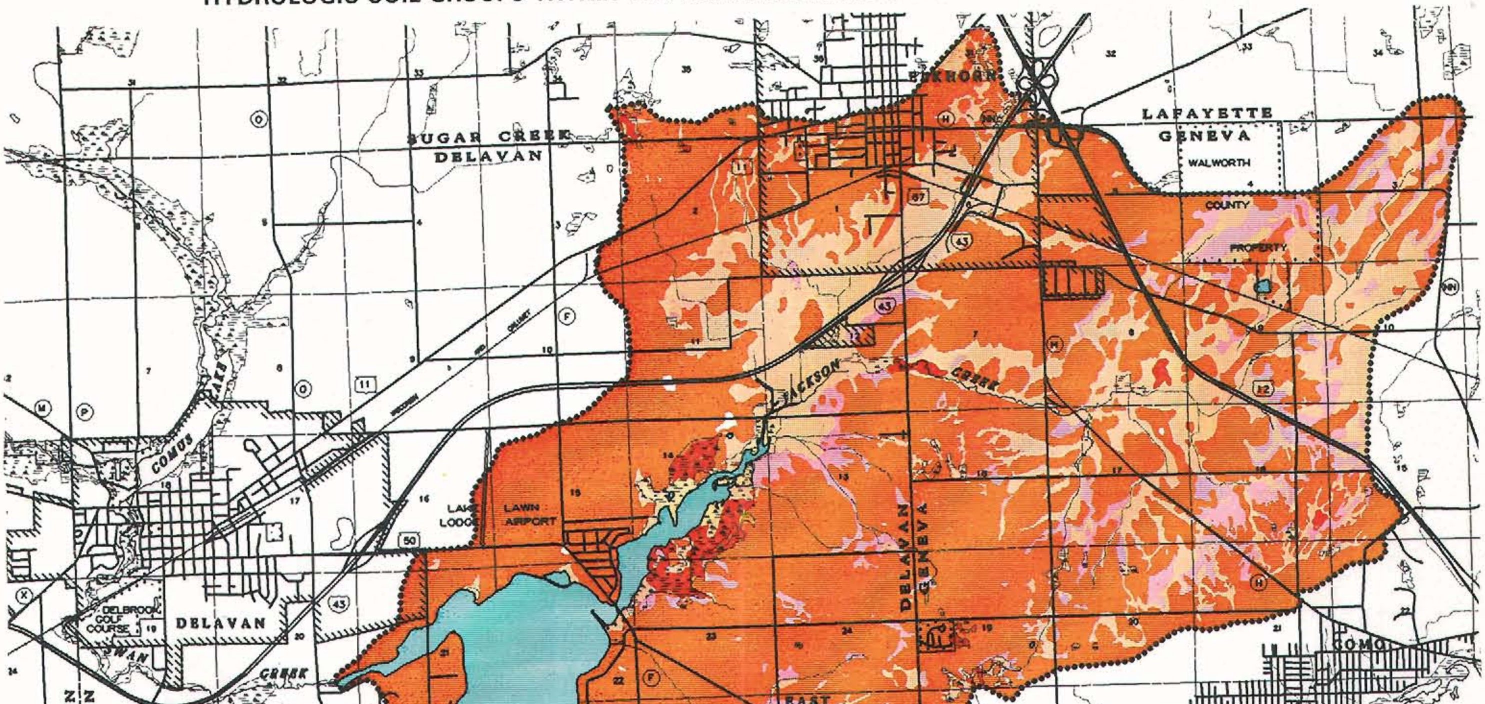
## LAKE HYDROLOGY

Long-term average monthly air temperature and precipitation values for the Delavan Lake area are set forth in Table 3. In addition, Table 3 provides monthly air temperature and precipitation data for 1997 during the period that lake hydrology and water quality data were obtained for use in this report. Table 3 also provides runoff data for both the long-term and for 1997 water year, derived from U.S. Geological Survey flow records for the Swan Creek, U.S. Geological Survey gauging station numbered 05431022, at the Delavan Lake outflow, Walworth County, Wisconsin.

The mean summer and winter temperatures of 64.5°F and 31.5°F reported from the Lake Geneva meteorological station and set forth in Table 3 are similar to those of other recording locations in Southeastern Wisconsin. Mean annual precipitation at the Lake Geneva station is about 36.9 inches. More than one-half of the normal yearly precipitation falls during the growing season, from May through September. Runoff rates are generally low during this period because evapotranspiration rates are high, vegetation cover is abundant, and soils are not frozen.

Map 7

## HYDROLOGIC SOIL GROUPS WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE




- GROUP A/D: Well-drained soils/Very poorly drained soils 1
- GROUP B: Moderately drained soils
- GROUP B/D: Moderately drained soils/Very poorly drained soils 2
- GROUP C: Poorly drained soils
- GROUP C/D: Poorly drained soils/Very poorly drained soils 3
- Hydrologic soil group not determined
- SURFACE WATER

*Source: SEWRPC.*

1 Well-drained if water table is lowered through provision of a drainage system. Very poorly drained if water table is not lowered.

2 Moderately drained if water table is lowered through provision of a drainage system. Very poorly drained if water table is not lowered.

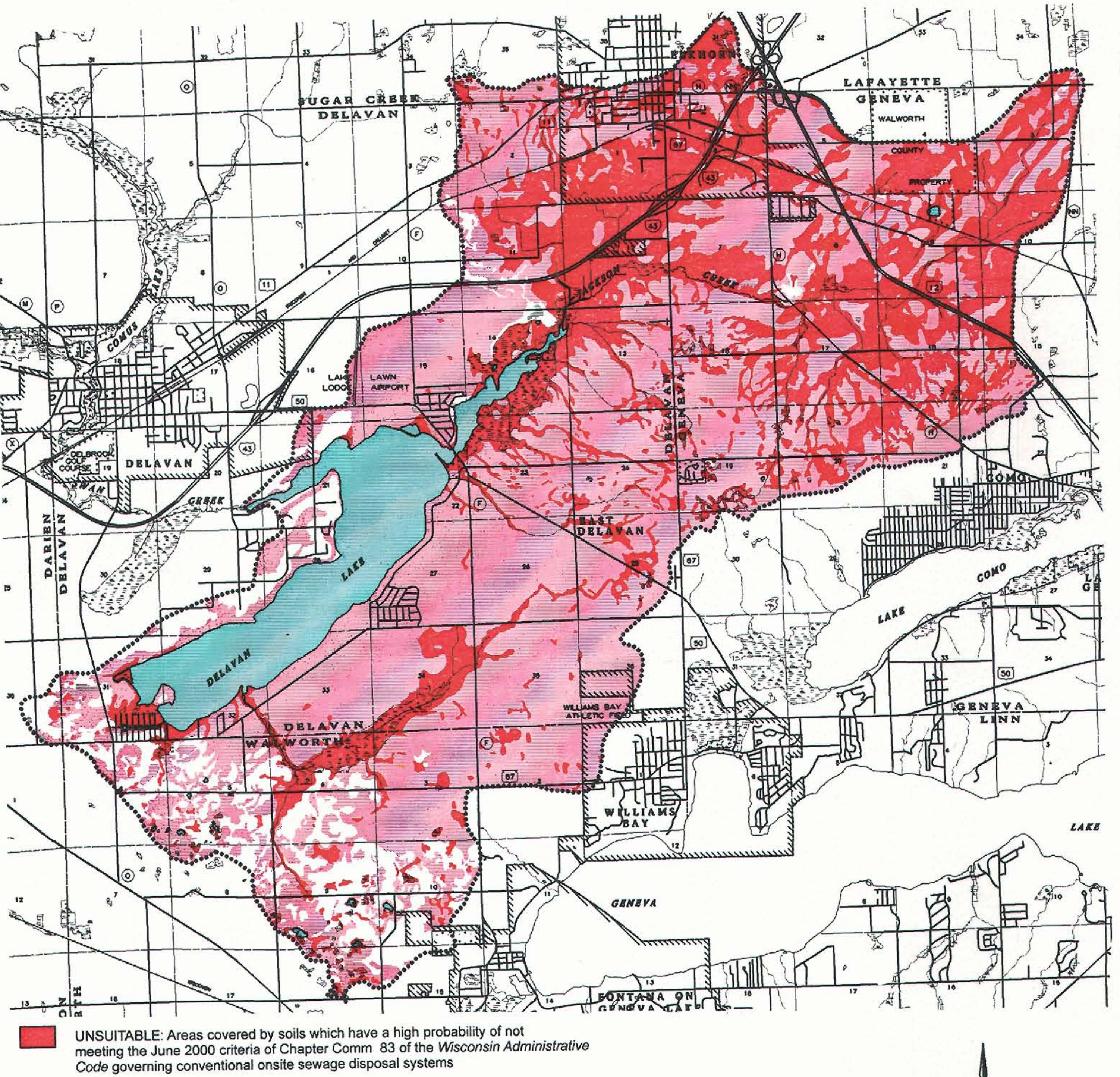
3 Poorly drained if water table is lowered through provision of a drainage system. Very poorly drained if water table is not lowered.

0 3600 7200

GRAPHIC SCALE IN FEET

Map 8

## SUITABILITY OF SOILS WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE FOR CONVENTIONAL ONSITE SEWAGE DISPOSAL SYSTEMS




UNSUITABLE: Areas covered by soils which have a high probability of not meeting the June 2000 criteria of Chapter Comm 83 of the *Wisconsin Administrative Code* governing conventional onsite sewage disposal systems

UNDETERMINED: Areas covered by soils having a range of characteristics and/or slopes which span the June 2000 criteria of Chapter Comm 83 of the *Wisconsin Administrative Code* governing conventional onsite sewage disposal systems so that no classification can be assigned

SUITABLE: Areas covered by soils having a high probability of meeting the June 2000 criteria of Chapter Comm 83 of the *Wisconsin Administrative Code* governing conventional onsite sewage disposal systems

OTHER: Areas consisting for the most part of disturbed land for which no interpretive data are available

SURFACE WATER

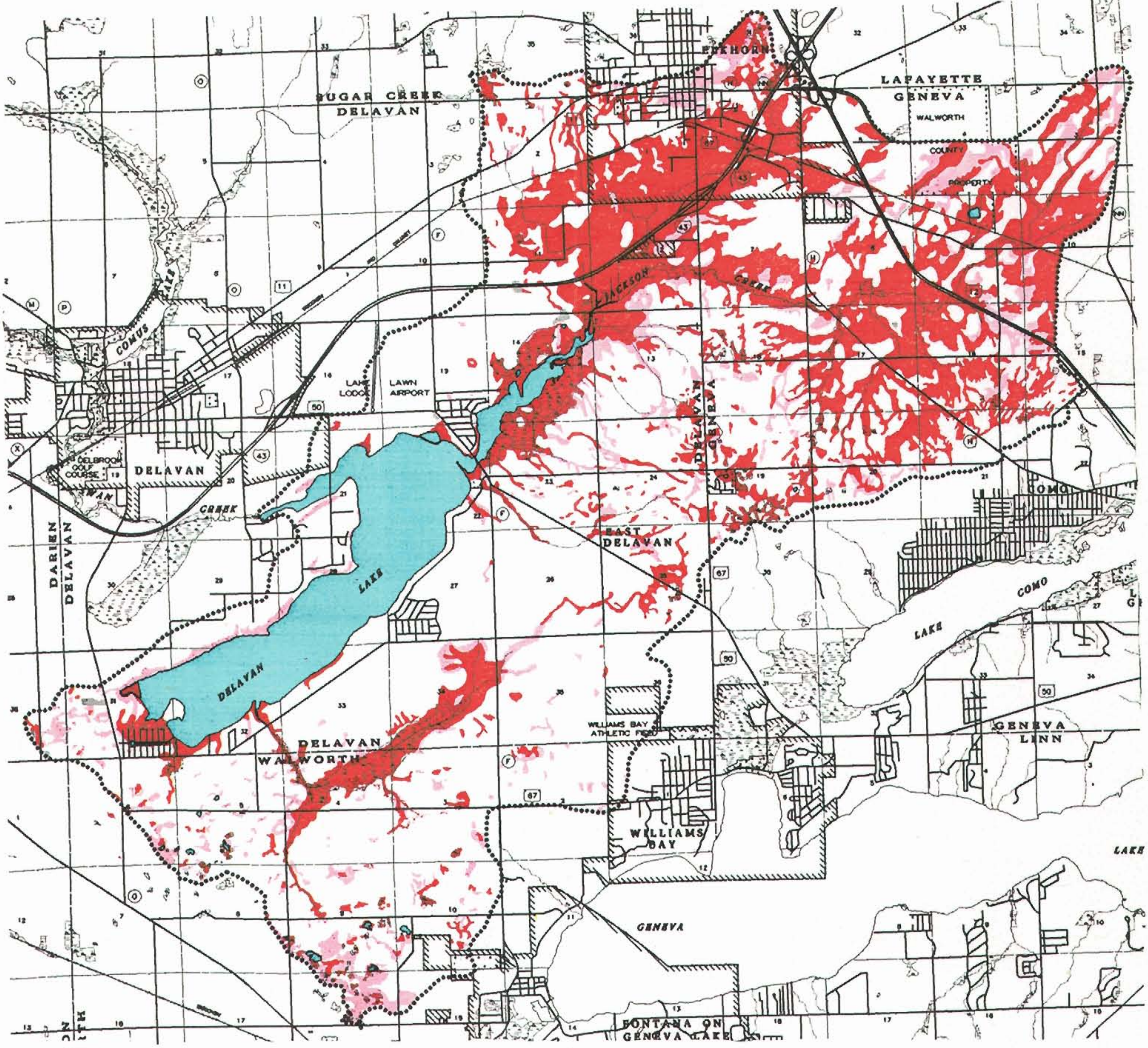
0 3600 7200

GRAPHIC SCALE IN FEET

 *Source: SEWRPC.*

Map 9

SUITABILITY OF SOILS WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE FOR MOUND-TYPE SEWAGE DISPOSAL SYSTEMS




| | |
|---|---|
| ■ | UNSUITABLE: Areas covered by soils which have a high probability of not meeting the June 2000 criteria of Chapter Comm 83 of the *Wisconsin Administrative Code* governing conventional mound sewage disposal systems |
| ■ | UNDETERMINED: Areas covered by soils having a range of characteristics and/or slopes which span the June 2000 criteria of Chapter Comm 83 of the *Wisconsin Administrative Code* governing conventional mound sewage disposal systems so that no classification can be assigned |
| □ | SUITABLE: Areas covered by soils having a high probability of meeting the June 2000 criteria of Chapter Comm 83 of the *Wisconsin Administrative Code* governing conventional mound sewage disposal systems |
| ■ | OTHER: Areas consisting for the most part of disturbed land for which no interpretive data are available |
| ■ | SURFACE WATER |

0 3600 7200

GRAPHIC SCALE IN FEET

*Source: SEWRPC.*

## Table 3

### LONG-TERM AND 1997 STUDY YEAR TEMPERATURE, PRECIPITATION, AND RUNOFF DATA FOR THE DELAVAN LAKE AREA[a]

| Temperature | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Temperature Data (°F) | January | February | March | April | May | June | July | August | September | October | November | December | Mean |
| Long-Term Mean Monthly | 19.2 | 23.8 | 34.9 | 47.5 | 59.0 | 68.8 | 73.5 | 71.3 | 63.5 | 51.8 | 38.5 | 24.7 | 48.0 |
| 1997 Mean Monthly | 18.5 | 27.4 | 36.4 | 45.5 | 53.4 | 69.5 | 73.3 | 69.3 | 65.0 | 53.5 | 35.5 | 30.4 | 48.1 |
| Departure from Long-Term Mean | -0.7 | 3.6 | 1.5 | -2.0 | -5.6 | 0.7 | -0.2 | -2.0 | 1.5 | 1.7 | -3.0 | 5.7 | 0.1 |

| Precipitation | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Precipitation Data (inches) | January | February | March | April | May | June | July | August | September | October | November | December | Mean | Total |
| Long-Term Mean Monthly | 1.84 | 1.46 | 2.78 | 3.66 | 3.25 | 3.88 | 4.30 | 3.92 | 4.09 | 2.74 | 2.65 | 2.34 | 3.08 | 36.91 |
| 1997 Mean Monthly | 2.14 | 2.95 | 0.90 | 2.64 | 3.15 | 5.36 | 3.20 | 2.03 | 4.25 | 1.82 | 1.71 | 1.52 | 2.64 | 31.67 |
| Departure from Long-Term Mean | 0.30 | 1.49 | -1.88 | -1.02 | -.10 | 1.48 | -1.10 | -1.89 | 0.16 | -0.92 | -0.94 | -0.82 | -0.44 | -5.24 |

| Runoff | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Runoff Data (inches) | January | February | March | April | May | June | July | August | September | October | November | December | Mean |
| Long-Term Mean Monthly | 0.52 | 0.74 | 0.88 | 0.96 | 0.49 | 0.56 | 0.32 | 0.15 | 0.46 | 0.64 | 0.55 | 0.58 | 0.57 |
| 1997 Mean Monthly | 0.53 | 1.53 | 1.13 | 0.52 | 0.77 | 0.60 | 0.14 | 0.09 | 0.38 | 0.03 | 0.03 | 0.18 | 0.49 |
| Departure from Mean Monthly | 0.01 | 0.79 | 0.25 | -0.44 | 0.28 | 0.04 | -0.18 | -0.06 | -0.08 | -0.61 | -0.52 | -0.40 | -0.08 |

[a]*Data on temperature and precipitation were obtained from the Lake Geneva Station; runoff data were estimated from the Delavan Lake outlet gauging station.*

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

Normally, about 10 percent of the summer precipitation is expressed as surface runoff, but intense summer storms occasionally produce high runoff. Peak runoff usually occurs during early spring, from February through April, when about 20 percent of the annual precipitation, in the form of snowmelt and/or rain, falls on frozen ground.

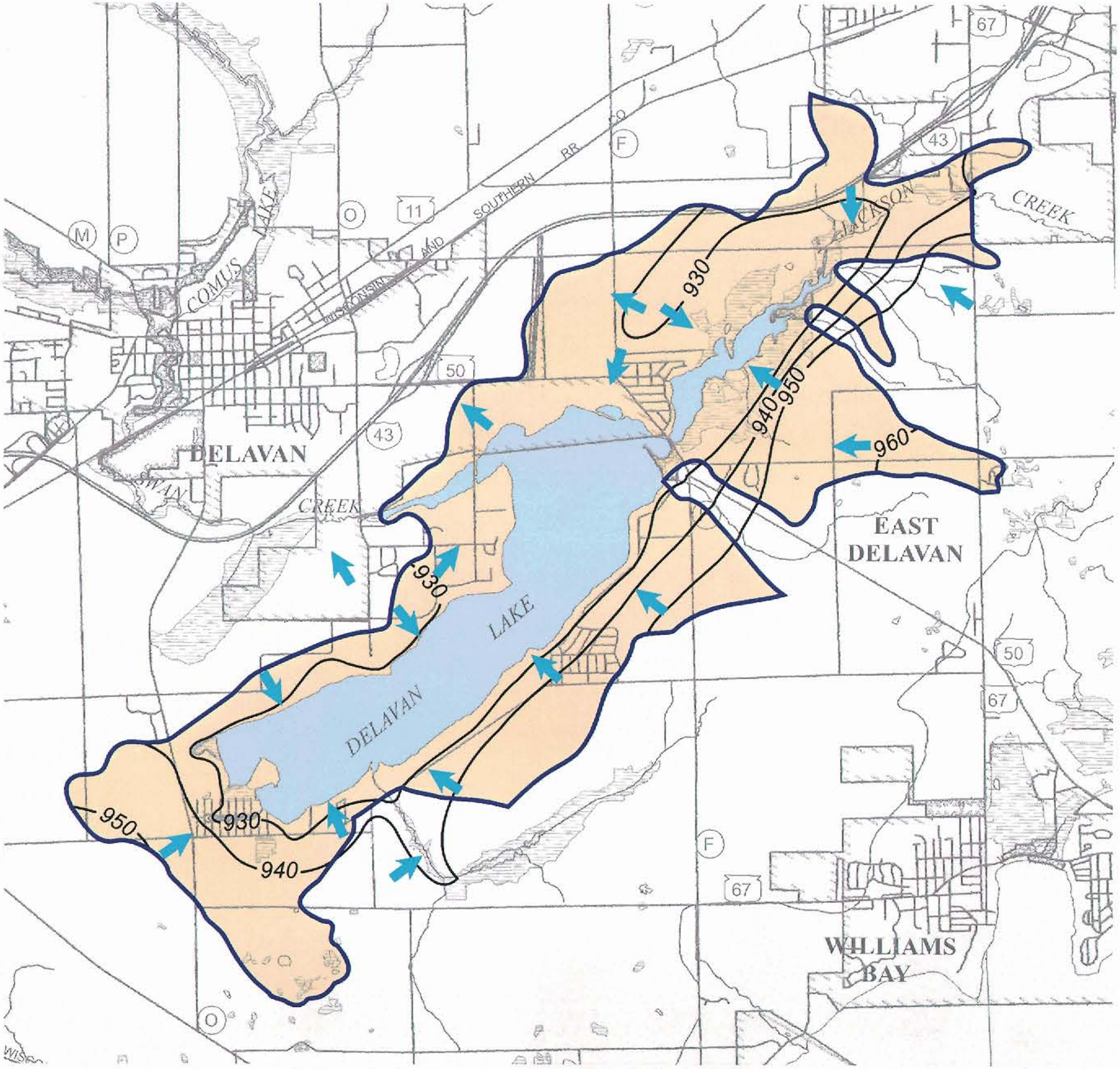
As shown in Table 3, precipitation during 1997 was about 31.7 inches, or about 14 percent below the long-term average at Lake Geneva. In June, July and August, the wettest months, about 5.4, 3.2, and 2.0 inches of precipitation were experienced, respectively, or about 1.5 inches above the long-term average and about 1.1 and 1.9 inches below the long-term average, respectively. This pattern of precipitation was reflected during much of the remainder of the year, with the net result being less than normal runoff volumes being recorded during 1997 at the U.S. Geological Survey streamflow gauge.

### Groundwater Flow

Thirteen shallow wells installed along the shoreline of Delavan Lake, as shown on Map 10, were used to determine the direction, and estimate rate, of local groundwater flow, during the two-year study period of 1984

Map 10

## DIRECTION OF GROUNDWATER FLOW IN THE DELAVAN LAKE AREA




—930— WATER TABLE CONTOUR (SHOWS ELEVATION OF WATER TABLE ON JANUARY 5 AND 6, 1984. CONTOUR INTERVAL 10 FEET. IN NATIONAL GEODETIC VERTICAL DATUM-1929)

DIRECTION OF GROUNDWATER FLOW

DIRECT DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE

GRAPHIC SCALE

0 4000 8000 FEET

*Source: U.S. Geological Survey and SEWRPC.*

and 1985.[6] Groundwater discharge to the Lake during the 1984 water year was computed from data acquired between January 22, 1985, and February 8, 1985, and averaged 5.0 cubic feet per second. During the 1985 water year, the average groundwater inflow to Delavan Lake was computed from data acquired between February 1, 1986, and February 8, 1986, and averaged 7.9 cubic feet per second.

**Water Budget**

Based on available data, an average annual water budget for Delavan Lake was computed and is set forth in Figure 1. Over the longer term, 1984 through 1999, annual water flows into and out of Delavan Lake are estimated to amount to about 23,000 acre-feet per year.

Surface and net groundwater inflows were estimated to be 23,000 acre-feet per year. Surface inflow from the Jackson Creek tributary averaged about 9,000 acre-feet per year during this period. Groundwater inflow, based upon the average estimated groundwater flows recorded during 1984 through 1986, was estimated to have contributed a net volume of about 5,000 acre-feet of water to the Lake annually. Approximately 6,000 acre-feet were contributed by direct rainfall onto the lake surface.

Outflows from the Lake were estimated to be 16,500 acre-feet per year through Swan Creek and 6,500 acre-feet through evaporation from the lake surface.

More detailed water budgets have been calculated for Delavan Lake by the U.S. Geological Survey. During the 12-month period from October 1, 1983, to September 30, 1984, an estimated 20,288 acre-feet of water entered the Lake. Approximately 2,035 acre-feet, or about 10 percent, of the known inflow were contributed by runoff from the drainage area directly tributary to the Lake. Jackson Creek and wetland complex tributary to the northeast end of the Lake contributed approximately 8,738 acre-feet, or about 43 percent, and the tributary on the south side of the Lake contributed about 1,184 acre-feet, or about 6 percent, of the known inflow. Groundwater contributed an estimated 3,618 acre-feet, or about 18 percent of the inflow. The remaining 4,713 acre-feet, or about 23 percent, of the known inflow came from direct precipitation onto the lake surface. An estimated 20,085 acre-feet of water was lost from the Lake, including 15,825 acre-feet, or about 78 percent, via the outlet, and about 4,260 acre-feet, or about 21 percent, by evaporation from the lake surface. The net change in water storage volume in Delavan Lake was estimated to be 203 acre-feet, or approximately one inch in lake surface elevation, during the hydrologic year.[7]

A similar budget was calculated for the 12-month period from October 1, 1984, to September 30, 1985. Over this year an estimated 24,913 acre-feet of water entered the Lake. Approximately 2,819 acre-feet, or about 11 percent, of the known inflow were contributed by runoff from the drainage area directly tributary to the Lake. Jackson Creek and wetland complex tributary to the northeast end of the Lake contributed approximately 9,560 acre-feet or about 38 percent and the tributary on the south side of the Lake contributed approximately 1,010 acre-feet, or about 4 percent of the known inflow. Groundwater contributed an estimated 5,720 acre-feet, or about 23 percent of the inflow. The remaining 5,804 acre-feet, or about 24 percent, of the known inflow came from direct precipitation onto the lake surface. An estimated 24,996 acre-feet of water was lost from the Lake, including approximately 19,913 acre-feet, or about 79 percent, via the outlet, and approximately 5,000 acre-feet, or about 20 percent, by evaporation from the lake surface. The net change in water storage volume in Delavan Lake was estimated to be 83 acre-feet, or a loss of approximately one-half inch in lake surface elevation, during the year.[8]

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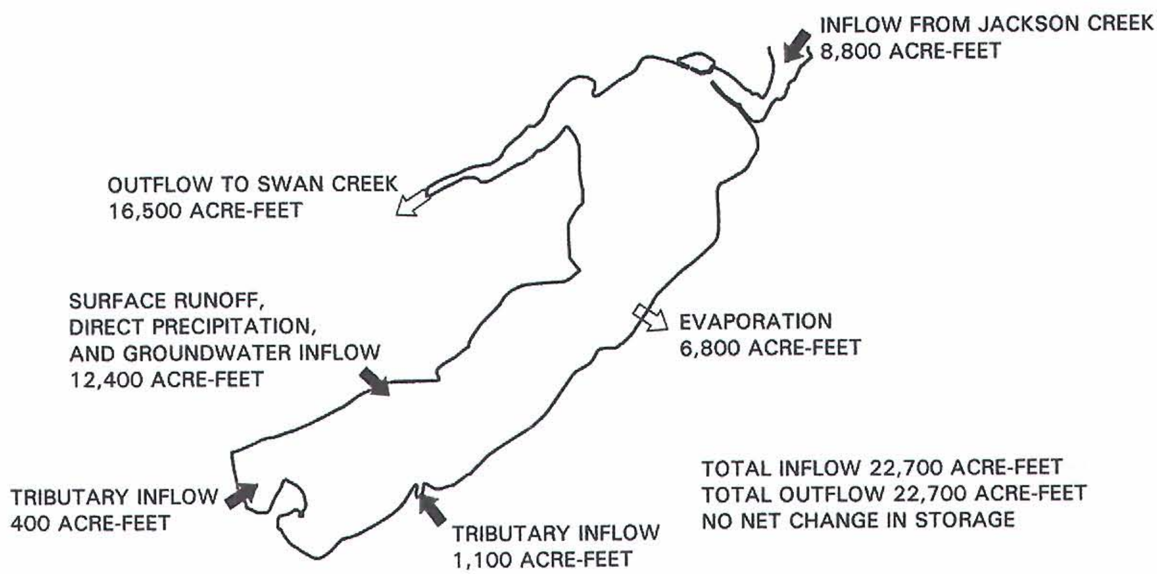
[6] *U.S. Geological Survey Water-Resources Investigations Report 87-4168,* op. cit.

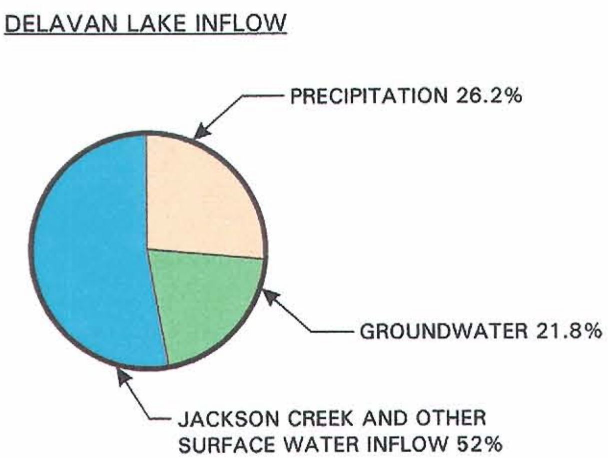
[7] Ibid.

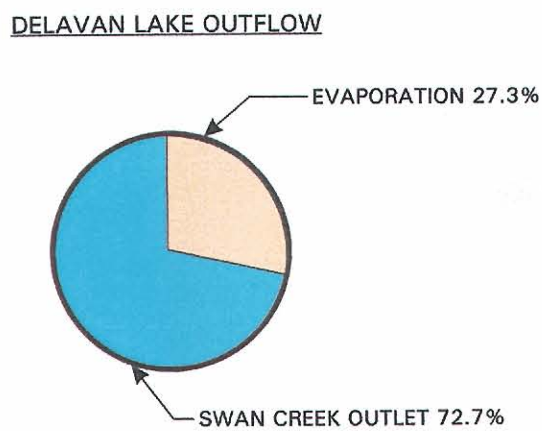
[8] Ibid.

Figure 1

HYDROLOGIC BUDGET FOR DELAVAN LAKE: 1984-1999




*Source: U.S. Geological Survey and SEWRPC.*

The hydraulic residence time, or the time required for a volume equivalent to the full volume of the Lake to enter the lake basin, during the 1984 and 1985 water years, was approximately two years, during both the study period and an average year. The hydraulic residence time is important in determining the expected response time of a lake to increased or decreased nutrient and pollutant loadings. The smaller the lake volume and/or greater the rate of inflow, the shorter the hydraulic residence time will be, and the more quickly the lake will respond to changes in nutrient or pollutant loadings. The residence time of Delavan Lake implies that the water quality of the Lake will be resistant to rapid changes in these rates, and will be strongly influenced by the quality of water running off the land surface and entering the Lake either directly or indirectly. Nonpoint source pollutants, therefore, form the largest portion of the controllable pollution load to the Lake (see Chapter IV).

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## Chapter III

# HISTORICAL, EXISTING, AND PLANNED LAND USE AND POPULATION

## INTRODUCTION

Water pollution problems, recreational use conflicts, and deterioration of the natural environment are all primarily a function of the human activities within the drainage area of a waterbody, as are the ultimate solutions to these problems. This is especially true with respect to lakes that are highly susceptible to deterioration by human activities because of relatively long pollutant retention times, and because of the variety of often conflicting uses to which lakes are subjected. Furthermore, urban development is often concentrated in the direct drainage areas and around the shorelines of lakes, where there are no intermediate stream segments to attenuate pollutant runoff and loadings. Accordingly, the population levels and land use and management in the tributary drainage area of a lake are important considerations in any lake management efforts.

## CIVIL DIVISIONS

The geographic extent and functional responsibilities of civil divisions and special-purpose units of government are important factors related to land use and management, since these local units of government provide the basic structure of the decision-making framework within which land use development and redevelopment must be addressed. Superimposed on the Delavan Lake drainage area are the local civil division boundaries shown on Map 11. The drainage area tributary to Delavan Lake is located primarily in the City of Elkhorn, and the Towns of Delavan, Geneva and Walworth. However, the total tributary drainage area also includes small portions of the City of Delavan; the Villages of Fontana-on-Geneva Lake and Williams Bay; and, the Towns of Darien, Lafayette, Sharon and Sugar Creek, all in Walworth County. The area and proportion of the drainage area lying within each jurisdiction concerned, as of 1995, is set forth in Table 4.

## POPULATION

The resident population of the drainage area tributary to Delavan Lake has increased relatively steadily since 1960. The 2000 resident population of the drainage area, estimated at 7,990 persons, is about 87 percent greater than the estimated 1960 population. Population forecasts prepared by the Regional Planning Commission, as a basis for the preparation of the adopted regional land use plan,[1] indicate that the resident population of the drainage area tributary to Delavan Lake will be likely to increase to between 9,100 and 13,350 persons during the two decades, as indicated in Table 5.

The number of resident households in the drainage area tributary to Delavan Lake also increased steadily since 1960. The number of resident households in the area may be expected to increase from about 3,190 households in 2000, to between 3,660 and 5,160 households by the year 2020.

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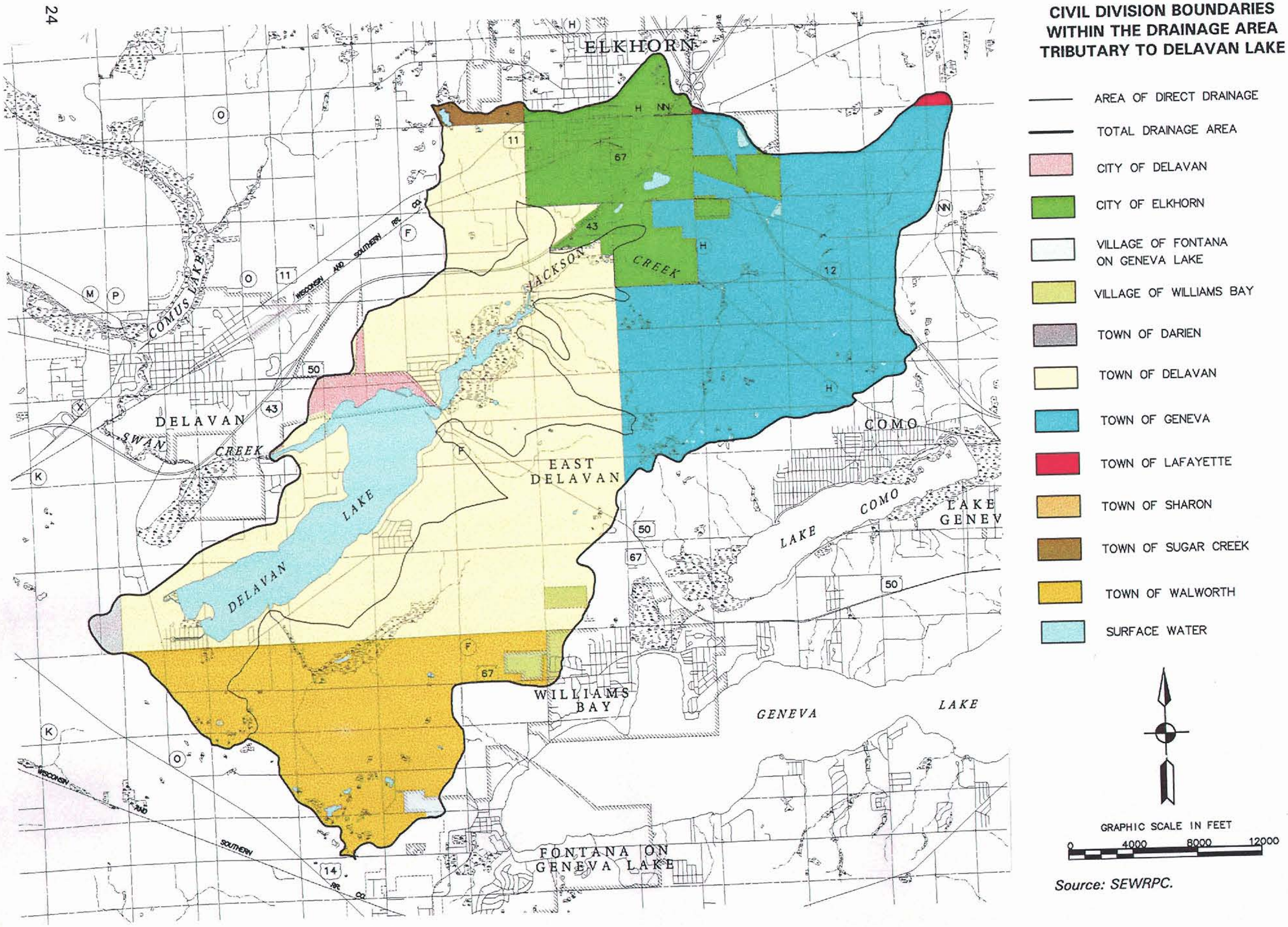
[1]*SEWRPC Planning Report No. 45*, A Regional Land Use Plan for Southeastern Wisconsin: 2020, *December 1997*.

Map 11

## CIVIL DIVISION BOUNDARIES WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE




Source: SEWRPC.

Table 4

AREAL EXTENT OF CIVIL DIVISION BOUNDARIES WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE: 1995

| Civil Division | Civil Division Area within Area (acres) | Percent of Area within Civil Division | Percent of Civil Division within Area |
|---|---|---|---|
| Town of Sharon | 1 | <1 | <1 |
| Town of Lafayette | 40 | <1 | <1 |
| Village of Fontana-on-Geneva Lake | 71 | <1 | 3 |
| Town of Darien | 108 | <1 | <1 |
| Town of Sugar Creek | 126 | <1 | 1 |
| Village of Williams Bay | 241 | 1 | 12 |
| City of Delavan | 414 | 2 | 11 |
| City of Elkhorn | 2,611 | 10 | 57 |
| Town of Walworth | 4,081 | 16 | 21 |
| Town of Geneva | 6,486 | 25 | 33 |
| Town of Delavan | 11,936 | 46 | 64 |
| Total | 26,115 | 100 | -- |

*Source: SEWRPC.*

In addition to the year-round residences, there were about 1,070 seasonal housing units within the drainage area tributary to Delavan Lake in 2000.

## LAND USE

The type, intensity, and spatial distribution of the various land uses within the drainage area tributary to Delavan Lake are important determinants of lake water quality and recreational use demands. The current and planned land use patterns placed in the context of the historical development of the area are, therefore, important considerations in any lake management planning effort for Delavan Lake.

The movement of European settlers into the Southeastern Wisconsin Region began about 1830. Completion, within Southeastern Wisconsin, of the U.S. Public Land Survey in 1836, and the subsequent sale of public lands in Wisconsin, brought a rapid influx of settlers into the area. Significant urban development began to occur in the drainage area tributary to Delavan Lake in the early 1900s. Map 12 indicates the historical urban growth pattern in the tributary drainage area since 1850. As shown on Map 12, the most rapid increase in urban land use development occurred between 1900 and 1963.

The existing land use pattern in the Delavan Lake tributary drainage area, as of 1995, is shown on Map 13 and is quantified in Table 6. As indicated in Table 6, by 1995, about 3,950 acres, or about 15 percent of the drainage area, were devoted to urban land uses. The dominant urban land use was residential, encompassing 1,763 acres, or about 45 percent of the area in urban use. As of 1995, about 22,165 acres, or about 85 percent of the drainage area tributary to Delavan Lake, were still devoted to rural land uses. About 18,210 acres, or about 82 percent of the rural area, were in agricultural land uses. Woodlands, wetlands, and surface water, including the surface area of Delavan Lake, accounted for approximately 3,870 acres, or about 17 percent of the area in rural uses.

Table 5

**HISTORIC AND FORECAST RESIDENT POPULATION AND HOUSEHOLD LEVELS WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE: 1960-2020[a]**

| Year | Number of Residents | Number of Households |
|---|---|---|
| 1960 | 4,280 | 1,210 |
| 1970 | 7,200 | 2,060 |
| 1980 | 6,590 | 2,440 |
| 1990 | 7,450 | 2,930 |
| 2000 | 7,990 | 3,190 |
| 2020 Intermediate-Growth Centralized Regional Plan | 9,100 | 3,660 |
| 2020 High-Growth Decentralized Plan | 13,350 | 5,160 |

NOTE: Loss of population from 1970 to 1980 due in part to loss of some group quartered facilities (at 460 people in 1970.

[a]*Study area approximated using whole U.S. Public Land Survey one-quarter sections and U.S. Bureau of Census data.*

*Source: SEWRPC.*

Under planned 2020 land use conditions, the trend toward more intense urban land usage is also expected to be reflected in the total drainage area tributary to the Lake.[2] Agricultural lands are likely to be converted to urban lands, primarily for residential use and commercial and industrial uses within and adjacent to the Cities of Delavan and Elkhorn, as indicated on Map 14. In addition, the redevelopment of properties and the reconstruction of existing single-family homes may be expected on lakeshore properties, with limited in-filling of existing platted lots. Recent surveillance also indicates that large-lot subdivision development is occurring in the area, generally west of CTH O and east of the Lake along Town Hall Road. Given this trend, some of the open space areas remaining within the drainage area may be replaced, over time, with urban development. To minimize the loss of open lands within the drainage area, the Regional Planning Commission has recommended that consideration be given to development in the form of residential clusters on smaller lots, thereby, preserving portions of the remaining open space, and, thus, reducing impacts upon the Lake.[3] Associated commercial and industrial developments, and increased pressures for recreational use of the Lake, also may be anticipated, especially to the north of the Lake within and adjacent to the Cities of Delavan and Elkhorn.

## EXISTING ZONING REGULATIONS

The 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. As already noted, the Delavan Lake drainage area includes portions of the Cities of Delavan and Elkhorn; the Towns of Darien, Delavan, Geneva, Lafayette, Sharon, Sugar Creek, and Walworth; and the Villages of Fontana-on-Geneva Lake and Williams Bay. The Cities of Delavan and Elkhorn, and the Villages of Fontana-on-Geneva Lake and Williams Bay, administer their own zoning ordinances. The Towns of Darien, Delavan, Geneva, Lafayette, Sharon, Sugar Creek and Walworth are under the jurisdiction of Walworth County and its Zoning Ordinance. The elements of these ordinances are summarized in Table 7, and the Walworth County zoning code is summarized in Table 8.

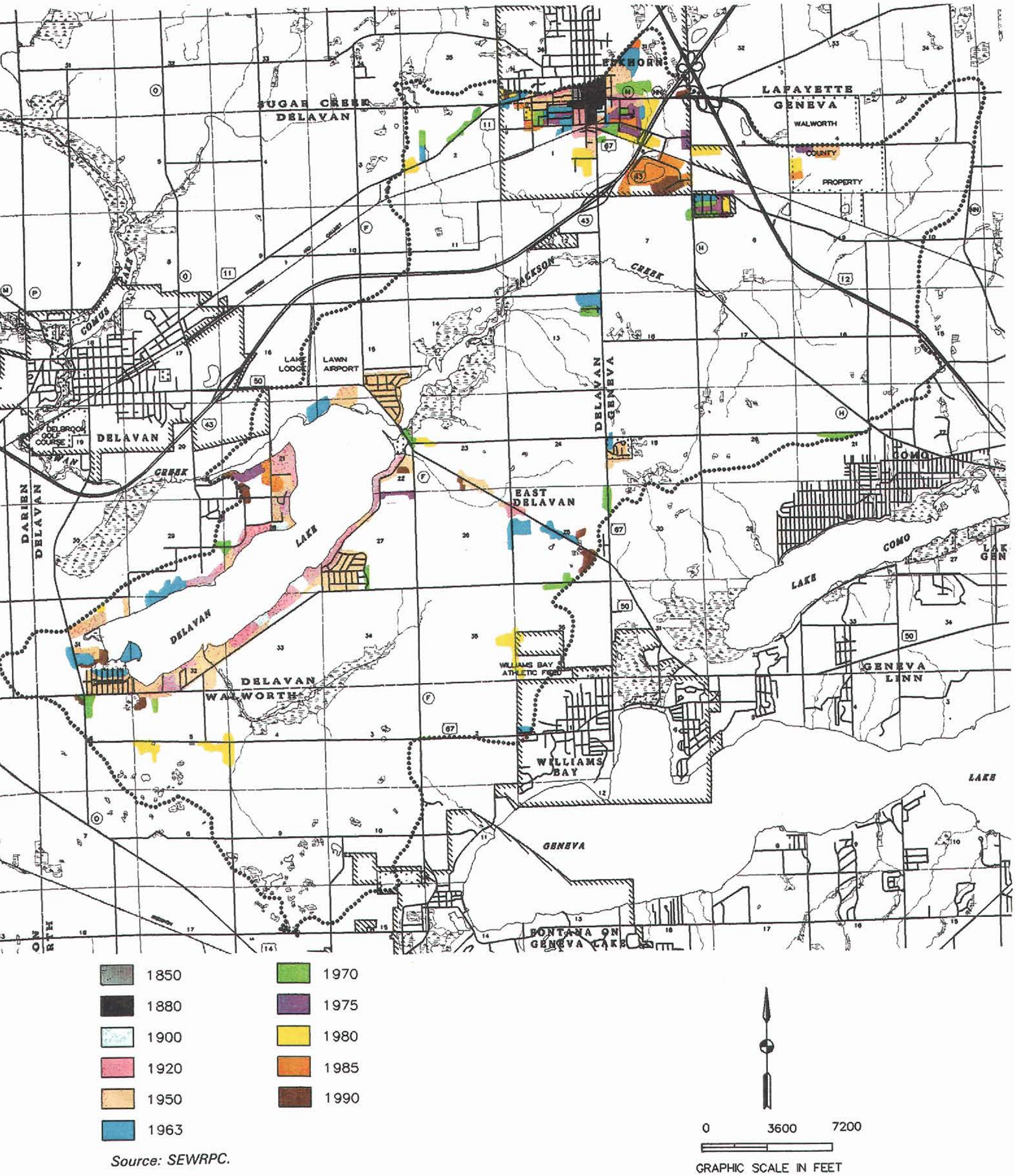
The Walworth County zoning code for the drainage area directly tributary to Delavan Lake generally provides for conservancy zoning of wetland portions of the primary environmental corridors. These areas are zoned as C-4 and C-1, lowland resource conservation zoning districts, with the C-4 lowland resource conservation district applying to shoreland wetland areas in the vicinity of the lake inlet and outlet. These districts prohibit residential and commercial developments. Small portions of the upland areas around the Lake are zoned as C-2, upland resource conservation district, while the Town Park and public recreational boating access site is zoned as P-1, recreational

[2]SEWRPC Community Assistance Planning Report No. 252, *A Land Use Plan for Walworth County, Wisconsin: 2020*, April 2001.

[3]*SEWRPC Planning Guide No. 7,* Rural Cluster Development Guide, *December 1996.*

Map 12

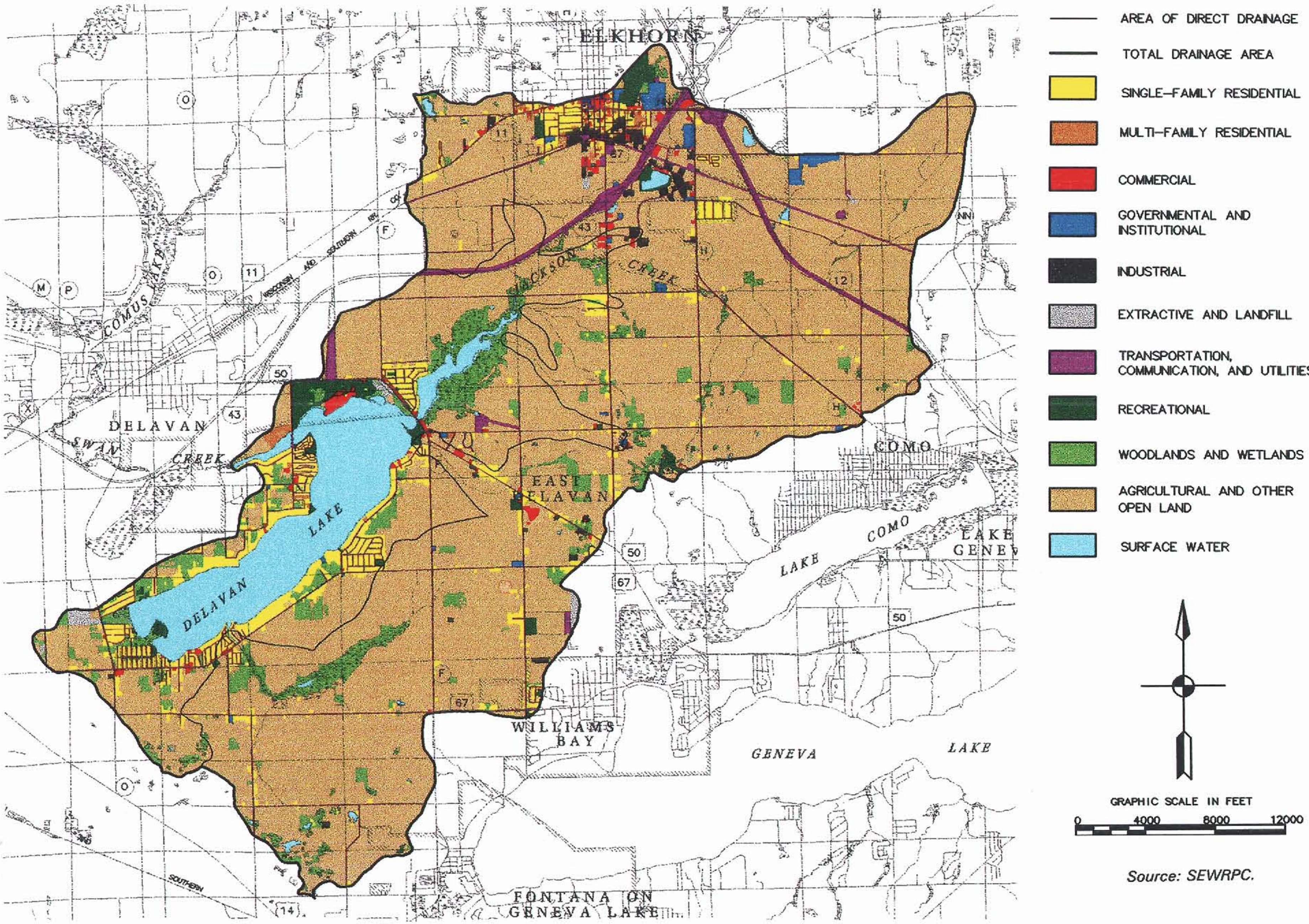
HISTORIC URBAN GROWTH WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE




*Source: SEWRPC.*

## Map 13

### EXISTING LAND USE WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE: 1995




*Source: SEWRPC.*

Table 6

EXISTING AND PLANNED LAND USE WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE: 1995 AND 2020

| Land Use Categories[a] | 1995 Acres | 1995 Percent of Total Tributary Drainage Area | 2020 Acres | 2020 Percent of Total Tributary Drainage Area |
|---|---|---|---|---|
| Urban | | | | |
| Residential | 1,763 | 6.8 | 4,579 | 17.5 |
| Commercial | 185 | 0.7 | 596 | 2.3 |
| Industrial | 181 | 0.7 | 860 | 3.3 |
| Governmental | 166 | 0.6 | 388 | 1.5 |
| Transportation, Communication, and Utilities | 1,303 | 5.0 | 2,281 | 8.7 |
| Recreation | 352 | 1.3 | 1,413 | 5.4 |
| Subtotal | 3,950 | 15.1 | 10,117 | 38.7 |
| Rural | | | | |
| Agricultural | 18,214 | 69.8 | 12,047 | 46.2 |
| Wetlands | 778 | 3.0 | 778 | 3.0 |
| Woodlands | 1,024 | 3.9 | 1,024 | 3.9 |
| Water | 2,068 | 7.9 | 2,068 | 7.9 |
| Extractive | 81 | 0.3 | 81 | 0.3 |
| Subtotal | 22,165 | 84.9 | 15,998 | 61.3 |
| Total | 26,115 | 100.0 | 26,115 | 100.0 |

[a]*Parking included in associated uses.*

*Source: SEWRPC.*

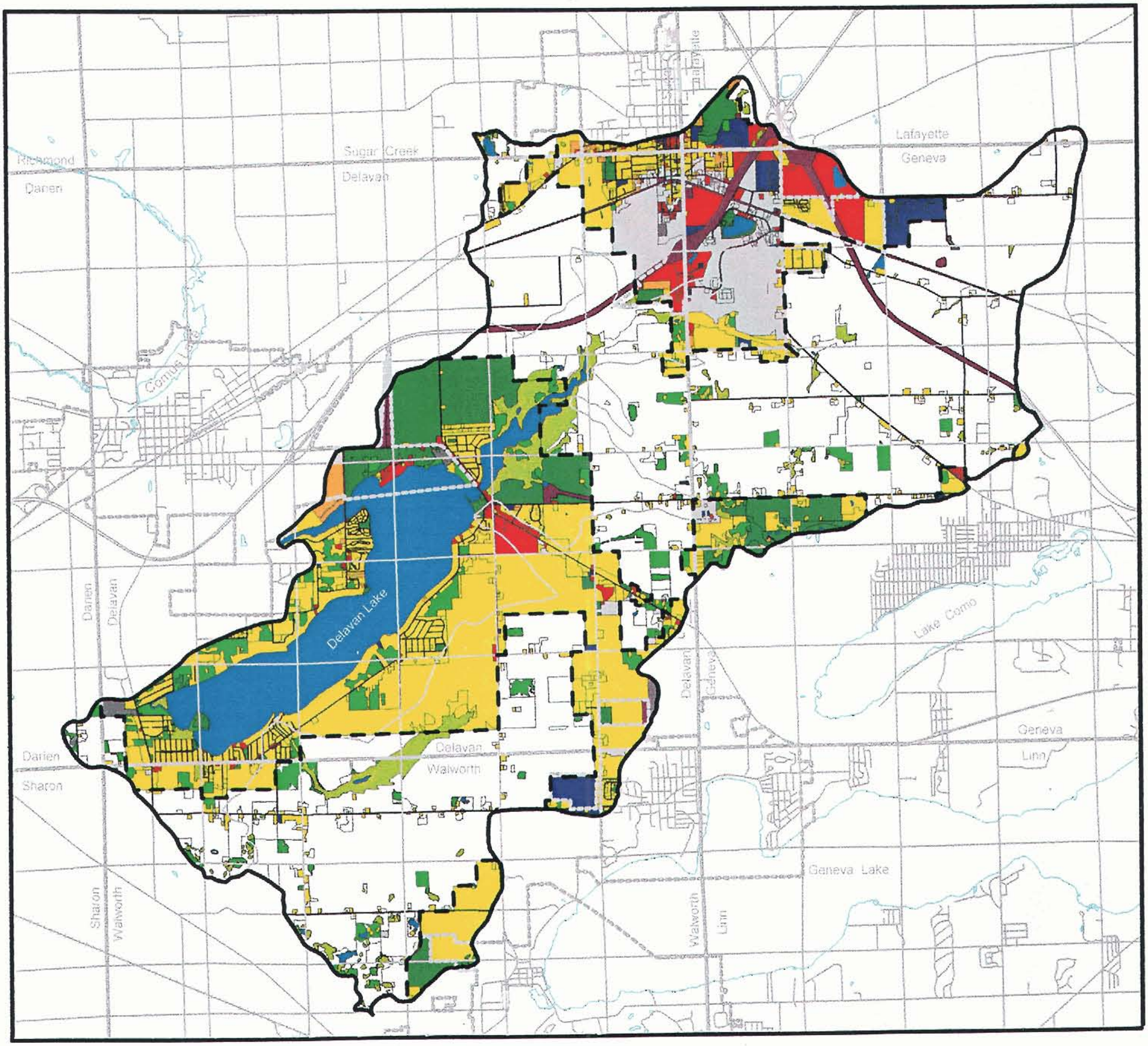
park lands. Both of these zoning classes permit more intensive recreational usage as principal and conditional uses under the Walworth County zoning code.

The upland portions of the drainage area directly tributary to the Lake are predominately included in the R-2, single-family residential zoning district, which provides for medium-density, single-family residential development. Within the larger drainage area, the lands draining to Delavan Lake outside of the incorporated municipalities have been placed within the A-1, prime agricultural, and A-3, agricultural holding, zoning districts, and in the A-2, agricultural, and A-5, agricultural rural residential, zoning districts. The R-2 single-family residential zoning district permits development of homestead properties on lots with a minimum area of 15,000 square feet, where soil conditions allow placement of onsite sewage disposal systems, or where lands are served by public sanitary sewerage systems. Similar requirements apply to lands identified as agricultural rural residential lands, designated as A-5 in the Walworth County code, although the minimum lot size is increased to a minimum of 40,000 square feet. Lands designated as A-1 and A-3, and as A-2, provide for a minimum area of 35 acres and 20 acres, respectively.

Other lands, primarily within the Town of Delavan, have been placed within a variety of zoning districts, including upland and lowland resource conservation, business commercial, multi-family residential, and mineral extraction-industrial zoning districts. Much of the agricultural land in the vicinity of the Lake is in the process of being converted from agricultural use to urban density, residential development. Where appropriate, it is anticipated that such development may be as clustered residential development on smaller lots, thereby preserving portions of the open space on each property or group of properties considered for development.

Map 14

LAND USE WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE: 2020




SINGLE-FAMILY RESIDENTIAL

MULTI-FAMILY RESIDENTIAL

COMMERCIAL

MANUFACTURING, WHOLESALE, AND STORAGE

TRANSPORTATION, COMMUNICATION, AND UTILITIES

GOVERNMENTAL AND INSTITUTIONAL

EXTRACTIVE

RECREATIONAL

WOODLAND

WETLAND

AGRICULTURE AND OTHER OPEN LAND

SURFACE WATER

GRAPHIC SCALE
0 4000 8000 FEET



Source: SEWRPC.

Table 7

**LAND USE REGULATIONS WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE**

| Community | Type of Ordinance | | | | |
|---|---|---|---|---|---|
| | General Zoning | Floodland Zoning | Shoreland or Shoreland-Wetland Zoning | Subdivision Control | Erosion Control and Stormwater Management |
| Walworth County.......... | Adopted | Adopted | Adopted and Wisconsin Department of Natural Resources approved | Adopted | Adopted |
| City of Delavan............. | Adopted | Adopted | Adopted | Adopted | Adopted |
| City of Elkhorn.............. | Adopted | None[a] | None | Adopted | None |
| Village of Fontana-on-Geneva Lake............... | Adopted | Adopted | Adopted | Adopted | Adopted[b] |
| Village of Williams Bay.... | Adopted | Adopted | Adopted | Adopted | Adopted |
| Town of Darien............. | County ordinance | County ordinance | County ordinance | County ordinance | County ordinance |
| Town of Delavan........... | County ordinance | County ordinance | County ordinance | Adopted | Adopted |
| Town of Geneva........... | County ordinance | County ordinance | County ordinance | County ordinance | County ordinance |
| Town of Lafayette......... | County ordinance | County ordinance | County ordinance | County ordinance | County ordinance |
| Town of Sharon............ | County ordinance | County ordinance | County ordinance | County ordinance | County ordinance |
| Town of Sugar Creek...... | County ordinance | County ordinance | County ordinance | Adopted | County ordinance |
| Town of Walworth......... | County ordinance | County ordinance | County ordinance | Adopted | County ordinance |

[a]*No flood hazard areas have been identified or mapped.*

[b]*Erosion control ordinance only.*

*Source: SEWRPC.*

In addition to the zoning code, the Walworth County Land Disturbance, Erosion Control and Storm Water Management Ordinance governs the amount of sediment and other pollutants from construction sites and land disturbing activities in the County that occur on platted lots within a subdivision plat; lots developed under a certified survey map; areas of 4,000 square feet or greater; works where fill and/or excavation volumes exceed 400 cubic yards; public streets, roads or highways; watercourses; and utilities. In addition, the soil erosion control and stormwater management provisions of the Walworth County land division ordinance would apply to residential developments of five acres or more, and other developments of three acres or more. All control measures are administered and enforced by the Walworth County Land Conservation.

The Walworth County Board of Supervisors also exercises special-purpose shoreland wetland and floodland zoning authority in the shoreland portions of the drainage area. These special-purpose zoning ordinances, prepared pursuant to the requirements of Chapter 30 of the *Wisconsin Statutes*, impose special land use regulations on all unincorporated 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 shoreland and floodland protection zoning ordinances include regulations intended to protect waterways and the attendant shorelines. Counties, pursuant to Chapters 23 and 330 of the *Wisconsin Statutes*, also are required to regulate the use of all wetlands five acres or larger located in the shoreland areas of unincorporated municipalities within 300 feet of a stream and 1,000 feet of a lake, or to the landward side of the floodplain, whichever is greater. Wetland maps for Walworth County were prepared for the Wisconsin Department of Natural Resources by the Regional Planning Commission in 1981. In accordance with Chapter NR 115 of the *Wisconsin Administrative Code*, Walworth County has amended its shoreland zoning regulations and attendant maps to preclude further loss of wetlands in the shoreland areas.

Table 8

**GENERALIZED ZONING CLASSES APPLIED TO LANDS WITHIN UNINCORPORATED AREAS OF WALWORTH COUNTY**

| County Zoning Class | Regional Class | Minimum Area per Dwelling Unit | Notes |
|---|---|---|---|
| A-1 Prime Agricultural | A-1 | 35 acres | Two single-family or one two-family dwelling units permitted for owners or children engaged in farming; second dwelling must be placed on a parcel of at least 40,000 square feet, but not larger than five acres |
| A-2 Agricultural Land | A-2 | 20 acres | - - |
| A-3 Agricultural Holding | A-1 | 35 acres | Two single-family or one two-family dwelling units permitted for owners or children engaged in farming; second dwelling must be placed on a parcel of at least 40,000 square feet, but not larger than five acres |
| A-4 Agriculture-Related Manufacturing | M | - - | All uses are conditional |
| A-5 Agricultural Rural Residential | A-4 | 40,000 square feet | - - |
| B-1 Local Business | B | - - | - - |
| B-2 General Business | B | - - | - - |
| B-3 Waterfront Business | B | - - | - - |
| B-4 Highway Business | B | - - | - - |
| B-5 Planned Commercial Recreation | P | - - | All uses are conditional; provides for mixed use recreation, residential and commercial development |
| C-1 Lowland Resource Conservation | C-1 | - - | Basic lowland conservation district: residential and commercial uses are prohibited |
| C-2 Upland Resource Conservation | C-2 | 5 acres | - - |
| C-3 Conservancy Residential | C-3 | 100,000 square feet | Applies to upland corridor and wooded areas that have been previously divided into smaller parcels, or that, because of their proximity to urban areas, have very high residential value potential |
| C-4 Lowland Resource Conservation | C-1 | - - | Shoreland wetland district; residential and commercial uses are prohibited |
| M-1 Industrial | M | - - | All uses are conditional |
| M-3 Mineral Extraction | E | - - | - - |
| M-4 Sanitary Landfill | M | - - | All uses are conditional |
| P-1 Recreational Park | P | - - | More intensive recreational uses are conditional uses |
| P-2 Institutional Park | G | - - | Outdoor recreational uses are conditional uses |
| R-1 Single-Family | R-3 | 40,000 square feet | Where soils allow septic systems |
| R-2 Single-Family | R-2 | 15,000 square feet | Applies to areas served by public sanitary sewerage systems only |
| R-4 Multi-Family | R-2 | 7,260 square feet | Six dwelling units per net developable acre with a 20 percent open space requirement; all uses are conditional |
| R-6 Planned Mobile Home Park | R-6 | 8,700 square feet | Five dwelling units per acre; all uses are conditional |

*Source: SEWRPC.*

The existing zoning ordinances have proven to be relatively effective in protecting the wetlands and water resources of the Delavan Lake drainage area. Nevertheless, some concern has been expressed by residents of the area over the widespread urban-density residential development on former agricultural lands in the vicinity of the Lake. In addition, infilling and replacement of existing housing with larger structures, especially within the shoreland surrounding Delavan Lake has, to a limited extent, taken place. Such redevelopment of the watershed and lakefront may be undesirable from the point of view of water quality protection, as it generally results in a greater area of impervious surface, increased runoff, and increased pollutant loading.

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# Chapter IV

# WATER QUALITY

## INTRODUCTION

The earliest, definitive data on water quality conditions in Delavan Lake were collected by the Wisconsin Department of Natural Resources in 1960.[1] Other sources of information on the historical water quality of Delavan Lake include the results of monitoring studies conducted by Limnetics, Inc., from July through December 1968,[2] and sampling done in 1972 by the U.S. Environmental Protection Agency as a part of the National Eutrophication Survey.[3] These data all indicated evidence of nutrient enrichment. Throughout this period, the residents of the Delavan Lake community expressed concerns about deteriorating water quality conditions in the Lake. As a consequence, the Town of Delavan created the Delavan Lake Sanitary District to provide public sanitary sewer service to the lakeshore, and convey wastewater to the Walworth County Metropolitan Sewerage District facility for treatment. The public sanitary sewer system was completed during 1981.

Notwithstanding, citizen concern continued, and the Town of Delavan, in cooperation with the Delavan Lake Sanitary District and the Wisconsin Department of Natural Resources, initiated further measures, during 1983, to address citizen concerns regarding the state of the Lake. These measures included implementation of some nonpoint source pollution abatement measures within the watershed, including enhancement of the wetland complex in the vicinity of Mound Road upstream of the Lake inlet, eradication and restocking of the Lake's fish populations, and treatment of the Lake with aluminum sulfate (alum) to reduce in-lake phosphorus concentrations. These measures not only affect, but are affected by, water quality and changes in water quality within the Lake. A summary of the management measures is set forth in Chapter VI. This Chapter presents a summary of the lake water quality data gathered during the period from October 1983 through September 1999.

Beginning in October 1983, the U.S. Geological Survey, in cooperation with the Delavan Lake Sanitary District and later with the Town of Delavan, initiated an ongoing water quality monitoring program for Delavan Lake.[4]

[1]*Wisconsin Conservation Department,* Surface Water Resources of Walworth County, *1961.*

[2]*Limnetics, Inc.,* Lake Delavan Limnological Survey, Wisconsin, *1968.*

[3]*U.S. Environmental Protection Agency,* Report on Delavan Lake, Walworth County, Wisconsin, *National Eutrophication Survey Working Paper No. 36.*

[4]*U.S. Geological Survey Water-Resources Investigations Report 87-4168,* Hydrology and Water Quality of Delavan Lake in Southeastern Wisconsin, *August 1988; see also Dale M. Robertson, Gerald L. Goddard, Daniel R. Helsel, and Kevin L. MacKinnon, "Rehabilitation of Delavan Lake, Wisconsin,"* Lake and Reservoir Management, *Volume 16, Number 3, pages 155-176, 2000. Data are reported in U.S. Geological Survey Water-Data Reports No. WI-84-1 through WI-93-1,* Water Resources Data, Wisconsin, *published annually for* Water Year 1984 *through* Water Year 1993, *and subsequently, annually in U.S. Geological Survey Open-File Report No. 95-190,* Water-Quality and Lake-Stage Data for Wisconsin Lakes, Water Year 1994, *and following years.*

This monitoring program involves the determination of the physical and chemical characteristics of the Lake's water, including dissolved oxygen concentration and water temperature profiles, pH and specific conductance profiles, water clarity measurements, and nutrient and chlorophyll-*a* concentrations, as well as the determination of selected physical and chemical characteristics of the inflowing river water. Fisheries, zooplankton abundance, and water clarity data also were collected during this period by the Wisconsin Department of Natural Resources and the Delavan Lake Sanitary District. These data form a baseline against which to assess the efficacy of the lake management measures implemented within Delavan Lake and its drainage area.

The water quality monitoring investigations reported herein were funded, in part, through the Chapter NR 119, now the Chapter NR 190, Lake Management Planning Grant Program. The data obtained through this program and the earlier investigations were used in the development of this lake management plan, which is also funded, in part, through the Chapter NR 190 Lake Management Planning Grant Program. Additional data were provided through a diagnostic and feasibility study funded, in part, through the Chapter NR 191 Lake Protection Grant Program.

## EXISTING WATER QUALITY CONDITIONS

Data collected during the study period, October 1983 through September 1999, were used to determine water quality conditions in the Lake and to characterize the suitability of the Lake for recreational use and the support of fish and aquatic life. Water quality samples typically were taken from the main basin of the Lake. In most years, samples were taken at least once per year during the monitoring period. In some years, samples for analysis with respect to particular variables were taken multiple times. The primary sampling station was located at the deepest point in the Lake, as shown on Map 3 in Chapter II of this report. The findings are summarized in Tables 9 and 10. Table 9 shows water quality from the period between October 1983 and March 1991, prior to the application of alum to the Lake, and Table 10 shows data from the period between April 1991 and September 1999, following the application of alum.

**Thermal Stratification**

Thermal and dissolved oxygen profiles for Delavan Lake are shown in Figure 2. Water temperatures ranged from approximately 32°F during the winter to approximately 84°F during the summer. Complete mixing of the Lake was restricted by thermal stratification in the summer and by ice cover in the winter.

Thermal stratification is the result of differential heating of lake water and the resulting water temperature-density relationships. Water is unique among liquids because it reaches its maximum density, or mass per unit volume, at about 39.2°F, well above its freezing point. The development of thermal stratification begins in early summer, reaches its maximum in late summer, and disappears in the fall as illustrated diagrammatically in Figure 3. Stratification may also occur under ice-cover. The process is described below.

As summer begins, the lake water absorbs solar energy at the surface. Wind action, and, to some extent, internal heat-transfer mechanisms, transmit this energy to the underlying portions of the waterbody. As the upper layers of water are heated by solar energy, a physical, density barrier begins to form between the warmer surface water and the lower, heavier, colder water, as illustrated by the June, July and August profiles in Figure 2. This "barrier" is marked by a sharp temperature gradient known as the thermocline and is characterized by an approximately 1°F to 2°F drop in temperature per three feet of depth that separates the warmer, lighter, upper layers of water, called the epilimnion, from the lower layer, called the hypolimnion. Although this barrier is readily crossed by fish, provided sufficient oxygen exists, it essentially prohibits the exchange of water between the two layers. This condition, illustrated diagrammatically in Figures 3 and 4, has a great impact on both the chemistry and biology of the Lake, which is also commonly stratified as a result.

The autumnal mixing period occurs when air temperatures cool the surface water and wind action results in the erosion of the thermocline: as the surface waters cool, they become heavier, sinking and displacing the now

## Table 9

## SEASONAL WATER QUALITY DATA FOR DELAVAN LAKE: 1983-1991

| Parameter[a] | Fall (mid-September to mid-December) | | Winter (mid-December to mid-March) | | Spring (mid-March to mid-June) | | Summer (mid-June to mid-September) | |
|---|---|---|---|---|---|---|---|---|
| | Shallow[b] | Deep[c] | Shallow[b] | Deep[c] | Shallow[b] | Deep[c] | Shallow[b] | Deep[c] |
| **Physical Properties** | | | | | | | | |
| Alkalinity (mg/l), as $CaCO_3$ | | | | | | | | |
| Range | -- | -- | -- | -- | 180-180 | 178-181 | -- | -- |
| Mean | -- | -- | -- | -- | 180 | 179.5 | -- | -- |
| Standard Deviation | -- | -- | -- | -- | 0 | 2.1 | -- | -- |
| Number of Samples | -- | -- | -- | -- | 2 | 2 | -- | -- |
| Color (Pt-Co scale) | | | | | | | | |
| Range | -- | -- | -- | -- | 13.0-13.0 | 13.0-13.0 | -- | -- |
| Mean | -- | -- | -- | -- | 13.0 | 13.0 | -- | -- |
| Standard Deviation | -- | -- | -- | -- | -- | -- | -- | -- |
| Number of Samples | -- | -- | -- | -- | 1 | 1 | -- | -- |
| Dissolved Oxygen (mg/l) | | | | | | | | |
| Range | 6.0-12.1 | 0.0-11.6 | 9.2-19.2 | 0.1-7.2 | 7.4-18.7 | 0.0-18.0 | 5.7-15.2 | 0.0-8.4 |
| Mean | 8.7 | 6.5 | 12.4 | 1.5 | 11.5 | 6.5 | 9.5 | 0.5 |
| Standard Deviation | 1.5 | 3.8 | 2.7 | 2.4 | 2.8 | 5.2 | 2.1 | 1.7 |
| Number of Samples | 15 | 15 | 11 | 11 | 20 | 20 | 30 | 30 |
| Hardness (mg/l), as $CaCO_3$ | | | | | | | | |
| Range | -- | -- | -- | -- | 220-240 | 240-240 | -- | -- |
| Mean | -- | -- | -- | -- | 230 | 240 | -- | -- |
| Standard Deviation | -- | -- | -- | -- | 10 | 0 | -- | -- |
| Number of Samples | -- | -- | -- | -- | 3 | 2 | -- | -- |
| pH (units) | | | | | | | | |
| Range | 8.0-8.9 | 7.2-8.7 | 7.4-10.2 | 7.2-8.9 | 7.8-9.7 | 7.5-8.9 | 8.2-9.3 | 6.9-8.6 |
| Mean | 8.4 | 8.2 | 8.6 | 7.8 | 8.6 | 8.2 | 8.8 | 7.5 |
| Standard Deviation | 0.3 | 0.4 | 0.7 | 0.50 | 0.4 | 0.4 | 0.3 | 0.4 |
| Number of Samples | 19 | 19 | 13 | 13 | 25 | 24 | 36 | 36 |
| Secchi Depth (feet) | | | | | | | | |
| Range | 1.6-13.8 | -- | 1.6-24.6 | -- | 2.6-18.0 | -- | 1.6-8.6 | -- |
| Mean | 5.9 | -- | 12.5 | -- | 8.2 | -- | 4.2 | -- |
| Standard Deviation | 3.6 | -- | 7.8 | -- | 4.2 | -- | 1.6 | -- |
| Number of Samples | 20 | -- | 10 | -- | 23 | -- | 34 | -- |
| Dissolved Solids at 180°C (mg/l) | | | | | | | | |
| Range | -- | -- | -- | -- | 316-338 | 308-342 | -- | -- |
| Mean | -- | -- | -- | -- | 324.7 | 321.7 | -- | -- |
| Standard Deviation | -- | -- | -- | -- | 11.7 | 18 | -- | -- |
| Number of Samples | -- | -- | -- | -- | 3 | 3 | -- | -- |
| Specific Conductance (μS/cm) | | | | | | | | |
| Range | 480-568 | 490-686 | 458-613 | 510-1104 | 490-564 | 480-760 | 430-563 | 516-684 |
| Mean | 517 | 532.1 | 527.1 | 746 | 526.6 | 552.1 | 500.8 | 598.4 |
| Standard Deviation | 31.3 | 44.8 | 45.7 | 146 | 19 | 49.9 | 32.9 | 37.5 |
| Number of Samples | 19 | 19 | 13 | 13 | 25 | 24 | 36 | 36 |
| Temperature (°F) | | | | | | | | |
| Range | 36.5-68.9 | 36.5-68 | 32.9-40.1 | 32.54-40.46 | 37.4-67.1 | 39.2-63.5 | 58.1-82.4 | 53.6-67.1 |
| Mean | 55.22 | 54.14 | 34.52 | 37.76 | 53.78 | 49.28 | 73.76 | 60.8 |
| Standard Deviation | 42.8 | 41.18 | 33.98 | 33.98 | 41.18 | 39.02 | 36.68 | 35.78 |
| Number of Samples | 20 | 20 | 14 | 13 | 24 | 23 | 36 | 36 |
| Turbidity (NTU) | | | | | | | | |
| Range | -- | -- | -- | -- | 1.3-1.3 | 1.5-1.5 | -- | -- |
| Mean | -- | -- | -- | -- | 1.3 | 1.5 | -- | -- |
| Standard Deviation | -- | -- | -- | -- | -- | -- | -- | -- |
| Number of Samples | -- | -- | -- | -- | 1 | 1 | -- | -- |
| **Metals/Salts** | | | | | | | | |
| Dissolved Calcium (mg/l) | | | | | | | | |
| Range | -- | -- | -- | -- | 40.0-41.0 | 40.0-41.0 | -- | -- |
| Mean | -- | -- | -- | -- | 40.5 | 40.5 | -- | -- |
| Standard Deviation | -- | -- | -- | -- | 0.7 | 0.7 | -- | -- |
| Number of Samples | -- | -- | -- | -- | 2 | 2 | -- | -- |
| Dissolved Chloride (mg/l) | | | | | | | | |
| Range | -- | -- | -- | -- | 45-58 | 45-64 | -- | -- |
| Mean | -- | -- | -- | -- | 49.7 | 54.5 | -- | -- |
| Standard Deviation | -- | -- | -- | -- | 7.2 | 13.4 | -- | -- |
| Number of Samples | -- | -- | -- | -- | 3 | 2 | -- | -- |
| Dissolved Iron (μg/l) | | | | | | | | |
| Range | -- | -- | -- | -- | 3.0-6.0 | 3.0-4.0 | 80.0-150.0 | 80.0-250.0 |
| Mean | -- | -- | -- | -- | 4.5 | 3.5 | 105.0 | 135.0 |
| Standard Deviation | -- | -- | -- | -- | 2.1 | 0.7 | 31.1 | 61.9 |
| Number of Samples | -- | -- | -- | -- | 2 | 2 | 4 | 6 |

## Table 9 (continued)

| Parameter[a] | Fall (mid-September to mid-December) | | Winter (mid-December to mid-March) | | Spring (mid-March to mid-June) | | Summer (mid-June to mid-September) | |
|---|---|---|---|---|---|---|---|---|
| | Shallow[b] | Deep[c] | Shallow[b] | Deep[c] | Shallow[b] | Deep[c] | Shallow[b] | Deep[c] |
| **Metals/Salts (continued)** | | | | | | | | |
| Dissolved Magnesium (mg/l) | | | | | | | | |
| Range | - - | - - | - - | - - | 32.0-33.0 | 33.0-33.0 | - - | - - |
| Mean | - - | - - | - - | - - | 32.5 | 33.0 | - - | - - |
| Standard Deviation | - - | - - | - - | - - | 0.7 | 0.0 | - - | - - |
| Number of Samples | - - | - - | - - | - - | 2 | 2 | - - | - - |
| Dissolved Manganese (μg/l) | | | | | | | | |
| Range | - - | - - | - - | - - | 1.0-1.0 | 1.0-1.0 | 10.0-40.0 | 20.0-400.0 |
| Mean | - - | - - | - - | - - | 1.0 | 1.0 | 17.5 | 241.7 |
| Standard Deviation | - - | - - | - - | - - | 0 | - - | 15.0 | 147.6 |
| Number of Samples | - - | - - | - - | - - | 2 | 1 | 4 | 6 |
| Dissolved Potassium (mg/l) | | | | | | | | |
| Range | - - | - - | - - | - - | 2.6-3.3 | 2.70-3.30 | - - | - - |
| Mean | - - | - - | - - | - - | 3.0 | 3.00 | - - | - - |
| Standard Deviation | - - | - - | - - | - - | 0.5 | 0.4 | - - | - - |
| Number of Samples | - - | - - | - - | - - | 2 | 2 | - - | - - |
| Dissolved Silica (mg/l) | | | | | | | | |
| Range | 0.1-2.1 | 0.1-1.7 | 0.10-0.50 | 0.10-5.90 | 0.1-0.60 | 0.1-1.9 | 0.10-1.40 | 1.40-10.00 |
| Mean | 0.5 | 0.5 | 0.2 | 3.0 | 0.3 | 0.7 | 0.5 | 4.5 |
| Standard Deviation | 0.7 | 0.5 | 0.2 | 2.7 | 0.2 | 0.6 | 0.4 | 2.1 |
| Number of Samples | 9 | 9 | 4 | 5 | 13 | 13 | 13 | 13 |
| Dissolved Sodium (mg/l) | | | | | | | | |
| Range | - - | - - | - - | - - | 19.0-26.0 | 19.0-26.0 | - - | - - |
| Mean | - - | - - | - - | - - | 22.5 | 22.5 | - - | - - |
| Standard Deviation | - - | - - | - - | - - | 4.9 | 4.9 | - - | - - |
| Number of Samples | - - | - - | - - | - - | 2 | 2 | - - | - - |
| Dissolved Sulfate $SO_4$ (mg/l) | | | | | | | | |
| Range | - - | - - | - - | - - | 27.0-27.0 | 25.0-27.0 | - - | - - |
| Mean | - - | - - | - - | - - | 27.0 | 26.0 | - - | - - |
| Standard Deviation | - - | - - | - - | - - | 0 | 1.4 | - - | - - |
| Number of Samples | - - | - - | - - | - - | 2 | 2 | - - | - - |
| **Nutrients** | | | | | | | | |
| Dissolved Nitrogen, Ammonia (mg/l) | | | | | | | | |
| Range | 0.46-0.89 | 0.50-0.84 | 0.51-0.51 | 1.5-1.8 | 0.02-0.59 | 0.21-1.30 | 0.01-0.25 | 0.64-4.50 |
| Mean | 0.613 | 0.67 | 0.51 | 1.65 | 0.266 | 0.522 | 0.081 | 1.987 |
| Standard Deviation | 0.24 | 0.24 | - - | 0.212 | 0.19 | 0.32 | 0.092 | 1.33 |
| Number of Samples | 3 | 2 | 1 | 2 | 12 | 11 | 9 | 9 |
| Dissolved Nitrogen, $NO_2+NO_3$ (mg/l) | | | | | | | | |
| Range | 0.10-0.40 | 0.10-0.40 | 0.40-1.10 | 0.30-1.70 | 0.20-1.10 | 0.30-1.10 | 0.10-0.60 | 0.1-1.10 |
| Mean | 0.156 | 0.156 | 0.675 | 0.74 | 0.617 | 0.600 | 0.2 | 0.231 |
| Standard Deviation | 0.113 | 0.113 | 0.31 | 0.568 | 0.307 | 0.263 | 1.78 | 2.81 |
| Number of Samples | 9 | 9 | 4 | 5 | 12 | 12 | 13 | 13 |
| Total Nitrogen, Organic (mg/l) | | | | | | | | |
| Range | 1.70-2.30 | 1.80-3.80 | 1.50-2.20 | 1.30-3.90 | 1.20-3.50 | 1.50-4.00 | 1.50-1.90 | 1.60-6.40 |
| Mean | 2.0 | 2.80 | 1.88 | 2.68 | 2.03 | 2.21 | 1.70 | 4.1 |
| Standard Deviation | 0.30 | 1.058 | 0.30 | 1.23 | 0.581 | 0.689 | 0.163 | 2.191 |
| Number of Samples | 3 | 3 | 4 | 5 | 12 | 12 | 4 | 5 |
| Dissolved Orthophosphorus (mg/l) | | | | | | | | |
| Range | 0.010-0.430 | 0.032-0.170 | 0.010-0.199 | 0.058-0.492 | 0.003-0.111 | 0.007-0.230 | 0.001-0.071 | 0.001-1.100 |
| Mean | 0.111 | 0.111 | 0.080 | 0.234 | 0.047 | 0.114 | 0.017 | 0.517 |
| Standard Deviation | 0.086 | 0.04 | 0.054 | 0.129 | 0.035 | 0.070 | 0.0188 | 0.270 |
| Number of Samples | 19 | 20 | 13 | 14 | 24 | 24 | 32 | 33 |
| Total Phosphorus (mg/l) | | | | | | | | |
| Range | 0.041-0.470 | 0.092-0.880 | 0.064-0.332 | 0.130-0.775 | 0.041.160 | 0.640-0.326 | 0.018-0.136 | 0.43-1.500 |
| Mean | 0.154 | 0.202 | 0.144 | 0.328 | 0.099 | 0.174 | 0.068 | 0.644 |
| Standard Deviation | 0.084 | 0.166 | 0.071 | 0.167 | 0.038 | 0.075 | 0.032 | 0.293 |
| Number of Samples | 20 | 20 | 15 | 16 | 24 | 24 | 33 | 33 |
| **Biological** | | | | | | | | |
| Chlorophyll-*a* (μg/l) | | | | | | | | |
| Range | 0.20-24.00 | - - | 0.100-120.00 | - - | 0.10-31.00 | - - | 1.7-300.0 | - - |
| Mean | 10.00 | - - | 17.4 | - - | 8.20 | - - | 39 | - - |
| Standard Deviation | 8.30 | - - | 33.7 | - - | 8.0 | - - | 54.6 | - - |
| Number of Samples | 19 | - - | 14 | - - | 24 | - - | 32 | - - |

[a] *Milligrams per liter unless otherwise indicated.*

[b] *Depth of sample approximately 1.5 to three feet.*

[c] *Depth of sample greater than 45 feet.*

*Source: Wisconsin Department of Natural Resources, U.S. Geological Survey, Delavan Lake Sanitary District, and SEWRPC.*

## Table 10

## SEASONAL WATER QUALITY DATA FOR DELAVAN LAKE: 1991-1999

| Parameter[a] | Fall (mid-September to mid-December) | | Winter (mid-December to mid-March) | | Spring (mid-March to mid-June) | | Summer (mid-June to mid-September) | |
|---|---|---|---|---|---|---|---|---|
| | Shallow[b] | Deep[c] | Shallow[b] | Deep[c] | Shallow[b] | Deep[c] | Shallow[b] | Deep[c] |
| **Physical Properties** | | | | | | | | |
| Alkalinity (mg/l), as $CaCO_3$ | | | | | | | | |
| Range | 169-170 | 170-214 | -- | -- | 174-200 | 180-200 | 155-163 | 198-217 |
| Mean | 169.5 | 192 | -- | -- | 184.6 | 188.4 | 159 | 205 |
| Standard Deviation | 0.7 | 31.1 | -- | -- | 7.6 | 5.9 | 3.3 | 7.1 |
| Number of Samples | 2 | 2 | -- | -- | 13 | 13 | 5 | 5 |
| Color (Pt-Co scale) | | | | | | | | |
| Range | -- | -- | -- | -- | 5.0-15.0 | 5.0-12.0 | -- | -- |
| Mean | -- | -- | -- | -- | 8.2 | 8.1 | -- | -- |
| Standard Deviation | -- | -- | -- | -- | 3.2 | 2.4 | -- | -- |
| Number of Samples | -- | -- | -- | -- | 9 | 9 | -- | -- |
| Dissolved Oxygen (mg/l) | | | | | | | | |
| Range | 6.8-12.1 | 0.1-11.3 | 9.0-19.8 | 0.4-6.3 | 8.9-16.6 | 0.2-13.8 | 6.4-12.4 | 0.1-1.0 |
| Mean | 9.8 | 8.0 | 14.5 | 2.4 | 11.2 | 7.6 | 9.0 | 0.4 |
| Standard Deviation | 1.6 | 4.1 | 3.6 | 2.3 | 1.6 | 4.3 | 1.3 | 0.3 |
| Number of Samples | 10 | 10 | 8 | 8 | 26 | 26 | 27 | 27 |
| Hardness (mg/l), as $CaCO_3$ | | | | | | | | |
| Range | -- | -- | -- | -- | 230-250 | 240-250 | -- | -- |
| Mean | -- | -- | -- | -- | 242.4 | 246.3 | -- | -- |
| Standard Deviation | -- | -- | -- | -- | 6.9 | 5.2 | -- | -- |
| Number of Samples | -- | -- | -- | -- | 8 | 8 | -- | -- |
| pH (units) | | | | | | | | |
| Range | 8.1-8.5 | 7.2-8.4 | 7.7-8.8 | 7.4-7.8 | 7.8-8.9 | 7.5-8.8 | 8.1-8.8 | 7.0-7.6 |
| Mean | 8.3 | 8.1 | 8.4 | 7.6 | 8.4 | 8.1 | 8.5 | 7.4 |
| Standard Deviation | 0.1 | 0.4 | 0.4 | 0.1 | 0.3 | 0.4 | 0.2 | 0.1 |
| Number of Samples | 10 | 10 | 8 | 8 | 26 | 26 | 27 | 27 |
| Secchi Depth (feet) | | | | | | | | |
| Range | 5.5-22.0 | -- | 2.0-24.9 | -- | 2.6-35.1 | -- | 4.6-21.9 | -- |
| Mean | 13.1 | -- | 12.1 | -- | 19.7 | -- | 9.8 | -- |
| Standard Deviation | 4.2 | -- | 8.8 | -- | 7.5 | -- | 4.2 | -- |
| Number of Samples | 30 | -- | 8 | -- | 45 | -- | 69 | -- |
| Dissolved Solids at 180°C (mg/l) | | | | | | | | |
| Range | -- | -- | -- | -- | 308-336 | 311-344 | -- | -- |
| Mean | -- | -- | -- | -- | 325.6 | 327.1 | -- | -- |
| Standard Deviation | -- | -- | -- | -- | 8.3 | 11.8 | -- | -- |
| Number of Samples | -- | -- | -- | -- | 9 | 9 | -- | -- |
| Specific Conductance (μS/cm) | | | | | | | | |
| Range | 525-601 | 558-679 | 527-614 | 704-920 | 527-625 | 566-630 | 489-594 | 594-670 |
| Mean | 570.5 | 597.1 | 545.5 | 808 | 582.5 | 597.3 | 552.9 | 634.4 |
| Standard Deviation | 20.8 | 41.8 | 119 | 67.4 | 20.3 | 17.9 | 28.3 | 20.5 |
| Number of Samples | 10 | 10 | 8 | 8 | 26 | 26 | 27 | 27 |
| Temperature (°F) | | | | | | | | |
| Range | 39.2-73.04 | 39.2-54.14 | 32-37.4 | 35.6-40.1 | 32-73.22 | 37.4-55.4 | 66.74-84.2 | 52.16-68 |
| Mean | 57.74 | 47.84 | 33.98 | 38.3 | 56.12 | 48.74 | 75.2 | 55.22 |
| Standard Deviation | 41.72 | 37.58 | 33.8 | 33.44 | 42.08 | 36.86 | 35.6 | 35.06 |
| Number of Samples | 36 | 10 | 14 | 8 | 49 | 26 | 70 | 27 |
| Turbidity (NTU) | | | | | | | | |
| Range | -- | -- | -- | -- | 0.2-2.3 | 0.3-2.5 | -- | -- |
| Mean | -- | -- | -- | -- | 1.0 | 1.4 | -- | -- |
| Standard Deviation | -- | -- | -- | -- | 0.7 | 0.9 | -- | -- |
| Number of Samples | -- | -- | -- | -- | 9 | 9 | -- | -- |
| **Metals/Salts** | | | | | | | | |
| Dissolved Calcium (mg/l) | | | | | | | | |
| Range | -- | -- | -- | -- | 42.0-46.0 | 42.0-47.0 | -- | -- |
| Mean | -- | -- | -- | -- | 44.3 | 44.6 | -- | -- |
| Standard Deviation | -- | -- | -- | -- | 1.3 | 1.6 | -- | -- |
| Number of Samples | -- | -- | -- | -- | 9 | 9 | -- | -- |
| Dissolved Chloride (mg/l) | | | | | | | | |
| Range | -- | -- | -- | -- | 54.0-68.0 | 54.0-67.0 | 56.0-60.0 | 56.0-58.0 |
| Mean | -- | -- | -- | -- | 58.8 | 59.2 | 58.0 | 57.0 |
| Standard Deviation | -- | -- | -- | -- | 4.4 | 3.9 | 2.0 | 1.0 |
| Number of Samples | -- | -- | -- | -- | 10 | 9 | 3 | 3 |
| Dissolved Iron (μg/l) | | | | | | | | |
| Range | -- | -- | -- | -- | 3.0-13.0 | 3.0-12.0 | -- | -- |
| Mean | -- | -- | -- | -- | 7.8 | 8.1 | -- | -- |
| Standard Deviation | -- | -- | -- | -- | 3.8 | 2.9 | -- | -- |
| Number of Samples | -- | -- | -- | -- | 9 | 9 | -- | -- |

## Table 10 (continued)

| Parameter[a] | Fall (mid-September to mid-December) | | Winter (mid-December to mid-March) | | Spring (mid-March to mid-June) | | Summer (mid-June to mid-September) | |
|---|---|---|---|---|---|---|---|---|
| | Shallow[b] | Deep[c] | Shallow[b] | Deep[c] | Shallow[b] | Deep[c] | Shallow[b] | Deep[c] |
| **Metals/Salts (continued)** | | | | | | | | |
| Dissolved Magnesium (mg/l) | | | | | | | | |
| Range | - - | - - | - - | - - | 31.0-33.0 | 31.0-34.0 | - - | - - |
| Mean | - - | - - | - - | - - | 32.2 | 32.4 | - - | - - |
| Standard Deviation | - - | - - | - - | - - | 0.8 | 0.9 | - - | - - |
| Number of Samples | - - | - - | - - | - - | 9 | 9 | - - | - - |
| Dissolved Manganese (μg/l) | | | | | | | | |
| Range | - - | - - | - - | - - | 0.4-9.0 | 1.0-8.0 | - - | - - |
| Mean | - - | - - | - - | - - | 2.3 | 2.5 | - - | - - |
| Standard Deviation | - - | - - | - - | - - | 2.6 | 2.4 | - - | - - |
| Number of Samples | - - | - - | - - | - - | 9 | 9 | - - | - - |
| Dissolved Potassium (mg/l) | | | | | | | | |
| Range | - - | - - | - - | - - | 3.00-3.30 | 3.00-3.30 | - - | - - |
| Mean | - - | - - | - - | - - | 3.0 | 3.0 | - - | - - |
| Standard Deviation | - - | - - | - - | - - | 0.10 | 0.10 | - - | - - |
| Number of Samples | - - | - - | - - | - - | 9 | 9 | - - | - - |
| Dissolved Silica (mg/l) | | | | | | | | |
| Range | - - | - - | - - | - - | 0.1-1.30 | 0.1-1.20 | - - | - - |
| Mean | - - | - - | - - | - - | 0.4 | 0.5 | - - | - - |
| Standard Deviation | - - | - - | - - | - - | 0.4 | 0.4 | - - | - - |
| Number of Samples | - - | - - | - - | - - | 9 | 9 | - - | - - |
| Dissolved Sodium (mg/l) | | | | | | | | |
| Range | - - | - - | - - | - - | 22.0-27.0 | 22.0-27.0 | - - | - - |
| Mean | - - | - - | - - | - - | 24.8 | 25.1 | - - | - - |
| Standard Deviation | - - | - - | - - | - - | 1.5 | 1.5 | - - | - - |
| Number of Samples | - - | - - | - - | - - | 9 | 9 | - - | - - |
| Dissolved Sulfate $SO_4$ (mg/l) | | | | | | | | |
| Range | - - | - - | - - | - - | 27.0-42.0 | 27.0-42.0 | - - | - - |
| Mean | - - | - - | - - | - - | 31.4 | 31.7 | - - | - - |
| Standard Deviation | - - | - - | - - | - - | 4.3 | 4.4 | - - | - - |
| Number of Samples | - - | - - | - - | - - | 9 | 9 | - - | - - |
| **Nutrients** | | | | | | | | |
| Dissolved Nitrogen, Ammonia (mg/l) | | | | | | | | |
| Range | 0.002-0.17 | - - | 0.00-0.186 | - - | 0.00-0.19 | 0.04-0.48 | 0.002-0.034 | - - |
| Mean | 0.084 | - - | 0.063 | - - | 0.047 | 0.202 | 0.015 | - - |
| Standard Deviation | 0.074 | - - | 0.084 | - - | 0.051 | 0.175 | 0.009 | - - |
| Number of Samples | 5 | - - | 5 | - - | 12 | 6 | 9 | - - |
| Dissolved Nitrogen, $NO_2+NO_3$ (mg/l) | | | | | | | | |
| Range | 0.007-0.24 | - - | 0.179-0.58 | - - | 0.055-0.85 | 0.093-0.75 | 0.005-0.019 | - - |
| Mean | 0.125 | - - | 0.31 | - - | 0.310 | 0.399 | 0.01 | - - |
| Standard Deviation | 0.074 | - - | 0.159 | - - | 0.232 | 0.283 | 0.005 | - - |
| Number of Samples | 8 | - - | 5 | - - | 13 | 6 | 11 | - - |
| Total Nitrogen, Organic (mg/l) | | | | | | | | |
| Range | 0.68-0.93 | - - | 0.81-1.30 | - - | 0.70-1.70 | 0.80-1.50 | 0.50-1.10 | 0.78-0.78 |
| Mean | 0.825 | - - | 1.004 | - - | 0.956 | 1.06 | 0.786 | 0.78 |
| Standard Deviation | 0.099 | - - | 0.197 | - - | 0.328 | 0.297 | 0.187 | - - |
| Number of Samples | 6 | - - | 5 | - - | 14 | 5 | 10 | 1 |
| Dissolved Orthophosphorus (mg/l) | | | | | | | | |
| Range | 0.001-0.092 | 0.005-0.721 | 0.001-0.414 | 0.070-0.190 | 0.001-0.104 | 0.001-0.165 | 0.001-0.140 | 0.001-0.804 |
| Mean | 0.032 | 0.121 | 0.085 | 0.118 | 0.027 | 0.060 | 0..011 | 0.291 |
| Standard Deviation | 0.036 | 0.227 | 0.139 | 0.038 | 0.026 | 0.042 | 0.030 | 0.245 |
| Number of Samples | 12 | 9 | 8 | 8 | 26 | 26 | 30 | 27 |
| Total Phosphorus (mg/l) | | | | | | | | |
| Range | 0.009-0.126 | 0.021-0.861 | 0.011-0.577 | 0.110-0.240 | 0.013-0.150 | 0.017-0.190 | 0.007-0.170 | 0.007-1.019 |
| Mean | 0.077 | 0.184 | 0.138 | 0.151 | 0.061 | 0.098 | 0.042 | 0.407 |
| Standard Deviation | 0.037 | 0.250 | 0.182 | 0.041 | 0.028 | 0.050 | 0.028 | 0.292 |
| Number of Samples | 26 | 11 | 8 | 8 | 43 | 24 | 68 | 26 |
| **Biological** | | | | | | | | |
| Chlorophyll-*a* (μg/l) | | | | | | | | |
| Range | 0.40-6.20 | - - | 0.10-24.00 | - - | 0.10-6.40 | - - | 0.50-37.60 | - - |
| Mean | 1.9 | - - | 5.1 | - - | 1.1 | - - | 7.0 | - - |
| Standard Deviation | 1.8 | - - | 8.2 | - - | 1.4 | - - | 8.0 | - - |
| Number of Samples | 10 | - - | 8 | - - | 26 | - - | 25 | - - |

[a] *Milligrams per liter unless otherwise indicated.*

[b] *Depth of sample approximately 1.5 to three feet.*

[c] *Depth of sample greater than 45 feet.*

*Source: Wisconsin Department of Natural Resources, U.S. Geological Survey, Delavan Lake Sanitary District, and SEWRPC.*

Figure 2

**TEMPERATURE AND DISSOLVED OXYGEN PROFILES FOR DELAVAN LAKE: 1986-1999**

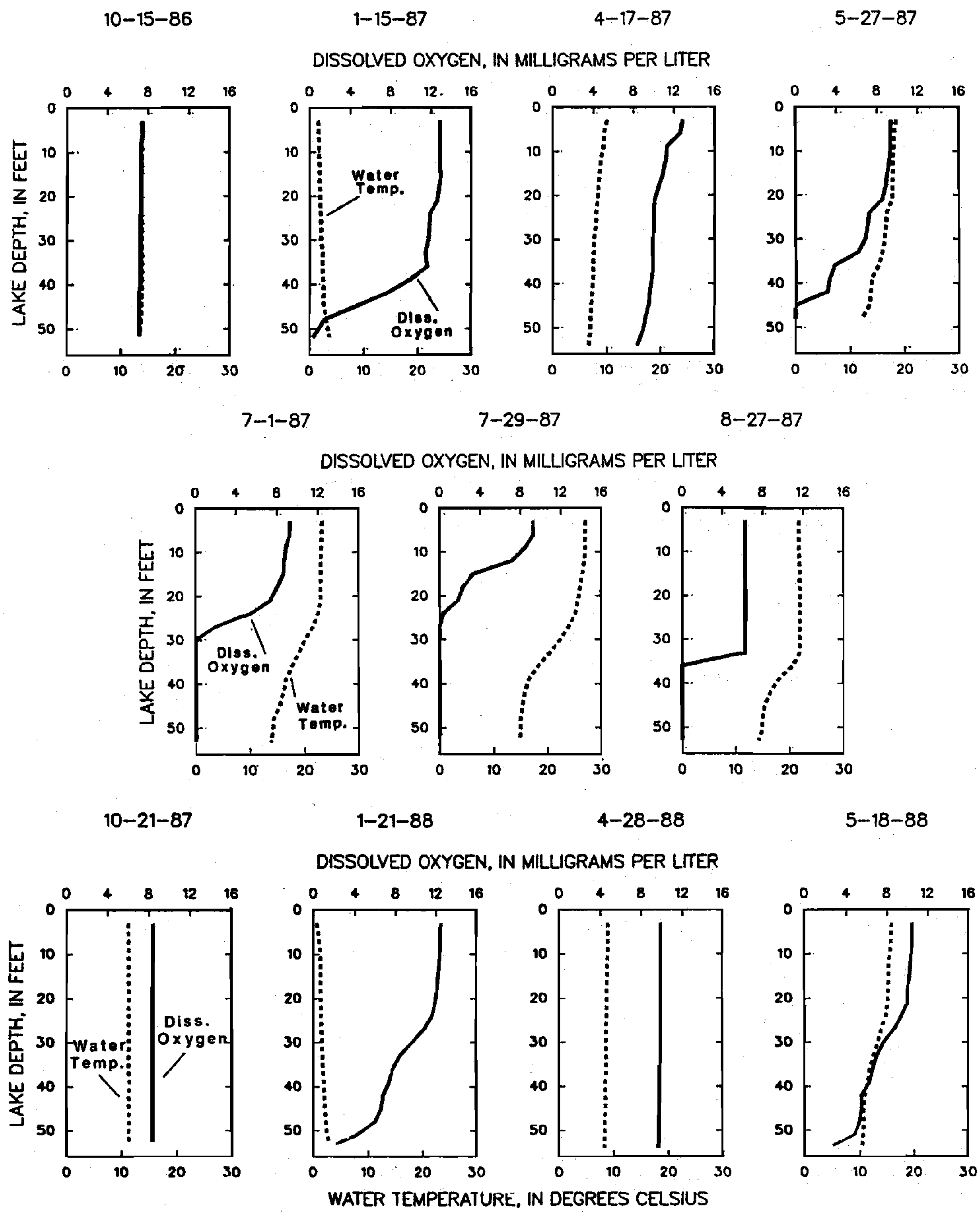


**Figure 2 (continued)**

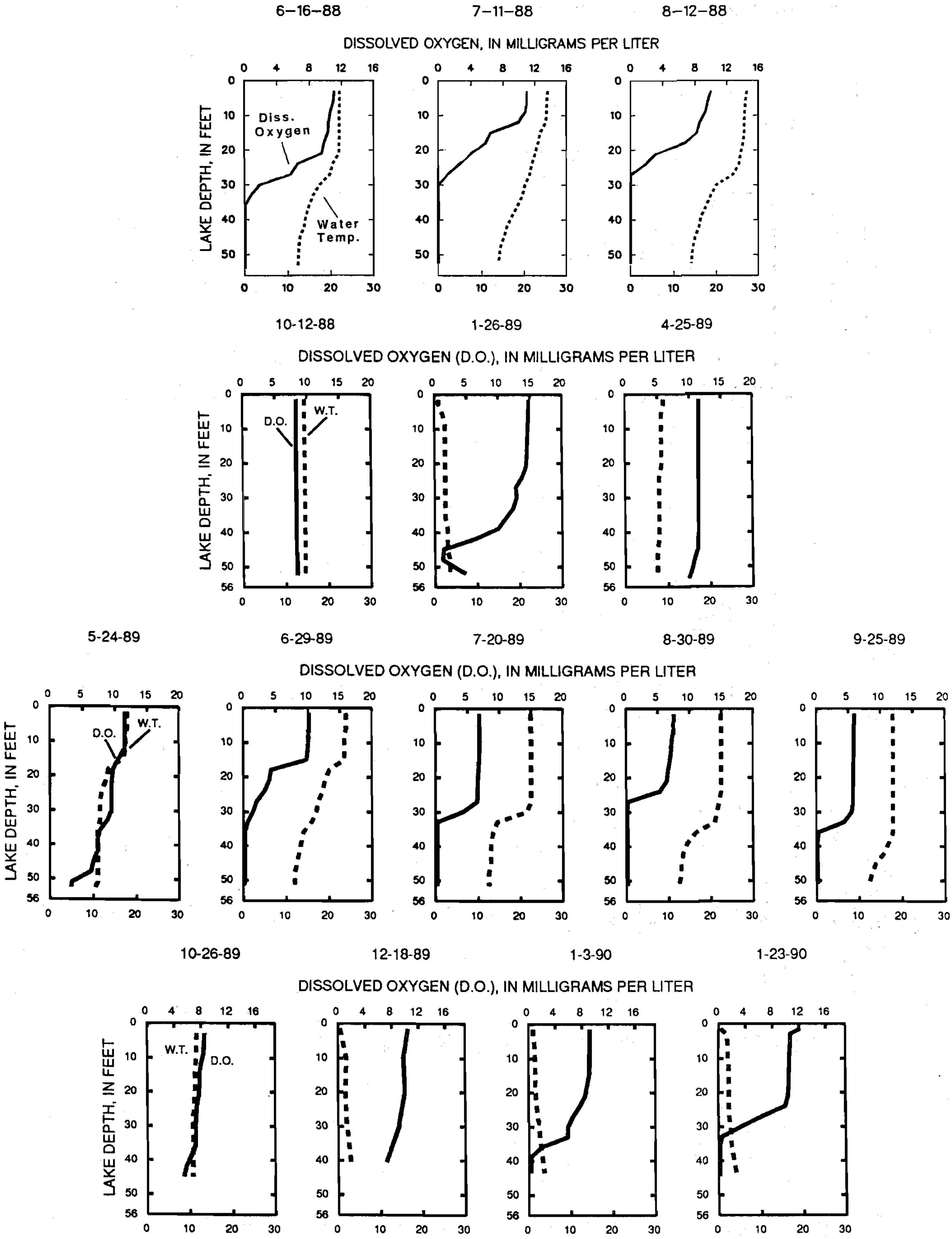


**Figure 2 (continued)**

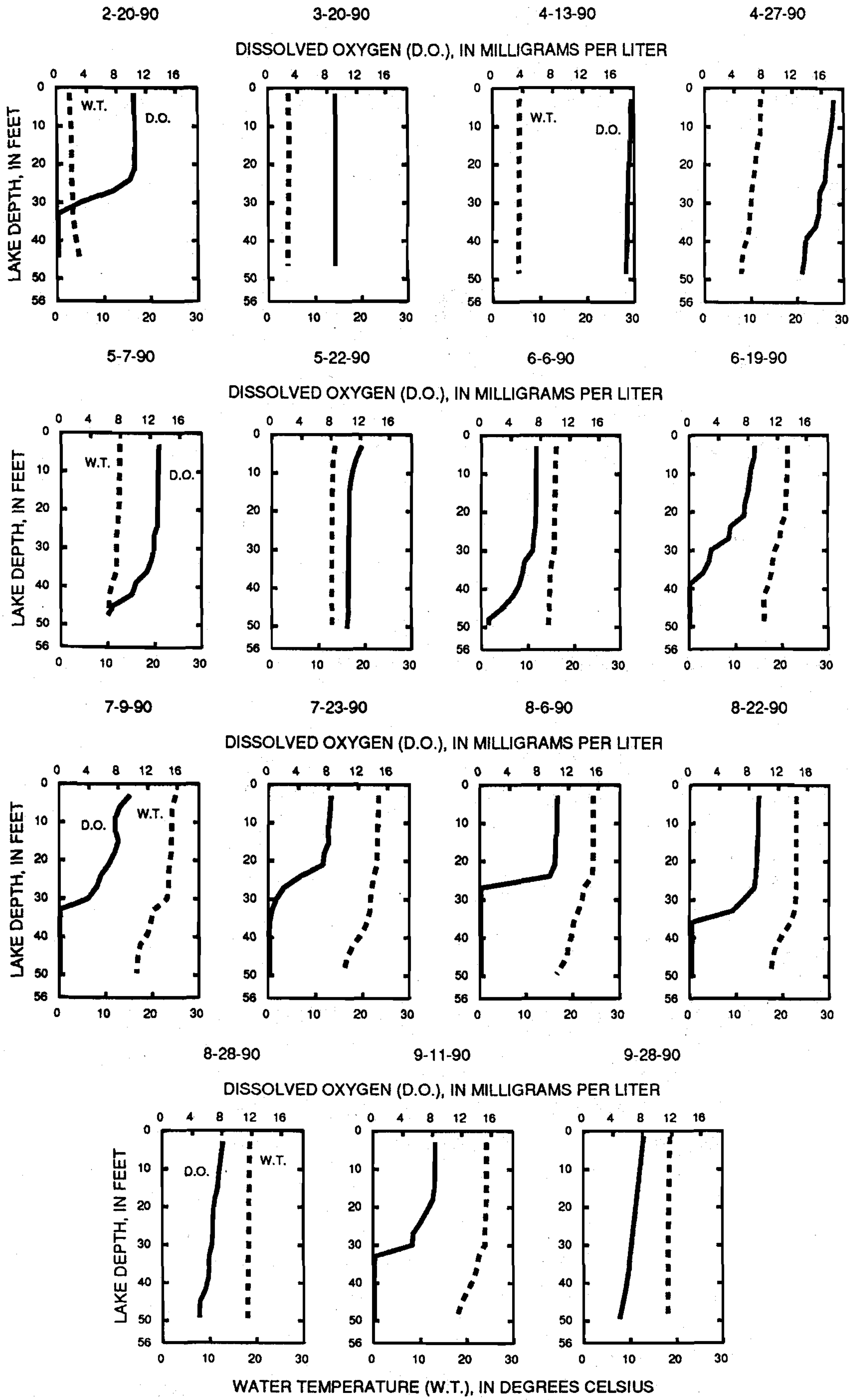


Figure 2 (continued)

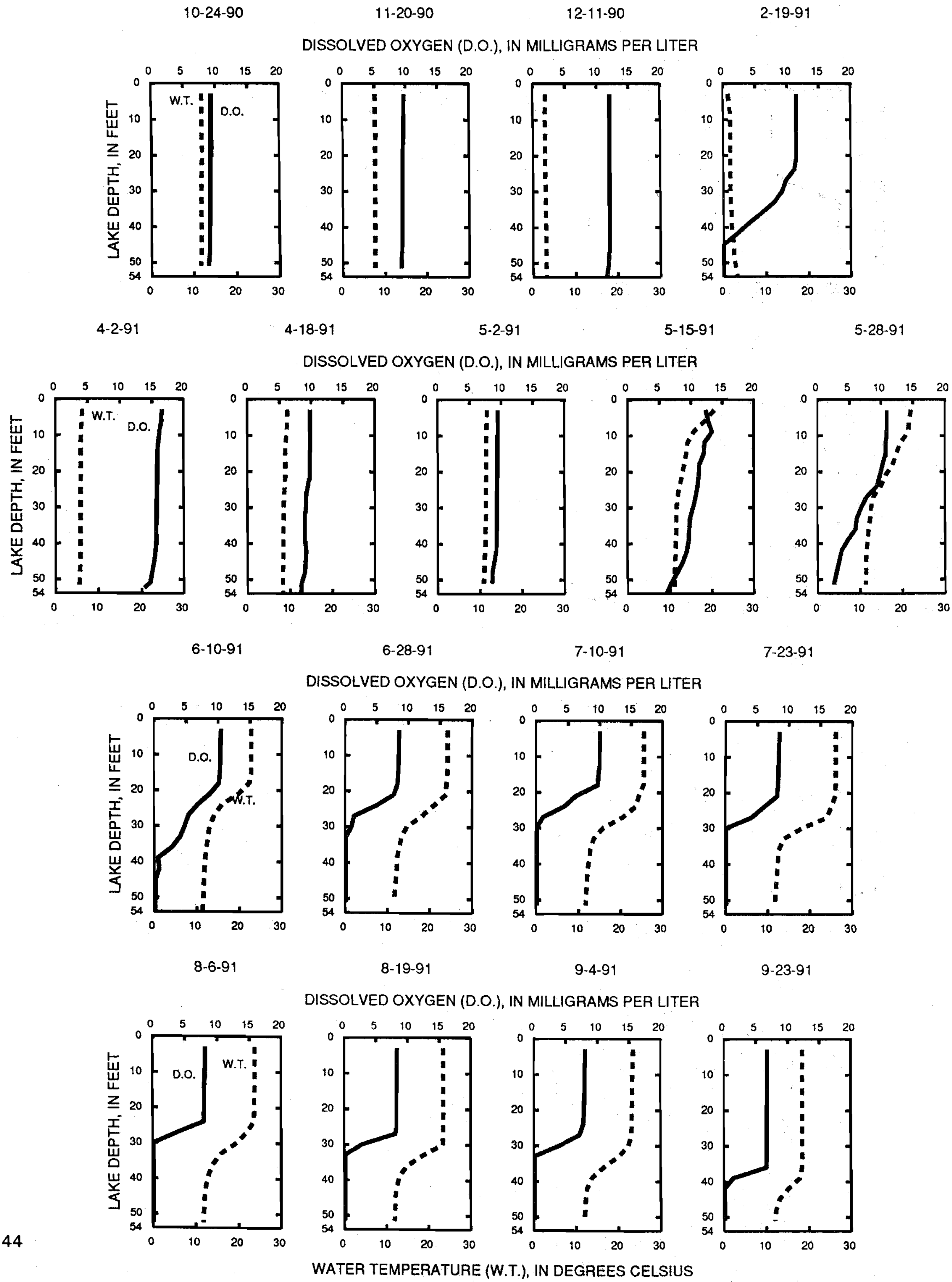


**Figure 2 (continued)**

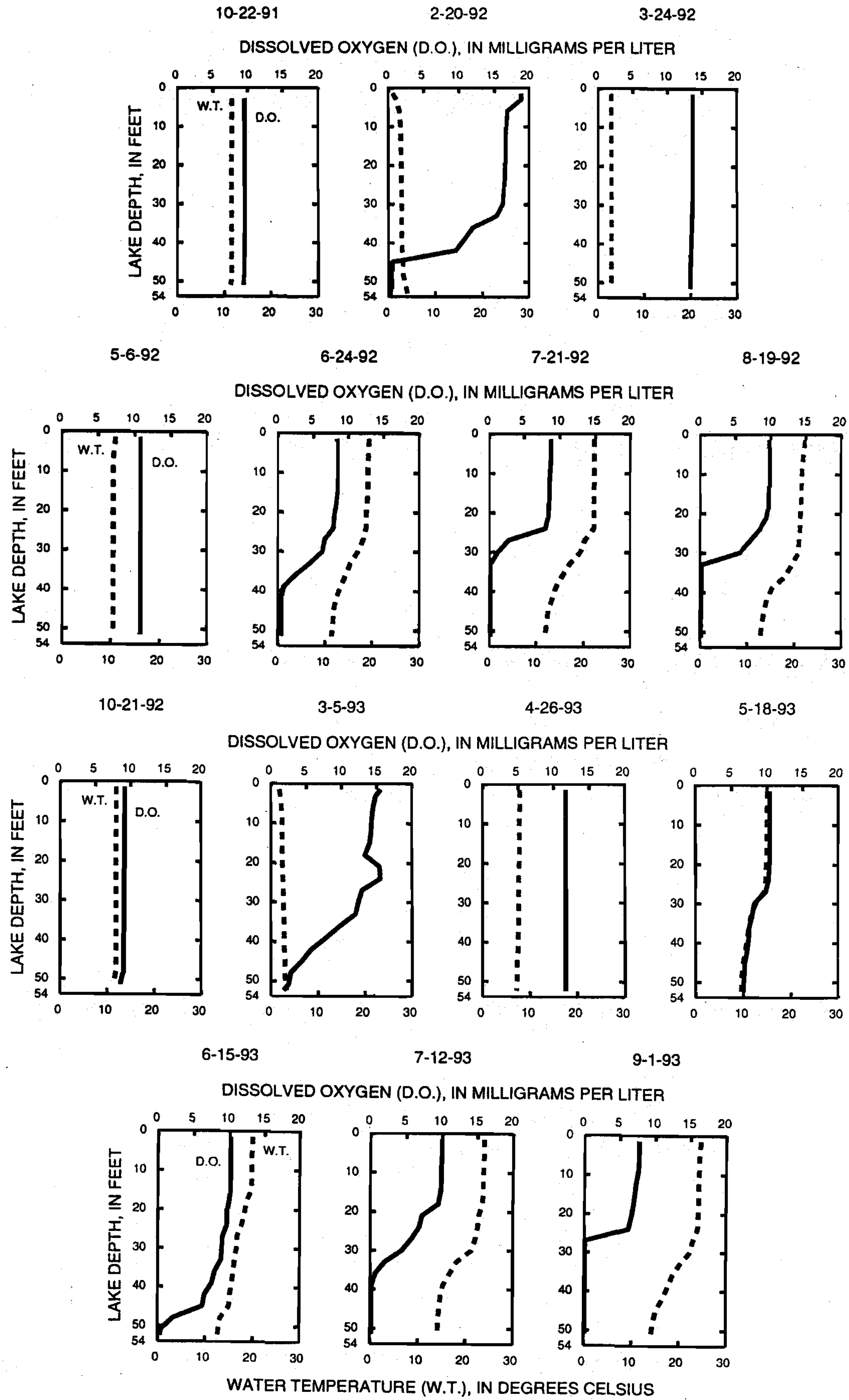


**Figure 2 (continued)**

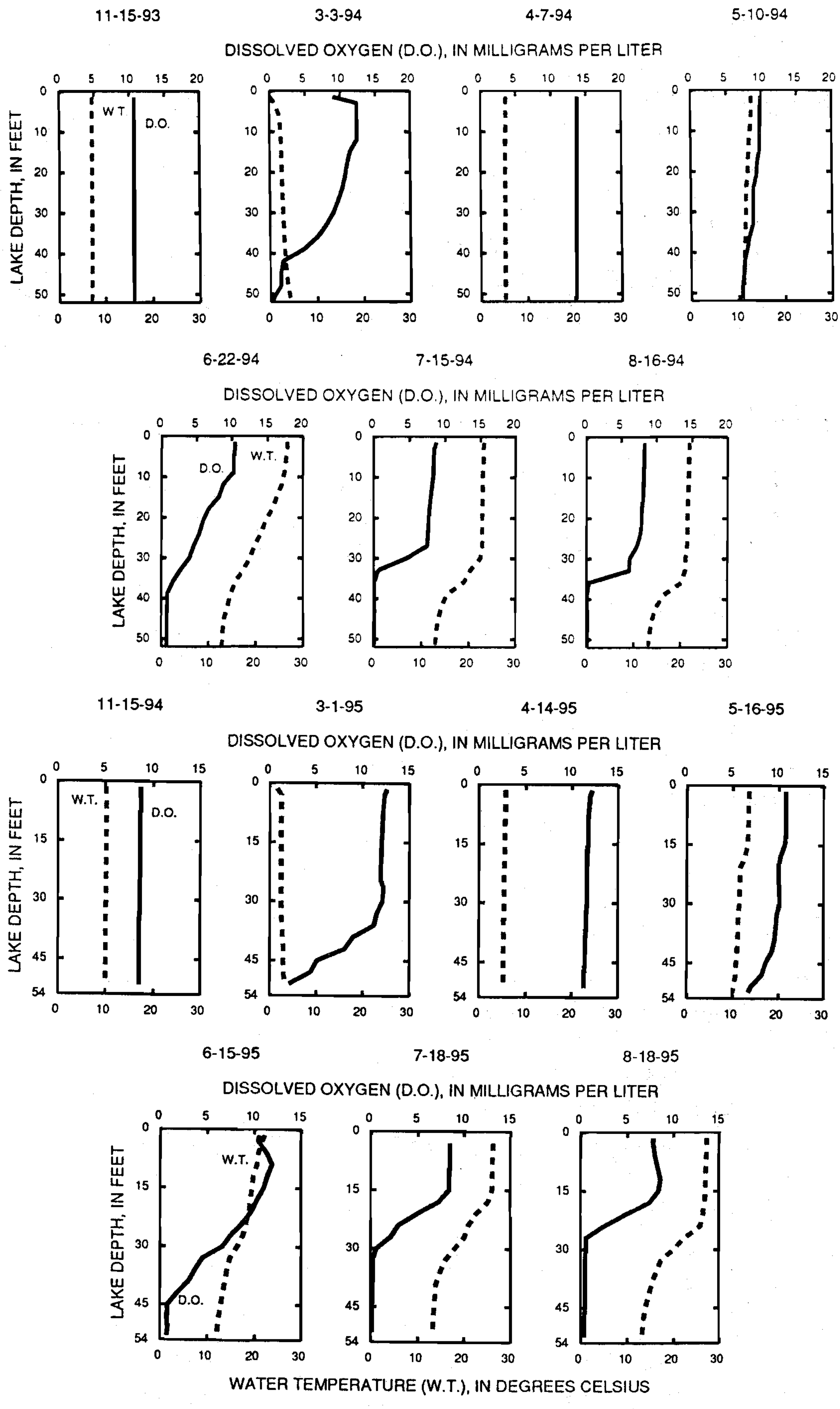


**Figure 2 (continued)**

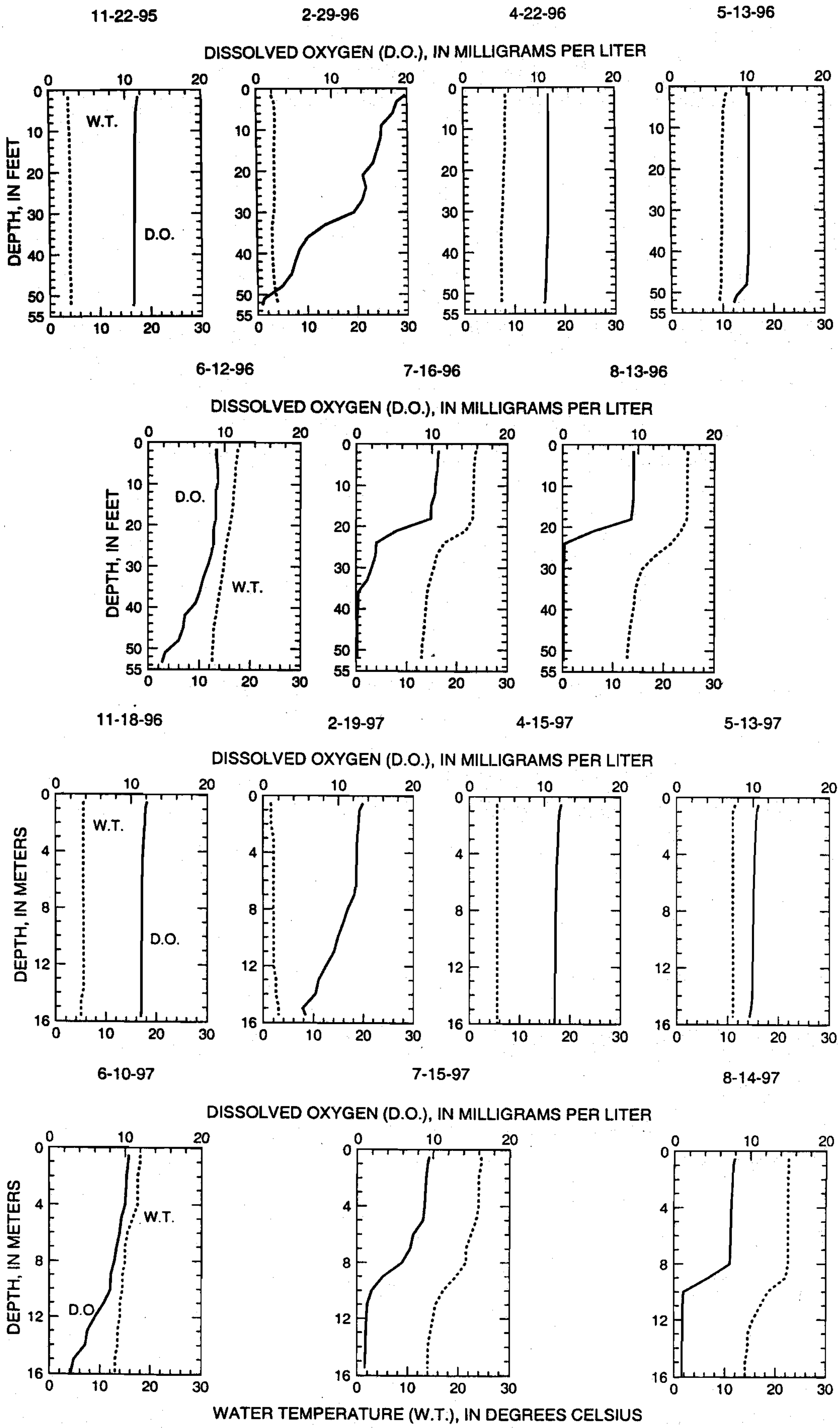


**Figure 2 (continued)**

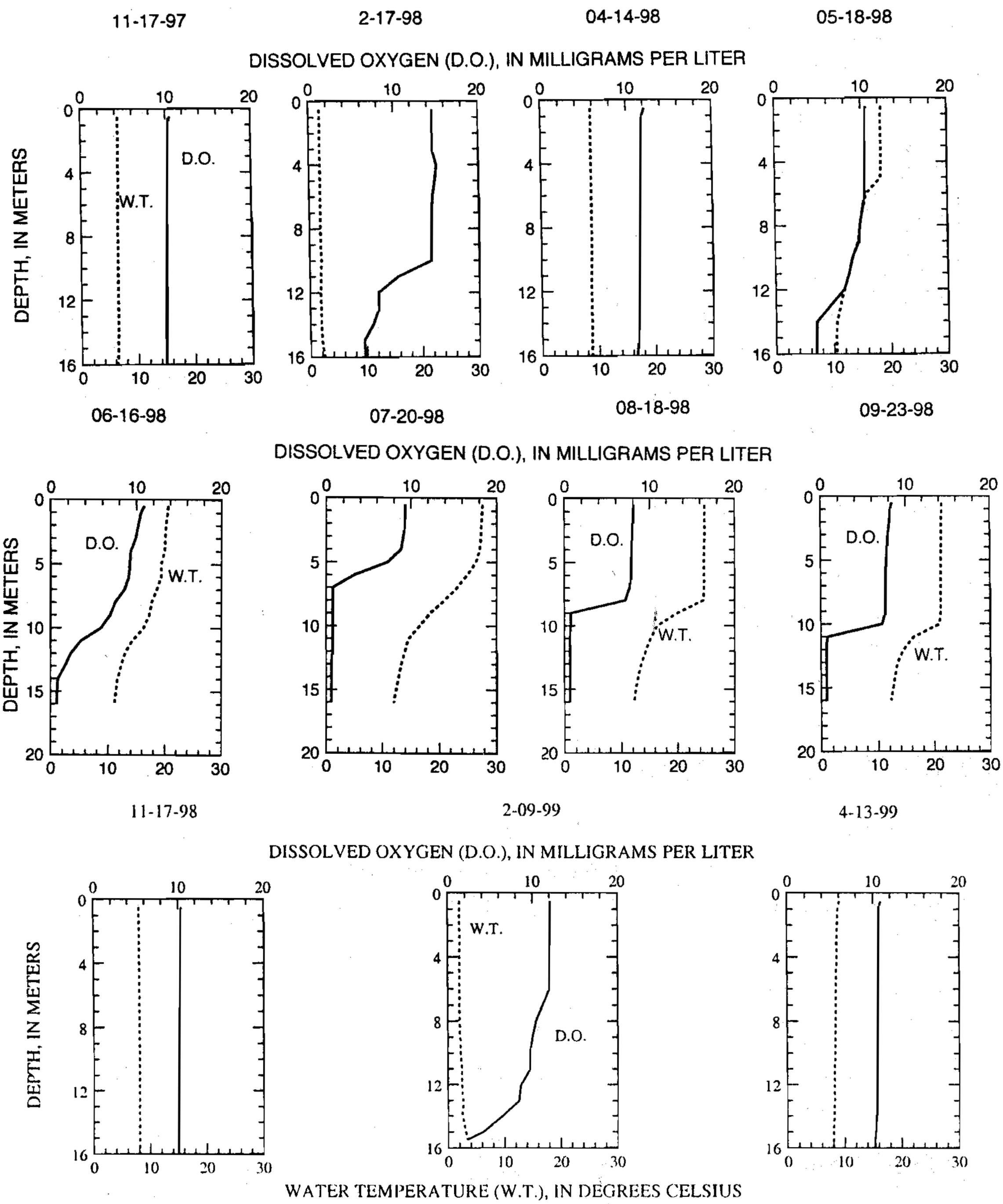
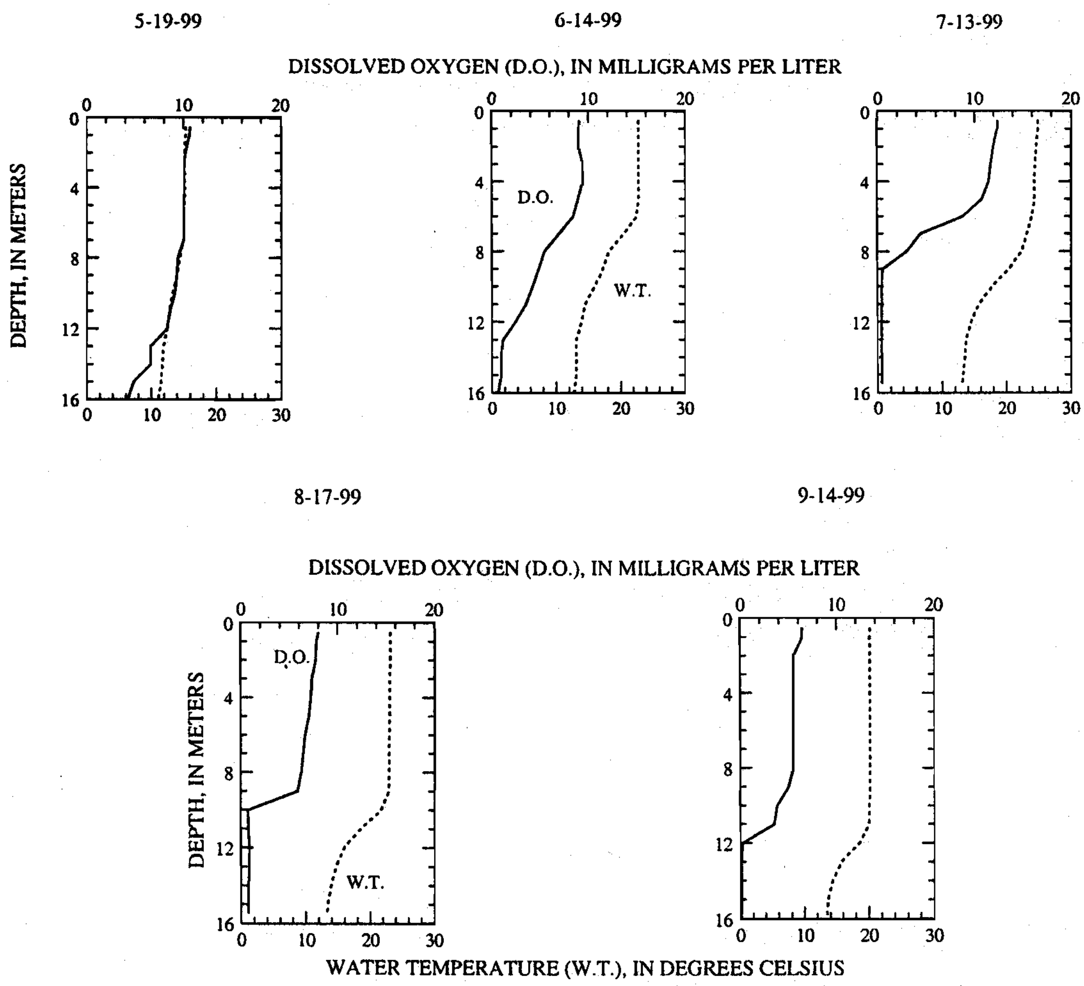


**Figure 2 (continued)**




*Source: U.S. Geological Survey.*

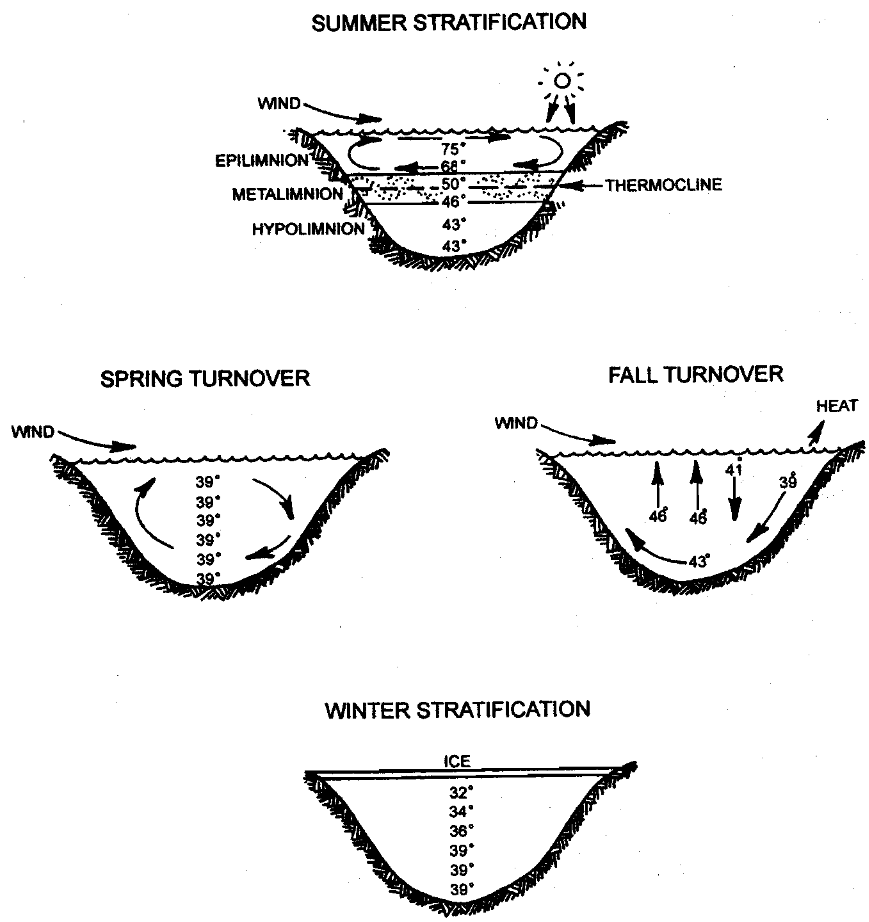
relatively warmer water below. The colder water sinks and mixes under wind action until the entire column of water is of uniform temperature. This process is known as "fall turnover" and is illustrated in the November profiles in Figure 2.

When the water temperature drops to the point of maximum water density, 39.2°F, the water at the lake surface becomes denser than the now warmer, less dense bottom water of the lake, and "sinks" to the bottom. Eventually, the water column is cooled to the point where the surface water, cooled to about 32°F and now lighter than the bottom water which remains close to 39°F, become ice, covering the surface of the lake and isolating it from the atmosphere for a period of up to four months, as illustrated in the February profiles in Figure 2. Winter stratification occurs as the colder, lighter waters and ice remain at the lake surface, now separated from the relatively warmer, heavier water near the bottom of the lake.

Spring brings a reversal of this process. As the ice thaws, and the upper layers of water warm, they again become more dense and begin to approach the temperature of the warmer, deeper water until the entire water column reaches the same temperature from surface to bottom. This is referred to as "spring turnover" and usually occurs within weeks after the ice goes out, as illustrated by the April profiles in Figure 2. After spring turnover, the

Figure 3

THERMAL STRATIFICATION OF LAKES




*Source: University of Wisconsin-Extension and SEWRPC.*

waters at the surface again warm and become lighter, causing them to float above the colder, deeper water. Wind and resulting waves carry some of the energy of the warmer, lighter water to lower depths, but only to a limited extent. Thus begins the formation of the thermocline and another period of summer thermal stratification.

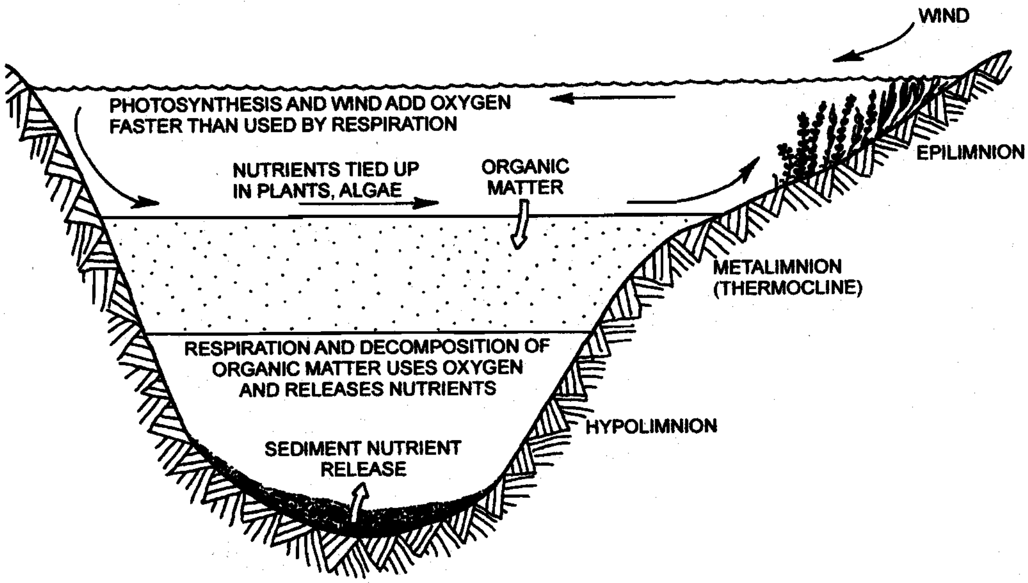
## Dissolved Oxygen

Dissolved oxygen levels are one of the most critical factors affecting the living organisms of a lake ecosystem. As shown in Figure 2, dissolved oxygen levels were generally higher at the surface of Delavan Lake, where there was an interchange between the water and the atmosphere, stirring by wind action, and production of oxygen by plant photosynthesis. Dissolved oxygen levels were lowest at the bottom of the Lake, where decomposer organisms and chemical oxidation processes, collectively known as biochemical oxygen demand or BOD, utilized oxygen in the decay process.

When any lake becomes thermally stratified, as described above, the surface supply of dissolved oxygen to the hypolimnion is cut off. Gradually, if there is not enough dissolved oxygen to meet the total demands from the

Figure 4

LAKE PROCESSES DURING SUMMER STRATIFICATION




*Source: University of Wisconsin-Extension and SEWRPC.*

decaying material, the dissolved oxygen levels in the bottom waters may be reduced, even to zero, a condition known as anoxia or anaerobiasis.

The hypolimnion of Delavan Lake became anoxic during summer stratification. During the period from 1972 through 1991, prior to the alum treatment, dissolved oxygen levels at the bottom of Delavan Lake commonly fell to zero or to near zero during the summer months, as shown in Table 9 and Figure 2. Similar conditions were seen during much of the period from 1991 through 1999, following the alum treatment, as shown in Table 10 and Figure 2. For example, by mid-June 1999, dissolved oxygen concentrations dropped to below five milligrams per liter (mg/l), or the minimum level necessary to support many species of fish, at a depth of approximately 26 feet, with concentrations decreasing to near zero at about 42 feet, as shown in Figure 2. Figure 2 also shows that by mid-July, dissolved oxygen concentrations dropped below five mg/l at a depth of approximately 21 feet and decreased to zero at a depth of approximately 30 feet.

Fall overturn, between September and October in most years, naturally restores the supply of oxygen to bottom waters, although hypolimnetic anoxia can be reestablished during the period of winter stratification. Winter anoxia is more common during years of heavy snowfall, when snow covers the ice, reducing the degree of light penetration and reducing algal photosynthesis that takes place under the ice. In Delavan Lake, hypolimnetic dissolved oxygen concentrations were generally low during the winter, as shown in Tables 9 and 10. This condition may result in fish winterkills if the supply of dissolved oxygen in the water is not sufficient to meet the total winter demand. Epilimnetic dissolved oxygen levels during the winter in the Lake were found to be adequate for the support of fish throughout the winter. At the end of winter, dissolved oxygen concentrations in the bottom waters of the Lake are restored during the period of spring turnover, which generally occurs between March and May in most years.

Hypolimnetic anoxia is common in many of the lakes in Southeastern Wisconsin during summer stratification. The depleted oxygen levels in the hypolimnion cause fish to move upward, nearer to the surface of the lake, where higher dissolved oxygen concentrations exist. This migration, when combined with temperature, can select against some fish species that prefer the cooler water temperatures that generally prevail in the lower portions of lakes. When there is insufficient oxygen at these depths, these fishes are susceptible to summer-kills, or, alternatively, are driven into the warmer water portions of the lake where their condition and competitive success may be severely impaired.

In addition to these biological consequences of hypolimnetic anoxia, the lack of dissolved oxygen at depth can enhance the release of nutrients, especially phosphorus, and some salts into the water column from the sediments. For example, sediment-water exchange of elements such as phosphorus, iron and manganese is increased under anaerobic conditions, resulting in higher hypolimnetic concentrations of these elements, as illustrated in Figure 4. Under anaerobic conditions, iron and manganese change oxidation state to assume more soluble forms, enabling the release of phosphorus from the iron and manganese complexes to which they were bound under aerobic conditions. This phenomenon is apparent in the pH and specific conductance profiles for Delavan Lake shown in Figure 5. This "internal loading" can affect water quality significantly if these nutrients are mixed into the epilimnion, especially during early summer, when these nutrients can become available for algal or plant growth.

**Specific Conductance**
Specific conductance is an indicator of the concentration of dissolved solids in the water; as the amount of dissolved solids increases, the specific conductance increases. During periods of thermal stratification, specific conductance can increase at the lake bottom due to an accumulation of dissolved materials in the hypolimnion, referred to as "internal loading." This phenomenon was noticeable in Delavan Lake during both summer and winter stratification, and was most pronounced between mid-December and mid-March, as shown in Tables 9 and 10 and Figure 5. Table 10 also shows that the specific conductance of surface waters of Delavan Lake during the period from 1991 through 1999 ranged from 489 to 625 microSiemens per centimeter (µS/cm) at 25°C. Significant surface to bottom conductivity gradients were observed during periods of summer and winter thermal stratification. The range of specific conductance in Delavan Lake at depths below 45 feet was 558 and 920 µS/cm. Mean values and maxima of specific conductance in Delavan Lake have increased since the alum treatment in 1991; however; this may not represent a significant change as the means and ranges for dissolved solids are similar for the pre-treatment and post-treatment periods, as shown in Tables 9 and 10.

**Hydrogen Ion Concentration (pH)**
The pH is a logarithmic measure of hydrogen ion concentration on a scale of 0 to 14 standard units, with 7 indicating neutrality. A pH above 7 indicates basic (or alkaline) water, a pH below 7 indicates acidic water. In Delavan Lake, the pH was found to range between 6.9 and 10.2 standard units, as shown in Tables 9 and 10 and in Figure 5. These values are within the normal range of lakes in Southeastern Wisconsin,[5] and the range in values is similar to that reported before the alum treatment, as shown in Table 9. Since Delavan Lake has a high alkalinity, or buffering capacity, the pH does not fluctuate much below 7 and the Lake is not susceptible to the harmful effects of acidic deposition.

**Chloride**
Chloride concentrations in Delavan Lake ranged from 54 to 68 mg/l during spring, as shown in Table 10. These concentrations appear to be somewhat higher than the chloride concentrations reported prior to 1991, as shown by comparison of the data in Table 10 with those in Table 9, and are higher than the values reported during the 1960s and 1970s.[6] This suggests that the concentration of chloride may be increasing in Delavan Lake, possibly

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[5]*Richard A. Lillie and John W. Mason, Wisconsin Department of Natural Resources Technical Bulletin No. 138,* Limnological Characteristics of Wisconsin Lakes, *1983.*

[6]Ibid.

**Figure 5**

**SPECIFIC CONDUCTANCE AND pH PROFILES FOR DELAVAN LAKE: 1986-1999**

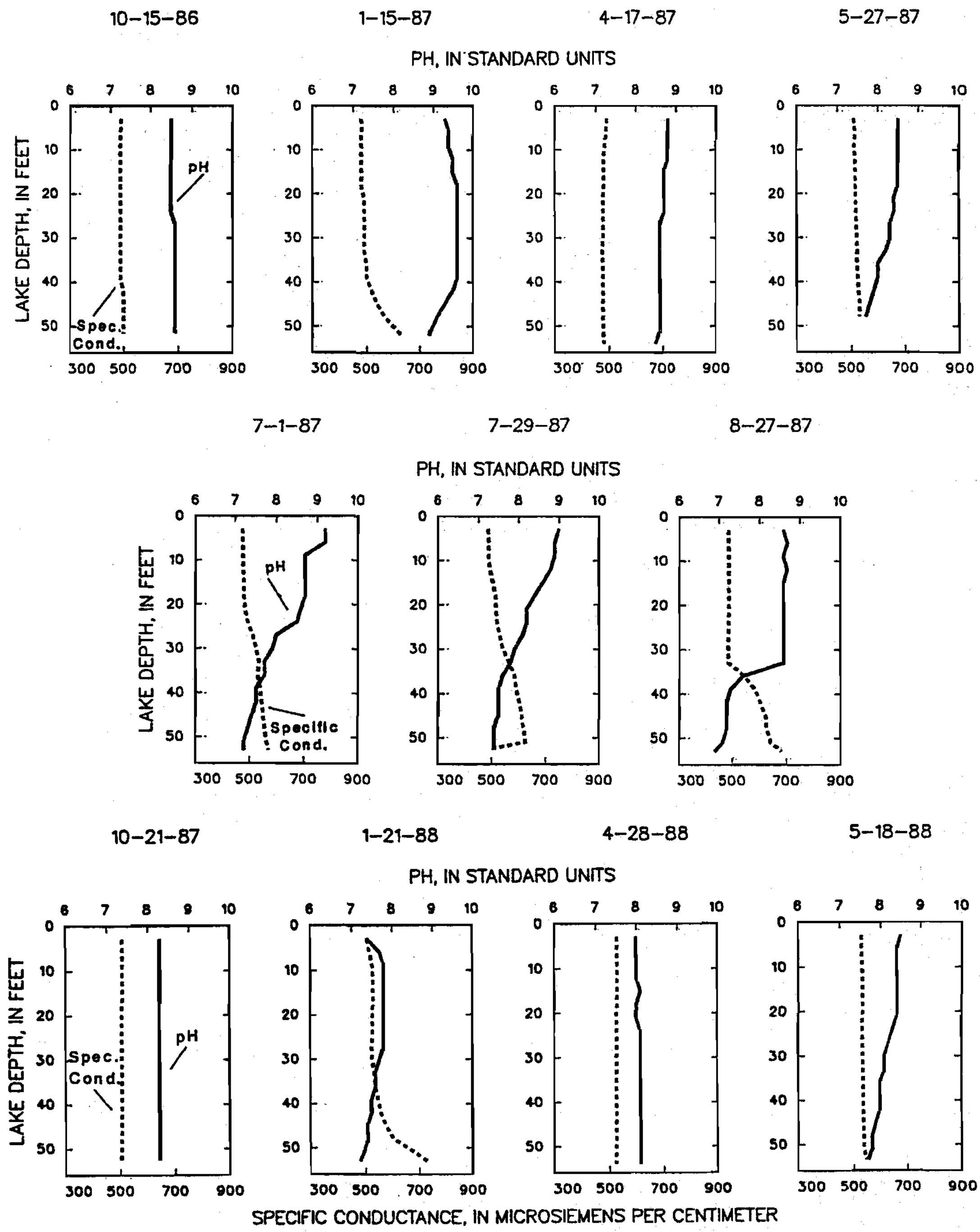


**Figure 5 (continued)**

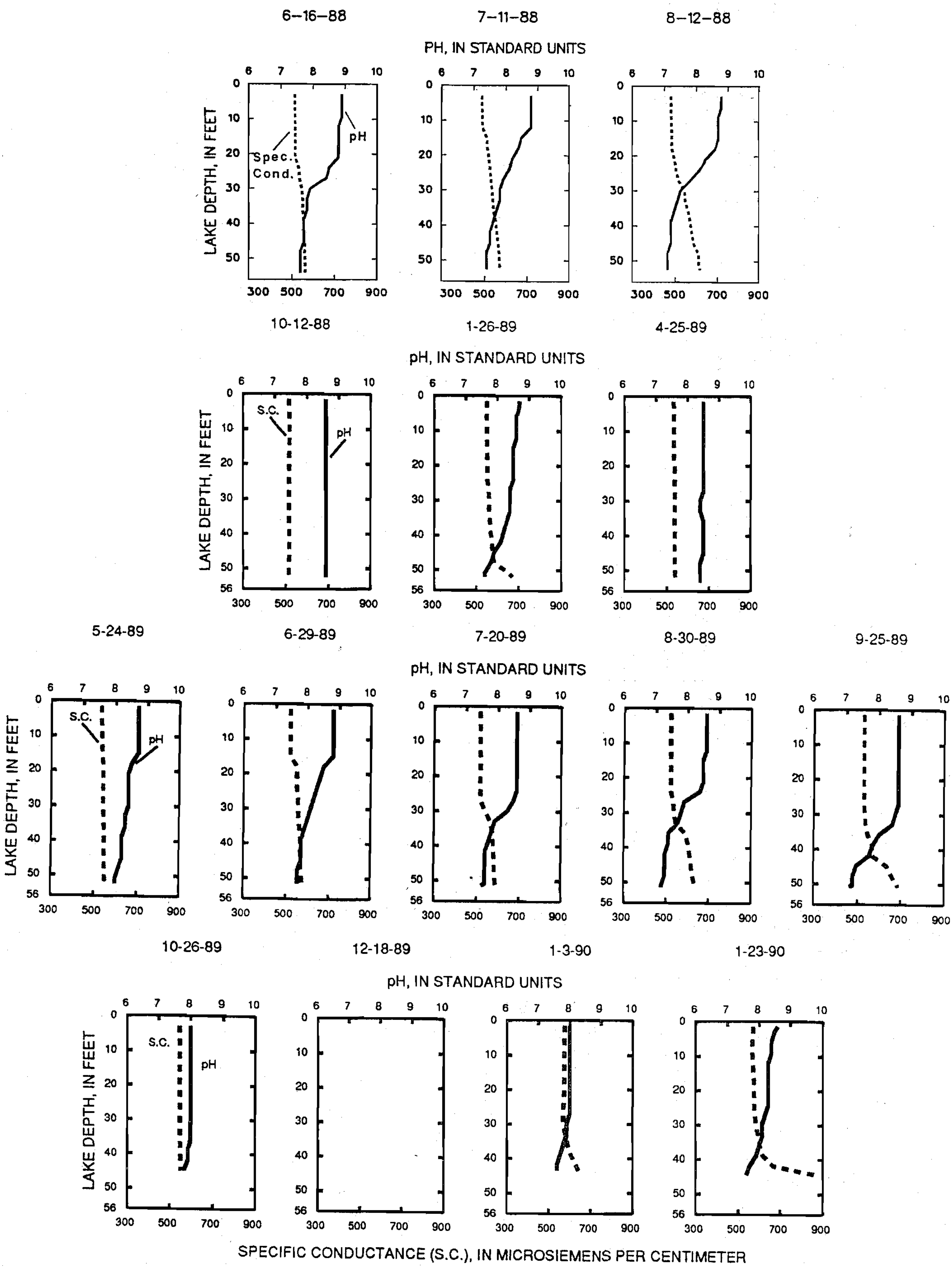


**Figure 5 (continued)**

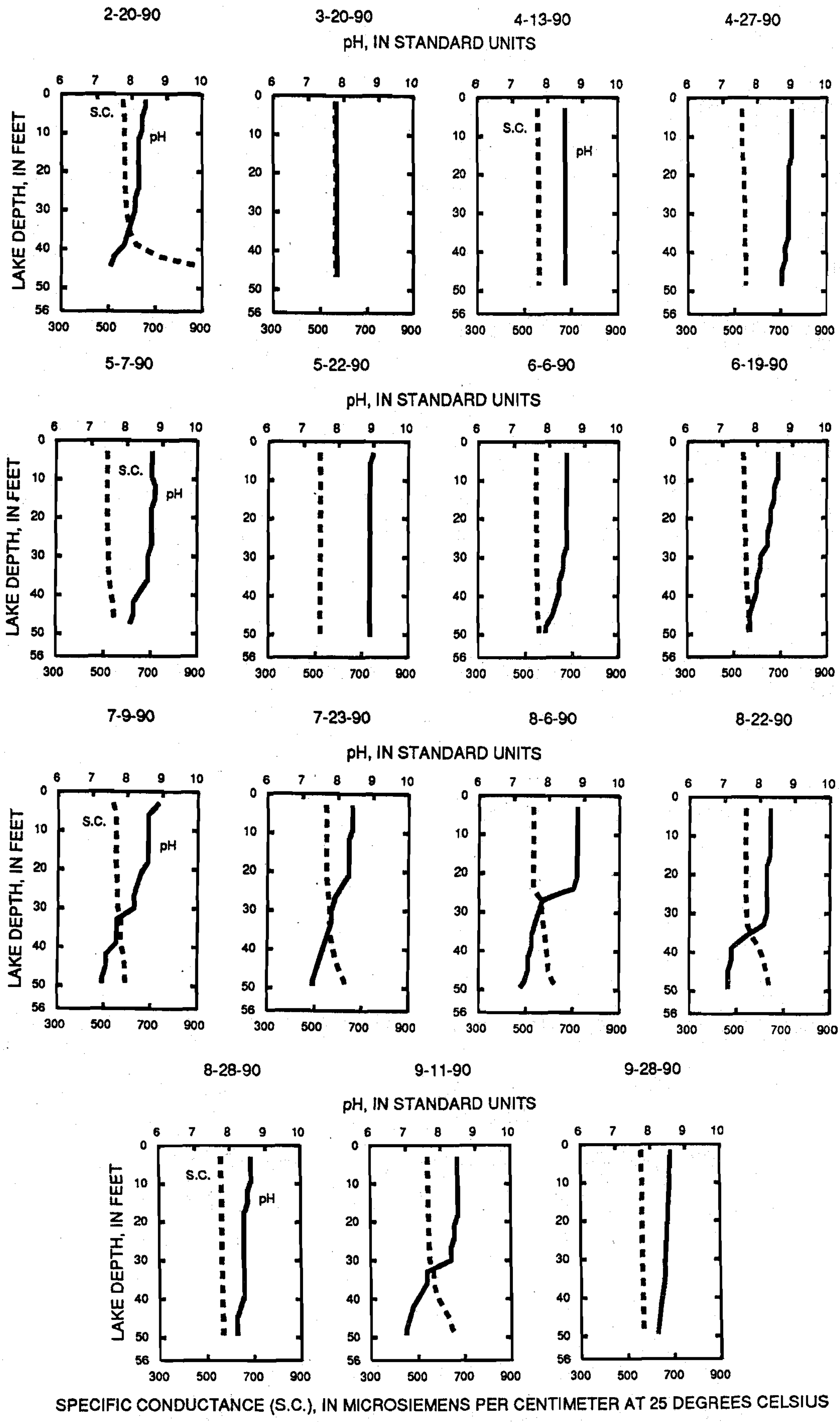


**Figure 5 (continued)**

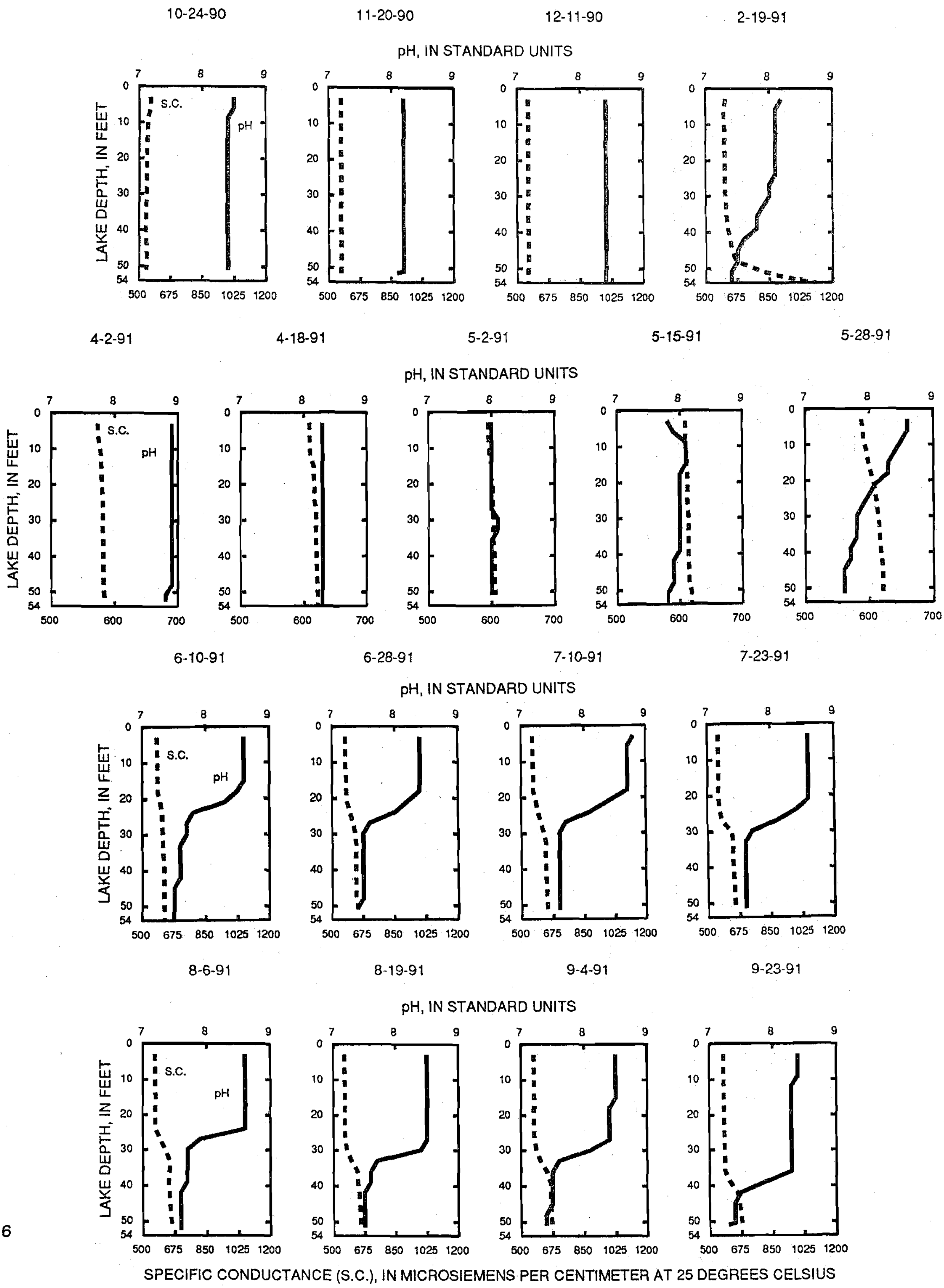


**Figure 5 (continued)**

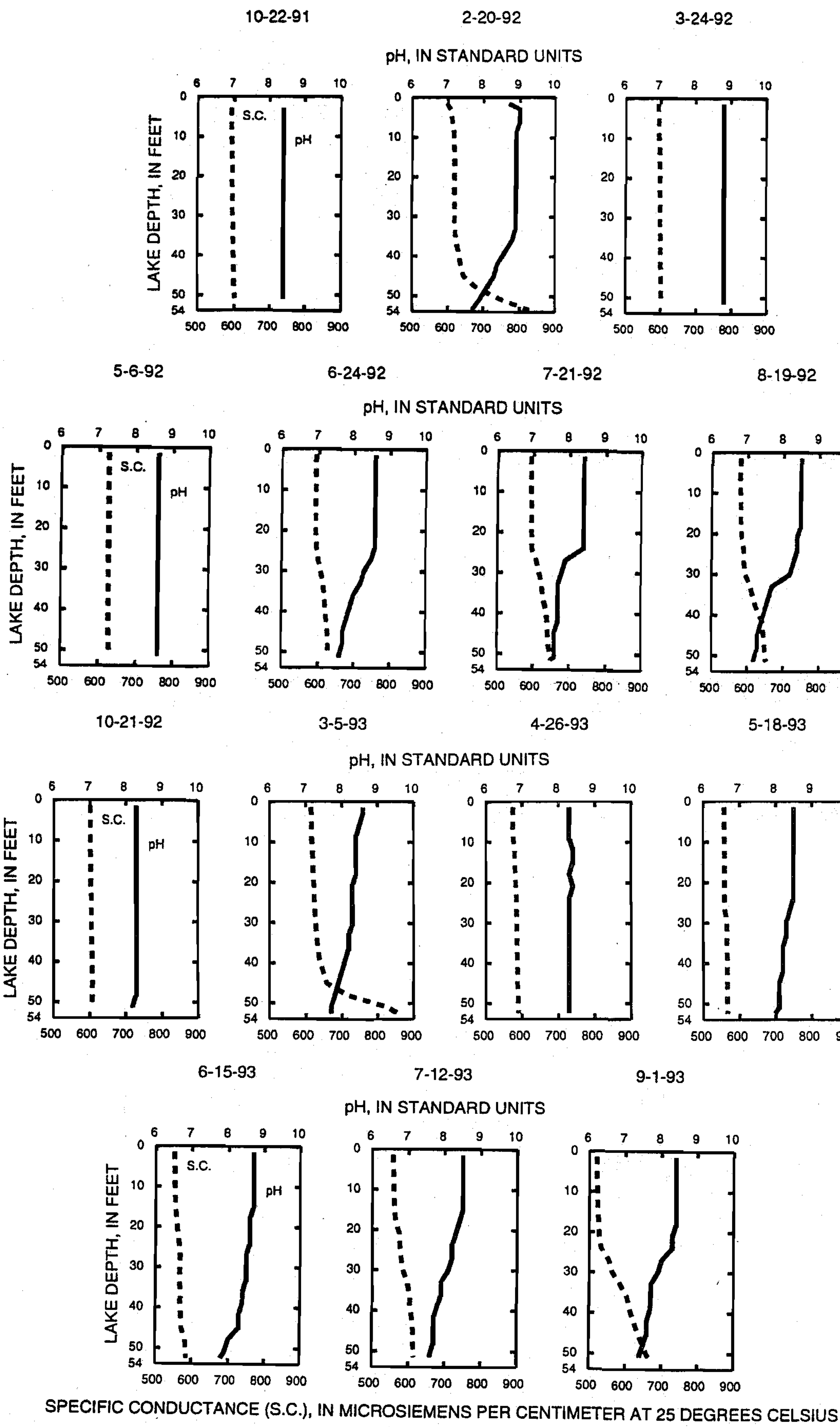


**Figure 5 (continued)**

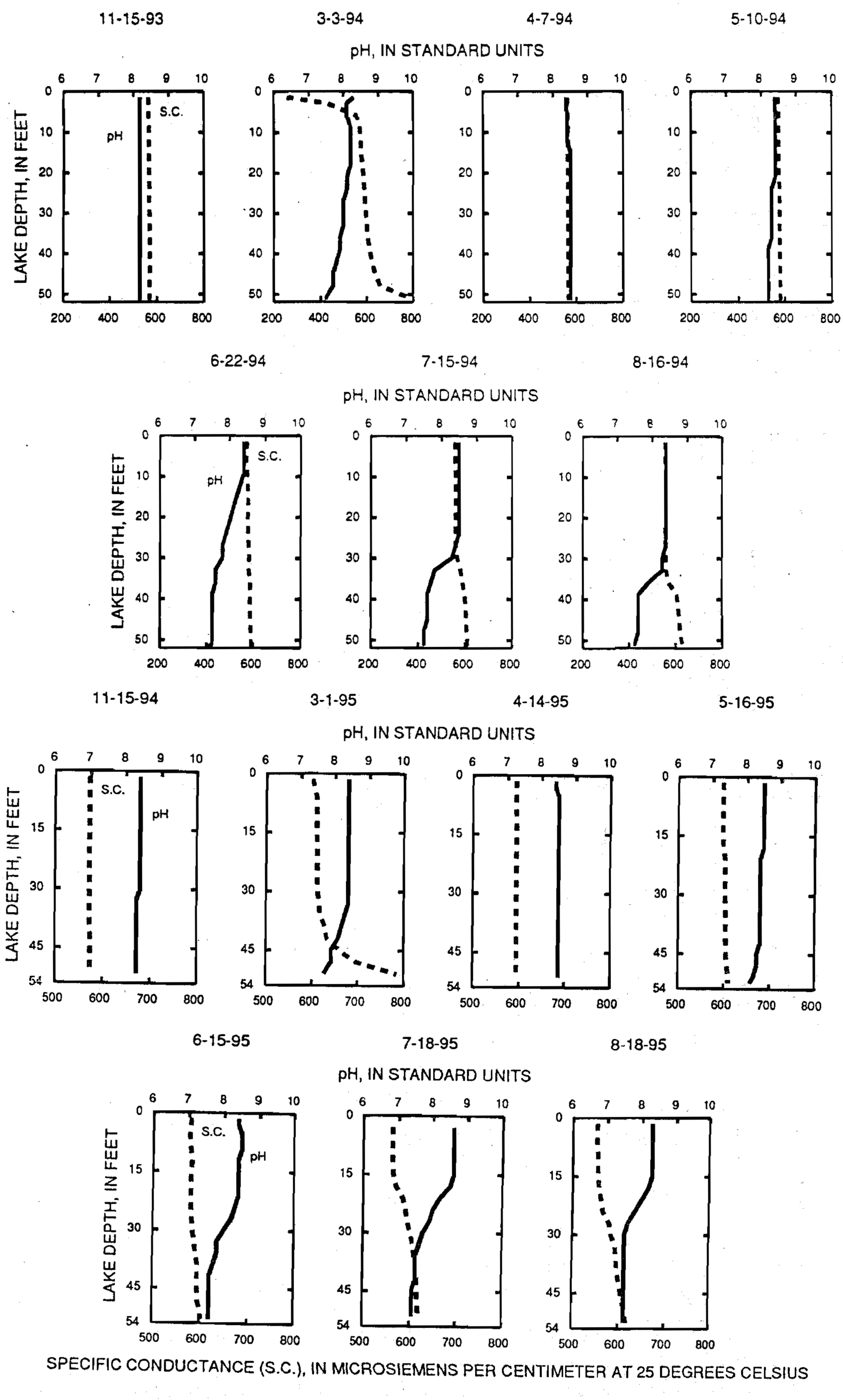


**Figure 5 (continued)**

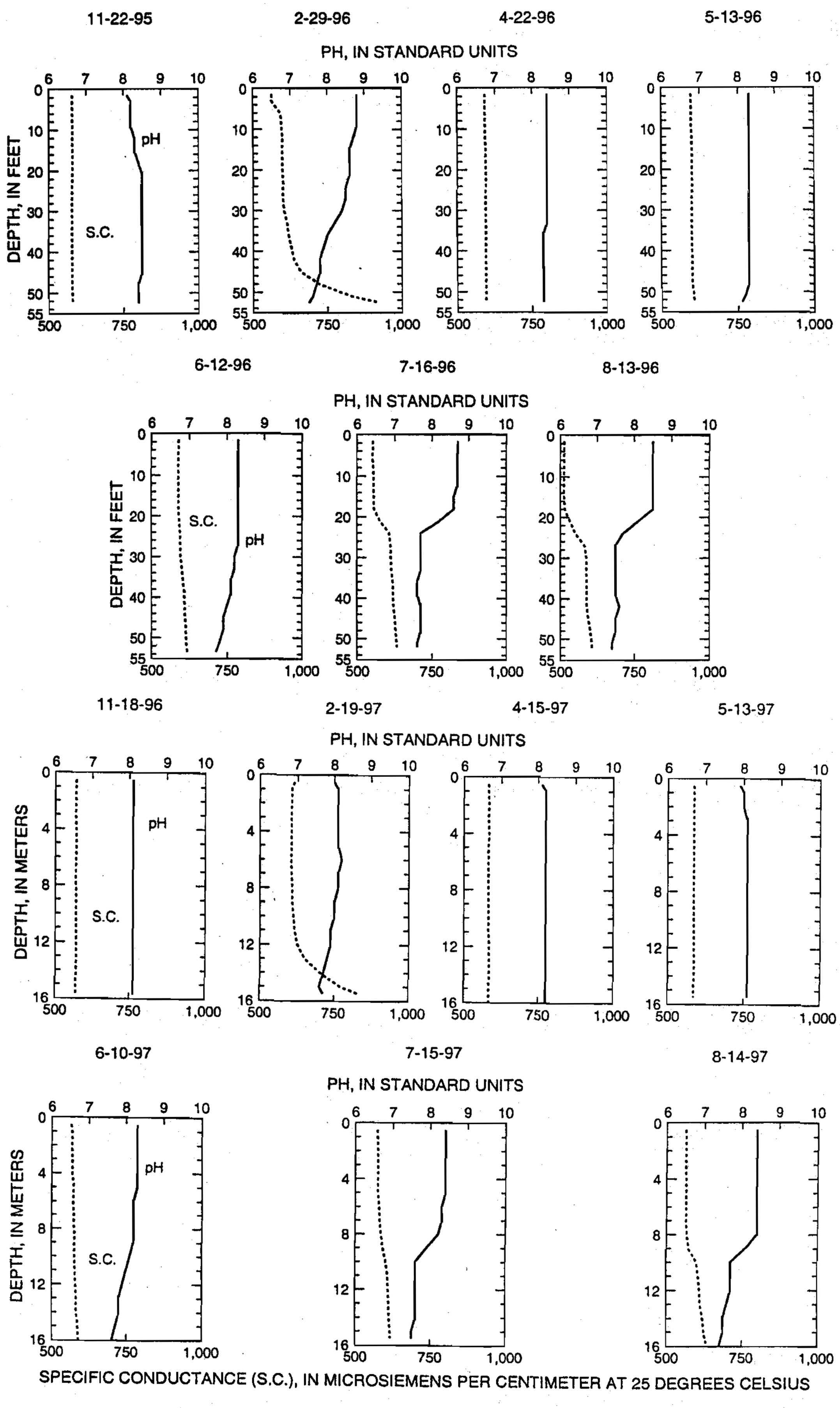


**Figure 5 (continued)**

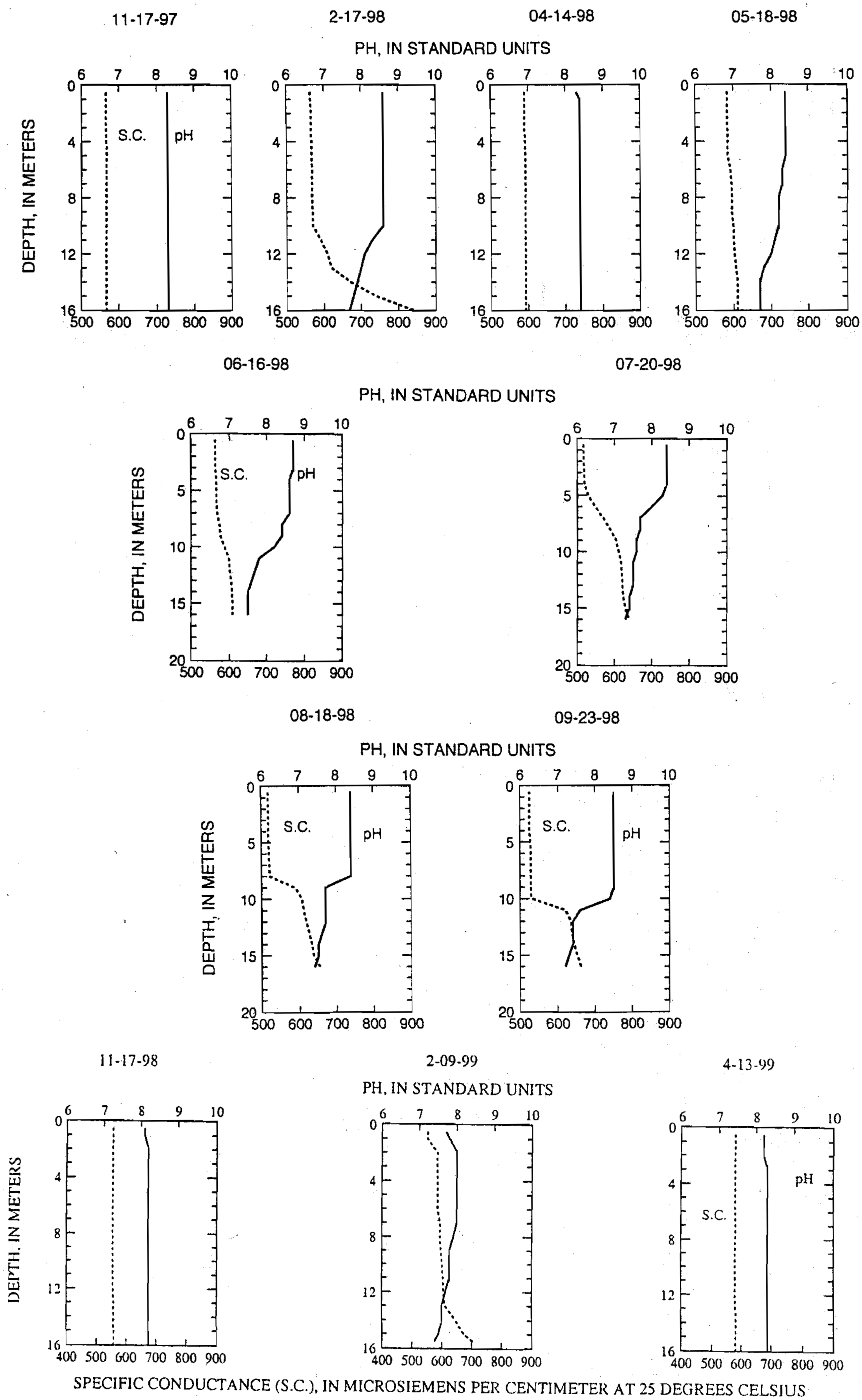
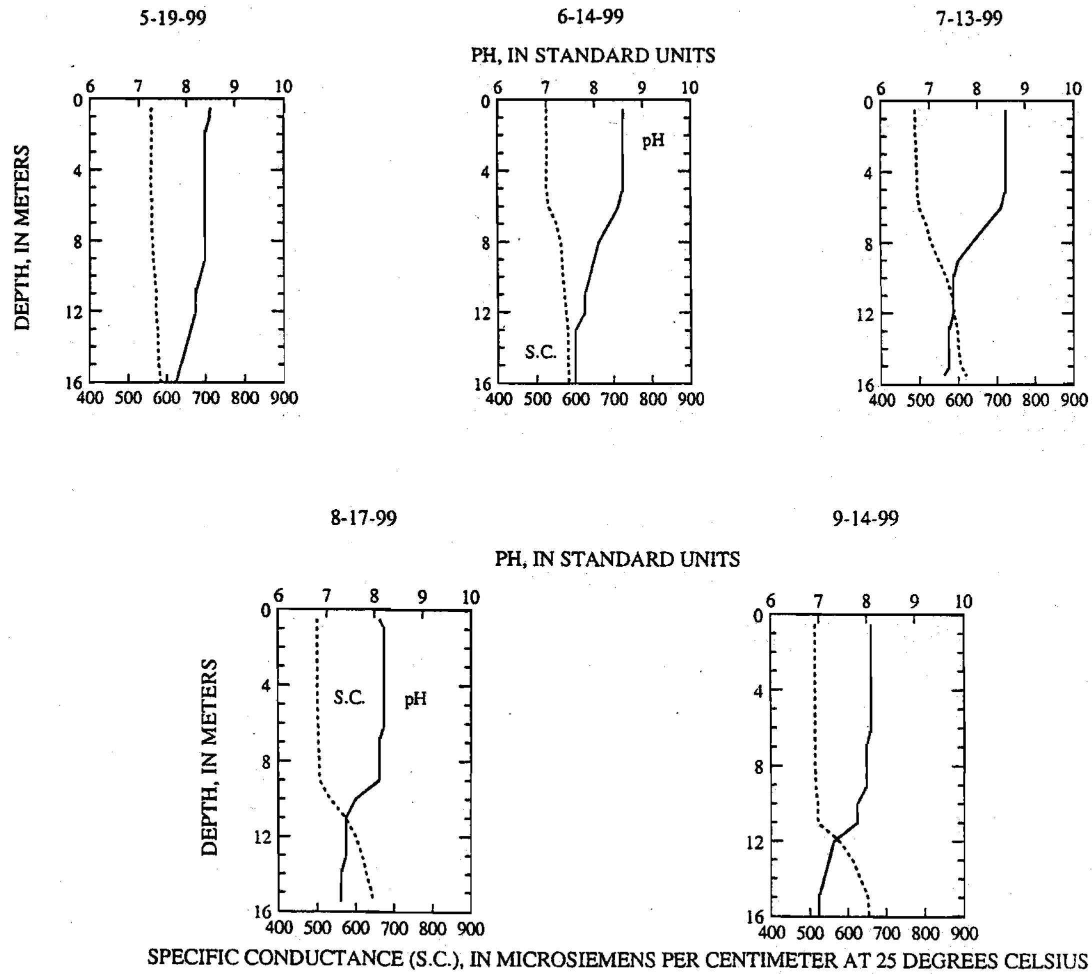


**Figure 5 (continued)**




*Source: U.S. Geological Survey.*

due to anthropogenic inputs. The most important anthropogenic source of chlorides is believed to be the salts used on streets and highways for winter snow and ice control. The mean concentrations measured in Delavan Lake were slightly above the normal range of lakes in Southeastern Wisconsin.[7]

**Alkalinity and Hardness**

Alkalinity is an index of the buffering capacity of a lake, or the capacity of a lake to absorb and neutralize acids. The alkalinity of a lake depends on the levels of bicarbonate, carbonate, and hydroxide ions present in the water. Lakes in Southeastern Wisconsin typically have a high alkalinity because of the types of soil covering, and the bedrock underlying, the watersheds. In contrast, water hardness is a measure of the multivalent metallic ions, such as calcium and magnesium, present in the lake. Hardness is usually reported as an equivalent concentration of

[7]Ibid.

calcium carbonate ($CaCO_3$). Applying these measures to the Delavan Lake, the Lake may be classified as an hard-water alkaline lake. During the spring, alkalinity averaged 186 mg/l, while hardness averaged 244 mg/l, as listed in Table 10. These values were within the normal range of lakes for Southeastern Wisconsin.[8]

**Water Clarity**

Water clarity, or transparency, provides an indication of overall water quality; clarity may decrease because of turbidity caused by high concentrations of suspended materials, such as algae and zooplankton, or because of color caused by high concentrations of dissolved organic substances. Water clarity is measured with a Secchi disk, an eight-inch-diameter, black-and-white disk, which is lowered into the water until a depth is reached at which the disk is no longer visible. This depth is known as the "Secchi disk reading." Such readings comprise an important part of the Wisconsin Department of Natural Resources Self-Help Monitoring Program in which citizen volunteers assist in lake water quality monitoring efforts.

Water clarity generally varies throughout the year as algal populations increase and decrease, and as the amount of inorganic suspended material and humic coloration vary, in response to changes in weather conditions and nutrient loadings. These same factors make Secchi-disk readings vary from year to year as well. Before the alum treatment in 1991, Secchi disk readings for Delavan Lake were between about two and 25 feet, with an average of about eight feet. Greatest water clarity was reported during winter, and water clarity was least during summer, as shown in Table 9. These values indicated very poor to excellent water quality compared to other lakes in Southeastern Wisconsin.[9] The average value indicated fair to good water quality conditions. Subsequent to the alum treatment, Secchi disk readings for the Lake have generally ranged from about two to 35 feet, with an annual average of about 14 feet. Water clarity was least during the summer months, as shown in Table 10. While these values also indicate a range from very poor to excellent water quality, the average value indicates very good water quality, which is much improved from the pre-1991 measurements.

**Chlorophyll-*a***

Chlorophyll-*a* is the major photosynthetic ("green") pigment in algae. The amount of chlorophyll-*a* present in the water is an indication of biomass or amount of algae in the water. Before the alum treatment in 1991, chlorophyll-*a* concentrations in Delavan Lake ranged from a low below 0.1 micrograms per liter (µg/l) to a high of 300 µg/l. These values were within the range of chlorophyll-*a* concentrations recorded in other lakes in the Region[10] and indicated excellent to very poor water quality, depending upon the season. Peak concentrations, or algal blooms, occurred during winter and summer periods, as shown in Table 9. The average value prior to the alum treatment was about 20 µg/l, and indicative of poor water quality. Following the alum treatment, chlorophyll-*a* concentrations ranged from 0.01 µg/l to 37.6 µg/l, as shown in Table 10. The peak concentration occurs during summer. These values are indicative of excellent to very poor water quality. The average value following the alum treatment was about 4 µg/l and indicative of very good water quality.

**Nutrient Characteristics**

Aquatic plants and algae require such nutrients as phosphorus, nitrogen, carbon, calcium, chloride, iron, magnesium, sulfur, and silica for growth. In hard-water alkaline lakes, most of these nutrients are generally found in concentrations that exceed the needs of growing plants. However, in lakes where the supply of one or more of these nutrients is limited, plant growth is limited by the amount of that nutrient available. Two of the most important nutrients, in this respect, are phosphorus and nitrogen.

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[8]Ibid.

[9]Ibid.

[10]Ibid.

The ratio of total nitrogen to total phosphorus in lake water, or the N:P ratio, can indicate which nutrient is likely to be limiting plant growth. A nitrogen-to-phosphorus ratio of greater than 14 to 1 indicates that phosphorus is probably the limiting nutrient, while a ratio of less than 10 to 1 indicates that nitrogen is probably the limiting nutrient.[11] As shown in Table 11, the nitrogen-to-phosphorus ratios in samples collected from Delavan Lake during the period from 1984 through 1999 were usually between 10 and 16. This suggests that plant production was at some times limited by phosphorus and at other times was limited by nitrogen. At 92, the N:P ratio in the sample from 1992 was an exception to this general trend. The N:P ratio during that year was significantly higher due to the removal of phosphorus from the water column following the alum treatment of the Lake in 1991. During that year, plant production was most likely extremely limited by the lack of availability of phosphorus in the water column. By the following year, the N:P ratio had declined to a level similar to that seen prior to the alum treatment. Other factors, such as light, turbulence, and through-flow, may also limit plant growth, and these factors are considered further below.

Both total phosphorus and soluble phosphorus concentrations were measured for Delavan Lake. Soluble phosphorus, being dissolved in the water column, is readily available for plant growth. However, its concentration can vary widely over short time periods as plants take up and release this nutrient. Therefore, total phosphorus is usually considered a better indicator of nutrient status. Total phosphorus includes the phosphorus contained in plant and animal fragments suspended in the lake water, phosphorus bound to sediment particles, and phosphorus dissolved in the water column.

The Southeastern Wisconsin Regional Planning Commission recommends that total phosphorus concentrations in lakes not exceed 0.020 mg/l during the period of spring mixing, or turnover. This is the level considered necessary to prevent nuisance algal and macrophyte growths. During the study years, the total spring phosphorus concentrations in Delavan Lake were generally greater than 0.020 mg/l, as shown in Tables 9 and 10. Prior to the 1991 alum treatment, the total phosphorus in the surface waters of Delavan Lake in the spring averaged about 0.100 mg/l, as shown in Table 9, while following the alum treatment, the average total phosphorus concentration in the surface waters of Delavan Lake was about 0.060 mg/l, as shown in Table 10.

Total phosphorus concentrations were found to be higher in the bottom waters of the Lake prior to the alum treatment, ranging from 0.092 mg/l to 1.500 mg/l, as shown in Table 9. Following the alum treatment, these concentrations were reduced to between 0.007 mg/l and 1.017 mg/l, as shown in Table 10. Average spring bottom water total phosphorus concentrations in Delavan Lake before and after the alum treatment were 0.174 mg/l and 0.098 mg/l, respectively.

The occurrence of higher concentrations of phosphorus in the bottom waters of a lake reflects the influence of biotic production of the distribution of the nutrient within the water column. When aquatic organisms die, they usually sink to the bottom of the lake, where they are decomposed. Phosphorus from these organisms is then either stored in the bottom sediments or rereleased into the water column. Because phosphorus is not highly soluble in water, it readily forms insoluble precipitates with calcium, iron, and aluminum under aerobic conditions and accumulates, predominantly, in the lake sediments. If the bottom waters become depleted of oxygen during stratification, however, certain chemical changes occur, especially the change in the oxidation state of iron from the insoluble $Fe^{3+}$ state to the more soluble $Fe^{2+}$ state. The effect of these chemical changes is that phosphorus becomes soluble and is more readily released from the sediments. This process also occurs under aerobic conditions, but generally at a slower rate than under anaerobic conditions. As the waters mix, especially during spring and fall turnovers, this phosphorus can be widely dispersed throughout the lake and become available for algal growth.

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

Table 11

NITROGEN:PHOSPHORUS RATIOS FOR DELAVAN LAKE: 1984-1999

| Date | Nutrient Levels | | |
|---|---|---|---|
| | Nitrogen (mg/l) | Phosphorus (mg/l) | N:P Ratio |
| April 17, 1984 | 2.00 | 0.150 | 13 |
| April 3, 1985 | 2.10 | 0.150 | 14 |
| April 13, 1990 | 2.50 | 0.153 | 16 |
| March 24, 1992 | 1.70 | 0.019 | 92 |
| April, 26,1993 | 0.70 | 0.055 | 13 |
| March 1, 1995 | 1.10 | 0.090 | 12 |
| April 22, 1996 | 0.70 | 0.071 | 10 |
| April 15, 1997 | 0.88 | 0.054 | 16 |
| April 14, 1998 | 0.97 | 0.086 | 11 |
| April 13, 1999 | 1.00 | 0.065 | 15 |

*Source: Wisconsin Department of Natural Resources, U.S. Geological Survey, and SEWRPC.*

The 1991 through 1999 data indicated that there was internal loading of phosphorus from the bottom sediments of Delavan Lake. As shown in Table 10, the dissolved phosphorus concentrations in the bottom waters were often relatively high, ranging from 0.001 mg/l to 0.804 mg/l for samples collected during the summer, when such releases of phosphorus are most likely to occur. In addition, at certain times of the year, phosphorus appears to be released from the sediment in the inlet, while at other times the inlet sediments may be acting to store phosphorus. Based upon the studies conducted during 1994,[12,13] the movement of phosphorus form the inlet sediments as a consequence of both chemical and biological processes would appear to contribute phosphorus to the Lake during the summer months. The mass of phosphorus mobilized during the summer is estimated to be sufficient to form a significant portion of the phosphorus load entering Delavan Lake from the inlet.[14] Further, as shown in Table 12, U.S. Geological Survey staff estimated that internal loading contributed about 11,000 pounds, or more than one-half of the total phosphorus load to Delavan Lake, during 1998. Thus, the potential contribution of phosphorus to the water column from the bottom waters of Delavan Lake may be considered significant in terms of the total phosphorus load. However, under "normal" conditions, the majority of the phosphorus released from the Lake sediments is generally returned to the Lake sediments as the iron is oxidized at the time of the autumn turnover.

## CHARACTERISTICS OF BOTTOM SEDIMENT

The substrate characteristics of Delavan Lake were assessed at four depths along 25 transects by Aron & Associates during an aquatic plant survey conducted during 1992.[15] This survey augmented a previous survey of the entire lake bottom conducted by the U.S. Geological Survey conducted during the 1980s. The sediment distribution is shown on Map 5 in Chapter II of this report. Throughout most of the Lake, the nearshore sediments were found to consist almost entirely of muck. There are several exceptions to this. The sediment in the northern portion of the lake basin was reported to consist of sand, sand and marl, and sand and silt, becoming muck at depths of greater than 20 feet. Much of the southeastern shoreline, to the inlet of the small tributary, was reported to consist of rock down to about 45 feet. Southwest of this latter portion of the shoreline, the sediment at depths of less than 10 feet was reported to consist of a combination of sand, sand and marl, sand and silt, and sand and gravel. Much of the substrate of the southern embayment was reported to consist of sand. The substrate along the head of the peninsula between the two bays situated at the southwestern end of the main lake basin was reported to consist of rock. Adjacent to this was an area of silt. The sediment along the northwestern shore was reported to

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[12]*D.M. Robertson, S.J. Field, J.F. Elder, G.L. Goddard and W.F. James*, Phosphorus Dynamics in Delavan Lake Inlet, Southeastern Wisconsin, 1994, *U. S. Geological Survey Water-Resources Report 96-4160, 1996.*

[13]*W.F. James, C.S. Smith, J.W. Barko, and S.J. Field,* Direct and Indirect Influences of Aquatic Macrophyte Communities on Phosphorus Mobilization from Littoral Sediments of an Inlet Region in Lake Delavan, Wisconsin, *U. S. Army Corps of Engineers, Technical Report W-95-2, September 1995.*

[14]*D.M. Robertson,* et. al., op. cit.

[15]*Aron & Associates, letter received April 28,1999.*

Table 12

ESTIMATED PHOSPHORUS LOADINGS TO DELAVAN LAKE: 1972-1998

| Year | Loading from Tributary Area, Excluding Direct Drainage (pounds) | Total Groundwater Loading[a] (pounds) | Total Atmospheric Loading[a] (pounds) | Direct Drainage[a] (pounds) | Internal Loading (summer) (pounds) | Total Loading (pounds) | Percent Internal Loading | Percent Average Year Internal Loading[b] |
|---|---|---|---|---|---|---|---|---|
| 1972 | - - | - - | - - | - - | 8,800 | - - | - - | 48 |
| 1984 | 7,800 | 250 | 240 | 1,000 | 11,000 | 20,300 | 54 | 54 |
| 1995 | 5,200 | 250 | 240 | 1,000 | 5,500 | 12,200 | 45 | 37 |
| 1996 | 8,700 | 250 | 240 | 1,000 | 5,000 | 15,200 | 33 | 35 |
| 1997 | 6,000 | 250 | 240 | 1,000 | 6,200 | 13,700 | 45 | 40 |
| 1998 | 5,500 | 250 | 240 | 1,000 | 10,700 | 17,700 | 60 | 53 |

[a]*Estimated by: S.J. Field and M.D. Duerk,* Hydrology and Water Quality of Delavan Lake in Southeastern Wisconsin. *U.S. Geological Survey Water-Resources Investigations Report 87-4168.*

[b]*Total tributary loading in an average year (1984-1997) was about 7,700 pounds.*

*Source: U.S. Geological Survey and SEWRPC.*

consist of patches of sand, sand and silt, sand and marl, sand and gravel, and gravel, while the sediments in the inlet and outlet areas was reported to consist almost entirely of muck.

Analyses of the upper four inches of sediment cores from three locations in the inlet were conducted by the Wisconsin Department of Natural Resources to determine the levels of phosphorus in the surfacial sediments. The mean phosphorus concentrations from these locations were found to be 1,392 milligrams per kilogram (mg/kg).[16] According to the U.S. Environmental Protection Agency classification system for sediments, phosphorus concentrations greater than 650 mg/kg are indicative of "heavily polluted"[17] lakes. In Delavan Lake, this indicator was more than twice this threshold value.

Ammonia-nitrogen concentrations in the lake sediments were reported to range from 111 mg/kg to 147 mg/kg. Organic nitrogen fractions, reported as total Kjeldahl nitrogen in Table 13, ranged from 1,530 mg/kg to 3,570 mg/kg; nitrate nitrogen concentrations in the sediment were at or about the level of detection; and nitrate nitrogen concentrations were reported to be about 0.4 mg/kg. The ammonia nitrogen concentrations reported were in excess of the Wisconsin Department of Natural Resources lowest effect level (LEL) guidelines of 75 mg/kg, shown in Table 14.

Copper, the active ingredient in many algicides, may accumulate in the bottom sediments. Excessive levels of copper have been found to be toxic to fish and benthic organisms, but have rarely been found to be harmful to humans.[18] The accumulation of copper within the sediments of Delavan Lake has been reported,[19] with peak concentrations of copper being found to be about 45 mg/kg, as shown in Table 15. This concentration was found

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[16]*W.F. James,* et. al., op cit.

[17]*U.S. Environmental Protection Agency, Guidelines for the Pollutional Classification of Great Lakes Harbor Sediment, 1977.*

[18]*Jeffrey A. Thornton and Walter Rast, "The Use of Copper and Copper Compounds as Algicides," in H. Wayne Richardson,* Handbook of Copper Compounds and Applications, *Marcel Dekker, New York, 1997, pp. 123-142.*

[19]*R.S. Wakeman,* The Preservation of Historical Copper Loadings in the Recent Sedimentary Record of a Hardwater Lake in Southeastern Wisconsin, *M.S. Thesis, University of Wisconsin-Milwaukee, 1985.*

Table 13

**CONCENTRATION OF METALS AND NUTRIENTS IN SEDIMENTS IN DELAVAN LAKE: 1968**

| Parameter | Sediment Sample Analytical Results (mg/kg) | | | |
|---|---|---|---|---|
| | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
| Arsenic | 0.7 | 1.8 | 1.6 | 2.1 |
| Copper | 6.0 | 7.0 | 9.0 | 11.0 |
| Ammonia Nitrogen | 119.0 | 147.0 | 126.0 | 111.0 |
| Kjeldahl Nitrogen | 3,340.0 | 2,450.0 | 3,570.0 | 1,530.0 |
| Nitrate Nitrogen | <1.0 | <1.0 | 1.0 | <1.0 |
| Nitrite Nitrogen | 0.4 | 0.4 | 0.4 | 0.3 |
| Oil and Grease | 211.0 | 141.0 | 304.0 | 110.0 |
| Total Solids (percent) | 13.6 | 25.3 | 15.1 | 36.2 |
| Total Organic Carbon | 960.0 | 1,021.0 | 304.0 | 205.0 |

*Source: Swanson Environmental, Inc., and SEWRPC.*

Table 14

**WISCONSIN DEPARTMENT OF NATURAL RESOURCES DRAFT SEDIMENT QUALITY SCREENING CRITERIA[a]**

| Chemical | Lowest Effect Level (LEL) | Medium Effect Level (MEL) | Severe Effect Level (SEL) |
|---|---|---|---|
| Arsenic | 6.00 | 33.0 | 85.0 |
| Copper | 25.00 | 110.0 | 390.0 |
| Lead | 31.00 | 110.0 | 250.0 |
| Mercury | 0.15 | 0.2 | 1.3 |
| Ammonia-Nitrogen | 75.00 | - - | - - |

[a]*Units are in mg/kg—dry sediment.*

*Source: Wisconsin Department of Natural Resources.*

at a depth of about eight inches into the sediment, and corresponds to sediment deposited in about 1962. Copper concentrations from the upper eight inches of the sediment core sample exceed the LEL guidelines of 25 mg/kg proposed by the Wisconsin Department of Natural Resources, as shown in Table 14. Copper concentrations from sediment deeper than about 12 inches were less than those reported in the upper eight inches of sediment, and were within the LEL guidelines proposed by the Wisconsin Department of Natural Resources.[20] The lower copper concentrations found at depth in the sediment are similar to sediment copper concentrations reported from Delavan Lake sediments during the 1960s and shown in Table 13. The higher copper concentrations in the upper portions of the sediment suggest a lack of bioturbation and resuspension, and are consistent with the relatively recent application of copper-based algicides to the Lake, as shown in Table 20 in Chapter V.

Arsenic concentrations varied spatially within the sediments, ranging from 0.7 mg/kg to 2.1 mg/kg. Between 1950 and 1969, about 10,400 pounds of sodium arsenite were applied to Delavan Lake to control aquatic plant growth

[20]*Wisconsin Department of Natural Resources, draft,* Inventory of Statewide Contaminated Sediment Sites and Development of a Prioritization System, *June 1994.*

in the Lake basin, as shown in Table 23 in Chapter V. No applications of sodium arsenite have taken place in the Lake since 1969. Concentrations of arsenic in the lake sediments were reported to be within the guidelines proposed by the Wisconsin Department of Natural Resources and set forth in Table 14.

Table 15

**COPPER CONCENTRATIONS IN SEDIMENTS IN DELAVAN LAKE: 1985**

| Sediment Depth (cm) | Copper Concentration (mg/kg) |
|---|---|
| Surface | 46 |
| 10 | 38 |
| 20 | 45 |
| 30 | 19 |
| 40 | 15 |
| 50 | 10 |

*Source:* *R.S. Wakeman,* The Preservation of Historical Copper Loadings in the Recent Sedimentary Record of a Hardwater Lake in Southeastern Wisconsin, *M.S. Thesis, University of Wisconsin-Milwaukee, 1985; and SEWRPC.*

## POLLUTION LOADINGS AND SOURCES

Currently, there are no known point source discharges of pollutants to Delavan Lake or to surface waters tributary to Delavan Lake. For this reason, the contaminants entering Delavan Lake are from diffused or nonpoint sources. Nonpoint sources of water pollution include both urban sources, such as runoff from residential, commercial, transportation, construction, and recreational activities, and rural sources, such as runoff from agricultural lands and onsite sewage disposal systems. The tributary drainage area of Delavan Lake is about 40.8 square miles in areal extent, including about 12.7 square miles that drain directly to the Lake without passing through the streams tributary to the Lake. About 28.1 square miles drain to the Lake through Jackson Creek and the unnamed tributary streams that form the major surface drainages to the Lake. The Jackson Creek tributary passes through the upstream Mound Road Wetland prior to entering Delavan Lake. The water quality significance of this is related to the retention of phosphorus and sediments within the upstream wetland area, and the potential reduction in loading entering Delavan Lake as a result.

As summarized in Table 12, the U.S. Geological Survey measured sediment and phosphorus loads at several points in the watersheds associated with Delavan Lake during the period between 1990 and 1998. The Petrie Road site is located about one mile upstream of the Mound Road wetland. The Jackson Creek Tributary site is located near the point where Jackson Creek enters the Mound Road wetland. The Mound Road site is located at the point where Jackson Creek flows from the Mound Road wetland into the Delavan Lake inlet upstream of STH 50. The STH 50 site is located near the point at which the inflowing water leaves the inlet and enters the main lake basin. In addition, the U.S. Geological Survey also measured the phosphorus load at the outlet of Delavan Lake, at Borg Road. During 1990, phosphorus loads also were computed for the unnamed tributary entering Delavan Lake at Southshore Drive. These data are further elaborated below.

### Phosphorus Loads

Based upon the measurements reported in Table 12, the U.S. Geological Survey constructed a phosphorus budget for Delavan Lake. As shown in Table 16, the annual phosphorus load contributed to Delavan Lake by external sources during 1984 was calculated to be about 20,000 pounds of phosphorus. This mass of phosphorus is generally greater than that calculated during more recent years. With the exception of 1996, external loadings of phosphorus to Delavan Lake have generally been calculated to range from about 12,000 pounds to 18,000 pounds of phosphorus. Table 17 shows proportions of the external phosphorus loadings contributed by the various land use categories, as estimated by the WILMS model, for both current land use and forecast 2020 conditions.

The foregoing, calculated phosphorus loads were compared to estimated phosphorus loads generated on the basis of land use within the drainage area tributary to Delavan Lake and computed utilizing the Wisconsin Lake Model Spreadsheet (WILMS) version 3.0.[21] The resulting phosphorus loads reported using the model are similar to, but

[21] *Wisconsin Department of Natural Resources Publication No. PUBL-WR-363 96 REV,* Wisconsin Lake Model Spreadsheet, Version 2.00, User's Manual, *June 1994; Version 3.0 is a subsequently refined version of this model.*

### Table 16

### MEASURED TOTAL PHOSPHORUS LOADS AT SELECTED LOCATIONS IN THE DELAVAN LAKE WATERSHED: 1990-1998

| Water Year | Jackson Creek at Petrie Road (pounds) | Jackson Creek Tributary near Elkhorn (pounds) | Jackson Creek at Mound Road (pounds) | Delavan Lake Inlet at Highway 50 (pounds) | Delavan Lake Outlet at Borg Road (pounds) | Delavan Lake Tributary at Southshore Drive (pounds) |
|---|---|---|---|---|---|---|
| 1990 | - -[a] | 1,200 | - -[a] | 6,300 | 2,000 | 1,400 |
| 1991 | - -[a] | 1,200 | - -[a] | 3,900 | 3,000 | - -[a] |
| 1992 | - -[a] | 1,200 | - -[a] | 8,100 | 1,300 | - -[a] |
| 1993 | 6,250[b] | 1,200[b] | - -[a] | - -[a] | 6,900[b] | - -[a] |
| 1994 | 2,700 | 1,300 | 3,300 | 6,000 | 4,000 | - -[a] |
| 1995 | 1,200 | 900 | 2,400 | 4,600 | 1,300 | - -[a] |
| 1996 | - -[a] | 1,700 | 7,400 | 7,800 | 3,300 | - -[a] |
| 1997 | - -[a] | 1,400 | 4,700 | 5,400 | 3,700 | - -[a] |
| 1998 | - -[a] | 1,200 | 2,500 | 5,000 | 3,100 | - -[a] |

[a]*Data not available.*

[b]*Data cover the period from February 1993 through October 1993.*

*Source: U.S. Geological Survey and SEWRPC.*

### Table 17

### ESTIMATED EXTERNAL SOURCES OF PHOSPHORUS TO DELAVAN LAKE

| Source | 1995 | | 2020 | |
|---|---|---|---|---|
| | Pounds[a] | Percentage[a] | Pounds[a] | Percentage[a] |
| Urban[b] | | | | |
| High-Density | 2,200 | 11 | 4,900 | 26 |
| Low-Density | 800 | 4 | 2,100 | 11 |
| Subtotal | 3,000 | 15 | 7,000 | 37 |
| Rural | | | | |
| Mixed Agricultural | 16,200 | 81 | 10,700 | 57 |
| Pasture/Grass | 100 | <1 | 400 | 2 |
| Wetlands | 70 | <1 | 70 | <1 |
| Woodlands | 80 | <1 | 80 | <1 |
| Water | 550 | 3 | 550 | 3 |
| Subtotal | 17,000 | 85 | 11,800 | 63 |
| Total | 20,000 | 100 | 18,800 | 100 |

[a]*Percentages estimated from WILMS model results.*

[b]*Includes the contribution from onsite sewage disposal systems that remain in use outside of the portion of the tributary drainage area to Delavan Lake served by public sanitary sewerage systems, estimated within the WILMS model as ranging from approximately 50 pounds per year to as much as 1,300 pounds per year, depending upon soil type, system condition, and system location. For purposes of this analysis, 50 pounds per year were used as the contribution from onsite sewage disposal systems as that value provided the loading that was best correlated to the measured in-lake phosphorus concentrations.*

*Source: SEWRPC.*

slightly exceed, those reported by U.S. Geological Survey based upon their field measurements. The WILMS model estimated the total external phosphorus loadings to Delavan Lake to range from 15,600 pounds to 29,600 pounds per year, with a most likely value of 20,000 pounds per year, based upon 1995 land use conditions, as shown in Table 17. The difference between the predicted and observed phosphorus loads is likely to be related to the fact that the model does not take into account the effects of phosphorus retention within the Mound Road wetland. During some periods of the year, the wetland may remove phosphorus from the water that ultimately enters the Lake, or delay the delivery of phosphorus to the Lake during the growing season, thereby moderating the biological effects of the phosphorus load.

The mass of phosphorus estimated to be contributed to Delavan Lake under forecast 2020 conditions is approximately 18,800 pounds per year. This loading rate is calculated based upon a most likely estimate for total loading under planned 2020 land use conditions, as shown in Table 17. Future phosphorus loadings to the Lake, therefore, are expected to be approximately equal to, or slightly less than, the total loading to the Lake calculated by the WILMS model for current land use conditions.

There are some evident trends in the phosphorus loading data. Though they may not be statistically significant due to the high variability in phosphorus loading observed from year to year, linear regression analysis of the amount of phosphorus entering the inlet at STH 50, set forth in Table 16, against time suggests that phosphorus loading into Delavan Lake through Jackson Creek and the Delavan Lake inlet is likely to be decreasing. This conclusion is further substantiated based upon the results of the WILMS model for forecast 2020 land use conditions. Such a conclusion would be consistent with the effects of the diversion of treated wastewater from the tributary drainage area and the implementation of watershed management measures, such as the construction of the Mound Road wetland, during the period between 1980 and 2000.

***Effects of the Mound Road Wetland Complex***

With respect to the influence of the Mound Road wetland on the phosphorus loading to Delavan Lake, the differences between the loads, shown in Table 16, entering the wetland from the drainage area tributary to Jackson Creek and that leaving the wetland at Mound Road suggest some degree of phosphorus retention within the wetland complex. During 1994 and 1995, it is estimated that about 4,000 pounds and 2,100 pounds of phosphorus entered the Mound Road wetland from Jackson Creek, while approximately 3,300 pounds and 2,400 pounds of phosphorus were exported from the wetland at Mound Road. Thus, the constructed wetland would appear to have the attributes of both a source—during 1995—and sink—during 1994—of phosphorus during specific years based upon prevailing climatic conditions. For this reason, interpretation of these data relative to the functioning of the wetland must be undertaken with caution. Nevertheless, the principal beneficial function of the wetland is to modify the timing of the delivery of the phosphorus load to the Lake such that the phosphorus does not enter Delavan Lake during the summer growing season, thereby moderating the biological response to the annual load to phosphorus to the Lake, regardless of whether the wetland is acting as a source or a sink for phosphorus.

The data set forth in Table 16 further suggest that, during these years, there was a significant input of phosphorus to Jackson Creek between Mound Road and the inlet to the Lake basin at STH 50. During 1994 and 1995, about 3,300 pounds and 2,400 pounds of phosphorus, respectively, were exported from the Mound Road wetland, while about 6,000 pounds and 4,600 pounds of phosphorus entered Delavan Lake at STH 50. These results suggest that processes associated with the inlet, such as phosphorus releases from sediments or phosphorus loadings from sites other than Jackson Creek, may be occurring and contributing to the phosphorus loading of the Lake. In some years, these differences are relatively small; as set forth in Table 16, the amounts of phosphorus contributed by the inlet during 1996 and 1997, for example, were about 400 pounds and 700 pounds respectively. In other years, the amounts are more substantial; the difference reported during 1998 suggested that the inlet contributed about 2,500 pounds of phosphorus to the Lake during that year.

***Internal Loading from Lake Sediments***

Phosphorus release from the lake bottom sediments—internal loading, as noted above—may also contribute phosphorus to the Lake. For the period from 1995 through 1998, the U.S. Geological Survey estimated the amount of internal loading to range from 5,000 pounds to 10,500 pounds of phosphorus per year.[22] Should this mass of phosphorus, contributed through internal loading from the Lake sediments, reach the surface waters of the Lake, it would represent between about 35 percent and 60 percent of the total phosphorus load to Delavan Lake during this period. Typically, these loads do not significantly influence surface water phosphorus concentrations, except when the overturn event is sudden and accomplished within hours. During "normal" years, overturn occurs gradually as the surface waters warm and cool, allowing the sediment phosphorus to be readsorbed and returned to the sediments.[23]

***Onsite Sewage Disposal Systems***

As of 1999, most of the total drainage area tributary to Delavan Lake had been provided with public sanitary sewer service through the Delavan Lake Sanitary District and the Walworth County Metropolitan Sewage District (WalCoMet). As noted above, wastewater from properties currently served by the Delavan Lake Sanitary District is conveyed to the WalCoMet sewage treatment facility for treatment. The Delavan Lake Sanitary District currently serves about 2,800 households. The existing and planned sanitary sewer service areas, as well as treatment system capacity, is documented in the WalCoMet sanitary sewer service area plan.[24]

Those onsite sewage disposal systems that remain within the drainage area tributary to Delavan Lake are almost exclusively within rural areas. These onsite sewage disposal systems discharge to the groundwater system, some of which, in turn, may discharge to surface waters within the area tributary to Delavan Lake. However, this source of phosphorus, included within the urban residential component of the phosphorus load to the Lake set forth in Table 17, is considered to be insignificant.

From 1995 through 1998, an average of about 5,400 pounds of phosphorus, representing about 80 percent of the total phosphorus loading to the Lake, was estimated by the U.S. Geological Survey[25] to have been used by the biomass within the Lake or deposited in the lake sediments each year.[26] This resulted in an average net downstream transport of phosphorus amounting to about 2,900 pounds, or about 20 percent of the total phosphorus loading to the Lake. A portion of the phosphorus mass retained in the Lake is typically removed through the Town of Delavan and Delavan Lake Sanitary District aquatic plant harvesting program, which removes phosphorus from the Lake[27] as a component of the aquatic plant biomass.

**Sediment Loads**

Bottom sediment conditions have an important effect on the condition of a lake. As sediment is deposited, valuable benthic habitats may be buried, macrophyte-prone substrates may be increased, fish spawning areas may be covered, and aesthetic nuisances may develop. Sediment particles also can act as transport mechanisms for

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[22]*U.S. Geological Survey Water-Resources Investigations Report 87-4168,* op. cit.

[23]*R.D. Robarts, P.J. Ashton, J.A. Thornton, H.J. Taussig, and L.M. Sephton, "Overturn in a Hypertrophic, Warm, Monomictic Impoundment (Hartbeespoort Dam, South Africa),"* Hydrobiologia, *Volume 97, pp. 209-224, 1982.*

[24]*SEWRPC Community Assistance Planning Report No. 56, 2nd Edition,* Sanitary Sewer Service Areas for the Walworth County Metropolitan Sewerage District, Walworth County, Wisconsin, *November 1991.*

[25]*U.S. Geological Survey Water-Resources Investigations Report 87-4168,* op. cit.

[26]*D.P. Larsen and H.T. Mercier, "Phosphorus retention capacity of lakes,"* Journal of the Fisheries Research Board of Canada, *Volume 33, pp. 1742-1750, 1976.*

[27]*T.M. Burton, D.L. King, and J.L. Ervin, "Aquatic Plant Harvesting As A Lake Restoration Technique,"* Proceedings of the U.S. Environmental Protection Agency National Lake Restoration Conference, *EPA 440/5-79-OD1, 1979. See also, U.S. Environmental Protection Agency Report No. EPA-440/4-90-006,* The Lake and Reservoir Restoration Guidance Manual, Second Edition, *August 1990.*

other substances, such as phosphorus, nitrogen, organic materials, pesticides, and heavy metals, which accumulate within the lake sediments and may reenter the water column as a result of internal loading processes.

Table 18 shows suspended sediment loadings at various sites within the tributary drainage area to Delavan Lake, based upon U.S. Geological Survey sampling data. The sampling sites are the same as those used to calculate the phosphorus loads shown in Table 16. The average annual sediment loading to the inlet reported by the U.S. Geological Survey was about 600 tons of sediment, though this mass showed considerable variability during the period of record.[28] The sediment loadings to the Lake downstream of STH 50 during the period between 1994 and 1995 suggest that between about 40 and 70 percent of the total sediment load generated from the Jackson Creek tributary drainage area may be expected to be deposited in the inlet, with the remainder being conveyed into the Lake. Recent data on sediment exported from Delavan Lake are not available. During the period from 1990 through 1991, the last years for which data are available, sediment export from the Lake amounted to between about 30 to 50 percent of the sediment load entering the Lake at STH 50. As shown in Table 18, two additional trends are apparent in these data. During the period from 1990 through 1995, the amount of sediment loading to the Lake downstream of STH 50 declined, and during 1994 and 1995, the wetland complex served as a net depositional area. These trends are supported by the observation that the eastern and northern sedimentation basins located within the Mound Road wetland complex have accumulated about two to three feet and about one foot of retained sediment, respectively.

## RATING OF TROPHIC CONDITION

Lakes are commonly classified according to their degree of nutrient enrichment or trophic status. The ability of a lake to support a variety of recreational activities and healthy fish and aquatic life communities is often correlated to the degree of nutrient enrichment that has occurred. There are three terms usually 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. Because of the naturally fertile soils and the intensive land use practices employed in the State, there are relatively few oligotrophic lakes in Southeastern Wisconsin. Mesotrophic lakes are moderately fertile lakes that support abundant aquatic plant growths and may support productive fisheries. Nuisance growths of algae and weeds are usually not exhibited by mesotrophic lakes. Many of the cleaner lakes in Southeastern Wisconsin are classified as mesotrophic. Eutrophic lakes are defined as nutrient-rich lakes. These lakes are often characterized by excessive growths of aquatic weeds and frequent algal blooms. Many eutrophic lakes support very productive fisheries. In shallow eutrophic lakes, fish winterkills may also be common. Many of the more polluted lakes in Southeastern Wisconsin are classified as eutrophic. Extremely eutrophic lakes may be described by a further descriptor, hypertrophic or hypereutrophic.

Several numeric "scales," based on one or more water quality indicators, have been developed to define the trophic condition of a lake. Because trophic state is actually a continuum from very nutrient poor to very nutrient rich, a numeric scale is useful for comparing lakes and for evaluating trends in water quality conditions. Care must be taken, however, that the particular scale used is appropriate for the lake to which it is applies. In this case, two indices, specific to Wisconsin lakes, have been used; namely, the Vollenweider-OECD open-boundary trophic classification system,[29] and the Wisconsin Trophic State Index value (WTSI).[30] The WTSI is a refinement

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[28]*U.S. Geological Survey Water-Resources Investigations Report 87-4168,* op. cit.

[29]*H. Olem and G. Flock,* The Lake and Reservoir Restoration Guidance Manual, Second Edition, *U.S. Environmental Protection Agency Report EPA-440/4-90-006, Office of Water (WH-553), Washington, D.C., August 1990.*

[30]*See R.A. Lillie, S. Graham, and P. Rasmussen, "Trophic State Index Equations and Regional Predictive Equations for Wisconsin Lakes,"* Research and Management Findings, *Wisconsin Department of Natural Resources Publication No. PUBL-RS-735 93, May 1993.*

Table 18

ANNUAL LOADS OF SUSPENDED SEDIMENT TO DELAVAN LAKE AND THE JACKSON CREEK WATERSHED: 1990-1998

| Water Year | Jackson Creek at Petrie Road (tons) | Jackson Creek Tributary near Elkhorn (tons) | Jackson Creek at Mound Road (tons) | Delavan Lake Inlet at Highway 50 (tons) | Delavan Lake Outlet at Borg Road (tons) |
|---|---|---|---|---|---|
| 1990 | - -[a] | 220 | - -[a] | 460 | 215 |
| 1991 | - -[a] | 280 | - -[a] | 270 | 85 |
| 1992 | - -[a] | 180 | - -[a] | 140 | - -[a] |
| 1993 | 1,400[b] | 580 | - -[a] | - -[a] | - -[a] |
| 1994 | 455 | 220 | 250 | 155 | - -[a] |
| 1995 | 130 | 180 | 290 | 95 | - -[a] |
| 1996 | - -[a] | 440 | 1,700 | - -[a] | - -[a] |
| 1997 | - -[a] | 380 | 525 | - -[a] | - -[a] |
| 1998 | - -[a] | - -[a] | 240 | - -[a] | - -[a] |

[a]*Data not available.*

[b]*Data cover the period from February 1993 through October 1993.*

*Source: U.S. Geological Survey and SEWRPC.*

of the Carlson TSI designed to account for the greater humic acid content—brown water color—present in Wisconsin lakes, and has been adopted by the Wisconsin Department of Natural Resources for use in lake management investigations.[31] A third measure of lake water quality, a comparison of conditions in an individual waterbody with typical conditions in similar waterbodies within a specific geographic area, has been developed for Wisconsin Lakes by Lillie and Mason,[32] and also is used herein.

**Vollenweider-OECD Trophic Classification System**

The European Organization for Economic Cooperation and Development (OECD) investigated numerous lakes and reservoirs from around the world with the majority of their approximately 750 lakes being in Europe and North America and developed a number of empirical relationships between chlorophyll-*a*, phosphorus, and nitrogen concentrations, Secchi-disk transparency, primary productivity, and trophic state. The result was a set of predictive models and a set of trophic descriptors, summarized in the probability diagrams reproduced as Figure 6. Applying the total phosphorus data for Delavan Lake to these relationships indicated that the Lake had about a 60 percent probability of being eutrophic and about a 35 percent probability of being mesotrophic. Similarly, using the mean chlorophyll-*a* concentration, the model indicated that Delavan Lake had about a 60 percent probability of being eutrophic, a 20 percent probability of being mesotrophic, and a 15 percent chance of being hypertrophic. Based upon the Secchi-disk reading, Delavan Lake had about a 45 percent chance of being eutrophic and a 40 percent chance of being mesotrophic. Thus, Delavan Lake could be classified as meso-eutrophic or having water quality that would be considered impaired for some uses.

**Trophic State Index**

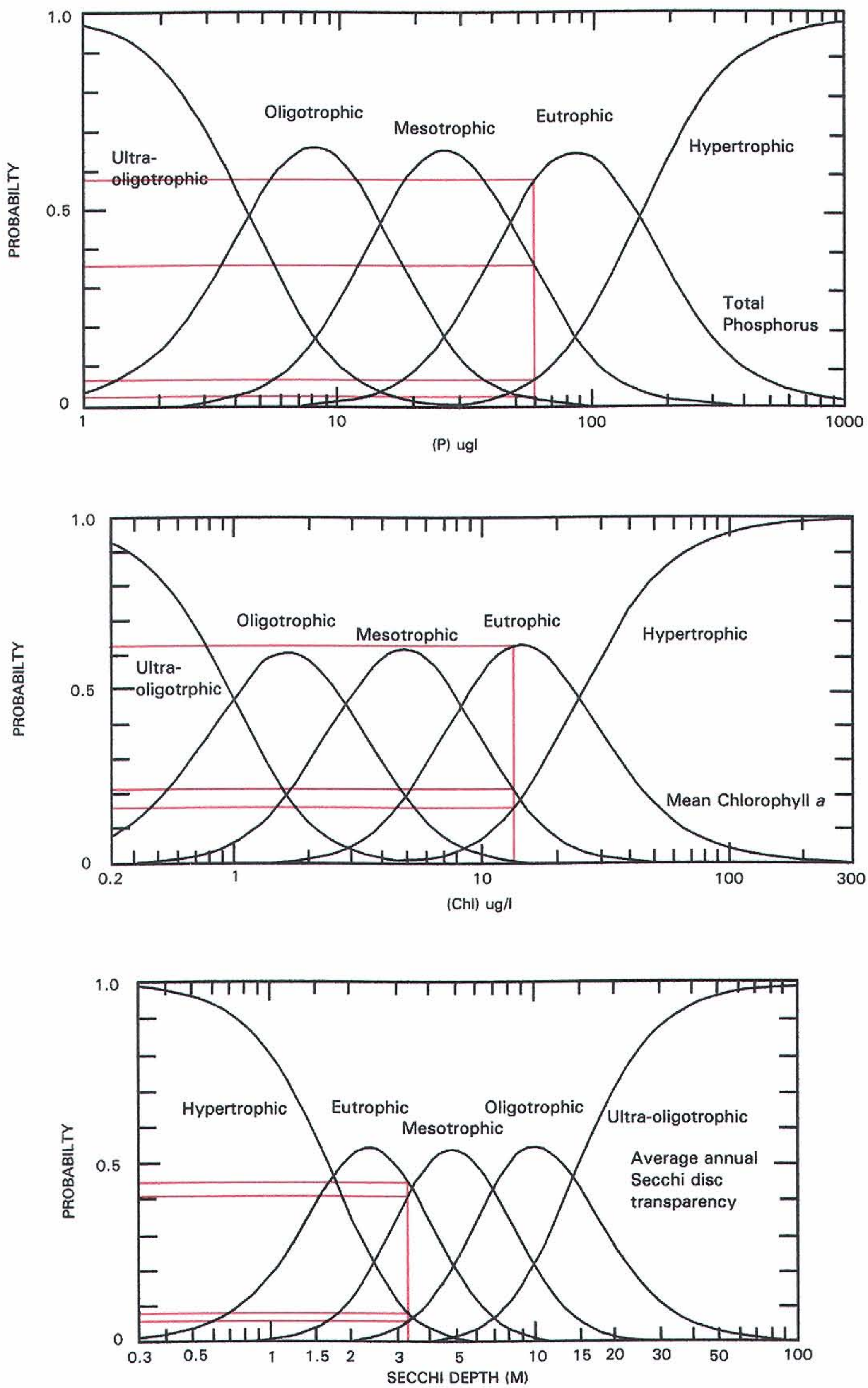
The Wisconsin Trophic State Index (WTSI) assigns a numerical trophic condition rating based on Secchi-disk transparency, and total phosphorus and chlorophyll-*a* concentrations. The original Trophic State Index (TSI), developed by Professor R.E. Carlson, was modified for use on Wisconsin lakes by the Wisconsin Department of

[31]*R.E. Carlson*, "A Trophic State Index for Lakes," *Limnology and Oceanography,* Vol. 22, No. 2, 1977.

[32]*Lillie and Mason*, op. cit.

Figure 6

TROPHIC STATE CLASSIFICATION OF DELAVAN LAKE BASED UPON THE VOLLENWEIDER MODEL




Source: Organization for Economic Cooperation and Development and SEWRPC.

Natural Resources using data from 184 lakes throughout the State.[31] The Wisconsin Trophic State Index ratings for Delavan Lake are shown in Figure 7, as a function of sampling date. Though there is much variability in the data, the WTSI ratings for Delavan Lake, based upon total phosphorus, were generally between 50 and 70, while those based upon chlorophyll-*a* and Secchi-disk depth ranged from about 25 to 65. These ratings suggest that Delavan Lake may be classified as a meso-eutrophic lake under this system.

**Water Quality Index**

The Lillie and Mason Water Quality Index compares the range of conditions in a specific waterbody to a range of conditions observed in other Wisconsin lakes. Ratings of water quality, ranging from very poor to excellent reflect a statistical analysis of lake condition as related to multiple recreational uses, as shown in Figure 8. This rating system is approximately analogous to the trophic state rating system described above and to other indices, with excellent water quality being equivalent to ultraoligotrophic conditions and very poor water quality being equivalent to hypertrophic conditions. The ratings applied to Delavan Lake ranged from excellent to very poor. Average total phosphorus concentration data suggested that Delavan Lake had fair to poor water quality on average. Average chlorophyll-*a* concentration data suggested better water quality, ranging from excellent to fair. Average water clarity data suggested that water quality was very good. Some of this variability probably reflects the size of the data set. The ratings based on Secchi-disk readings and total phosphorus concentrations each reflect over 150 measurements taken over all seasons, while the ratings based on chlorophyll-*a* reflect over 70 measurements. Given this variability, this rating system could be interpreted as suggesting that Delavan Lake be classified as meso-eutrophic, having characteristics spanning the range of lake water quality classes.

## SUMMARY

Delavan Lake represents a typical hard-water, alkaline lake. While the Lake has been subjected to high levels of pollution, the completion of the public sanitary sewerage systems around the Lake during 1981 and subsequent diversion of treated effluent from the Lake, has contributed to the recovery of the waterbody to a lesser state of enrichment. As of 2000, the physical and chemical parameters measured during the post-1991 study period indicated that the water quality was within the "good" range, compared to other regional lakes, and the Lake currently appears to be meso-eutrophic.

There were no known point sources of pollutants in the Delavan Lake watershed, the discharge from the City of Elkhorn sewage treatment plant having been diverted from the Jackson Creek in 1981, pursuant to recommendations set forth in the adopted regional water quality management plan. Sewage from the lakeshore area is conveyed by the Delavan Lake Sanitary District to the Walworth County Metropolitan Sewerage District treatment plan, discharging to Turtle Creek, downstream of Delavan Lake.

Nonpoint sources of pollution included stormwater runoff from urban and agricultural areas. Sediment and phosphorus loadings from the watershed were estimated by both direct measurement at various points within the drainage area, and using the Wisconsin Lake Model Spreadsheet and unit area loads. Based upon measurements reported by the U.S. Geological Survey, about 12,000 pounds to 18,000 pounds of phosphorus entered the Lake annually during the study period. This is similar to, but slightly less than, the phosphorus load estimated using the WILMS model. This difference between the modeled and measured data are well within the level of accuracy of the modeling and measurement procedures. However, such a difference between the total estimated loading to the Lake and the measured loading would be consistent with the implementation of lake management measures, including the construction of the Mound Road wetland on Jackson Creek upstream of Delavan Lake. Of this annual phosphorus load, approximately 80 percent is retained within the Lake, and about 20 percent is transmitted downstream. The behavior of sediment entering Delavan Lake is similar. A total of 600 tons of sediment was estimated to enter the Lake annually, about 40 percent of which was transmitted downstream.

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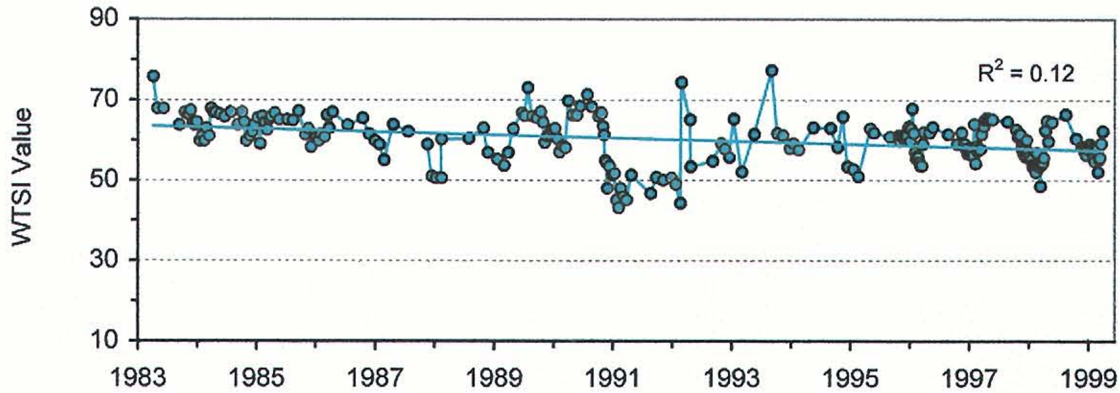
[31]*R.A. Lillie, S. Graham, and P. Rasmussen,* op. cit.

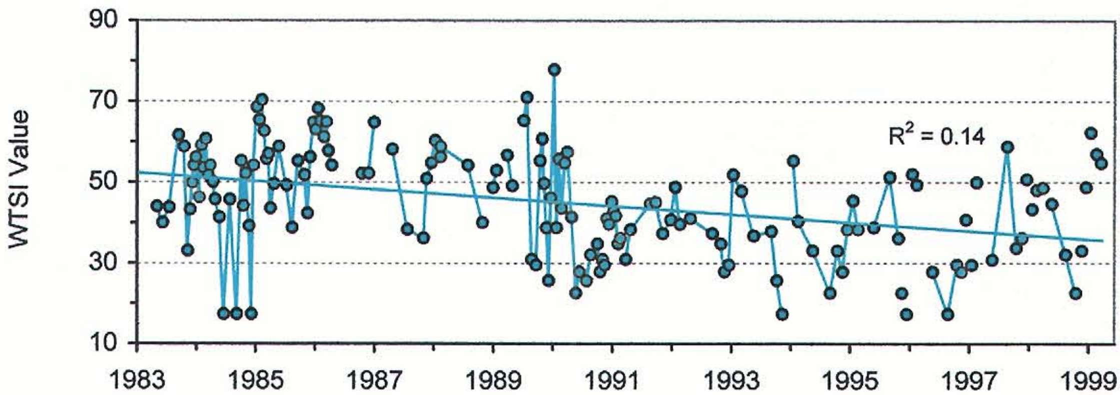
Figure 7

TROPHIC STATE CLASSIFICATION OF DELAVAN LAKE BASED UPON THE WISCONSIN TROPHIC STATE INDEX

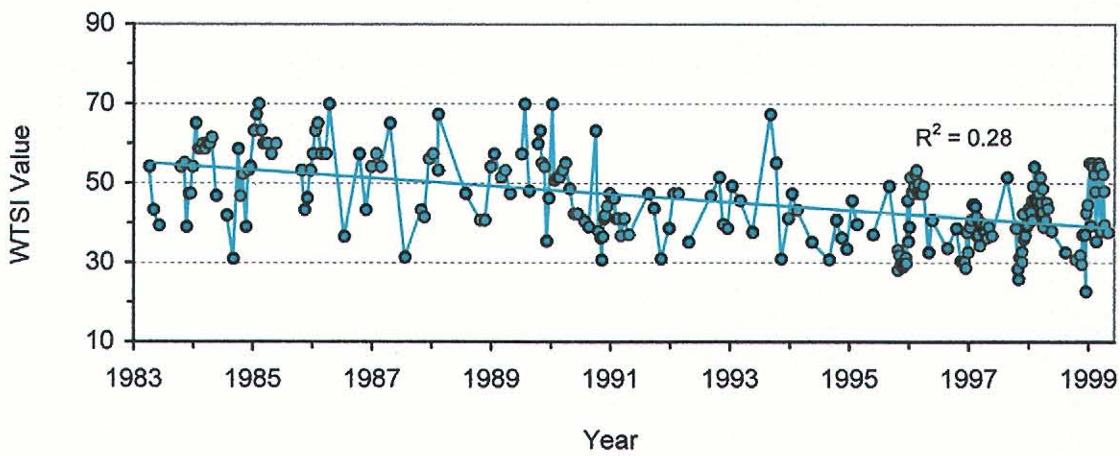
**Total Phosphorus**




**Chlorophyll-a**



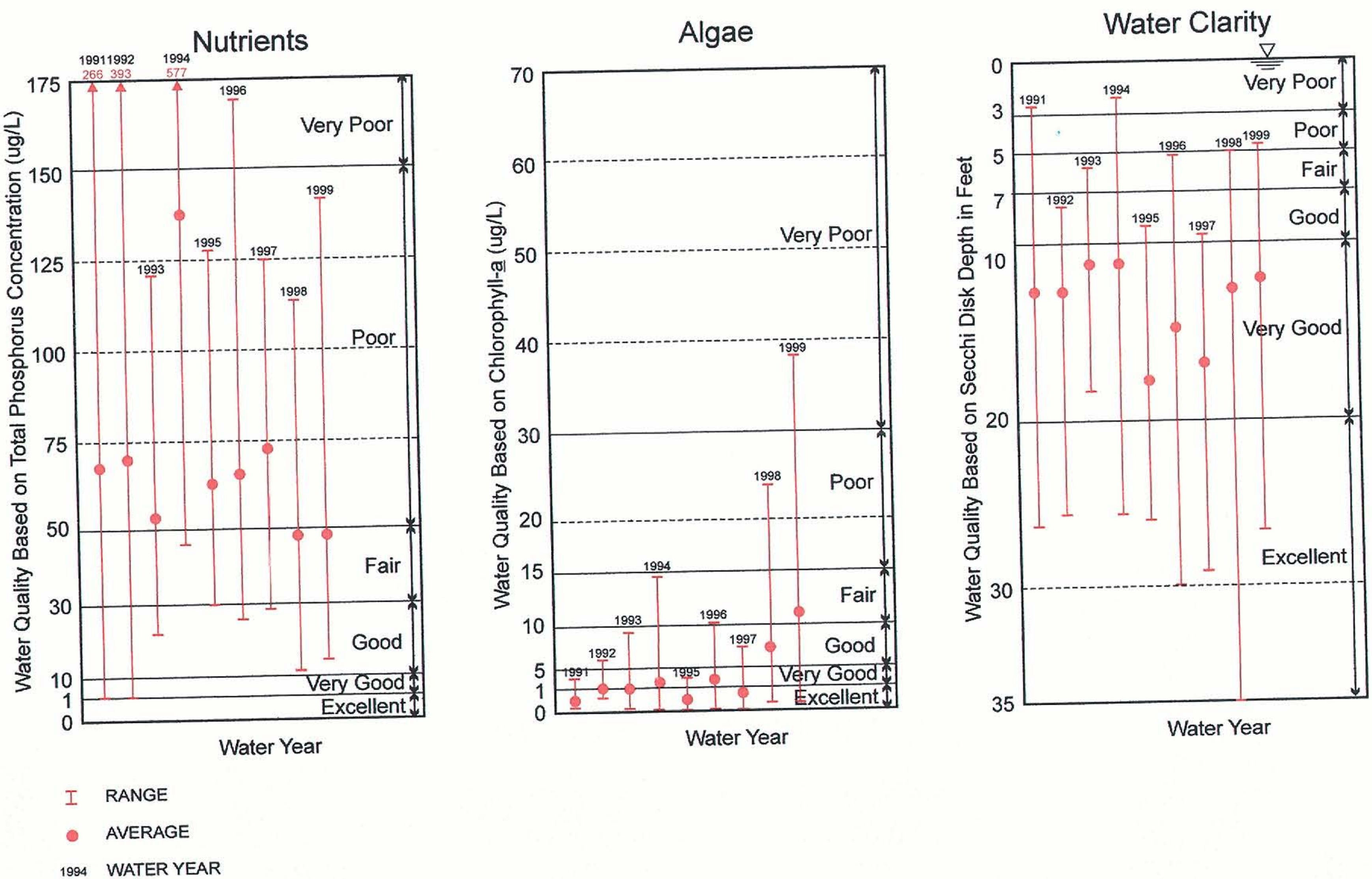

**Secchi Depth**




*Source: Wisconsin Department of Natural Resources and SEWRPC.*

Figure 8

DELAVAN LAKE PRIMARY WATER QUALITY INDICATORS: 1991-1999




*Source: Wisconsin Department of Natural Resources and SEWRPC.*

# Chapter V

# AQUATIC BIOTA AND ECOLOGICALLY VALUABLE AREAS

## INTRODUCTION

Delavan Lake is an important element of the natural resource base of the Town of Delavan and its neighboring communities. The Lake, its biota, and the adjacent residential and open space lands combine to contribute to the quality of life in the area. When located in urban settings, resource features, such as lakes and wetlands, are typically subject to extensive recreational use and high levels of pollutant discharges, common forms of stress to aquatic systems, and this may result in the deterioration of these natural resource features. For this reason, the formulation of sound management strategies must be based on a thorough knowledge of the pertinent characteristics of the individual resource features, as well as of the urban development in the area concerned. Accordingly, this chapter provides information concerning the natural resource features of the Delavan Lake watershed, including data on primary environmental corridors, wetlands, aquatic macrophytes, fish, and wildlife.

## AQUATIC PLANTS

Aquatic plants include larger plants, or macrophytes, and microscopic algae, or phytoplankton. These form an integral part of the aquatic food web, converting inorganic nutrients present in the water and sediments into organic compounds that are directly available as food for other aquatic organisms. In this process, known as photosynthesis, plants utilize energy from sunlight and release oxygen required by other aquatic life forms.

### Phytoplankton

Phytoplankton, or 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 in colonies, and can be either attached or free-floating. Phytoplankton abundance varies seasonally with fluctuations in light levels or solar irradiance, turbulence due to prevailing winds, grazing by zooplankton, and nutrient availability. In lakes with high nutrient levels, heavy growths of phytoplankton, or algal blooms, may occur. Algal blooms, historically, have been perceived as a problem in Delavan Lake. A list of algal species detected in Delavan Lake is given in Table 19. Blue-green algal species, that typically cause floating mats of algae that interfere with recreational and other water uses, are known to occur within the Lake. Algal blooms, when they occur, have been subjected to algicide treatments to control nuisance levels of phytoplankton growth.

After a severe blue-green algae outbreak on Delavan Lake, during the summer of 1983, the U.S. Geological Survey, in cooperation with the Delavan Lake Sanitary District and the Wisconsin Department of Natural Resources, began a two-year water-quality and hydrologic investigation to describe water-quality conditions in Delavan Lake and its drainage basin and probable causes of continuing algal problems.[1]

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[1]*S.J. Field and M.D. Duerk,* Hydrology and Water Quality of Delavan Lake in Southeastern Wisconsin, *Water-Resources Investigations Report 87-4168, August 1988.*

**Table 19**

**DELAVAN LAKE PHYTOPLANKTON SURVEY RESULTS[a]**

| |
|---|
| Bacillariophyta (diatoms)<br>*Cyclotella* sp.<br>*Fragillaria* sp.<br>*Melosira* sp.<br>*Navicula* sp.<br>*Nitzschia acilularis*<br>*Stauroneis* sp.<br>*Stephanodiscus tenius*<br>*Synedra* sp. |
| Chlorophyta (green algae)<br>*Actinastrum* sp.<br>*Chlamydomonas flagellate*<br>*Chlorella* sp.<br>*Cladophora* sp.<br>*Phytoconis* sp.<br>*Scenedesmus* sp.<br>*Spirogyra* sp.<br>*Staurastrum* sp. |
| Chrysophyta (golden algae)<br>*Dinobryon* sp. |
| Cryptophyta (cryptomonad flagellates) |
| Cyanobacteria (blue-green algae)<br>*Anabaena circinalis*<br>*Anabaena* sp.<br>*Anacystis* sp.<br>*Aphanizomenon flos-aquae*<br>*Aphanizomenon* sp.<br>*Chroococcus* sp.<br>*Gomphosphaeria* sp.<br>*Microcystis* sp.<br>*Nodularia* sp.<br>*Polycystis* sp.<br>*Oscillatoria* sp.<br>*Synechocystis* sp. |
| Euglenophyta (euglenoid flagellates)<br>*Phacus* sp. |
| Pyrrophyta (dinoflagellates) |

[a]*Information obtained from U.S. Environmental Protection Agency,* Report on Delavan Lake, Walworth County Wisconsin, *National Eutrophication Survey Working Paper No. 36, 1974; W.L. Gross and D. Falkner,* Bacteriological Survey of Delavan Lake with Notes on the Algal Nuisance Problem, *Report submitted to the Delavan Lake Sanitary District, November, 1975; S.J. Field and M.D. Duerk,* Hydrology and Water Quality of Delavan Lake in Southeastern Wisconsin, *U.S. Geological Survey Water-Resources Investigations Report 87-4168, 1988.*

*Source: SEWRPC.*

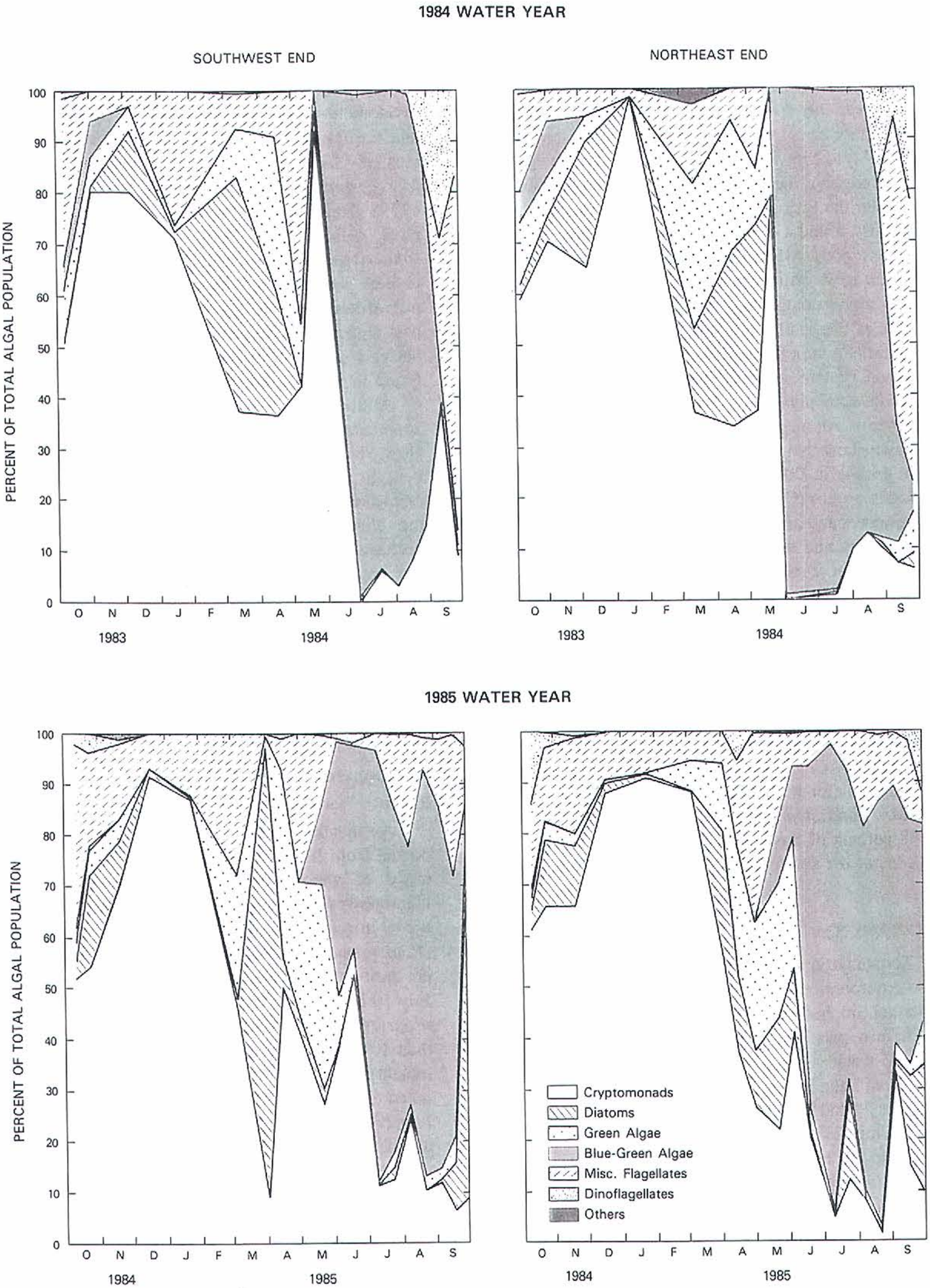
During the study period, from October 1983 through September 1985, blue-green algae numerically dominated the algal population in Delavan Lake during the months of June, July, August, and on into September, as shown in Figure 9. In winter most green and blue-green algae were reduced in number by colder temperatures and low light levels, and cryptomonad flagellates dominated the phytoplankton, sometimes accounting for over 90 percent of algal cells present. Following the melting of the ice, diatoms peaked as light conditions improved, comprising over 80 percent of the algal population during March in early spring. Diatoms require silica for growth and are typically associated with a decline in dissolved silica concentrations in the surface waters of the Lake, as suggested in Table 9 in Chapter IV. Diatoms also lack structures such as flagella and gas vacuoles that can give them motility in the water column, depending, instead, on wind-induced turbulence to keep them within the zone of light penetration. As the thermocline formed, the diatom population declined, probably because of silica depletion, grazing by zooplankton, and sedimentation, as the spring winds turned to summer breezes.

As the water temperatures warmed and diatoms disappeared from the water column, the small, fast-growing green algae became more common during the two-year study period. This group reached its maximum representation within the phytoplankton community during the months of April and May, accounting for as much as 40 percent of the phytoplankton population. Following this early summer peak in green algae, blue-green algae become the most common phytoplankton group in the Lake as summer progressed. Declines in green algae were most likely due to a combination of grazing by zooplankton, some species of which were becoming abundant in May and June, and depletion of nitrogen, especially in years when the phosphorus concentrations in the epilimnion were high.

During the 1983 through 1985 study period, blue-green algae dominated the phytoplankton community of Delavan Lake during the summer. The blue-green species often persist through the summer because they have slow growth rates and low loss rates. Many blue-green species, such as *Microcystis*, *Anabaena* and *Aphanizomenon*, have gas vacuoles which allow them to regulate their buoyancy and minimize their losses due to sedimentation. They also can maximize their growth by moving vertically in the water column to

## Figure 9

## ALGAL POPULATIONS IN DELAVAN LAKE: 1983-1985




NOTE: Percent of total population is based upon numerical abundance rather than biomass.

*Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.*

obtain optimal levels of light and nutrients. Because of their gas vacuoles, species such as *Microcystis* and *Aphanizomenon*, float higher in the water and form conspicuous algal mats or blooms. Other blue-green species can float to the surface, forming a scum layer. Blue-green algae are not ordinarily used as food by zooplankton, because of their large size, unpalatability and/or toxicity. In addition, blue-green algae are less sensitive to growth limitation from nitrogen depletion than other algal groups because many species are capable of converting atmospheric nitrogen gas, which is generally unusable by living organisms, to compounds such as nitrate or ammonia, which is readily used for plant growth. Given the low N:P ratios that are generally seen in Delavan Lake during spring overturn shown in Table 11, nitrogen depletion probably accounts for the dominance of the phytoplankton community by blue-green algae during late summer and early fall.

Average algal cell densities are reported to be considerably lower than they were prior to the alum treatment. This is reflected in the reduced chlorophyll-*a* concentrations reported in the Lake during the period subsequent to 1991, as shown in Tables 9 and 10 in Chapter IV. Nevertheless, algal blooms continue to occur occasionally in Delavan Lake. A common definition of an algal bloom is when a population of a particular alga exceeds 500,000 cells per liter.[2] Since the lake rehabilitation program began during the 1989-1990 hydrological year, filamentous algae have, at times, attained nuisance levels in the Lake.[3] During such blooms, algae may accumulate onshore, producing noxious odors and creating unsightly conditions as they die and decompose. Their decay consumes oxygen and, if dissolved oxygen levels are depleted sufficiently, fish kills may result.

**Aquatic Macrophytes**

Aquatic macrophytes play an important role in the ecology of Southeastern Wisconsin lakes. They can be either beneficial or a nuisance, depending on their type, distribution and abundance, and the activities taking place on and around the waterbody. Macrophytes are usually an asset because they provide food and habitat for fish and other aquatic life, produce oxygen, and may remove nutrients and pollutants from the water that could otherwise cause algal blooms or other problems. Aquatic macrophytes can become a nuisance, depending upon their extent and spatial location, when their presence reaches densities that interfere with aesthetic and recreational uses and the normal functioning of a lake ecosystem. Many factors, including lake configuration, depth, water clarity, nutrient availability, bottom substrate, wave action, and type of fish populations present, determine the distribution and abundance of aquatic macrophytes in a lake. Some nonnative plant species, lacking natural controls, may be especially favored by the habitats available in this Region and can exhibit explosive growths to the detriment not only of lake users but also of indigenous aquatic life and native plant species.

***Declining Aquatic Plant Communities***

The Wisconsin Conservation Department, now the Wisconsin Department of Natural Resources, initially conducted a number of aquatic plant surveys on Delavan Lake between 1948 and 1975, usually in conjunction with fisheries surveys. The aquatic macrophyte species reported as being present in Delavan Lake during the surveys conducted between 1948 and 1975 are shown in Table 20.[4] Over this period, a total of 25 species were reported as being present. However, not all of the aquatic plant species were present during each year of record, and as many as possibly 15 species were not detected in the years subsequent to 1975 but prior to the Lake rehabilitation project of the 1990s.

[2]*L.J. Britton* et. al., An Introduction to the Processes, Problems, and Management of Urban Lakes, *U.S. Geological Survey Circular 601-K, 1975.*

[3]*Aron & Associates,* Delavan Lake Aquatic Plant Management Plan, *1993.*

[4]*E.R. Schumacher and L. Burns*, General Fishery Survey and Management Recommendations, Delavan Lake, 1975, *Wisconsin Department of Natural Resources Intradepartmental Memo, 1978.*

Table 20

DELAVAN LAKE MACROPHYTE SURVEY RESULTS: 1948-1975[a]

| Aquatic Plant Species Present | Date of Last Report Prior to Initiation of Lake Rehabilitation Project | Notes |
|---|---|---|
| *Ceratophyllum demersum* (coontail) | 1962 | -- |
| *Elodea canadensis* (waterweed) | 1972 | -- |
| *Lemna* sp. (duckweed) | 1972 | Last report is for *Lemna minor* |
| *Myriophyllum exalbescens* (spiked water milfoil) | 1952 | -- |
| *Najas flexilis* (bushy pondweed) | 1972 | -- |
| *Nelumbo lutea* (American lotus) | 1952 | -- |
| *Nuphar advena* (yellow water lily) | 1956 | Reclassified as *Nuphar lutea* forma *advena* |
| *Nymphaea odorata* (American white water lily) | -- | -- |
| *Potamogeton americanus* (long-leaf pondweed) | 1952 | Reclassified as *Potamogeton nodosus* |
| *Potamogeton amplifolius* (large-leaf pondweed) | 1952 | -- |
| *Potamogeton confervoides* (Tuckerman's pondweed) | 1951 | -- |
| *Potamogeton crispus* (curly-leaf pondweed) | -- | -- |
| *Potamogeton demersum* | 1972 | -- |
| *Potamogeton filiformis* (narrow-leaf pondweed) | 1963 | Reclassified as *Stuckenia filiformis* forma *filiformis* |
| *Potamogeton gramineus* (variable pondweed) | 1952 | -- |
| *Potamogeton natans* (floating-leaf pondweed) | 1972 | -- |
| *Potamogeton nodosus* (strap-leaf pondweed) | 1968 | -- |
| *Potamogeton pectinatus* (Sago pondweed) | 1962 | -- |
| *Potamogeton praelongus* (white-stem pondweed) | 1951 | -- |
| *Potamogeton vaginatus* (large-sheath pondweed) | 1952 | Reclassified as *Stuckenia vaginatus* |
| *Potamogeton zosteriformis* (flat-stemmed pondweed) | 1952 | -- |
| *Potamogeton* sp. (flat-leaf pondweed) | 1962 | -- |
| *Ranunculus* sp. (buttercup) | 1948 | Last report is for *Ranunculus longirostris* |
| *Sagittaria latifolia* (arrowhead) | 1972 | Last report is for *Sagittaria* sp. |
| *Vallisneria americana* (water celery) | 1972 | -- |

[a]*Information obtained from E.R. Schumacher and L. Burns,* General Fishery Survey and Management Recommendations, Delavan Lake, 1975, *Wisconsin Department of Natural Resources Intradepartmental Memo.*

*Source: SEWRPC.*

In 1948, Delavan Lake was reported to have supported 14 species of aquatic macrophytes.[5] Sago pondweed and coontail were reported as abundant. Nevertheless, during the 1950s, there was a general decline in the number of species found in the Lake, and five species of pondweeds—*Potamogeton americanus*, *P. amplifolius*, *P. gramineus*, *P. praelonus*, and *P .vaginatus*—that had been recorded as abundant or common during the surveys of 1948 and the early 1950s, were not reported subsequently.[6] This decline was apparently an issue of concern at the

[5]Ibid.

[6]Ibid.

time. According to an area resident, during 1955, the Izaak Walton League obtained and planted a number of desirable plant species at the southwest end of the Lake, in an attempt to limit the loss of aquatic plant species in the Lake.[7]

Notwithstanding such attempts to limit the decline in aquatic plant diversity, the loss of species previously reported as being recorded from Delavan Lake continued. In the 1960s, only seven species were reported as being present, with this number declining to four species by 1968.[8] Several additional pondweed species were not reported after 1962, while other species, such as coontail, declined in abundance. Strap-leaf pondweed and white water lily were reported to be the dominant aquatic plants. By the mid-1970s, white water lily was still considered to be a dominant plant species present in the Lake, but the strap-leaf pondweed had been replaced by curly-leaf pondweed as the dominant pondweed species. Neither plant species could be considered abundant. By 1972, all major "weed" beds were reported to have disappeared, and only single plants and scattered patches of plants were reported in the Lake, including the two dominant species, which were reported to be "scarce."

During the 1980s, two additional aquatic plant surveys were conducted, prior to the major lake rehabilitation efforts on Delavan Lake, by the U.S. Geological Survey in association with the Delavan Lake Sanitary District. The surveys were conducted between June 12 and August 21, 1984, and between May 21 and August 27, 1985. During these surveys, three species of aquatic macrophytes were identified in Delavan Lake. The dominant aquatic plant species was curly-leaf pondweed, *Potamogeton crispus*. The other aquatic macrophytes present during these surveys were white water lily and another, unidentified pondweed.

***Recovering Aquatic Plant Communities***

Since the beginning of the lake restoration project on Delavan Lake during the fall of 1989, a number of additional, annual aquatic plant surveys have been conducted. These surveys were conducted during 1990 and 1991 by the Wisconsin Department of Natural Resources, and from 1992 through 1999 by Aron & Associates. The latter surveys were conducted under contract to the Town of Delavan during 1992, and under contract to the Delavan Lake Sanitary District during more recent years. Many changes in aquatic macrophyte populations and densities were reported to have occurred during this period, due, in part, to increased water clarity and a decrease in rough fish populations. Both seasonal and year-to-year variations in community composition were reported. In the surveys conducted between 1990 and 1994, as well as in those conducted between 1996 and 1999, 29 species of aquatic macrophytes—including the two emergent plant species, *Typha latifolia* and *Scirpus* sp.—were reported to occur in Delavan Lake.[9] Species that interfere with the recreational and aesthetic use of the Lake, such as *Myriophyllum spicatum*, *Ceratophyllum demersum*, and *Potamogeton crispus*, also were found to be present, especially in areas of the Lake subject to the greater disturbances. The distributions of aquatic plants in the Lake during 1998 are shown on Map 15.

During the July 1999 survey, plant growth occurred throughout the Lake where depth was 14 feet or less, with 13 species of aquatic macrophytes being identified. This did not include species of bulrush (*Scirpus* sp.) and

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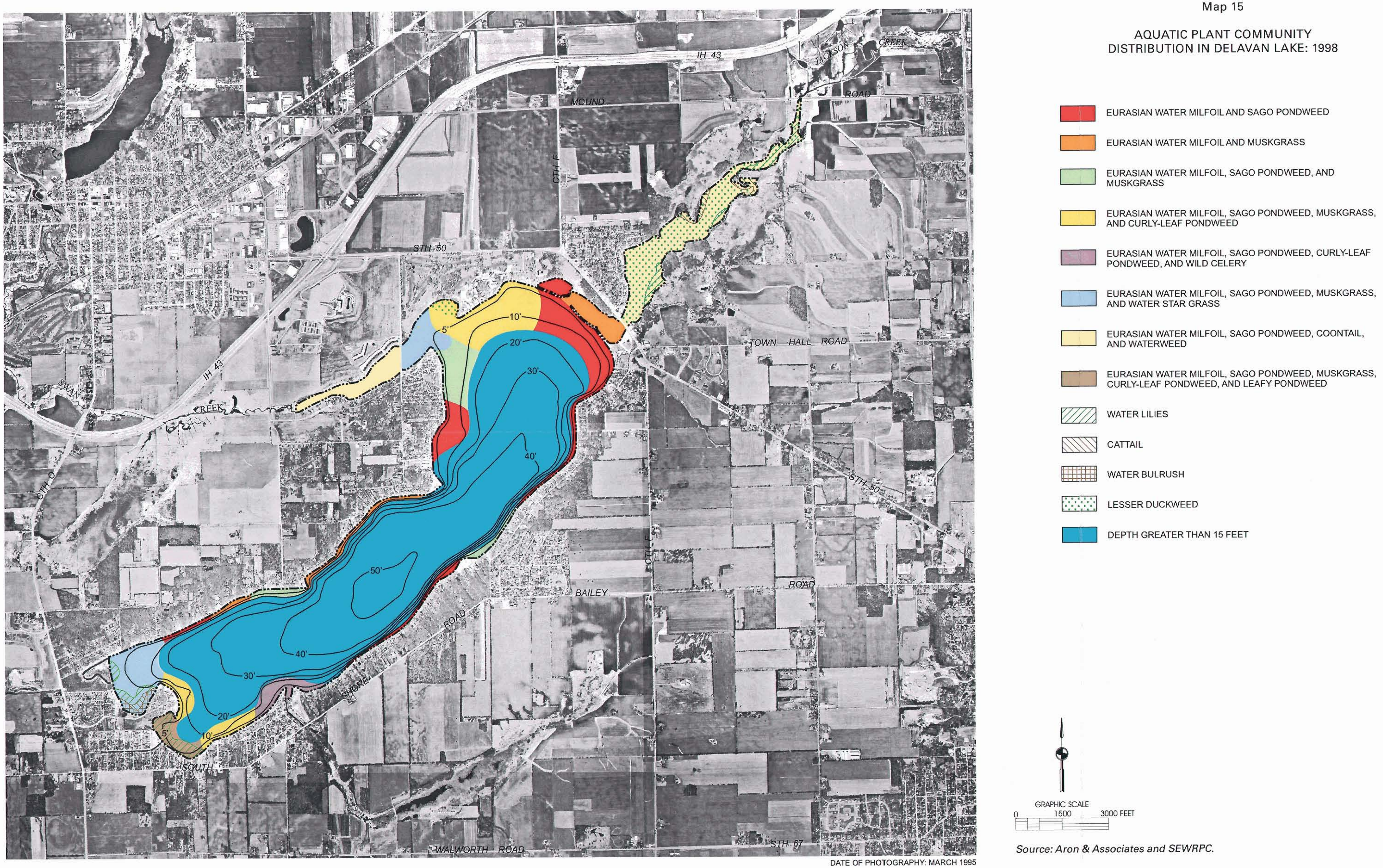
[7]*Communication with F.M. Clopper, cited in E.R. Schumacher and L. Burns*, General Fishery Survey and Management Recommendations, Delavan Lake, 1975, *Wisconsin Department of Natural Resources Intradepartmental Memo, 1978.*

[8]*Schumacher and Burns,* op. cit.

[9]*Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1992; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1993; Aron & Associates,* Delavan Lake Plant Management Plan, *September 1993; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1994; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1996; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1997; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1998; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1999.*

Map 15

AQUATIC PLANT COMMUNITY DISTRIBUTION IN DELAVAN LAKE: 1998




*Source: Aron & Associates and SEWRPC.*

cattail (*Typha* sp.) associated with the wetland complexes along the inlet channel and the southwestern bay, which, although present during this survey, were not considered part of the submergent plant community. Eurasian water milfoil, *Myriophyllum spicatum*, was the dominant species in many areas of the Lake. This nonnative plant has been the most abundant macrophyte species in the Lake since 1996. Curly-leaf pondweed, *Potamogeton crispus*, was also abundant during this period and was reported to be at nuisance levels. *Potamogeton pectinatus*, *Chara* sp., and *Ceratophyllum demersum*, respectively, were the next most common species in the Lake. Wild celery, *Vallisneria americana*, appeared to be spreading in the Lake, at least locally near the small tributary inlet on the southeastern shore of the Lake. The area covered by this species increased considerably from the first reported occurrence during 1992 and the 1999 survey.

A list of aquatic plants reported from the Lake since 1990, compiled from the results of the aquatic plant surveys conducted during the period from 1990 through 1999, is set forth in Table 21.

**Aquatic Plant Management**

Records of aquatic plant management efforts on Wisconsin lakes were not maintained by the Wisconsin Department of Natural Resources prior to 1950. Therefore, while previous interventions occurred, the first recorded efforts to manage the aquatic plants in Delavan Lake took place in 1950. Aquatic plant management activities in Delavan Lake can be categorized as macrophyte harvesting, chemical macrophyte control, and chemical algal control.

***Macrophyte Harvesting***

Excessive macrophyte growth on Delavan Lake has historically resulted in a control program that used both harvesting and chemicals. The existing macrophyte control program follows an aquatic management plan developed for the Lake in 1993.[10] The harvesting program emphasizes removal of nuisance plants necessary to facilitate recreational use, rather than 100 percent plant removal. Under this program, the Town of Delavan contracts with the Delavan Lake Sanitary District to conduct the harvesting. The Delavan Lake Sanitary District harvests macrophytes using several pieces of equipment leased from the Town of Delavan. This equipment includes three Aquarius Systems harvesters, one each of models H-850, H-420, and H-220, a high-speed transport barge, and two off-loading shore conveyers.

Typically, harvesting prior to June 15 is limited to cutting access channels to facilitate navigation to piers and channels. After mid-June, the harvesting operation is expanded to include all areas of the Lake that experience nuisance plant conditions. The volume of aquatic plant biomass harvested, and the general location of the harvesting operations, for the period between 1997 and 1999, are listed in Table 22. These Lake areas correspond to the zones shown on Map 16. No permit is currently required to cut vegetation in lakes mechanically, although the harvested plant material must be removed from the water.

***Chemical Macrophyte Control***

Since 1941, the use of chemicals to control aquatic plants has been regulated in Wisconsin. Chemical herbicides are known to have been applied to Delavan Lake since the 1930s. In 1926, sodium arsenite, an agricultural herbicide, was first applied to lakes in the Madison area, and, by the 1930s, sodium arsenite was widely used throughout the State for aquatic plant control. No other chemicals were applied in significant amounts to control macrophytes until recent years, when a number of organic chemical herbicides came into general use. The amounts of sodium arsenite applied to Delavan Lake, and years of application during the period 1950 through 1969, are listed on Table 23; the total amount of sodium arsenite applied over this 19-year period being about 10,400 pounds.

[10]Ibid.

Table 21

**AQUATIC PLANT SPECIES PRESENT IN DELAVAN LAKE AND THEIR ECOLOGICAL SIGNIFICANCE: 1990-1999**

| Aquatic Plant Species Present | Ecological Significance[a] |
|---|---|
| *Brasenia schreberi* (water-shield)[b] | Provides food, shelter and shade for some fish, and food for some wildfowl |
| *Ceratophyllum demersum* (coontail) | Provides good shelter for young fish and supports insects valuable as food for fish and ducklings |
| *Chara* sp. (muskgrass) | Excellent producer of fish food, especially for young trout, bluegills, and small and largemouth bass; stabilizes bottom sediments; and has softening effect on the water by removing lime and carbon dioxide |
| *Elodea canadensis* (waterweed) | Provides shelter and support for insects which are valuable as fish food |
| *Heteranthera dubia* (water stargrass) | Provides food and shelter for fish |
| *Lemna minor* (lesser duckweed) | A nutritious food source for ducks and geese, also provides food for muskrat, beaver and fish, while rafts of duckweed provide shade and cover for insects, in addition extensive mats of duckweed can inhibit mosquito breeding |
| *Myriophyllum* sp. (native milfoil) | Provides valuable food and shelter for fish; fruits eaten by many waterfowl |
| *Myriophyllum exalbescens (spiked water milfoil)* | None known |
| *Myriophyllum spicatum* (Eurasian water milfoil) | None known |
| *Najas flexilis* (bushy pondweed) | Stems, foliage, and seeds important wildfowl food and produces good food and shelter for fish |
| *Najas marina* (spiny naiad) | Provides good food and shelter for fish and food for ducks |
| *Nitella* sp. (nitella) | Provides important food for wildfowl and attracts small aquatic animals |
| *Nymphaea tuberosa* (white water lily) | Provides shade and shelter for fish; seeds eaten by wildfowl; rootstocks and stalks eaten by muskrats; roots eaten by beaver, deer, moose, and porcupine |
| *Potamogeton amplifolius* (large-leaf pondweed)[b] | Provides food, shelter and shade for some fish and food for some wildfowl. Provides shelter and support for insects, which are valuable as fish food. |
| *Potamogeton crispus* (curly-leaf pondweed) | Provides food, shelter, and shade for some fish and food for wildfowl |
| *Potamogeton foliosus*[c] (leafy pondweed) | Provides important food for wildfowl, and shelter and support for insects and young fish |
| *Potamogeton friesii* (Fries' pondweed) | Provides food and shelter for some fish and food for wildfowl |
| *Potamogeton pectinatus* (Sago pondweed)[b] | This plant is the most important pondweed for ducks, in addition to providing food and shelter for young fish |
| *Potamogeton praelongus* (white-stem pondweed)[b] | Provides feeding grounds for muskellunge; also good food producer for trout; good food producer for ducks |
| *Potamogeton richardsonii* (clasping-leaf pondweed)[b] | Provides food, shelter and shade for some fish, food for some wildfowl and food for muskrat. Provides shelter and support for insects, which are valuable as fish food. |
| *Potamogeton zosteriformis* (flat-stemmed pondweed) | Provides some food for ducks |
| *Ranunculus longirostris* (water buttercup) | Provides food for trout, upland game birds, and wildfowl |
| *Sagittaria* sp. (arrowhead) | Provides food for ducks, muskrats, porcupines, beavers and fish, and provides shelter for young fish |
| *Scirpus* sp. (bulrush)[b] | Seeds provide food for wildfowl and upland birds; plant stalks and roots are eaten by geese and muskrats, are habitat for insects, shelter for young fish, and nesting material and cover for wildfowl and muskrats |
| *Sparganium eurycarpum* (common bur-reed) | Colonies stabilize sediments, food and nesting for wildfowl, and is grazed on by muskrat and deer |

Table 21 (continued)

| Aquatic Plant Species Present | Ecological Significance[a] |
|---|---|
| *Typha latifolia* (broad-leaved cattail) | Supports insects; stalks and roots important food for muskrats and beavers; attracts marsh birds, wildfowl, and songbirds, in addition to being used as spawning grounds by sunfish and shelter for young fish |
| *Vallisneria americana* (water celery)[b] | Provides good shade and shelter, supports insects, and is valuable fish food |
| *Zannichellia palustris* (horned pondweed)[b] | Provides food for ducks and some food value for trout |
| *Zosterella dubia* (water stargrass) | Provides food and shelter for fish, locally important food for waterfowl |

[a]*Information obtained from* A Manual of Aquatic Plants *by Norman C. Fassett,* Guide to Wisconsin Aquatic Plants, *Wisconsin Department of Natural Resources, and* Through the Looking Glass...A Field Guide to Aquatic Plants, *by Wisconsin Lakes Partnership.*

[b]*Considered a high-value aquatic plant species known to offer important values in specific aquatic ecosystems under Section NR 107.08 (4) of the* Wisconsin Administrative Code.

[c]*Identified in 1992 as* Potamogeton pusillus.

*Source: Aron & Associates and SEWRPC.*

Sodium arsenite was typically sprayed onto the surface of Delavan Lake within an area of up to 200 feet from the shoreline. Treatment typically occurred between mid-June and mid-July. The amount of sodium arsenite used was calculated to result in a concentration of about 10 milligrams per liter (mg/l) sodium arsenite (about five mg/l arsenic) in the treated lake water. The sodium arsenite typically remained in the water column for less than 120 days. Although the arsenic residue was naturally converted from a highly toxic form to a less toxic and less biologically active form, much of the arsenic residue was deposited in the lake sediments.

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 applications and accumulations of arsenic were found to present potential health hazards to both humans and aquatic life. In drinking water supplies, arsenic was suspected of being carcinogenic and, under certain conditions, arsenic has leached into and contaminated groundwater, especially in sandy soils that serve as a source of drinking water in some communities. The U.S. Environmental Protection Agency-recommended drinking water standard for arsenic is a maximum level of 0.05 mg/l.

Since anaerobic conditions occur in the hypolimnion in Delavan Lake, some arsenic may be released from the bottom sediments to the water column during the periods of anaerobiasis. In this way, some arsenic probably continues to be "flushed out" of Delavan Lake. However, the sediments contaminated with arsenic are continually being covered by new sediments; thus, the concentrations of arsenic in the water and in the surface sediments may be expected to decrease with passage of time.

As shown in Table 23, the aquatic herbicides diquat, endothall, glyphosate, and 2,4-D have also been applied to Delavan Lake in recent years to control aquatic macrophyte growth. Diquat and endothall are contact herbicides and kill plant parts exposed to the active ingredient. Diquat use is restricted to the control of duckweed (*Lemna* sp.), milfoil (*Myriophyllum* spp.), and waterweed (*Elodea* sp.). However, this herbicide is nonselective and will kill many other aquatic plants, such as pondweeds (*Potamogeton* spp.), bladderwort (*Utricularia* sp.), and naiads (*Najas* spp.). Endothall kills primarily pondweeds, but does not control such nuisance species as Eurasian water milfoil (*Myriophyllum spicatum).* Glyphosate (Rodeo) and 2,4-D are systemic herbicides that are absorbed by the leaves and translocated to other parts of the plant. They are more selective than the other herbicides listed above. Glyphosate is registered for use on many species of plants in Wisconsin, but is most frequently used to control purple loosestrife (*Lythrum salicaria*) and cattails (*Typha* spp.). 2,4-D is generally used to control Eurasian water milfoil. However, it will also kill more valuable species, such as water lilies (*Nymphaea* spp.) and (*Nuphar* spp.). The present restrictions on water use after application of these herbicides are given in Table 24. In addition, the systemic herbicide, fluridone (Sonar), has been used experimentally in Delavan Lake to control the growth of Eurasian water milfoil in the southwestern embayment of the Lake. Use restriction applicable to this herbicide are similar to endothall.

Table 22

AQUATIC PLANT HARVESTING RECORDS: 1997-1999

| 1997 | Lake Area[a] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
| May | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 28 |
| June | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 49 | 0 | 656 | 756 |
| July | 48 | 5 | 5 | 182 | 14 | 8 | 1 | 7 | 0 | 0 | 412 | 495 | 1,177 |
| August | 72 | 21 | 10 | 148 | 61 | 128 | 10 | 10 | 28 | 85 | 268 | 262 | 1,103 |
| September | 0 | 0 | 0 | 22 | 15 | 19 | 0 | 0 | 0 | 222 | 0 | 445 | 723 |
| October | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 46 | 0 | 0 | 46 |
| Total | 171 | 26 | 15 | 352 | 90 | 155 | 11 | 17 | 28 | 402 | 680 | 1,886 | 3,833 |
| Percent of Total | 4.5 | 0.7 | 0.4 | 9.2 | 2.3 | 4.0 | 0.3 | 0.4 | 0.7 | 10.5 | 17.7 | 49.2 | 100.0 |

| 1998 | Lake Area[a] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
| May | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 37 | 52 |
| June | 0 | 0 | 0 | 103 | 36 | 9 | 9 | 0 | 0 | 24 | 28 | 0 | 200 |
| July | 0 | 0 | 1 | 173 | 95 | 10 | 4 | 0 | 0 | 56 | 0 | 44 | 383 |
| August | 0 | 0 | 0 | 171 | 90 | 0 | 0 | 0 | 0 | 98 | 0 | 0 | 359 |
| September | 0 | 0 | 0 | 49 | 50 | 53 | 0 | 0 | 0 | 136 | 0 | 134 | 422 |
| October | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 14 |
| Total | 0 | 0 | 1 | 496 | 271 | 72 | 4 | 0 | 0 | 329 | 28 | 229 | 1,430 |
| Percent of Total | 0.0 | 0.0 | 0.1 | 34.7 | 19.0 | 5.0 | 0.3 | 0.0 | 0.0 | 23.0 | 2.0 | 16.0 | 100.0 |

| 1999 | Lake Area[a] | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
| May | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 76 | 76 |
| June | 180 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 149 | 200 | 390 |
| July | 31 | 32 | 0 | 97 | 0 | 11 | 0 | 0 | 0 | 87 | 89 | 159 | 506 |
| August | 0 | 0 | 0 | 14 | 0 | 13 | 0 | 0 | 0 | 129 | 0 | 156 | 312 |
| September | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 115 | 0 | 165 | 280 |
| October | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 211 | 57 | 0 | 111 | 0 | 24 | 0 | 0 | 0 | 367 | 238 | 756 | 1,764 |
| Percent of Total | 12.0 | 3.2 | 0.0 | 6.3 | 0.0 | 1.4 | 0.0 | 0.0 | 0.0 | 20.8 | 13.5 | 42.8 | 100.0 |

NOTE: Values represent cubic yards of plants harvested.

[a] *Lake areas for harvests are shown in Map 16.*

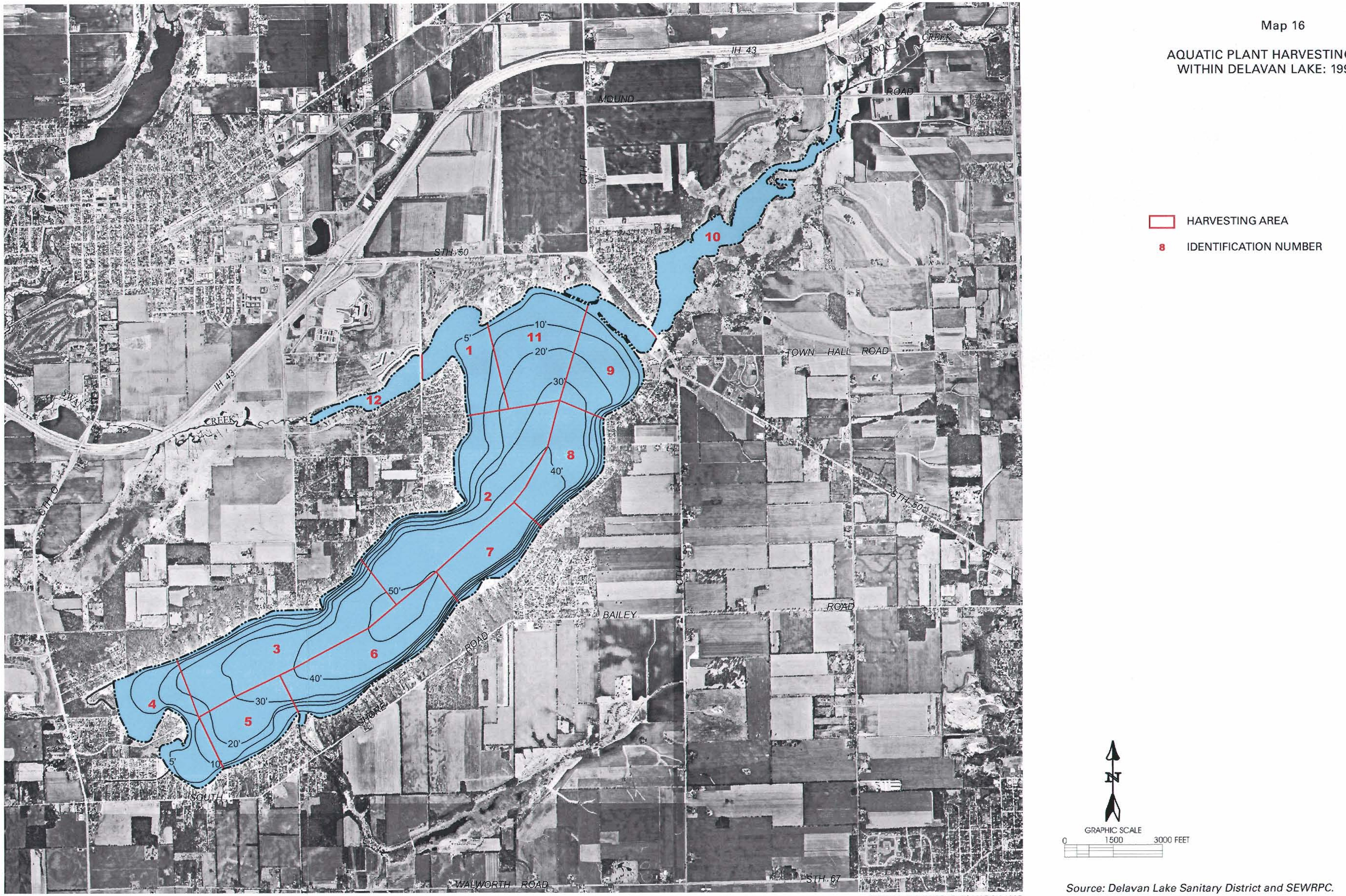
*Source: Delavan Lake Sanitary District and SEWRPC.*

## *Chemical Algal Control*

In addition to the chemical herbicides used to control large aquatic plants, algicides have also been applied to Delavan Lake. As shown in Table 23, a variety of copper compounds—including copper sulfate, AV-70, and Cutrine Plus—has been applied to Delavan Lake. The total amount of copper contained in these various algicides and applied since 1950 represents about 33,100 pounds of elemental copper. Copper is a nutrient required by plants in very low amounts. At higher concentrations, it is toxic to most species of planktonic and filamentous algae. Blue-green algae are especially susceptible to copper toxicity. Copper formulations are also toxic to higher plants, but their use as an aquatic herbicide has been limited outside of the southern states. Like arsenic, copper, the active ingredient in many algicides—including copper sulfate, AV-70, and Cutrine Plus—may accumulate in the bottom sediments. Excessive levels of copper have been found to be toxic to fish and benthic organisms but

Map 16

AQUATIC PLANT HARVESTING AREAS
WITHIN DELAVAN LAKE: 1997-1999




DATE OF PHOTOGRAPHY: MARCH 1995

*Source: Delavan Lake Sanitary District and SEWRPC.*

Table 23

CHEMICAL CONTROL OF AQUATIC PLANTS IN DELAVAN LAKE: 1950-1999

| Year | Sodium Arsenite (pounds) | Macrophyte Control | | | | | Algae Control | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Diquat (gallons) | Glyphosate (gallons) | Endothall (gallons) | 2,4-D (gallons) | 2,4-D (pounds) | Copper Sulfate (pounds) | Cutrine Plus (gallons) | AV-70 (gallons) |
| 1950-1969 | 10,396 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 81,113 | 0.00 | 0 |
| 1970 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 4,095 | 0.00 | 0 |
| 1971 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 9,200 | 0.00 | 0 |
| 1972 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 7,000 | 0.00 | 0 |
| 1973 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 2,433 | 0.00 | 0 |
| 1974 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 2,667 | 0.00 | 0 |
| 1975 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 2,595 | 0.00 | 865 |
| 1976 | -- | -- | -- | -- | -- | -- | -- | -- | 1,130 |
| 1977 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 700 | 0.00 | 875 |
| 1978 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 115 | 0.00 | 566 |
| 1979 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 20 | 0.00 | 627 |
| 1980 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 0.00 | 660 |
| 1981 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 0.00 | 67 |
| 1982 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 0.00 | 213 |
| 1983 | -- | -- | -- | -- | -- | -- | -- | -- | 884 |
| 1984 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 0.00 | 915 |
| 1985 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 0.00 | 508 |
| 1986 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 15.00 | 723 |
| 1987 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 5.00 | 10 |
| 1988 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 0.00 | 0 |
| 1989 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 0.00 | 0 |
| 1990 | 0 | 0.00 | 0.2 | 0.00 | 0.0 | 0 | 0 | 0.00 | 0 |
| 1991 | 0 | 10.00 | 1.3 | 0.00 | 0.0 | 0 | 0 | 2.0 | 10 |
| 1992 | 0 | 1.50 | 0.0 | 0.00 | 0.0 | 0 | 0 | 1.50 | 4 |
| 1993 | 0 | 19.00 | 0.0 | 0.0 | 0.0 | 0 | 0 | 33.75 | 0 |
| 1994 | 0 | 25.10 | 0.0 | 0.00 | 0.0 | 0 | 0 | 27.50 | 0 |
| 1995 | 0 | 37.50 | 0.0 | 40.50 | 0.0 | 0 | 0 | 79.25 | 0 |
| 1996 | 0 | 11.00 | 0.0 | 15.00 | 57.5 | 0 | 0 | 11.00 | 0 |
| 1997 | 0 | 23.50 | 0.0 | 25.75 | 0.0 | 2,339 | 0 | 134.50 | 0 |
| 1998 | 0 | 6.75 | 0.0 | 8.25 | 0.0 | 900 | 0 | 123.75 | 0 |
| 1999 | 0 | 31.25 | 0.0 | 47.25 | 32.5 | 2,930 | 0 | 178.00 | 0 |
| Total | 10,396 | 155.60 | 1.5 | 136.75 | 90.0 | 6,169 | 109,938 | 611.25 | 8,057 |

*Source: Wisconsin Department of Natural Resources, Delavan Lake Sanitary District, and SEWRPC.*

have not been found to be harmful to humans.[11] Accumulation of copper in the sediment of Delavan Lake has been reported.[12] Peak concentrations of copper found in the sediment, as noted in Table 15 of Chapter IV, were approximately 45 milligrams per kilogram (mg/kg) occurring at depths of up to 20 centimeters (cm), which depths correspond to sediments deposited in the Lake since about 1962. These copper concentrations exceed the lowest effect level (LEL) guidelines of 25 mg/kg proposed by the Wisconsin Department of Natural Resources. Copper

[11] *J.A. Thornton and W. Rast, "The Use of Copper and Copper Compounds as Algicides," in H. Wayne Richardson,* Handbook of Copper Compounds and Applications, *Marcel Dekker, New York, 1997, pp. 123-142.*

[12] *R.S. Wakeman,* The Preservation of Historical Copper Loadings in the Recent Sedimentary Record of a Hardwater Lake in Southeastern Wisconsin, *M.S. Thesis, University of Wisconsin-Milwaukee, 1985.*

Table 24

PRESENT RESTRICTIONS ON WATER USES AFTER APPLICATION OF AQUATIC HERBICIDES[a]

| Use | Days after Application | | | | |
|---|---|---|---|---|---|
| | Cutrine-Plus | Diquat | Glyphosate | Endothall | 2,4-D |
| Drinking | - -[b] | 14 | - -[c] | 7-14 | - -[d] |
| Fishing | 0 | 14 | 0 | 3 | 0 |
| Swimming | 0 | 1 | 0 | - - | 0 |
| Irrigation | 0 | 14 | 0 | 7-14 | - -[d] |

[a]*The U.S. Environmental Protection Agency has indicated that, if these restrictions are observed, pesticide residues in water, irrigated crops, or fish will not pose an unacceptable risk to humans and other organisms using or living in the treatment zone.*

[b]*According to the Wisconsin Department of Natural Resources, if water is to be used as potable water, the residual copper content cannot exceed one part per million (ppm).*

[c]*According to the Wisconsin Department of Natural Resources, if water is to be used as potable water, the drinking water tolerance of glyphosate is one part per million (ppm).*

[d]*2,4-D products are not to be applied to waters used for irrigation, animal consumption, drinking, or domestic uses, such as cooking and watering vegetation.*

*Source: Wisconsin Department of Natural Resources.*

concentrations from sediments at a depth greater than 30 cm were less than 20 mg/kg, and within the LEL guidelines proposed by the Wisconsin Department of Natural Resources.[13] Restrictions on water uses after application of Cutrine Plus are also given in Table 24.

## AQUATIC ANIMALS

Aquatic animals include microscopic zooplankton; benthic, or bottom-dwelling invertebrates; fish and reptiles; amphibians; mammals; and waterfowl that inhabit the Lake and its shorelands. These make up the primary and secondary consumers of the food web.

### Zooplankton

Zooplankton are minute, free-floating animals inhabiting the same environment as phytoplankton. Zooplankton are primary consumers in the aquatic food chain, feeding to a large extent on such phytoplankton as green algae and diatoms. The zooplankton, in turn, are preyed upon by fish, particularly the larvae and fry of bluegills, pumpkinseeds, sunfish, and largemouth bass. One of the goals of the fishery rehabilitation program discussed below was to alter fishery in such a way as to promote domination of the zooplankton community by large-bodied cladoceran species, especially large-bodied *Daphnia* species, which are regarded as highly effective grazers of phytoplankton. The intended result of this biological manipulation, or biomanipulation, of the Lake was a reduction in algal densities and an accompanying increase in water clarity.

Prior to the biomanipulation, zooplankton were sampled by the U.S. Geological Survey during the period from October 1984 through September 1985.[14] Subsequently, there was ongoing monitoring of selected zooplankton

[13]*Wisconsin Department of Natural Resources,* op. cit.

[14]*Field and Duerk,* op. cit.

populations by the Wisconsin Department of Natural Resources throughout the 1990s. As shown in Table 25, the diversity of zooplankton species found in Delavan Lake is typical of eutrophic lakes within Wisconsin. The major groups of zooplankton present in the Lake included rotifers, copepods, and cladocerans. During the study period, 19 species of rotifers, nine species of copepods, and 27 species of cladocerans were found in Delavan Lake.

***Rotifers***

In eutrophic lakes in Southeastern Wisconsin, rotifers typically are only an important part of the zooplankton community during the early spring. Most rotifers are nonpredatory and feed on small algae, bacteria, and particulate matter. In spring, small phytoplankton are available as food for zooplankton, as larval fish are not yet present within the lake ecosystem to feed on the rotifers. Prior to the biomanipulation, *Conochiloides* spp. and *Synchaeta* spp. tended to be the dominant rotifers in Delavan Lake. No data were available regarding any changes to the rotifer community since the biomanipulation. These smaller-sized zooplankton were not within the size ranges selected for during the process of biomanipulation, and, consequently, were not sampled for during the Wisconsin Department of Natural Resources post-biomanipulation sampling programs.

***Copepods***

Copepods were present in Delavan Lake throughout the study period, but their diversity was low, with nine species being reported by the U.S. Geological Survey and Wisconsin Department of Natural Resources during their zooplankton surveys of the Lake. Prior to the biomanipulation, raptorial-feeding predatory cyclopoid species, such as *Cyclops vernalis*, tended to be more common than suspension feeding, herbivorous calanoid species such as *Diaptomus siciloides*. Copepod densities tended to be lower in the summer than in the spring, perhaps due to encystment of some species within the lake bottom sediments during summer. Following the biomanipulation, densities of copepods during summer tended to be lower, while calanoid species densities tended to be slightly higher than those of the cyclopoid species, reversing the previous tendency of these animals within the Lake.

***Cladocerans***

Considerable changes in the cladoceran assemblage present in Delavan Lake were reported by the Wisconsin Department of Natural Resources following the biomanipulation. Prior to the biomanipulation, the dominant species of zooplankton in the lake was *Cydorus sphaericus*, a small-bodied cladoceran. Bosminids and smaller *Daphnia* species, such as *Daphnia galeata, D. ambigua, D. dubia, D. longeremis,* and *D. rosea,* were more common during the summer than large-bodied species, such as *D. catawba, D. pulicaria, D. pulex,* and *D. schodleri*. Densities of these larger species were highest in the spring. As shown in Figure 10, *Daphnia* species went through a seasonal succession, with large-bodied species such as *D. pulex* and *D. schodleri* attaining peak densities during spring and early summer. This peak was followed by higher densities of relatively smaller-bodied animals during the late summer and fall. In 1985, for example, the U.S. Geological Survey reported that *D. pulex, D. schodleri, D. galeata,* and *D. retrocurva* reached peak densities during late-June, mid-July, early-September, and late-September, respectively. Periods of higher growth rates, as suggested by the large numbers of immature daphniids shown in Figure 10, occurred during the late-spring and again in the fall.

Table 26 suggests that, on average, large-bodied *Daphnia* species have dominated the cladoceran assemblage in the Lake; however, important changes have been observed since 1997. Figure 11 shows the population dynamics of *D. pulicaria* and *D. galeata* for the years between 1996 and 1999. During the period between 1996 and 1999, only the large-bodied zooplankter, *D. pulicaria*, was reported as being present. This species persisted in the water column throughout most of the summer. Since 1999, the smaller-bodied *D. galeata* has begun to be reported in the Lake during the spring, reaching peak levels during the late-summer to early-fall. *D. pulicaria* was reported to reach peak densities during mid-June, and the density of this species declined rapidly to low levels by early-July.

Figure 12 shows the egg-ratios, or average number of eggs carried per adult zooplankter, for the period between 1996 and 1997. The egg-ratio is an indicator of zooplankton growth rate, with higher ratios indicating faster growth rates or more production of young. Since 1997, high egg-ratios have been observed only in late summer and fall, suggesting that *Daphnia* species are experiencing fast growth only during this period.

Table 25

DELAVAN LAKE ZOOPLANKTON SURVEY RESULTS: 1984-1985

| Cladocera | Copepoda |
|---|---|
| *Alona barbulata* | *Cyclops bicuspidatus thomasi* |
| *Alona circumfibriata* | *Cyclops vernalis* |
| *Alona quadrangula* | *Diaptomus siciloides* |
| *Alona* sp. | *Ergasilus argus* |
| *Arcoperus harpae* | *Ergasilus* spp. |
| *Bosmina longirostris* | *Eulcyclops agilis* |
| *Bosmina* sp. | *Leptodiaptomus siciloides* |
| *Ceriodaphnia lacustris* | *Macrocyclops albidus* |
| *Ceriodaphnia* sp. | *Mesocyclops edax* |
| *Chydorus sphaericus* | Rotifera |
| *Daphnia ambigua* | *Ascomorpha* spp. |
| *Daphnia catawba* | *Asplanchna* spp. |
| *Daphnia dubia* | *Brachionus angularis* |
| *Daphnia galeata mendotae* | *Brachionus calyciflorus* |
| *Daphnia longiremis* | *Chromogaster* spp. |
| *Daphnia pulicaria* | *Collotheca* spp. |
| *Daphnia pulex* | *Conochiloides* spp. |
| *Daphnia retrocurva* | *Filinia* spp. |
| *Daphnia rosea* | *Keratella cochlearis* |
| *Daphnia schodleri* | *Keratella crassa* |
| *Diaphanosoma birgeii* | *Keratella earlinae* |
| *Diaphanosoma leuchtenbergianum* | *Keratella quadrata* |
| *Disparalona* sp. | *Keratella* spp. |
| *Eubosmina coregoni* | *Polyarthra* spp. |
| *Eubosmina longispina* | *Synchaeta* spp. |
| *Leptodora kindtii* | *Trichocerca capucina* |
| *Pseudochydorus* sp. | *Trichocerca multicrinis* |
| | *Trichocerca similis* |
| | *Trichocerca* spp. |

*Source: U.S. Geological Survey and SEWRPC.*

Because of the limited amount of data, predictions of the future dynamics of the zooplankton community must be viewed with caution. Two possible scenarios can be discerned, however. On the one hand, it may be that smaller-bodied cladoceran species, such as *D. galeata*, are beginning to displace larger-bodied species, such as *D. pulicaria*, in Delavan Lake. Alternatively, the daphniid assemblage may have resumed the sort of seasonal succession that was observed during 1985, prior to the biomanipulation. In either case, it is likely that the effects of the biomanipulation on algal densities will not be as pronounced in the future as they were in the earlier years of the biological manipulation.

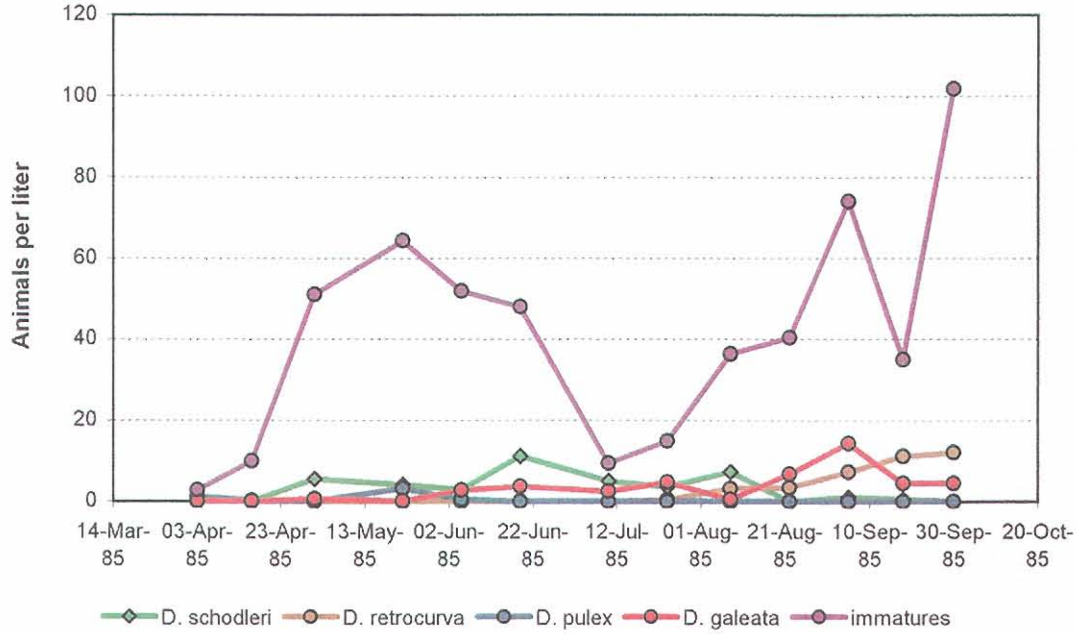
**Benthic Invertebrates**

Benthic, or bottom-dwelling, invertebrates include a number of different organisms from a variety of groups. Some act as primary or secondary consumers in the aquatic food chain, while others feed on detritus and organic debris in the sediment. Feeding and other activities by these animals can affect how organic materials and nutrients are transferred between the sediment and water column of a lake. In addition, many of these animals serve as food for fish, amphibians, and other larger animals that are a part of the lake ecosystem. Burrowing and feeding activities by these species which prey upon the benthic invertebrates can act to resuspend sediments into the water column. In Delavan Lake, information on the benthic invertebrate community is sparse, although data do exist on three groups: clams, midges, and phantom midges.

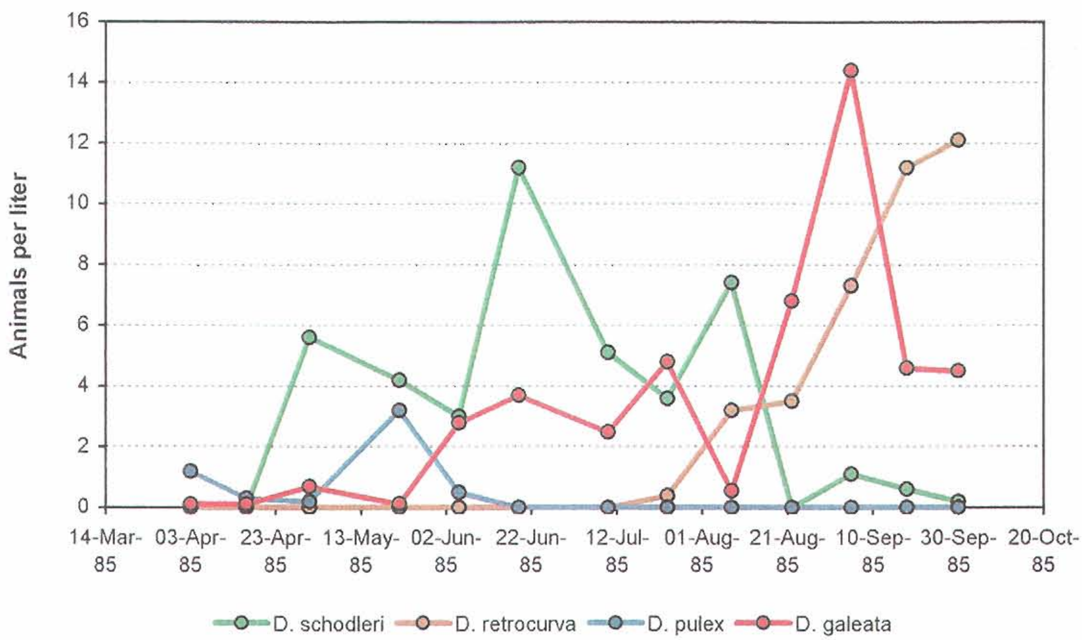
Figure 10

ZOOPLANKTON SPECIES AND ABUNDANCE IN DELAVAN LAKE: 1985

All Daphnia




Adult Daphnia




*Source: U.S. Geological Survey and SEWRPC.*

Table 26

AVERAGE DENSITIES OF ZOOPLANKTON IN DELAVAN LAKE
BEFORE AND AFTER THE BIOMANIPULATION: 1984-1999

| Species | 1984-1989 | | 1992-1999 | |
|---|---|---|---|---|
| | April to May | June to August | April to May | June to August |
| Cladocera | | | | |
| Large Daphnids | 19.0 | 4.5 | 22.0 | 15.0 |
| Medium Daphnids | 2.2 | 31.0 | 0.0 | 0.4 |
| Bosminids | 7.1 | 31.0 | 1.8 | 0.2 |
| Chydorid | 37.1 | 140.0 | 0.6 | 3.8 |
| Others | 1.0 | 0.7 | 0.9 | 0.2 |
| Copepoda | | | | |
| Cyclopoid | 41.2 | 37.3 | 43.5 | 12.0 |
| Calanoid | 29.6 | 24.7 | 13.3 | 15.0 |

NOTE: Values represent animals per liter.

*Source: Wisconsin Department of Natural Resources and SEWRPC.*

Freshwater clams feed by filtering particulate material from the water column. Some species sit on top of the sediment, while others tend to burrow into it. As shown in Table 27, nine species of clams were stocked into Delavan Lake by the Wisconsin Department of Natural Resources following the drawdown in 1994. However, no follow-up activities to assess their survival were undertaken, and no data are available regarding the current status of these organisms in the Lake.

The larvae of midges, in the genus *Chironomus*, are commonly found in temperate lakes and can be present in densities as high as 50,000 per square meter.[15] Young larvae are generally planktonic, but older juveniles dwell in burrows that they dig in the lake sediments. This burrowing action can disturb or resuspend lake sediments. In addition, the juvenile midges feed by filtering suspended material from the water column or gathering material from the surface of the sediment. Table 28 shows the densities of *Chironomus* during winter in the profundal, or deep water, zone of Delavan Lake. The densities of *Chironomus* in Delavan Lake have been reported to have increased since the alum treatment and the rehabilitation of the lake fishery. Prior to the alum treatment, the densities were probably low due to the disturbance of lake sediments by carp.

The larvae of the phantom midges, *Chaoborus* spp., are a common member of the benthos in temperate lake communities. These animals are generally predatory, feeding primarily on zooplankton. As shown in Table 28, the densities of *Chaoborus*, are probably close to the levels reported prior to the alum treatment and rehabilitation of the fishery. However, these data should be interpreted with caution, as *Chaoborus* was found in the sediment only at one site, in the deepest part of the Lake, and the reported numbers are probably not representative of the Lake as a whole.

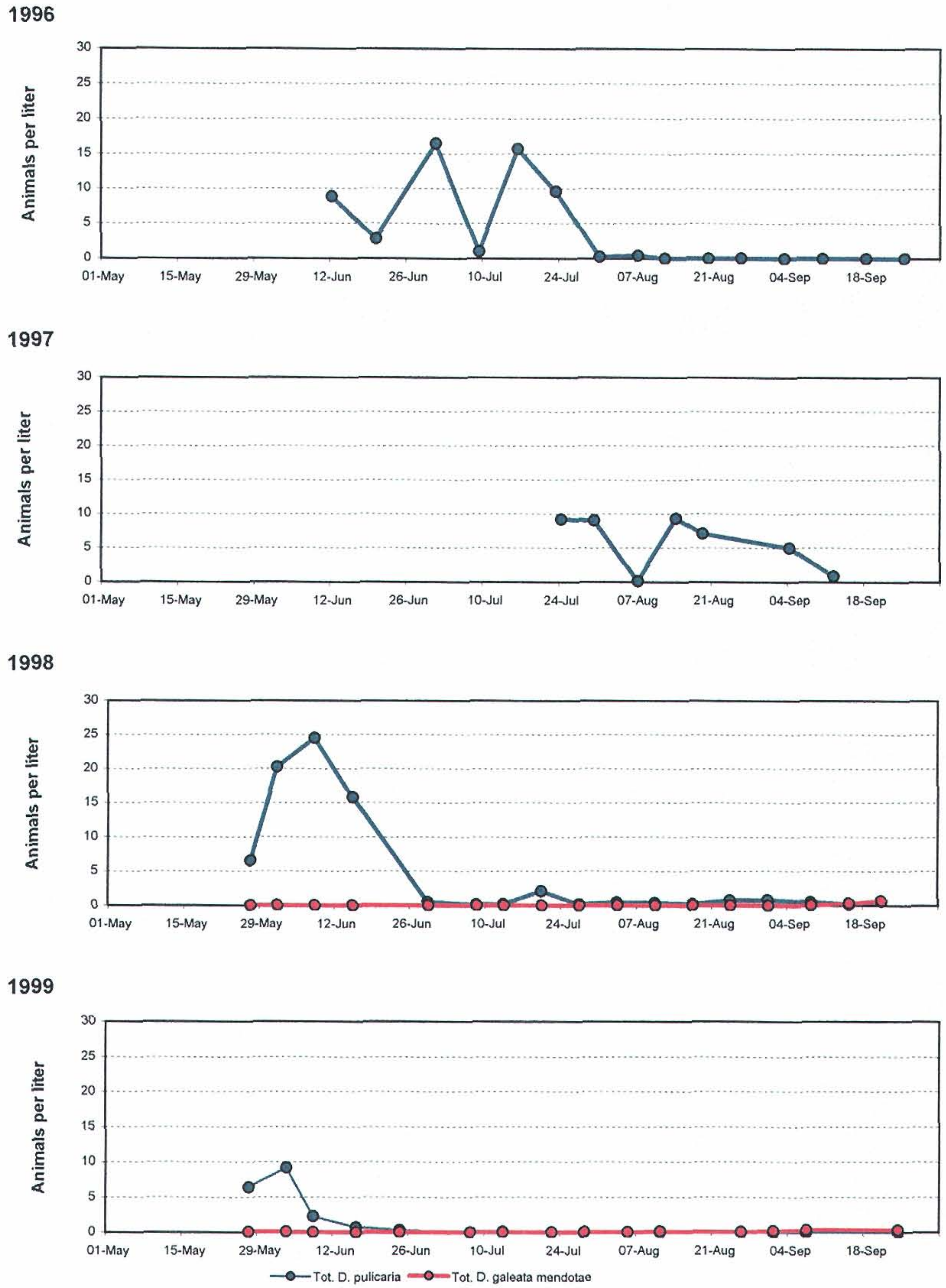
## Fishes of Delavan Lake

"Panfish" is a common term applied to a broad group of smaller fish with a relatively short and usually, but not always, broad shape. Panfish species known to exist in Delavan Lake include bluegill, pumpkinseed, rock bass,

[15]*R.M. Merritt and K.W. Cummins (eds.),* An Introduction to the Aquatic Insects of North America, *3rd Edition, 1996.*

Figure 11

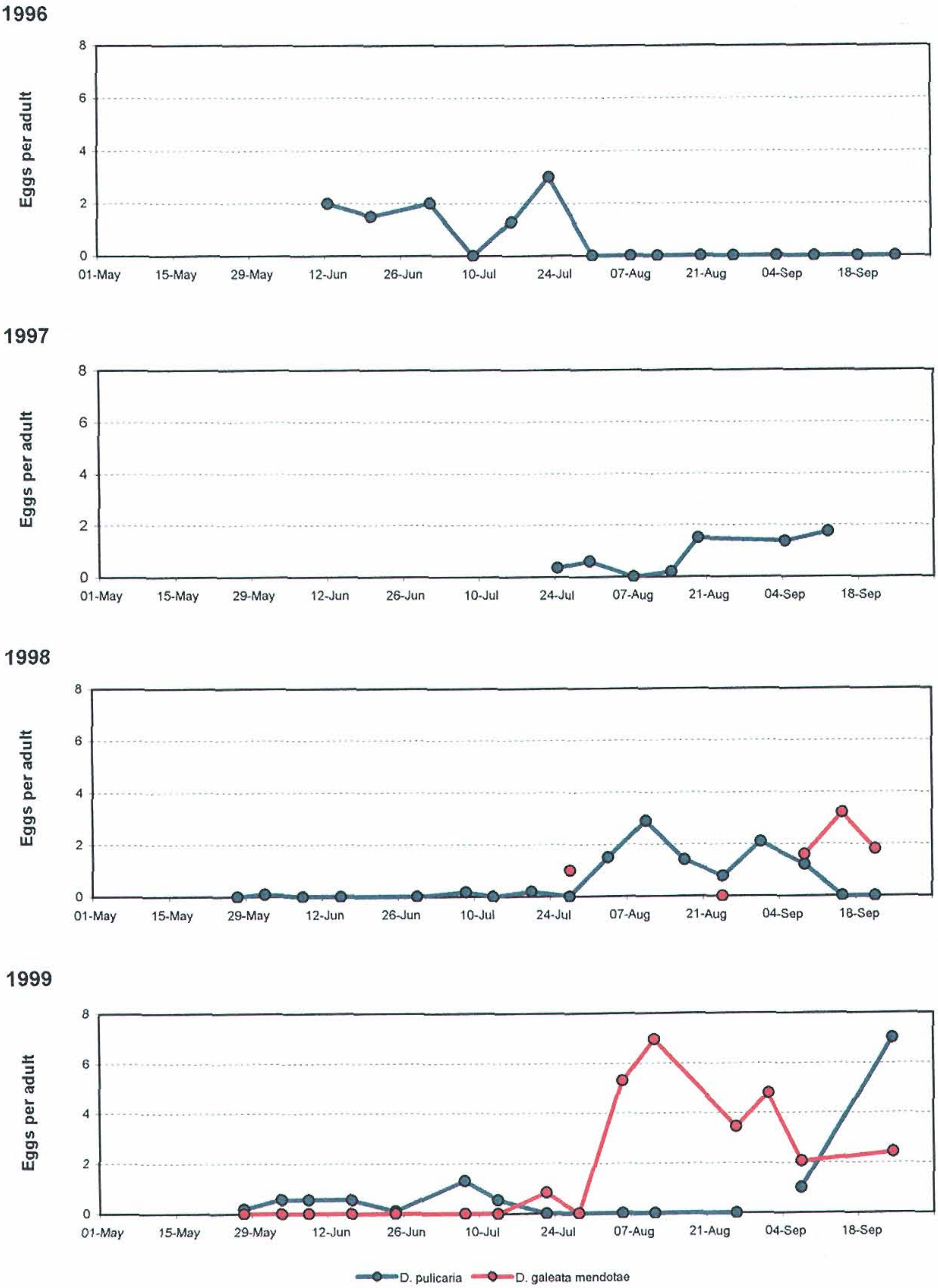
DAPHNID POPULATION DYNAMICS IN DELAVAN LAKE: 1996-1999




*Source: Wisconsin Department of Natural Resources and SEWRPC.*

*Figure 12*

ZOOPLANKTON EGG-RATIOS IN DELAVAN LAKE: 1996-1999




*Source: Wisconsin Department of Natural Resources and SEWRPC.*

Table 27

DELAVAN LAKE AQUATIC BENTHIC INVERTEBRATE SPECIES STOCKING RECORD: 1990-1999

| Common Name | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1998 | 1999 | Total |
|---|---|---|---|---|---|---|---|---|---|
| Crayfish | 300 pounds | - - | - - | - - | - - | - - | - - | - - | 300 pounds |
| Clams | - - | - - | - - | - - | 9 species<br>355 clams | - - | - - | - - | 9 species<br>355 clams |

*Source: Wisconsin Department of Natural Resources and SEWRPC.*

yellow perch, green sunfish, and black crappies. The habitats of panfish vary widely among the different species, but their cropping of the plentiful supply of insects and plants, coupled with prolific breeding rates, typically leads to large populations with rapid turnover. Panfish frequently feed on the fry of predator fish and, if the panfish population is overabundant, they may quickly deplete the predator fry population. As a consequence, some lakes within Southeastern Wisconsin have stunted, or slow-growing, panfish populations because their numbers are not controlled by predator fishes. Figure 13 illustrates the importance of a balanced predator-prey relationship, using walleyed pike and perch as an example.

The species composition of the panfish assemblage in Delavan Lake may be changing. Currently, black crappie is the dominant panfish in the Lake. In addition, yellow perch, previously reported in the Lake, have not been reported in the more recent 1998 and 1999 surveys. This fact may reflect either low population densities or an absence of this species from the Lake. Further, the proportion of bluegill recorded in the Wisconsin Department of Natural Resources fisheries surveys has been reported to have declined considerably since 1997, and anglers have expressed concerns about the absence of larger bluegills in the creel.[16] This observation suggests that the bluegill population may be experiencing stunting. The Wisconsin Department of Natural Resources has hypothesized that an overharvest of larger bluegills may be contributing to an unbalanced, slow-growing panfish population.

"Game fish" are popular angling species and generally include the larger predator species present within lakes in Southeastern Wisconsin. These species include walleyed and northern pike, and largemouth and smallmouth bass, all of which have been reported from Delavan Lake. Currently, the Wisconsin Department of Natural Resources manages Delavan Lake for the production of game fish, such as walleyed pike, northern pike, and largemouth bass, as well as for panfish.

"Rough fish" is a broad term applied to species, such as carp, that do not readily bite on hook and line, but feed on game fish and destroy habitat needed by more desirable species. Rough fish are commonly considered to be undesirable for human consumption in Southeastern Wisconsin. Rough fish species that were historically found in Delavan Lake include carp and bigmouth buffalo. These fish species were largely eradicated from the Lake during the rehabilitation of the fishery. According to the Wisconsin Department of Natural Resources, carp have been detected in recent fishery surveys in Delavan Lake, but do not represent a significant problem.[17]

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[16]*D.E. Welch and R. Dauffenbach,* Fisheries Survey Report for Delavan Lake (WBIC 0793600), Walworth County 1990-1997, *Wisconsin Department of Natural Resources, 1997.*

[17]*According to the Wisconsin Department of Natural Resources, carp are typically considered a significant problem if they are the most populous fish species in the lake, or if they appear stressed or cause stress among other fish populations in the lake.*

Table 28

DENSITIES OF AQUATIC BENTHIC INVERTEBRATES OBSERVED IN THE PROFUNDAL ZONE OF DELAVAN LAKE: 1988-1996

| Year | *Chironomus* per square meter[a] | *Chaoborus* per square meter[b] |
|---|---|---|
| 1988-1989 | 100 | 2,000-6,000 |
| 1990 | 0[c] | 0[c] |
| 1991-1993 | 2,000-6,000 | 2,000-6,000 |
| 1994-1996 | 4,000-20,000 | - -[d] |

[a]*Winter samples taken from deep water sediments.*

[b]*Found in one site in the deepest part of the profundal zone.*

[c]*No animals were observed during the period of drawdown preceding alum treatment.*

[d]*No data are available.*

*Source: Wisconsin Department of Natural Resources and SEWRPC.*

### *Fisheries Surveys*

Beginning in the 1940s, the quality of the fishery in Delavan Lake was perceived to have declined as a result of the heavy nutrient loading of the Lake with treated sewage effluent, runoff from urban shoreline development, and agricultural runoff. A survey conducted in 1948 found that largemouth bass were the dominant game fish and yellow perch and black crappies were the dominant panfish in the Lake.[18] Walleyed pike and northern pike were reported to be present but not common. Several other species, including warmouth, smallmouth bass and black crappies, were also present.

By 1959, largemouth bass were reported to be less common,[19] while summer surveys found young-of-the-year; no adults were reported. Nevertheless, catches of smallmouth bass and walleyed pike were reported to be comparable to those reported in the 1948 survey. Bluegill population levels were reported to be low.

During 1966, a fall electrofishing survey by the Wisconsin Department of Natural Resources found that smallmouth bass had become the most commonly encountered fish in the Lake.[20] Largemouth bass were reported to be very scarce. Black crappies and yellow perch were reported to be very abundant, and bluegill population levels were reported to be increasing. Similar surveys conducted during 1968 and 1969 found evidence that natural reproduction of walleyed pike was occurring,[21] and large numbers of smallmouth bass and fair numbers of bluegills and perch were also reported.

Subsequently, a comprehensive fishery survey, conducted on Delavan Lake during 1972,[22] reported that walleyed pike had become the principal game fish in the Lake. Northern pike were reported to be scarce and largemouth bass remained nearly absent. Smallmouth bass, while still present, were reported to have declined in abundance.

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[18]*K.M. Mackenthun,* A Biological Survey of Lake Como and Lake Delavan, Walworth County, *Wisconsin Conservation Department Investigational Report No. 651, 1948.*

[19]*W.R. Byam,* Fyke Net Survey of Delavan Lake, Walworth County, *Wisconsin Conservation Department Intradepartmental Memo, 1960.*

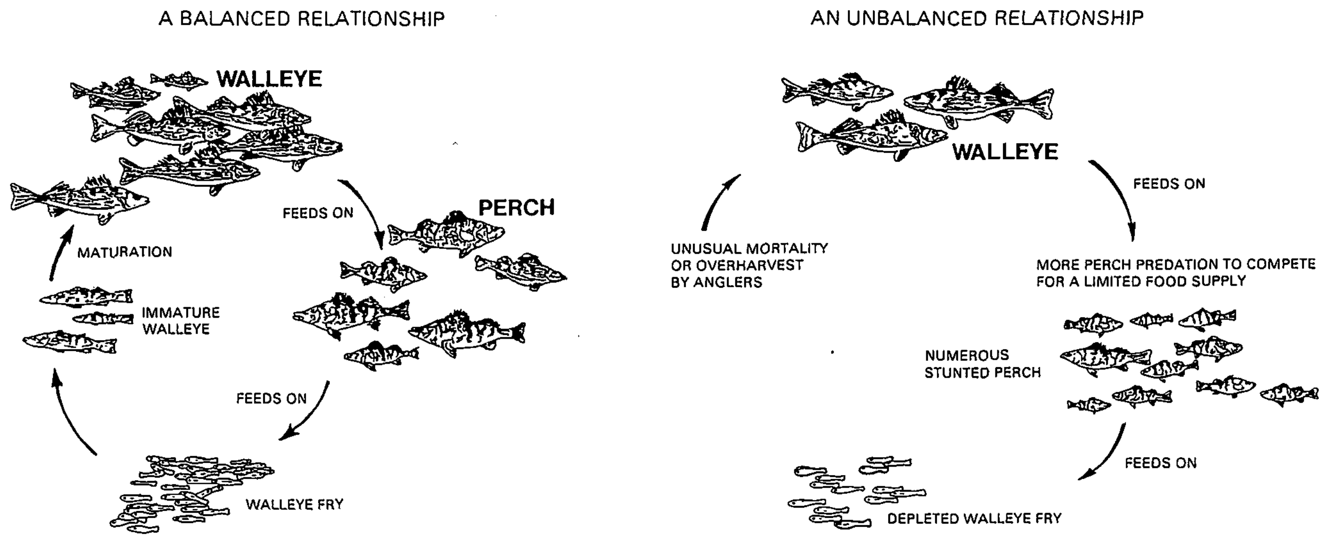
[20]*D. Mraz,* Electrofishing Survey, September 23, 1966, *Wisconsin Conservation Department Intradepartmental Memo, 1966.*

[21]*R. Piening,* Walleye Sampling in Delavan Lake, Walworth County, *Wisconsin Conservation Department Intradepartmental Memo, 1969, H.S. Druckenmiller,* Walleye Survey of Delavan Lake, *Wisconsin Conservation Department Intradepartmental Memo, 1969.*

[22]*R. Piening,* F-1D2 Report with Fisheries Management Recommendations for Delavan Lake, Walworth County, *Wisconsin Department of Natural Resources Intradepartmental Memo, 1973.*

Figure 13

**THE PREDATOR-PREY RELATIONSHIP**




*Source: Wisconsin Department of Natural Resources.*

White bass had become numerically important, and yellow perch were abundant, as were black crappies. It was difficult to locate bluegills in the Lake. A further survey, conducted during 1975, found that Delavan Lake contained an adult population of northern pike reported to be of poor abundance,[23] while walleyed pike remained common. Smallmouth bass were reported to be present at a low population density. There were sizable populations of white bass, yellow perch, and crappies reported during this survey. Bluegills, largemouth bass, and rock bass continued to be quite scarce.

By the 1980s, two undesirable species, carp and bigmouth buffalo, were reported to be dominating the Lake fishery. The habits of these fish contributed to a decrease in rooted aquatic vegetation and an increase in algal densities, resulting in reductions in water clarity and perceived declines in water quality. The lake rehabilitation program, begun during fall 1989 with the drawdown of the lake level and rotenone treatment of the Lake and its watershed tributaries, and followed by the alum treatment of the lake water column during spring 1990, was intended to improve water quality and the fishery. Restocking of the lake fishery by the Department of Natural Resources was begun during spring 1990 with the intent on establishing a diverse fish community in Delavan Lake dominated by predator fish. In order to establish a predator fish population capable of controlling potential rough fish, fishing was prohibited for two years following the restocking. Table 29 shows the numbers and species of fish stocked into Delavan Lake between 1990 and 1999.

Delavan Lake currently supports a moderately diverse fish community. Wisconsin Department of Natural Resources fish surveys conducted between 1990 and 1999 recorded the presence of 16 species of fish representing five families, as shown in Table 30. The Wisconsin Department of Natural Resources currently regulates the harvest of fishes from the Lake under current State fishing regulations, which provide for special size and bag

[23]*Schumacher and Burns,* op. cit.

Table 29

DELAVAN LAKE FISH STOCKING RECORD: 1990-1999

| Common Name | 1990 | 1991 | 1992 | 1993 | 1994 | 1997 | 1998 | 1999 | Total |
|---|---|---|---|---|---|---|---|---|---|
| Muskellunge | 100,000 fry | 17,800 fry<br>2,500 fingerlings | 2,850 fingerlings<br>383 yearling | 2,670 fingerlings<br>398 yearlings | 2,505 fingerlings | 2,500 fingerlings | 1,135 fingerlings | 2,500 fingerlings | 117,800 fry<br>13,990 fingerlings<br>781 yearlings |
| Northern Pike | 400,000 fry<br>4,914 fingerlings | 4,000 fingerlings | 3,160 fingerlings | 2,500 fingerlings | 2,500 fingerlings | 1,181 fingerlings | - - | - - | 400,000 fry<br>18,255 fingerlings |
| Largemouth Bass | 1,039 adults | - - | - - | - - | - - | - - | - - | - - | 1,039 adults |
| Smallmouth Bass | 241 adults | - - | - - | 17,920 fry | - - | - - | 75,500 fingerlings | 69,861 fingerlings | 17,920 fry<br>145,361 fingerlings<br>241 adults |
| Walleyed Pike | 2,000,000 fry | 2,150,000 fry | - - | - - | - - | - - | 1,350,000 fry<br>213,500 fingerlings | 400,000 fry | 5,900,000 fry<br>213,500 fingerlings |
| Bluegill | - - | 70,830 | 130,927 | 62,584 | - - | - - | - - | - - | 264,341 |
| Yellow Perch | 44 | 95,564 | 91,364 | 57,353 | - - | - - | - - | - - | 244,325 |
| Black Crappie | - - | 6,220 | 264 | | - - | - - | - - | - - | 6,484 |
| Mimic Shiners | 1,550 pounds | 3,156 pounds | 2,445 pounds | 144 pounds | - - | - - | - - | - - | 7,295 pounds |
| Fathead Minnows | 1,325 pounds | - - | - - | - - | - - | - - | - - | - - | 1,325 pounds |

NOTE: No stocking occurred during 1995 and 1996.

*Source: Wisconsin Department of Natural Resources and SEWRPC.*

Table 30

FISH SPECIES REPORTED IN DELAVAN LAKE: 1990-1999

| Common Name | Family Name | Scientific Name | Relative Abundance |
|---|---|---|---|
| Walleyed Pike | *Percidae* | *Stizostedion vitreum vitreum* | Abundant |
| Yellow Perch | *Percidae* | *Perca flavescens* | Present |
| Northern Pike | *Esocidae* | *Esox lucius* | Common |
| Muskellunge | *Esocidae* | *Esox masquinongy* | Present |
| Largemouth Bass | *Centrarchidae* | *Micropterus salmoides* | Common |
| Smallmouth Bass | *Centrarchidae* | *Micropterus dolomieui* | Present |
| Bluegill | *Centrarchidae* | *Lepomis macrochirus* | Common |
| Pumpkinseed | *Centrarchidae* | *Lepomis gibbosus* | Present |
| Green Sunfish | *Centrarchidae* | *Lepomis cyanellus* | Present |
| Black Crappie | *Centrarchidae* | *Pomoxis nigromaculatus* | Present |
| Rock Bass | *Centrarchidae* | *Ambloplites rupestris* | Present |
| Black Bullhead | *Ictaluridae* | *Ictalurus melas* | Present |
| White Sucker | *Catostomidae* | *Catostomus commersoni* | Present |
| Mimic Shiner | *Cyprinidae* | *Notropis volucellus* | Present |
| Fathead Minnow | *Cyprinidae* | *Pimephales promelas* | Present |
| Common Carp | *Cyprinidae* | *Cyprinus carpio* | Present |

*Source: Wisconsin Department of Natural Resources.*

limits on the daily harvest in specific cases. Such specific regulations, designed to maintain the biomanipulation of Delavan Lake, are summarized in Table 31. The Department plans to continue to stock Delavan Lake with walleyed pike, northern pike, muskellunge, smallmouth bass, and largemouth bass annually, depending on their availability from the Department's fish hatcheries.

***Fish Population Dynamics***

Important predator fishes in Delavan Lake include walleyed pike, northern pike, and largemouth bass. These three species are carnivorous, feeding primarily on other fish, crayfish, and frogs. Further, these species are among the largest and most prized game fish sought by anglers on the Lake. Based upon recent fisheries surveys conducted between 1997 and 1999 by the Wisconsin Department of Natural Resources, summarized above, walleyed pike were reported to be abundant, while the largemouth bass and northern pike were considered common.[24] During this period, the proportion of game fish population of the Lake represented by largemouth bass has been reported to be increasing, and the walleyed pike population decreasing.

Walleyed pike currently remain the most abundant game fish in Delavan Lake. The Wisconsin Department of Natural Resources estimated the walleyed pike population to be about 58,000 fish during 1996, based upon the results of a "mark and recapture" survey.[25] Using standard statistical formulae, Commission staff have estimated a 95 percent confidence interval around this population level that ranged from about 54,000 to 64,000 fishes.[26] As noted above, since 1996, it would appear that the number of walleyed pike in Delavan Lake has declined from this level. According to the Wisconsin Department of Natural Resources, there are currently about seven adult walleyed pike per acre, or about 14,000 fishes, based upon catch per unit effort (CPUE) data recorded during the Department's autumn fishery surveys. The current population consists of individuals from two year-classes that apparently represent fish stocked into the Lake during 1990 and fish stocked into the Lake during 1998. While some natural reproduction has occurred, these data would suggest that few young have been successfully recruited into the population. This can be seen in the size frequency data for the populations in Figure 14. Based upon these data, it can be expected that walleyed pike densities will continue to decline over the short term as fish from the 1990 year-class reach the end of their natural life span.

In addition to the declining population levels, the average growth rate of individual walleyed pike in Delavan Lake is low. The growth rate has been estimated by the Wisconsin Department of Natural Resources to be less than 1.2 inches per year, as shown in Figure 15. This means that, at about 10 years of age, or within about two years of the end of their natural life spans, many fishes from the 1990 year-class are still shorter than the 18-inch-minimum size limit established for anglers. Anglers fishing on Delavan Lake have complained about being unable to catch any legal-sized walleyed pike.[27]

The slow growth rates and poor recruitment of young are probably due to intense competition for food, and predation of young walleyes by adult walleyes. At seven adult fish per acre, walleyed pike densities in Delavan Lake are quite high, higher than is often seen, even in heavily stocked lakes. The fishery report also indicated that the panfish and minnow recruitment, as well as recruitment of other predators, such as smallmouth bass and muskellunge, are low due to the number of walleyed pike.[28] Competition with walleyed pike may also be responsible for the small sizes of the muskellunge and smallmouth bass populations. In response to this possible

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[24] *Welch and Dauffenbach*, op. cit.

[25] Ibid.

[26] *C.J. Krebs*, Ecological Methodology, *Harper-Collins, New York, 1989.*

[27] *Welch and Dauffenbach*, op. cit.

[28] Ibid.

Table 31

2000-2001 OPEN SEASON, SIZE LIMITS, AND BAG LIMITS FOR FISH SPECIES IN DELAVAN LAKE[a]

| Species | Open Season | Daily Limit | Minimum Size |
|---|---|---|---|
| Northern Pike | May 6 to March 1 | 1 | 32 inches |
| Walleyed Pike | May 6 to March 1 | 3 | 18 inches |
| Largemouth and Smallmouth Bass | May 6 to March 1 | 1 | 18 inches |
| Muskellunge | May 6 to November 30 (southern zone) | 1 | 40 inches |
| Bluegill, Pumpkinseed (sunfish), Crappie, and Yellow Perch | Open all year | 25 in total | None |
| Bullhead and Rough Fish | Open all year | None | None |

[a] *The limits and sizes set forth in this table are for Delavan Lake. Daily limits and minimum sizes vary between lakes.*

*Source: Wisconsin Department of Natural Resources Publication and SEWRPC.*

over-populations of walleyed pike in Delavan Lake, the Wisconsin Department of Natural Resources removed several thousand fishes from Delavan Lake during 1998 and relocated them to other area waterbodies.

In contrast to the declining population of walleyed pike, the proportion of largemouth bass in the game fish population of Delavan Lake has been reported to be increasing since 1997. The population dynamics for this species are summarized in Figure 16. The population appears to be reproducing naturally. The size distributions shown in Figure 16 indicate that the largemouth bass population is likely to contain as many as three year-classes. Natural reproduction is also indicated by the consistently higher mean length of bass seen in the spring surveys compared with that reported in the fall surveys, as shown in Figure 17. Since the spring surveys are done before spawning and hatching of eggs, the decline in mean size from spring to fall is consistent with younger, shorter fish being recruited into the population through natural reproduction.

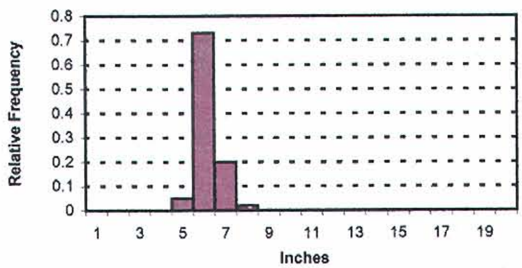
Smallmouth bass are currently a small component of the game fish community in Delavan Lake. During 1990, a small number of adult smallmouth bass were stocked into Delavan Lake, as shown in Table 29. This species has not become well established in the Lake. As shown in Figure 18, CPUE data from Wisconsin Department of Natural Resources fisheries surveys show declining numbers of smallmouth bass. The population size-structure data, shown in Figure 19, show little evidence of natural reproduction or recruitment, though the data from fall 1994 onwards should be interpreted with caution due to low sample sizes. No smallmouth bass were detected in the fall 1996 or spring 1997 fishery surveys. Small numbers of this fish were detected in subsequent surveys, perhaps related to stocking undertaken during 1998 and 1999.

At least three factors could account for the failure of smallmouth bass to become established in the Lake. First, competition with, and predation by, other fish species could be causing the failure of young-of-the-year of this species to be recruited into the population. High densities of walleyed pike and largemouth bass could be subjecting young smallmouth bass to intense predation pressure. Second, losses due to angling might have reduced the population density to below the level necessary to permit the population to remain viable. Third, the smallmouth bass population might be declining due to sampling-related stress imposed upon the fishes during the fisheries surveys. Sampling fish using electrofishing techniques subjects individual fish to stresses that can cause

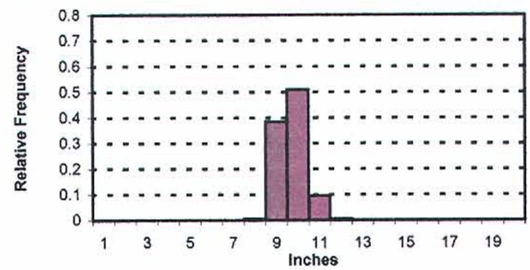
Figure 14

PERCENT FREQUENCY OF SIZE/AGE CLASS DISTRIBUTION
AMONG YEARS WITHIN DELAVAN LAKE: WALLEYED PIKE

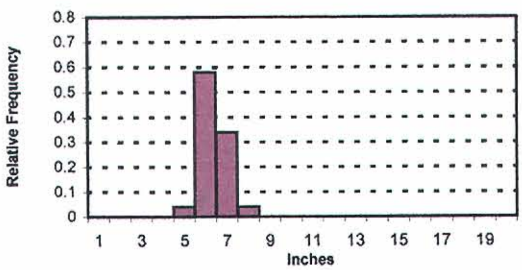
**Fall 1990**



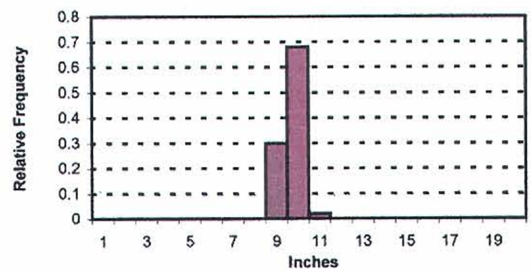

**Fall 1992**



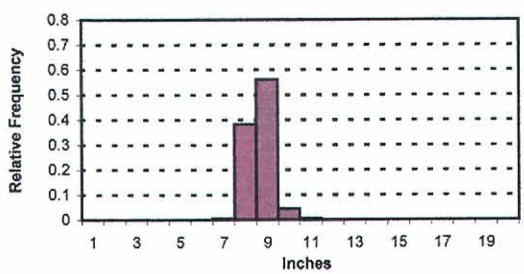

**Spring 1991**



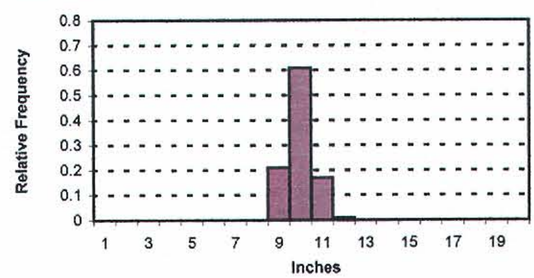

**Spring 1993**



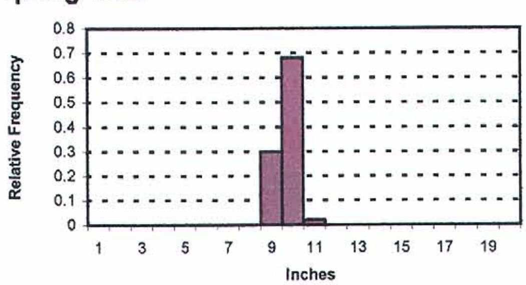

**Fall 1991**




**Fall 1993**




**Spring 1992**




**Fall 1994**

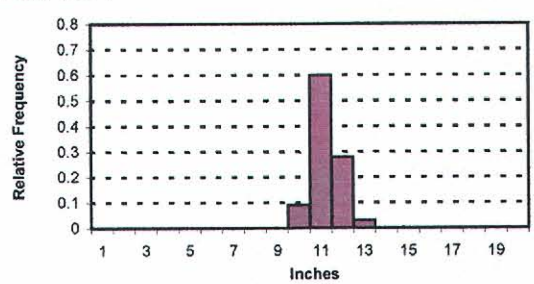
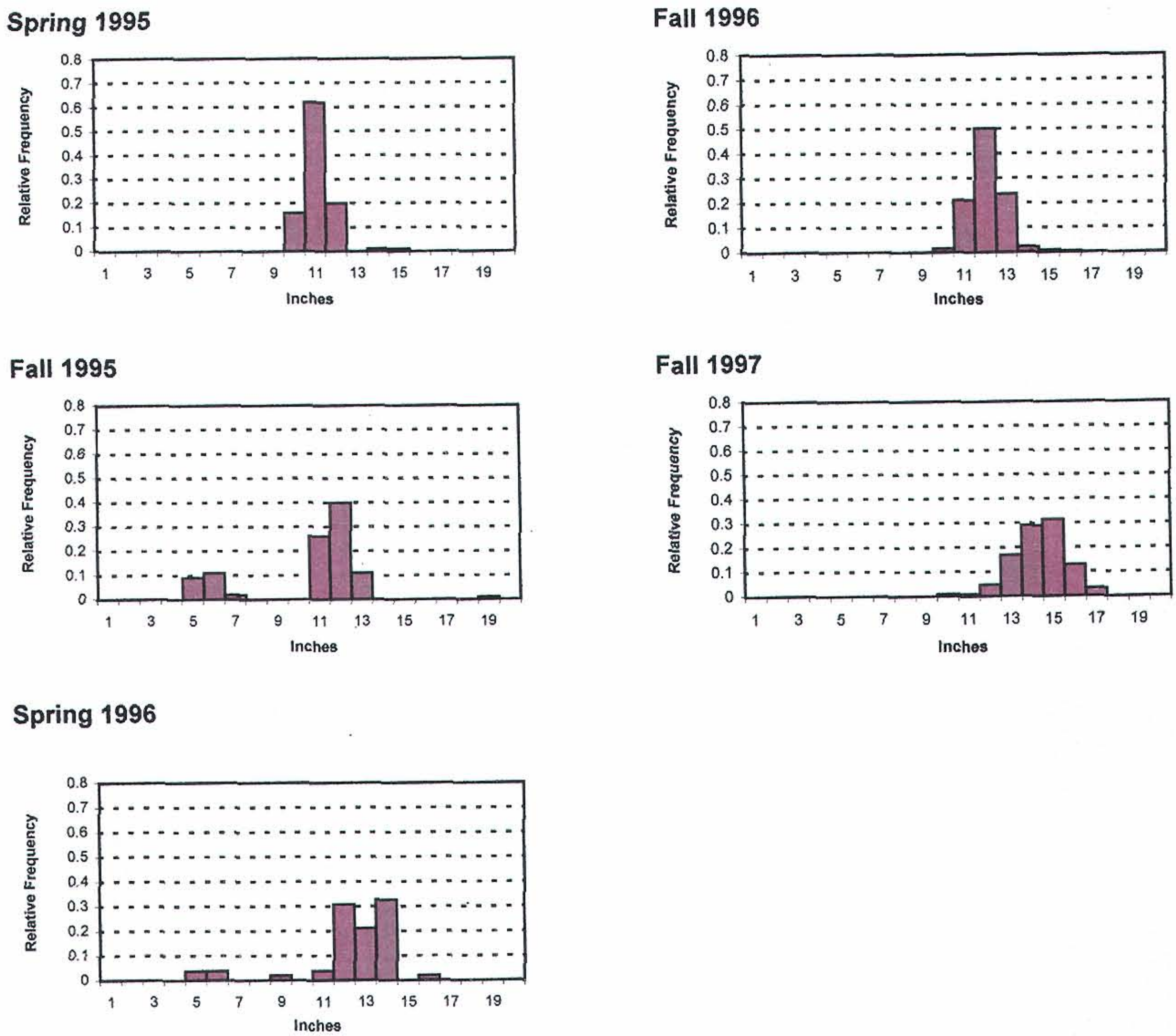


Figure 14 (continued)




*Source: Wisconsin Department of Natural Resources and SEWRPC.*

mortality.[29] Population-sampling theory generally assumes that the number of organisms sampled from a population do not constitute a significant portion of the population. For this reason, mortality due to sampling should not constitute a significant loss to the population. However, between 1990 and 1996, about 290 smallmouth bass, or about 50 more fish than were stocked during 1990, were sampled in the annual fishery surveys. Consequently, such sampling related mortality could represent another loss to this population, which, when combined with other pressures on the smallmouth bass population, could limit the ability of that population to become established in the Lake.

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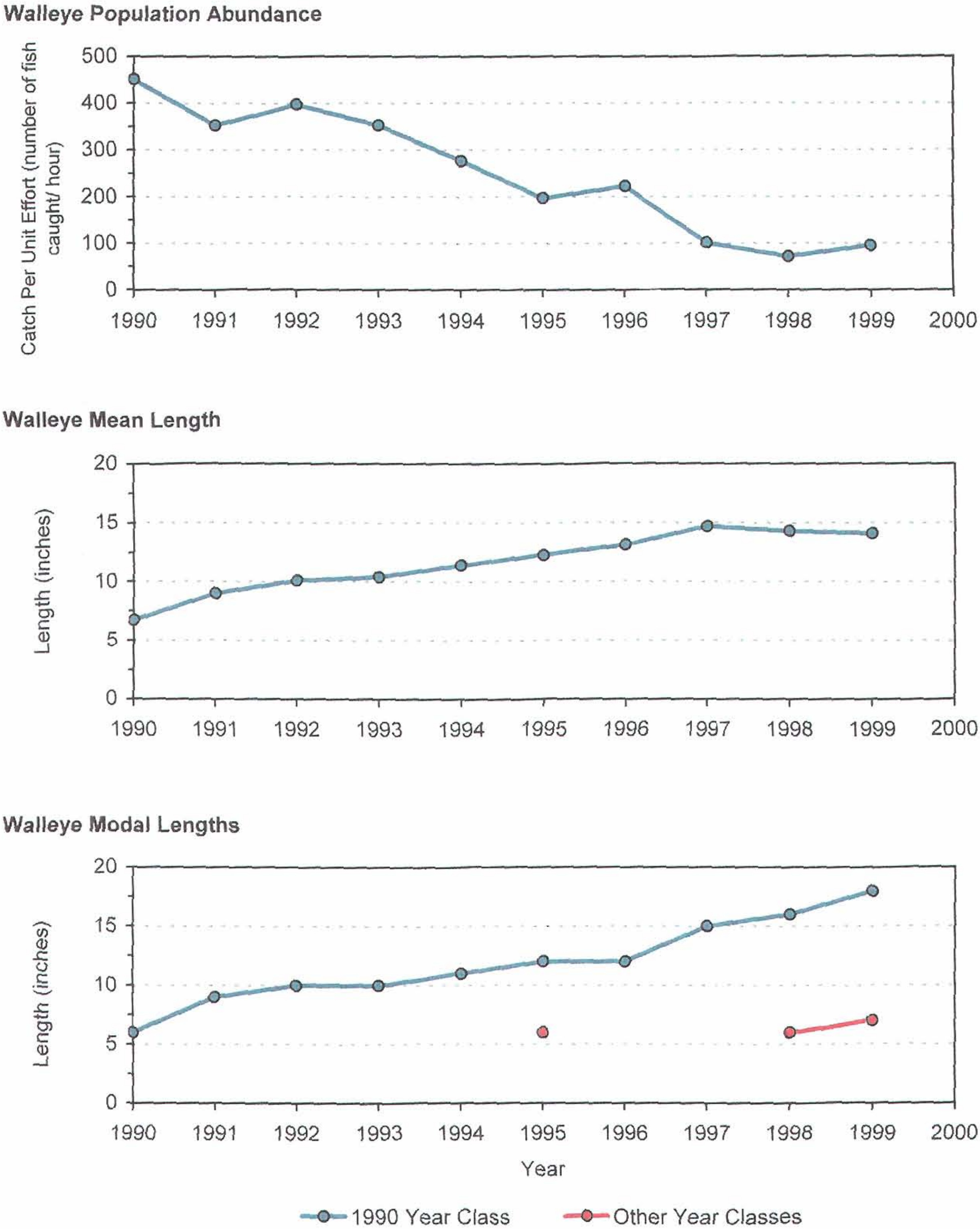
[29]*D.G. Cross and B. Stott, "The Effect of Electrofishing on the Subsequent Capture of Fish,"* Journal of Fish Biology, *Volume 7, 1975, pp. 349-357.*

Figure 15

DELAVAN LAKE FISH POPULATION DYNAMICS: WALLEYED PIKE




*Source: Wisconsin Department of Natural Resources and SEWRPC.*

Figure 16

PERCENT FREQUENCY OF SIZE/AGE CLASS DISTRIBUTION
AMONG YEARS WITHIN DELAVAN LAKE: LARGEMOUTH BASS

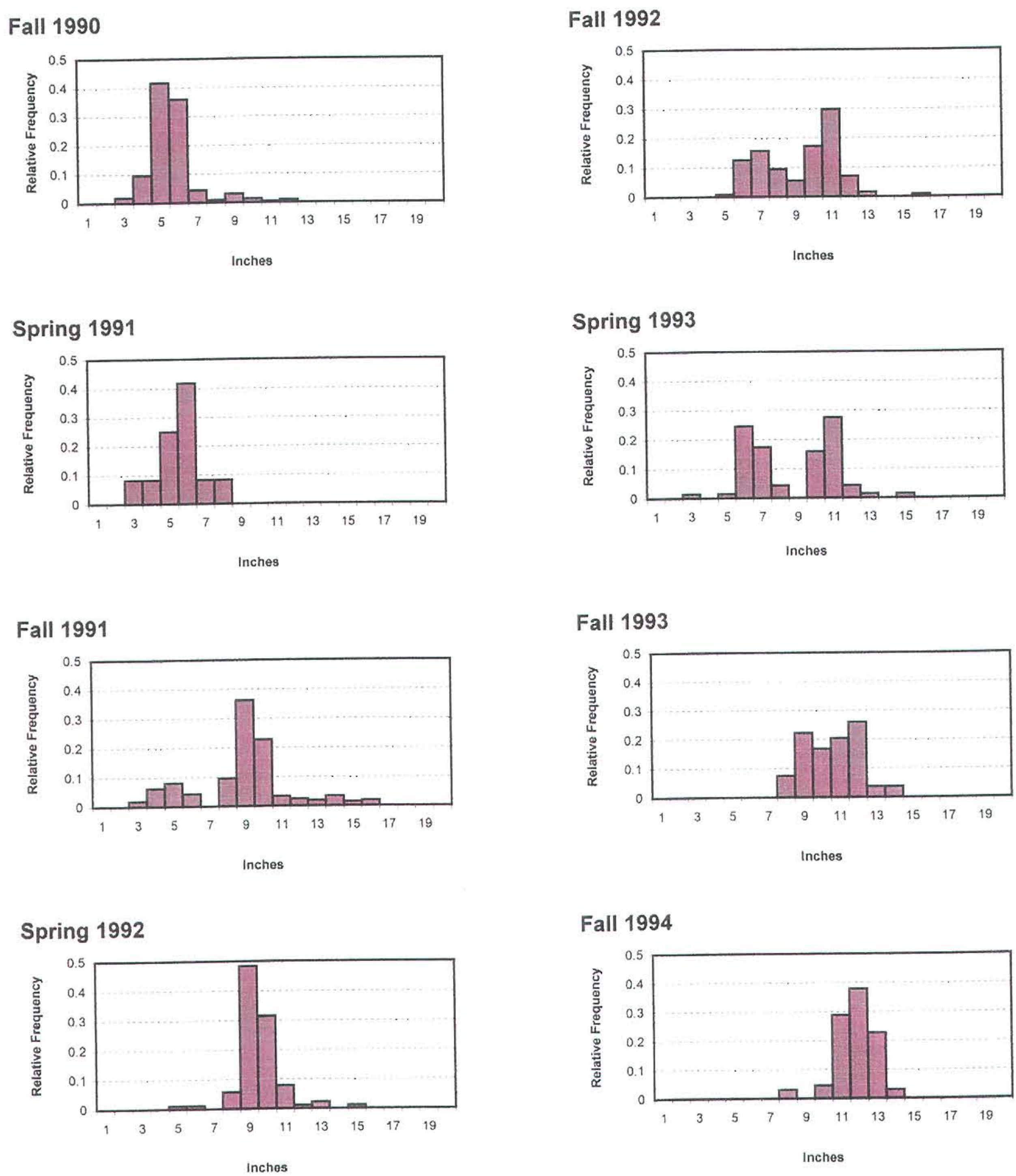
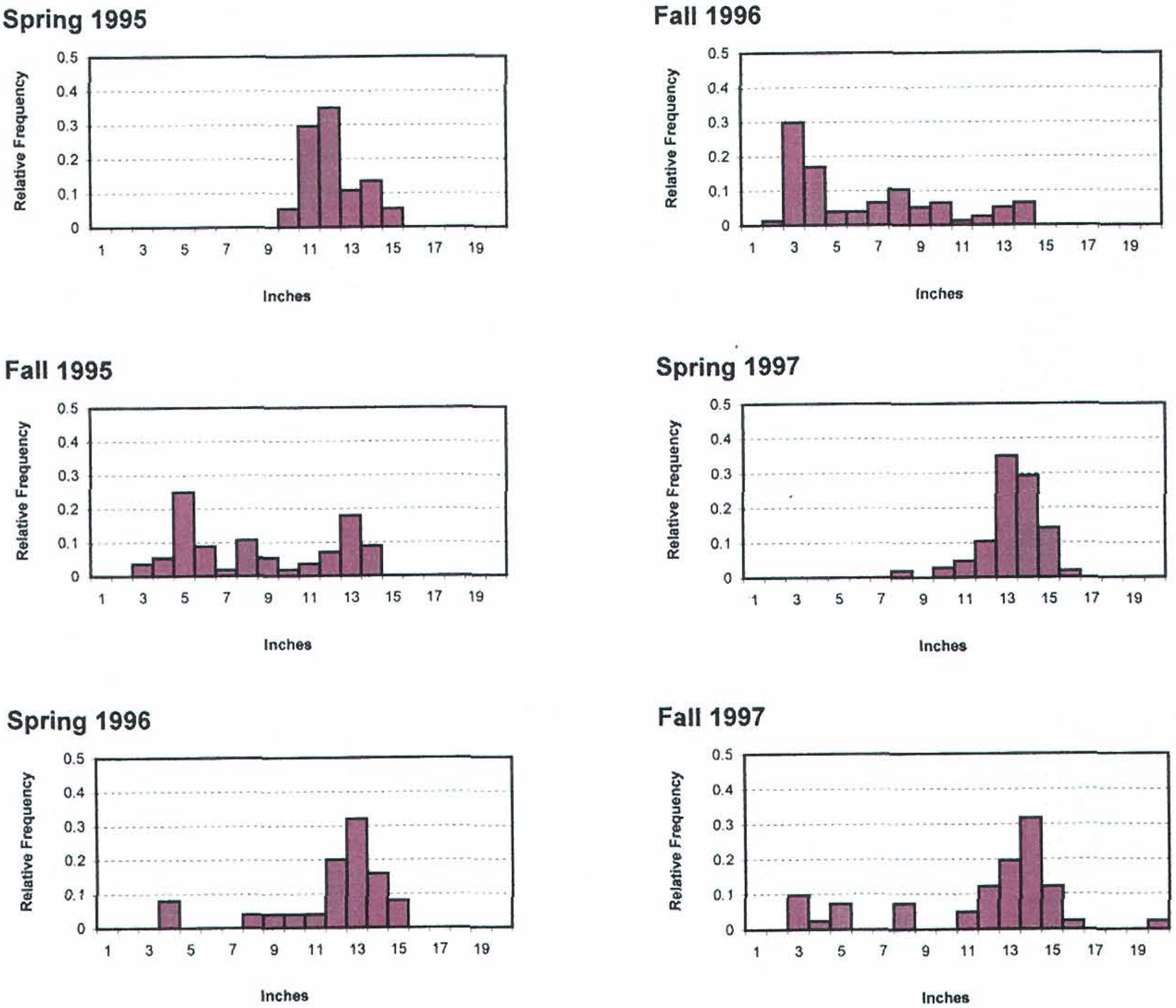


Figure 16 (continued)




*Source: Wisconsin Department of Natural Resources and SEWRPC.*

Northern pike also represent a small proportion of the predatory fish population in Delavan Lake. In contrast to the smallmouth bass population, the size of the northern pike population appears be increasing, as suggested by the CPUE data shown in Figure 20. The presence of eight-inch fingerlings within the 1996 size-structure data reported by the Wisconsin Department of Natural Resources, and summarized in Figure 21, indicates that natural reproduction of northern pike is occurring in the Lake.[30]

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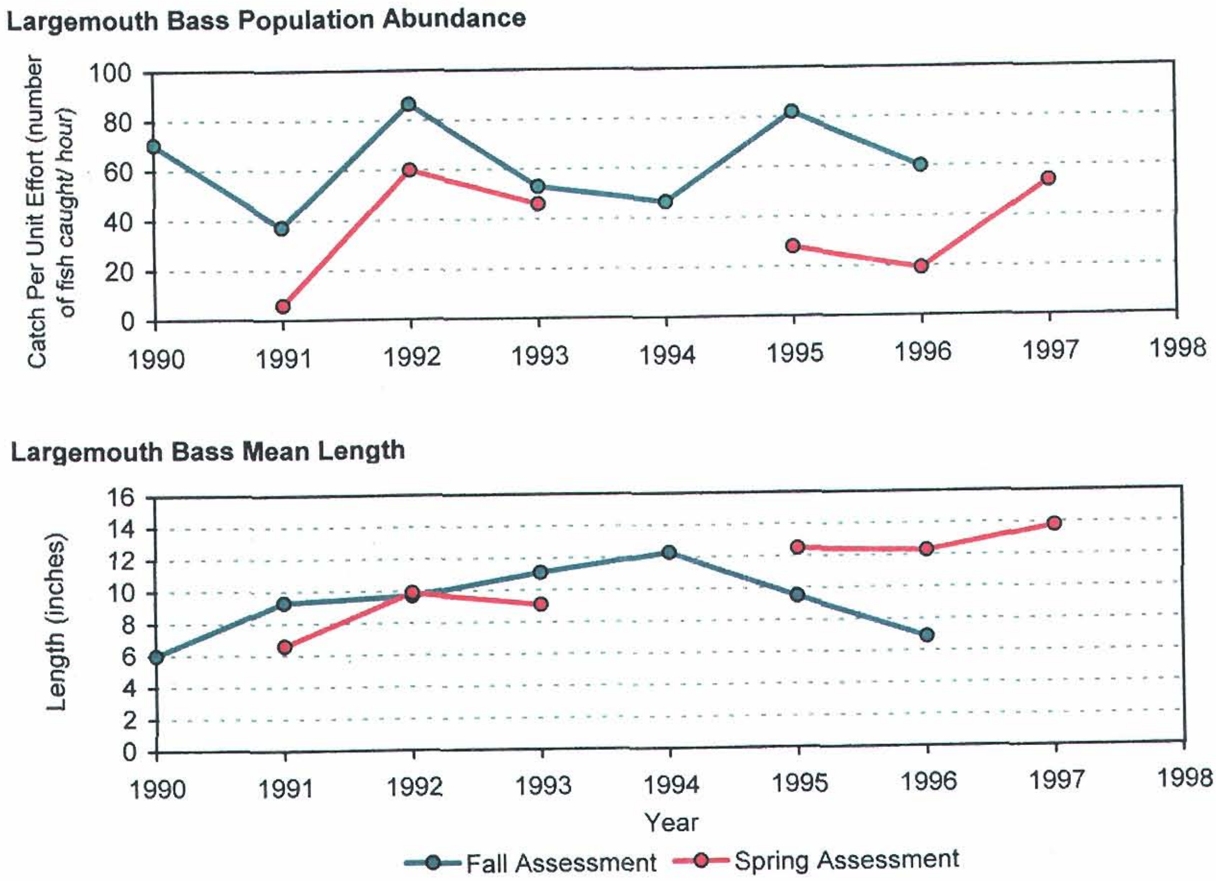
[30] *Welch and Dauffenbach*, op. cit.

Figure 17

DELAVAN LAKE FISH POPULATION DYNAMICS: LARGEMOUTH BASS




*Source: Wisconsin Department of Natural Resources and SEWRPC.*

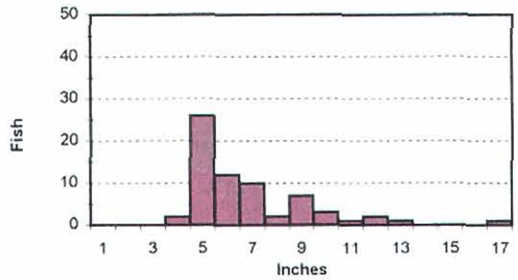
## BIOMANIPULATION

Lakes with high phosphorus loadings generally support nuisance levels of algal growth. Biomanipulation is a biological approach to managing a waterbody where high levels of algae present problems by using the top predator in a biological community to influence the structure of the biological community of the waterbody. Manipulating a lake's food web so that the lake contains a large population of predatory fish should lead to an increase in water clarity. A large population of piscivorous fish will exert heavy feeding pressure on smaller, planktivorous fish. Since these planktivores feed on zooplankton, especially large-bodied cladoceran species, a decrease in planktivore abundance should lead to an increase in the population of large-sized zooplankton. These large-sized zooplankters are especially efficient at consuming algae. Since clear water is associated with low levels of algae, a decrease in algal density due to increased zooplankton feeding should be accompanied by an increase in water clarity. The effects of increasing the numbers of predatory fish can thus cascade down the food web to influence water clarity. In addition to this, a large predator fish population will prey on rough fish. As noted above, rough fish tend to reduce zooplankton populations, minimizing the predation of zooplankters on algae, and increasing phosphorus level through their feeding habits.

Figure 18

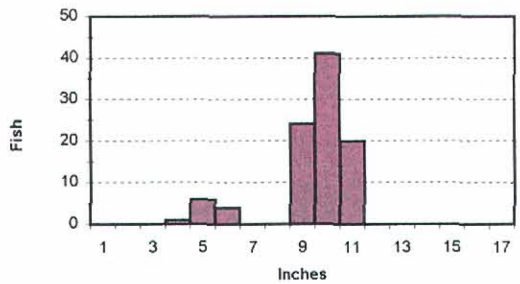
PERCENT FREQUENCY OF SIZE/AGE CLASS DISTRIBUTION
AMONG YEARS WITHIN DELAVAN LAKE: SMALLMOUTH BASS

## Fall 1990



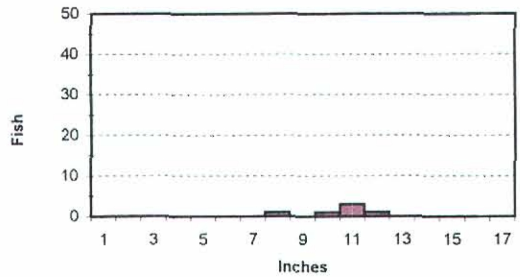

## Spring 1991


## Fall 1991

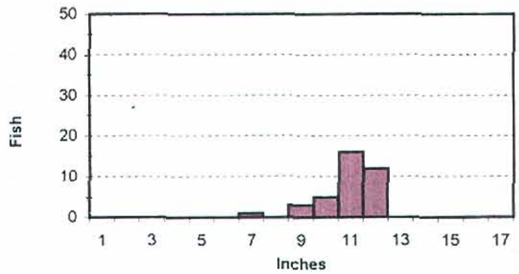



## Spring 1992

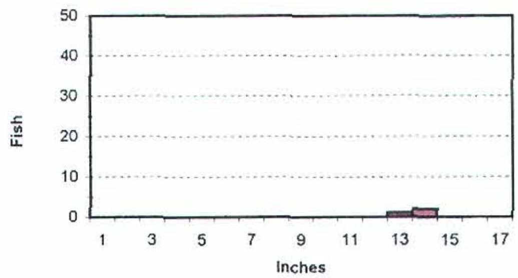

## Fall 1992




## Spring 1993



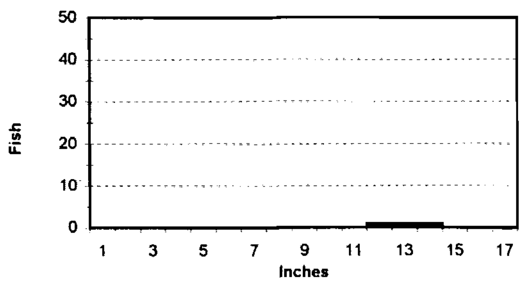

## Fall 1994




## Spring 1995

Figure 18 (continued)

**Fall 1995**




**Spring 1996**


*Source: Wisconsin Department of Natural Resources and SEWRPC.*

Several factors can act to offset these food web effects. Copper-based chemical herbicides, used to control algal growth in lakes, also are toxic to zooplankton. Likewise, over-harvesting of predatory fishes can result in a reduction of the feeding pressure that they place on planktivorous fish populations, allowing these fishes to increase in abundance and ultimately reduce the size of the zooplankton populations. In addition, some species of algae may be toxic or unpalatable to zooplankton. Finally, any chemical or physical lake conditions that either limit zooplankton populations or favor algal populations also can act to offset these food web effects and reduce the effectiveness of a biomanipulation in increasing water clarity.

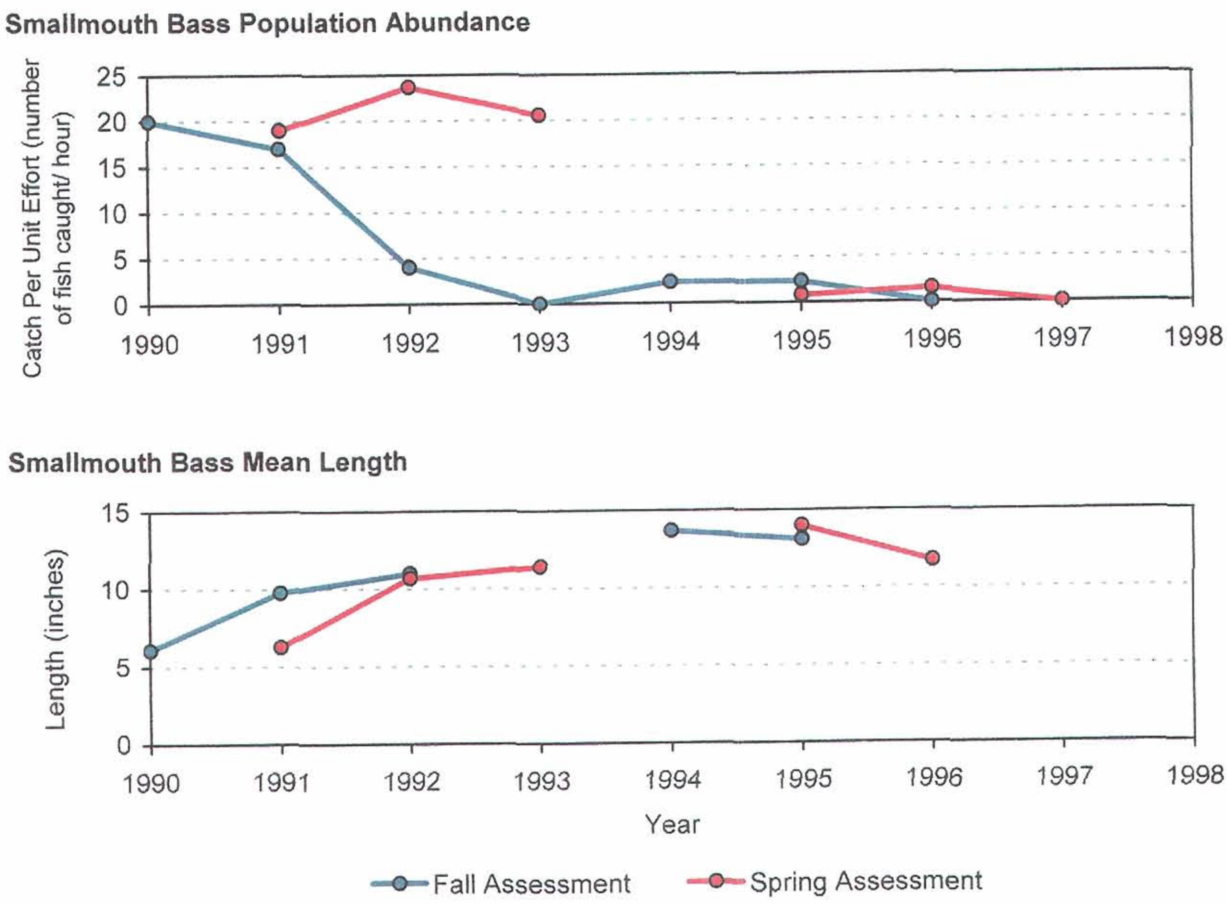
Since the restocking of fish into Delavan Lake in 1990, the Wisconsin Department of Natural Resources has worked toward achieving a unique balance within the food web of Delavan Lake. The Wisconsin Department of Natural Resources is seeking to maintain a very large population of walleyed pike in the Lake to help maintain a low population of zooplankton feeding fish. This will allow the zooplankton grazing to maintain low algal numbers and increased water clarity. While this strategy has been relatively successful, heavy predation by adult walleyed pike has limited recruitment of other predatory fish like smallmouth bass, muskellunge, and young walleyed pike into the fish population of the Lake. Nevertheless, the changes in the zooplankton community reported by the Wisconsin Department of Natural Resources during the last three years, discussed above, suggest that the effects of the biomanipulation upon the zooplankton community are declining in effectiveness. This may continue to become more pronounced through the year 2005 as the large 1990 year-class of walleyed pike reach the end of their natural life spans and disappear from the fish community. The absence of this year-class of predatory fish may allow a resurgence of planktivores that will further erode the effectiveness of the biomanipulation in achieving the management objectives intended.

## WILDLIFE RESOURCES

Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of the Delavan Lake study, it is possible, by polling naturalists and wildlife managers familiar with the area, to compile lists of amphibians, reptiles, birds, and mammals which may be expected to be found in the area under existing conditions. The technique used in compiling the wildlife data involved obtaining lists of those amphibians, reptiles, birds, and mammals known to exist, or known to have existed in the Delavan Lake area, associating these lists with the historic and remaining habitat areas in the Delavan Lake area as inventoried, and projecting the appropriate amphibian, reptile, bird, and mammal species into the Delavan Lake area. The net result of the application of this technique is a listing of those species which were probably once present in the drainage area, those species which may be expected to still be present under currently prevailing conditions, and those

Figure 19

*DELAVAN LAKE FISH POPULATION DYNAMICS: SMALLMOUTH BASS*




*Source: Wisconsin Department of Natural Resources and SEWRPC.*

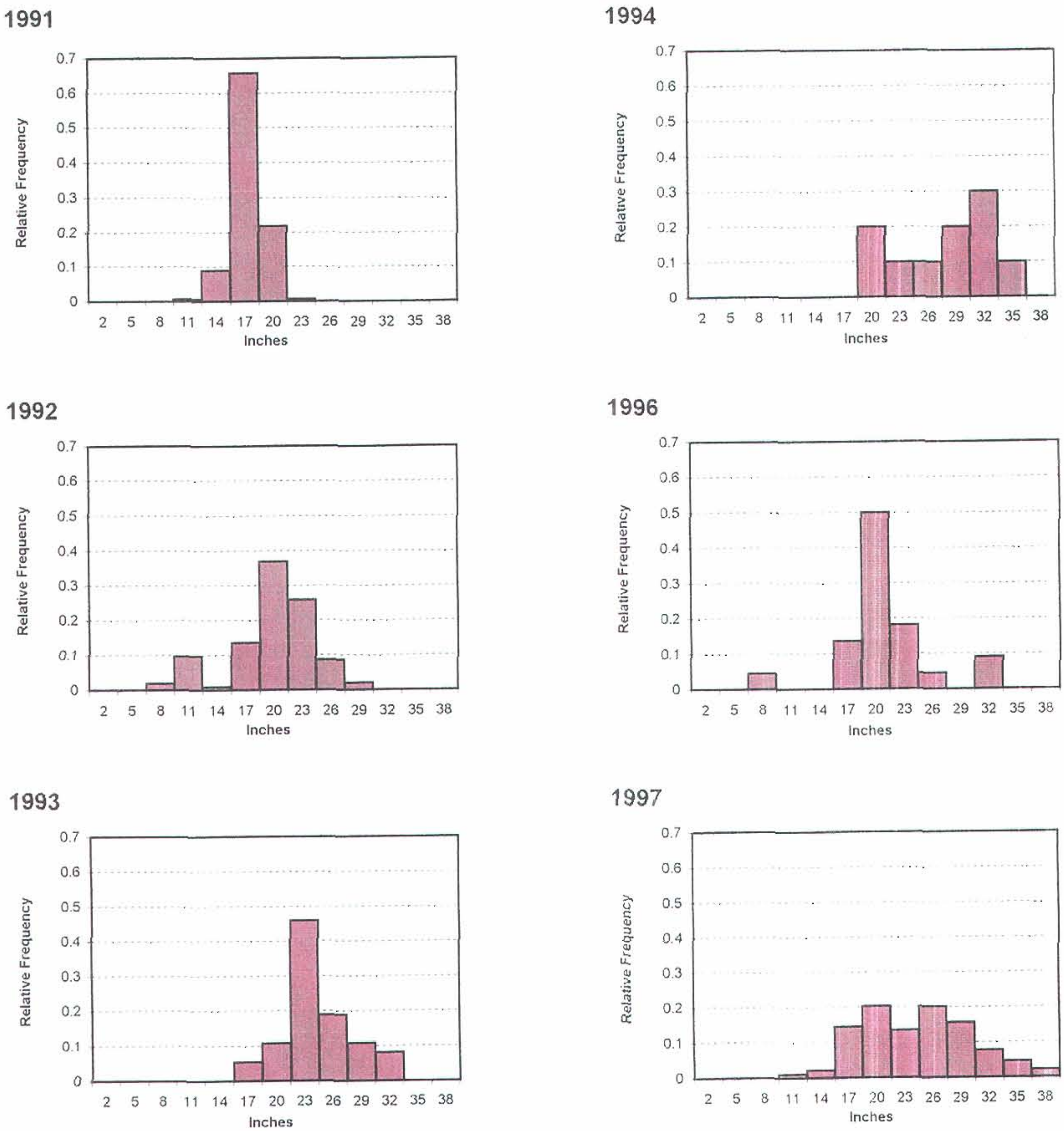
species which may be expected to be lost or gained as a result of urbanization within the area. Given the rural nature of all but the immediate shoreland area of Delavan Lake, many animals and numbers of waterfowl may be expected to commonly inhabit areas of the watershed, especially in the mostly undeveloped Delavan Lake inlet area.

## Mammals

A variety of mammals, ranging in size from large animals, like the white-tailed deer, to small animals, like the meadow vole, are found in the Delavan Lake area. Table 32 lists mammals whose ranges are known to extend into the area. The larger mammals that are still fairly common in the less densely populated areas of the drainage area include the white-tailed deer, cottontail rabbits, gray squirrels, fox squirrels, muskrats, minks, weasels, raccoons, red foxes, skunks, and opossums. The first four may be considered game mammals, while the rest may be classified as fur-bearing mammals. White-tailed deer are generally restricted to the larger wooded areas, the open meadows and croplands adjacent to the woodlots, and to the shrub swamps. Deer may create problems in the more densely developed urban and suburban areas. When deer wander, or are forced, into residential, commercial, or industrial areas, they typically exhibit panic, and may run wildly, presenting a threat to the safety of people, as

Figure 20

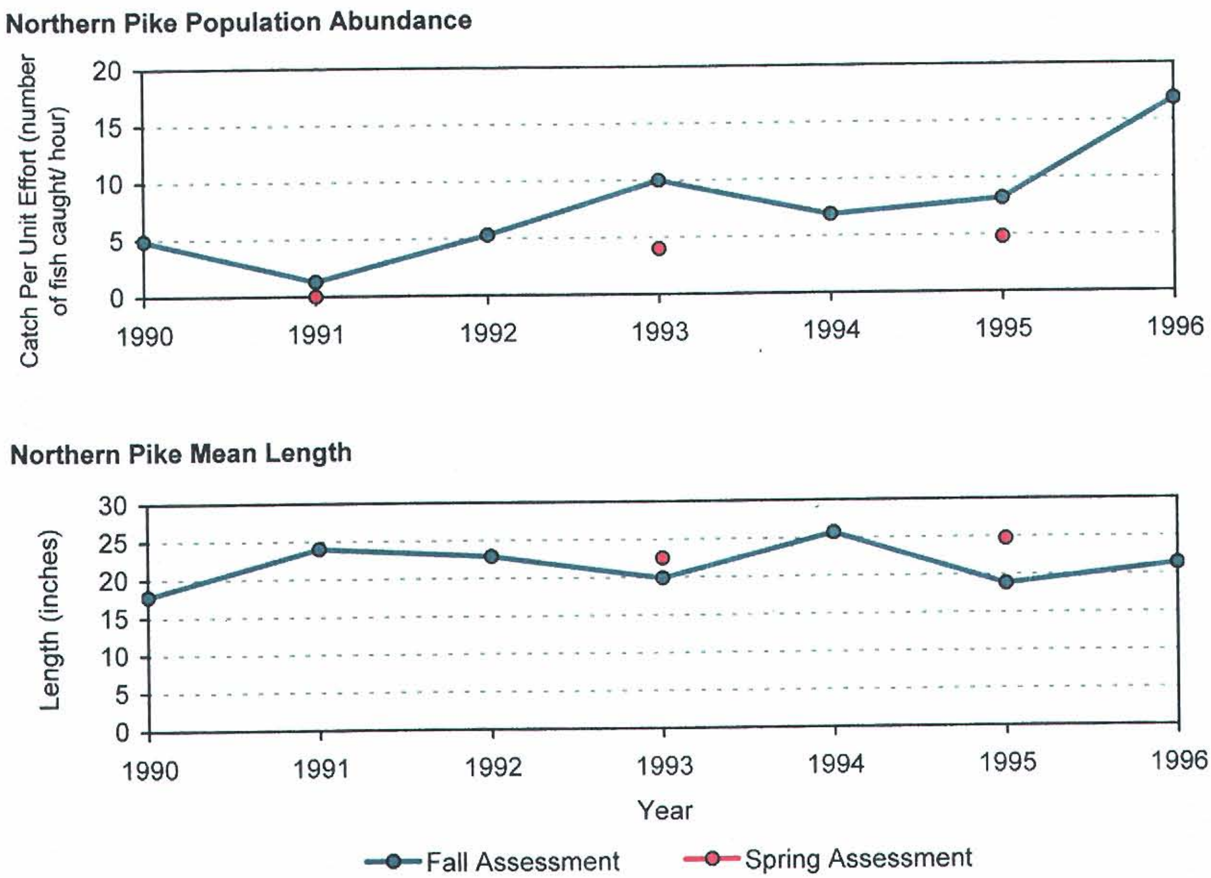
PERCENT FREQUENCY OF SIZE/AGE CLASS DISTRIBUTION
AMONG YEARS WITHIN DELAVAN LAKE: NORTHERN PIKE




*Source: Wisconsin Department of Natural Resources and SEWRPC.*

Figure 21

DELAVAN LAKE FISH POPULATION DYNAMICS: NORTHERN PIKE




*Source: Wisconsin Department of Natural Resources and SEWRPC.*

well as to themselves. Foraging deer may cause damage to gardens, ornamental trees, cropland, and orchards. Deer-automobile collisions often occur on the fringes of urban areas, while hunters stalking the animals in urbanizing areas may create yet another hazard. The muskrat is a second species that may create problems around the Lake. Muskrats will sometimes dig burrows along the shoreline of lakes. These burrows can undermine bank stability and threaten the integrity of shoreline structures. Citizens have reported the presence of muskrat burrows within the berms alongside the outlet dam, which constitutes an issue of concern.

Small mammals fairly common in the area include short-tailed shrews, gophers, white-footed mice, and little brown bats. These small mammals, with the exception of the bats, are commonly associated with meadows, fence rows, and utility and transportation rights-of-way. People view their importance differently depending on whether they consider these mammals to be insect predators and food sources for larger mammals and such raptors as hawks and owls, or pests in croplands, gardens, and lawns.

Table 32

MAMMALS OF THE DELAVAN LAKE AREA

| Scientific (family) and Common Name | Scientific Name |
|---|---|
| *Didelphidae* | |
| Virginia Opossum | *Didelphis virginiana* |
| *Soricidae* | |
| Cinereous Shrew | *Sorex cinereus* |
| Short-Tailed Shrew | *Blarina brevicauda* |
| *Vespertilionidae* | |
| Little Brown Bat | *Myotis lucifugus* |
| Silver-Haired Bat | *Lasionycteris octivagans* |
| Big Brown Bat | *Eptesicus fuscus* |
| Red Bat | *Lasiurus borealus* |
| Hoary Bat | *Lasiurus cinereus* |
| *Leporidae* | |
| Eastern Cottontail Rabbit | *Sylvilgus floridanus* |
| *Sciuridae* | |
| Southern Woodchuck | *Marmota monax* |
| Thirteen-Lined Ground Squirrel (gopher) | *Spermophilus tridecemlineatus* |
| Eastern Chipmunk | *Tamias striatus* |
| Grey Squirrel | *Sciurus carolinensis* |
| Western Fox Squirrel | *Sciurus niger* |
| Southern Flying Squirrel | *Glaucomys volans* |
| *Castoridae* | |
| American Beaver | *Castor canadensis* |
| *Cricetidae* | |
| Woodland Deer Mouse | *Peromyscus maniculatus gracilis* |
| Prairie Deer Mouse | *Peromyscus maniculatus bairdii* |
| White-Footed Mouse | *Peromyscus leucopus* |
| Meadow Vole | *Microtus pennsylvanicus* |
| Prairie Vole | *Microtus ochrogaster* |
| Common Muskrat | *Ondatra zibethicus* |
| *Muridae* | |
| Norway Rat (introduced) | *Rattus norvegicus* |
| House Mouse (introduced) | *Mus musculus* |
| *Zapodidae* | |
| Meadow Jumping Mouse | *Zapas hudonius* |
| *Canidae* | |
| Coyote | *Canis latrans* |
| Eastern Red Fox | *Vulpes vulpes* |
| Gray Fox | *Urocyon cinereoargenteus* |
| *Procyonidae* | |
| Raccoon | *Procyon lotor* |
| *Mustelidae* | |
| Least Weasel | *Mustela nivalis* |
| Short-Tailed Weasel (ermine) | *Mustela erminea* |
| Long-Tailed Weasel | *Mustela frenata* |
| Mink | *Mustela vison* |
| Badger | *Taxidea taxus* |
| Striped Skunk | *Mephitis mephitis* |
| Otter (occasional visitor) | *Lontra canadensis* |
| *Cervidae* | |
| White-Tailed Deer | *Odecoileus virginianus* |

*Source: H.T. Jackson,* Mammals of Wisconsin, *1961, and SEWRPC.*

**Birds**

A large number of birds, ranging in size from large game birds to small songbirds, are found in the Delavan Lake area. Table 33 lists those birds that normally occur in the drainage area. Each bird is classified as to whether it breeds within the area, visits the area only during the annual migration periods, or visits the area only on rare occasions. The Delavan Lake drainage area supports a significant population of waterfowl, including mallard, wood duck, teal, and Canada geese. Larger numbers move through the drainage area during migrations when most of the regional species may also be present.

Mallards, wood duck, and blue-winged teal are the most numerous waterfowl and are known to nest in the area. Many game birds, songbirds, waders, and raptors also reside or visit the Lake or its environs. Sandhill cranes and loons are notable migratory visitors. In addition, a number of special-concern, threatened, or endangered species—including bald eagles, osprey, black terns, Forester's tern, loggerhead shrikes, merlins, and Cooper's hawks—have been reported to have been seen in the vicinity of Delavan Lake.

Because of the mixture of lowlands and upland woodlots, wetlands, and agricultural lands still present in the area, along with the favorable summer climate, the area supports many other species of birds. Hawks and owls function as major rodent predators within the ecosystem. Swallows, woodpeckers, nuthatches, flycatchers, and several other species serve as major insect predators. In addition to their ecological roles, such birds such as robins, red-winged blackbirds, orioles, cardinals, kingfishers, and mourning doves serve as subjects for bird watchers and photographers.

Not all birds are viewed as an asset from an ecological, economic, or social point of view. With the advance of urbanization and the concomitant loss of natural habitat, conditions have become less compatible with the more desirable bird species. English sparrow, starlings, grackles, cowbirds, and pigeons have replaced more desirable birds, in certain areas, because of their greater tolerance for urban conditions. The red-winged blackbird, in particular, has been impacted by urbanization as wetland area, particularly cattail marshes, are drained and filled. Citizens have also expressed concerns about the

Table 33

BIRDS KNOWN OR LIKELY TO OCCUR IN THE DELAVAN LAKE AREA

| Scientific (family) and Common Name | Scientific Name | Breeding | Wintering | Migrant |
|---|---|---|---|---|
| *Gaviidae* | | | | |
| Common Loon[a] | *Gavia immer* | - - | - - | X |
| *Podicipedidae* | | | | |
| Pied-Billed Grebe | *Podylimbos podiceps* | X | - - | X |
| Horned Grebe | *Podiceps auritus* | - - | - - | X |
| *Ardeidae* | | | | |
| American Bittern[a] | *Botaurus lentiginosus* | X | - - | X |
| Least Bittern[a] | *Ixobrychus exilis* | X | - - | X |
| Great Blue Heron[a] | *Ardea herodias* | X | R | X |
| Great Egret[b] | *Casmerodius albus* | - - | - - | X |
| Cattle Egret[c] | *Bulbulcus ibis* | - - | - - | R |
| Green-Backed Heron | *Butrodes striatus* | X | - - | X |
| Black-Crowned Night Heron[a] | *Nycticorax nycticorax* | - - | - - | X |
| *Gruidae* | | | | |
| Sandhill Crane | *Grus canadensis* | X | - - | X |
| *Anatidae* | | | | |
| Tundra Swan | *Cygnus columbianus* | - - | - - | X |
| Mute Swan[c] | *Cygnus olor* | X | X | X |
| Snow Goose | *Chen caerulescens* | - - | - - | X |
| Canada Goose | *Branta canadensis* | X | X | X |
| Wood Duck | *Aix sponsa* | X | - - | X |
| Green-Winged Teal | *Anas crecca* | - - | - - | X |
| American Black Duck[a] | *Anas rubripes* | - - | X | X |
| Mallard | *Anas platyrhynchos* | X | X | X |
| Northern Pintail[a] | *Anas acuta* | - - | - - | X |
| Blue-Winged Teal[a] | *Anas discors* | X | - - | X |
| Northern Shoveler | *Anas clypeata* | - - | - - | X |
| Gadwall | *Anas strepera* | - - | - - | X |
| American Wigeon[a] | *Anas americana* | - - | - - | X |
| Canvasback[a] | *Aythya valisineria* | - - | - - | X |
| Redhead[a] | *Aythya americana* | - - | - - | X |
| Ring-Necked Duck | *Aythya collaris* | - - | - - | X |
| Lesser Scaup[a] | *Aythya affins* | - - | - - | X |
| Common Goldeneye[a] | *Bucephala clangula* | - - | X | X |
| Bufflehead | *Bucephala albeola* | - - | - - | X |
| Hooded Merganser | *Lophodytes cucullatus* | R | - - | X |
| Common Merganser[a] | *Mergus merganser* | - - | - - | X |
| Red-Breasted Merganser[a] | *Mergus serrator* | - - | - - | X |
| Ruddy Duck | *Oxyura jamaicensis* | - - | - - | X |
| *Cathartidae* | | | | |
| Turkey Vulture | *Cathartes aura* | X | - - | X |
| *Accipitridae* | | | | |
| Osprey[b] | *Pandion haliaetus* | - - | - - | X |
| Bald Eagle[b,d] | *Haliaeetus leucocephalus* | - - | - - | R |
| Northern Goshawk[a] | *Accipiter gentilis* | - - | R | R |
| Cooper's Hawk[a] | *Accipiter cooperi* | X | X | X |
| Sharp-Shinned Hawk | *Accipiter striatus* | - - | X | X |

Table 33 (continued)

| Scientific (family) and Common Name | Scientific Name | Breeding | Wintering | Migrant |
|---|---|---|---|---|
| *Accipitridae* (continued) | | | | |
| Northern Harrier[a] | *Circus cyaneus* | X | X | X |
| Red-Shouldered Hawk[b] | *Buteo lineatus* | R | - - | X |
| Broad-Winged Hawk | *Buteo platypteris* | - - | - - | X |
| Red-Tailed Hawk | *Buteo jamaicensis* | X | X | X |
| Rough-Legged Hawk | *Buteo lagopus* | - - | X | X |
| *Falconidae* | | | | |
| American Kestrel | *Falco sparverius* | X | X | X |
| Merlin[a] | *Falco columbarius* | - - | - - | X |
| *Phasianidae* | | | | |
| Gray Partridge[c] | *Perdix perdix* | R | R | - - |
| Ring-Necked Pheasant[c] | *Phasianus colchicus* | X | X | - - |
| Wild Turkey | *Meleagris galloparvo* | X | X | - - |
| Northern Bobwhite[e] | *Corlinus virginianus* | X | - - | - - |
| *Rallidae* | | | | |
| Virginia Rail | *Rallus limicola* | X | - - | X |
| Sora | *Porzana carolina* | X | - - | X |
| Common Moorhen | *Gallinula chlorapus* | X | - - | X |
| American Coot | *Fulca americana* | X | R | X |
| *Charadriidae* | | | | |
| Black-Bellied Plover | *Pluvialis squatarola* | - - | - - | X |
| Lesser Golden Plover | *Pluvialis dominica* | - - | - - | X |
| Killdeer | *Charadrius vociferus* | X | - - | X |
| *Scolopacidae* | | | | |
| Greater Yellowlegs | *Tringa melanolueca* | - - | - - | X |
| Lesser Yellowlegs | *Tringa flavipes* | - - | - - | X |
| Solitary Sandpiper | *Tringa solitaria* | - - | - - | X |
| Spotted Sandpiper | *Actitis macularia* | X | - - | X |
| Upland Sandpiper[a] | *Bartramia longicauda* | R | - - | X |
| Pectoral Sandpiper | *Calidria melantos* | - - | - - | X |
| Common Snipe | *Capella gallinago* | R | R | X |
| American Woodcock | *Philohela minor* | X | - - | X |
| Wilson's Phalarope | *Steganopus tricolor* | - - | - - | X |
| *Laridae* | | | | |
| Bonaparte's Gull[a] | *Larus philadelphia* | - - | - - | X |
| Ring-Billed Gull | *Larus delawarensis* | - - | - - | X |
| Herring Gull | *Larus argentatus* | - - | X | X |
| Common Tern[f] | *Sterna hirunda* | - - | - - | R |
| Forster's Tern[f] | *Sterna forsteri* | R | - - | X |
| Black Tern | *Chlidonias niger* | X | - - | X |
| *Columbidae* | | | | |
| Rock Dove[c] | *Columba livia* | X | X | - - |
| Mourning Dove | *Zenaida macroura* | X | X | X |
| *Cuculidae* | | | | |
| Black-Billed Cuckoo | *Coccyzus erythropthalmus* | X | - - | X |
| Yellow-Billed Cuckoo[a] | *Coccyzus americanus* | X | - - | X |

Table 33 (continued)

| Scientific (family) and Common Name | Scientific Name | Breeding | Wintering | Migrant |
|---|---|---|---|---|
| *Strigidae* | | | | |
| Eastern Screech Owl | *Otus asio* | X | X | - - |
| Great Horned Owl | *Bubo virginianus* | X | X | - - |
| Snowy Owl | *Nyctea scandiaca* | - - | R | X |
| Barred Owl | *Strix varia* | X | X | - - |
| Long-Eared Owl[a] | *Asio otus* | R | R | X |
| Short-Eared Owl[a] | *Asio flammeus* | - - | R | X |
| Northern Saw-Whet Owl | *Aegolius acadicus* | - - | - - | X |
| *Caprimulgidae* | | | | |
| Common Nighthawk | *Chordeiles minor* | X | - - | X |
| *Apodidae* | | | | |
| Chimney Swift | *Chaetura pelagica* | X | - - | X |
| *Trochilidae* | | | | |
| Ruby-Throated Hummingbird | *Archilocus colubris* | X | - - | X |
| *Alcedinidae* | | | | |
| Belted Kingfisher | *Megaceryle alcyon* | X | X | X |
| *Picidae* | | | | |
| Red Bellied Woodpecker | *Melanerpes carolinus* | X | X | - - |
| Red-Headed Woodpecker[a] | *Melanerpes erythrocephalus* | X | R | X |
| Yellow-Bellied Sapsucker | *Sphyrapicus varius* | - - | R | X |
| Downy Woodpecker | *Picoides pubescens* | X | X | - - |
| Hairy Woodpecker | *Picoides villosus* | X | X | - - |
| Northern Flicker | *Colaptes auratus* | X | R | X |
| *Tyrannidae* | | | | |
| Olive-Sided Flycatcher | *Nuttallornis borealis* | - - | - - | X |
| Eastern Wood-Pewee | *Contopus virens* | X | - - | X |
| Yellow-Bellied Flycatcher[a] | *Empidonax flaviventris* | - - | - - | X |
| Acadian Flycatcher[b] | *Empidonax virescens* | X | - - | X |
| Alder Flycatcher | *Empidonax alnorum* | R | - - | X |
| Willow Flycatcher | *Empidonax traillii* | X | - - | X |
| Least Flycatcher | *Empidonax minimus* | X | - - | X |
| Eastern Phoebe | *Sayornia phoebe* | X | - - | X |
| Great Crested Flycatcher | *Myiarchus crinitus* | X | - - | X |
| Eastern Kingbird | *Tyrannus tyrannus* | X | - - | X |
| *Alaudidae* | | | | |
| Horned Lark | *Eremophila alpestris* | X | X | X |
| *Hirundinidae* | | | | |
| Purple Martin[a] | *Progne subris* | X | - - | X |
| Tree Swallow | *Iridoprocne bicolor* | X | - - | X |
| Northern Rough-Winged Swallow | *Stelgidopteryx serripennis* | X | - - | X |
| Bank Swallow | *Riparia riparia* | X | - - | X |
| Cliff Swallow | *Pertocheliden pyrrhonota* | X | - - | X |
| Barn Swallow | *Hirundo rustica* | X | - - | X |
| *Corvidae* | | | | |
| Blue Jay | *Cyanocitta cristata* | X | X | X |
| American Crow | *Corvus brachyrhynchos* | X | X | X |
| *Paridae* | | | | |
| Black-Capped Chickadee | *Parus atricapillus* | X | X | X |

Table 33 (continued)

| Scientific (family) and Common Name | Scientific Name | Breeding | Wintering | Migrant |
|---|---|---|---|---|
| *Sittidae* | | | | |
| Red-Breasted Nuthatch | *Sitta canadensis* | - - | X | X |
| White-Breasted Nuthatch | *Sitta carolinensis* | X | X | - - |
| *Certhiidae* | | | | |
| Brown Creeper | *Certha familiaris* | - - | X | X |
| *Troglodytidae* | | | | |
| House Wren | *Troglodytes aedon* | X | - - | X |
| Winter Wren | *Troglodytes troglodytes* | - - | - - | X |
| Sedge Wren | *Cistothorus platensis* | X | - - | X |
| Marsh Wren | *Cistothorus palustrus* | X | - - | X |
| *Regulidae* | | | | |
| Golden-Crowned Kinglet | *Regulus satrapa* | - - | X | X |
| Ruby-Crowned Kinglet[a] | *Regulus calendula* | - - | - - | X |
| *Sylviidae* | | | | |
| Blue-Gray Gnatcatcher | *Polioptila caerulea* | X | - - | X |
| *Turidae* | | | | |
| Eastern Bluebird | *Sialia sialis* | X | - - | X |
| Veery[a] | *Catharus fuscenscens* | X | - - | X |
| Gray-Cheeked Thrush | *Catharus minimus* | - - | - - | X |
| Swainson's Thrush[a] | *Catharus ustulatus* | - - | - - | X |
| Hermit Thrush | *Catharus guttatus* | - - | - - | X |
| Wood Thrush[a] | *Hylocichla mustelina* | X | - - | X |
| American Robin | *Turdus migratorius* | X | X | X |
| *Mimidae* | | | | |
| Gray Catbird | *Dumetalla carolinensis* | X | - - | X |
| Brown Thrasher | *Toxostoma rufum* | X | - - | X |
| *Motacillidae* | | | | |
| American Pipit | *Anthus spinoletta* | - - | - - | X |
| *Bombycillidae* | | | | |
| Bohemian Waxwing | *Bombycilla garrulus* | - - | R | - - |
| Cedar Waxwing | *Bombycilla cedorum* | X | X | X |
| *Lanniidae* | | | | |
| Northern Shrike | *Lanius excubitor* | - - | X | X |
| Loggerhead Shrike[f] | *Lanius ludovicianus* | - - | - - | R |
| *Sturnidae* | | | | |
| European Starling[c] | *Sturnus vulgaris* | X | X | X |
| *Vireonidae* | | | | |
| White-Eyed Vireo[a] | *Vireo griseus* | - - | - - | X |
| Solitary Vireo | *Vireo solitarius* | - - | - - | X |
| Yellow-Throated Vireo | *Vireo flavifrons* | X | - - | X |
| Warbling Vireo | *Vireo gilvus* | X | - - | X |
| Red-Eyed Vireo | *Vireo olivaceus* | X | - - | X |
| *Parulidae* | | | | |
| Blue-Winged Warbler | *Vermivora pinus* | X | - - | X |
| Golden-Winged Warbler[a] | *Vermivora chrysoptera* | - - | - - | X |
| Tennessee Warbler[a] | *Vermivora peregrina* | - - | - - | X |
| Orange-Crowned Warbler | *Vermivora celata* | - - | - - | X |
| Nashville Warbler[a] | *Vermivora ruficapilla* | - - | - - | X |
| Northern Parula | *Parula americana* | - - | - - | X |

Table 33 (continued)

| Scientific (family) and Common Name | Scientific Name | Breeding | Wintering | Migrant |
|---|---|---|---|---|
| *Parulidae* (continued) | | | | |
| Yellow Warbler | *Dendroica patechia* | X | - - | X |
| Chestnut-Sided Warbler | *Dendroica pensylvanica* | - - | - - | X |
| Magnolia Warbler | *Dendroica magnolia* | - - | - - | X |
| Cape May Warbler[a] | *Dendroica tigrina* | - - | - - | X |
| Black-Throated Blue Warbler | *Dendroica caerulescens* | - - | - - | X |
| Yellow-Rumped Warbler | *Dendroica coronata* | - - | X | X |
| Black-Throated Green Warbler | *Dendroica virens* | - - | - - | X |
| Blackburnian Warbler | *Dendroica fusca* | - - | - - | X |
| Pine Warbler | *Dendroica pinus* | - - | - - | R |
| Prairie Warbler | *Dendroica discolor* | - - | - - | X |
| Palm Warbler | *Dendroica palmarum* | - - | - - | X |
| Bay-Breasted Warbler | *Dendroica castanea* | - - | - - | X |
| Blackpoll Warbler | *Dendroica striata* | - - | - - | X |
| Cerulean Warbler[b] | *Dendroica cerulea* | R | - - | R |
| Black-and-White Warbler | *Mniotilta varia* | - - | - - | X |
| American Redstart | *Setophaga ruticilla* | X | - - | X |
| Prothonotary Warbler[a] | *Protonotaria citrea* | - - | - - | R |
| Ovenbird | *Seiurus aurocapillus* | X | - - | X |
| Northern Waterthrush | *Seiurus noveboracensis* | - - | - - | X |
| Louisiana Waterthrush[a] | *Seiurus motacilla* | - - | - - | X |
| Common Yellowthroat | *Geothlypis trichas* | X | - - | X |
| Connecticut Warbler[a] | *Oporonis agilis* | - - | - - | X |
| Wilson's Warbler[a] | *Wilsonia pusilla* | - - | - - | X |
| Mourning Warbler | *Oporonis philadelphia* | R | - - | X |
| Canada Warbler | *Wilsonia canadensis* | - - | - - | X |
| Yellow-breasted Chat[a] | *Icteria virens* | R | - - | R |
| *Thraupidae* | | | | |
| Scarlet Tanager | *Piranga rubra* | X | - - | X |
| *Cardinalidae* | | | | |
| Northern Cardinal | *Cardinalis cardinalis* | X | X | - - |
| Rose-Breasted Grosbeak | *Pheucticus ludovicianus* | X | - - | X |
| Indigo Bunting | *Passerina cyanea* | X | - - | X |
| *Emberizidae* | | | | |
| Dickcissel[a] | *Spiza americana* | R | - - | X |
| Rufous-Sided Towhee | *Pipilo erythrophthalmus* | X | - - | X |
| American Tree Sparrow | *Spizella arborea* | - - | X | X |
| Chipping Sparrow | *Spizella passerina* | X | - - | X |
| Field Sparrow[a] | *Spizella pusilla* | X | - - | X |
| Vesper Sparrow[a] | *Pooecetes graminues* | X | - - | X |
| Lark Sparrow | *Chondestes grammacus* | - - | - - | R |
| Savannah Sparrow[a] | *Passerculus sandwichensis* | X | - - | X |
| Grasshopper Sparrow[a] | *Ammodramus savannarum* | X | - - | X |
| Henslow's Sparrow[b] | *Ammodramus henslowii* | R | - - | X |
| Fox Sparrow | *Passerella iliaca* | - - | R | X |
| Song Sparrow | *Melospiza melodia* | X | X | X |
| Lincoln's Sparrow | *Melospiza lincolnii* | - - | - - | X |
| Swamp Sparrow | *Melospiza georgiana* | X | X | X |
| White-Throated Sparrow | *Zonotrichia albicollis* | - - | R | X |
| White-Crowned Sparrow | *Zonotrichia leucophrys* | - - | - - | X |
| Dark-Eyed Junco | *Junco hymealis* | - - | X | X |
| Lapland Longspur | *Calcarius lapponicus* | - - | X | X |
| Snow Bunting | *Plectrophenax nivalis* | - - | X | X |

Table 33 (continued)

| Scientific (family) and Common Name | Scientific Name | Breeding | Wintering | Migrant |
|---|---|---|---|---|
| *Icteridae* | | | | |
| Bobolink[a] | *Dolichonyx oryzivorus* | X | - - | X |
| Red-Winged Blackbird | *Agelius phoeniceus* | X | X | X |
| Eastern Meadowlark[a] | *Sturnella magna* | X | R | X |
| Western Meadowlark[a] | *Sturnella neglecta* | R | - - | X |
| Yellow-Headed Blackbird | *Xanthocephalus xanthocephalus* | X | - - | X |
| Rusty Blackbird | *Euphagus carolinus* | - - | R | X |
| *Icteridae* (continued) | | | | |
| Common Grackle | *Quiscalus quiscula* | X | X | X |
| Brown-Headed Cowbird | *Molothrus ater* | X | R | X |
| Orchard Oriole[a] | *Icterus spurius* | R | - - | X |
| Northern Oriole | *Icterus galbula* | X | - - | X |
| *Fringillidae* | | | | |
| Purple Finch | *Carpodacus purpureus* | - - | X | X |
| House Finch | *Carpodacus mexicanus* | X | X | X |
| Common Redpoll | *Carduelis flammea* | - - | X | X |
| Pine Siskin[a] | *Carduelis pinus* | - - | X | X |
| American Goldfinch | *Carduelis tristis* | X | X | X |
| Evening Grosbeak | *Hesperiphona vespertina* | - - | X | X |
| *Passeridae* | | | | |
| House Sparrow[c] | *Passer domesticus* | X | X | - - |

NOTE: Total number of bird species: 216
Number of alien, or nonnative, bird species: 6 (3 percent)

Breeding: Nesting species
Wintering: Present January through February
Migrant: Spring and/or fall transient

X - Present, not rare
R - Rare

[a]*State-designated species of special concern. Fully protected Federal and State laws under the Migratory Bird Act.*

[b]*State-designated threatened species.*

[c]*Alien, or nonnative, bird species.*

[d]*Federally designated threatened species.*

[e]*Occurs in the lake study area as escapes from managed hunt programs.*

[f]*State-designated endangered species.*

*Source: John E. Bielefeldt, Racine County Naturalist, and SEWRPC.*

presence of nonmigratory Canada geese in portions of the watershed. On and around Delavan Lake itself, this local goose population can be a source of aesthetic and recreational use problems—including acting as a vector for the schistosomes known to cause swimmer's itch—and can contribute to Lake pollution problems—being a potentially significant nutrient source to the Lake.

## Amphibians and Reptiles

Amphibians and reptiles are vital components of the ecosystem in an environmental unit like the Delavan Lake drainage area. Examples of amphibians native to the area include frogs, toads, and salamanders. Turtles and snakes are examples of reptiles common to the Delavan Lake area. Table 34 lists the 11 amphibian and 17 reptile

## Table 34

## AMPHIBIANS AND REPTILES OF THE DELAVAN LAKE AREA

| Scientific (family) and Common Name | Scientific Name | Species Reduced or Dispersed with Full Area Urbanization | Species Lost with Full Area Urbanization |
|---|---|---|---|
| Amphibians | | | |
| *Proteidae* | | | |
| Mudpuppy | *Necturus maculosus maculosus* | X | - - |
| *Ambystomatidae* | | | |
| Blue-Spotted Salamander | *Ambystoma laterale* | - - | X |
| Eastern Tiger Salamander | *Ambystoma tigrinum tigrinum* | X | - - |
| *Salamandridae* | | | |
| Central Newt | *Notophthalmus viridescens louisianenis* | X | - - |
| *Bufonidae* | | | |
| American Toad | *Bufo americanus americanus* | X | - - |
| *Hylidae* | | | |
| Western Chorus Frog | *Pseudacris triseriata triseriata* | X | - - |
| Blanchard's Cricket Frog[a,b] | *Acris crepitans blanchardi* | X | - - |
| Northern Spring Peeper | *Hyla crucifer crucifer* | - - | X |
| Cope's Gray Tree Frog | *Hyla chrysocelis* | - - | X |
| *Ranidae* | | | |
| Green Frog | *Rana clamitans melanota* | X | - - |
| Northern Leopard Frog | *Rana pipiens* | - - | X |
| Reptiles | | | |
| *Chelydridae* | | | |
| Common Snapping Turtle | *Chelydra serpentina serpentina* | X | - - |
| *Kinosternidae* | | | |
| Musk Turtle (stinkpot) | *Sternotherus odoratus* | X | - - |
| *Emydidae* | | | |
| Western Painted Turtle | *Chrysemys picta belli* | X | - - |
| Midland Painted Turtle | *Chrysemys picta marginata* | X | - - |
| Blanding's Turtle[c] | *Emydoidea blandingii* | - - | X |
| *Trionychidea* | | | |
| Eastern Spiny Softshell | *Trionyx spiniferus spiniferus* | X | - - |
| *Colubridae* | | | |
| Northern Water Snake | *Nerodia sipedon sipedon* | X | - - |
| Queen Snake[b] | *Regina septemvittata* | - - | X |
| Midland Brown Snake | *Storeria delcayi wrightorum* | X | - - |
| Northern Redbelly Snake | *Storeia occipitormaculata occipitormaculata* | X | - - |
| Eastern Garter Snake | *Thamnophis sirtalis sirtalis* | X | - - |
| Chicago Garter Snake | *Thamnophis sirtalis semifasciata* | X | - - |
| Eastern Plaines Garter Snake | *Thamnophis radix radix* | X | - - |
| Eastern Hognose Snake | *Heterodon platyrhinos* | - - | X |
| Eastern Smooth Green Snake | *Opheodrys vernalis vernalis* | - - | X |
| Eastern Milk Snake | *Lampropeltis triangulum triangulum* | - - | X |
| *Viperidae* | | | |
| Eastern Massasaga Rattlesnake[b] | *Sistrurus catenatus catenatus* | - - | X |

[a]*Likely to be extirpated from the watershed.*

[b]*Identified as endangered in Wisconsin.*

[c]*Identified as threatened in Wisconsin.*

*Source: Gary S. Casper,* Geographical Distribution of the Amphibians and Reptiles of Wisconsin, *1996, Wisconsin Department of Natural Resources, R.C. Vogt,* Natural History of the Ampibians and Reptiles of Wisconsin, *1981, U.S. Department of Agriculture Integrated Taxonomic Information System, and SEWRPC.*

species normally expected to be present in the Delavan Lake area under present conditions and identifies those species most sensitive to urbanization.

Most amphibians and reptiles have specific habitat requirements that are adversely affected by advancing urban development, as well as by certain agricultural land management practices. The major detrimental factors affecting the maintenance of amphibians in a changing environment is the destruction of breeding ponds, urban development occurring in migration routes, and changes in food sources brought about by urbanization.

## WILDLIFE HABITAT

The complete spectrum of wildlife species originally native to Walworth County has, along with its habitat, undergone significant change in terms of diversity and population size since the European settlement of the area. This change is a direct result of the conversion of land by the settlers from its natural state to agricultural and urban uses, beginning with the clearing of the forest and prairies, the draining of wetlands, and ending with the development of extensive urban areas. Successive cultural uses and attendant management practices, both rural and urban, have been superimposed on the land use changes and have also affected the wildlife and wildlife habitat. In agricultural areas, these cultural management practices include draining land by ditching and tiling and the expanding use of fertilizers, herbicides, and pesticides. In urban areas, cultural management practices that affect wildlife and their habitat include the use of fertilizers, herbicides, and pesticides; road salting for snow and ice control; heavy motor vehicle traffic that produces disruptive noise levels and air pollution and nonpoint source water pollution; and the introduction of domestic pets.

Wildlife habitat areas remaining in the Region were inventoried by the Regional Planning Commission in 1985 in cooperation with the Wisconsin Department of Natural Resources. The five major criteria used to determine the value of these wildlife habitat areas are listed below:

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

2. Territorial Requirements: The maintenance of proper spatial relationships among species, allowing for a certain minimum population level, can occur only 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 Delavan Lake drainage area were categorized as either Class I, High-Value; Class II, Medium-Value; or Class III, Good-Value, habitat areas.

Class I 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. Class II wildlife habitat areas generally fail to meet one of the five criteria in the preceding list for a high-value wildlife habitat. However, they do retain a good plant and animal diversity. Class III wildlife habitat areas are remnant in nature in that they generally fail to meet two or more of the five criteria for a high-value wildlife habitat, but may, nevertheless, be important if located in proximity to medium- or high-value habitat areas, if they provide corridors linking wildlife habitat areas of higher value or if they provide the only available range in an area.

As shown on Map 17, about 640 acres, or about 2 percent of the drainage area tributary to Delavan Lake, were classified in the 1985 inventory as Class I habitat; 900 acres, or about 3 percent, were classified as Class II habitat; and 1,640 acres, or about 6 percent, were classified as Class III habitat.

## WETLANDS

Wetlands are defined by the Regional Planning Commission as, "areas that have a predominance of hydric soils and that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions." This definition, which is also used by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency, is essentially the same as the definition used by the U.S. Natural Resource Conservation Service.[31]

Another definition, which is applied by the State of Wisconsin Department of Natural Resources and which is set forth in Chapter 23 of the *Wisconsin Statutes*, defines a wetland as "an area where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation, and which has soils indicative of wet conditions." In practice, the Department definition differs from the Regional Planning Commission definition in that the Department considers very poorly drained, poorly drained, and some of the somewhat poorly drained soils as wetland soils meeting the Department "wet condition" criterion. The Commission definition only considers the very poorly drained and poorly drained soils as meeting the "hydric soil" criterion. Thus, the State definition as actually applied is more inclusive than the Federal and Commission definitions in that the Department may include some soils that do not show hydric field characteristics as wet soils capable of supporting wetland vegetation, a condition that may occur in some floodlands.[32]

As a practical matter, experience has shown that application of the Wisconsin Department of Natural Resources, the U.S. Environmental Protection Agency and U.S. Army Corps of Engineers, and the Regional Planning Commission definitions, produce reasonably consistent wetland identifications and delineations in the majority of situations within the Southeastern Wisconsin Region. That consistency is due in large part to the provision in the Federal wetland delineation manual that allows for the application of professional judgement in cases where satisfaction of the three criteria for wetland identification is unclear.

Wetlands in Southeastern Wisconsin are classified predominantly as deep marsh, shallow marsh, southern sedge meadow, fresh (wet) meadow, shrub carr, alder thickets, low prairie, fens, bogs, southern wet- and wet-mesic hardwood forest, and conifer swamp. Wetlands form an important part of the landscape in and adjacent to Delavan Lake in that they perform an important set of natural functions which make them ecologically and

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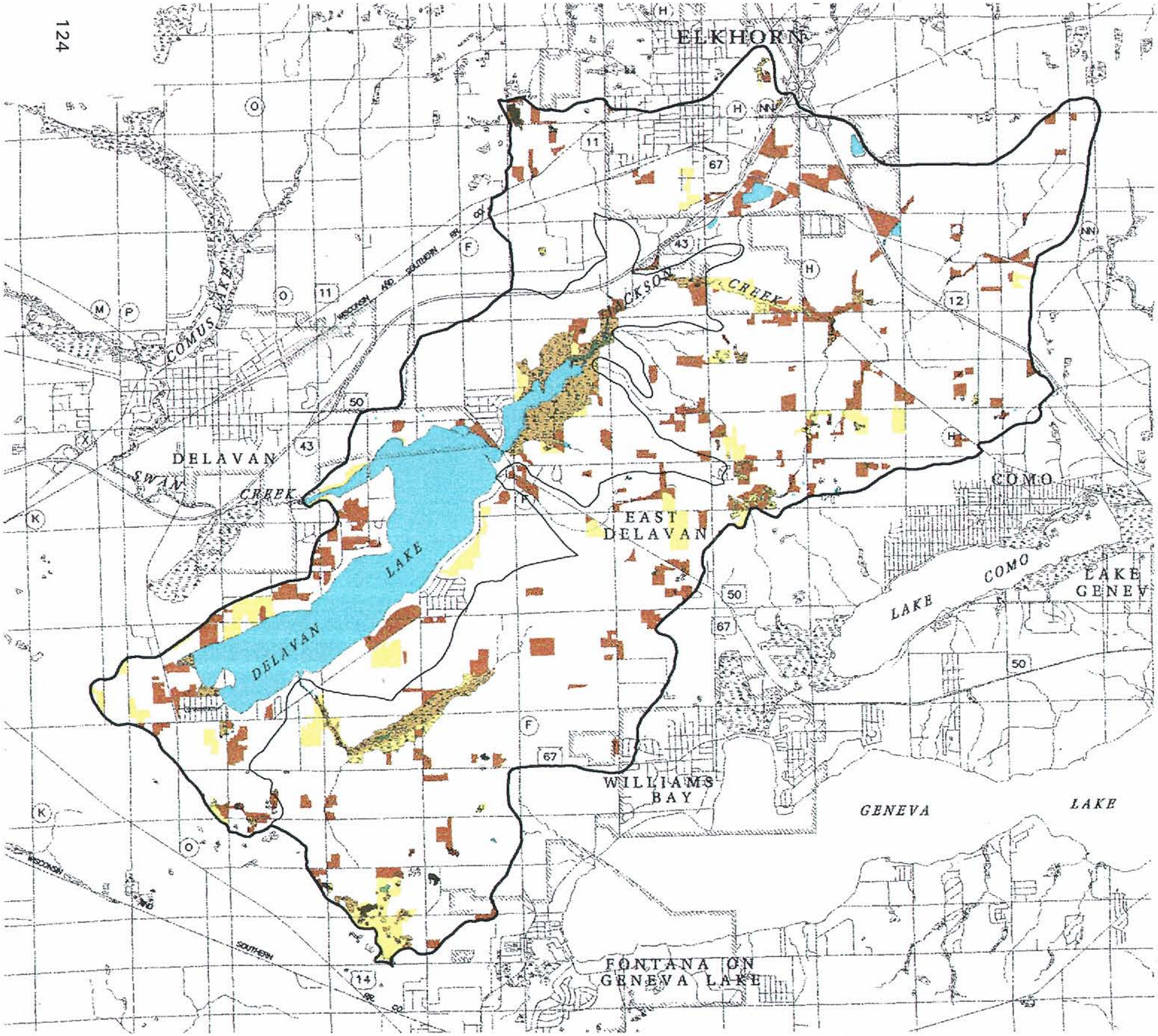
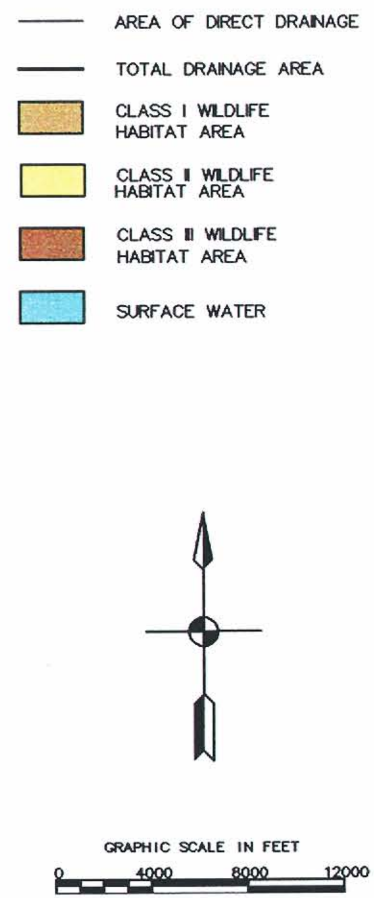
[31]*Lands designated as prior converted cropland, that is, lands that were cleared, drained, filled, or otherwise manipulated to make them capable of supporting a commodity crop prior to December 23, 1985, may meet the criteria of the U.S. Natural Resource Conservation Service wetland definition, but they would not be regulated under Federal wetland programs. If such lands are not cropped, managed, or maintained for agricultural production, for five consecutive years, and in that time the land reverts back to wetland, the land would then be subject to Federal wetland regulations.*

[32]*Although prior converted cropland is not subject to Federal wetland regulations unless cropping ceases for five consecutive years and the land reverts to a wetland condition, the State may consider prior converted cropland to be subject to State wetland regulations if the land meets the criteria set forth in the State wetland definition before it has not been cropped for five consecutive years.*

Map 17

**WILDLIFE HABITAT AREAS WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE**




Source: SEWRPC.

environmentally invaluable resources. Wetlands affect the quality of water by acting as a filter or a buffer zone allowing silt and sediments to settle out. They also influence the quantity of water by providing water during periods of drought and holding it back during periods of flood. When located along shorelines of lakes and streams, wetlands help protect those shorelines from erosion. Wetlands also may serve as groundwater discharge and recharge areas, in addition to being important resources for overall ecological health and diversity by providing essential breeding and feeding grounds, shelter, and escape cover for many forms of fish and wildlife.

Wetlands are poorly suited to urban use. This is due to the high soil compressibility and instability, high water table, low load-bearing capacity, and high shrink-swell potential of wetland soils, and, in some cases, to the potential for flooding. In addition, metal conduits placed in some types of wetland soils may be subject to rapid corrosion. These constraints, if ignored, may result in flooding, wet basements and excessive operation of sump pumps, unstable foundations, failing pavements, broken sewer and water lines, and excessive infiltration of clear water into sanitary sewerage systems. In addition, there are significant onsite preparation and maintenance costs associated with the development of wetlands, particularly as they relate to roads, foundations, and public utilities.

The Regional Planning Commission maintains an inventory of wetlands within the Region, which is updated every five years. As shown on Map 18, in 1990, wetlands covered about 380 acres, or about 5 percent of the direct drainage area tributary to Delavan Lake, and about 780 acres, or about 3 percent of the total drainage area tributary to Delavan Lake. The amount and distribution of wetlands in the area should remain relatively constant if the recommendations contained in the adopted regional land use plan are followed.

## WOODLANDS

Woodlands are defined by the Regional Planning Commission as those areas containing a minimum of 17 trees per acre with a diameter of at least four inches at breast height (4.5 feet above the ground).[33] The woodlands are classified as dry, dry-mesic, mesic, wet-mesic, wet hardwood, and conifer swamp forests; the last three are also considered wetlands. The Regional Planning Commission also maintains an inventory of woodlands within the Region that is updated every five years. In the drainage area directly tributary to Delavan Lake, shown on Map 18, approximately 530 acres of woodland were inventoried in 1990. These woodlands covered about 6 percent of the drainage area. About 780 acres of woodlands were present in the total drainage area tributary to Delavan Lake. The major tree species include black willow, *Salix nigra*; cottonwood, *Populus deltoides*; white oak, *Quercus alba*; burr oak, *Quercus macrocarpa*; black cherry, *Prunus serotina*; green ash, *Fraxinus pennsylvanica*; silver maple, *Acer saccharinum*; American elm, *Ulmus americana*; northern red oak, *Quercus borealis*; black oak, *Quercus velutina*; and, shagbark hickory, *Carya ovata*.

The amount and distribution of woodlands in the area should also remain relatively stable if the recommendations contained in the regional land use plan are followed.

## ENVIRONMENTAL CORRIDORS

One of the most important tasks undertaken by the Regional Planning Commission in its work program has been the identification and delineation of those areas of the Region having concentrations of natural, recreational, historic, aesthetic, and scenic resources and which, as such, should be preserved and protected in order to maintain the overall quality of the environment. Such areas normally include one or more of the following seven elements of the natural resource base which are essential to the maintenance of both the ecological balance and the natural beauty of the Region: 1) lakes, rivers, and streams and the associated undeveloped shorelands and floodlands; 2) wetlands; 3) woodlands; 4) prairies; 5) wildlife habitat areas; 6) wet, poorly drained, and organic

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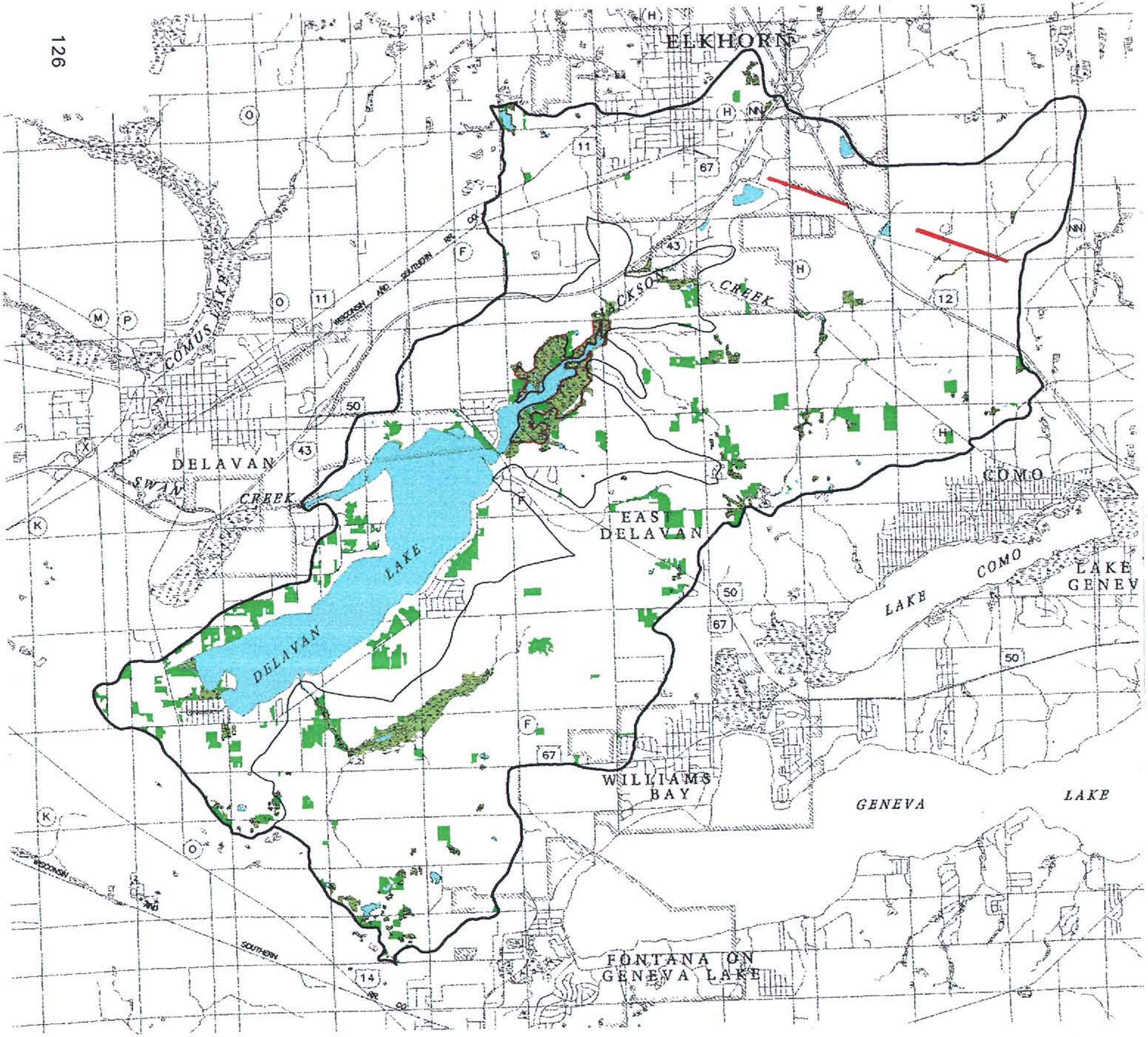
[33]*SEWRPC, "Refining the Delineation of the Environmental Corridors in Southeastern Wisconsin,"* Technical Record, *Vol. 4, No. 2, March 1981.*

## Map 18

## EXISTING WETLANDS AND WOODLANDS WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE




AREA OF DIRECT DRAINAGE

TOTAL DRAINAGE AREA

WETLANDS

WOODLANDS

CRITICAL SPECIES HABITAT AREAS

NATURAL AREAS

SURFACE WATER

GRAPHIC SCALE IN FEET

0 4000 8000 12000

*Source: SEWRPC.*

soils; and 7) rugged terrain and high-relief topography. While the foregoing seven elements constitute integral parts of the natural resource base, there are five additional elements which, although not a part of the natural resource base *per se*, are closely related to, or centered on, that base and, therefore, are important considerations in identifying and delineating areas with scenic, recreational, and educational value. These additional elements are: 1) existing outdoor recreation sites; 2) potential outdoor recreation and related open space sites; 3) historic, archaeological, and other cultural sites; 4) significant scenic areas and vistas; and 5) natural and scientific areas.

In Southeastern Wisconsin, the delineation of these 12 natural resource and natural resource-related elements on maps results in an essentially linear pattern of relatively narrow, elongated areas which have been termed "environmental corridors" by the Commission. Primary environmental corridors include a wide variety of the aforementioned important resource and resource-related elements and are, by definition, at least 400 acres in size, two miles in length, and 200 feet in width. The primary environmental corridors identified in the Delavan Lake drainage area are contiguous with environmental corridors and isolated natural areas lying within the Turtle Creek watershed, and, consequently, meet these size and natural resource element criteria.

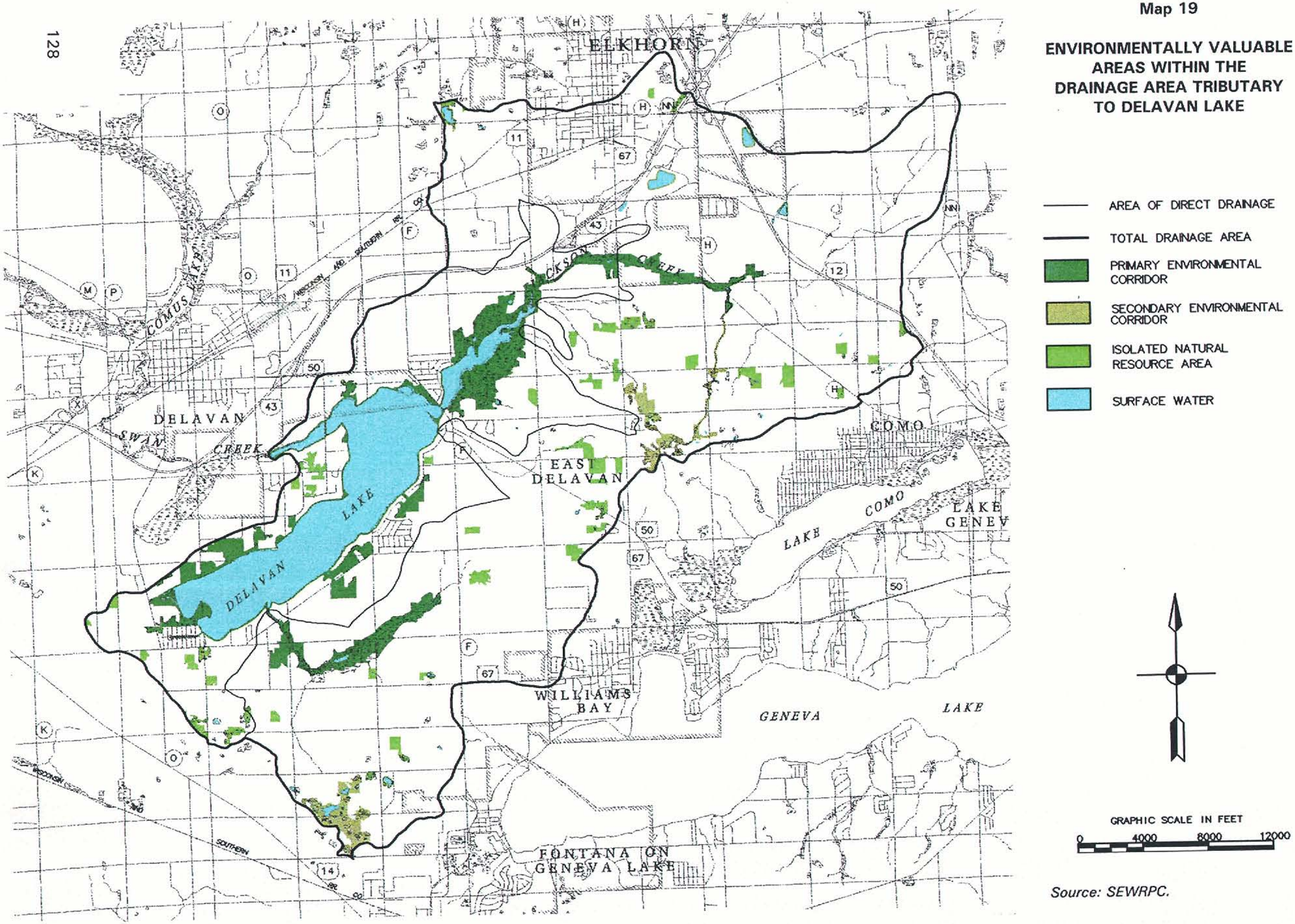
It is important to note here that, because of the many interlocking and interacting relationships between living organisms and their environment, the destruction or deterioration of one element of the total environment may lead to a chain reaction of deterioration and destruction. The drainage of wetlands, for example, may have far-reaching effects, since such drainage may destroy fish spawning grounds, wildlife habitat, groundwater recharge areas, and natural filtration and floodwater storage areas in interconnected lake and stream ecosystems. The resulting deterioration of surface water quality may, in turn, lead to a deterioration of the quality of the groundwater that serves as a source of domestic, municipal, and industrial water supplies and provides a basis for low flows in rivers and streams. Similarly, the destruction of woodland cover, which may have taken a century or more to develop, may result in soil erosion and stream siltation, and in more rapid runoff and increased flooding, as well as in the destruction of wildlife habitat. Although the effects of any one of these environmental changes may not in and of itself be overwhelming, the combined effects may lead eventually to the deterioration of the underlying and supporting natural resource base, and of the overall quality of the environment for life. The need to protect and preserve the remaining environmental corridors within the Delavan Lake direct drainage area thus becomes apparent and critical.

Environmental corridors were first identified within the Region in 1963 as part of the original regional land use planning effort of the Commission and were subsequently refined under the Commission watershed studies and regional park and open space planning programs. The environmental corridors in Southeastern Wisconsin generally lie along major stream-valleys and around major Lakes and contain almost all the remaining high-value woodlands, wetlands, and wildlife habitat areas, and all the major bodies of surface water and related undeveloped floodlands and shorelands. Environmental corridors within the drainage area directly tributary to Delavan Lake are shown on Map 19. About 985 acres, or 12 percent of the drainage area directly tributary to Delavan Lake, were identified as primary environmental corridor. Approximately an additional 150 acres, or about 2 percent of the drainage area, were identified as isolated natural features located within the drainage area. In the total drainage area tributary to Delavan Lake, about 1,400 acres, or about 5 percent of the drainage area, were identified as primary environmental corridor; 320 acres, or about 1 percent of the drainage area, were identified as secondary environmental corridor; and, about 570 acres, or about 2 percent of the drainage area, were isolated natural features.

Environmental corridors are subject to urban encroachment because of their desirable natural resource amenities. Unplanned or poorly planned intrusion of urban development into these corridors not only tends to destroy the very resources and related amenities sought by the development, but also tends to create severe environmental and developmental problems as well. These problems include, among others, water pollution, flooding, wet basements, failing foundations for roads and other structures, and excessive infiltration of clear water into sanitary sewerage systems. The preservation of as yet undeveloped corridors is one of the major ways in which the water quality can be protected and perhaps improved at relatively little additional cost to the taxpayers of the area.

Map 19

**ENVIRONMENTALLY VALUABLE AREAS WITHIN THE DRAINAGE AREA TRIBUTARY TO DELAVAN LAKE**




Source: SEWRPC.

In the Delavan Lake drainage area, the river banks and lakeshores located within the environmental corridors should be candidates for immediate protection through proper zoning or through public ownership. Of the areas not already publicly owned, the remaining areas of natural shoreline, and riparian wetland area, shown on Map 19, are perhaps the most sensitive areas in need of greatest protection. In this regard, the regional natural areas and critical species habitat protection and management plan recommends public acquisition of specific lands, as shown on Map 18.[34] Within the drainage area directly tributary to Delavan Lake, extension of the Wisconsin Department of Natural Resources ownership of the Lake Lawn Wetland Complex, totaling about 280 acres, is recommended. Within the total tributary drainage area to the Lake, the Elkhorn Railroad Prairie Remnant is recommended for Wisconsin Department of Transportation acquisition.

## SUMMARY

Delavan Lake has suffered in the past from a lake dominated with rough fish and excessive green and blue-green algal booms. Recent rehabilitation efforts have led to the establishment of a predator dominated fishery and have improved water clarity resulting in an abundance of aquatic plants. While the diversity of aquatic macrophytes has increased, Eurasian water milfoil (*Myriophyllum spicatum*) had become the dominant species in many areas of the Lake. Curly-leaf pondweed (*Potamogeton crispus*) is also abundant and can be found at nuisance levels. These plants are currently being managed using a combination of chemical and mechanical controls. Chemical controls, previously effected with sodium arsenite, copper sulfate, and have more recently been accomplished with Cutrine Plus and various synthetic organic herbicides, such as diaquat, endothall, and 2,4-D, are applied in late spring, with a possible follow-up treatment in late summer. Mechanical harvesting is carried out with three harvesters during the entire aquatic plant growing season.

The Lake is currently managed for a predator dominated fish community of walleyed pike, northern pike, largemouth bass, and panfish as stocked by the Department of Natural Resources. This had encouraged the dominance of large bodied cladoceran zooplankton species that are efficient grazers of phytoplankton. Recently, relatively smaller-bodied cladoceran species have reappeared in the lake.

Other aquatic life and wildlife in the drainage area of the Lake include amphibians and reptiles, birds, and small and large mammals. While many of the wetland habitats frequented by many of these animals are expected to remain intact, the predominantly agricultural lands with scattered woodlots that house much of the terrestrial fauna are potential areas for further urban residential and recreational development. Nevertheless, the Delavan Lake drainage area provides an adequate refuge for a healthy and diverse fauna.

[34] *SEWRPC Planning Report No. 42*, A Regional Natural Areas and Critical Species Habitat Protection and Management Plan for Southeastern Wisconsin, *September 1997.*

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# Chapter VI

# CURRENT WATER USES, LAKE MANAGEMENT PRACTICES, AND WATER USE OBJECTIVES

## INTRODUCTION

Nearly all major lakes in the Southeastern Wisconsin Region serve multiple purposes, ranging from recreation to receiving waters for stormwater runoff. Recreational uses range from noncontact, passive recreation, such as picnicking and walking along the shoreline, to full-contact, active recreation, such as swimming and waterskiing. Water use objectives and supporting water quality standards have been adopted by the Wisconsin Department of Natural Resources and the Southeastern Wisconsin Regional Planning Commission for all major lakes and streams in the Region. The current water uses and a summary of past water quality remedial measures, as well as the water use objectives and supporting water quality standards for Delavan Lake, are discussed in this chapter.

## SUMMARY OF REMEDIAL MEASURES

Remedial measures implemented in the Delavan Lake basin were intended to achieve and maintain fishable and swimmable conditions within Delavan Lake, pursuant to the mandate established by the Federal Clean Water Act. The measures are selected to achieve fishable and swimmable conditions in the Lake provided for both immediate and long-term reduction of nutrient levels, improvement of water clarity, reduction of nuisance blooms of algae, and rehabilitation of the sport fishery. In addition, the Delavan Lake Sanitary District carries out an extensive aquatic plant management program as described in Chapter V. Many of these efforts were identified as recommendations set forth in a multi-faceted lake rehabilitation report developed during 1986 by the University of Wisconsin Water Resources Management Program Workshop,[1] and elaborated in the Wisconsin Department of Natural Resources environmental assessment.[2] The specific goals set forth in that 1986 report included: reducing in-lake phosphorus concentrations to below 35 micrograms per liter (μg/l), increasing summer Secchi-disk transparencies to a depth of greater than or equal to 1.5 meters, reducing nuisance blooms of algae, and converting the lake fishery from one dominated by carp and bigmouth buffalo to one dominated by northern pike and walleyed pike.

### Reduction of External Nutrient Inputs

Several efforts were undertaken to reduce external loading of phosphorus into the Lake. In 1981, sewage treatment plant effluent was diverted from the Jackson Creek basin. In addition, the discharge of wastewater from a fertilizer plant on the Jackson Creek Tributary was discontinued in 1984, and various other agricultural and urban management practices (BMPs) were implemented in the watershed beginning in 1985. These included the

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[1] *Institute for Environmental Studies, University of Wisconsin-Madison,* Water Resources Management Program Workshop, Delavan Lake: A Recovery and Management Plan, *1986.*

[2] *Wisconsin Department of Natural Resources,* Environmental Impact Statement on the Delavan Lake Rehabilitation Project, Walworth County, Wisconsin, *March 1989; see also Wisconsin Department of Natural Resources,* Turtle Creek Priority Watershed Plan, *March 1984; Wisconsin Department of Natural Resources,* Turtle Creek Priority Watershed Plan Amendment—The Delavan Lake Restoration Project, *August 1989.*

reconstruction and restoration of a wetland on Jackson Creek upstream of the Lake. This wetland restoration project was designed to trap incoming sediment from the Jackson Creek drainage area. A small, 15-acre wetland that had been prior converted to agricultural use was acquired and expanded into a 94-acre shallow marsh and low prairie marsh. Three sedimentation ponds were constructed at the inlet to the marsh in an effort to encourage sheet flow across the wetland and enhance nutrient and sediment removal from the inflowing stream. Construction was completed and native wetland plants initially were introduced during 1992. Wetland vegetation subsequently became well established during 1994.

**Short-Circuiting of Water Flow through Delavan Lake**
Nutrients can affect the water quality of a lake only if they remain in the lake long enough to be consumed by algae and macrophytes, which, if present in overabundant quantities, interfere with and limit human recreational and other uses of the lake. Unbalanced aquatic plant growth in a lake also limits habitat and food resource availability, thereby modifying and affecting the fishery and other wildlife use of the lake. In throughflow lakes, like Delavan Lake, the primary source of plant nutrients is typically from external sources. These nutrients are generally delivered to the lake by the inflowing streams, with a portion of the nutrients being removed before outflow. Because of the close proximity of the Jackson Creek inlet to the Swan Creek outlet of Delavan Lake, it was considered possible to limit the volume of inflowing water and associated nutrient load entering the Lake, by redirecting some of the inflowing water from Jackson Creek into the outlet. Several measures were undertaken from 1989 to 1990 to enhance this potential "short-circuiting" of water flow. These measures included modifying the outlet dam and altering its operational regime. Channels near the inlet and outlet were deepened through dredging. The peninsula in the northeast part of the Lake was extended about 1,000 feet. In addition, the lake level was drawn down to facilitate these measures and fish eradication.

**Fishery Rehabilitation and Biomanipulation**
Because of the dominance of rough fish in Delavan Lake, it was felt that fisheries rehabilitation could only be accomplished through completely eradicating all fish in the Lake and its tributaries, and reintroducing game fish and sufficient forage fish to maintain the game fish. In addition, restocking efforts were designed to manipulate the food web in the Lake so that the dominance of piscivorous fish would keep planktivorous fish at low densities. This would encourage and maintain the presence of large populations of large-bodied zooplankton species, which are efficient consumers of algae. This potential change in the dominant primary producers in the system, from phytoplankton to macrophytes, was anticipated to lead to a concomitant improvement in water clarity.

To accomplish this goal, the fish in Delavan Lake and its tributaries were eradicated through application of rotenone during the autumn of 1989. To minimize the volume of rotenone required, and to manage the high cost of this operation, the Lake was drawn down prior to the rotenone application. Fish were restocked initially during 1990 and 1991. To maximize the success of restocking, fishing was completely prohibited on the Lake through to the spring of 1992. Beginning in spring 1992, size limits were placed on all game fish to limit the angling harvest so as to maintain the desired predator-prey balance. Since 1992, there has been ongoing stocking of selected game fish species.

**Removal of Phosphorus from the Water Column and Reduction of Phosphorus Release from Sediment**
When aluminum sulfate (alum) is added to water, it is converted to aluminum hydroxide, which strongly adsorbs inorganic phosphorus from within the water column. Because aluminum phosphates are insoluble in water, the resultant flocculent materials precipitates to the lakebed, forming a blanket that also adsorbs inorganic phosphorus at the sediment-water interface, forming a barrier that prevents phosphorus release from the sediment, even under anoxic conditions. In April and May 1991, the main basin of Delavan Lake was treated with about 660,000 gallons of aluminum sulfate at a concentration of 58 grams per liter (g/l). The treatment was administered at the time when the Lake was drawn down to facilitate the carp eradication program described above.

## RECREATIONAL USE

**Existing Recreation Use and Facilities**
Delavan Lake, lying adjacent to an urbanizing area, provides an ideal setting for the provision of parks and open space sites and facilities. There is a publicly and privately owned open space site, being part of the Delavan Lake

inlet, known as the Lake Lawn Wetland Complex, a publicly owned town park known as the Mound Road wetland restoration site, and two publicly owned lake-access sites. The major public access is the Town of Delavan Park located at the northeast end of the Lake near STH 50. This site provides a boat ramp, two docks, picnic area, swimming beach, pavilion, bank fishing and parking for more than 100 vehicles with trailers. The other publicly owned site consists of a single boat ramp located at the end of Blue Gill Road. This site has no parking or other improvements. Small boats and canoes can be launched at the inlet at Mound Road and the outlet at North Shore Drive.[3] In addition, there are four privately owned recreational sites with boat access. These consist of a resort with a golf course and marina, a local yacht club, and two marinas. Finally, numerous private boat-launching sites exist around the lakeshore. The public and selected private sites are shown on Map 20.[4] Existing recreational facilities in the vicinity of Delavan Lake, including surrounding park areas, the Delavan Assembly Grounds Park, South Shore Manor Subdivision Park, Subdivision Park, Highlands Subdivision Park, Sportsman's Park, Subdivision Park Tot Lot, Town Park, Delavan Camp, and House-in-the-Woods Camp situated on or near the lakeshore, are also shown on Map 20.

The town-owned lake-access site on the northeastern shore of Delavan Lake near the Delavan Lake inlet provides adequate public recreational boating access pursuant to Chapter NR 1 of the *Wisconsin Administrative Code.* Access to lakes with 1,000 to 4,999 open water acres is considered to be adequate if there are one or more access sites which in total provide one car-trailer unit per 50 acres open water, but no less than 29 units for lakes with 1,000 to 1,450 open water acres.

Water-based outdoor recreational activities on Delavan Lake include boating, fishing, swimming, and other active and passive recreational pursuits. Because of its size, Delavan Lake receives a significant amount of boating usage. Records of boats launched from the Town Park public access, shown in Table 35, indicate that the number of boats launched increased five-fold from 2,412 boats launched in 1988 to 12,336 in 1996. The number of launches at this site declined to 7,899 in 1999. Records were not available for launches from other access points. The Delavan Lake Sanitary District has conducted annual riparian watercraft surveys since 1987. The results of the 1999 survey, shown in Table 36, indicate that about 1,982 watercraft were moored on the Lake or stored on shore. Most of the watercraft not in use were powerboats, pontoon boats, and fishing boats, with lesser numbers of canoes, paddleboats, sailboats, and personal watercraft ("jetskis"). Figure 22 summarizes the results of the surveys from 1987 through 1999. The size of the fleet has been increasing at an average rate of about 77 boats per year. Changes in the composition of the fleet from 1994 to 1999 are shown in Figure 23. Over this period, the proportions of the fleet represented by motorboats and sailboats have declined. Motorboats represented about 65 percent of the riparian watercraft during the 1994 survey; in 1999, they accounted for about 50 percent of the fleet. Similarly, the proportion of the fleet represented by sailboats declined from about 10 percent to about 8 percent over the same period. The fractions of the fleet represented by pontoon boats, personal watercraft, and canoes and other nonpowered craft all increased from 1996 to 1999.

In addition to recreational boating activities, other community and private events and activities take advantage of the aesthetic qualities of the Lake during all four seasons. Community picnics are held during the summer months, and the annual Independence Day celebrations include events along the lakeshore. The Delavan Lake Improvement Association, Inc., holds their annual meeting at the Town Park during the late spring, generally coincident with the Memorial Day weekend.

During the winter months, ice fishing, cross-country skiing, and snowmobiling are popular pastimes on Delavan Lake.

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[3]*Delavan Lake Sanitary District,* Lake Water Quality Report, 1998, Delavan Lake, Wisconsin, *March 1999.*

[4]*SEWRPC Community Assistance Planning Report No. 135, 2nd Edition,* A Park and Open Space Plan for Walworth County, *September 2000.*

Map 20

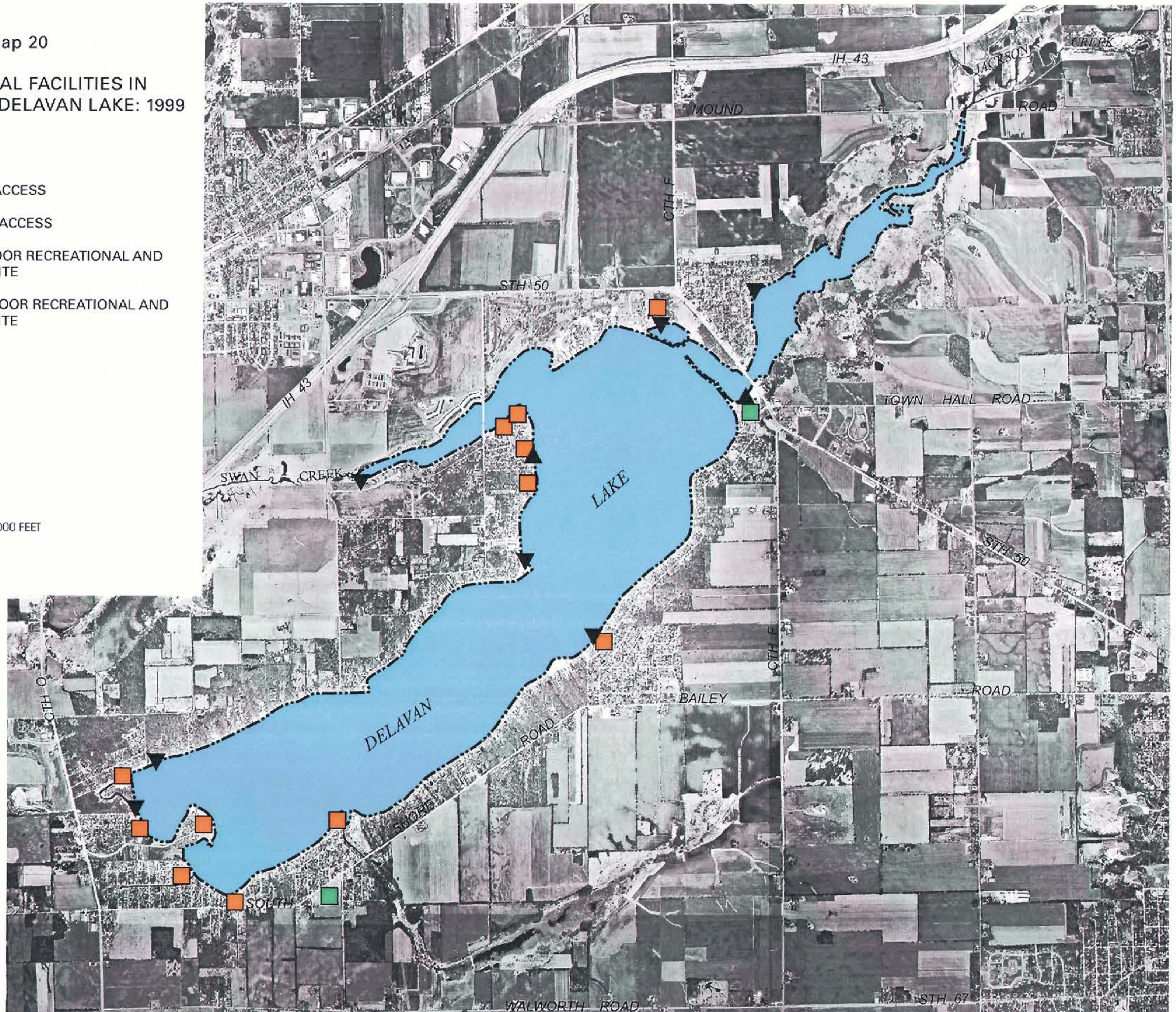
## RECREATIONAL FACILITIES IN THE VICINITY OF DELAVAN LAKE: 1999

▲ PUBLIC BOAT ACCESS

▼ PRIVATE BOAT ACCESS

PUBLIC OUTDOOR RECREATIONAL AND OPEN SPACE SITE

PRIVATE OUTDOOR RECREATIONAL AND OPEN SPACE SITE




N

GRAPHIC SCALE

0 2000 4000 FEET

*Source: SEWRPC.*

DATE OF PHOTOGRAPHY: MARCH 1995

## Table 35

### BOATS LAUNCHED FROM TOWN PARK PUBLIC ACCESS TO DELAVAN LAKE: 1988-1998

| Year | Month | | | | | |
|---|---|---|---|---|---|---|
| | May | June | July | August | September | Total |
| 1988 | 312 | 554 | 878 | 557 | 111 | 2,412 |
| 1989 | - -[a] | 591 | 1,037 | 703 | - -[a] | 2,331 |
| 1991 | 137 | 604 | 854 | 721 | 253 | 2,569 |
| 1992 | 1,335 | 1,350 | 1,545 | 1,663 | 574 | 6,467 |
| 1993 | 1,178 | 1,816 | 2,296 | 1,789 | 781 | 7,860 |
| 1994 | 1,985 | 1,905 | 2,302 | 1,426 | 1,026 | 8,644 |
| 1995 | 1,505 | 2,361 | 2,497 | 1,182 | 926 | 8,471 |
| 1996 | 1,512 | 2,939 | 2,690 | 2,806 | 2,389 | 12,336 |
| 1997 | 1,632 | 2,891 | 2,391 | 1,937 | 733 | 9,584 |
| 1998 | 2,116 | 1,644 | 1,913 | 1,658 | 815 | 8,146 |
| 1999 | 1,716 | 1,864 | 1,356 | 1,568 | 1,395 | 7,899 |

[a]*Data unavailable.*

*Source: Delavan Lake Sanitary District, Town of Delavan, and SEWRPC.*

## Table 36

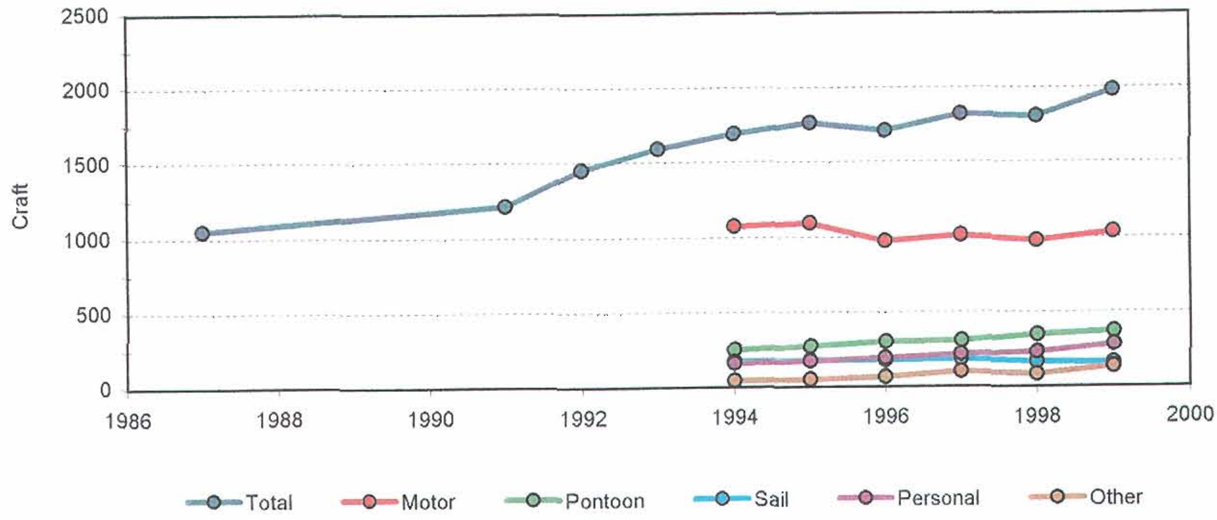
### BOAT SURVEY OF DELAVAN LAKE: 1999

| Shoreline Location | Type of Watercraft | | | | | |
|---|---|---|---|---|---|---|
| | Motor Boat | Pontoon Boat | Sail Boat | Personal Craft | Other | Total |
| Inlet | | | | | | |
| East of Highway 50 | 61 | 13 | 0 | 23 | 9 | 106 |
| Outlet | | | | | | |
| West of North Shore Drive Bridge | 85 | 73 | 2 | 36 | 19 | 215 |
| North Shore | | | | | | |
| Lake Lawn Lodge Marina | 124 | 29 | 10 | 8 | 3 | 174 |
| North Shore Drive to Assembly Park Beach | 73 | 48 | 7 | 12 | 8 | 148 |
| Assembly Park Beach to Yacht Club | 112 | 35 | 49 | 23 | 10 | 229 |
| Yacht Club to Willow Point | 78 | 15 | 24 | 36 | 13 | 166 |
| Willow Point to Viewcrest | 28 | 7 | 3 | 10 | 7 | 55 |
| West End | | | | | | |
| Viewcrest Channel | 54 | 29 | 3 | 2 | 7 | 95 |
| Ravenswood–The Island | 37 | 18 | 7 | 5 | 23 | 90 |
| Highlands Channel | 62 | 31 | 1 | 1 | 2 | 97 |
| South Shore | | | | | | |
| Highlands to South Shore Manor | 100 | 34 | 9 | 37 | 7 | 187 |
| South Shore Manor Channel | 37 | 16 | 0 | 15 | 7 | 76 |
| South Shore to Delmar Beach | 64 | 7 | 16 | 22 | 11 | 120 |
| Delmar Beach to Town Park | 119 | 14 | 29 | 53 | 96 | 224 |
| Total | 1,035 | 369 | 160 | 283 | 135 | 1,982 |
| Percent of Total | 52.2 | 18.6 | 8.1 | 14.3 | 6.8 | 100.0 |

*Source: Delavan Lake Sanitary District and SEWRPC.*

Figure 22

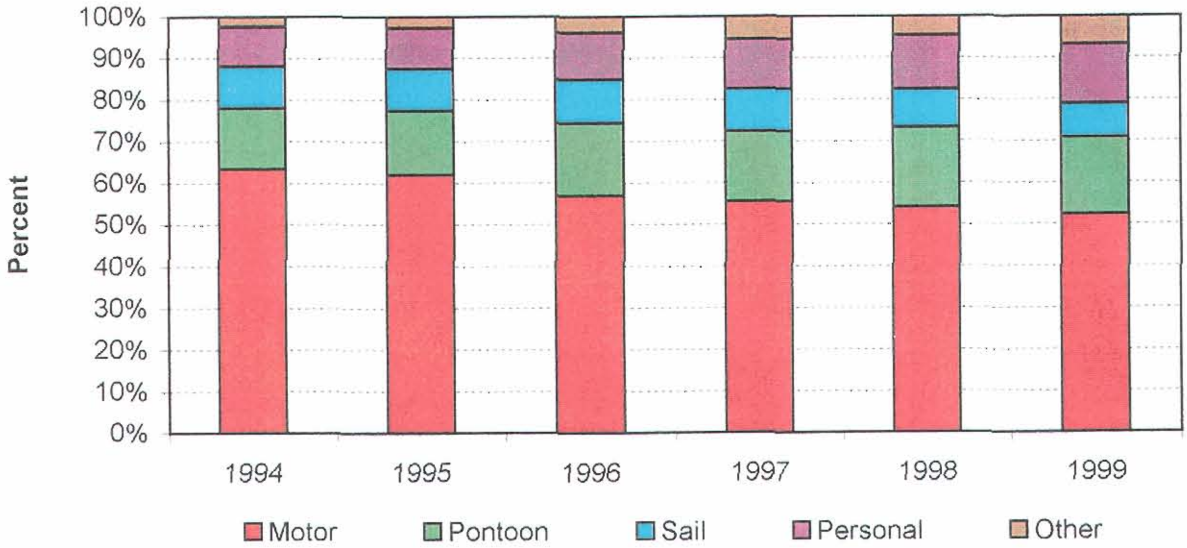
NUMBERS OF WATERCRAFT IN AND AROUND DELAVAN LAKE: 1986-2000




*Source: Delavan Lake Sanitary District and SEWRPC.*

Figure 23

TYPES OF WATERCRAFT IN USE ON DELAVAN LAKE: 1994-1999




*Source: Delavan Lake Sanitary District and SEWRPC.*

It is important to note that the provision of park and open space sites in the drainage area tributary to Delavan Lake should be guided, to a large extent, by the recommendations contained in the Walworth County park and open space plan.[5] The purpose of that plan is to guide the preservation, acquisition, and development of land for park, outdoor recreation, and related open space purposes and to protect and enhance the underlying and sustaining natural resource base of the County, including the Town. With respect to the Delavan Lake drainage area, the plan recommends the maintenance of existing park and open space sites in the area. In addition, the plan recommends that the undeveloped lands in the primary environmental corridor drainage area tributary to Delavan Lake be retained and maintained as natural open space.

**Wisconsin Department of Natural Resources Recreational Rating**

A recreational rating technique has been developed by the Wisconsin Department of Natural Resources to characterize the recreational value of inland lakes. Based upon a 1999 assessment by SEWRPC staff, Delavan Lake provides a moderately diverse recreational experience, with a rating of 52 out of 72 points, as shown in Table 37. Favorable features include the boating and angling opportunities provided, while unfavorable features include variable water quality, primarily as a result of turbidity, and extensive algae and aquatic macrophyte growth. In general, Delavan Lake provides good opportunities for a variety of outdoor recreational activities, particularly boating, fishing, and aesthetic enjoyment, consistent with the aforereferenced, adopted county park and open space plan.

**Recreational Use Conclusions**

The scope of uses engaged in on Delavan Lake is sufficiently broad to be consistent with the recommended use objectives of full recreational use and the support of a healthy warmwater sport fishery as set forth in the regional water quality management plan.

## WATER USE OBJECTIVES

The regional water quality management plan recommended the adoption of full recreational and warmwater sport fisheries objectives for Delavan Lake. These objectives are consistent with the current Wisconsin Department of Natural Resources water use objectives, and lake and stream classifications, for the Lake, and with Federal Clean Water Act objectives of fishable and swimmable waters. The findings of the inventories of the natural resource base, set forth in Chapters III through V, indicate that the use of the Lake and the resources of the area are generally supportive of such objectives, although it is expected that remedial measures will be required if the Lake is to fully meet the objectives.

The recommended warmwater sport fishery objective is supported in Delavan Lake by a sport fishery based largely on walleyed pike, northern pike, bass, and panfish. These fishes have traditionally been sought after in Delavan Lake.

## WATER QUALITY STANDARDS

The water quality standards supporting the warmwater fishery and full recreation use objectives as established for planning purposes in the regional water quality management plan, are set forth in Table 38. These standards are similar to those set forth in Chapters NR 102 and 104 of the *Wisconsin Administrative Code*, but were refined for planning purposes in terms of their application. Standards are recommended for temperature and pH, and for dissolved oxygen, fecal coliforms, and total phosphorus concentrations. These standards apply to the epilimnion of the lakes and to streams. The total phosphorus standard applies to spring turnover concentrations measured in the surface waters. Such contaminants as oil, debris, scum; or odor, taste, and color-producing substances; and toxins are not permitted in concentrations harmful to the aquatic life as set forth in Chapters NR 102 of the *Wisconsin Administrative Code*.

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[5]*SEWRPC Community Assistance Planning Report No. 135, 2nd Edition,* op. cit.

Table 37

WISCONSIN DEPARTMENT OF NATURAL RESOURCES RECREATIONAL RATING OF DELAVAN LAKE

| | | | | | |
|---|---|---|---|---|---|
| Space: Total Area—2,072 acres | | | Total Shore Length—13.0 miles | | |
| Ratio of Total Area to Total Shore Length–0.249:1 | | | | | |
| Quality (18 maximum points for each item) | | | | | |
| Fish: | | | | | |
| __ 9 | High production | X 6 | Medium production | __ 3 | Low production |
| __ 9 | No problems | X 6 | Modest problems, such as infrequent winterkill, small rough fish problems | __ 3 | Frequent and overbearing problems, such as winterkill, carp, excessive fertility |
| Swimming: | | | | | |
| __ 6 | Extensive sand or gravel substrate (75 percent or more) | X 4 | Moderate sand or gravel substrate (25 to 50 percent) | __ 2 | Minor sand or gravel substrate (less than 25 percent) |
| __ 6 | Clean water | X 4 | Moderately clean water | __ 2 | Turbid or darkly stained water |
| __ 6 | No algae or weed problems | X 4 | Moderate algae or weed problems | __ 2 | Frequent or severe algae or weed problems |
| Boating: | | | | | |
| X 6 | Adequate water depths (75 percent of basin more than five feet deep) | __ 4 | Marginally adequate water depths (50 to 75 percent of basin more than five feet deep) | __ 2 | Inadequate depths (less than 50 percent of basin more than five feet deep) |
| X 6 | Adequate size for extended boating (more than 1,000 acres) | __ 4 | Adequate size for some boating (200 to 1,000 acres) | __ 2 | Limit of boating challenge and space (less than 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 |
| Aesthetics: | | | | | |
| __ 6 | Existence of 25 percent or more wild shore | X 4 | Less than 25 percent wild shore | __ 2 | No wild shore |
| __ 6 | Varied landscape | X 4 | Moderately varied | __ 2 | Unvaried landscape |
| __ 6 | Few nuisances, such as excessive algae carp, etc. | X 4 | Moderate nuisance conditions | __ 2 | High nuisance condition |
| Total Quality Rating: 52 out of a possible 72 | | | | | |

*Source: Wisconsin Department of Natural Resources and SEWRPC.*

The adoption of these standards is intended to specify conditions in the waterways concerned that mitigated against excessive macrophyte and algal growths and promoted all forms of recreational use, including angling, in these waters. Of particular concern in Delavan Lake is the standard for total phosphorus of 0.02 milligrams per liter (mg/l). Based upon review of the past and current conditions and the controllable phosphorus inputs into Delavan Lake, it is expected that the phosphorus standard will likely not be attainable. Thus, the alternative lake management measures considered in Chapter VII include not only measures to reduce the pollutant loading to the Lake, but also in-lake measures, such as aquatic plant management, to treat the symptoms of higher-than-desirable nutrient concentrations.

Table 38

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 3°F for lakes.*

[b]*Dissolved oxygen and temperature standards apply to 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 level of 400 per 100 ml in more than 10 percent of all samples during any month.*

[d]*This standard for lakes applies only to total phosphorus concentrations measured 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 any 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 material present are toxic to fish or other aquatic life. Standards for toxic substances are set forth in Chapter NR 105 of the Wisconsin Administrative Code.*

*Source: SEWRPC.*

## EFFECTIVENESS TO DATE OF REMEDIAL MEASURES

The effectiveness of the remedial measures implemented prior to the year 2000 in mitigating the undesirable conditions observed within Delavan Lake during the 1980s has been reviewed.[6] The full text of this review is set forth in Appendix A. Specific elements of the Delavan Lake rehabilitation project as it has been implemented through the year 2000 are relevant to the determination of appropriate future management measures required to maintain the Lake within the range of conditions necessary to meet the water use objectives that have been established for the Lake. Figures 24 and 25 summarize the data presented in Chapter IV and V. In addition,

[6]*See Dale M. Robertson, Gerald L. Goddard, Daniel R. Helsel, and Kevin L. MacKinnon, "Rehabilitation of Delavan Lake, Wisconsin,"* Lake and Reservoir Management, *Vol. 16, No. 3, 2000, pp. 155-176.*

the figures can be used to evaluate the degree to which the initial management objectives for Delavan Lake have been addressed to date. Figures 24 and 25 show the trends in trophic state and water quality indicators observed in Delavan Lake.

**Reducing In-lake Phosphorus Concentrations**

Based upon the trophic state indicators shown in Figure 24, mean total phosphorus concentrations in Delavan Lake appear to have responded to the diversion of treated wastewater and the elimination of other point sources on the Jackson Creek tributary, and to the alum treatment, resulting in a decline in the in-lake total phosphorus concentration during 1984, from about 0.30 mg/l in 1983 to about 0.10 mg/l in the years preceding the alum treatment. Notwithstanding, hypolimnetic total phosphorus concentrations remained high through 1990, generally approaching a mean total phosphorus concentration of 0.40 mg/l during this period.

The mass of phosphorus in the bottom waters of the Lake provided a significant reservoir of phosphorus that, under the certain conditions, could potentially continue to stimulate algal growth in the surface waters of the Lake and contribute to the continuing degradation of the resource. This hypolimnetic reservoir provided the impetus to treat the Lake with alum in an effort to reduce the in-lake phosphorus concentration to below 35 μg/l (= 0.035 mg/l). In response to the alum treatment, the mean total phosphorus concentrations in the surface waters of Delavan Lake appear to have declined during 1992, from about 0.10 mg/l in 1991 to about 0.02 mg/l in the year following the alum treatment, although this concentration has increased over time to about 0.05 mg/l.

The alum treatment appeared to be somewhat successful in reducing in-lake phosphorus concentrations in the bottom waters of the Lake. Hypolimnetic total phosphorus concentrations in Delavan Lake declined from about 0.40 mg/l in 1990 to about 0.20 mg/l in the years following the alum treatment. The most significant effects of the alum treatment were observed in the data for a relatively short period: 1991 through 1993, when concentrations in the hypolimnion were about 0.15 mg/l. By 1994, mean hypolimnetic concentrations of total phosphorus had risen to about 0.20 mg/l, and, by the late 1990s, the mean hypolimnetic total phosphorus concentration had again approached 0.40 mg/l.

Even though the total phosphorus concentrations have continued to increase through the study period, the surface water concentrations have remained relatively low. Nevertheless, the observed concentrations continue to exceed the guideline of 0.02 mg/l established by the Regional Planning Commission for spring total phosphorus concentrations. These concentrations also continue to exceed the target total phosphorus concentrations in the surface waters of the Lake of 0.035 mg/l, the goal established for the alum treatment project. Therefore, it would appear that additional actions are necessary to further reduce the mean total phosphorus concentrations observed in Delavan Lake.

**Increasing Summer Secchi Disk Transparencies**

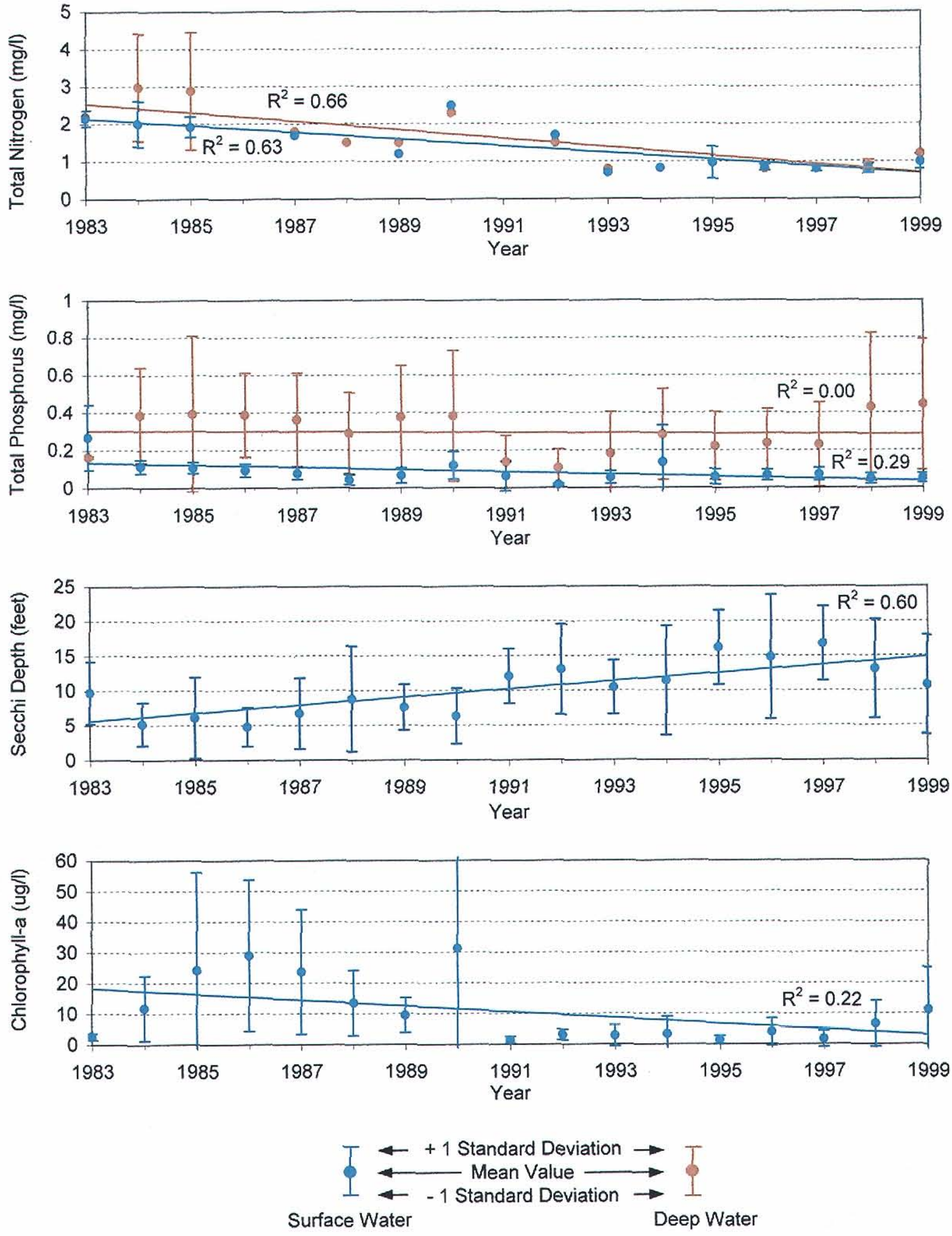
Figure 24 also shows the response of Secchi disk transparency values in Delavan Lake to the diversion of treated wastewater and the alum treatment. Prior to the alum treatment, and up through 1990, the mean Secchi disk transparency observed in Delavan Lake was about six feet. The alum treatment not only reduced the concentrations of total phosphorus in the Lake as described above, limiting the potential for algal growth within the system, but also resulted in the flocculation of particulate matter within the lake water column. The combined effect of the treatment resulted in increased water clarity. Secchi disk transparency values, reported from the Lake during period since 1990, increased to about 14 feet. These values exceed the target transparency of about 1.5 meters, or about five feet. The current program of lake rehabilitation has, therefore, achieved the desired increase in water clarity. Notwithstanding, Secchi disk transparencies have declined during the period from 1997 through 1999, suggesting a trend that merits ongoing water quality monitoring within the system.

**Reducing Nuisance Blooms of Algae**

Chlorophyll-*a* concentrations in Delavan Lake have been somewhat variable during the period of record, as shown in Figure 24. Prior to the alum treatment, through 1990, chlorophyll-*a* concentrations were generally in

Figure 24

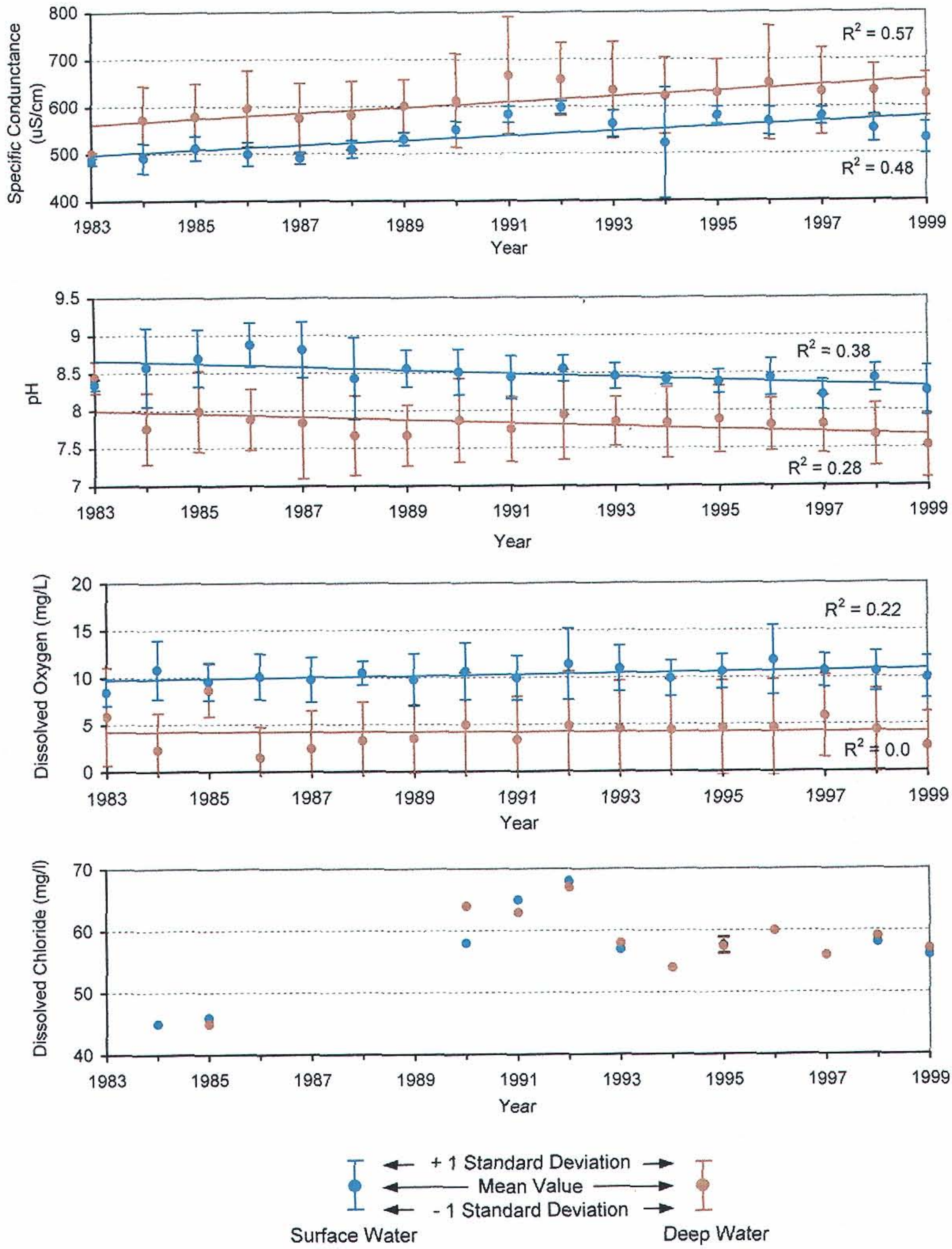
TREND IN TROPIC STATE INDICATORS WITHIN DELAVAN LAKE: 1983-1999




*Source: U.S. Geological Survey and SEWRPC.*

Figure 25

TRENDS IN WATER QUALITY INDICATORS WITHIN DELAVAN LAKE: 1983-1999




Source: U.S. Geological Survey and SEWRPC.

excess of 10 μg/l, and often approached 30 μg/l. This concentration represents that which would cause most observers to report a green coloration to the lake waters.[7]

Subsequent to the alum treatment and concomitant decline in total phosphorus concentrations in the Lake, chlorophyll-*a* concentrations in the surface waters of Delavan Lake have declined to less than about four μg/l. Notwithstanding, it should be noted that, during 1999, the chlorophyll-*a* concentration in the surface waters of Delavan Lake again exceeded the threshold value of 10 μg/l. Consequently, the Delavan Lake Sanitary District staff noted an increasing number of public concerns regarding algal blooms in the Lake. This increase in chlorophyll-*a* concentration is consistent with the increase in surface water total phosphorus concentration and decline in Secchi disk transparency also shown in Figure 24. As suggested above, these data would suggest that additional actions may be necessary to maintain chlorophyll-*a* concentrations in Delavan Lake at a concentration of less than 10 μg/l.

A corollary to the decline in algal blooms within Delavan Lake consequent to the alum treatment is the decline in pH within the Lake. Prior to the alum treatment, surface water pH values generally exceeded 8.5 units. Elevated pH values are consistent with the presence of blue-green algae, typically associated with algal blooms and the formation of surface scums.[8] Subsequently, the pH values in the Lake have been below 8.5 units. The decline in pH is significant, considering that the pH scale is logarithmic, as shown in Figure 25. Such a decline is consistent with the decline in chlorophyll-*a* concentrations described above. The decline is also consistent with the slightly acidic pH of the alum slurry applied to the Lake during the process of the alum treatment. However, the slurry used in Delavan Lake was buffered to minimize pH shock and aluminum toxicity impacts that are sometimes associated with the application of acidic mixtures of alum,[9] and the likely impact of alum application itself on the Lake is probably minimal. Thus, the observed decline in pH is most likely to be indicative of the shift in algal populations away from bloom forming blue greens. As noted in Chapter V, there has been a parallel observed shift in plant populations within the Lake toward rooted aquatic macrophytes during the study period.

**Converting the Lake Fishery**

Based upon data set forth in Chapter V, the lake rehabilitation measures implemented in Delavan Lake to date have been successful in shifting the fishery from one dominated by carp and bigmouth buffalo to one dominated by northern pike and walleyed pike.

**Summary and Emerging Issues of Concern**

The foregoing analysis suggests that the current lake rehabilitation measures being implemented in and around Delavan Lake have been successful in part in remediating the deteriorating water quality conditions observed in the Lake during the 1980s. This analysis further suggests that the program of action that has been implemented in and around Delavan Lake to date has not fully achieved the objectives established for the program. Therefore, additional measures are required to be implemented in order to fully achieve the water use and recreational use objectives desired for the Lake.

An emerging issue of concern within the drainage area tributary to Delavan Lake is the increasing concentrations of chloride, leading to increased in-lake chloride concentrations as shown in Figure 25. This trend is manifested in

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[7]*Jeffrey A. Thornton, "Perceptions of Public Waters: Water Quality and Water Use in Wisconsin," in T. van Valey, S. Crull and L. Walker,* The Small City and Regional Community, *Vol. 10, pp. 469-478, 1993.*

[8]*Erik Jeppeson, Martin Sondergaard, Ole Sortkjaer, Erik Mortensen and Peter Kristensen, "Interactions Between Phytoplankton, Zooplankton and Fish in a Shallow, Hypertrophic Lake: A Study of Phytoplankton Collapses in Lake Sobygard, Denmark,"* Hydrobiologia, *Vol. 191, 1990, pp. 149-164.*

[9]*See G. Dennis Cooke, Eugene B. Welch, Spencer A. Peterson and Peter R. Newroth,* Restoration and Management of Lakes and Reservoirs, 2nd Edition, *1993.*

the increasing conductivity also shown in Figure 25. While the trend observed in Delavan Lake is unusual compared with other major lakes in the Southeastern Wisconsin Region, in that Figure 25 shows a decline in chloride concentrations between 1992 and 1993 following the alum treatment, there is a generally increasing trend in chloride concentrations both prior to and following 1993. The decline observed during 1993 is likely to be a function of the higher-than-usual inflows, and increased flushing, that occurred during spring of that year, combined with the diversion of wastewater away from Jackson Creek subsequent to the upgrading of the WalCoMet sewage treatment plant in 1981. Much of the chloride entering the aquatic environment of southeastern Wisconsin may be assumed to be of anthropogenic origin. The primary sources of chloride in the Region include water softeners that usually add salts to the water used for domestic consumption and household purposes, chlorides used by the City of Elkhorn water utility to reduce radon concentrations in the public water supply, and roadway salting conducted to minimize ice-related traffic casualties during the winter months, this latter being the most likely source of chloride to Delavan Lake subsequent to the diversion of treated sewage from Jackson Creek in 1981. For this reason, the increasing trend in chloride concentrations is an issue to be considered.

Additionally, the recent increases in total phosphorus concentrations in the Lake, noted above, would suggest the need for the implementation of an ongoing program of lake management in and around Delavan Lake. To this end, alternative measures to fully achieve the water use and recreational use objectives for Delavan Lake are set forth in Chapter VII.

## Chapter VII

# ALTERNATIVE WATER QUALITY MANAGEMENT MEASURES

## INTRODUCTION

Based upon the review of the inventory and analyses set forth in Chapters II through V, and consideration of the water use and recreational use objectives set forth in Chapter VI, the following issues were identified as requiring consideration in the formulation of alternative and recommended lake management measures: 1) water quality improvement, 2) aquatic plant management, 3) onsite and public sanitary sewage disposal, 4) recreational lake use and lake use management, 5) fisheries management, and 6) water level control and short-circuiting.

Potentially effective measures for the management of Delavan Lake include land use planning and zoning, watershed management, and in-lake rehabilitation techniques. Land use planning and zoning, and watershed management measures, can serve to protect the Lake by promoting and maintaining a sound land use pattern in the area. Sound land use patterns can aide in reducing the runoff of nonpoint source pollutants to the Lake. In-lake rehabilitation techniques would seek to treat directly the identified problems.

## LAND USE PLANNING AND ZONING ALTERNATIVES

A basic element of any water quality management effort for a lake is the promotion of sound land use development and management in the tributary watershed. The type and location of future urban and rural land uses in the tributary drainage area to Delavan Lake will, to a large degree, determine the character, magnitude, and distribution of nonpoint sources of pollution; the practicality of, as well as the need for, stormwater management; and, to some degree, the water quality of the Lake. Thus, application of sound land management practices is considered a viable element of the lake management plan for Delavan Lake.

Existing 1990 and planned year 2020 land use patterns and existing zoning regulations in the tributary area to Delavan Lake have been described in Chapter III. If the recommendations set forth in the adopted county and regional land use plans are followed, under year 2020 conditions, some changes in land use conditions within the drainage area tributary to Delavan Lake would occur.[1] Some infilling of existing, platted lots, and some backlot development would be expected to occur and the redevelopment and reconstruction of existing single-family homes on lakefront properties may be expected. In addition, large-lot subdivision development is occurring in the area, notably in the vicinity of the Lake inlet east of Town Hall Road and west of CTH O, in the Town of Delavan. Additional development adjacent to the existing urban center is also planned . If this trend continues, some of the agricultural and open space areas remaining in the drainage area of the Lake may be replaced over time with large-lot urban development. This may be expected to increase the pollutant loadings to the Lake associated with urbanization and increase the pressure for recreational use of the Lake.

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[1]*SEWRPC Community Assistance Planning Report No. 252,* A Land Use Plan for Walworth County, Wisconsin: 2020, *April 2001; see also SEWRPC Planning Report No. 45,* A Regional Land Use Plan for Southeastern Wisconsin: 2020, *December 1997.*

Based upon historic trends and the County land use plan, the long-term, full buildout conditions will result in increased levels of low-density and suburban-density residential development of lands directly tributary to Delavan Lake. Given the foregoing, it would be desirable to carefully evaluate land use development, or redevelopment, proposals around the shoreline of Delavan Lake, and within the drainage area tributary to the Lake, for potential impacts on the Lake. One option for minimizing the effect of future development on Delavan Lake and within the watershed is to carefully review the applicable zoning ordinances and propose changes addressing the concerns noted. Changes in the zoning ordinance could be considered to minimize the areal extent of the development by providing specific provisions and incentives to cluster residential development on smaller lots while preserving portions of the open space on each property or group of properties considered for development.[2]

The existing land use zoning in the total drainage area to Delavan Lake is generally consistent with the recommended planned land use conditions set forth in the adopted county and regional land use plans. However, significant development is anticipated in the tributary drainage area to Delavan Lake as a consequence of the expansion of the Village of Williams Bay to the southeast of the Lake, the City of Elkhorn to the north of the Lake, and the City of Delavan to the west of the Lake.[3] Such expansion would modify the nonpoint sources of water pollution, potentially affecting lake water quality and suggest that intergovernmental cooperation is an important issue in watershed management likely to affect Delavan Lake.

Wetlands are intimately connected to the hydrological cycle, and provide natural areas for retention of floodwaters, pollutant removal, wildlife habitat, and open space with potential aesthetic value. The protection of the valuable resources can be accomplished through land use regulation and public acquisition of sensitive sites. Both measures have been applied to wetland sites within the drainage area tributary to Delavan Lake. Wetlands in the drainage area tributary to Delavan Lake are shown on Map 18 in Chapter V. These wetland areas are currently protected to a substantial degree under the U.S. Army Corps of Engineers Section 404 Permit Program, the Wisconsin Shoreland Zoning Program, and local zoning ordinances. The Walworth County zoning code provides for protection of wetlands and the riparian portions of the environmental corridor lands within lowland resource conservation zoning districts, and portions of the upland areas within upland resource conservation zoning districts. Nearly all wetland areas within the drainage area tributary to Delavan Lake are included within the environmental corridors delineated by the Regional Planning Commission, as shown on Map 19 in Chapter V.

## WATERSHED MANAGEMENT ALTERNATIVES

Watershed management measures may be used to reduce nonpoint source pollutant loadings from such rural sources as runoff from crop and pasture lands and from livestock wastes; from such urban sources as runoff from residential, commercial, industrial, transportation, and recreational land uses; from construction activities; and from onsite sewage disposal systems. The subsequently described watershed-based nonpoint source pollution control measures considered in this report are based upon the recommendations set forth in the adopted regional water quality management plan,[4] the Turtle Creek priority watershed plan,[5] the Walworth County land and water

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[2]*See SEWRPC Planning Guide No. 7,* Rural Cluster Development Guide, *December 1996.*

[3]*See, for example, Map 7, "Annexations to Cities and Villages in Walworth County: 1990-1999", SEWRPC Community Assistance Planning Report No. 252,* op. cit.

[4]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, *Volume One,* Inventory Findings, September 1978; *Volume Two,* Alternative Plans, *February 1979*; and *Volume Three,* Recommended Plan, *June 1979*; *SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995.*

[5]*Wisconsin Department of Natural Resource,* Turtle Creek Priority Watershed Plan, *1984.*

resources management plan,[6] and information presented by the U.S. Environmental Protection Agency.[7] The application of appropriate, selected watershed management practices within the Delavan Lake drainage area is considered a viable element of the recommended lake management plan for Delavan Lake.

An estimate of nonpoint source pollutant loadings from the various pollution sources in the drainage area of the Lake has been presented in Table 17 in Chapter IV. The inventory identified nonpoint pollution sources within the Delavan Lake drainage area, which included upland agricultural field and open land erosion. Streambank and lakeshore erosion were not identified as significant potential sources of nonpoint source pollution in this watershed. However, urban runoff and construction site erosion were considered to be potentially significant sources. Urban and construction site sources also were estimated to be the single largest source of heavy metal loadings to the Lake. Given that many of these sources are anthropogenic in nature, the control of nonpoint sources of water pollution from human activities in these rural and residential lands in the tributary watershed can be achieved, to some degree, through relatively low-cost measures. Such controls were recommended in the aforereferenced Turtle Creek priority watershed plan. Properly applied, such measures can reduce the pollutant loadings to the Lake by about 25 percent. The pollutant loadings that are the most controllable include runoff from the residential lands adjacent to the Lake and maintenance of the remaining onsite sewage disposal systems within the watershed. The potential exists within the watershed for significant construction site erosion impacts if development continues in the tributary watershed, as has been the recent trend. Such impacts are partially controllable by application of sound construction site erosion control practices.

Appendix B presents a list of nonpoint source pollution management measures that could be considered for use in the Delavan Lake area to reduce loadings from nonpoint sources of pollution. Information on the cost and effectiveness of the measures is also presented in this appendix.

**Urban Nonpoint Source Controls**

Established urban uses comprise about 3,706 acres, or about 14 percent, of the total drainage area tributary to Delavan Lake. The annual phosphorus loading from the urban lands, including phosphorus loading from the remaining onsite sewage disposal systems in the drainage area, is estimated to be 3,000 pounds. As described in Table 17 in Chapter IV, all of these loadings together constitute about 15 percent of the total phosphorus loading to Delavan Lake.

The Turtle Creek priority watershed plan, as amended,[8] recommended a 75 percent reduction in phosphorus loading from urban nonpoint sources, which, at that time, accounted for about 7 percent of the total phosphorus load to the Lake. This reduction was proposed to be achieved, in part, through the construction of a wetland and sedimentation basin complex at Mound Road, downstream of the City of Elkhorn, but upstream of Delavan Lake. With respect to the influence of the Mound Road wetland on the phosphorus loading to Delavan Lake, data presented in Table 16 in Chapter IV indeed suggest some degree of phosphorus retention within the wetland complex. However, as noted in Chapter IV, the principal benefit of the wetland appears to be in modifying the

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[6]*Walworth County Land Conservation Department,* Walworth County Land & Water Resource Management Plan, *February 1999; see also Walworth County Land Conservation Department and R.A. Smith and Associates, Inc.,* Walworth County Soil Erosion Control Plan, *November 1988.*

[7]*U.S. Environmental Protection Agency, Report No. EPA-440/4-90-006,* The Lake and Reservoir Restoration Guidance Manual, Second Edition, *August 1990, and its technical supplement, U.S. Environmental Protection Agency, Report No. EPA-841/R-93-002,* Fish and Fisheries Management in Lakes and Reservoirs: Technical Supplement to: The Lake and Reservoirs Restoration Guidance Manual, *May 1993.*

[8]*Wisconsin Department of Natural Resources,* Turtle Creek Priority Watershed Plan—Amendment—The Delavan Lake Restoration Project, *August 1989.*

timing of the delivery of the phosphorus load to the Lake, thereby moderating the biological response to the annual phosphorus load to the Lake. This conclusion is consistent with that of the Wisconsin Department of Natural Resources (WDNR) at the conclusion of the Turtle Creek priority watershed plan implementation period, during which the wetland was constructed.[9]

The refined regional water quality management plan recommends that the nonpoint source pollutant loadings from urban areas tributary to Delavan Lake be further reduced by about 25 percent.[10] In addition, reductions from urban construction erosion control, onsite sewage disposal system management, and streambank and shoreline erosion control measures also are recommended. Consideration should be given to reducing the pollutant loadings from the controllable sources to the extent practicable in order to minimize the negative results of nutrient loadings on the Lake.

Potentially applicable urban pollution control measures include wet detention basins, grassed swales, and good urban "housekeeping" practices. Generally, the application of low-cost urban housekeeping practices may be expected to reduce nonpoint source loadings from urban lands by about 25 percent. Public information programs can be developed to encourage good urban housekeeping practices, to promote the selection of building and construction materials which reduce runoff contributions of metals and other toxic pollutants, and to promote the acceptance and understanding of the proposed pollution abatement measures and importance of lake water quality protection. Urban housekeeping practices and nonpoint source controls include restricted use of fertilizers and pesticides, improved pet waste and litter control, the substitution of plastic for galvanized steel and copper roofing materials and gutters, proper disposal of motor-vehicle fluids, proper disposal or recycling of leaves and yard waste, and reduced use of street deicing salts.

Proper design and application of urban nonpoint source control measures, such as grassed swales and detention basins, requires preparation of a detailed stormwater management system plan that addresses stormwater drainage problems and control of nonpoint sources of pollution. Based upon a preliminary evaluation, however, it is estimated that the practices that could be effective in the tributary area are limited largely to good urban housekeeping practices and grassed swales.[11] Review of the distribution of the pollutant loadings relative to the location of the potential sites for detention basins within existing areas of urban development surrounding Delavan Lake indicates that such basins would be relatively ineffective, as well as costly, since stormwater flow to the Lake generally occurs in the form of short overland sheet flows, making it difficult to collect and detain stormwater runoff from reasonably large areas at discrete locations. However, such measures could be considered for use should future residential development in the drainage area tributary to Delavan Lake be at such densities as to make the collection and detention of stormwater economically feasible. Stormwater management measures are considered a viable element of the lake management plan for Delavan Lake, especially for use in future clustered developments.

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[9]*Wisconsin Department of Natural Resources Publication No. PUBL-WR-359 94,* Turtle Creek Priority Watershed Bioassessment Final Report, *1994, as cited in Wisconsin Department of Natural Resources Publication No. PUBL-WT-280-98 REV,* Lower Rock River Basin Water Quality Management Plan: A Five-Year Plan to Protect and Enhance Our Water Resources, *October 1998, which states that "the effectiveness of best management practice implementation was evident on a site-by-site basis, but there was no discernable watershedwide reduction in nonpoint source (runoff) pollutant loads."*

[10]*SEWRPC Memorandum Report No. 93,* op. cit.

[11]*Rust Environment & Infrastructure, Inc.,* Nonpoint Source Management Plan for Jackson Creek Watershed, Delavan Lake, WI, *December 1996.*

**Developing Area Nonpoint Source Controls**

Developing areas can generate significantly higher pollutant loadings than established areas of similar size. Developing areas include a wide array of activities, including urban renewal projects, individual site development within the existing urban area, and new land subdivision development. Between 1970 and 1990, development was occurring on an average of 40 acres of land per year within the total drainage area tributary to Delavan Lake. The County land use plan envisions additional urban growth within the drainage area tributary to Delavan Lake primarily contiguous with, and adjacent to, existing urban developments in the Cities of Delavan and Elkhorn. As previously noted, additional urban development is occurring within the Town of Delavan, particularly in the vicinity of the inlet to Delavan Lake where agricultural lands are being converted to residential land uses at urban densities, as is infilling and redevelopment of existing platted lots along the lakeshore.

Construction sites, especially, may be expected to produce suspended solids and phosphorus loadings at rates several times higher than established urban land uses. Control of sediment loss from construction sites can be provided by measures set forth in the construction erosion control ordinances, based on the model ordinance developed by the Wisconsin League of Municipalities and Wisconsin Department of Natural Resources.[12] Walworth County has adopted a Land Disturbance, Erosion Control and Storm Water Management Ordinance that governs the amount of sediment and other pollutants contributed to waterbodies from construction sites and land disturbing activities in the County, as noted in Table 7 in Chapter III. The ordinance requirements apply to development that occurs on platted lots within a subdivision plat; lots developed under a certified survey map; areas of 4,000 square feet or greater; works where fill and/or excavation volumes exceed 400 cubic yards; public streets, roads or highways; watercourses; and utilities. In addition, the soil erosion control and stormwater management provisions of the Walworth County land division ordinance would apply to residential developments of five acres or more, and other developments of three acres or more. All control measures are administered and enforced by the Walworth County Land Conservation Department. In addition, as indicated in Table 7, the Town of Delavan and the Villages of Fontana-on-Geneva Lake and Williams Bay have adopted their own erosion control ordinances. The provisions of these local ordinances apply to all development except single- and two-family residential construction. Single- and two-family construction erosion control measures are specified as part of the building permit process.

The control measures required under these ordinances are temporary measures taken to reduce pollutant loadings from construction sites during stormwater runoff events. Construction erosion controls may be expected to reduce pollutant loadings from construction sites by about 75 percent. Such controls are important measures to take in order to prevent localized short-term loadings of phosphorus and sediment from the tributary drainage area, and may be anticipated to have a potentially significant impact on the total pollutant loading to the Lake as the intensity of land use development increases. Control measures include such revegetation practices as temporary seeding, mulching, and sodding, and such runoff control measures as filter fabric fences, straw bale barriers, storm sewer inlet protection devices, diversion swales, sediment traps, and sedimentation basins.

Because of the potential for development in the drainage area tributary to Delavan Lake, construction erosion control programs, including vigorous and sustained ordinance enforcement, are considered viable elements of the lake management plan for Delavan Lake.

**Rural Nonpoint Source Controls**

Rural uses comprise about 22,409 acres, or about 86 percent, of the total drainage area tributary to Delavan Lake. The annual phosphorus loadings from the rural lands are estimated to be 17,000 pounds. Upland erosion from

[12]*Wisconsin League of Municipalities and Wisconsin Department of Natural Resources,* Wisconsin Construction Site Best Management Practices Handbook, *latest revision April 1994. These ordinances define the land disturbance activities subject to control, set forth standards and criteria for erosion control, describe permit application and administrative procedures, and identify enforcement and appeal procedures.*

agricultural and other rural lands remains a major contributor of sediment to Jackson Creek and Delavan Lake. Such lands comprise about 18,810 acres, or about 72 percent, of the drainage area tributary to Delavan Lake. While the sediment loadings estimated from inventories compiled by the Turtle Creek Nonpoint Source Pollution Control Priority Watershed Program did not generally exceed the target level of agricultural erosion control of five tons per acre per year identified in the Walworth County agricultural soil erosion control plan, about 1,900 acres of the approximately 7,700 acres inventoried by the Wisconsin Department of Natural Resources were considered to be in need of control measures to reduce soil loss to tolerable levels.[13]

For this reason, the refined regional water quality management plan recommends measures be taken to provide about a 25 percent reduction in nonpoint source pollution loading from rural lands in the watershed.[14] As described in Chapter IV, loadings from rural lands constitute about 90 percent of the total phosphorus loadings to Delavan Lake. It is estimated that the largest portion of these pollutant loadings, about 16,000 pounds of phosphorus, or about 90 percent of these rural loadings, are contributed annually from the agricultural lands in the total drainage area tributary to Delavan Lake. Potentially applicable rural pollution control measures include conservation tillage, and establishment and maintenance of streambank buffer strips (streambank management zones), especially around drain tiles in the watershed. Implementation of these recommendations is considered to be adequate for water quality management purposes related to Delavan Lake.

Detailed farm conservation plans will be required to adapt and refine erosion control practices for individual farms. These plans are generally prepared with the assistance of the U.S. Natural Resources Conservation Service or County Land Conservation Department staffs. Such plans identify desirable tillage practices, cropping patterns, and rotation cycles, while considering the specific topography, hydrology, and soil characteristics of the farm; identify the specific resources of the farm operator; and articulate the operator objectives of the owners and managers of the land.

In terms of other rural lands, wetlands serve many important functions, such as nutrient cycling, sediment settling and provide wildlife habitat. The continuing losses of wetland areas throughout the watershed increase the need for wetland preservation, restoration and creation. In an attempt to reduce upstream phosphorus and sediment loads, especially during stormwater events from entering the Lake, a wetland restoration and creation project with three stormwater detention ponds was constructed at the downstream reach of Jackson Creek, north of Mound Road and the Delavan Lake inlet. The wetland functions to slow the flow of water, trap and use nutrients during the growing season, and filter out sediments to the detention ponds. Over the last few years, the effectiveness of the wetland at removing suspended sediments and nutrients has declined due to deposition within two of the ponds. According to staff at Earth Tech, Inc., formerly Rust Environment & Infrastructure, Inc., consultants to the Town of Delavan, and the U.S. Geological Survey, the east pond has two to three feet of deposition. Similarly, the north pond has about one foot of deposition. In addition, there has been a tendency for channelized flow to develop in portions of the wetland. Maintenance and enhancements of this wetland would act to reduce phosphorus and sediment loadings to Delavan Lake from Jackson Creek.

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[13] *Wisconsin Department of Natural Resource*, Turtle Creek Priority Watershed Plan, op. cit.

[14] *As recommended in the regional water quality management and county agricultural soil erosion control plans, detailed farm conservation plans will be required to adapt and refine these recommendations for individual farm units. Conservation plans are detailed plans, generally prepared with the assistance of the U.S. Natural Resources Conservation Service or County Land Conservation Department staffs, intended to guide agricultural activity in a manner which conserves soil and water resources. The conservation plan indicates desirable soil management practices, cropping patterns, and rotation cycles, considering the specific topography, hydrology, and soil characteristics of the farm, together with the specific resources of the farm operator and the operator's objectives as owner or manager of the land.*

Management alternatives for the Mound Road wetland are given in Table 39. The success of a wetland as a water quality management practice is a function of the amount of plant surface area exposed to the inflow. To maximize this contact, shallow overland flow, or sheet flow, is the preferred way in which water should be conveyed through the site. Modifications to the design of the wetland, including the creation of additional low head berms, the filling of channels associated with the detention ponds, and the installation of a flow disperser at the input to the north detention pond, would act to enhance sheet flow across this wetland, improving the measure of pre-treatment it provides to waters prior to their reaching Delavan Lake. Modifications to the design of the stormwater detention ponds would enhance the efficacy of these systems in reducing contaminant loading to Delavan Lake, controlling channelization within the wetland, and minimizing short-circuiting through the ponds. Periodic controlled burnings of the vegetation in the wetland would act to maintain the wetland community by removing both invasive plants and woody shrubs that can act to displace wetland plant communities. To minimize nutrient inputs to the Lake that can be associated with such burnings, conducting this measure in the autumn would be preferred.

Additional reductions of sediment and phosphorus loadings to Delavan Lake might be attainable through the creation of permanently vegetated corridors along portions of Jackson Creek and its tributaries. While they did not identify streambank erosion as a major component of the sediment and phosphorus loadings to Delavan Lake, Earth Tech, Inc., and the Wisconsin Department of Natural Resources, calculated that reductions in loadings to Delavan Lake of approximately 300 pounds of phosphorus and approximately 35 tons of sediment per year could be obtained through establishing permanent cover on four sites. These sites comprised about 156 acres along approximately 34,000 linear feet of Jackson Creek and its tributaries.[15] The reductions assumed that the strips extended 100 feet from the stream on both sides. These corridors would act to stabilize the streambanks, minimize erosion, and reduce overland flow velocities, promoting adsorption, sedimentation, and filtration of pollutants from surface runoff. While the pollution reduction efficiency of this sort of buffer depends upon several factors, such as the width of the corridor, the vegetation type, the slope, and soil characteristics, some studies have estimated pollution reduction ranges of between 60 percent and 90 percent for phosphorus and of between 33 percent and 95 percent for suspended sediment.[16] Additional benefits of the corridors might include the provision of additional habitat for fish and wildlife, and open space for recreation, depending on the ownership of the corridors.

Various mechanisms could be used to finance these buffers. Funding is available through the U.S. Department of Agriculture Environmental Quality Incentive Program (EQIP) and the State of Wisconsin Conservation Reserve Enhancement Program (CREP). Both of these programs could be used to acquire permanent easements for streamside buffers. Acquisition of temporary easements, while perhaps less costly, would probably not be viable over the long-term due to the need to periodically renegotiate the easements. Alternatively, a governmental unit or nonprofit organization could acquire ownership of the land for the corridors. Though this would provide permanent and complete control over the management of the property, the costs would be considerably higher.

## Onsite and Public Sewage Disposal System Management

### *Onsite Sewage Disposal Systems*

As described in Chapter IV, while the lakeshore areas of Delavan Lake are served by public sanitary sewerage services, onsite sewage disposal systems continue to be used for waste disposal in other portions of the Town of Delavan and surrounding areas. Onsite sewage disposal systems are estimated to contribute 174 pounds, or about

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[15]*Rust Environment & Infrastructure, Inc.*, op. cit.

[16]*A.J. Castelle, A.W. Johnson, and C. Conolly, "Wetland and Stream Buffer Requirements: A Review,"* Journal of Environmental Quality, *Vol. 25(5), p. 878.*

## Table 39

## MANAGEMENT ALTERNATIVES FOR THE MOUND ROAD WETLAND

| Management Alternatives | Summary Description | Estimated Cost | Advantages | Disadvantages | Considered Viable for Inclusion in Lake Management Plan |
|---|---|---|---|---|---|
| Periodic Controlled Burning of Wetland | Vegetation is burned on the wetland when Invasive plants or woody shrubs enter the site | - - | Increases functioning of wetland by removing invasive plants and improving germination of wetland plant seeds | May result in short-term addition of nutrients and sediment to lake | Yes |
| Modify Wetland to Enhance Sheet Flow of Water through Wetland | Create additional low head berms, Fill in channels that radiate from sedimentation ponds. Install flow disperser in north sedimentation pond | - - | Increases hydraulic retention on site<br>Lowers sediment and nutrient loading to lake | May result in short-term reduction of wetland functioning<br>May have high cost to implement | Yes |
| Modification of Sedimentation Ponds | Increase depths of north and east sedimentation pond to 10 feet to increase sedimentation of suspended sediment and adsorbed nutrients | - - | Lowers sediment and nutrient loading to lake | High cost to implement<br>May require permit | Yes |

*Source: SEWRPC.*

2 percent, of the total external phosphorus loading to Delavan Lake.[17] In addition to lake water quality considerations, sewage disposal options in the area have implications for groundwater quality and property values. Thus, onsite sewage disposal remains an important consideration in the Delavan Lake area.

Abatement of potential pollution from onsite sewage disposal systems would require ongoing management of the onsite sewage disposal systems. For those onsite sewage disposal systems installed after 1983, the Walworth County Code requires inspections of the systems be conducted every three years. However, this inspection requirement does not yet apply to older systems, installed prior to 1984. Therefore, informational and educational efforts regarding the management of onsite sewage systems could be considered by local governments having jurisdiction in those portions of the watershed that are not located within sanitary sewer service areas. Homeowners should be advised of the rules, regulations, and system limitations governing onsite sewage disposal systems, and should be encouraged to undertake preventive maintenance programs. Maintenance of onsite sewage disposal systems in the drainage area tributary to Delavan Lake is considered a viable element of the lake management plan for Delavan Lake.

***Public Sanitary Sewerage Services***

As noted in Chapter IV, it is anticipated that the Delavan Lake Sanitary District sanitary sewer service area will be further refined by the year 2005. The maintenance and extension of the public sewage system is one of the most important actions controlling and reducing nutrient loadings to Delavan Lake. Prior to the provision of public

[17] *Wisconsin Department of Natural Resources Publication No. PUBL-WR-363-96 REV,* Wisconsin Lake Model Spreadsheet Version 2.00 User's Manual, *June 1996.*

sanitary sewerage services to the Delavan Lake residential community and the abandonment of the City of Elkhorn sewage treatment facility, as recommended in the adopted regional water quality management plan, significant amounts of phosphorus were introduced into Delavan Lake. Since 1981, when the Walworth County Metropolitan Sewerage District (WalCoMet) treatment facility was completed, these loads have been diverted to a point on Turtle Creek downstream of Delavan Lake, and the quality of the effluent substantially improved.[18]

The Delavan Lake Sanitary District currently serves 2,800 households. Under current design limitations, the Delavan Lake Sanitary District could potentially serve a maximum of 4,000 households. Currently the costs of connecting a household to the Delavan Lake Sanitary District sewerage system are about $4,700. This cost is over and above the cost for the local sewers and private building lateral connections. Operating costs for the Delavan Lake Sanitary District are about $1.5 million to $1.6 million, or about $2.00 per 1,000 gallons sewage treated. The Delavan Lake Sanitary District has a pumping capacity of 10 million gallons per day. Sewage is pumped to the WalCoMet sewage treatment facility for treatment.

Maintenance and extension of public sanitary sewerage service pursuant to the adopted sanitary sewer service area plan for the WalCoMet Sewerage District are considered viable elements of the lake management plan for Delavan Lake.

## IN-LAKE MANAGEMENT ALTERNATIVES

The reduction of external nutrient loadings to Delavan Lake by the aforedescribed measures has contributed to the mitigation of water quality deterioration in the Lake. However, these measures are not expected to eliminate all of the existing water quality and lake-use problems.[19] Mesotrophic and eutrophic lakes in southeastern Wisconsin have water quality and other in-lake conditions that can result in abundant macrophyte growths that restrict water use potentials and diminish the aesthetic appeal of the resources. In addition, lake water level, shoreline protection, and recreational use problems require the application of direct or in-lake treatment measures. Given the concerns of the Delavan Lake community expressed in this regard, the application of in-lake rehabilitation measures to Delavan Lake should be considered. Alternative in-lake rehabilitation measures include in-lake water quality, lake level, aquatic plant, fisheries, shoreline protection, and recreational use management measures. Each of these groups of management measures is described briefly below.

The applicability of in-lake rehabilitation techniques is highly dependent upon specific lake characteristics. The success of any lake rehabilitation technique can seldom be guaranteed, since the technology is still in the early stages of development and long-term monitoring of the effectiveness of the technology is limited. Because of the relatively high cost of applying most techniques, a cautious approach to implementing in-lake rehabilitation techniques is generally recommended. Certain in-lake rehabilitation techniques should be applied only to lakes in which: 1) nutrient inputs have been reduced below the critical level; 2) there is a high probability of success in applications of the particular technology to lakes of similar size, shape, and quality; and 3) the possibility of adverse environmental impacts is minimal. Finally, it should be noted that some in-lake rehabilitation techniques require the issuance of permits from appropriate State and Federal agencies prior to implementation.

### Water Quality Management Measures

The in-lake management practices set forth in Table 40 include a variety of measures designed to directly modify the magnitude of either a water quality determinant or biological response. Specific measures aimed at managing aquatic plants and fishes are considered separately.

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[18]*SEWRPC Community Assistance Planning Report No. 56, 2nd Edition,* Sanitary Sewer Service Area for the Walworth County Metropolitan Sewerage District, Walworth County, Wisconsin, *December 1991.*

[19]*Dale M. Robertson, Gerald L. Goddard, Daniel R. Helsel, and Kevin L. MacKinnon, "Rehabilitation of Delavan Lake, Wisconsin,"* Lake and Reservoir Management, *Vol. 16, No. 3, 2000, pp. 155-176.*

***Phosphorus Precipitation and Inactivation***

Nutrient inactivation is a restoration measure designed to limit the biological availability of phosphorus by chemically binding the element in the lake sediments using a variety of divalent or trivalent cations, highly positively charged elements. Aluminum sulfate (alum), calcium carbonate (lime), ferric chloride, and ferric sulfate are commonly used cation sources. The use of these techniques to remove phosphorus from nutrient-rich lake waters is an extension of common water supply and wastewater treatment processes. Costs depend on the lake volume and type and dosage of chemical used. Delavan Lake is susceptible to internal and external phosphorus loading from mixing of phosphorus rich hypolimnetic water from spring and fall turnover, as well as ineffective and inefficient short-circuiting of external nutrient inputs to the Lake from the Jackson Creek tributary. In addition, both the Lake and the Jackson Creek tributary contain significant sedimentary reservoir of phosphorus, deposited within these systems as a result of nonpoint source pollutant loadings and historic wastewater discharges to the Creek prior to the abandonment of the City of Elkhorn wastewater treatment plant. In an effort to control the degree of internal loading to Delavan Lake, the Lake was treated with alum during 1991, making Delavan Lake one of the largest and also one of the earliest lakes subjected to phosphorus precipitation and inactivation.[20]

Alum is applied to the deeper parts of a lake in liquid form, forming a precipitate of aluminum hydroxide. This precipitate combines with phosphorus and with particulate matter within the lake water column, and settles to the lake bottom within a few hours. Typically, a one- to two-inch-thick layer of flocculent will cover the sediments, forming a chemical and physical barrier that retards the transfer of nutrients from the sediments, making them unavailable to algae.

As in the case of Delavan Lake, alum treatments can be effectively utilized to reduce high rates of internal phosphorus recycling and to reduce nuisance algal growths dependent on high phosphorus levels in lake water.[21] Alum is not directly effective in controlling aquatic macrophytes, but the abundance of rooted and floating plants may be reduced by limiting the availability of phosphorus. A potentially negative effect of alum treatment is that the increase in water transparency may allow existing nuisance plants to spread to deeper water.

Nutrient inactivation with alum is a long-term control method, and one treatment may reduce the phosphorus concentration in the water column by as much as 80 percent for five to 10 years. Currently, the degree of water quality improvement being experienced within Delavan Lake as a result of the 1991 alum treatment is diminishing, and consideration is being given to a further alum treatment of the Lake. Effectiveness decreases if the layer of flocculent becomes dispersed or buried in loose, organic sediments. Incoming sediment from nonpoint sources can cover the layer of flocculent and substantially reduce its effectiveness, and the presence of certain animals, such as carp, can disperse the flocculent through their movement and feeding in a process referred to as bioturbation. In shallower water, wave action may wash much of the alum to the center of the lake, reducing the efficiency of the treatment. Thus, alum treatments should be complemented by the reduction or elimination of external nutrient sources to achieve long-term water quality improvement.

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[20]*See E.B. Welch and G.D. Cooke, "Effectiveness and Longevity of Phosphorus Inactivation with Alum,"* Lake and Reservoir Management, *Vol. 15, No. 1, March 1998, pp. 5-27; see also J.C. Panuska and D.M. Robertson, "Estimating Phosphorus Concentrations Following Alum Treatment Using Apparent Settling Velocity,"* Lake and Reservoir Management, *Vol. 15, No. 1, March 1998, pp. 28-38.*

[21]Ibid.

Table 40

**MANAGEMENT ALTERNATIVES CONSIDERED FOR WATER QUALITY IN DELAVAN LAKE**

| Management Alternatives | Summary Description | Estimated Cost | Advantages | Disadvantages | Considered Viable for Inclusion in Lake Management Plan |
|---|---|---|---|---|---|
| Phosphorus Precipitation and Inactivation | Positively-charged elements, such as aluminum, iron and calcium, chemically bind phosphorus in a form that limits the availability of the nutrient for plant growth within the lake and further limits the potential for the nutrient to be released from the lake sediments during periods of anoxia | $150 per ton, 2.5 tons per acre; or about $300 per acre | Removes phosphorus from the water column<br>Improves water clarity | Limited effectiveness in shallow waters<br>Must be reapplied<br>High cost to implement | No[a] |
| Nutrient Load Reduction (external) | Land management measures reduce the mass of contaminants reaching the lake | - - | Addresses contamination at source<br>Consistent with good housekeeping and sound land development practices | May be difficult to implement as it requires changes in current practices<br>May have high cost to implement | Yes |
| Nutrient Load Reduction (internal)[b] | Contaminated sediments are removed or encapsulated | $15 per cubic yard | Minimizes resuspension and release of contaminants | High cost to implement<br>Variable results | No |

[a]*Phosphorus precipitation and inactivation may be considered in the future once nonpoint source phosphorus loads to the Lake, primarily from the Jackson Creek tributary, are controlled to the extent practicable.*

[b]*See also dredging and sediment removal measures set forth in Table 41.*

*Source: SEWRPC.*

Diminution in the effectivity of the 1991 alum treatment of Delavan Lake was reported as early as 1998, and early signs of diminished effectiveness were reported as early as 1994 or 1995.[22] Three factors may account for the short-lived effectiveness of the Delavan Lake alum treatment.[23] First, it appears that the amount of alum used in the 1991 treatment may not have been sufficient to obtain the recommended concentration of 10 milligrams per liter. In 1991, alum, containing 145,000 kilograms (kg) of aluminum, was applied to the surface of the Lake. The results of jar tests conducted in the 1980s indicated that the required amount of aluminum was 235,000 kg for a treatment that was applied to lake waters below 20 feet (six meters) in depth. These same tests indicated that 527,000 kg of aluminum would be required for a surface application.[24] Second, the actions of benthic animals

[22]*Dale M. Robertson, Gerald L. Goddard, Daniel R. Helsel, and Kevin L. MacKinnon,* op. cit.

[23]*J.C. Panuska and D.M. Robertson,* op. cit.

[24]*See G.D. Cooke, E.B. Welch, S.A. Peterson and P.R. Newroth,* Lake and Reservoir Restoration, *1986. It should be noted, however, that Delavan Lake had been drawn down prior to the application of the alum. This fact was taken into account in calculating the mass of aluminum to be applied to the Lake at the time of the 1991 treatment.*

may have contributed to dispersion of the flocculent. While carp and bigmouth buffalo were removed from the Lake during the fish eradication conducted during 1989, the WDNR staff have reported invertebrate species that burrow into lake sediments, such as midges in the genus *Chironomus*, to be present in Delavan Lake since completion of the alum treatment. Burrowing by these animals can act to disperse the alum flocculents. Finally, the effects of the alum treatment may have been short-lived due to persistently high external phosphorus loadings. Even had additional alum been applied in 1991, the longevity of its effectiveness may not have been substantially different from that observed due to the high external loadings to the Lake.[25]

Because of the expense and limited expected duration of benefits, largely as a result of continued nonpoint source phosphorus loads from the Jackson Creek tributary, further treatment of Delavan Lake to achieve in-lake nutrient inactivation is to be considered a viable element of the lake management plan for Delavan Lake only as a future, long-term management measure.

***Nutrient Load Reduction***

Nutrient diversion is a restoration measure designed to reduce the trophic state, or degree of over-feeding, of a waterbody and thereby control the growth response of the aquatic plants in the system. Control of nutrients in surface water runoff in the watershed is generally preferable to attempting such control within a lake. Many of the good housekeeping techniques presented in the watershed management section above are designed for this purpose. In addition, one of the first external management actions completed with respect to the rehabilitation of Delavan Lake was the replacement of the City of Elkhorn wastewater treatment facility and the diversion of nutrients in the treated sewage effluent to a discharge point downstream of the Lake. As noted above, these actions have proven very successful in reducing the external nutrient loadings to the Lake.

In contrast to such external controls, controlling in-lake nutrients generally involves removing contaminated sediments or encapsulating nutrients by chemical binding. Costs are generally high, as in-lake nutrient control involves an engineered design and usually some form of pumping or excavation. Effectiveness is variable. While some limited dredging of Delavan Lake was undertaken during 1989, the purpose of the sediment removal operation was to redirect the inflowing waters of Jackson Creek to the Lake outlet, as described below.

Given the variability inherent in sediment nutrient removal, internal nutrient load reduction measures are not considered a viable element of the lake management plan for Delavan Lake. Notwithstanding, evidence of a large and potentially mobile sedimentary pool of phosphorus within the inlet and portion of Jackson Creek downstream of the Mound Road wetland might indicate further consideration of such an option once the nonpoint source phosphorus loads from this subwatershed are adequately controlled. However, the extremely high cost of such a management measure would be likely to preclude its feasibility. This management measure, therefore, is considered a viable element of the lake management plan for Delavan Lake only for limited areas and only for maintenance of navigation. It is not considered viable for water quality improvement purposes.

**Water Quantity and Water Level Management Measures**

The in-lake management measures set forth in Table 41 consist of actions designed to modify the depth of water in the waterbody. Generally, the objective of such manipulation is to enhance a particular class of recreational use and/or to control the types and densities of organisms within the waterbody. In the case of Delavan Lake, these measures have also been implemented for water quality improvement purposes.

***Outlet Control Modifications and Short-Circuiting***

During the 1980s, studies of Delavan Lake suggested that some of the water flow into Delavan Lake from Jackson Creek could be directed out of the Lake with little mixing of the water into the Lake, given the proximity of the

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[25]*Dale M. Robertson, Gerald L. Goddard, Daniel R. Helsel, and Kevin L. MacKinnon*, op. cit.

Table 41

MANAGEMENT ALTERNATIVES FOR WATER LEVELS AND WATER QUANTITY IN DELAVAN LAKE

| Management Alternatives[a] | Summary Description | Estimated Cost | Advantages | Disadvantages | Considered Viable for Inclusion in Lake Management Plan |
|---|---|---|---|---|---|
| Outlet Control and Short Circuiting | Nutrient-rich water entering the Lake is diverted to the outlet using a constructed berm and dredged channel in order to limit the deposition of phosphorus within the Lake basin and its mixing with the Lake water | - - | Nutrients are diverted from the Lake<br>Improved water quality can result | Variable results<br>May limit the use of some areas of the waterbody | No[a] |
| Drawdown | Changes in water level are used to manipulate species composition of fishes and aquatic plants and control nutrient release from lake bottom sediments | - - | May affect species composition<br>Can result in sediment compaction and stabilization<br>Can enhance rough fish control | Variable results<br>May result in an initial nutrient surge on reflooding<br>May limit the use of some areas of the waterbody<br>Must be reapplied | No |
| Dredging[b] | Accumulated sediment and associated contaminants are removed from the waterbody | $15 per cubic yard | Increases lake depth<br>Removes nutrients and toxic pollutants<br>Can remove oxygen demanding substances<br>May be applied to specific locations | Short-term negative consequences on aquatic habitats<br>May encourage nuisance species colonization of the disturbed lakebed<br>Effectiveness varies with level of source control applied<br>High cost to implement<br>Impacts may be temporary | Yes[c] |

[a]*Control of discharges from Delavan Lake is required to maintain minimum flows downstream for fisheries management purposes. Ongoing maintenance of the dam structure and associated berms is also required pursuant to the operating permit of the dam.*

[b]*Dredging and drawdowns may require local, State, or Federal permits.*

[c]*Recommended for maintenance of navigational access only.*

*Source: SEWRPC.*

outlet and the inlet.[26] As part of the major remediation works constructed during the early 1990s, provisions were made by selected channelization and construction of a berm to encourage this short-circuiting. Due to concerns expressed by riparian owners adjacent to STH 50 on the northern shore of the Lake, the berm was not completed to recommended design specifications. Hence the short-circuiting induced has proven only partially effective, being found to be dependent upon wind conditions and the presence of ice cover. Technical difficulties associated with the automated control of the outlet structure gates also reduced the effectiveness of the bypass proposal in practice. A recent study of the effectiveness of the bypass strategy, conducted by the University of Wisconsin-

[26]*B. Sigurdsson,* Development and Application of a Steady-state Water Circulation Model for Delavan Lake, *M.S. Thesis, University of Wisconsin, Madison, Wisconsin, 1987.*

Madison, suggested that the short-circuiting could be enhanced by significantly extending an existing peninsula near the inlet, creating channels for water flow in the inlet and outlet. Nevertheless, ongoing concerns expressed by riparian property owners continue to limit the potential for such construction.

The outflow from Delavan Lake is controlled by a dam with two electric gates and a low-level outlet with an electric gate. During the planning program period, the gates of the dam were controlled by a computer synchronized with a water-level monitoring station at STH 50 in the vicinity of the Lake inlet. This system was intended to regulate the outlet control structure to maximize outflows during storm events at any time of the day or night. This would theoretically allow the nutrient pulses that typically accompany the initial flush of stormwater from the land surface to bypass the main basin of the Lake. By linking the outlet control gates to an inflow monitoring station and utilizing electronic gate mechanisms, the need for manual operation of the gates was precluded. Likewise, the operation of the gates in response to predicted storm events was obviated, given the difficulties associated with accurate weather forecasting in localized areas. Unfortunately, synchronizing the inflow gauge with the outlet structure gate operations proved problematic, with both technical difficulties and variations in travel time of flood flows from the inlet to the outlet resulting in erratic operation of the outlet control structure and poor performance overall. In fact, data reviewed by Robertson and his co-authors suggest that a greater mass of phosphorus was retained in the Lake following completion of the attempted short-circuit than in the years prior to the attempt.[27]

In addition to serving the lake water quality control purposes described above, the electronic outlet control system governing water flows leaving Delavan Lake also was required, from 1997, to meet a minimum outflow requirement mandated by the Wisconsin Department of Natural Resources of 0.66 cubic feet per second to maintain the downstream fishery.[28] It is for this latter reason that continued control of lake water discharges is considered a viable element of the lake management plan for Delavan Lake. However, while it is assumed that the technical difficulties regarding the outlet control system could be largely overcome, manual control of the gates would appear to be adequate for this purpose.

In this regard, it has been noted that some of the seepage through the dam may be attributed to the presence of muskrat burrows in the eastern portion of the dam. Thus, one component of the outlet control management program would include the Delavan Lake Sanitary District working in cooperation the landowners of the berm adjacent to the concrete dam structure to minimize the muskrat impacts on seepage through the berm.

***Drawdown***

Water level management refers to the manipulation of lake water levels, especially in man-made lakes, in order to change or create specific types of habitat and thereby manage species composition within a waterbody. Drawdown may be used to control aquatic plant growth and to manage fisheries. In addition, a drawdown during the fall can sometimes act to remove nutrients from the lake by removing water after fall turnover, when nutrient concentrations are generally high, and replacing the water during the spring, when nutrient concentrations are lower. The results of this can be unpredictable.

Drawdowns have been used as a management strategy in Delavan Lake. The water level in Delavan Lake was drawn down approximately 10 feet between September and November 1989. This action was done primarily to reduce the volume of water in the Lake to facilitate a number of remedial actions, including control of rough fish and application of alum for nutrient inactivation purposes. These actions are summarized in Table 41. To effect the drawdown, the dam at the outlet was opened and pumps were use to speed to removal of water from the Lake into Swan Creek. Following the completion of the remedial measures, the Lake was allowed to refill over the period from January 1990 to January 1991.

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[27]*Dale M. Robertson, Gerald L. Goddard, Daniel R. Helsel, and Kevin L. MacKinnon,* op. cit.

[28]*Delavan Lake Sanitary District,* Lake Water Quality Report, 1998, Delavan Lake Wisconsin, *March 1999.*

Prior to 1990, Delavan Lake was subjected to an annual fall drawdown of about nine inches. These drawdowns were conducted to reduce shoreline erosion and ice damage during the winter months, and to provide lake residents an opportunity to remove or repair docks, piers and shoreline structures before winter. Since 1991, the lake level has been held constant throughout the year at 927.91 feet above mean sea level. Water levels in Delavan lake are managed by the Delavan Lake Sanitary District on behalf of the Town of Delavan.

Estimates of the probable impact of a seasonal drawdown were made by Commission staff. Assuming that a nine-inch drawdown over the winter of 1997-1998 was conducted, and that the Lake was allowed to refill during the spring of 1997, Commission staff have estimated that 12 pounds of additional phosphorus would have been retained in the Lake over the mass of phosphorus likely to have been retained in the Lake if a constant lake level had been maintained. While this mass of additional phosphorus is negligible, adding less than 0.001 milligrams per liter to the in-lake phosphorus concentration, the net increase in the mass of phosphorus retained in the Lake mediates against the use of over-winter lake drawdowns as a nutrient management measure. Though considerable uncertainty is attached to this result because of the numerous simplifying assumptions made in its calculation, the potential for a net increase in in-lake phosphorus concentrations under some conditions, leading to higher spring nutrient concentrations than would otherwise have occurred, indicates that a significant drawdown is not considered a viable element of the lake management plan for Delavan Lake at this time.

***Dredging***

Sediment removal is a restoration measure that is carried out using a variety of both land-based and water-based techniques, depending on the extent and nature of the sediment removal to be carried out. Both methods are expensive, especially if a suitable disposal site is not located close to the dredge site. The effectiveness of dredging varies with the effectiveness of watershed controls in reducing or minimizing the sediment source. The potential negative environmental effects of a large-scale lakewide dredging project and the high cost associated with dredge spoil disposal, indicates that this option should be considered only on a limited basis for small-scale projects designed to improve hydraulic capacity or boating access.

While dredging results in an immediate increase in lake depth, such increases may be short-lived if the sources of sediment being deposited in the Lake are not controlled within the drainage area tributary to the Lake. As noted in Chapter IV, the sediment load reaching Delavan Lake comes primarily from urban and agricultural lands tributary to the Jackson Creek and other surface water features draining to Delavan Lake. Further sediment is generated from streambank erosion, although, in the case of Delavan Lake, this was considered to be a minor source. All of these sources are subject to effective control through the adoption, and implementation, and maintenance of recommended control measures with the watershed, which should be considered the primary means of limiting sediment accumulation in Delavan Lake prior to consideration being given to dredging. Only after such practices are implemented should major sediment removal projects be considered and then only in limited areas of the Lake.

Dredging of a navigational channel in the Delavan Lake inlet would be recommended to aid in boat navigation and reduce sediment resuspension. Sedimentation and infilling of the channel is a concern, and should be considered during channel design. Limited dredging of both the inlet and outlet channels of Delavan Lake was undertaken during 1989 to encourage through-flow of nutrient-rich flood waters entering the Lake from the Jackson Creek tributary. As limited maintenance dredging of the navigational channel may be required, any such dredging should be consistent with the maintenance of the through-flow channel.

Dredging of the lakebed material from navigable waters of the State requires a Wisconsin Department of Natural Resources Chapter 30, *Wisconsin Statutes*, permit and a U.S. Army Corps of Engineers Chapter 404 permit. In addition, current solid waste disposal regulations define dredge materials as a solid waste. Pursuant to Chapter NR 180 of the *Wisconsin Administrative Code*, any dredging project generating more than 3,000 cubic yards of spoils is required to submit preliminary disposal plans to the Wisconsin Department of Natural Resources as part of the permitting process. Because of the likely presence of sodium arsenite in the lake sediments of Delavan Lake, as discussed in Chapter V, sediment samples may need to be analyzed for arsenic to determine whether specific disposal requirements are to be applied to any dredge spoils removed from the Lake.

Large-scale dredging of Delavan Lake is not considered a viable element of the lake management plan for Delavan Lake. However, consideration should be given to limited, small-scale dredging for the maintenance of navigational access in specific areas of the Lake, including the Lake inlet.

**Aquatic Plant Management Measures**

The management measures set forth in Table 42 are aimed at both the removal of nuisance vegetation and the manipulation of aquatic plant species composition in order to enhance and provide for recreational water use. Generally, aquatic plant management measures are classed into four groups: physical measures which include lake bottom coverings and water level management; mechanical removal measures which include harvesting and manual removal; chemical measures which include the use of aquatic herbicides; and biological control measures which include the use of various organisms, including insects. Harvesting is probably the measure best suited to large areas of open water, while chemical controls may be best suited to use in confined areas and for initial control of invasive plants. All aquatic plant management practices are stringently regulated and require a State of Wisconsin permit.

***Aquatic Herbicides***

Chemical treatment with aquatic herbicides is a short-term method for controlling heavy growths of aquatic macrophytes and algae. Chemicals are applied to the growing plants in either liquid or granular form. Because of the demonstrated need to control aquatic plants in selected areas of Delavan Lake, the relatively low cost of chemical treatment, and current management decisions which have indicated a need for some limited chemical treatment in specific areas of the Lake, chemical treatment is considered a viable element of the lake management plan for Delavan Lake. Use of chemical control measures to control blue-green algae, such as *Synechosystis* sp., *Anabena* sp., and *Aphanizomenon* sp., is also considered to be a viable element of the lake management plan for Delavan Lake.

***Aquatic Plant Harvesting***

Aquatic macrophytes are mechanically harvested with specialized equipment consisting of a cutting apparatus, which cuts up to five feet below the water surface, and a conveyor system which picks up the cut plants and hauls them to shore. Because of the demonstrated need for aquatic plant control in Delavan Lake, and because the current lake management decisions have indicated a need for aquatic plant harvesting, harvesting remains a viable element of the lake management plan for Delavan Lake. The current aquatic plant management program on Delavan Lake began in 1990, and was operated by the Town of Delavan until January 1, 1997. Since 1997, the Delavan Lake Sanitary District has assumed the responsibility for the program under a 1997 intergovernmental agreement with the Town. The Delavan Lake Sanitary District currently operates and leases from the Town of Delavan, three aquatic plant harvesters of varying sizes, a transport barge, two shore conveyor systems, and storage space for winter storage of this equipment at the village park site. The Delavan Lake Sanitary District provides a dump truck, and one full-time and three to four seasonal employees for the harvesting season.

***Manual Harvesting***

Due to an inadequate depth of water, it is not always possible for harvesters to reach the shoreline of every property. Also, aquatic plant harvesting equipment is often too large and cumbersome to permit harvesting around piers and in confined spaces. Therefore, in these areas, manual harvesting provides an alternative means of removing plant material from areas where plants are not desired. Manual harvesting can be facilitated by the purchase of specially designed rakes, designed specifically to manually cut and remove aquatic plants from the shoreline area. The advantage of the rakes is that they are easy and quick to use. Unlike chemical treatments that involve a waiting period, the rakes immediately remove the plants from the lake. Removing the plants from the lake avoids the accumulation of organic matter on the lake bottom, which adds to the nutrients that favor more plant growth. Manual harvesting is considered a viable element of the lake management plan for Delavan Lake, especially for smaller, shallow water areas of Delavan Lake.

Table 42

MANAGEMENT ALTERNATIVES FOR AQUATIC PLANTS IN DELAVAN LAKE

| Management Alternatives | Summary Description | Estimated Cost | Advantages | Disadvantages | Considered Viable for Inclusion in Lake Management Plan |
|---|---|---|---|---|---|
| Aquatic Herbicides[a] | Chemical agents applied to the lake water in liquid or granular form control the growth of undesirable aquatic plants and algae | $250 to $500 per acre per year | Easy to use<br>Convenient to apply<br>Delivers rapid control of plants<br>May be selective<br>Cost-effective | May have short-term, lethal effects and long-term, sublethal effects<br>May lead to algal blooms<br>Releases nutrients into the water and adds organic matter to the sediments<br>May lead to depletion of dissolved oxygen<br>Destroys habitat<br>Must be reapplied each summer<br>May be nonselective<br>Affects water uses for some period | Yes |
| Aquatic Plant Harvesting | Removal or harvesting of aquatic macrophytes using specialized mechanical equipment consisting of a cutting apparatus which cuts up to five feet below the water surface and a conveyor system to cut plants and haul them to shore | Operating and maintenance costs equals $10,000 to $20,000 per year; capital costs equals $100,000 per decade | Removes plant bio-mass and nutrients<br>Can affect the regrowth of certain plants<br>May remove filament-ous algae<br>Retains habitat and stabilizes lake sediments<br>May reduce stunted populations of panfish by increas-ing predation in opened areas<br>Cut plants can be used as mulch | Cannot be used in shallow water<br>Difficult to use around docks and buoys<br>Can increase turbidity and bottom-dwelling fauna<br>May lead to algal blooms<br>May catch young-of-the-year fish and fish-food organisms<br>May adversely affect habitat<br>May favor Eurasian water milfoil which propagate from cut fractions<br>High cost to implement | Yes |
| Manual Harvesting | Aquatic plants are removed by hand or hand-operated devices in limited areas | $100 per rake | Selective<br>Cost-effective | Effective only in very small areas<br>Physically demanding to employ | Yes |

**Table 42 (continued)**

| Management Alternatives | Summary Description | Estimated Cost | Advantages | Disadvantages | Considered Viable for Inclusion in Lake Management Plan |
|---|---|---|---|---|---|
| Biological Controls[b] | Biological control agents such as fish, aquatic insects, and competing aquatic plant species are used to manipulate the species composition of aquatic plants in lakes | - - | Acts in a "natural" manner<br>May be selective<br>Easy to apply | May not be selective<br>May not be compatible with other aquatic plant control measures<br>May be prohibited in Wisconsin | No |
| Lake Bottom Covering | Placement of bottom coverings on the lakebed shade out undesirable plants in small areas of the Lake | $50 to $250 per 700 square feet | Site-specific<br>Unobtrusive | Difficult to install<br>Nonselective<br>May be expensive to acquire and install properly<br>May be subject to movement or recreational interference<br>Ongoing annual removal requirement | No |
| Public Information | Informing lake users and riparian residents of the value of native aquatic plants in lakes, and the location of environmentally sensitive or ecologically valuable areas within the lake basin, as well as identification and control measures, minimizes the spread of nuisance plant species, such as Eurasian water milfoil, and encourages the use of alternative measures to control undesirable aquatic plant growth | - - | Low cost<br>Uses materials which are readily available<br>Can be undertaken by lake residents and/or school groups, service organizations, or units of government | None known | Yes |

[a]*Herbicide application should be undertaken by a licensed applicator; chemical herbicide applications in aquatic environments require a Wisconsin Department of Natural Resources permit.*

[b]*Use of biological organisms to control aquatic plant growth may require State permits; use of grass carp as a control organism is not permitted in Wisconsin; use of the milfoil weevil,* Eurhychiopsis lecontei *is presently being employed on an experimental basis in selected Wisconsin lakes by the Wisconsin Department of Natural Resources and University of Wisconsin-Stevens Point, College of Natural Resources, between 1995 through 1998. The costs associated with the use of the milfoil weevil are similar to those of aquatic herbicides, at $500 to $1,000 per acre.*

*Source: SEWRPC.*

*Biological Controls*
An alternative approach to controlling nuisance weeds, particularly Eurasian water milfoil, is biological control. Classical biological control has been successfully used to control both weeds and herbivorous insects.[29] Recent documentation shows that *Eurhychiopsis lecontei*, an aquatic weevil species, has potential as a biological control agent for Eurasian water milfoil.[30] The use of this species as a means of aquatic plant management control is being studied in selected lakes within Wisconsin.[31] Because of its experimental nature, it is not considered to be a viable element of the management plan for Delavan Lake at this time. Grass carp (*Ctenopharyngodon idella*), another potential biological control agent, are not permitted for use in Wisconsin.

Controlling Eurasian water milfoil by planting native plant species also is largely experimental. While it has worked well in a specialized shoreland management zone at the water's edge, where it has been used extensively to restore natural shoreline landscapes, its use in deeper water environments has been less successful. Planting aquatic flora is difficult and survival rates of the plants relatively low. In addition, the ability of native plant species to outcompete the Eurasian water milfoil is limited by the same factors as affects naturally occurring plant stocks in the lakes; namely, the advantage that the Eurasian water milfoil has in an early growth cycle, growth starting at lower water temperatures and therefore earlier in spring, and in its ability to capture sunlight by forming a surface blanket of vegetation. Permits are required for the collection and transplantation of aquatic plants. Because of its experimental nature and poor success elsewhere in the Region, it is not considered a viable element of the lake management plan for Delavan Lake at this time.

*Lake Bottom Covering*
Lake bottom covers and light screens provide limited control of rooted plants by creating a physical barrier which reduces or eliminates the sunlight available to the plants. They have been used to create swimming beaches on muddy shores, to improve the appearance of lakefront property, and to open channels for motorboating. Sand and gravel are usually readily available and relatively inexpensive to use as cover materials, but plants easily recolonize areas so covered in about a year. Synthetic material, such as polyethylene, polypropylene, fiberglass, and nylon, can provide relief from rooted plants for several years, but must be removed annually to avoid displacement of the material and/or deposition of sediment over the material during the winter months, both of which would negate the effectivity of lake bottom covers as an aquatic plant management measure. Both methods require permits from the Wisconsin Department of Natural Resources. Because of the limitations involved, lake bottom covers as a method to control aquatic plant growth are not considered viable elements of the lake management plan for Delavan Lake.

*Public Information*
Aquatic plant management usually centers on the eradication of nuisance aquatic plants for the improvement of recreational lake use. The majority of the public views all aquatic plants as "weeds" and residents often spend considerable time and money removing desirable plant species from a lake without considering the environmental impact. Thus, public information is considered an important component of an aquatic plant management program

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[29]*C.B. Huffacker, D.L. Dahlsen, D.H. Janzen, and G.G. Kennedy, "Insect Influences in the Regulation of Plant Population and Communities," 1984, pp. 659-696; C.B. Huffacker and A.P. Gutierrez, editors,* Ecological Entomology, *2nd Edition, 1998.*

[30]*Sallie P. Sheldon, "The Potential for Biological Control of Eurasian Water Milfoil* (Myriophyllum spicatum) *1990-1995 Final Report," Department of Biology Middlebury College, February 1995; U.S. Environmental Protection Agency Report No. EPA-841/F-97-002, Number 3,* Use of Aquatic Weevils to Control a Nuisance Weed in Lake Bomoseen, Vermont, *1997.*

[31]*L.L. Jester, M.A. Bozek, and S.P. Sheldon, "Researching the Use of an Aquatic Weevil for Biological Control of Eurasian Water Milfoil in Wisconsin,"* LakeLine, *Vol. 17, No. 3, September 1997, pp. 18-19, 32-34.*

and viable element of the lake management plan for Delavan Lake. Posters and pamphlets are available from the University of Wisconsin-Extension and Wisconsin Department of Natural Resources that provide information and illustrations of aquatic plants, that detail their importance in providing habitat and food resources in aquatic environments, and explain the need to control the spread of undesirable and nuisance plant species.

**Fisheries Management Measures**

The fish population of Delavan Lake is presently dominated by panfish and game fish, such as walleyed pike, largemouth bass, and northern pike. The walleyed pike and smallmouth bass populations are maintained through stocking. The Lake provides a suitable habitat for a warmwater fishery with adequate water quality and dissolved oxygen levels and a diverse aquatic plant community that contribute to the maintenance of a fish population that is dominated by desirable sport fish. Extensive fisheries data show suitable conditions exist for the maintenance of a sport fish population in the Lake.[32] The management measures set forth in Table 43 are designed to protect and enhance the lake fishery.

***Habitat Protection***

Habitat protection refers to a range of conservation measures designed to maintain existing fish spawning habitat, including measures, such as restricting recreational and other intrusions into gravel-bottomed shoreline areas during the spawning season (for bass this is spring, mid-April to mid-June), use of natural vegetation in shoreland management zones, and other "soft" shoreline protection options that aid in habitat protection. Because these alternatives are preventative in nature, no cost is associated with them and application of these practices along the Delavan Lake shoreline is considered a viable element of the lake management plan for Delavan Lake.

***Habitat Creation***

In lakes where vegetation is lacking or where plant species diversity is low, artificial habitat may need to be developed. As discussed in Chapter V, the results of the aquatic plant surveys of Delavan Lake indicate that there is sufficient habitat for a healthy fish community. Therefore, habitat creation programs are not considered a viable element of the lake management plan for Delavan Lake. Notwithstanding, the use of natural shoreline landscaping techniques can enhance available fish and wildlife habitat around lakes. The use of natural shoreline vegetation for lakeshorescaping around Delavan Lake is considered a viable element of the lake management plan for Delavan Lake.

***Modification of Species Composition/Biomanipulation***

Species composition management refers to a group of conservation and restoration measures that include the selective harvesting of undesirable fish species and the stocking of desirable species designed to enhance the angling resource value of a lake. These measures include water level manipulation, which can aid in promoting successful breeding of desirable species. By increasing water levels in spring, for example, additional breeding habitat for pike can be created. Similarly, lake drawdown can disadvantage undesirable species by concentrating forage fish, and thus increasing predation success. This can also strand juveniles and desiccate the eggs of undesirable species. More extreme measures include "fisherees" that place a bounty on undesirable species as a means of increasing angling pressure on, or selectively cropping, certain fishes, poisoning, and enhancement of predation by stocking. In lakes with an unbalanced fishery, dominated by carp and other rough fish, chemical eradication has been used to manage the fishery. Lake drawdown is often used with the chemical treatments to expose spawning areas and eggs and concentrate fish in shallow pools, thereby increasing their availability to anglers, commercial harvesters, or chemical eradication treatments. This method was employed on Delavan Lake during 1989 and 1990 in an effort to eradicate carp from the Lake.

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[32]*Douglas Welch and Rick Dauffenbach,* Fisheries Index Survey Report, Delavan Lake, (WBIC 0793600), *Wisconsin Department of Natural Resources, 1997.*

## Table 43

## MANAGEMENT ALTERNATIVES FOR FISH IN DELAVAN LAKE

| Management Alternatives | Summary Description | Estimated Cost | Advantages | Disadvantages | Considered Viable for Inclusion in Lake Management Plan |
|---|---|---|---|---|---|
| Habitat Protection | Measures designed to maintain fish breeding habitat, feeding areas and food stuffs, and shelter, through shoreline erosion control and use of natural shoreline materials | - - | Low cost<br>Promotes shoreline aesthetics while protecting habitat<br>Encourages natural reproduction<br>Contributes to maintaining healthy fish populations | May limit application of other lake management measures by restricting areas in which other measures may be applied | Yes |
| Habitat Creation | Placement of rock cribs, brush piles, or other structures within a lake replaces or recreates habitat lost due to prior pollution, or lacking due to low numbers of aquatic plants | - - | Replaces lost habitat<br>Provides habitat in situations where natural habitat availability is limited | High cost to implement<br>May require permits | No[a] |
| Modification of Species Composition/ Biomanipulation | Stocking or removal of fishes manipulates the fishery and encourages healthy and balanced fish populations | - - | Can potentially restore balance and diversity | Uncertain effects<br>May require chemical treatments or removal of rough fish<br>Can be offset by recruitment<br>High cost to implement<br>Dependent on availability of fishes to be stocked<br>May have undesirable consequences if stocked fishes compete with native fishes | Yes |
| Regulations and Public Information | Legal and informational measures limit the harvest of fishes from waterbodies, typically including public participation campaigns such as "catch-and-release" programs and regulatory programs, such as fishing license, fish size and numbers, and fishing season requirements | - - | Traditional approach<br>Low cost | May be difficult to implement as it requires changes in current practices<br>May not be fully observed<br>Requires enforcement | Yes |

[a] *Use of natural vegetation in shoreland landscaping is considered a viable element of the lake management plan for Delavan Lake.*

*Source: SEWRPC.*

The more common management measure is stocking game fishes. The mixture of species is determined by the stocking objectives. These are usually to: supplement an existing population; maintain a population that cannot reproduce itself; add a new species to a vacant niche in the food web; replace species lost to a natural or man-made disaster; or establish a fish population in a depopulated lake. Rehabilitation efforts on Delavan Lake have focused on managing for a large predator fish population that feeds on smaller fishes that feed on zooplankton. This enhances zooplankton populations and predation upon algae, as mentioned in Chapter V. Continued monitoring and stocking are likely to be needed to sustain this population structure once the fishes reach a size that make them vulnerable to fishing pressures. This would be especially true for walleyed pike, an important element in maintaining a large predatory fish population. Thus, continued stocking to retain the large predatory fish population required to maintain water clarity through zooplankton grazing of phytoplankton within the lake water column is considered a viable element of the lake management plan for Delavan Lake.

***Regulations and Public Information***

To reduce the risk of overharvest, the Wisconsin Department of Natural Resources has placed restrictions on the number and size of certain fish species caught by anglers. The open season, size limits, and bag limits for the fish species of Delavan Lake are given in Table 31 in Chapter V. Enforcement of these regulations is important to the success of any sound fish management program, and the continued use of fishing regulations for this purpose is considered a viable element of the management plan for Delavan Lake. Modification of these regulations is not anticipated by the WDNR.

**Shoreline Maintenance**

Shoreline maintenance refers to a group of measures designed to reduce and minimize shoreline loss due to erosion by waves, ice, or related action of the water. Currently, about 65 percent of the shoreline of Delavan Lake is protected by some type of structural measure including bulkheads, vertical walls, revetments, sloping stonewalls, and areas where riprap had been used to stabilize the shoreline. Most of the observed shoreline protection measures were in a good state of repair.

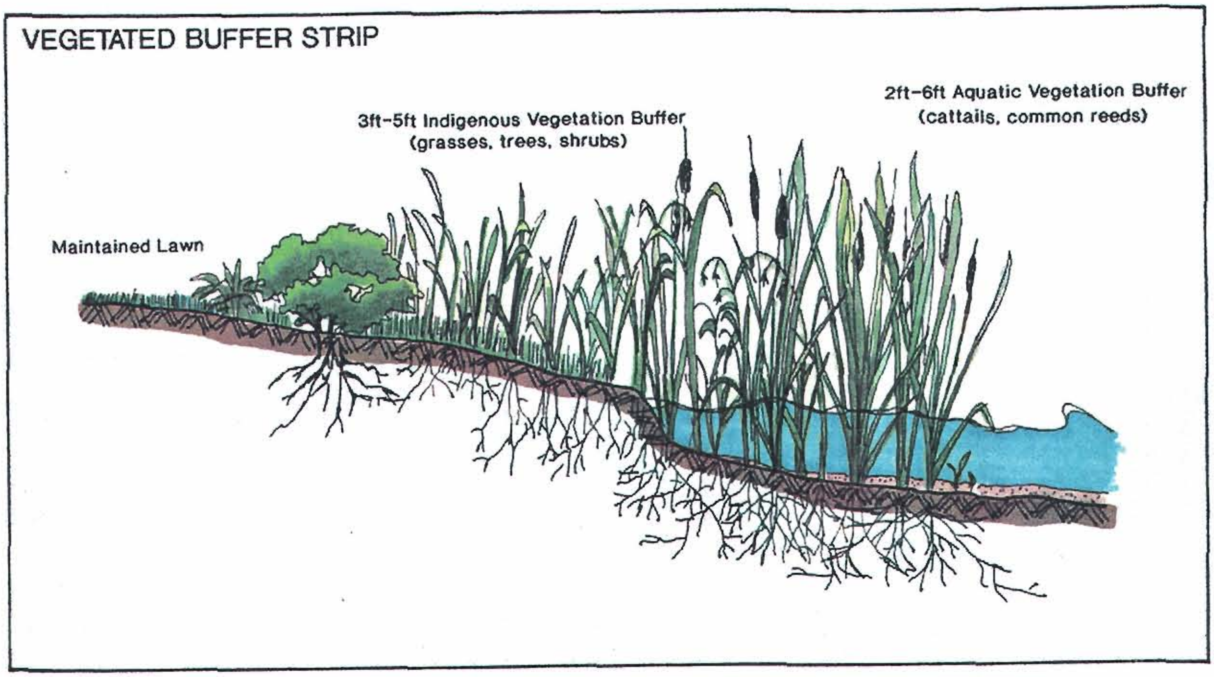
Shoreline erosion was found to exist only at isolated locations on Delavan Lake, and no serious problems were identified. However, because of the system of shoreline armor already in place at Delavan Lake, armoring the additional unprotected shoreline in the main basin of the Lake, as and when necessary, would appear to be a viable option. Two shoreline erosion control techniques, set forth in Figure 26, are considered viable elements of the lake management plan for Delavan Lake: vegetative buffer strips, and riprap. These alternatives were selected because they can be constructed, at least partially, by local residents; because most of the construction materials involved are readily available; because the measures would, in most cases, enable the continued use of the immediate shoreline; and because the measures are visually "natural" or "semi-natural" and should not significantly affect the aesthetic qualities of the lake shoreline. If additional shore protection is installed, it is recommended that consideration be given to the visual aesthetics of blending various types of construction along the shore. This will not only enhance the visual appeal of the shoreline, but will also minimize the edge effects that can occur as the result of two dissimilar abutting styles of construction. Vegetative buffer strips may also be desirable for selected areas in this Lake.

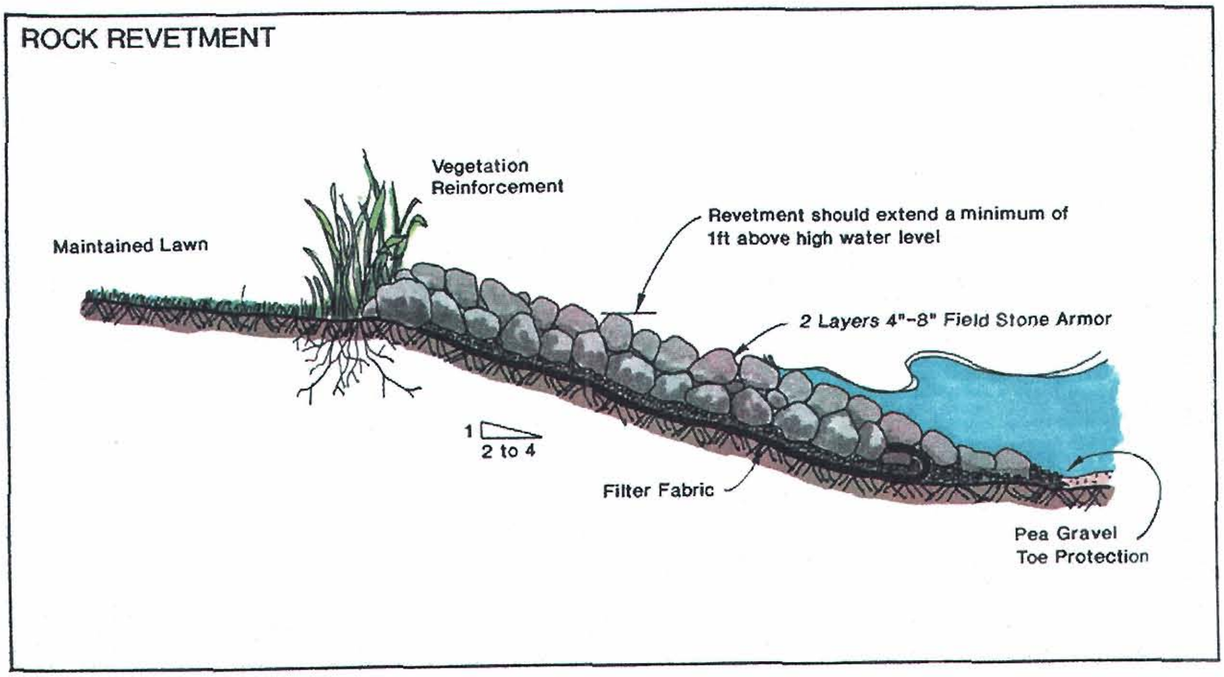
**Recreational Use Zoning**

Regulatory measures provide a basis for controlling lake use and use of the shorelands around a waterbody. On land, shoreland zoning, requiring set backs and shoreland buffers, can protect and preserve views both from the water and from the land, control development around a lake to minimize its environmental impacts, and manage public and private access to a waterbody. On water, recreational use zoning can provide for safe and multi-purpose use of lakes by various groups of lake users and protect environmentally sensitive areas of a lake. At present, the current zoning and boating ordinances adopted by the Town of Delavan are generally consistent with the types of shoreland development and recreational uses indicated in and around Delavan Lake. In addition, public recreational boating access to the Lake is consistent with the requirements set forth in Chapter NR 1 of the *Wisconsin Administrative Code*. Thus, these components of the recreational use management plan element may be considered to be in place.

*Figure 26*

**PLAN ALTERNATIVES FOR SHORELINE EROSION CONTROL**




NOTE: Design specifications shown within are for typical structures. The detailed design of shore protection measures must be based upon detailed analysis of local conditions.

*Source: SEWRPC.*

**Public Informational and Educational Programs**
Educational and informational brochures and pamphlets, of interest to homeowners and supportive of the lake management program, are available from the University of Wisconsin-Extension, the Wisconsin Department of Natural Resources, the Walworth County Offices, and many Federal government agencies. These brochures could be provided to homeowners through local media, direct distribution, or targeted library/civic center displays. Alternately, they could be incorporated into the newsletters produced and distributed by the Delavan Lake Sanitary District. Many of the ideas contained in these publications can be integrated into ongoing, larger-scale activities, such as anti-littering campaigns, recycling drives and similar pro-environment activities.

Finally, the participation of Delavan Lake in the State-sponsored volunteer "Self-Help Monitoring" program, which involves citizens in taking Secchi-disk transparency readings in the Lake at regular intervals, should be continued. Data gathered as part of this program should be presented annually by the volunteers at a meeting of the Town of Delavan Lake Committee and/or the Delavan Lake Improvement Association, where the citizen monitors could be given some recognition for their work. The Lake Coordinator of the Wisconsin Department of Natural Resources-Southeast Region could assist in enlisting more volunteers in this program. The information gained at first hand by the public from participation in this program can increase the credibility of the proposed changes in the nature and intensity of use to which the Lake is subjected.

Public informational and educational programming is considered a viable element of the lake management plan for Delavan Lake.

## SUMMARY

This chapter has described a number of options that could be employed in managing the types of problems recorded as occurring in Delavan Lake. These options, either singly or in combination, could assist the Delavan Lake community in achieving and maintaining the water quality objectives set forth in Chapter VI. Selected characteristics of those measures considered feasible for use on Delavan Lake are summarized in Table 44. These measures were selected following evaluation of their effectiveness, cost, and technical feasibility. Those alternative measures not considered further at this time are: drawdown, large-scale dredging, biological control of aquatic plants, lake bottom covering, and fish habitat creation. The remaining measures were considered to be viable elements of the recommended lake management plan for Delavan Lake, and are further described in Chapter VIII.

## Table 44

## SELECTED CHARACTERISTICS OF ALTERNATIVE LAKE MANAGEMENT MEASURES FOR DELAVAN LAKE

| Alternative Measure | Description | Estimated Costs | | Considered Viable for Inclusion in Lake Management Plan |
|---|---|---|---|---|
| | | Capital | Operation and Maintenance | |
| Land Use Planning and Zoning | Shoreland zoning | - - | - - | Yes |
| | Wetland protection | - - | - - | Yes |
| Urban Nonpoint Source Controls | Detention and infiltration basins | - - | Variable | Yes |
| | Good urban housekeeping practices | - - | Low | Yes |
| Developing Area Nonpoint Source Controls | Soil stabilization, surface roughening, and construction site erosion controls | $250 per acre | $25 per acre | Yes |
| Rural Nonpoint Source Controls | Conservation tillage and streambank management | - - | - - | Yes |
| | Streambank buffer strip | - - | - - | Yes |
| Onsite and Public Sewage Disposal System Management | Septic tank management program | Variable | Up to $100 per year | Yes |
| | Public sanitary sewer system | $4,700 plus local sewer and connection costs | $2.00 per 1,000 gallons | Yes |
| Phosphorus Precipitation and Inactivation | Alum treatment | - - | About $300 per acre | No[a] |
| Nutrient Load Reduction | Nutrient load reduction (external) | - - | Variable | Yes |
| Water Quantity and Water Level Management Measures | Outlet control modifications and short-circuiting | - - | - - | No[b] |
| | Dredging | - - | $15 per cubic yard | Yes[c] |
| Aquatic Plant Management Measures | Aquatic herbicides | - - | $250 to $500 per acre | Yes |
| | Aquatic plant harvesting | $150,000 | $50,000 per year | Yes |
| | Manual harvesting | $100 per rake | - - | Yes |
| | Biological controls | - - | $500 to $1,000 per acre | No[d] |
| | Public information | - - | - - | Yes |
| Fisheries Management Measures | Habitat protection | - - | - - | Yes |
| | Habitat creation | - - | - - | No[e] |
| | Modification of species composition/ Biomanipulation | - - | $13,000 per fish survey | Yes |
| | Regulations and public information | - - | - - | Yes |
| Shoreline Maintenance | Maintenance of structures | $7.50 to $36 per linear foot | - - | Yes |

Table 44 (continued)

| Alternative Measure | Description | Estimated Costs | | Considered Viable for Inclusion in Lake Management Plan |
|---|---|---|---|---|
| | | Capital | Operation and Maintenance | |
| Recreational Use Zoning | Provision of public recreational boating access and enforcement of boating ordinances | - - | - - | Yes[f] |
| Public Informational and Educational Programs | Public informational programming | - - | - - | Yes |
| | Participation in the WDNR Self-Help Monitoring Program | $600 initial equipment cost | - - | Yes |

[a]*May be considered as a long term management measure following implementation of nonpoint source controls to the extent practicable*

[b]*Required for maintenance of minimum downstream flows for fisheries management purposes. Ongoing structural maintenance of the dam and associated berms is also required pursuant to the operating permit for the dam.*

[c]*For maintenance of navigational access in limited areas only.*

[d]*Use of the milfoil weevil may be considered in future following the conclusion of the experimental applications elsewhere in Wisconsin.*

[e]*Use of natural vegetation for shoreland landscaping is recommended.*

[f]*Currently fully implemented by the Town of Delavan.*

*Source: SEWRPC.*

## Chapter VIII

# RECOMMENDED MANAGEMENT PLAN FOR DELAVAN LAKE

## INTRODUCTION

This chapter presents a recommended management plan, including attendant costs, for Delavan Lake. The plan is based upon inventories and analyses of land use and land and water management practices; pollution sources in the drainage area tributary to Delavan Lake; the physical and biological quality of the waters of the Lake; the land use and population forecasts; and an evaluation of alternative lake management plans. The recommended plan sets forth means for: 1) providing water quality conditions suitable for full-body contact recreational use and the maintenance of healthy communities of warmwater fish and other aquatic life; 2) reducing the severity of existing nuisance problems due to excessive macrophyte and algal growths, which constrain or preclude desired water uses; 3) protecting environmentally sensitive areas; 4) promoting sound recreational use of the Lake; and 5) minimizing shoreline erosion. These actions taken together should be adequate to maintain the Lake in fishable and swimmable condition as set forth in the Federal Clean Water Act. The recommended plan elements were selected from among the alternatives described in Chapter VII, and evaluated on the basis of which of the feasible alternatives may be expected to be implementable and meet the plan objectives at a reasonable cost.

Analyses of water quality and biological conditions indicate that the general condition of the water in Delavan Lake is fair to good. Despite high nutrient loadings, this condition appears to be maintained through manipulation of the fish and plankton communities, primarily through maintaining extremely high populations of piscivorous fishes, specifically, the walleyed pike, that control planktivores, allowing zooplankton communities to flourish and control the magnitude of the phytoplankton population. Notwithstanding, water-based recreation is somewhat limited by growths of aquatic macrophytes in the nearshore areas of the Lake. The recommended plan sets forth recommendations for: land use regulation and land management in the drainage area tributary to Delavan Lake; in-lake management measures, including water quality monitoring, aquatic plant management, fisheries management, and habitat protection and shoreline protection measures; recreational use management measures; and informational and educational programming. These recommended plan elements complement the watershedwide land use control and management measures recommended in the regional water quality management and land use management plans,[1] the Turtle Creek priority watershed

[1]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000, *Volume Three,* Recommended Plan, *June 1979, as refined by SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report, *March 1995; SEWRPC Planning Report No. 45,* A Regional Land Use Plan for Southeastern Wisconsin: 2020, *December 1997.*

plan,[2] and related measures set forth in the county land and water resource management plan,[3] park and open space plan,[4] and land use plan.[5]

The recommended management measures for Delavan Lake are graphically summarized on Map 21 and are listed in Table 45. The recommended measures are more fully described in the following paragraphs.

**LAND USE PLANNING AND ZONING MEASURES**

A fundamental element of a sound lake management plan and lake management program for Delavan Lake is the promotion of a sound and appropriate pattern of land use within the drainage area tributary to the Lake. The type and location of urban and rural land uses in the drainage area will, to a considerable degree, determine the character, magnitude, and distribution of nonpoint sources of pollution; the practicality of, as well as the need for, various land management measures; and, ultimately, the water quality of the Lake.

The current and likely future buildout land use pattern in the drainage area tributary to Delavan Lake is described in Chapter III. This development framework is generally consistent with that set forth in the regional land use plan as refined in the county land use plan.[6] The recommended land use plan envisions limited additional urban land use development at low to moderate densities within the Delavan Lake drainage area. Such development is generally adjacent to and contiguous with existing urban-density development within the Cities of Elkhorn and Delavan, the Village of Williams Bay, and along the lakeshore. Development is recommended to be limited to those areas which are covered by soils suitable for the intended use, which are not subject to special hazards such as flooding or that are steeply sloping, and which are not environmentally sensitive; that is, not encompassed within the Regional Planning Commission delineated environmental corridors described in Chapter V. These lands are designated as urban service areas in the aforereferenced county land use plan.

A major land use issue which has the potential to affect Delavan Lake is the potential conversion of agricultural and other open space lands to urban land uses, and the redevelopment of existing riparian properties at higher densities or with greater areas of impervious surface. As noted in Chapters III and VII, the majority of development occurring within the drainage area tributary to Delavan Lake is generally consistent with the recommendations set forth in the adopted county and regional land use plan. While the extent of development is currently limited, portions of the open space areas remaining in the drainage area to Delavan Lake could be replaced over time with large-lot urban development. Of greater concern is the redevelopment of existing lakefront properties, replacing lower-density uses with higher-density, multi-family dwellings with increased roof

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[2] *Wisconsin Department of Natural Resource,* Turtle Creek Priority Watershed Plan, *1984; Wisconsin Department of Natural Resources,* Turtle Creek Priority Watershed Plan—Amendment—The Delavan Lake Restoration Project, *August 1989.*

[3] *Walworth County Land Conservation Department,* Walworth County Land & Water Resource Management Plan, *February 1999.*

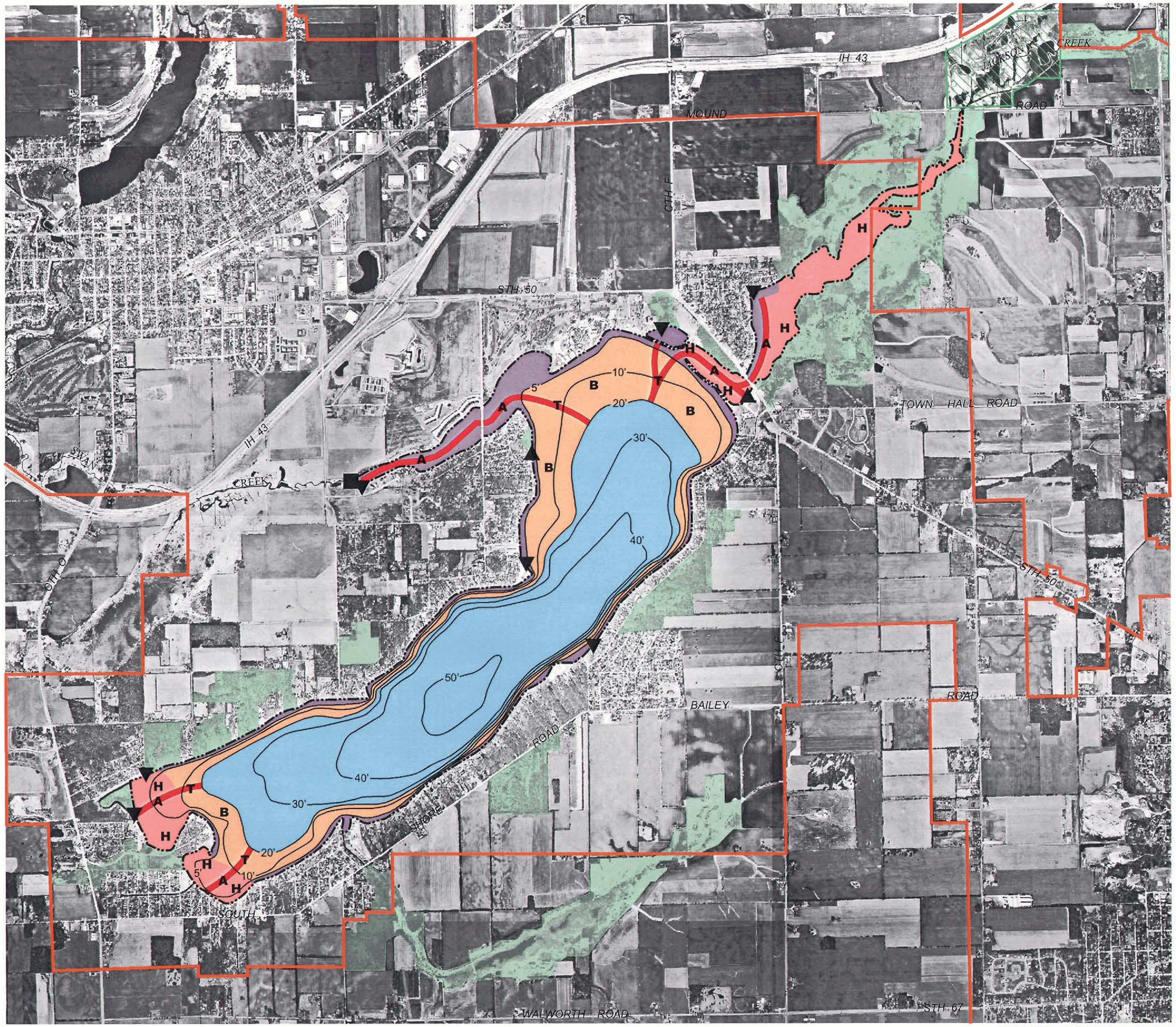
[4] *SEWRPC Community Assistance Planning Report No. 135, 2nd Edition,* A Park and Open Space Plan for Walworth County, *September 2000.*

[5] *SEWRPC Community Assistance Planning Report No. 252,* A Land Use Plan for Walworth County, Wisconsin: 2020, *April 2001.*

[6] *SEWRPC Planning Report No. 45,* op. cit.*; SEWRPC Community Assistance Planning Report No. 252,* op. cit.

Map 21

## RECOMMENDED LAKE MANAGEMENT PLAN FOR DELAVAN LAKE




DATE OF PHOTOGRAPHY: MARCH 1995

—20'— WATER DEPTH CONTOUR IN FEET

■ WATER LEVEL CONTROL STRUCTURE

▲ PUBLIC ACCESS SITE AND HARVESTER OFF-LOAD AREA

▼ PRIVATE ACCESS SITE

AQUATIC PLANT MANAGEMENT

A — ACCESS: HARVEST RECREATIONAL BOATING ACCESS CHANNELS APPROXIMATELY 50 FEET WIDE

T — TRANSIT LANES: HARVEST RECREATIONAL BOATING ACCESS CHANNELS APPROXIMATELY 50 FEET WIDE

B — BOATING / RECREATION: SURFACE CUT OF EURASIAN WATER MILFOIL, HARVESTING MODERATE PRIORITY

H — HABITAT: ECOLOGICALLY-VALUABLE AREAS - NO AQUATIC PLANT MANAGEMENT MEASURES RECOMMENDED DURING FISH BREEDING SEASON

LITTORAL ZONE: MAINTAIN SHORELINE PROTECTION STRUCTURES AS NECESSARY, INSTALL VEGETATIVE BUFFERS, MANUALLY HARVEST AQUATIC PLANTS AROUND PIERS AND DOCKS

OPEN WATER: DEPTH GREATER THAN 20 FEET - NO AQUATIC MANAGEMENT MEASURES RECOMMENDED

LAND USE MANAGEMENT

PROTECT ENVIRONMENTAL CORRIDOR LANDS

MANAGE AND MAINTAIN THE MOUND ROAD WETLAND

- OBSERVE GUIDELINES SET FORTH IN THE REGIONAL LAND USE PLAN, MAINTAIN HISTORIC LAKEFRONT RESIDENTIAL DWELLING DENSITIES
- PROMOTE GOOD HOUSEKEEPING PRACTICES IN URBAN AREAS

BOUNDARY OF SANITARY SEWER SERVICE AREA: WALWORTH COUNTY METROPOLITAN SEWERAGE DISTRICT - PROVIDE PUBLIC SANITARY SEWERAGE SERVICES, REFINE AS NECESSARY

WATER QUALITY MANAGEMENT

- CONTINUE PARTICIPATION IN WISCONSIN DEPARTMENT OF NATURAL RESOURCES SELF-HELP MONITORING PROGRAM

FISHERIES MANAGEMENT

- CONTINUE TO MONITOR FISH POPULATIONS, MODIFY STOCKING/ HARVESTING PROGRAM AND REGULATIONS, AS NECESSARY

PUBLIC INFORMATION AND EDUCATION

- CONTINUE PUBLIC AWARENESS PROGRAM

N

GRAPHIC SCALE
0 1500 3000 FEET

*Source: SEWRPC.*

Table 45

RECOMMENDED LAKE MANAGEMENT PLAN ELEMENTS FOR DELAVAN LAKE

| Plan Element | Subelement | Location | Management Measures |
|---|---|---|---|
| Land Use Planning and Zoning Measures | Land use development planning | Entire watershed | Observe guidelines set forth in the county land use plan |
| | | Lakeshore areas | Maintain historic medium- and low-density residential uses |
| | Zoning ordinance review and possible refinement | Entire watershed | Maintain zoning ordinances to minimize open space losses through appropriate conservancy zoning; consider development of a lake classification system for the county |
| | | Entire watershed | Develop stormwater management ordinance for watershed within the Town of Delavan; continue to enforce county erosion control ordinance |
| | Density management | Entire watershed | Encourage cluster development to preserve open space to the greatest extent possible |
| | Protection of environmental corridors | Entire watershed | Preserve environmental corridor areas as recommended in county land use plan and regional natural areas and critical species habitat protection and management plan |
| Watershed Management Measures | Nonpoint source controls | Entire watershed | Reduce nonpoint source pollution loads by 25 percent |
| | | Urban areas of the watershed | Promote good urban housekeeping practices |
| | | New clustered developments | Develop stormwater management systems where appropriate densities exist |
| | | Developing areas of the watershed | Continue enforcement of existing ordinances; review ordinance for concurrency with proposed NR 152 |
| | | Rural areas of the watershed | Implement good soil conservation and nutrient management practices based upon detailed farm plans<br>Promote installation of best management practices, including streambank buffers using natural vegetation |
| | Onsite and public sewage disposal system management | Unsewered portions of the watershed | Consider development of an onsite sewage disposal system management program; promote sound maintenance practices and periodic inspections |
| | | Sewered portions of the watershed | WalCoMet, DLSD, and the incorporated municipalities to regularly review current facilities plan to continue to provide water-borne sewerage service to urban areas of the watershed |
| | Mound Road wetland | Jackson Creek subwatershed | Conduct periodic controlled burns of wetland vegetation to minimize occurrence of undesirable species<br>Modify site to encourage sheet flow through wetland<br>Modify sedimentation ponds to increase hydraulic capacity and reduce channelized flows |

## Table 45 (continued)

| Plan Element | Subelement | Location | Management Measures |
|---|---|---|---|
| Water Quality Management Measures | Water quality monitoring | Entire Lake | Continue participation in WDNR Self-Help TSI Monitoring Program |
| Water Quantity and Water Level Management Measures | Dam operations | Entire Lake | Continue manual operation of the outlet structure based upon storm events reported from the Elkhorn metropolitan area<br>Maintain outlet structure; monitor lake levels |
| Aquatic Plant Management | Aquatic plant monitoring | Entire Lake | Continue monitoring of aquatic plants on a three- to five-year basis; update or modify aquatic plant management measures accordingly |
| | Chemical treatment | Within 50 feet of the shoreline, and areas of nuisance growth | Limit use of selective chemicals to control Eurasian water milfoil around docks, purple loosestrife and reed canary grass in wetlands, and blue-green algae along shorelines<br>Undertake spring herbicide applications for control of Eurasian water milfoil (to minimize affects on native plants) |
| | | Eurasian water milfoil control | Control dense, nuisance areas of Eurasian water milfoil as necessary, using appropriate methods and techniques pursuant to WDNR guidelines |
| | | Algal control | Control "swimmer's itch" outbreaks as necessary |
| | Major channel harvesting | Boating access and recreation zones | Harvest aquatic plants as required, especially in the inlet and outlet areas of the Lake and southern embayments<br>Avoid disturbance of lake bottom during harvesting |
| | Minor channel harvesting | Fishing zones | Harvest fishing and shared boating access lanes<br>Avoid disturbance of ecologically valuable areas |
| | Shoreline maintenance | Lakeshore zones | Collect floating plant fragments from shoreland areas to minimize rooting of Eurasian water milfoil and deposition of organic materials in Lake |
| | Restriction of aquatic plant management activities | Habitat and fishing zones | Restrict harvesting in spring and autumn to avoid disturbances in fish breeding areas |
| Fisheries Management | Fish survey | Entire Lake | Continue to monitor fish populations through regular WDNR fishery surveys<br>Monitor rough fish populations in cooperation with WDNR |
| | Assess harvesting pressures | Entire Lake | Undertake an assessment of angling pressures with assistance of WDNR |
| | Refine fishery management program | Entire Lake | Utilize survey findings to refine fishery management strategy and request WDNR to set harvest and size limits accordingly<br>Assess stocking needs and manage fishery accordingly in cooperation with WDNR |

Table 45 (continued)

| Plan Element | Subelement | Location | Management Measures |
|---|---|---|---|
| Shoreline Maintenance | Maintain shoreland structures | Entire Lake | Maintain existing structures |
| | Install vegetative buffer strips and/or structures | Along lakeshore and tributary streams | Install and maintain erosion control measures |
| Recreational Use Management | Recreational boating access | Inlet and outlet areas and public access sites | Maintain navigational channel to permit recreational boating access to Lake |
| | Recreational boating safety | Entire Lake | Maintain recreational boating safety patrols on Lake |
| Informational and Educational Program | Public informational and educational programming | Entire watershed | Continue and refine public awareness and informational programming |

*Source: SEWRPC.*

areas, parking areas, and other areas of impervious surfaces, and replacing existing residences with much larger homes. Replacement of a pervious land surface with an impervious surface will increase the rate of stormwater runoff to the Lake; increase pollutant loadings on the Lake; and reduce groundwater recharge. While these effects can be moderated to some extent through structural stormwater management measures, there may be an adverse impact on the Lake from any redevelopment in the drainage area tributary to the Lake involving conversion to higher-density land uses. For this reason, maintenance of the historic low- and medium-density residential character of the shoreline of Delavan Lake to the maximum extent practical is recommended. To the extent practicable, it also is recommended that the Delavan Lake Sanitary District provide public sanitary sewerage services to those developments contiguous to their service area, as provided in the aforereferenced, adopted sanitary sewer service area plan as amended, and as recommended in the adopted county land use plan.

The existing zoning in the Delavan Lake drainage basin permits urban development generally on large, suburban-density lots over much of the remaining open lands other than within the environmental corridors and prime agricultural lands. As noted in Chapter III, shoreland zoning controls governing new construction are incorporated into the Walworth County zoning ordinances applicable to the Delavan Lake drainage area. Control of shoreland redevelopment, and the related intensification of use, however, is not specifically addressed in the existing zoning codes, although new construction is required to meet specific compliance and, for those lands situated outside the Delavan Lake Sanitary District service area, inspection requirements for onsite sewage disposal systems. It is recommended that the impact of future land use development on Delavan Lake be minimized through review and modification of the applicable zoning ordinance regulations and zoning district maps, as appropriate, to address the concerns noted. Consideration by Walworth County of incorporating elements of a lake classification system[7] into the shoreland zoning ordinance is suggested as one means of potentially addressing shoreland development and redevelopment concerns. Consequently, changes in the zoning ordinance could be recommended where necessary to minimize the areal extent of development by providing specific provisions for the clustering

[7]*See University of Wisconsin-Extension,* A Guide for County Lake Classification, *June 1999; the Wisconsin Legislature created a lake classification grant program under Chapter NR 191 of the* Wisconsin Administrative Code *during 1997. This cost-share program is administered by the Wisconsin Department of Natural Resources as part of the existing Lake Protection Grant Program, and is intended to further the degree of protection of lakeshore habitat within the state. Within the Southeastern Wisconsin Region, Washington County has adopted the concept of lake classification in their shoreland, wetland and floodplain zoning code, and Waukesha County is reviewing the basis for lake classification as a mechanism for lake protection in that county.*

of residential development on smaller lots. Clustering allows development while preserving portions of the open space on each property or group of properties considered for development.[8]

Wetland protection can be accomplished through land use regulation under one or more of the existing Federal, State, County, or local regulations, and through public land acquisition. Both measures are included in the recommended Delavan Lake management plan. Portions of the wetlands in the drainage area currently are in public ownership. In the vicinity of the Delavan Lake inlet, there are wetland areas owned by the Wisconsin Department of Natural Resources, at the northern extreme of the inlet, and by the Town of Delavan, north of Mound Road. As noted in Chapters IV and VII, the Mound Road wetland system was reclaimed from prior converted agricultural lands for lake protection purposes, as recommended in the amended Turtle Creek priority watershed plan, and currently serves to modify the timing of the delivery of the phosphorus load to the Lake, thereby moderating the biological response to the annual phosphorus load to the Lake. Other, nonpublicly owned wetland areas within the drainage area tributary to the Lake currently are largely protected through the U.S. Army Corps of Engineers Section 404 Permit Program, State shoreland zoning requirements, and local zoning ordinances. Nearly all the wetlands in the Delavan Lake drainage area are included within the environmental corridors delineated by the Regional Planning Commission, as noted in Chapter V. In this regard, implementation of the recommendations set forth in the adopted county land use plan would provide for the continued protection and preservation of these environmentally sensitive lands.

## WATERSHED MANAGEMENT MEASURES

The recommended watershed management measures are specifically aimed at reducing the water quality impacts on Delavan Lake from nonpoint sources of pollution within the tributary drainage area. These measures are set forth in the aforereferenced regional water quality management and priority watershed plans.

As indicated in Chapter IV, the only significant sources of phosphorus loading to the Lake that are subject to control are urban and rural nonpoint sources and onsite sewage disposal systems. Continued maintenance of those onsite sewage disposal systems within portions of the watershed not served by public sanitary sewerage services presents one opportunity for the management of nonpoint source contaminants, and is recommended. In addition, as noted above, extension of the public sanitary sewerage services provided by the Delavan Lake Sanitary District to properties within the planned urban and sewer service areas, as amended, is recommended.

Nonpoint source pollution control measures are recommended for the lands tributary to Delavan Lake, including the upstream tributary drainage area. While the nonpoint source pollution control measures implemented under the Turtle Creek Priority Watershed Program proved effective on a site-by-site basis, there was "no discernable watershedwide reduction" in nonpoint source pollutant loads reported by the Wisconsin Department of Natural Resources.[9] The regional water quality management plan recommends a reduction of about 25 percent in both urban and rural nonpoint sources, in addition to streambank erosion controls, construction site erosion controls, and, where appropriate, onsite sewage disposal system management. Such nonpoint source pollution controls within the drainage area tributary to Delavan Lake are recommended to be achieved through a combination of urban stormwater management, construction site erosion controls, and rural agricultural nonpoint controls. The implementation of the land management practices described below may be expected to result in an overall reduction of total phosphorus loadings to Delavan Lake from both urban and rural sources of about 25 percent. This level of reduction is a level of reduction that is considered to be the maximum practicable based upon the inventory findings and analyses conducted under this planning program.

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[8]*See SEWRPC Planning Guide No. 7,* Rural Cluster Development Guide, *December 1996.*

[9]*Wisconsin Department of Natural Resources Publication No. PUBL-WR-359 94,* Turtle Creek Priority Watershed Bioassessment Final Report, *1994.*

**Urban Nonpoint Source Controls**
The development of urban nonpoint source pollution abatement measures for the Delavan Lake areas are recommended to be the primary responsibility of Walworth County and the Delavan Lake Sanitary District in cooperation with the Cities of Delavan and Elkhorn, the Villages of Fontana-on-Geneva Lake and Williams Bay, and the Towns of Darien, Delavan, Geneva, Lafayette, Sharon, Sugar Creek, and Walworth. Accordingly, it is recommended that these governmental units continue to take an active role in promoting urban nonpoint source pollution abatement. Urban nonpoint source pollution abatement practices are required pursuant to Chapter 281 of the *Wisconsin Statutes*. Performance standards governing urban and nonagricultural nonpoint source pollution abatement practices for developed areas, and post-construction development and redevelopment including nonmunicipal property fertilization, are currently being developed by the Wisconsin Department of Natural Resources and are to be codified as Chapters NR 151 through NR 155 of the *Wisconsin Administrative Code.*

Recommended urban nonpoint pollution abatement measures are set forth in the priority watershed plan for the tributary drainage area to Delavan Lake, and include shoreline protection for streambanks and lakeshores, settling basins, leaf collection, street sweeping, and stormwater infiltration systems. It is further recommended that the Delavan Lake Sanitary District support the application of urban nonpoint source pollution abatement practices within its service area through appropriate informational programming. Urban nonpoint source pollution abatement projects would be undertaken by the local units of government within the drainage area tributary to Delavan Lake, working cooperatively with the Wisconsin Department of Natural Resources and Walworth County. Cost-share funding for specific urban nonpoint source pollution control practice may be available from the Wisconsin Department of Natural Resources through the Targeted Runoff Management (TRM) and Urban Nonpoint Source Pollution Abatement grant programs as proposed in Chapters NR 153 through NR 155 of the *Wisconsin Administrative Code.*

The most viable measures for controlling urban nonpoint sources of pollution are the application of good urban land management practices and urban good housekeeping practices within the drainage area tributary to Delavan Lake. Good housekeeping practices include appropriate fertilizer and pesticide use management, litter and pet waste controls, and leaf and yard waste management. The promotion of these measures will require an ongoing public informational and educational program, as provided for in the adopted county land and water resource management plan. Additionally, the public informational programming in those areas outside the sewered portion of the watershed should present information on onsite sewage disposal system management and on solid waste disposal.

Management of urban nonpoint source pollutants may also require the use of land management practices, such as provision of stormwater management and treatment facilities, such as detention basins. These measures are likely to be most effective in those urban areas with curb-and-gutter paving and moderate-density development where a practical means of concentrating the stormwater flow at treatment facilities exists. Elsewhere the use of grassed swales and other, less-engineered options to slow stormwater runoff and encourage deposition of pollutants is recommended. These areas lack opportunities for effectively utilizing structural measures due to the minimal nature of the development. Most of the development in the drainage area tributary to the Lake continues to have a rural character in which the drainage system utilizes roadside swales, as opposed to curb-and-gutter storm sewers. Notwithstanding, the use of structural stormwater management measures within urbanizing areas of the drainage area tributary to Delavan Lake is recommended for new, clustered developments where residential densities are such that collection and detention of stormwater is economically feasible. Application of these measures should be determined on a site-specific basis in accordance with individual cluster development plans.

Further, as an initial step in carrying out the recommended urban nonpoint source pollution control practices, it is recommended that fact sheets identifying specific residential land management measures beneficial to the water quality of Delavan Lake be distributed by the Town of Delavan to property owners in the watershed. These fact sheets are available from the University of Wisconsin-Extension and the Walworth County Land Conservation Department offices.

These measures are expected to achieve about a 25 percent reduction in phosphorus loading from urban nonpoint sources, or about a 24 percent reduction in phosphorus loading to the Lake from urban sources

**Developing Area Nonpoint Source Controls**
It is recommended that Walworth County, in association with the Town of Delavan, continue its efforts to control soil erosion from construction activities in accordance with existing ordinances. As noted in Chapters III and VII, Walworth County has adopted a construction site erosion control ordinance. Construction site erosion control practices are required pursuant to Chapter 281 of the *Wisconsin Statutes*. Enforcement of the existing Walworth County ordinance is generally considered effective. However, it is recommended that this ordinance be reviewed following adoption promulgation of Chapters NR 151 through 155 of the *Wisconsin Administrative Code* to ensure compliance with State requirements.[10]

Construction site erosion controls may include the use of silt fences, sedimentation basins, and rapid revegetation of disturbed areas; the control of "tracking" from the site; and careful planning of the construction sequence to minimize areas disturbed. Construction site erosion control is particularly important in minimizing the more severe localized short-term nutrient and sediment loadings into Delavan Lake that can result from uncontrolled construction sites. Performance standards governing construction site erosion control practices for new development and redevelopment are currently being developed by the Wisconsin Department of Natural Resources as Chapters NR 151 through NR 155 of the *Wisconsin Administrative Code.*

Construction site erosion control measures may be expected to reduce the phosphorus loading from that source by about 75 percent. Nevertheless, given the limited area of land under development at any given time, the annualized benefit of construction site erosion control is minimal. The cost for construction site erosion control will vary depending upon the amount of land under construction at any given time. Typical costs are $250 to $500 per acre under development.

**Rural Nonpoint Source Controls**
Performance standards governing agricultural nonpoint source pollution abatement practices for cropland and riparian soil erosion control and manure and nutrient management are currently being developed by the Wisconsin Department of Agriculture, Trade and Consumer Protection and the Wisconsin Department of Natural Resources as Chapters ATCP 50, and Chapters NR 151 through NR 155, respectively, of the *Wisconsin Administrative Code.*

The implementation of nonpoint source pollution controls in rural areas is recommended in the adopted county land and water resource management plan to be a cooperative effort between Walworth County and private landowners. Technical assistance can be provided by the U.S. Department of Agriculture Natural Resources Conservation Service; the Wisconsin Department of Agriculture, Trade and Consumer Protection; the Wisconsin Department of Commerce; and the Walworth County Land Conservation Department offices. As discussed previously, it is recommended that the Delavan Lake Sanitary District support the ongoing efforts of Walworth County, and the local units of government involved, in addressing nonpoint source pollution. State and Federal soil erosion control and water quality management programs, individually or in combination, can be used to achieve pollutant reduction goals. Such programs include the U.S. Department of Agriculture Environmental

[10]*Subchapter IV of the proposed* Wisconsin Administrative Code *Chapter NR 151 defines transportation facilities as including roads, public mass transit systems, highways, public airports, railroads, public trails, and other public transportation works. Performance standards governing these facilities include both the construction and operational phases of facility development.*

Quality Incentive Program (EQIP), and the Wisconsin Department of Natural Resources Nonpoint Source Pollution Abatement, Lake Management Planning Grant, Lake Protection Grant, and Stewardship Programs, as well as other local land acquisition initiatives. During 2001, the Walworth County Land Conservation Department secured an EQIP grant to partially support implementation of agricultural management practices in the Delavan Lake watershed.

Highly localized, detailed, and site-specific measures are required to effectively reduce soil loss and contaminant runoff in rural areas. These measures are best defined and implemented at the local level through the preparation of detailed farm conservation plans. Practices which are considered most applicable to the Delavan Lake area include conservation tillage, integrated nutrient and pesticide management, and pasture management. In addition, it is recommended that consideration be given to cropping patterns and crop rotation cycles, with attention to the specific topography, hydrology, and soil characteristics for each farm. In accordance with the recommendations set forth in the adopted County agricultural soil erosion control and land and water resource management plans, erosion control practices should achieve or better "tolerable" soil loss levels, or those levels which can be sustained without impairing the productivity of the soil. A reduction of about 25 percent in the nonpoint source loading from rural lands is recommended in the adopted regional water quality management plan. Application of rural conservation practices within agricultural areas of the drainage area tributary to Delavan Lake can be expected to reduce phosphorus loading from that source by up to about 50 percent, providing about a 48 percent reduction in phosphorus loading to the Lake from rural sources.

The cost of the needed measures will vary depending upon the details of the recommended farm conservation plans. To a large extent, the costs of agricultural land erosion controls may be expected to be incurred regardless, as a result of good farm management practices.

**Onsite and Public Sewage Disposal System Management**

As reported in Chapter IV, onsite sewage disposal systems are estimated to contribute 2 percent of the total phosphorus loading to Delavan Lake. As it is anticipated that portions of the drainage area tributary to Delavan Lake will remain served by onsite sewage disposal systems, it is recommended that Walworth County, in cooperation with the Town of Delavan, assume the lead in providing the public informational and educational programs to encourage affected property owners to have the existing onsite systems inspected and any needed remediation measures undertaken, as appropriate. Homeowners should be advised of the rules and regulations governing, and the limitations of, onsite sewage disposal systems, and should be encouraged to undertake preventive maintenance programs, especially of those older systems not yet subject to the inspection requirements of the County ordinance. The cost of this measure is included as part of the cost for the public informational and educational measures and is provided through the operating budget of the County. The costs of a basic annual inspection and maintenance service typically are $100 to $200, but it can be higher for more extensive programs.

For those portions of the drainage area tributary to Delavan Lake served by public sanitary sewerage systems, it is recommended that the Delavan Lake Sanitary District, in cooperation with the Town of Delavan, assume the lead in providing the public informational and educational programs to encourage affected property owners to use their sewerage systems appropriately and wisely. In an analogous recommendation, stenciling of storm drains and related informational programming encourages District residents to dispose of waste products safely, avoiding discharge directly to the surface waters or indirectly through the wastewater treatment works to the environment.

**Mound Road Wetland**

As shown in Chapter IV, the Mound Road wetland system represents an important element of the current lake management program. However, periodic maintenance of the wetland system to ensure sheet flow within the wetland, prevention of channelization, and efficient pollutant removal is required. Based upon a review of the functioning of this system conducted by Earth Tech, Inc., restoration of the sediment retention ponds on the northern and eastern branches of Jackson Creek is required.[11] Additional interventions to minimize channelized flows would also be desirable. These modifications would enhance the character of the wetland as a deep water marsh. In addition, periodic inspection of the wetland to limit the growth of nonnative, invasive wetland plant species, such as purple loosestrife and reed canary grass, is recommended. Use of controlled burns and other management measures are essential elements in the management of the wetland, and it is recommended that the timing of these management actions be such as to minimize the potential export of nutrients from the wetland prior to the summer growing season, and wildlife impacts. Therefore, controlled burns should be conducted during autumn. Other vegetation management measures, including control of nonnative species by cutting, mowing or hand-pulling, as well as planting of more desirable species, may be required to be conducted on an annual basis. Maintenance of the sedimentation basins is anticipated to be required approximately every 10 years. The cost of restoring the functioning of the sedimentation ponds and establishing sheet flows through the wetlands is estimated to be about $150,000.

## IN-LAKE MANAGEMENT MEASURES

The recommended in-lake management measures for Delavan Lake are summarized in Table 45 and are graphically summarized on Map 21. The major recommendations include water quality monitoring, aquatic plant management, fisheries management and habitat protection, shoreline protection, recreational use zoning, and public informational and educational programming.

### Water Quality Monitoring and Management Measures

Continued water quality monitoring of Delavan Lake is recommended. Continued enrollment of one or more Delavan Lake Sanitary District staff, or other lake residents, as Wisconsin Department of Natural Resources Self-Help Monitoring Program volunteers is recommended. In addition, participation in the expanded or Trophic State Index (TSI) Self-Help Monitoring Program, measuring nutrients, chlorophyll-*a*, dissolved oxygen, and temperature, is recommended. Such monitoring should be conducted five times per year at the same location that is currently being used by the U.S. Geological Survey in the deep water area of the Lake. Ongoing U.S. Geological Survey monitoring is anticipated.

Water quality management actions are inherent in the nonpoint source pollution abatement measures set forth above. Reductions in pollutant and nutrient loadings from the drainage area tributary to Delavan Lake are considered to be the most effective means of achieving and maintaining the Lake in a meso-eutrophic condition. Notwithstanding, a further alum treatment of the Lake to limit future internal loading to the Lake from the lake sediments could be considered in the longer term, subject to control of external nutrient sources to the fullest extent practicable. Conduct of an alum treatment of the Lake in the near term is not recommended.

### Water Quantity and Water Level Monitoring and Management Measures

Maintenance of the water levels in Delavan Lake within the minimum and maximum levels established under the operating permit for the dam impounding the Lake is recommended, to the extent practicable. Manual operation of the gates controlling the water level appears to provide an adequate degree of water level control. It is recommended that the dam operators maintain a record of lake levels, based upon measurements taken from the staff gauge located at the dam wall. Daily readings are suggested. Notwithstanding, continued discharges of water to meet downstream fisheries management requirements are also recommended, pursuant to Wisconsin Department of Natural Resources requirements. To achieve this recommended degree of water level control, it is recommended that the dam structure and appurtenances be maintained, subject to Wisconsin Department of Natural Resources inspection requirements. Specifically, it is recommended that the Town of Delavan work cooperatively

[11] *As of May 2001, the Town of Delavan was applying for Chapter NR 191 Lake Protection Grant funds for the purpose of restoring the functioning of the Mound Road wetland system. Included within this project was provision for ongoing, "before and after" monitoring of the wetland. The recommended project is described in the project description appended hereto as Appendix C.*

with landowners of the berm adjacent to the concrete structure to minimize the seepage through the berm due, in part, to muskrat burrows.

Limited dredging within the Lake basin for navigational purposes is recommended. However, sediment removal is not considered to be a viable management alternative for nutrient management, and large-scale dredging of the Lake is not recommended. Maintenance of navigational access should be focused on the creation of recreational boating access channels, shown as Zones A and T on Map 21.

**Aquatic Plant Monitoring and Management Measures**

It is recommended that aquatic macrophyte surveys of the Lake be conducted at three- to five-year intervals, depending upon the observed degree of change in the plant communities in the Lake, and the aquatic plant management program on Delavan Lake updated or modified as necessary. Information on the aquatic plant communities should be recorded as an ongoing activity coincident with the aquatic plant management activities conducted by the Town of Delavan and Delavan Lake Sanitary District. Such records should include descriptions of: major areas of nuisance plant growth; areas harvested and/or chemically treated; species harvested and amounts of plant material removed from Lake; and species and approximate numbers of fish and other wildlife caught in the harvest. A daily harvester log containing this information should be maintained. This information, in conjunction with the recommended aquatic macrophyte surveys, will allow long-term evaluation of the effectiveness of the aquatic plant control program such that adjustments can be made in the program to maximize its benefit.

An aquatic macrophyte management plan consistent with Chapters NR 103, NR 107, and NR 109 of the *Wisconsin Administrative Code* has been prepared for the Lake by Aron & Associates, consultants to the Town of Delavan and to the Delavan Lake Sanitary District. This plan is incorporated herein by reference. However, modifications of the existing aquatic plant management program are recommended to enhance the use of the Delavan Lake while maintaining the quality and diversity of the biological communities. The following recommendations are made:

1. Mechanical harvesting is recommended as the primary management method. As indicated in Chapter VII, in the long-term, this will help to maintain good water quality conditions by removing plant materials which are currently contributing to an accumulation of decomposing vegetation and the associated nutrient recycling. The harvesting should be carried out by the Delavan Lake Sanitary District using the existing harvesters and transport equipment owned by the Town of Delavan.

2. It is recommended that shared access and boating transit lanes be harvested, rather than clear-cutting large open areas, to minimize the potential detrimental effects on the fish and invertebrate communities. Directing boat traffic through these common lanes should delay the regrowth of vegetation in these areas.

3. Surface harvesting of nonnative aquatic plants, such as the Eurasian water milfoil, cutting to a depth of approximately two feet, is recommended. This should provide a competitive advantage to the low-growing native plants present in the Lake. By not disturbing the low-growing species, which generally grow within one to two feet of the lake bottom and in relatively low densities, leaving the root stocks and stems of all cut plants in place, the resuspension of sediments in Delavan Lake will be minimized. Furthermore, cutting should be focused on boating lanes placed around the perimeter of the main lake basin.

4. It is recommended that the use of chemical herbicides be limited to controlling nuisance growth of exotic species in shallow water around docks and piers, where the harvester is unable to reach. Such use should be evaluated annually and the herbicide applied only on an as needed basis. Only herbicides that selectively control milfoil, such as 2,4-D, should be used.

5. It is recommended that chemical applications, if required, be made in early spring to maximize their effectiveness on nonnative plant species, to minimize their impacts on native plant species, and to act

as a preventative measure to reduce the development of nuisance conditions. The widespread use of algicides, such as Cutrine Plus, is not recommended, although algicides could be used in limited areas along the shoreline to control blue-green algae, such as *Synechosystis* sp., *Anabena* sp., and *Aphanizomenon* sp.

6. The control of rooted vegetation between adjacent piers is recommended to be left to the riparian owners concerned, as it is time consuming and costly for the mechanical harvester to maneuver between piers and boats, and such maneuvering may entail liability for damage to boats and piers. The conduct of a pierhead pick up service for manually harvested aquatic plants is recommended. Alternatively, riparian residents should be encouraged to compost accumulated plant materials. Owners should be provided with appropriate informational materials to assist them with composting and other shoreline management alternatives.

7. It is recommended that ecologically valuable areas be excluded from aquatic plant management activities, especially during fish spawning seasons in early summer and autumn.

8. The incorporation by the Delavan Lake Sanitary District and Town of Delavan of an overall public educational program into the aquatic plant management program is recommended. Information to be disseminated should include information on the types of aquatic plants found in Delavan Lake; on the value of and the impacts of these plants on water quality, fish, and on wildlife; and on alternative methods for controlling existing nuisance plants, including the positive and negative aspects of each method. In addition, it is recommended that the Delavan Lake Sanitary District and Town of Delavan obtain informational brochures regarding shoreline maintenance, manual harvesting of aquatic plants using hand held specialty rakes, and composting of aquatic plants, as part of the riparian owner informational and educational program.

The use of biological controls, such as the milfoil weevil, is not recommended at this time. However, reconsideration of the use of biological control agents remains subject to the outcome of the statewide assessment program currently being conducted by the Wisconsin Department of Natural Resources. To the extent that biological control agents are proven to be successful in limiting the extent and distribution of nonnative aquatic and wetland plants, it is recommended that the use of these agents be determined as part of the recommended process of aquatic plant management plan refinement.

Notwithstanding, the recommended plan partitions Delavan Lake into zones for aquatic plant management, with control measures in each zone designed to optimize desired recreational opportunities and to protect the aquatic resources. The recommended aquatic plant control zones are shown on Map 21 and the controls recommended for each zone are described in Table 46. It is recommended that a single agency, the Delavan Lake Sanitary District, coordinate, manage, and conduct the aquatic plant management program on Delavan Lake. Implementation of such an action will enhance consistency in application of recommended management measures and better enable the Delavan Lake community to comply with the necessary regulatory permits for harvesting, planting, and chemical control application on the Lake.

The recommended aquatic plant management plan represents an expansion of the ongoing aquatic plant management program conducted by the Town of Delavan and Delavan Lake Sanitary District. Implementation of this plan would entail a capital cost of about $150,000, the majority of which would be required for the eventual replacement of equipment and an annual operation and maintenance cost of about $50,000.

**Fisheries Monitoring and Management Measures**

The aquatic plant management strategy set forth above recognizes the importance of fishing as a recreational use of Delavan Lake. Additionally, the strategy recognizes the importance of the fish community as the change agent responsible for maintaining good water clarity within the Lake. For these reasons, the protection and preservation of fish breeding habitat, especially in the marsh-like areas along the northern shores of the Lake, is integral to the aquatic plant management strategy. Any interventions in these areas should be confined to the navigation access channels, shown as Zone A on Map 21.

Table 46

RECOMMENDED AQUATIC PLANT MANAGEMENT TREATMENTS FOR DELAVAN LAKE

| Zone and Priority | Recommended Aquatic Plant Management Plan |
|---|---|
| Access: Zone A | Harvest channels, approximately 50 feet wide, to provide boating access, via a pier lane connecting the narrow channels to common access lanes, to the main body of Delavan Lake<br>Chemical use, if required, should be restricted to pier and dock areas within 150 feet from shore in this area |
| Boating/Recreational: Zone B | Harvest nuisance aquatic macrophyte growth within 150 feet of the shoreline, or within 30 feet of pierheads and docks, to provide maximum opportunities for boating, fishing, and limited swimming. Additional 50-foot-wide shared-access channels should extend to the center of the Lake. Harvesting of an access lane connecting the boat launching site on the northern shore of the Lake to the main body of the Lake should be undertaken<br>No harvesting or in-lake chemical application should be conducted prior to mid-June of each year. Some limited harvesting, especially the top-cutting and/or herbicide application, may be required for the control of Eurasian water milfoil or curly-leaf pondweed thereafter<br>The entire area may not require intensive management. Harvesting should be concentrated in areas of abundant macrophyte growth. Patterns of harvesting will vary yearly, depending on macrophyte abundance<br>Chemical use, if required, would be restricted to pier and dock areas and would extend more than 150 feet from shore, but not more than 300 feet from shore |
| Habitat: Zone H | This zone and adjacent lands would be managed for fish habitat. Portions of the Lake should be preserved as a high-quality habitat area<br>No harvesting or in-lake chemical application should be conducted prior to mid-June of each year. Some limited harvesting may be required for the control of Eurasian water milfoil or curly-leaf pondweed thereafter<br>Debris and litter cleanup would be needed in some adjacent areas; the immediate shoreline would be preserved in natural, open use to the extent possible |
| Littoral: Zone L | Maintain shoreline protection structures as necessary. Where appropriate, install vegetated buffers both landward and lakeward of the high water mark to promote fish and wildlife habitat<br>Manually harvest around piers and docks to allow boat access<br>Chemical use, if required, would be restricted to pier and dock areas and would not extend more than 150 feet from shore |
| Open Water: Zone O | This zone includes those areas of the Lake having a water depth greater than 20 feet which do not have excessive macrophyte growth<br>Harvesting is not anticipated as being necessary in this area of deeper water<br>No chemicals should be used |
| Transit: Zone T | Harvest a 50-foot-wide channel in the central portion of the bays to connect to channels perpendicular to shore to allow access to main body of the Lake<br>Chemical use, if required, should be restricted to nuisance Eurasian water milfoil and curly-leaf pondweed control |

*Source: SEWRPC.*

Two specific actions are recommended with respect to fisheries management: the conduct of ongoing fisheries surveys and the assessment of angling pressures. The ongoing fishery survey is recommended to be conducted by the Wisconsin Department of Natural Resources with the following objectives:

1. To identify changes in fish species composition that may have taken place in the Lake since previous surveys conducted by the Wisconsin Department of Natural Resources;

2. To permit any changes in fish populations, species composition and condition factors to be related to such known interventions as stocking programs, water pollution control activities, and aquatic plant management programs, and to set size and bag limits for selected game fish species harvested from the Lake;

3. To determine the survival rates and success of stocked fishes introduced into Delavan Lake by the Wisconsin Department of Natural Resources, and to permit an assessment of fish stocking needs and the ongoing fisheries management program;

4. To refine and update information on fish spawning areas, breeding success, and survival rates; and

5. To identify any disturbance of the Lake ecosystem by rough fish populations.

The second recommended action relative to a fishery management program is an assessment of angling pressures on the Lake. This assessment should:

1. Provide data to determine the intensity of public use of the Delavan Lake fishery through creel surveys, citizen reporting activities, and evaluation of the fish survey data; and

2. Provide data to assess harvesting pressures on various fish species on the Lake.

While the acquisition of fisheries data could be undertaken by trained volunteers, the assessment of fishing pressures is recommended to be carried out by the Wisconsin Department of Natural Resources. These actions will provide a quantitative basis for refining and managing the fisheries on Delavan Lake. A regular review and updating of the current fisheries management program, based upon the foregoing surveys and assessments, is recommended, with a view toward maintaining the effectiveness of the whole lake biomanipulation to the fullest extent possible.

***Habitat Protection***

The habitat protection measures recommended for Delavan Lake are, in part, provided within the recommended aquatic plant management program, as noted above. The aquatic plant management plan is designed to provide for habitat protection by avoiding disturbances in fish breeding areas during spring and autumn, minimizing the use of aquatic plant herbicides, and maintaining stands of native aquatic plants. Use of vegetation for shoreline protection is also recommended wherever practicable, as set forth below.

In addition, it is recommended that environmentally sensitive lands, including wetlands along the lakeshore, be preserved and protected. In particular, this recommendation extends to the maintenance of the wetlands located in the northern portion of the lake basin, adjacent to the recreational boating access lanes shown as Zones A, B, and T on Map 21. This recommendation is consistent with the wetland protection and shoreland buffer development goals set forth in the adopted county land and water resource management plan.

**Shoreline Maintenance**

Most of the Delavan Lake shoreline was found to be in stable condition, with only isolated areas of erosion being identified at specific locations along the shore. Potential shoreland protection measures were described in Chapter VII. Adoption of the vegetated buffer strip method is recommended for use in lakeshore areas wherever practical in order to maintain habitat value and the natural ambience of the lakeshore, as set forth in the adopted county land and water resource management plan. However, in some cases, the steep shoreline grade and/or composition of the shoreline may require structural measures to prevent erosion. In such cases, use of appropriate structural measures, such as riprap, is recommended.

Continued maintenance of existing shoreline protection structures is also recommended. Replacement of structural measures with vegetative shoreline protection measures is recommended where appropriate and practicable.

**Recreational Use Management**
Continued provision of public recreational boating access opportunities consistent with the standards set forth in Chapter NR 1 of the *Wisconsin Administrative Code*, is recommended. Further, ongoing enforcement of recreational boating regulations to minimize recreational use conflicts is also recommended. The boating regulation ordinance adopted by the Town of Delavan forms the legal basis necessary to carry out such actions, with enforcement remaining a function of the Town of Delavan Police Department.

## PUBLIC INFORMATIONAL AND EDUCATIONAL PROGRAMS

It is recommended that the Town of Delavan, in association with the Delavan Lake Sanitary District and Delavan Lake Improvement Association, Inc., assume the lead in the development of a public informational and educational program dealing with various lake management related topics including: water quality management, land management, aquatic plant management, fisheries management, and recreational use. The Delavan Lake Sanitary District newsletter can provide a medium for the conduct of such a program. In addition, it is recommended that "welcome packets" be prepared and distributed to new homeowners. Such packets would include a variety of lake management educational materials.

Educational and informational brochures and pamphlets, of interest to homeowners and supportive of the existing recreational use and shoreland zoning regulations, are available from the Wisconsin Department of Natural Resources and the University of Wisconsin-Extension. These materials cover topics such as beneficial lawn care practices and household chemical use. Such brochures should be provided to homeowners through local media, direct distribution, or targeted library and civic center displays. Such distribution can also be integrated into ongoing, larger-scale activities, such as lakeside litter collections, which can reinforce anti-littering campaigns, recycling drives, and similar environmental protection activities. The cost for conducting this program is estimated to be $1,200 per year.

## ANCILLARY PLAN RECOMMENDATIONS

**Institutional Arrangements**
The Town of Delavan Lake Committee is the principal organizational mechanism whereby the lake management program conducted by the Town is delivered. This Committee works in close cooperation with the Delavan Lake Sanitary District, the agency that is largely responsible for the day-to-day conduct of the lake management program. The Sanitary District is assisted in specific functions by the Town of Delavan law enforcement, public works, and parks department staff. The Committee has broadly based representation, including representatives of the Delavan Lake Improvement Association, the Town of Delavan Board, and the City of Delavan. In general, this institutional arrangement, with support from Federal, State, regional, and county governmental agencies provides an exceptional basis for the conduct of lake management activities on Delavan Lake. Notwithstanding, given the importance of the Jackson Creek watershed to the nutrient loading to the Lake, inclusion of an additional representative from the City of Elkhorn is recommended to be considered. Such a representative would encourage closer cooperation between the City of Elkhorn and Town of Delavan in the management of the Jackson Creek watershed and protection of Delavan Lake. Further, inclusion of representation from the City of Elkhorn would encourage the City of Elkhorn to transfer and apply the lessons learned during the conduct of the Honey and Sugar Creeks Priority Watershed Program to the southern portions of the City draining to Delavan Lake. Such actions would benefit not only Delavan Lake, but also the residents of the City and Town living along Jackson Creek.

## PLAN IMPLEMENTATION AND COSTS

The actions recommended in this plan largely represent an extension of ongoing actions being carried out by the Delavan Lake Sanitary District and the Town of Delavan. The recommended plan introduces few new elements, although some of the plan recommendations represent refinements of current programs. Generally, the fisheries and aquatic plant management practices, such as monitoring, stocking/harvesting, and public awareness programming currently implemented by the Town of Delavan in association with the Delavan Lake Sanitary District are recommended to be continued. Some aspects of these programs lend themselves to citizen involvement through volunteer-based creel surveys, participation in the Wisconsin Department of Natural Resources Self-Help Monitoring Program, and identification with environmentally sound owner-based land management activities. It is recommended that the Town assume the lead in the promotion of such citizen actions, with a view toward building community commitment and involvement. Assistance is generally available from the Wisconsin Department of Natural Resources, the County University of Wisconsin-Extension office, and the Southeastern Wisconsin Regional Planning Commission. The recommended management agency responsibilities for watershed and lake management are set forth in Table 47.

The major costs relating to the management practices herein recommended relate to the eventual replacement of aquatic plant harvesting equipment. Implementation of the recommended plan would entail a capital expenditure of about $150,000 and an annual operations and maintenance expenditure of about $50,000, including existing expenditures, as shown in Table 48. This is consistent with the current annual operation and maintenance budgets of the Town and Sanitary District associated with the management and monitoring of Delavan Lake. A portion of the capital cost of the aquatic plant harvesting equipment could be met with a cost-share grant from the Wisconsin Waterways Commission. The other major expense associated with the recommended plan is the ongoing management and maintenance of the Mound Road wetland. The suggested lead agency or agencies for initiating program-related activities, by plan element, and possible funding sources where such are available, are also summarized in Table 48.

## SUMMARY

Delavan Lake is a valuable natural resource in the Southeastern Wisconsin Region. Increases in population, urbanization, income, leisure time, and individual mobility forecast for the Region may be expected to result in additional pressure for development in the drainage area tributary to the Lake and for water-based recreation on the Lake. Adoption and administration of an effective lake management program for Delavan Lake, based upon the recommendations set forth herein, will provide the water quality protection needed to maintain conditions in Delavan Lake suitable for recreational use and for fish and other aquatic life.

## Table 47

## LOCAL GOVERNMENTAL MANAGEMENT AGENCY RESPONSIBILITIES FOR PLAN IMPLEMENTATION

| Plan Element | Subelement | Agency: Walworth County | Town of Delavan | Delavan Lake Sanitary District | Municipalities within Watershed[a] | Wisconsin Department of Natural Resources |
|---|---|---|---|---|---|---|
| Land Use Planning and Zoning | Land use development planning | X | X | - - | X | - - |
| | Zoning review | X | X | X | X | - - |
| | Density management | X | X | - - | X | - - |
| | Protection of primary environmental corridors | X | X | - - | X | X |
| Watershed Management Measures | Urban nonpoint source controls | X | X | X | X | X |
| | Developing area nonpoint source controls | X | X | - - | X | - - |
| | Rural nonpoint source controls | X | X | - - | - - | WDATCP |
| | Onsite and public sewage disposal system management | X | X | X[b] | X[b] | - - |
| | Mound Road wetland | - - | X | - - | - - | X |
| Water Quality Management Measures | Water quality monitoring | - - | X | X | - - | X |
| Water Quantity and Water Level Management Measures | Outlet control structure | - - | - - | X | - - | X |
| Aquatic Plant Management | Comprehensive plan refinement | - - | X | X | - - | X[c] |
| | Chemical treatment | - - | X | X | - - | X[d] |
| | Major and minor channel harvesting | - - | X | X | - - | - - |
| | Shoreline maintenance | X | X | X | - - | - - |
| Fisheries Management | Fish survey | - - | X | X | - - | X |
| | Assess harvesting pressures | - - | - - | X | - - | X |
| | Refine fishery management program | - - | X | X | - - | X |
| Shoreline Maintenance | Maintain structures | - - | - - | X[b] | - - | - - |
| | Install vegetative buffer strips and/or structures | X | - - | X[b] | - - | X[d] |
| Recreational Use Management | Recreational boating access | - - | X | - - | X | X |
| | Recreational boating safety | - - | X | - - | X | X |
| Informational and Educational Program | Public informational and educational programming | X[e] | X[e] | X | X | X |

[a] *Municipalities include the Cities of Delavan and Elkhorn, the Towns of Darien, Delavan, Geneva, Lafayette, Sharon, Sugar Creek, and Walworth, and the Villages of Fontana-on-Geneva Lake and Williams Bay in Walworth County.*

[b] *Resident responsibility; the District and municipalities can provide guidance and facilitate technical support.*

[c] *The Wisconsin Department of Natural Resources reviews aquatic plant management plans, shoreline protection structure designs, and boating ordinances, and revisions thereof, for compliance with State rules; county, state and/or federal permits may also be required.*

[d] *This activity requires a Wisconsin Department of Natural Resources permit.*

[e] *County assistance may be provided through Walworth County Land Conservation, and the University of Wisconsin-Extension.*

*Source: SEWRPC.*

Table 48

## ESTIMATED COST OF RECOMMENDED LAKE MANAGEMENT MEASURES FOR DELAVAN LAKE

| Plan Element | Subelement | Estimated Cost[a] Capital | Estimated Cost[a] Average Annual Operation and Maintenance | Potential Funding Sources[b] |
|---|---|---|---|---|
| Land Use Planning and Zoning Measures | Land use development planning | - -[c] | $1,000[c] | Walworth County |
| | Zoning ordinance review and possible refinement | - -[c] | $1,000[c] | WDNR, Walworth County, Municipalities, DLSD |
| | Density management | - -[c] | $1,000[c] | Walworth County, Municipalities |
| | Protection of environmental corridors | - - | - - | WDNR, Walworth County, Municipalities |
| Watershed Management Measures | Urban nonpoint source controls | - -[d] | - -[d] | Walworth County, Municipalities, DLSD, WDNR, individuals |
| | Developing areas nonpoint source controls | $250 per acre[e] | $25 per acre[e] | Walworth County, Municipalities, Private firms, individuals |
| | Rural nonpoint source controls | - -[d,f] | - -[d,f] | Walworth County, USDA, WDNR, WDATCP, individuals |
| | Onsite sewage disposal system management | - - | $100 per year | Walworth County, Municipalities, individuals |
| | Public sewage disposal system management | $4,700 plus local sewer and connection costs | $2.00 per 1,000 gallons | DLSD, individuals, Municipalities |
| | Mound Road wetland | $150,000 | - - | Town of Delavan, WDNR |
| Water Quality Management Measures | Water quality monitoring | $600 initial equipment cost (Self-Help TSI) | $22,200[g] | WDNR and DLSD, USGS, Town of Delavan |
| | Alum treatment[h] | - - | $300 per acre | Town of Delavan, WDNR |
| Water Quantity and Water Level Management Measures | Dam operations | - - | - - | WDNR, Town of Delavan, DLSD |
| Aquatic Plant Management | Comprehensive plan refinement | - - | $1,000 | DLSD, Town of Delavan, WDNR |
| | Chemical treatment | - - | $40,000 | Town of Delavan, DLSD |
| | Major and minor channel harvesting | $150,000[i] | $50,000 | Town of Delavan, WDNR (Waterways Commission) |
| | Shoreline maintenance | $7.50 to $36 per linear foot | - - | Individuals |
| Fisheries Management | Fish survey | - -[g] | $16,000[g] | WDNR |
| | Assess harvesting pressures | - -[j] | - -[j] | WDNR |
| | Refine fishery management program | - -[j] | $13,000[j] | WDNR |

**Table 48 (continued)**

| Plan Element | Subelement | Estimated Cost[a] Capital | Estimated Cost[a] Average Annual Operation and Maintenance | Potential Funding Sources[b] |
|---|---|---|---|---|
| Shoreline Maintenance | Maintain shoreland structures | - - | - - | Individuals |
| | Install vegetative buffer strips and/or structures | - - | - - | Individuals, Walworth County |
| Recreational Use Management | Recreational boating access | - - | Dredging costs to provide navigational access estimated at $15 per cubic yard | City and Town of Delavan, WDNR |
| | Recreational boating safety | - - | - - | City and Town of Delavan, WDNR |
| Informational and Educational Program | Public informational and educational programming | - - | $1,200 | UWEX, WDNR, DLSD, Town of Delavan |
| Total | - - | $300,600[k] | $146,500[k] | - - |

[a]*All costs expressed in December 2001 dollars.*

[b]*Unless otherwise specified, USDA is the U.S. Department of Agriculture, USGS is the U.S. Geological Survey, WDNR is the Wisconsin Department of Natural Resources, DLSD is the Delavan Lake Sanitary District and UWEX is the University of Wisconsin-Extension. Municipalities, unless specified, include the Cities of Delavan and Elkhorn, Villages of Fontana-on-Geneva Lake and Williams Bay, and the Towns of Darien, Delavan, Geneva, Lafayette, Sharon, Sugar Creek, and Walworth. Individuals and private firms include riparian landowners and householders within the drainage area tributary to Delavan Lake, as well as commercial enterprises offering specific services to landowners and householders.*

[c]*Cost-share assistance may be available for ordinance review, revision, and writing under the NR 191 Lake Protection Grant Program. Indicative costs for periodic ordinance development and review are shown, but may not need to be recurring expenditures.*

[d]*Portion of costs included under public informational and educational program. Cost-share assistance may be available under the Targeted Runoff Management (TRM) and Urban Nonpoint Source Grant Programs, the Federal Environmental Quality Incentives Program (EQIP), and various local, county and state water quality improvement and protection initiatives. Cost of structural measures will vary depending upon stormwater management plan.*

[e]*Cost varies with amount of land under development in any given year.*

[f]*Costs vary and will depend upon preparation of individual farm plans.*

[g]*The WDNR Self-Help Monitoring Program and proposed creel survey involves no ongoing costs, but do entail a time commitment from the volunteer, and an initial equipment charge of about $600, potentially cost-sharable under the Chapter NR 190 Lake Management Planning Grant Program. Participation in the U.S. Geological Survey Trophic State Index monitoring program includes laboratory charges and other fees shown as annual operational costs; Federal cost-share incentives may be available to participants in the monitoring program. Similarly, participation in the Wisconsin Department of Natural Resources fisheries management program may involve additional charges; cost-share funds may be available under the NR 190 Lake Management Planning Grant Program.*

[h]*Recommended as a potential future lake management action following implementation of nonpoint source pollution controls to the fullest extent practicable.*

[i]*Costs are based on the assumption that the existing harvester and ancillary equipment may eventually need replacement; cost-share assistance for harvester purchase may be available from the Wisconsin Waterways Commission Recreational Boating Facilities Grant Program.*

[j]*Involves little or no additional cost if undertaken as part of a comprehensive fishery survey.*

[k]*Excludes unit costs which are dependent upon the degree of implementation of various elements; for example, the costs of erosion control practices are incurred only if development activities take place.*

*Source: SEWRPC.*

# APPENDICES

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## Appendix A

# SUMMARY MINUTES OF THE DELAVAN LAKE COMMITTEE OF EXPERTS MEETING

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**SUMMARY MINUTES OF A MEETING OF THE DELAVAN LAKE COMMITTEE OF EXPERTS CONVENED TO IDENTIFY A SET OF MANAGEMENT MEASURES TO ACHIEVE THE MAINTENANCE OF FISHABLE/SWIMMABLE CONDITIONS WITHIN DELAVAN LAKE**
**February 23, 2000**

The meeting of the Delavan Lake Committee of Experts was convened at the offices of the Delavan Lake Sanitary District, CTH F, Delavan, Wisconsin at 10:00 a.m.

In attendance at the meeting were the following individuals:

| Name | Representing |
|---|---|
| Fay U. Amerson | Walworth County Department of Land Conservation |
| Joseph E. Boxhorn | Southeastern Wisconsin Regional Planning Commission |
| John Ferris | Earth Tech, Inc. |
| Paul Garrison | Wisconsin Department of Natural Resources, Bureau of Research |
| Jerry Goddard | U.S. Geological Survey |
| Ruth C. Johnson | Wisconsin Department of Natural Resources, Southeast Region |
| Robert Leff | Town of Delavan Lake Committee |
| Kevin MacKinnon | Delavan Lake Sanitary District |
| John Panuska | Wisconsin Department of Natural Resources |
| Dale Robertson | U.S. Geological Survey |
| Carroll Schaal | Wisconsin Department of Natural Resources, Lakes Partnership |
| Thomas M. Slawski | Southeastern Wisconsin Regional Planning Commission |
| Brian Smetana | Walworth County Department of Land Conservation |
| Jeffrey A. Thornton | Southeastern Wisconsin Regional Planning Commission |
| Scott Toshner | Wisconsin Department of Natural Resources, Southeast Region |
| Robert S. Wakeman | Wisconsin Department of Natural Resources, Southeast Region |
| Douglas Welch | Wisconsin Department of Natural Resources, Southeast Region |
| June Yantis | Town of Delavan Lake Committee |

Following introductions, the Committee appointed Dr. Thornton to be moderator and Ms. Yantis as timekeeper. Ms. Yantis then welcomed the Committee on behalf of the Town of Delavan Lake Committee and expressed the Town's appreciation for the efforts be to undertaken during the course of the day. Mr. MacKinnon then welcomed the Committee to the offices of the Delavan Lake Sanitary District (DLSD) and reviewed the layout of the facilities.

The Committee then approved the Agenda, attached hereto as Exhibit A, with one modification. Mr. MacKinnon reported that the restaurant had indicated that they would prefer to provide luncheon service at 12:30 p.m. rather than at 11:45 a.m. Therefore, the nutrient loading discussion indicated under Technical discussion II would be conducted during the morning session.

Dr. Thornton then introduced the objective of the meeting as identifying a set of management measures to achieve the maintenance of fishable/swimmable conditions within Delavan Lake, based upon ensuring the continuity of the program of nutrient reduction and biological manipulation begun in 1992, and including other such measures to be determined in the context of a cost-effective, long-term, comprehensive lake management plan. The goals of the nutrient reduction and biomanipulation program, established in 1989, were reviewed and were as follows:

1. Immediate and long-term reduction of nutrient levels in the Lake, with a target total phosphorus concentration of 26.4 micrograms per liter (μg/l) phosphorus,

2. Improve water quality, with a target summer Secchi-disk transparency of greater than or equal to 1.5 meters,

3. Reduce nuisance blooms of algae, and

4. Maintain the long-term quality of the sport fishery, dominated by northern pike and walleyed pike, but containing all native fish originally present in the Lake.

The moderator posed the question: to what extent have these goals been achieved and to what extent are they still relevant and realistic? The following points were brought out during the ensuing discussion:

- It was agreed that the goal of a total phosphorus concentration of about of 26.4 μg/l was overly optimistic, and that the actual goal established for the Delavan Lake restoration project was refined upwards to about 35 μg/l as a more correct target level. It was noted that in-lake phosphorus concentrations currently are not meeting the goal. Total phosphorus concentrations observed in the Lake average 70 μg/l during spring, 40 μg/l during summer, and 90 μg/l during the fall. Phosphorus concentrations will probably remain higher than the targeted levels, and generally exceed 40 μg/l phosphorus, except possibly during the period of summer stratification.

- Chlorophyll concentrations are also in excess of the goal.

- Monthly mean Secchi-disk transparencies during the period from July through September average about 2.5 meters, and are currently meeting the goal.

- There currently is a nearly balanced, diversified sport fishery in the Lake, that is continuing to be monitored by the Wisconsin Department of Natural Resources (WDNR) and who intend to maintain this fishery, by stocking if and when necessary. Mr. Welch reported a winter-kill of bluegills during early January 2000, but indicated that this was probably due to overly high dissolved oxygen concentrations occurring under the ice. These conditions typically occur when there was no snow cover on the ice, creating unique conditions leading to the supersaturation of oxygen in the littoral zone of the Lake.

Ms. Amerson then stated that Walworth County would like to add a goal that the Lake meets the criteria needed to keep the Lake off the list of threatened or impaired waters on the State's 303(d) list. This list is compiled by the State of Wisconsin in response to requirements set forth in Section 1313, Water Quality Standards and Implementation Plans, paragraph (d) Identification of Areas with Insufficient Controls; Maximum Daily Load; Certain Effluent Limitations Revision, of the Federal Clean Water Act—formerly Section 303 of the Federal Water Pollution Control Act. This amendment was agreed as being consistent with the goal of maintaining fishable and swimmable conditions in Delavan Lake, and the goals, including the refined total phosphorus concentration, were adopted as relevant and realistic.

The meeting then moved to a series of technical discussions.

## TECHNICAL DISCUSSION I

### Point Sources and Wastewater Management

It was noted that maintenance and extension of the public sewage system will continue to be the single most important action for controlling and reducing nutrient loadings to Delavan Lake. Mr. MacKinnon stated that an update of the DLSD service area was scheduled to take place within the next one to two years. Additional portions of the watershed were anticipated to be incorporated into an expanded sewer service area at that time. He noted that the DLSD currently serves 2,800 households. Under current design limitations, the DLSD could potentially serve a maximum of 4,000 households, although, with minor pumping station changes, this capacity could ultimately be increased to 6,000 households. Expanding capacity over 6,000 households will require major line improvements and additional pumping stations. Currently the costs of connecting a household to the DLSD sewerage system are $4,700. This cost is over and above the cost of laying sewer mains. Operating costs for the DLSD are about $1.5 to 1.6 million, or about $2.00 per 1,000 gallons sewage treated. The District has a pumping capacity of 10 million gallons per day.

It was noted that Section 1313 (d) of the Federal Clean Water Act requires establishment of limits on the total maximum daily load (TMDL) of pollutants that can be discharged into channels. This includes a target goal for phosphorus discharges from sewage treatment plants that generally provides for discharge of plant effluents with no more than one milligram per liter (mg/l) of total phosphorus. For comparison, raw sewage generally enters treatment plants with phosphorus concentrations of between five and 10 mg/l, necessitating use of auxiliary wastewater treatment methods. Auxiliary treatment methods for phosphorus reduction may increase the amount of sewage sludge produced. Such an increase in sludge production could significantly increase sludge disposal costs.

Because the entire Delavan Lake watershed is not served by public sanitary sewerage service, discussion turned toward the possible impact of recent amendments to Chapter Comm 83 of the *Wisconsin Administrative Code*, governing onsite sewage disposal systems, on the watershed. Comm 83 would provide for the use of an increased number of onsite sewage disposal systems and change the requirements for the use of historically approved systems. Ms. Amerson indicated that these changes were unlikely to be a factor in Walworth County, as the County will continue to control the impact of residential development through existing countywide zoning. She suggested that the movement toward towns administering their own land use plans might pose a greater concern in this respect. Mr. MacKinnon noted that extraterritorial zoning authority may also be a threat. He pointed out that significant development is anticipated in the tributary drainage area to Delavan Lake as a consequence of the expansion of the Village of Williams Bay to the southeast of the Lake, the City of Elkhorn to the north of the Lake, and the City of Delavan to the west of the Lake. With the exception of the City of Delavan, these incorporated municipalities have already indicated a desire to expand toward the Lake. Such expansion would modify the nonpoint sources of water pollution affecting Lake water quality.

### Nonpoint Sources and Stormwater Management

The moderator then introduced the subject of managing nonpoint sources of water pollution. Ms. Yantis noted that the Town of Delavan had written to Walworth County asking them to prepare an overall stormwater management plan for Walworth County. Ms. Amerson agreed that such a plan would be desirable, observing that the often-used stormwater retention ponds often fail to perform as anticipated. She noted that sound site- and land-use planning would be a better approach. Concern was expressed about the inappropriate layout of subdivisions, with little up-front thought being given to stormwater management issues. It was suggested that limits to the amounts of impervious surfaces on lots would be helpful, since, once a certain level of imperviousness is reached, the effectiveness of best management practices (BMPs) and retention ponds is significantly reduced. Some communities limit impervious surface to 20 to 30 percent of the area of a lot.

The issue of extraterritorial zoning begged the question about how to involve other communities in the watershed. The Committee agreed that intergovernmental cooperation is an important element in watershed management. Ms. Yantis noted that the City of Delavan has been represented on the Lake Committee for many years. However, the Village of Williams Bay and the City of Elkhorn have not expressed much interest in participating. Nevertheless, some potential for changing this was reported as the result of recent flooding in the City of Elkhorn.

Fertilizer use near the lake was identified as a major area of concern. Typically suburban lawns can receive 10 to 20 times the amount of agrochemicals as active agricultural fields. 2,4-D, especially, was noted to be exceeding limits in some areas of the United States. It was suggested that soil testing for homeowners might help by providing individuals with recommendations for appropriate fertilization of their yards and gardens. It was noted that, generally, there are adequate levels of nutrients in the soils of the Region for most domestic purposes. It was suggested that a "welcome packet" be provided to new homeowners. This would have to be an ongoing project because of the amount of turnover of riparian homeowners around Delavan Lake.

## TECHNICAL DISCUSSION II

### Nutrient Loading and Hydrological Management

The maintenance of the riparian wetland plant community around the Mound Road sedimentation ponds was discussed. Ms. Yantis asked about the possible impacts of a spring burn versus a fall burn to help control invasive plant species within the wetland. Dr. Boxhorn reported that he had discussed the possibility of doing a burn on the wetland with Mr. Donald M. Reed, a wetland specialist with the Southeastern Wisconsin Regional Planning Commission (SEWRPC). Mr. Reed suggested that a burn would be desirable, and, for the purpose of minimizing nutrient release to the Lake, a fall burn would be preferable to a spring burn.

With respect to the maintenance of the sedimentation ponds themselves, the U.S. Geological Survey staff reported on their surveys of sedimentation within the three ponds. The eastern pond was reported to have two to three feet of deposition, the northern pond had about one foot of deposition, and the western pond had minimal deposition. The eastern and northern ponds effect most of the sediment removal; there has been a 46 percent reduction in the concentration of suspended sediments coming out of the wetland over the past two to three years and about a 25 percent reduction in the concentration of the total phosphorus within the wetland. Mr. Ferris reported that the eastern and northern ponds are filled with so much sediment that the effectiveness of the ponds in removing sediment has been reduced. He recommended dredging both the eastern and northern pond to a depth of 10 feet, with the eastern pond being in the most immediate need of restoration. He also recommended modifying the pond design to improve sheet flow through the wetland by placing a flow disperser at the inlet to the northern pond and filling in the channels that radiate from both ponds. There was an indication that some funds for redesigning the ponds might be available under State grant programs administered by the WDNR, but that no funding was available for dredging.

Because of an indication that deposition had occurred within the inlet area of the Lake, the question was asked as to whether dredging the inlet would help control nutrient loading. Dr. Robertson stated that the inlet has probably reached equilibrium, and is no longer acting as a depositional area.

[Secretary's Note: The meeting adjourned for luncheon, reconvening at 2:00 p.m., at which time the discussion resumed.]

Mr. Smetana of the Walworth County staff joined the meeting to report on the award to the of a U.S. Department of Agriculture Environmental Quality Incentive Program (EQIP) grant for the Delavan Lake watershed. Federal funds for BMPs have been approved, and are expected to be received by January 2001. The focus of the BMPs to be implemented with these funds would be on agricultural operations. He noted that additional funds were potentially available through the State Conservation Reserve Enhancement Program (CREP). Under these two programs, up to $200 million of EQIP funds and $40 million of CREP funds were potentially available. Using these funds to acquire permanent easements for streamside buffers might be attractive enough for people to participate in these programs. Acquisition of temporary easements was not considered viable in the long-term. With respect to the CREP program, it is anticipated that only 100,000 acres of easement are likely to be eligible, although the mechanics of implementing the program are still to be worked out.

The discussion then turned to management of the internal loading of phosphorus to the Lake and the utility of another alum treatment of Delavan Lake. The 1991 alum treatment was reported to have been completely effective for about two years and about 50 percent effective for the third year. The short duration of its effectiveness may have been due to inadequate amounts of alum applied during the 1991 treatment. A second alum treatment was estimated to cost about $1.3 million, and was estimated to remain effective for only one to two years longer. Because of this, it was felt that another alum treatment would not be desirable. Mr. Panuska noted that the effectivity of the alum treatment should be weighed against the effectivity of controlling the external nutrient load. Without internal loading, he reported that the external loading was sufficient to result in phosphorus concentrations of about 50 to 55 μg/l. With internal loading, he reported that the Lake would continue to have phosphorus concentrations of about 70 μg/l.

Ms. Yantis asked whether lowering the Lake level by a few inches in the fall, and refilling the Lake in the spring when nutrient levels are lower, would be a practical means of nutrient reduction. After some discussion, it was suggested that this probably would not have a significant effect on the in-lake phosphorus concentrations. Likewise, based upon a review of the effectivity of short-circuiting of water from the inlet to the outlet, the Committee noted that this technique had not proven to be effective at reducing the nutrient loading tot he Lake.

**Aquatic Plant Management**

Mr. MacKinnon presented data on the volumes and locations of aquatic macrophytes harvested by the DLSD during 1997 through 1999. Harvests were particularly high during 1997 due to clearer water. In 1999, harvesting in the outlet and inlet accounted for about 63 percent of the plants removed. He noted that, based upon plant surveys conducted by Aron & Associates, there have been some changes in the plant community in the Lake. For example, harvesting in the outlet apparently encouraged the growth of Eurasian water milfoil, while, in some other areas, there has been a shift from coontail and curly-leaf pondweed to filamentous green algae. Over the last several years, species diversity of macrophytes declined from 21 species immediately following the drawdown to 12 species, although, in the latest survey, it had climbed to 14 species.

With respect to the inlet, Mr. MacKinnon reported citizen concerns regarding navigational access. He noted that the water depth is shallow enough that any plant growth will impede navigation outside of the dredged navigational channel. He also suggested that this may be less of an "aquatic plant" problem and more of a water depth and public perception problem that would be better addressed through public informational programming. Nevertheless, because of the continued integrity of the navigational channel within the inlet, further deepening was not considered desirable at this time. However, given the projected future evolution of the inlet into an increasingly marsh-like character, the possibility of the Town of Delavan putting together an acquisition plan for property along the inlet was mooted. It was suggested that such action be considered as part of the long-range plan for wetland restoration in the upper reaches of Delavan Lake. Mr. Schaal noted that State program to cost-share such an initiative were potentially available; he also noted some procedural aspects that the Town would have to follow with respect to such acquisitions.

## TECHNICAL DISCUSSION III

### Fisheries Management and Biomanipulation

Mr. Welch noted that the objective of a balanced fishery had nearly been achieved. Walleye is the dominant fish in the Lake. Densities of walleye are approximately seven to eight adults, over 12 inches in length, per acre. Total densities of walleye are about 12 fish per acre. This is higher than in a typical stocked lake. Mr. Welch reported that there are two, or possibly three, year classes of walleye present. The WDNR is continuing an annual stocking of muskellunge and will stock for walleye and smallmouth bass. He also noted that about two dozen carp were harvested during the last survey, but that the carp population was probably not large enough to be of concern.

With respect to the biomanipulation of the Lake, Dr. Garrison stated that, at this time, the biomanipulation probably is not very effective. He noted a shift in the zooplankton from large Daphnia (e.g., *Daphnia pulicaria*) to smaller Daphnia (e.g., *Daphnia galeata mendotae*) in recent years, suggesting a return to conditions more indicative of undisturbed lakes in the Region. These smaller Daphnids are less efficient harvesters of algae, implying a limited degree of control of algae within the water column of the Lake.

### Informational programming

Development of a "welcome wagon" type of informational packet for new residents, to inform them of issues such as lake-friendly lawn care and use of buffer strips, was proposed by Ms. Johnson, who noted the effectiveness of such informational programming in other lake communities. The importance of public informational programming was agreed.

### Miscellaneous

Mr. MacKinnon noted that some of the seepage through the dam may be related to the presence of muskrat burrows. Maintenance of the earthen portions of the structure could be problematical. He noted that, while the Town of Delavan owns the concrete structure of the dam, the earthen berms abutting the dam are in private ownership. For this reason, dam maintenance would have to be conducted in partnership with these private individuals.

Dr. Thornton then thanked the participants for their participation in a frank and far-ranging discussion, noting that the results of this technical meeting would be conveyed to the Town of Delavan Lake Committee at their next scheduled meeting, set for 7:00 p.m. on Thursday, March 23, 2000, at the DLSD Offices. Pending further inputs from this Committee, he indicated that the SEWRPC would proceed with the drafting of a comprehensive lake management plan for Delavan Lake during the course of the spring. The draft plan would then be made available to the Town of Delavan Lake Committee and the participants in the meeting of the Technical Advisory Committee for review at that time. There being no further business to come before the Committee, the meeting was adjourned at 4:00 p.m.

# Appendix B

# NONPOINT SOURCE POLLUTION CONTROL MEASURES

Nonpoint, or diffuse, sources of water pollution include urban sources such as runoff from residential, commercial, industrial, transportation, and recreational land uses; construction activities; and onsite sewage disposal systems and rural sources such as runoff from cropland, pasture, and woodland, atmospheric contributions, and livestock wastes. These sources of pollutants discharge to surface waters by direct overland drainage, by drainage through natural channels, by drainage through engineered stormwater drainage systems, and by deep percolation into the ground and subsequent return flow to the surface waters.

A summary of the methods and estimated effectiveness of nonpoint source water pollution control measures is set forth in Table B-1. These measures have been grouped for planning purposes into two categories: basic practices and additional. Application of the basic practices will have a variable effectiveness in terms of control level of pollution control depending upon the subwatershed area characteristics and the pollutant considered. The additional category of nonpoint source control measures has been subdivided into four subcategories based upon the relative effectiveness and costs of the measures. The first subcategory of practices can be expected to generally result in about a 25 percent reduction in pollutant runoff. The second and third subcategory of practices, when applied in combination with the minimum and additional practices, can be expected to generally result in up to a 75 percent reduction in pollutant runoff, respectively. The fourth subcategory would consist of all of the preceding practices, plus those additional practices that would be required to achieve a reduction in ultimate runoff of more than 75 percent.

Table B-1 sets forth the diffuse source control measures applicable to general land uses and diffuse source activities, along with the estimated maximum level of pollution reduction which may be expected upon implementation of the applicable measures. The table also includes information pertaining to the costs of developing the alternatives set forth in this chapter.[1] These various individual nonpoint source control practices are summarized by group in Table B-2.

Of the sets of practices recommended for various levels of diffuse source pollution control presented in Table B-2, not all practices are needed, applicable, or cost-effective for all watersheds, due to variations in pollutant loadings and land use and natural conditions among the watersheds. Therefore, it is recommended that the practices indicated as needed for nonpoint source pollutant control be refined by local level nonpoint source control practices planning, which would be analogous to sewerage facilities planning for point source pollution abatement. A locally prepared plan for nonpoint abatement measures should be better able to blend knowledge of current problems and practices with a quickly evolving technology to achieve a suitable, site-specific approach to pollution abatement.

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[1]*Costs are presented in more detail in the following SEWRPC Technical Reports: No. 18,* State of the Art of Water Pollution Control in Southeastern Wisconsin, *Volume Three,* Urban Storm Water Runoff, *July 1977, and Volume Four,* Rural Storm Water Runoff, *December 1976; and No. 31,* Costs of Urban Nonpoint Source Water Pollution Control Measures, *June 1991.*

## Table B-1

## GENERALIZED SUMMARY OF METHODS AND EFFECTIVENESS OF NONPOINT SOURCE WATER POLLUTION ABATEMENT

| Applicable Land Use | Control Measures[a] | Summary Description | Approximate Percent Reduction of Released Pollutants[b] | 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 to 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 to 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 to 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 \$5,000 to \$6,000 and the cost of an alternative system is \$10,000. The annual maintenance cost of a disposal system is \$250. An in-ground pressure system is estimated to cost \$6,000 to \$10,000 with an annual operation and maintenance cost of \$250. A holding tank would cost \$5,500 to \$6,500, with an annual operation and maintenance cost of \$1,800 |
| | 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 to 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 \$120,000. The cost of the operation and maintenance of a sweeper is about \$25 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 to 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 \$180 to \$200 per ton of leaves |
| | 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 to 5 | Determine curb-miles for street sweeping; vary percent of urban areas 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 \$10 |
| | 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 plan, 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 |

## Table B-1 (continued)

| Applicable Land Use | Control Measures[a] | Summary Description | Approximate Percent *Reduction of* Released Pollutants[b] | Assumptions for Costing Purposes |
|---|---|---|---|---|
| Urban (continued) | 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 to 5 | Increase current expenditures by approximately 15 percent |
| | Parking lot stormwater 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 to 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 stormwater detention and treatment facilities is estimated at $40,000 to $80,000 per acre of parking lot area, with an annual operation and maintenance cost of about $200 per acre |
| | Onsite storage—residential | Remove connections to sewer systems; construct onsite stormwater storage measures for subdivisions | 5 to 10 | Remove roof drains and other connections from sewer system wherever needed; use lawn aeration, if applicable; apply dutch drain storage facilities to 15 percent of residences. The capital cost would approximate $500 per house, with an annual operation and maintenance cost of about $25 |
| | Stormwater Infiltration—urban | Construct gravel-filled trenches for areas of less than 10 acres or basins to collect and store temporarily stormwater runoff to reduce volume, provide groundwater recharge and augment low stream flows | 45 to 90 | Design gravel-filled trenches or basins to store the first 0.5 inch of runoff; provide at least a 25-foot grass buffer strip to reduce sediment loadings. The capital cost of stormwater infiltration is estimated at $12,000 for a six-foot-deep, 10-foot-wide trench, and at $70,000 for a one-acre basin, with an annual maintenance cost of about $10 to $350 for the trench and about $2,500 for the basin |
| | Stormwater storage—urban | Store stormwater runoff from urban land in surface storage basins or, where necessary, subsurface storage basins | 10 to 35 | Design all storage facilities for a 1.5-inch 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 stormwater storage would range from $35,000 to $110,000 per acre of basin, with an annual operation and maintenance cost of about $40 to $60 per acre |
| | Stormwater 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 stormwater following storage | 10 to 50 | To be applied only in combination with stormwater storage facilities above; general cost estimates for microstrainer treatment and ozonation were used; some costs were applied to existing urban land and proposed new urban development. Stormwater treatment has an estimated capital cost of from $900 to $7,000 per acre of tributary drainage area, with an average annual operation and maintenance cost of about $35 to $100 per acre |

## Table B-1 (continued)

| Applicable Land Use | Control Measures[a] | Summary Description | Approximate Percent Reduction of Released Pollutants[b] | Assumptions for Costing Purposes |
|---|---|---|---|---|
| Rural | Conservation practices | Includes such practices as strip cropping, contour plowing, crop rotation, pasture management, critical area protection, grading and terracing, grassed waterways, diversions, woodlot management, fertilization and pesticide management, and chisel tillage | Up to 50 | Cost for Natural Resources Conservation Service (NRCS) 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 $3,000 to $5,000 per acre of rural land, with an average annual operation and maintenance cost of from $5.00 to $10 per rural acre |
| | Animal waste control system | Construct streambank 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 to 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 $100 per animal unit and $25 per animal unit, respectively. The capital cost of a liquid and slurry storage facility is about $1,000 per animal unit, with an annual operation and maintenance cost of about $75 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 to 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 $500 per tributary acre, with an annual operation and maintenance cost of $25 per acre |
| | Bench terraces | Construct bench terraces, thereby reducing the need for many other conservation practices on sloping agricultural land | 75 to 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 $1,500 per acre, with an annual operation and maintenance cost of $100 per acre |

## Table B-1 (continued)

| Applicable Land Use | Control Measures[a] | Summary Description | Approximate Percent Reduction of Released Pollutants[b] | 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 contract 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 for every 50,000 population. The cost of one person, materials, and support is estimated at $55,000 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 to 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 $250 to $5,500 and $250 to $1,500 per acre under construction, respectively |
| | Materials storage and runoff control facilities | Enclose industrial storage sites with diversion; divert runoff to acceptable outlet or storage facility; enclose salt piles and other large storage sites in crib and dome structures | 5 to 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 $2,500 per acre of industrial land. Material storage control costs are estimated at $75 per ton of material |
| | Stream protection measures | Provide vegetative buffer zones along streams to filter direct pollutant runoff to the stream; construct streambank protection measures, such as rock riprap, brush mats, tree revetment, jacks, and jetted willow poles, where needed | 5 to 10 | Apply a 50-foot-wide vegetative buffer zone on each side of 15 percent of the stream length; apply streambank 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 to 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 required for each subwatershed. 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 selection and estimation of costs of specific practices for any one subwatershed. 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]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.*

*[c]For highly urbanized areas which require retrofitting of facilities into developed areas, the costs can range from $400,000 to $1,000,000 per acre of storage.*

*Source: SEWRPC.*

Table B-2

**ALTERNATIVE GROUPS OF DIFFUSE SOURCE WATER POLLUTION CONTROL MEASURES PROPOSED FOR STREAMS AND LAKE WATER QUALITY MANAGEMENT**

| Pollution Control Category | Level of Pollution[a] Control | Practices to Control Diffuse Source Pollution from Urban Areas[b] | Practices to Control Diffuse Source Pollution from Rural Areas[a] |
|---|---|---|---|
| Basic Practices | Variable | Construction erosion control; onsite sewage disposal system management; streambank erosion control | Streambank erosion control |
| | 25 percent | Public education programs; litter and pet waste control; restricted use of fertilizers and pesticides; construction erosion control; critical areas protection; improved timing and efficiency of street sweeping, leaf collection, and catch basin cleaning; material storage facilities and runoff control | Public education programs; fertilizer and pesticide management; critical area protection; crop residue management; chisel tillage; pasture management; contour plowing; livestock waste control |
| Additional Diffuse Source Control Practices[c] | 50 percent | Above, plus: Increased street sweeping; improved street maintenance and refuse collection and disposal; increased catch basin cleaning; stream protection; increased leaf and vegetation debris collection and disposal; stormwater storage; stormwater infiltration | Above, plus: crop rotation; contour strip-cropping; grass waterways; diversions; wind erosion controls; terraces; stream protection |
| | 75 percent | Above, plus: An additional increase in street sweeping, stormwater storage and infiltration; additional parking lot stormwater runoff storage and treatment | Above, plus: Base-of-slope detention storage |
| | More than 75 percent | Above, plus: Urban stormwater treatment with physical-chemical and/or disinfection treatment measures | Bench terraces[b] |

[a]*Groups of practices are presented here for general analysis purposes only. Not all practices are applicable to, or recommended for, all lake and stream tributary watersheds. For costing purposes, construction erosion control practices, public education programs, and material storage facilities and runoff controls are considered urban control measures and stream protection is considered a rural control measure.*

[b]*The provision of bench terraces would exclude most basic conversation practices and base-of-slope detention storage facilities.*

[c]*In addition to diffuse source control measures, lake rehabilitation techniques may be required to satisfy lake water quality standards.*

*Source: SEWRPC.*

## Appendix C

# PROPOSED PROJECT DESCRIPTION FOR MOUND ROAD WETLAND RESTORATION

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# PROPOSED WISCONSIN LAKE PROTECTION GRANT
# WETLAND RESTORATION PROJECT
# FOR DELAVAN LAKE, WALWORTH COUNTY

## PROJECT DESCRIPTION

## INTRODUCTION

Delavan Lake is a 1,790-acre drainage lake located in the Town of Delavan in Walworth County. The Lake has adequate public access as defined in Chapter NR 1 of the *Wisconsin Administrative Code*. This wetland restoration project is proposed pursuant to recommended actions identified in the lake management plan for Delavan Lake,[1] and is designed to implement measures to mitigate the impacts of stormwater, construction, and urban development in the Lake's watershed, as recommended in the Lower Rock River Basin water quality management plan.[2]

Delavan Lake has been the subject of a major lake management and water quality improvement projects begun in 1979, with the diversion of treated wastewater and the sewering of the urban development surrounding the lake, and continuing, with the restoration of the Mound Road wetland at the headwaters of the Lake, through to the present. Because the Lake experienced severe algal blooms during the summer months in the early 1980s, culminating in the worst-known blue-green algal bloom in the Lake during the summer of 1983, interventions were deemed necessary, and were designed and implemented with funds provided under the Clean Water Act by the U.S. Environmental Protection Agency. Details of the project design and construction are set forth in the report, *Delavan Lake: A Recovery and Management Study*, published by the University of Wisconsin-Madison, Institute for Environmental Studies, in September 1986, as refined and modified by the Wisconsin Department of Natural Resources (WDNR) report, *Environmental Impact Statement: Delavan Lake Rehabilitation Project*, published in March 1989.

The construction of a high-flow diversion berm within the lake designed to "short-circuit" nutrient-rich inflows past the main lake basin was completed during 1992. In addition, as noted above, treated wastewater, previously discharged upstream of Delavan Lake, is now released downstream of the waterbody. Additional actions, including hydraulic improvements to the outflow channel, alum-dosing of the lake basin, and biocide-based aquatic plant and fisheries management programs, were also completed during the period between 1981 through 1992. An integral part of the lake rehabilitation project was the restoration of a wetland area upstream of the Jackson Creek inflow to the Lake. This wetland restoration in the vicinity of IH 43 upstream of Mound Road was the last remaining action to be completed. Prior to restoration, this wetland area had been in agricultural use. The grading and landscaping associated with this restoration project, to restore the hydrology of the site, was completed during 1992, and the replanting of the wetland and the conduct of related maintenance tasks associated with the reestablishment of a healthy wetland flora on this site was conducted between 1992 through 1998. These actions essentially completed the Delavan Lake restoration project as envisaged in the 1986 and 1989 plans referenced above.

Notwithstanding the above management actions, recent investigations carried out by the U.S. Geological Survey, Wisconsin Department of Natural Resources, Delavan Lake Sanitary District, and Earth Tech, Inc., have

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[1]*SEWRPC Community Assistance Planning Report No. 253, (draft),* A Lake Management Plan for Delavan Lake, Walworth County, Wisconsin, *February 2002.*

[2]*Wisconsin Department of Natural Resources Publication No. PUBL-WT-280 98 REV,* Lower Rock River Basin Water Quality Management Plan: A Five-Year Plan to Protect and Enhance Our Water Resources, *October 1998.*

suggested that further effort is now required to maintain or improve the efficacy of the measures carried out during the preceding 20-year period. Specifically, studies carried out by the U.S. Geological Survey and Earth Tech, Inc., have determined that a significant degree of water quality benefit experienced during this period is derived from the functioning of the Mound Road wetland. These studies also have indicated that the sedimentation basins associated with the wetland are reaching the end of their effectiveness period, and that channelized flow is being observed within the wetland complex, reducing the efficacy of that biological system. Therefore, the Town of Delavan, in cooperation and consultation with the U.S. Geological Survey, Wisconsin Department of Natural Resources, University of Wisconsin-Extension, Southeastern Wisconsin Regional Planning Commission (SEWRPC), Walworth County, the Delavan Lake Sanitary District, and Earth Tech, Inc., have determined to seek cost-share funding for the purpose of restoring and improving the efficacy and the proven benefits to be derived from the Mound Road wetland.[3] Actions proposed include the redesign of the sedimentation basins so as to improve their effectivity as stilling basins, thereby enhancing sheet flow from the pond outlets across the native prairie and wetland vegetation previously established in the Mound Road wetland. Monitoring of water quality prior and subsequent to any changes in the wetland system is also proposed as an integral part of this project. To this end, the Town of Delavan has requested the Southeastern Wisconsin Regional Planning Commission to provide assistance in preparing a project description for a Wetland Restoration Project to emplace an appropriate monitoring program and support the engineering design and construction costs attendant to the necessary remedial measures to ensure to continued functioning of this important lake management measure. This project description is based upon information provided to the Commission staff by the Town and its consultants and cooperators. The Commission responsibilities were to incorporate that information into a project description suitable for grant application purposes.

The proposed program of wetland redesign, restoration, reconstruction and maintenance, set forth below, follows the recommended format of Section VI.6, Project Scope/Description of the Grant application, WDNR Form 8700-283 Rev. 3/01, and is appended thereto.

## DESCRIPTION OF THE PROJECT AREA

The Mound Road wetland is situated in the Town of Delavan to the north of Mound Road and immediately south of the IH 43 corridor on Jackson Creek. The wetland site was included in the Turtle Creek Priority Watershed study area[4] and is about 135 acres in areal extent. The site is wholly owned by the Town of Delavan.

As noted above, the initial site design and landscaping associated with the Mound Road wetland restoration project was completed during the autumn of 1992. The site was first allowed to develop a wetland plant community from the remnant seed bank contained within the wetland soils present on the site prior to its conversion for agricultural uses. Among the high-quality vegetation that subsequently grew on the site were native plant species characteristic of shallow marshes and sedge meadows: *Anemone canadensis* (Canada anemone), *Scirpus validus* (soft-stem bulrush), *Scirpus americanus* (three-square bulrush), *Angelica atro purpurea* (angelica), *Aster novae-anglicae* (New England aster), *Alisma plantaga-aquatica* (water plantain), *Carex* spp., and *Equisetum* sp. Less-desirable species also occurred on the site, including the declared noxious weed, *Cirsium arvense* (Canada thistle), and other less-desirable species such as *Phalaris arundinaceae* (reed canary grass), *Amaranthus retroflexus* (pigweed), *Taraxacum officinale* (dandelion), *Phleum pratense* (timothy), and *Agropyron repens* (quack grass).

Extensive stands of *Typha* spp. (cattail) occur immediately downstream of this site on the shores of the Delavan Lake inlet, and are hydrologically and ecologically linked to the wetland. For this reason, actions to restore this extended wetland area and improve the quality of the wetland for both water quality improvement and habitat creation purposes, and to prevent this wetland from being dominated by less desirable forms of vegetation, were also subsequently undertaken. Current and past management measures to control the extent of undesirable

[3]*SEWRPC Community Assistance Planning Report No. 253, op. cit.*

[4]*Wisconsin Department of Natural Resources,* Turtle Creek Priority Watershed Plan, *March 1984.*

vegetation within the wetland, including herbicide applications to control Canada thistle, and the planting of native grasses and wildflowers in some areas of the wetland. One controlled burn has been conducted to encourage the growth of native grasses and further burns are anticipated in the near future.

Based upon inventory data cited in the lake management plan for Delavan Lake, it is likely that these wetland areas form a significant element of the local natural resource base within the Delavan area, and, hence, are likely to support a number of state threatened and endangered species, and species of special concern. Species likely to be present in and around Delavan Lake include both avian species as well as amphibians and reptiles. These are enumerated in the aforereferenced lake management plan. Bird species include the common loon, great blue herons, and osprey, among others. Reptile and amphibian species include Blanding's Turtle.

## REASON FOR THE PROPOSED PROJECT

Delavan Lake had been subjected to increasingly intense summer algal blooms since the 1940s, and, by the 1980s, the quality of the Lake was so poor that Walworth County issued annual "swim at your own risk" warnings due to the intensity of the blue-green algal blooms occurring on the Lake. While the causes of these blooms included both point and nonpoint sources of contaminants within the Delavan Lake watershed, the larger part of the additional nutrient load was deemed to be controllable to the extent that the Lake could be restored to a swimmable and fishable condition.[5] To that end, an extensive program of lake rehabilitation was proposed and funded under the Clean Lakes Program of the U.S. Environmental Protection Agency.

The rehabilitation program included the diversion of treated wastewaters from the portion of Jackson Creek flowing into Delavan Lake, initiated in 1979 and completed in 1981; the removal of rough fish and weedy aquatic plant species, initiated in 1981 and completed in 1992; the diversion of floodwaters through the Lake, completed in 1991; the removal of dissolved phosphorus from the water column and control of internal nutrient loading through an alum treatment, completed in 1992; and the reconstruction of a portion of the extensive riverine wetlands upstream of Lake Delavan on Jackson Creek, initiated in 1992 and completed in 1998.

In addition, subsequent lake management activities were funded by the Town of Delavan with funding provided, in part, through the Chapter NR 190 Lake Management Planning Grant and Chapter NR 191 Lake Protection Grant cost-share programs managed by the Wisconsin Department of Natural Resources. These ongoing activities have included automation of lake level controls, aquatic plant management through program of harvesting and chemical treatments, limnological monitoring to assess lake health, and the conduct of planting projects and controlled burns to enhance the quality and natural structure and function of the Mound Road wetland.

With respect to the proposed wetland restoration program, the purpose of the project carried out in the headwater reaches of Delavan Lake is to provide a significant measure of pretreatment of the influent waters, especially flood flows, prior to these waters reaching Lake Delavan, as recommended in the aforereferenced lake management plan and basin water quality management plan. To accomplish this purpose, the wetland was designed to pass base flows as sheet flow through a reconstructed deep water marsh, including instream sedimentation basins and their associated swales, placed along Jackson Creek and its unnamed tributary. Under high-flow conditions, the swales were designed to pass flood waters along the swales and across the sedge meadows and wet prairies adjacent to the deep water marsh. Under both high- and low-flow conditions, therefore, the swale system was designed to create sheet flow across the wetland site.

The hydrology of the wetland is governed by the lake stage, stream flow, groundwater flow, evapotranspiration, and site topography. Due to siltation in the sedimentation basins, as well as to the development of channelized flow paths through the wetland, the efficiency of the swale and wetland system is diminishing. Based upon experience with similar wetland system designs, it is likely that creation of sheet flow conditions within the

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[5]Ibid.

wetland may be impaired as a result. Thus, restoration of the functional capacity of the wetland system is required.

Restoration and enhancement of the Mound Road wetland has been deemed to be a grant-eligible water quality improvement practice in terms of the Turtle Creek Priority Watershed plan as amended, and is consistent with recommendations set forth in the lake management plan and basin water quality management plan. The site is totally within the Jackson Creek floodplain and a majority of the site is within the floodway. No significant hydraulic effects are predicted due to wetland operation outside of the site boundaries which are under the control and ownership of the Town of Delavan.

Funds are being requested under the Chapter NR 191 Lake Protection Grant Program to cost-share the engineering design of wetland improvements to recreate sheet flow through the wetland; to reconstruct, extend, and enhance the shallow and deep water marsh areas within the wetland; to restore the functioning of the sedimentation ponds and distribution system to promote sheet flow through the wetland; and, to cost-share the monitoring of the wetland's functioning, as necessary to ensure the continued benefits to be derived from these lake protection measures.

## PROJECT GOALS AND OBJECTIVES

The goals of the proposed protection project are:

1. To redesign and reconstruct the sedimentation ponds to further restore the extensive wetland system located in the southeast one-quarter of U.S. Public Land Survey Section 11 and the southwest one-quarter of Section 12, Township 2 North, Range 16 East, Town of Delavan, Walworth County, on the approximately 135-acre site bounded to the north by IH 43 and to the south by Mound Road.

2. To enhance the essential structure and function of this wetland, and reestablish and improve sheet flow through the wetland, in order to continue to ensure positive water quality benefits to the downstream Delavan Lake.

3. To continue to reestablish the variety of habitats commonly found in natural floodplains in Southeastern Wisconsin, thereby promoting a variety of recreational and educational opportunities for the Town of Delavan community in this public open space.

4. To monitor the efficiency of the wetland treatment system prior to and following the conduct of this phase of the wetland restoration program, and assess the impact of these actions on the water quality of Delavan Lake.

Accomplishment of these goals is consistent with the recommendations set forth in the relevant lake and watershed management plans, and will result in the maintenance of a healthy wetland flora and area of diverse wetland habitat capable of providing the desired water quality benefits to the Delavan Lake, consistent with the objectives of Chapter NR 191 of the *Wisconsin Administrative Code*. Such benefits are consistent with ongoing lake management actions being undertaken by the Town of Delavan in cooperation with Federal, State, and other local agencies.

## METHODS AND ACTIVITIES, DELIVERABLES, AND PUBLIC PARTICIPATION PLAN

The initial construction and restoration of the Mound Road wetland was carried out beginning in 1992 with funding provided in terms of the Delavan Lake Restoration Project by the U.S. Environmental Protection Agency Clean Lakes Program and cost-shared by the State of Wisconsin, and continued through 1998 with funding provided by the Wisconsin Department of Natural Resources and cost-shared by the Town of Delavan. Additional funding is now requested for the conduct of a wetland restoration and monitoring program, including design, construction and monitoring, relating to the overall lake management project set forth above, and as recommended in the lake management plan for Delavan Lake. Six elements are included in the proposed program. These are enumerated below:

1. Improvement of Sheet Flow: The success of the wetland as a water quality management practice is a function of the amount of plant surface area exposed to the inflow. To maximize this contact, shallow overland flow, or sheet flow, is the preferred way in which water should be conveyed across the site. Due to the larger than average number of extreme—greater than a one in two-year return interval storms—storm events experienced in 1993, there has been a tendency for channelized flow to develop in portions of the wetland. Such flow provides limited contact between the inflowing water and the wetland plants and leads to reduced efficiencies in the water quality management practice. In order to rectify this situation, and restore sheet flows within the wetland, additional interventions are necessary. This task will include the engineering design of modifications to the configuration of the wetland to restrict channelized flow and construction activities designed to restore sheet flows across the wetland. Actions taken to improve sheet flow through the wetland will create additional areas of shallow water marsh habitat. Outputs of this task element will include design standards for the reconfiguration of the system.

2. Enhancement of Hydraulic Functioning of the Wetland System: Studies conducted by the Town of Delavan using funds provided, in part, through the Chapter NR 190 Lake Management Planning Grant and Chapter NR 191 Lake Protection Grant programs have indicated that, in addition to restoring sheet flows across the wetlands, modification of the flow regime within the system could yield additional, quantifiable water quality benefits to downstream Delavan Lake. In order to enhance the hydraulic functioning of the system, some further refinement of the wetland design specifications is required. Conceptually, studies completed to date would suggest that the creation of some additional low head berms would facilitate greater hydraulic retention on the site. Further, these studies also suggest that modification of the sedimentation basin design parameters would further enhance the efficacy of these systems in reducing the contaminant loading to Delavan Lake. Such measures as may be determined under the activities conducted under this task would complement the actions taken under Task 1 above. Outputs of this task element will include the engineering design drawings and construction plans necessary to implement modifications to the hydraulic capacity of the system while enhancing sheet flows throughout the wetland complex.

3. Determination of Engineering Requirements and Appropriate Methodologies to Accomplish Improved Sheet Flows and Enhanced Hydraulic Functioning: Under this task element, the contractor will prepare the necessary engineering documents and bid materials to facilitate contracting for services to carry out the measures necessary to achieve improved sheet flows and enhanced hydraulic functioning identified in Tasks 1 and 2 above. This task will include a review of the engineering designs and requirements necessary to improve and enhance the Mound Road wetland. An inspection of the engineering documentation will be undertaken to ensure that complete details of the project are in hand; additional materials will be prepared as necessary to complete the design work needed prior to the Town of Delavan going to bid for construction services. This review will include the determination of appropriate methodologies to accomplish the desired wetland enhancements, and, through a cost-benefit and feasibility assessment process, identify those methodologies that will allow the Town of Delavan to maintain the efficiency and habitat value of the Mound Road wetland. The output of this task element will be a set of bid specifications and contracting requirements necessary for the Town of Delavan to implement the proposed onsite program of wetland enhancement, identified above.

4. Wetland Restoration and Reconstruction: The major work effort associated with this wetland restoration program for the Mound Road wetland, upstream of Delavan Lake, will be comprised of construction, revegetation, and related activities designed to implement actions necessary to achieve the goals of the project: namely, the restoration of sheet flow across the wetland and maintenance of

the pollutant retention capacity of the related management measures associated with the wetland system. It is anticipated, based upon the completion of tasks 1 through 4 above, that the wetland reconstruction and restoration activities will include the reconfiguration of the stilling basins situated at the headwaters of the wetland system so as to enhance the potential for creating sheet flow conditions within the wetland, elimination of channelized areas within the wetland, provision of additional berms and landscape features so as to increase wetland habitat and variety within the Mound Road wetland ecosystem, and the revegetation of portions of the wetland to continue to minimize the occurrence of undesirable plant species and promote the growth of native plant communities within the variety of wetland habitats and types. Specifically, the revegetation portion of the project will encourage vegetative communities representative of deep water marshes, complementing and grading into the existing wet meadow habitat within the system. It is estimated that the reconstructed wetland system will function within design parameters for a period in excess of a decade, providing water quality benefit to Delavan Lake and the Turtle Creek watershed. The output of this task element will be the implementation of the program of wetland enhancement, and reconstruction and restoration of this extensive wetland complex.

5. Monitoring and Evaluation: The Town of Delavan currently conducts an in-lake monitoring program that includes not only a program of TSI (Trophic State Index) monitoring within the lake basin, but also inflow and outflow monitoring. To date, this monitoring has allowed a quantitative assessment of the efficacy of the remedial efforts applied to Delavan Lake. This assessment is set forth in the SEWRPC Community Assistance Planning Report No. 253, draft, *A Lake Management Plan for Delavan Lake, Walworth County, Wisconsin*, currently being completed with grant funding provided in part through the Chapter NR 190 Lake Management Planning Grant Program. This task will encourage the Town to continue to monitor and evaluate the efficacy of the Mound Road wetland by supplementing the expenditures currently authorized by the Town Board. Specifically, this task would relocate the upstream gauging station on Jackson Creek to a site downstream of the current location. The current site would be impacted by the construction activities associated with the upgrading of STH 67 and the relocation of the highway corridor. In addition, this task would support the installation of two further partial gauging stations within the wetland complex; one along the northern unnamed tributary upstream of the wetland, previously utilized, but subsequently abandoned in recent years, and one at the outlet of the wetland. In addition, this task would provide for the analysis of water quality samples up to 104 samples per site per year for suspended sediment content and phosphorus content, with a total of 560 samples for each parameter being obtained from the sites over a two-year period. The gauge stations and associated sampling would permit the quantitative determination of the efficacy of the modified wetland, and, in addition, would allow determination of changes in loading to the wetland site as a result of urbanization along the upstream reaches of Jackson Creek. Two years of monitoring, one prior to modifying the wetland system and one following the completion of the modifications, are proposed to be conducted. Samples will be analyzed by the USGS National Water Quality Laboratory. The output of this task element would be a U.S. Geological Survey Water-Data Report or equivalent document.

6. Ongoing Public Involvement: The Mound Road wetland is wholly owned by the Town of Delavan. It is the intention of the Town of Delavan to continue to encourage use of the wetland as an outdoor laboratory and educational resource for the community through the design and development of nature walks and interpretive structures placed throughout the wetland. Currently community groups assist in the maintenance of the wetland through their participation in the seeding and planting tasks that have led to the creation of an onsite nursery area for native plant seedlings. Planting and "weed" control will continue to be effected by the Town in accordance with practices set forth in the draft lake management plan referenced above. This activity extends and expands the current community-based initiatives. In the longer term, it is anticipated that the level of management will decrease from that required during the wetland establishment phase of the project and become analogous to that required on other public lands owned by the Town of Delavan. An outline of the longer-term

maintenance plan was previously provided to the Wisconsin Department of Natural Resources and remains in effect.

Grant funding in terms of this application is requested for five of these project elements: improvement of sheet flow, enhancement of hydraulic functioning, determination of engineering requirements and methodologies, construction, and monitoring and evaluation. The sixth element, that concerning the ongoing public involvement and maintenance of the wetland site, will be carried out by the Town of Delavan and is expected to be funded from that source.

## PARTNERSHIPS

The Town of Delavan has retained Earth Tech, Inc., to complete the engineering designs, drawings, evaluations and site plans identified under task elements 1 and 2 above, and to produce the engineering specifications and bid documents identified under task element 3 above, relating to this project. The actual reconstruction and restoration of the wetland as set forth in Task element 4 will be conducted in a manner consistent with the bid specifications being developed through previous tasks. Task element 5 above will be carried out by the U.S. Geological Survey under contract to the Town of Delavan. As noted under task element 6 above, it is the intention of the Town of Delavan to maximize community involvement in this project. Hence, portions of the work will continue to be carried out by community groups as part of the educational and community involvement program.

## CONSISTENCY WITH OTHER PLANS

**Relationship to Water Quality Improvements in Delavan Lake**

The situation of the Mound Road wetland astride the Jackson Creek inflow to Delavan Lake places the wetland in an ideal position to intercept contaminants about to enter the Lake from the more highly urbanized portions of the watershed. The Jackson Creek watershed is the larger of the tributary watersheds to Delavan Lake, draining about 13.3 square miles of urban and agricultural lands south of the City of Elkhorn. Jackson Creek and its tributary streams which join the Creek within the Mound Road wetland contributes approximately 75 percent of the external nutrient and sediment loads to Delavan Lake, over half of which is delivered during high-flow periods.[6] The University of Wisconsin study[7] suggested that the reestablishment of a 100-acre wetland in this location could reduce the phosphorus input from Jackson Creek by up to 3,000 pounds per year, or by between 16 and 50 percent of the total annual input to the Lake. Recent data obtained by the U.S. Geological Survey are consistent with such estimates,[8] and confirm a measurable improvement in lake water quality.[9]

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[6] *U.S. Geological Survey Water-Resources Investigations Report No. 87-4168,* Hydrology and Water Quality of Delavan Lake in Southeastern Wisconsin, *August 1988.*

[7] *University of Wisconsin-Institute for Environmental Studies Water Resources Management Workshop Report,* Delavan Lake: A Recovery and Management Study, *September 1986.*

[8] *U.S. Geological Survey Water-Resources Investigations Report No. 96-4160,* Phosphorus Dynamics in Delavan Lake Inlet, Southeastern Wisconsin, 1994, *1996.*

[9] *The data on which this assessment is based are set forth in annual data reports published by the U.S. Geological Survey as U.S. Geological Survey Open-File Reports 95-190 through 00-89,* Water-Quality and Lake-Stage Data for Wisconsin Lakes, Water Year 1994, *1995, through* Water Year 1999, *2000; see Dale M. Robertson, Gerald L. Goddard, Daniel R. Helsel, and Kevin L. MacKinnon, "Rehabilitation of Delavan Lake, Wisconsin,"* Lake and Reservoir Management, *Vol. 16, No. 3, 2000, pp. 155-176.*

**Relationship to Other Lake Management Efforts**
Local concern over the state of the Lake prompted the formation of a Section 60.70, *Wisconsin Statutes*, town sanitary district around Delavan Lake during 1969. Since that time, the lake residents have enrolled in the Wisconsin Department of Natural Resources Self-Help Monitoring Program, and the Delavan Lake Improvement Association and other nongovernmental bodies have undertaken an extensive program of public informational programming in an effort to increase awareness of lake protection activities and measures. These actions have provided the residents of Delavan Lake with a better understanding of their Lake. Nevertheless, continued concerns expressed by the lake residents over the water quality conditions in the Lake led to the appointment of the Town of Delavan Lake Committee to act in a technical advisory capacity to the Town Board. This Committee has overseen the program of lake restoration and rehabilitation being conducted on Delavan Lake since 1986. The resulting program of lake restoration and rehabilitation was consistent with the objectives established by the Turtle Creek Priority Watershed Project,[10] as elaborated and refined in the abovereferenced University of Wisconsin and WDNR plans and environmental assessments, and other previously published plans for the management of water quality in the Lake including the adopted regional water quality management plan.

As noted, a key element of the comprehensive lake management program being undertaken on and around Delavan Lake is the wetland restoration project at Mound Road. Some portions of this program have been, or are being, undertaken by the Town of Delavan in cooperation with other local, State, and Federal agencies, including the U.S. Environmental Protection Agency, U.S. Geological Survey, U.S. Army Corps of Engineers, Wisconsin Department of Natural Resources, the University of Wisconsin, and the Delavan Lake Sanitary District. In addition, citizens living within the Delavan Lake drainage area continue to play an important role in the conduct of this extensive program of lake management activities and restoration efforts. By implementing lake-sensitive measures within the drainage area tributary to Delavan Lake, these citizens form a significant part of the Town's overall program of community-based, environmentally sound lake management on Delavan Lake.

This proposed wetland restoration-lake protection project is consistent with the approved regional water quality management plan, the amended priority watershed plan developed for the Turtle Creek watershed, the basin water quality management plan, and the lake management plan.

**Environmental Impacts and Consequences**
There are no known environmental hazards on the site. The Wisconsin Department of Natural Resources approved an Environmental Impact Statement relative to this project in March 1989. The WDNR has determined that the project meets all applicable local, State, and Federal requirements, including actions required to comply with Chapters 23, 30, and 114, Stats., and Chapters NR 1, NR 102, NR 103, NR 115, NR 116, NR 117 and NR 150, *Wisconsin Administrative Code*.

## MANAGEMENT PLAN AND SITE MAINTENANCE

A wetland management plan has been prepared previously by RUST Environment & Infrastructure, Inc. (now Earth Tech, Inc.) and has been provided to the Wisconsin Department of Natural Resources as noted above. The essential features of this plan included:

1. An emphasis on water quality improvements relating to the inflow to Delavan Lake;

2. An additional benefit in terms of the recreation of a variety of wetland habitats within a natural floodplain setting;

3. A desire to enhance community ownership of the project through community participation in the wetland restoration process;

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[10]*Wisconsin Department of Natural Resources,* Turtle Creek Priority Watershed Plan, *March 1984.*

4. A commitment to public use of, and access to, this publicly owned land through provision of trails and interpretive facilities; and

A continuing process of environmentally sound management of Delavan Lake and its watershed by the Town of Delavan, consistent with the areawide water quality management plan and Turtle Creek Priority Watershed plan.

## WATER REGULATORY PERMITS

The proposed protection program will result in the completion of the rehabilitation efforts on Delavan Lake. The necessary permit to complete these efforts has been issued by the Wisconsin Department of Natural Resources—Permit No. 3-SE-88-0114/414/536/7302/808, dated September 6, 1991. Any additional permitting required will be identified under task element 3 above.

## TIMETABLE

The proposed wetland restoration project will be undertaken between October 1, 2002, and December 31, 2005. The construction works proposed to be conducted based upon the engineering designs prepared under this lake protection program, are expected to be conducted during calendar year 2003, with the preconstruction monitoring and engineering design being completed between October 1, 2002, and September 30, 2003, and the post-construction monitoring between October 1, 2003, and September 30, 2004. The final reports on the project will be prepared no later than December 31, 2005.

## PROJECT COSTS

| | | |
|---|---|---|
| 1. | Engineering Design Costs | $ 70,000 |
| 2. | Construction Costs: Hydrologic Restoration<br>and Wetland Revegetation | $200,000<br>$ 27,000 |
| 3. | Monitoring & Evaluation | $ 63,750 |
| 4. | Non-State Laboratory of Hygiene analyses | $ 14,250 |
| 5. | Public Involvement Programming | $ - -[a] |
| | Total Project Costs | $375,000 |
| | State Share Requested | $200,000 |
| | Local Share Provided | $175,000 |

[a]*Covered under ongoing lake management programming.*

The local share of this Grant application will be borne by the Town of Delavan using funds provided in part through a U.S. Geological Survey cooperative agreement estimated to be $31,200.

## AUTHORIZING RESOLUTION AND LETTERS OF SUPPORT

The Resolution of the Town of Delavan, together with letters of support from Walworth County and the City of Delavan, is appended hereto.

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# Appendix D

# AN AQUATIC PLANT MANAGEMENT PLAN FOR DELAVAN LAKE, WALWORTH COUNTY, WISCONSIN

## INTRODUCTION

This aquatic plant management plan is an integral part of the lake management plan for Delavan Lake and represents an important element of the ongoing commitment of the Town of Delavan and Delavan Lake Sanitary District to sound environmental management with respect to the Lake. The aquatic plant management portion of the lake management plan was prepared during 2002 by the Regional Planning Commission, and is based on field surveys conducted by the consultant to the Town, during 1992, and the Sanitary District, between 1993 and 1999. The plan follows the format adopted by the Wisconsin Department of Natural Resources (WDNR) for aquatic plant management plans pursuant to Chapters NR 103, NR 107, and NR 109 of the *Wisconsin Administrative Code*. Its scope is limited to those management measures which can be effective in the control of aquatic plant growth; those measures which can be readily undertaken by the Town of Delavan and Delavan Lake Sanitary District in concert with the riparian residents; and those measures which will directly affect the uses of Delavan Lake. The aquatic plant management plan for the Delavan Lake is comprised of seven elements:

1. A set of aquatic plant management objectives;
2. A brief description of the Lake and its watershed;
3. A statement of the current use restrictions and the need for aquatic plant management in the Delavan Lake;
4. An evaluation of alternative means of aquatic plant management and a recommended plan for such management;
5. A description of the recommended plan;
6. A description of the equipment needs for the recommended plan; and
7. A recommended means of monitoring and evaluating the efficacy of the plan.

## STATEMENT OF AQUATIC PLANT MANAGEMENT OBJECTIVES

The aquatic plant management program objectives for the Delavan Lake were developed in consultation with the Town of Delavan and Delavan Lake Sanitary District by the Town of Delavan Lake Committee, which Committee included representation from the City of Delavan. The objectives are to:

1. Effectively control the quantity and density of aquatic plant growths in Delavan Lake to enhance water-related recreational activities; to improve the aesthetic character of the resource; and to preserve and enhance the overall value of the waterbody;

2. Contribute to the overall conservation and wise use of Delavan Lake through the environmentally sound management of vegetation, fishes, and wildlife populations in and around the Lake; and,

3. Promote a high-quality, water-based recreational experience for residents and visitors to Delavan Lake.

## DELAVAN LAKE AND ITS WATERSHED CHARACTERISTICS

Delavan Lake is located in the west-central portion of Walworth County, encompassed within the City and Town of Delavan, as shown on Map D-1. The Lake is a drainage lake located in the upper portion of the Turtle Creek watershed: Jackson Creek forms the primary inflow entering the Lake on the northeastern shore, and Swan Creek, the only outlet draining the northwestern embayment of the Lake.

Delavan Lake is a 2,072-acre drainage lake located within U.S. Public Land Survey Sections 13, 14, 20, 21, 22, 23, 27, 28, 29, 31, and 33, Township 2 North, Range 16 East, City and Town of Delavan, Walworth County. The Lake offers a variety of water-based recreational opportunities and is the focus of the communities surrounding the Lake. Portions of the lakeshore, particularly in the vicinity of the northernmost embayment known as the "Inlet," present a rural character among changing land uses in an urbanizing area. Elsewhere, the shoreline is well developed, primarily for residential uses.

### Land Use and Shoreline Development

The Lake's total tributary drainage area is about 26,000 acres in areal extent. As of 1995, approximately 85 percent of the total tributary drainage area to the Lake remained in rural land uses, with the dominant land usage being agricultural. Agricultural lands comprised about 70 percent of the total tributary drainage area. Woodlands, wetlands, and other open lands comprised a further 8 percent of the total tributary drainage area to the Lake. About 15 percent of the tributary drainage area was in urban land uses. Residential land usage comprised about 7 percent of the total tributary drainage area. Commercial, industrial, transportation, and recreational land uses comprised a further 8 percent of the total tributary drainage area to the Lake.

Under planned year 2020 conditions, the Walworth County development plan and regional land use plan forecast about 6,200 acres of additional urban development within the drainage area tributary to the Lake. About 2,800 acres of this development are anticipated to be for residential uses. Thus, a significant portion of the lands in that portion of the drainage basin tributary to Delavan Lake would be in residential or other urban usage.

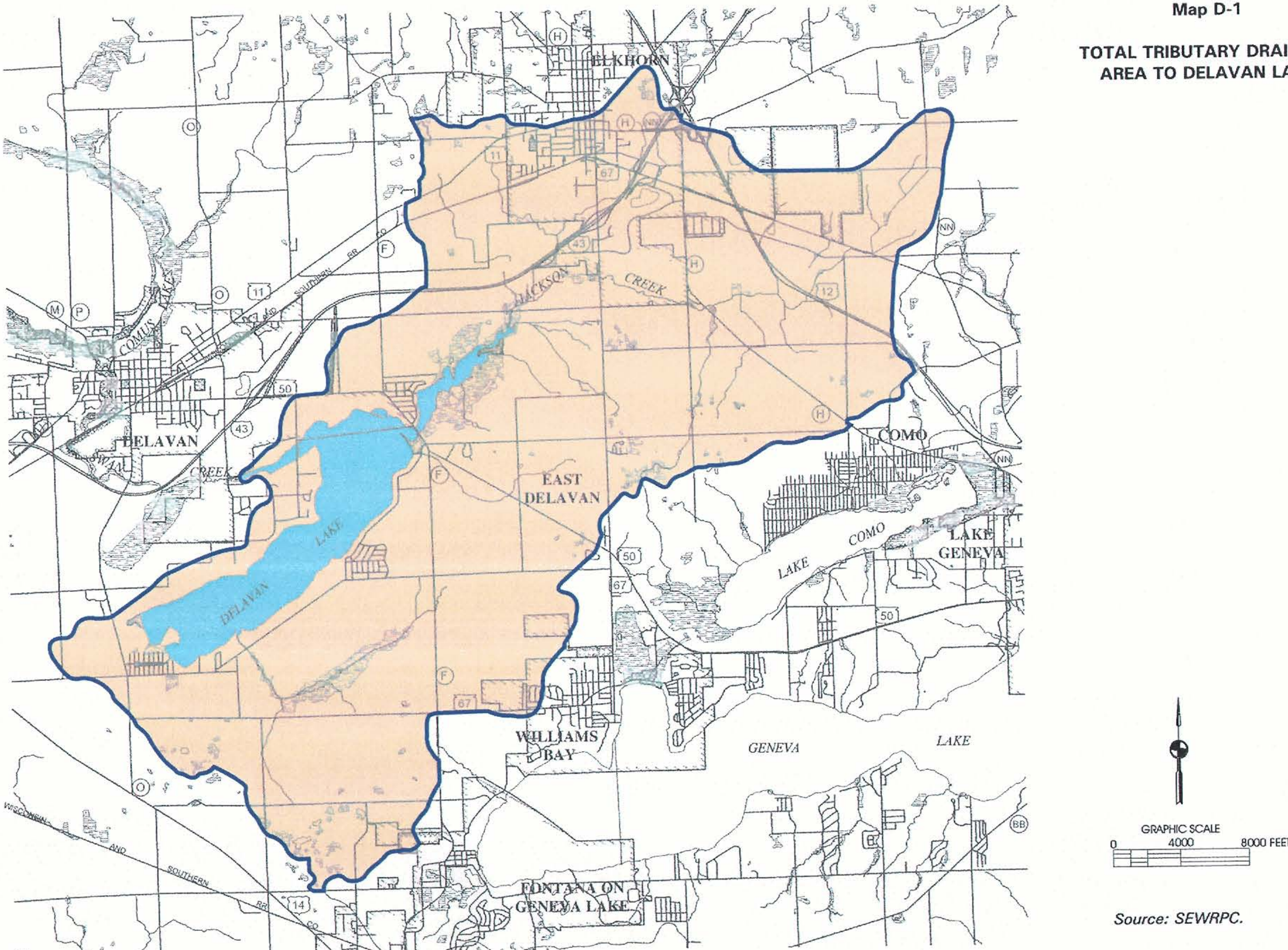
### Aquatic Plants, Distribution, and Management Areas

The Wisconsin Conservation Department, now the Wisconsin Department of Natural Resources, initially conducted a number of aquatic plant surveys on Delavan Lake between 1948 and 1975, usually in conjunction with fisheries surveys. The aquatic macrophyte species reported as being present in Delavan Lake during the surveys conducted between 1948 and 1975 are shown in Table D-1.[1] Over this period, a total of 25 species were reported as being present. However, not all of the aquatic plant species were present during each year of record, and as many as possibly 15 species were not detected in the years subsequent to 1975, but prior to the Lake rehabilitation project of the 1990s.

In 1948, Delavan Lake was reported to have supported 14 species of aquatic macrophytes.[2] Sago pondweed and coontail were reported as abundant. Nevertheless, during the 1950s, there was a general decline in the number of

[1]*E.R. Schumacher and L. Burns*, General Fishery Survey and Management Recommendations, Delavan Lake, 1975, *Wisconsin Department of Natural Resources Intradepartmental Memo, 1978.*

[2]Ibid.




Map D-1

**TOTAL TRIBUTARY DRAINAGE AREA TO DELAVAN LAKE**

*Source: SEWRPC.*

Table D-1

DELAVAN LAKE MACROPHYTE SURVEY RESULTS: 1948-1975[a]

| Aquatic Plant Species Present | Date of Last Report Prior to Initiation of Lake Rehabilitation Project | Notes |
|---|---|---|
| *Ceratophyllum demersum* (coontail) | 1962 | - - |
| *Elodea canadensis* (waterweed) | 1972 | - - |
| *Lemna* sp. (duckweed) | 1972 | Last report is for *Lemna minor* |
| *Myriophyllum exalbescens* (spiked water milfoil) | 1952 | - - |
| *Najas flexilis* (bushy pondweed) | 1972 | - - |
| *Nelumbo lutea* (American lotus) | 1952 | - - |
| *Nuphar advena* (yellow water lily) | 1956 | Reclassified as *Nuphar lutea* forma *advena* |
| *Nymphaea odorata* (American white water lily) | - - | - - |
| *Potamogeton americanus* (long-leaf pondweed) | 1952 | Reclassified as *Potamogeton nodosus* |
| *Potamogeton amplifolius* (large-leaf pondweed) | 1952 | - - |
| *Potamogeton confervoides* (Tuckerman's pondweed) | 1951 | - - |
| *Potamogeton crispus* (curly-leaf pondweed) | - - | - - |
| *Potamogeton demersum* | 1972 | - - |
| *Potamogeton filiformis* (narrow-leaf pondweed) | 1963 | Reclassified as *Stuckenia filiformis* forma *filiformis* |
| *Potamogeton gramineus* (variable pondweed) | 1952 | - - |
| *Potamogeton natans* (floating-leaf pondweed) | 1972 | - - |
| *Potamogeton nodosus* (strap-leaf pondweed) | 1968 | - - |
| *Potamogeton pectinatus* (Sago pondweed) | 1962 | - - |
| *Potamogeton praelongus* (white-stem pondweed) | 1951 | - - |
| *Potamogeton vaginatus* (large-sheath pondweed) | 1952 | Reclassified as *Stuckenia vaginatus* |
| *Potamogeton zosteriformis* (flat-stemmed pondweed) | 1952 | - - |
| *Potamogeton* sp. (flat-leaf pondweed) | 1962 | - - |
| *Ranunculus* sp. (buttercup) | 1948 | Last report is for *Ranunculus longirostris* |
| *Sagittaria latifolia* (arrowhead) | 1972 | Last report is for *Sagittaria* sp. |
| *Vallisneria americana* (water celery) | 1972 | - - |

[a]*Information obtained from E.R. Schumacher and L. Burns,* General Fishery Survey and Management Recommendations, Delavan Lake, 1975, *Wisconsin Department of Natural Resources Intradepartmental Memo.*

*Source: SEWRPC.*

species found in the Lake, and five species of pondweeds—*Potamogeton americanus*, *P. amplifolius*, *P. gramineus*, *P. praelonus*, and *P. vaginatus*—that had been recorded as abundant or common during the surveys of 1948 and the early 1950s, were not reported subsequently.[3] This decline was apparently an issue of concern at the time. According to an area resident, during 1955, the Izaak Walton League obtained and planted a number of desirable plant species at the southwest end of the Lake, in an attempt to limit the loss of aquatic plant species in the Lake.[4]

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[3]Ibid.

[4]*Communication with F.M. Clopper, cited in E.R. Schumacher and L. Burns*, General Fishery Survey and Management Recommendations, Delavan Lake, 1975, *Wisconsin Department of Natural Resources Intradepartmental Memo, 1978.*

Notwithstanding such attempts to limit the decline in aquatic plant diversity, the loss of species previously reported as being recorded from Delavan Lake continued. In the 1960s, only seven species were reported as being present, with this number declining to four species by 1968.[5] Several additional pondweed species were not reported after 1962, while other species, such as coontail, declined in abundance. Strap-leaf pondweed and white water lily were reported to be the dominant aquatic plants. By the mid-1970s, white water lily was still considered to be a dominant plant species present in the Lake, but the strap-leaf pondweed had been replaced by curly-leaf pondweed as the dominant pondweed species. Neither plant species could be considered abundant. By 1972, all major "weed" beds were reported to have disappeared, and only single plants and scattered patches of plants were reported in the Lake, including the two dominant species, which were reported to be "scarce."

During the 1980s, two additional aquatic plant surveys were conducted, prior to the major lake rehabilitation efforts on Delavan Lake, by the U.S. Geological Survey in association with the Delavan Lake Sanitary District. The surveys were conducted between June 12 and August 21, 1984, and between May 21 and August 27, 1985. During these surveys, three species of aquatic macrophytes were identified in Delavan Lake. The dominant aquatic plant species was curly-leaf pondweed, *Potamogeton crispus*. The other aquatic macrophytes present during these surveys were white water lily and another, unidentified pondweed.

***Recovering Aquatic Plant Communities***

Since beginning of the lake restoration project on Delavan Lake during the fall of 1989, a number of additional, annual aquatic plant surveys have been conducted. These surveys were conducted during 1990 and 1991 by the Wisconsin Department of Natural Resources, and from 1992 through 1999 by Aron & Associates. The latter surveys were conducted under contract to the Town of Delavan during 1992, and under contract to the Delavan Lake Sanitary District during more recent years. Many changes in aquatic macrophyte populations and densities were reported to have occurred during this period, due, in part, to increased water clarity and a decrease in rough fish populations. Both seasonal and year-to-year variations in community composition were reported. In the surveys conducted between 1990 and 1994, as well as in those conducted between 1996 and 1999, 29 species of aquatic macrophytes, including the two emergent plant species, *Typha latifolia* and *Scirpus* sp., were reported to occur in Delavan Lake.[6] Species that interfere with the recreational and aesthetic use of the Lake, such as *Myriophyllum spicatum*, *Ceratophyllum demersum*, and *Potamogeton crispus*, also were found to be present, especially in areas of the Lake subject to the greater disturbances. The distributions of aquatic plants in the Lake during 1998 are shown on Map D-2.

During the July 1999 survey, plant growth occurred throughout the Lake where depth was 14 feet or less, with 13 species of aquatic macrophytes being identified. This did not include species of bulrush (*Scirpus* sp.) and cattail (*Typha* sp.) associated with the wetland complexes along the inlet channel and the southwestern bay, which, although present during this survey, were not considered part of the submergent plant community. Eurasian water milfoil, *Myriophyllum spicatum*, was the dominant species in many areas of the Lake. This nonnative plant has been the most abundant macrophyte species in the Lake since 1996. Curly-leaf pondweed, *Potamogeton crispus*, was also abundant during this period and was reported to be at nuisance levels. *Potamogeton pectinatus*, *Chara* sp., and *Ceratophyllum demersum*, respectively, were the next most common species in the Lake. Wild celery, *Vallisneria americana*, appeared to be spreading in the Lake, at least locally near the small tributary inlet on the southeastern shore of the Lake. The area covered by this species increased considerably from the first reported occurrence during 1992 and the 1999 survey.

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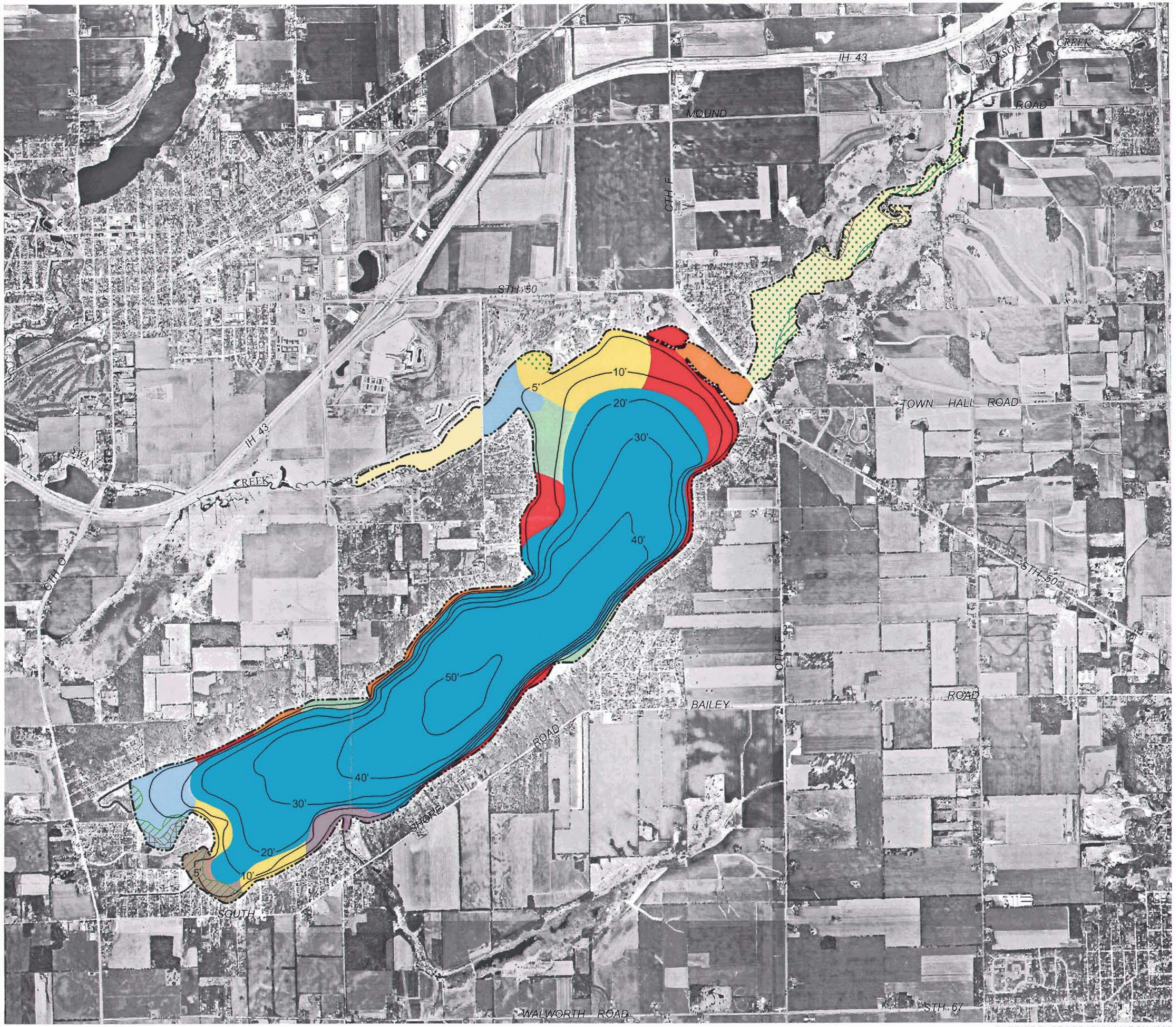
[5]*Schumacher and Burns,* op. cit.

[6]*Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1992; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1993; Aron & Associates,* Delavan Lake Plant Management Plan, *September 1993; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1994; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1996; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1997; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1998; Aron & Associates,* Delavan Lake Aquatic Plant Survey, *1999.*

## Map D-2

## AQUATIC PLANT COMMUNITY DISTRIBUTION IN DELAVAN LAKE: 1998




DATE OF PHOTOGRAPHY: MARCH 1995

- EURASIAN WATER MILFOIL AND SAGO PONDWEED
- EURASIAN WATER MILFOIL AND MUSKGRASS
- EURASIAN WATER MILFOIL, SAGO PONDWEED, AND MUSKGRASS
- EURASIAN WATER MILFOIL, SAGO PONDWEED, MUSKGRASS, AND CURLY-LEAF PONDWEED
- EURASIAN WATER MILFOIL, SAGO PONDWEED, CURLY-LEAF PONDWEED, AND WILD CELERY
- EURASIAN WATER MILFOIL, SAGO PONDWEED, MUSKGRASS, AND WATER STAR GRASS
- EURASIAN WATER MILFOIL, SAGO PONDWEED, COONTAIL, AND WATERWEED
- EURASIAN WATER MILFOIL, SAGO PONDWEED, MUSKGRASS, CURLY-LEAF PONDWEED, AND LEAFY PONDWEED
- WATER LILIES
- CATTAIL
- WATER BULRUSH
- LESSER DUCKWEED
- DEPTH GREATER THAN 15 FEET

GRAPHIC SCALE
0 1500 3000 FEET

*Source: Aron & Associates and SEWRPC.*

A list of aquatic plants reported from the Lake since 1990, compiled from the results of the aquatic plant surveys conducted during the period from 1990 through 1999, is set forth in Table D-2. Representative illustrations of these aquatic plants can be found at the end of this appendix.

Eurasian water milfoil is an exotic aquatic plant species, not native to North America, which proliferates excessively creating thick beds of vegetation. In shallower depths of water, such as are present over much of Delavan Lake, Eurasian water milfoil is able to grow to the surface making certain recreational uses less enjoyable, if not dangerous, and impairing the aesthetic quality of the waterbodies. In addition to interfering with recreational activities, Eurasian water milfoil disrupts the ecosystem of the Lake. This particular species of milfoil has been known to become the dominant plant present in the Lake with its ability to regenerate, to replace native vegetation, and to reduce the quality of fish and wildlife habitat. Further, when Eurasian water milfoil is fragmented by boat propellers, or any other means, the torn shoots are able to sprout new roots, colonizing new sites. These shoots can also cling to boats, trailers, motor propellers, or bait buckets; and can stay alive for weeks facilitating transfer to other lakes. For this reason it very important to remove all vegetation from boats and trailers after removing them from the water.[7]

**Phytoplankton**

Phytoplankton, or 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 in colonies, and can be either attached or free-floating. Phytoplankton abundance varies seasonally with fluctuations in light levels or solar irradiance, turbulence due to prevailing winds, grazing by zooplankton, and nutrient availability. In lakes with high nutrient levels, heavy growths of phytoplankton, or algal blooms, may occur. Algal blooms, historically, have been perceived as a problem in Delavan Lake. A list of algal species detected in Delavan Lake is given in Table D-3.

Blue-green algal species, that typically cause floating mats of algae that interfere with recreational and other water uses, are known to occur within the Lake. Algal blooms, when they occur, have been subjected to algicide treatments to control nuisance levels of phytoplankton growth.

After a severe blue-green algal outbreak on Delavan Lake, during the summer of 1983, the U.S. Geological Survey, in cooperation with the Delavan Lake Sanitary District and the Wisconsin Department of Natural Resources, began a two-year water-quality and hydrologic investigations to describe water-quality conditions in Delavan Lake and its drainage basin and probable causes of continuing algal problems. During the study period, from October 1983 through September 1985, blue-green algae numerically dominated the algal population in Delavan Lake during the months of June, July, August, and on into September, as shown in Figure D-1.

In winter most green and blue-green algae were reduced in number by colder temperatures and low light levels, and cryptomonad flagellates dominated the phytoplankton, sometimes accounting for over 90 percent of algal cells present. Following the melting of the ice, diatoms peaked as light conditions improved, comprising over 80 percent of the algal population during March in early spring. Diatoms require silica for growth and are typically associated with a decline in dissolved silica concentrations in the surface waters of the Lake. Diatoms also lack structures such as flagella and gas vacuoles that can give them motility in the water column, depending, instead, on wind-induced turbulence to keep them within the zone of light penetration. As the thermocline formed, the diatom population declined, probably because of silica depletion, grazing by zooplankton, and sedimentation, as the spring winds turned to summer breezes.

As the water temperatures warmed and diatoms disappeared from the water column, the small, fast-growing green algae became more common during the two-year study period. This group reached its maximum representation within the phytoplankton community during the months of April and May, accounting for as much as 40 percent of

[7] *Wisconsin Department of Natural Resources,* Eurasian Water Milfoil in Wisconsin: A Report to the Legislature, *1992.*

Table D-2

**AQUATIC PLANT SPECIES PRESENT IN DELAVAN LAKE AND THEIR ECOLOGICAL SIGNIFICANCE: 1990-1999**

| Aquatic Plant Species Present | Ecological Significance[a] |
|---|---|
| *Brasenia schreberi* (water-shield)[b] | Provides food, shelter and shade for some fish, and food for some wildfowl |
| *Ceratophyllum demersum* (coontail) | Provides good shelter for young fish and supports insects valuable as food for fish and ducklings |
| *Chara* sp. (muskgrass) | Excellent producer of fish food, especially for young trout, bluegills, and small and largemouth bass; stabilizes bottom sediments; and has softening effect on the water by removing lime and carbon dioxide |
| *Elodea canadensis* (waterweed) | Provides shelter and support for insects which are valuable as fish food |
| *Heteranthera dubia* (water stargrass) | Provides food and shelter for fish |
| *Lemna minor* (lesser duckweed) | A nutritious food source for ducks and geese, also provides food for muskrat, beaver and fish, while rafts of duckweed provide shade and cover for insects, in addition extensive mats of duckweed can inhibit mosquito breeding |
| *Myriophyllum* sp. (native milfoil) | Provides valuable food and shelter for fish; fruits eaten by many waterfowl |
| *Myriophyllum exalbescens (spiked water milfoil)* | None known |
| *Myriophyllum spicatum* (Eurasian water milfoil) | None known |
| *Najas flexilis* (bushy pondweed) | Stems, foliage, and seeds important wildfowl food and produces good food and shelter for fish |
| *Najas marina* (spiny naiad) | Provides good food and shelter for fish and food for ducks |
| *Nitella* sp. (nitella) | Provides important food for wildfowl and attracts small aquatic animals |
| *Nymphaea tuberosa* (white water lily) | Provides shade and shelter for fish; seeds eaten by wildfowl; rootstocks and stalks eaten by muskrats; roots eaten by beaver, deer, moose, and porcupine |
| *Potamogeton amplifolius* (large-leaf pondweed)[b] | Provides food, shelter and shade for some fish and food for some wildfowl. Provides shelter and support for insects, which are valuable as fish food. |
| *Potamogeton crispus* (curly-leaf pondweed) | Provides food, shelter, and shade for some fish and food for wildfowl |
| *Potamogeton foliosus*[c] (leafy pondweed) | Provides important food for wildfowl, and shelter and support for insects and young fish |
| *Potamogeton friesii* (Fries' pondweed) | Provides food and shelter for some fish and food for wildfowl |
| *Potamogeton pectinatus* (Sago pondweed)[b] | This plant is the most important pondweed for ducks, in addition to providing food and shelter for young fish |
| *Potamogeton praelongus* (white-stem pondweed)[b] | Provides feeding grounds for muskellunge; also good food producer for trout; good food producer for ducks |
| *Potamogeton richardsonii* (clasping-leaf pondweed)[b] | Provides food, shelter and shade for some fish, food for some wildfowl and food for muskrat. Provides shelter and support for insects, which are valuable as fish food. |
| *Potamogeton zosteriformis* (flat-stemmed pondweed) | Provides some food for ducks |
| *Ranunculus longirostris* (water buttercup) | Provides food for trout, upland game birds, and wildfowl |
| *Sagittaria* sp. (arrowhead) | Provides food for ducks, muskrats, porcupines, beavers and fish, and provides shelter for young fish |
| *Scirpus* sp. (bulrush)[b] | Seeds provide food for wildfowl and upland birds; plant stalks and roots are eaten by geese and muskrats, are habitat for insects, shelter for young fish, and nesting material and cover for wildfowl and muskrats |
| *Sparganium eurycarpum* (common bur-reed) | Colonies stabilize sediments, food and nesting for wildfowl, and is grazed on by muskrat and deer |

Table D-2 (continued)

| Aquatic Plant Species Present | Ecological Significance[a] |
|---|---|
| *Typha latifolia* (broad-leaved cattail) | Supports insects; stalks and roots important food for muskrats and beavers; attracts marsh birds, wildfowl, and songbirds, in addition to being used as spawning grounds by sunfish and shelter for young fish |
| *Vallisneria americana* (water celery)[b] | Provides good shade and shelter, supports insects, and is valuable fish food |
| *Zannichellia palustris* (horned pondweed)[b] | Provides food for ducks and some food value for trout |
| *Zosterella dubia* (water stargrass) | Provides food and shelter for fish, locally important food for waterfowl |

[a]*Information obtained from* A Manual of Aquatic Plants *by Norman C. Fassett,* Guide to Wisconsin Aquatic Plants, *Wisconsin Department of Natural Resources, and* Through the Looking Glass...A Field Guide to Aquatic Plants, *by Wisconsin Lakes Partnership.*

[b]*Considered a high-value aquatic plant species known to offer important values in specific aquatic ecosystems under Section NR 107.08 (4) of the* Wisconsin Administrative Code.

[c]*Identified in 1992 as* Potamogeton pusillus.

*Source: Aron & Associates and SEWRPC.*

the phytoplankton population. Following this early summer peak in green algae, blue-green algae became the most common phytoplankton group in the Lake as summer progressed. Declines in green algae were most likely due to a combination of grazing by zooplankton, some species of which were becoming abundant in May and June, and depletion of nitrogen, especially in years when the phosphorus concentrations in the epilimnion were high.

During the 1983 through 1985 study period, blue-green algae dominated the phytoplankton community of Delavan Lake during the summer. The blue-green species often persist through the summer because they have slow growth rates and low loss rates. Many blue-green species, such as *Microcystis*, *Anabaena* and *Aphanizomenon*, have gas vacuoles which allow them to regulate their buoyancy and minimize their losses due to sedimentation. They also can maximize their growth by moving vertically in the water column to obtain optimal levels of light and nutrients. Because of their gas vacuoles, species such as *Microcystis* and *Aphanizomenon*, float higher in the water and form conspicuous algal mats or blooms. Other blue-green species can float to the surface, forming a scum layer. Blue-green algae are not ordinarily used as food by zooplankton, because of their large size, unpalatability and/or toxicity. In addition, blue-green algae are less sensitive to growth limitation from nitrogen depletion than other algal groups because many species are capable of converting atmospheric nitrogen gas, which is generally unusable by living organisms, to compounds, such as nitrate or ammonia, which is readily used for plant growth. Given the low N:P ratios that are generally seen in Delavan Lake during spring overturn, nitrogen depletion probably accounts for the dominance of the phytoplankton community by blue-green algae during late summer and early fall.

Average algal cell densities are reported to be considerably lower than they were prior to the alum treatment. This is reflected in the reduced chlorophyll-*a* concentrations reported in the Lake during the period subsequent to 1991. Nevertheless, algal blooms continue to occur occasionally in Delavan Lake. A common definition of an algal bloom is when a population of a particular alga exceeds 500,000 cells per liter.[8] Since the lake rehabilitation program began during the 1989-1990 hydrological year, filamentous algae have, at times, attained nuisance levels in the Lake.[9] During such blooms, algae may accumulate onshore, producing noxious odors and creating

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[8]*L.J. Britton* et. al., An Introduction to the Processes, Problems, and Management of Urban Lakes, *U.S. Geological Survey Circular 601-K, 1975.*

[9]*Aron & Associates,* Delavan Lake Aquatic Plant Management Plan, *1993.*

unsightly conditions as they die and decompose. Their decay consumes oxygen and, if dissolved oxygen levels are depleted sufficiently, fish kills may result.

## PAST AND PRESENT AQUATIC PLANT MANAGEMENT PRACTICES

Records of aquatic plant management efforts on Wisconsin lakes were not maintained by the Wisconsin Department of Natural Resources prior to 1950. Therefore, while previous interventions occurred, the first recorded efforts to manage the aquatic plants in Delavan Lake took place in 1950. Aquatic plant management activities in Delavan Lake can be categorized as macrophyte harvesting, chemical macrophyte control, and chemical algal control.

### *Macrophyte Harvesting*

Excessive macrophyte growth on Delavan Lake has historically resulted in a control program that used both harvesting and chemicals. The existing macrophyte control program follows an aquatic management plan developed for the Lake in 1993.[10] The harvesting program emphasizes removal of nuisance plants necessary to facilitate recreational use, rather than 100 percent plant removal. Under this program, the Town of Delavan contracts with the Delavan Lake Sanitary District to conduct the harvesting. The Delavan Lake Sanitary District harvests macrophytes using several pieces of equipment leased from the Town of Delavan. This equipment includes three Aquarius Systems harvesters, one each of models H-850, H-420, and H-220, a high-speed transport barge, and two off-loading shore conveyers.

Typically, harvesting prior to June 15th is limited to cutting access channels to facilitate navigation to piers and channels. After mid-June, the harvesting operation is expanded to include all areas of the Lake that experience nuisance plant conditions. The volume of aquatic plant biomass harvested, and the general location of the harvesting operations, for the period between 1997 and 1999, are listed in Table D-4. These Lake areas correspond to the zones shown on Map D-3. No permit is currently required to cut vegetation in lakes mechanically, although the harvested plant material must be removed from the water.

[10]Ibid.

**Table D-3**

**DELAVAN LAKE PHYTOPLANKTON SURVEY RESULTS[a]**

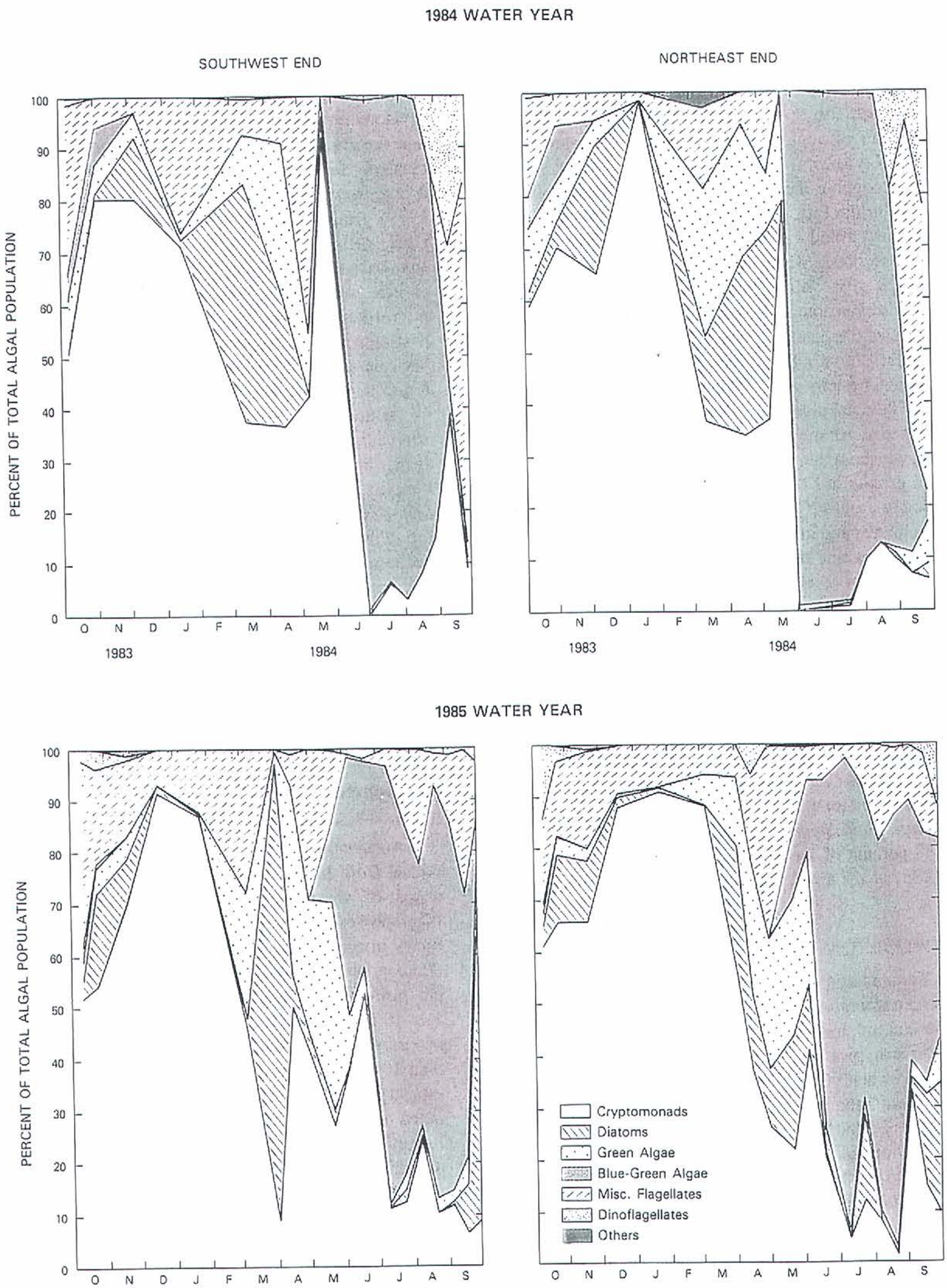
| |
|---|
| Bacillariophyta (diatoms)<br>*Cyclotella* sp.<br>*Fragillaria* sp.<br>*Melosira* sp.<br>*Navicula* sp.<br>*Nitzschia acilularis*<br>*Stauroneis* sp.<br>*Stephanodiscus tenius*<br>*Synedra* sp. |
| Chlorophyta (green algae)<br>*Actinastrum* sp.<br>*Chlamydomonas flagellate*<br>*Chlorella* sp.<br>*Cladophora* sp.<br>*Phytoconis* sp.<br>*Scenedesmus* sp.<br>*Spirogyra* sp.<br>*Staurastrum* sp. |
| Chrysophyta (golden algae)<br>*Dinobryon* sp. |
| Cryptophyta (cryptomonad flagellates) |
| Cyanobacteria (blue-green algae)<br>*Anabaena circinalis*<br>*Anabaena* sp.<br>*Anacystis* sp.<br>*Aphanizomenon flos-aquae*<br>*Aphanizomenon* sp.<br>*Chroococcus* sp.<br>*Gomphosphaeria* sp.<br>*Microcystis* sp.<br>*Nodularia* sp.<br>*Polycystis* sp.<br>*Oscillatoria* sp.<br>*Synechocystis* sp. |
| Euglenophyta (euglenoid flagellates)<br>*Phacus* sp. |
| Pyrrophyta (dinoflagellates) |

[a]*Information obtained from U.S. Environmental Protection Agency,* Report on Delavan Lake, Walworth County Wisconsin, *National Eutrophication Survey Working Paper No. 36, 1974; W.L. Gross and D. Falkner,* Bacteriological Survey of Delavan Lake with Notes on the Algal Nuisance Problem, *Report submitted to the Delavan Lake Sanitary District, November, 1975; S.J. Field and M.D. Duerk,* Hydrology and Water Quality of Delavan Lake in Southeastern Wisconsin, *U.S. Geological Survey Water-Resources Investigations Report 87-4168, 1988.*

*Source: SEWRPC.*

Figure D-1

## ALGAL POPULATIONS IN DELAVAN LAKE: 1983-1985




NOTE: Percent of total population is based numerical abundance rather than biomass.



*Source: U.S. Geological Survey, Wisconsin Department of Natural Resources, and SEWRPC.*

Table D-4

AQUATIC PLANT HARVESTING RECORDS: 1997-1999

| 1997 | Lake Area[a] 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 28 |
| June | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 49 | 0 | 656 | 756 |
| July | 48 | 5 | 5 | 182 | 14 | 8 | 1 | 7 | 0 | 0 | 412 | 495 | 1,177 |
| August | 72 | 21 | 10 | 148 | 61 | 128 | 10 | 10 | 28 | 85 | 268 | 262 | 1,103 |
| September | 0 | 0 | 0 | 22 | 15 | 19 | 0 | 0 | 0 | 222 | 0 | 445 | 723 |
| October | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 46 | 0 | 0 | 46 |
| Total | 171 | 26 | 15 | 352 | 90 | 155 | 11 | 17 | 28 | 402 | 680 | 1,886 | 3,833 |
| Percent of Total | 4.5 | 0.7 | 0.4 | 9.2 | 2.3 | 4.0 | 0.3 | 0.4 | 0.7 | 10.5 | 17.7 | 49.2 | 100.0 |

| 1998 | Lake Area[a] 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 37 | 52 |
| June | 0 | 0 | 0 | 103 | 36 | 9 | 9 | 0 | 0 | 24 | 28 | 0 | 200 |
| July | 0 | 0 | 1 | 173 | 95 | 10 | 4 | 0 | 0 | 56 | 0 | 44 | 383 |
| August | 0 | 0 | 0 | 171 | 90 | 0 | 0 | 0 | 0 | 98 | 0 | 0 | 359 |
| September | 0 | 0 | 0 | 49 | 50 | 53 | 0 | 0 | 0 | 136 | 0 | 134 | 422 |
| October | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 14 |
| Total | 0 | 0 | 1 | 496 | 271 | 72 | 4 | 0 | 0 | 329 | 28 | 229 | 1,430 |
| Percent of Total | 0.0 | 0.0 | 0.1 | 34.7 | 19.0 | 5.0 | 0.3 | 0.0 | 0.0 | 23.0 | 2.0 | 16.0 | 100.0 |

| 1999 | Lake Area[a] 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 76 | 76 |
| June | 180 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 149 | 200 | 390 |
| July | 31 | 32 | 0 | 97 | 0 | 11 | 0 | 0 | 0 | 87 | 89 | 159 | 506 |
| August | 0 | 0 | 0 | 14 | 0 | 13 | 0 | 0 | 0 | 129 | 0 | 156 | 312 |
| September | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 115 | 0 | 165 | 280 |
| October | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 211 | 57 | 0 | 111 | 0 | 24 | 0 | 0 | 0 | 367 | 238 | 756 | 1,764 |
| Percent of Total | 12.0 | 3.2 | 0.0 | 6.3 | 0.0 | 1.4 | 0.0 | 0.0 | 0.0 | 20.8 | 13.5 | 42.8 | 100.0 |

NOTE: Values represent cubic yards of plants harvested.

[a]*Lake areas for harvests are shown in Map D-3.*

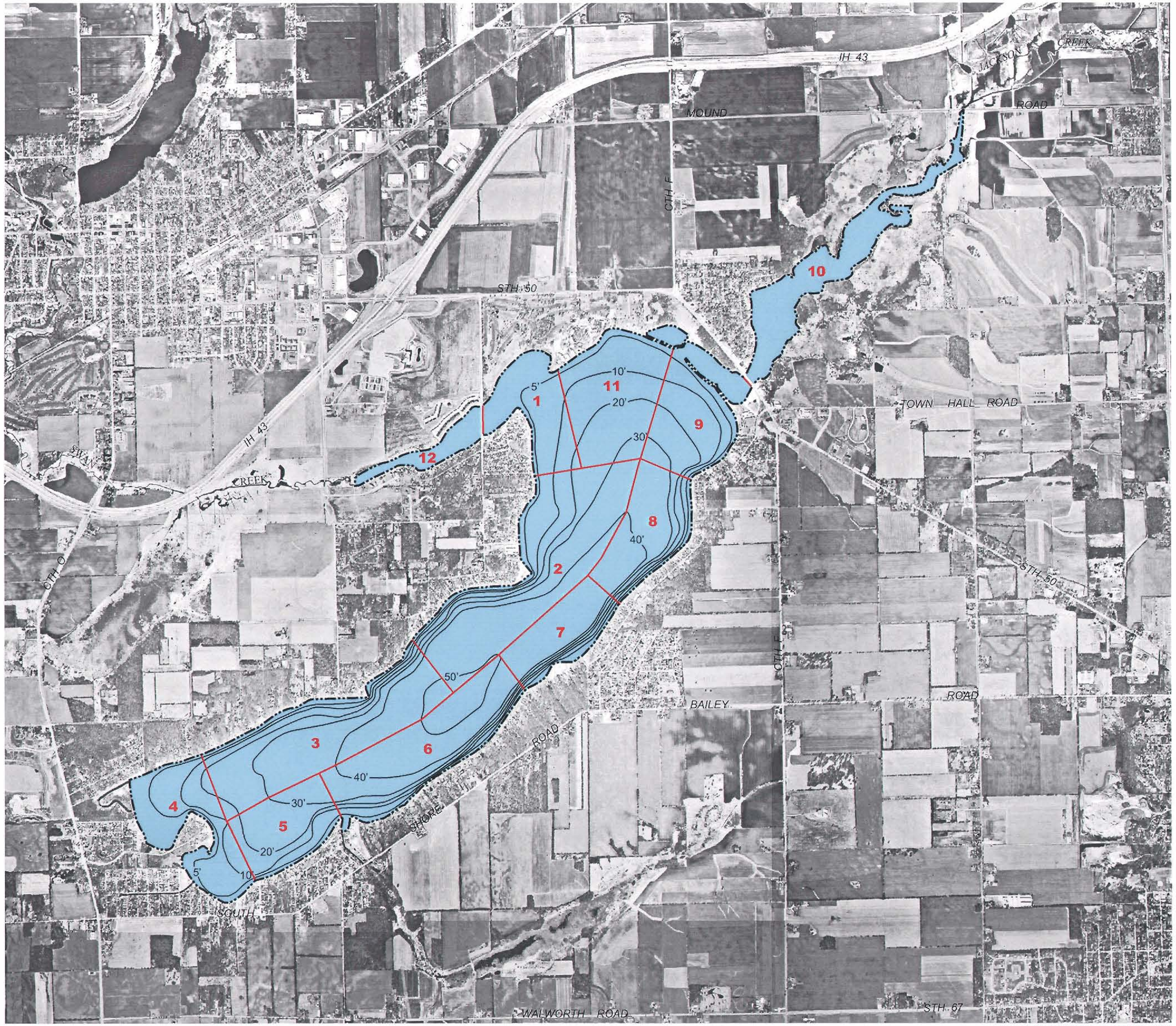
*Source: Delavan Lake Sanitary District and SEWRPC.*

### *Chemical Macrophyte Control*

Since 1941, the use of chemicals to control aquatic plants has been regulated in Wisconsin. Chemical herbicides are known to have been applied to Delavan Lake since the 1930s. In 1926, sodium arsenite, an agricultural herbicide, was first applied to lakes in the Madison area, and, by the 1930s, sodium arsenite was widely used throughout the State for aquatic plant control. No other chemicals were applied in significant amounts to control macrophytes until recent years, when a number of organic chemical herbicides came into general use. The amounts of sodium arsenite applied to Delavan Lake, and years of application during the period 1950 through 1969, are listed on Table D-5; the total amount of sodium arsenite applied over this 19-year period being about 10,400 pounds. Sodium arsenite was typically sprayed onto the surface of Delavan Lake within an area of up to

Map D-3

AQUATIC PLANT HARVESTING AREAS
WITHIN DELAVAN LAKE: 1997-1999




HARVESTING AREA

8 IDENTIFICATION NUMBER

N

GRAPHIC SCALE
0 1500 3000 FEET

*Source: Delavan Lake Sanitary District and SEWRPC.*

Table D-5

CHEMICAL CONTROL OF AQUATIC PLANTS IN DELAVAN LAKE: 1950-1999

| | | Macrophyte Control | | | | | Algae Control | | |
|---|---|---|---|---|---|---|---|---|---|
| | Sodium Arsenite | | | | 2,4-D | | Copper Sulfate | Cutrine Plus | |
| Year | (pounds) | Diquat (gallons) | Glyphosate (gallons) | Endothall (gallons) | (gallons) | (pounds) | (pounds) | (gallons) | AV-70 (gallons) |
| 1950-1969 | 10,396 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 81,113 | 0.00 | 0 |
| 1970 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 4,095 | 0.00 | 0 |
| 1971 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 9,200 | 0.00 | 0 |
| 1972 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 7,000 | 0.00 | 0 |
| 1973 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 2,433 | 0.00 | 0 |
| 1974 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 2,667 | 0.00 | 0 |
| 1975 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 2,595 | 0.00 | 865 |
| 1976 | - - | - - | - - | - - | - - | - - | - - | - - | 1,130 |
| 1977 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 700 | 0.00 | 875 |
| 1978 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 115 | 0.00 | 566 |
| 1979 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 20 | 0.00 | 627 |
| 1980 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 0.00 | 660 |
| 1981 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 0.00 | 67 |
| 1982 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 0.00 | 213 |
| 1983 | - - | - - | - - | - - | - - | - - | - - | - - | 884 |
| 1984 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 0.00 | 915 |
| 1985 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 0.00 | 508 |
| 1986 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 15.00 | 723 |
| 1987 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 5.00 | 10 |
| 1988 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 0.00 | 0 |
| 1989 | 0 | 0.00 | 0.0 | 0.00 | 0.0 | 0 | 0 | 0.00 | 0 |
| 1990 | 0 | 0.00 | 0.2 | 0.00 | 0.0 | 0 | 0 | 0.00 | 0 |
| 1991 | 0 | 10.00 | 1.3 | 0.00 | 0.0 | 0 | 0 | 2.0 | 10 |
| 1992 | 0 | 1.50 | 0.0 | 0.00 | 0.0 | 0 | 0 | 1.50 | 4 |
| 1993 | 0 | 19.00 | 0.0 | 0.0 | 0.0 | 0 | 0 | 33.75 | 0 |
| 1994 | 0 | 25.10 | 0.0 | 0.00 | 0.0 | 0 | 0 | 27.50 | 0 |
| 1995 | 0 | 37.50 | 0.0 | 40.50 | 0.0 | 0 | 0 | 79.25 | 0 |
| 1996 | 0 | 11.00 | 0.0 | 15.00 | 57.5 | 0 | 0 | 11.00 | 0 |
| 1997 | 0 | 23.50 | 0.0 | 25.75 | 0.0 | 2,339 | 0 | 134.50 | 0 |
| 1998 | 0 | 6.75 | 0.0 | 8.25 | 0.0 | 900 | 0 | 123.75 | 0 |
| 1999 | 0 | 31.25 | 0.0 | 47.25 | 32.5 | 2,930 | 0 | 178.00 | 0 |
| Total | 10,396 | 155.60 | 1.5 | 136.75 | 90.0 | 6,169 | 109,938 | 611.25 | 8,057 |

*Source: Wisconsin Department of Natural Resources, Delavan Lake Sanitary District, and SEWRPC.*

200 feet from the shoreline. Treatment typically occurred between mid-June and mid-July. The amount of sodium arsenite used was calculated to result in a concentration of about 10 milligrams per liter (mg/l) sodium arsenite (about five mg/l arsenic) in the treated lake water. The sodium arsenite typically remained in the water column for less than 120 days. Although the arsenic residue was naturally converted from a highly toxic form to a less toxic and less biologically active form, much of the arsenic residue was deposited in the lake sediments.

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 applications and accumulations of arsenic were found to present potential health hazards to both humans and aquatic life. In drinking water supplies, arsenic was suspected of being carcinogenic and, under certain conditions, arsenic has leached into and contaminated groundwater, especially in sandy soils that serve as a source of drinking water in some communities. The U.S. Environmental Protection Agency-recommended drinking water standard for arsenic is a maximum level of 0.05 mg/l.

Since anaerobic conditions occur in the hypolimnion in Delavan Lake, some arsenic may be released from the bottom sediments to the water column during the periods of anaerobiasis. In this way, some arsenic probably continues to be "flushed out" of Delavan Lake. However, the sediments contaminated with arsenic are continually being covered by new sediments; thus, the concentrations of arsenic in the water and in the surface sediments may be expected to decrease with passage of time.

As shown in Table D-5, the aquatic herbicides diquat, endothall, glyphosate, and 2,4-D have also been applied to Delavan Lake in recent years to control aquatic macrophyte growth. Diquat and Endothall (Aquathol-K) are contact herbicides and kill plant parts exposed to the active ingredient. Diquat use is restricted to the control of duckweed (*Lemna* sp.), milfoil (*Myriophyllum* spp.), and waterweed (*Elodea* sp.). However, this herbicide is nonselective and will kill many other aquatic plants, such as pondweeds (*Potamogeton* spp.), bladderwort (*Utricularia* sp.), and naiads (*Najas* spp.). Endothall kills primarily pondweeds, but does not control such nuisance species as Eurasian water milfoil (*Myriophyllum spicatum).* Glyphosate (Rodeo) and 2,4-D are systemic herbicides that are absorbed by the leaves and translocated to other parts of the plant. They are more selective than the other herbicides listed above. Glyphosate is registered for use on many species of plants in Wisconsin, but is most frequently used to control purple loosestrife (*Lythrum salicaria*) and cattails (*Typha* spp.). 2,4-D is generally used to control Eurasian water milfoil. However, it will also kill more valuable species, such as water lilies (*Nymphaea* spp.) and (*Nuphar* spp.). The present restrictions on water use after application of these herbicides are given in Table D-6. Most recently, the systemic herbicide, fluridone (Sonar), has been used experimentally in Delavan Lake to control growths of Eurasian water milfoil in the southwestern embayment of the Lake. Use restrictions applicable to this herbicide are similar to those applied to endothall.

***Chemical Algal Control***

In addition to the chemical herbicides used to control large aquatic plants, algicides have also been applied to Delavan Lake. As shown in Table D-5, a variety of copper compounds, including copper sulfate, AV-70, and Cutrine Plus, has been applied to Delavan Lake. The total amount of copper contained in these various algicides and applied since 1950 represents about 33,100 pounds of elemental copper. Copper is a nutrient required by plants in very low amounts. At higher concentrations, it is toxic to most species of planktonic and filamentous algae. Blue-green algae are especially susceptible to copper toxicity. Copper formulations are also toxic to higher plants, but their use as an aquatic herbicide has been limited outside of the southern states. Like arsenic, copper, the active ingredient in many algicides, including copper sulfate, AV-70, and Cutrine Plus, may accumulate in the bottom sediments. Excessive levels of copper have been found to be toxic to fish and benthic organisms but have not been found to be harmful to humans.[11] Accumulation of copper in the sediment of Delavan Lake has been reported.[12] Peak concentrations of copper found in the sediment were approximately 45 milligrams per kilogram (mg/kg) occurring at depths of up to 20 centimeters (cm), which depths correspond to sediments deposited in the Lake since about 1962. These copper concentrations exceed the lowest effect level (LEL) guidelines of 25 mg/kg proposed by the Wisconsin Department of Natural Resources. Copper concentrations from sediments at a depth greater than 30 cm were less than 20 mg/kg, and within the LEL guidelines proposed by the Wisconsin Department of Natural Resources.[13] Restrictions on water uses after application of Cutrine Plus are also given in Table D-6.

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[11]*J.A. Thornton and W. Rast, "The Use of Copper and Copper Compounds as Algicides," in H. Wayne Richardson,* Handbook of Copper Compounds and Applications, *Marcel Dekker, New York, 1997, pp. 123-142.*

[12]*R.S. Wakeman,* The Preservation of Historical Copper Loadings in the Recent Sedimentary Record of a Hardwater Lake in Southeastern Wisconsin, *M.S. Thesis, University of Wisconsin-Milwaukee, 1985.*

[13]*Wisconsin Department of Natural Resources,* op. cit.

Table D-6

PRESENT RESTRICTIONS ON WATER USES AFTER APPLICATION OF AQUATIC HERBICIDES[a]

| Use | Days after Application | | | | |
|---|---|---|---|---|---|
| | Cutrine-Plus | Diquat | Glyphosate | Endothall | 2,4-D |
| Drinking | - -[b] | 14 | - -[c] | 7-14 | - -[d] |
| Fishing | 0 | 14 | 0 | 3 | 0 |
| Swimming | 0 | 1 | 0 | - - | 0 |
| Irrigation | 0 | 14 | 0 | 7-14 | - -[d] |

[a]*The U.S. Environmental Protection Agency has indicated that, if these restrictions are observed, pesticide residues in water, irrigated crops, or fish will not pose an unacceptable risk to humans and other organisms using or living in the treatment zone.*

[b]*According to the Wisconsin Department of Natural Resources, if water is to be used as potable water, the residual copper content cannot exceed one part per million (ppm).*

[c]*According to the Wisconsin Department of Natural Resources, if water is to be used as potable water, the drinking water tolerance of Glyphosate is one part per million (ppm).*

[d]*2,4-D products are not to be applied to waters used for irrigation, animal consumption, drinking, or domestic uses, such as cooking and watering vegetation.*

*Source: Wisconsin Department of Natural Resources.*

**Fisheries, Wildlife, and Waterfowl**

Delavan Lake currently supports a moderately diverse fish community. Wisconsin Department of Natural Resources fish surveys conducted between 1990 and 1999 recorded the presence of 16 species of fish representing five families, as shown in Table D-7. The Wisconsin Department of Natural Resources currently regulates the harvest of fishes from the Lake under current State fishing regulations, which provide for special size and bag limits on the daily harvest in specific cases. Such specific regulations are designed to maintain the biomanipulation of Delavan Lake. The Department plans to continue to stock Delavan Lake with walleyed pike, northern pike, muskellunge, smallmouth bass, and largemouth bass annually, depending on their availability from the Department's fish hatcheries.

Although a quantitative field inventory of amphibians, reptiles, birds, and mammals was not conducted as a part of the Delavan Lake study, it is possible, by polling naturalists and wildlife managers familiar with the area, to compile lists of amphibians, reptiles, birds, and mammals which may be expected to be found in the area under existing conditions. Given the rural nature of all but the immediate shoreland area of Delavan Lake, many animals and numbers of waterfowl may be expected to commonly inhabit areas of the watershed, especially in the mostly undeveloped Delavan Lake inlet area.

A variety of mammals, ranging is size from large animals, like the white-tailed deer, to small animals, like the meadow vole, are found in the Delavan Lake area. The larger mammals that are still fairly common in the less densely populated areas of the drainage area include the white-tailed deer, cottontail rabbits, gray squirrels, fox squirrels, muskrats, minks, weasels, raccoons, red foxes, skunks, and opossums.

Amphibians native to the area include frogs, toads, and salamanders, while turtles and snakes are examples of reptiles common to the Delavan Lake area. Eleven amphibian and 17 reptile species would normally expected to be present in the Delavan Lake area under present conditions.

Table D-7

FISH SPECIES REPORTED IN DELAVAN LAKE: 1990-1999

| Common Name | Family Name | Scientific Name | Relative Abundance |
|---|---|---|---|
| Walleyed Pike | *Percidae* | *Stizostedion vitreum vitreum* | Abundant |
| Yellow Perch | *Percidae* | *Perca flavescens* | Present |
| Northern Pike | *Esocidae* | *Esox lucius* | Common |
| Muskellunge | *Esocidae* | *Esox masquinongy* | Present |
| Largemouth Bass | *Centrarchidae* | *Micropterus salmoides* | Common |
| Smallmouth Bass | *Centrarchidae* | *Micropterus dolomieui* | Present |
| Bluegill | *Centrarchidae* | *Lepomis macrochirus* | Common |
| Pumpkinseed | *Centrarchidae* | *Lepomis gibbosus* | Present |
| Green Sunfish | *Centrarchidae* | *Lepomis cyanellus* | Present |
| Black Crappie | *Centrarchidae* | *Pomoxis nigromaculatus* | Present |
| Rock Bass | *Centrarchidae* | *Ambloplites rupestris* | Present |
| Black Bullhead | *Ictaluridae* | *Ictalurus melas* | Present |
| White Sucker | *Catostomidae* | *Catostomus commersoni* | Present |
| Mimic Shiner | *Cyprinidae* | *Notropis volucellus* | Present |
| Fathead Minnow | *Cyprinidae* | *Pimephales promelas* | Present |
| Common Carp | *Cyprinidae* | *Cyprinus carpio* | Present |

*Source: Wisconsin Department of Natural Resources.*

The Delavan Lake drainage area also supports a significant population of waterfowl, both resident and migratory. Mallards, wood duck, and blue-winged teal are the most numerous waterfowl and are known to nest in the area. Many game birds, songbirds, waders, and raptors also reside or visit the Lake or its environs. Sandhill cranes and loons are notable migratory visitors. In addition, a number of special-concern, threatened, or endangered species, including bald eagles, osprey, black terns, Forester's tern, loggerhead shrikes, merlins, and Cooper's hawks, have been reported to have been seen in the vicinity of Delavan Lake. Hawks and owls function as major rodent predators within the ecosystem. Swallows, woodpeckers, nuthatches, flycatchers, and several other species serve as major insect predators.

## Recreation

Water-based, outdoor recreational activities on Delavan Lake include boating, fishing, swimming, and other active and passive recreational pursuits. Because of its size, Delavan Lake receives a significant amount of boating usage, and the town-owned lake-access site, on the northeastern shore of Delavan Lake near the Delavan Lake inlet, provides adequate public recreational boating access pursuant to Chapter NR 1 of the *Wisconsin Administrative Code*. In addition to recreational boating activities, other community and private events and activities take advantage of the aesthetic qualities of the Lake during all four seasons. Community picnics are held during the summer months, and the annual Independence Day celebrations include events along the lakeshore. The Delavan Lake Improvement Association, Inc., hold their annual meeting at the Town Park during the late spring, generally coincident with the Memorial Day weekend. During the winter months, ice fishing, cross-country skiing, and snowmobiling are popular pastimes on Delavan Lake. A recreational rating technique, developed by the Wisconsin Department of Natural Resources to characterize the recreational value of inland lakes, based upon a 1999 assessment by Southeastern Wisconsin Regional Planning Commission staff, indicated that Delavan Lake provides a moderately diverse recreational experience, with a rating of 52 out of 72 points. Favorable features include the boating and angling opportunities provided, while unfavorable features include variable water quality, primarily as a result of turbidity, and extensive algae and aquatic macrophyte growth.

## USE RESTRICTIONS IMPOSED BY AQUATIC PLANTS

Excessive plant growth on Delavan Lake impedes boat traffic, making some areas of the Lake impassable without aquatic plant control. The dense plant growths generally occur in the northeastern and northwestern portions of the Lake basin, within the embayments forming the inlet and outlet of the Lake, and along portions of the southern shoreline of the Lake. Such plant growths severely restrict boating and shoreline angling and swimming, impairing the aesthetic enjoyment of the waterbody and limiting recreational use of the Lake and shoreline. Consequently, public complaints arise throughout the summer season. Failure to remove floating vegetation which is left behind by the plant harvesters, or cut by boat propellers, leads to the buildup of vegetation along the shoreline, and, during the summer months, these beds of vegetation can become foul smelling and unsightly. The excessive plant growth also contributes to the accumulation of organic sediment on the bottom of the Lake.

## ALTERNATIVE METHODS FOR AQUATIC PLANT CONTROL[14]

**Physical Controls**

One physical method of aquatic plant control involves the drawing down of a waterbody in order to change or create specific types of habitat and thereby manage species composition within the waterbody. Such drawdown was not considered to be practicable on Delavan Lake due to the heavy recreational demands placed on the Lake throughout the year.

Other physical controls, such as the placement of bottom barriers and use of shoreline protection structures, such as riprap, may be practicable. Bottom barriers provide limited control of rooted plants by creating a physical barrier which reduces or eliminates the sunlight available to the plants. Barriers should not be used in areas of strong surf, heavy angling, or shallow water where motorboating occurs. Extensive use has been made of shoreline protection structures along the developed areas of the Delavan Lake shoreline, as shown on Map D-4. Because of the uniqueness of each shoreline situation these control methods are recommended for Delavan Lake only for installation by homeowners on a site-specific basis.

Both types of controls require permits from the Wisconsin Department of Natural Resources.

**Chemical Controls**

Chemical control measures are viewed by the community as having uncertain long-term environmental impacts, as well as possible consequences for human health. While the herbicides recently used on the Delavan Lake have met applicable U.S. Environmental Protection Agency standards and are applied by licensed personnel, the use of chemical control measures can contribute to an ongoing aquatic plant problem by augmenting the natural rates of accumulation of decayed organic matter in the lake sediments, releasing the nutrients contained in the plants back into the water column where they can be reused in new plant, including algal, biomass production. The use of chemical control measures may also damage or destroy nontarget plant species that provide needed habitat for fish and other aquatic life. Accordingly, chemical control measures should not be relied upon to fully control the infestations of aquatic plants in Delavan Lake.

However, chemical control measures are recommended for the control of the nuisance conditions over relatively small areas of the Lake. If considered necessary, chemical applications should be made in accordance with current Wisconsin Department of Natural Resources rules, under the authority of a State permit, by a licensed applicator working under the supervision of State staff. Records accurately delineating treated areas and the type and amount of herbicide used in each area, should be carefully recorded and used as a reference in applying for permits in the following year. A recommended checklist is provided as Figure D-2.

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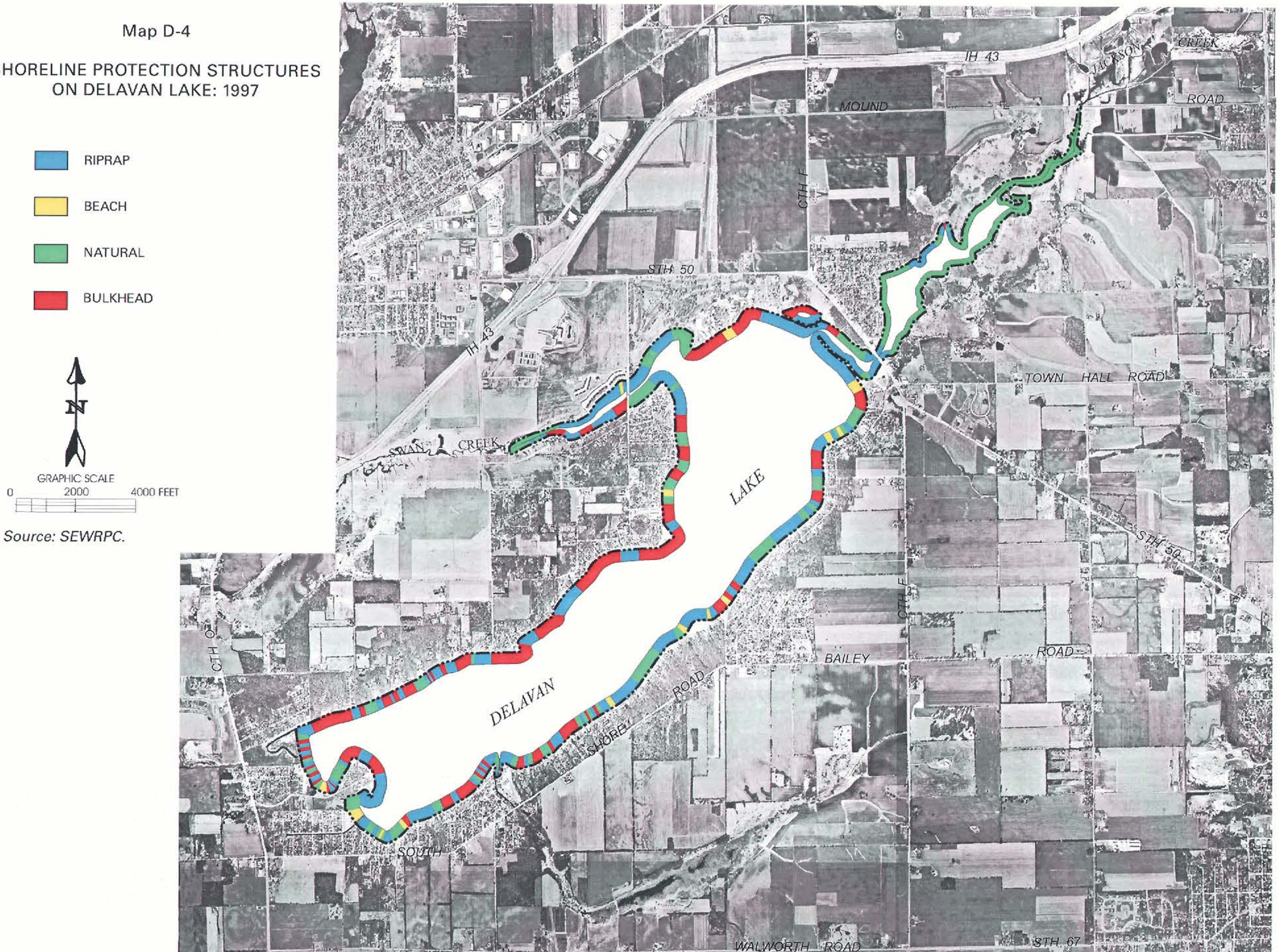
[14]*The various methods referred to in the text are described in more detail in U.S. Environmental Protection Agency Report No. EPA-440/4-90-006,* The Lake and Reservoir Restoration Guidance Manual, *August 1990.*

Map D-4

SHORELINE PROTECTION STRUCTURES ON DELAVAN LAKE: 1997




Source: SEWRPC.

DATE OF PHOTOGRAPHY: MARCH 1995

Figure D-2

DISTRICT CHECKLIST FOR HERBICIDE APPLICATION

- [ ] Nuisance report completed defining areas of potential treatment
- [ ] Permit filed with the Wisconsin Department of Natural Resources
- [ ] Certified applicator hired[a]
- [ ] Required public notice in the newspaper
- [ ] Public informational meeting (required if five or more parties request a meeting)
- [ ] Posting of areas to be treated in accordance with regulations (discussed previously in report)
- [ ] Weather conditions cooperating
  - Wind direction and velocity
  - Temperature

[a]*A licensed applicator will determine the amount of herbicide to be used, based upon discussions with appropriate staff from the Wisconsin Department of Natural Resources, and will keep records of the amount applied.*

*Source: SEWRPC.*

## Manual Controls

Manual methods of aquatic plant control, such as raking or hand-pulling, while environmentally sound, are difficult to employ on a large-scale. Although very effective in small-scale applications, for example, in and around docks and piers, manual techniques are generally not practicable for large-scale plant control methods. Manual means are considered a viable option on the Delavan Lake to control nearshore plant growths, and for removal of rooted vegetation along shorelines and around docks by individual riparian land owners. The advantage of these manual control methods, as opposed to chemical treatment, is that the response is immediate, no permits are required, and potential long-term affects of chemicals are not a concern.

## Mechanical Controls

Based on previous experience employing mechanical harvester technologies on the Delavan Lake, mechanical harvesting of aquatic plants appears to be a practicable and efficient primary means of controlling plant growth in the Lake in an environmentally sensitive manner. Harvesting removes the plant biomass, and nutrients from the Lake. While mechanical harvesting can potentially impact fish and other aquatic life caught up by the machine, disturb loosely consolidated lake bottom sediments, and result in the fragmentation and spread of some aquatic plants, it has also been shown to have some benefit in ultimately reducing the regrowth of other plants and removing phosphorus from the Lake.[15] Harvesting also removes attached, epiphytic algal growths with the

[15]*Environmental Protection Agency,* The Lake and Reservoir Restoration Guidance Manual, *2nd Edition, August 1990, p. 146.*

harvested plant material, and leaves sufficient plant material in the Lake to continue to provide forage and shelter for fish and other aquatic life, while stabilizing the lake sediments to prevent increased turbidity due to wave resuspension.

Of the various types of harvesters available, one alternative would be to purchase a smaller harvester, with about a seven-foot removable cutter bar which could then also be operated for cleanup of floating aquatic plants. The removal of the cutting bar would allow the harvester to operate in somewhat shallower water, such as in the constructed channels located on the northeastern and northwestern shores of the Lake. This type of harvester has the ability to cut and hold about 8,500 pounds of vegetation and to operate in areas as shallow as three feet. Options exist which could allow for the replacement of the paddlewheels with an hydraulically powered propeller system decreasing the width of the machine. This particular system can be operated with diesel fuel which is more economical than the standard paddlewheel option and is compatible with a transporter.

Accessory equipment needed to accompany a new harvester would include a trailer to move the harvester and a shore conveyor to unload the plants, if the new and currently owned harvesters are to work simultaneously. The options exist to buy each piece of equipment separately or to purchase one piece of equipment which is designed for both needs.

A harvesting program should be designed to provide optimal benefits and minimal adverse impacts. Small fish are common in dense macrophyte beds, but larger fish, such as largemouth bass, do not normally utilize these dense beds. Narrow channels may be harvested to provide navigational access and "cruising lanes" for predator fish to migrate into the macrophyte beds to feed on smaller fish. Shared access lanes may also be cut, allowing several residents to use the same lane. Increased use of these lanes should keep them open for longer periods than would be the case if a less directed harvesting program was followed. Because of the demonstrated need for control of aquatic plants in Delavan Lake and because the current lake management decisions have indicated a need for aquatic plant harvesting, harvesting is considered a viable management option which should be continued by the Town of Delavan and Delavan Lake Sanitary District.

**Biological Controls**

Another alternative approach to controlling nuisance aquatic plant conditions, in this particular case Eurasian water milfoil, is biological control. Classical biological control has been successfully used to control both weeds and herbivorous insects.[16] Recent documentation states that *Euhrychiopsis lecontei*, an aquatic weevil species, has the potential as a biological control agent for Eurasian water milfoil. In 1989, the weevil was discovered during a study investigating a decline of Eurasian water milfoil growth in a Vermont pond. *Euhrychiopsis* proved to have significant effects on Eurasian water milfoil in the field and in the laboratory. The adult weevil feeds on the milfoil causing lesions which make the plant more susceptible to pathogens, such as bacteria or fungi, while the weevil burrows in the stem of the plant causing enough tissue damage for the plant to lose buoyancy and collapse.[17] Although studies thus far indicate that the weevil has the potential to be a biological control for Eurasian water milfoil, at present there is not enough supporting evidence and actual exposure to warrant recommending this type of control on Delavan Lake, except on an experimental basis.

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[16]*C.B. Huffacker, D.L. Dahlsen, D.H. Janzen and G.G. Kennedy,* Insect Influences in the Regulation of Plant Population and Communities, *1984, pp. 659-696; C.B. Huffacker and R.L. Rabb, editors,* Ecological Entomology, *Kohl Wiley, New York, New York, USA.*

[17]*Sally P. Sheldon, "The Potential for Biological Control of Eurasian Water Milfoil (*Myriophyllum spicatum*) 1990-1995 Final Report," Department of Biology Middlebury College, February 1995.*

**Information and Education**
In addition to these in-lake rehabilitation methods, an ongoing campaign of community information would help to support the aquatic plant management program by encouraging the use of shoreland buffer strips, responsible use of household and garden chemicals, and environmentally friendly household and garden practices to minimize the input of nutrients from these riparian areas. This information program would also remind riparian residents of the habitat and other benefits, such as shoreline stabilization, provided by the aquatic flora of the Lake, and promote the preservation of an healthy aquatic flora in Delavan Lake.

## RECOMMENDED AQUATIC PLANT MANAGEMENT PLAN

It is recommended that aquatic macrophyte surveys of the Lake be conducted at three- to five-year intervals, depending upon the observed degree of change in the plant communities in the Lake, and the aquatic plant management program on Delavan Lake updated or modified, as necessary. Information on the aquatic plant communities should be recorded as an ongoing activity coincident with the aquatic plant management activities conducted by the Town of Delavan and Delavan Lake Sanitary District. Such records should include descriptions of: major areas of nuisance plant growth, areas harvested and/or chemically treated, species harvested and amounts of plant material removed from Lake, and species and approximate numbers of fish and other wildlife caught in the harvest. A daily harvester log containing this information should be maintained. This information, in conjunction with the recommended aquatic macrophyte surveys, will allow long-term evaluation of the effectiveness of the aquatic plant control program such that adjustments can be made in the program to maximize its benefit.

An aquatic macrophyte management plan consistent with Chapters NR 103, NR 107, and NR 109 of the *Wisconsin Administrative Code* has been prepared for the Lake by Aron & Associates, consultants to the Town of Delavan and to the Delavan Lake Sanitary District. This plan is incorporated herein by reference. However, modifications of the existing aquatic plant management program are recommended to enhance the use of the Delavan Lake while maintaining the quality and diversity of the biological communities. The following recommendations are made:

1. Mechanical harvesting is recommended as the primary management method. In the long-term, this will help to maintain good water quality conditions by removing plant materials which are currently contributing to an accumulation of decomposing vegetation and the associated nutrient recycling. The harvesting should be carried out by the Delavan Lake Sanitary District using the existing harvesters and transport equipment owned by the Town of Delavan.

2. It is recommended that shared access lanes be harvested, rather than clear-cutting large open areas, to minimize the potential detrimental effects on the fish and invertebrate communities. Directing boat traffic through these common lanes should delay the regrowth of vegetation in these areas.

3. Surface harvesting of nonnative aquatic plants, such as the Eurasian water milfoil, cutting to a depth of approximately two feet, is recommended. This should provide a competitive advantage to the low-growing native plants present in the Lake. By not disturbing the low-growing species, which generally grow within one to two feet of the lake bottom and in relatively low densities, leaving the root stocks and stems of all cut plants in place, the resuspension of sediments in Delavan Lake will be minimized. Furthermore, cutting should be focused on boating lanes placed around the perimeter of the main lake basin.

4. It is recommended that the use of chemical herbicides be limited to controlling nuisance growth of exotic species in shallow water around docks and piers, where the harvester is unable to reach. Such use should be evaluated annually and the herbicide applied only on an as needed basis. Only herbicides that selectively control milfoil, such as 2,4-D, should be used.

5. It is recommended that chemical applications, if required, be made in early spring to maximize their effectiveness on nonnative plant species, to minimize their impacts on native plant species, and to act as a preventative measure to reduce the development of nuisance conditions. The widespread use of algicides, such as Cutrine Plus, is not recommended, although algicides could be used in limited areas along the shoreline to control blue-green algae, such as *Synechosystis* sp., *Anabena* sp., and *Aphanizomenon* sp.

6. The control of rooted vegetation between adjacent piers is recommended to be left to the riparian owners concerned, as it is time consuming and costly for the mechanical harvester to maneuver between piers and boats, and such maneuvering may entail liability for damage to boats and piers. The conduct of a pierhead pick up service for manually harvested aquatic plants is recommended. Alternatively, homeowners are encouraged to use the aquatic plant fragments that they collect as compost for home gardening purposes.

7. It is recommended that ecologically valuable areas be excluded from aquatic plant management activities, especially during fish spawning seasons in early summer and autumn.

8. The incorporation by the Delavan Lake Sanitary District and Town of Delavan of an overall public educational program into the aquatic plant management program is recommended. Information to be disseminated should include information on the types of aquatic plants in Delavan Lake; on the value of and the impacts of these plants on water quality, fish, and on wildlife; and on alternative methods for controlling existing nuisance plants, including the positive and negative aspects of each method. In addition, it is recommended that the Delavan Lake Sanitary District and Town of Delavan obtain informational brochures regarding shoreline maintenance, manual harvesting of aquatic plants using hand held specialty rakes, and composting of aquatic plants, as part of the riparian owner informational and educational program.

The use of biological controls, such as the milfoil weevil, is not recommended at this time. However, reconsideration of the use of biological control agents remains subject to the outcome of the statewide assessment program currently being conducted by the Wisconsin Department of Natural Resources. To the extent that biological control agents are proven to be successful in limiting the extent and distribution of nonnative aquatic and wetland plants, it is recommended that the use of these agents be determined as part of the recommended process of aquatic plant management plan refinement.

**Harvesting Plan**

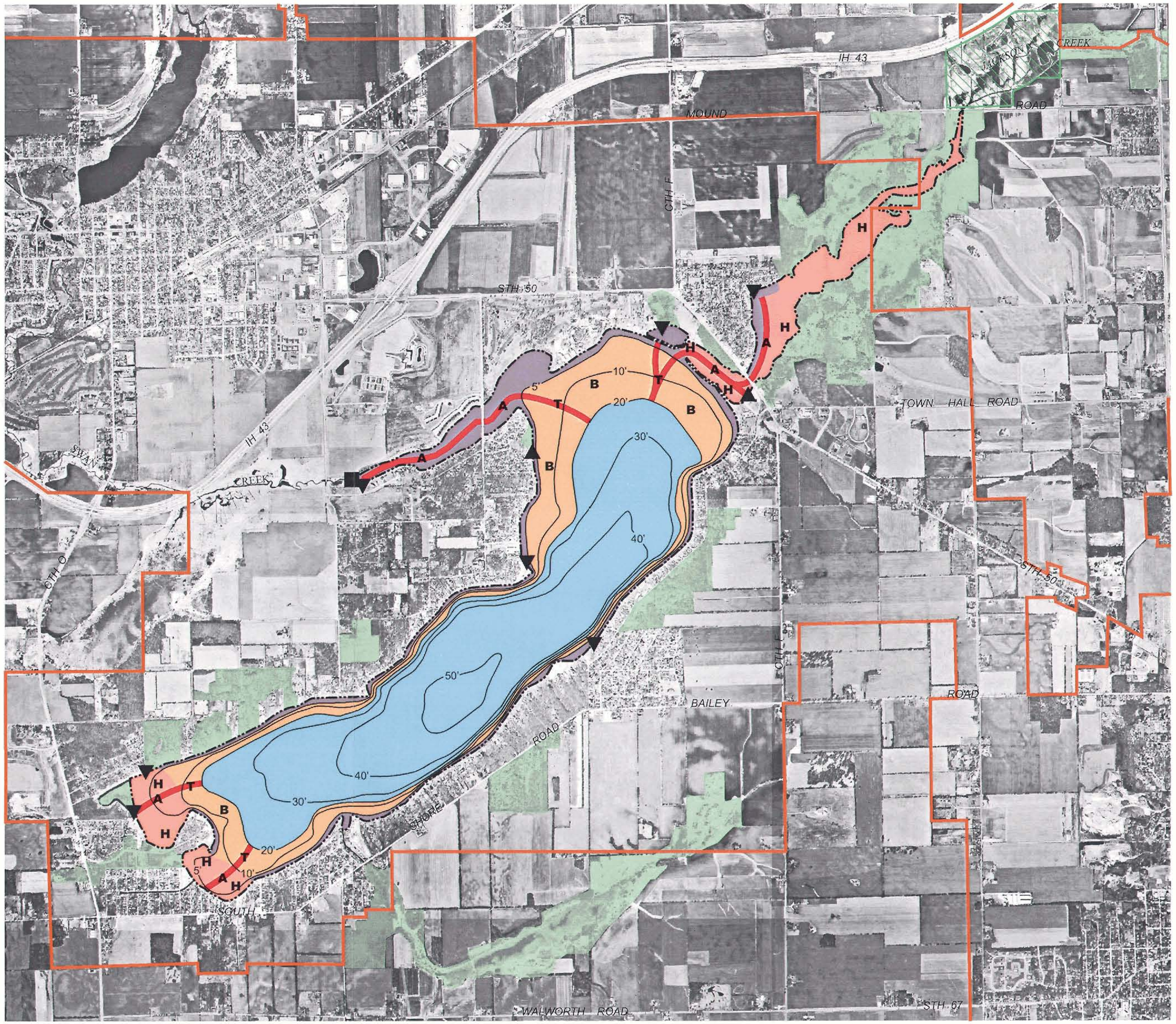
The recommended plan partitions Delavan Lake into zones for aquatic plant management, with control measures in each zone designed to optimize desired recreational opportunities and to protect the aquatic resources. The recommended aquatic plant control zones are shown on Map D-5 and the controls recommended for each zone are described in Table D-8.

As indicated on the map, it is proposed that aquatic plant management activities be restricted in certain ecologically valuable areas of the Lake. For this reason, aquatic plant management activities should be confined to zones related to recreational boating access and recreational uses (Zones A, B, and T), and open water (Zone O). Further, aquatic plant management operations will be concentrated in the areas identified for Eurasian water milfoil control, and targeted on the boating access ramps and in the principal boating use areas. A majority of the lake basin is comprised of deep water habitat requiring no aquatic plant management intervention, about 65 percent of the Lake being greater than five-feet in depth.

The primary objective of the management program is to accommodate the multiple recreational uses of the Lake, and to enhance the public perception of the Lake without inflicting irreparable damage on the structure and functioning of the lake ecosystem. To accomplish this objective, only specified control measures should be

## Map D-5

## AQUATIC PLANT MANAGEMENT PLAN FOR DELAVAN LAKE




DATE OF PHOTOGRAPHY: MARCH 1995

—20'— WATER DEPTH CONTOUR IN FEET

■ WATER LEVEL CONTROL STRUCTURE

▲ PUBLIC ACCESS SITE AND HARVESTER OFF-LOAD AREA

▼ PRIVATE ACCESS SITE

AQUATIC PLANT MANAGEMENT

A — ACCESS: HARVEST RECREATIONAL BOATING ACCESS CHANNELS APPROXIMATELY 50 FEET WIDE

T — TRANSIT LANES: HARVEST RECREATIONAL BOATING ACCESS CHANNELS APPROXIMATELY 50 FEET WIDE

B — BOATING / RECREATION: SURFACE CUT OF EURASIAN WATER MILFOIL, HARVESTING MODERATE PRIORITY

H — HABITAT: ECOLOGICALLY-VALUABLE AREAS - NO AQUATIC PLANT MANAGEMENT MEASURES RECOMMENDED DURING FISH BREEDING SEASON

LITTORAL ZONE: MAINTAIN SHORELINE PROTECTION STRUCTURES AS NECESSARY, INSTALL VEGETATIVE BUFFERS, MANUALLY HARVEST AQUATIC PLANTS AROUND PIERS AND DOCKS

OPEN WATER: DEPTH GREATER THAN 20 FEET - NO AQUATIC MANAGEMENT MEASURES RECOMMENDED

LAND USE MANAGEMENT

PROTECT ENVIRONMENTAL CORRIDOR LANDS

MANAGE AND MAINTAIN THE MOUND ROAD WETLAND

- OBSERVE GUIDELINES SET FORTH IN THE REGIONAL LAND USE PLAN, MAINTAIN HISTORIC LAKEFRONT RESIDENTIAL DWELLING DENSITIES
- PROMOTE GOOD HOUSEKEEPING PRACTICES IN URBAN AREAS

BOUNDARY OF SANITARY SEWER SERVICE AREA: WALWORTH COUNTY METROPOLITAN SEWERAGE DISTRICT - PROVIDE PUBLIC SANITARY SEWERAGE SERVICES, REFINE AS NECESSARY

WATER QUALITY MANAGEMENT

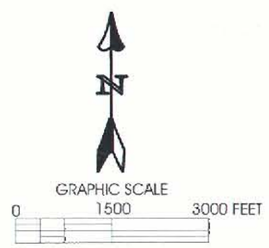
- CONTINUE PARTICIPATION IN WISCONSIN DEPARTMENT OF NATURAL RESOURCES SELF-HELP MONITORING PROGRAM

FISHERIES MANAGEMENT

- CONTINUE TO MONITOR FISH POPULATIONS, MODIFY STOCKING/ HARVESTING PROGRAM AND REGULATIONS, AS NECESSARY

PUBLIC INFORMATION AND EDUCATION

- CONTINUE PUBLIC AWARENESS PROGRAM




*Source: SEWRPC.*

Table D-8

RECOMMENDED AQUATIC PLANT MANAGEMENT TREATMENTS FOR DELAVAN LAKE

| Zone and Priority | Recommended Aquatic Plant Management Plan |
|---|---|
| Access: Zone A | Harvest channels, approximately 50 feet wide, to provide boating access, via a pier lane connecting the narrow channels to common access lanes, to the main body of Delavan Lake<br>Chemical use, if required, should be restricted to pier and dock areas within 150 feet from shore in this area |
| Boating/Recreational: Zone B | Harvest nuisance aquatic macrophyte growth within 150 feet of the shoreline, or within 30 feet of pierheads and docks, to provide maximum opportunities for boating, fishing, and limited swimming. Additional 50-foot-wide shared-access channels should extend to the center of the Lake. Harvesting of an access lane connecting the boat launching site on the northern shore of the Lake to the main body of the Lake should be undertaken<br>No harvesting or in-lake chemical application should be conducted prior to mid-June of each year. Some limited harvesting, especially the top-cutting and/or herbicide application, may be required for the control of Eurasian water milfoil or curly-leaf pondweed thereafter<br>The entire area may not require intensive management. Harvesting should be concentrated in areas of abundant macrophyte growth. Patterns of harvesting will vary yearly, depending on macrophyte abundance<br>Chemical use, if required, would be restricted to pier and dock areas and would extend more than 150 feet from shore but not more than 300 feet from shore |
| Habitat: Zone H | This zone and adjacent lands would be managed for fish habitat. Portions of the Lake should be preserved as a high-quality habitat area<br>No harvesting or in-lake chemical application should be conducted prior to mid-June of each year. Some limited harvesting may be required for the control of Eurasian water milfoil or curly-leaf pondweed thereafter<br>Debris and litter cleanup would be needed in some adjacent areas; the immediate shoreline would be preserved in natural, open use to the extent possible |
| Littoral: Zone L | Maintain shoreline protection structures as necessary. Where appropriate, install vegetated buffers both landward and lakeward of the high water mark to promote fish and wildlife habitat<br>Manually harvest around piers and docks to allow boat access<br>Chemical use, if required, would be restricted to pier and dock areas and would not extend more than 150 feet from shore |
| Open Water: Zone O | This zone includes those areas of the Lake having a water depth greater than 20 feet which do not have excessive macrophyte growth<br>Harvesting is not anticipated as being necessary in this area of deeper water<br>No chemicals should be used |
| Transit: Zone T | Harvest a 50-foot-wide channel in the central portion of the bays to connect to channels perpendicular to shore to allow access to main body of the Lake<br>Chemical use, if required, should be restricted to nuisance Eurasian water milfoil and curly-leaf pondweed control |

*Source: SEWRPC.*

applied in each of the various lake zones identified on Map D-5. The recommended sequence of the harvester operations on Delavan Lake is portrayed in Figure D-3. The recommended aquatic plant management treatments that should be applied in each of the lake zones are shown in Table D-8.

It is envisioned that the harvesting crew will be required to spend about 25 to 35 hours per week on Delavan Lake to accomplish the stated goals.

The recommended aquatic plant management plan represents an expansion of the ongoing aquatic plant management program conducted by the Town of Delavan and Delavan Lake Sanitary District. Implementation of this plan would entail a capital cost of about $150,000, the majority of which would be required for the eventual replacement of equipment and an annual operation and maintenance cost of about $50,000.

**Depth of Harvesting and Treatment of Fragments**
The harvesting equipment proposed to be used has a maximum cutting depth of five feet. While this may exceed the actual water depth in some areas it is not the intention of the owners or operators of the equipment to denude the Lake of aquatic plants given the heavy angling use of the waterbody, its morphology (which is not conducive to extensive motorized boat traffic), and the program goals. All plant cuttings and fragments will be collected *in situ* by the harvester. Those fragments accumulating along the shoreland areas will be collected by the riparian homeowners. Fragments can be used by the homeowners as garden mulch.

**Buoyage**
Temporary marker buoys may be used to direct harvesting operations in the lake basin by marking the areas to be cut. However, the size of the Lake generally precludes the need for such buoys, except insofar as they are required for the control of boating traffic on the Lake. The harvester operators will be provided with a laminated copy of the harvesting plan and made familiar with the plan and local landmarks to the degree necessary to carry out the plan without the use of buoyage.

**Harvested Plant Material Transfer Site(s)**
Plant material will be removed from the harvester at the off-loading area adjacent to the Town Park public recreational boating access site, where it will be transferred to a dump truck using a conveyor and transported to disposal sites identified by the Town of Delavan and Delavan Lake Sanitary District. Plant material will be collected and disposed of daily to avoid leaching of nutrients back into the Lake and to minimize the visual degradation of the environment near the boat launching site. The operators will stringently police the off-loading site to ensure minimal disruption of boaters and of the people using the riparian areas of the Lake.

**Disposal of Harvested Plant Material**
Harvested plant material will be land-spread on area farms or disposed of by land disposal. Harvested plant material will be used as compost.

**Precautions to Protect Wildlife and Ecologically Valuable Areas**
Operators will be provided with a laminated copy of the approved harvesting plan map as set forth in Map D-5, showing the limits of harvesting operations. A copy of the map will be kept on the harvester at all times. Operations should normally not be carried out in those areas with less than three feet of depth to protect bass habitat and spawning areas. Harvesting operations in the areas identified as suitable for bass spawning will be restricted until mid-June to permit undisturbed spawning.

**Public Information**
It is the policy of the Town of Delavan and Delavan Lake Sanitary District Lake Committee to maintain an active dialogue with the community. This dialogue is carried out through the medium of the public press and in public fora through various public meetings and other scheduled hearings.

Figure D-3

HARVESTING SEQUENCE FOR DELAVAN LAKE[a]

A. HARVEST RECREATIONAL BOATING ACCESS LANES WITHIN **ZONE T**, LINKING THE ACCESS SITES TO THE MAIN LAKE BASIN, USING NAVIGATIONAL CHANNELS 50 FEET IN WIDTH PARALLEL TO THE SHORELINE, AS SHOWN ON MAP D-5

B. HARVEST 50-FOOT-WIDE SHARED-ACCESS LANES PERPENDICULAR TO THE SHORELINE EXTENDING TOWARDS THE CENTER OF THE LAKE, AS SHOWN IN **ZONE A** ON MAP D-5.

C. HARVEST WITHIN **ZONE B**, AS SHOWN ON MAP D-5. THIS ENTIRE AREA MAY NOT REQUIRE INTENSIVE MANAGEMENT

NOTE: Sequence A and B could be done concurrently in one area of the Lake as a time-saving measure.

*[a]No harvesting would be conducted in Zone H during the fish spawning season; thereafter, control Eurasian water milfoil and curly-leaf pondweed as necessary.*

*Source: SEWRPC.*

### Harvesting Schedule

The harvesting season will begin no earlier than May 15th and will end about September 30th of each year. Actual harvesting time, not including unloading, maintenance, and downtime, will average 30 to 35 hours per week over a five-day week on average, depending on weather conditions and plant growth, to minimize recreational conflicts. During peak-growth periods, this time requirement may be increased somewhat. Further, harvesting will be confined to daylight hours to minimize public disturbances resulting from harvester and plant removal operations.

## EQUIPMENT NEEDS AND OPERATION

### Equipment Needs and Total Costs

***Manufacturer***: Aquarius Systems, D&D Products, Inc., North Prairie, Wisconsin, or other manufacturer with comparable equipment.

### Existing Equipment Requiring Replacement

| | | |
|---|---|---|
| ***Harvester***: | Aquarius Systems model HM-420 or equivalent. | |
| ***Costs***: | HM-420 Aquatic Plant Harvester or equivalent | $ 65,000 |
| | TR 12 trailer | 5,000 |
| | Shore conveyor (for Delavan Lake) | 15,000 |
| ***Shore Barge***: | | |
| ***Costs***: | Shore Barge with conveyor | $ 15,000 |
| ***Total Cost*** | | $100,000 |

**Maintenance Schedule, Storage, and Related Costs**
Routine maintenance will be performed by the Town of Delavan and Delavan Lake Sanitary District in accordance with the manufacturer's recommended maintenance schedule. Maintenance costs will be borne by the Town. Winter storage of the harvesting equipment will be the responsibility of the Town of Delavan and Delavan Lake Sanitary District. The harvesting equipment will be stored in the Town of Delavan facility on the lakeshore at the Town Park.

**Insurance Coverage**
Insurance coverage on the harvesting equipment will be incorporated into the policy held by the Town of Delavan and Delavan Lake Sanitary District on all capital equipment. Liability insurance for the operation of the harvesting equipment will also be borne by the City. The relevant certificates of insurance will be held by the Town of Delavan and Delavan Lake Sanitary District.

**Operators, Training, and Supervision**
The harvesting equipment will be owned and operated by the Town of Delavan and Delavan Lake Sanitary District, who will be responsible for day-to-day operations of the equipment. The District will provide operator training as required. District staff have extensive experience in the operation of this type of machinery. Initial training will be provided by the manufacturers on delivery of the machinery.

Day-to-day supervision will be by the District staff.

## EVALUATION AND MONITORING

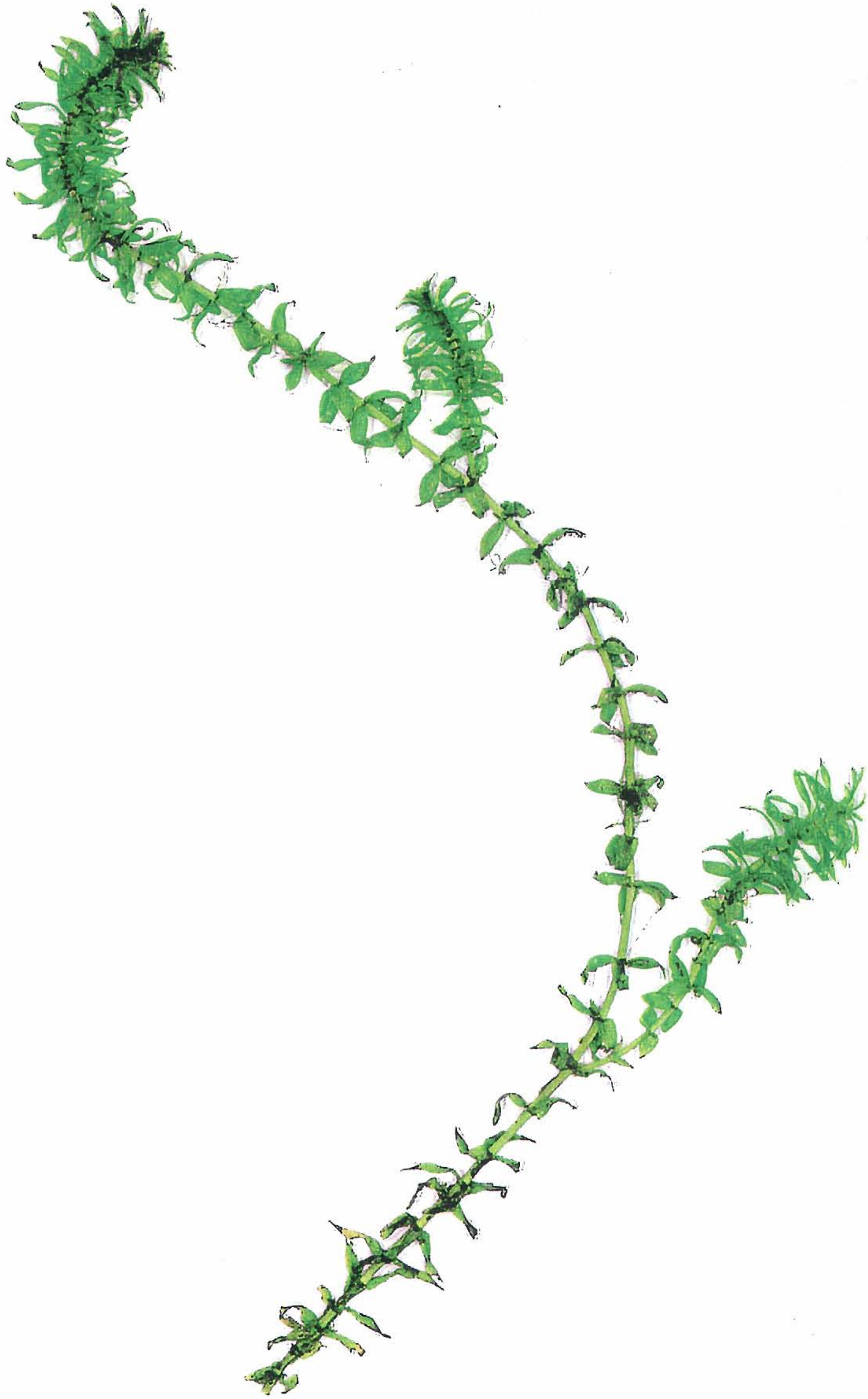
**Daily Record-Keeping Relating to the Harvesting Operation**
Daily harvesting activities will be recorded by the operators of the harvesting equipment in an operations log. An annual summary of the harvesting program will be submitted to the Town of Delavan and Delavan Lake Sanitary District (or designated Committee thereof), and made available to the public at that time.

It is the intention of the Town of Delavan and Delavan Lake Sanitary District to undertake a periodic, formal review of the harvesting program as set forth in the management plan for Delavan Lake, a copy of which has been lodged with the Department's Southeast Region Office.

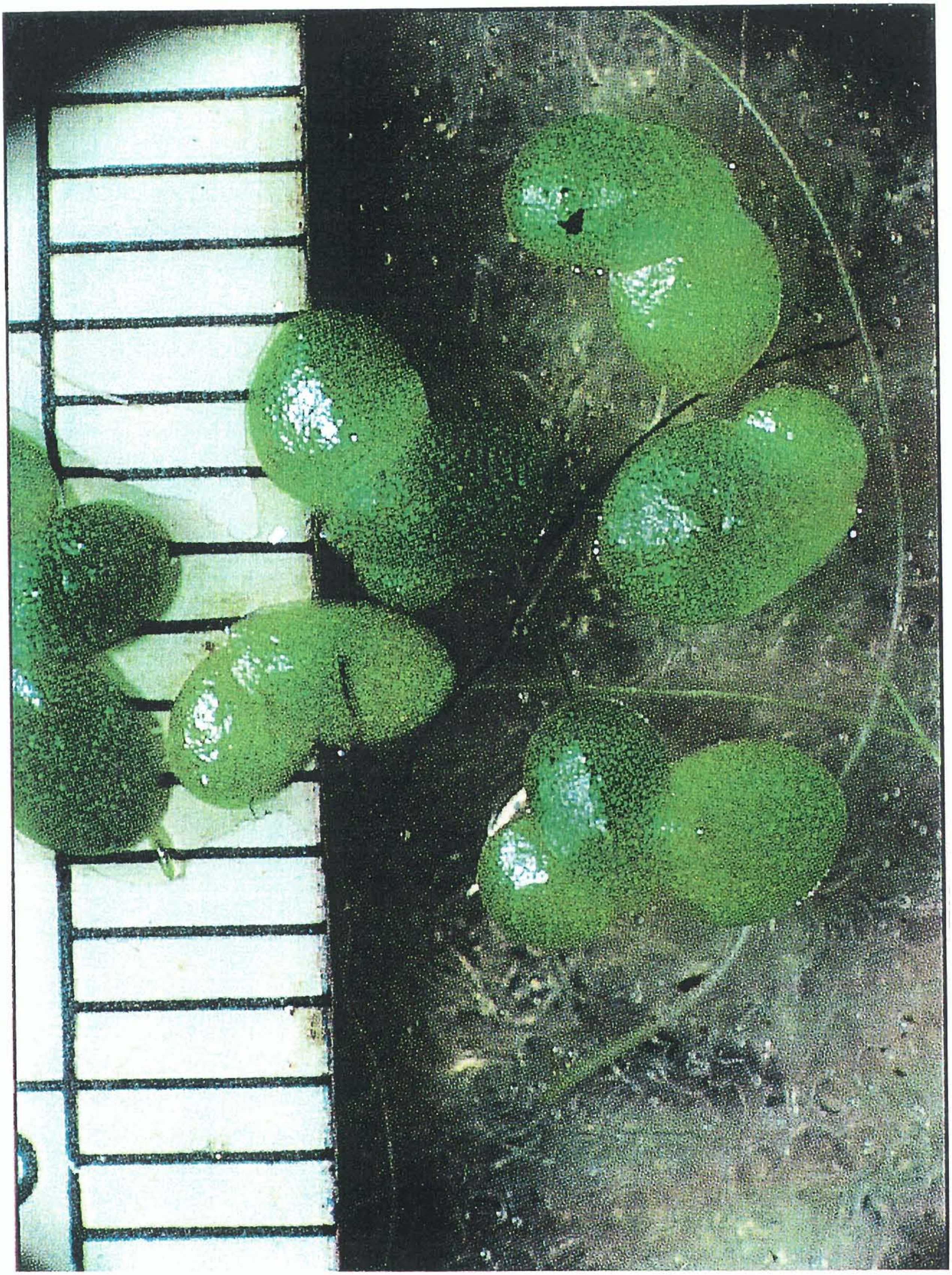
**Daily Record-Keeping Relating to the Harvester**
Daily maintenance and service records showing engine hours, fuel consumed, and oil used will be recorded in a harvester operations log.

Coontail (Ceratophyllum demersum)

Muskgrass (Chara vulgaris)



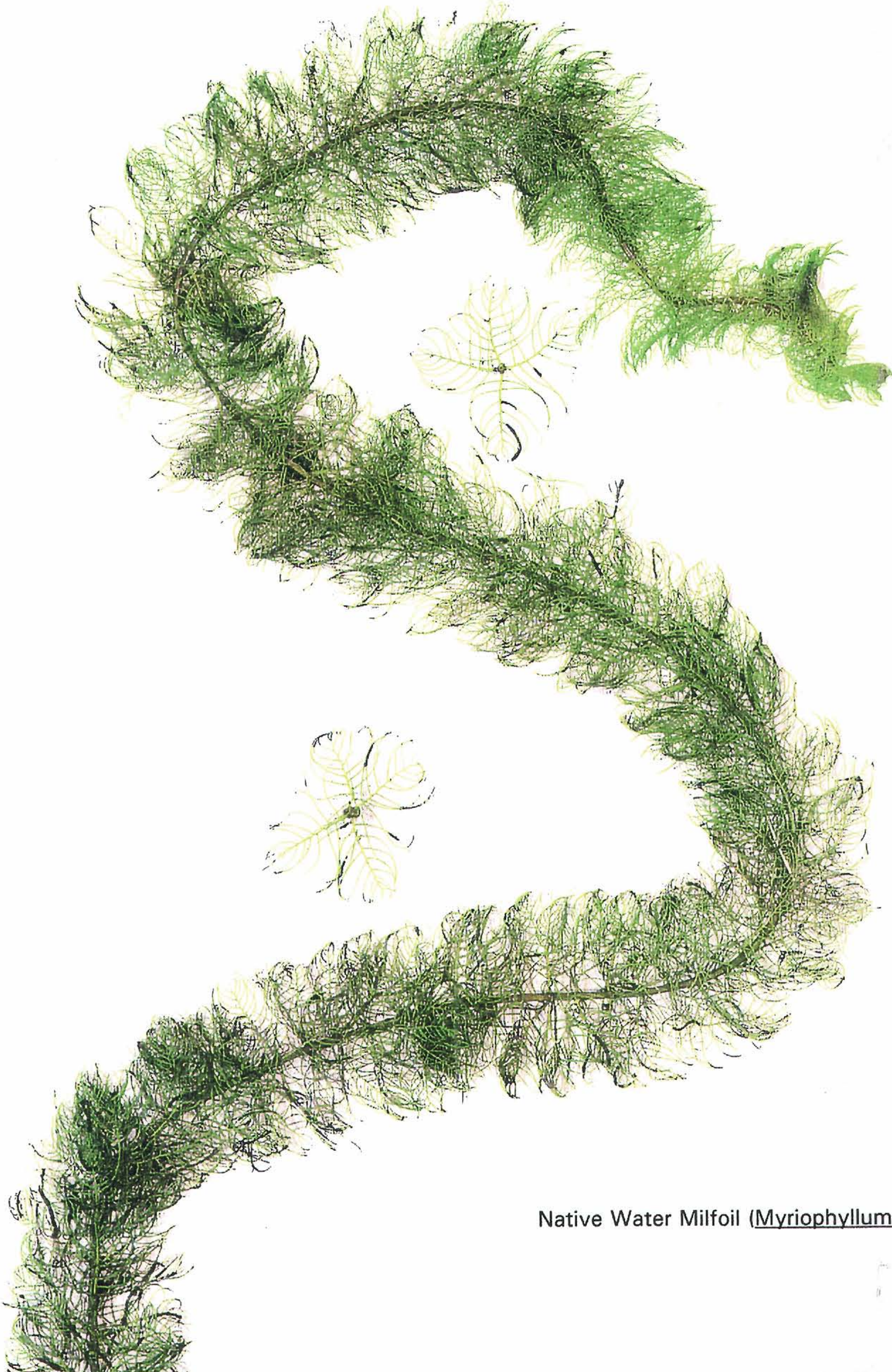
Waterweed (Elodea canadensis)



Lesser Duckweed (Lemna minor)

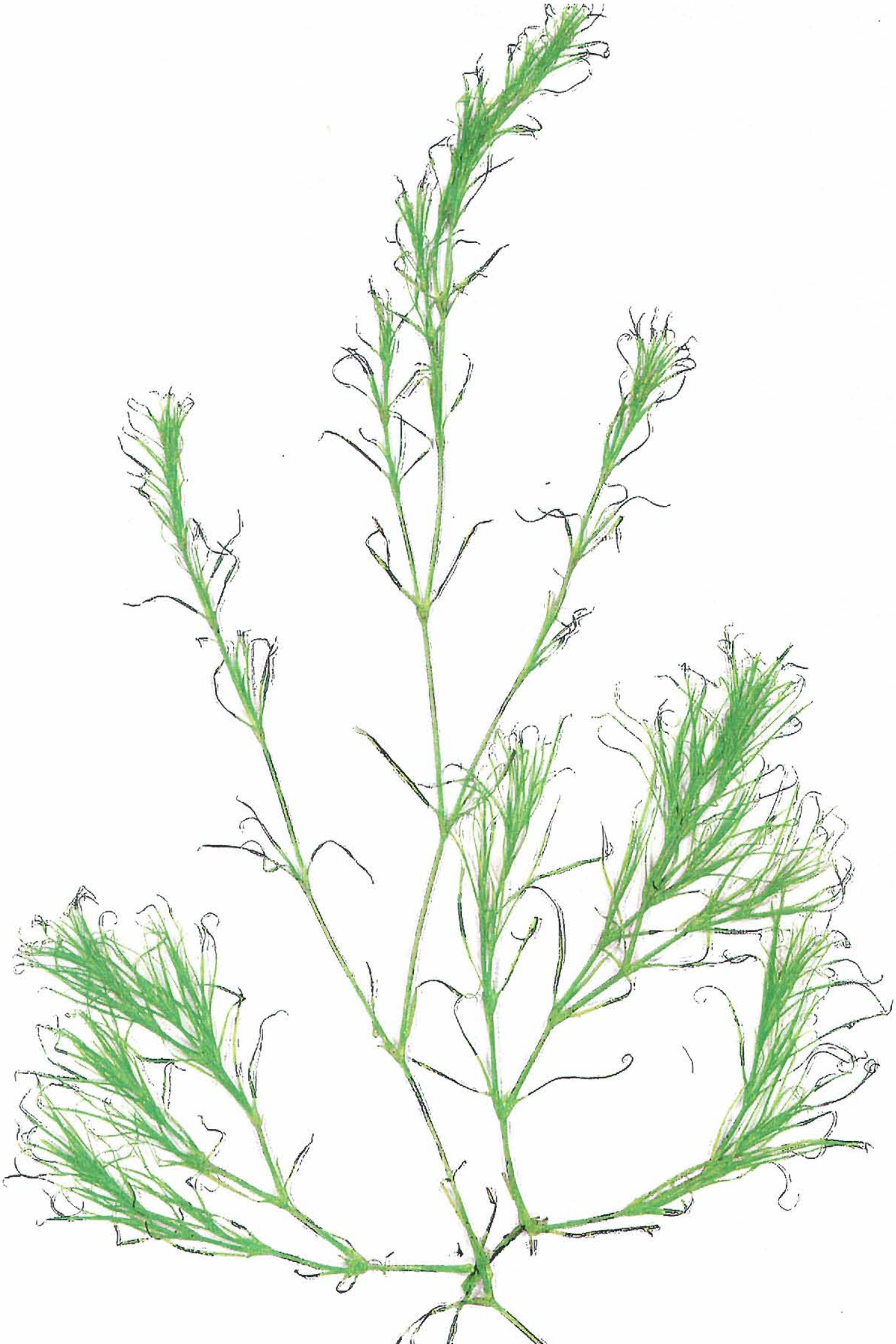
NOTE: Plant species in photograph are not shown proportionate to actual size

*Source: Steve D. Eggers and Donald M. Reed, Wetland Plants and Plant Communities of Minnesota & Wisconsin, 2nd Edition, 1997.*



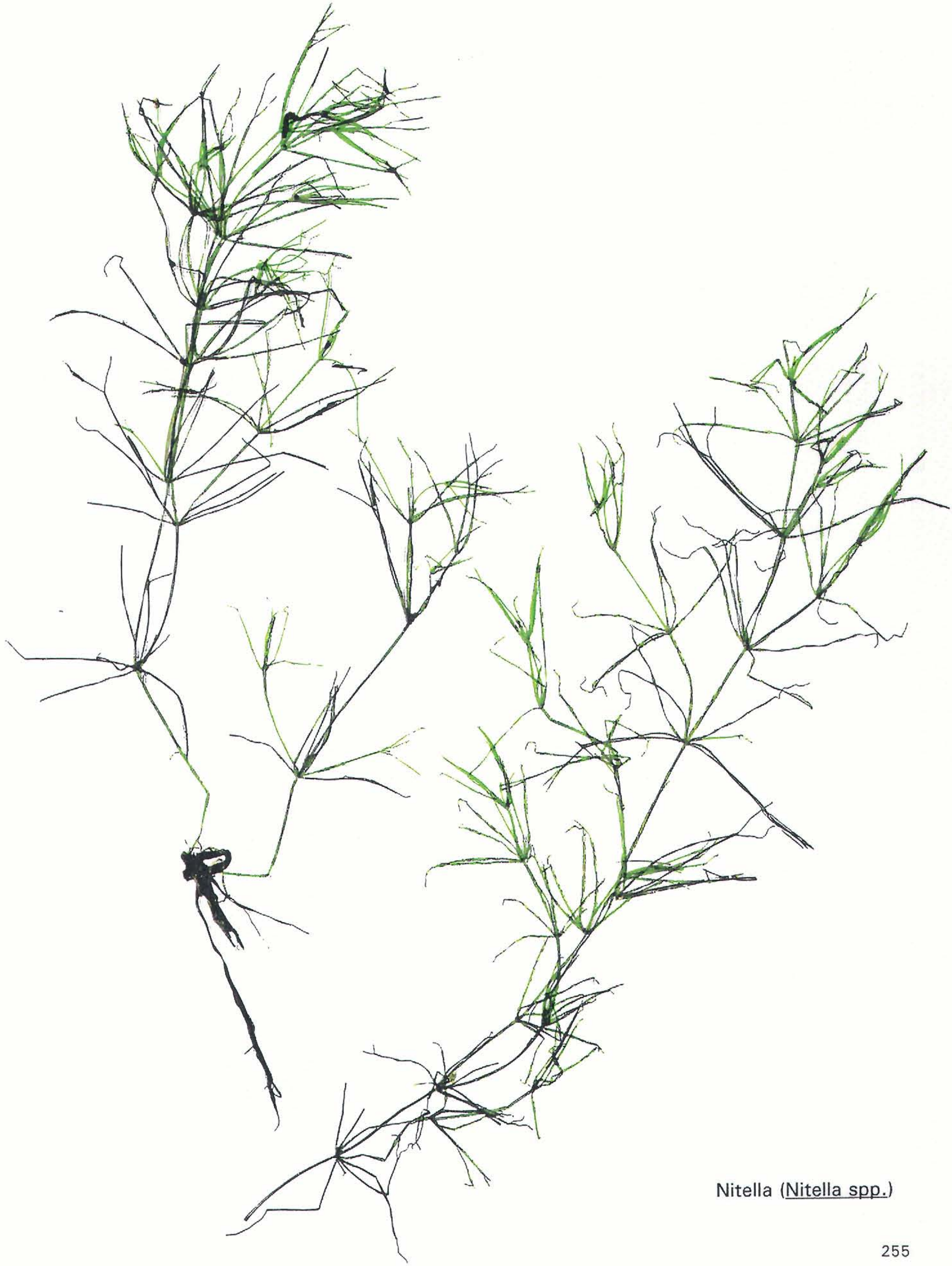
Native Water Milfoil (Myriophyllum sp.)

Eurasian Water Milfoil (Myriophyllum spicatum)



Bushy Pondweed (Najas flexilis)

Spiny Naiad (Najas marina)

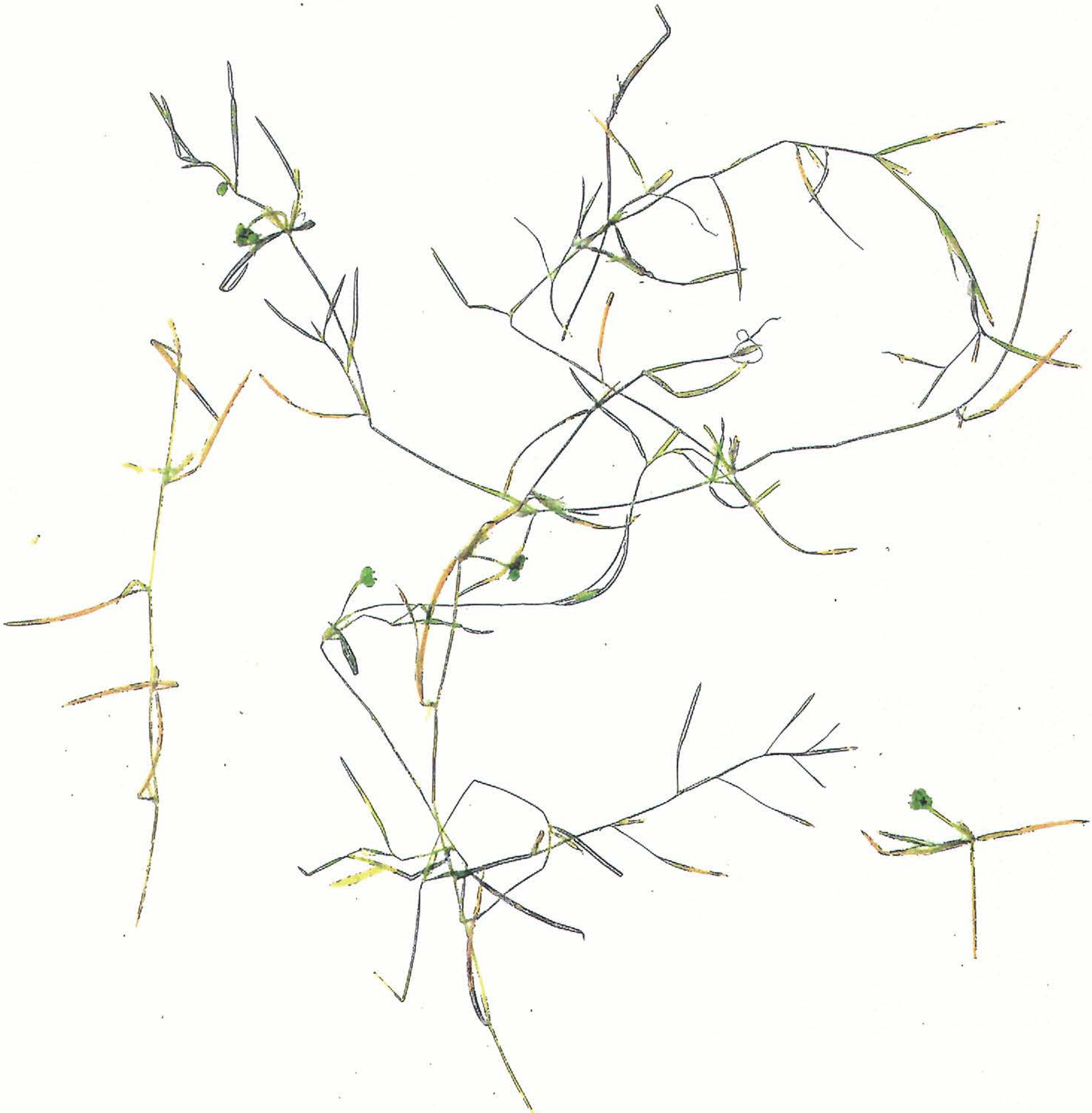


Nitella (Nitella spp.)

White Water Lilly (Nymphaea tuberosa)

Large Leaf Pondweed (Potamogeton amplifolius)

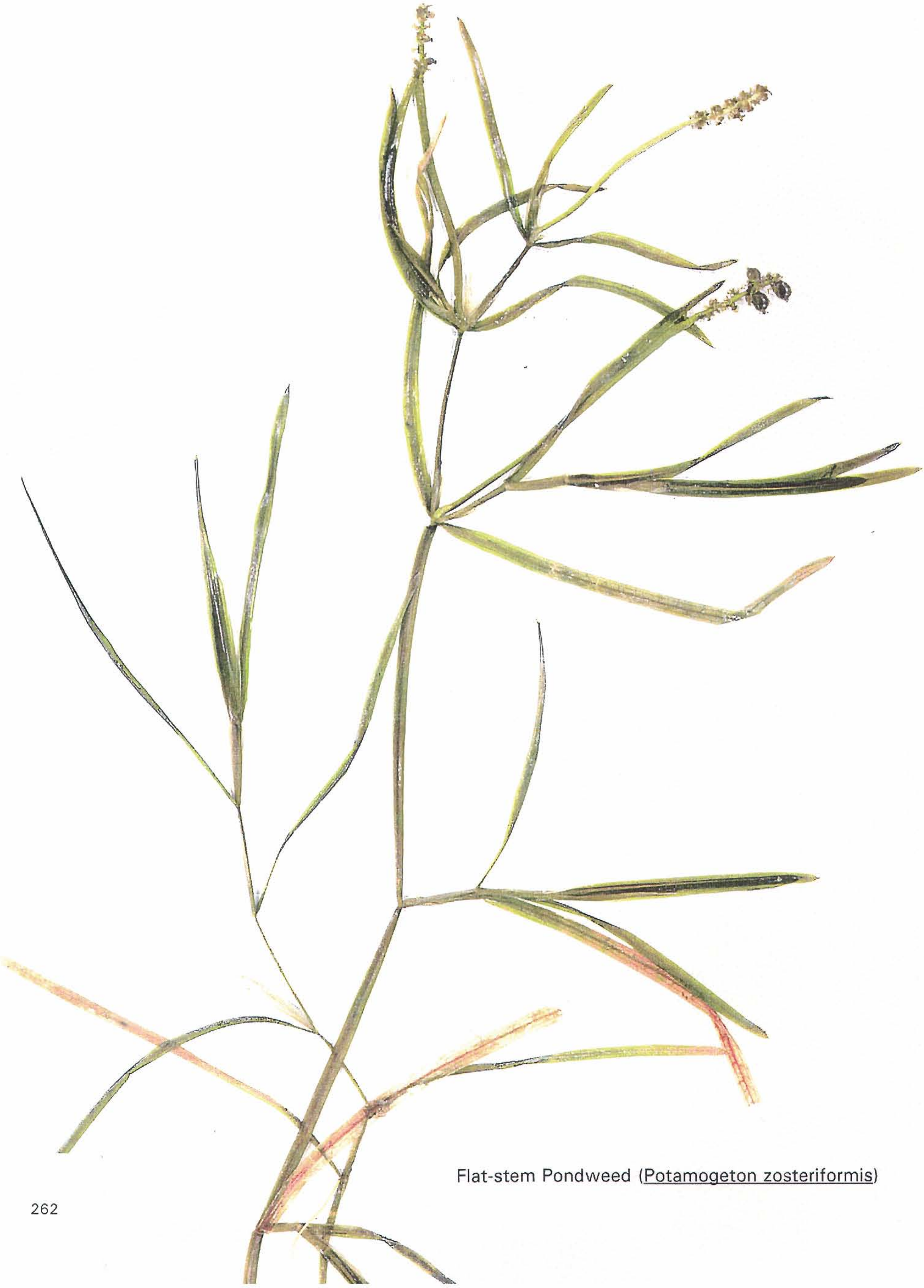
Curly-Leaf Pondweed (Potamogeton crispus)



Leafy Pondweed (Potamogeton foliosus)

Sago Pondweed (Potamogeton pectinatus)

Clasping Leaf Pondweed
(<u>Potamogeton richardsonii</u>)



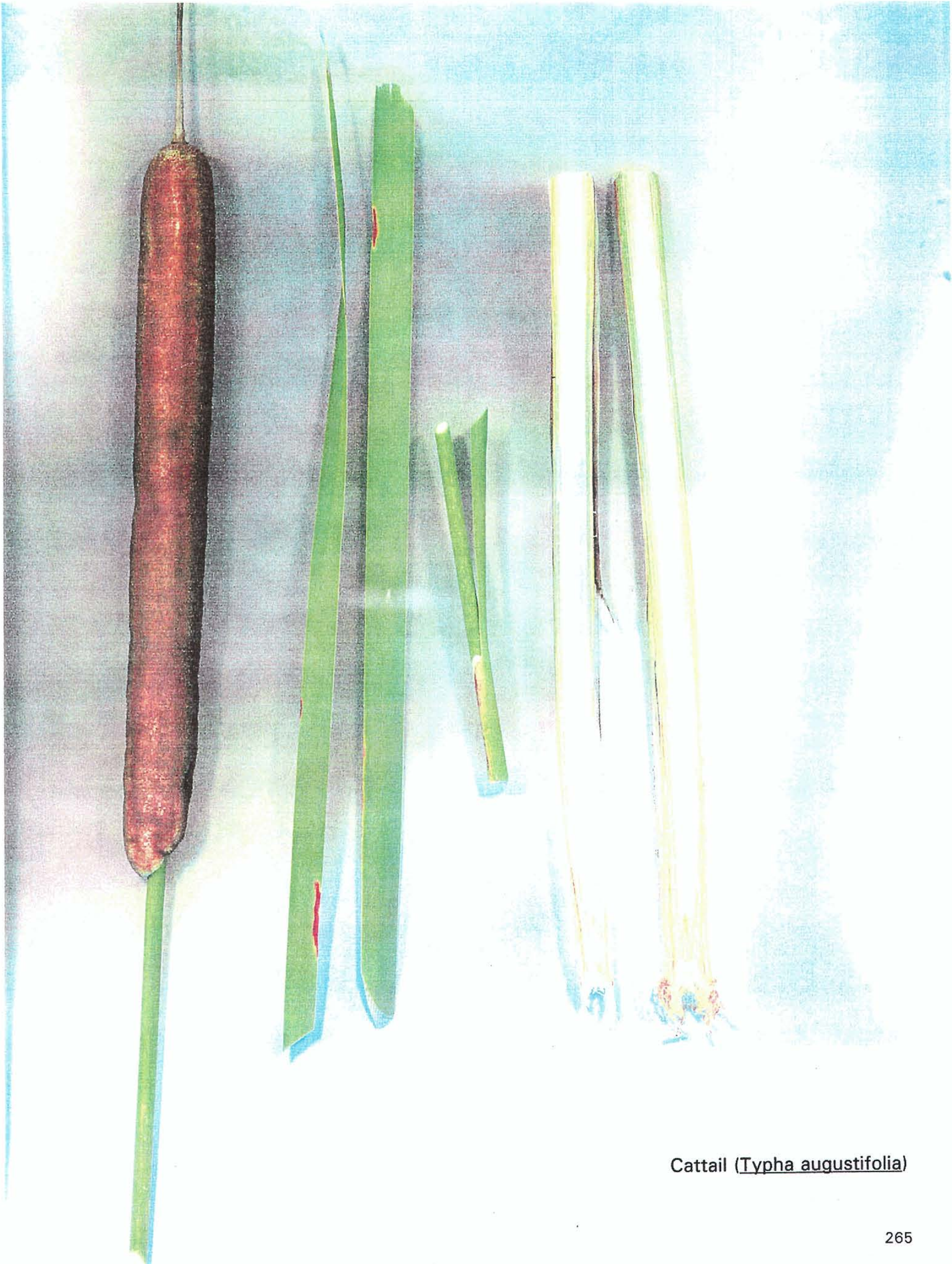
Flat-stem Pondweed (Potamogeton zosteriformis)

Arrowhead (Sagitarria sp.)

NOTE: Plant species in photograph are not shown proportionate to actual size

*Source: Steve D. Eggers and Donald M. Reed, Wetland Plants and Plant Communities of Minnesota & Wisconsin, 2nd Edition, 1997.*

Water Bulrush (Scirpus subterminalis)



Cattail (Typha augustifolia)

Eel Grass / Wild Celery (Vallisneria americana)

Water Star Grass (Zosterella dubia)