Claude Monet: *Water-lilies harmony in blue and violet*, 1918/21

Lake Noquebay Comprehensive Lake Management Plan

December 1994

Submitted to:
Lake Noquebay Rehabilitation District
Marinette County, Wisconsin

Prepared by:
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Land Conservation Department

LPL-76

Lake Noquebay, Marinette County, Wisconsin
Comprehensive Lake Management Plan

--Contents--

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Comprehensive Lake Management Plan

Summary

Goals

The goals of this project were:

- to review all existing information on Lake Noquebay.
- to examine existing lake conditions.
- to develop a lake management plan that protects, maintains, and enhances the lake's water quality.

Watershed characteristics

- The entire Lake Noquebay Priority Watershed size is 83,852 acres. The acreage that drains to Lake Noquebay is 69,504.
- The watershed is dominated by forest (44% of the acreage) and wetlands (29%).
- There are approximately 459 dwellings around the lakeshore.

Lake Characteristics

- Lake area is 2,409 acres
- The maximum depth is 54 feet (16.5 meters) and the average depth is 10 feet (3.0 meters)

Dissolved Oxygen and Temperature

- Lake Noquebay's temperature is uniform in the water column indicating it is well mixed for most of the year.

Nutrients

- We are assuming that phosphorus is the limiting nutrient based on TKN to TP ratios of over 30:1. Average summertime phosphorus concentrations have ranged from 14 to 25 parts per billion in 1991-1993.

Water Clarity

- Average summer water transparency in 1992 was 11.3 feet (3.4 meters) and in 1993 was 7.2 feet (2.2 meters). This is close to the average for lakes in this part of the state.

Macrophyte Status

- Rooted plants were found to a water depth of 15 feet.
- Plant coverage in 1992 was approximately 80%.

Lake Modeling

- The WILMES Lake Modeling Program predicted a lake concentration of 13 parts per billion (ppb) of phosphorus. The actual lake phosphorus concentration (in ppb) is in this range. The model predicted a slightly lower lake phosphorus concentration than has been found in the last few years.

Current Lake Status and Trends: How Close Are Lakes to the Danger Zone?

The Trophic State Index (TSI) rates a lake from 1 to 100, with low numbers being the best. The current average TSI for Lake Noquebay is 45 which is good (TSI ratings are based on the chlorophyll a level, total phosphorus concentrations, and secchi disc transparency). Lake Noquebay is currently rated as a mesotrophic lake. Lake Noquebay has characteristics of relatively unimpacted lakes for the Ecoregion.

We estimate that Lake Noquebay could become a eutrophic lake if an additional 8,800 pounds of phosphorus were added to the lake on an annual basis. Currently it is estimated that roughly 3,400 pounds of phosphorus enters the Lake Noquebay water column on an annual basis.

Recommended Lake Management Projects

In terms of water quality, Lake Noquebay is in the enviable position (compared to more eutrophic lakes) of protecting its good water rather than needing expensive lake restoration projects. A list of projects that are designed to protect and maintain good water quality for Lake Noquebay are listed below:

1. Implement watershed Best Management Practices based on the Priority Watershed study.
2. Pursue adapting a County ordinance for erosion control at construction sites.
3. Pursue adopting a County ordinance for maintaining and upgrading septic tanks.
4. Implement lake shoreland projects.
5. Perform Aquascaping projects.
6. Continue the Aquatic Plant Management Program of harvesting.
7. Continue a lake monitoring program. The primary objective is to monitor nutrient loading to Lake Noquebay.
8. Form a long-range planning committee that would work with DNR and other state staff to develop contingency plans for future Lake Noquebay problems. Contingency plans could be prepared for drought years lake level management, flood years lake level management, Eurasian watermilfoil invasion, or zebra mussel invasion.

1. INTRODUCTION AND PROJECT SETTING

Lake Noquebay is a mesotrophic lake located in Marinette County, Wisconsin with a total watershed of 83,852 acres (Figure 1). Lake Noquebay is a drainage lake with an average depth of 10 feet and a maximum depth of 54 feet (Figure 2). It has a good average summer phosphorus level (14 ug/l in 1991 and 25 ug/l in 1992) and a very good secchi disc transparency (11.3 feet in summer). It has the unusual characteristics of having a lush growth of broadleaf milfoil that has been a nuisance since the mid 1970's.

The Lake Noquebay Rehabilitation District was formed in 1974 in part, to address the plant condition in the lake. However, the Department of Natural Resources has been working on Lake Noquebay since the 1930's, conducting fish surveys, stocking gamefish and panfish and conducting aquatic plant studies.

The goals of this project were to summarize previous information collected and synthesize lake protection and lake management projects.

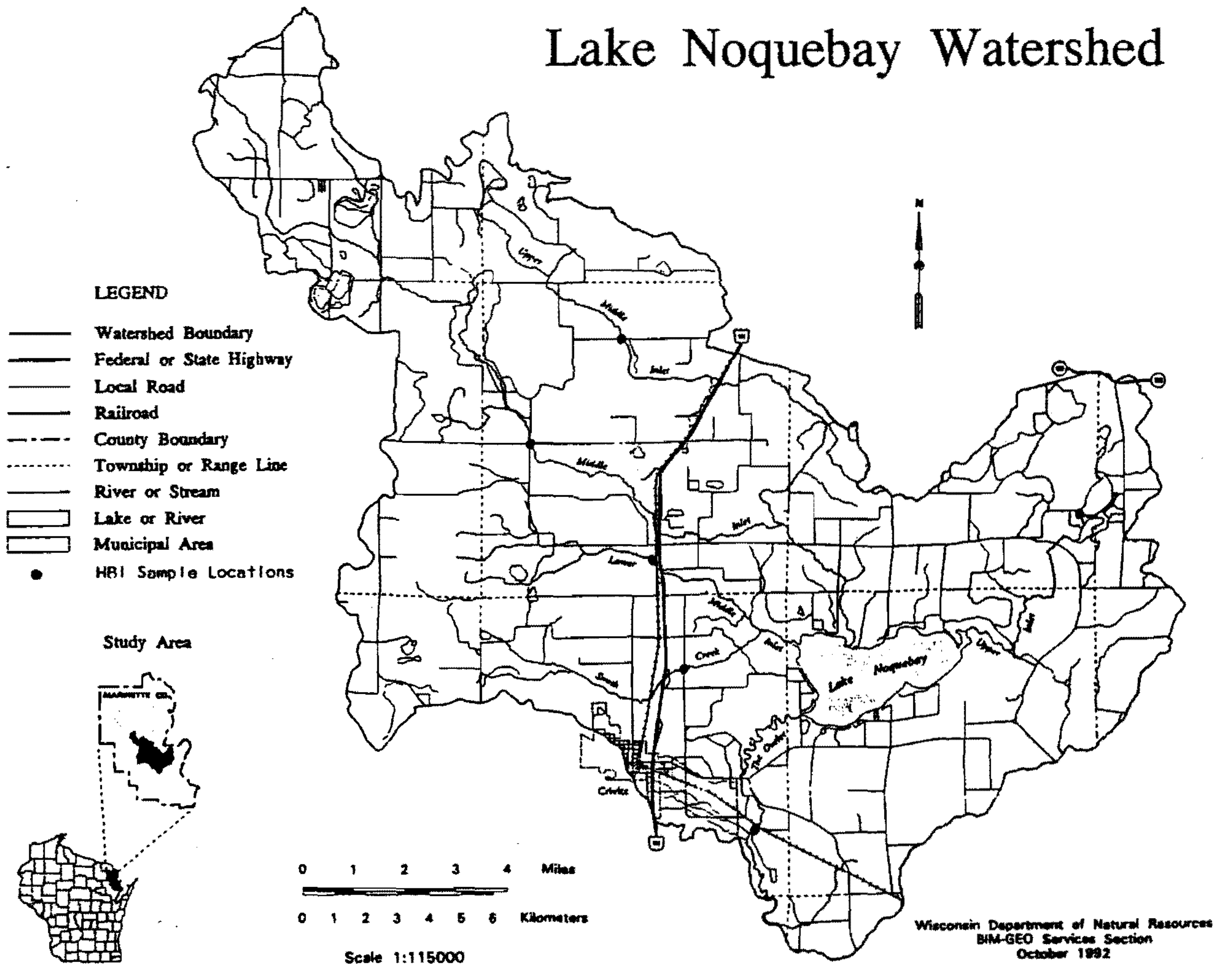


Figure 1. Watershed of Lake Noquebay.

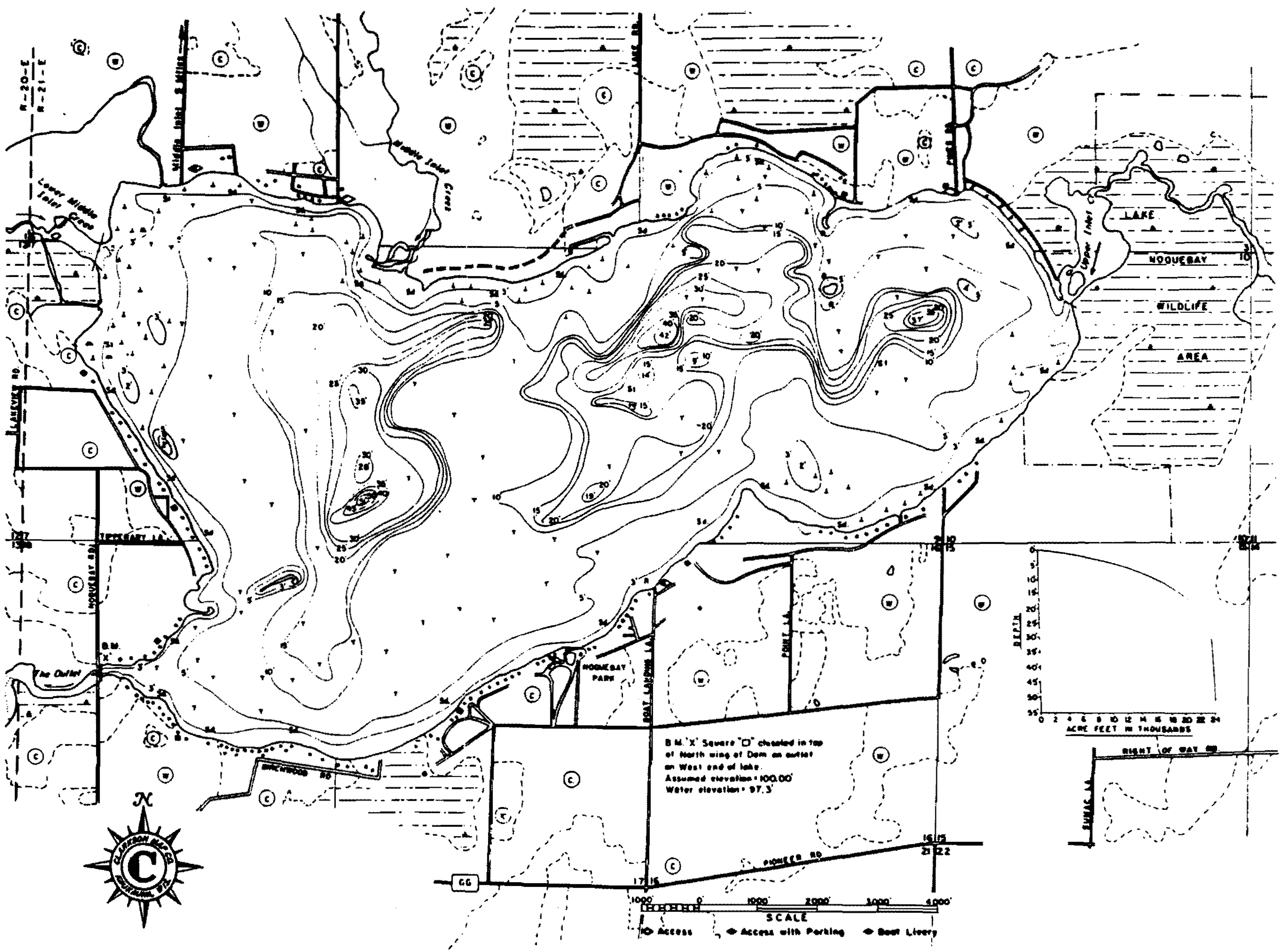


Figure 2. Lake Noquebay bathymetric map.

2. HISTORY OF PROJECTS ON LAKE NOQUEBAY

When	Who	What	Why
1930's to present	WDNR	Fish stocking	to maintain fishery
1940's	WDNR	Rough fish removal	to remove rough fish
1950-1960	Marinette County	Copper sulfate was added	to decrease plants and swimmers itch
1970's	University of Wisconsin	3-phase interdisciplinary	growth of milfoil alarmed homeowners
1974	Lake Noquebay RD	Lake District formed	to address lake problems
1970-1980	EPA, WDNR Dr. Bedrosian Northern Lake Service	Lake Management Study Lake Management Study Macrophyte Study	management study management study to see if any changes in plants
1991	Northern Lake Service Blue Water Science	Macrophyte Study Planning Grant	to see if any changes in plants organize all information collected
1992	Land & Water Cons Depart (LWCD)	Priority Lake Watershed Status	decrease nonpoint source pollution to Lake Noquebay
1992	LWCD	Aquatic plant management plan	aided in obtaining grant for new harvester
1994	LWCD	Lakescaping project	Demonstration, to serve as a prototype for other projects of this kind

3. GEOLOGIC SETTING

Lake Noquebay is located in Marinette County, Wisconsin. Marinette County is the third largest county in Wisconsin and Lake Noquebay is the county's largest lake.

Lake Noquebay was created by the retreat of the Green Bay Ice Lobe, about 11,000 years ago (Figure 3, Map 6). The State of Wisconsin has been divided into five geographic provinces, Lake Noquebay is located in the Central Plain (Figure 3, Map 8). Lake Noquebay flows into the Pestigo River system (Figure 3, Map 9). The major land use in Lake Noquebay's watershed is forest as shown in Figure 3, Map 11.

4. WATERSHED CHARACTERISTICS

General land use in the watershed is shown in Figure 4. The Lake Noquebay Watershed encompasses approximately 83,852 acres (WDNR Lake Model -- Rasman, 1994). Breakdown of land use is shown in Table 2. Of the residential land around the lake, there are 459 tier one cabins that are about evenly divided between seasonal and permanent (235 seasonal, 224 permanent).

Table 2. Land use in the Lake Noquebay watershed (Source: WDNR Lake Model -- Rasman 1994).

Forest	37,032 acres
Open Grass Land	3,787 acres
Agriculture	15,279 acres
Wetlands	24,131 acres
Lake	2,409 acres
Urban	1,214 acres

	83,852 acres

4.1. Soils

The major soil associations within the Lake Noquebay watershed are: Menominee-Emmet, Cunard-Emmet, Mancelona-Emmet-Menahga, Seelyeville-Markey. The eastern portion of the watershed is composed of primary poorly drained, mucky soils. Wetlands are common in this area. The western portion of the watershed is mostly well drained, sandy and loamy soils (WDNR, 1994: (Gansberg, Mary) Lake Noquebay watershed stream water resource appraisal). A general soils map is shown in Figure 4 and several soil series profiles are shown in Figures 5, 6, 7, and 8. The soil series with severe septic tank absorption rating are shown in Table 3.

Table 3. Soil series with severe on-site system absorption rating. Source: Soil Survey of Marinette County, Wisconsin, 1991.

Soils	Absorption	Why?
Cunard	Severe	thin layer, seepage
Emmet	Severe	slope
Mancelona	Severe	poor filter, slope
Markey	Severe	subsoils, pooling, poor filter
Menahga	Severe	poor filter
Seelyeville	Severe	ponding, subsoils

Soils with septic tank limitations are shown in Figure 9.

SOIL LEGEND*

AREAS DOMINATED BY SOILS THAT FORMED IN GLACIAL TILL

1 — Emmet-Charlevoix association: Deep, nearly level to steep, well drained and somewhat poorly drained, loamy soils on moraines and drumlins

Menominee-Emmet association: Deep, nearly level to steep, well drained, sandy and loamy soils on outwash plains, moraines, and drumlins

Cunard-Emmet association: Moderately deep and deep, nearly level to steep, well drained, loamy soils on moraines and drumlins

Sarona-Keweenaw association: Deep, nearly level to steep, well drained, loamy and sandy soils on moraines

AREAS DOMINATED BY SOILS THAT FORMED IN GLACIAL OUTWASH AND TILL

5 — Wainola-Deford association: Deep, nearly level and gently sloping, somewhat poorly drained to very poorly drained, sandy and mucky soils in glacial lake basins

6 — Mancelona-Emmet-Menahga association: Deep, nearly level to steep, well drained to excessively drained, sandy and loamy soils primarily on end moraines

7 — Menahga association: Deep, nearly level to steep, excessively drained, sandy soils on moraines, outwash plains, and stream terraces

8 — Pence-Padus association: Deep, nearly level to very steep, w drained, loamy soils on outwash plains, stream terraces, moraines, kames, and eskers

Ishpeming-Michigamme-Rock outcrop association: Moderately deep, gently sloping to moderately steep, somewhat excessively drained and well drained, sandy and loamy soils, and rock outcrop, on outwash plains and moraines

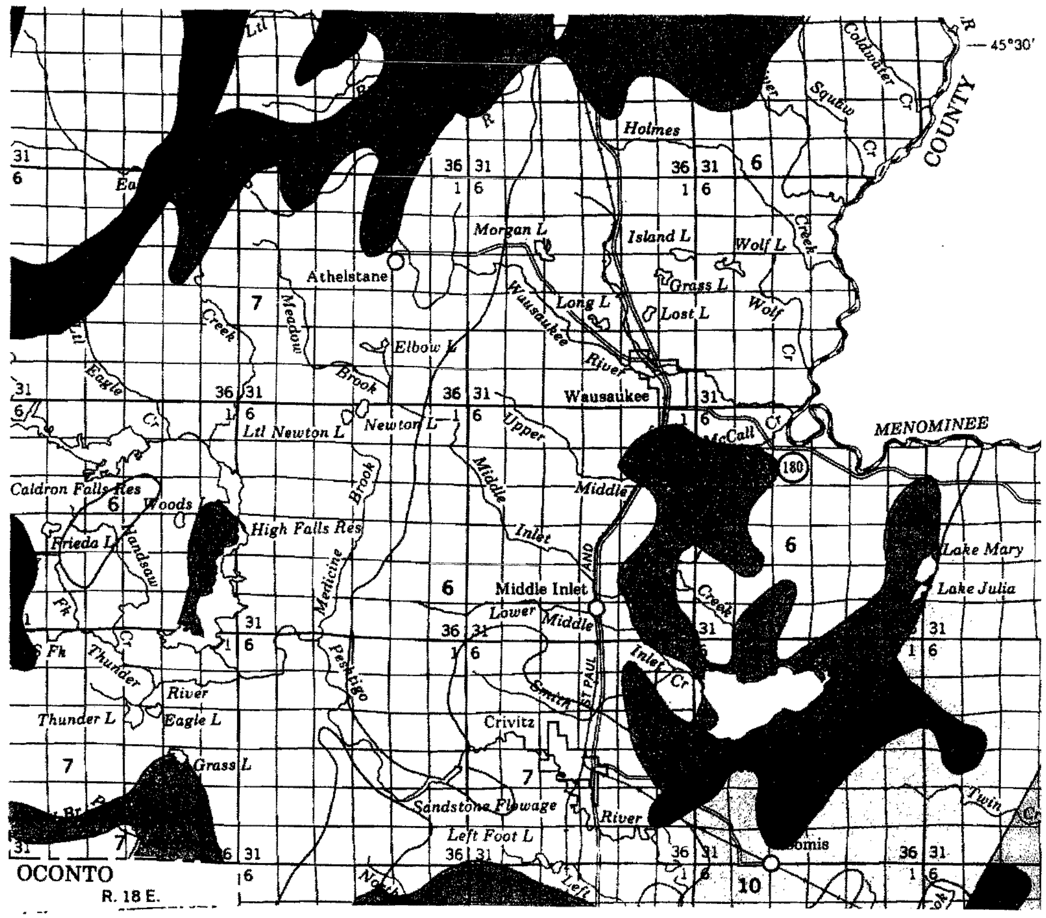
Figure 4. **GENERAL SOIL MAP**

MARINETTE COUNTY, WISCONSIN

Scale 1:316,800

1 0 1 2 3 4 5 Miles

1 0 5 10 Km



AREAS DOMINATED BY ORGANIC SOILS

10 — Seelyeville-Markey-Emmet association: Deep, nearly level to steep, very poorly drained and well drained, mucky and loamy soils in glacial lake basins, on stream terraces, outwash plains, and moraines, or on upland moraines and drumlins

Seelyeville-Markey association: Deep, nearly level, very poorly drained, mucky soils in glacial lake basins and on stream terraces, outwash plains, and moraines

*Texture terms in the descriptive headings refer to the surface layer of the major soils in the associations.

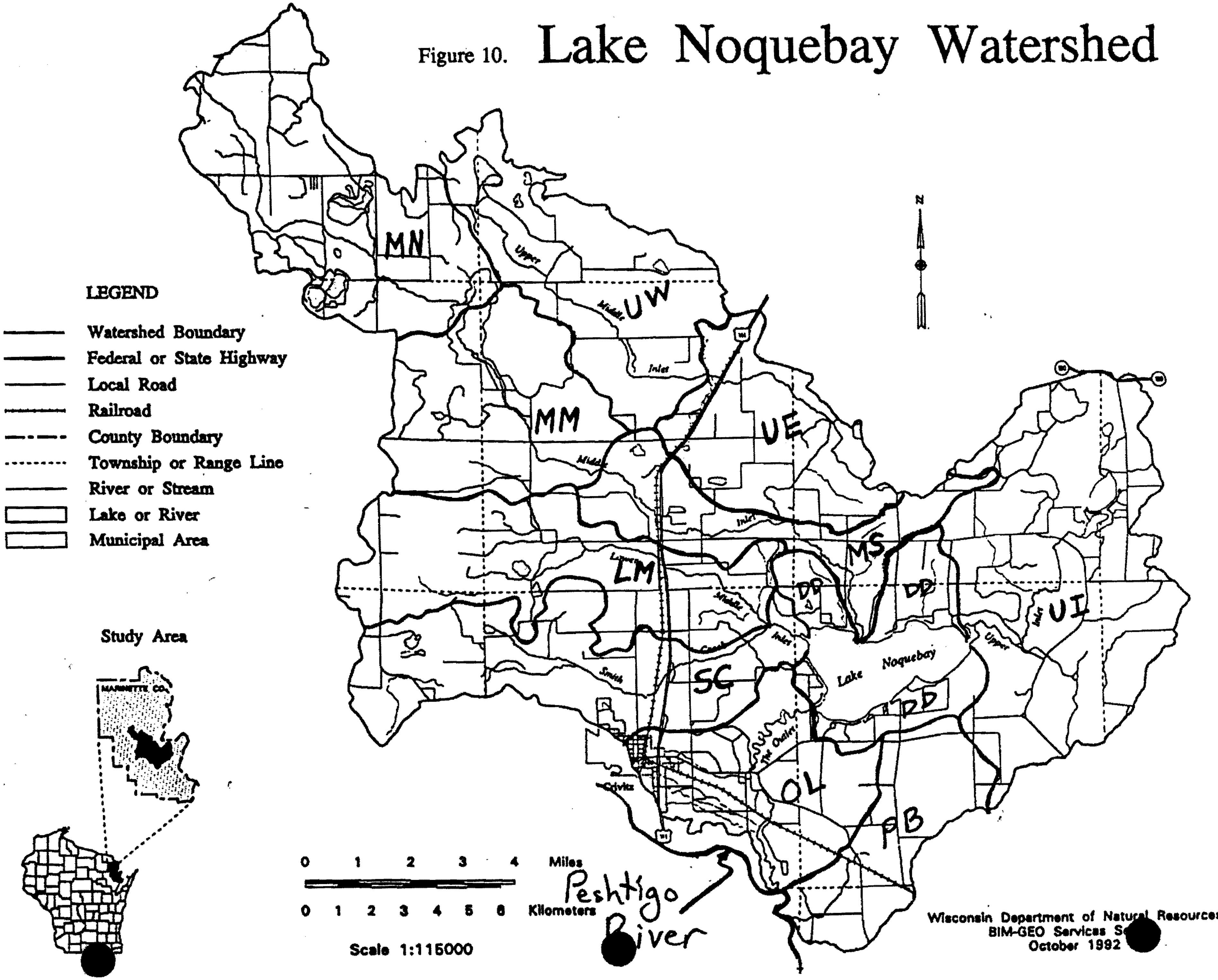
Compiled 1988

4.2. Land Use Evaluation

Land use in the watershed has been evaluated as part of the Priority Watershed project. Listed below are descriptions of subwatersheds that were summarized by Chuck Druckrey in his report: Lake Noquebay Priority Watershed Projects : Inventory Results Summary, June 17, 1994. The full summary is in Appendix A. There will be several references to the WINHUSLE model. This is a watershed model used to evaluate sediment and pollution sources from the 11 subwatersheds in the project area.

> The Lake Noquebay Watershed Project Area encompasses more than 140 square miles (89,000 acres) of land. Approximately 86% of the project area (75,000 acres) drains to Lake Noquebay. Also included in the project area is 7,073 acres which drains to Lake Noquebay's outlet (aptly named The Outlet), which empties into the Peshtigo River. Peterman Brook, located south of Lake Noquebay drains 5,133 acres of land and also empties into the Peshtigo River just downstream from The Outlet.
>
> Lake Noquebay is fed by three major inlets, Smith Creek, Upper Middle Inlet, and Upper Inlet. The lake drains to the Peshtigo River via The Outlet. There are 28 named lakes in the watershed and more then 65 miles of streams. Four of the watersheds lakes are heavily developed, Lake Noquebay, Lake Mary, Big Newton Lake, and Little Newton Lake.
>
> The project area is divided into 11 separate subwatersheds (Figure 10). A brief description of each subwatershed follows:
>
> <u>SC - Smith Creek</u>
> There are 7 farms located in the 9,521 acre Smith Creek subwatershed. Much of the farmed land in this subwatershed is rather steep. WINHUSLE model results attribute 26% of the sediment delivery to streams to this subwatershed. A portion of the Village of Crivitz drains to this subwatershed.
>
> <u>LM - Lower Middle Inlet</u>
> Two farms are located in this 9,578 acre subwatershed, including the largest farm in the watershed. This is the only subwatershed where gully erosion was found to be a problem.
>
> <u>MS - Middle Inlet (South)</u>
> There are 4 farms in this 5,743 acre subwatershed. One barnyard drains to Engleman Lake which is located in a closed depression within this subwatershed. More than 90% of the land that drains to Engleman Lake is agricultural, and cattle have access to the lake.
>
> <u>MM - Middle Inlet (Middle)</u>
> Subwatershed MM accounts for only 8.6% of the sediment delivered to streams in the watershed. There are 4 farms located in this 5,696 acre subwatershed.
>
> <u>MN - Middle Inlet (North)</u>
> There are no active farms and no cropped acres in the MM subwatershed. The WINHUSLE model which was designed for use in a predominantly agricultural watershed was not used for this subwatershed. Little Newton Lake and Big Newton Lake are located in this subwatershed. Both of these pothole lakes are heavily developed. Urban NPS inventories and lake modeling will be completed later in the project to determine major nonpoint sources and management strategies. The MM subwatershed is 7.026 acres in size.

Figure 10. Lake Noquebay Watershed



UE - Upper Middle Inlet (East)
The Upper Middle Inlet (East) subwatershed contains more cropped acres (36%) than any other subwatershed in the project area. There are 8 farms located in this 6,696 acre subwatershed.

UW - Upper Middle Inlet (West)
There are 5 farms located in this 9,150 acre subwatershed. This area has the lowest modelled upland phosphorus delivery of any subwatershed.

UI - Upper Inlet
Upper Inlet drains 16,363 acres east of Lake Noquebay. Much of this subwatershed is Marinette County Forest Land. Less than 3% of this large subwatershed is cropland, and only 1 barnyard is located here. The WINHUSLE model was not run for this subwatershed.

DD - Direct Drainage
This 4,546 acre subwatershed is made up of land surrounding Lake Noquebay which drains directly to the lake via overland flow or minor perennial and intermittent streams. Only 10% of this subwatershed is agricultural. Urban areas surrounding Lake Noquebay account for 55% of the phosphorus delivery to the lake. Phosphorus delivery was calculated using runoff coefficients from "Phosphorus Control in Lake Watersheds" published by the Maine Dept. of Environmental Protection, and coefficients supplied by the WDNR.

PB - Peterman Brook
The 5,133 acre Peterman Brook subwatershed contains 3 barnyards. Modeled phosphorus delivery from upland sources is high even through the majority of the cropland is on relatively flat land.

OL - The Outlet
The 7,073 acres which drains to The Outlet contain a low percentage of cropland, and no barnyards are located in this subwatershed. As with the PB subwatershed, modelled phosphorus delivery is high while the majority of the cropland is relatively level. Part of the Village of Crivitz is located in this subwatershed.

SEDIMENT INVENTORY RESULTS (from Druckrey, 1994)

The WINHUSLE runoff model was used to estimate sediment and phosphorus delivery for the 8 subwatersheds which have a significant percentage of land in agricultural production. Subwatersheds MN, UI, and DD contain little or no cropland and were not modeled using WINHUSLE.

The WINHUSLE model only requires a partial field inventory. Information from this partial inventory is then extrapolated to the rest of the subwatershed in question. Acceptable estimates of phosphorus and sediment loading are reportedly achieved with a 20% field inventory. The 8 subwatersheds modelled using WINHUSLE and the percent inventoried is listed below.

Subwatershed	%
SC	36%
LM	29%
MS	39%
MM	35%
UE	26%
UW	36%
PB	46%
OL	24%

The WINHUSLE model reports the amount of sediment delivered to streams, the amount of in-stream sediment deposition, and the amount of sediment and phosphorus flowing out of the subwatershed. Details these results for each subwatershed are shown in Appendix A (Table 4).

A sediment mass balance from WINHUSLE model results, streambank inventories, and gully inventories is shown in Table 5. Streambank and gully erosion were not found to be significant sources of sediment in most subwatersheds.

TABLE 5.

SEDIMENT MASS BALANCE BY SUBWATERSHED

	UPLAND (TONS)	%	STREAMBANKS (TONS)	%	GULLIES (TONS)	%	TOTAL (TONS)
SC	1775	100.0%		0.0%		0.0%	1775
LM	1282	94.6%		0.0%	72.500	5.4%	1354.5
MS	996	100.0%		0.0%		0.0%	996
MM	348	100.0%		0.0%		0.0%	348
MN*	----		----		----		----
UE	1615	100.0%		0.0%		0.0%	1615
UW	190	100.0%		0.0%		0.0%	190
UI*	----		----		----		----
PB	1575	100.0%		0.0%		0.0%	1575
OL	1152	99.4%	7.13	0.6%		0.0%	1159.13
DD**	----		----		----		----
TOTAL	8933	99.1%	7.13	0.1%	72.5	0.8%	9012.63

* Subsheds MN and UI have little or no farmed land and were not modeled with WINHUSLE

** Subshed DD model does not predict sediment delivery

PHOSPHORUS INVENTORY RESULTS (from Druckrey, 1994)

Phosphorus from 4 sources were considered when modeling each subwatershed: upland sources, urban areas, barnyards, and winter spread manure. However, the Barny, WINHUSLE, and Urban models are not connected, and the results from each should be compared with caution. WINHUSLE estimates phosphorus delivery through the watershed, Barny, Urban SLAMM, and urban coefficients all estimate phosphorus export from the source but not necessarily phosphorus delivery to the streams.

Phosphorus results from the WINHUSLE model are reported in Table 4.

Barny inventory results for the entire watershed are listed in Table 8, the list is ranked by phosphorus export. Table 9 contains a list of barnyards sorted by subwatershed and ranked by phosphorus export. Internally drained barnyards are noted with an asterisk.

A phosphorus loading analysis for subwatershed DD is presented in Appendix A. Phosphorus export coefficients were taken from "Phosphorus Control in Lake Watersheds" published by the Maine Dept. of Environmental Protection, and coefficients supplied by the WDNR.

Phosphorus export from the Village of Crivitz was estimated by Jeff Prey - WDNR WR/2 using the Urban SLAMM model. The complete urban model results are contained in Appendix B.

Phosphorus from winter spread manure has been estimated to be approximately equal to phosphorus export from barnyards according to Sue Porter - DATCP. A more detailed manure spreading/storage inventory is discussed in Appendix A (page 24).

A phosphorus "mass balance" for each subwatershed is shown in Table 6.

TABLE 6.

PHOSPHORUS MASS BALANCE BY SUBWATERSHED
LAKE NOQUEBAY WATERSHED

	UPLAND (lbs)	%	BARNYARDS (lbs)	%	WINTER SPREAD MANURE (lbs)	%	URBAN (lbs)	%	TOTAL (lbs)
SC	744.0	54.0%	263.2	19.1%	263.2	19.1%	107.0	7.8%	1377.4
LM	594.0	62.0%	181.7	19.0%	181.7	19.0%		0.0%	957.4
MS	450.0	83.1%	30.4	5.6%	61.1	11.3%		0.0%	541.5
MM	331.0	77.0%	49.5	11.5%	49.5	11.5%		0.0%	430.0
MN*	------		------		------		------		
UE	782.0	65.2%	97.9	8.2%	319.4	26.6%		0.0%	1199.3
UW	193.0	48.6%	149.8	37.7%	54.1	13.6%		0.0%	396.9
UI*	------		------		------		------		
PB	718.0	91.4%	33.6	4.3%	33.6	4.3%		0.0%	785.2
OL	681.0	73.4%		0.0%		0.0%	247.0	26.6%	928.0
DD**	263.7	27.1%	119.1	12.2%	119.1	12.2%	472.8	48.5%	974.7
TOTAL	4756.7	62.7%	925.2	12.2%	1081.7	14.3%	826.8	10.9%	7590.4

* Subsheds MN ans UI have little or no farmed land and were not modeled with WINHUSLE
** Phosphorus delivery for subshed DD was calculated using export coefficients from "Phosphorus Control in Lake Watershec by the Maine Dept. of Env. Protection.

OTHER INVENTORIES (from Druckrey, 1994)

STREAMBANKS
A streambank erosion inventory was conducted on most major streams in the watershed. A total of 16.8 miles (25%) of streams were inventoried for streambank erosion. With the exception of The Outlet, no significant streambank erosion was noted, and none of the eroding sites were caused by cattle access. Several sites were located where cattle access had caused damage in the past, however these sites were healed over.

GULLY EROSION
Gully erosion was only found to be an important source of sediment in subwatershed LM. All of the gullies located here can be found on one farm. Wherever the topography was steep, LWCD staff located numerous ephemeral gullies which are repaired with annual tillage. Location of these areas are noted in each landowner file.

MANURE SPREADING
Due to the recent 590 standards required for nutrient management, it was decided that the Manure Storage Rating Guide (MSRG) would be used to determine eligibility and need for manure storage systems. The results of the MSRG are listed in Table 13. The MSRD calculates the amount of manure produced for each operation and the amount of spreadable acres available after high hazard acres are subtracted and crop rotations are accounted for. The MSRG then compares the acres needed for safe spreading to the acres available and assigns eligibility based on the number of spreadable acres a farmer is short.

NUTRIENT MANAGEMENT
At the time of each initial farm visit each operator was surveyed concerning their nutrient management practices. Only 4 of 38 farmers reported crediting for legumes or manure, and fertilizer use varied greatly between farms. Some farmers reported using close to double the recommended amount of commercial fertilizer on fields that has also received manure applications.

SEPTIC LOADING
All of the dwellings surrounding Lake Noquebay, Newton Lakes, and all other lakes in the watershed are served by on-site sewage disposal systems. A septic loading analysis based on soil suitability was conducted for Lake Noquebay. A conservative estimate of 642 lbs of phosphorus is discharged to Lake Noquebay annually. This estimate assumes that systems located on suitable soils are properly functioning. A septic loading estimate for Newton Lakes will be completed in the future.

WETLANDS
Wetland acres were determined using WDNR Wetland Inventory Maps. Lists the wetlands acres and percentage for each subwatershed are found in Appendix A. Drained wetlands and farmed wetlands are rare in the Lake Noquebay watershed. Wetlands and other marginal lands which may have been farmed in the past have been abandoned in favor of more suitable upland sites which are readily available for rent.

GROUNDWATER
A total of 40 well samples have been received to date (Table 7). Results indicate that nitrate contamination is rather widespread throughout the watershed. Atrazine contamination is less common, with only 1 sample above the drinking water standard. More than 100 nitrate sample kits have been distributed to watershed residents in the last month. When results are returned, high nitrate wells will be located and any contamination will be noted.

Table 7. Well sample results from the Lake Noquebay watershed.

NITRATE		
<2.0 mg/l	13	32.5%
2.0 - 10.0 mg/l	16	40.0%
>10.0 mg/l	11	27.8%
ATRAZINE		
<0.3 ug/l	37	88.0%
0.3 - 3.0 ug/l	4	10.0%
>3.0 ug/l	1	2.0%

Table 8. Physical characteristics of streams in the Lake Noquebay watershed.

Stream	Average Depth	Average Width	Substrate	Habitat*	Classification	Resources Water
Upper Inlet	0.6 ft	12 ft	generally soft & mucky with little rock & gravel	good/fair	warmwater sport fish	--
Upper Middle	0.7 ft	13 ft	mostly sand soft sediment & silt near edge	good/good	Class I & II	Outstanding
Middle (Eagle's Nest Creek)	9 ft	15 ft	sand riffle areas-rock, rubble	good/good	Class I & II	Outstanding
Lower Middle	0.9 ft	10 ft	slow areas-silt, sediment riffle areas-rock, rubble	good/good	Class I & II	Exceptional
Smith Creek	0.5 ft	5 ft	sand riffle area-rock, rubble	good/fair	Class I	Exceptional
Outlet	1.7 ft	73 ft	sand	good	warmwater sport fish	--

Table 9. **Water Resource Conditions for Stream in the Lake Noquebay Watershed**

Stream	Location	Habitat Rating[1] 1992	Habitat Rating[1] 1993	Biotic Index[2] 1992	Biotic Index[2] 1993	Stream Classification[3]	Special Status[4]
Upper Inlet	Lake Mary Road	good/160	fair/136	5.94/ Fair	6.67/ Fairly Poor	WWSF	—
Upper Middle Inlet	Nejedlo Road	good/103	good/114	2.93/ Excellent	3.40/ Excellent	Class I & II	ORW
Middle Inlet	Camp 5 Road & Moonshine Hill Road	good/102	good/110	2.71/ Excellent	3.29/ Excellent	Class I & II	ORW
Lower Middle Inlet	Cemetery Road	good/96	good/94	1.61/ Excellent	1.96/ Excellent	Class I	ERW
Smith Creek	St. Paul Road	good/110	fair/143	2.73/ Excellent	4.73/ Good	Class I	ERW
The Outlet	St. Paul Road	—	good/79	—	4.04/ V.Good	WWSF	—

1. Habitat Rating (See Appendix A):
   - <70 = excellent habitat
   - 71 - 129 = good habitat
   - 130 -200 = fair habitat
   - >200 = poor habitat

2. Hilsenhoff Biotic Index (HBI):

Biotic Index	Water Quality	Degree of Organic Pollution
0-3.50	Excellent	No apparent organic pollution
3.51-4.50	Very good	Possible slight organic pollution
4.51-5.50	Good	Some organic pollution
5.51-6.50	Fair	Fairly significant organic pollution
6.51-7.50	Fairly poor	Significant organic pollution
7.51-8.50	Poor	Very significant organic pollution
8.51-10.0	Very poor	Severe organic pollution

3. Stream Classification:
   - Cold - cold water trout stream
     - Class I - natural reproduction
     - Class II - some natural reproduction
     - Class III - no natural reproduction
   - WWSF - warm water sport fishery
   - WWFF - warm water forage fishery
   - LFF - limited forage fishery

4. Special Resource Status:
   - ORW - Outstanding Resource Waters
   - ERW - Exceptional Resource Waters

Table 10.

Lake Noquebay Priority Watershed
Water Chemistry

Location	Flow cfs	BOD_5 mg/l	BOD_5 lbs/day	Ammonia mg/l	Ammonia lbs/day	Nitrate Nitrite-N mg/l	Nitrate Nitrite-N lbs/day	Total Kjel-N mg/l	Total Kjel-N lbs/day	Total Phos mg/l	Total Phos lbs/day	Diss Phos mg/l	Diss Phos lbs/day	Susp Solids mg/l	Susp Solids lbs/day	Temp °C	Diss oxygen mg/l	pH
Date: 3/25/93																		
Middle Inlet	23.9	<1	---	0.009	1.16	0.157	20.22	0.2	25.76	<0.02	---	0.002	0.26	6	772.93			
Upper Middle Inlet	9.1	1.1	53.95	0.012	0.59	0.399	19.57	0.3	14.71	<0.02	---	0.003	0.15	9	441.44			
Smith Creek	6.2	1.2	40.10	0.022	0.74	0.704	23.53	0.4	13.37	<0.02	---	0.005	0.17	7	233.93			
Upper Inlet	2.4	1.0	12.94	0.043	0.56	0.085	1.10	0.6	7.76	<0.02	---	0.002	0.03	<2	---			
Lower Middle Inlet	10.7	8.3	478.69	0.501	28.89	0.703	40.54	1.9	109.58	0.19	10.96	0.10	5.77	16	922.77			
Date: 6/10/93																		
The Outlet	---	<1	---	0.026	---	0.011	---	0.5	---	<0.02	---	0.002	---	<2	---	18.3	7.6	9.4
Upper Middle Inlet	43.2	<1	---	0.021	4.89	0.039	9.08	0.5	116.42	<0.02	---	0.006	1.40	4	931.39	12.2	6.4	7.3
Middle Inlet	65.9	<1	---	0.018	6.39	0.052	18.47	0.7	248.64	0.03	10.66	0.003	1.07	18	6,393.62	14.0	9.2	8.2
Lower Middle Inlet	27.5	<1	---	0.030	4.45	0.110	16.30	0.7	103.76	0.03	4.45	0.010	1.48	4	592.90	14.7	7.2	8.9
Smith Creek	23.6	1.1	139.92	0.026	3.31	0.059	7.50	1.0	127.20	0.03	3.82	0.003	0.38	11	1,399.24	15.0	5.7	9.2

* Note: All samples collected during rain or snowmelt runoff.

UPPER INLET

Upper Inlet originates at Stephenson Lake, travels through Mud Lake, Lake Mary, and Lake Julia before entering into Lake Noquebay's northeast side. Sampling was conducted at Lake Mary Road where the Upper Inlet leaves Lake Mary.

Upper Inlet has an average depth of 0.6 feet and an average width of 12 feet. This stream is classified as warm water sport fish communities. Soils in this area are poorly drained and have a considerable amount of adjoining wetlands.

Upper Inlet at Lake Mary Road received a habitat evaluation ranking of good and fair during two different times of the year. The creek substrate is generally soft and mucky with little rock, gravel, and other stable habitat. This is likely due to the wetland influence on the stream. Macrophytes in the stream are common. The biotic index scores of 5.94 and 6.67 rates the Upper Inlet as fair and fairly poor water quality with fairly significant to significant organic pollution. I (M. Gansberg) believe the lack of a suitable monitoring location contributes to the fair rating and not necessarily organic pollution.

Water chemistry samples collected during snowmelt runoff show low concentrations and loading of nutrients, biochemical oxygen demand and suspended solids.

UPPER MIDDLE INLET

Upper Middle Inlet is a perennial tributary to the Middle Inlet. The stream has an average depth of 0.7 feet and an average width of 13 feet. Sampling was conducted on the Upper Middle Inlet at Nejedlo Road and McMahon Road.

This stream is classified as a Cold Water Class I and II trout stream fully meeting its potential use. The Upper Middle Inlet is also classified as Outstanding Resource Waters.

Habitat evaluation on tow occasions ranked this stream as having good habitat. Much of the stream corridor consists of wetland areas. The creek bed is mostly sand with significant deposition of soft sediment and silt near the creek edges. The tributary has dark stained water; however, macrophytes such as *Vallisneria* (Water Celery) are quite abundant. Macroinvertebrate samples received biotic index values of 2.93 and 3.40 which rates the Upper Middle Inlet as excellent water quality with no apparent organic pollution. Fisheries Management has identified stream bank pasturing as a concern in this stream, however at Nejeldo and McMahon Roads there was no evidence of bank erosion problems.

Water chemistry samples collected during rain and snowmelt runoff show very low concentrations and loadings of nutrients, biochemical oxygen demand, and suspended solids.

MIDDLE INLET

Middle Inlet is a perennial stream that drains directly to lake Noquebay's north side. This creek has also been known a s Eagle's Nest Creek. Sampling on the Middle Inlet was conducted at CTH "X", Sweetheart City Road, and the junction of Moonshine Hill Road and Camp 5 Road.

This stream is classified as a Cold Water Class I and II trout stream that is fully meeting its potential use. Middle Inlet is also designated as Outstanding Resource Waters.

Habitat evaluations on two occasions ranked this stream as having good habitat. The creek has an average width of 15 feet and an average depth of 9 feet. Macrophytes in the stream are common. The creek bed consists mostly of sand with some silt present near the banks. Rock, rubble, and other stable habitat is generally limited to riffle areas below bridge abutments where rip-rap is present. the upper reaches of this watershed is mostly wooded with some wetlands and little agriculture land. Macroinvertebrate samples received biotic index values of 2.71 and 3.29 which rates the Middle Inlet as excellent water quality with no apparent organic pollution.

Water chemistry results show very low concentrations of nutrients, biochemical oxygen demand, and suspended solids during both rain and snowmelt runoff.

LOWER MIDDLE INLET

Lower Middle Inlet is a perennial tributary which discharges to the northwest side of Lake Noquebay. The stream has an average depth of 0.9 feet and an average width of 10 feet. Sampling was conducted on the Lower Middle Inlet at Cemetery Road and Quarry Road.

Lower Middle Inlet is classified as a Cold Water Class I trout stream only partly meeting it's potential use. Lower Middle Inlet is designated as Exceptional Resource Waters.

Much of the stream riparian area is wetland. Habitat evaluations ranked this stream as having good habitat. It has extensive stretches of rock and rubble riffle areas and also many deep pools. Silt and sediment are common in the slow moving areas of bends and near the banks. Vegetation is common in this creek. In the unshaded open rocky areas, a combination of *Bryophya* - a leafy moss and strands of filamentous algae are present. In the shaded areas, *Vallisneria* is very common. Macroinvertebrates samples received biotic index values of 1.61 and 1.96 which rates the Lower Middle Inlet as excellent water quality with no apparent organic pollution. Mayflies (*Ephemeroptera*) were the most abundant organism present.

Water chemistry samples collected during snowmelt runoff showed slightly elevated concentrations of biochemical oxygen demand, ammonia, phosphorus, and suspended solids compared to other chemistry samples in the watershed during the same runoff event.

SMITH CREEK

Smith Creek is a perennial tributary to Lower Middle Inlet. The creek has an average width of 5 feet and an average depth of 0.5 feet. Sampling was conducted on Smith Creek at St. Paul Road and Louisa Road.

This stream is classified as a Cold Water Class I trout stream that is fully meeting it's potential use. Smith Creek is also designated as Exceptional Resource Waters.

Habitat evaluations at different times of the year ranked Smith Creek as having good to fair habitat. Most of the riparian area is wetland. Sand is the predominant stream bed substrate with some silt accumulated near the banks. Rock and rubble is generally limited to riffle areas below bridge abutments where rip-rap is present. Macrophytes in the stream are common. Macroinvertebrate samples received biotic index values of 4.73 and 2.73 which rates Smith Creek as good to excellent water quality with some to no apparent organic pollution.

Water chemistry results show very low concentrations of nutrients, biochemical oxygen demand, and suspended solids during both rain and snowmelt runoff. However, a dissolved oxygen measurement os 5.7 mg/l was noted on June 10, 1993. This is below the state standard of 6 mg/l. This depressed level does not appear to correlate with high water temperature or elevated nutrient runoff.

THE OUTLET

The Outlet is a large river that originates from Lake Noquebay and drains to the Peshtigo River about six miles downstream. The Outlet has an average depth of 1.7 feet and an average width of 73 feet. Sampling was conducted on the Outlet at St. Paul Road and CTH "W".

The Outlet is classified as Warm Water Sport Fish Communities fully meeting its potential use.

Habitat evaluations ranked this stream as having f\good habitat. The river at St. Paul Road is very fast and hazardous to sample. The substrate is mostly rock, rubble, and other stable habitat. Filamentous algae was present on many of the boulders. A macroinvertebrate sample in Spring, 1993 received a biotic index value of 4.04 which rates The Outlet as very good water quality with possible slight organic pollution.

Water chemistry samples collected during a summer rain runoff event shows very low

concentrations of nutrients, biochemical oxygen demand, and suspended solids.

Table 11. Lake Noquebay lake characteristics.

Area (lake):	2,409 acres (974 ha)
Mean depth:	15 feet (4.6 m)
Maximum depth:	54 feet (16.5 m)
Volume:	36,135 acre-feet (4,485 Ha-M)
Watershed area:	84,479 acre (34,189 ha)

Watershed: Lake surface ratio 35:1

Estimated average water residence time 0.45 years

Public accesses (#): 5

Inlets: 3 Outlets: 1

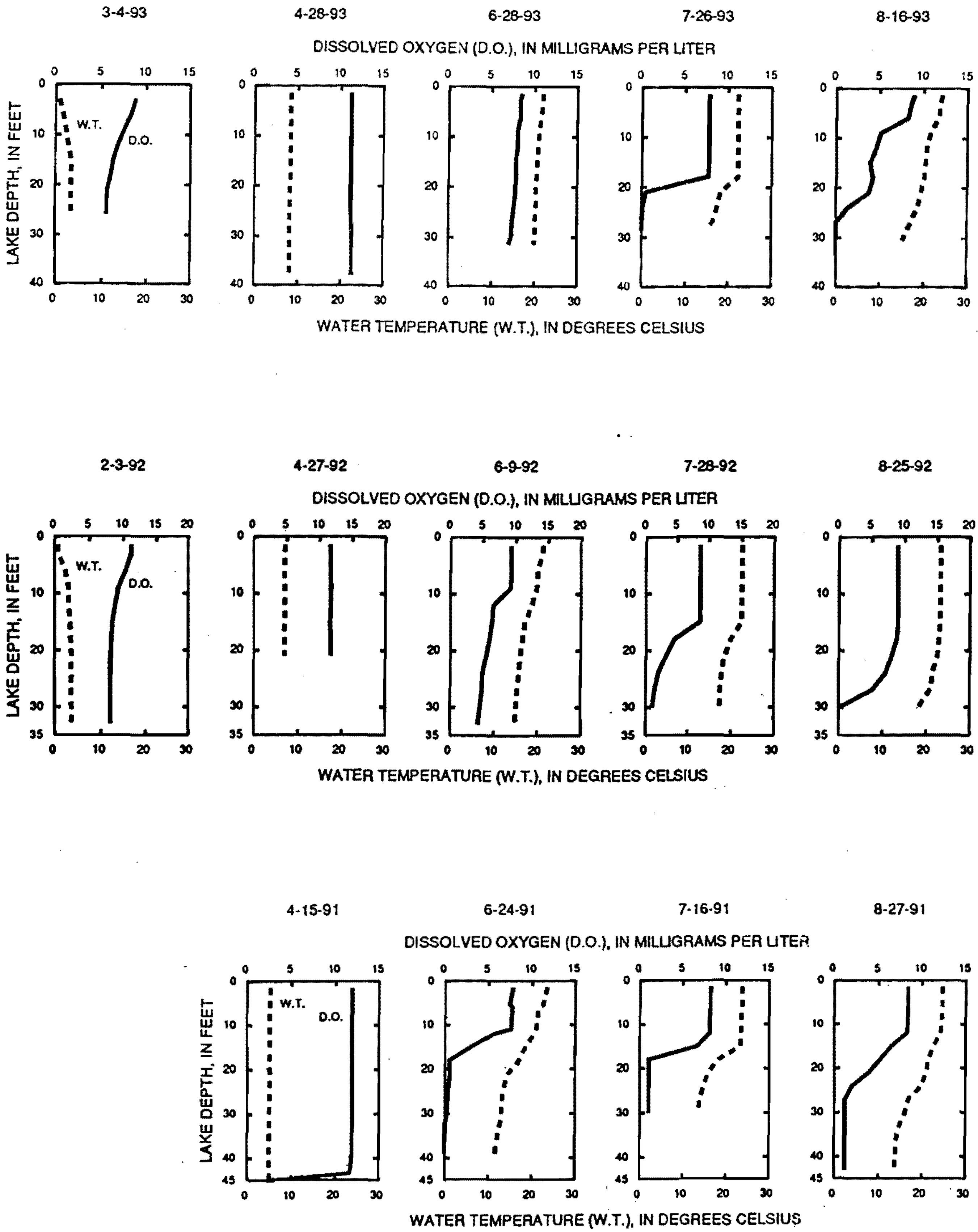


Figure 11. Dissolved oxygen/temperature profiles for Lake Noquebay from 1991 to 1993.

5.2. Phosphorus, Secchi Disc, and Chlorophyll a

Other water data have been collected in addition to water temperature and dissolved oxygen profiles. A summary of collected data from 1991 to 1993 is shown in Table 12. Results show that the lake is phosphorus limited (based on an average total nitrogen:total phosphorus ratio of 49:1).

The secchi disc transparency had an average summer depth of 3.4 meters (11.3 feet) over the last few years. Some variability is observed in spring and fall. This is a natural variation based on factors such as temperature, rainfall, sunlight, snowfall, and wind that may affect transparency in spring and fall. Midsummer secchi disc depths (late June, July, and August) appear to be fairly consistent from year-to-year.

The Trophic State Index (TSI)(Carlson's Index) was calculated for the summer data for 1991, 1992, and 1993. Results indicate Lake Noquebay is a mesotrophic lake (Table 13). For summer, water transparency had an average (for 1991 to 1993) value of 48 on the TSI while total phosphorus had a reading of 49. Usually the TSI numbers should be nearly the same. Data from 1987 to 1993 for total phosphorus, chlorophyll a, and secchi disc for the West end (deep hole) of Lake Noquebay is shown in Figure 12. Data from 1991 to 1993 for total phosphorus, chlorophyll a, and secchi disc for the east end of Lake Noquebay near Crivitz, Wisconsin.

Table 12. Water clarity and water-quality analyses and their associated Trophic State Indices (TSI) for Lake Noquebay, deep hole, near Crivitz, Wisconsin. Source: USGS, 1991, 1992, 1993.

Date	Secchi Disk Depth (meters)	Secchi Disk Depth (feet)	Secchi Disk T.S.I.	Sampling Depth (feet)	Total Phosphorus Conc. (mg/l)	Total Phosphorus Conc. (ug/l)	Total Phosphorus T.S.I.	Chlorophyll a Conc. (ug/l)	Chlorophyll a T.S.I.	Dissolved Othro-phosphate Phosphorus Conc. (mg/l)
4/15/91	3.5	11.6	46	1.5	0.014	14	45	3	42	0.004
	-	-	-	43	0.012	12	-	-	-	0.004
6/24/91	2.5	8.2	47	1.5	<0.020	<20	50	3	42	-
	-	-	-	39	<0.020	<20	-	-	-	-
7/16/91	2.4	7.8	48	1.5	0.012	12	42	4	44	-
	-	-	-	28	0.012	12	-	-	-	-
8/27/91	2.6	8.5	46	1.5	0.011	11	41	5	46	-
	-	-	-	42	0.080	80	-	-	-	-

Date	Secchi Disk Depth (meters)	Secchi Disk Depth (feet)	Secchi Disk T.S.I.	Sampling Depth (feet)	Total Phosphorus Conc. (mg/L)	Total Phosphorus Conc. (µg/L)	Total Phosphorus T.S.I	Chlorophyll a Conc. (µg/L)	Chlorophyll a T.S.I.	Dissolved Ortho-phosphate Phosphorus Conc. (mg/L)
4/27/92	3.2	10.5	43	1.5	0.011	11	47	3	43	0.002
	-	-	-	22	0.011	11	-	-	-	0.002
6/09/92	2.9	9.5	45	1.5	0.013	13	48	4	45	--
	-	-	-	32	0.011	11	-	-	-	--
7/28/92	4.2	13.8	39	1.5	0.008	8	44	3.18	44	--
	-	-	-	30	0.020	20	-	-	-	--
8/25/92	2.8	9.2	45	1.5	0.013	13	48	4.74	47	--
	-	-	-	30	0.020	20	-	-	-	--

Date	Secchi Disk Depth (meters)	Secchi Disk Depth (feet)	Secchi Disk T.S.I.	Sampling Depth (feet)	Total Phosphorus Conc. (mg/L)	Total Phosphorus Conc. (µg/L)	Total Phosphorus T.S.I	Chlorophyll a Conc. (µg/L)	Chlorophyll a T.S.I.	Dissolved Ortho-phosphate Phosphorus Conc. (mg/L)
04/28/93	3.0	9.8	44	1.5	0.017	17	50	3.8	45	<0.002
	-	-	-	38	0.011	11	-	-	-	<0.002
06/28/93	1.6	5.2	53	1.5	0.022	22	52	5.43	48	--
	-	-	-	31	0.013	13	-	-	-	--
07/26/93	1.8	5.9	52	1.5	0.015	15	49	5.88	48	--
	-	-	-	28	0.017	17	-	-	-	--
08/16/93	2.4	7.9	47	1.5	0.015	15	49	4.99	47	--
	-	-	-	30	0.031	31	-	-	-	--

Table 13a. Average concentrations for the summers of 1991, 1992, and 1993.

	1991	1992	1993
Total phosphorus (ppb)	14	11	17
Chlorophyll a (ppb)	4	4	5
Secchi Disc (ft)	8.2	10.8	6.3

Table 13b. Trophic State Index (TSI) values for the summers of 1991, 1992, and 1993. Equations used to calculate TSI are shown below.

Trophic State Index Parameter	1991 TSI Value	1992 TSI Value	1993 TSI Value
Total phosphorus	44	47	50
Chlorophyll a	44	45	48
Secchi disc	47	43	51
Mean	45	45	50

TSI (Chl a)(ppb or ug/l) = $36.25 + 15.5 \log_{10}$ (Chl a)
TSI (TP)(ppb or ug/l) = $60 - 33.2 \log_{10} (40.5/TP)$
TSI (Secchi)(meters) = $60 - (SD \log_{10} \times 33.2)$

5.3. Algae and Zooplankton

Algae

Algae (phytoplankton) are small, generally microscopic plants found in all lakes and are primary producers that form the base of the aquatic feed chain. They convert energy and nutrients through photosynthesis into the compounds necessary to support life in the aquatic system. Oxygen, which is vital to higher forms of life in a lake, also is produced in the photosynthetic process.

Algal blooms may reach nuisance proportions in fertile or eutrophic lakes and cause surface scum or slime. High concentrations of wind-blown algae may accumulate on shorelines, where they die and decompose, causing noxious odors and unsightly conditions. The decay process consumes oxygen; decay sometimes depletes available oxygen supplies and results in fish kills. Certain species of decomposing blue-green algae release toxic materials into the water.

Genera of blue-green algae including *Microcystis, Anabaene, Aphanizomenon, Gloetrichis, Oscillatoria,* and *Lyngbya* are capable of producing toxins under certain conditions during algal blooms; incidents of domestic animal deaths and positive laboratory tests for toxins have been reported in Wisconsin (Repavich and others, written commun.). It is important to note, however, that even if a genera is present, it does not mean toxins will be produced. In Delavan Lake in southeast Wisconsin, for example, the lake exhibited toxicity before 1986 but not during s study in 1986 (Repavich and others, written commun.)(Fields, 1993). There is little data on algae for Lake Noquebay. Good transparencies and low to moderate chlorophyll a would indicate that the blue-greens are not much of a nuisance. In the future it would be good to characterize the algal community.

Zooplankton

Zooplankton are microscopic animals that inhabit the same environments as phytoplankton. Zooplankton are an important link in the aquatic food chain. They feed on algae and, in turn, provide a food source for fish. However, as with the algae for Lake Noquebay, data are scarce on zooplankton for Lake Noquebay. Paleoecology (Section 6) shows some zooplankton dynamics over the years, however I haven't seen any recent data (1990's) on live zooplankton. It would be appropriate to collect some zooplankton data along with phytoplankton data in the future.

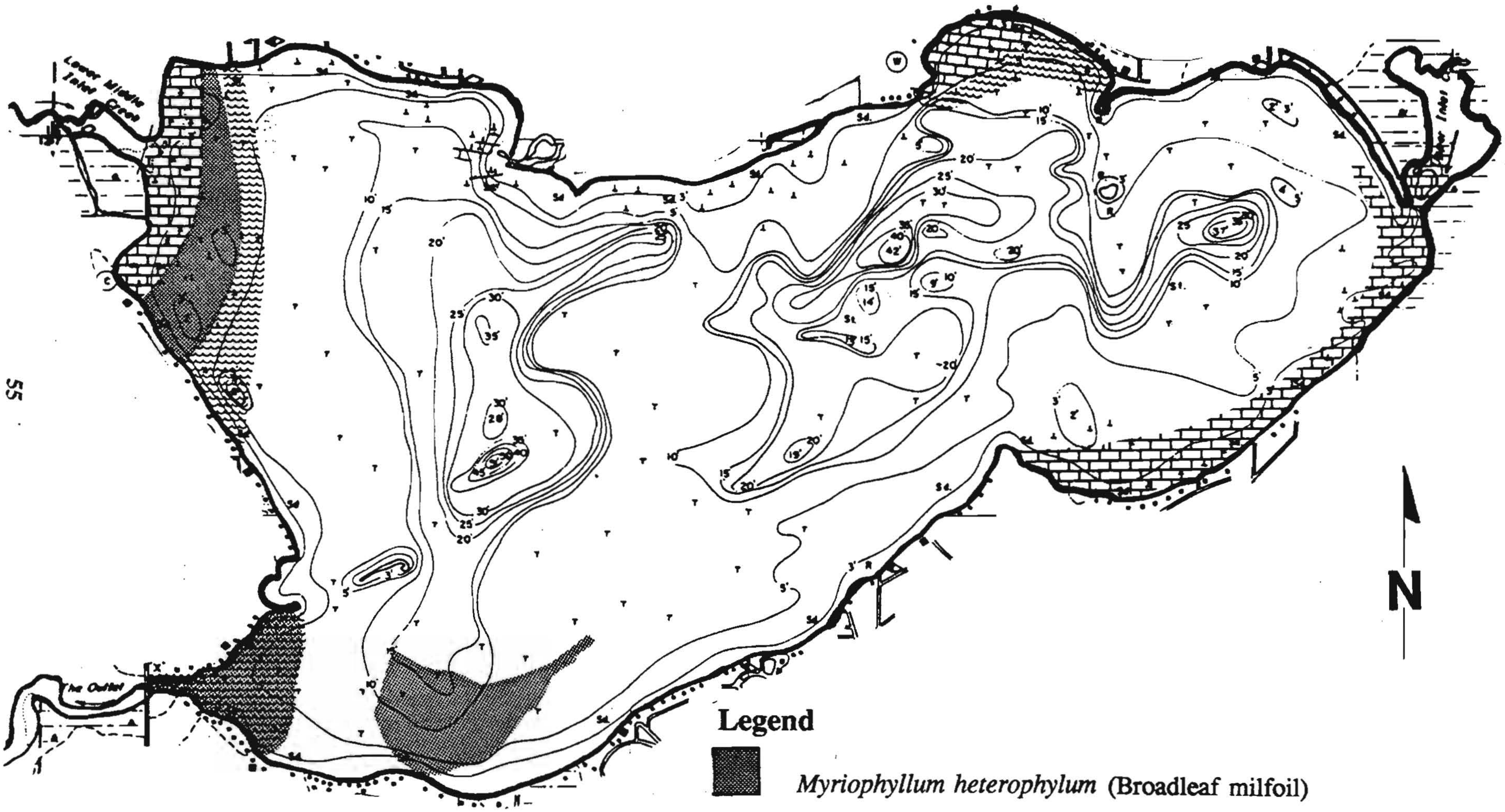
<u>**Source: USGS**</u>

5.4. Macrophytes

Since the 1950s residents around Lake Noquebay have been commenting on the excessive amounts of milfoil. In 1931 and 1942 aquatic plant studies were conducted on Lake Noquebay. Both studies found a species of milfoil but plants were found only occasionally. Another aquatic plant study was conducted in 1968, milfoil was now found to be common. It was not until the 1970 plant study that broadleaf milfoil, *Myriophyllum heterophyllum*, was officially identified. Since the 1970 study broadleaf milfoil has been growing and expanding rapidly. In 1978 mechanical weed harvesting was started on Lake Noquebay, but not without its fair share of problems, including machine problems, administrative problems, and activists problems.

Harvesting of the milfoil has continued to date. Figures 14, 15, and 16 show the plant distribution for 1970, 1991, and 1992 respectively.

Macrophyte Survey, 1970



Legend

Myriophyllum heterophylum (Broadleaf milfoil)

Submergent: *Potamogeton amplifolius* (largeleaf pondweed), *Chara* (Chara) *P. illinoensis* (Illinois pondweed), *P. praelongus* (Whitestem pondweed), *Najas quadalupensis* (Southern pondweed)

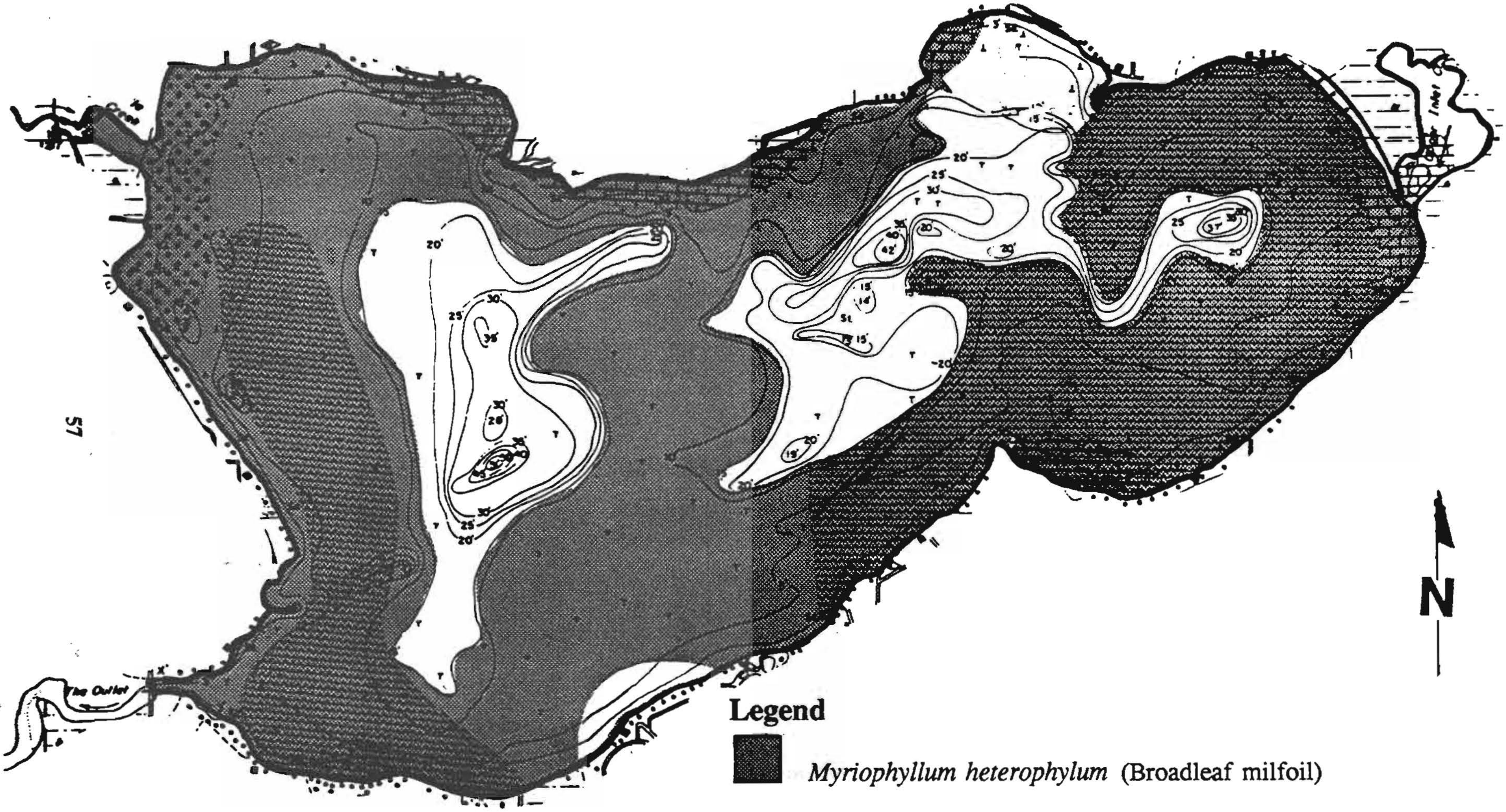
Floatingleaf plants: *Nuphar variegatum* (waterlily)

Emergent: *Scirpus validus* (softstem bulrush).

Lake Noquebay
Marinette County, WI

Figure 14. 1970 Lake Noquebay macrophyte survey. Source:Thompson, 1972).

Macrophyte Survey, 1992



Legend

Myriophyllum heterophylum (Broadleaf milfoil)

Submergent: *Potamogeton amplifolius* (largeleaf pondweed), *Chara* (Char
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Najas quadalupensis (Southern pondweed)

Floatingleaf plants: *Nuphar variegatum* (waterlily)

Emergent: *Scirpus validus* (softstem bulrush)

Lake Noquebay
Marinette County, WI

Figure 16. 1992 Lake Noquebay macrophyte survey.
Source: Krueger, 1992).

Existing Conditions

The macrophyte community, as of the 1992 study, consists of twenty-nine species of plants: three floating-leaf, four emergents, and twenty-two submergents. Plants were not found any deeper than thirteen feet of water. The percent of plant coverage is about 80%, more than enough bottom coverage to maintain clear water conditions.

Floating-leaf plants and filamentous algae were found concentrated around the lower Middle Inlet. This area has not, and will not, be harvested because it is a protected nesting site. Emergent plants were found along the north shore, the far east shore, and at the Upper Inlet. Submergent plants were found throughout the lake in water depths less than thirteen feet. Broadleaf milfoil was found to be the dominant species.

How the Plant Community has Changed

Since the 1931 plant survey, the amount of plant biomass has been slowly increasing until the use of mechanical harvesting was implemented. This practice has seemed to reverse the trend of more plant biomass. The cutting process of harvesting the plants has eliminated the complete life cycle of the milfoil, it is unable to produce the seeds needed to regenerate. Once the plants are cut they do not grow as tall as before and grow more closely at the base. This stunted growth has allowed additional plant species to become reestablished thus creating a greater species diversity.

Broadleaf milfoil (*Myriophyllum heterophyllum*) is a native plant to the United States, although it is usually found in the southern states with Tennessee being the northern boundary. Broadleaf watermilfoil (BLWM) is also called variable-leaf milfoil because its leaves look different above and below water. Below the water line the leaves are divided into thread-like segments and are feather-like. Above the waterline the leaves are blade-like, with serrated edges. BLWM grows almost entirely underwater and is rooted to the lake bottom. Its hearty stems can reach many feet in length and its feathery underwater leaves are arranged on the stem in whorls of four to six. Each leaf has 7-10 paris of thread-like divisions. BLWM's leaf shape and arrangement are what differentiates it from other milfoils such as Eurasian. BLWM has the ability to spread by seed production, but it seems to spread primarily by stem fragmentation, winter buds, and rhizome growth. BLWM prefers cool, deep water and a muddy bottom. The plants also tend to thrive in slightly alkaline water with a high calcium content.

BLWM appears to have peaked, and its distribution is no longer expanding, an din fact appears to be declining in some areas of the lake, most notably, the northeastern. Mechanical harvesting may have contributed to this.

5.5. Fish

The fish community of Lake Noquebay has been considered to be good with heavy fishing pressure since the 1930s. The main gamefish are northern pike and largemouth bass. The main panfish are bluegill sunfish. Standard length distributions from a 1985 survey are shown in Figure 17. A good number of bluegills over 6 inches in size. It does not appear to be a stunted community. Northern pike showed up in good numbers with a majority between 16 - 18 inches in length. We have taken the analyses one step further than the conventional length distribution charts. We were interested in the predator/prey relationships in the fish community.

Mouth Width and Body depth of Fish Community: Using the 1985 fish data from the Wisconsin DNR, the mouth width of the gamefish and the body depth of the preyfish were calculated. Equations for the mouth width and body depth came from Lawrence (1957) and Hambright et al (1991). By converting total length to mouth width for gamefish and total length to body depth for preyfish we were able to see what percent of the preyfish were available to the gamefish. One assumption that we made was that any fish with a body depth less than the mouth width of a gamefish was considered to be potential forage.

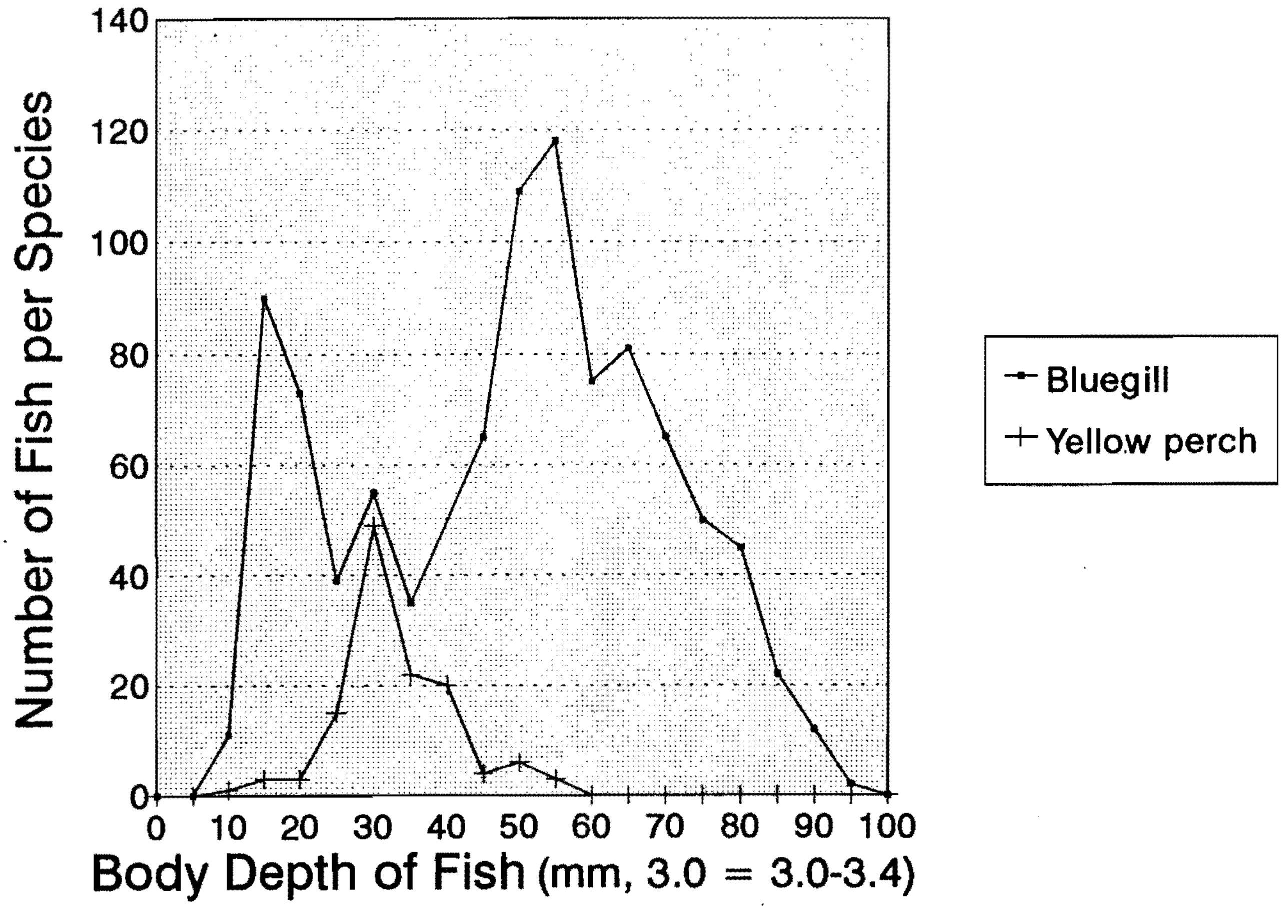
This relationship between gamefish mouth width and a prey body depth is shown in Figure 18. A 4-inch bluegill sunfish has a body depth similar to a 5.3-inch yellow perch. A 12-inch bass could swallow either one, but it would take a 21-inch walleye to swallow the same preyfish.

For Lake Noquebay, we have looked at the year class distribution for northern pike and walleye from the 1985 survey results (Figure 19). Although walleyes were represented by older year classes, the older fish did not necessarily have the ability to ingest bigger preyfish. Walleye mouth widths don't get much bigger after they are five years old in Lake Noquebay. Northern pike mouth width's are larger, at 5-years which gives them a larger potential prey forage base, and a potential competitive advantage.

So a question becomes what does the preyfish community look like. We have graphed the body depth distribution of two preyfish species -- bluegill and perch (Figure 20). Although there are some big bluegills, there are small ones as well. The yellow perch have a body depth peak at 30 mm. Just below the preyfish body depth graph is a gamefish graph. All these gamefish have mouth widths that peak or that are greater than 30 mm. This means most of the yellow perch are potential prey, but many of the bluegill are in a size class that minimizes their encounter with a gamefish that could eat them.

When we combine all gamefish and then preyfish and look at the overlays, we see that a good percentage of the preyfish are not very vulnerable to predation (Figure 21). Gamefish mouth width's peak at 30 mm. This means once a preyfish gets to 40 mm or so, their chances of being eaten are reduced.

As mouth width frequency distribution changes, there may be impacts on prey body depth distribution. At this point, there are not enough data sets worked up to establish clear interpretation of these distributions. But, for Lake Noquebay, it would be interesting to compare the spring survey results to see if there have been any shifts.



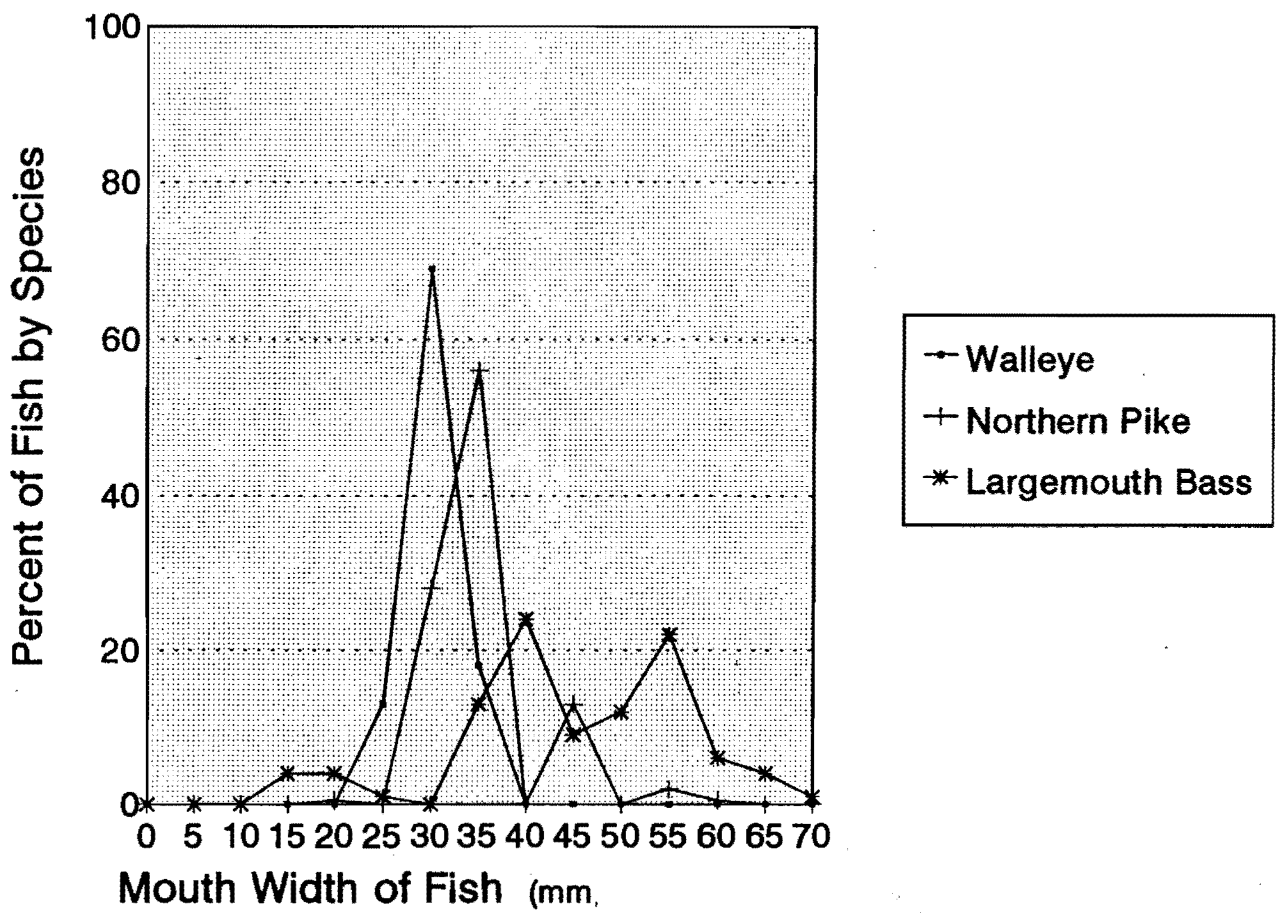


Figure 20. Body depth distributions for bluegill and yellow perch (upper fig). Mouth width distributions for walleye, northern pike, and largemouth bass in Lake Noquebay (lower fig).

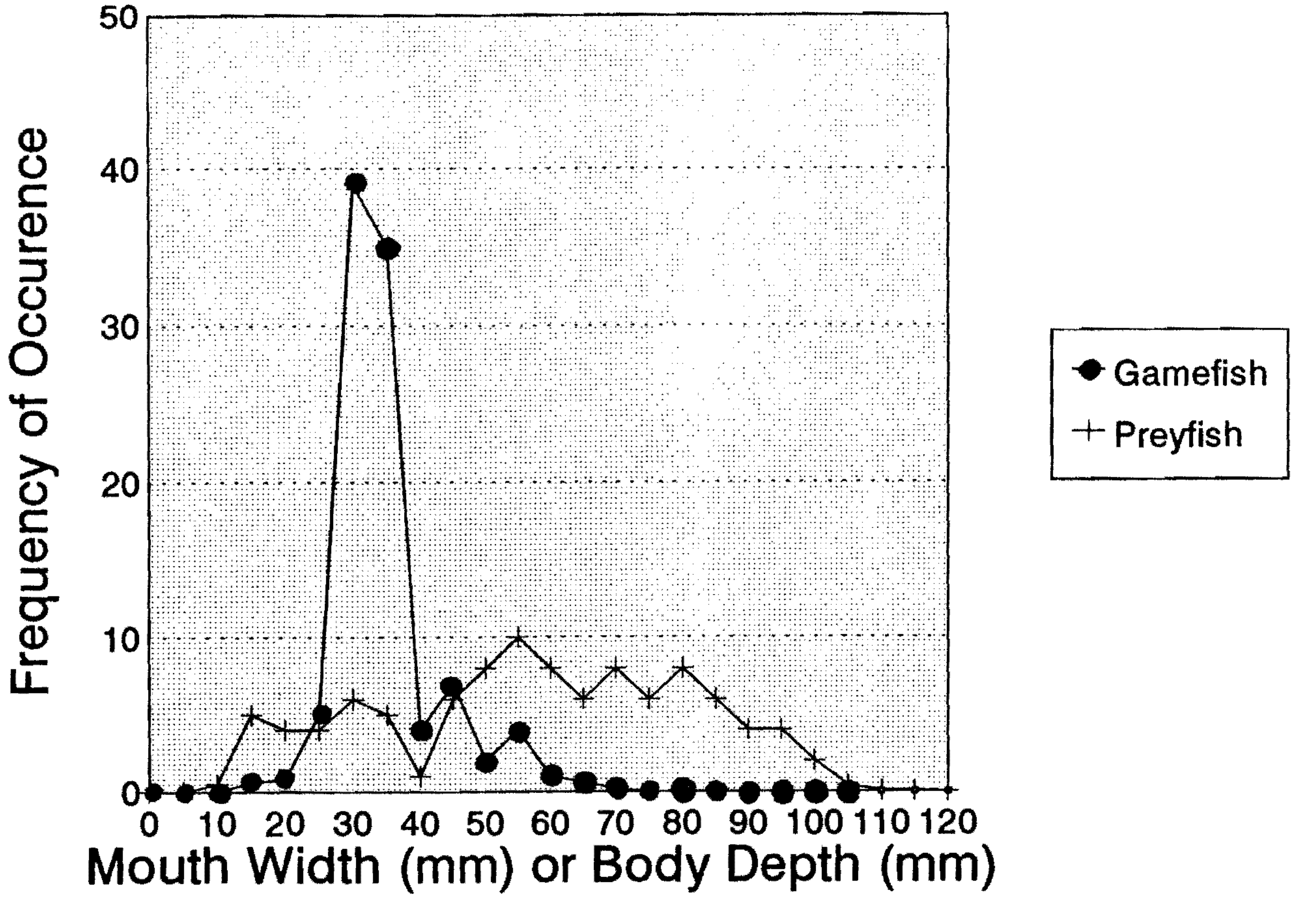


Figure 21. Mouth width and body depth of gamefish and preyfish in Lake Noquebay 1985. Preyfish body depths were combined and the following species were used: bluegill, pumpkinseed, black crappie, black bullhead, yellow perch, and rock bass. Gamefish mouth widths were combined from the following species: northern pike, walleye and largemouth bass.

6. PALEOLIMNOLOGY OF LAKE NOQUEBAY

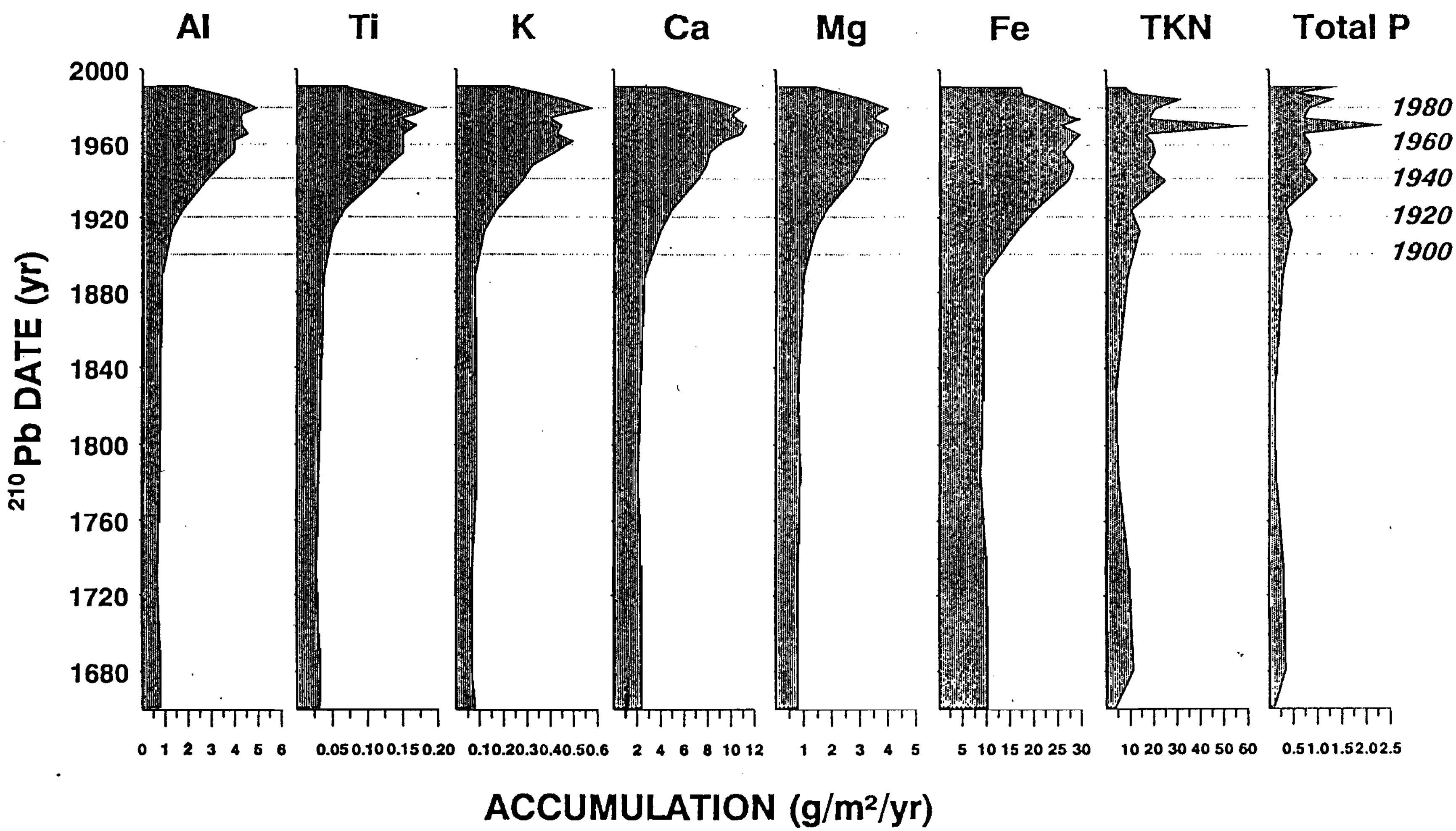
In 1993 a sediment core was taken from Lake Noquebay to determine the recent history of Lake Noquebay. The results were evaluated by Paul Garrison, WDNR.

His narrative is given below (The full memo is found in Appendix D):

> The core indicates that watershed erosional rates began to increase about 1900. This is indicated by increases in the accumulation (sedimentation) of aluminum (Al), titanium (Ti), potassium (K), calcium (Ca), magnesium (Mg), and perhaps iron (Fe). This most likely was the result of logging. Erosional rates continued to increase until about 1960 and they remained at elevated levels until about 1980. It appears, that erosion has declined in the last decade. The input of nutrients to the lake (N and P) increased later, about 1940. While nitrogen levels have declined in the last few years phosphorus levels have remained the same. The bulk sedimentation rate is very similar to that of the accumulation of metals That is, increasing sedimentation around 1900. The sedimentation rate continued to increase until about 1965 and then has declined during the last decade. Organic mater accumulation, which is an increase of the lake's productivity, began to increase around 1900 and continued to increase until about 1980. In the last decade, organic matter accumulation has declined. This may be due in part to the weed harvesting.
>
> The cladoceran zooplankton (the only group preserved in the sediments) are a good indication of the lake's trophic status. Some change in the lake's ecology began around 1850 when *Daphnia pulex* increased. Although at this time I am not sure why this occurred it may be a result of less fish predation. The most important change in the cladoceran community occurred around 1940. At this time there was a drastic decline in the *D. pulex* population and an increase in both *Alona spp* and *Chydorus spp.* populations. This is the same time period when N and P increased. Both *Alona* and *Chydorus* are usually found on and amongst macrophytes. The increase in their numbers most likely indicates an increase in the extent and size of the macrophyte community. The decline in *Alona* during the last decade may be a result of the macrophyte community. The decline in *D. pulex* about 1940 most likely is a result of increased fish predation following the increase in the macrophyte community. Macrophytes provide a refuge for planktivorous fish so that their numbers would increase thus putting more pressure on the larger zooplankton such as *D. pulex*.
>
> In conclusion, it appears that land disturbance around the turn of the century caused increased erosion in the watershed. These elevated erosional rates continued to increase until about 1960 and have declined during the last decade. The water quality probably was not dramatically affected by this until about 1940 when both N and P increased resulting in an expansion of the macrophyte community. the increase in the macrophyte community may have resulted in an increase in the planktivorous fish community with a resultant decline in the larger zooplankters. The macrophyte community appears to be declining in the past decade probably as a result of the harvesting operation. With the completion of the pigment work we should be able to increase our interpretative ability of this core.

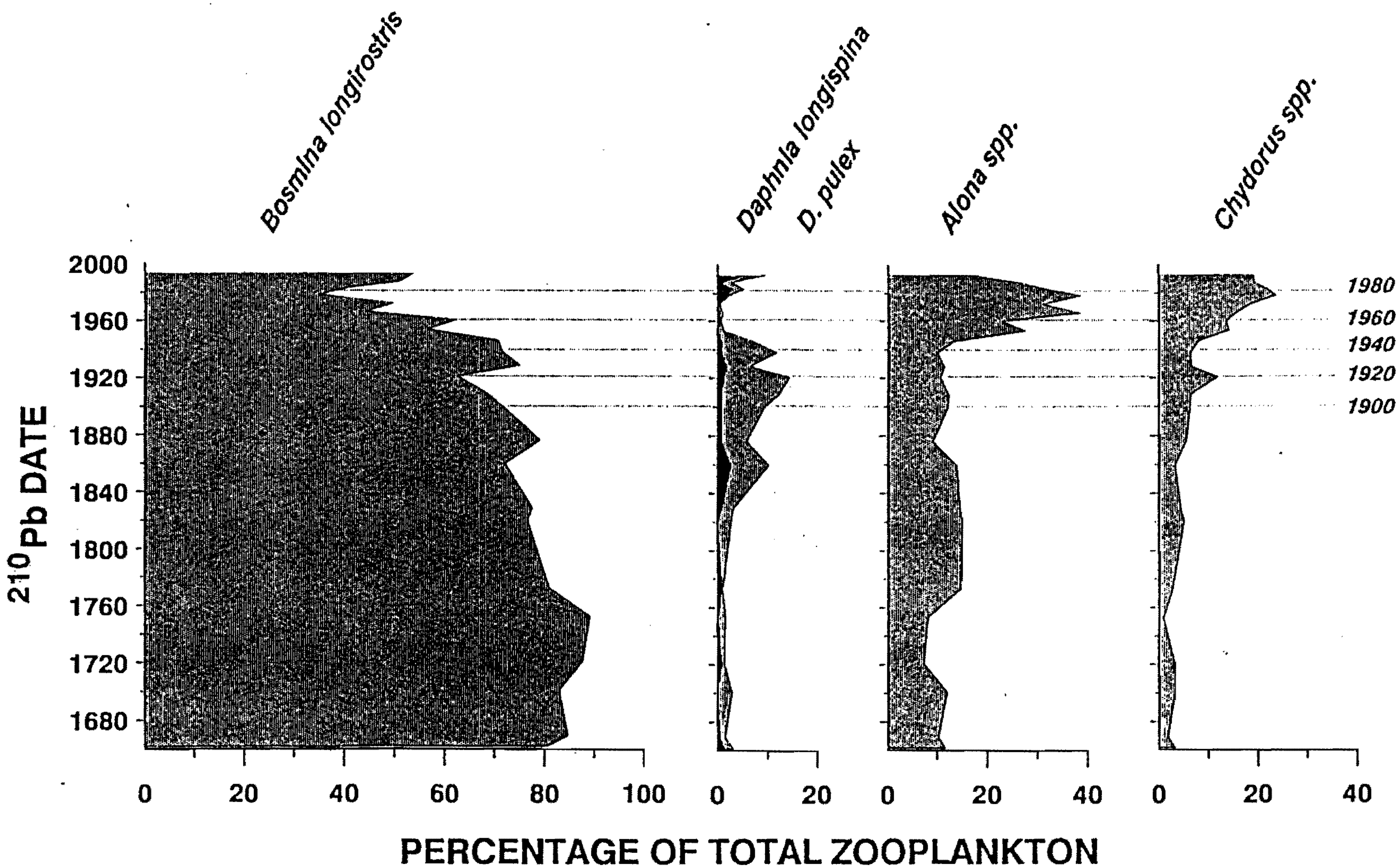
LAKE NOQUEBAY

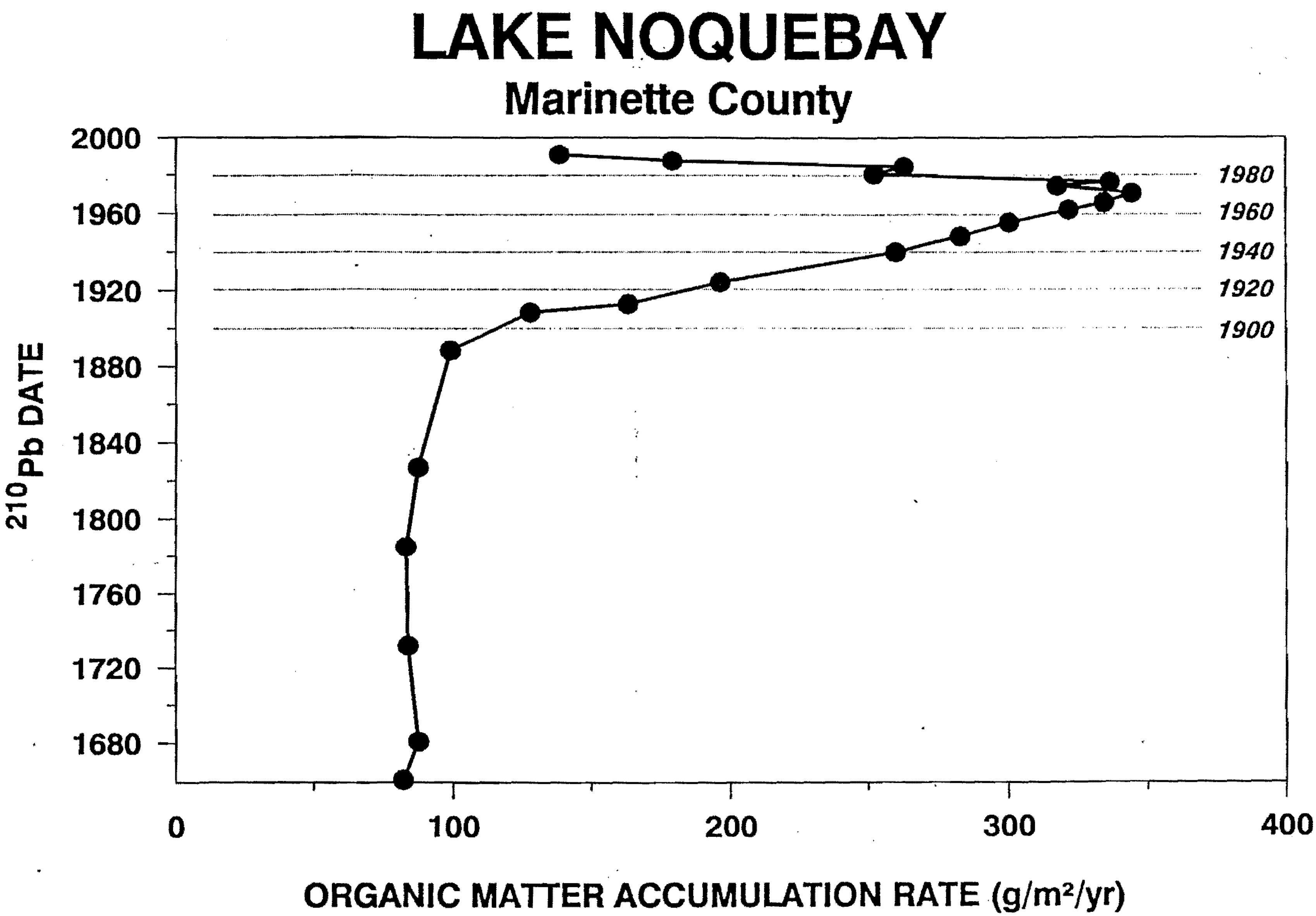
Marinette County



LAKE NOQUEBAY

Marinette County




LAKE NOQUEBAY
Marinette County
210Pb DATE
2000
1960
1920
1880
1840
1800
1760
1720
1680
1980
1960
1940
1920
1900
0
100
200
300
400
ORGANIC MATTER ACCUMULATION RATE (g/m²/yr)
70

7. LAKE NOQUEBAY PHOSPHORUS MODEL

Lake modeling is a tool that aids in predicting the lake phosphorus concentration based on the amount of nutrients that comes into a lake on an annual basis. A lake model can also be used to predict what future conditions could be if changes occur that bring more phosphorus or less phosphorus into the water column.

The phosphorus model used in this study was the Wisconsin Lake Model Spreadsheet (1994) that is a package of 10 different models. Before the models can be run, a nutrient and water budget for Lake Noquebay is needed.

One way to estimate the nutrient budget, is to assign phosphorus export numbers to various land use delineations and then knowing the acreage for each land use, we can estimate phosphorus inputs from various land uses. A summary of phosphorus export coefficients for each land use and then the total estimated phosphorus input to Lake Noquebay is shown in Table 14.

However, the stream concentrations and inflows can also be used to calculate phosphorus loading. We used a phosphorus input that was used by Tim Rasman in his model run (Rasman, 1994). The Canfield/Bachmann model run if shown in Table 14.

The phosphorus model predictions and the actual observed phosphorus concentrations are shown in Table 14. For Lake Noquebay the Canfield and Bachmann model prediction was 13 ppb, while the average found for Lake Noquebay was 14 ppb (in 1991) and 25 ppb (in 1992) phosphorus concentration.

The WLMES program actually runs 10 different lake phosphorus models. Those results are shown in Table 15. Based on a phosphorus input of 1,520 kg-P per year, the models predicted a lake phosphorus concentration from 8 to 15 ppb. The observed spring lake concentration was 13 ppb. All the models were pretty close.

8. LAKE AND WATERSHED STATUS

The status of Lake Noquebay is good. Based on water quality criteria, it consistently rates as mesotrophic (Figure 22). For lakes in the geologic and geographic setting as Noquebay, Lake Noquebay is acting about normal. Lake Noquebay is in the Northern Lakes and Forest Ecoregion (Figure 23). It's water quality characteristics fall within a range that would be expected for lakes in the Northern Lakes and Forests Ecoregion (Table 17).

The status of the watershed is also good. Although criteria for streams in the ecoregion are not as well as defined as lakes, stream investigations show good water quality indicators (Section 4.3). Both the lake and watershed status are good. Therefore most of the future water quality work will be geared toward protection and maintenance, with specific projects to address watershed nutrient sources as they are found.

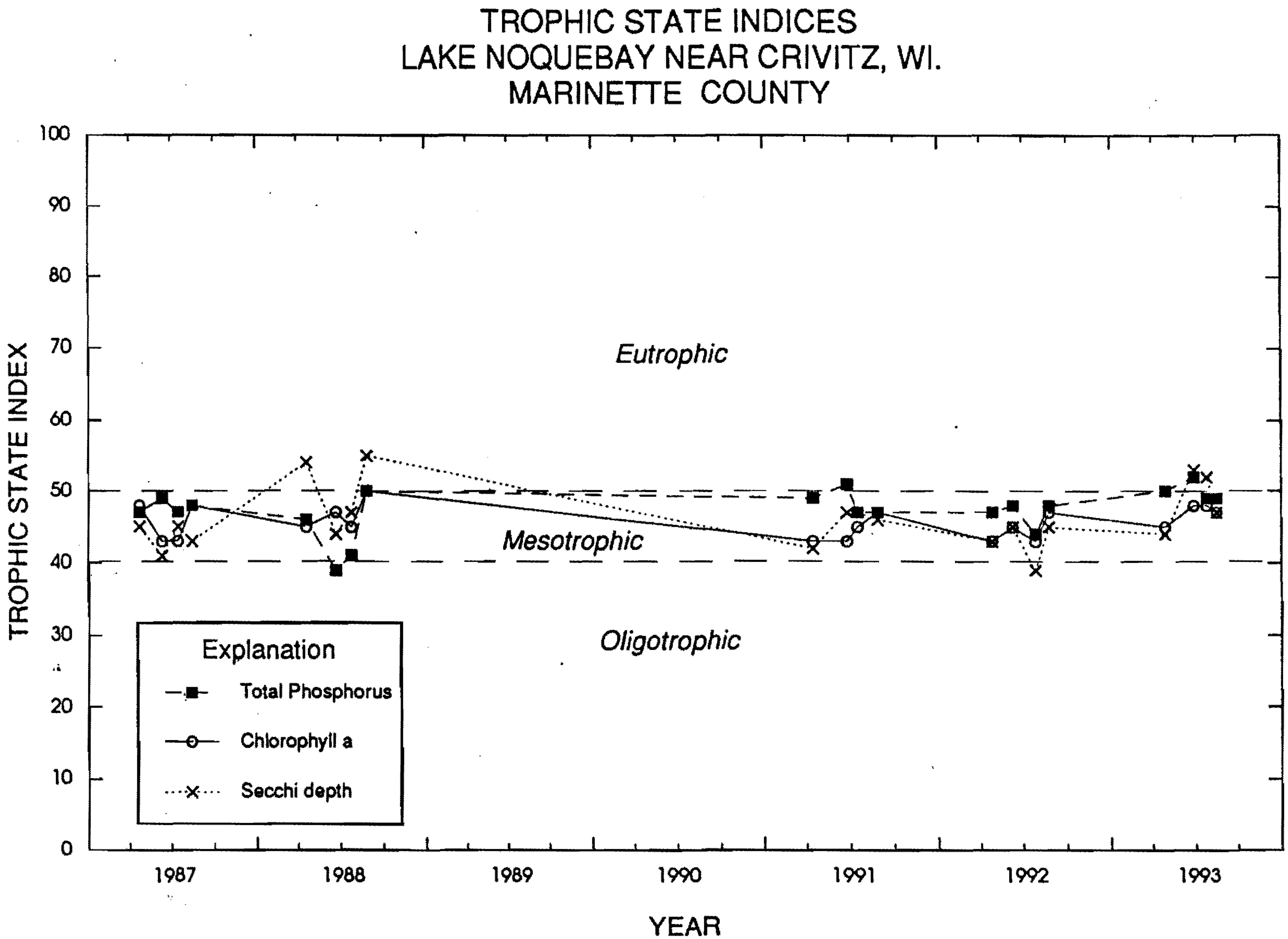


Figure 22. Trophic State Indices for Lake Noquebay, deep hole, near Crivitz, Wisconsin

6. AQUATIC PLANT MANAGEMENT

Aquatic plant management for Lake Noquebay has several components. The most important component is managing broadleaf water milfoil (BLWM). Secondarily, the approach is to maintain and encourage diversity of both submersed and emergent plants. The last component is managing the aquatic plant community for water quality and fishery benefits.

Broadleaf Watermilfoil Management: This project area has been ongoing since 1974 when the weed committee became the Lake Noquebay Rehabilitation District. Work by many investigators including Dr. Bedrosian and Dr. Thompson, developed the harvesting program, and it is still ongoing.

I have reviewed lake reports and the details of the harvesting approach. My conclusions are that this is the best method for milfoil management and I don't know of a better cost effective in-lake management technique.

There are some hints from the literature that nitrogen is important for Eurasian Watermilfoil control and it could be for broadleaf milfoil as well. If watershed projects reduce nitrogen inputs into Lake Noquebay, this may help control BLWM as well.

If harvesting can continue it will keep on removing phosphorus and nitrogen from the lake as well. At some point this may reduce a limiting nutrient to a lower threshold which may constrain the growth of BLWM. A harvesting record from 1978 to 1993 is shown in Table 18.

Approximately 13,000 pounds of nitrogen are removed in an average harvesting year. Is this a lot? It is difficult to say. What would be beneficial is a lake sediment sampling program that would characterize the lake sediments in terms of chemistry and texture.

From the program, a lake sediment map could be constructed. The next step would be to see if there are obvious correlations with sediment chemistry and BLWM distribution. The last step would be to test sediment/plant distribution hypotheses with lab and field experiments. Results of a testing program could give some insight into BLWM ecology and future distribution in Lake Noquebay.

Promote Plant Diversity: Good diversity is already present in Lake Noquebay. The 1992 plant survey found 29 species of plants. Therefore, a robust seed bank is present. Continued harvesting and watershed project implementation may promote good plant diversity. Nearshore aquascaping, as described in Project 6 may aid to a degree. Because of the existing seed bank, additional transplanting of new species is not necessary.

Managing the Plant Community for Water Quality and Fish: Canfield and Hoyer (1992) described aquatic plant and water quality relationships they found in Florida Lakes. In broad terms, they found if 40% or more of the lake bottom had some sort of aquatic macrophyte colonization, they usually found clear water conditions. If less than 40%, algae were often a nuisance condition. For optional fish communities (from an angler's view point) they found optional plant coverage of between 20% to 80%. Therefore for Lake Noquebay, in order to maintain clear water and provide for an optimal fishery, plant colonization should be between 40% to 80%. Currently it is some place between 40% and 80%. The plant community in Lake Noquebay appears to be in the range required for good water quality and for a good fish community. The Lake District needs to update its aquatic plant distribution at least once every two years. In years with heavy growth, they could consider hiring another harvester for a period of time.

7. CONTINUE A LAKE MONITORING PROGRAM

To evaluate Lake Noquebay, a monitoring program should be ongoing. This program should address the issues of:

o Effectiveness of watershed projects in regard to phosphorus in runoff;

o Characterizing stream for phosphorus and nitrogen;

o Changes in lake quality as measured by total phosphorus, secchi disc, algae and macrophyte distribution.

Lake Monitoring Details

Secchi Disc transparencies should be taken through the summer monthly. The surface water samples should be analyzed for the total phosphorus, total nitrogen, and chlorophyll a. Either the U.S.G.S., the County, or volunteers could collect water samples. University of Wisconsin-Stevens Point has a good lake testing program, but lakes are sampled only in the spring and the fall. The cost is about $120 per lake per year. The UW-Stevens Point contact is Byron Shaw. It would be optimal to collect water samples through the summer (June, July, and August) as well as stream sampling at snowmelt and at summer baseflow. Sampling every year would be ideal, sampling every two years would be ok.

If an aquatic plant program starts studying broadleaf watermilfoil in the lake, then more intense lake and watershed sampling would be appropriate (more sampling data, additional parameters).

8. ORGANIZE A LONG RANGE PLANNING COMMITTEE

Because Lake Noquebay has relatively good water quality at this time, it's management is in a protective mode, meaning it can act before trouble occurs (proactive approach).

A Long Range Planning Committee should organized, composed of interested lake residents along with WDNR and County personnel to set up a framework for addressing future contingencies. Questions to address include the following:

o Is any action needed for jet skies and related water craft?

o How long does the harvesting program go on? When is the next machine needed.

o What steps should be taken for drought years -- if any?

o What steps should be taken for years with excessive high water?

o If Eurasian watermilfoil comes into the lake, how much area could it colonize, should chemicals be used or strictly mechanical removal, and would lake residents be willing to contribute?

o What will be the impact of zebra mussels on Lake Noquebay ... what should be done if they are found in the lake?

o If rusty crayfish are found in Lake Noquebay, what is the potential impact on the milfoil and should they be aggressively removed?

These are examples of some of the contingencies that could be addressed by the Long Range Planning Committee. For example, how much of a cash reserve is there for contingencies? Is a fund needed and if so what amount should be put in there? Planning would be cooperative effort with the Lake District, WDNR, the Land and Water Conservation Department and other agencies.