U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

REPORT

ON

BARTON LAKE

KALAMAZOO COUNTY

MICHIGAN

EPA REGION V

WORKING PAPER No. 183

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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With the cooperation of the

Michigan Department of Natural Resources

and the

Michigan National Guard

February, 1975

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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; 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 identfying point sources and soliciting municipal participation in the Survey.

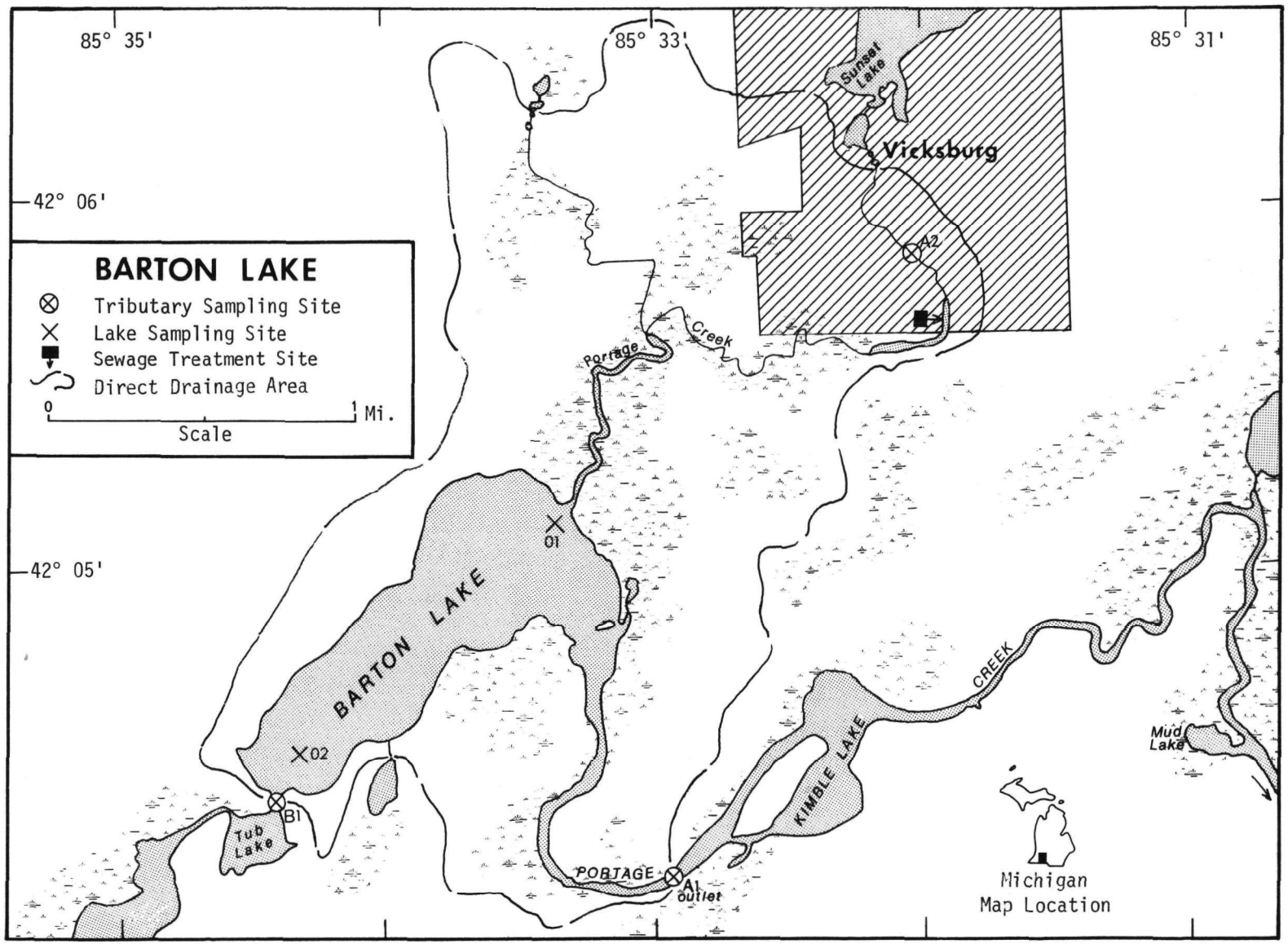
Major General Clarence A. Schnipke (Retired), then the Adjutant General of Michigan, and Project Officer Colonel Albert W. Lesky, who directed the volunteer efforts of the Michigan National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

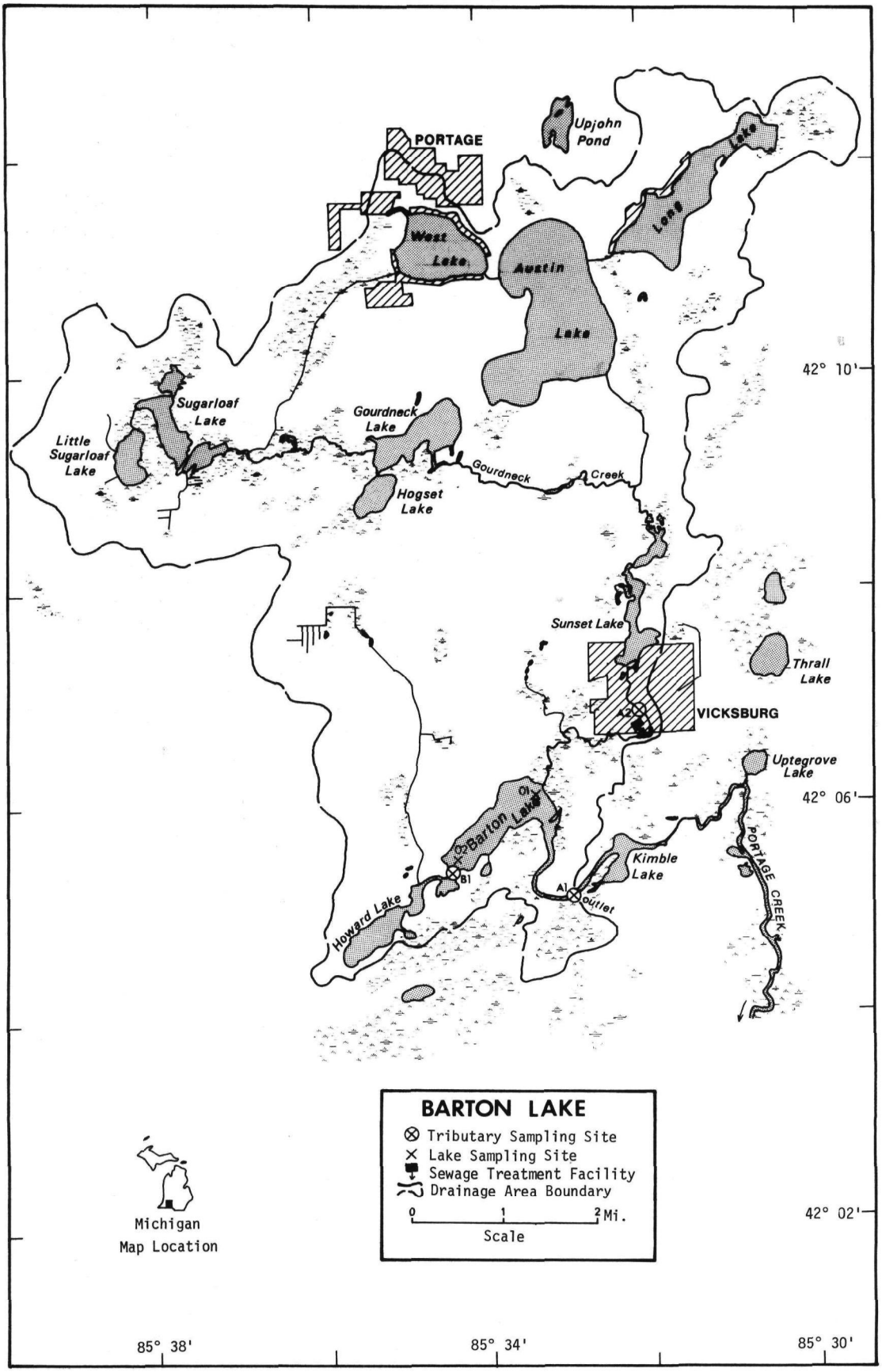
NATIONAL EUTROPHICATION SURVEY

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


85° 35'
85° 33'
85° 31'
42° 06'
42° 05'
BARTON LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Site
Direct Drainage Area
0
1 Mi.
Scale
Sunset Lake
Vicksburg
A2
Portage
Creek
O1
BARTON LAKE
O2
B1
Tub Lake
PORTAGE
A1
outlet
KIMBLE LAKE
CREEK
Mud Lake
Michigan
Map Location


PORTAGE
Upjohn Pond
West Lake
Austin Lake
Long Lake
Sugarloaf Lake
Little Sugarloaf Lake
Gourdneck Lake
Hogset Lake
Gourdneck Creek
Sunset Lake
Thrall Lake
VICKSBURG
Uptegrove Lake
Barton Lake
Kimble Lake
Howard Lake
Outlet
PORTAGE CREEK
42° 10'
42° 06'
42° 02'
85° 38'
85° 34'
85° 30'
BARTON LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Drainage Area Boundary
0 1 2 Mi.
Scale
Michigan
Map Location

BARTON LAKE

STORET NO. 2606

I. CONCLUSIONS

A. Trophic Condition:

Survey data and the records of others (Fetterolf, 1962; et al.) show that Barton Lake is eutrophic. Of the 35 Michigan lakes sampled in the fall of 1972, when essentially all were well-mixed, 26 had less mean total phosphorus, 27 had less mean dissolved phosphorus, and 29 had less mean inorganic nitrogen; of the 41 Michigan lakes sampled, 27 had greater Secchi disc transparency, and 29 had less mean chlorophyll a than Barton Lake*.

Barton Lake has a history of severe algal blooms and generally poor water quality. Survey limnologists noted algal blooms on all sampling dates, and hydrogen sulfide was detected in samples taken below 15 feet at station 2 in June and September.

B. Rate-Limiting Nutrient:

The results of the algal assay show that phosphorus was the limiting nutrient at the time the sample was collected. The lake data indicate that phosphorus was the limiting nutrient at the other sampling times as well (i.e., all N/P ratios were greater than 14/1).

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* See Appendix A.

C. Nutrient Controllability:

1. Point sources--During the sampling year, Barton Lake received a total phosphorus load at a rate a little more than twice the rate proposed by Vollenweider (in press) as "dangerous"; i.e., a eutrophic rate (see page 14). It is calculated that the Village of Vicksburg contributed nearly 66% of the total load.

Provision of 80% phosphorus removal at the Vicksburg waste treatment plant would reduce the loading rate to about 9 lbs/acre/yr or 1.01 $g/m^2/yr$. This rate is just equal to Vollenweider's eutrophic rate and, considering the relatively short detention time of Barton Lake (81 days), should result in a marked improvement in the trophic condition of the lake. In particular, it would be expected that the incidence and severity of nuisance algal blooms would be reduced once a new phosphorus equilibrium becomes established.

During the sampling year, there appeared to be very little retention of phosphorus in the lake (60 pounds) and a loss of nitrogen (over 50,000 pounds). While this could have been due to insufficient sampling, it is possible that some portion of the unmeasured nutrient loads from the Simpson-Lee Paper Company at Vicksburg reached the lake and resulted in the nutrient imbalance noted above (see page 13).

2. Non-point sources (see page 13)--It is calculated that non-point sources, including precipitation, contributed about 33% of the phosphorus load to Barton Lake during the sampling year. However, the phosphorus exports of the sampled Barton Lake tributaries were rather low and compare well with the exports of unimpacted Michigan streams sampled elsewhere.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 347 acres.

2. Mean depth: 20 feet.

3. Maximum depth: 53 feet.

4. Volume: 6,940 acre-feet.

5. Mean hydraulic retention time: 81 days.

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

1. Tributaries -

Name	Drainage area*	Mean flow*
Portage Creek	35.0 mi^2	30.4 cfs
Tub Lake outlet (B-1)	3.4 mi^2	3.0 cfs
Minor tributaries & immediate drainage -	11.0 mi^2	10.0 cfs
Totals	49.4 mi^2	43.4 cfs

2. Outlet -

Portage Creek	49.9 mi^2**	43.4 cfs

C. Precipitation***:

1. Year of sampling: 40.7 inches.

2. Mean annual: 32.2 inches.

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† Mean and maximum depths were estimated by Fetterolf (1973); volume and retention time were calculated using these estimates.
* 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

Barton 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 usually from a number of depths at each station (see map, page v). During each visit, a single depth-integrated (15 feet or near bottom 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 analysis. The maximum depths sampled were 22 feet at station 1 and 24 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 was essentially 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 (11/12/72)		
Temperature (Cent.)	7.9	7.9	7.9	7.9
Dissolved oxygen (mg/l)	9.0	9.3	9.4	9.6
Conductivity (μmhos)	400	401	400	410
pH (units)	7.8	7.8	7.8	7.9
Alkalinity (mg/l)	168	176	178	183
Total P (mg/l)	0.101	0.121	0.127	0.131
Dissolved P (mg/l)	0.081	0.086	0.086	0.093
$NO_2 + NO_3$ (mg/l)	0.350	0.377	0.380	0.400
Ammonia (mg/l)	1.040	1.111	1.130	1.170
		ALL VALUES		
Secchi disc (inches)	22	44	34	72

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Number per ml
06/13/72	1. Fragilaria	476
	2. Melosira	301
	3. Oscillatoria	259
	4. Synedra	169
	5. Tabellaria	84
	Other genera	163
	Total	1,452
09/17/72	1. Anabaena	2,651
	2. Melosira	904
	3. Flagellates	281
	4. Lyngbya	221
	5. Flagilaria	100
	Other genera	160
	Total	4,317
11/12/72	1. Asterionella	1,022
	2. Melosira	542
	3. Fragilaria	289
	4. Stephanodiscus	126
	5. Anabaena	118
	Other genera	28
	Total	2,125

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)
06/13/72	01	67.9
	02	12.0
09/17/72	01	22.8
	02	16.8
11/12/72	01	22.6
	02	24.7

C. Limiting Nutrient Study:

1. Filtered and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.032	0.852	3.3
0.010 P	0.042	0.852	6.7
0.020 P	0.052	0.852	10.2
0.050 P	0.082	0.852	11.5
0.050 P + 5.0 N	0.082	5.852	23.0
0.050 P + 10.0 N	0.082	10.852	22.5
10.0 N	0.032	10.852	3.1

2. Discussion -

The control yield of the assay alga, *Selenastrum capricornutum*, indicates that the potential primary productivity of Barton Lake was moderately high at the time the sample was collected.

Also, the increased yields with increased increments of orthophosphorus show that the lake was phosphorus limited

(note that the addition of only nitrogen resulted in a yield no greater than the control yield).

The lake data indicate phosphorus limitation at the other sampling times as well (i.e., the N/P ratios exceeded 14/1, and phosphorus limitation would be expected).

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 the months of April, May, August, and December 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 Vicksburg wastewater treatment plant provided monthly effluent samples and corresponding flow data.

The Simpson-Lee Paper Company discharged wastewater to Portage Creek prior to December, 1971. Since then, the wastes have been disposed of by spray irrigation on a highland area adjacent to and east of Portage Creek. However, during the winter months, the wastes are directed to

* See Working Paper No. 1.

a marsh area nearer the creek. About three million gallons of water per day are used, and Company records show that about 20 pounds of total phosphorus and about 56 pounds of total nitrogen were discharged per day as of September, 1973 (Fetterolf, 1974). Although there is no direct evidence of it, it is possible that some portion of these nutrients reached Barton Lake and resulted in the minimal accumulation of phosphorus and the loss of nitrogen shown in the following loading tables.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (mgd)	Receiving Water
Vicksburg	1,700	trickling filter	0.150	Portage Creek

2. Known industrial** -

Name	Product	Treatment	Mean Flow (mgd)	Receiving Water
Simpson-Lee Paper Co.	paper	spray irrigation	3.000	?

* Eyer, 1973.
** Fetterolf, 1974.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Portage Creek	1,570	23.6
Tub Lake outlet (B-1)	120	1.8
b. Minor tributaries & immediate drainage (non-point load) -	440	6.6
c. Known municipal STP's -		
Vicksburg	4,380	66.0
d. Septic tanks* -	80	1.2
e. Known industrial -		
Simpson-Lee Paper Company	?	-
f. Direct precipitation** -	50	0.8
Total	6,640	100.0

2. Outputs -

Lake outlet - Portage Creek 6,580

3. Net annual P accumulation - 60 pounds

* Estimated 121 seasonal shoreline 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) -		
Portage Creek	48,010	45.5
Tub Lake outlet (B-1)	12,540	11.9
b. Minor tributaries & immediate drainage (non-point load) -	27,830	26.4
c. Known municipal STP's -		
Vicksburg	10,970	10.4
d. Septic tanks* -	2,850	2.7
e. Known industrial -		
Simpson-Lee Paper Company	?	-
f. Direct precipitation** -	3,340	3.1
Total	105,540	100.0

2. Outputs -

Lake outlet - Portage Creek 156,390

3. Net annual N loss - 50,850 pounds

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

Tributary	lbs P/mi^2/yr	lbs N/mi^2/yr
Portage Creek	45	1,372
Tub Lake outlet (B-1)	35	3,688

* Estimated 121 seasonal shoreline dwellings; 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 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	19.1	0.2	304.1	loss*
grams/m^2/yr	2.14	0.02	34.1	-

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

"Dangerous" (eutrophic rate)	1.00
"Permissible" (oligotrophic rate)	0.50

* There was an apparent loss of nitrogen during the sampling year. This may have been due to nitrogen fixation in the lake, solubilization of previously sedimented nitrogen, recharge with nitrogen-rich ground water, unknown and unsampled point sources discharging directly to the lake, or possible nitrogen loads from the Simpson-Lee Paper Company. Whatever the cause, a similar nitrogen loss has occurred at Shagawa Lake, Minnesota, which has been intensively studied by EPA's National Eutrophication and Lake Restoration Branch.

V. LITERATURE REVIEWED

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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 2606 BARTON LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 49.90

TRIBUTARY	SUB-DRAINAGE AREA(SQ MI)	NORMALIZED FLOWS(CFS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2606A1	49.90	46.20	56.50	69.90	80.50	57.00	41.30	29.10	22.20	21.70	24.30	30.80	42.50	43.39
2606A2	35.00	32.40	39.60	49.10	56.50	40.00	28.90	20.40	15.50	15.20	17.00	21.60	29.80	30.42
2606B1	3.40	3.20	3.80	4.80	5.50	3.90	2.80	2.00	1.50	1.50	1.70	2.10	2.90	2.97
2606ZZ	11.50	10.70	13.00	16.10	18.50	13.10	9.60	6.70	5.10	5.00	5.60	7.10	9.80	10.00

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 49.90 TOTAL FLOW IN = 522.00
SUM OF SUB-DRAINAGE AREAS = 49.90 TOTAL FLOW OUT = 522.00

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2606A1	10	72	31.00	28	37.00				
	11	72	43.00						
	12	72	51.00	2	40.00	31	112.00		
	1	73	89.00						
	2	73	56.00	11	59.00				
	3	73	79.00	11	75.00				
	4	73	81.00	14	70.00	23	121.00		
	5	73	67.00	8	70.00	24	72.00		
	6	73	59.00	30	34.00				
	7	73	32.00						
	8	73	30.00	6	33.00	29	25.00		
	9	73	22.00						
	10	73	40.00	24	37.00				
2606A2	10	72	22.00	28	26.00				
	11	72	30.00						
	12	72	36.00	2	28.00	31	78.00		
	1	73	63.00						
	2	73	39.00	11	42.00				
	3	73	55.00	11	52.00				
	4	73	57.00	14	49.00	23	85.00		
	5	73	47.00	8	49.00	24	51.00		
	6	73	41.00	30	24.00				
	7	73	22.00						
	8	73	21.00	6	23.00	29	17.00		
	9	73	15.00						
	10	73	28.00	24	26.00				

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2606 BARTON LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2606B1	10	72	2.10	28	2.50				
	11	72	3.00						
	12	72	3.50	2	2.70	31	7.60		
	1	73	6.10						
	2	73	3.80	11	4.00				
	3	73	5.40	11	5.10				
	4	73	5.60	14	4.80	23	8.20		
	5	73	4.60	8	4.80	24	5.00		
	6	73	4.00	30	2.30				
	7	73	2.20						
	8	73	2.10	6	2.20	29	1.70		
	9	73	1.50						
	10	73	2.70	24	2.50				
2606Z2	10	72	7.10						
	11	72	10.00						
	12	72	12.00						
	1	73	21.00						
	2	73	13.00						
	3	73	18.00						
	4	73	19.00						
	5	73	16.00						
	6	73	14.00						
	7	73	7.30						
	8	73	7.00						
	9	73	5.10						
	10	73	9.30						

APPENDIX C

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 75/02/04

260501
42 06 00.0 085 33 30.0
BARTON LAKE
26 MICHIGAN

11EPALES 2111202
4 0004 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
72/06/13	11 00	0004	20.8	11.4	30	400	8.70	161	0.090	0.090	0.032	0.017
72/09/17	15 50	0000			22	350	8.38	136	0.140	0.160	0.057	0.017
	15 50	0004	19.9	9.1		350	8.20	134	0.110	0.130	0.063	0.014
72/11/12	11 30	0000			72	410	7.90	179	0.360	1.170	0.101	0.088
	11 30	0004	7.9	9.6		400	7.90	180	0.360	1.140	0.105	0.085
	11 30	0015	7.9	9.6		400	7.90	182	0.350	1.120	0.131	0.093
	11 30	0022	7.9	9.6		400	7.90	183	0.350	1.140	0.128	0.088

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/13	11 00	0000	57.9J
72/09/17	15 50	0000	22.6J
72/11/12	11 30	0000	22.6J

J VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 75/02/04

260602
42 05 30.0 085 34 30.0
BARTON LAKE
26 MICHIGAN

11EPALES 2111202
4 0025 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
72/06/13	11 55	0000	19.8	10.5	36	355	8.65	164	0.160	0.030	0.022	0.020
	11 55	0008	18.9	8.9		380	8.50	165	0.140	0.090	0.025	0.017
	11 55	0016	12.5	1.7		440	7.90	181	0.380	0.580	0.015	0.010
	11 55	0024	11.8	0.1		400	7.80	183	0.030	0.980	0.059	0.043
72/09/17	16 16	0000			31	350	8.30	138	0.120	0.130	0.057	0.015
	16 16	0004	18.9	7.4		360	8.05	136	0.110	0.150	0.047	0.011
	16 16	0010	18.7	6.9		350	8.10	137	0.110	0.220	0.034	0.012
	16 16	0015	18.5	6.4		360	8.00	138	0.120	0.280	0.036	0.013
	16 16	0021	13.2	0.0		430	7.23	186	0.040	3.090	0.331	0.244
72/11/12	11 50	0000			72	400	7.80	168	0.400	1.080	0.130	0.084
	11 50	0004	7.9	9.2		400	7.80	169	0.400	1.150	0.119	0.081
	11 50	0012	7.9	9.1		400	7.80	171	0.400	1.050	0.128	0.088
	11 50	0019	7.9	9.0		400	7.80	176	0.400	1.040	0.127	0.083

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/13	11 55	0000	12.0J
72/09/17	16 16	0000	16.8J
72/11/12	11 50	0000	24.7J

J VALUE KNOWN TO BE IN ERROR

APPENDIX D

TRIBUTARY FLOW DATA

STORET RETRIEVAL DATE 75/02/04

2606A1 LS2606A1
42 05 00.0 085 33 00.0
PORTAGE CREEK
26 7.5 VICKSBURG
0/BARTON LAKE
22ND ST BRDG 2 MI SSW VICKSBURG
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	15 20		0.340	1.300	0.770	0.085	0.150
72/12/02	14 45		0.360	1.540	0.490	0.039	0.095
72/12/31	14 15		0.470	1.300	0.410	0.029	0.056
73/02/11	14 30		0.760	1.890	0.260	0.019	0.055
73/03/11	10 30		0.520	1.100	0.240	0.026	0.075
73/04/14	15 30		0.450	0.840	0.034	0.008	0.050
73/04/23	12 30		0.510	1.300	0.069	0.031	0.090
73/05/08	15 33		0.440		0.080	0.021	0.060
73/05/24	21 05		0.350	1.100	0.094	0.018	0.060
73/06/30	09 00		0.025	1.470	0.069	0.015	0.075
73/08/06	14 40		0.013	1.500	0.029	0.022	0.070
73/08/29	15 30		0.014	3.100	0.092	0.016	0.060
73/10/24	15 50		0.140	1.350	0.210	0.019	0.090

STORET RETRIEVAL DATE 75/02/04

2606A2 LS2606A2
42 07 00.0 085 32 00.0
PORTAGE CREEK
26 7.5 VICKSBURG
T/BARTON LAKE
AT "W" AVE BRDG IN VICKSBURG ABOVE STP
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	15 00		0.043	0.500	0.044	0.005K	0.022
72/12/02	15 40		0.042	0.440	0.077	0.008	0.024
72/12/31	13 20		0.230	0.820	0.036	0.005K	0.021
73/03/11	10 35		0.138	0.400	0.042	0.009	0.030
73/04/14	15 00		0.060	0.560	0.050	0.006	0.042
73/04/23	12 00		0.010K	1.100	0.025	0.007	0.030
73/05/08	15 22		0.042	0.710	0.060	0.010	0.020
73/05/24	20 35		0.066	0.640	0.099	0.011	0.030
73/06/30	08 30		0.017	0.670	0.029	0.005K	0.020
73/08/06	14 10		0.010K	0.920	0.033	0.013	0.015
73/08/29	14 50		0.012	1.570	0.093	0.024	0.025
73/10/24	15 30		0.010K	0.500	0.017	0.005K	0.030

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

260681 LS260681
42 05 30.0 085 34 30.0
TOB LK/BARTON LK CONNECT
26 7.5 VICKSBURG
I/BARTON LAKE
XY AVE BRDG 2 MI SW VICKSBURG
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	15 35		1.110	0.800	0.231	0.005K	0.020
72/12/31	14 35		2.050	3.200	0.198	0.010	0.036
73/02/11	14 15		2.000	0.560	0.049	0.006	0.010
73/03/11	10 15		1.780	0.520	0.062	0.006	0.015
73/04/14	15 45		1.680	0.540	0.044	0.005K	0.025K
73/04/23			1.660	1.050	0.016	0.005K	0.030
73/05/08	16 05		1.620	0.640	0.050	0.006	0.020
73/05/24	21 15		1.540	0.880	0.031	0.006	0.030
73/06/30	09 15		1.260	0.510	0.042	0.005K	0.010
73/08/06	14 55		1.100	0.600	0.024	0.010	0.010
73/08/29	15 40		1.060	0.600	0.087	0.005K	0.020
73/10/24	16 05		1.320	0.500	0.084	0.007	0.015

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

260650 TF260650 P001700
42 07 00.0 085 32 00.0
VICKSBURG
26 7.5 VICKSBURG
T/BARTON LAKE
PORTAGE CREEK
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
73/01/03	08 00								
CP(T)-			0.560	22.000	7.400	5.100	9.800	0.156	0.113
73/01/04	08 00								
73/02/12	08 00								
CP(T)-			3.400	23.000	9.900	9.300	12.000	0.125	0.124
73/02/13	08 00								
73/03/06	08 00								
CP(T)-			2.300	21.000	8.400	8.300	8.750	0.116	0.114
73/03/07	08 00								
73/04/05	08 00								
CP(T)-			2.300	22.000	7.300	5.900	8.500	0.114	0.119
73/04/06	08 00								
73/05/10	08 00								
CP(T)-			1.260	20.000	7.100	7.800	9.100	0.123	0.117
73/05/11	08 00								
73/12/04	08 00								
CP(T)-			2.200	27.000	10.000	7.200	9.900	0.175	0.179
73/12/05	08 00								
73/12/12	08 00								
CP(T)-			4.800	24.000	8.500	7.700	10.000	0.178	0.179
73/12/13	08 00								
74/01/04	08 00								
CP(T)-			5.520	19.000	7.200	7.500	9.300	0.119	0.161
74/01/05	08 00								
74/01/09	08 00								
CP(T)-			3.900	20.000	8.300	7.300	9.000	0.166	0.169
74/01/10	08 00								
74/02/05	08 00								
CP(T)-			5.040	15.000	4.000	6.200	8.300	0.164	0.166
74/02/06	08 00								
74/03/08	08 00								
CP(T)-			5.280	16.000	3.600	6.400	8.050	0.215	0.194
74/03/09	08 00								
74/04/03	08 00								
CP(T)-			4.500	8.600	4.600	6.400	8.500	0.215	0.203
74/04/04	08 00								

STORET RETRIEVAL DATE 75/02/04

260650 TF260650 P001700
42 07 00.0 085 32 00.0
VICKSBURG
26 7.5 VICKSBURG
T/BARTON LAKE
PORTAGE CREEK
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
74/06/07	08	00							
CP(T)-			2.880	17.000	4.400	5.800	7.350	0.191	0.204
74/06/08	08	00							