U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

REPORT

ON

MARSH LAKE

STEUBEN COUNTY

INDIANA

EPA REGION V

WORKING PAPER No. 333

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON

and

ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

☆G.P.O. 699-440

REPORT
ON
MARSH LAKE
STEUBEN COUNTY
INDIANA
EPA REGION V
WORKING PAPER No. 333

WITH THE COOPERATION OF THE
INDIANA STATE BOARD OF HEALTH
AND THE
INDIANA NATIONAL GUARD
MARCH, 1976

CONTENTS

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 Indiana State Board of Health for professional involvement, to the Indiana National Guard for conducting the tributary sampling phase of the Survey, and to those Indiana wastewater treatment plant operators who provided effluent samples and flow data.

The staff of the Division of Water Pollution Control, Indiana State Board of Health, provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

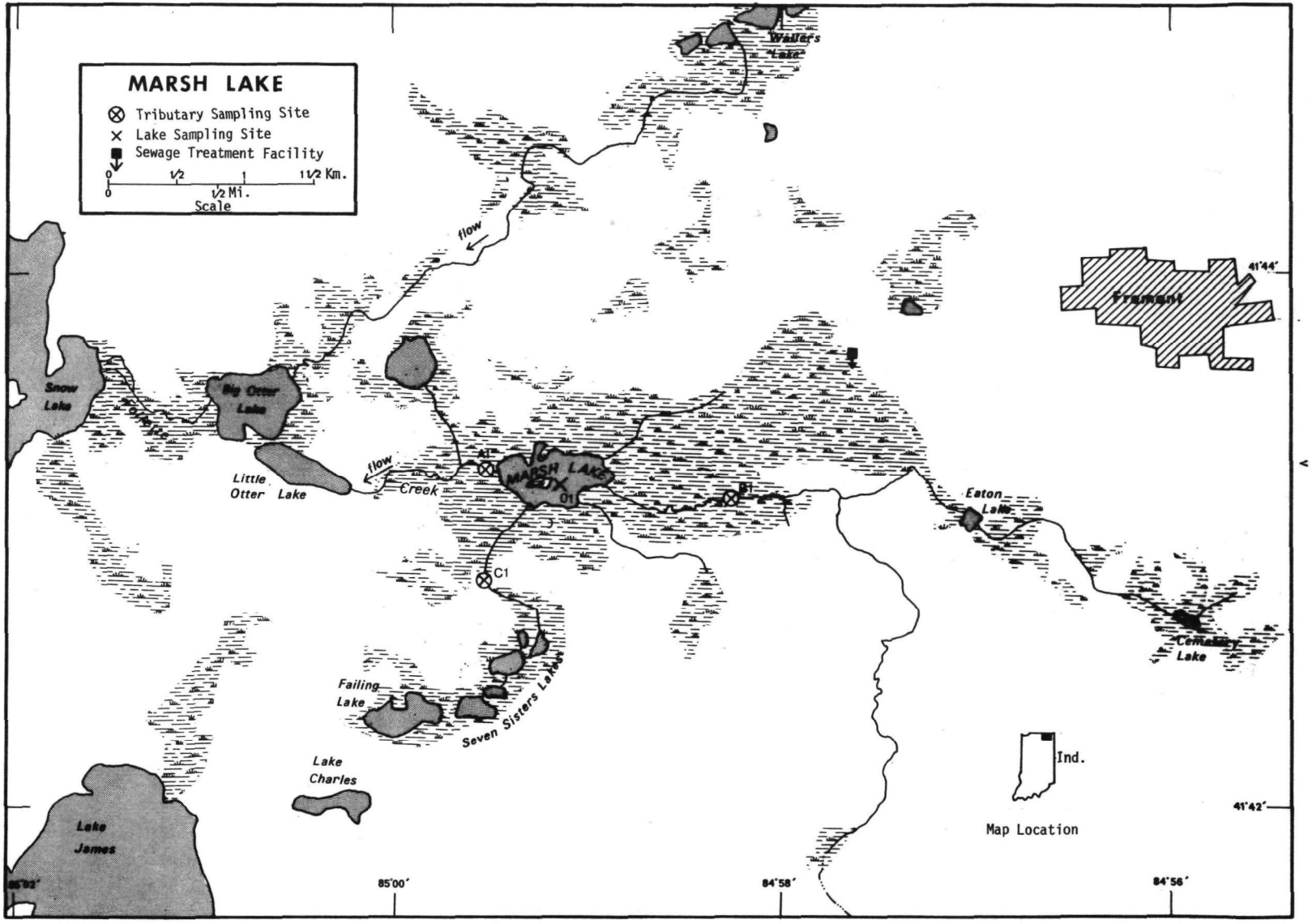
Major General Alfred F. Ahner, Adjutant General of Indiana, and Project Officers Lt. Colonel Charles B. Roberts (Retired) and Colonel Robert L. Sharp, who directed the volunteer efforts of the Indiana National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF INDIANA

LAKE NAME	COUNTY
Bass	Starke
Cataract	Owen, Putnam
Crooked	Steuben
Dallas	LaGrange
Geist	Hamilton, Marion
Hamilton	Steuben
Hovey	Posey
James	Kosciusko
James	Steuben
Long	Steuben
Marsh	Steuben
Mississinewa	Grant, Miami, Wabash
Maxinkuckee	Marshall
Monroe	Brown, Monroe
Morse	Hamilton
Olin	LaGrange
Oliver	LaGrange
Pigeon	Steuben
Sylvan	Noble
Tippecanoe	Kosciusko
Versailles	Ripley
Wawassee	Kosciusko
Webster	Kosciusko
Westler	LaGrange
Whitewater	Union
Winona	Kosciusko
Witmer	LaGrange


MARSH LAKE
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
0 1/2 1 1 1/2 Km.
0 1/2 Mi.
Scale
Waller's Lake
flow
Fremont
41°44'
Snow Lake
Big Otter Lake
Little Otter Lake
flow
Creek
A1
MARSH LAKE
01
B1
Eaton Lake
C1
Failing Lake
Seven Sisters Lakes
Lake Charles
Lake James
Cemetery Lake
Ind.
Map Location
41°42'
85°02'
85°00'
84°58'
84°56'

MARSH LAKE

STORET NO. 1856

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Marsh Lake is eutrophic. It ranked 21st in overall trophic quality when the 27 Indiana lakes sampled in 1973 were compared using a combination of six parameters*. Twenty-two of the lakes had less median total phosphorus, 25 had less median dissolved phosphorus, seven had less median inorganic nitrogen, 22 had less mean chlorophyll a, and 17 had greater mean Secchi disc transparency. Dissolved oxygen was depleted in the hypolimnion in August and October.

Survey limnologists reported emergent macrophytes in the shoreline shallows around the lake and the island.

B. Rate-Limiting Nutrient:

Because of a significant loss of nutrients in the sample before the algal assay was begun, the results are not representative of conditions in the lake at the time the sample was taken (05/03/73).

The lake data indicate nitrogen limitation at all sampling times.

C. Nutrient Controllability:

1. Point sources--During the sampling year, Marsh Lake

* See Appendix A.

received a total phosphorus loading more than four times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 12). The Village of Fremont contributed 80% of that load.

It is calculated that removal of 97% of the phosphorus at the Fremont wastewater treatment plant would reduce the phosphorus loading to just equal the eutrophic loading. Short of effluent diversion, it is questionable whether removal at that level can be accomplished on a continuing basis. However, a high degree of phosphorus removal at the point source is likely to result in persistent phosphorus limitation in Marsh Lake and should at least reduce the incidence and severity of nuisance algal blooms.

2. Non-point sources--The non-point source phosphorus load was estimated to be 20% of the total. The gaged tributaries were estimated to have contributed 13.6% of the total, and the ungaged tributaries were estimated to have contributed 6.1%.

The phosphorus export rate of Unnamed Creek C-1 (7 $kg/km^2/yr$) was quite low as compared to Indiana streams sampled elsewhere (see page 11).

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 0.23 kilometers^2.
2. Mean depth: 6.1 meters.
3. Maximum depth: 11.6 meters.
4. Volume: 1.403×10^6 m^3.
5. Mean hydraulic retention time: 45 days.

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

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Unnamed Creek B-1	21.0	0.20
Unnamed Creek C-1	5.4	0.05
Minor tributaries & immediate drainage -	12.0	0.11
Total	38.4	0.36

2. Outlet -

Follett Creek	38.6**	0.36

C. Precipitation***:

1. Year of sampling: 111.6 centimeters.
2. Mean annual: 91.3 centimeters.

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† Table of metric conversions--Appendix B.
†† Winters, 1973.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake.
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Marsh Lake was sampled three times during the open-water season of 1973 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at a single station on the lake (see map, page v). During each visit, a single depth-integrated (4.6 m to surface) sample was collected for phytoplankton identification and enumeration, and a similar sample was taken for chlorophyll *a* analysis. During the first visit, a single 18.9-liter depth-integrated sample was collected for algal assays. The maximum depth sampled was 10.7 meters.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR MARSH LAKE
STORET CODE 1856

PARAMETER	1ST SAMPLING (5/ 3/73) 1 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (8/ 6/73) 1 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING (10/15/73) 1 SITES RANGE	MEAN	MEDIAN
TEMP (C)	8.7 - 12.7	11.4	12.7	10.1 - 25.4	16.2	13.5	8.9 - 16.7	13.1	13.4
DISS OXY (MG/L)	5.2 - 10.0	8.5	9.4	0.0 - 18.0	7.0	2.8	0.0 - 9.4	3.1	1.5
CNDCTVY (MCROMO)	625. - 650.	643.	650.	470. - 611.	525.	489.	497. - 557.	527.	527.
PH (STAND UNITS)	8.0 - 8.4	8.3	8.3	7.4 - 8.6	8.0	7.9	7.1 - 8.4	7.7	7.7
TOT ALK (MG/L)	210. - 250.	233.	238.	258. - 420.	304.	276.	270. - 355.	307.	301.
TOT P (MG/L)	0.045 - 0.215	0.084	0.053	0.078 - 1.480	0.388	0.101	0.053 - 0.808	0.385	0.180
ORTHO P (MG/L)	0.009 - 0.194	0.053	0.019	0.019 - 1.300	0.324	0.066	0.009 - 0.688	0.236	0.123
NO2+NO3 (MG/L)	0.060 - 0.310	0.142	0.070	0.070 - 0.240	0.106	0.070	0.070 - 0.110	0.087	0.085
AMMONIA (MG/L)	0.060 - 0.620	0.198	0.080	0.070 - 3.900	0.894	0.090	0.080 - 7.680	2.595	1.310
KJEL N (MG/L)	1.000 - 1.400	1.120	1.100	0.900 - 5.500	2.020	1.200	1.000 -10.100	3.850	2.150
INORG N (MG/L)	0.120 - 0.930	0.340	0.150	0.140 - 4.140	1.000	0.170	0.150 - 7.770	2.682	1.405
TOTAL N (MG/L)	1.060 - 1.710	1.262	1.170	0.980 - 5.740	2.126	1.270	1.070 -10.190	3.937	2.245
CHLRPYL A (UG/L)	33.4 - 33.4	33.4	33.4	19.4 - 19.4	19.4	19.4	50.6 - 50.6	50.6	50.6
SECCHI (METERS)	1.2 - 1.2	1.2	1.2	1.3 - 1.3	1.3	1.3	1.2 - 1.2	1.2	1.2

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
05/03/73	1. Dinobryon sp.	19,189
	2. Flagellates	5,586
	3. Cryptomonas sp.	811
	4. Cyclotella sp.	450
	5. Raphidiopsis sp.	360
	Other genera	541
	Total	26,937
08/06/73	1. Gloeocystis sp.	124
	2. Oscillatoria sp.	74
	3. Melosira sp.	74
	4. Anabaena sp.	50
	5. Microcystis sp.	25
	Other genera	50
	Total	397
10/15/73	1. Fragilaria sp.	9,824
	2. Aphanizomenon sp.	1,027
	3. Cryptomonas sp.	469
	4. Oscillatoria sp.	67
	5. Anabaena sp.	22
	Other genera	66
	Total	11,475

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
05/03/73	1	33.4
08/06/73	1	19.4
10/15/73	1	50.6

C. Limiting Nutrient Study:

There was a 62% loss of orthophosphorus in the assay sample from the time of collection to the beginning of the assay, and the results are not representative of conditions in the lake at the time the sample was taken (05/03/73).

The lake data indicate nitrogen limitation; i.e., the mean inorganic nitrogen/orthophosphorus ratios were 11/1 or less at all sampling times, and nitrogen limitation would be expected.

Nitrogen limitation, as indicated by in-lake nitrogen to phosphorus ratios, does not necessarily mean that the trophic condition of the lake can be improved by controlling nitrogen inputs. In many cases, the apparent condition of nitrogen-limitation results from excessive phosphorus input from point sources and is often accompanied by a corresponding increase in primary production. In such cases, the reversal of the enriched condition depends upon phosphorus control, not nitrogen control.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Indiana National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of February and March when two samples were collected. Sampling was begun in June, 1973, and was completed in May, 1974.

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

Except for phosphorus in Unnamed Creek B-1, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. The phosphorus load measured in Unnamed Creek B-1 was less than the Fremont wastewater treatment plant load, and the background phosphorus load of this stream was estimated in the same way as the "ZZ" load (see below). However, note that the nitrogen load given for this stream is that measured at B-1 minus the Fremont load.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the nutrient loads, in $kg/km^2/year$, at station C-1 and multiplying by the ZZ area in km^2.

* See Working Paper No. 175.

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

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Fremont	1,043**	tr. filter	541.7	Unnamed Creek B-1

2. Known industrial - None

* Anonymous, 1971.
** 1970 Census.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (non-point load) -		
Unnamed Creek B-1	150	10.7
Unnamed Creek C-1	40	2.8
b. Minor tributaries & immediate drainage (non-point load) -	85	6.1
c. Known municipal STP's -		
Fremont	1,120	80.0
d. Septic tanks - Unknown	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	5	0.4
Total	1,400	100.0

2. Outputs -

Lake outlet - Follett Creek 1,310

3. Net annual P accumulation - 90 kg.

* See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Unnamed Creek B-1	9,560	49.7
Unnamed Creek C-1	1,570	8.2
b. Minor tributaries & immediate drainage (non-point load) -	3,490	18.1
c. Known municipal STP's -		
Fremont	4,380	22.8
d. Septic tanks - Unknown	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	250	1.2
Total	19,250	100.0

2. Outputs -

Lake outlet - Follett Creek	19,705

3. Net annual N loss - 455 kg.

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

Tributary	kg P/km^2/yr	kg N/km^2/yr
Unnamed Creek B-1	-	455
Unnamed Creek C-1	7	291

* See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

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

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	6.09	0.39	83.7	loss*

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Marsh Lake:	
"Dangerous" (eutrophic loading)	1.34
"Permissible" (oligotrophic loading)	0.67

* 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 insufficient outlet sampling in relation to the relatively short hydraulic retention time of the lake. Whatever the cause, a similar nitrogen loss has occurred at Shagawa Lake, Minnesota, which has been intensively studied by EPA's former National Eutrophication and Lake Restoration Branch (Malueg et al., 1975).

V. LITERATURE REVIEWED

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Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

Winters, John, 1975. Personal communication (lake morphometry). IN Div. of Water Poll. Contr., Indianapolis.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
1805	CATARACT LAKE	0.058	1.660	466.667	10.744	15.000	0.013
1811	GEIST RESERVOIR	0.074	1.080	472.500	45.950	11.600	0.009
1817	JAMES LAKE	0.024	1.030	434.000	11.533	15.000	0.008
1827	MISSISSINEWA RESERVOIR	0.107	2.400	473.444	15.778	15.000	0.029
1828	MONROE RESERVOIR	0.025	0.325	438.823	6.947	15.000	0.007
1829	MORSE RESERVOIR	0.084	3.325	473.222	56.167	15.000	0.009
1836	WAWASEE LAKE	0.012	0.210	364.500	5.000	14.600	0.003
1837	WEBSTER LAKE	0.025	0.790	431.000	11.500	15.000	0.005
1839	WHITEWATER LAKE	0.084	1.620	470.167	33.083	15.000	0.012
1840	WINONA LAKE	0.035	1.250	444.667	11.211	15.000	0.011
1841	WESTLER LAKE	0.035	0.860	427.125	10.712	15.000	0.013
1842	WITMER LAKE	0.035	0.900	440.333	11.917	15.000	0.011
1843	LAKE MAXINKUCKEE	0.020	0.220	400.400	5.483	15.000	0.003
1844	TIPPECANOE LAKE	0.019	0.195	391.500	6.050	15.000	0.005
1845	DALLAS LAKE	0.029	0.830	413.333	10.067	15.000	0.014
1846	OLIN LAKE	0.012	1.460	403.333	4.867	14.900	0.003
1847	OLIVER LAKE	0.009	0.920	392.000	3.767	14.800	0.004
1848	SYLVAN LAKE	0.170	0.130	469.833	47.480	14.800	0.017
1849	HOVEY LAKE	0.062	1.050	489.333	84.267	7.600	0.024
1850	VERSAILLES LAKE	0.139	1.090	482.000	25.078	14.500	0.019
1851	BASS LAKE	0.040	0.250	471.375	29.367	7.000	0.012
1852	CROOKED LAKE	0.019	0.120	410.111	5.578	15.000	0.005
1853	LAKE JAMES	0.016	0.190	352.444	4.856	15.000	0.005
1854	LONG LAKE	0.204	1.920	442.667	16.100	15.000	0.150
1855	PIGEON LAKE	0.058	1.945	442.667	11.900	15.000	0.015
1856	MARSH LAKE	0.093	0.270	451.333	34.467	15.000	0.055
1857	HAMILTON LAKE	0.033	0.720	413.167	17.450	15.000	0.018

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

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
1805	CATARACT LAKE	37 (9)	15 (4)	31 (8)	62 (16)	35 (0)	37 (9)	217
1811	GEIST RESERVOIR	27 (7)	35 (9)	15 (4)	12 (3)	92 (24)	62 (16)	243
1817	JAMES LAKE	73 (19)	42 (11)	58 (15)	50 (13)	35 (0)	65 (17)	323
1827	MISSISSINEWA RESERVOIR	12 (3)	4 (1)	8 (2)	38 (10)	35 (0)	8 (2)	105
1828	MONROE RESERVOIR	67 (17)	69 (18)	54 (14)	73 (19)	35 (0)	69 (18)	367
1829	MORSE RESERVOIR	23 (6)	0 (0)	12 (3)	4 (1)	35 (0)	58 (15)	132
1836	WAWASEE LAKE	94 (24)	85 (22)	96 (25)	88 (23)	85 (22)	98 (25)	546
1837	WEBSTER LAKE	67 (17)	62 (16)	62 (16)	54 (14)	35 (0)	81 (21)	361
1839	WHITEWATER LAKE	19 (5)	19 (5)	23 (6)	19 (5)	35 (0)	42 (11)	157
1840	WINONA LAKE	50 (12)	27 (7)	38 (10)	58 (15)	35 (0)	52 (13)	260
1841	WESTLER LAKE	50 (12)	54 (14)	65 (17)	65 (17)	35 (0)	37 (9)	306
1842	WITMER LAKE	50 (12)	50 (13)	50 (13)	42 (11)	35 (0)	52 (13)	279
1843	LAKE MAXINKUCKEE	77 (20)	81 (21)	85 (22)	85 (22)	35 (0)	98 (25)	461
1844	TIPPECANOE LAKE	85 (22)	88 (23)	92 (24)	77 (20)	35 (0)	85 (22)	462
1845	DALLAS LAKE	62 (16)	58 (15)	69 (18)	69 (18)	35 (0)	31 (8)	324
1846	OLIN LAKE	94 (24)	23 (6)	81 (21)	92 (24)	73 (19)	92 (24)	455
1847	OLIVER LAKE	100 (26)	46 (12)	88 (23)	100 (26)	79 (20)	88 (23)	501
1848	SYLVAN LAKE	4 (1)	96 (25)	27 (7)	8 (2)	79 (20)	23 (6)	237
1849	HOVEY LAKE	31 (8)	38 (10)	0 (0)	0 (0)	96 (25)	12 (3)	177
1850	VERSAILLES LAKE	8 (2)	31 (8)	4 (1)	27 (7)	88 (23)	15 (4)	173
1851	BASS LAKE	42 (11)	77 (20)	19 (5)	23 (6)	100 (26)	46 (12)	307
1852	CROOKED LAKE	81 (21)	100 (26)	77 (20)	81 (21)	35 (0)	75 (19)	449
1853	LAKE JAMES	88 (23)	92 (24)	100 (26)	96 (25)	35 (0)	75 (19)	486
1854	LONG LAKE	0 (0)	12 (3)	44 (11)	35 (9)	35 (0)	0 (0)	126
1855	PIGEON LAKE	37 (9)	8 (2)	44 (11)	46 (12)	35 (0)	27 (7)	197
1856	MARSH LAKE	15 (4)	73 (19)	35 (9)	15 (4)	35 (0)	4 (1)	177
1857	HAMILTON LAKE	58 (15)	65 (17)	73 (19)	31 (8)	35 (0)	19 (5)	281

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	1836	WAWASEE LAKE	546
2	1847	OLIVER LAKE	501
3	1853	LAKE JAMES	486
4	1844	TIPPECANOE LAKE	462
5	1843	LAKE MAXINKUCKEE	461
6	1846	OLIN LAKE	455
7	1852	CROOKED LAKE	449
8	1828	MONROE RESERVOIR	367
9	1837	WEBSTER LAKE	361
10	1845	DALLAS LAKE	324
11	1817	JAMES LAKE	323
12	1851	BASS LAKE	307
13	1841	WESTLER LAKE	306
14	1857	HAMILTON LAKE	281
15	1842	WITMER LAKE	279
16	1840	WINONA LAKE	260
17	1811	GEIST RESERVOIR	243
18	1848	SYLVAN LAKE	237
19	1805	CATARACT LAKE	217
20	1855	PIGEON LAKE	197
21	1856	MARSH LAKE	177
22	1849	HOVEY LAKE	177
23	1850	VERSAILLES LAKE	173
24	1839	WHITEWATER LAKE	157
25	1829	MORSE RESERVOIR	132
26	1854	LONG LAKE	126
27	1827	MISSISSINEWA RESERVOIR	105

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR INDIANA 03/29/76

LAKE CODE 1856 MARSH LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 38.6

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1856A1	38.6	0.459	0.552	0.790	0.736	0.473	0.362	0.218	0.074	0.071	0.074	0.190	0.351	0.361
1856B1	21.0	0.244	0.300	0.433	0.402	0.258	0.198	0.116	0.037	0.037	0.037	0.102	0.193	0.196
1856C1	5.4	0.059	0.076	0.113	0.105	0.065	0.051	0.031	0.008	0.008	0.009	0.026	0.051	0.050
1856ZZ	12.2	0.139	0.173	0.252	0.232	0.147	0.116	0.068	0.020	0.021	0.021	0.059	0.113	0.113

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 38.6
SUM OF SUB-DRAINAGE AREAS = 38.6
TOTAL FLOW IN = 4.32
TOTAL FLOW OUT = 4.35

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
1856A1	6	73	0.646	9	0.595				
	7	73	0.708	15	0.340				
	8	73	0.292	12	0.272				
	9	73	0.130	17	0.153				
	10	73	0.092	15	0.144				
	11	73	0.107	11	0.079				
	12	73	0.240	8	0.227				
	1	74	1.107	6	0.280				
	2	74	0.765	10	0.481	24	0.566		
	3	74	0.657	10	0.566	26	0.340		
	4	74	0.504	9	0.481				
	5	74	0.555	5	0.215				
1856B1	6	73	0.351	9	0.246				
	7	73	0.385	15	0.099				
	8	73	0.158	12	0.133				
	9	73	0.071	17	0.091				
	10	73	0.051	15	0.085				
	11	73	0.058	11	0.062				
	12	73	0.131	8	0.122				
	1	74	0.603	6	0.147				
	2	74	0.416	10	0.207	24	0.238		
	3	74	0.357	10	0.235	26	0.161		
	4	74	0.274	9	0.215				
	5	74	0.303	5	0.125				

TRIBUTARY FLOW INFORMATION FOR INDIANA 03/29/76

LAKE CODE 1856 MARSH LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
1856C1	6	73	0.091	9	0.068				
	7	73	0.100	15	0.020				
	8	73	0.041	12	0.011				
	9	73	0.018	17	0.003				
	10	73	0.013	15	0.003				
	11	73	0.015	11	0.001				
	12	73	0.034	8	0.008				
	1	74	0.156	6	0.012				
	2	74	0.108	10	0.037	24	0.057		
	3	74	0.093	10	0.054	26	0.018		
	4	74	0.071	9	0.042				
	5	74	0.078	5	0.007				
1856ZZ	6	73	0.053	9	0.040				
	7	73	0.058	15	0.012				
	8	73	0.024	12	0.007				
	9	73	0.011	17	0.002				
	10	73	0.008	15	0.001				
	11	73	0.009	11	0.001				
	12	73	0.020	8	0.005				
	1	74	0.091	6	0.007				
	2	74	0.063	10	0.021	24	0.034		
	3	74	0.054	10	0.031	26	0.010		
	4	74	0.041	9	0.025				
	5	74	0.046	5	0.004				

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/03/30

185601
41 43 12.0 084 54 09.0 3
MARSH LAKE
18151 INDIANA

083291

11EPALES 2111202
0038 FEET DEPTH CLASS 00

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	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/05/03	13 50	0000	12.7		48	625	8.40	230	0.060	1.100	0.070	0.009
	13 50	0006	12.7	10.0		640	8.40	238	0.080	1.100	0.070	0.016
	13 50	0015	12.7	9.2		650	8.30	238	0.060	1.000	0.060	0.019
	13 50	0024	10.3	9.6		650	8.20	210	0.170	1.000	0.200	0.026
	13 50	0034	8.7	5.2		650	8.00	250	0.620	1.400	0.310	0.194
73/08/06	09 30	0000	25.4	14.2	50	600	8.60	258	0.080	1.500	0.070	0.019
	09 30	0005	24.3	18.0		611	7.90	276	0.070	1.200	0.070	0.044
	09 30	0010	21.6	2.8		600	8.20	294	0.090	0.900	0.080	0.066
	09 30	0015	14.7	0.0		502	7.70	270	0.330	1.000	0.070	0.191
	09 30	0020	12.3			476						
	09 30	0025	11.1			470						
	09 30	0030	10.4			470						
	09 30	0035	10.1	0.0		471	7.40	420	3.900	5.500	0.240	1.300
73/10/15	15 45	0000	16.7	9.4	48	547	8.40	270	0.080	1.000	0.070	0.009
	15 45	0015	15.1	2.6		557	7.90	296	0.340	1.100	0.080	0.097
	15 45	0020	11.7	0.0		497	7.60	305	2.280	3.200	0.110	0.688
	15 45	0033	8.9	0.5		506	7.10	355	7.680	10.100	0.090	0.150

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/05/03	13 50	0000	0.045	33.4
	13 50	0006	0.053	
	13 50	0015	0.051	
	13 50	0024	0.055	
	13 50	0034	0.215	
73/08/06	09 30	0000	0.078	19.4
	09 30	0005	0.086	
	09 30	0010	0.101	
	09 30	0015	0.194	
	09 30	0035	1.480	
73/10/15	15 45	0000	0.053	50.6
	15 45	0015	0.157	
	15 45	0020	0.808	
	15 45	0033	0.204	

APPENDIX E

TRIBUTARY DATA

STORET RETRIEVAL DATE 76/03/30

1856A1
41 43 16.0 084 59 33.0 4
FOLLETTE CREEK
18 7.5 E ANGOLA
O/MARSH LAKE 083291
BANK 300 YDS N END RD 4 MI W OF FREMONT
11EPALES 2111204
0000 FEET DEPTH CLASS 00

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
73/06/09	15	10	0.010K	1.320	0.027	0.050	0.095
73/07/15	10	20	0.040	1.380	0.069	0.052	0.092
73/08/12	09	40	0.016	2.200	0.030	0.022	0.070
73/09/17	09	50	0.054	1.470	0.135	0.017	0.055
73/10/15	14	35	0.034	0.900	0.050	0.017	0.050
73/11/11	09	30	0.116	1.450	0.507	0.320	0.360
73/12/08	11	15	0.264	1.200	0.430	0.240	0.250
74/01/06	10	15	1.340	0.900	0.224	0.080	0.110
74/02/10	10	30	1.440	1.000	0.100	0.040	0.065
74/02/24	10	10	0.920	1.000	0.060	0.050	0.105
74/03/10	10	20	0.970	1.100	0.145	0.095	0.135
74/03/26	09	50	0.755	0.900	0.108	0.080	0.115
74/04/09	10	10	0.620	1.000	0.035	0.045	0.080
74/05/05	14	55	0.012	0.800	0.020	0.005K	0.015

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/03/30

185681
41 43 06.0 084 58 15.0 4
UNNAMED CREEK
18 7.5 E ANGOLA
I/MARSH LAKE 083291
BRDG RUNNING N&S 2 MI W OF FREMONT
11EPALES 2111204
0000 FEET DEPTH CLASS 00

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
73/06/09	14 30		0.280	2.100	0.198	0.099	0.170
73/07/15	09 50		0.340	1.980	0.320	0.099	0.170
73/08/12	09 20		0.340	1.650	0.420	0.189	0.280
73/09/17	09 00		0.470	1.470	0.450	0.154	0.185
73/10/15	14 00		0.350	1.550	0.370	0.190	0.300
73/11/11	09 20		0.490	1.000	0.312	0.152	0.250
73/12/08	10 50		1.040	0.700	0.168	0.104	0.104
74/01/06	09 30		1.600	1.200	0.312	0.064	0.085
74/02/10	13 00		6.000	1.400	0.085	0.015	0.035
74/02/24	09 30		0.960	1.400	0.060	0.050	0.120
74/03/10	09 30		1.440	1.500	0.025	0.070	0.125
74/03/26	09 20		0.860	1.100	0.210		
74/04/09	09 30		1.090	1.400	0.040	0.065	0.105
74/05/05	14 45		0.312	1.100	0.055	0.115	0.160

STORET RETRIEVAL DATE 76/03/30

1856C1
41 42 28.0 084 42 48.0 4
UNNAMED CREEK
18 7.5 E ANGOLA
T/MARSH LAKE 060191
BRDG RUNNING E & W 3.5 MI W OF FREMONT
11EPALES 2111204
0000 FEET DEPTH CLASS 00

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
73/06/09	14 50		0.015	0.760	0.038	0.020	0.040
73/07/15	10 00		0.027	1.200	0.056	0.020	0.040
73/08/12	09 27		0.010K	0.840	0.056	0.022	0.040
73/09/17	09 25		0.028	1.600	0.230	0.019	0.060
73/10/15	14 20		0.016	1.000	0.078	0.018	0.035
73/11/11	09 35		0.032	0.550	0.068	0.016	
73/12/08	11 02		0.060	0.600	0.084	0.010	0.012
74/01/06	09 50		0.116	0.700	0.112	0.008	0.020
74/02/10	10 15		0.160	0.800	0.040	0.005K	0.015
74/02/24	09 50		1.360	0.600	0.085	0.015	0.015
74/03/10	09 55		0.116	0.800	0.035	0.005	0.005
74/03/26	09 10		0.048	0.500	0.030	0.005	0.015
74/04/09	09 50		0.012	0.600	0.020	0.010	0.015
74/05/05	14 35		0.008	1.100	0.025	0.005	0.015

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/03/30

1856XA TF1856XA P001043
41 42 30.0 084 58 00.0 4
FREMONT
18 7.5 ANGOLA E
T/MARSH LAKE 083291
NO NAME SWANP
11EPALES 2141204
0000 FEET DEPTH CLASS 00

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
73/06/14	07 30		1.500	15.000	8.700		5.700	0.089	0.145
73/07/13	12 10		4.400	16.800	5.900	3.570	4.200	0.126	0.140
73/08/14	12 37		0.920	28.000	7.500	3.000	7.100	0.046	0.167
73/09/14	12 15		4.000	17.000	8.100	2.100	6.350	0.098	0.125
73/10/15	12 40		2.600	25.000	9.750	1.750	7.600	0.125	0.173
73/11/14	09 40		2.200	19.500	8.000	3.050	6.500	0.106	0.146
73/12/14	08 30		3.100	15.000	7.700	1.320	2.900	0.143	0.120
74/01/14	13 00		1.520	24.000	15.600	4.100	6.300	0.110	0.143
74/02/13	08 30		0.920	17.000	9.600	3.600	5.000	0.113	0.146
74/03/13	12 50		0.400	26.000			6.600	0.112	0.126
74/04/15	08 30		0.440	17.000	10.500	3.000	6.100		
74/05/14	08 35		0.520	24.000	9.900	4.200	5.900		
74/06/14	08 10		2.240	16.000	8.000	3.750	4.300		