U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

REPORT

ON

MANISTEE LAKE

MANISTEE COUNTY

MICHIGAN

EPA REGION V

WORKING PAPER No. 201

PACIFIC NORTHWEST ENVIRONMENTAL RESEARCH LABORATORY

An Associate Laboratory of the

NATIONAL ENVIRONMENTAL RESEARCH CENTER - CORVALLIS, OREGON

and

NATIONAL ENVIRONMENTAL RESEARCH CENTER - LAS VEGAS, NEVADA

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201

WITH THE COOPERATION OF THE

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

AND THE

MICHIGAN NATIONAL GUARD

MARCH, 1975

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Michigan Department of Natural Resources for professional involvement and to the Michigan National Guard for conducting the tributary sampling phase of the Survey.

A. Gene Gazlay, former Director, and David H. Jenkins, Acting Director, Michigan Department of Natural Resources; and Carlos Fetterolf, Chief Environmental Scientist, and Dennis Tierney, Aquatic Biologist, Bureau of Water Management, Department of Natural Resources, provided invaluable lake documentation and counsel during the course of the Survey. John Vogt, Chief of the Bureau of Environmental Health, Michigan Department of Public Health, and his staff were most helpful in identifying point sources and soliciting municipal participation in the Survey.

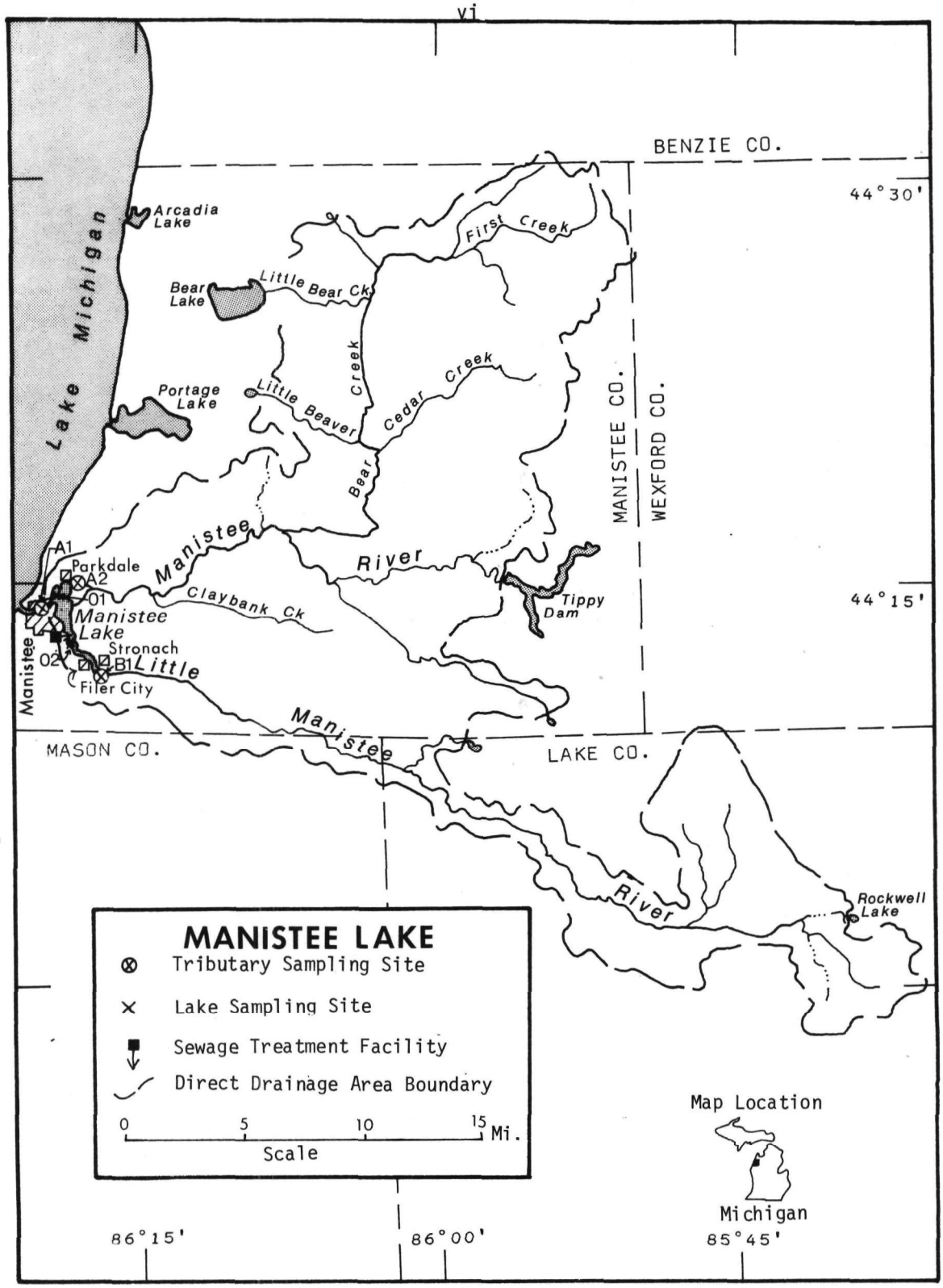
Major General Clarence A. Schnipke (Retired), then the Adjutant General of Michigan, and Project Officer Colonel Albert W. Lesky, who directed the volunteer efforts of the Michigan National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

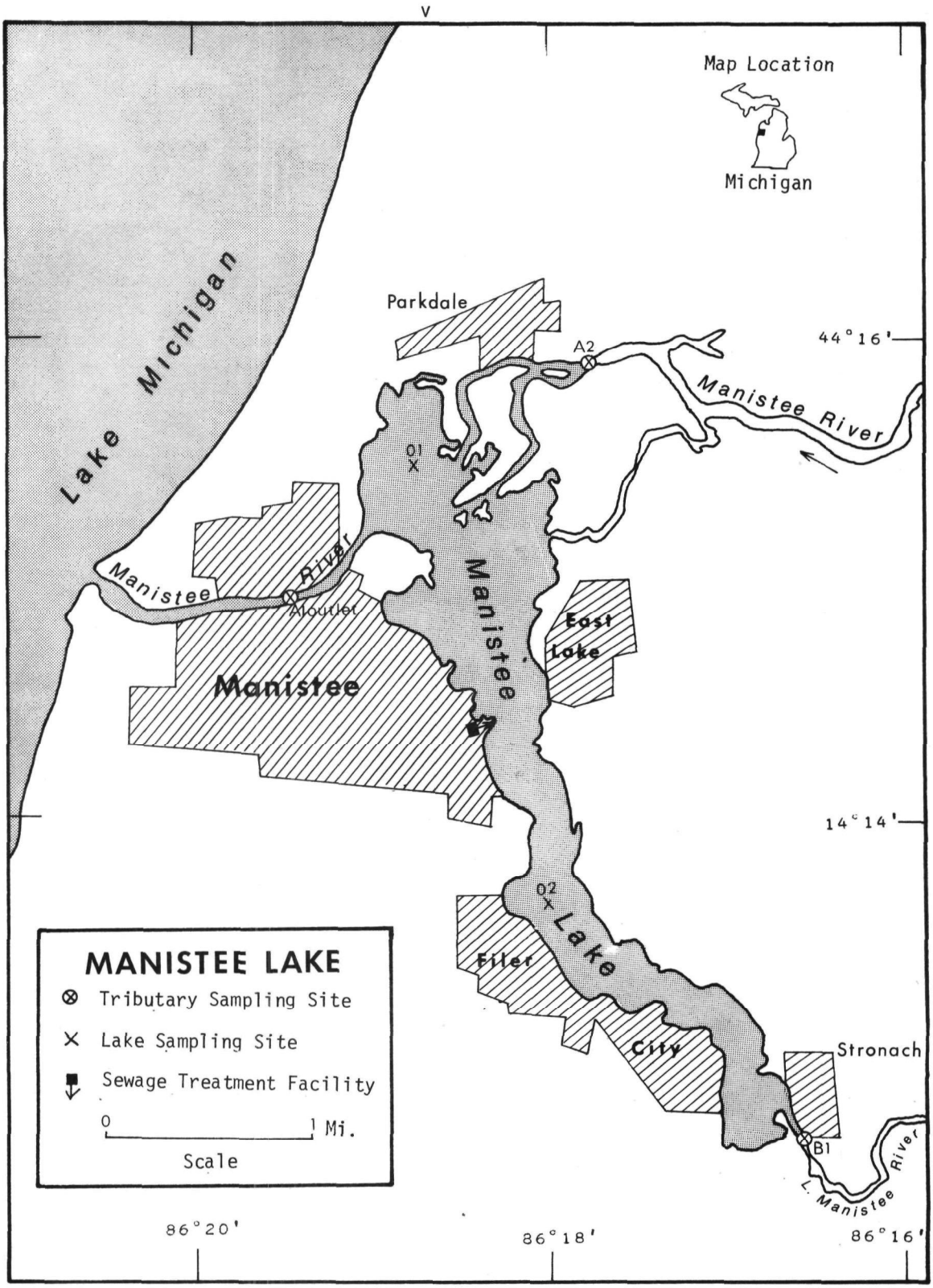
NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MICHIGAN

LAKE NAME	COUNTY
Allegan Res.	Allegan
Barton	Kalamazoo
Belleville	Wayne
Betsie	Benzie
Brighton	Livingston
Caro Res.	Tuscola
Charlevoix	Charlevoix
Chemung	Livingston
Constantine Res.	St. Joseph
Crystal	Montcalm
Deer	Marquette
Ford	Washtenaw
Fremont	Newago
Higgins	Roscommon
Holloway Res.	Genesee, Lapeer
Houghton	Roscommon
Jordon	Ionia, Barry
Kent	Oakland
Long	St. Joseph
Macatawa	Ottawa
Manistee	Manistee
Mona	Muskegon
Muskegon	Muskegon
Pentwater	Oceana
Pere Marquette	Mason
Portage	Houghton
Randall	Branch
Rogers Pond	Mecosta
Ross	Gladwin
St. Louis Res.	Gratiot
Sanford	Midland
Strawberry	Livingston
Thompson	Livingston
Thornapple	Barry
Union	Branch
White	Muskegon


BENZIE CO.
44°30'
Lake Michigan
Arcadia Lake
First Creek
Bear Lake
Little Bear Ck
Portage Lake
Little Beaver Creek
Cedar Creek
Bear Creek
MANISTEE CO.
WEXFORD CO.
A1
Parkdale
A2
Manistee River
Claybank Ck
Tippy Dam
44°15'
O1
Manistee Lake
Stronach
O2
B1
Little Manistee
Filer City
MASON CO.
LAKE CO.
Rockwell Lake
MANISTEE LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Direct Drainage Area Boundary
0 5 10 15 Mi.
Scale
Map Location
Michigan
86°15'
86°00'
85°45'


Map Location
Michigan
Lake Michigan
Parkdale
A2
44°16'
Manistee River
O1
Manistee River
Outlet
Manistee
East Lake
Manistee
14°14'
O2
Lake
Filer
City
Stronach
B1
L. Manistee River
86°20'
86°18'
86°16'
MANISTEE LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
0
1 Mi.
Scale

MANISTEE LAKE

STORET NO. 2649

I. CONCLUSIONS

A. Trophic Condition:

Survey data and the records of others (Ketelle and Uttormark, 1971) show that Manistee Lake is eutrophic. Of the 35 Michigan lakes sampled in November when essentially all were well-mixed, five had less mean total phosphorus eight had less mean dissolved phosphorus, and seven had less mean inorganic nitrogen (the relatively low nutrient levels probably are due to a very short hydraulic retention time); of the 41 lakes sampled, 22 had greater mean Secchi disc transparency, and 11 had less mean chlorophyll a*.

Marked depression of dissolved oxygen at 22 feet and deeper occurred at station 2 in September, 1972.

B. Rate-Limiting Nutrient:

A significant loss of dissolved phosphorus occurred in the algal assay sample between the time of collection and the beginning of the assay, and the results are not representative of conditions in the lake when the sample was taken (09/15/72).

The lake data indicate phosphorus limitation in November and nitrogen limitation in June and September.

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* See Appendix A.

C. Nutrient Controllability:

1. Point sources--During the sampling year, Manistee Lake received a total phosphorus load at a rate nearly three times the rate proposed by Vollenweider (in press) as "dangerous"; i.e., a eutrophic rate (see page 12). However, Vollenweider's model probably does not apply to water bodies with short hydraulic retention times, and the hydraulic retention time of Manistee Lake is certain to be short. For example, if the mean depth of the lake is as much as one-half of the maximum depth of 49 feet (i.e., a mean depth of 25 feet), the mean hydraulic retention time would be a very short five days, so it is quite likely that Vollenweider's model does not apply in this case.

It is calculated that the City of Manistee contributed nearly 12% of the total phosphorus load to Manistee Lake during the sampling year. The Manistee wastewater treatment facilities that were operational during the Survey sampling year have been replaced by a land-disposal system which does not discharge to Manistee Lake. It is calculated that the elimination of the City of Manistee phosphorus load reduced the loading rate to about 12 $g/m^2/yr$. In view of the hydraulic retention time of the lake, which is certain to be very short,

it is likely that the lower loading rate will result in persistent phosphorus limitation and a reduction in the incidence and severity of nuisance algal blooms, as well as provide additional protection for Lake Michigan.

2. Non-point sources--Despite the renowned quality of the Manistee and Little Manistee rivers (Fetterolf, 1970), it appears that the very high drainage area to lake area ratio of 1,368 to 1 will ensure a relatively high phosphorus loading to Manistee Lake regardless of point sources. For example, if the low mean annual phosphorus export rate of the Little Manistee River is characteristic of the entire Manistee Lake drainage (see page 11), the total phosphorus loading rate to the lake would be nearly 7 $g/m^2/yr$. This emphasizes the need to reduce all phosphorus inputs to the lake to the greatest practicable degree.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 929 acres.
2. Mean depth: unknown.
3. Maximum depth: 49 feet.
4. Volume: unknown.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
Manistee River	1,820.0 mi^2	1,997.2 cfs
Little Manistee River	218.0 mi^2	186.4 cfs
Minor tributaries & immediate drainage -	14.5 mi^2	19.9 cfs
Totals	2,052.5 mi^2	2,203.5 cfs

2. Outlet -

Manistee River	2,054.0 mi^2**	2,203.5 cfs

C. Precipitation***:

1. Year of sampling: 30.7 inches.
2. Mean annual: 31.7 inches.

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† Fetterolf, 1973.

* Drainage areas are accurate within ±5%; mean daily flows for 74% of the sampling sites are accurate within ±25% and the remaining sites up to ±40%; and mean monthly flows, normalized mean monthly flows, and mean annual flows are slightly more accurate than mean daily flows.

** Includes area of lake.

*** See Working Paper No. 1, "Survey Methods, 1972".

III. LAKE WATER QUALITY SUMMARY

Manistee Lake was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two stations on the lake and from a number of depths at each station (see map, page v). During each visit, a single depth-integrated (15 feet to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the second visit, a single five-gallon depth-integrated sample was composited for algal assays. Also each time, depth-integrated samples were collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 22 feet at station 1 and 38 feet at station 2.

The results obtained are presented in full in Appendix C, and the data for the fall sampling period, when the lake essentially was well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix C.

A. Physical and chemical characteristics:

Parameter	Minimum	Mean	Median	Maximum
		FALL VALUES (11/13/72)		
Temperature (Cent.)	6.5	7.3	7.3	7.8
Dissolved oxygen (mg/l)	7.0	8.7	8.4	11.0
Conductivity (μmhos)	315	746	760	1,300
pH (units)	7.5	7.8	7.9	8.0
Alkalinity (mg/l)	125	135	140	144
Total P (mg/l)	0.013	0.018	0.017	0.029
Dissolved P (mg/l)	0.007	0.010	0.010	0.017
NO_2 + NO_3 (mg/l)	0.120	0.186	0.150	0.300
Ammonia (mg/l)	0.040	0.119	0.120	0.240
		ALL VALUES		
Secchi disc (inches)	31	49	51	60

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Number per ml
06/17/72	1. Chroococcus	1,320
	2. Dinobryon	1,139
	3. Melosira	1,031
	4. Anabaena	850
	5. Microcystis	452
	Other genera	1,230
	Total	6,022
09/15/72	1. Melosira	2,405
	2. Microcystis	1,320
	3. Dinobryon	361
	4. Flagellates	72
	Other genera	489
	Total	4,647
11/13/72	1. Chroococcus	3,367
	2. Flagellates	2,312
	3. Fragilaria	2,111
	4. Anabaena	1,055
	5. Cryptomonas	955
	Other genera	4,773
	Total	14,573

2. Chlorophyll a -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll a (µg/l)
06/17/72	01	6.0
	02	8.5
09/15/72	01	9.5
	02	12.4
11/13/72	01	0.5
	02	1.0

C. Limiting Nutrient Study:

The control yield of the assay alga, Selenastrum capricornutum, was an unexpectedly low 1.0 mg/l dry weight. At least in part, this was due to a 35% loss of dissolved phosphorus in the assay sample from the time of collection to the beginning of the assay, but heavy metals also may have inhibited growth. Analysis of a sub-sample of the assay sample indicated 96 µg/l total zinc and 9 µg/l total copper.

Had the phosphorus loss and/or heavy metals inhibition not occurred, the expected control yield would have been a relatively high 5 mg/l dry weight based on yields obtained in other algal assay samples with similar nutrient levels.

The lake data indicate phosphorus limitation in November (N/P = 30/1), nitrogen limitation in September (N/P = 8/1), but a borderline nitrogen limitation in June (N/P = 13/1).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Michigan National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for high runoff months when two samples were collected. Sampling was begun in October, 1972, and was completed in October, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Michigan District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loadings for "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the means of the nutrient loads, in lbs/mi^2/year, at stations A-2 and B-1 and multiplying the means by the ZZ area in mi^2.

The operator of the Manistee wastewater treatment plant provided monthly effluent samples and corresponding flow data.

A number of industries discharge waste and/or cooling water to Manistee Lake, but these discharges are not believed to be significant in terms of primary nutrients.

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* See Working Paper No. 1.

A. Waste Sources:

1. Known municipal† -

Name	Pop. Served*	Treatment	Mean Flow (mgd)	Receiving Water
Manistee	7,723	pr. clarifier	1.081	Manistee Lake

2. Known industrial** -

Name	Mean Flow (mgd)	Receiving Water
Morton Intn. Chemical Co.	?	Manistee Lake
Morton Salt Company	?	Manistee Lake
Hardy Salt Company	?	Manistee Lake
Manistee Drop Forge Company	?	Manistee Lake
Packaging Corp. of Amer.	cooling water	Manistee Lake
Standard Lime & Refractories, Inc.	cooling water	Manistee Lake

† Wetzel, 1973.
* 1970 Census.
** Fetterolf, 1970; Hesse, 1971.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Manistee River	92,160	81.6
Little Manistee River	6,210	5.5
b. Minor tributaries & immediate drainage (non-point load) -	570	0.5
c. Known municipal STP's		
Manistee	13,060	11.6
d. Septic tanks* -	850	0.7
e. Known industrial -	?	-
f. Direct precipitation** -	140	0.1
Total	112,990	100.0

2. Outputs -

Lake outlet - Manistee River 94,700

3. Net annual P accumulation - 18,290 pounds

* Estimated 3,400 contributing population in Filer, Stronach, East Lake, and Parkdale; see Working Paper No. 1.
** See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/yr	% of total
a. Tributaries (non-point load) -		
Manistee River	2,354,960	90.4
Little Manistee River	136,420	5.2
b. Minor tributaries & immediate drainage (non-point load) -	13,920	0.6
c. Known municipal STP's -		
Manistee	58,370	2.2
d. Septic tanks* -	31,960	1.2
e. Known industrial -	?	-
f. Direct precipitation** -	8,950	0.4
Total	2,604,580	100.0

2. Outputs -

Lake outlet - Manistee River 3,230,040

3. Net annual N loss 625,460 pounds

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	lbs $P/mi^2/yr$	lbs $N/mi^2/yr$
Manistee River	51	1,294
Little Manistee River	28	626

* Estimated 3,400 contributing population in Filer, Stronach, East Lake, and Parkdale; see Working Paper No. 1.
** See Working Paper No. 1.

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving water would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with very short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
Units	Total	Accumulated	Total	Accumulated
lbs/acre/yr	121.6	19.7	2,803.6	loss*
grams/m^2/yr	13.63	2.21	314.2	-

Vollenweider loading rates for phosphorus ($g/m^2/yr$) based on surface area and mean outflow of Manistee Lake:

"Dangerous" (eutrophic rate)	4.80
"Permissible" (oligotrophic rate)	2.40

* The apparent loss of nitrogen during the sampling year may have been due to nitrogen fixation, solubilization of previously sedimented nitrogen, nitrogen-rich ground water recharge, or unmeasured point sources. However, a similar loss of nitrogen has been observed at Shagawa Lake, Minnesota, which has been intensively studied by EPA's National Eutrophication and Lake Restoration Branch.

V. LITERATURE REVIEWED

Fetterolf, Carlos, 1970. Summary of past staff and Commission activities in the Manistee area and a status report on Manistee Lake and discharges thereto. MI Dept. Nat. Resources, Lansing.

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Ketelle, Martha J., and Paul D. Uttormark, 1971. Problem lakes of the United States. EPA Water Poll. Contr. Res. Ser., Proj. #16010 EHR.

Vollenweider, Richard A. (in press). Input-output models. Schweiz. Z. Hydrol.

Wetzel, Michael C., 1973. Treatment plant questionnaire (Manistee STP). MI Dept Publ. Health, Lansing.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500-MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15-MIN DO
26A0	HOLLOWAY RESERVOIR	0.062	0.043	1.461	439.375	10.678	9.200
26A1	CARO RESERVOIR	0.117	0.022	3.835	473.000	11.967	9.500
26A2	BOARDMAN HYDRO POND	0.006	0.005	0.358	363.500	1.267	6.600
2603	ALLEGAN LAKE	0.123	0.057	1.168	470.222	20.311	12.600
2606	BARTON LAKE	0.121	0.086	1.489	456.167	27.800	14.850
2609	BELLEVILLE LAKE	0.118	0.048	1.420	465.250	28.262	8.200
2610	BETSIE LAKE	0.025	0.008	0.273	461.667	4.567	7.400
2613	BRIGHTON LAKE	0.109	0.073	1.015	456.000	44.233	7.500
2617	LAKE CHARLEVOIX	0.007	0.006	0.230	351.250	3.008	9.240
2618	LAKE CHEMUNG	0.044	0.014	0.132	404.333	13.483	14.800
2621	CONSTANTINE RESERVOIR	0.027	0.008	0.910	456.167	39.317	7.500
2629	FORD LAKE	0.105	0.058	1.536	456.167	14.733	14.000
2631	FREMONT LAKE	0.372	0.342	1.406	441.667	28.500	14.800
2640	JORDAN LAKE	0.180	0.144	1.998	427.667	20.517	14.900
2643	KENT LAKE	0.040	0.015	0.417	455.000	33.944	13.000
2648	LAKE MACATAWA	0.197	0.120	2.358	477.600	25.600	12.200
2649	MANISTEE LAKE	0.018	0.010	0.304	451.333	6.317	11.380
2659	MUSKEGON LAKE	0.087	0.043	0.469	436.444	9.511	14.800
2665	PENTWATER LAKE	0.027	0.017	0.496	430.667	16.083	14.800
2671	RANDALL LAKE	0.246	0.183	0.818	457.333	27.217	8.020
2672	ROGERS POND	0.026	0.015	0.183	435.500	8.133	9.600
2673	ROSS RESERVOIR	0.034	0.021	0.460	465.333	10.383	8.200
2674	SANFORD LAKE	0.016	0.008	0.307	458.750	13.791	8.300
2683	THORNAPPLE LAKE	0.042	0.032	1.737	442.833	14.650	10.800
2685	UNION LAKE	0.083	0.064	1.252	455.500	15.667	8.200
2688	WHITE LAKE	0.027	0.019	0.367	417.778	9.211	13.400
2691	MONA LAKE	0.307	0.241	0.963	451.667	27.783	14.100
2692	LONG LAKE	0.163	0.148	0.749	418.400	10.067	13.600

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES MEAN TOTAL P	FALL VALUES MEAN DISS P	FALL VALUES MEAN INORG N	ALL VALUES 500- MEAN SEC	ALL VALUES MEAN CHLORA	ALL VALUES 15- MIN DO
2693	ST LOUIS RESERVOIR	0.134	0.093	1.227	462.667	5.583	8.420
2694	CRYSTAL LAKE	0.009	0.006	0.164	380.000	2.986	13.000
2695	HIGGINS LAKE	0.007	0.005	0.058	268.500	1.043	9.400
2696	HOUGHTON LAKE	0.018	0.008	0.136	420.833	9.217	8.200
2697	THOMPSON LAKE	0.043	0.029	0.436	407.889	11.967	14.800
2698	PERE MARQUETTE LAKE	0.032	0.024	0.346	448.667	11.833	8.600
2699	STRAWBERRY LAKE	0.069	0.050	0.567	419.800	11.117	13.600

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500- MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15- MIN DO	INDEX NO
26A0	HOLLOWAY RESERVOIR	46 (16)	43 (15)	17 (6)	57 (20)	60 (21)	63 (22)	286
26A1	CARO RESERVOIR	29 (10)	54 (19)	0 (0)	3 (1)	49 (17)	54 (19)	189
26A2	BOARDMAN HYDRO POND	97 (34)	97 (34)	69 (24)	91 (32)	94 (33)	97 (34)	545
2603	ALLEGAN LAKE	20 (7)	31 (11)	31 (11)	6 (2)	29 (10)	40 (14)	157
2606	BARTON LAKE	23 (8)	20 (7)	14 (5)	29 (9)	14 (5)	3 (1)	103
2609	BELLEVILLE LAKE	26 (9)	37 (13)	20 (7)	11 (4)	11 (4)	79 (26)	184
2610	BETSIE LAKE	77 (27)	77 (27)	80 (28)	17 (6)	86 (30)	94 (33)	431
2613	BRIGHTON LAKE	31 (11)	23 (8)	34 (12)	34 (12)	0 (0)	90 (31)	212
2617	LAKE CHARLEVOIX	91 (32)	91 (32)	83 (29)	94 (33)	89 (31)	60 (21)	508
2618	LAKE CHEMUNG	49 (17)	71 (25)	94 (33)	86 (30)	46 (16)	11 (2)	357
2621	CONSTANTINE RESERVOIR	71 (25)	83 (29)	40 (14)	29 (9)	3 (1)	90 (31)	316
2629	FORD LAKE	34 (12)	29 (10)	11 (4)	29 (9)	37 (13)	23 (8)	163
2631	FREMONT LAKE	0 (0)	0 (0)	23 (8)	54 (19)	9 (3)	11 (2)	97
2640	JORDAN LAKE	11 (4)	11 (4)	6 (2)	69 (24)	26 (9)	0 (0)	123
2643	KENT LAKE	57 (20)	69 (24)	63 (22)	40 (14)	6 (2)	36 (12)	271
2648	LAKE MACATAWA	9 (3)	14 (5)	3 (1)	0 (0)	23 (8)	43 (15)	92
2649	MANISTEE LAKE	80 (28)	74 (26)	77 (27)	46 (16)	80 (28)	46 (16)	403
2659	MUSKEGON LAKE	37 (13)	40 (14)	54 (19)	60 (21)	69 (24)	11 (2)	271
2665	PENTWATER LAKE	69 (24)	63 (22)	51 (18)	66 (23)	31 (11)	11 (2)	291
2671	RANDALL LAKE	6 (2)	6 (2)	43 (15)	23 (8)	20 (7)	86 (30)	184
2672	ROGERS POND	74 (26)	66 (23)	86 (30)	63 (22)	77 (27)	51 (18)	417
2673	ROSS RESERVOIR	60 (21)	57 (20)	57 (20)	9 (3)	63 (22)	79 (26)	325
2674	SANFORD LAKE	86 (30)	80 (28)	74 (26)	20 (7)	43 (15)	71 (25)	374
2683	THORNAPPLE LAKE	54 (19)	46 (16)	9 (3)	51 (18)	40 (14)	49 (17)	249
2685	UNION LAKE	40 (14)	26 (9)	26 (9)	37 (13)	34 (12)	79 (26)	242
2688	WHITE LAKE	66 (23)	60 (21)	66 (23)	80 (28)	74 (26)	31 (11)	377
2691	MONA LAKE	3 (1)	3 (1)	37 (13)	43 (15)	17 (6)	20 (7)	123
2692	LONG LAKE	14 (5)	9 (3)	46 (16)	77 (27)	66 (23)	27 (9)	239

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500- MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15- MIN DO	INDEX NO
2693	ST LOUIS RESERVOIR	17 (6)	17 (6)	29 (10)	14 (5)	83 (29)	69 (24)	229
2694	CRYSTAL LAKE	89 (31)	89 (31)	89 (31)	89 (31)	91 (32)	36 (12)	483
2695	HIGGINS LAKE	94 (33)	94 (33)	97 (34)	97 (34)	97 (34)	57 (20)	536
2696	HOUGHTON LAKE	83 (29)	86 (30)	91 (32)	71 (25)	71 (25)	79 (26)	481
2697	THOMPSON LAKE	51 (18)	49 (17)	60 (21)	83 (29)	51 (18)	11 (2)	305
2698	PERE MARQUETTE LAKE	63 (22)	51 (18)	71 (25)	49 (17)	54 (19)	66 (23)	354
2699	STRAWBERRY LAKE	43 (15)	34 (12)	49 (17)	74 (26)	57 (20)	27 (9)	284

APPENDIX B

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2649 MANISTEE LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 2054.00

TRIBUTARY	SUB-DRAINAGE AREA(SQ MI)	NORMALIZED FLOWS(CFS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2649A1	2054.00	2061.00	2068.00	2460.00	3308.00	2487.00	2143.00	1912.00	1796.00	1849.00	2001.00	2174.00	2191.00	2203.48
2649A2	1820.00	1873.00	1878.00	2235.00	3012.00	2241.00	1935.00	1728.00	1623.00	1674.00	1818.00	1972.00	1985.00	1997.17
2649B1	218.00	169.00	171.00	203.00	266.00	224.00	189.00	167.00	157.00	158.00	165.00	182.00	186.00	186.41
2649ZZ	16.00	19.00	19.00	22.00	30.00	22.00	19.00	17.00	16.00	17.00	18.00	20.00	20.00	19.91

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 2054.00
SUM OF SUB-DRAINAGE AREAS = 2054.00
TOTAL FLOW IN = 26450.00
TOTAL FLOW OUT = 26450.00

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2649A1	10	72	2354.00	29	2923.00				
	11	72	2194.00						
	12	72	2070.00	2	2090.00				
	1	73	2860.00	6	2820.00				
	2	73	2300.00	4	2830.00				
	3	73	3140.00	4	2330.00	31	2392.00		
	4	73	2688.00	29	2143.00				
	5	73	2479.00	16	2393.00				
	6	73	2169.00	10	2183.00	26	1958.00		
	7	73	1963.00	9	1632.00	17	1758.00		
	8	73	1816.00						
	9	73	1754.00	9	1493.00				
	10	73	1964.00	2	1849.00				
2649A2	10	72	2160.00	29	2713.00				
	11	72	2000.00						
	12	72	1890.00	2	1907.00				
	1	73	2620.00	6	2620.00				
	2	73	2090.00	4	2570.00				
	3	73	2860.00	4	2080.00	31	2190.00		
	4	73	2430.00	29	1920.00				
	5	73	2235.00	16	2160.00				
	6	73	1958.00	10	1970.00	26	1780.00		
	7	73	1776.00	9	1460.00	17	1591.00		
	8	73	1650.00						
	9	73	1591.00	9	1336.00				
	10	73	1787.00	2	1683.00				

LAKE CODE 2649 MANISTEE LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2649B1	10	72	171.00	29	181.00				
	11	72	172.00						
	12	72	161.00	2	162.00				
	1	73	208.00	6	174.00				
	2	73	185.00	4	229.00				
	3	73	254.00	4	222.00	31	218.00		
	4	73	230.00	29	204.00				
	5	73	219.00	16	209.00				
	6	73	190.00	10	192.00	26	164.00		
	7	73	168.00	9	157.00	17	150.00		
	8	73	148.00						
	9	73	146.00	9	142.00				
	10	73	158.00	2	148.00				
2649ZZ	10	72	23.00						
	11	72	22.00						
	12	72	20.00						
	1	73	28.00						
	2	73	23.00						
	3	73	31.00						
	4	73	27.00						
	5	73	25.00						
	6	73	21.00						
	7	73	19.00						
	8	73	18.00						
	9	73	17.00						
	10	73	19.00						

APPENDIX C

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 75/02/04

264901
44 15 30.0 086 19 00.0
MANISTEE LAKE
26101 MICHIGAN

11EPALES 2111202
5 0024 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/17	15 48	0000	18.2	9.4	42	330	8.11	150	0.140	0.030	0.014	0.005
	15 48	0015	17.8	6.8								
	15 48	0020	17.3	7.6		440	7.90	152	0.120	0.080	0.026	0.008
72/09/15	16 00	0000			54	415	8.00	153	0.130	0.070	0.020	0.012
	16 00	0004	18.3	8.2		430	8.00	153	0.130	0.060	0.023	0.010
	16 00	0015	18.3	8.0		440	8.00	153	0.120	0.060	0.021	0.012
	16 00	0022	18.2	7.8		440	8.00	154	0.130	0.070	0.026	0.011
72/11/12	16 00	0000			57	315	7.60	127	0.300	0.050	0.013	0.008
	16 00	0004	6.5	11.0		335	7.80	126	0.290	0.040	0.014	0.007
	16 00	0015	7.3	9.3		760	7.60	129	0.220	0.160	0.020	0.013
	16 00	0022	7.8	8.4		1100	7.50	125	0.190	0.240	0.029	0.017

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/17	15 48	0000	6.0J
72/09/15	16 00	0000	9.5J
72/11/12	16 00	0000	0.5J

J VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 75/02/04

264902
44 13 30.0 086 18 00.0
MANISTEE LAKE
26101 MICHIGAN

11EPALES 2111202
5 0030 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/17	16	09 0000	18.5	6.2	60	530	7.95	149	0.080	0.060	0.037	0.015
	16	09 0015	18.7	7.6		530	7.93	149	0.070	0.060	0.026	0.016
	16	09 0028	18.0	7.8		480	7.72	151	0.050	0.070	0.026	0.016
72/09/15	15	15 0000			48	580	7.98	162	0.030	0.060	0.027	0.016
	15	15 0004	19.0	6.8		580	7.95	161	0.030	0.060	0.030	0.018
	15	15 0015	18.9	6.4		590	7.88	155	0.040	0.060	0.026	0.019
	15	15 0022	18.7	4.9		675	7.73	155	0.050	0.160	0.047	0.031
	15	15 0030	18.2	3.8		825	7.67	157	0.060	0.260	0.063	0.046
	15	15 0038	18.2	3.6		960	7.65	156	0.060	0.300	0.069	0.051
72/11/13	10	10 0000			31	675	8.00	140	0.130	0.080	0.015	0.009
	10	10 0004	7.2	8.8		630	8.00	140	0.120	0.070	0.017	0.008
	10	10 0015	7.2	8.4		775	8.00	143	0.150	0.120	0.017	0.011
	10	10 0025	7.5	8.2		825	8.00	144	0.140	0.130	0.017	0.011
	10	10 0034	7.6	7.0		1300	7.90	142	0.130	0.180	0.019	0.010

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/17	16	09 0000	8.5J
72/09/15	15	15 0000	12.4J
72/11/13	10	10 0000	1.0J

J VALUE KNOWN TO BE IN ERROR

APPENDIX D

TRIBUTARY and WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 75/02/04

2649A1 LS2649A1
44 16 00.0 086 19 30.0
MANISTEE RIVER
26 15 MANISTEE
0/MANISTEE LAKE
MAPLE ST BRDG IN MANISTEE
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	15 35		0.193	0.350	0.084	0.005	0.020
72/12/02	13 30		0.280	0.460	0.078	0.010	0.020
73/01/06	13 00		0.320	1.490	0.105	0.005K	0.015
73/02/04	09 40		0.315	0.290	0.042	0.006	0.025
73/03/04	09 40		0.370	0.230	0.042	0.015	0.020
73/03/31	13 00		0.230	0.260	0.032	0.011	0.025
73/04/29	11 00		0.180	0.285	0.034	0.007	
73/05/16	12 00		0.160	0.340	0.022	0.005K	0.025
73/06/10	13 50		0.120	0.660	0.020	0.005K	0.025
73/06/26	16 00		0.095	0.780	0.036	0.007	0.015
73/07/09	19 00		0.110	1.050	0.040	0.006	0.020
73/07/17	18 00		0.082	0.960	0.030	0.008	0.025
73/09/09	13 00		0.021	0.360	0.063	0.008	0.025
73/10/02	19 00		0.077	0.320	0.017		

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2649A2 LS2649A2
44 16 00.0 086 17 30.0
MANISTEE RIVER
26 15 BAR LAKE
T/MANISTEE LAKE
N CHANNEL ST HWY 55 BRDG SEPARKDALE
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	15 45		0.250	0.350	0.099	0.005K	0.017
72/12/02	16 00		0.312	0.290	0.016	0.007	0.015
73/01/06	13 15		0.330	0.235	0.023	0.005K	0.015
73/02/04	09 30		0.340	0.190	0.024	0.006	0.025
73/03/04	09 30		0.350	0.290	0.042	0.010	0.025
73/03/31	13 20		0.252	0.250	0.019	0.008	0.025
73/04/29	11 30		0.230	0.620	0.031	0.005K	0.045
73/05/16	12 30		0.190	0.720	0.009	0.005K	0.020
73/06/10	13 00		0.150	0.200	0.007	0.005K	0.025
73/06/26	16 30		0.160	0.420	0.007	0.007	0.020
73/07/09	20 00		0.189	0.265	0.019	0.005K	0.020
73/07/17	18 30		0.132	0.750	0.042	0.005K	0.020
73/09/09	13 15		0.012	0.250	0.071	0.009	0.030

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2649B1 LS2649B1
44 12 30.0 086 16 30.0
LITTLE MANISTEE LAKE
26 15 MANISTEE
T/MANISTEE LAKE
SECONDARY BRDG SW OF STRONACH
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/29	16 20		0.065	0.450	0.062	0.006	0.014
72/12/02	15 40		0.084	0.310	0.021	0.006	0.013
73/01/06	14 00		0.105	0.215	0.024	0.005K	0.012
73/02/04	09 20		0.147	0.220	0.024	0.006	0.020
73/03/04	08 45		0.126	0.210	0.021	0.005K	0.015
73/03/31	13 45		0.078	0.160	0.008	0.006	0.020
73/04/29	12 30		0.032	0.220	0.020	0.007	0.007
73/05/16	18 00		0.016	1.680	0.010	0.005K	0.015
73/06/10	12 45		0.010K	0.200	0.008	0.005K	0.020
73/06/26	17 30		0.021	0.480	0.013	0.009	0.015
73/07/09	19 30		0.032	0.210	0.016	0.005K	0.015
73/07/17			0.017	0.380	0.025	0.006	0.015
73/09/09	13 45		0.252	0.210	0.210	0.020	0.025
73/10/02	18 40		0.066	0.520	0.038	0.005K	0.030

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

264950 PR264950 P007200
44 14 00.0 086 18 00.0
MANISTEE
26101 15 MANISTEE
0/MANISTEE LAKE
MANISTEE LAKE
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/01/31	08 00								
CP(T)-			0.030	21.000	7.000	3.200	4.720	1.110	1.000
73/01/31	17 00								
73/02/26	09 00								
CP(T)-			0.500	28.000	7.800	4.200	8.800	0.610	0.880
73/02/26	21 00								
73/03/29	08 00								
CP(T)-			0.340	23.000	7.900	3.300	7.000	1.060	0.930
73/03/29	17 00								
73/04/24	00 00								
CP(T)-			0.620	19.800	4.400	2.200	4.700	1.550	1.400
73/04/24	12 00								
73/10/16	08 00								
CP(T)-			0.154	5.100	0.400	0.840	1.600	1.800	1.700
73/10/16	21 00								
73/11/01	08 00								
CP(T)-			0.720	13.000	0.059	1.980	4.100	1.380	1.500
73/11/01	16 00								
73/11/11	08 30								
CP(T)-			0.260	26.000	13.700	1.890	2.800	0.820	0.900
73/11/11	17 00								
73/12/19	08 00								
CP(T)-			0.380	24.000	7.100	1.800	3.700	0.800	0.930
73/12/19	17 00								
74/01/31	08 00								
CP(T)-			0.040	11.000	0.150	0.800	2.000	0.860	0.890
74/01/31	16 00								
74/02/25	08 00								
CP(T)-			0.840	19.000	7.300	1.200	5.000	0.600	0.850
74/02/25	16 00								
74/03/21	08 00								
CP(T)-			0.680	15.000	5.500	1.450	3.000	0.690	0.780
74/03/21	17 00								
74/04/24	08 00								
CP(T)-			0.520	18.000	2.000	1.200	3.100	1.380	1.210
74/04/24	21 00								

STORET RETRIEVAL DATE 75/02/04

264950 PR264950 P007200
44 14 00.0 086 18 00.0
MANISTEE
26101 15 MANISTEE
U/MANISTEE LAKE
MANISTEE LAKE
11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
74/06/17	08 00								
CP(T)-			0.360	9.150	0.480	0.395	2.150	2.830	1.950
74/06/17	21 00								