

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



REPORT  
ON  
THORNAPPLE LAKE  
BARRY COUNTY  
MICHIGAN  
EPA REGION V  
WORKING PAPER No. 215

PACIFIC NORTHWEST ENVIRONMENTAL RESEARCH LABORATORY

An Associate Laboratory of the

NATIONAL ENVIRONMENTAL RESEARCH CENTER - CORVALLIS, OREGON

and

NATIONAL ENVIRONMENTAL RESEARCH CENTER - LAS VEGAS, NEVADA

REPORT  
ON  
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EPA REGION V  
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203

WITH THE COOPERATION OF THE  
MICHIGAN DEPARTMENT OF NATURAL RESOURCES  
AND THE  
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MARCH, 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; 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.

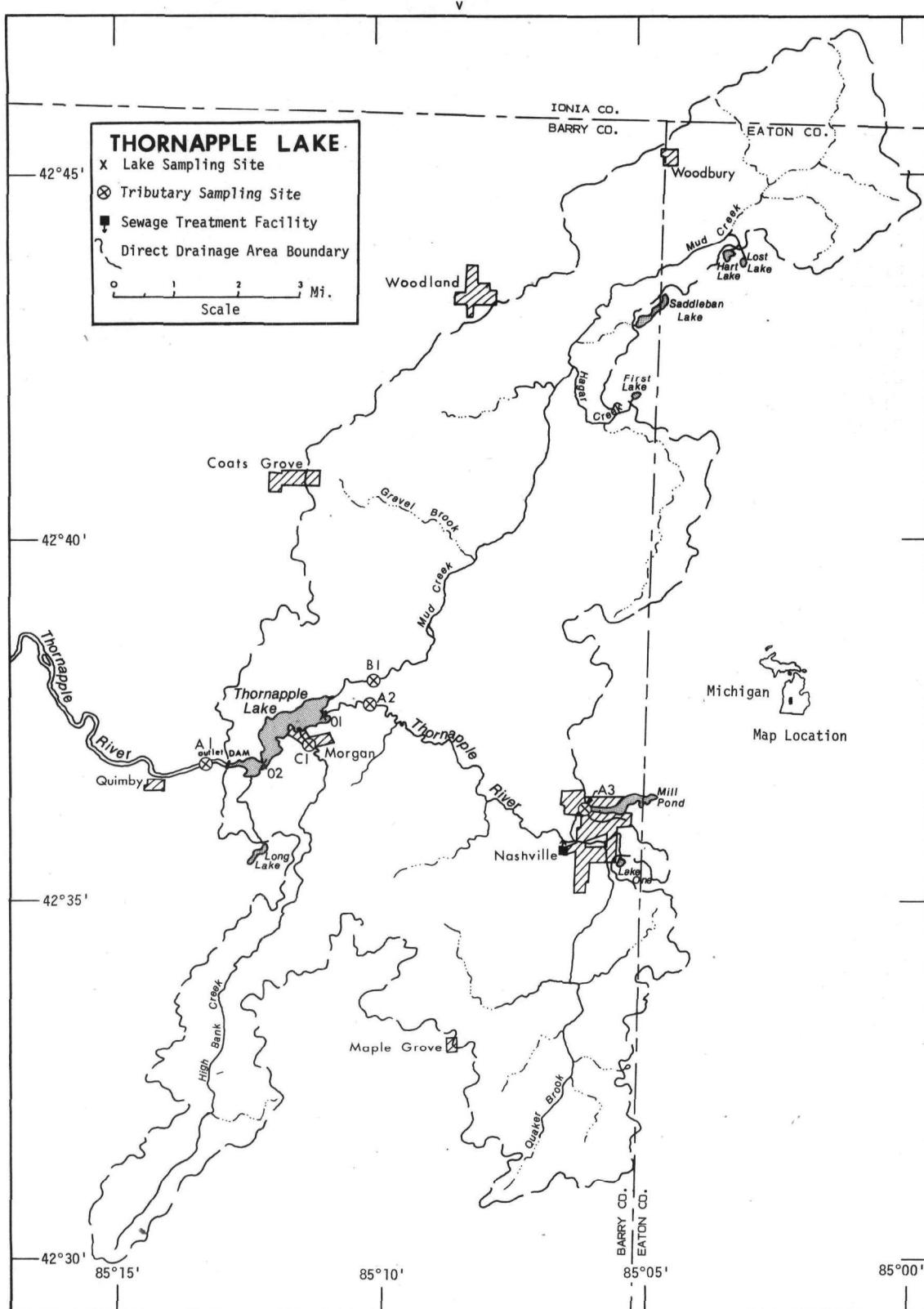
Major General Clarence A. Schnipke (Retired), then the Adjutant General of Michigan, and Project Officer Colonel Albert W. Lesky, who directed the volunteer efforts of the Michigan National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

## NATIONAL EUTROPHICATION SURVEY

## STUDY LAKES

STATE OF MICHIGAN

| <u>LAKE NAME</u> | <u>COUNTY</u>   |
|------------------|-----------------|
| 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        |



THORNAPPLE LAKE

STORET NO 2683

I. CONCLUSIONS

A. Trophic Condition:

Survey data show that Thornapple Lake is eutrophic. Of the 35 Michigan lakes sampled in November when essentially all were well-mixed, 15 had less mean total phosphorus, 18 had less mean dissolved phosphorus, and only three lakes had more mean inorganic nitrogen; of all 41 lakes sampled, 20 had greater Secchi disc transparency, and 25 had less mean chlorophyll a\*. Dissolved oxygen was depleted at both stations at the 4-foot level in September.

Survey limnologists noted an algal bloom in progress in September.

B. Rate-Limiting Nutrient:

A significant loss of phosphorus occurred in the algal assay sample, and the results are not representative of conditions in the lake at the time the sample was taken.

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

C. Nutrient Controllability:

1. Point sources--During the sampling year, Thornapple Lake received a total phosphorus load at a rate over four times

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\* See Appendix A.

that proposed by Vollenweider (in press) as "dangerous"; i.e., a eutrophic rate (see page 12). However, it is probable that Vollenweider's model does not apply to water bodies with short hydraulic retention times. Thornapple Lake has a mean hydraulic retention time of only 11 days, and it is likely that the model is not applicable.

It is calculated that the Village of Nashville contributed 6.5% of the total phosphorus load to the lake during the sampling year. While complete removal of phosphorus at this source would only reduce the loading rate to about  $6 \text{ g/m}^2/\text{yr}$ , it is possible that a high degree of phosphorus removal would result in persistent phosphorus limitation (see page 7) and a reduction in the incidence and severity of nuisance algal blooms. However, it appears that a significant improvement in the trophic condition of the lake will require reduction of the phosphorus loads from other sources as well (see below).

2. Non-point sources--During the sampling year, the mean phosphorus export rate of the Thornapple Lake tributaries was a relatively high 87 pounds per square mile (see page 12), and Mud Creek had a particularly high export rate of  $112 \text{ lbs/mi}^2$ .

It is believed that the high export rate of Mud Creek is due to four known point sources beyond the 25-mile limit of the

Survey\*; and, if a marked improvement in the trophic condition of Thornapple Lake is to be achieved, all phosphorus inputs will have to be minimized to the greatest practicable degree.

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

## II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

### A. Lake Morphometry<sup>†</sup>:

1. Surface area: 409 acres.
2. Mean depth: 13.9 feet.
3. Maximum depth: 31 feet.
4. Volume: 5,685 acre-feet.
5. Mean hydraulic retention time: 11 days.

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

#### 1. Tributaries -

| <u>Name</u>                              | <u>Drainage area*</u>     | <u>Mean flow*</u> |
|--|---------------------------|-------------------|
| Thornapple River                         | 260.0 mi <sup>2</sup>     | 187.9 cfs         |
| Mud Creek                                | 57.6 mi <sup>2</sup>      | 41.8 cfs          |
| High Bank Creek                          | 33.9 mi <sup>2</sup>      | 24.6 cfs          |
| Minor tributaries & immediate drainage - | <u>7.9 mi<sup>2</sup></u> | <u>6.5 cfs</u>    |
| Totals                                   | 359.4 mi <sup>2</sup>     | 260.8 cfs         |

#### 2. Outlet -

Thornapple River\*\*                            360.0 mi<sup>2</sup>\*\* 260.8 cfs\*\*

### C. Precipitation\*\*\*:

1. Year of sampling: 34.6 inches.
2. Mean annual: 32.4 inches.

<sup>†</sup> MI Dept. Cons. Lake inventory map (1949); mean depth by random-dot method.

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

\*\* Includes area of lake; outflow adjusted to equal sum of inflows.

\*\*\* See Working Paper No. 1.

### III. LAKE WATER QUALITY SUMMARY

Thornapple 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 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 11 feet at station 1 and 20 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

(11/14/72)

| <u>Parameter</u>                   | <u>Minimum</u> | <u>Mean</u> | <u>Median</u> | <u>Maximum</u> |
|------------------------------------|----------------|-------------|---------------|----------------|
| Temperature (Cent.)                | 5.6            | 5.7         | 5.6           | 5.8            |
| Dissolved oxygen (mg/l)            | 9.1            | 9.6         | 9.2           | 10.4           |
| Conductivity ( $\mu\text{mhos}$ )  | 585            | 593         | 590           | 600            |
| pH (units)                         | 7.7            | 7.7         | 7.7           | 7.7            |
| Alkalinity (mg/l)                  | 170            | 201         | 200           | 250            |
| Total P (mg/l)                     | 0.035          | 0.042       | 0.043         | 0.049          |
| Dissolved P (mg/l)                 | 0.028          | 0.032       | 0.034         | 0.039          |
| $\text{NO}_2 + \text{NO}_3$ (mg/l) | 1.530          | 1.644       | 1.640         | 1.780          |
| Ammonia (mg/l)                     | 0.050          | 0.093       | 0.120         | 0.130          |

ALL VALUES

|                      |    |    |    |    |
|----------------------|----|----|----|----|
| Secchi disc (inches) | 32 | 57 | 60 | 84 |
|----------------------|----|----|----|----|

## B. Biological characteristics:

## 1. Phytoplankton\* -

| <u>Sampling Date</u> | <u>Dominant Genera</u>   | <u>Number per ml</u>                                |
|----------------------|--|---|
| 09/18/72             | 1. Lyngbya<br>2. Sy nedra<br>3. Microcystis<br>4. Flagellates<br>5. Mallomonas<br>Other genera       | 2,620<br>1,084<br>904<br>632<br>542<br><u>2,622</u> |
|                      | Total  | 8,404   |
| 11/14/72             | 1. Flagellates<br>2. Aphanethece<br>3. Raphidiopsis<br>4. Fragilaria<br>5. Dinobryon<br>Other genera | 803<br>582<br>150<br>110<br>100<br><u>363</u>       |
|                      | Total  | 2,108   |

\* 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.)

| <u>Sampling Date</u> | <u>Station Number</u> | <u>Chlorophyll a (<math>\mu\text{g/l}</math>)</u> |
|----------------------|-----------------------|---|
| 06/13/72             | 01                    | 30.7  |
|                      | 02                    | 24.2  |
| 09/18/72             | 01                    | 20.6  |
|                      | 02                    | 11.3  |
| 11/14/72             | 01                    | 0.4   |
|                      | 02                    | 0.7   |

## C. Limiting Nutrient Study:

There was a loss of about 55% of the dissolved phosphorus in the algal assay sample from the time of collection to the time the assay was begun, and the results are not representative of conditions in the lake at the time the sample was taken.

The lake data indicate nitrogen limitation in June and September (N/P ratios were 9/1 and 12/1, respectively) but phosphorus limitation in November (N/P ratio = 54/1).

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 high runoff months of April and May, when two samples were collected, and the colder months when one or more samples were omitted depending on the site. 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 means of the nutrient loads, in  $\text{lbs}/\text{mi}^2/\text{year}$ , in High Bank Creek at station C-1 and multiplying the means by the ZZ area in  $\text{mi}^2$ .

The operator of the Nashville wastewater treatment plant provided monthly effluent samples and corresponding flow data, and it is assumed

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\* See Working Paper No. 1.

the entire nutrient load from this plant reached Thornapple Lake during the sampling year.

The nutrient loads attributed to the Thornapple River are those measured at station A-2 minus the Nashville loads.

A. Waste Sources:

1. Known municipal\* -

| <u>Name</u> | <u>Pop.<br/>Served</u> | <u>Treatment</u> | <u>Mean<br/>Flow (mgd)</u> | <u>Receiving<br/>Water</u> |
|-------------|------------------------|------------------|----------------------------|----------------------------|
| Nashville   | 1,558**                | Imhoff           | 0.121                      | Thornapple River           |

2. Known industrial - None

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\* Cowles, 1973.

\*\* 1970 Census.

## B. Annual Total Phosphorus Loading - Average Year:

## 1. Inputs -

| <u>Source</u>  | <u>lbs P/<br/>yr</u> | <u>% of<br/>total</u> |
|--|----------------------|-----------------------|
| a. Tributaries (non-point load) -                            |                      |                       |
| Thornapple River   | 22,300               | 66.2                  |
| Mud Creek  | 6,450                | 19.1                  |
| High Bank Creek  | 2,130                | 6.3                   |
| b. Minor tributaries & immediate drainage (non-point load) - |                      |                       |
|  | 500                  | 1.5                   |
| c. Known municipal STP's -                                   |                      |                       |
| Nashville  | 2,200                | 6.5                   |
| d. Septic tanks* -   |                      |                       |
|  | 60                   | 0.2                   |
| e. Known industrial - None                                   |                      |                       |
|  | -                    | -                     |
| f. Direct precipitation** -                                  |                      |                       |
|  | 60                   | 0.2                   |
| Total  | 33,700               | 100.0                 |

## 2. Outputs -

Lake outlet - Thornapple River 26,610

3. Net annual P accumulation - 7,090 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 -

| <u>Source</u>  | <u>lbs N/<br/>yr</u> | <u>% of<br/>total</u> |
|--|----------------------|-----------------------|
| a. Tributaries (non-point load) -                            |                      |                       |
| Thornapple River   | 708,340              | 75.6                  |
| Mud Creek  | 154,730              | 16.5                  |
| High Bank Creek  | 49,380               | 5.3                   |
| b. Minor tributaries & immediate drainage (non-point load) - | 11,510               | 1.2                   |
| c. Known municipal STP's -                                   |                      |                       |
| Nashville  | 7,210                | 0.8                   |
| d. Septic tanks* -   | 2,350                | 0.2                   |
| e. Known industrial - None                                   | -                    | -                     |
| f. Direct precipitation** -                                  | <u>3,940</u>         | <u>0.4</u>            |
| Total  | 937,460              | 100.0                 |

## 2. Outputs -

Lake outlet - Thornapple River 828,330

3. Net annual N accumulation - 109,130 pounds

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\* 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:

| <u>Tributary</u> | <u>1bs P/mi<sup>2</sup>/yr</u> | <u>1bs N/mi<sup>2</sup>/yr</u> |
|------------------|--------------------------------|--------------------------------|
| Thornapple River | 86                             | 2,724                          |
| Mud Creek        | 112                            | 2,686                          |
| High Bank Creek  | 63                             | 1,457                          |

## 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.

| <u>Units</u>             | <u>Total Phosphorus</u> |                    | <u>Total Nitrogen</u> |                    |
|--------------------------|-------------------------|--------------------|-----------------------|--------------------|
|                          | <u>Total</u>            | <u>Accumulated</u> | <u>Total</u>          | <u>Accumulated</u> |
| lbs/acre/yr              | 82.4                    | 17.3               | 2,303.9               | 278.8              |
| grams/m <sup>2</sup> /yr | 9.24                    | 1.94               | 258.2                 | 31.2               |

Vollenweider loading rates for phosphorus (g/m<sup>2</sup>/yr) based on mean depth and mean hydraulic retention time of Thornapple Lake:

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|                                   |      |
|-----------------------------------|------|
| "Dangerous" (eutrophic rate)      | 2.20 |
| "Permissible" (oligotrophic rate) | 1.10 |

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V. LITERATURE REVIEWED

Cowles, Fred E., 1973. Treatment plant questionnaire (Nashville STP). MI Dept. Publ. Health, Lansing.

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<br>CODE | LAKE NAME             | FALL VALUES     |                |                 | ALL VALUES       |                |               |
|--------------|-----------------------|-----------------|----------------|-----------------|------------------|----------------|---------------|
|              |                       | MEAN<br>TOTAL P | MEAN<br>DISS P | MEAN<br>INORG N | 500-<br>MEAN SEC | MEAN<br>CHLORA | 15-<br>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         | RUSS 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<br>CODE | LAKE NAME           | FALL VALUES----- |                |                 | ALL VALUES-----  |                |               |
|--------------|---------------------|------------------|----------------|-----------------|------------------|----------------|---------------|
|              |                     | MEAN<br>TOTAL P  | MEAN<br>DISS P | MEAN<br>INORG N | 500-<br>MEAN SEC | MEAN<br>CHLORA | 15-<br>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<br>CODE | LAKE NAME             | FALL VALUES     |                |                 | ALL VALUES       |                |               |     | INDEX<br>NO |
|--------------|-----------------------|-----------------|----------------|-----------------|------------------|----------------|---------------|-----|-------------|
|              |                       | MEAN<br>TOTAL P | MEAN<br>DISS P | MEAN<br>INORG N | 500-<br>MEAN SEC | MEAN<br>CHLORA | 15-<br>MIN DO |     |             |
| 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<br>CODE | LAKE NAME           | -----FALL VALUES----- |                |                 | -----ALL VALUES----- |                |               | INDEX<br>NO |
|--------------|---------------------|-----------------------|----------------|-----------------|----------------------|----------------|---------------|-------------|
|              |                     | MEAN<br>TOTAL P       | MEAN<br>DISS P | MEAN<br>INORG N | 500-<br>MEAN SEC     | MEAN<br>CHLORA | 15-<br>MIN DO |             |
| 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 2683 THURNAPPLE LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 360.00

| TRIBUTARY | SUB-DRAINAGE<br>AREA(SQ MI) | NORMALIZED FLOWS(CFS) |        |        |        |        |        |        |       |       |        |        |        | MEAN   |
|-----------|-----------------------------|-----------------------|--------|--------|--------|--------|--------|--------|-------|-------|--------|--------|--------|--------|
|           |                             | JAN                   | FEB    | MAR    | APR    | MAY    | JUN    | JUL    | AUG   | SEP   | OCT    | NOV    | DEC    |        |
| 2683A1    | 360.00                      | 273.00                | 295.00 | 604.00 | 538.00 | 392.00 | 209.00 | 115.00 | 89.00 | 97.00 | 137.00 | 166.00 | 214.00 | 260.98 |
| 2683A2    | 260.00                      | 197.00                | 213.00 | 440.00 | 388.00 | 283.00 | 151.00 | 83.10  | 64.10 | 70.20 | 99.20  | 120.00 | 148.00 | 187.91 |
| 2683B1    | 57.60                       | 43.70                 | 47.10  | 97.40  | 86.60  | 62.70  | 33.40  | 18.40  | 14.20 | 15.60 | 22.00  | 26.50  | 34.30  | 41.80  |
| 2683C1    | 33.90                       | 25.70                 | 27.70  | 57.30  | 50.60  | 36.90  | 19.60  | 10.80  | 8.40  | 9.20  | 12.90  | 15.60  | 20.20  | 24.56  |
| 2683ZZ    | 8.50                        | 6.80                  | 7.40   | 15.20  | 13.40  | 9.80   | 5.20   | 2.90   | 2.20  | 2.40  | 3.40   | 4.10   | 5.40   | 6.51   |

## SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 360.00  
 SUM OF SUB-DRAINAGE AREAS = 360.00      TOTAL FLOW IN = 3131.60  
 TOTAL FLOW OUT = 3134.00

## MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

| TRIBUTARY | MONTH | YEAR | MEAN FLOW | DAY | FLOW    | DAY | FLOW   | DAY | FLOW |
|-----------|-------|------|-----------|-----|---------|-----|--------|-----|------|
| 2683A1    | 10    | 72   | 274.00    | 28  | 597.00  |     |        |     |      |
|           | 11    | 72   | 485.00    | 28  | 463.00  |     |        |     |      |
|           | 12    | 72   | 510.00    |     |         |     |        |     |      |
|           | 1     | 73   | 982.00    | 8   | 1160.00 |     |        |     |      |
|           | 2     | 73   | 339.00    | 4   | 496.00  | 28  | 222.00 |     |      |
|           | 3     | 73   | 935.00    |     |         |     |        |     |      |
|           | 4     | 73   | 718.00    | 6   | 954.00  | 20  | 449.00 |     |      |
|           | 5     | 73   | 379.00    | 4   | 521.00  | 25  | 335.00 |     |      |
|           | 6     | 73   | 328.00    | 10  | 587.00  |     |        |     |      |
|           | 7     | 73   | 277.00    | 4   | 583.00  | 27  | 138.00 |     |      |
|           | 8     | 73   | 121.00    | 31  | 95.00   |     |        |     |      |
|           | 9     | 73   | 103.00    | 24  | 109.00  |     |        |     |      |
| 2683A2    | 10    | 72   | 198.00    | 28  | 431.00  |     |        |     |      |
|           | 11    | 72   | 350.00    | 28  | 334.00  |     |        |     |      |
|           | 12    | 72   | 368.00    |     |         |     |        |     |      |
|           | 1     | 73   | 709.00    | 8   | 837.00  |     |        |     |      |
|           | 2     | 73   | 245.00    | 4   | 358.00  | 28  | 160.00 |     |      |
|           | 3     | 73   | 675.00    |     |         |     |        |     |      |
|           | 4     | 73   | 518.00    | 6   | 688.00  | 20  | 324.00 |     |      |
|           | 5     | 73   | 273.00    | 4   | 370.00  | 25  | 242.00 |     |      |
|           | 6     | 73   | 237.00    | 8   | 254.00  |     |        |     |      |
|           | 7     | 73   | 200.00    | 4   | 421.00  | 27  | 100.00 |     |      |
|           | 8     | 73   | 87.00     | 31  | 69.00   |     |        |     |      |
|           | 9     | 73   | 74.00     | 24  | 79.00   |     |        |     |      |

## TRIBUTARY FLOW INFORMATION FOR MICHIGAN

2/3/75

LAKE CODE 2683 THORNAPPLE LAKE

## MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

| TRIBUTARY | MONTH | YEAR | MEAN FLOW | DAY | FLOW   | DAY | FLOW  | DAY | FLOW |
|-----------|-------|------|-----------|-----|--------|-----|-------|-----|------|
| 2683B1    | 10    | 72   | 44.00     | 28  | 96.00  |     |       |     |      |
|           | 11    | 72   | 78.00     | 28  | 74.00  |     |       |     |      |
|           | 12    | 72   | 82.00     |     |        |     |       |     |      |
|           | 1     | 73   | 158.00    | 8   | 186.00 |     |       |     |      |
|           | 2     | 73   | 54.00     | 4   | 80.00  | 28  | 36.00 |     |      |
|           | 3     | 73   | 150.00    |     |        |     |       |     |      |
|           | 4     | 73   | 115.00    | 6   | 153.00 | 20  | 72.00 |     |      |
|           | 5     | 73   | 61.00     | 4   | 84.00  |     |       |     |      |
|           | 6     | 73   | 53.00     | 10  | 94.00  |     |       |     |      |
|           | 7     | 73   | 44.00     | 4   | 93.00  | 28  | 22.00 |     |      |
|           | 8     | 73   | 19.00     | 31  | 15.00  |     |       |     |      |
|           | 9     | 73   | 16.00     | 24  | 18.00  |     |       |     |      |
| 2683C1    | 10    | 72   | 26.00     | 28  | 56.00  |     |       |     |      |
|           | 11    | 72   | 46.00     | 28  | 44.00  |     |       |     |      |
|           | 12    | 72   | 48.00     |     |        |     |       |     |      |
|           | 1     | 73   | 92.00     | 8   | 109.00 |     |       |     |      |
|           | 2     | 73   | 32.00     | 4   | 47.00  | 28  | 21.00 |     |      |
|           | 3     | 73   | 88.00     |     |        |     |       |     |      |
|           | 4     | 73   | 68.00     | 6   | 90.00  | 20  | 42.00 |     |      |
|           | 5     | 73   | 36.00     | 4   | 49.00  | 25  | 32.00 |     |      |
|           | 6     | 73   | 31.00     | 10  | 55.00  |     |       |     |      |
|           | 7     | 73   | 26.00     | 4   | 55.00  | 27  | 13.00 |     |      |
|           | 8     | 73   | 11.00     | 31  | 9.00   |     |       |     |      |
|           | 9     | 73   | 9.70      | 24  | 10.00  |     |       |     |      |
| 2683ZZ    | 10    | 72   | 6.40      |     |        |     |       |     |      |
|           | 11    | 72   | 11.00     |     |        |     |       |     |      |
|           | 12    | 72   | 12.00     |     |        |     |       |     |      |
|           | 1     | 73   | 23.00     |     |        |     |       |     |      |
|           | 2     | 73   | 8.00      |     |        |     |       |     |      |
|           | 3     | 73   | 22.00     |     |        |     |       |     |      |
|           | 4     | 73   | 17.00     |     |        |     |       |     |      |
|           | 5     | 73   | 8.90      |     |        |     |       |     |      |
|           | 6     | 73   | 7.70      |     |        |     |       |     |      |
|           | 7     | 73   | 6.50      |     |        |     |       |     |      |
|           | 8     | 73   | 2.80      |     |        |     |       |     |      |
|           | 9     | 73   | 2.40      |     |        |     |       |     |      |

## **APPENDIX C**

### **PHYSICAL and CHEMICAL DATA**

STORET RETRIEVAL DATE 75/02/04

268301  
42 37 30.0 085 11 00.0  
THORNAPPLE LAKE  
26 MICHIGAN

| DATE<br>FROM<br>TO | TIME<br>OF<br>DAY | DEPTH<br>FEET | 00010<br>WATER<br>TEMP | 00300<br>DO | 00077<br>TRANSP<br>SECCHI | 00094<br>CONDUTCTVY<br>FIELD | 00400<br>PH | 00410<br>ALK<br>CACUS | 00630<br>NO2&NO3<br>N-TOTAL | 00610<br>NH3-N<br>TOTAL | 00665<br>PHOS-TOT | 00666<br>PHOS-DIS |
|--------------------|-------------------|---------------|------------------------|-------------|---------------------------|------------------------------|-------------|-----------------------|-----------------------------|-------------------------|-------------------|-------------------|
|                    |                   |               | CENT                   | MG/L        | INCHES                    | MICROMHO                     | SU          | MG/L                  | MG/L                        | MG/L                    | MG/L              | MG/L P            |
| 72/06/13           | 09 55             | 0000          | 19.4                   | 11.0        | 60                        | 600                          | 8.40        | 263                   | 0.090                       | 0.050                   | 0.026             | 0.019             |
|                    | 09 55             | 0006          | 18.5                   | 9.7         |                           | 600                          | 8.45        | 272                   | 0.160                       | 0.040                   | 0.029             | 0.019             |
|                    | 09 55             | 0011          | 17.0                   | 7.0         |                           | 620                          | 8.10        | 276                   | 0.210                       | 0.160                   | 0.050             | 0.034             |
| 72/09/13           | 14 30             | 0000          |                        |             | 32                        | 540                          | 8.55        | 250                   | 0.390                       | 0.070                   | 0.050             | 0.027             |
|                    | 14 30             | 0004          |                        | 0.0         |                           | 550                          | 8.35        | 246                   | 0.430                       | 0.060                   | 0.055             | 0.029             |
|                    | 14 30             | 0011          | 19.0                   | 0.0         |                           | 550                          | 8.43        | 238                   | 0.350                       | 0.060                   | 0.056             | 0.022             |
| 72/11/14           | 16 25             | 0000          |                        |             | 84                        | 600                          | 7.70        | 180                   | 1.670                       | 0.050                   | 0.036             | 0.028             |
|                    | 16 25             | 0004          | 5.8                    | 10.4        |                           | 600                          | 7.70        | 170                   | 1.640                       | 0.050                   | 0.035             | 0.028             |
|                    | 16 25             | 0008          | 5.7                    | 10.3        |                           | 600                          | 7.70        | 200                   | 1.780                       | 0.050                   | 0.038             | 0.028             |

| DATE<br>FROM<br>TO | TIME<br>OF<br>DAY | DEPTH<br>FEET | 32217<br>CHLORPHYL<br>A |
|--------------------|-------------------|---------------|-------------------------|
|                    |                   |               | UG/L                    |
| 72/06/13           | 09 55             | 0000          | 30.70                   |
| 72/09/13           | 14 30             | 0000          | 20.60                   |
| 72/11/14           | 16 25             | 0000          | 0.40                    |

J VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 75/02/04

268302  
 42 37 00.0 085 11 30.0  
 THURNAPPLE LAKE  
 26 MICHIGAN

| DATE<br>FROM<br>TO | TIME<br>OF<br>DAY | DEPTH<br>FEET | WATER<br>TEMP<br>CENT | 00010 | 00300  | 00077  | 00094    | 00400 | 00410 | 00630   | 00610 | 00665    | 00666  |
|--------------------|-------------------|---------------|-----------------------|-------|--------|--------|----------|-------|-------|---------|-------|----------|--------|
|                    |                   |               |                       | DO    | TRANSP | SECCHI | CNDUCTVY | PH    | T ALK | N02&N03 | NH3-N | PHOS-TOT | MG/L P |
| 72/06/13           | 10 23             | 0000          | 19.5                  | 9.8   | 72     | 600    | 8.40     | 268   | 0.130 | 0.060   | 0.019 | 0.010    |        |
|                    | 10 23             | 0010          | 19.0                  | 5.9   |        | 610    | 8.15     | 272   | 0.110 | 0.170   | 0.045 | 0.033    |        |
|                    | 10 23             | 0015          | 12.8                  | 4.2   |        | 560    | 7.85     | 256   | 0.020 | 0.170   | 0.059 | 0.043    |        |
|                    | 10 23             | 0018          | 12.1                  | 0.0   |        | 540    | 7.80     | 256   | 0.070 | 0.460   | 0.111 | 0.055    |        |
| 72/09/18           | 15 00             | 0000          |                       |       | 35     | 530    | 8.65     | 248   | 0.100 | 0.060   | 0.046 | 0.023    |        |
|                    | 15 00             | 0004          | 18.9                  | 0.0   |        | 525    | 8.45     | 260   | 0.120 | 0.050   | 0.039 | 0.015    |        |
|                    | 15 00             | 0015          | 17.3                  | 0.0   |        | 550    | 8.00     | 268   | 0.110 | 0.650   | 0.123 | 0.081    |        |
| 72/11/14           | 16 00             | 0000          |                       |       | 60     | 590    | 7.70     | 180   | 1.530 | 0.120   | 0.049 | 0.039    |        |
|                    | 16 00             | 0004          | 5.6                   | 9.2   |        | 590    | 7.70     | 210   | 1.560 | 0.120   | 0.043 | 0.035    |        |
|                    | 16 00             | 0015          | 5.6                   | 9.1   |        | 585    | 7.70     | 220   | 1.630 | 0.130   | 0.045 | 0.035    |        |
|                    | 16 00             | 0020          | 5.6                   | 9.2   |        | 585    | 7.70     | 250   | 1.700 | 0.130   | 0.048 | 0.034    |        |

32217  
 DATE TIME DEPTH CHLRPHYL  
 FROM OF A  
 TO DAY FEET UG/L

|          |       |      |       |
|----------|-------|------|-------|
| 72/06/13 | 10 23 | 0000 | 24.2J |
| 72/09/18 | 15 00 | 0000 | 11.3J |
| 72/11/14 | 16 00 | 0000 | 0.7J  |

J VALUE KNOWN TO BE IN ERROR

## **APPENDIX D**

### **TRIBUTARY and WASTEWATER TREATMENT PLANT DATA**

STORET RETRIEVAL DATE 75/02/04

2683A1 LS2683A1  
 42 37 00.0 085 12 30.0  
 THURNAPPLE RIVER  
 26 15 NASHVILLE  
 0/THURNAPPLE LAKE  
 BRDG 1 MI NE OF QUIMBY  
 11EPALES 2111204  
 4 0000 FEET DEPTH

| DATE<br>FROM<br>TO | TIME<br>OF<br>DAY | DEPTH<br>FEET | 00630<br>N02&N03<br>N-TOTAL<br>MG/L | 00625<br>TOT KJEL<br>N<br>MG/L | 00610<br>NH3-N<br>TOTAL<br>MG/L | 00671<br>PHOS-DIS<br>URTHO<br>MG/L P | 00665<br>PHOS-TOT<br>MG/L P |
|--------------------|-------------------|---------------|-------------------------------------|--------------------------------|---------------------------------|--------------------------------------|-----------------------------|
| 73/01/08           | 15                | 09            | 2.700                               | 1.380                          | 0.042                           | 0.042                                | 0.077                       |
| 73/02/04           | 12                | 15            | 1.520                               | 0.560                          | 0.028                           | 0.013                                | 0.030                       |
| 73/02/28           | 07                | 55            | 1.120                               | 0.540                          | 0.060                           | 0.012                                | 0.030                       |
| 73/04/06           | 12                | 26            | 1.020                               | 0.800                          | 0.031                           | 0.009                                | 0.040                       |
| 73/04/20           | 14                | 53            | 0.600                               | 0.687                          | 0.013                           | 0.005K                               | 0.025                       |
| 73/05/04           | 12                | 15            | 0.300                               | 0.915                          | 0.016                           | 0.009                                | 0.065                       |
| 73/05/25           | 15                | 20            | 0.100                               | 0.920                          | 0.011                           | 0.012                                | 0.035                       |
| 73/06/10           | 17                | 00            | 0.480                               | 1.300                          | 0.035                           | 0.034                                | 0.085                       |
| 73/07/04           | 19                | 50            | 0.700                               | 1.150                          | 0.082                           | 0.026                                | 0.070                       |
| 73/07/27           | 11                | 35            | 0.021                               | 0.820                          | 0.009                           | 0.005K                               | 0.025                       |
| 73/08/31           | 11                | 45            | 0.010K                              | 0.570                          | 0.011                           | 0.005K                               | 0.030                       |
| 73/09/24           | 12                | 55            | 0.046                               | 0.900                          | 0.058                           | 0.038                                | 0.100                       |

K VALUE KNOWN TO BE  
 LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2683A2 LS2683A2  
 42 38 00.0 085 09 30.0  
 THURNAPPLE RIVER  
 20 15 NASHVILLE  
 T/THURNAPPLE LAKE  
 BRDG 23/4 MI NW NASHVILLE BELOW STP  
 11EPALES 2111204  
 4 0000 FEET DEPTH

| DATE<br>FROM<br>TO | TIME<br>OF<br>DAY | DEPTH<br>FEET | *00630<br>NO2&N03<br>N-TOTAL<br>MG/L | 00625<br>TOT KJEL<br>N<br>MG/L | 00610<br>NH3-N<br>TOTAL<br>MG/L | 00671<br>PHOS-DIS<br>ORTHO<br>MG/L P | 00665<br>PHOS-TOT<br>MG/L P |
|--------------------|-------------------|---------------|--------------------------------------|--------------------------------|---------------------------------|--------------------------------------|-----------------------------|
| 72/10/28           | 09 50             |               | 1.400                                | 2.250                          | 0.150                           | 0.044                                | 0.081                       |
| 72/11/28           | 14 40             |               | 0.420                                | 0.580                          | 0.015                           | 0.016                                | 0.030                       |
| 73/01/08           | 15 28             |               | 2.900                                | 1.260                          | 0.050                           | 0.036                                | 0.061                       |
| 73/02/04           | 17 35             |               | 1.440                                | 0.460                          | 0.033                           | 0.018                                | 0.035                       |
| 73/02/28           | 08 10             |               | 1.000                                | 0.480                          | 0.048                           | 0.016                                | 0.045                       |
| 73/04/06           | 12 05             |               | 1.120                                | 0.850                          | 0.018                           | 0.009                                | 0.025                       |
| 73/04/20           | 14 28             |               | 0.680                                | 0.720                          | 0.019                           | 0.011                                | 0.035                       |
| 73/05/04           | 12 35             |               | 0.620                                | 1.890                          | 0.044                           | 0.020                                | 0.065                       |
| 73/05/25           | 15 00             |               | 0.590                                | 1.300                          | 0.064                           | 0.023                                | 0.065                       |
| 73/06/08           | 12 00             |               | 0.840                                | 1.400                          | 0.078                           | 0.054                                | 0.090                       |
| 73/07/04           | 19 30             |               | 1.040                                | 1.260                          | 0.057                           | 0.040                                | 0.130                       |
| 73/07/27           | 11 12             |               | 0.290                                | 0.630                          | 0.030                           | 0.046                                | 0.090                       |
| 73/08/31           | 11 23             |               | 0.270                                | 0.420                          | 0.039                           | 0.053                                | 0.095                       |
| 73/09/24           | 13 10             |               | 0.310                                | 0.380                          | 0.063                           | 0.038                                | 0.065                       |

STORET RETRIEVAL DATE 75/02/04

2683A3 LS2683A3  
 42 30 30.0 085 05 30.0  
 THURNAPPLE RIVER  
 26 15 NASHVILLE  
 T/THURNAPPLELAKE  
 BRDG AT N EDGE OF NASHVILLE ABOVE STP  
 11EPALES 2111204  
 4 0000 FEET DEPTH

| DATE     | TIME | DEPTH | 00630<br>NO2&NO3 | 00625<br>TOT KJEL | 00610<br>NH3-N | 00671<br>PHOS-DIS | 00665<br>PHOS-TOT |       |
|----------|------|-------|------------------|-------------------|----------------|-------------------|-------------------|-------|
| FROM     | OF   |       | N-TOTAL          | N                 | TOTAL          | ORTHO             |                   |       |
| TO       | DAY  | FEET  | MG/L             | MG/L              | MG/L           | MG/L P            | MG/L P            |       |
| 72/10/28 | 09   | 15    |                  | 1.500             | 0.850          | 0.088             | 0.039             | 0.075 |
| 72/11/28 | 14   | 30    |                  | 0.350             | 0.600          | 0.012             | 0.016             | 0.031 |
| 73/01/08 | 14   | 54    |                  | 3.000             | 1.200          | 0.027             | 0.032             | 0.056 |
| 73/02/04 | 17   | 50    |                  | 1.540             | 0.480          | 0.028             | 0.012             | 0.030 |
| 73/04/06 | 11   | 55    |                  | 1.240             | 0.780          | 0.016             | 0.005K            | 0.025 |
| 73/04/20 | 14   | 15    |                  | 0.770             | 0.840          | 0.018             | 0.011             | 0.035 |
| 73/05/04 | 12   | 50    |                  | 0.730             | 1.000          | 0.024             | 0.022             | 0.063 |
| 73/05/25 | 14   | 45    |                  | 0.630             | 1.260          | 0.062             | 0.023             | 0.065 |
| 73/06/10 | 11   | 45    |                  | 0.880             | 1.260          | 0.072             | 0.048             | 0.110 |
| 73/07/04 | 19   | 19    |                  | 1.140             | 1.745          | 0.130             | 0.058             | 0.130 |
| 73/07/27 | 11   | 00    |                  | 0.198             | 0.780          | 0.072             | 0.037             | 0.095 |
| 73/08/31 | 11   | 11    |                  | 0.126             | 0.600          | 0.090             | 0.039             | 0.115 |
| 73/09/24 | 12   | 25    |                  | 0.231             | 0.460          | 0.058             | 0.023             | 0.070 |

K VALUE KNOWN TO BE  
 LESS THAN INDICATED

STORET RETRIEVAL DATE 75/02/04

2683B1 LS2683B1  
 42 38 30.0 085 09 30.0  
 MUD CREEK  
 26 15 NASHVILLE  
 T/THORNAPPLE LAKE  
 BRUG 3 MI NW OF NASHVILLE  
 11EPALES 2111204  
 4 0000 FEET DEPTH

| DATE<br>FROM<br>TO | TIME<br>OF<br>DAY | DEPTH<br>FEET | 00630<br>N02&N03<br>N-TOTAL | 00625<br>TUT KJEL<br>N | 00610<br>NH3-N<br>TOTAL | 00671<br>PHOS-DIS<br>ORTHO | 00665<br>PHOS-TOT<br>MG/L P |
|--------------------|-------------------|---------------|-----------------------------|------------------------|-------------------------|----------------------------|-----------------------------|
| 72/10/28           | 10 00             |               | 1.500                       | 0.950                  | 0.063                   | 0.060                      | 0.105                       |
| 72/11/28           | 14 45             |               | 0.430                       | 1.400                  | 0.096                   | 0.014                      | 0.029                       |
| 73/01/08           | 15 32             |               | 2.800                       | 1.150                  | 0.022                   | 0.030                      | 0.054                       |
| 73/02/04           | 17 40             |               | 1.620                       | 0.800                  | 0.040                   | 0.018                      | 0.040                       |
| 73/02/28           | 08 15             |               | 1.240                       | 1.400                  | 0.113                   | 0.018                      | 0.045                       |
| 73/04/06           | 12 10             |               | 1.060                       | 0.660                  | 0.013                   | 0.010                      | 0.025                       |
| 73/04/20           | 14 35             |               | 0.460                       | 0.750                  | 0.016                   | 0.016                      | 0.045                       |
| 73/05/04           | 12 40             |               | 0.710                       | 1.000                  | 0.029                   | 0.050                      | 0.090                       |
| 73/06/10           | 12 07             |               | 0.700                       | 1.200                  | 0.084                   | 0.102                      | 0.135                       |
| 73/07/04           | 19 35             |               | 0.820                       | 1.050                  | 0.048                   | 0.080                      | 0.135                       |
| 73/07/28           | 11 19             |               | 0.410                       | 0.580                  | 0.088                   | 0.060                      | 0.105                       |
| 73/08/31           | 11 30             |               | 0.370                       | 0.540                  | 0.168                   | 0.064                      | 0.120                       |
| 73/09/24           | 13 15             |               | 0.273                       | 0.340                  | 0.052                   | 0.032                      | 0.075                       |

STORET RETRIEVAL DATE 75/02/04

2683C1 LS2683C1  
 42 37 30.0 085 11 00.0  
 BANK CREEK  
 26 15 NASHVILLE  
 T/THURNAPPLE LAKE  
 ROAD CROSSING AT W EDGE OF MORGAN  
 11EPALES 2111204  
 4 0000 FEET DEPTH

| DATE<br>FROM<br>TO | TIME<br>OF<br>DAY | DEPTH<br>FEET | 00630<br>NO2&N03<br>N-TOTAL<br>MG/L | 00625<br>TOT KJEL<br>N<br>MG/L | 00610<br>NH3-N<br>TOTAL<br>MG/L | 00671<br>PHOS-DIS<br>ORTHO<br>MG/L P | 00665<br>PHOS-TOT<br>MG/L P |
|--------------------|-------------------|---------------|-------------------------------------|--------------------------------|---------------------------------|--------------------------------------|-----------------------------|
| 72/10/28           | 10                | 10            | 0.200                               | 0.800                          | 0.066                           | 0.010                                | 0.042                       |
| 72/11/28           | 14                | 55            | 0.260                               | 0.630                          | 0.014                           | 0.007                                | 0.019                       |
| 73/01/08           | 15                | 22            | 0.357                               | 0.640                          | 0.015                           | 0.011                                | 0.031                       |
| 73/02/04           | 17                | 25            | 0.294                               | 0.640                          | 0.028                           | 0.008                                | 0.025                       |
| 73/02/28           | 08                | 05            | 0.330                               | 0.600                          | 0.048                           | 0.015                                | 0.020                       |
| 73/04/06           | 12                | 18            | 0.105                               | 0.690                          | 0.020                           | 0.006                                | 0.025                       |
| 73/04/20           | 14                | 45            | 0.050                               | 0.800                          | 0.014                           | 0.009                                | 0.030                       |
| 73/05/04           | 12                | 30            | 0.091                               | 0.800                          | 0.018                           | 0.015                                | 0.045                       |
| 73/05/25           | 15                | 10            | 0.126                               | 2.150                          | 0.069                           | 0.018                                | 0.060                       |
| 73/06/10           | 12                | 14            | 0.250                               | 1.260                          | 0.044                           | 0.037                                | 0.100                       |
| 73/07/04           | 19                | 45            | 0.240                               | 0.720                          | 0.027                           | 0.028                                | 0.085                       |
| 73/07/27           | 11                | 27            | 0.250                               | 0.660                          | 0.020                           | 0.015                                | 0.045                       |
| 73/08/31           | 11                | 37            | 0.310                               | 0.350                          | 0.052                           | 0.016                                | 0.050                       |
| 73/09/24           | 13                | 05            | 0.189                               | 0.270                          | 0.019                           | 0.014                                | 0.030                       |

STORED RETRIEVAL DATE 75/02/04

268350 1P268350 P000470  
42 36 00.0 085 06 00.0  
NASHVILLE  
26 15 NASHVILLE  
T/THORNAPPLE LAKE  
THORNAPPLE RIVER  
11EPALES 2141204  
4 0000 FEET DEPTH

| DATE<br>FROM<br>TO | TIME<br>OF<br>DAY | DEPTH<br>FEET | 00630<br>NO2&NO3<br>N-TOTAL<br>MG/L | 00625<br>TOT KJEL<br>N<br>MG/L | 00610<br>NH3-N<br>TOTAL<br>MG/L | 00671<br>PHOS-DIS<br>URTHO<br>MG/L P | 00665<br>PHOS-TOT<br>MG/L P | 50051<br>FLOW<br>RATE<br>INST MGD | 50053<br>CONDUIT<br>FLOW-MGD<br>MONTHLY |
|--------------------|-------------------|---------------|-------------------------------------|--------------------------------|---------------------------------|--------------------------------------|-----------------------------|-----------------------------------|---|
| 73/01/05           | 08 00             |               |                                     |                                |                                 |                                      |                             |                                   |   |
| CP(T)-             |                   |               | 2.400                               | 9.700                          | 0.147                           | 1.475                                | 2.000                       | 0.203                             | 0.183                                   |
| 73/01/05           | 16 00             |               |                                     |                                |                                 |                                      |                             |                                   |   |
| 73/02/05           | 10 00             |               |                                     |                                |                                 |                                      |                             |                                   |   |
| CP(T)-             |                   |               | 0.890                               | 13.800                         | 0.155                           | 2.700                                | 12.000                      | 0.150                             | 0.138                                   |
| 73/02/05           | 16 00             |               |                                     |                                |                                 |                                      |                             |                                   |   |
| 73/03/01           | 13 00             |               |                                     |                                |                                 |                                      |                             |                                   |   |
| CP(T)-             |                   |               | 0.630                               | 19.800                         | 1.100                           | 2.237                                | 3.200                       | 0.126                             | 0.092                                   |
| 73/03/01           | 15 00             |               |                                     |                                |                                 |                                      |                             |                                   |   |
| 73/04/17           | 10 30             |               | 0.035                               | 27.300                         | 22.300                          | 7.200                                | 8.200                       | 0.151                             | 0.125                                   |
| 73/05/10           | 13 30             |               |                                     |                                |                                 |                                      |                             |                                   |   |
| CP(T)-             |                   |               | 0.570                               | 17.600                         | 0.410                           | 2.900                                | 7.100                       | 0.129                             | 0.136                                   |
| 73/05/10           | 16 00             |               |                                     |                                |                                 |                                      |                             |                                   |   |
| 73/06/12           | 14 30             |               |                                     |                                |                                 |                                      |                             |                                   |   |
| CP(T)-             |                   |               | 0.650                               | 24.000                         | 1.600                           | 3.200                                | 9.600                       | 0.169                             | 0.098                                   |
| 73/06/12           | 16 30             |               |                                     |                                |                                 |                                      |                             |                                   |   |
| 73/08/16           | 13 00             |               |                                     |                                |                                 |                                      |                             |                                   |   |
| CP(T)-             |                   |               | 0.048                               | 33.600                         | 12.400                          |                                      | 5.300                       | 0.079                             | 0.082                                   |
| 73/08/16           | 15 00             |               |                                     |                                |                                 |                                      |                             |                                   |   |
| 73/09/05           | 10 00             |               | 0.250                               | 30.000                         |                                 | 5.800                                |                             | 0.061                             | 0.080                                   |
| 73/10/05           | 09 30             |               | 0.480                               | 23.000                         | 5.600                           | 2.400                                | 6.700                       | 0.059                             | 0.063                                   |
| 74/01/07           | 12 00             |               | 0.680                               | 15.000                         | 1.680                           | 3.200                                | 4.700                       | 0.196                             | 0.089                                   |
| 74/02/05           | 10 35             |               | 1.320                               | 14.000                         | 6.290                           | 1.080                                | 2.900                       | 0.226                             | 0.126                                   |
| 74/04/24           | 09 15             |               | 0.640                               | 18.000                         | 6.725                           | 2.100                                | 3.200                       | 0.140                             | 0.229                                   |
| 74/05/03           | 16 20             |               | 0.520                               | 22.000                         | 4.300                           | 3.150                                | 8.900                       | 0.089                             | 0.126                                   |