

NUTRIENT (N,P) DYNAMICS, HYDROLOGY,  
AND SEDIMENTATION RATES OF  
LAKE NESHONOC, LA CROSSE, WISCONSIN

A Thesis

Submitted to the Faculty

of

University of Wisconsin - La Crosse  
La Crosse, Wisconsin 54601

by

Paul Gerard Ritter

In Partial Fulfillment of the  
Requirements for the Degree

of

Master of Science in Biology

June 1986

UNIVERSITY OF WISCONSIN - LA CROSSE  
La Crosse, Wisconsin 54601  
COLLEGE OF ARTS, LETTERS, AND SCIENCES

Candidate: Paul G. Ritter

We recommend acceptance of this thesis to the College of Arts, Letters, and Sciences in partial fulfillment of this candidate's requirements for the degree Master of Science in Biology. The candidate has completed his oral defense of the thesis.

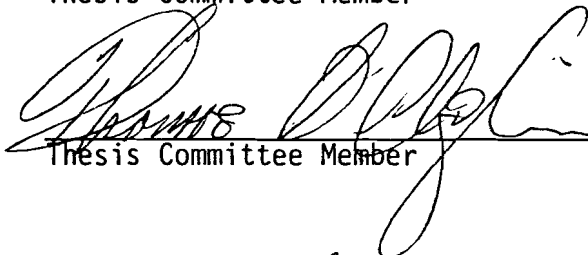
Thesis approved:

  
Thesis Committee Chairperson

19 June 1986  
Date

Thomas Weeks  
Thesis Committee Member

19 June 1986  
Date

  
Thesis Committee Member

19 June 86  
Date

John Scheidt  
Thesis Committee Member

19 June 1986  
Date

A Vincent Weber  
Dean, College of Arts, Letters, and Sciences

June 24, 1986  
Date

Howard E. Rose  
Dean, Office of Graduate Studies

25 JUNE, 1986  
Date

## ABSTRACT

Lake Neshonoc is a reservoir (243 ha) on the La Crosse River in the Driftless Area of southwestern Wisconsin. Water samples were collected from the four influent waters (Adam's Valley Creek, Burn's Creek, Dutch Creek, and the La Crosse River), the marsh upstream from the lake, four sites within the lake, and one site downstream from the dam. Two deep water sites in the lake were sampled at the surface, middle, and near-bottom of the water column. Samples were collected from all sites from February through September, 1985, at which time the lake was drained for dam repairs. Influent samples were collected through December, 1985. Temperature, dissolved oxygen, and Secchi disk transparency were recorded in the field. Non-filterable residues, specific conductance, pH, total alkalinity, nitrate, nitrite, ammonia, ortho-phosphorus, and total phosphorus were analyzed in the laboratory.

Total alkalinity, pH, and conductivity were typical of a well-buffered lake. Dissolved oxygen in the lake fluctuated from top to bottom on a biweekly basis during the summer. Of the influent waters, Adam's Valley Creek consistently had the highest concentrations of nutrients. Within the lake, nitrate and ortho-phosphorus concentrations decreased 35% from the inflow sites to the outflow site. This was likely due to assimilation by phytoplankton, which may have increased the biological oxygen demand and decreased the dissolved oxygen in the deeper waters (3 m) of the lake.

The La Crosse River supplies a majority of the water entering Lake Neshonoc, which explains the similarity between the lake and river water chemistry. The lake has lost 73 ha in the past 29 years, 23% of its original surface area. Most of the loss occurred with the encroachment of the marsh. The lake volume has decreased  $0.42 \times 10^6 \text{ m}^3$  during the past 19 years. Hydraulic residence time for Lake Neshonoc is 4.85 days. Improvements in watershed management must be implemented to prolong the benefits of this reservoir.

## ACKNOWLEDGEMENTS

My sincere thanks and gratitude to Dr. Ronald G. Rada for his unwavering demand of the best of my abilities. My thanks also to Drs. T.O. Claflin, T.F. Weeks, and J.K. Scheidt for their advice and guidance in reviewing this paper. Thanks to my fellow office-mates, the "amblyops", for their inputs and camaraderie. A special thanks to Sherri for her support and understanding.

This project was supported in part by the Lake Neshonoc Protection and Rehabilitation District, Joleen Hundt, Chairperson. Laboratory materials and equipment were provided by University of Wisconsin-La Crosse Biology Department and the River Studies Center. My appreciation to Mark Schultz for providing help and support throughout the project.

## TABLE OF CONTENTS

	Page
LIST OF TABLES . . . . .	vi
LIST OF FIGURES . . . . .	vii
LIST OF APPENDICES . . . . .	ix
INTRODUCTION . . . . .	1
DESCRIPTION OF STUDY AREA . . . . .	3
METHODS AND MATERIALS . . . . .	10
Site Selection . . . . .	10
Field Methods . . . . .	10
Hydrology and Hydrography . . . . .	11
Laboratory Methods . . . . .	13
Quality Assurance . . . . .	13
RESULTS AND DISCUSSION . . . . .	16
Temperature . . . . .	16
Transparency . . . . .	16
Non-filterable Residues . . . . .	17
Dissolved Oxygen . . . . .	20
Specific Conductance . . . . .	20
pH . . . . .	22
Total Alkalinity . . . . .	24
Nitrate . . . . .	24
Ammonia . . . . .	28
Phosphorus . . . . .	28
Hydrology and Hydrography . . . . .	30

	Page
SUMMARY . . . . .	38
RECOMMENDATIONS . . . . .	42
REFERENCES . . . . .	43

## LIST OF TABLES

Table		Page
1.	Data from Previous studies on Lake Neshonoc . . . . .	8
2.	Parameters measured, reporting units, and methods employed in the Lake Neshonoc study, 1985 . . . . .	14
3.	Dimensions of Lake Neshonoc determined from 1983 aerial photographs (USGS) and 1985 hydrographic data (this study) . . . . .	32
4.	Discharges for the four waters flowing into Lake Neshonoc as determined on August 15, 1985 . . . . .	32
5.	Lake Neshonoc surface areas in 1954, 1966, and 1983; and lake volumes in 1966 and 1985 . . . . .	34

## LIST OF FIGURES

Figure		Page
1.	Map of Lake Neshonoc, Wisconsin, and its immediate tributaries. Sampling sites for the present study (1985) are indicated by the numbers 1-11 . . . . .	4
2.	Watershed of the La Crosse River to the Lake Neshonoc Dam . . . . .	5
3.	The area covered by the four glacial periods and the Driftless Area of southwestern Wisconsin (Redrawn from Matsch 1976) . . . . .	6
4.	Map showing the area of the La Crosse River basin near West Salem, Wisconsin before the formation of Lake Neshonoc (Redrawn from Hansen 1933) . . . . .	6
5.	A diagram of the in-stream samplers used on Adam's Valley Creek, Burn's Creek, Dutch Creek, and the La Crosse River in this study (1985) . . . . .	12
6.	Total non-filterable residue (TNFR) (annual mean standard deviation) for Lake Neshonoc and its tributaries (1985) . . . . .	18
7.	Non-filterable fixed residue (NFFR) (annual mean standard deviation) for Lake Neshonoc and its tributaries (1985) . . . . .	19
8.	Percent saturation of dissolved oxygen at Site 2 at the surface and bottom (3 m) in Lake Neshonoc (1985) .	21
9.	Specific Conductance (annual mean standard deviation) for Lake Neshonoc and its tributaries (1985) . . . . .	23
10.	Ammonia, pH, and % dissolved oxygen saturation at Site 2 near the bottom (3 m) in Lake Neshonoc (1985) .	25
11.	Total alkalinity (annual mean standard deviation) for Lake Neshonoc and its tributaries (1985) . . . . .	26
12.	Nitrate-nitrogen (annual mean standard deviation) for Lake Neshonoc and its tributaries (1985) . . . . .	27
13.	Ortho-phosphorus (annual mean standard deviation) for Lake Neshonoc and its tributaries (1985) . . . . .	29
14.	Total phosphorus (annual mean standard deviation) for Lake Neshonoc and its tributaries (1985) . . . . .	31

Figure		Page
15.	Areal encroachment of the marsh vegetation on the east end of Lake Neshonoc in 1954, 1966, and 1983 . .	35
16.	The hydrographic bottom contours of Lake Neshonoc as measured in August, 1985 . . . . .	36

## LIST OF APPENDICES

Appendix	Page
1. Sampling site landmarks or triangulation locations used in the Lake Neshonoc Study, 1985 . . . . .	45
2. Temperature ( $^{\circ}\text{C}$ ) for Lake Neshonoc at Sites 2 and 3 (1985) . . . . .	46
3. Secchi disk transparencies for Lake Neshonoc at Sites 2 and 3 (1985) . . . . .	47
4. Total non-filterable residue (TNFR) (mg/L) and the annual mean TNFR for Lake Neshonoc and its tributaries (1985) . . . . .	48
5. Non-filterable fixed residue (NFFR) (mg/L) and the annual mean NFFR for Lake Neshonoc and its tributaries (1985) . . . . .	49
6. Non-filterable volatile residue (NFVR) (mg/L) and the annual mean NFVR for Lake Neshonoc and its tributaries (1985) . . . . .	50
7. Dissolved oxygen (mg/L) for Lake Neshonoc at Sites 2 and 3 (1985) . . . . .	51
8. Percent dissolved oxygen saturation for Lake Neshonoc at Sites 2 and 3 (1985) . . . . .	52
9. Specific conductance ( $\mu\text{S}/\text{cm}^2$ ) and the annual mean specific conductance for Lake Neshonoc and its tributaries (1985) . . . . .	53
10. The pH for Lake Neshonoc and its tributaries (1985). . . . .	54
11. Total alkalinity (mg/L as $\text{CaCO}_3$ ) and annual mean alkalinity for Lake Neshonoc and its tributaries (1985) . . . . .	55
12. Nitrate-N (mg $\text{NO}_3\text{-N/L}$ ) and annual mean nitrate-N for Lake Neshonoc and its tributaries (1985) . . . . .	56
13. Ammonia-N (mg $\text{NH}_3\text{-N/L}$ ) and annual mean ammonia-N for Lake Neshonoc and its tributaries (1985) . . . . .	57
14. Nitrite-N (mg $\text{NO}_2\text{-N/L}$ ) and annual mean nitrite-N for Lake Neshonoc and its tributaries (1985) . . . . .	58

Appendix	Page
15. Ortho-phosphate-P (mg PO <sub>4</sub> <sup>-</sup> -P/L) and annual mean ortho-phosphate-P for Lake Neshonoc and its tributaries (1985) . . . . .	59
16. Total-P (mg/L) and annual mean total-P for Lake Neshonoc and its tributaries (1985) . . . . .	60

## INTRODUCTION

Lake Neshonoc is a small reservoir in westcentral Wisconsin that has problems similar to other small reservoirs in agricultural regions. The lake is highly turbid due to sediments washed in from the watershed. The input of sediments has a two-fold affect on the lake: first, the sediments decrease lake depth and area and second, nutrients adsorbed onto the surface of the sediment particles may increase the rate of eutrophication in the lake. The lake also has other problems. Common carp (Cyprinus carpio) dominate the fishery of the lake, comprising 80% of the fish biomass (Ritter unpublished data). The carp and high turbidity combine to prevent sustained growth of rooted aquatic plants (Ritter unpublished data). The Lake Neshonoc Protection and Rehabilitation District has begun to mitigate the carp problem with a large-scale carp removal project in September, 1985 and by utilizing annual water-level drawdowns to desiccate the carp eggs. The Lake District is also attempting to establish an aquatic macrophyte community by planting tubers of wild celery (Valisneria americana) (Korschgen 1985).

Several studies have been conducted on Lake Neshonoc, but there is still a lack of information on the nutrient and sedimentation characteristics of the lake. The objectives of this study were:

- 1) establish a data base for Lake Neshonoc in its present state with specific information on:
  - (a) nutrient and suspended materials entering the lake via Adam's Valley Creek, Burn's Creek, Dutch Creek, and the La Crosse River;
  - (b) effects of the marsh area upstream of the lake on the quality of water entering the lake; and

(c) changes in the quality of the water as it flows through  
the lake.

- 2) estimate the sedimentation rate of the lake via loss of surface  
area and loss of volume.

## DESCRIPTION OF STUDY AREA

Lake Neshonoc is a small impoundment of the La Crosse River located in northeast La Crosse County (T17N R5-6W Sec 35-36) near the village of West Salem (Fig. 1). Adam's Valley and Burn's Creeks flow south and Dutch Creek flows north into the La Crosse River, which enters the lake through a marsh at the east end of the lake. The La Crosse River exits from the northwest reach of the lake and flows into the Mississippi River near La Crosse, Wisconsin. Several homes and a trailer campsite are located on the north shore and a new subdivision is being developed along the southeast shore of the lake.

The total watershed for the La Crosse River at the Lake Neshonoc dam is  $1030.8 \text{ km}^2$  ( $398 \text{ mi}^2$ ) (Fig. 2). The area of direct drainage into the lake covers  $53.9 \text{ km}^2$  ( $20.8 \text{ mi}^2$ ). The surface coverage of the watershed consists of 42% cropland, 40% woodland, 15% pasture or grassland, and 3% urban areas (Kruger 1984).

The La Crosse River basin is located entirely within the Driftless Area of southwestern Wisconsin (Fig. 3). This area was never covered during the four glacial periods (Matsch 1976). The valley of the river has been filled with alluvial sediment to a depth of 34 m (112 ft) at West Salem (Hansen 1933). The area flooded by Lake Neshonoc was originally one of two Tamarack bogs on the La Crosse River in La Crosse County (Fig. 4).

The first dam was built on the La Crosse River in 1851 by Monrow Palmer as a waterpowered sawmill and gristmill. The dam had a 2.7-m (8.8-ft) head and functioned as a mill until 1895 when it was converted to produce electrical power for West Salem. In 1940, a new dam was constructed with a 4.25-m (14-ft) head and two retainer gates to replace

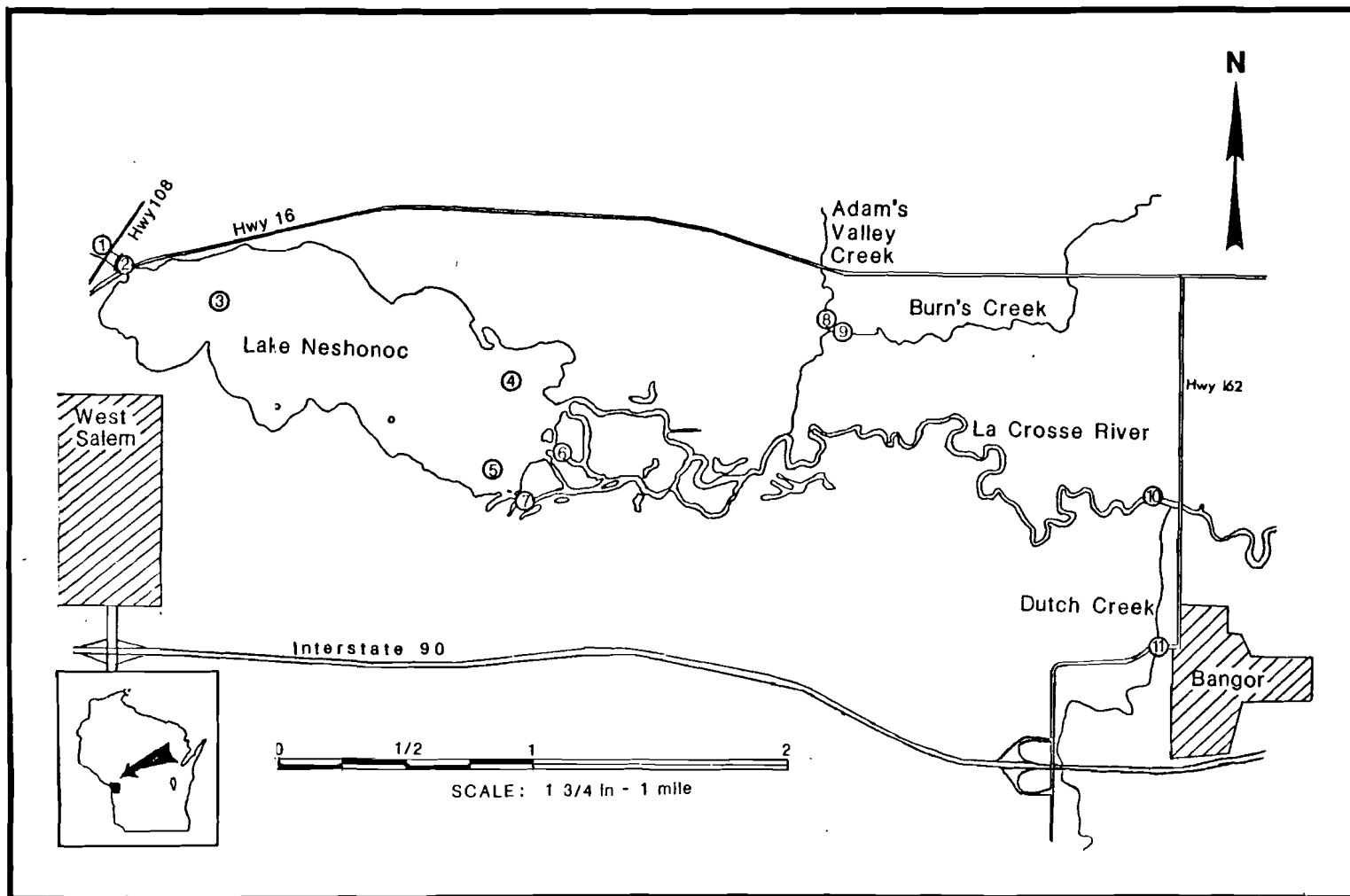


Figure 1. Map of Lake Neshonoc, Wisconsin and its immediate tributaries. Sampling sites are indicated by numbers 1-11 for the present study (1985).

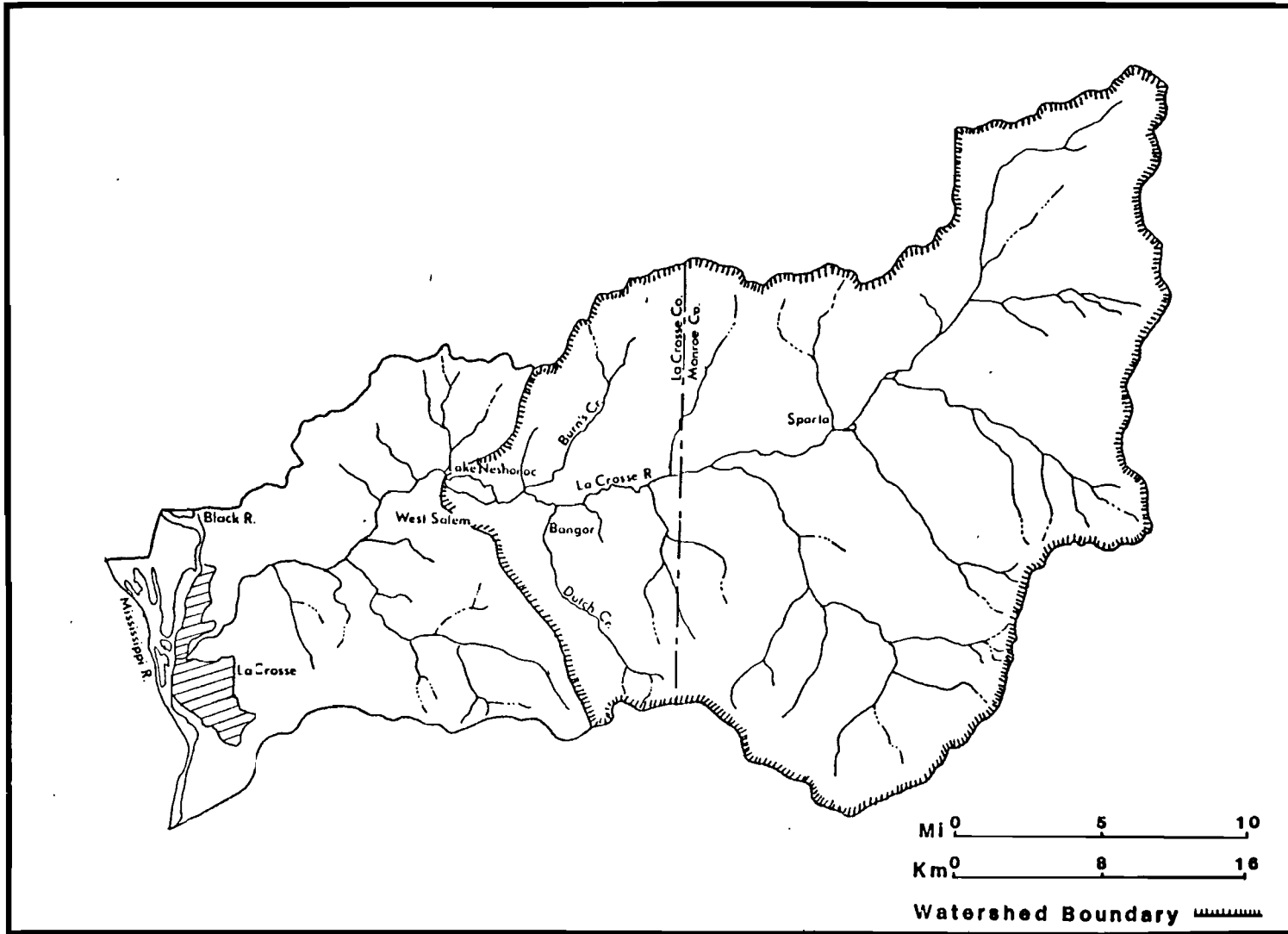


Figure 2. Watershed of the La Crosse River to the Lake Neshonoc Dam.

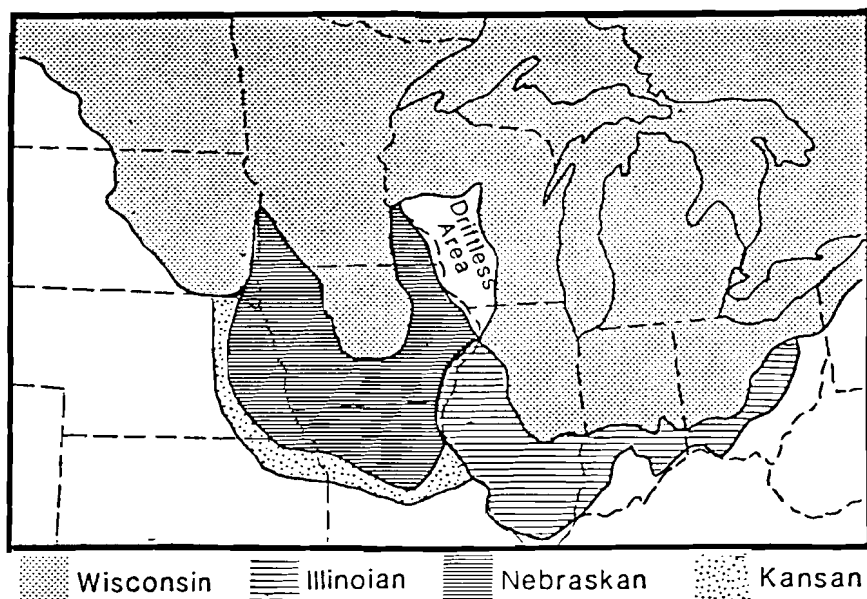


Figure 3. The area covered by the four glacial periods and the Driftless Area of southeastern Wisconsin (Redrawn from Matsch 1976).

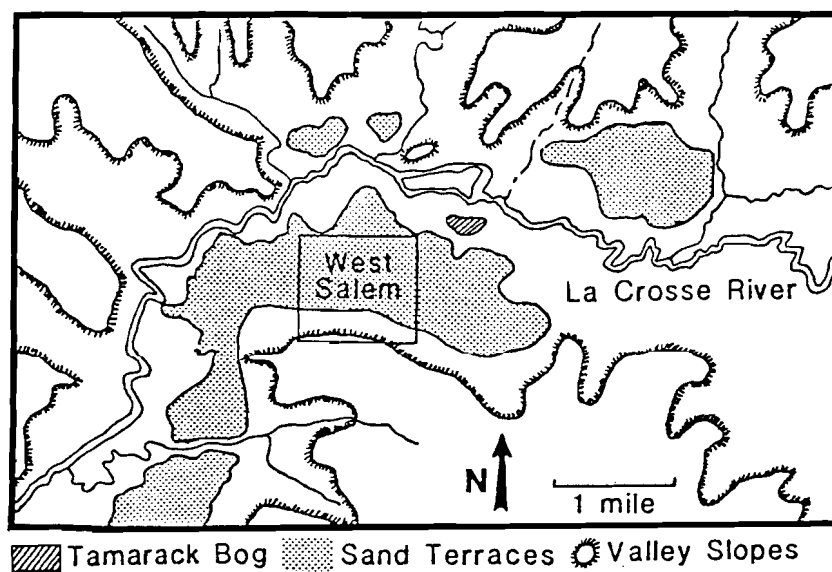


Figure 4. Map showing the area of the La Crosse River basin near West Salem, Wisconsin before the formation of Lake Neshonoc (Redrawn from Hansen 1933).

the old dam, which by then was a patchwork of logs and stones. The new dam raised the water 1.5 m (5 ft) to form the present Lake Neshonoc. Northern States Power (NSP) purchased the dam, powerhouse, and lake in 1947. Production of electricity ended in 1960 when the water wheel broke. La Crosse County bought NSP's holdings in 1970 for one dollar. The dam is now owned by North American Hydro. The firm has installed new turbines and an automatic regulating system and has resumed production of electricity.

Lake Neshonoc has been studied periodically by the Wisconsin Department of Natural Resources (WDNR) (formerly the Wisconsin Conservation Department-WCD) from 1950 to 1975 (Table 1). A 1950 reconnaissance survey of the lake noted a lack of submerged vegetation. Primary sources of pollution were agricultural runoff, siltation, and stream-bank erosion. The existing problem was stated as "a typical millpond that is fast approaching extinction" (WCD 1950). A 1965 study indicated a small depletion of oxygen near the bottom, absence of a thermocline, and Secchi disk transparencies of 0.4-0.5 m (16-20 in); turbidity was reportedly due to algae (WCD 1965). A later study also revealed the absence of a thermocline, a high turbidity with Secchi disk transparencies of 0.5 m (20 in), an alkalinity of 87 mg/L (as CaCO<sub>3</sub>), pH of 8.8, and a specific conductance of 238 uS/cm<sup>2</sup> (WDNR 1969).

A study conducted in 1971, which also considered biological aspects of the lake, yielded similar limnological results. Vegetation was absent except for sparse stands of cattail (Typha) and green algae. Common carp and black crappie (Pomoxis nigromaculatus) were the most abundant fishes.

The most complete limnological study to date was conducted from July

Table 1. Data from Previous Studies of Lake Neshonoc.

Parameter	June	Sept.	Aug.	Aug.	Aug.	7/73-4/75. (WDNR) <sup>c</sup>			
	1956 (WCDA 1956)	1963 (WDNR <sup>b</sup> 1963)	1964 (WDNR 1964)	1968 (WDNR 1969)	1970 (WDNR 1971)	Lake (surface)	Lake (3 m)	Burn's Creek	La Crosse River
<b>Bottom Type (%)</b>									
Sand	--	20	20	5	5	--	--	--	--
Silt/Muck	--	60	60	85	85	--	--	--	--
Detritus	--	20	20	5	5	--	--	--	--
Clay	--	--	--	5	5	--	--	--	--
<b>Water Temperature (°C)</b>									
Surface	28	22	27	27	--	--	--	--	--
Bottom (2 m)	26	--	25	--	--	--	--	--	--
<b>Dissolved Oxygen (mg/L)</b>									
Surface	8.9	--	--	--	--	8.8-13.4	--	--	--
Bottom (3 m)	6.3	--	--	--	--	--	8.0-12.8	--	--
<b>Alkalinity (mg/L as CaCO<sub>3</sub>)</b>									
Surface	101	--	--	87	87	63-124	--	105-176	47-114
Bottom (3 m)	107	--	--	--	--	--	70-124	--	--
Conductivity (μS/cm <sup>2</sup> )	--	--	--	238	238	157-277	165-271	250-377	124-248
NO <sub>3</sub> -N (mg/L)	--	--	--	--	--	0.43-1.19	0.42-1.43	1.08-2.58	0.56-1.31
NO <sub>2</sub> -N (mg/L)	--	--	--	--	--	0.015-0.053	0.010-0.080	0.003-0.047	0.004-0.050
NH <sub>3</sub> -N (mg/L)	--	--	--	--	--	0.03-1.88	0.03-1.74	0.03-1.87	0.03-1.58
Total-N (mg/L)	--	--	--	--	--	1.2-4.94	1.13-4.64	1.19-5.81	1.1-4.48
PO <sub>4</sub> -P (mg/L)	--	--	--	--	--	0.106-0.415	0.085-0.362	0.077-0.523	0.166-0.350
Total-P (mg/L)	--	--	--	--	--	0.10-0.70	0.10-0.48	0.08-0.69	0.21-0.47
pH	--	--	9.4	8.8	8.8	7.0-8.0	7.0-8.1	7.4-8.1	7.0-7.9
Transparency (m)	0.55	0.45	0.45	0.55	0.55	0.3-1.50	--	--	--

<sup>a</sup>Wisconsin Conservation Department.<sup>b</sup>Wisconsin Department of Natural Resources.<sup>c</sup>Range of data at indicated sampling sites during July 1973-April 1975.

1973 to April 1975 (WDNR 1975). Eight water samples were taken on an irregular basis during that period. Sampling sites were located upstream from the lake on Burn's Creek at the Wisconsin State Hwy 16, on the La Crosse River at the County Hwy 162 bridge, and in the lake upstream of the dam in 3 m of water. Sampling sites on Burn's Creek and the La Crosse River were not representative of the total influx of nutrients to Lake Neshonoc. The Burn's Creek site did not include Adam's Valley Creek, which joins Burn's Creek downstream from the Wisconsin State Hwy 16 bridge. The La Crosse River site was upstream from the confluence with Dutch Creek and the Bangor Wastewater Treatment Plant. In-lake temperature profiles revealed weak or undetectable stratification and slightly decreased dissolved oxygen concentrations during mid-summer. Secchi disk transparencies ranged from 0.3 m (12 in) during the summer to 1.5 m (60 in) on 6 February 1975. Nutrient concentrations varied throughout the year with maximum concentrations occurring during spring runoff (WDNR 1975) (Table 1).

## METHODS AND MATERIALS

### Site Selection

Eleven sampling sites were selected using topographic maps and aerial photographs before sampling began (Fig. 1). Sites were inspected to determine the best means of access and any modifications of site locations. The precise location of each site was established on the first sampling trip. Triangulation or single landmarks were used to relocate sites on subsequent sampling trips. Landmarks and triangulation instructions for locating sampling site are given in Appendix 1.

### Field Methods

A total of 25 sampling trips were made from January 11 to December 7, 1985. During the period of ice cover, holes were made with an ice spud or a motorized ice auger, depending on ice thickness. In-lake samples at Site 2 were taken from the Wisconsin State Hwy 16 bridge (Fig. 1) during spring snowmelt (February 20-21) when the ice was unsafe. A flatboat was used to access the in-lake sites during the ice-free period. The inflows, Sites 6 and 7, were approached from the lake by walking over the delta, carrying the equipment to avoid disrupting the lake bottom with the boat motor.

On September 26, 1985 the lake was drained to facilitate repairs on the dam. The lake was refilled on November 20, 1985, at which time it was beginning to freeze. Therefore, lake samples were not taken during and after the drawdown. Influent samples were, however, collected during this time. A sample of the effluent lake water was taken on December 7, after refilling of the lake, to document changes in the nutrient concentrations.

Water samples were collected between 0800 h and 1500 h. The in-lake samples (Sites 2-7) were collected first between 0800 h and 1200 h, then Sites 1, 8, 9, 10, and 11, respectively. Dissolved oxygen and temperature were measured with an oxygen meter (Yellow Springs Instrument Co. Model 54A D.O. meter). A small weight was suspended from the probe to pull the cord straight down in water column. Data were recorded at 0.5-m intervals starting at the surface. Transparency was measured with a 20-cm diam Secchi disk with readings rounded to the nearest 5 cm. Winter Secchi disk transparencies may have been underestimated because of the small diameter of the ice hole.

Water samples were collected with a Kemmerer bottle or by hand-filling sampling bottles. One-liter polyethylene bottles were rinsed with sample water and then filled to overflowing. Sample bottles were held in an empty cooler to prevent freezing in the winter or packed with ice in the summer to reduce biological activity.

In addition to regular water collections, an attempt was made to sample runoff events. A steel stake was placed in the stream bed. One-liter polyethylene bottles were attached to the stake at various heights above low flow water levels. As the water level rose during a runoff event, each successively higher bottle was filled (Fig. 5). This was successful for the small streams, but the La Crosse River often remained at a higher water level between precipitation events. The bottles captured more sediments the longer they were under water; consequently, runoff data for the La Crosse River was not used.

#### Hydrology and Hydrography

The lake area and shore length were determined from 1983 aerial photographs with a planimeter and a cartometer, respectively. The lake

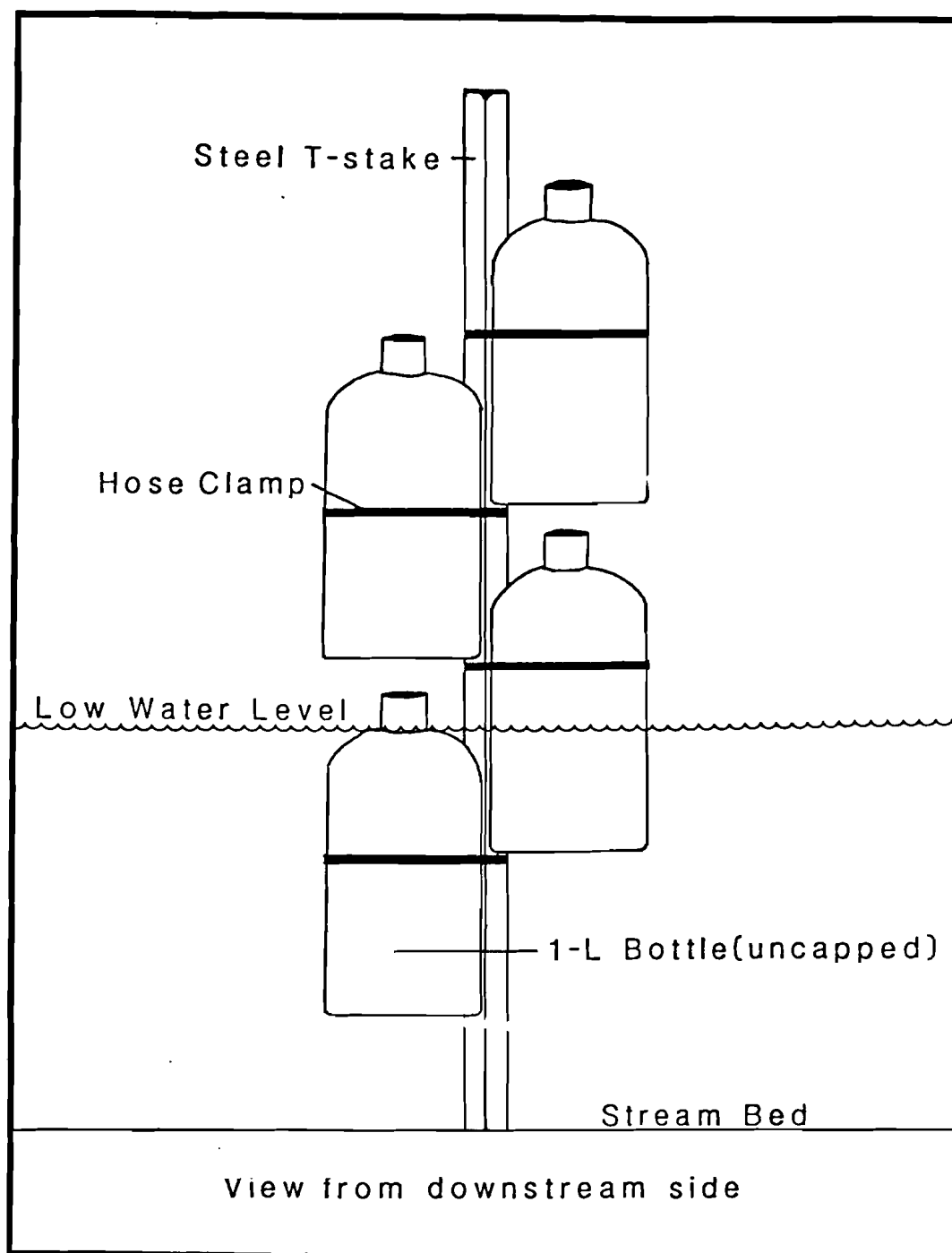


Figure 5. A diagram of the in-stream samplers used on Adam's Valley Creek, Burn's Creek, Dutch Creek, and the La Crosse River in this study (1985).

bottom was mapped with a fathometer (Raytheon Survey Fathometer, model DE-719B). A contour map of the lake was constructed and was then used to calculate the lake volume by summation of Frustrum volumes (Lind 1979). Cross-sectional areas and current velocities of Adam's Valley Creek, Burn's Creek, Dutch Creek, and the La Crosse River were measured with a metric tape measurer and a current meter (Scientific Instruments, Inc., Price model AA), respectively. Discharge for each inflow was then estimated from these data.

#### Laboratory Methods

The parameters measured, reporting units, and methods used are presented in Table 2. Conductivity, pH, and total alkalinity were measured on the same 100-mL aliquant of each sample. Total alkalinity was determined by titrating with 0.1 N  $H_2SO_4$  to a pH of 4.5. The filters for Total Non-filterable Residues (TNFR) were placed on a teflon cookie sheet and dried at 105 °C. Air-drying the filters for a short time, lifting them off the tray, and setting them back down prevented the filters from sticking to the tray.

#### Quality Assurance

All glassware and sample bottles were acid washed with concentrated  $H_2SO_4$  and rinsed with tap and deionized water. The same sample bottles and test flasks were used for each analysis for each site throughout the study. Reagents were prepared with analytical grade chemicals and remade before expiration of their respective shelf lives. Standard solutions for total-P, dissolved ortho-P, nitrite-N, and nitrate-N were prepared in large volumes ahead of time. Standard solutions for ammonia-N were prepared immediately prior to each analytical batch. A complete set of standards and reagent blanks were analyzed with each

Table 2. Parameters measured, reporting units, and methods employed in the Lake Neshonoc Study, 1985.

Variable and Reporting Unit	Method	Reference
Dissolved Oxygen (mg/L)	Oxygen Meter	US EPA 1983
Total Non-Filterable Residue (mg/L)	Gravimetric	US EPA 1983
Volatile Residue (mg/L)	Gravimetric, Ignition	APHA 1981
Transparency (m)	Secchi Disk	Lind 1979
pH	Potentiometric	US EPA 1983
Specific Conductance ( $\mu\text{S}/\text{cm}^2$ )	Conductivity Meter	US EPA 1983
Alkalinity (mg/L as $\text{CaCO}_3$ )	Potentiometric	US EPA 1983
Nitrite (mg/L as $\text{NO}_2\text{-N}$ )	Colorometric	US EPA 1983
Nitrate (mg/L as $\text{NO}_3\text{-N}$ )	Mullin-Riley Reduction Colorometric	Barnes 1959
Ammonia (mg/L as $\text{NH}_3\text{-N}$ )	Colorometric	US EPA 1983
Ortho-P (mg/L as $\text{PO}_4\text{-P}$ )	Colorometric	US EPA 1983
Total P (mg/L)	Persulfate Digestion Colorometric	US EPA 1983

batch of samples. Environmental Protection Agency Quality Control Samples (nutrients and minerals), spiked samples, and standard additions were analyzed once during the sampling period to validate analytical procedures. Triplicate analyses to evaluate precision were performed on one sample for each type of analysis on each sampling date.

## RESULTS AND DISCUSSION

Temperature

Lake Neshonoc has a typical northern latitude temperature regime throughout the year ranging from 0.0 to 25.0 °C (Appendix 2). No thermal stratification was observed; however, the temperature decreased about 3 °C from the surface to the bottom (3 m) during the summer months. This coincided with a decrease in dissolved oxygen. Similar trends were observed in July 1973 and August 1974 by WDNR (1975). The temperature of the La Crosse River outflow was 1.5 to 5.0 °C warmer than that of the inflow during the summer which was a result of the river flowing through the reservoir.

The target temperature of the Lake Neshonoc Protection and Rehabilitation District for water level drawdowns to control carp reproduction is 15.5 °C (60 °F). This corresponds to the temperature at which carp begin to spawn. Lake Neshonoc reached that temperature by April 13, which is earlier than other lakes and is due to its small size, low volume, and rapid flushing rate with relatively warm influent water during spring (see Hydrology and Hydrography section).

Transparency

Secchi disk transparencies ranged from 1.8 m (5.9 ft) on February 9 to 0.3 m (1 ft) on September 21 (Appendix 3). Data from previous studies on Lake Neshonoc for similar sampling dates show similar transparencies (Table 1). Transparency decreased substantially as a result of spring runoff and then varied slightly during the summer due to precipitation events. Preliminary observations indicated that the water clarity in April 1986 had increased as

compared to past years. This could have been the result of a less severe loading of suspended sediments during the spring runoff or a decrease in the resuspension of sediments by carp following the September 1985 carp removal project. Further data collection and observations are needed before any conclusions can be made.

#### Non-filterable Residues

Non-filterable residues (total non-filterable residue-TNFR, non-filterable fixed residue-NFFR, and non-filterable volatile residue-NFVR) for Lake Neshonoc and its tributaries are presented in Appendices 4,5, and 6, respectively. Of the tributaries, Adam's Valley Creek always had the greatest TNFR with an annual mean 3 times that of Burn's Creek, 3.5 times the La Crosse River, and 4.5 times Dutch Creek (Fig. 6). The TNFRs at Sites 6 and 7 in the marsh were similar to the La Crosse River, which indicated that there was no substantial sedimentation as the water flowed through the confined channels of the marsh. Surface waters in the lake had less suspended matter than bottom waters. TNFR of the outflow (Site 1) was similar to the La Crosse River inflows at Sites 6 and 7 (42.2, 45.7, and 45.2 mg/L, respectively). However, NFFR (inorganic suspended sediments) at the outflow was 27.4 mg/L as compared to about 37 mg/L at the inflows (Fig. 7). This indicates that about 25% of the inorganic suspended sediments were being trapped in the lake. The outflow had a higher percentage of organic matter than the inflow, which may have been due to phytoplankton production within the lake. This would explain the similar TNFRs at the inflow and outflow and the decrease in NFFR at the outflow. Past studies did not report non-filterable residue data so historical comparisons were not possible.

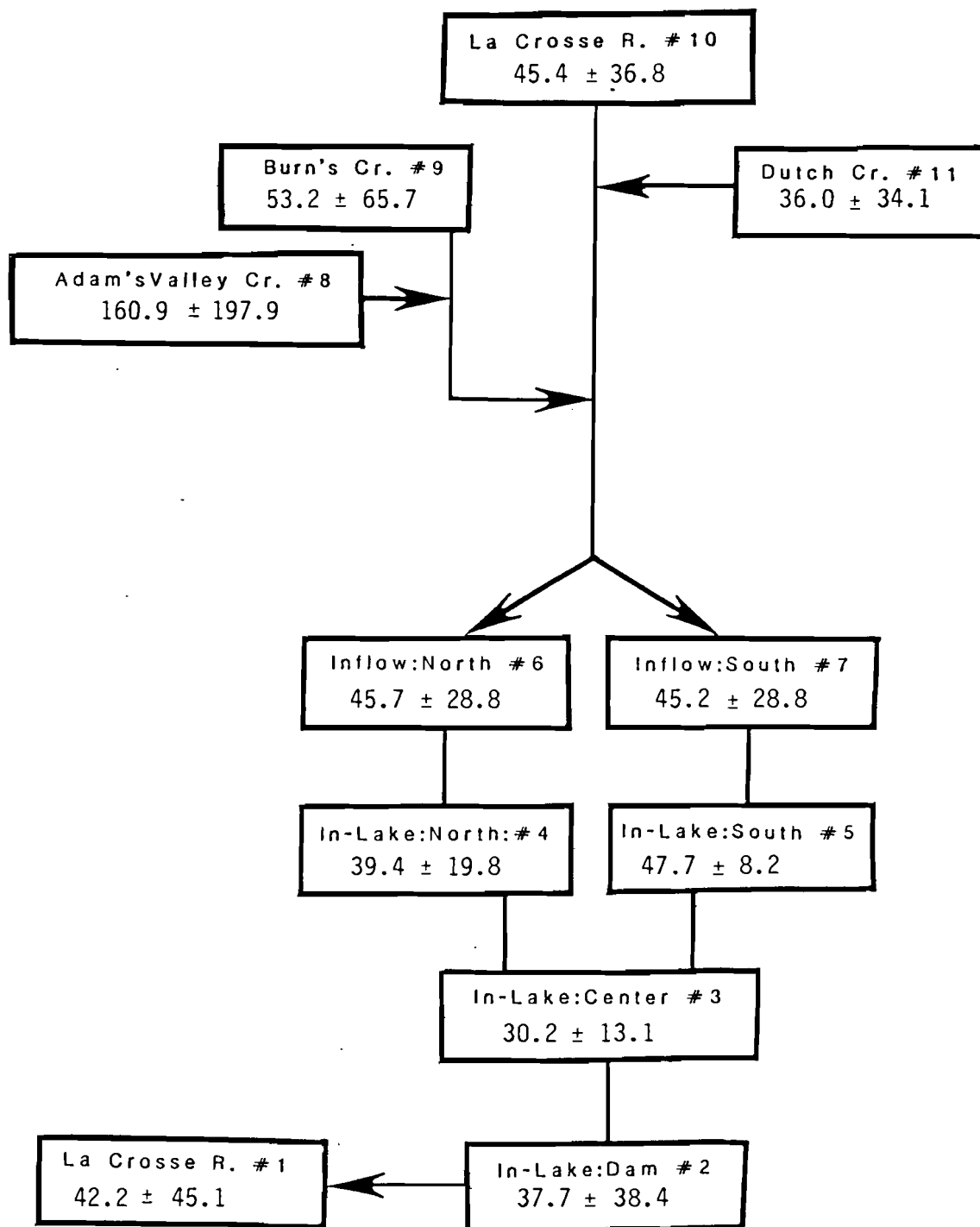


Figure 6. Total non-filterable residue (TNFR) (annual mean  $\pm$  standard deviation) for Lake Neshonoc and its tributaries (1985).

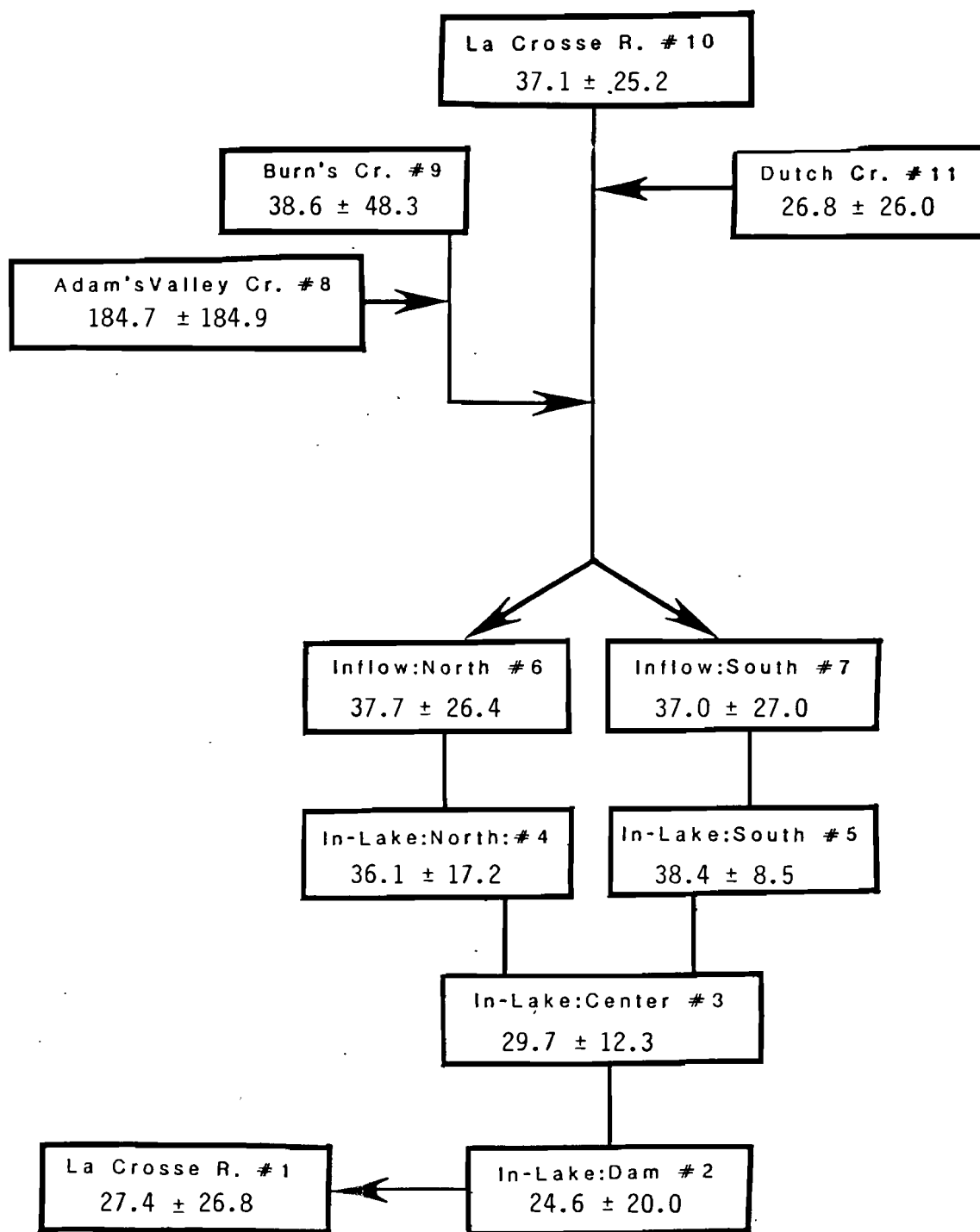


Figure 7. Non-filterable fixed residue (NFFR) (annual mean  $\pm$  standard deviation) for Lake Neshonoc and its tributaries (1985).

### Dissolved Oxygen

Dissolved oxygen (DO) of the four inflows was usually between 70 and 100% saturation throughout the sampling period due to the turbulence of tributaries maintaining an equilibrium with the atmosphere. Concentrations of DO in the inflows appear to have had little effect on in-lake concentrations. The DO in the lake fluctuated from top to bottom on a biweekly basis during the summer. There was a negative correlation ( $P < 0.01$ ) between the % DO saturation at the surface and the bottom (3 m) during the summer (Fig. 8). This may have been a result of algae increasing the % DO saturation at the surface by photosynthesis and decreasing it at the bottom by increasing the biological oxygen demand (BOD). Furthermore, there was a strong negative correlation between NFVR and % DO saturation ( $P < 0.05$ ) throughout the study. This supports the hypothesis that the decrease in oxygen in deeper water was due to an increase in BOD from settling of phytoplankton. The exact duration and extent of these periods of oxygen depletion cannot be determined from these data. Other studies of Lake Neshonoc have reported a decrease in dissolved oxygen concentrations from the surface to the bottom, but they did not observe the extremes nor the biweekly fluctuations as found during this study (WNDR 1975, WCD 1956).

The Lake District has installed "fish cribs" in the deeper waters of the lake to increase the amount of structure for fish habitat. Periods of oxygen depletion at these locations could reduce the effectiveness of that project.

### Specific Conductance

The average specific conductance of the four inflows decreased as stream size increased (e.g., Dutch Creek > Adam's Valley Creek >

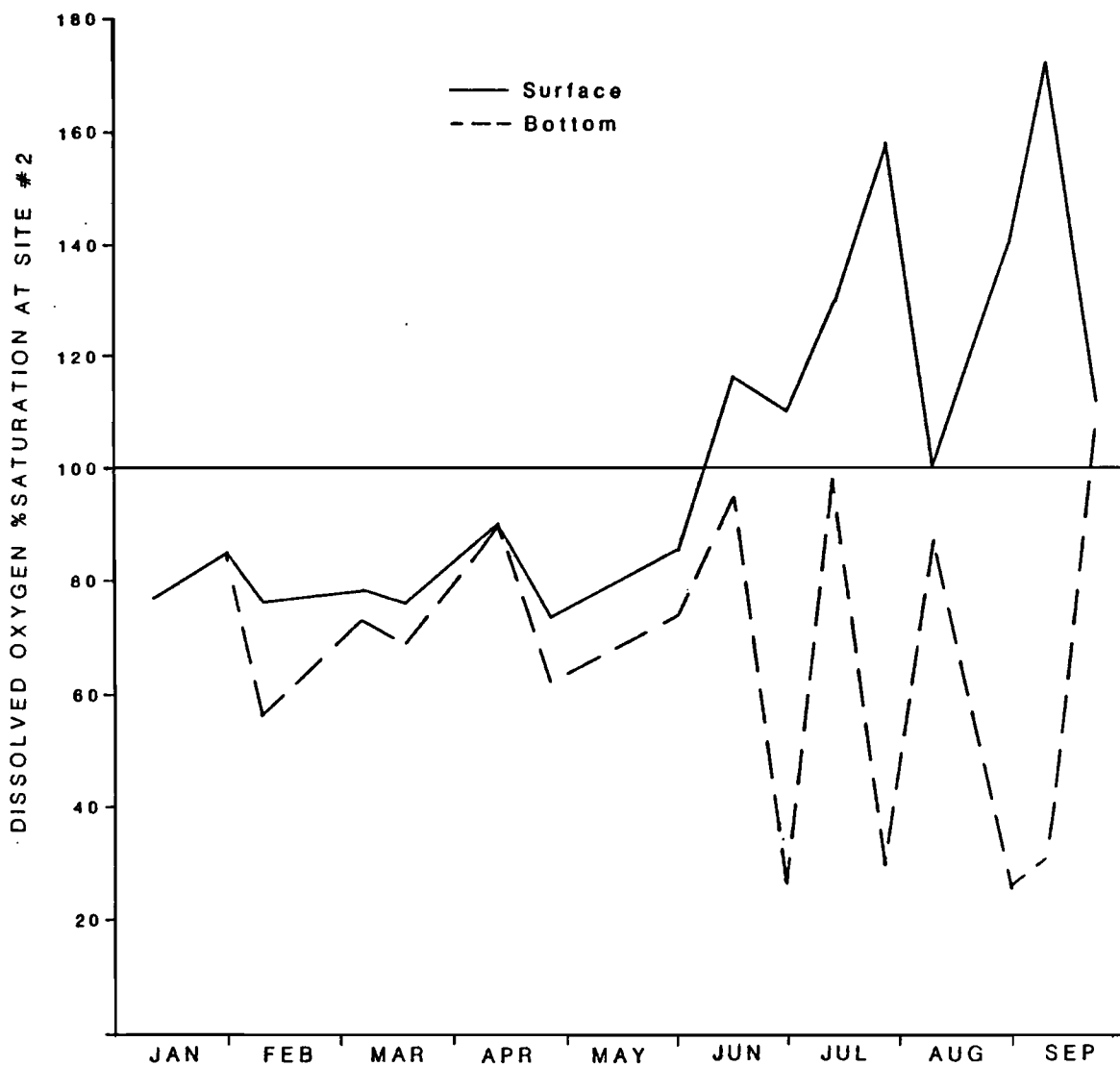


Figure 8. Percent saturation of dissolved oxygen at Site 2 at the surface and bottom (3 m) in Lake Neshonoc (1985).

Burn's Creek > La Crosse River) (Fig. 9). Inflow conductivities were lowest during spring runoff due to the dilution effect from snowmelt. The greater conductivities in the three creeks appear to have had a minimal affect on conductivity of the La Crosse River inflow at Sites 6 and 7. The conductivity of the in-lake sites corresponded directly to the conductivity of the La Crosse River inflow throughout the study. There is commonly a positive correlation between the specific conductance and pH (Wetzel 1983), and this relationship was evident in Lake Neshonoc and especially in the inflowing creeks and river.

#### pH

The pH of Lake Neshonoc and its tributaries was circumneutral throughout the sampling period (Appendix 10). The pH of Adam's Valley, Burn's, and Dutch Creeks had notably higher pHs than the La Crosse River. In contrast, pHs of Sites 6 and 7 closely followed the pH of the La Crosse River at Site 10. This indicated that the three creeks and the marsh area did not markedly influence the pH of the La Crosse River water entering the lake.

The pH for all the inflows was lowest during spring runoff. A one-day decrease in pH of 0.7 for all the inflows (February 20-21) coincided with a large amount of the winter snowmelt discharging into the streams. The in-lake pHs were not recorded during this runoff event; however, a similar decrease in inflow pH corresponded to a decrease of in-lake pH on March 12. Outflow pH was representative of the in-lake pH; therefore, it appears that the in-lake pH remained low (6.9-6.5) throughout the spring. For the remainder of the study, the pH was higher (> 7.5) for all sites with the in-lake sites generally

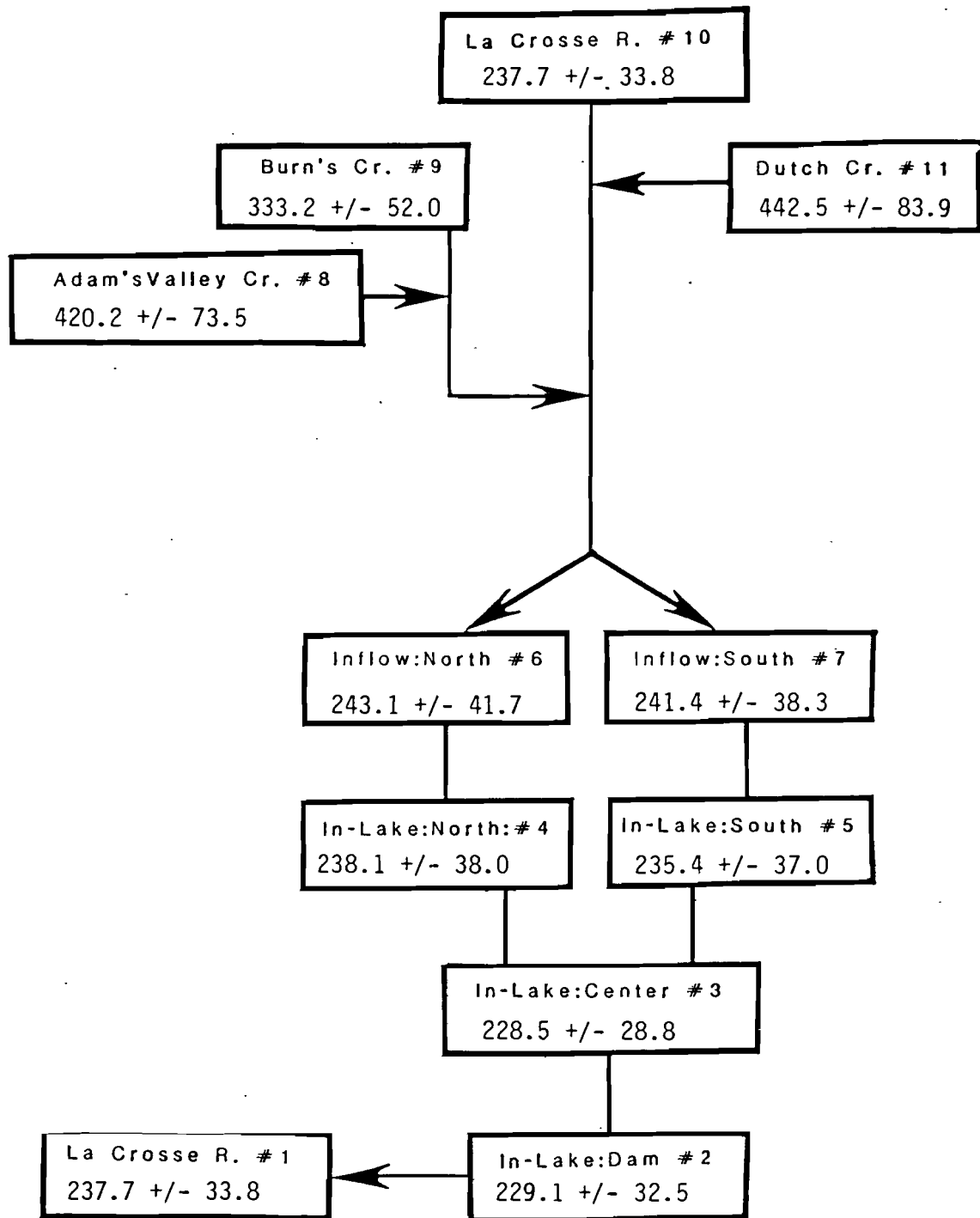


Figure 9. Specific Conductance (annual mean  $\pm$  standard deviation) for Lake Neshonoc and its inflowing waters (1985).

being higher than the the inflow sites.

The pH in the lake was directly related to the % DO saturation during the summer, increasing at the surface during periods of high % saturation and decreasing at the bottom with low % saturation (Fig. 10). After the drawdown, the pH of the outflow (Site 1) on December 7 was lower than the months before the drawdown but was similar to the pH during the previous winter. Therefore, the drawdown seems to have had little immediate effect on the pH of the lake.

#### Total Alkalinity

The total alkalinity for Lake Neshonoc and its tributaries (Fig. 11) shows that the entire system was well buffered. A fivefold decrease in alkalinity was observed in the inflows as a result of dilution during spring runoff (February 20-21). A second runoff event on March 12 lowered the alkalinities of the La Crosse River inflow, Site 2 near the dam, and the La Crosse River outflow (Appendix 11). Alkalinity at all sites increased by the next sampling date and remained high for the rest of the study. The small creeks were dominated by groundwater flow during most of the sampling period and consequently had greater alkalinities than the La Crosse River. The alkalinity at the La Crosse River outflow on December 7 was similar to the alkalinity before the drawdown. There was no discernable difference between the seasonal alkalinities of Burn's Creek, the La Crosse River or Lake Neshonoc during this study and those from previous studies.

#### Nitrate

Nitrate concentrations include the nitrate and nitrite nitrogen. The annual mean nitrate concentrations (Fig. 12) show Burn's Creek

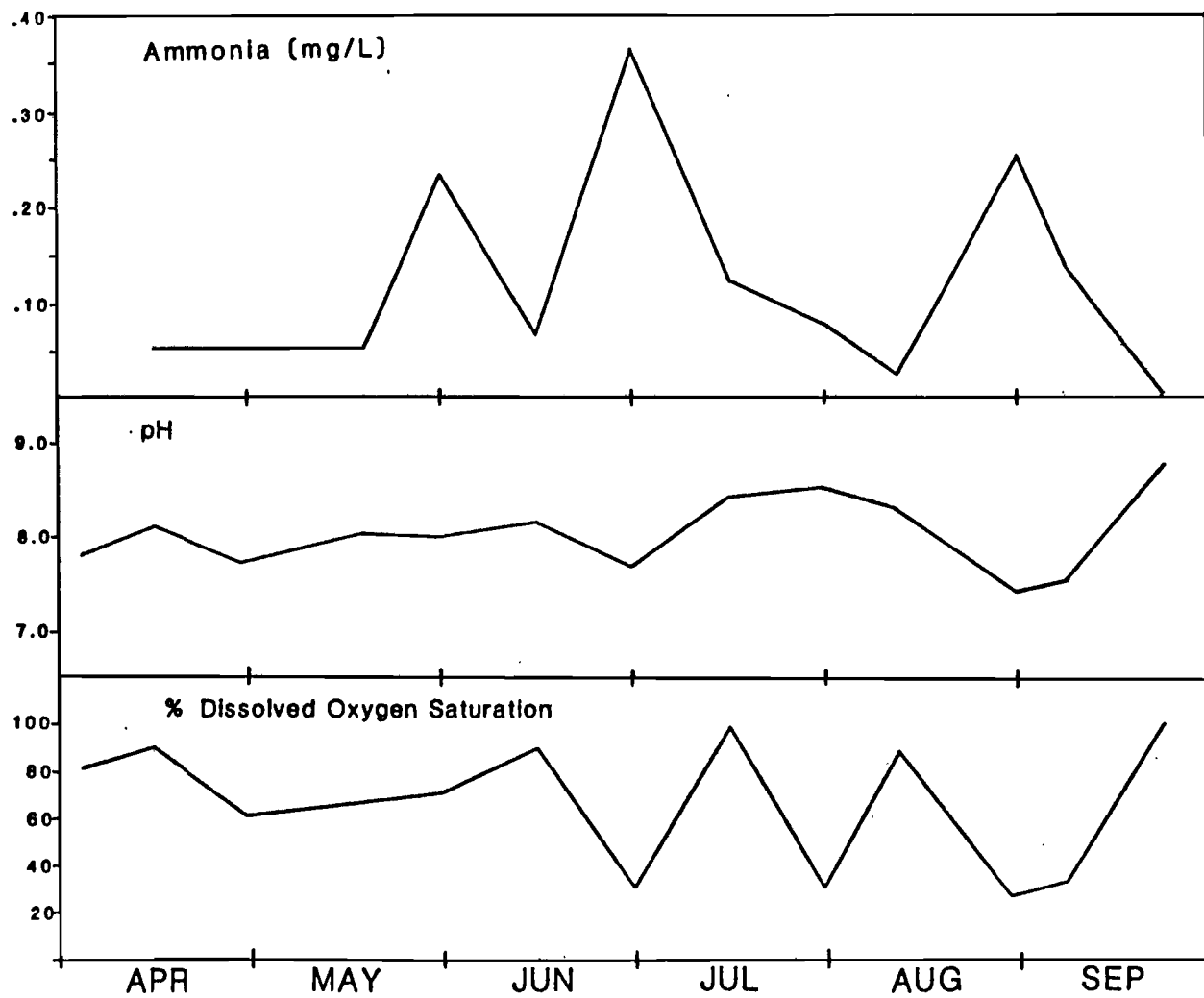


Figure 10. Ammonia, pH, and % dissolved oxygen saturation at Site 2 near the bottom (3 m) in Lake Neshonoc (1985).

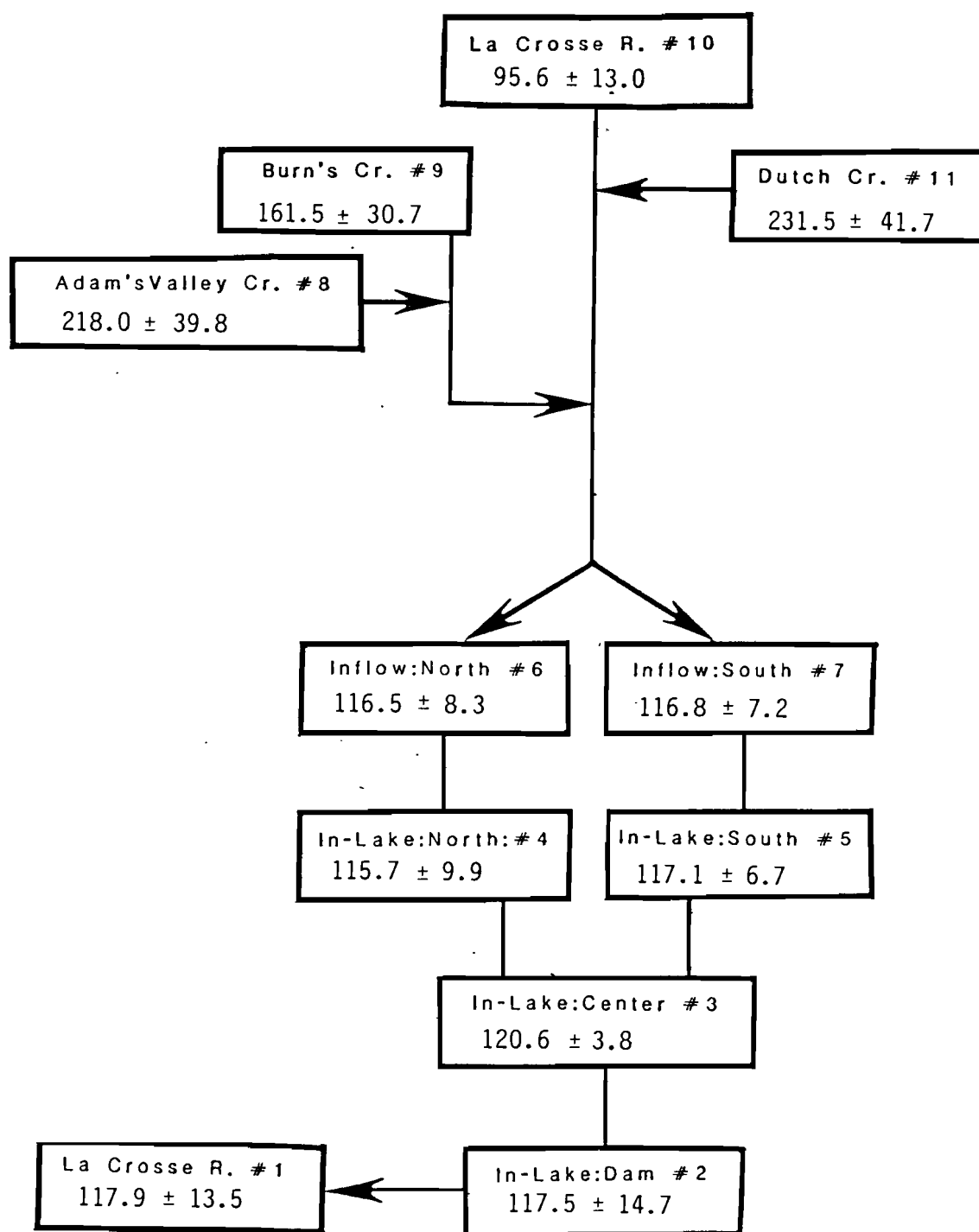


Figure 11. Total alkalinity (annual mean  $\pm$  standard deviation) for Lake Neshonoc and its tributaries (1985).

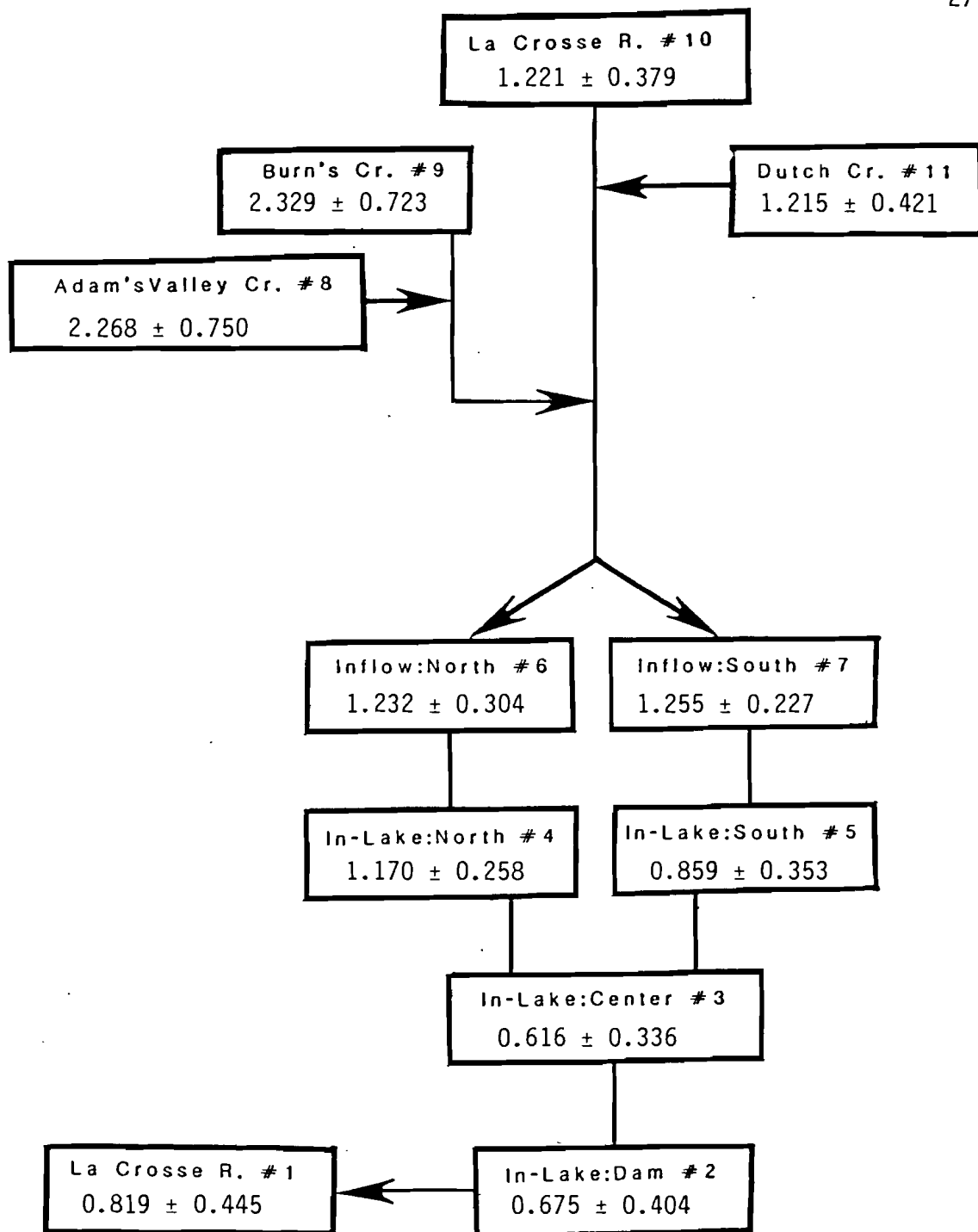


Figure 12. Nitrate-nitrogen (annual mean ± standard deviation) for Lake Neshonoc and its tributaries (1985).

slightly higher than Adam's Valley Creek, but both of these creeks had almost two times the concentration of nitrate as the La Crosse River and Dutch Creek. Unlike other variables, the highest concentrations for all the inflows occurred during the summer and fall, not during spring runoff (Appendix 12). However, nitrate concentrations in the lake were highest during spring runoff events. The annual mean nitrate concentration at Site 1 was about 34% less than Sites 6 and 7. This could be the result of uptake of nitrate by phytoplankton during the summer; thereby decreasing the concentration as the water flowed through the reservoir.

#### Ammonia

Ammonia concentrations were higher in Adam's Valley Creek than in the other three inflows during most of the sampling period (Appendix 13). The highest concentrations were recorded during spring runoff. There was no difference between the concentration of ammonia entering the lake at Sites 6 and 7 and the concentration leaving the lake at Site 1. The in-lake ammonia concentrations were low and homogeneous from the surface to the bottom when the % DO saturation was also homogeneous (Fig. 10). When % DO saturation was high at the surface and low at the bottom, ammonia concentrations were low at the surface and high at the bottom. This was most pronounced at Site 2 near the dam. This may have been due to uptake of ammonia by phytoplankton at the surface and the regeneration of ammonia by decomposition of phytoplankton at the bottom.

#### Phosphorus

The greatest concentrations of ortho-phosphorus for the inflows were observed for Adam's Valley Creek; its annual mean was two times greater than the other three inflows (Fig. 13). During the spring snowmelt (February 20-21), the ortho-phosphorus concentrations of

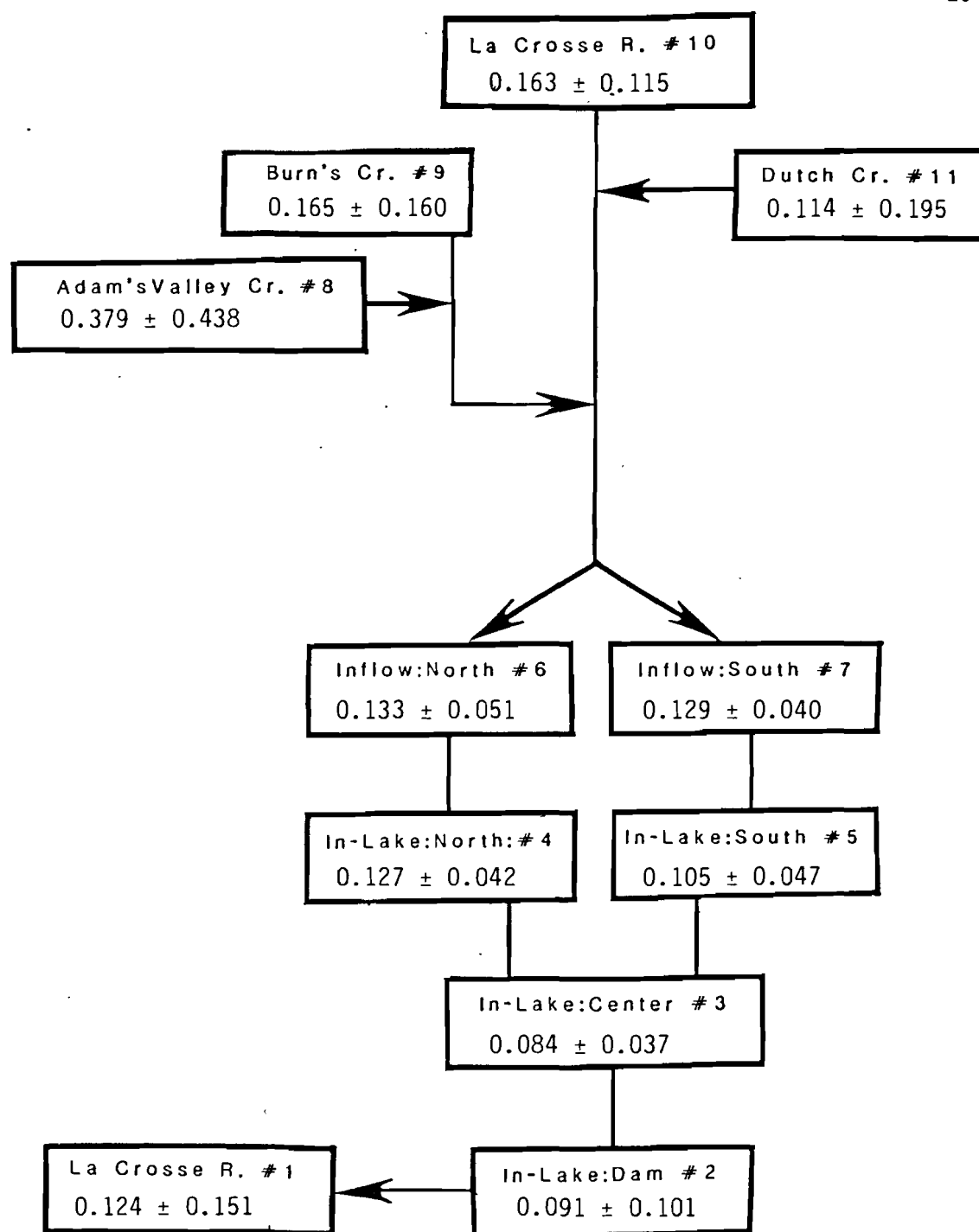


Figure 13. Ortho-phosphorus (annual mean ± standard deviation) for Lake Neshonoc and its tributaries (1985).

the inflows increased by a factor of 20 in Dutch Creek, 13 in Adam's Valley Creek, 10 in Burn's Creek, and 6 in the La Crosse River. Ortho-phosphorus concentrations of the La Crosse River outflow (Site 1) also increased 10-fold during the same one-day period. Ortho-phosphorus in the lake was usually homogeneous from the surface to the bottom with the bottom the having slightly greater concentrations. A comparison of data for the inflow at Sites 6 and 7 to the outflow at Site 1 revealed a 35% decrease in the average ortho-phosphorus concentration at the outflow.

Total phosphorus concentrations were two to three times greater than ortho-phosphorus concentrations for all the sites and followed similar trends (Fig. 14). The greatest concentrations of the four inflows were observed in Adam's Valley Creek. Distributions were nearly homogeneous within the lake, but concentrations were slightly greater in bottom waters. The concentrations of total phosphorus entering and leaving the lake were similar when comparing similar sampling dates; however, the annual mean ortho-phosphorus concentration of the outflow was 35% less than that of the inflow. The ortho-phosphorus may have been assimilated by phytoplankton. A portion of the phytoplankton may have then been washed out of the lake, resulting in lower ortho-phosphorus concentrations at the outflow yet maintaining similar total phosphorus concentrations at both the inflow and outflow.

#### Hydrology and Hydrography

Hydrology and hydrography data for Lake Neshonoc and the four inflowing waters are presented in Tables 3 and 4. The La Crosse River provides a majority (89% on August 15, 1985) of the water entering the lake, which explains the similarity in water chemistry

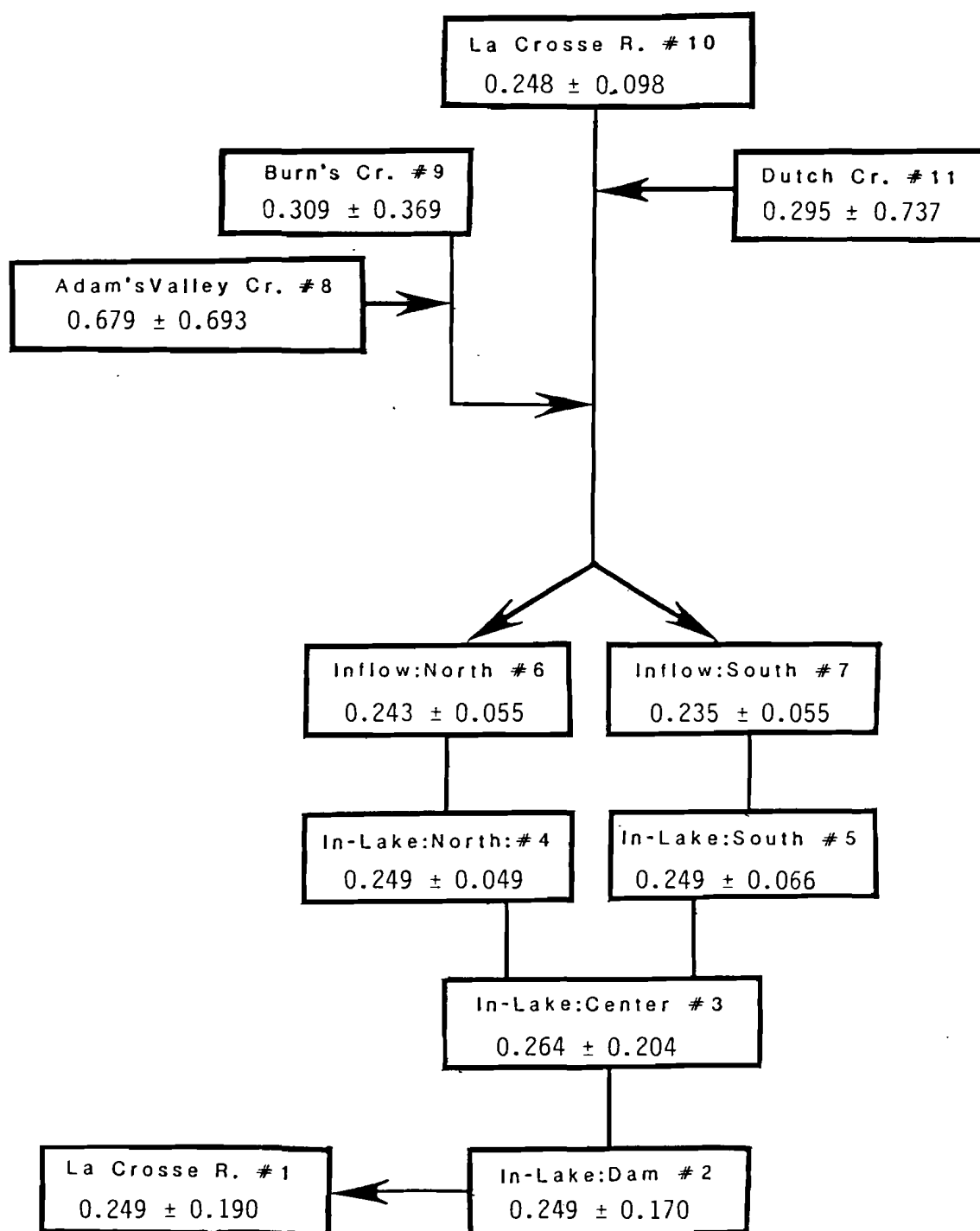


Figure 14. Total phosphorus (annual mean  $\pm$  standard deviation) for Lake Neshonoc and its tributaries (1985).

Table 3. Discharges for the four tributaries flowing into Lake Neshonoc as determined on August 15, 1985.

Inflow	Discharge (m <sup>3</sup> /s)	% of Total Discharge
La Crosse River	7.252	89.0
Dutch Creek	0.473	5.8
Burn's Creek	0.322	4.0
Adam's Valley Creek	0.093	1.1
Total Discharge	8.145 (287.6 ft <sup>3</sup> /s)	

Table 4. Dimensions of Lake Neshonoc determined from 1983 aerial photographs (USGS) and 1985 hydrographic data (this study).

Characteristic	Metric Units	English Units
Area <sup>a</sup>	242.6 ha	599.4 acres
Length <sup>a</sup>	3.0 km	1.8 mi
Width <sup>a</sup>	1.2 km	0.8 mi
Depth <sup>b</sup> -maximum	3.3 m	11.0 ft
-mean	1.4 m	6.3 ft
Volume <sup>b</sup>	3.41x10 <sup>6</sup> m <sup>3</sup>	2,762.8 acre-ft
Shoreline Development <sup>a</sup>	0.074	

a. USGS 1983 aerial photographs.

b. 1985 hydrographic data, this study.

between the lake and river. Burn's Creek presently joins the La Crosse River east of the marsh before the river begins to branch out. Burn's Creek previously followed a separate channel into the north side of the marsh closer to the lake. The north and south sampling sites (Sites 4 and 6, and Sites 5 and 7, respectively) were established without knowledge of this recent course change. A thorough mixture of water from Adam's Valley Creek, Burn's Creek, and Dutch Creek, and the La Crosse River now occurs before they enter the marsh. During periods of average discharge, the La Crosse River remains in well defined channels as it flows through the marsh until it reaches the delta area of the lake

The surface areas and lake volumes of Lake Neshonoc in 1954, 1966, 1983, and 1985 are presented in Table 5. The lake has lost 73 ha (180 acres) during the past 29 years, representing a loss of 23.1% of its original surface area. Most of the areal loss occurred at the east end of the lake with the encroachment of the marsh, which is most evident at the three bays along the southeast shore (Fig. 15). The lake lost 11.9% of the surface area from 1954 to 1966 and 12.8% from 1966 to 1983. These data indicate a decrease in the rate of loss of surface area between the two periods.

Two-foot depth contours for Lake Neshonoc were constructed from hydrographic data collected on August 15, 1985 (Fig. 16). The lake volume was determined from this map. The volume of the lake decreased  $0.42 \times 10^6 \text{ m}^3$  (341 acre-ft) during the past 19 years, which represents an 11.0% loss in volume. The hydraulic residence time for Lake Neshonoc is 4.85 days (75.3 times/yr), as calculated from August 15, 1985 inflow discharges and August 1985 lake volume data. In comparison, the hydraulic

Table 5. Lake Neshonoc surface areas in 1954, 1966, and 1983, and lake volumes in 1966 and 1985.

Year/Period	Surface Area ha(acre)	Loss of Surface Area ha(acre)	% Loss of Surface Area	Volume $10^6 m^3$ (acre-ft)	Loss of Volume $10^6 m^3$ (acre-ft)	% Loss of Volume
1954 <sup>a</sup>	315.6(779.8)	----	----	----	----	----
1966 <sup>b</sup>	278.1(687.2)	----	----	3.83(3,104.5)	----	----
1983 <sup>c</sup>	242.6(599.4)	----	----	----	----	----
1985 <sup>d</sup>	----	----	----	3.41(2,762.8)	----	----
1954-1966	----	37.5(92.6)	11.9	----	----	----
1966-1983	----	35.5(87.8)	12.8	----	----	----
1966-1985	----	----	----	----	0.42(341.7)	11.0
1954-1983	----	73.0(180.4)	23.1	----	----	----

a. U.S.G.S. aerial photographs, 1954.

b. Wisconsin Conservation Department Lake Survey Map, June 1966.

c. U.S.G.S. aerial photographs, 1983.

d. Lake Survey Map, August 1985, this study.

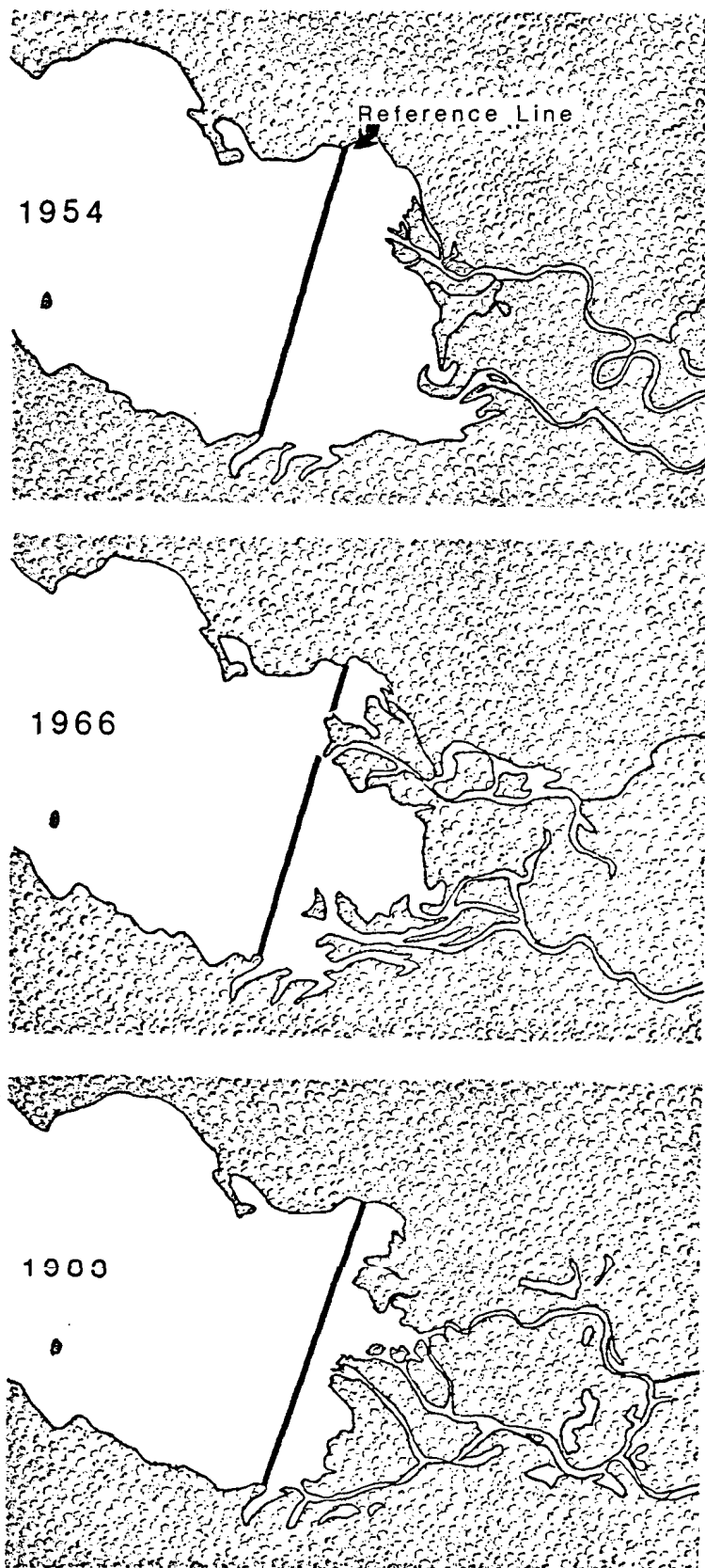


Figure 15. Areal encroachment of the marsh vegetation on the east end of Lake Neshonoc in 1954, 1966, and 1983.

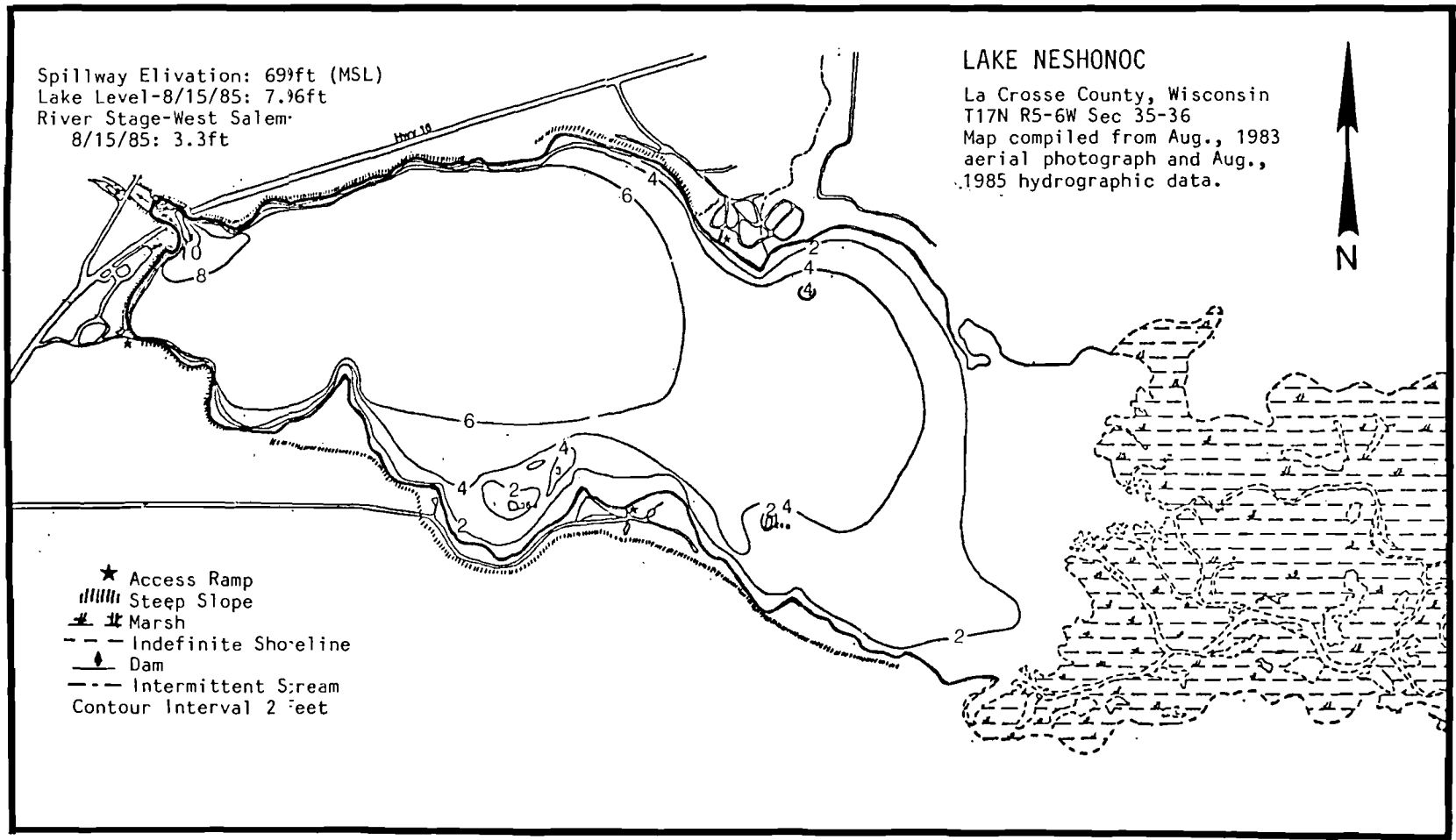


Figure 16. The hydrographic bottom contours of Lake Neshonoc as measured in August 1985.

residence time for the lake in 1966 was 5.43 days (67.1 times/yr) as calculated from the 53 year average discharge (288 cfs) (Kline 1971) and the June 1966 lake volume data.

## SUMMARY

Lake Neshonoc is a small reservoir on the La Crosse River in west-central Wisconsin. The lake is primarily used as a recreational resource. The lake was first impounded in 1851 and the present lake was formed in 1940 with the construction of the present dam and powerhouse. Power production at the dam resumed in 1986. Lake Neshonoc covers 242.6 ha, maximum depth is 3 m, and mean depth is 1.4 m. The total watershed area is 1030.8 km<sup>2</sup> and surface coverage within the watershed is 42% cropland, 40% woodland, 15% pasture and grassland, and 3% urban areas. Previous studies of the lake reported high turbidity, lack of aquatic macrophytes, and an overabundance of carp.

Lake Neshonoc has a typical northern latitude temperature regime throughout the year. No thermal stratification was observed. The temperature of the La Crosse River increased 1.5 to 5.0 °C as it flowed through the reservoir.

Total non-filterable residue (TNFR) was always greatest in Adam's Valley Creek with an annual mean 3 times that of Burn's Creek 3.5 times the La Crosse River, and 4.5 times that of Dutch Creek. The marsh area did not have a notable effect on the TNFR of water entering the lake. The TNFR of the outflow was similar to the inflow; however, the outflow NFFR (inorganic suspended sediments) was 25% less than that of the inflow. This indicates that about 25% of the inorganic suspended sediments were being trapped in the lake and that phytoplankton production within the lake probably accounted for the higher percentage of organic matter in the outflow. Secchi disk transparencies in the lake ranged from 1.8 m on February 9 to 0.3 m on September 21. Transparency decreased substantially as a result of spring runoff. The average

summer transparency was 0.5 m.

Dissolved oxygen in the lake fluctuated from surface to bottom on a biweekly basis during the summer. There was a negative correlation between the % DO saturation at the surface and at the bottom (3 m). Furthermore, there was a strong negative correlation between non-filterable volatile residue (NFVR) and % DO saturation. Therefore, the decrease in oxygen in deeper water was likely due to an increase in biological oxygen demand (BOD) from the settling of phytoplankton. The duration and extent of the periods of oxygen depletion cannot be determined from this data.

Specific conductance was greater in the smaller creeks than in the La Crosse River. The conductivity of the in-lake sites corresponded directly to the conductivity of the La Crosse River throughout the study. The pH of Lake Neshonoc and its tributaries was circumneutral throughout the sampling period. The three creeks and the marsh did not markedly alter the pH of the La Crosse River water entering the lake. The in-lake pH was low (6.9-6.5) during the spring. For the remainder of the study, the pH was higher (>7.5) for all sites with in-lake sites generally being higher than inflow sites. The pH in the lake was positively correlated to the % DO saturation during the summer. The total alkalinity for Lake Neshonoc and its tributaries shows that the entire system is well buffered. There was a fivefold decrease in alkalinity due to dilution during spring runoff. The smaller creeks, dominated by groundwater flow during most of the study, had greater alkalinities than the La Crosse River.

The annual mean nitrate concentrations show that Burn's Creek and Adam's Valley Creek had about two times the concentration of nitrate

as the La Crosse River and Dutch Creek. The greatest concentrations for all the inflow sites occurred during the summer and fall; however, in-lake nitrate concentrations were greatest during spring runoff. Nitrate concentrations of the outflow were about 34% less than the inflow concentrations. This could have been the result of uptake of nitrate by phytoplankton as the water flowed through the lake. Ammonia concentrations were greater in Adam's Valley Creek than the other inflows during most of the sampling period. In-lake ammonia concentrations were indirectly related to the % DO saturation.

Adam's Valley Creek had the greatest ortho-phosphorus concentrations of the four inflows. During the spring snowmelt (February 20-21), the ortho-phosphorus concentrations increased by a factor of 20 in Dutch Creek, 13 in Adam's Valley Creek, 10 in Burn's Creek, and 6 in the La Crosse River. Annual mean ortho-phosphorus concentrations of the outflow were about 35% less than those of the inflow. Total phosphorus concentrations were about 2 to 3 times greater than the ortho-phosphorus and followed similar trends. Total phosphorus concentrations entering and leaving the lake were similar. The ortho-phosphorus may have been assimilated by phytoplankton. A portion of the phytoplankton may then have been washed out of the lake, resulting in lower ortho-phosphorus concentrations at the outflow yet maintaining similar total phosphorus concentrations at both the inflow and outflow.

The La Crosse River provides a majority of the water entering the lake, which explains the similarity in water chemistry between the lake and river. A thorough mixture of water from Adam's Valley Creek, Burn's Creek, Dutch Creek, and the La Crosse River occurs before it enters the marsh area.

Lake Neshonoc has lost 73 ha during the past 29 years, representing a 23% decrease of its original surface area. Most of the areal loss occurred at the east end of the lake with the encroachment of the marsh. The lake volume has decreased  $0.42 \times 10^6 \text{ m}^3$  during the past 19 years, representing an 11% loss in volume. The hydraulic residence time is 4.85 days.

## RECOMMENDATIONS

1. Monitor any changes in water clarity, suspended sediments, and nutrient concentrations to determine possible effects of the carp control and vegetation planting projects.
2. Determine the extent and duration of the periods of oxygen depletion and use that information to select placement sites for other fish habitat structures.
3. Improve watershed land use management, especially in Adam's Valley, to reduce the inputs of nutrients and sediments to the lake.
4. Evaluate the relative importance of phytoplankton and aquatic macrophyte production in the lake.
5. Evaluate the effect of increased water clarity which may promote phytoplankton production to the extent that it would shade rooted macrophytes.
6. Determine the amount of wind-generated resuspension of sediments in the shallow east end of the lake addressing the question of whether the turbidity is primarily due to inputs of suspended sediments or resuspension of in-lake sediments.

## REFERENCES

- American Public Health Association. Standard Methods for the Examination of Water and Wastewater. 15th ed. Washington, DC: American Public Health Association; 1981.
- Barnes, H. H. Inorganic Nitrogen: Nitrate. In: Apparatus and Methods of Oceanography. New York: Interscience Publishers, Inc., 1959: 113-125.
- Cline C. Lake Survey Work Sheet-Lake Neshonoc, 6 September, 1950. Wisconsin Conservation Department, Madison. Available from: Wisconsin Department of Natural Resources, La Crosse, WI.
- Environmental Protection Agency. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020 revised 3-83.: 1983.
- Fernholz, W. 17 September 1963. Boom Shocker Survey Report-Lake Neshonoc. Wisconsin Department of Natural Resources. La Crosse, WI.
- Fernholz, W. 4 August 1964. Boom Shocker Survey Report-Lake Neshonoc. Wisconsin Department of Natural Resources. La Crosse, WI.
- Hansen, H. P. The Tamarack bogs of the Driftless Area of Wisconsin. Milwaukee, WI.: Bulletin of the Public Museum of the City of Milwaukee. vol 7(2): 231-304. June 1933.
- Klick, T. A. 15 March 1971. Limnology-Lake Neshonoc, La Crosse County. Wisconsin Department of Natural Resources. La Crosse, WI.
- Kline, A. K.; Gebken, D. F.; and Treinen, C. W. Surface water resources of La Crosse County, lake and stream classification project. Dept. of Natural Resources, Div. of Forestry, Wildlife, and Recreation, Madison, WI. 1971.
- Korschgen, C. E.; Green, W. L. American wild celery (Valisneria americana), A literature review. November, 1985. Available from: National Prairie Wildlife Research Center, La Crosse, WI.
- Kruger, J. A. 14 February 1984. Inventory and Evaluation Report of Lake Neshonoc Watershed. U.S. Soil Conservation Service. La Crosse, WI
- Lake Neshonoc [Aerial Photograph] La Crosse, WI: U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service; 1983 August. T17N R6W Sec 35 and T17N R6W Sec 36 (color slide).
- Lipford, C. Neshonoc has busy history. The La Crosse Tribune. 1982 Nov 28: 38 (col 1).
- Lind, O. T. Handbook of Common Methods in Limnology. 2nd ed. St. Louis, MO: C.V. Mosby Co.; 1979.
- Matsch, C. L. North America and the great Ice Age. New York: McGraw-Hill Book Co.; 1976.

- Ritter, P. G. Lake fishery survey, Lake Neshonoc, La Crosse Co., Wisconsin. 1984 October. Available from: The Lake Neshonoc Protection and Rehabilitation District, West Salem, WI.
- Ritter, P. G. Qualitative survey of aquatic vegetation of Lake Neshonoc. 1985 July. Available from: The Lake Neshonoc Protection and Rehabilitation District, West Salem, WI.
- Talley, J. G. Lake Survey-Lake Neshonoc, La Crosse County. 27 March, 1969. Wisconsin Department of Natural Resources-Intra Department Memorandum-Black River Falls.
- Wisconsin Conservation Department. Lake Survey Report-Lake Neshonoc. 6 September 1956. Fish Management Division-West Central Area. Available from: Wisconsin Department of Natural Resources, La Crosse, WI.

Appendix 1. Landmarks and triangulation instructions for locating sampling sites in the Lake Neshonoc Study, 1985.  
(Also see Fig. 1)

Site #	Landmarks or Triangulation Instructions
1	East bank of the La Crosse River approximately 50 m (160 ft) north of the County Hwy 108 bridge.
2	Looking north, align the west wall of the powerhouse with the east end of the County Hwy 108 bridge guard rail. The site is approximately 15 m (50 ft) north of the Wisconsin State Hwy 16 bridge.
3	Looking northwest, align the west pier of the Wisconsin State Hwy 16 bridge with the two large pine trees on shore behind the bridge; and looking north align the the shore-front house that has a large front deck with the yellow house up the hill in back of the shorefront house.
4	The isolated straight stump located in the northeast end of the lake.
5	In the southeast end of the lake looking southeast, align the telephone pole with the west end of the red barn with a silver roof; and looking southwest, align the northwest corner of the shorefront house with the birch tree in the front yard.
6	In the marsh area at the east end of the lake the north branch of the inflowing river upstream from the small island.
7	In the marsh area at the east end of the lake the south branch of the inflowing river upstream from the point where the stream cuts into the south bay.
8	Adam's Valley Creek 30 m (100 ft) upstream from its confluence with Burn's Creek.
9	Burn's Creek 30 m (100 ft) upstream from its confluence with Adam's Valley Creek.
10	La Crosse River 300 m (1000 ft) downstream from its confluence with Dutch Creek; 350 m (1150 ft) west of the County Hwy 162 bridge north of Bangor on the north bank.
11	Dutch Creek under the County Hwy 162 bridge in Bangor.

Appendix 2. Temperature ( $^{\circ}\text{C}$ ) for Lake Neshonoc at Sites 2 and 3 (1985).

Date	Site 2 (In-Lake:Dam)							Site 3 (In-Lake:Center)				
	Surf.	0.5 m	1.0 m	1.5 m	2.0 m	2.5 m	3.0 m	Surf.	0.5 m	1.0 m	1.5 m	2.0 m
1/11	0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	-1.0
1/30	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0
2/9	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.5
3/7	0.0	0.0	0.0	0.0	0.0	0.2	1.0	---	---	---	---	---
3/12	0.5	0.5	0.5	0.5	0.7	0.7	0.7	---	---	---	---	---
4/4	6.5	6.5	6.5	6.0	6.0	6.0	6.0	---	---	---	---	---
4/13	15.0	15.0	15.0	14.5	13.0	13.0	12.5	13.0	12.5	12.5	12.5	12.5
4/27	13.5	13.5	13.5	13.5	13.0	13.0	13.0	12.5	12.5	12.5	12.5	12.5
5/18	16.0	15.1	14.8	14.4	14.4	14.4	14.4	15.5	15.2	15.0	14.9	14.8
6/1	19.0	18.9	18.7	18.3	18.1	18.1	18.1	19.0	18.9	18.0	18.6	18.3
6/14	20.0	20.0	19.5	19.5	19.5	19.3	19.3	20.0	20.0	19.5	19.5	19.3
6/30	23.5	23.0	23.0	22.7	22.3	21.8	21.5	24.0	23.0	22.8	22.5	21.0
7/13	25.0	25.0	25.0	25.0	25.0	24.5	24.5	24.8	24.8	24.8	24.5	24.0
7/27	23.0	23.0	23.0	23.0	23.0	22.5	22.0	23.0	23.0	23.0	23.0	22.0
8/10	23.2	23.2	23.2	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
8/28	19.2	19.1	18.0	17.2	16.3	16.1	16.1	19.5	19.5	19.2	18.0	17.0
9/7	25.0	25.0	23.7	22.1	21.0	20.7	20.5	25.0	25.0	24.1	24.0	21.8
9/21	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.0	18.0	18.0	18.0	18.0

Appendix 3. Secchi disk transparencies for Lake Neshonoc at Sites 2 and 3 (1985).

Date	Secchi Disk Transparencies (m)	
	Site 2	Site3
1/11	1.40	1.50
1/30	1.70	1.60
2/9	1.60	1.80
4/4	0.60	----
4/13	0.40	0.35
4/27	0.35	0.40
5/18	0.55	0.50
6/1	0.50	0.50
6/14	0.45	0.40
7/13	0.55	0.45
7/27	0.55	0.60
8/10	0.45	0.40
8/28	0.50	0.60
9/7	0.70	0.65
9/21	0.30	0.35

Appendix 4. Total non-filterable residue (TNFR) (mg/L) and annual mean TNFR for Lake Neshonoc and its tributaries (1985).

Date	Site 2			Site 3			Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
	Site 1	Surf.	1.5 m	3.0 m	Surf.	1.0 m								
2/20	22.3	---	---	---	---	---	---	---	19.3	22.3	58.3	38.3	27.3	38.3
3/7	16.3	19.3	21.0	19.0	---	---	---	---	---	---	79.3	71.7	40.3	56.3
3/12	199.0	168.0	202.0	---	---	---	---	---	---	---	927.0	300.0	166.0	154.0
4/4	15.7	23.7	21.3	23.3	---	---	---	---	---	---	118.3	29.3	27.3	68.3
4/13	35.3	34.7	38.3	63.2	48.0	43.5	49.5	64.6	51.0	75.1	107.0	44.1	17.0	69.5
5/18	---	36.1	29.7	47.4	37.3	33.3	40.7	59.8	51.7	58.8	54.8	249.0	54.3	67.6
6/1	33.8	22.8	44.7	48.4	21.5	25.8	31.3	15.1	50.1	103.7	83.1	194.8	47.7	81.5
6/14	45.7	33.3	45.7	73.6	42.3	44.9	45.0	51.0	45.7	76.0	49.7	127.0	54.0	48.0
6/30	28.7	17.7	23.0	60.0	14.3	21.7	26.7	35.7	40.7	45.0	41.7	106.0	34.0	57.3
7/13	35.0	22.7	25.3	46.3	26.3	27.7	32.0	37.0	51.0	30.8	39.3	180.0	17.0	34.3
7/27	29.2	21.0	17.0	33.3	14.7	18.3	20.3	64.7	54.0	43.3	47.0	131.7	37.7	47.0
8/10	43.3	36.0	39.7	45.7	43.0	45.0	46.7	---	61.0	50.7	21.0	92.7	25.3	31.7
8/28	33.0	27.3	30.7	54.3	21.0	19.3	20.0	31.7	36.0	13.7	13.0	92.7	30.0	32.3
9/7	20.7	20.3	30.3	71.0	18.7	21.7	20.0	21.3	34.0	25.0	18.3	149.7	37.0	42.3
9/21	60.3	44.7	49.3	56.3	45.3	51.3	51.0	13.0	40.7	8.3	---	82.7	13.7	9.3
10/16	---	---	---	---	---	---	---	---	---	---	---	82.7	30.3	15.0
11/4	---	---	---	---	---	---	---	---	---	---	---	83.0	---	14.3
12/7	14.7	---	---	---	---	---	---	---	---	---	---	97.7	67.3	6.3
Mean	42.2	37.7	44.1	49.4	30.2	32.0	34.8	39.4	47.7	45.7	45.2	160.9	53.2	45.4

Appendix 5. Non-filterable fixed residue (NFFR) (mg/L) and annual mean NFFR for Lake Neshonoc and its tributaries (1985).

Date	Site 2			Site 3			Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
	Site 1	Surf.	1.5 m	3.0 m	Surf.	1.0 m								
2/20	7.3	---	---	---	---	---	---	---	7.0	10.0	41.7	24.3	12.7	20.7
3/7	3.3	9.7	14.3	9.3	---	---	---	---	---	---	64.7	61.3	29.0	46.7
3/12	114.0	89.0	133.0	---	---	---	---	---	---	---	843.0	217.0	101.0	98.0
4/4	8.7	19.0	17.7	16.0	---	---	---	---	---	---	106.7	16.0	22.7	62.7
4/13	23.0	25.0	24.6	50.0	40.3	34.8	39.8	52.3	40.3	62.8	97.0	40.4	13.0	61.5
5/18	---	31.8	26.7	36.7	26.0	27.3	35.4	54.8	49.4	51.8	47.5	212.7	45.6	65.0
6/1	23.8	18.5	41.7	42.4	16.3	19.8	23.7	40.5	36.0	85.7	65.8	167.5	33.7	63.8
6/14	36.4	26.6	39.0	66.6	33.3	35.0	38.0	47.3	42.4	71.3	46.0	19.7	50.3	46.7
6/30	18.4	7.7	13.0	46.0	5.3	6.7	12.0	25.4	29.7	34.3	30.0	84.0	23.7	43.4
7/13	26.0	16.0	19.3	38.3	17.6	21.4	29.3	31.8	42.3	28.1	34.0	166.7	15.3	30.3
7/27	19.4	13.0	6.7	21.3	5.0	8.6	10.0	57.0	37.0	33.6	38.3	116.4	32.4	40.0
8/10	25.7	29.0	27.0	38.3	34.0	35.3	38.7	---	54.3	44.7	16.0	71.3	11.0	27.0
8/28	26.3	18.7	21.7	42.7	12.0	11.7	12.7	29.0	28.7	9.0	6.0	82.0	24.0	24.3
9/7	14.0	12.0	17.3	56.0	10.7	12.3	13.3	15.7	27.0	21.3	15.7	126.3	30.3	32.0
9/21	37.0	29.0	26.0	42.0	29.7	36.0	37.3	6.7	35.0	3.3	---	68.0	9.3	2.0
10/16	---	---	---	---	---	---	---	---	---	---	---	51.7	10.7	2.0
11/4	---	---	---	---	---	---	---	---	---	---	---	48.3	---	---
12/7	---	---	---	---	---	---	---	---	---	---	---	53.0	39.0	---
Mean	27.4	24.6	30.0	38.0	29.7	22.6	26.4	36.7	38.4	37.7	37.0	184.7	38.6	37.1

Appendix 6. Non-filterable volatile residue (NFVR) (mg/L) and annual mean NFVR for Lake Neshonoc and its tributaries (1985).

Date	Site 1	Site 2			Site 3			Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
		Surf.	1.5 m	3.0 m	Surf.	1.0 m	2.0 m								
2/20	15.0	---	---	---	---	---	---	---	---	12.3	12.3	16.6	14.0	14.6	17.6
3/7	13.0	9.6	5.7	9.7	---	---	---	---	---	---	---	14.6	10.4	11.3	9.6
3/12	85.0	79.0	69.0	---	---	---	---	---	---	---	---	84.0	83.0	56.0	56.0
4/4	7.0	4.7	3.6	7.3	---	---	---	---	---	---	---	16.6	13.3	4.6	5.6
4/13	12.3	9.7	13.7	12.7	7.7	8.7	9.7	12.3	10.7	12.3	9.7	3.7	4.0	8.0	---
5/18	---	4.3	3.0	10.7	11.3	6.0	5.3	5.2	2.3	7.0	7.3	36.3	8.7	11.6	2.8
6/1	10.0	4.3	3.0	6.0	5.3	6.0	7.6	11.0	14.0	18.0	17.3	27.3	14.0	17.7	12.0
6/14	9.3	6.7	9.0	9.0	9.0	7.0	3.7	3.3	4.4	3.7	17.3	3.7	1.3	0.3	---
6/30	10.3	10.0	10.0	14.3	9.0	15.0	14.7	10.3	11.0	11.7	11.7	22.0	10.3	14.3	7.0
7/13	9.0	8.7	6.0	8.0	8.7	6.3	2.7	5.2	8.7	2.7	5.0	14.3	1.7	4.0	1.3
7/27	9.6	8.0	10.3	12.0	9.7	9.7	10.3	7.7	17.0	9.7	8.7	15.3	5.3	7.0	11.0
8/10	17.6	7.0	12.7	7.4	9.0	9.7	8.0	---	6.7	6.0	5.0	21.4	14.3	4.3	5.7
8/28	6.7	8.6	9.0	11.6	9.0	7.6	7.3	2.7	7.3	4.7	7.0	9.3	6.0	8.0	3.0
9/7	6.7	8.3	13.0	15.0	8.0	9.4	6.7	5.6	7.3	3.7	2.6	23.4	6.7	10.3	9.0
9/21	23.3	15.7	23.3	14.3	15.6	15.3	13.7	6.3	5.3	5.0	---	14.7	4.4	7.3	5.3
10/16	---	---	---	---	---	---	---	---	---	---	---	30.6	19.7	13.0	22.6
11/4	---	---	---	---	---	---	---	---	---	---	---	36.7	---	---	---
12/7	---	---	---	---	---	---	---	---	---	---	---	44.7	28.3	---	---
Mean	16.8	13.2	13.5	10.6	9.3	9.3	8.5	7.0	8.5	8.1	8.2	24.9	14.6	12.2	14.4

Appendix 7. Dissolved oxygen (mg/L) for Lake Neshonoc at Sites 2 and 3 (1985).

Date	Site 2 (In-Lake:Dam)							Site 3 (In-Lake:Center)				
	Surf.	0.5 m	1.0 m	1.5 m	2.0 m	2.5 m	3.0 m	Surf.	0.5 m	1.0 m	1.5 m	2.0 m
1/11	11.1	11.8	11.5	11.5	12.0	11.9	9.5	12.6	11.4	11.3	10.8	8.4
1/30	12.0	12.6	13.2	13.6	13.6	13.6	11.8	12.8	13.5	14.0	13.4	11.0
2/9	10.8	10.4	10.2	9.8	9.3	9.0	7.9	11.2	11.0	10.8	9.6	8.7
3/7	11.2	11.2	11.3	11.2	11.3	11.0	10.4	----	----	----	----	----
3/12	10.8	10.6	10.2	10.0	9.9	9.9	9.8	----	----	----	----	----
4/4	10.1	10.2	10.2	10.2	10.2	10.2	10.1	----	----	----	----	----
4/13	9.0	9.0	8.8	8.8	8.6	9.0	9.0	10.0	10.0	10.0	10.0	9.9
4/27	7.7	7.7	7.2	7.1	6.5	6.6	6.5	6.5	6.5	6.3	6.3	6.3
6/1	8.0	7.9	7.7	7.7	7.2	7.2	6.9	7.6	7.3	7.3	7.3	6.8
6/14	10.6	10.3	9.9	9.6	9.1	8.6	8.6	13.0	12.6	9.8	9.7	8.4
6/30	9.3	8.9	8.2	7.0	4.8	3.4	2.4	11.8	12.2	11.0	8.9	4.4
7/13	10.6	11.1	10.8	9.9	9.3	9.8	8.2	10.9	10.9	11.2	10.0	7.2
7/27	13.5	13.5	12.5	12.5	10.5	6.0	2.5	13.0	13.0	12.5	12.0	2.0
8/10	8.5	8.3	7.6	7.6	7.6	7.6	7.4	8.1	8.0	8.0	7.9	7.1
8/28	12.7	12.5	6.3	7.0	3.4	2.7	2.5	13.2	13.0	12.2	6.0	3.1
9/7	14.3	14.2	9.9	6.5	4.0	3.1	2.8	14.3	13.0	12.5	12.2	5.8
9/21	10.4	10.3	10.3	10.3	10.4	10.0	10.0	10.5	10.4	10.4	10.4	10.4

Appendix 8. Percent oxygen saturation for Lake Neshonoc at Sites 2 and 3 (1985).

Date	Site 2 (In-Lake:Dam)							Site 3 (In-Lake:Center)				
	Surf.	0.5 m	1.0 m	1.5 m	2.0 m	2.5 m	3.0 m	Surf.	0.5 m	1.0 m	1.5 m	2.0 m
1/11	77	81	80	80	85	81	---	88	80	80	74	---
1/30	85	88	92	95	95	95	85	87	93	95	92	77
2/9	76	73	78	78	78	79	73	76	75	74	66	61
3/7	78	78	78	78	78	79	73	---	---	---	---	---
3/12	76	75	72	71	70	70	69	---	---	---	---	---
4/4	85	85	85	83	83	83	82	---	---	---	---	---
4/13	90	90	88	87	82	85	90	95	94	94	94	94
4/27	74	74	70	69	62	57	62	61	61	59	59	59
6/1	86	85	82	81	71	72	74	82	79	77	78	72
6/14	116	114	107	105	99	95	95	145	138	107	105	91
6/30	110	104	96	82	56	39	27	142	142	128	103	49
7/13	129	134	131	120	112	112	98	132	131	135	120	85
7/27	158	160	147	147	122	69	29	152	150	145	140	23
8/10	100	97	89	88	88	88	87	95	93	93	92	83
8/28	140	137	67	73	35	28	26	145	140	131	63	32
9/7	173	172	117	75	45	35	31	174	156	148	142	64
9/21	112	111	111	111	112	107	107	112	110	110	110	110

Appendix 9. Specific conductance ( $\mu\text{S}/\text{cm}^2$ ) and annual mean specific conductance for Lake Neshonoc and its tributaries (1985).

Date	Site 1	Site 2			Site 3			Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
		Surf.	1.5 m	3.0 m	Surf.	1.0 m	2.0 m								
2/9	290	275	290	295	285	290	290	300	275	295	270	445	395	280	515
2/20	270	---	---	---	---	---	---	---	---	285	270	510	400	270	585
2/21	290	---	---	---	---	---	---	---	---	---	---	235	205	270	240
3/7	262	270	280	280	---	---	---	---	---	---	---	455	380	270	575
3/12	190	180	180	185	---	---	---	---	---	---	---	375	270	175	490
4/4	251	260	240	237	---	---	---	---	---	---	---	425	300	232	530
4/13	195	205	195	190	200	200	190	200	190	195	195	330	270	190	355
4/27	200	205	200	220	225	215	220	240	210	---	215	385	300	210	420
5/18	---	245	230	225	215	225	230	225	230	250	230	380	320	215	445
6/1	215	225	215	225	225	235	235	185	195	185	185	375	310	195	420
6/14	220	210	215	215	215	210	215	220	225	210	235	390	305	205	400
6/30	220	221	225	240	215	220	220	220	220	220	220	400	310	220	410
7/13	200	185	200	200	210	205	215	235	230	220	225	360	310	210	360
7/27	200	195	200	200	190	195	195	195	195	200	210	350	300	195	400
8/10	275	270	270	270	270	270	270	285	285	285	285	480	380	255	490
8/28	248	250	255	265	250	250	258	270	280	280	280	480	380	255	520
9/7	240	240	245	270	240	240	260	265	260	275	280	485	385	255	520
9/21	225	230	230	235	230	230	240	255	265	260	260	450	355	240	485
10/16	---	---	---	---	---	---	---	---	---	---	---	465	360	240	505
11/4	---	---	---	---	---	---	---	---	---	---	---	455	365	220	530
12/7	255	---	---	---	---	---	---	---	---	---	---	455	350	230	510
Mean	237.7	229.1	220.4	234.5	228.5	229.6	233.7	238.1	235.4	243.1	241.4	420.2	333.2	231.7	442.5

Appendix 10. The pH for Lake Neshonoc and its tributaries (1985).

Date	Site 2			Site 3			Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	
	Site 1	Surf.	1.5 m	3.0 m	Surf.	1.0 m									2.0 m
2/9	7.20	7.20	7.20	7.10	7.20	7.20	7.10	7.30	7.20	7.30	7.20	8.20	7.70	7.20	8.10
2/20	6.90	---	---	---	---	---	---	---	---	6.90	6.80	7.60	7.40	7.10	7.70
2/21	6.80	---	---	---	---	---	---	---	---	---	---	6.90	6.70	6.70	6.90
3/7	6.60	6.85	6.90	6.88	---	---	---	---	---	---	---	7.08	7.30	6.97	7.35
3/12	6.50	6.60	6.60	6.60	---	---	---	---	---	---	---	6.80	6.80	6.70	7.20
4/4	8.00	8.00	8.00	7.80	---	---	---	---	---	---	---	8.00	8.00	7.80	7.90
4/13	8.00	8.03	8.03	8.10	8.10	8.33	8.39	7.91	8.18	7.85	7.90	8.26	8.53	7.90	8.32
4/27	7.81	8.38	8.16	7.72	7.71	7.73	7.75	7.77	7.73	---	7.73	8.17	8.26	7.79	8.16
5/17	---	8.26	8.22	8.07	8.30	8.26	8.19	7.88	7.78	7.82	7.88	8.08	8.14	7.86	8.07
6/1	8.10	8.14	8.12	8.01	8.04	8.05	8.08	7.61	7.53	7.60	7.58	8.09	8.18	7.60	8.07
6/14	8.53	8.47	8.30	8.16	8.70	8.70	8.44	7.86	7.64	7.72	7.77	8.00	8.06	7.75	8.05
6/30	8.44	8.36	8.21	7.71	8.56	8.51	8.25	7.98	7.73	7.82	7.89	7.98	8.16	7.94	8.15
7/13	8.71	8.74	8.65	8.43	8.69	8.69	8.68	8.61	7.75	7.70	7.69	7.93	8.02	7.69	7.94
7/27	8.80	8.81	8.76	8.53	8.77	8.78	8.68	7.52	8.25	7.44	7.48	7.92	7.98	7.55	7.92
8/10	8.22	8.22	8.25	8.31	8.54	8.55	8.52	7.76	7.70	7.73	7.77	7.90	8.00	7.63	7.85
8/28	8.16	8.52	8.11	7.46	8.69	8.56	8.44	8.64	7.76	7.60	7.71	7.86	7.85	7.63	7.89
9/7	8.55	9.08	8.21	7.54	8.98	8.97	8.75	8.15	8.78	7.56	7.52	7.81	7.92	7.58	7.92
9/21	8.63	8.71	8.78	8.80	8.77	8.78	8.81	7.79	7.70	7.69	7.78	7.97	7.94	7.77	7.90
10/16	---	---	---	---	---	---	---	---	---	---	---	7.90	7.75	7.50	7.78
11/4	---	---	---	---	---	---	---	---	---	---	---	8.00	7.93	7.45	7.89
12/7	7.11	---	---	---	---	---	---	---	---	---	---	7.77	7.51	7.14	7.70

Appendix 11. Total alkalinity (mg/L as CaCO<sub>3</sub>) and annual mean alkalinity for Lake Neshonoc and its tributaries (1985).

Date	Site 1	Site 2			Site 3			Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
		Surf.	1.5 m	3.0 m	Surf.	1.0 m	2.0 m								
2/9	130.0	125.0	127.5	127.5	122.5	125.0	122.5	125.0	120.0	125.0	127.5	235.0	200.0	115.0	257.5
2/20	133.8	---	---	---	---	---	---	---	---	112.5	112.5	231.3	167.5	110.0	248.8
2/21	123.8	---	---	---	---	---	---	---	---	---	---	58.8	53.8	90.0	57.5
3/7	110.0	112.5	112.3	112.3	---	---	---	---	---	---	---	223.8	162.5	106.3	250.0
3/12	67.5	65.0	65.0	67.5	---	---	---	---	---	---	---	170.0	100.0	55.0	212.5
4/4	115.0	115.0	115.0	115.0	---	---	---	---	---	---	---	225.0	145.0	97.5	227.5
4/13	122.5	122.5	117.5	120.0	120.0	115.0	115.0	117.5	117.5	120.0	120.0	185.0	165.0	105.0	255.0
4/27	112.5	117.5	115.0	115.0	115.0	120.0	120.0	115.0	120.0	---	115.0	235.0	195.0	102.5	255.0
5/18	---	120.0	120.0	125.0	122.5	122.5	122.5	122.0	122.5	122.0	125.0	240.0	175.0	110.0	252.5
6/1	122.5	122.5	122.0	130.0	130.0	125.0	125.0	90.0	100.0	95.0	100.0	237.5	172.5	90.0	250.0
6/14	117.5	125.0	112.5	127.5	117.5	115.0	115.0	115.0	115.0	115.0	115.0	230.0	170.0	105.0	210.0
6/30	120.0	125.0	115.0	120.0	122.5	117.5	120.0	115.0	117.0	117.5	120.0	227.5	165.0	100.0	240.0
7/13	120.0	125.0	125.0	120.0	122.5	122.5	122.5	122.5	122.5	117.5	120.0	222.5	165.0	80.0	252.5
7/27	120.0	115.0	115.0	115.0	115.0	115.0	120.0	102.5	107.5	105.0	105.0	222.5	167.5	105.0	215.0
8/10	120.0	120.0	120.0	120.0	120.0	122.5	125.0	125.0	117.5	122.5	117.5	225.0	162.5	100.0	222.5
8/28	122.5	120.0	122.5	117.5	120.0	120.0	117.5	112.5	120.0	122.5	117.5	227.5	170.0	105.0	247.5
9/7	130.0	130.0	120.0	120.0	120.0	120.0	120.0	120.0	125.0	120.0	120.0	225.0	160.0	110.0	240.0
9/21	117.5	120.0	120.0	117.5	120.0	120.0	120.0	122.5	117.5	120.0	120.0	225.0	175.0	107.5	240.0
10/16	---	---	---	---	---	---	---	---	---	---	---	225.0	182.5	100.0	255.0
11/4	---	---	---	---	---	---	---	---	---	---	---	225.0	160.0	90.0	245.0
12/7	115.0	---	---	---	---	---	---	---	---	---	---	260.0	180.0	105.0	240.0
Mean	117.9	117.5	115.3	116.9	120.6	120.0	120.4	115.7	117.1	116.5	116.8	218.0	161.5	95.0	231.5

Appendix 12. Nitrate-N (mg NO<sub>3</sub>-N/L) and annual mean nitrate-N for Lake Neshonoc and its tributaries (1985).

Date	Site 2			Site 3			Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	
	Site 1	Surf.	1.5 m	3.0 m	Surf.	1.0 m									2.0 m
2/9	0.680	0.890	0.760	0.72	0.770	0.770	0.620	0.680	0.590	0.490	0.760	0.740	1.340	0.570	0.770
2/20	1.465	---	---	---	---	---	---	---	---	1.445	1.430	2.286	2.286	1.370	1.180
2/21	1.200	1.400	1.350	1.400	---	---	---	---	---	---	---	1.150	0.850	1.350	0.575
3/7	0.887	0.725	0.725	---	---	---	---	---	---	---	---	1.90	2.450	1.325	1.375
3/12	1.250	1.325	1.300	1.300	---	---	---	---	---	---	---	1.825	1.925	0.800	1.650
4/4	---	---	---	---	---	---	---	---	---	---	---	2.450	2.775	1.225	1.750
4/13	0.800	0.850	0.750	0.750	0.825	0.850	0.700	0.725	0.650	0.850	---	1.125	1.600	0.775	0.850
4/27	0.775	0.500	0.500	0.855	0.950	1.025	0.850	1.000	0.925	---	1.075	2.275	1.000	1.300	0.850
5/18	---	0.850	0.825	0.850	1.000	0.900	0.900	1.325	0.950	1.400	1.150	2.075	2.225	1.225	1.125
6/1	0.775	0.775	0.825	0.825	0.850	0.800	0.875	0.975	0.925	1.025	1.000	2.750	2.950	1.200	1.375
6/14	0.825	0.875	0.975	0.975	0.700	0.775	1.050	1.475	1.275	1.575	1.525	2.950	3.150	1.700	1.275
6/30	0.625	0.625	0.625	0.570	0.750	0.675	0.725	1.300	1.125	1.400	1.250	2.500	2.525	1.200	1.050
7/13	---	---	---	---	---	---	---	1.225	0.450	1.300	1.325	2.150	2.875	1.175	0.800
7/27	0.075	0.075	0.125	0.025	0.025	0.025	0.250	1.125	0.275	1.075	1.100	2.200	2.225	1.150	1.100
8/10	0.590	0.690	0.750	0.620	0.320	0.380	0.380	1.340	1.140	1.480	1.480	1.350	1.300	1.310	1.230
8/28	0.125	0.000	0.250	0.475	0.100	0.250	0.275	1.425	1.000	1.250	1.425	2.825	3.375	1.975	1.625
8/30	0.950	---	---	---	---	---	---	---	---	---	---	3.750	2.175	1.350	1.200
9/7	0.730	0.210	0.530	0.780	0.800	0.800	0.460	1.200	0.430	1.250	1.320	2.460	2.340	1.290	1.170
9/21	0.550	0.340	0.340	0.410	0.300	0.310	0.300	1.410	1.430	1.470	1.470	2.950	2.950	1.420	1.340
10/16	---	---	---	---	---	---	---	---	---	---	---	2.050	2.550	1.525	1.300
11/4	---	---	---	---	---	---	---	---	---	---	---	2.525	1.375	0.250	0.350
12/7	1.625	---	---	---	---	---	---	---	---	---	---	3.600	3.725	1.675	2.350
Mean	0.819	0.675	0.705	0.761	0.616	0.630	0.597	1.170	0.859	1.232	1.255	2.268	2.329	1.221	1.215

Appendix 13. Ammonia-N (mg NH<sub>3</sub>-N/L) and annual mean ammonia-N for Lake Neshonoc and its tributaries (1985).

Date	Site 1	Site 2			Site 3			Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
		Surf.	1.5 m	3.0 m	Surf.	1.0 m	2.0 m								
2/9	0.260	0.180	0.200	0.250	0.270	0.290	0.280	0.200	0.160	0.170	0.220	0.071	0.061	0.230	0.020
2/20	0.230	---	---	---	---	---	---	---	---	0.196	0.200	0.140	0.091	0.230	0.111
3/7	0.357	0.252	0.280	0.280	---	---	---	---	---	---	---	0.210	0.357	0.252	0.294
4/13	0.056	0.051	0.047	0.051	0.000	0.009	0.009	0.000	0.028	0.070	0.061	0.000	0.000	0.009	0.000
4/27	0.064	0.014	0.034	0.055	0.055	0.081	0.055	0.054	0.054	---	0.051	0.060	0.014	0.024	0.036
5/18	---	0.055	0.055	0.055	0.054	0.054	0.055	0.084	0.084	0.084	0.081	0.121	0.067	0.066	0.094
6/1	0.328	0.234	0.236	0.234	0.200	0.234	0.234	0.160	0.252	0.124	0.126	0.168	0.064	0.112	0.117
6/14	0.044	0.037	0.040	0.069	0.037	0.030	0.042	0.058	0.150	0.061	0.085	0.218	0.138	0.133	0.087
6/30	0.050	0.002	0.067	0.364	0.006	0.046	0.076	0.032	0.076	0.021	0.020	0.216	0.021	0.028	0.031
7/13	0.076	0.022	0.036	0.126	0.035	0.047	0.086	0.076	0.183	0.058	0.061	0.086	0.041	0.058	0.050
7/27	0.067	0.028	0.024	0.079	0.032	0.036	0.037	0.074	0.035	0.072	0.072	0.112	0.045	0.063	0.024
8/10	0.035	0.000	0.021	0.024	0.073	0.054	0.050	0.057	0.098	0.050	0.048	0.074	0.041	0.052	0.019
8/28	0.077	0.035	0.038	0.257	0.020	0.022	0.053	0.081	0.038	0.053	0.053	0.072	0.064	0.034	0.047
9/7	0.000	0.010	0.010	0.140	0.152	0.014	0.019	0.028	0.020	0.045	0.042	0.211	0.041	0.022	0.063
9/21	0.000	0.009	0.010	0.006	0.006	0.006	0.006	0.011	0.052	0.029	0.026	0.081	0.021	0.021	0.036
10/16	---	---	---	---	---	---	---	---	---	---	---	0.033	0.007	0.036	0.024
11/4	---	---	---	---	---	---	---	---	---	---	---	0.085	0.034	0.035	0.052
12/7	0.160	---	---	---	---	---	---	---	---	---	---	0.085	0.094	0.134	0.093
Mean	0.120	0.066	0.091	0.142	0.072	0.071	0.077	0.070	0.128	0.079	0.082	0.113	0.067	0.085	0.067

Appendix 14. Nitrite-N (mg NO<sub>2</sub>-N/L) and annual mean nitrite-N for Lake Neshonoc and its tributaries (1985).

Date	Site 1	Site 2			Site 3			Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
		Surf.	1.5 m	3.0 m	Surf.	1.0 m	2.0 m								
2/9	0.110	0.087	0.078	0.095	0.087	0.095	0.095	0.150	0.142	0.135	0.150	0.095	0.078	0.110	0.078
2/20	0.023	---	---	---	---	---	---	---	---	0.022	0.022	0.029	0.020	0.027	0.031
2/21	---	---	---	---	---	---	---	---	---	---	---	0.065	0.053	0.024	0.074
3/7	0.022	0.012	0.013	0.015	---	---	---	---	---	---	---	0.017	0.011	0.012	0.014
3/12	0.086	0.096	0.092	0.094	---	---	---	---	---	---	---	0.044	0.047	0.087	0.027
4/4	0.016	0.016	0.016	0.016	---	---	---	---	---	---	---	0.028	0.012	0.012	0.016
4/13	0.027	0.031	0.030	0.024	0.023	0.023	0.023	0.036	0.028	0.034	0.035	0.033	0.017	0.029	0.031
4/27	0.018	0.021	0.021	0.019	0.019	0.019	0.019	0.019	0.019	---	0.019	0.022	0.012	0.015	0.013
5/18	---	0.024	0.024	0.023	0.025	0.024	0.023	0.066	0.024	0.041	0.038	0.047	0.022	0.022	0.025
6/14	0.031	0.031	0.031	0.031	0.035	0.033	0.032	0.024	0.025	0.021	0.021	0.061	0.021	0.020	0.016
6/30	0.034	0.034	0.035	0.035	0.033	0.034	0.034	0.022	0.028	0.019	0.019	0.074	0.019	0.019	0.020
7/13	0.019	0.018	0.020	0.022	0.018	0.019	0.019	0.029	0.035	0.029	0.027	0.038	0.020	0.021	0.021
7/27	0.020	0.021	0.017	0.020	0.018	0.017	0.017	0.032	0.028	0.031	0.031	0.044	0.023	0.025	0.028
8/10	0.028	0.028	0.028	0.021	0.025	0.025	0.026	0.042	0.026	0.053	0.054	0.039	0.024	0.027	0.048
8/28	0.031	0.029	0.030	0.034	0.031	0.029	0.031	0.024	0.025	0.024	0.024	0.032	0.023	0.018	0.028
8/30	0.030	---	---	---	---	---	---	---	---	---	---	0.110	0.132	0.068	0.057
9/7	0.031	0.029	0.031	0.036	0.036	0.032	0.032	0.030	0.032	0.029	0.029	0.072	0.033	0.024	0.076
9/21	0.024	0.026	0.026	0.025	0.027	0.027	0.026	0.021	0.017	0.021	0.024	0.031	0.013	0.020	0.032
10/16	---	---	---	---	---	---	---	---	---	---	---	0.016	0.012	0.019	0.020
11/4	---	---	---	---	---	---	---	---	---	---	---	0.019	0.015	0.019	0.017
12/7	0.017	---	---	---	---	---	---	---	---	---	---	0.017	0.012	0.018	0.013
Mean	0.033	0.033	0.033	0.034	0.031	0.031	0.031	0.041	0.036	0.038	0.038	0.044	0.029	0.030	0.033

Appendix 15. Ortho-phosphate-P (mg PO<sub>4</sub>-P/L) and annual mean ortho-phosphate-P for Lake Neshonoc and its tributaries (1985).

Date	Site 2			Site 3			Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	
	Site 1	Surf.	1.5 m	3.0 m	Surf.	1.0 m									2.0 m
2/9	0.081	0.069	0.086	0.086	0.081	0.086	0.075	0.091	0.075	0.092	0.092	0.103	0.086	0.097	0.064
2/20	0.068	---	---	---	---	---	---	---	---	0.076	0.074	0.084	0.074	0.097	0.046
2/21	0.638	---	---	---	---	---	---	---	---	---	---	1.106	0.787	0.574	0.926
3/12	0.405	0.430	0.385	0.405	---	---	---	---	---	---	---	0.930	0.320	0.320	0.160
4/4	0.072	0.055	0.050	0.072	---	---	---	---	---	---	---	0.345	0.102	0.105	0.090
4/13	0.055	0.050	0.053	0.038	0.050	0.043	0.038	0.058	0.035	0.070	0.080	1.325	0.080	0.080	0.020
4/27	0.078	0.045	0.050	0.080	0.083	0.083	0.080	0.103	0.105	---	0.105	0.105	0.083	0.013	0.035
5/18	---	0.158	0.160	0.363	0.173	0.178	0.173	0.243	0.215	0.265	0.223	0.575	0.193	0.235	0.098
6/1	0.078	0.000	0.098	0.115	0.098	0.098	0.115	0.128	0.128	0.115	0.128	0.128	0.128	0.128	0.070
6/14	0.035	0.053	0.045	0.050	0.035	0.045	0.047	0.102	0.085	0.105	0.132	0.142	0.115	0.110	0.147
6/30	0.075	0.075	0.075	0.115	0.045	0.050	0.070	0.113	0.080	0.110	0.100	0.168	0.113	0.113	0.048
7/13	0.078	0.063	0.083	0.118	0.090	0.085	0.075	0.135	0.138	0.165	0.145	0.178	0.140	0.160	0.048
7/27	0.110	0.090	0.083	0.115	0.095	0.078	0.105	0.140	0.090	0.140	0.140	0.175	0.143	0.153	0.073
8/10	0.110	0.098	0.012	0.012	0.110	0.112	0.110	0.132	0.116	0.132	0.136	0.154	0.132	0.154	0.090
8/28	0.045	0.043	0.050	0.065	0.043	0.025	0.050	0.130	0.085	0.155	---	---	---	---	---
8/30	0.051	---	---	---	---	---	---	---	---	---	---	1.385	0.270	0.155	0.055
9/7	0.062	0.028	0.050	0.068	0.086	0.040	0.046	0.126	0.056	0.134	0.162	0.188	0.178	---	0.114
9/21	0.108	0.106	0.102	0.140	0.102	0.096	0.084	0.146	0.160	0.168	0.162	0.190	0.124	0.188	0.096
10/16	---	---	---	---	---	---	---	---	---	---	---	0.092	0.086	0.116	0.040
11/4	---	---	---	---	---	---	---	---	---	---	---	0.106	0.076	0.120	0.026
12/7	0.074	---	---	---	---	---	---	---	---	---	---	0.094	0.072	0.094	0.034
Mean	0.124	0.091	0.098	0.129	0.084	0.078	0.082	0.127	0.105	0.133	0.129	0.379	0.165	0.163	0.114

Appendix 16. Total-P (mg/L) and annual mean total-P for Lake Neshonoc and its tributaries (1985).

Date	Site 2			Site 3			Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
	Site 1	Surf.	1.5 m	3.0 m	Surf.	1.0 m								
2/9	0.200	0.250	0.200	0.200	0.150	0.200	0.250	0.250	0.250	0.300	0.200	0.150	0.300	0.250
2/20	0.180	---	---	---	---	---	---	---	---	0.180	0.150	0.170	0.110	0.200
2/21	0.250	---	---	---	---	---	---	---	---	---	---	3.150	1.700	0.250
3/7	0.200	0.150	0.250	0.100	---	---	---	---	---	---	---	0.270	0.220	0.110
3/12	0.984	0.860	0.955	1.035	---	---	---	---	---	---	---	1.865	0.905	0.620
4/4	0.205	0.180	0.152	0.180	---	---	---	---	---	---	---	0.750	0.160	0.200
4/13	0.183	0.190	0.530	0.905	0.918	0.813	0.195	0.260	0.210	0.248	0.290	0.208	0.143	0.240
4/27	0.210	0.223	0.228	0.215	0.208	0.213	0.205	0.203	0.193	---	0.213	0.230	0.130	0.238
5/18	---	0.158	0.160	0.363	0.173	0.178	0.173	0.243	0.215	0.265	0.223	0.575	0.193	0.235
6/1	0.213	0.215	0.223	0.278	0.193	0.213	0.203	0.290	0.288	0.373	0.353	0.478	---	0.318
6/14	0.203	0.210	0.210	0.258	0.205	0.215	0.228	0.223	0.218	0.255	0.230	0.708	0.205	0.208
6/30	0.215	0.190	0.195	0.305	0.173	0.183	0.198	0.240	0.243	0.220	0.218	0.718	0.190	0.243
7/13	0.193	0.190	0.193	0.275	0.215	0.215	0.223	0.243	0.293	0.203	0.235	0.440	0.140	0.220
7/27	0.238	0.233	0.233	0.253	0.238	0.243	0.233	0.298	0.355	0.293	0.275	0.440	0.218	0.263
8/10	0.284	0.264	0.279	0.304	0.323	0.337	0.330	0.369	0.350	0.282	0.238	0.460	0.231	0.301
8/28	0.210	0.193	0.188	0.230	0.165	0.160	0.165	0.213	0.225	0.185	0.180	0.368	0.188	0.225
8/30	0.285	---	---	---	---	---	---	---	---	---	---	1.450	0.625	0.300
9/7	0.232	0.140	0.116	0.384	0.154	0.156	0.188	0.232	0.114	0.232	0.212	1.060	0.282	0.276
9/21	0.354	0.334	0.334	0.354	0.320	0.350	0.344	0.176	0.282	0.176	0.170	0.436	0.150	0.190
10/16	---	---	---	---	---	---	---	---	---	---	---	0.304	0.180	0.186
11/4	---	---	---	---	---	---	---	---	---	---	---	0.262	0.160	0.172
12/7	0.116	---	---	---	---	---	---	---	---	---	---	0.406	0.206	0.156
Mean	0.261	0.249	0.278	0.352	0.264	0.267	0.226	0.249	0.249	0.243	0.235	0.679	0.309	0.248