U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY
WORKING PAPER SERIES

REPORT
ON
JORDAN LAKE
IONIA AND BARRY COUNTIES
MICHIGAN
EPA REGION V
WORKING PAPER No. 198

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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REPORT

ON

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EPA REGION V

WORKING PAPER No. 198

209

WITH THE COOPERATION OF THE

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

AND THE

MICHIGAN NATIONAL GUARD

MARCH, 1975

CONTENTS

F O R E W O R D

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; Carlos Fetterolf, Chief Environmental Scientist, Bureau of Water Management; and John Robinson, Chief, Dennis Tierney, Aquatic Biologist, and Albert Massey, Aquatic Biologist, Water Quality Appraisal Section, 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.

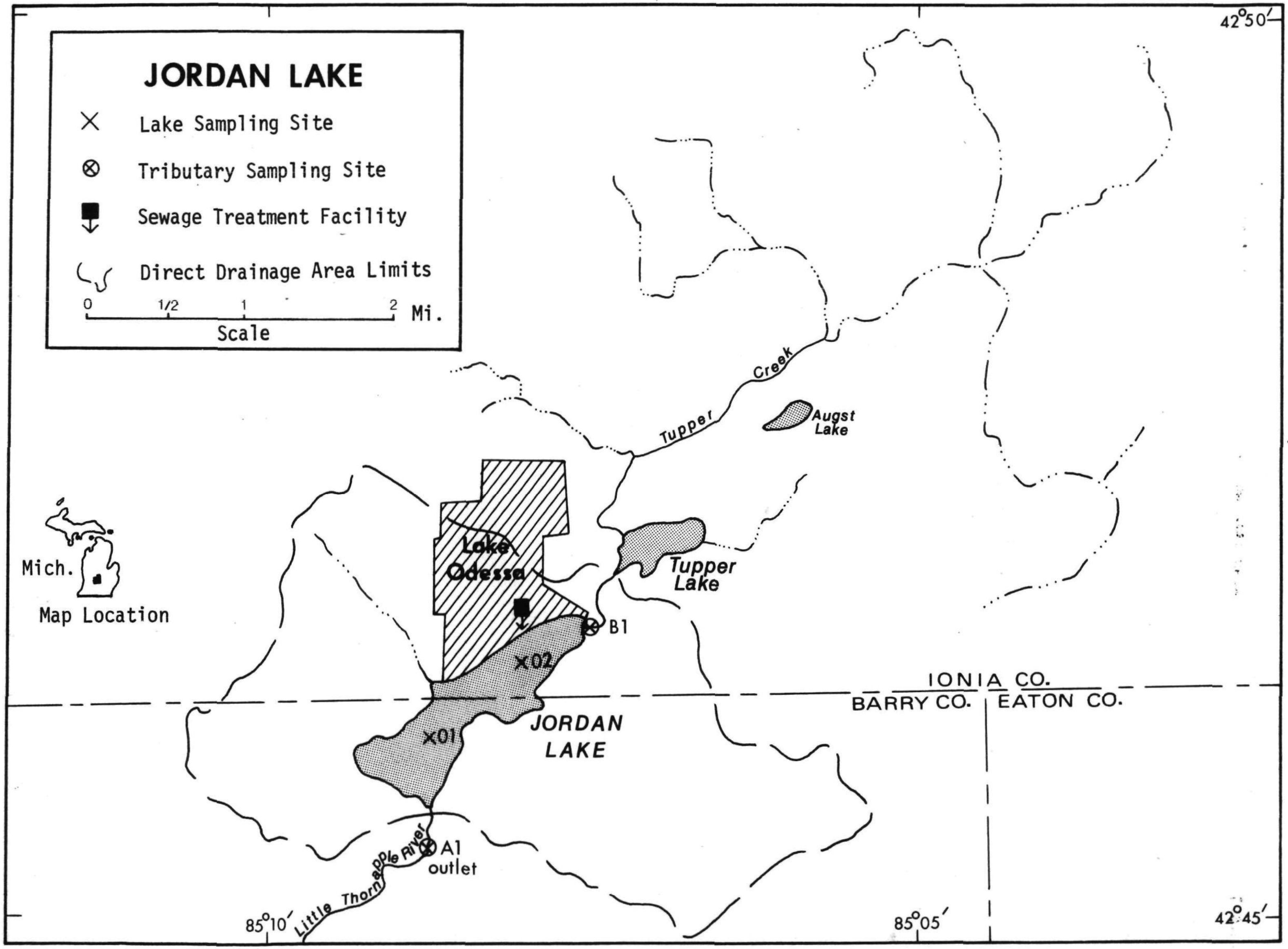
Major General Clarence A. Schnipke (Retired), then the Adjutant General of Michigan, and Project Officer Colonel Albert W. Lesky, who directed the volunteer efforts of the Michigan National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

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


JORDAN LAKE
Lake Sampling Site
Tributary Sampling Site
Sewage Treatment Facility
Direct Drainage Area Limits
0
1/2
1
2
Mi.
Scale
Mich.
Map Location
42°50′
42°45′
85°10′
85°05′
Tupper Creek
Augst Lake
Lake Odessa
Tupper Lake
B1
X02
X01
JORDAN LAKE
IONIA CO.
BARRY CO.
EATON CO.
Little Thornapple River
A1
outlet

JORDAN LAKE

STORET NO. 2640

I. CONCLUSIONS

A. Trophic Condition:

Survey data and the records of others (Fetterolf, 1964) show that Jordan Lake is eutrophic. Of the 35 Michigan lakes sampled in November when essentially all were well-mixed, only four had greater mean total and dissolved phosphorus, only two had greater mean inorganic nitrogen, and only nine had greater mean chlorophyll a; overall, 31 of the 35 lakes exhibited better water quality*.

Depletion of dissolved oxygen at 23 feet and deeper occurred at both lake stations in September.

Jordan Lake is listed in "Problem Lakes in the United States" (Ketelle and Uttormark, 1971).

B. Rate-Limiting Nutrient:

The results of the algal assay show that Jordan Lake was nitrogen limited in September.

Lake data indicate phosphorus limitation in June and November.

C. Nutrient Controllability:

1. Point sources--During the sampling year, Jordan Lake received a total phosphorus load at a rate nearly twice that

* See Appendix A.

proposed by Vollenweider (in press) as "dangerous"; i.e., nearly twice the eutrophic rate (see page 13).

It is estimated that the Village of Lake Odessa contributed about 14% of the total phosphorus load to the lake during the sampling year. However, wastewater from the village is treated in three different ways and is discharged through three separate outfalls, but only two of the discharges affect the lake (see page 9). Since the village did not participate in the Survey, it was necessary to make assumptions as to the amount of wastewater discharged, the proportional flows in the three outfalls, and the nutrient concentrations in the three effluents (see page 10). Because of these constraints, the impact of the Village of Lake Odessa on Jordan Lake cannot be properly assessed, and a need for a more-detailed study is indicated.

2. Non-point sources--During the sampling year, the phosphorus export rate of Tupper Creek was a high 146 pounds per square mile of drainage (see page 13). Whether this high export rate is due to underestimation of the phosphorus load in one of the village wastewater outfalls, or to cultural practices in the drainage, or both, is not known.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 430 acres.
2. Mean depth: 24.5 feet.
3. Maximum depth: 58 feet.
4. Volume: 10,535 acre-feet.
5. Mean hydraulic retention time: 304 days.

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

1. Tributaries -

Name	Drainage area*	Mean flow*
Tupper Creek	18.3 mi^2	12.4 cfs
Minor tributaries & immediate drainage -	6.8 mi^2	5.1 cfs
Totals	25.1 mi^2	17.5 cfs

2. Outlet -

Little Thornapple River	25.8 mi^2**	17.5 cfs

C. Precipitation***:

1. Year of sampling: 32.6 inches.
2. Mean annual: 31.2 inches.

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† MI Dept. Cons. lake inventory map (1957); mean depth by random-dot method.
* 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

Jordan 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, a depth-integrated sample was collected from each of the stations for chlorophyll _a_ analyses. The maximum depths sampled were 44 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:

FALL VALUES

(11/15/72)

Parameter	Minimum	Mean	Median	Maximum
Temperature (Cent.)	6.3	6.4	6.4	6.4
Dissolved oxygen (mg/l)	8.6	9.0	9.0	9.4
Conductivity (µmhos)	420	428	425	440
pH (units)	7.7	7.7	7.7	7.7
Alkalinity (mg/l)	160	163	162	170
Total P (mg/l)	0.164	0.180	0.184	0.197
Dissolved P (mg/l)	0.134	0.144	0.147	0.152
NO_2 + NO_3 (mg/l)	0.530	0.605	0.540	0.790
Ammonia (mg/l)	1.210	1.393	1.340	1.660

ALL VALUES

Parameter	Minimum	Mean	Median	Maximum
Secchi disc (inches)	60	72	70	96

B. Biological characteristics:

1. Phytoplankton* -

Sampling Date	Dominant Genera	Number per ml
09/18/72	1. Merismopedia	1,887
	2. Marssoniella	1,094
	3. Aphanocapsa	1,019
	4. Microcystis	868
	5. Fragilaria	604
	Other genera	2,641
	Total	8,113
11/15/72	1. Asterionella	217
	2. Fragilaria	190
	3. Flagellates	136
	4. Anabaena	131
	5. Stephanodiscus	118
	Other genera	288
	Total	1,080

* The June sample was lost in shipment.

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)
06/15/72	01	21.8
	02	16.3
09/18/72	01	14.7
	02	9.3
11/15/72	01	30.0
	02	31.0

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.105	0.670	22.2
0.005 P	0.110	0.670	26.1
0.010 P	0.115	0.670	23.7
0.020 P	0.125	0.670	25.6
0.050 P	0.155	0.670	26.7
0.050 P + 10.0 N	0.155	10.670	59.5
10.0 N	0.105	10.670	45.1

2. Discussion -

The control yield of the assay alga, *Selenastrum capricornutum*, indicates that the potential primary productivity of Jordan Lake was very high at the time the assay sample was collected. Also, the lack of significant change in yields with increased levels of orthophosphorus, until nitrogen was also added, shows that the lake was nitrogen limited when sampled. Note that the addition of only nitrogen resulted in a yield far greater than the control yield.

The September lake data also indicate nitrogen limitation (N/P ratio = 11/1); however, phosphorus limitation is indicated in June and November (N/P ratios = 14/1).

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 v), except for the months of April, May, and July, when two samples were collected, and December when low flows prevented sampling. Sampling was begun in October, 1972, and was completed in September, 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 unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S) were estimated by using the nutrient loads, in lbs/mi^2/year, in Tupper Creek at station B-1 and multiplying by the ZZ area in mi^2.

The treated wastewater of the Village of Lake Odessa is discharged through three outfalls. Reportedly (Cowles, 1973), part is spray irrigated, part receives secondary treatment plus phosphorus removal (discharged to Tupper Creek), and part receives primary treatment plus

* See Working Paper No. 1.

phosphorus removal (discharged to Jordan Lake). In this report, it is assumed that the discharges are equal in volume and that the phosphorus removal results in a mean effluent concentration of 1 mg/l of P for a total load of 900 lbs P and 14,250 lbs N (7.5 lbs/capita/yr).

In the following loading tables, the nutrient loads attributed to Tupper Creek are those measured at station B-1 minus the loads attributed to one-third of the Village of Lake Odessa discharge. The loads attributed to Lake Odessa do not include the one-third estimated to have been spray irrigated.

A. Waste Sources:

1. Known municipal† -

Name	Pop.* Served	Treatment	Mean** Flow (mgd)	Receiving Water
Lake Odessa	1,924	aer. pond + P-removal	0.150	Tupper Creek
		primary + P-removal	0.150	Jordan Lake
		land disposal	0.150	Merrill drain

2. Known industrial - None

† Cowles, 1973.
* 1970 Census.
** Estimated.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Tupper Creek	2,670	60.8
b. Minor tributaries & immediate drainage (non-point load) -	990	22.6
c. Known municipal STP's -		
Lake Odessa	600	13.7
d. Septic tanks* -	60	1.4
e. Known industrial - None	-	-
f. Direct precipitation** -	70	1.6
Total	4,390	100.0

2. Outputs -

Lake outlet - Little Thornapple River	3,660

3. Net annual P accumulation - 730 pounds

* Estimate based on 100 lakeshore dwellings; 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) -		
Tupper Creek	75,000	62.5
b. Minor tributaries & immediate drainage (non-point load) -	27,870	23.2
c. Known municipal STP's -		
Lake Odessa	9,260	8.5
d. Septic tanks* -	2,350	2.1
e. Known industrial - None	-	-
f. Direct precipitation** -	4,140	3.7
Total	118,980	100.0

2. Outputs -

Lake outlet - Little Thornapple River	88,380

3. Net annual N accumulation - 30,600 pounds

* Estimate based on 100 lakeshore dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

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

Tributary	lbs P/mi^2/yr	lbs N/mi^2/yr
Tupper Creek	146	4,098

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 waters 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	10.2	1.7	276.4	70.9
grams/m^2/yr	1.14	0.19	30.9	7.9

Vollenweider loading rates for phosphorus (g/m^2/yr) based on the mean depth and mean hydraulic retention time of Jordan Lake:

"Dangerous"	(eutrophic rate)	0.58
"Permissible"	(oligotrophic rate)	0.29

V. LITERATURE REVIEWED

Cowles, F. E. 1973. Treatment plant questionnaire (Lake Odessa). MI Dept. Nat. Resources, Lansing.

Fetterolf, Carlos M., 1964. A discussion of some biological aspects of Jordan Lake, Lake Odessa, Michigan, 1964. MS, MI Water Res. Comm., Lansing.

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

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

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEAN TOTAL P	MEAN DISS P	MEAN INORG N	500- MEAN SEC	MEAN CHLORA	15- MIN DO
		FALL VALUES			ALL VALUES		
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	MEAN DISS P	MEAN INORG N	------------ALL VALUES---------- 500- MEAN SEC	MEAN CHLORA	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	MEAN DISS P	MEAN INORG N	------------ALL VALUES--------- 500- MEAN SEC	MEAN CHLORA	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	MEAN DISS P	MEAN INORG N	----ALL VALUES---- 500- MEAN SEC	MEAN CHLORA	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 2640 JORDAN LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 25.80

TRIBUTARY	SUB-DRAINAGE AREA(SQ MI)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
		NORMALIZED FLOWS(CFS)												
2640A1	25.80	15.60	20.70	36.30	27.90	21.20	14.10	9.33	8.55	8.69	14.00	16.40	17.90	17.54
2640B1	18.30	11.10	14.70	25.80	19.80	15.00	9.99	6.62	6.07	6.16	9.92	11.70	12.70	12.45
2640ZZ	7.50	4.55	6.02	10.60	8.11	6.17	4.10	2.71	2.49	2.53	4.07	4.78	5.20	5.11

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 25.80 TOTAL FLOW IN = 210.89
SUM OF SUB-DRAINAGE AREAS = 25.80 TOTAL FLOW OUT = 210.67

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2640A1	10	72	30.00	28	28.00				
	11	72	37.00	28	34.00				
	12	72	60.00						
	1	73	44.00	8	24.00				
	2	73	27.00	4	37.00	28	22.00		
	3	73	63.00						
	4	73	50.00	6	37.00	20	30.00		
	5	73	53.00	4	37.00	24	78.00		
	6	73	42.00	8	30.00				
	7	73	26.00	4	32.00	27	19.00		
	8	73	18.00	31	14.00				
	9	73	20.00	24	15.00				
2640B1	10	72	21.00	28	20.00				
	11	72	26.00	28	24.00				
	12	72	43.00						
	1	73	31.00	8	17.00				
	2	73	19.00	4	26.00	28	16.00		
	3	73	45.00						
	4	73	35.00	6	26.00	20	21.00		
	5	73	37.00	4	26.00	24	55.00		
	6	73	30.00	8	22.00				
	7	73	18.00	4	22.00	27	14.00		
	8	73	12.00	31	9.60				
	9	73	14.00	24	11.00				
2640ZZ	10	72	8.60						
	11	72	11.00						
	12	72	18.00						
	1	73	13.00						
	2	73	7.80						
	3	73	18.00						
	4	73	14.00						
	5	73	15.00						
	6	73	12.00						
	7	73	7.50						
	8	73	5.10						
	9	73	5.70						

APPENDIX C

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 75/02/04

264001
42 46 00.0 085 08 42.0
JORDAN LAKE
26 MICHIGAN

11EPALES 2111202
3 0037 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
72/06/15	06 00	0000	20.2	8.4	66	375	8.75	134	1.000	0.100	0.039	0.023
	06 00	0020	11.5	2.5		460	7.35	166	0.820	0.510	0.039	0.029
	06 00	0037	8.5	0.1		430	7.33	177	1.500	0.640	0.342	0.324
72/09/18	15 20	0000			72	340	9.00	118	0.070	0.180	0.021	0.010
	15 20	0004	19.9	8.4		340	8.90	119	0.070	0.200	0.021	0.011
	15 20	0015	19.0	6.1		345	8.75	111	0.050	0.260	0.023	0.010
	15 20	0023	15.2	0.0		420	7.75	148	0.080	2.020	0.122	0.096
	15 20	0030	10.3	0.0		480	7.65	180	0.080	3.090	0.373	0.326
	15 20	0038	8.6	0.0		500	7.55	202	0.080	4.960	0.600	0.600
72/11/15	09 10	0000			72	440	7.70	161	0.540	1.430	0.184	0.151
	09 10	0004	6.3	9.0		425	7.70	162	0.540	1.320	0.197	0.152
	09 10	0015	6.4	9.0		420	7.70	160	0.540	1.420	0.190	0.150
	09 10	0022	6.4	9.0		420	7.70	161	0.530	1.360	0.188	0.149
	09 10	0032	6.4	9.0		420	7.70	161	0.540	1.340	0.190	0.147
	09 10	0044	6.3	8.6		440	7.70	162	0.530	1.270	0.187	0.149

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/15	06 00	0000	21.8J
72/09/18	15 20	0000	14.7J
72/11/15	09 10	0000	30.0J

J VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 75/02/04

264002
42 46 24.0 085 08 00.0
JORDAN LAKE
26 MICHIGAN

11EPALES 2111202
3 0032 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
72/06/15	06 30	0000	20.6	9.6	60	350	8.91	130	0.910	0.080	0.044	0.034
	06 30	0015	17.0	4.5		440	7.75	165	1.800	0.560	0.049	0.042
	06 30	0032	9.5	0.2		450	7.40	175	1.000	1.600	0.311	0.296
72/09/18	16 00	0000			68	340	9.00	107	0.060	0.140	0.016	0.008
	16 00	0004	19.8	7.8		322	9.00	108	0.050	0.150	0.016	0.008
	16 00	0015	19.0	6.4		340	8.75	110	0.060	0.280	0.015	0.008
	16 00	0023	12.6	0.0		440	7.80	162	0.130	2.690	0.182	0.156
	16 00	0030	9.8	0.0		470	7.58	183	0.140	4.030	0.504	0.440
	16 00	0038	8.6	0.0		500	7.45	210	0.100	5.980	0.730	0.685
72/11/15	08 40	0000			96	440	7.70	164	0.600	1.210	0.176	0.145
	08 40	0004	6.3	9.4		420	7.70	166	0.680	1.340	0.164	0.136
	08 40	0015	6.4	9.0		420	7.70	165	0.680	1.310	0.167	0.138
	08 40	0022	6.4	8.8		430	7.70	164	0.690	1.660	0.171	0.136
	08 40	0035	6.3	8.8		435	7.70	170	0.790	1.660	0.168	0.134

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/15	06 30	0000	16.3J
72/09/18	16 00	0000	9.3J
72/11/15	08 40	0000	31.0J

J VALUE KNOWN TO BE IN ERROR

APPENDIX D

TRIBUTARY DATA

STORET RETRIEVAL DATE 75/02/04

2640A1 LS2640A1
42 45 30.0 085 09 00.0
LITTLE THORNAPPLE RIVER
26 15 IONIA
O/JORDAN LAKE
BROWN RD BRDG S JORDAN LAKE
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
72/10/28	08 50		0.299	2.100	0.825	0.138	0.190
72/11/28	15 30		0.860	1.760	0.560	0.120	0.171
73/01/08	15 50		2.200	1.400	0.390	0.095	0.132
73/02/04			1.900	1.260	0.270	0.066	0.115
73/02/28	07 30		2.080	1.100	0.160	0.034	0.106
73/04/06	11 35		2.200	1.100	0.060	0.036	0.080
73/04/20	15 15		2.040	1.260	0.027	0.028	0.100
73/05/04	11 55		1.840	1.000	0.075	0.040	0.070
73/05/24	15 30		1.260	0.940	0.032	0.011	0.065
73/06/08	11 27		1.160	1.180	0.105	0.016	0.050
73/07/04	20 28		0.450	1.500	0.031	0.019	0.070
73/07/27	19 40		0.220	1.320	0.110	0.017	0.065
73/08/31	12 21		0.189	0.780	0.065	0.009	0.070
73/09/24	13 23		0.294	0.750	0.100		

STORET RETRIEVAL DATE 75/02/04

264081 LS264081
42 46 30.0 085 07 30.0
TUPPER LAKE/JORDAN LAKE CONNECT
26 15 IONIA
1/JORDAN LAKE
RD BRDG ACROS TUPPER CRK NEOF JORDAN LK
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
72/10/28	08 30		0.500	3.350	0.490	0.105	0.147
73/01/08	10 00		3.500	1.400	0.160	0.095	0.140
73/02/04	16 45		3.300	0.575	0.082	0.050	0.085
73/02/28	07 20		2.900	3.300	1.600	0.200	0.340
73/04/06	11 30		2.200	0.960	0.060	0.030	0.080
73/04/20	15 30		2.200	1.320	0.023	0.015	0.085
73/05/04	11 45		2.120	1.100	0.039	0.014	0.050
73/05/24	15 40		1.400	1.050	0.092	0.038	0.075
73/06/08	11 17		1.900	1.400	0.110	0.072	0.095
73/07/04	20 40		1.340	1.260	0.072	0.042	0.090
73/07/27	20 00		0.660	1.000	0.062	0.069	0.115
73/08/31	12 11		0.200	0.960	0.110	0.060	0.125
73/09/24			0.198	0.620	0.091	0.030	0.050